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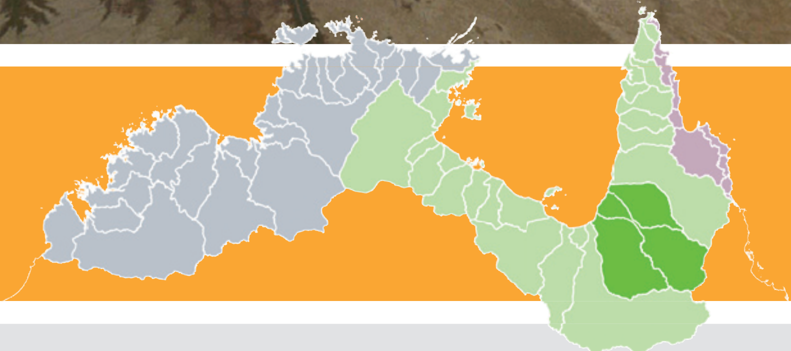

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Water in the South-East Gulf region of the Gulf of Carpentaria Drainage Division

A report to the Australian Government from the CSIRO Northern Australia Sustainable Yields Project

August 2009

Australian Government
National Water Commission
Raising National Water Standards Program

Northern Australia Sustainable Yields Project acknowledgments

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The Project was guided and reviewed by a Steering Committee (Kerry Olsson, NWC – co-chair; Chris Schweizer, Department of the Environment, Water, Heritage and the Arts (DEWHA) – co-chair; Tom Hatton, CSIRO; Louise Minty, Bureau of Meteorology (BoM); Lucy, Vincent, Bureau of Rural Sciences (BRS); Tom Crothers, QDERM; Lyall Hinrichsen, QDERM; Ian Lancaster, NRETAS; Mark Pearcey, DoW; Michael Douglas, Tropical Rivers and Coastal Knowledge (TRaCK); Dene Moliere, Environmental Research Institute of the Supervising Scientist (*eriss*); secretariat support by Angus MacGregor, DEWHA) and benefited from additional reviews by a Technical Reference Panel and other experts, both inside and outside CSIRO.

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Director's Foreword

Following the November 2006 Summit on the southern Murray-Darling Basin (MDB), the then Prime Minister and MDB state Premiers commissioned CSIRO to undertake an assessment of sustainable yields of surface and groundwater systems within the MDB. The project set an international benchmark for rigorous and detailed basin-scale assessment of the anticipated impacts of climate change, catchment development and increasing groundwater extraction on the availability and use of water resources.

On 26 March 2008, the Council of Australian Governments (COAG) agreed to expand the CSIRO assessments of sustainable yield so that, for the first time, Australia would have a comprehensive scientific assessment of water yield in all major water systems across the country. This would allow a consistent analytical framework for water policy decisions across the nation. The Northern Australia Sustainable Yields Project, together with allied projects for Tasmania and south-west Western Australia, will provide a nation-wide expansion of the assessments.

The CSIRO Northern Australia Sustainable Yields Project is providing critical information on current and likely future water availability. This information will help governments, industry and communities consider the environmental, social and economic aspects of the sustainable use and management of the precious water assets of northern Australia.

The projects are the first rigorous attempt for the regions to estimate the impacts of catchment development, changing groundwater extraction, climate variability and anticipated climate change on water resources at a whole-of-region scale, explicitly considering the connectivity of surface and groundwater systems. To do this, we are undertaking the most comprehensive hydrological modelling ever attempted for the region, using rainfall-runoff models, groundwater recharge models, river system models and groundwater models, and considering all upstream-downstream and surface-subsurface connections.

To deliver on the projects CSIRO is drawing on the scientific leadership and technical expertise of national and state government agencies in Queensland, Tasmania, the Northern Territory and Western Australia, as well as Australia's leading industry consultants. The projects are dependent on the cooperative participation of over 50 government and private sector organisations. The projects have established a comprehensive but efficient process of internal and external quality assurance on all the work performed and all the results delivered, including advice from senior academic, industry and government experts.

The projects are led by the Water for a Healthy Country Flagship, a CSIRO-led research initiative established to deliver the science required for sustainable management of water resources in Australia. By building the capacity and capability required to deliver on this ambitious goal, the Flagship is ideally positioned to accept the challenge presented by this complex integrative project.

CSIRO has given the Sustainable Yields Projects its highest priority. It is in that context that I am very pleased and proud to commend this report to the Australian Government.

Dr Tom Hatton

Director, Water for a Healthy Country

National Research Flagships

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Contributors* to the Northern Australia Sustainable Yields Project

Project director	Tom Hatton
Sustainable Yields coordination	Mac Kirby
Project Leader	Richard Cresswell
Project Support	Andrea Davis, Malcolm Hodgen, Sue Jackson, Helen Beringen, Justin Story, Siobhan Duffy, Therese McGillion, Jeff Camkin
Data Management	Mick Hartcher
Climate	Tim McVicar, Randall Donohue, Janice Bathols, Francis Chiew, Dewi Kirono, Lingtao Li, Steve Marvanek, David Post, Nick Potter, Ian Smith, Tom Van Neil, Wenju Cai *New South Wales Department of Water and Energy*: Jin Teng
Catchment Yield	Cuan Petheram, Paul Rustomji, Jamie Vleeshouwer, Donna Hughes, Jean-Michel Perraud, Ang Yang, Lu Zhang *Sinclair Knight Merz*: Brad Neal, Amanda Bell, Werner Hennecke, Damon Grace, Derek Goodin, Rory Nathan, David Stephens, Nicola Logan, Sarah Gosling, Zuzanna Graszkiewicz *Queensland Department of Environment and Resource Management*: Alex Loy, Greg Hausler, Sarah Giles, David Li, Amanda Casey
Groundwater	Glenn Harrington, Russell Crosbie, Phil Davies, James McCallum, Warrick Dawes, Matthew Lenahan, David Rassam *Sinclair Knight Merz*: Rick Evans, Roger Cranswick, Eliza Wiltshire *Jolly Consulting*: Peter Jolly *Environmental Hydrology Associates*: Peter Evans, Jerome Arunakumaren, Wesley Burrows, Judith Raue *Northern Territory Department of Natural Resources, Environment, The Arts and Sport*: Anthony Knapton, Lynton Fritz, Steven Tickell *Queensland Department of Environment and Resource Management*: Linda Foster, Ralph DeVoil
Environment	Dave McJannet, Anne Henderson, Joe McMahon, Jim Wallace
Reporting	Susan Cuddy, Becky Schmidt, Heinz Buettikofer, Elissa Churchward, Alex Dyce, Simon Gallant, Chris Maguire, Frances Marston, Linda Merrin, Ben Wurcker *dmwcreative*: Maureen Wicks, David Wicks

* CSIRO unless otherwise indicated; Team Leaders underlined

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Abbreviations and acronyms

Abbreviation or acronym	Description
AHD	Australian Height Datum
AMTD	Adopted Middle Thread Distance (the distance along a river upstream from its outlet)
APET	Areal potential evapotranspiration
AR4	The fourth assessment report of the Intergovernmental Panel on Climate Change
ARI	Average recurrence interval – the statistical length of time that might be expected to pass before a similar condition is repeated
AWRC	Australian Water Resources Council
BFI	Baseflow index – the ratio of baseflow volume to total flow volume over a specified period, commonly assumed to be the amount of groundwater input to stream flow
BRS	Bureau of Rural Sciences, Department of Agriculture, Fisheries and Forestry
CLW	CSIRO Division of Land and Water
CMAR	CSIRO Division of Marine and Atmospheric Research
CMB	Chloride mass balance
CO_2	Carbon dioxide
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital elevation model
DERM	(Queensland) Department of Environment and Resource Management
DEWHA	Department of the Environment, Water, Heritage and the Arts, Australian Government
DNRM	Previous incantation of DERM
DNRW	Previous incantation of DERM
DTW	Depth to watertable
E	Extraction
E/B	Extraction to baseflow ratio
E/R	Extraction to recharge ratio
E_f	Future groundwater extraction
EC	Electrical conductivity, a measure of salinity. 1 EC (μS/cm) ≈ 0.6 mg/L TDS
ET	Evapotranspiration
FDC	Flow duration curve
GAB	Great Artesian Basin
GCM	Global climate model, also known as general circulation model
GDA	Geographic datum of Australia
GDE	Groundwater-dependent ecosystem
GRCI	Groundwater resource condition indicator
IQQM	Integrated Quantity and Quality Model – a river systems model
MAR	Managed aquifer recharge
MDB	Murray-Darling Basin
MGSH	Maximum gauged stage height
MSLP	Mean sea level pressure
NAILSMA	Northern Australia Indigenous Land and Sea Management Alliance
NAS	Network attached storage
NALWT	Northern Australia Land and Water Taskforce (http://www.nalwt.gov.au/)
NAWFA	Northern Australia Water Futures Assessment (http://www.environment.gov.au/nawfa/)
NRETA	Previous incantation of NRETAS
NRETAS	Northern Territory Department of Natural Resources, Environment, the Arts and Sport
NSE	Nash-Sutcliffe Efficiency coefficient used to assess the predictive power of hydrological models. Values range from -∞ to +1, where +1 is a perfect match to observations. Analogous to the R^2 coefficient of determination
PET	Potential evapotranspiration
R	Recharge
RAM	Random access memory
RSF	Recharge scaling factor
SAN	Storage area network

Abbreviation or acronym	Description
SILO	Enhanced meteorological datasets (http://www.bom.gov.au/silo/index.shtml)
SRN	Streamflow reporting node
TDS	Total Dissolved Solids (mg/L ≈ 1.7 EC)
TRaCK	Tropical Rivers and Coastal Knowledge Research Hub
WRON	Water Resources Observation Network

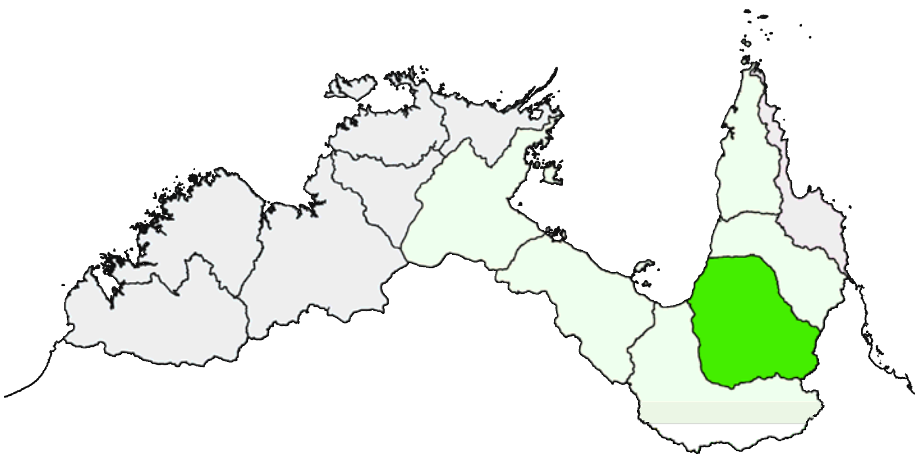
Units of measurement

Measurement units	Description
ML	Megalitres, 1,000,000 litres
GL	Gigalitres, 1,000,000,000 litres
TL	Teralitres, 1,000,000,000,000 litres
Cumecs	Cubic metres per second; m^3/sec; equivalent to 1,000 litres per second
1 Sydney Harbour	~500 GL
1 Lake Argyle	10,380 GL

Glossary of terms

Term	Description
Scenarios	Defined periods or conditions for comparative evaluation of water resource assessments. Each scenario has three variants: wet, mid and dry, representing the 90th, 50th and 10th percentile of ranked results for each modelled condition. These are referred to as the wet extreme, median and dry extreme variants for each scenario, A, B, C and D. Additional variants include: C range which represents the inter-quartile range of values (25-75% of values) and AN which represents the pre-development (i.e. near pristine) scenario based on Historical data. AN can be defined where river systems models are available
Historical	Scenario A: 1st September, 1930 to 31st August, 2007 – except for recurrence interval calculation, when Historical refers to the period 1st September, 1930 to 31st August, 1996 (i.e. prior to Recent)
Recent	Scenario B: 1st September, 1996 to 31st August, 2007
Future	Scenario C: Climate conditions estimated for ~2030 compared to ~1990 conditions
Development	The use of surface and groundwater supplies. This assessment assumes that all current entitlements are being fully used and, where possible, actual use is also considered. Future development assumes all entitlements projected to be made available in 2030 are fully utilised. This is referred to as Scenario D
Without development	Scenarios AN, BN and CN. Represent conditions that would be expected under the climate scenarios without development, i.e. near-pristine conditions. These can be defined for systems with river systems models
Water Resource Assessment	An assessment that identifies the partitioning of rainfall through the water cycle, i.e. how much water there is in all its guises, at any given location, at any given time
Water Availability Assessment	An assessment that determines the amount of water that could be diverted or extracted from each water source, at any given location, at any given time
Water Sustainable Yield Assessment	An assessment that determines the amount of existing water resources that are available for consumptive use after the informed and equitable allocation of the resource between human uses and the environment
FCFC	Forest Cover Flow Change (*see* <http://www.toolkit.net.au/Tools/FCFC>)
AWBM, Sacramento, SIMHYD, SMARG	Rainfall-runoff models (*see* http://www.toolkit.net.au/Tools/RRL)
IHACRES Classic	IHACRES (Identification of unit Hydrographs And Component flows from Rainfall, Evaporation and Streamflow data) is a catchment-scale, rainfall-streamflow, modelling methodology that characterises the dynamic relationship between rainfall and streamflow, using rainfall and temperature (or potential evaporation) data, and predicts streamflow, developed by the Integrated Catchment Assessment and Management (iCAM) Centre, Faculty of Science, The Australian National University
MODFLOW	A groundwater flow model (http://water.usgs.gov/nrp/gwsoftware/modflow.html)
WAVES	An analytical recharge model developed by Zhang and Dawes (1998) used to estimate groundwater recharge under different soils, vegetation and climate scenarios
SRES 1B	A future (2100) greenhouse gas emissions scenario used to compare climate model forecasts
Unallocated water	Water that is identified as water potentially available for future allocation
General Reserve	Unallocated water which may be granted for any purpose
Strategic Reserve	Unallocated water which may only be granted for a state purpose

Water in the South-East Gulf region



SE-1 Water availability and demand in the South-East Gulf region

The first part of this report (the Preamble, Chapter 1 and Chapter 2) reports at the division level, including division-wide descriptions of climate and geology and methods which apply to all regions. Subsequent chapters report at the region level. In particular, Chapters SE-1, SE-2 and SE-3 focus on the South-East Gulf region (Figure SE-1).

This chapter summarises the water resources of the South-East Gulf region, using information from Chapter SE-2 and Chapter SE-3, and directly addresses the Terms of Reference, specifically terms 3, 4 and 5 as listed in the Preamble. Essentially, this chapter provides a synoptic view of the region and covers:

- regional observations
- water resource assessment
- seasonality of water resources
- surface–groundwater interaction
- changes to flow regime at environmental assets
- water storage options
- data and knowledge gaps.

For further details on the context of the region (physical and climate descriptions, hydrogeology and legislation) see Chapter SE-2. Region-specific methods and results are provided in Chapter SE-3. Modelling results are reported under climate and development scenarios as defined at the division level in Section 2.1 of Chapter 2.

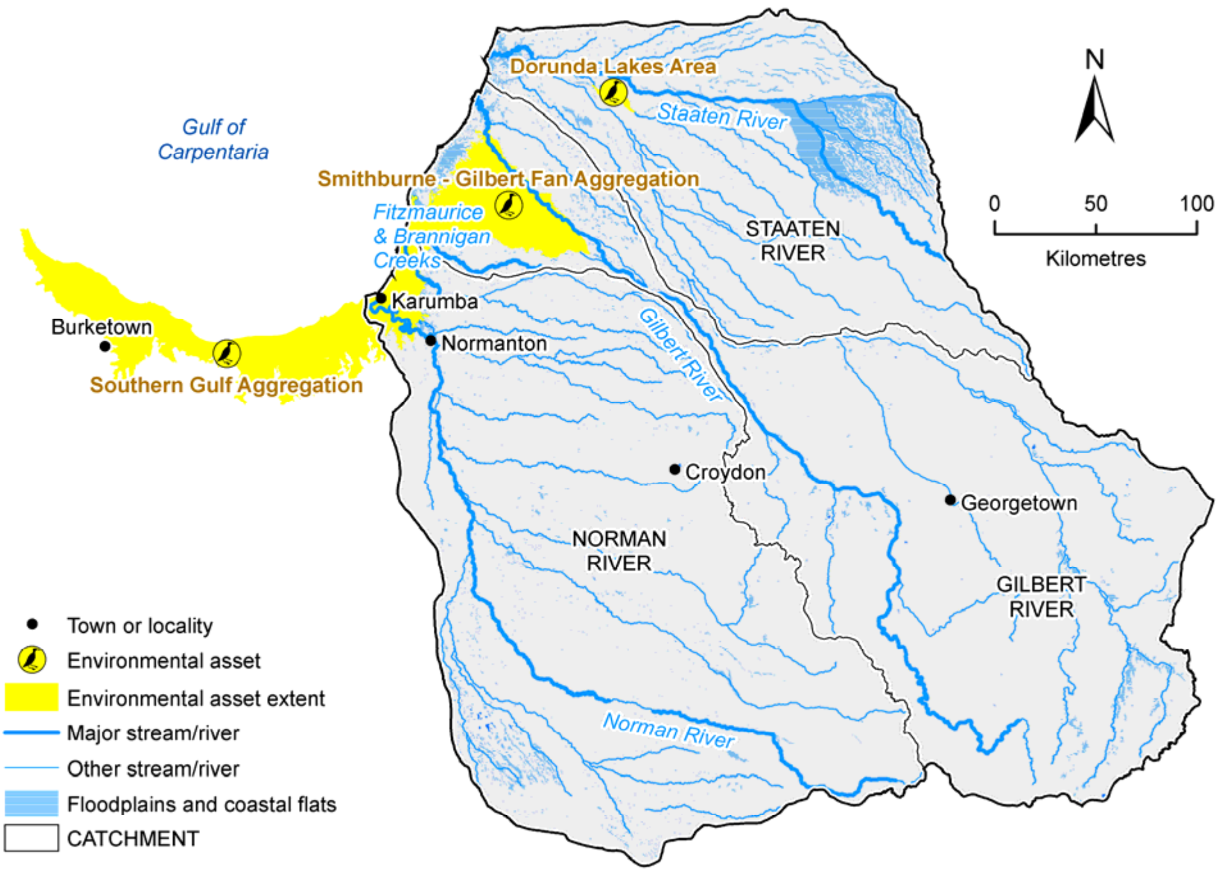


Figure SE-1. Major rivers, towns and location of environmental assets selected for assessment of changes to hydrological regime in the South-East Gulf region

SE-1.1 Regional summary

These regional observations summarise key modelling results and other relevant water resource information about the South-East Gulf region.

The South-East Gulf region has a high inter-annual variability in rainfall and hence runoff and recharge. Coefficients of variation are the highest of the regions across northern Australia and reflect multiple years over significantly below average and above average rainfall.

The mean annual rainfall for the region is 750 mm. Mean annual areal potential evapotranspiration (APET) is 1980 mm. The mean annual runoff averaged over the modelled area of the South-East Gulf region is 113 mm, 15 percent of rainfall. Compared to other regions, average rainfall is low and APET is high. Under the historical climate the mean annual streamflow over the South-East Gulf region is estimated to be 14,430 GL.

There is a strong seasonality in rainfall patterns, with 95 percent of rainfall falling between November and May, and a very high dry season potential evapotranspiration. The region has a relatively high rainfall intensity, and hence rapid runoff and short lag between rainfall and runoff with a slightly increasing amount and intensity of rainfall from 1930 to 2007.

There is a strong north–south rainfall gradient and between 10 and 30 percent of precipitation flows as runoff.

The region is water-limited; in other words there is more energy available to remove water than there is water available to be removed.

The South-East Gulf region has a recent (1996 to 2007) climate record that is statistically significantly similar to the historical (1930 to 2007) record. Modelling suggests that future (~2030) conditions will also be similar to historical conditions; hence, future runoff and recharge are likely similar to historical levels.

Deep aquifers contain the largest storage of water. The Gilbert River Formation of the Great Artesian Basin is the main groundwater resource in the region. This is predominantly a confined aquifer, but is found in rock outcrop to the south and east where it provides baseflow to the Norman River and is likely responsible for extending the duration of flow into the dry season. The Gilbert River Formation and Eulo Queen Group aquifers also provide groundwater discharge to the Gilbert River, Yappar River, Clara River and Boorabin Creek, allowing surface water flows in many rivers to be maintained well into the dry season.

The Great Artesian Basin springs discharging in the region provide an important source of water. The shallow alluvial aquifers are characterised by variable thickness and groundwater quality and are therefore a relatively undeveloped groundwater resource.

There are few opportunities for surface water storage and most are in the southern, drier headwater areas, where potential evapotranspiration is highest within the region. Lower reaches are flood determined and dominated. Generally the region has low relief.

None of the environmental assets in this region have any site-specific ecology related flow metrics by which to gauge the potential impacts of future climate change and development scenarios. Streamflow estimates in this region are not of a sufficient confidence level to even assess changes to flow regime at these assets.

Only the Gilbert River basin has a river systems model. Current average surface water availability in the Gilbert system is 3724 GL/year and on average about 29 GL/year (or less than 1 percent) of this water is used. This is a very low level of development.

The region is generally data poor.

The South-East Gulf region is a relatively isolated area with little development. There is minor demand for water in this region largely owing to the small population.

SE-1.2 Water resource assessment

Term of Reference 3a

SE-1.2.1 Under historical climate and current development

Term of Reference 3a (i)

Mean annual rainfall in the South-East Gulf region is 750 mm, with a standard deviation of 129 mm. Maximum recorded rainfall fell in 1974 with 2126 mm; the lowest was in 1952 with 329 mm. Mean annual areal potential evapotranspiration (APET) is 1980 mm, with a relatively small variation (standard deviation of 74 mm). Highest APET occurred in 1931 (2075 mm); lowest in 1974 (1804 mm). The mean annual modelled runoff averaged over the modelled area of the South-East Gulf region is 110 mm, 15 percent of rainfall. Rainfall and runoff generation both decline with distance from the coast but otherwise show little spatial variation.

Rainfall is very seasonal, with 95 percent falling during the wet season (November to April), and runoff is highest in February and March.

Rainfall values are low in comparison to other regions. Rainfall and runoff vary little across the region, in keeping with the subdued topography. Rainfall is very seasonal and runoff is highest in February and March.

Current average surface water availability is 3724 GL/year and on average about 29 GL/year (or less than 1 percent) of this water is allocated under full use of existing entitlements. This is a low level of development.

Licensed groundwater extraction is currently a very low 0.193 GL/year in the South-East Gulf region. All groundwater extraction from Great Artesian Basin (GAB) aquifers is licensed, including that used for stock and domestic purposes – although these purposes have no volumetric entitlement. Groundwater use for stock and domestic purposes in the region is estimated to be more than 11 GL/year, most of which comes from the GAB aquifers. Natural groundwater discharge from the GAB aquifers plays an important role in providing dry season flows in many of the streams in the region, as reflected in the dry season baseflow volumes estimated for the Einasleigh, Gilbert and Norman rivers and Elizabeth Creek (Table SE-1). It has been suggested that dry season baseflow is also important in the Clara and Yappar rivers, as well as Boorabin Creek (AGE, 2005).

Table SE-1. Estimated groundwater contribution (baseflow) to streamflow, modelled diffuse recharge and groundwater extraction for the for the South-East Gulf region under historical climate

Station	River	Station name	Annual BFI *	Dry season BFI *	Dry season baseflow **
					GL
916001A	Norman	Rocky Waterhole	0.18	0.16	0.5
917001D	Gilbert	Rockfields	0.09	0.14	0.6
917002A	Robertson	Robin Hood	0.07	0.23	0.2
917008A	Little	Inorunie	0.13	0.31	0.1
917104A	Etheridge	Roseglen	0.10	0.16	0.2
917105A	Copperfield	Narrawa No 2	0.11	0.28	1.5
917106A	Einasleigh	Einasleigh	0.11	0.26	3.1
917107A	Elizabeth Ck	Mount Surprise	0.26	0.76	3.4
917108A	McKinnons Ck	Possum Pad	0.05	0.06	0.1
917115A	Copperfield	Spanner Waterhole	0.14	0.40	1.0
917116A	Copperfield	Kidston Dam Headwater	0.12	0.16	0.1
917118A	Copperfield	Kidston Dam Tailwater	0.11	0.19	0.6
		Historical recharge **	Estimated groundwater extraction		
		GL/y			
Entire South-East Gulf region		8310			12

* BFI (baseflow index) and baseflow volume derived from gauged data.

** Aggregated recharge using Zhang and Dawes (1998).

Under a continued historical climate, mean annual groundwater recharge to the unconfined aquifers of the South-East Gulf region is likely to be similar to the historical (1930 to 2007) average. When coupled with current rates of groundwater extraction from the shallow aquifers, this means the groundwater balance of these systems is unlikely to change by 2030. Furthermore, because the GAB is such a large, regional groundwater flow system that is recharged in a relatively small area of intake beds, subtle changes in the recharge rates are unlikely to be reflected in the groundwater levels of this system by 2030.

SE-1.2.2 Under recent climate and current development

Term of Reference 3a (ii)

The mean annual rainfall under the recent (1930 to 2007) climate, averaged over the entire region, has increased by 7 percent relative to the historical average, but within the region varies from -10 to +30 percent. Only the slight increase recorded in the Staaten River basin is statistically significantly different from the historical average. Runoff over the last 11 years is lower by 13 percent relative to the historical (1930 to 2007) mean values.

Under a continued recent climate, mean annual groundwater recharge to unconfined aquifers in the South-East Gulf region may be slightly lower than the historical average rate. The fact that recharge is predicted to be lower when rainfall is higher than the historical value reflects the importance of climate variables other than total rainfall (e.g., rainfall intensity and temperature) in determining recharge (see division approaches section 2.3.3). Nevertheless, because groundwater extraction from these systems is currently very low, it is unlikely there would be measurable change in groundwater resource condition by 2030.

SE-1.2.3 Under future climate and current development

Term of Reference 3a (iii)

Future climate is expected to be similar to historical climate. Under the median future climate, annual rainfall is 750 mm; under the wet extreme future climate, annual rainfall is 855 mm; and under the dry extreme future climate, annual rainfall is 698 mm. Corresponding areal potential evapotranspiration (APET) under these scenarios is 2026, 2035 and 2065 mm, respectively, or 2.3 to 4.3 percent higher than historical results.

Rainfall-runoff modelling with climate change projections from global climate models indicates that future runoff in the South-East Gulf region is slightly more likely to decrease than increase. Rainfall-runoff modelling with climate change projections from three-fifths of the GCMs shows a reduction in mean annual runoff, while rainfall-runoff modelling with climate change projections from two-fifths of the GCMs shows an increase in mean annual runoff. The median estimate is for a -1 percent change to the mean annual runoff by 2030. The extreme estimates, which come from the high global warming scenario, range from a 46 percent increase to a 23 percent decrease in mean annual runoff. By comparison, the range from the low global warming scenario is a 24 percent increase to a 13 percent reduction in mean annual runoff.

Under the median future climate there would be a 7 percent increase in water availability and no change to diversions for all water products.

The climate extremes for 2030 indicate:

- under the wet extreme future climate, water availability increases 23 percent and no change to total diversions
- under the dry extreme future climate, water availability decreases 15 percent and total diversions decrease 3 percent.

Under the future climate, modelled mean annual groundwater recharge to the unconfined aquifers of the South-East Gulf region is likely to be higher than the historical average. This finding is counter-intuitive and reflects the fact that annual recharge is dependent on factors other than just annual rainfall (e.g., rainfall intensity). Without an appropriate groundwater model for the region, it is not possible to predict the magnitude of any resource condition change that might occur as a result of this increased recharge.

SE-1.2.4 Under future climate and future development

Term of Reference 3a (iv)

Most water in the Gilbert River basin (99 percent) and all in the Staaten and Norman river basins is not diverted, therefore future development scenarios for surface water are similar to the scenario under current development.

There is currently no existing numerical groundwater flow model for the South-East Gulf region that incorporates all of the main aquifer types, including the alluvial aquifers, Tertiary sediments and GAB aquifer. Without such a model, it was not possible to predict the impacts of future climate or potential future development on these groundwater resources.

SE-1.3 Changes to flow regime at environmental assets

Term of Reference 3b

Section 1.3 of the division-level Chapter 1 describes how environmental assets were shortlisted for assessment by this project. Three environmental assets were shortlisted for the South-East Gulf region: Dorunda Lakes Area, the Smithburne–Gilbert Fan Aggregation and the Southern Gulf Aggregation. These assets are characterised in Chapter SE-2.

In deciding whether it is feasible to report hydrological regime metrics for these shortlisted assets, it is important to consider the confidence levels in modelled streamflow (as described in Section 2.2.6 of the division-level Chapter 2). Confidence in results for low flows and high flows was calculated separately. Hydrological regime metrics (as defined in Section 2.5 of the division-level Chapter 2) for either low flows or high flows are reported only where confidence levels are sufficiently high. If confidence in the low flow or high flow is too low, metrics are not reported, and hence an important gap in our knowledge is identified.

Unfortunately there is insufficient confidence in the modelled streamflow to report hydrological regime metrics for any of the environmental assets in the region.

SE-1.4 Seasonality of water resources

Term of Reference 4

The rivers have a marked seasonal flow regime of high water levels and extensive flooding during the wet season (November to April) and decreased water flow and river stage towards the end of the dry season.

Approximately 95 percent of rainfall and 99 percent of runoff occurred during the wet season months under the historical and recent climate. Very similar seasonal percentages of rainfall and runoff are projected to occur at 2030.

SE-1.5 Surface–groundwater interaction

Term of Reference 4

The Norman River originates in the Gregory Range to the southeast and terminates at Alligator Point on the coast of the Gulf of Carpentaria. The smaller Carron, Clara and Yappar rivers all flow into the Norman. There is considerable interconnection between streams which results in widespread and severe flooding in times of high flow. Groundwater discharge from the Gilbert River Formation provides significant baseflow in a number of these streams, including the Norman, Yappar and Clara rivers.

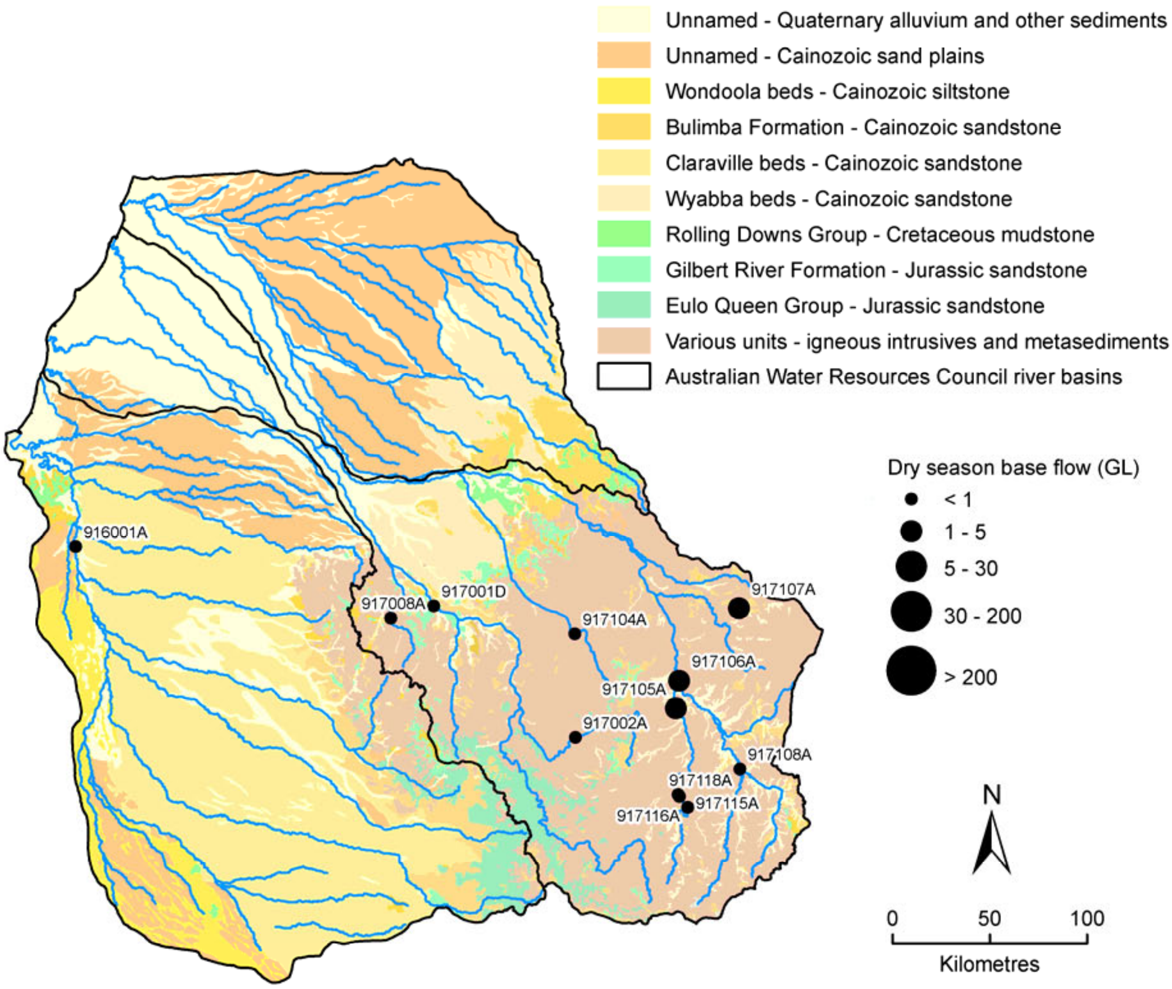


Figure SE-2. Surface geology and modelled mean dry season baseflow of the South-East Gulf region

The Einasleigh River joins the Gilbert River in the north of the Gilbert River basin, before flowing to the Gulf of Carpentaria. Groundwater discharge from the Gilbert River Formation provides baseflows to the upper reaches of the Gilbert River (DNRM, 2005) and its tributaries (Table SE-1 and Figure SE-2).

Spring discharge occurs in the outcrop areas of the Gilbert River Formation and Eulo Queen Group due to rejected recharge, where topography is relatively steep and incised compared with the remainder of the South-East Gulf region. Where rivers intersect these aquifers, they receive baseflow for much of the dry season. The Gilbert River Formation and Eulo Queen Group aquifers support significant surface water features in the outcrop areas such as Cobbold and Porcupine Gorge National Parks (DNRM, 2005). Throughflow from these aquifers to the west and south-west support mound springs and associated environments of the Flinders Spring Group. Figure SE-3 shows the river reaches potentially receiving baseflow as well as the location of GAB springs.

During the wet season, surface water infiltrates from the river to the surficial aquifers, either laterally via the incised sediments, or vertically via diffuse recharge when overbank flooding occurs.

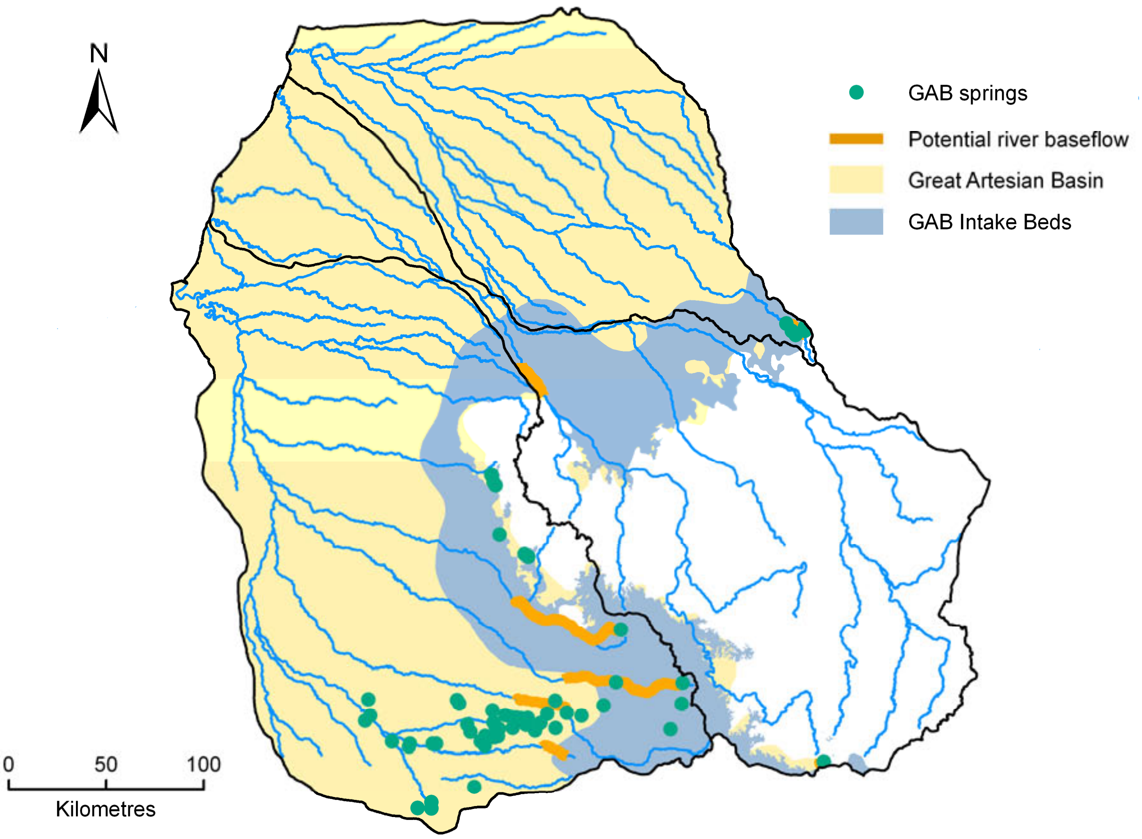


Figure SE-3. Locations of spring groups and potential river baseflow in the South-East Gulf region

SE-1.6 Water storage options

Term of Reference 5

SE-1.6.1 Surface water storages

There are few major storages in the region. The Kidston Dam on the Copperfield River in the far south-east of the Gilbert River basin is the largest with an active storage of 18.5 GL. The Norman River has a few small local storages. Storage options are restricted to small regions in the headwater areas of the region. The Staaten rivers basin is a declared wild river area. In stream dams and weirs cannot be constructed in wild rivers or their major tributaries.

SE-1.6.2 Groundwater storages

The main aquifer in the South-East Gulf region is the Gilbert River Formation of the GAB. Extraction from this resource for stock and domestic purposes is, by far, the greatest use of water in the region. Where the aquifer outcrops and is unconfined, recharge during the wet season fills any available storage before ‘rejecting’ excess recharge back into the rivers. Managed aquifer recharge (MAR) therefore has limited applicability in these areas. Further towards the north-west, the aquifer in the Gilbert River Formation becomes confined and ultimately artesian – a condition not favourable for MAR.

SE-1.7 Data gaps

Term of Reference 1e

There are 19 weather stations in the region that have better than 80 percent record completeness, and 11 that pass 90 percent, making the South-East Gulf region the second most data-rich region of northern Australia, at least for rainfall.

Floodplain gauging is lacking, hence only end-of-system flow is modelled. Flood extent and volume measurements would increase the accuracy of the river system models.

Confidence levels in the modelled streamflow were too low to allow flow metrics to be calculated at environmental assets and there is uncertainty as to the contribution of groundwater to certain rivers. This would suggest that more river gauging and groundwater monitoring is required.

Time series groundwater level and salinity data are required for each of the main aquifer types in the South-East Gulf region to provide greater understanding of recharge processes and inter-aquifer leakage, particularly for the GAB aquifers.

SE-1.8 Knowledge gaps

Term of Reference 1e

Dry season flows are poorly understood in this region – therefore the ability to predict the potential impacts of the various scenarios on low or zero flows at environmental assets is very limited. Improved monitoring of low streamflow conditions is needed along with the development of hydrological models that combine surface and groundwater regimes. Further monitoring of groundwater levels is also required so that the potential impacts of climate change and development scenarios on groundwater dependant ecosystems can be better understood.

Flooding is an important factor that sustains many environmental assets and this occurs when the stream breaks out of it's banks (a level known as bankfull stage or discharge). However, bank full discharge is not known for many streams, nor is the dependence of area flooded on increasing stream depth, so it is difficult to predict when assets are inundated. Further information about bank full stage and discharge are needed for most environmental assets.

None of the environmental assets in this region have any site-specific metrics by which to gauge the potential impacts of future climate change and development scenarios. In the absence of site-specific metrics a set of standard metrics related to high and low flows have been utilised; however, the conversion of these metrics into environmental impacts still requires development of quantitative relationships between flow and specific ecological entities (for example, macrophyte populations, fish passage, faunal and floral habitats, etc.).

Many environmental assets depend not simply on duration above or below certain flow levels, but on triggers (e.g. for reproduction or migration) set by the rate of change of flow. In addition, some environmental assets depend on the frequency and duration of events that occur less than annually (i.e. once every 5, 10 or 20 years or more). Further analysis is therefore required to look at how the timing, duration and rate of rise and fall in flow at critical times of the season will vary under the various scenarios.

Diffuse upward leakage of water out of the GAB aquifers and into overlying Tertiary sediments is yet to be quantified. Further research is required to estimate these discharge fluxes so that a detailed groundwater balance can be developed for the aquifers to guide future management in the region.

SE-1.9 References

AGE (2005) Great Artesian Basin water resource plan - potential for river baseflow from aquifers of the GAB. Prepared for the Department of Natural Resources and Mines. Australasian Groundwater & Environmental Consultants.

DNRM (2005) Hydrogeological framework report for the Great Artesian Basin resource plan area. Queensland Department of Natural Resources and Mines.

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SE-2 Contextual information for the South-East Gulf region

This chapter summarises the background information for the region, outlining existing knowledge of water resources and prior and current investigations relevant to the water resources of the region. This chapter also outlines the current and potential future legislation, water plans and other water resource management arrangements. This chapter is arranged into four sections:

- physical and climate descriptions
- data availability
- hydrogeology
- legislation, water plans and other arrangements.

SE-2.1 Overview of the region

SE-2.1.1 Geography and geology

The South-East Gulf region is located in the Gulf of Carpentaria Drainage Division and covers 122,530 km^2. It comprises the Australian Water Resource Council (AWRC) river basins of the Staaten (25,897 km^2), Gilbert (46,354 km^2) and Norman (50,279 km^2). These rivers rise in the Great Dividing Range south and east of Georgetown, flowing in a generally north-west direction to the coast, where the rivers spread out into extensive floodplains and deltas running north of Karumba.

The Norman river rises in the Gregory Range (Great Dividing Range) 200 km south-east of Croydon and flows in a north-westerly direction. It is joined by its major tributaries, the Clara and Yappar Rivers, near the river height and rainfall station of Yappar River. The river flows through the major town of Normanton, before finally entering the Gulf of Carpentaria through the major fishing port of Karumba. The only other town in the catchment is the old historic gold mining town of Croydon. Floods normally develop in the headwaters of the Norman, Clara and Yappar rivers; however, general heavy rainfall situations can develop from cyclonic influences causing widespread flooding, particularly in the lower delta country around Normanton and Karumba. There is considerable interconnection between streams in this catchment, hence high flow leads to severe flooding.

The Gilbert River flows in a north-westerly direction from the Great Dividing Range, 150 km south-east of Georgetown, and is joined by its major tributary, the Einasleigh River, downstream of Strathmore, before finally entering the Gulf of Carpentaria in a river delta 100 km wide. The other main tributary, the Etheridge River, joins the Einasleigh River downstream of Georgetown, which is the only town in this vast catchment. Smaller settlements can be found at Forsayth, Mt Surprise and Einasleigh. Floods develop almost annually in the headwaters of the Gilbert and Einasleigh rivers; however general heavy rainfall situations can develop from cyclonic influences resulting in widespread flooding, particularly in the lower reaches below Strathmore.

The Staaten river basin contains the catchments of the Staaten River and Vanrook Creek, and ten major tributaries. The river systems in the area are in near natural condition due to very low levels of development in their catchments. These river systems have extensive floodplains which are inundated in most wet seasons, further restricting the suitability of these areas for development. Also there are no towns, mining or heavy industry in the area; and large areas of land are within national parks within the wild river area.

Figure SE-4 shows the surface geology of the region, with major towns and relief shading.

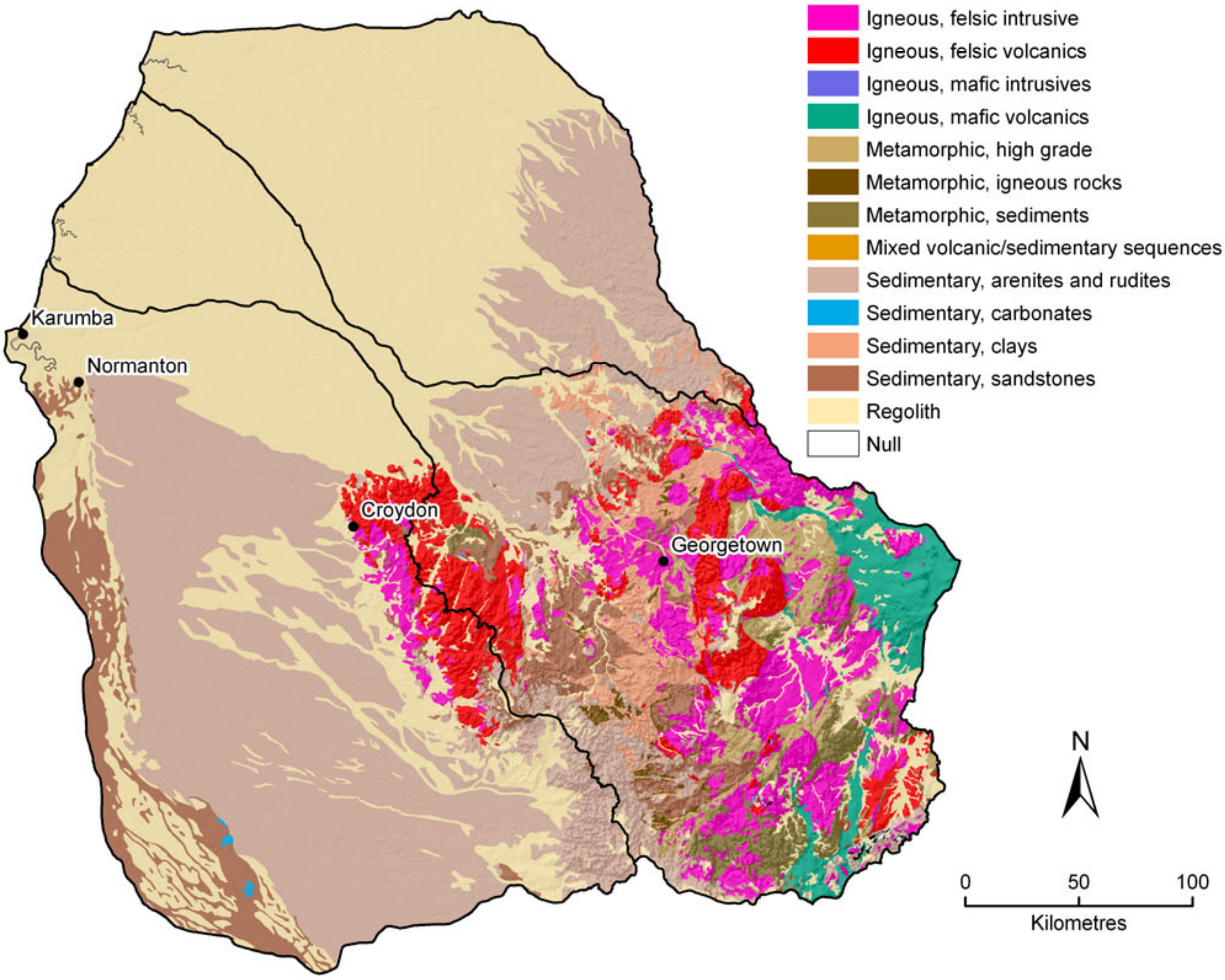

Figure SE-4. Surface geology of the South-East Gulf region overlaid on a relative relief surface

SE-2.1.2 Climate, vegetation and land use

The South-East Gulf region receives an average of 750 mm of rainfall over a water year (September to August), most of which (710 mm) falls in the November to April wet season (Figure SE-5). Across the region there is a strong north–south gradient in annual rainfall, ranging from 1078 mm in the north to 490 mm in the south. Over the historical (1930 to 2007) period, yearly rainfall has remained reasonably constant.

Areal potential evapotranspiration (APET) is very high across the region, averaging 1980 mm over a water year, and varies moderately across the seasons. APET generally remains higher than rainfall for most of the year resulting in near-year-round water-limited conditions. The exceptions to this are the months January to March, when more rain falls than can potentially be evaporated.

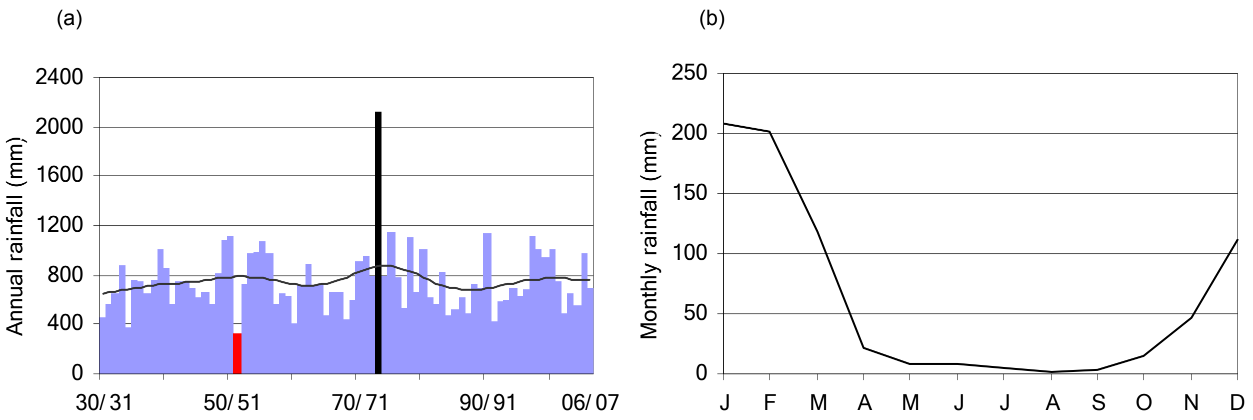

Figure SE-5. Annual and mean monthly rainfall for the South-East Gulf region. The low-frequency smoothed line in (a) indicates longer term variability

There is great variation in vegetation in the South-East Gulf region, ranging from dense eucalypt woodland in the vicinity of surface drainage features, to open grassland (Figure SE-6). The dominant vegetation of the region is medium density scrub with some parcels of swamp land. Highlands are dominated by eucalypt woodlands and flat country by melaleuca forest. The coastal region is characterised by saline coastal flats. There are substantial areas of flood prone land near major watercourses where consequently the vegetation increases in density.

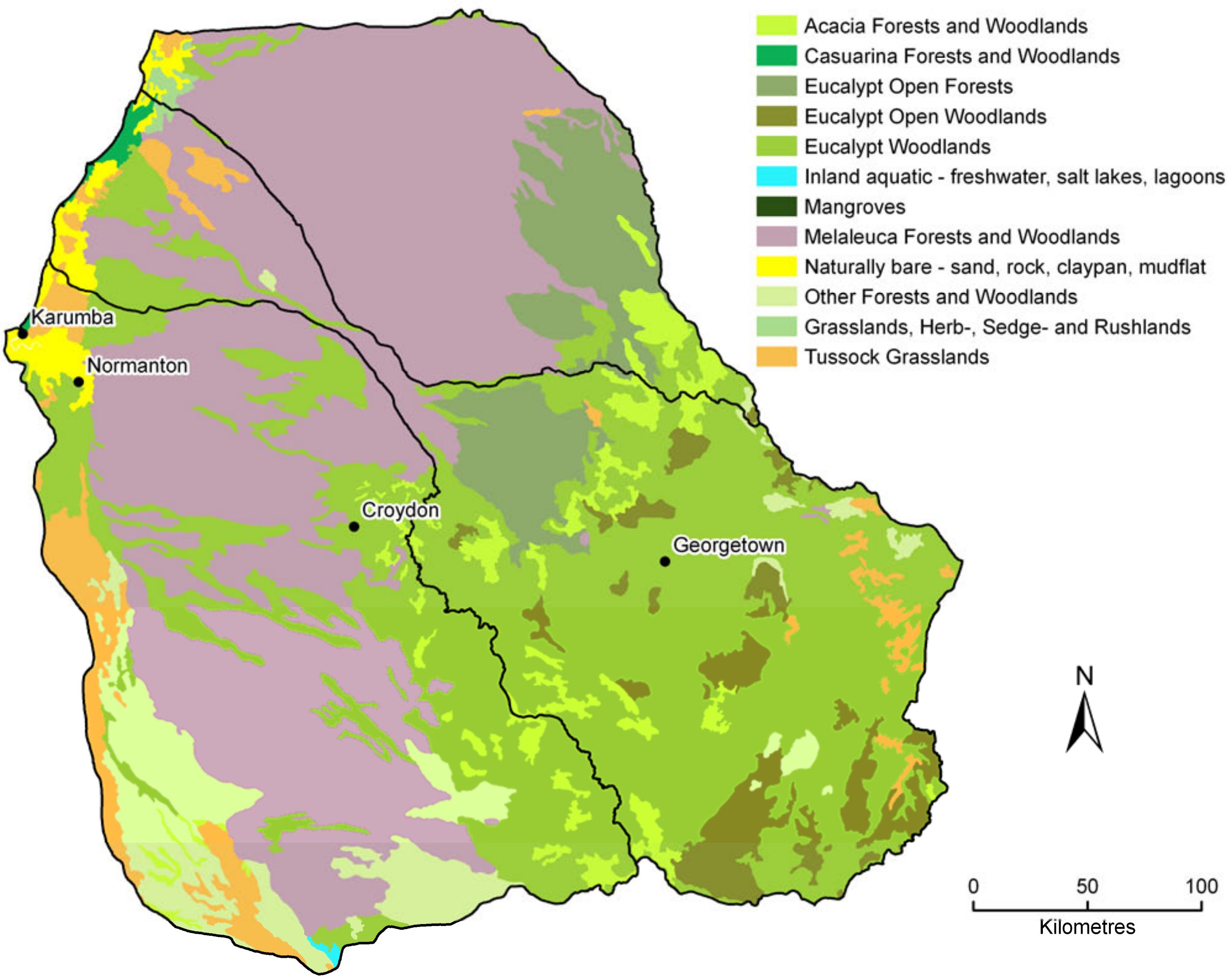

Figure SE-6. Map of current vegetation types across the South-East Gulf region (source DEWR, 2005)

The vast majority of the region remains uncleared and is considered an isolated area with little or no development. Pastoralism is the major industry (Figure SE-7).

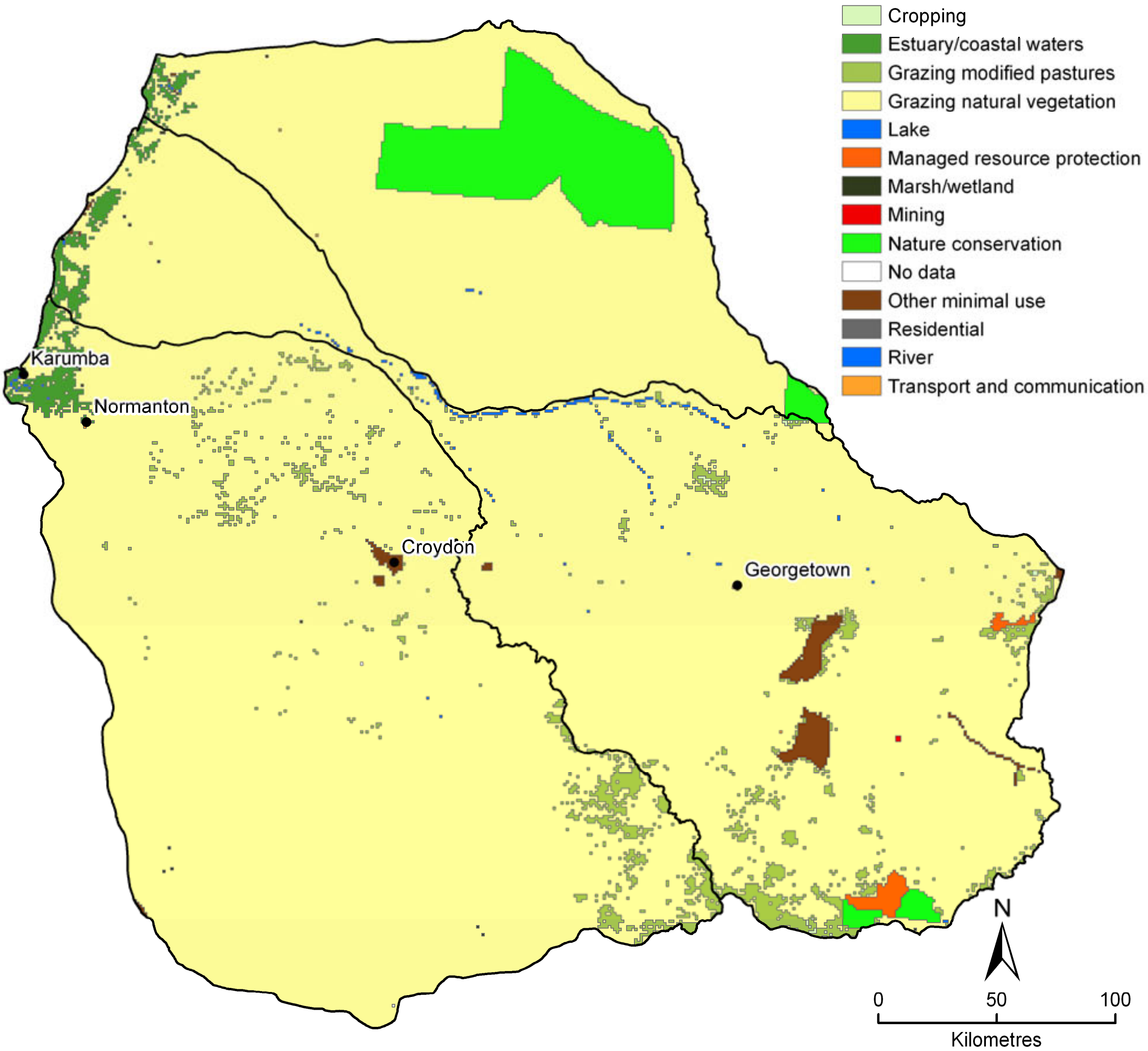

Figure SE-7. Map of dominant land uses of the South-East Gulf region (after BRS, 2002)

SE-2.1.3 Regional environmental asset description

Environmental assets were chosen from wetlands which are listed in the Directory of Important Wetlands in Australia (Environment Australia, 2001). From this directory, environmental assets were shortlisted for assessing changes to the hydrological regime under the climate and development scenarios. The selection of this shortlist was undertaken in consultation with state governments and the Australian Government through direct discussions and through internal reviews (see Section 1.3 in the division-level Chapter 1 for further detail).

All nationally, or internationally, important wetlands listed for the South-East Gulf region in the Directory of Important Wetlands in Australia (Environment Australia, 2001) are detailed in Table SE-2, with asterisks identifying the three shortlisted assets: Dorunda Lakes Area, Smithburne–Gilbert Fan Aggregation, and Southern Gulf Aggregation. The location of these shortlisted wetlands is shown in Figure SE-1. There are no wetlands classified as Ramsar sites in this region. Wetlands may be nationally or regionally significant depending on more locally specific criteria. All wetlands are important for a variety of ecological reasons or because they bear historical significance or have high cultural value, particularly to Indigenous people.

The following section characterises these shortlisted wetlands and is based largely on the description of these assets as outlined by Environment Australia (2001). Chapter ID-3 presents the assessment of those shortlisted assets, and reports hydrological regime metrics for those assets which have sufficient confidence in the modelled streamflow to enable analysis.

Table SE-2. List of Wetlands of National Significance located within the South-East Gulf region

Site code	Name	Area	Ramsar site
		ha	
QLD104 *	Dorunda Lakes Area	6,810	No
QLD107	Macaroni Swamp	258	No
QLD112 *	Smithburne–Gilbert Fan Aggregation	251,000	No
QLD113	Southeast Karumba Plain Aggregation	336,000	No
QLD114 *	Southern Gulf Aggregation	546,000	No
QLD094	Undara Lava Tubes	1,250	No

* Asterisk against the site code identifies those assets which are shortlisted for assessment of changes to flow regime

Dorunda Lakes Area

The Dorunda Lakes Area (Figure SE-8) is a particularly good example of a complex of permanent, semi permanent and seasonal wetland types with a localised occurrence within the Gulf Plains province of the Gulf Plains bioregion. It is an important refuge for wetland bird species. The Dorunda Lake site is a large semi abandoned riverine channel complex with associated oxbows and swamps. The catchment is a series of unnamed mostly unidirectional streams which drain part of an immense undulating alluvial plain with shallow, widely spaced valleys and a uniform pattern associated with the Mitchell, Staaten and Gilbert rivers. The site has an area of 6,810 ha and an elevation ranging between 10 and 20 m above sea level (Environment Australia, 2001).

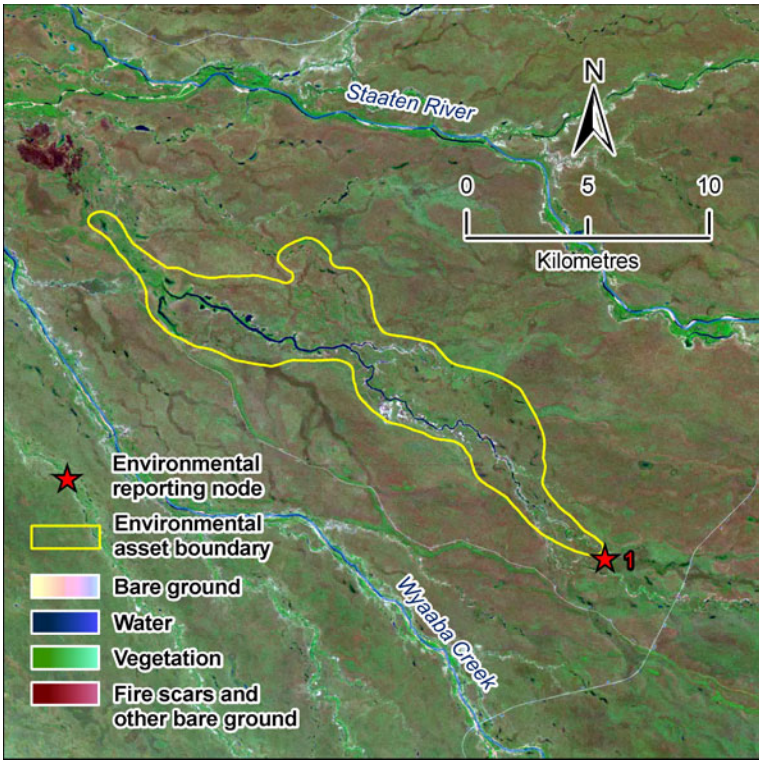

Figure SE-8. False colour satellite image of the Dorunda Lakes Area (derived from ACRES, 2000). Clouds may be visible in image

SE-2 Contextual information for the South-East Gulf region

The site's emergent vegetation communities line the large deep riverine pools and aquatic beds occur in the limnetic and littoral areas of the ox-bows and swamps. Upland areas are mostly woodland. The estuarine and freshwater crocodile are found in the area. This is one of the most pristine inland wetland sites in the Gulf Plains (Environment Australia, 2001).

Smithburne–Gilbert Fan Aggregation

The Smithburne–Gilbert Fan Aggregation (Figure SE-9) contains the best examples of alluvial plain wetlands characteristic of the southern portions of the Smithburne–Gilbert Fans Province of the Gulf Plains bioregion. The site encompasses portions of a stable alluvial plain incised by a complex system of active, mostly seasonal stream channels, frequently flooded depressions and older shallower channels, and partially flooded plains and level terraces. The broad alluvial plain also provides additional local catchment for the many wetlands of the aggregation. The site has an area of 251,000 ha and an elevation ranging between 10 m and 45 m above sea level (Environment Australia, 2001).

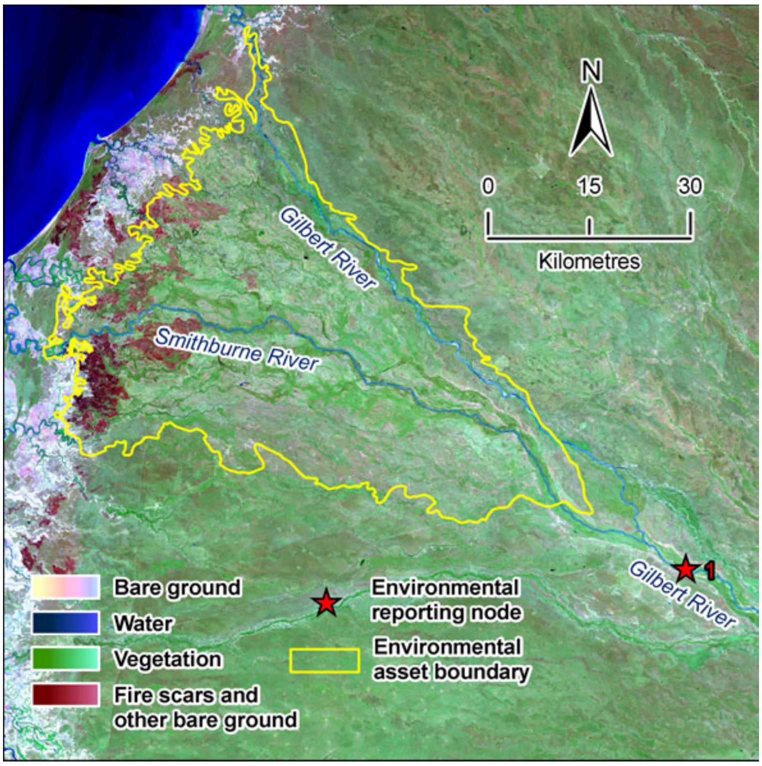

Figure SE-9. False colour satellite image of the Smithburne–Gilbert Fan Aggregation (derived from ACRES, 2000). Clouds may be visible in image

The Smithburne–Gilbert Fan Aggregation contains the greatest concentration of coastal floodplain lagoonal wetlands in the western Cape York Peninsula (Environment Australia, 2001). These provide important dry season (May to October) habitat for many birds. A breeding rookery on the Smithburne River is one of the largest in the western Cape York Peninsula.

Southern Gulf Aggregation

This huge coastal aggregation covers an area of 546,000 ha and ranges in elevation from zero to 10 m above sea level (Figure SE-10). This wetland area extends across three of the regions defined for this project: the Flinders-Leichhardt, South-West Gulf and South-East Gulf regions. In the South-East Gulf region we are considering reporting node 4. The Southern Gulf Aggregation is a complex continuous wetland aggregation (Blackman et al., 1992) that also encompasses several complex disjunct aggregations of closed depressions. Seaward to landward it comprises a continuum of extensive marine intertidal flats, beaches and foredunes, secondary dunes and swales, saline clay plains, seaward margins of saline clay plains, margins and levees of tidal channels, low elevated plains, and depressions within low elevated plains. The area is under the dominating influence of estuarine tides and massive freshwater flooding during wet season events.

Marine and estuarine tidal waters permanently inundate or regularly flood much of the area. This wet season flooding consists of freshwater from the streams and rivers of the inland catchment combined with local runoff from the plains of the Gulf Fall. The wetlands occurring along the inland margins of the area are brackish and all are seasonal. The aggregation has a major influence on nutrient flow into the Gulf of Carpentaria (Wolanski, 1993).The Southern Gulf Aggregation is the largest continuous estuarine wetland aggregation of its type in northern Australia. It is one of the three most important areas for shorebirds in Australia (Watkins, 1993).

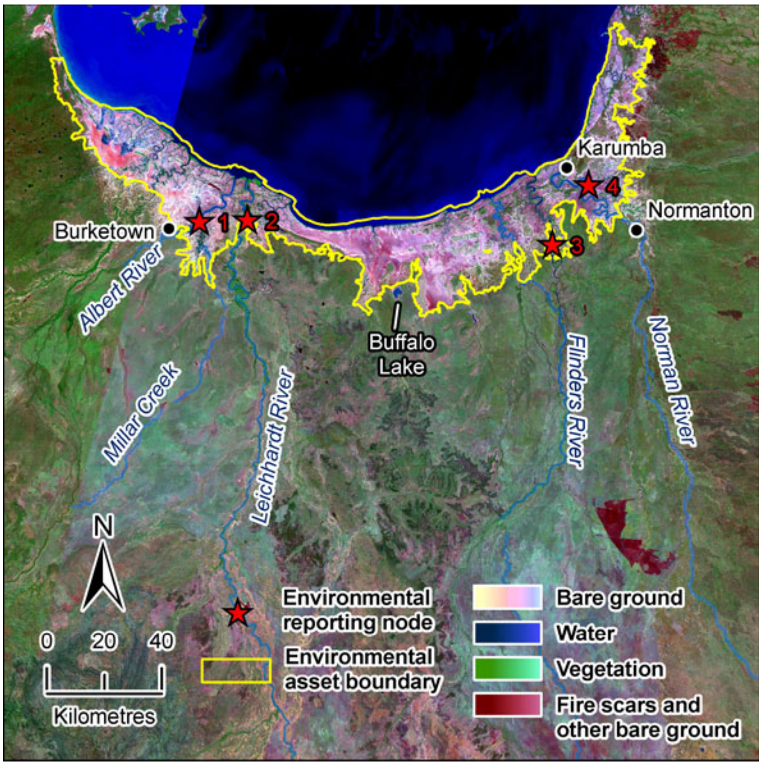

Figure SE-10. False colour satellite image of the Southern Gulf Aggregation (derived from (ACRES, 2000). Clouds may be visible in image

SE-2.2 Data availability

SE-2.2.1 Climate

The rainfall-runoff modelling uses historical daily climate data (Scenario A) from the SILO database for the period 1 September 1930 to 31 August 2007 at 0.05 x 0.05 degree (~ 5 x 5 km) grid cells. Full details and characterisation of the SILO database are provided at the division level in Section 2.1 of Chapter 2. Scenario B and Scenario C climate data are rescaled versions of the Scenario A data; this is also discussed in Section 2.1 of Chapter 2.

SE-2.2.2 Surface water

Streamflow gauging stations are or have been located at 41 locations within the South-East Gulf region. Fourteen of these gauging stations either: (i) are flood warning stations and measure stage height only; or (ii) have less than ten years of measured data. Of the remaining 27 stations, 18 recorded more than half of their total volume of flow during events that exceed the maximum gauged stage height (MGSH). Figure SE-11 shows the spatial distribution of good quality data (duration) and the percentage of flow above maximum gauged stage height (MGSH) (this assessment was only undertaken on stations with ten years or more data). The location of streamflow gauging stations in the South-East Gulf is biased to locations in the upper Gilbert catchment, although with the redirection of Commonwealth funding for surface water assessment in 1988 approximately 70 percent of the streamflow gauging stations in the Gilbert were closed (seven remain open). The closure of the gauging stations in the lower Gilbert catchment (i.e. Miranda Downs on the Gilbert River, 917009, and Minnie Dip on the Einasleigh River,G917111A) means that a large part of the catchment is now ungauged.

Locating suitable gauging stations and undertaking high flow gaugings in the Norman, Staaten and lower reaches of the Gilbert (the Great Southern Aggregation) is problematic due to extensive flooding that takes place and distributary inflows from neighbouring catchments.

There are ten gauging stations currently operating in the South-East Gulf region at density of one gauge for every 12,200 km^2. For the 13 regions the median number of current gauging stations per region is 12 and the median density of current gauging stations per region is one gauge for every 9,700 km^2. The South-East Gulf region has a low density of current gauging stations relative to the other 12 regions in northern Australia. The density of current gauging stations in the South-East Gulf region is considerably lower than the MDB average. The mean density of current stream gauging stations across the entire MDB is one gauge for every 1,300 km^2.

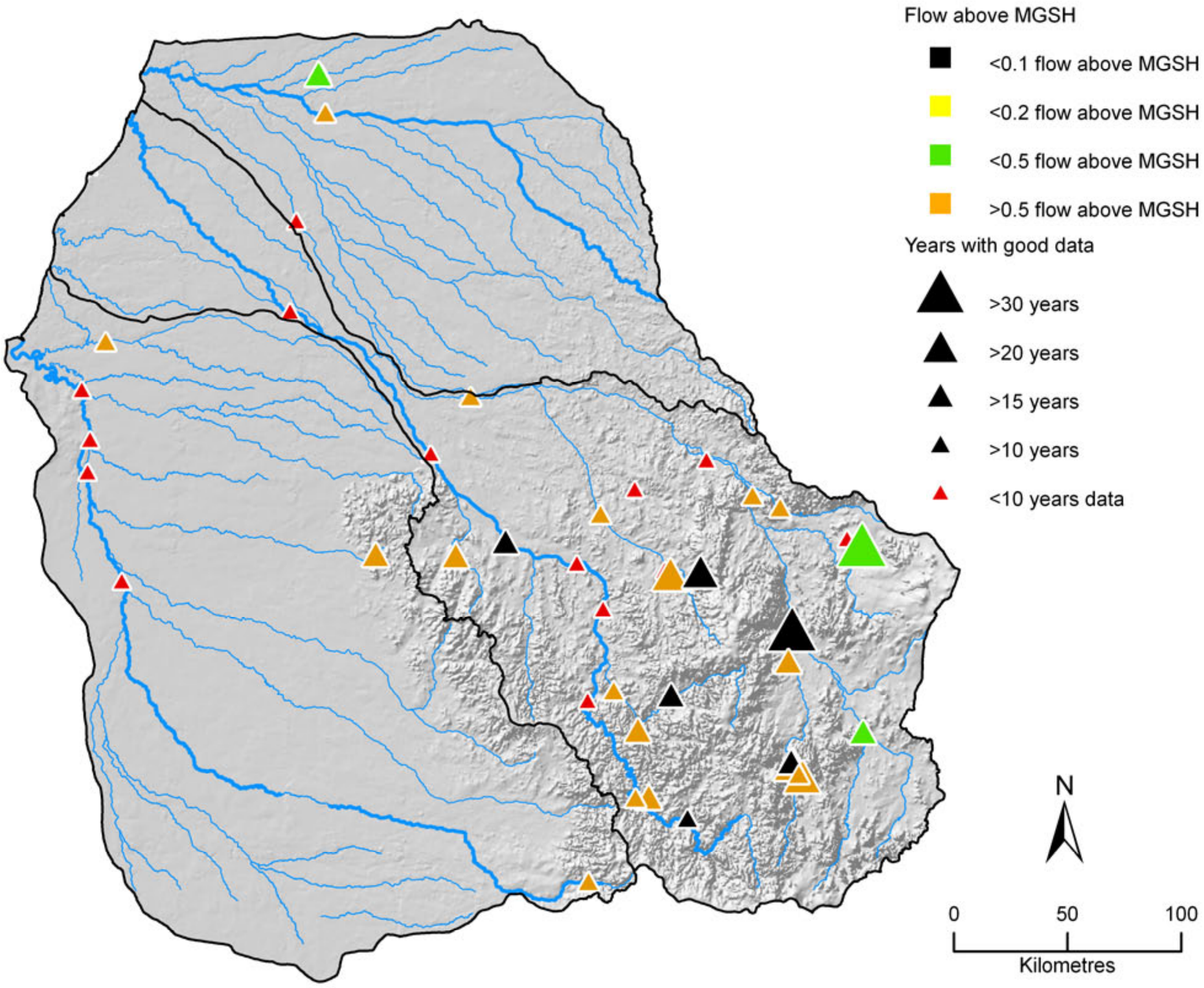

Figure SE-11. Location of streamflow gauging stations overlaid on a relative relief surface showing the proportion of gauges with flow above maximum gauged stage height across the South-East Gulf region

SE-2.2.3 Groundwater

The South-East Gulf region contains a total 811 registered groundwater bores. 375 of these bores have surveyed elevations that could enable a water table surface (or piezometric surface in the case of confined aquifers) to be constructed for the main aquifers. However these bores are not necessarily monitored on a regular basis. According to the Queensland Government databases, there are 27 water level monitoring bores in the region and all are current (Figure SE-12). Of the 27 current monitoring bores, 13 are for the Great Artesian Basin (GAB) aquifer and 14 are for sub-artesian aquifers.

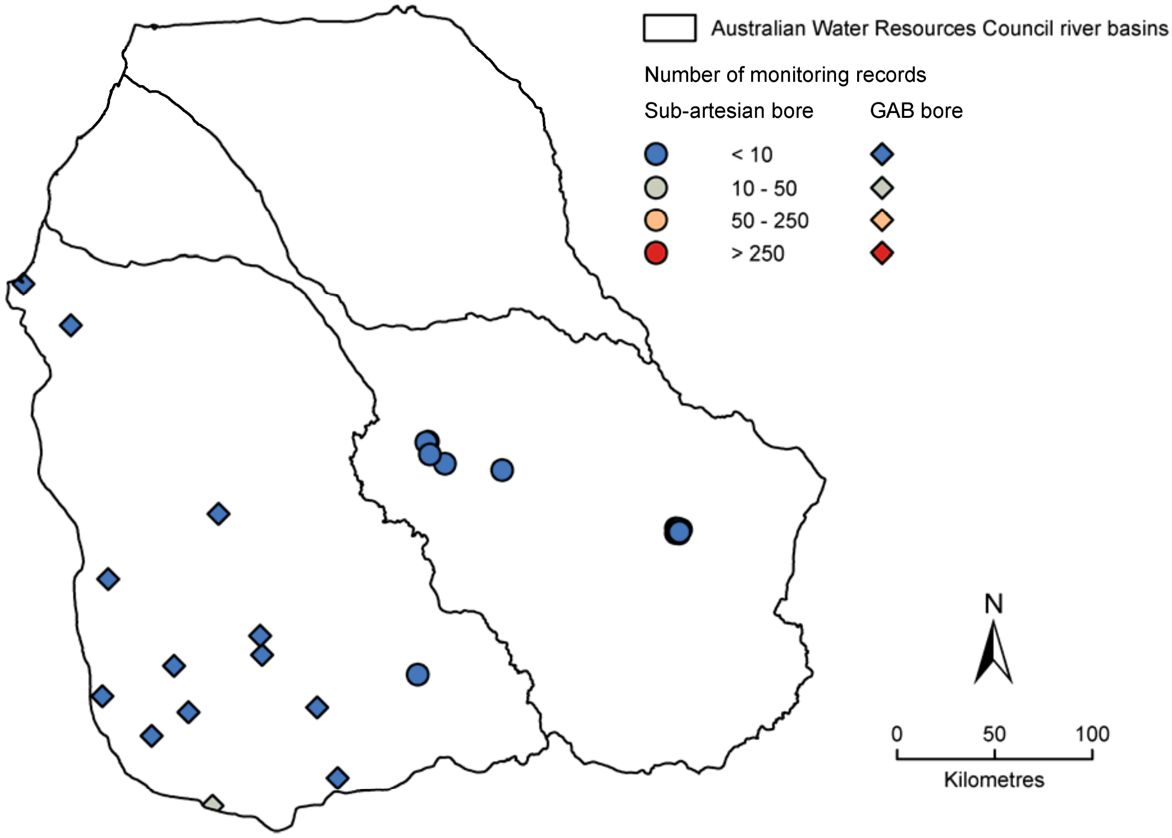

Figure SE-12. Current groundwater monitoring bores in the South-East Gulf region

SE-2.2.4 Data gaps

Additional time series groundwater level and salinity data are required for each of the main aquifer types in the South-East Gulf region to provide greater understanding of recharge processes and inter-aquifer leakage, particularly for the GAB aquifers.

SE-2.3 Hydrogeology

This section describes the key sources of groundwater in the South-East Gulf region.

SE-2.3.1 Aquifer types

The South-East Gulf region comprises four main types of aquifers: (i) fractured rock basement, (ii) sandstones within the Carpentaria Basin of the GAB, (iii) Tertiary sediments, and (iv) Quaternary alluvium and beach ridge deposits (Figure SE-2).

Basement aquifers

Palaeozoic and Precambrian intrusive, volcanic, metamorphic and sedimentary rocks form the basement fractured rock aquifer in this region. Basement outcrop occurs extensively to the east of the region (Smart, 1973). There is no potential for large-scale groundwater development of this aquifer due to low bore yields.

Great Artesian Basin aquifers

The GAB comprises a multi-layered confined aquifer system, with aquifers occurring in Triassic, Jurassic and Cretaceous age continental quartzose sandstones, predominantly confined by low permeability mudstones and siltstones.

The Jurassic Eulo Queen Group sandstone rests conformably on the basement and is limited in extent across the South-East Gulf region. Development of this unit is not significant because water quality and bore yields are variable.

The Gilbert River Formation (which has numerous equivalents including the Wrotham Park Sandstone (Warner, 1967) is the most widespread aquifer in the South-East Gulf region. It rests either on basement or the Eulo Queen Group and forms part of a continuous unit throughout the Carpentaria Basin (Smart et al., 1980). The Gilbert River Formation is often the shallowest major artesian aquifer in the GAB in Queensland and is variable in thickness, which is primarily controlled by basement structure. Aquifer thickness ranges from approximately zero to 100 m in this region (Bultitude & Rees, 1996; Needham and Doutch, 1973; Simpson, 1973; Doutch, 1977; Smart and Bain, 1977) and comprises fine to coarse-grained quartzose sandstone with pebble conglomerate and siltstone. Sediment deposition occurs in lakes, rivers and shallow marine environments. To the west of the region, the Gilbert River Formation is confined and provides artesian groundwater supplies. To the east, where the aquifer is near the surface, groundwater bores are sub-artesian with yields less than 5 L/second.

The Rolling Downs Group is a predominantly argillaceous confining unit and ranges in thickness from approximately 500 to 900 m in the area of the Gilbert and Staaten rivers (Warner, 1967). It comprises mudstone sequences (Wallumbilla Formation and Allaru Mudstone) separated by the calcareous Toolebuc Formation, which is in turn overlain by sandstone and siltstone of the Normanton Formation.

Cainozoic Aquifers

An unconformity exists between the GAB units and the Tertiary Bulimba Formation, with a thick lateritic profile developed on the early Tertiary erosion surface. In some bores the recorded thickness of this weathered material is in the order of 90 m, which indicates a significant hiatus prior to the start of deposition of the Bulimba Formation (Warner, 1967).

The Bulimba Formation comprises fluvial sediments derived mainly from weathering of the Gilbert River Formation outcrop in the eastern part of the region. Aquifers are typically constrained to paleochannels meandering through a matrix of clayey, less transmissive sediments and hence they are not continuous and not always in hydraulic connection with each other.

The Bulimba Formation is essentially present west of the basement margin, either in outcrop or in sub-crop beneath the Wyaaba Beds or Quaternary alluvium. Stratigraphic logs obtained during the 1971 BMR drilling program in the Carpentaria Basin, indicate there are three lithological units within the Bulimba Formation (Grimes, 1972):

- an upper hard, lateritic claystone (between 20 and 50 m thick)

- a clayey quartzose sand unit which contains the aquifer sands (between 50 and 80 m thick, thickening to the west)
- a lower claystone, similar to the uppermost unit, at least 35 m thick.

The Upper Tertiary Wyaaba Beds were deposited as outwash alluvium and consist of fluvial and marine quartzose clays, sandstone and clayey siltstone, with some calcareous sediments and limestone. The Wyaaba Beds unconformably overly the Bulimba Formation and range in thickness from 0 m to 120 m (Needham and Doutch, 1973; (Simpson, 1973). The marine facies of the Wyaaba Beds are characterised by muddy, coralline limestone and form the main aquifers in this formation. The limestone aquifers of the Wyaaba Beds are found near the base of the formation and are up to 50 m thick (DNRMW, 2006). The Wyaaba Beds limestone aquifer is limited to the present day coastline and only supplies artesian water 50 km inland from the coast (Horn et al., 1995). The Wyaaba Beds are not considered a significant groundwater resource outside of the area where the limestone occurs.

Quaternary cover is extensive in this region, however it can be thin or absent in places. The thickness of the Quaternary Cover is typically less than ten metres thick (Smart and Bain, 1977; Simpson, 1973).The Quaternary alluvial sediments consist of clean medium to coarse grained sand deposited in river channels, fine sand deposited on levee banks and extensive silt and clay flood plain deposits. McEniery (1980) described the unconsolidated sediments of alluvial, deltaic and lacustrine deposits in Northern Queensland; however no data exists for the Norman, Gilbert or Staaten River Basins (which comprise this region). McEniery (1980) hypothesised that groundwater supplies are likely to be poor in both yield and quality.

Warner (1967) identified three primary sources of shallow groundwater in the area, including:

- the channels of larger streams such as the Gilbert or Staaten rivers, which consist of clean, medium to coarse grained sands
- near abandoned stream channels, where the characteristically sandy ridges often act as areas of preferential recharge. Hence, although the watertable often resides below the Quaternary deposits, the sandy ridges act as an intake area for the underlying Wyaaba Beds
- coastal areas where fossil dunes contain lenses of fresh groundwater that may provide stock or domestic supplies.

SE-2.3.2 Inter-aquifer connection and leakage

The conceptual model of interconnection between GAB aquifers and overlying Cainozoic sediments is of regional upward leakage from the deep GAB aquifers to the shallow overlying aquifers. Although limited groundwater data suggests there is an upward hydraulic gradient, this does not necessary mean there is measurable leakage.

There are 23 water level readings from bores screened in the Gilbert River Formation and they range from 63 m above ground surface (mAGS) to 39 m below ground surface (mBGS).

There are six bores screened in the Cainozoic aquifers with water level readings. These range from 0.5 mBGS to 24 mBGS, with a median water level reading of 5.5 mBGS. This indicates an upward vertical gradient from the Gilbert River Formation aquifer to the overlying Cainozoic aquifers.

It should be noted that these water level readings are temporally variable, with records ranging from 1962 to 2005 and hence these assumptions have an inherent level of uncertainty.

SE-2.3.3 Recharge, discharge and groundwater storage

Basement aquifers

Recharge to the fractured rock aquifers is principally in the east of the region where they outcrop, and occurs via both vertical infiltration of rainfall and leakage from streams. Discharge occurs as evapotranspiration where the watertable is shallow in the recharge areas to the east, as a completely unknown volume of submarine discharge to the Gulf and via a small component of discharge to springs.

Great Artesian Basin aquifers

Recharge to the GAB aquifers primarily occurs where the sandstone outcrops, along the western slopes of the Great Dividing Range, in areas referred to as ‘recharge beds’ or ‘intake beds’ (Figure SE-2 and Figure SE-13).

Kellett et al. (2003) investigated recharge to the Queensland GAB intake beds from Goondiwindi in the south to approximately 150 km north of Torrens Creek, immediately south of the South-East Gulf region. This investigation identified three primary recharge mechanisms: diffuse rainfall recharge, preferred pathway flow and localised recharge beneath rivers, creeks and alluvial groundwater systems overlying the intake beds. The range of recharge rates associated with the three recharge processes are:

- diffuse rainfall 0.03 to 2.4 mm/year
- preferred pathway flow 0.5 to 28.2 mm/year
- river/aquifer leakage up to 30 mm/year.

Preferred pathway flow involves the movement of water through conduits such as fissures, joints, remnant tree roots or highly permeable beds and is considered the dominant recharge process for the intake beds. The rate of recharge via preferred pathway flow depends on the frequency of episodic high magnitude rainfall events.

Discharge from the GAB occurs in a number of ways:

- As natural discharge from springs. Springs are quite common in the recharge areas along the eastern margins of the GAB and are mainly associated with ‘overflow’ or the ‘rejection’ of recharge into aquifers, or with the interaction between the local topography and aquifers. Flowing springs are also typically associated with faults along which the groundwater flows upwards, with the abutment of aquifers against low hydraulic conductivity bedrock and with pressurised water breaking through thin confining beds near the discharge margin of the basin. Some springs immediately west of the outcrop of the Gilbert River Formation are derived from Gilbert River Formation groundwater penetrating the thin mudstone of the Rolling Downs Group. Small springs occur along the margins of the Gregory Range, although these springs are not all sourced from the GAB aquifers; some are fed from the alluvium and a few from fractured basement rocks.
- As vertical leakage from aquifers upwards through the confining beds towards the regional watertable. This occurs throughout the basin and despite the slow percolation rates, may constitute a significant volume of water.
- As subsurface outflow from the GAB into the Gulf of Carpentaria. Although little is known about the volume or significance of this form of discharge, it is likely to be complex as seismic sections indicate pinching out of GAB sediments in the Gulf.
- As artificial discharge via artesian flow and pumped extraction from bores drilled into aquifers.

Cainozoic aquifers

The Bulimba Formation is recharged via the vertical infiltration of rainfall in outcrop areas and via upward leakage from underlying GAB aquifers.

The Wyaaba limestone aquifer is completely confined and has no known onshore outcrop. The primary recharge mechanism is thought to be via lateral groundwater flow from east to west (DNRW, 2006).

Discharge from these aquifers is likely to occur in the form of evapotranspiration where watertables are close to the surface and as subsurface flow to the Gulf.

Recharge to the alluvial aquifers occurs primarily via the direct infiltration of rainfall (and floodwaters) and lateral flow through sandy river beds during high stage flow events in the wet season. There is also likely to be upward vertical leakage from the GAB aquifers where confining layers are thin and hydraulic pressures high, although the magnitude of such vertical leakage to the alluvium is unknown.

Alluvial deposits also receive recharge through the beach ridges and conversely, leakage of the beach ridge aquifers is likely to occur through the alluvial sediments (Horn et al., 1995).

Discharge from the alluvium predominantly occurs in the form of evapotranspiration; however during the dry season discharge to the rivers also occurs in the form of baseflow.

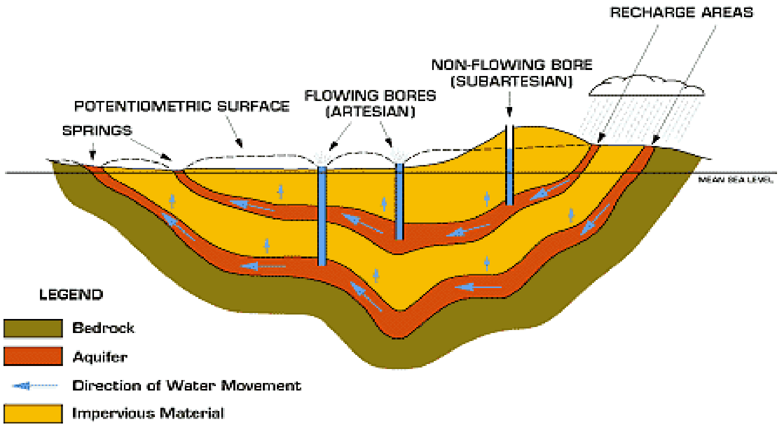

Figure SE-13. Operation of an artesian basin (from (GABCC, 2008)

SE-2.3.4 Groundwater quality

In the South-East Gulf region, good quality groundwater is available from the shallow aquifers, albeit most bores exhibit very low yields.

Between 1962 and 1973 the Queensland Governement recorded groundwater quality information for eight bores constructed in Quaternary alluvium and beach dune deposits (depths from 3 to 43 m). Groundwater salinity ranged from 118 mg/L total dissolved solids (TDS) to 20,100 mg/L TDS, with a mean value from all records of 1102 mg/L TDS.

Groundwater quality of the Wyaaba Beds and Bulimba Formation aquifers are extremely variable, with low salinity groundwater found in the vicinity of streams and higher salinities proximal to the coast. Between 1966 and 1993 the DNRW recorded groundwater quality information for 33 bores constructed in either the Wyaaba Beds or Bulimba Formation (depths from 5 to 229 m). Groundwater salinity ranged from 114 mg/L TDS to 67,000 mg/L TDS, with a mean value from all records of 1454 mg/L TDS.

The groundwater salinity of the Gilbert River Formation aquifers is typically low. However deeper parts of this aquifer typically contain groundwater with high fluoride concentration, thereby precluding its use for stock or human consumption. Between 1987 to 2005 the DNRW recorded groundwater quality information for eight bores in this region (depths from 146 to 343 m). Groundwater salinity ranged from 50 mg/L TDS to 536 mg/L TDS, with a mean value from all records of 290 mg/L TDS.

Figure SE-14 shows groundwater salinity for approximately 225 bores in the region, measured between 1962 and 2007. The salinity values are electrical conductivity (EC) measured in µS/cm (NB. 1 µS/cm ~ 0.6 mg/L TDS). Approximately 40 percent of the bores mapped have a recorded total depth and this ranges from 3 to 381 m; hence the salinity map represents groundwater from different aquifers. Nevertheless, a distinctive pattern is evident in the map with fresher groundwater (EC values of 0 to 750 µS/cm) prominent in the south of the region in the vicinity of the GAB recharge areas (intake beds) and much higher groundwater salinity in the direction of regional groundwater flow to the north west (EC values in excess of 8000 µS/cm). These EC patterns may reflect the pattern of drilling depths, thus spatially biasing the sampling to specific aquifers. For example, progressing towards the gulf the Gilbert River Formation is deeper and thus more expensive to tap, so there is a tendency to drill shallow bores that tap more saline aquifers such as the Rolling Downs Group.

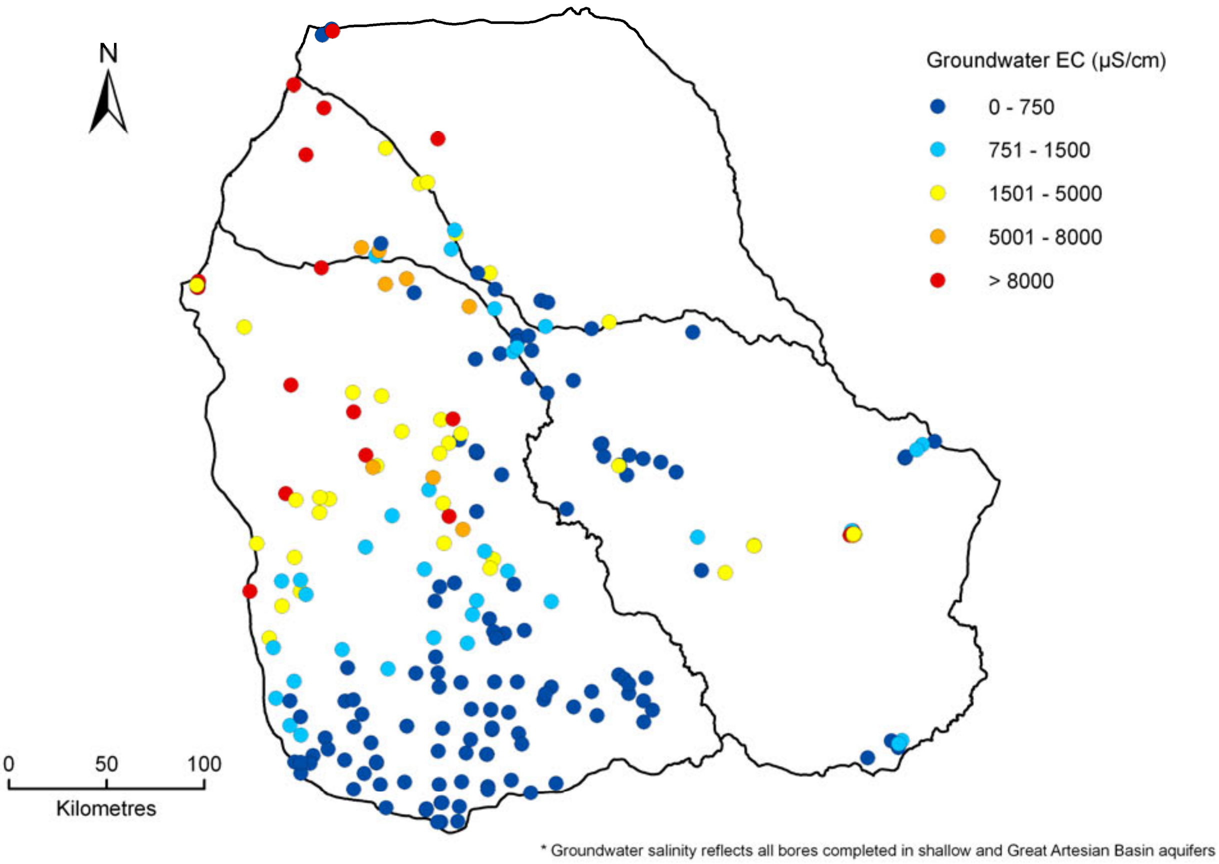

Figure SE-14. Groundwater salinity distribution for all bores drilled in the South-East Gulf region

SE-2.4 Legislation, water plans and other arrangements

SE-2.4.1 Legislated water use, entitlements and purpose

Water entitlements and use in the South-East Gulf region are governed by the *Water Resources (Gulf) Plan* (DNRW, 2007). Current surface water allocations are shown in Table SE-3. A Resource Operations Plan is currently under review and consultation.

Table SE-3. Current surface water allocations for the South-East Gulf region

Allocation type	Location	Total volume
		ML/y
Norman River Basin		
Irrigation	-	0
Town water supply and industrial	Not specified	2,100
Non-riparian stock and domestic	-	0
Gilbert River Basin		
Irrigation	Not specified	9,115
Town water supply and industrial	Not specified	20
Non-riparian stock and domestic	Not specified	4,880
Staatan River Basin		
-	-	0
Total volume		**16,115**

The Staaten River basin is a declared wild river area. The *Wild Rivers Act 2005* includes a process for the Minister for Environment and Resource Management to declare wild river areas. The intent of the *Staaten Wild River Declaration 2007* is to preserve the natural values of wild rivers in the Staaten wild river area. It does this by regulating most future development activities and resource allocations within the Staaten wild river area. Water allocations for the Staaten wild river area are dealt with under the *Water Resource (Gulf) Plan 2007*. In the wild river area new development activities will be regulated through existing development assessment process with wild river requirements applied through the wild river declaration or the wild rivers code. Developments and authorisations in place at the time the declaration was made are not affected.

SE-2.4.2 Groundwater use and entitlements

There is minor demand for groundwater across the South-East Gulf region due to its isolation and low population (ANRA, 2008a). Most stock and domestic supplies are obtained from permanent waterholes in creek and river courses, with only a small number of supplies (i.e. approximately 80 licences recorded by the DNRW) obtained from groundwater bores (Warner, 1967).

Groundwater entitlement volumes and estimated stock and domestic use volumes were reported as part of the *GAB Water Resource Plan* (DNRM, 2005). This information was collated in terms of the Management Areas defined for the GAB in Queensland (Figure SE-15) and has been reconfigured by the DNRW to estimate volumes for the Northern Australia Sustainable Yield project reporting regions.

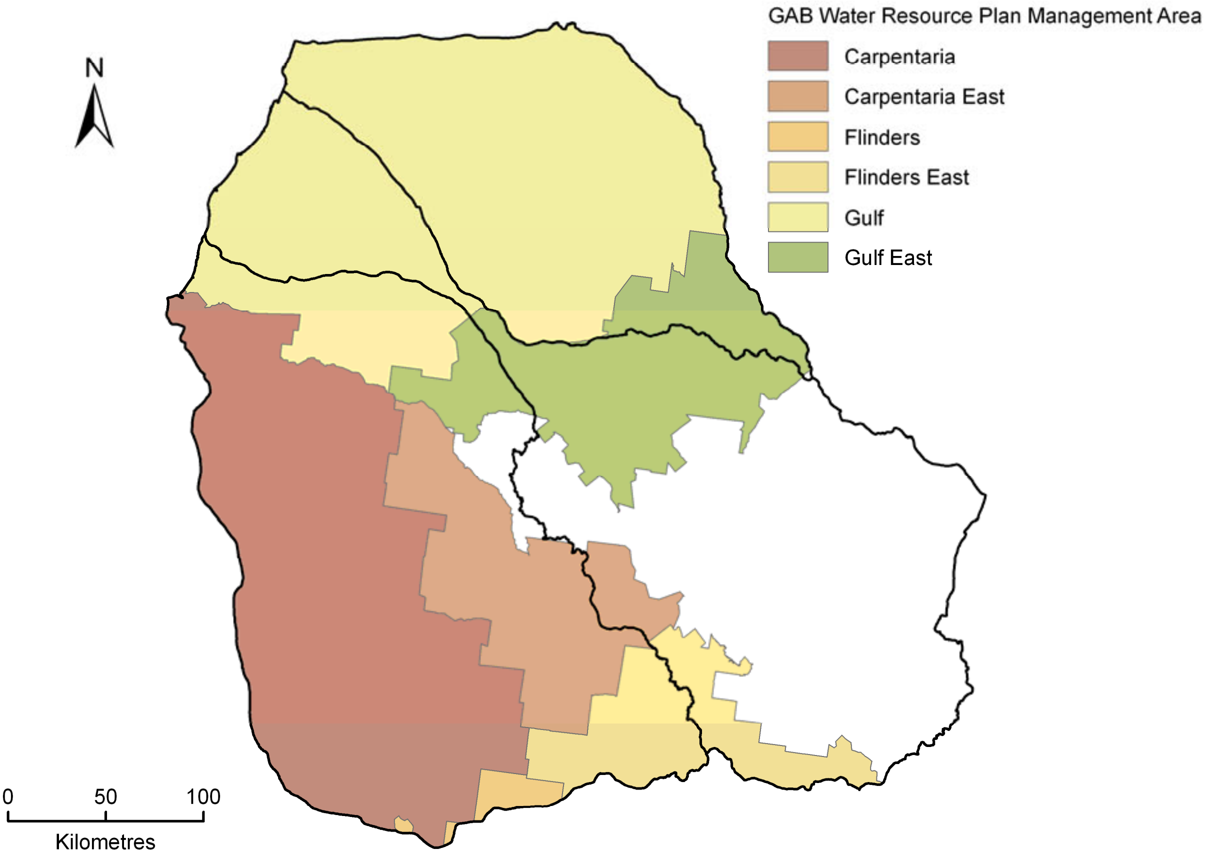

Figure SE-15. Groundwater management areas of the Great Artesian Basin in the South-East Gulf region

Groundwater of the GAB is vital to the outback regions of Queensland, as it is often the only water supply available for towns and properties for their stock and domestic requirements. It also supplies water for industrial purposes such as mining, power generation, aquaculture, feedlots and piggeries. However, the predominant current use in the GAB is by far, for stock and domestic purposes.

For the South-East Gulf region the estimated volume of stock and domestic use is approximately 11 GL/year and the volume of licensed entitlements is less than 1 GL/year (Table SE-4). This table shows that approximately 95 percent of stock and domestic use is extracted from the GAB aquifers, whilst the volume of licensed entitlements is smaller and predominantly associated with the Cainozoic sediments in the Karumba Basin.

Table SE-4. Estimated stock and domestic groundwater use and sum of groundwater entitlements for the South-East Gulf region

Formation	Stock and domestic use	Entitlement
	GL/y	
Quaternary alluvium	0.05	0.000
Cainozoic sediments/basalt (including Karumba Basin)	0.35	0.500
Jurassic/cretaceous sedimentary rocks	0.02	0.000
Jurassic – Early Cretaceous Great Artesian Basin aquifers	10.50	0.193
Palaeozoic rocks	0.05	0.000
Proterozoic rocks	0.160	0.000
Total volume	**11.122**	**0.693**

The Eulo Queen Group is developed only for stock and domestic purposes. Supplies from the Gilbert River Formation are also limited, due to low yields and a high fluoride concentration (DNRM, 2005). The Normanton Town bore however, is supplied from the Gilbert River Formation artesian aquifer, yielding 13 L/second (Simpson, 1973).

Very little extraction occurs from the Rolling Downs Group because of generally low yields and aquifers occurring only in isolated lenses of the Wallumbilla Formation. Although there has been an increase in the number of bores extracting groundwater from the Gilbert River and Wallumbilla formations over recent years, the density of bores is likely to be limited due to the prohibitive depth of the aquifer.

A limited number of bores utilise the Bulimba Formation or the Wyaaba Beds aquifers for groundwater use. Supplies are typically small, owing to poor permeability and in some cases the water from the Wyaaba Beds is saline and the fluoride content high (Smart and Bain, 1977).

SE-2.4.3 Rivers and storages

There are few major storages in the region. The Kidston Dam on the Copperfield River in the far south-east of the Gilbert River basin is the largest with an active storage of 18.5 GL. The Staaten has no major storages and the Norman River has two small local storages (Table SE-5).

Table SE-5. Instream storages in the Norman and Gilbert rivers (within the IQQM modelled area)

Storage name	River	Capacity
		ML
Norman river basin		
Belmore Creek Dam	Belmore Creek	2,500
Glenore Weir	Norman River	1,850
Total		**4,350**
Gilbert river basin		
Kidston Dam	Copperfield River	18,500
Mt Hogan water supply dam	Bernecker Creek	700
Total		**19,200**

SE-2.4.4 Unallocated water

Unallocated water in the river basins of the South-East Gulf region can be held as a general reserve (general unallocated water) or a strategic reserve (strategic unallocated water). There is currently no definition of the location from which future extraction of unallocated surface water may come.

Table SE-6. Current unallocated surface water allocations in the South-East Gulf region

Allocation type	Location	Total volume
		ML/y
Norman River Basin		
General allocation	Undefined	3,000
Strategic allocation (State purpose)	Undefined	2,000
Unlicensed extraction (overland flow)	-	Insignificant
Gilbert River Basin		
General allocation	Undefined	15,000
Strategic allocation (State purpose)	Undefined	5,000
Unlicensed extraction (overland flow)	-	Insignificant
Staatan River Basin		
General allocation	Undefined	1,000
Strategic allocation (State purpose)	Undefined	1,000
Unlicensed extraction (overland flow)	-	Insignificant
Total volume		**27,000**

SE-2.4.5 Social and cultural considerations

The *Gulf (draft) Resource Operations Plan* provides for ‘the protection of water-related cultural values of Aboriginal and Torres Strait Islander communities’ (DNRW, 2008). Under the plan, the health and needs of natural values are addressed through provisions that are consistent with the general and ecological outcomes of the water resource plan. These outcomes aim to sustain natural characteristics such as variability of flows and water levels, which provide for, and support, native animal and plant communities; protect the natural attributes of the river systems to support the habitats of native plants and animals in watercourses, floodplains, wetlands, lakes and springs, and ensure connectivity of river systems to allow for the passage of fish species, which maintains natural populations as well as enabling fresh water to reach estuaries and the Gulf of Carpentaria (DNRW, 2008).

SE-2.4.6 Changed diversion and extraction regimes

There is little demand for water in this region due to its isolation and low population.

SE-2.4.7 Changed land use

The region is in an isolated area with little or no development.

SE-2.4.8 Environmental and legislative constraints and implications of future development

The wetlands of the South-East region are amongst the most pristine and important wetlands of Australia (Environment Australia, 2001), with particular importance for shorebird breeding sites.

The *Gulf (draft) Resource Operations Plan* defines proposed conditions and requirements relating to existing and any future water licences to ensure that arrangements for the taking of water are consistent with local conditions. This includes defined pass flow requirements to ensure that downstream requirements will be met.

Environmental needs are met by provisions that will ensure total water use from existing and future entitlements does not amount to more than 0.35 percent of the overall mean annual discharge or the median annual discharge to the Gulf of Carpentaria, as stipulated under the *Water Resource (Gulf) Plan 2007*.

Within the Gilbert River Basin, specific ecological outcomes are to be achieved between AMTD 317 km and AMTD 263 km, such that:

- aquatic habitats for native plants and animals, particularly during dry seasons, are maintained
- riparian vegetation is supported
- there is contribution to the flow of the Gilbert River.

The *Staaten Wild River Declaration 2007* prohibits activities with greatest potential for negative impacts on the natural values of the wild river (such as dams and weirs, intensive animal husbandry, intensive agriculture and stream re-alignment). Prohibitions generally apply in the high preservation area, but can also apply in other management areas.

Prohibitions are generally applied through the legislation that regulates that particular type of activity. For example, instream weirs and dams are not permitted in high preservation area through provisions in the *Water Act 2000*.

SE-2.5 References

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SE-3 Water balance results for the South-East Gulf region

This chapter describes modelling results and the assessment of the water resources undertaken by this project for the South-East Gulf region. Detailed, quantified assessments are made where possible, and relevant, and confidence is estimated. Modelling results are reported under climate and development scenarios as defined at the division level in Section 2.1 of Chapter 2. This chapter is sub-divided into:

- climate
- recharge estimation
- conceptual groundwater models
- groundwater modelling results
- rainfall-runoff modelling results
- river system water balance
- changes to flow regimes at environmental assets.

SE-3.1 Climate

SE-3.1.1 Historical climate

The South-East Gulf region receives an average of 750 mm of rainfall over the September to August water year (Figure SE-16), most of which (710 mm) falls in the November to April wet season (Figure SE-17). Across the region there is a strong north–south gradient in annual rainfall (Figure SE-18), ranging from 1078 mm in the north to 490 mm in the south. Over the historical (1930 to 2007) period, yearly rainfall has remained reasonably constant. The highest regionally averaged yearly rainfall received was 2126 mm which fell in 1974, and the lowest was 329 mm in 1952.

Areal potential evapotranspiration (APET) under the historical climate is very high across the region, averaging 1980 mm over a water year (Figure SE-16), and varies moderately across the seasons (Figure SE-17). APET generally remains higher than rainfall for most of the year resulting in near-year-round water-limited conditions. The exceptions to this are the months January to March, when more rain falls than can potentially be evaporated.

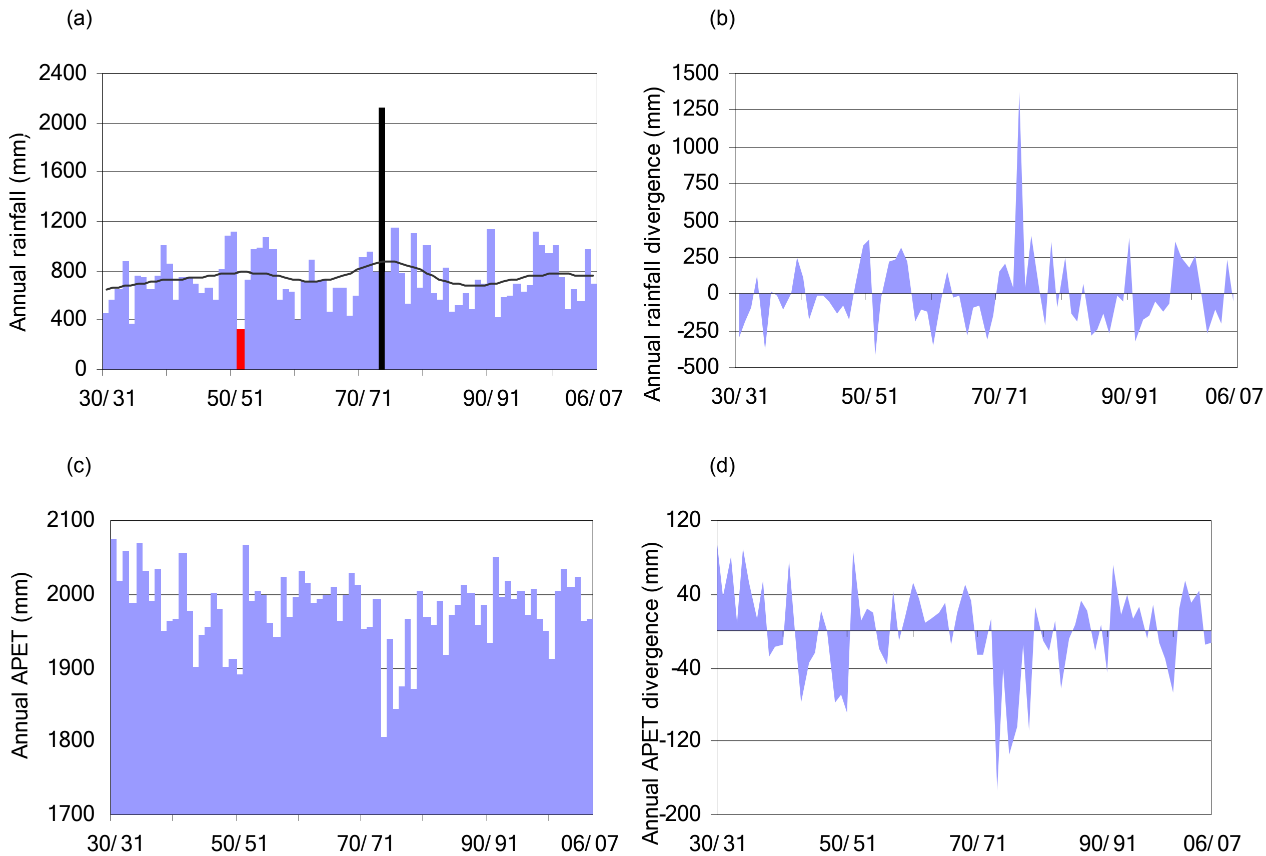


Figure SE-16. (a) Historical annual rainfall and (b) its divergence from the long-term mean; and (c) historical annual areal potential evapotranspiration and (d) its divergence from the long-term mean averaged over the South-East Gulf region. The low-frequency smoothed line in (a) indicates longer term variability

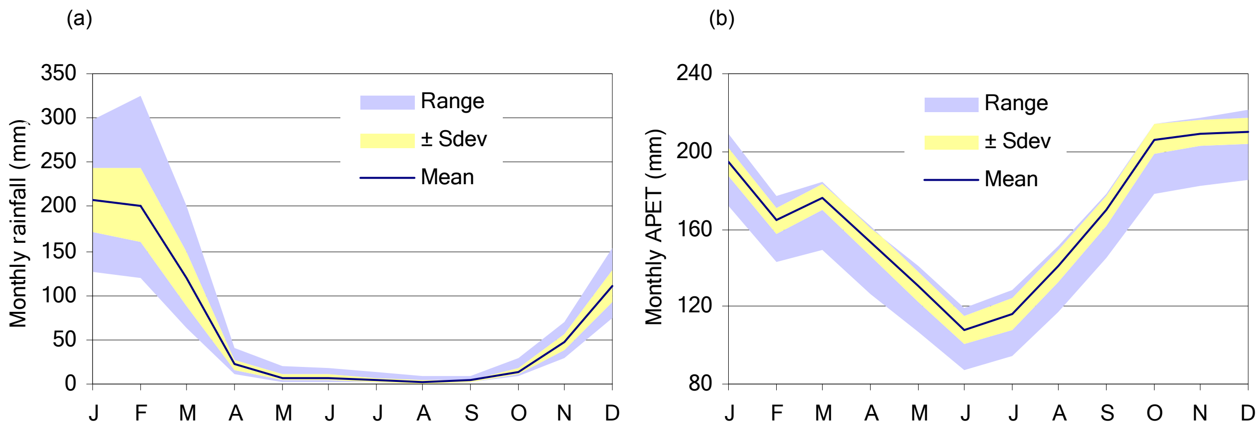


Figure SE-17. Historical mean monthly (a) rainfall and (b) areal potential evapotranspiration and their temporal variation (range and ± one standard deviation) averaged over the South-East Gulf region

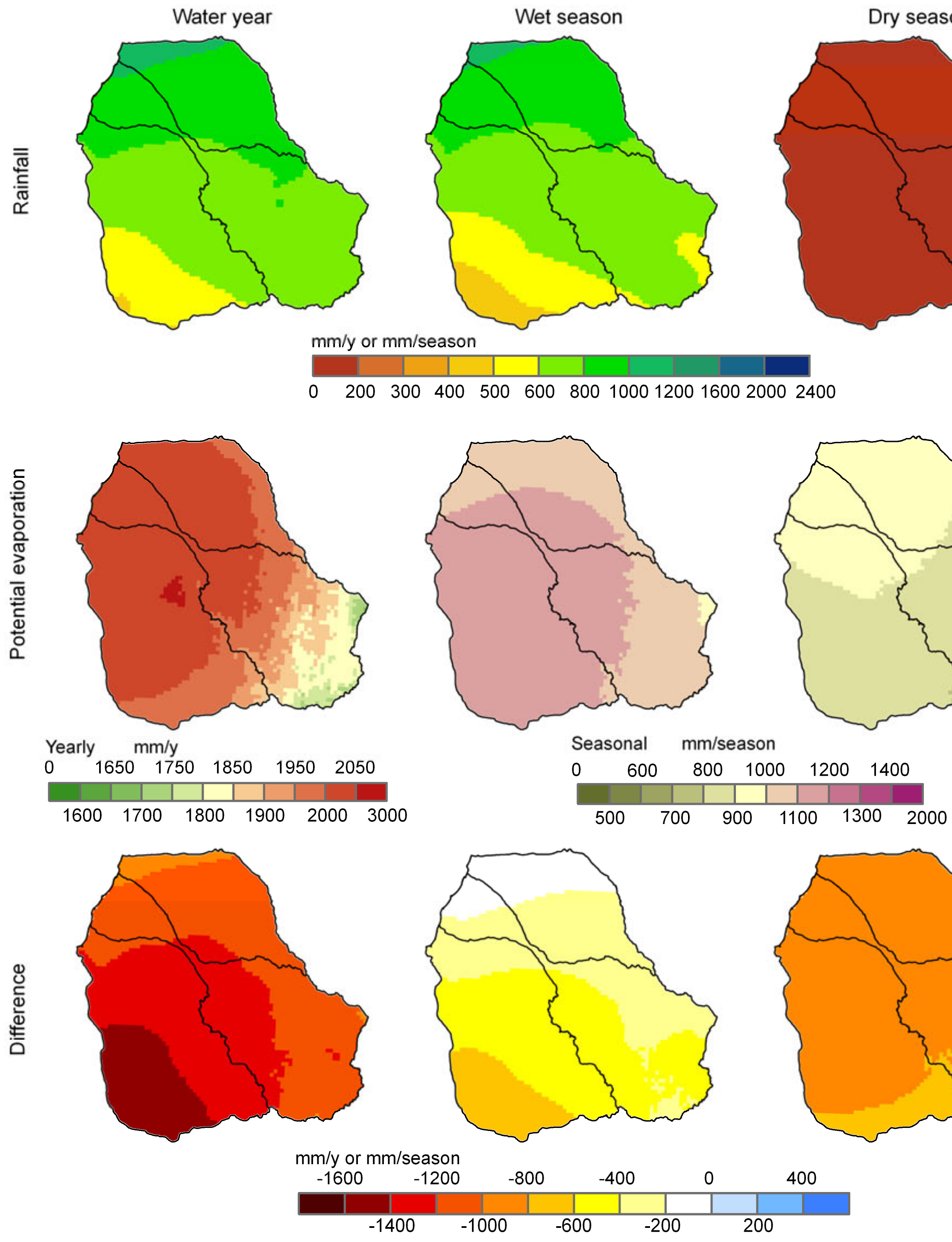


Figure SE-18. Spatial distribution of historical mean annual (water year), wet season and dry season rainfall and areal potential evapotranspiration (potential evaporation) and their difference (rainfall less areal potential evapotranspiration) across the South-East Gulf region

SE-3.1.2 Recent climate

Figure SE-19 compares recent (1996 to 2007) to the preceding 66-year period (1930 to 1996) mean annual rainfall for the South-East Gulf region. Across the whole region, recent rainfall is usually between zero and 20 percent higher than historical rainfall – a difference which is not statistically significant for the majority of the region.

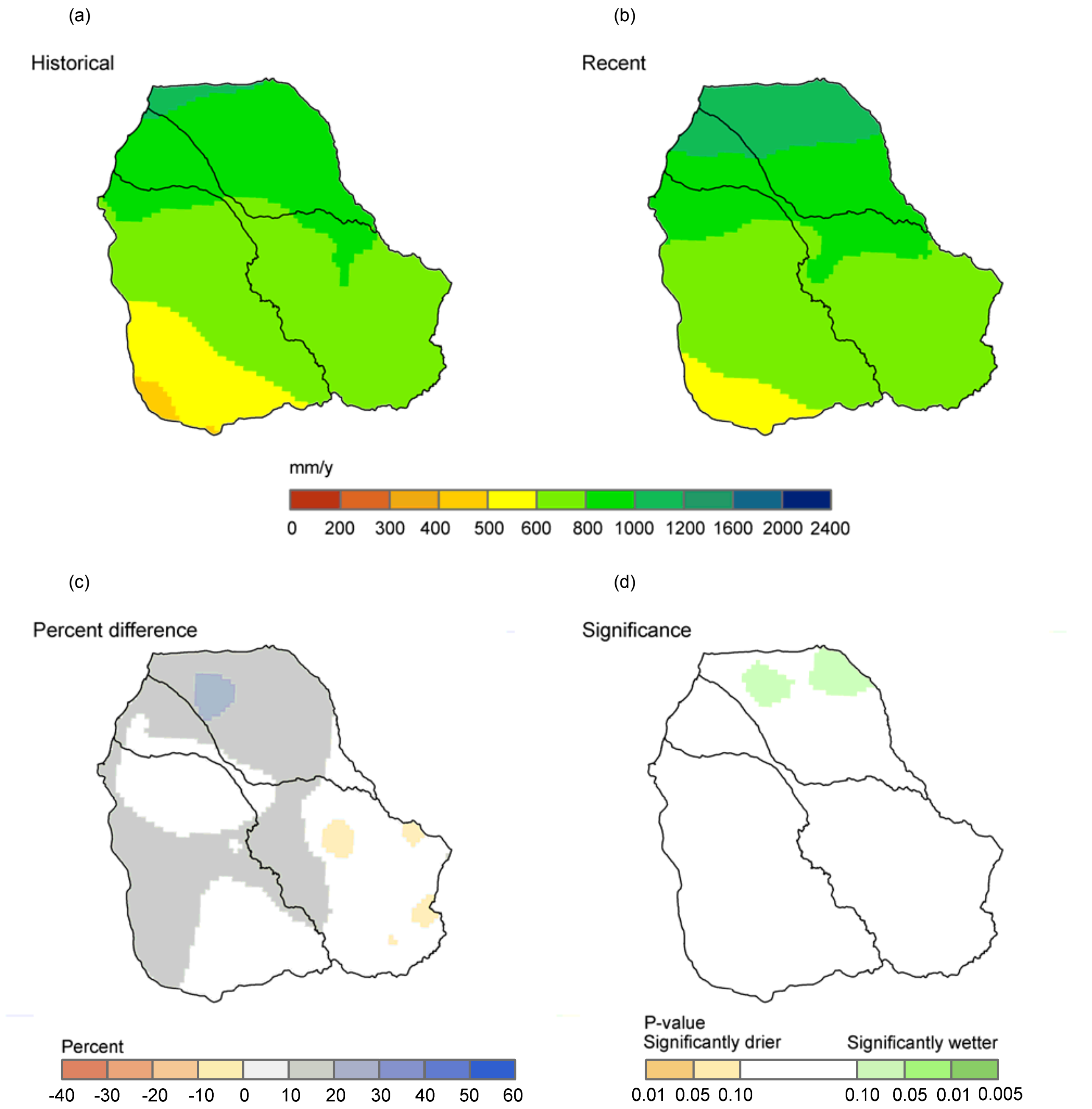


Figure SE-19. Spatial distribution of (a) historical and (b) recent mean annual rainfall; and (c) their relative percent difference and (d) the statistical significance of these differences across the South-East Gulf region. (Note that historical in this case is the 66-year period 1930 to 1996)

SE-3.1.3 Future climate

Under Scenario C annual rainfall varies between 698 mm and 855 mm (Table SE-7) compared to the historical mean of 750 mm. Similarly, APET ranges between 2026 and 2065 mm compared to the historical mean of 1980 mm.

A total of 45 variants of Scenario C were modelled (15 GCMs for each of the high, medium and low global warming scenarios). Subsequently, results from an extreme 'wet', median and extreme 'dry' variant are shown (referred to as scenarios Cwet, Cmid and Cdry). Under Scenario Cwet annual rainfall and APET increase by 14 percent and 3 percent, respectively. Under Scenario Cmid annual rainfall is the same as the historical mean and APET increases by 2 percent. Under Scenario Cdry annual rainfall decreases by 7 percent and APET increases by 4 percent.

Under Scenario Cmid long-term monthly averages of rainfall do not differ much from historical values (Figure SE-20). Rainfall under Scenario Cmid lies well within the range in values from all 45 future climate variants. APET is consistently slightly higher than historical values throughout the year under Scenario Cmid. The seasonality of both rainfall and APET is not expected to change substantially. Under Scenario Cmid APET lies at the lower end of the range in values derived from all 45 Scenario C variants, primarily in the wet season.

The spatial distributions of rainfall and APET under Scenario C are compared to the historical distribution in Figure SE-21 and Figure SE-22. Under Scenario C the strong north–south gradient in rainfall is retained, but with a southwards shift under Scenario Cwet and a northwards shift under Scenario Cdry. The spatial distribution of APET under Scenario C is similar to the historical distribution.

Table SE-7. Mean annual (water year), wet season and dry season rainfall and areal potential evapotranspiration averaged over the South-East Gulf region under historical climate and Scenario C

	Water year	Wet season	Dry season
	mm/y	mm/season	
Rainfall			
Historical	750	710	40
Cwet	855	803	42
Cmid	750	702	39
Cdry	698	657	32
Areal potential evapotranspiration			
Historical	1980	1109	871
Cwet	2035	1132	899
Cmid	2026	1128	894
Cdry	2065	1153	908

* Note that the sum of the wet season and dry season values does not always equal the water year values because the combined wet season and dry season period (November to October) is different to the water year period (September to August).

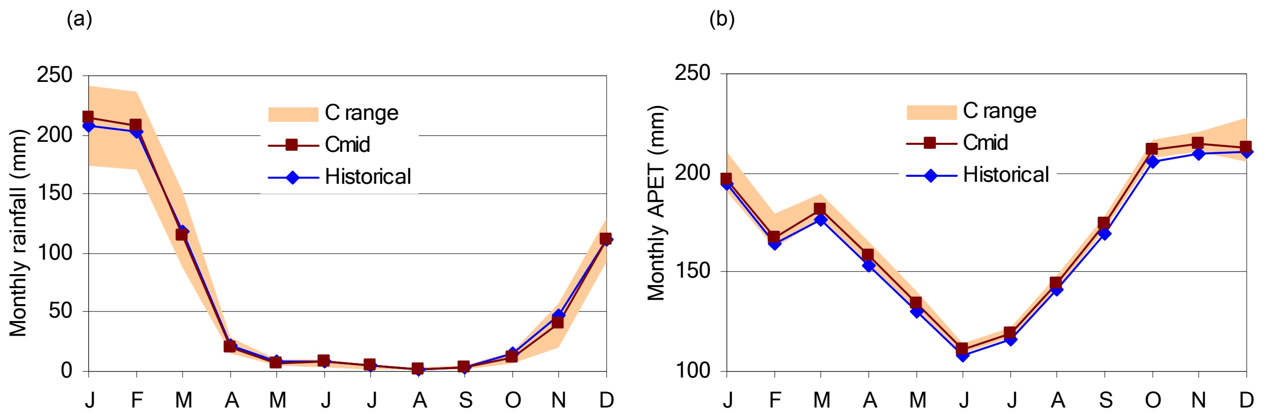


Figure SE-20. Mean monthly (a) rainfall and (b) areal potential evapotranspiration averaged over the South-East Gulf region under historical climate and Scenario C. (C range is the range under the 45 Scenario C simulations – the lower and upper limits in C range are therefore not the same as scenarios Cdry and Cwet)

SE-3.1.4 Confidence levels

Analysis of confidence of the climate data is presented in Section 2.1.4 in the division-level Chapter 2.

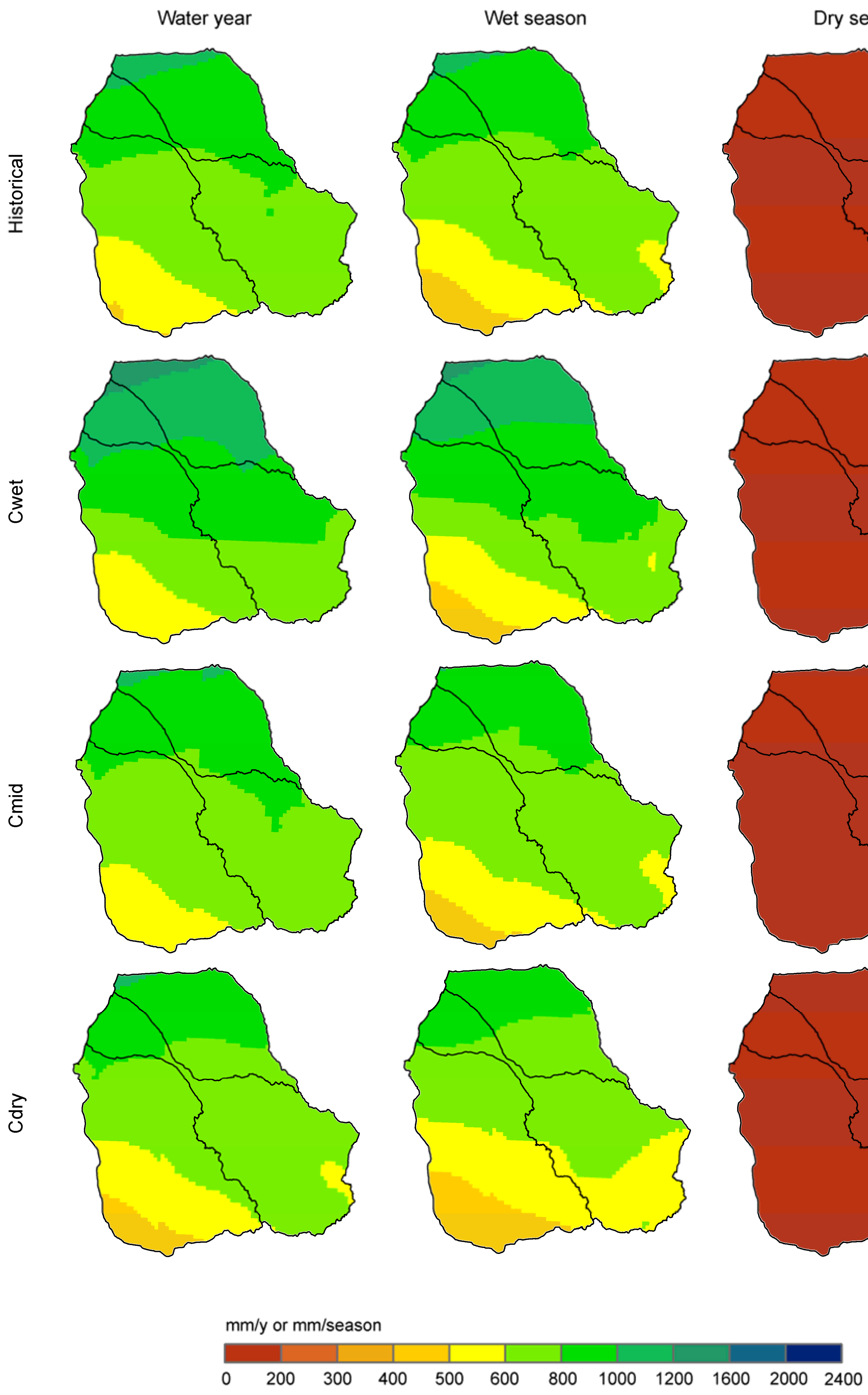


Figure SE-21. Spatial distribution of mean annual (water year), wet season and dry season rainfall across the South-East Gulf region under historical climate and Scenario C

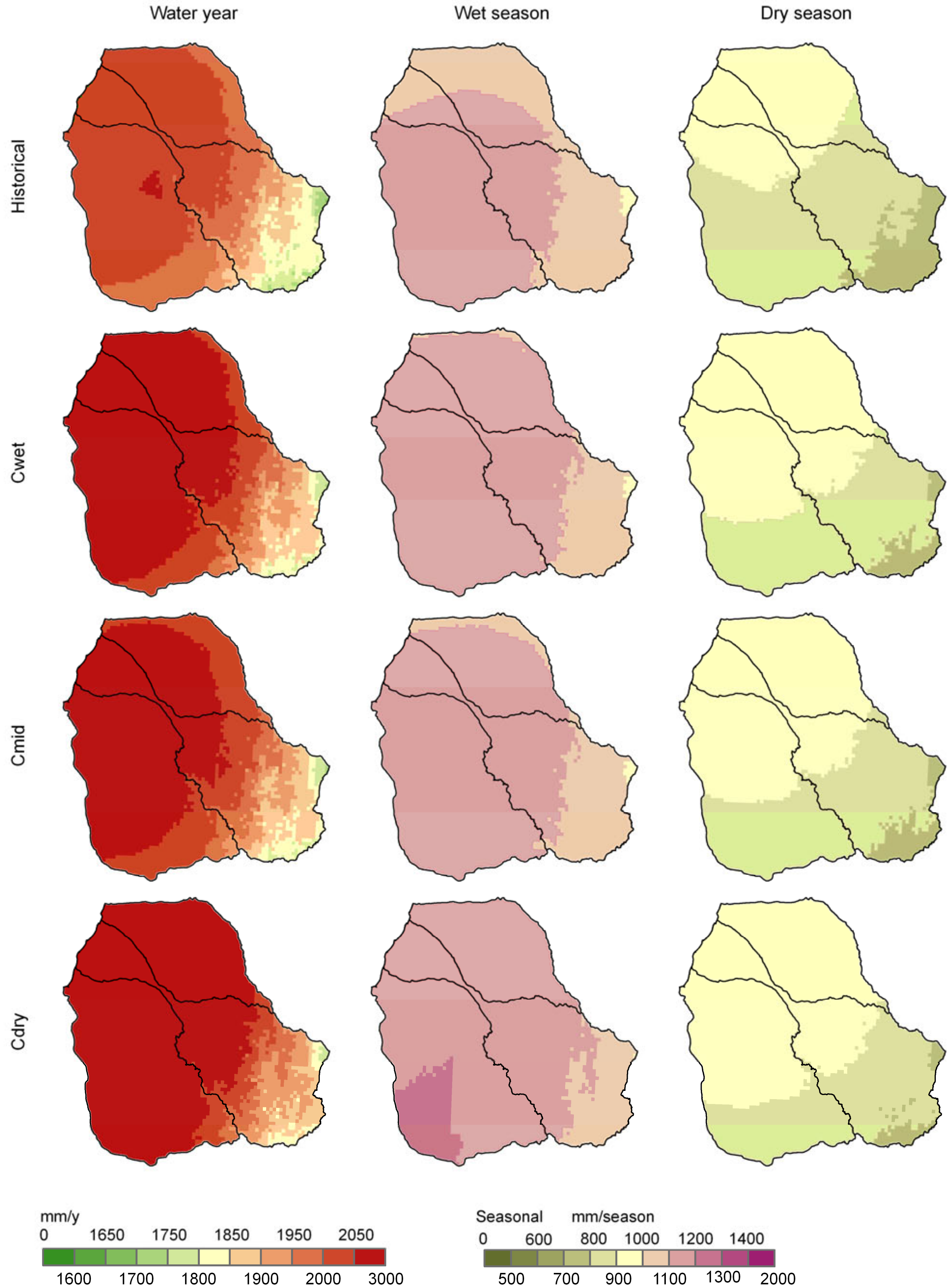


Figure SE-22. Spatial distribution of annual (water year), wet season and dry season areal potential evapotranspiration across the South-East Gulf region under historical climate and Scenario C

SE-3.2 WAVES potential diffuse recharge estimations

The WAVES model (Zhang and Dawes, 1998) was used to estimate the change in groundwater recharge across the South-East Gulf region under a range of different climate scenarios. WAVES is a vertical recharge flux model that can model plant physiological feedbacks in response to increased CO_2, as well as modelling the water balance of different soil, vegetation and climate regimes. It was chosen for its balance in complexity between plant physiology and soil physics. It was also used to assess recharge for the Murray-Darling Basin Sustainable Yields Project (Crosbie et al., 2008).

SE-3.2.1 Under historical climate

The calculated historical recharge for the South-East Gulf region shows that recharge is comparatively low when compared to the other regions. We assessed the historical record to establish any difference between wet and dry periods of recharge. We used a 23-year period, which allows us to project recharge estimates to 2030 – in other words, estimate recharge in 2030 assuming future climate is similar to historical climate (Scenario A). Under a wet historical climate (Awet) the South-East Gulf region is calculated to have a 12 percent increase in recharge. Under the median estimate of historical climate (Amid) the South-East Gulf region is calculated to have a 3 percent decrease in recharge. Under a dry historical climate (Adry) the South-East Gulf region is calculated to have a 14 percent decrease in recharge.

Table SE-8. Recharge scaling factors for scenarios A, B and C

Region	Awet	Amid	Adry	B	Cwet	Cmid	Cdry
South-East Gulf	1.12	0.97	0.86	0.94	1.49	1.10	0.98

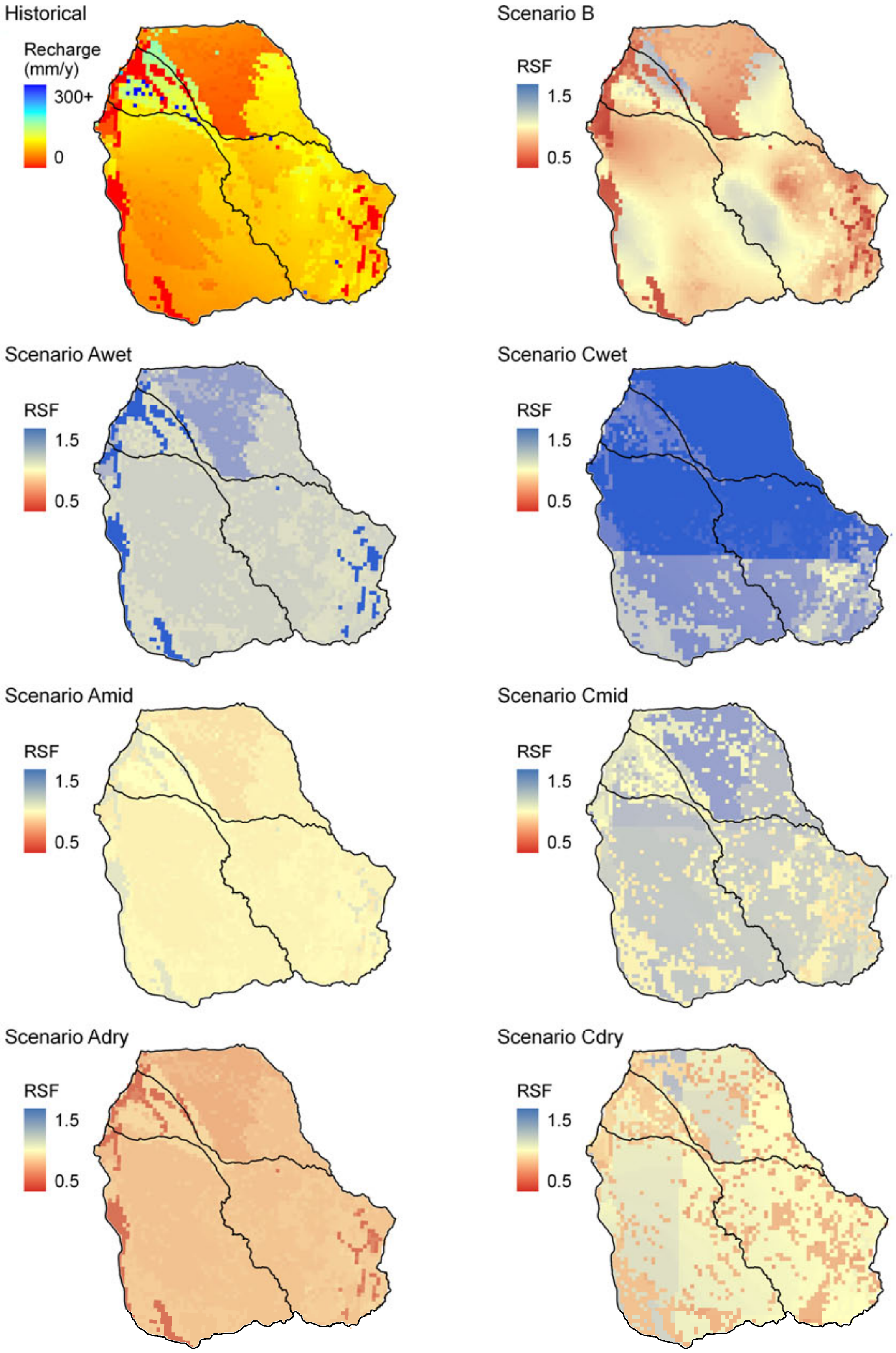


Figure SE-23. Spatial distribution of historical mean recharge rate; and recharge scaling factors for scenarios A, B and C across the South-East Gulf region

SE-3.2.2 Under recent climate

The years 1996 to 2007 in the South-East Gulf region have been drier than the historical (1930 to 2007) average and consequently the calculated recharge has, on average, decreased by 6 percent compared to the historical average

(Table SE-8). This decrease has not been uniform with some areas showing an increase in recharge and others a decrease in recharge (Figure SE-23).

SE-3.2.3 Under future climate

Figure SE-24 shows the percentage change in modelled mean annual recharge averaged over the South-East Gulf region for Scenario C relative to Scenario A for the 45 scenarios (15 GCMs for each of the high, medium and low global warming scenarios). The percentage change in the mean annual rainfall and recharge from the corresponding GCMs are also tabulated in Table SE-9. In some scenarios the recharge is projected to increase despite a decrease in rainfall. This is because total rainfall is not the only climate variable that has an influence over recharge, Daily rainfall intensity, temperature and CO_2 concentration are also important drivers (see Section 2.3.3 in the division-level Chapter 2), and specific situations can result in this counter-intuitive result. In particular, rainfall intensity is seen as a significant factor in this relationship.

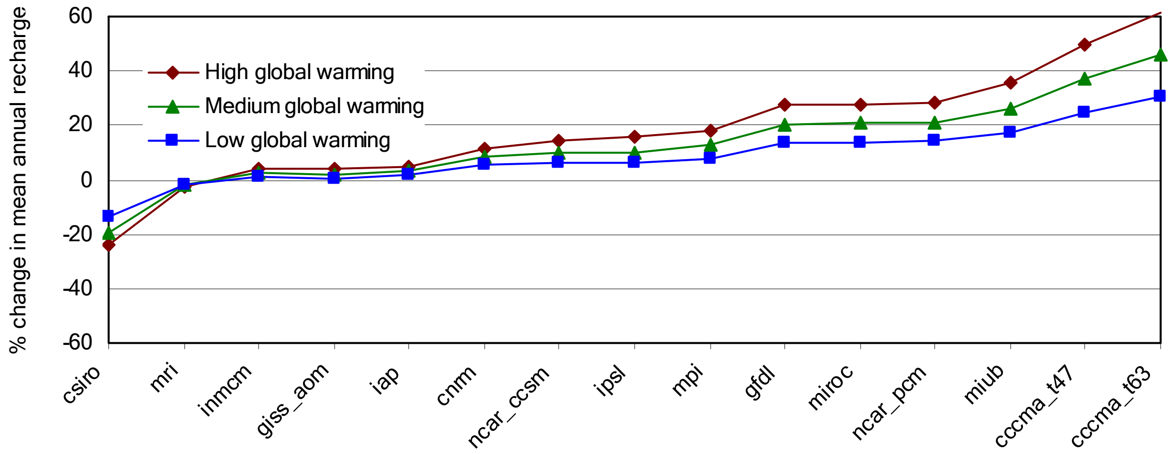


Figure SE-24. Percentage change in mean annual recharge under the 45 Scenario C simulations (15 global climate models and three global warming scenarios relative to Scenario A recharge

Table SE-9. Summary results under the 45 Scenario C simulations (numbers show percentage change in mean annual rainfall and recharge under Scenario C relative to Scenario A)

High global warming			Medium global warming			Low global warming		
GCM	Rainfall	Recharge	GCM	Rainfall	Recharge	GCM	Rainfall	Recharge
csiro	-22%	-24%	csiro	-17%	-19%	csiro	-12%	-14%
mri	**-7%**	**-2%**	mri	-5%	-2%	mri	-4%	-2%
inmcm	-2%	4%	inmcm	-1%	2%	inmcm	-1%	1%
giss_aom	-5%	4%	giss_aom	-4%	2%	giss_aom	-2%	1%
iap	-3%	5%	iap	-2%	4%	iap	-1%	2%
cnrm	-2%	12%	cnrm	-2%	8%	cnrm	-1%	6%
ncar_ccsm	2%	15%	ncar_ccsm	1%	10%	ncar_ccsm	1%	6%
ipsl	1%	16%	**ipsl**	**1%**	**10%**	ipsl	0%	6%
mpi	-1%	18%	mpi	-1%	13%	mpi	-1%	8%
gfdl	0%	28%	gfdl	0%	20%	gfdl	0%	14%
miroc	4%	28%	miroc	3%	21%	miroc	2%	13%
ncar_pcm	7%	28%	ncar_pcm	5%	21%	ncar_pcm	4%	14%
miub	6%	35%	miub	4%	26%	miub	3%	17%
cccma_t47	**14%**	**49%**	cccma_t47	11%	37%	cccma_t47	8%	25%
cccma_t63	14%	62%	cccma_t63	11%	46%	cccma_t63	8%	31%

Under the wet extreme future climate (Scenario Cwet) the South-East Gulf region is calculated to have a 49 percent increase in recharge with the greatest increases in the north. Under the median future climate (Scenario Cmid) the South-East Gulf region is calculated to have a 10 percent increase in recharge. Under the dry extreme future climate (Scenario Cdry) the South-East Gulf region is calculated to have a 2 percent decrease in recharge.

SE-3.2.4 Confidence levels

The estimation of recharge from WAVES is only indicative of the actual recharge and has not been validated with field measurements. A steady state groundwater chloride mass balance (CMB) has been conducted as an independent measure of recharge (Crosbie et al., 2009). The results in the South-East Gulf region show that the historical estimate of recharge using WAVES (68 mm/year) is greater than the best estimate using the CMB (57 mm/year) but it is within the confidence limits of the CMB (9 to 235 mm/year). It is noted that Kellett et al. (2003) report recharge rates of 10 to 15 mm/year around Torrens Creek to the south.

SE-3.3 Conceptual groundwater models

The basement fractured rock aquifer outcrops extensively to the east of the region and provides a poor source of groundwater largely owing to variable yields. Recharge to the fractured rock aquifer is principally via both vertical infiltration of rainfall and leakage from streams. Discharge occurs via several mechanisms, including: (i) evapotranspiration where the watertable is shallow in the recharge areas to the east; (ii) a small component of discharge to springs; and (iii) a small amount of baseflow (see Section SE-3.3.1). Groundwater may also discharge directly into the gulf, however there is no information to support this hypothesis.

The Gilbert River Formation is the most widespread aquifer in the South-East Gulf region. To the west of the region it is confined by the overlying Rolling Downs Group and provides artesian groundwater supplies, while to the east, where the aquifer is near the surface, groundwater bores are sub-artesian and low yielding. Recharge to the GAB aquifers primarily occurs where the sandstone outcrops, along the western slopes of the Great Dividing Range. Discharge from the GAB aquifers occurs as upward vertical leakage towards the regional watertable, subsurface outflow from the GAB into the Gulf, as discharge to springs and a minor component of groundwater extraction. The township of Normanton relies on artesian groundwater supply from the Gilbert River Formation, although because of elevated fluoride concentrations the groundwater must be blended with a surface water supply from Glenore weir.

Spring discharge occurs in the outcrop areas of the Gilbert River Formation and Eulo Queen Group due to rejected recharge, where topography is steep and incised. Where rivers intersect these aquifers, they receive baseflow for much of the dry season (May to October). Groundwater discharge from the Gilbert River Formation supports flow in the Norman River, Yappar River and Clara River, as well as Boorabin Creek. During the wet season (November to April), water infiltrates from the river to the aquifers, either laterally via the incised sediments, or vertically via diffuse floodout recharge when overbank flooding occurs.

The Bulimba Formation is present west of the basement margin, either in outcrop or sub-crop beneath the Wyaaba Beds or Quaternary alluvium. Aquifers are typically constrained to old stream channels and hence are not always in hydraulic connection with each other. Recharge occurs where the Bulimba Formation is found in outcrop and also from upward vertical leakage from underlying GAB aquifers. Discharge occurs as subsurface outflow and as baseflow to creeks, which helps maintain flow into the dry season.

The Upper Tertiary Wyaaba Beds unconformably overly the Bulimba Formation. The marine facies of the Wyaaba Beds form the main aquifers in this formation and is limited to 50 km inland from the present day coastline. It is completely confined and the primary recharge mechanism is considered to be via lateral groundwater inflow from the east. Discharge occurs as subsurface flow to the Gulf and via a small volume of groundwater extraction.

Quaternary cover is extensive in this region, but can be thin or absent in places. Groundwater supplies are considered poor in both yield and quality. Recharge to the alluvial aquifers is predominantly via the direct infiltration of rainfall. River valley alluvium also receives recharge via lateral flow through the sandy river beds during the wet season high river flows. Vertical infiltration occurs on the extensive floodplain when the river floods and upward vertical leakage from the GAB aquifers occurs where confining layers are thin and hydraulic pressures high. Discharge from the alluvium predominantly occurs in the form of evapotranspiration; however during the dry season discharge to the rivers also occurs in the form of baseflow.

SE-3.3.1 Baseflow index analysis

The results of the baseflow analysis for suitable gauges in the South-East Gulf region are provided in Table SE-1. The annual baseflow index (BFI) values range from 0.05 to 0.26 (n=12, median = 0.11). Figure SE-02 shows the surface geology of the South-East Gulf region and the average volume of dry season baseflow to rivers. This figure indicates that dry season baseflow is small at the gauges analysed, with a maximum volume of 5 GL. However, the majority of the river gauges analysed (i.e. 10 out of the 12) are located outside the GAB and incise the older fractured rock aquifers. Therefore baseflow could be more significant in other parts of the region where GAB aquifers are encountered.

SE-3.4 Groundwater modelling results

The limited data for the region precluded the development of quantitative groundwater models.

SE-3.5 Rainfall-runoff modelling results

In this section the term runoff is the sum of overland flow, interflow and baseflow. It is equivalent to streamflow expressed as a mm depth equivalent. All plots show data averaged over the modelled subcatchments of the South-East Gulf region. For this reason rainfall reported in this section may vary slightly from that reported elsewhere due to differences between the catchment boundaries (shown in Figure SE-1) and the DEM-derived catchment boundaries used here. In this section, where annual data are reported years are represented by numbers 1 through 77. Consistently throughout this report, annual data are based on the water year (1 September to 31 August) and the dry season is defined as 1 May to 31 October. Unless stated otherwise scenarios Cwet, Cmid and Cdry are selected on the basis of the ranked mean annual runoff. For more details on methods refer to Section 2.2 of the division-level Chapter 2.

SE-3.5.1 Regional synopsis

The rainfall-runoff modelling estimates runoff in 0.05 degree grid cells in 48 subcatchments (Figure SE-25). Optimised parameter values from ten calibration catchments are used. Seven of these calibration catchments are in the Gilbert catchment, one is on the Norman and one is in the Staaten. The remaining calibration catchment is in the Mitchell region to the north. The calibration catchments in the Gilbert are located in the mid to upper reaches.

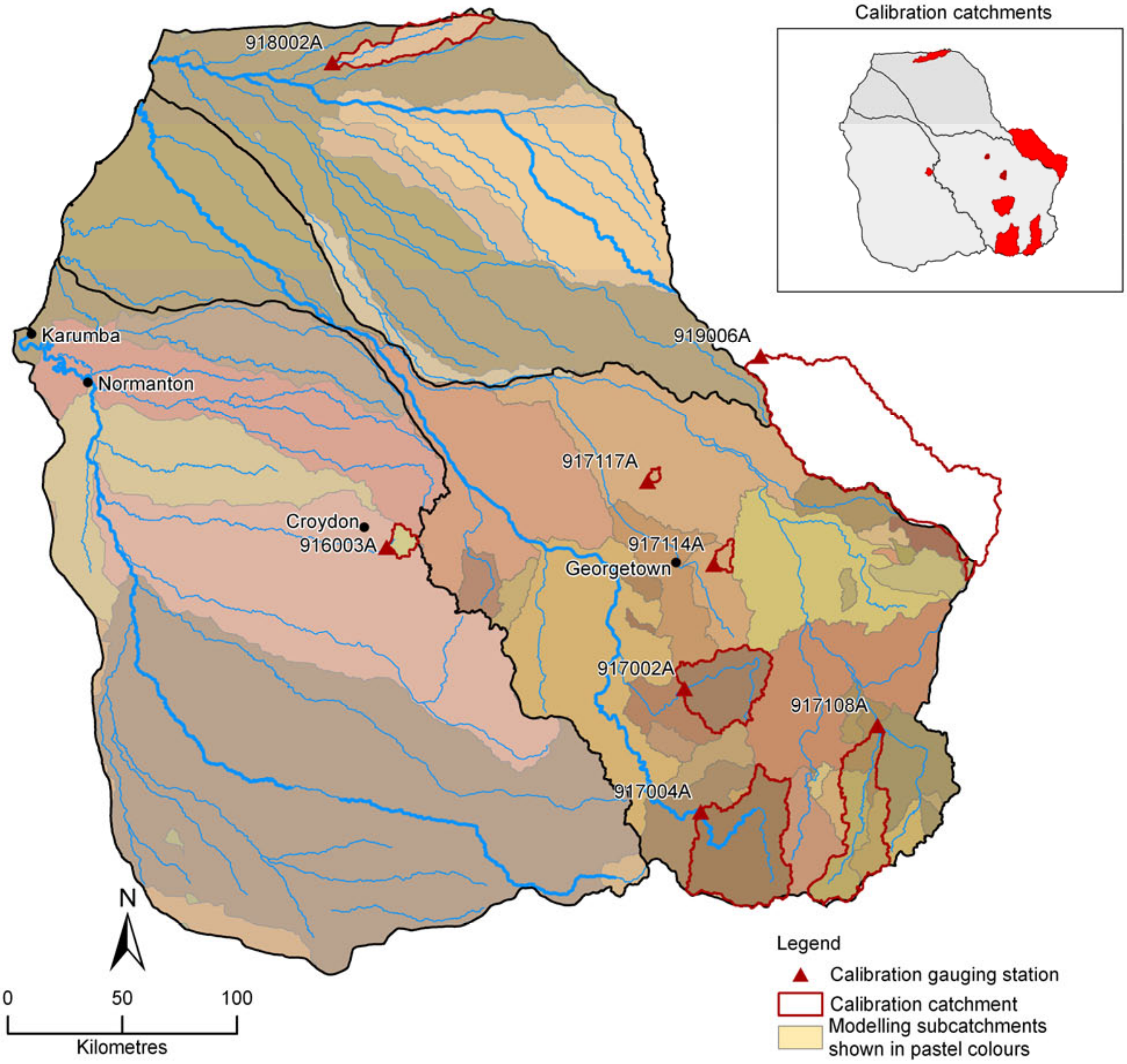


Figure SE-25. Map of the modelling subcatchments, calibration catchments and calibration gauging stations used for the South-East Gulf region with inset highlighting (in red) the extent of the calibration catchments

SE-3.5.2 Model calibration

Figure SE-26 compares the modelled and observed monthly runoff and the modelled and observed daily flow exceedance curves for the eight calibration catchments. Nash-Sutcliffe efficiency (NSE) values provide a quantitative measure of how well simulated values match observed values. NSE values are described in more detail in Section 2.2.3 of the division-level Chapter 2. On the monthly plots NSE is the monthly Nash-Sutcliffe efficiency value and NSE (dry season) is the dry season monthly Nash-Sutcliffe efficiency value. On the daily flow exceedance plots, NSE is the daily flow exceedance curve Nash-Sutcliffe efficiency value and NSE (50 to 100 percent) is the lower half of the daily flow exeedance curve Nash-Sutcliffe efficiency value.

The results indicate that the ensemble calibration of the rainfall-runoff models Sacramento and IhacresClassic can reasonably reproduce the observed monthly runoff series (NSE values generally greater than 0.7), but only satisfactorily reproduces the daily flow exceedance curves (NSE values generally greater than 0.9) for the purposes of simulating long-term average monthly and annual streamflow. The volumetric constraint used in the model calibration also ensures that the total modelled runoff is within 5 percent of the total observed runoff.

The calibration method places more importance on the simulation of high runoff, and therefore rainfall-runoff modelling of the medium and high runoff is considerably better than the modelling of low runoff. This is demonstrated by the relatively low NSE values for the monthly dry season and lower half of the daily flow exceedance curve. It should be noted, however, that while the relative difference between the observed and simulated low flow values may be large (which is what gives rise to the low monthly dry season NSE values for example), the absolute difference between the observed and simulated low flow values is generally small because both values are small. Nevertheless, an optimisation to reduce overall error variance can result in some underestimation of high runoff and overestimation of low runoff. This is evident in some of the scatter plots comparing the modelled and observed monthly runoff and many of the daily flow exceedance curves. In many of the catchments the disagreement between the modelled and observed daily runoff curves is discernable for runoff that at 1 percent of the time. This is accentuated in the plots because of the linear scale on the y-axis and normal probability scale on the x-axis. In any case, the volumetric constraint used in the model calibration ensures that the total modelled runoff is always within 5 percent of the total observed runoff.

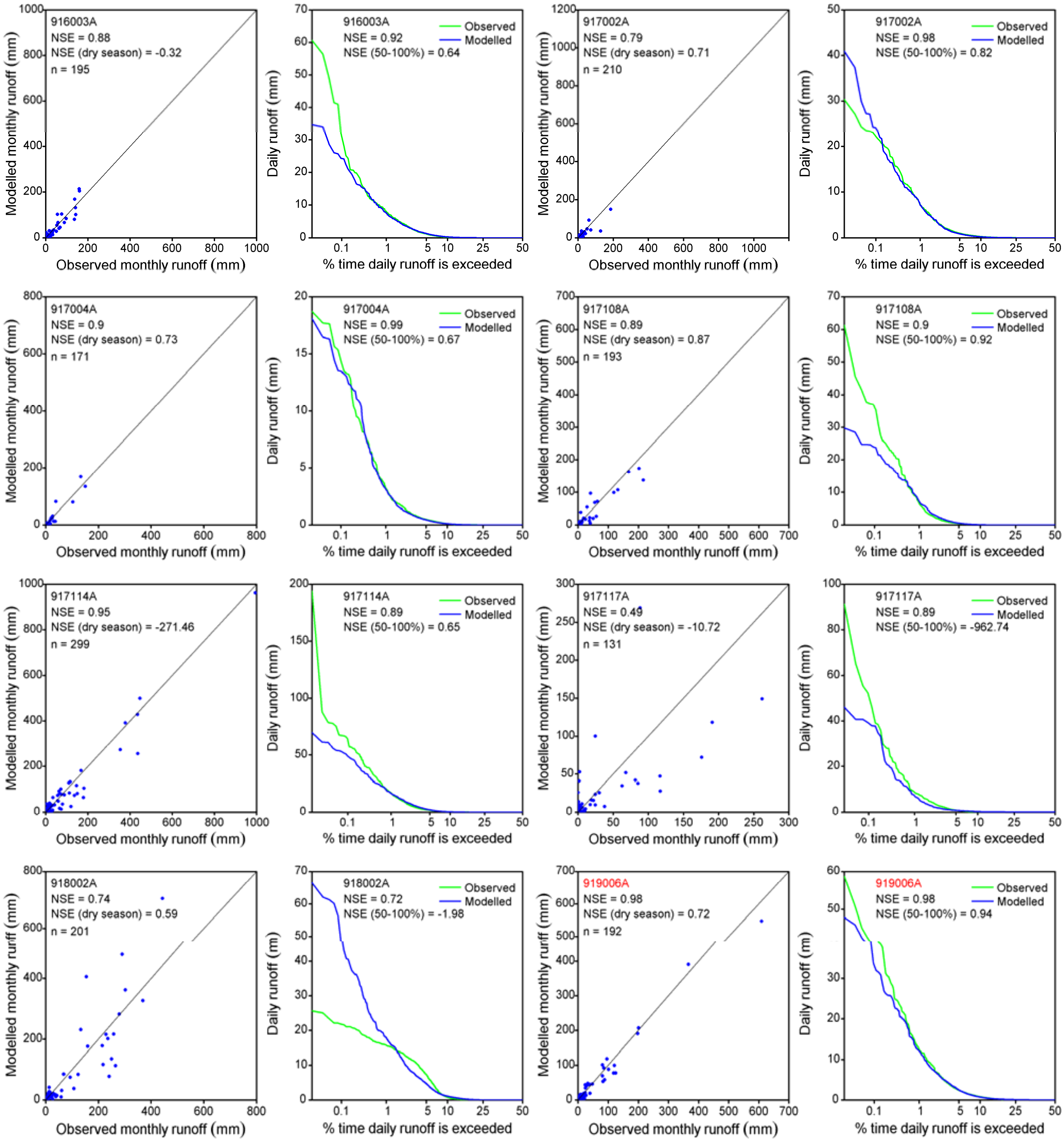


Figure SE-26. Modelled and observed monthly runoff and daily flow exceedance curve for each calibration catchment in the South-East Gulf region. (Red text denotes catchments located outside the region; blue text denotes gauges used to predict streamflow only)

SE-3.5.3 Under historical climate

Figure SE-27 shows the spatial distribution of mean annual rainfall and runoff under Scenario A (averaged over 1930 to 2007) across the South-East Gulf region. Figure SE-28 shows the mean annual rainfall and runoff averaged over the region.

The mean annual rainfall and runoff averaged over the South-East Gulf region are 752 mm and 113 mm respectively. The mean wet season and dry season runoff averaged over the South-East Gulf region are 112 mm and 1 mm respectively.

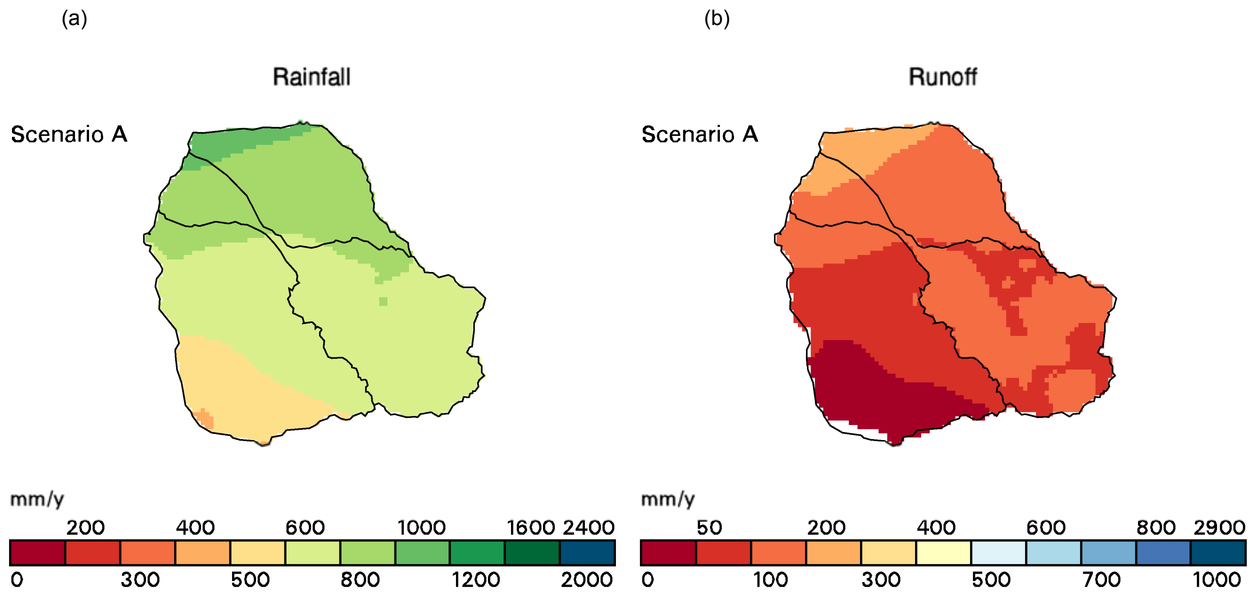


Figure SE-27. Spatial distribution of mean annual (a) rainfall and (b) modelled runoff across the South-East Gulf region under Scenario A

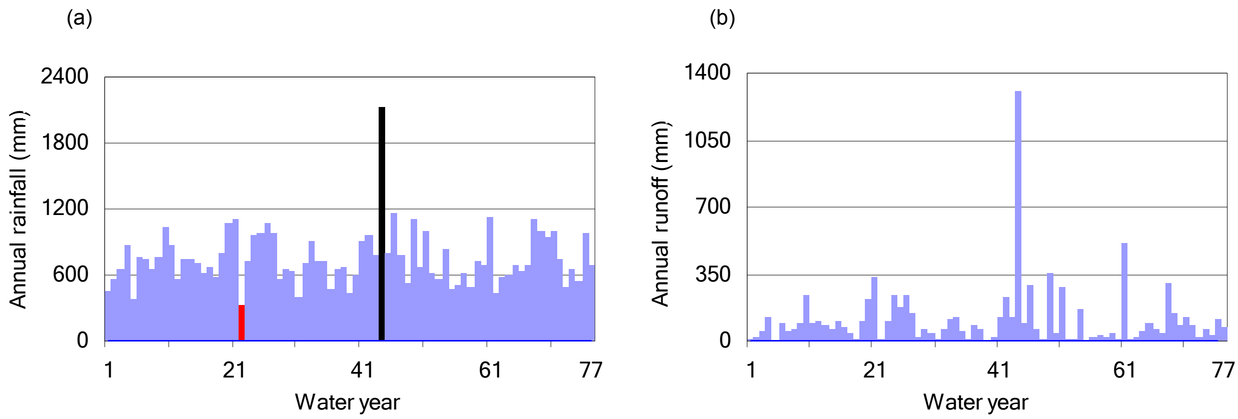


Figure SE-28. Annual (a) rainfall and (b) modelled runoff in the South-East Gulf region under Scenario A

In this project all runoff grids are presented as long-term mean annual values. However the distributions of monthly and annual runoff data in northern Australia can be highly skewed; consequently the median and additional percentile values spatially averaged over the region are also reported. The 10th percentile, median and 90th percentile annual runoff values across the South-East Gulf region are 244, 67 and 13 mm respectively. The median wet season and dry season runoff averaged over the South-East Gulf region are 67 mm and zero mm respectively.

The mean annual rainfall varies from nearly 1100 mm in the north-east to 700 mm in the south-east. The mean annual runoff varies from over 200 mm in the east to less than 25 mm in the south-east (Figure SE-27) and subcatchment runoff coefficients vary from less than 10 percent to nearly 30 percent of rainfall. The majority of rainfall and runoff occurs during the wet season months December to April (Figure SE-29). Rainfall and runoff can vary considerably from year to year with long periods over several years or decades that are considerably wetter or drier than others (Figure SE-28). The coefficients of variation of annual rainfall and runoff averaged over the South-East Gulf region are 0.34 and 1.50 respectively.

The South-East Gulf is one of 13 regions which cover the three divisions studied in this project. Mean annual rainfall and runoff, as well as coefficients of variation, have been calculated for all of these 13 regions, and it is useful to compare the South-East Gulf results to results across all 13 regions. Across all 13 regions in this project 10th percentile, median and 90th percentile values are 1371, 936 and 595 mm respectively for mean annual rainfall and 374, 153 and 78 mm respectively for mean annual runoff. The mean annual rainfall (752 mm) and runoff (113 mm) averaged over the South-

East Gulf region fall in the lower end of this range. Across all 13 regions in this project the 10th percentile, median and 90th percentile values are 0.34, 0.26 and 0.19 respectively for the coefficient of variation of annual rainfall and 1.39, 0.69 and 0.48 for the coefficient of variation of runoff. The coefficients of variation of annual rainfall (0.34) and runoff (1.50) averaged over the South-East Gulf region are the highest of the 13 reporting regions.

Figure SE-29(a,b) shows the minimum and maximum monthly rainfall and runoff and the range of values between the 25th and 75th percentile monthly rainfall and runoff. Figure SE-29(c,d) shows the mean and median monthly flows and the range of values between the 25th and 75th percentile monthly rainfall and runoff. The large difference in the mean and median wet season monthly runoff values indicates that the distribution of monthly runoff in the South-East Gulf region is highly skewed.

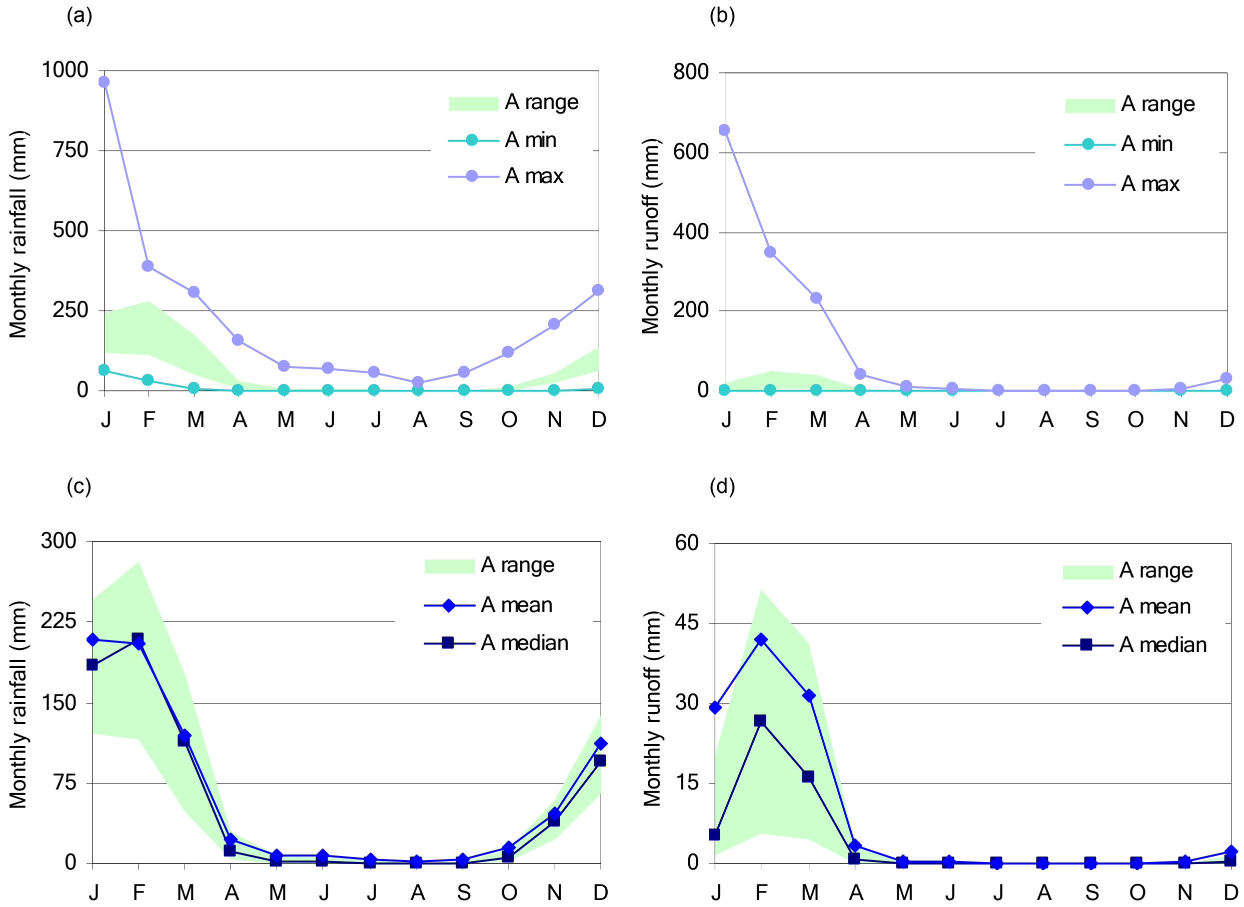


Figure SE-29. Minimum, maximum and A range monthly (a) rainfall and (b) modelled runoff; and mean, median and A range monthly (c) rainfall and (d) modelled runoff in the South-East Gulf region under Scenario A (A range is the 25th to 75th percentile monthly rainfall or runoff)

SE-3.5.4 Under recent climate

The mean annual rainfall and runoff under Scenario B (1996 to 2007) are 7.4 percent higher and 13 percent lower respectively than the historical (1930 to 2007) mean values. While the percentage change in rainfall and runoff vary in direction and consequently the results seem improbable, it can be explained by the large rainfall event in Year 44, which was not used to construct the Scenario B sequence. The relative amount of runoff in Year 44 compared to the 77-year runoff sequence was greater than the relative amount of rainfall in Year 44 compared to the 77-year rainfall sequence. When Year 44 is excluded from the analysis, the mean annual rainfall and runoff under Scenario B are 10 percent and 4 percent higher respectively than the longer term mean (76-year sequence). The spatial distribution of rainfall and runoff across the South-East Gulf region under Scenario B is shown in Figure SE-30.

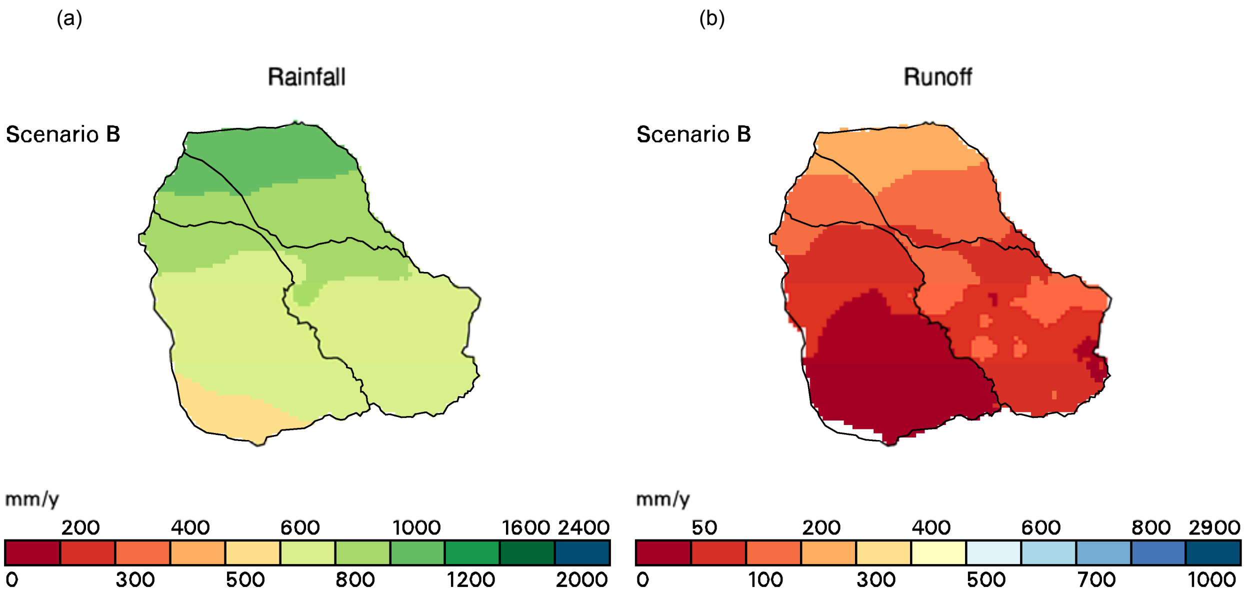


Figure SE-30. Spatial distribution of mean annual (a) rainfall and (b) modelled runoff across the South-East Gulf region under Scenario B

SE-3.5.5 Under future climate

Figure SE-31 shows the percentage change in the mean annual runoff averaged over the South-East Gulf region under Scenario C relative to Scenario A for the 45 scenarios (15 global climate models (GCMs) for each of the high, medium and low global warming scenarios). The percentage change in the mean annual runoff and rainfall from the corresponding GCMs are also tabulated in Table SE-10.

The figure and table indicate that the potential impact of climate change on runoff can be very significant. Although there is considerable uncertainty in the estimates, the results indicate that runoff in ~2030 in the South-East Gulf region is more likely to decrease than increase. Rainfall-runoff modelling with climate change projections from three-fifths of the GCMs shows a reduction in mean annual runoff, while rainfall-runoff modelling with climate change projections from two-fifths of the GCMs shows an increase in mean annual runoff. The wide range of mean annual runoff values shown in Figure SE-31 and Table SE-10 is primarily due to the wide range of future projections of rainfall by the 15 GCMs.

Because of the large variation between GCM simulations and the method used to obtain the climate change scenarios, the biggest increase and biggest decrease in runoff come from the high global warming scenario. For the high global warming scenario, rainfall-runoff modelling with climate change projections from six of the GCMs indicates a decrease in mean annual runoff greater than 10 percent while rainfall-runoff modelling with climate change projections from five of the GCMs indicates an increase in mean annual runoff greater than 10 percent.

In subsequent reporting here and in other sections, only results from an extreme 'wet', 'mid' and extreme 'dry' variant are shown (referred to as scenarios Cwet, Cmid and Cdry). Under Scenario Cwet, results from the second highest increase in mean annual runoff from the high global warming scenario are used. Under Scenario Cdry, results from the second highest reduction in mean annual runoff from the high global warming scenario are used. Under Scenario Cmid, the median mean annual runoff results from the medium global warming scenario are used. These are shown in bold in Table SE-10.

Under scenarios Cwet, Cmid and Cdry, mean annual runoff increases by 46 percent and decreases by 1 and 23 percent relative to Scenario A. The range based on the low global warming scenario is a 24 to -13 percent change in mean annual runoff, which is large relative to other regions in this project. Figure SE-32 shows the mean annual runoff across the South-East Gulf region under scenarios A and C. The linear discontinuities that are evident in Figure SE-32 are due to GCM grid cell boundaries.

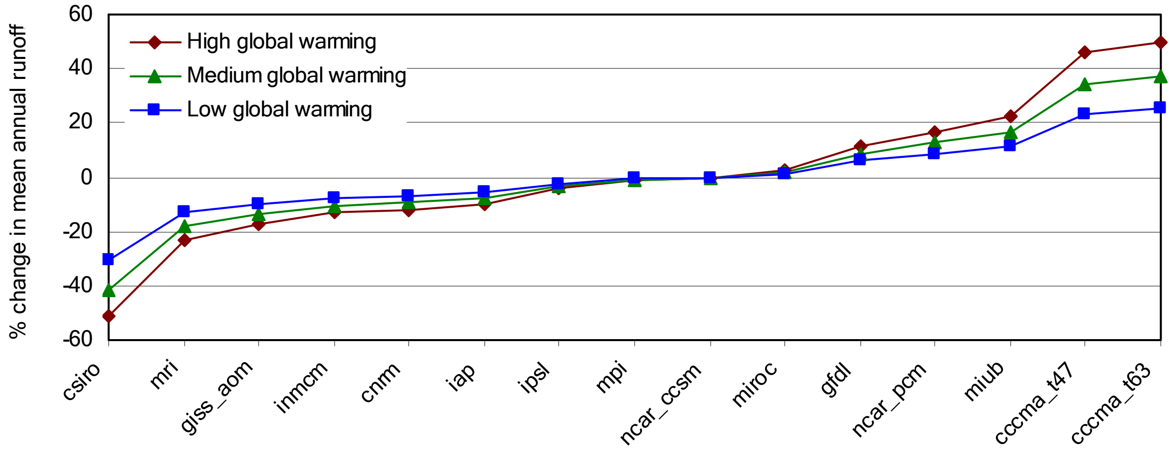


Figure SE-31. Percentage change in mean annual modelled runoff under the 45 Scenario C simulations (15 global climate models and three global warming scenarios) relative to Scenario A

Table SE-10. Summary results under the 45 Scenario C simulations for the modelling subcatchments (numbers show percentage change in mean annual rainfall and modelled runoff under Scenario C relative to Scenario A)

High global warming			Medium global warming			Low global warming		
GCM	Rainfall	Runoff	GCM	Rainfall	Runoff	GCM	Rainfall	Runoff
csiro	-22%	-51%	csiro	-17%	-42%	csiro	-12%	-31%
mri	-7%	-23%	mri	-6%	-18%	mri	-4%	-13%
giss_aom	-5%	-17%	giss_aom	-4%	-14%	giss_aom	-3%	-10%
inmcm	-2%	-13%	inmcm	-1%	-10%	inmcm	-1%	-7%
cnrm	-2%	-12%	cnrm	-2%	-10%	cnrm	-1%	-7%
iap	-3%	-10%	iap	-2%	-8%	iap	-2%	-6%
ipsl	1%	-4%	ipsl	0%	-3%	ipsl	0%	-2%
mpi	-1%	-1%	mpi	-1%	-1%	mpi	-1%	-1%
ncar_ccsm	1%	-1%	ncar_ccsm	1%	-1%	ncar_ccsm	1%	0%
miroc	4%	3%	miroc	3%	2%	miroc	2%	1%
gfdl	0%	11%	gfdl	0%	9%	gfdl	0%	6%
ncar_pcm	7%	17%	ncar_pcm	5%	13%	ncar_pcm	4%	9%
miub	5%	22%	miub	4%	17%	miub	3%	12%
cccma_t47	14%	46%	cccma_t47	11%	34%	cccma_t47	7%	24%
cccma_t63	14%	50%	cccma_t63	11%	37%	cccma_t63	8%	26%

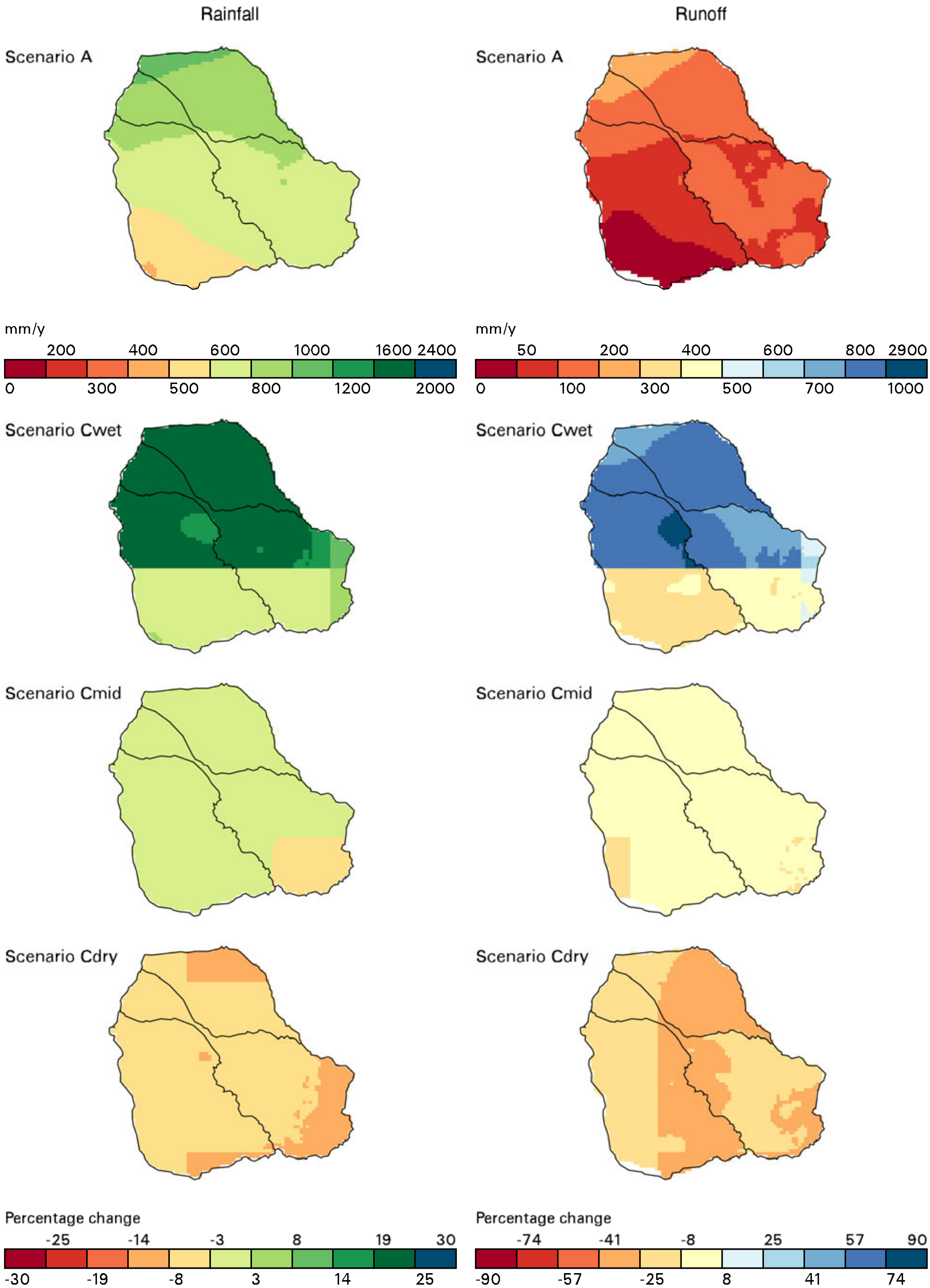


Figure SE-32. Spatial distribution of mean annual rainfall and modelled runoff across the South-East Gulf region under Scenario A and under Scenario C relative to Scenario A

SE-3.5.6 Summary results for all scenarios

Table SE-11 shows the mean annual rainfall, runoff and actual evapotranspiration under Scenario A averaged over the South-East Gulf region, and the percentage changes in the rainfall, runoff and actual evapotranspiration under scenarios B and C relative to Scenario A. The Cwet, Cmid and Cdry results are based on the mean annual runoff, and the rainfall changes shown in Table SE-10 are the changes in the mean annual value of the rainfall series used to obtain the runoff under scenarios Cwet, Cmid and Cdry. The changes in mean annual rainfall do not necessarily translate directly to the changes in mean annual runoff because of changes in seasonal and daily rainfall distributions and the relationship between rainfall and runoff is non-linear. The latter factor usually results in small changes in rainfall to be amplified in runoff (Table SE-10).

Figure SE-33 shows the mean monthly rainfall and runoff under scenarios A and C averaged over the 77 years for the region. Figure SE-34 shows the daily rainfall and flow exceedance curves under scenarios A and C averaged over the region. In Figure SE-33 scenarios Cwet, Cmid and Cdry are selected on a month-by-month basis, while in Figure SE-34 scenarios Cwet, Cmid and Cdry are selected for every day of the daily flow exceedance curve.

Table SE-11. Water balance over the entire South-East Gulf region under Scenario A and under scenarios B and C relative to Scenario A

Scenario	Rainfall	Runoff	Evapotranspiration
		mm	
A	752	113	640
		percent change from Scenario A	
B	7%	-13%	11%
Cwet	14%	46%	8%
Cmid	-1%	-1%	-1%
Cdry	-7%	-23%	-4%

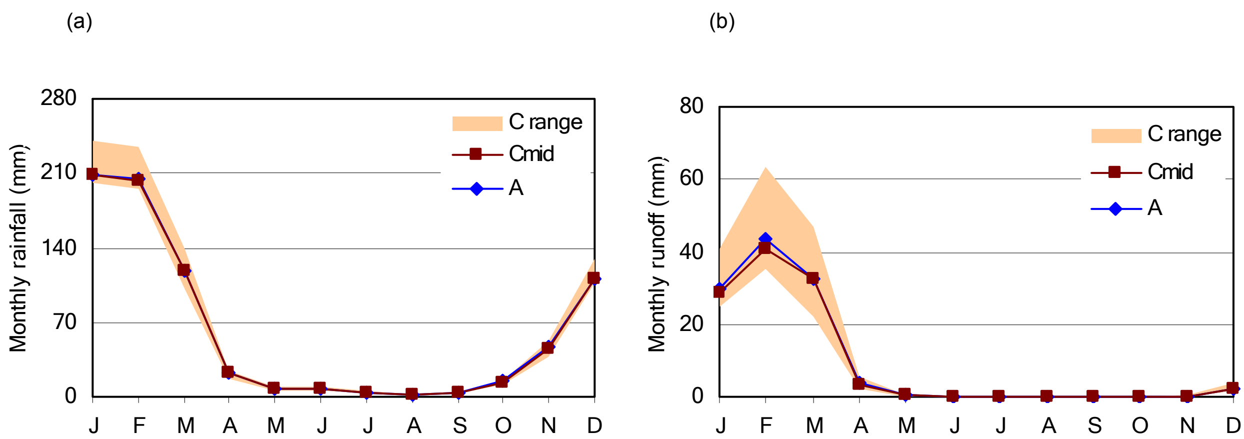
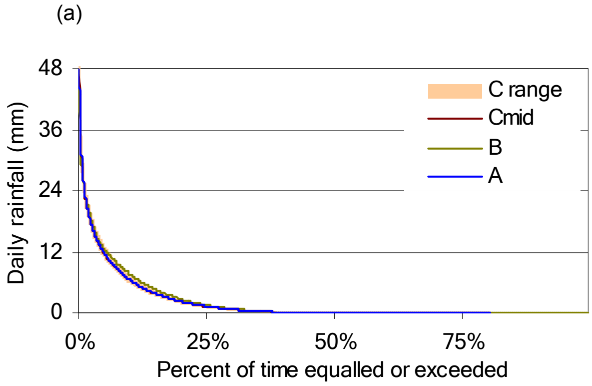


Figure SE-33. Mean monthly (a) rainfall and (b) modelled runoff in the South-East Gulf region under scenarios A and C



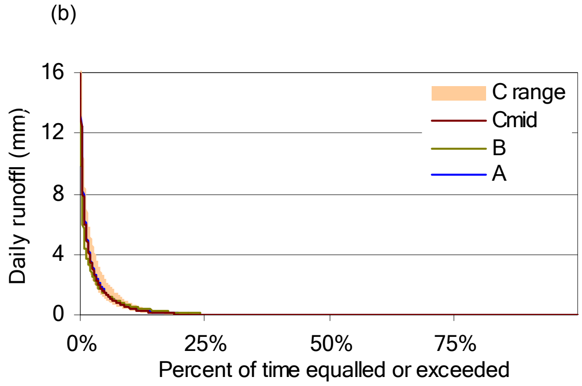


Figure SE-34. Daily flow exceedance curves for (a) rainfall and (b) modelled runoff in the South-East Gulf region under scenarios A, B and C. (C range is based on the consideration of each rainfall and runoff percentile separately – the lower and upper limits in C range are therefore not the same as scenarios Cdry and Cwet)

SE-3.5.7 Confidence levels

The level of confidence of the runoff estimates for the South-East Gulf region is variable. In the lower reaches (the Great Southern Aggregation), there are no high quality stations. Gauge 918002A, which was used to model the coastal plain regions, may be part of a distribution system of the Mitchell during very large flood events, though there is no clear evidence of large inflows in the observed record for this station. The rainfall-runoff modelling ensemble tended to under predict flows in this calibration catchment which may offset to some extent occasional distributary inflow. The majority of streamflow gauging stations are located in the upper reaches of the Gilbert. However, those gauges categorised as suitable have variable runoff characteristics, which makes transposing parameters from donor calibration catchments to target ungauged subcatchments problematic. The most downstream gauge in the Gilbert catchment was closed in 1989 and did not meet the criteria to be used in this project. Diagrams in Petheram et al. (2009a) illustrate which calibrated rainfall-runoff model parameter sets are used to model streamflow in which ungauged subcatchments in the South-East Gulf region.

The rainfall-runoff model verification analysis with data from 123 catchments from across all of northern Australia indicates that the mean annual runoff for ungauged catchments are under estimated or over estimated, when using optimised parameter values from a nearby catchment, by less than 20 percent in 40 percent of catchments and by less than 50 percent in 80 percent of the catchments.

Figure SE-35 illustrates the level of confidence in the modelling of the mid to high (i.e. peak flows) and dry season runoff events (respectively) for the subcatchments of the South-East Gulf region. It should be noted that these maps of level of confidence are not statistical confidence levels and are intended to only convey a broad reliability of prediction. The level of confidence in streamflow predictions will vary slightly from the level of confidence in runoff predictions shown below and as discussed in Section 2.2.6 of the division-level Chapter 2.

There is a high degree of confidence that dry season runoff in the South-East Gulf region is low because it is known that rainfall and baseflow are low during the dry season. The map of level of confidence for dry season flow shown in Figure SE-35 provides a relative indication of how well dry season metrics, such as cease-to-flow, are simulated.

Largely due to the very low level of confidence in modelling the Norman and Staatan catchments, the level of confidence in the long-term average monthly and annual results for the South-East Gulf region is low relative to other regions. As shown in Figure SE-35, in many areas of the South-East Gulf region localised studies will require more detailed analysis than undertaken and reported in this project and would most likely require the site to be visited and additional field measurements made.

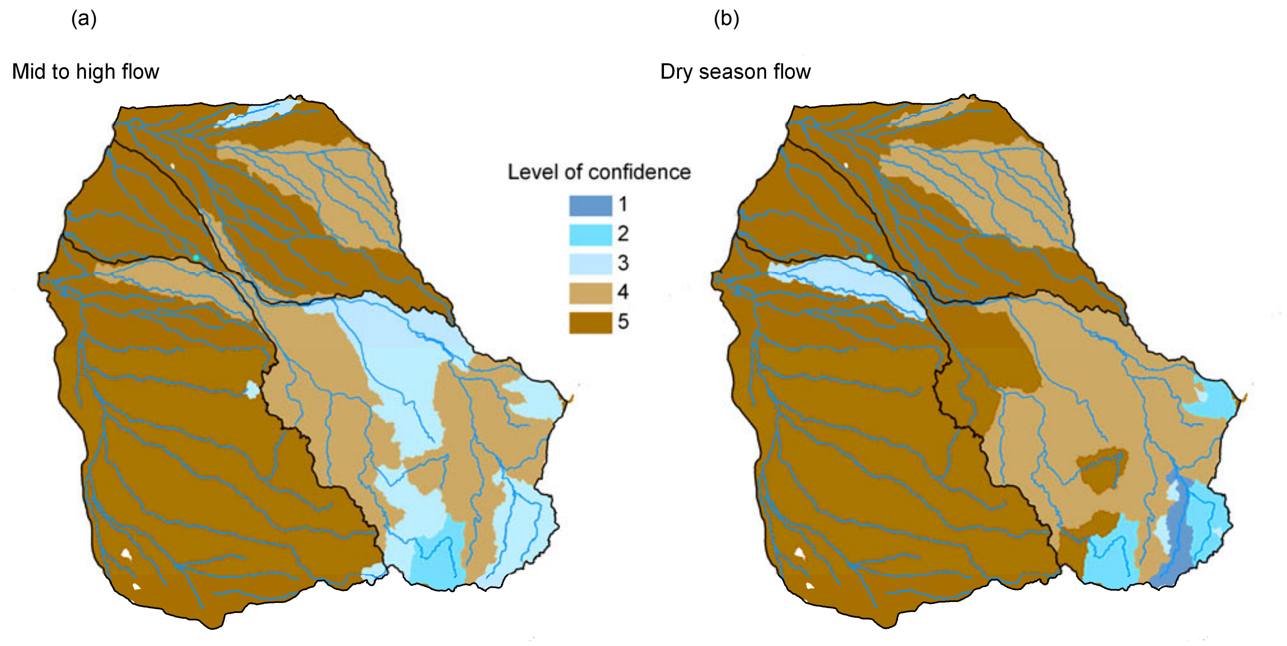


Figure SE-35. Level of confidence in the modelling of runoff for (a) mid- to high flow events and (b) monthly dry season flow events for the modelling subcatchments of the South-East Gulf region. 1 is the highest level of confidence, 5 is the lowest

SE-3.6 River system water balance

The South-East Gulf region is comprised of three Australian Water Resource Council (AWRC) river basins, the Norman, Staatan and Gilbert, and has an area of 122,094 km^2. Under the historical climate the mean annual runoff across the region is 110 mm (Section SE-3.5.3), which equates to a mean annual streamflow across the region of 13,430 GL. The Gilbert is the only catchment represented by an IQQM model and is discussed in detail later in this section.

Norman and Staatan river basins

For the Norman and Staatan river basins, no information on infrastructure, water demand and water management and sharing rules or future development were available, and consequently there is no river modelling section for these river basins. Streamflow time series have been generated for each streamflow reporting node (SRN) based on the upstream grid cell rainfall-runoff simulations, as described in Section 2.2.5 of the division-level Chapter 2. The locations of these nodes are shown in Figure SE-36. SRN for the Gilbert catchment are not shown on this figure. Summary streamflow statistics for each SRN are reported in Petheram et al. (2009a). In addition to the streamflow time series generated by the rainfall-runoff model ensemble, a range of hydrological metrics computed using regression analysis are also available for each SRN (as described in Section 2.2.7 of the division-level Chapter 2). The complete set of results for the multiple regression analysis is reported in SKM (2009). The merit of each approach is discussed in Section 2.2.7 of the division-level Chapter 2.

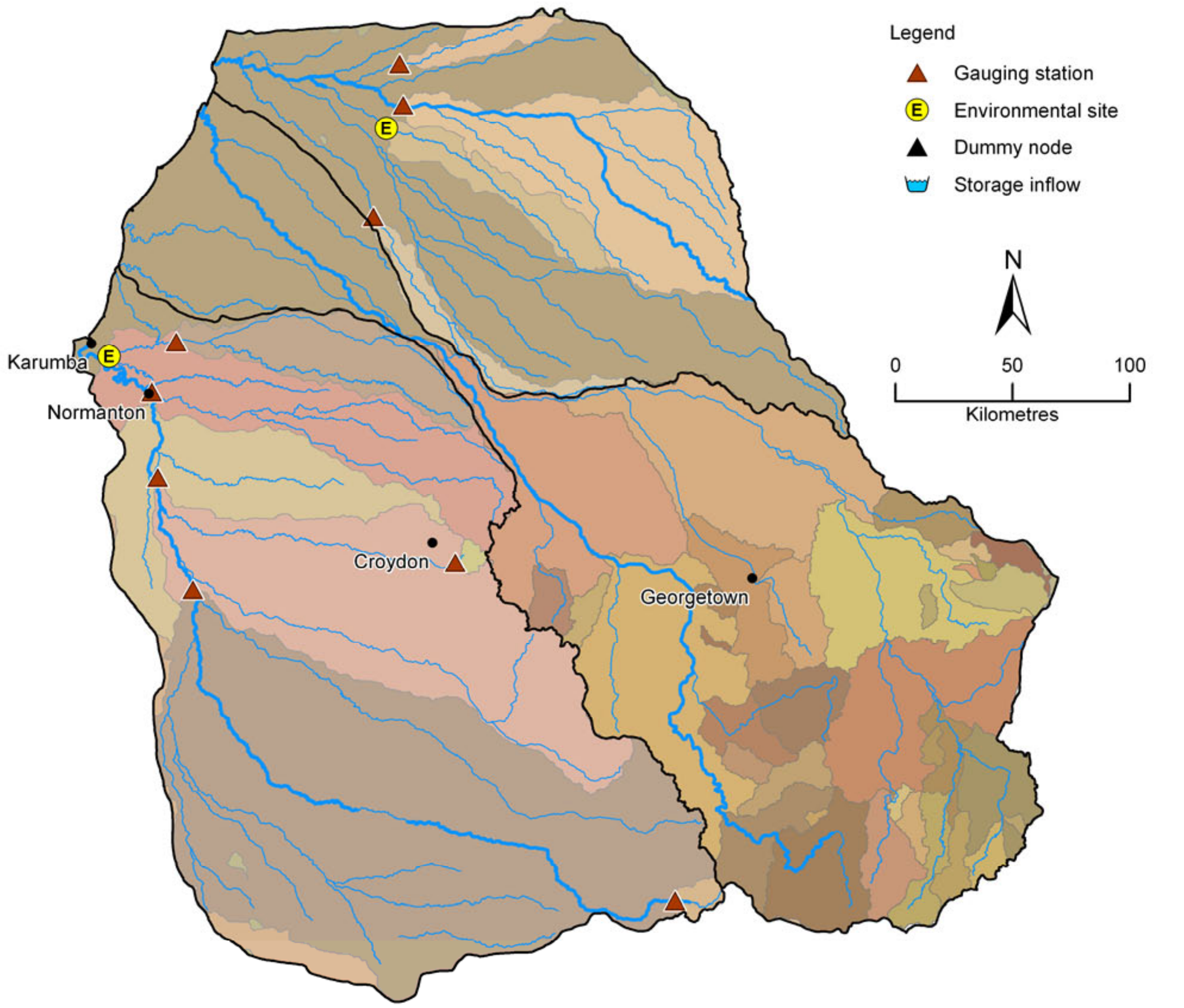


Figure SE-36. Location of streamflow reporting nodes (gauging stations, environmental sites, dummy nodes and storage inflows) in the Norman and Staatan catchments of the South-East Gulf region. (No dummy nodes or storage inflows are reported for this region)

Gilbert catchment

General information about river modelling methods is presented at the division-level in Chapter 2. In that chapter, scenarios are defined in Section 2.1 and river modelling methods which apply to all regions are described in Section 2.2. The following section summarises this generic river modelling approach as applied to the South-East Gulf region. The river modelling results for the South-East Gulf River model is reported using a range of metrics, which were consistently applied across all regions. The use of a common set of metrics across the entire project area enables comparisons between regions.

In this section where annual data are reported, years are represented by numbers 1 through 77. Consistently throughout the report, annual data are based on the water year (1 September to 31 August) and the dry season is defined as 1 May to 31 October. Scenarios Cwet, Cmid and Cdry are selected on the basis of the ranked mean annual rainfall for the modelled subcatchments in Section SE-3.5.

River system models can be used to assess the implications of the changes in inflows on the reliability of water supply to users. They may also be used to support water management planning by assessing the trade-offs between supplies to various competing categories of users. These models describe infrastructure, water demands, and water management and sharing rules. Given the time constraints of the project, and the need to link the assessments to state water planning processes, it is necessary to use the river system models currently used by state agencies.

The Gilbert catchment is modelled using the IQQM program (version 6.42.2). The river basin boundaries and the subdivision of the river basin into subcatchments for modelling purposes are shown in Figure SE-25. The model was set up by Department of Environment and Resource Management (DERM) to support the Queensland Water Resource Planning Process. Results from this model for the period from January 1890 to June 2003 were used to establish the water sharing rules in the draft Gulf Resource Operations Plan (DNRW, 2008). The level of development represented by the model is based on the full use of existing entitlements.

As part of the Northern Australia Sustainable Yields Project input data for the model were extended so that they covered the period 1 January 1890 to 30 June 2008. The results for this project are presented over 77-year sequences for the common modelling period 1 September 2007 to 31 August 2084. Results presented in DERM reports (Water Assessment Group, 2006) may differ from numbers published in this report due to the different modelling period and different initial conditions.

In this project the river system modelling for the South-East Gulf regions consist of ten scenarios:

- Scenario A – historical climate and full use of existing entitlements
  This scenario assumes a full use of existing entitlements. Full use of existing entitlements refers to the total entitlements within a plan area including existing water authorisations and unallocated reserves. This refers to the water accounted for in the resources operation plan, but the licences are interim or not allocated as yet. The period of analysis commences on 1 September 2007 and the results are reported based on modelling the 77-year historical climate sequence between 1 September 2007 and 31 August 2084. This scenario is used as a baseline for comparison with all other scenarios.
- Scenario AN – historical climate and without development
  Current levels of development such as storages and demand nodes are removed from the model to represent without-development conditions. Inflows were not modified for groundwater extraction, major land use change or farm dam development because the impact of these factors on catchment yield are currently considered to be negligible. This scenario uses the historical flow and climate inputs used for Scenario A.
- Scenario BN – recent climate and without-development
  Current levels of development such as storages and demand nodes are removed from the model to represent without-development conditions. Inflows were not modified for groundwater extraction, major land use change or farm dam development because the impact of these factors on catchment yield are currently considered to be negligible. This scenario uses seven consecutive climate sequences between 1 September 1996 and 31 August 2007 to generate a 77-year climate sequence representative of the 'recent climate' (for more detail see Section 2.1.2 in the division-level Chapter 2).
- Scenario CN – future climate and without-development
  Current levels of development such as public storages and demand nodes are removed from the model to represent without-development conditions. Inflows were not modified for groundwater extraction, major land use change or farm dam development because the impact of these factors on catchment yield are currently considered to be negligible. Scenarios CNwet, CNmid and CNdry represent a range of future climate conditions that are derived by adjusting the historical climate and flow inputs used in Scenario A.
- Scenario B – recent climate and full use of existing entitlements
  This scenario assumes the full use of existing entitlements and uses seven consecutive climate sequences between 1 September 1996 and 31 August 2007 to generate a 77-year climate sequence representative of the 'recent climate' (for more detail see Section 2.1.2 in the division-level Chapter 2).
- Scenario C – future climate and full use of existing entitlements
  Scenarios Cwet, Cmid and Cdry represent a range of future climate conditions that are derived by adjusting the historical climate and flow inputs used in Scenario A. The level of development for Scenario C assumes the full use of existing entitlements, i.e. the same as for Scenario A.

The changes in inflows between scenarios reported in this chapter differ from the changes in runoff reported in Chapter SE-3.5. These differences are due to difference in the methods by which the GCMs were ranked and difference in areas that are considered to contribute runoff to the surface water model. In Chapter SE-3.5 the entire region is considered while a subset of this area is considered here. The scenarios presented in this project may not eventuate but they encompass consequences that might arise if no management changes are made. Consequently results from this assessment are designed to highlight pressure points in the system, both now and in the future. This assessment does not elaborate on what management actions might be taken to address any of these pressure points. Where management changes to mitigate the effects of climate change have recently been implemented, the impacts of the changes predicted in this section may be an overestimate.

SE-3.6.1 River model configuration

Gilbert model description

The Gilbert region is described by the Gilbert IQQM system model (Water Assessment Group, 2006). The system is represented in the model by 43 river sections and 182 nodes. Figure SE-37 is a schematic of the Gilbert IQQM system model, showing the approximate location of main stream gauges and key demand and storage nodes.

The Miranda Downs gauge on the Gilbert River (917009A) is the most downstream flow monitoring station in the system. However this gauge was closed in 1989. The most downstream flow monitoring station which is still open is the Rockfields gauge on Gilbert River (917001D). The Gilbert River is the principal stream, and major tributaries are: Copperfield River, Einasliegh River, Etheridge River, Robertson River, Percy River, Little River, McKinnons Creek, Elizabeth Creek and Agate Creek. Copperfield Dam was constructed on the Copperfield River during 1984 to provide an assured freshwater supply for the Kidston Gold Mine, which is now closed. The dam has a storage capacity of 21,000 ML.

The development represented in the model is based on the full use of existing entitlements and therefore does not simulate current levels of development. Water use is modelled by 53 nodes as shown in Table SE-13. There is 1 node for a regulated supply from a private storage. Other extractions modelled include:

- 6 nodes for unregulated supplies from bedsand storage (there is significant natural storage in the bed sands of the Gilbert River)
- 35 nodes for unregulated supplies from run-of-river
- 11 nodes for high flow diversions (water harvesting).

There are 16 instream storages in the model. The only major storage is the Copperfield Dam on the Copperfield River. Details of storages are provided in Table SE-12. There is a passing flow requirement for Copperfield Dam that up to 1143 ML/day inflow is to be passed though the dam. The degree of regulation metric in Table SE-12 is the sum of the net evaporation and controlled released from the dam divided by the total inflows. Controlled releases exclude spillage. Storages with radial gates and without spillways are not reported in this table (there is only one known storage of this type in the project area, which is the Kununurra Diversion Dam in the Ord-Bonaparte region). The degree of regulation of Copperfield Creek Dam under the full use of existing entitlements is moderately high (0.3).

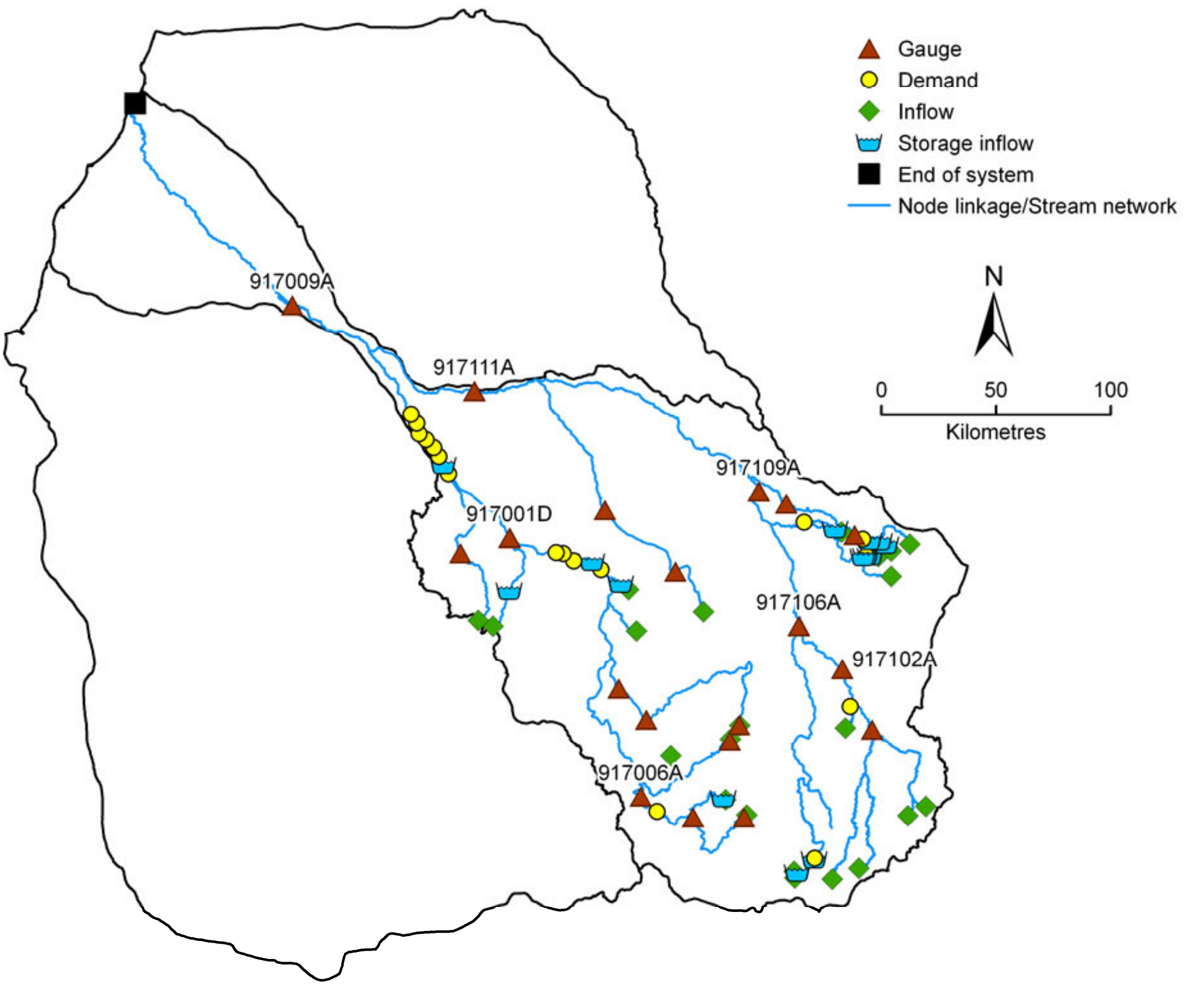


Figure SE-37. Schematic of the approximate location of gauging stations, main demand nodes and storages for the Gilbert system river model

Table SE-12. Storages in the Glibert system river model

	Active storage	Mean annual Inflow	Mean annual release	Mean annual net evaporation	Degree of regulation
	GL	GL/y			
Major reservoirs					
Copperfield Dam	18.5	127.2	38.3	2.6	0.3
Region total	**18.5**	**127.2**	**38.3**	**2.6**	0.3

In Table SE-13 and the sections that follow, 'volumetric limit' is defined as the maximum volume of water that can be extracted from a river system within this region under the resources operation plan. Unsupplemented water is defined as surface water that is not sourced from a water storage that is able to regulate or control supply to users.

Table SE-13. Modelled water use configuration in the Glibert system river model

Water users	Number of nodes	Volumetric limit	Model notes
		GL/y	
Town water supply			
Unsupplemented	1	0.1	Fixed demand
Agriculture			
General Security	13	4.0	No On Farm Storage
Unsupplemented	19	29.9	
Mining			
High Security	2	7.3	Fixed demand
Unsupplemented	1	0.4	Fixed demand
Other demands			
Unsupplemented	17	0.3	Fixed demand
Total	**53**	**42.136**	

Model setup

The original Gilbert systems river model and associated IQQM V6.42.2 executable code were obtained from DERM. The time series rainfall, evaporation and flow inputs to this model for the historical climate time series were set to cover the historical period from 1 September 1930 to 31 August 2007. The model was run for this period and validated against the original model run results for the same period.

For the scenarios that assume the full use of existing entitlements, the initial state of storages can influence the results obtained so the same initial storage levels were used for all scenarios. In this project all scenarios are reported for the 77-year period commencing on 1 September 2007. However, the demand simulated by an IQQM model for month *n* is dependent upon the simulation results for month *n-1*. For this reason the initial conditions (i.e. storage levels) are set to the levels simulated on the 1 August 2007 for all scenarios. The models are then run for 77 years and one month.

A without-development version of the Gilbert model was created by removing all instream storages, all irrigators and fixed demands.

Table SE-14. Gilbert system river model setup information

Model setup information		Version	Start date	End date
Gilbert	IQQM	6.42.2	01/01/1890	30/06/2008
Baseline models				
Warm-up period			1/08/2007	31/08/2007
Gilbert	IQQM	6.42.2	1/09/2007	31/08/2084
Modifications for Scenario A				
Data	Data extended by DRNW			
Inflows	No adjustment			
Initial storage volumes	set to level at 01/08/2007			
Copperfield Dam	19GL			
Other storages	set to level at 01/08/2007			

SE-3.6.2 River system water balance

The mass balance table (Table SE-12) shows volumetric components for Scenario A as GL/year, with all other scenarios presented as a percentage change from Scenario A. Mass balance includes the change in storage that is averaged over the 77-year period and is shown as GL/year.

The directly gauged inflows represent the inflows into the model that are based on data from a river gauge. The indirectly gauged inflows include inflows that are derived to achieve a mass balance between mainstream gauges. Diversions are listed based on the different water products in the region. The modelled end-of-system is the Gilbert River at the outflow to the sea.

Mass balance tables for the 12 reported subcatchments are provided in Petheram et al. (2009b). The mass balance of each of these river reaches and the overall mass balance were checked by taking the difference between total inflows, outflows of the system and change in storage volumes. In all cases the mass balance error was zero. Unattributed fluxes in Table SE-15 are the modelled river losses. River losses are estimated from loss relationships that are determined during calibration of the IQQM model such that flow is conserved between upstream and downstream gauging stations.

Results in Table SE-15 show that under scenarios Cwet and Cdry inflows in the Gilbert catchment increase by 32 percent and decrease by 16 percent respectively. End-of-system flows increase by 34 percent and decrease by 17 percent under scenarios Cwet and Cdry respectively. There is minimal impact to total diversions (<4 percent) as demands in the catchment are much smaller than the total inflows. Consumptive use is discussed further in SE-3.6.5.

The reason for the large reduction in inflows under Scenario B is discussed in Section SE-3.5.4.

Table SE-15. Glibert system river model mean annual water balance under Scenario A and under scenarios B and C relative to Scenario A

	A	B	Cwet	Cmid	Cdry
	GL/y				
Storage volume					
Change over period	0.0	0.0	0.0	0.0	0.0
Inflows					
	GL/y	percent change from Scenario A			
Subcatchments					
Gauged	774.8	-17%	9%	8%	-16%
Ungauged	5093.5	-20%	35%	8%	-17%
Sub-total	**5868.2**	**-20%**	**32%**	**8%**	**-16%**
Diversions					
Town Water Supply					
Unsupplemented	0.0	0%	0%	0%	0%
Agriculture					
General Security	3.0	0%	0%	0%	-2%
Unsupplemented	18.7	-2%	0%	1%	-4%
Mining					
High Security	6.6	0%	1%	0%	-2%
Unsupplemented	0.4	-5%	3%	-1%	-13%
Other Uses					
General Security	0.2	-1%	1%	0%	-1%
Sub-total	**29.0**	**-1%**	**0%**	**0%**	**-3%**
Outflows					
End-of-system flow	5304.2	-21%	34%	8%	-17%
Sub-total	**5304.2**	**-21%**	**34%**	**8%**	**-17%**
Net evaporation					
Storages	5.0	-2%	1%	3%	9%
Sub-total	**5.0**	**-2%**	**1%**	**3%**	**9%**
Unattributed fluxes					
	530.1	**-7%**	**9%**	**2%**	**-8%**

SE-3.6.3 Inflows

Inflows

There are several ways that the total inflows into the river system can be calculated. The obvious way would be to sum all of the inflows in the model. This is 5868 GL/year for the Gilbert IQQM (Table SE-15). The table also shows that a large proportion of the inflow is indirectly gauged and therefore estimated as part of model calibration. The approach used to calibrate these inflows varies considerably between reaches and model implementations. In some cases inflows are inflated and subsequently compensated for by loss relationships. In other cases the losses are inherent in the inflows. Totalling inflows does not provide a consistent assessment of total river system inflows across different models because of the different approaches to calibration.

An alternative is to locate the point of maximum average annual flow in the river system under without-development conditions. The gauge with maximum average annual flow is a common reference across all models irrespective of how mass balance is calibrated. This is because all river models are calibrated to achieve mass balance at mainstream gauges. The without-development scenarios remove the influences of upstream extractions and regulation and gives a reasonable indication of total inflows. For the IQQM catchments in northern Australia, where there have been minimal modifications to subcatchment inflows due to farm dams, commercial forestry plantations and groundwater use, Scenario AN can be considered to be broadly representative of pre-European settlement conditions.

A comparison between scenarios for reaches along the Gilbert River is presented in Figure SE-38. This shows that the maximum average annual mainstream gauged flow occurs at the last gauge 917009 (Gilbert River at Miranda Downs) with a value of 3724 GL/year under Scenario AN. This is typical of the Gulf catchments as rainfall increases towards the valley's outlet.

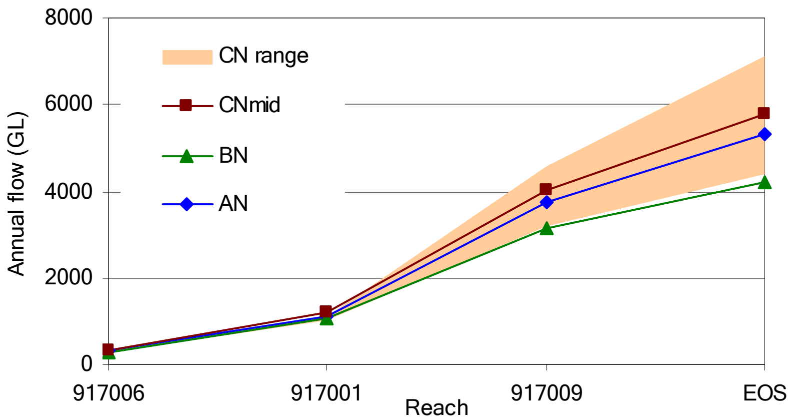


Figure SE-38. Transect of total mean annual river flow in the South-East Gulf region under scenarios AN, BN and CN

Water availability

In the Murray-Darling Basin Sustainable Yields Project, water availability was defined as the volume of water under the without-development scenario which occurs at the point of maximum mean annual flow along a river system. This generally occurred where a river system turned from a gaining reach to a losing reach. The major rivers in the Gulf of Carpentaria Drainage Division are, however, gaining systems, that is their highest mean annual flow occurs at their end-of-system. However end-of-system flow volumes are uncertain due to considerable ungauged flow contribution to these points. For this reason water availability is defined in this project as the volume of water under the without-development scenario which occurs at the gauged point of maximum mean annual flow along a river system. In the river systems of the Gulf of Carpentaria this point occurs at the most downstream gauge. When computing water availability for this project ecological, social, cultural and economic values are not considered.

It must also be noted, however, that not all of the water at the most downstream gauge is accessible for consumptive use. In the Gulf of Carpentaria the majority of suitable locations for large carry over storages are in the headwater catchments and not at or near the last gauge in the system. Further during large out of bank flows (flood flows) water harvesting operations, which are usually located in the lower reaches, are constrained by the rapid rise and fall in stage height (Petheram et al., 2008) and insufficient on-farm storage capacity.

A time series of total annual surface water availability under Scenario AN is shown in Figure SE-39. The lowest annual water availability was 98 GL in Year 22 while the greatest annual water availability was 30,149 GL in Year 44. Figure SE-40 shows the difference in annual total surface water availability under Scenario CN relative to Scenario AN.

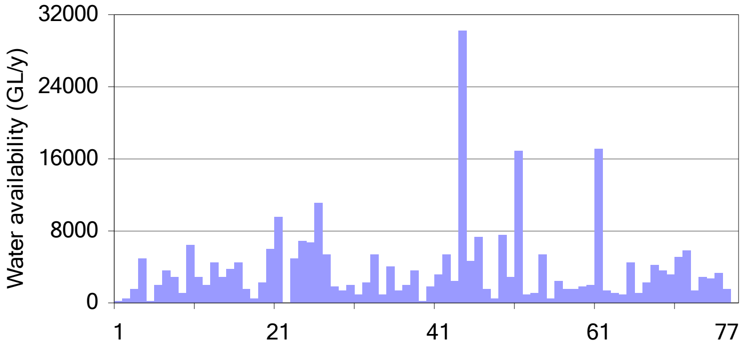


Figure SE-39. Annual water availability at streamflow gauging station 917009 under Scenario AN

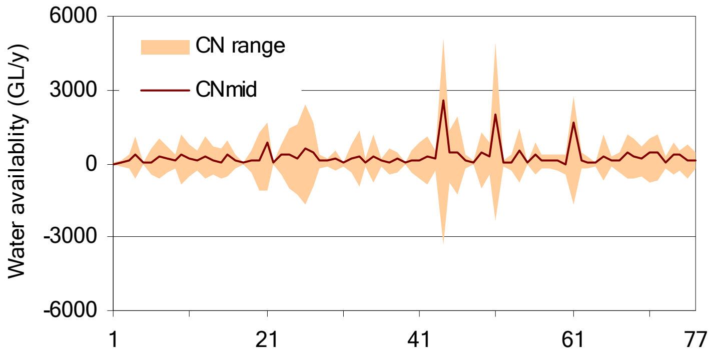


Figure SE-40. Change in total surface water availability at streamflow gauging station 917009 under Scenario CN relative to Scenario AN

SE-3.6.4 Storage behaviour

The modelled behaviour of major storages indicates how reliable the storage is during extended periods of low or no inflow. Table SE-16 provides indicators for Copperfield Dam that show for each scenario the lowest recorded storage volume and the corresponding date. The average and maximum years between spills is also provided. A spill commences when the storage exceeds full supply volume and ends when the storage falls below 90 percent of full supply volume. The end condition is applied to remove the periods when the dam is close to full and oscillates between spilling and just below full which would otherwise distort the analysis. The period between spills is the length of time from when one spill ends (i.e. the storage falls below 90 percent of the fully supply volume) until the next spill commences (i.e. when the storage exceeds the full supply volume).

The storage behaviour under all scenarios is similar to that under Scenario A indicating good reliability for various climate conditions.

Table SE-16. Details of dam behaviour

Copperfield Dam	A	B	Cwet	Cmid	Cdry
Minimum storage volume (GL)	1.6	1.6	1.6	1.6	1.5
Minimum storage date	29 Jan, Year 41	18 Jan, Year 65	18 Jan, Year 65	29 Jan, Year 41	18 Jan, Year 65
Average years between spills	1.5	1.5	1.5	1.5	1.5
Maximum years between spills	6.7	6.7	6.7	6.7	6.7

The time series of storage behaviour for Copperfield Dam for the maximum period between spills under each of the scenarios is shown in Figure SE-41.

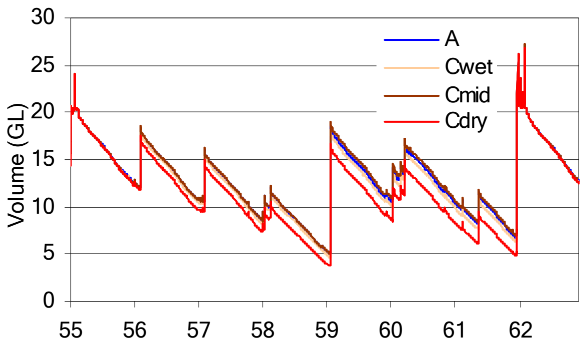


Figure SE-41. Storage behaviour over the maximum period between spills for Copperfield Dam under scenarios A and C

SE-3.6.5 Consumptive water use

Diversions

Table SE-17 shows the total mean annual diversions for each subcatchment (Figure SE-37) under Scenario A and the percentage change under scenarios B and C relative to Scenario A. Water harvesting of high river flows accounts for about 59 percent of total diversions (17.1 GL/year) under the full use of existing entitlements case. The change in total diversions decreases under Scenario Cdry because demands do not vary with change in climate, but less water is accessible for diversion.

Table SE-17. Mean annual diversions in each subcatchment in the South-East Gulf system under Scenario A and under scenarios B and C relative to Scenario A

Reach	A	B	Cwet	Cmid	Cdry
	GL/y	percent change from Scenario A			
9170061	1.8	-1%	0%	1%	-3%
9170131	0.0				
9170011	14.3	-2%	0%	1%	-4%
9171081	0.0	0%	0%	0%	0%
9171021	4.3	-1%	0%	0%	-2%
9171061	4.6	0%	0%	0%	0%
9171091	1.0	0%	0%	-1%	-1%
9171121	2.8	-1%	2%	-1%	-7%
9171131	0.2	-1%	1%	0%	-1%
9171111	0.0	-1%	2%	0%	-5%
9170091	0.0				
9179991	0.0				
Total	**29.0**	**-1%**	**0%**	**0%**	**-3%**

Figure SE-42 shows total average annual diversions under scenarios A, B and C for subcatchment reaches. The subcatchment with the most diversions is the Gilbert River between Percy Junction gauge (917006a) and Rockfields gauge (917001d).

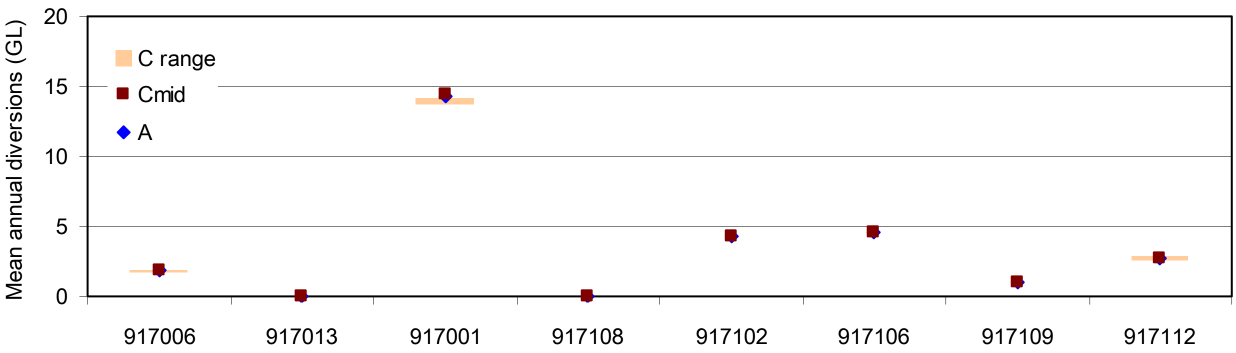


Figure SE-42. Total mean annual diversions for each subcatchment in the South-East Gulf system under scenarios A and C

Figure SE-43 shows the annual time series of total diversions under Scenario A and the difference between Scenario A and Scenario C. The maximum and minimum diversions under Scenario A are 35.1 GL in Year 44 and 9.7 GL in Year 22 respectively. The change in diversions is within 5 GL/year under scenarios Cwet, Cmid and Cdry.

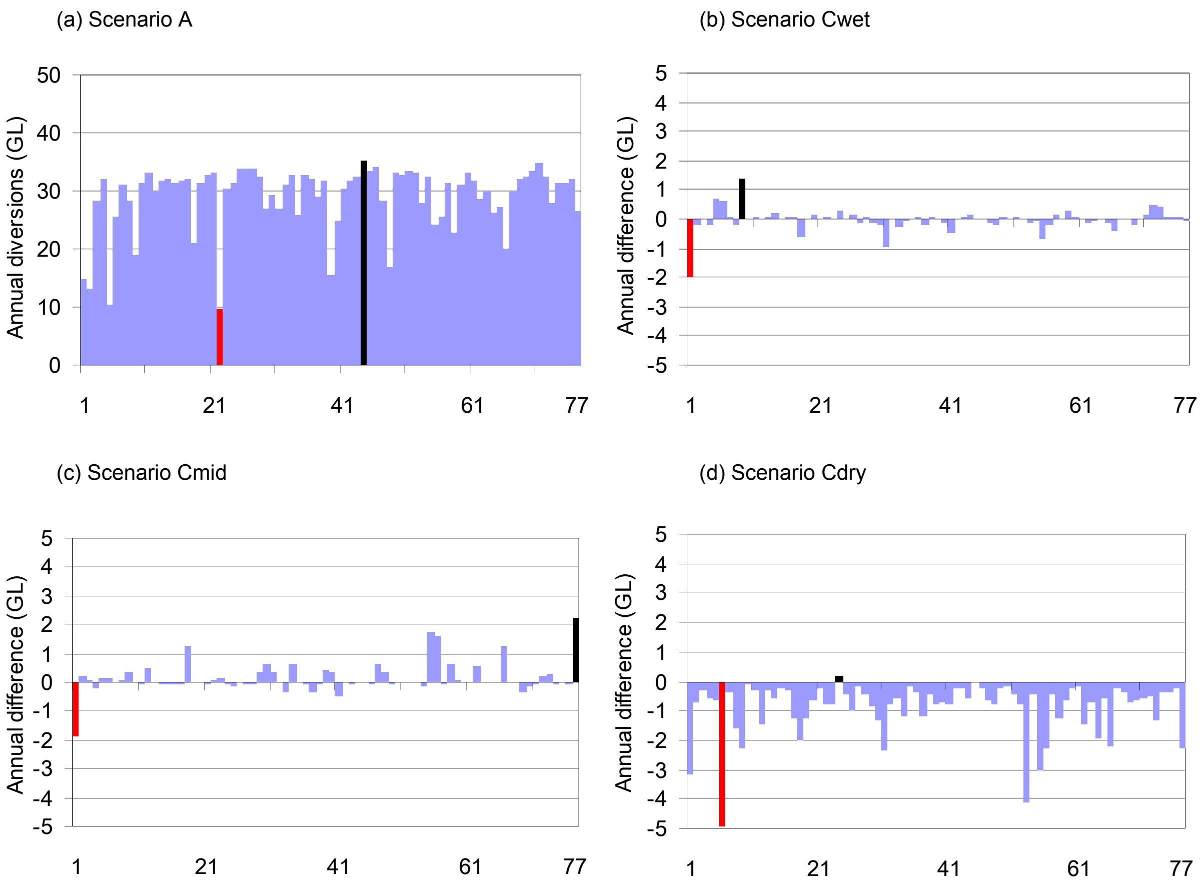


Figure SE-43. Total annual diversions under (a) Scenario A; and difference from Scenario A under (b) Scenario Cwet, (c) Scenario Cmid and (d) Scenario Cdry

Level of use

The level of use for the region is indicated by the ratio of total use to surface water availability. Total use comprises subcatchment use and streamflow extractions. There is no subcatchment use (i.e. water intercepted by farm dams or used by commercial forestry operations) within the Gilbert system. Streamflow extractions include total net diversions, which are defined as the net water diverted for the full range of water products. Streamflow use includes total net diversions, which are defined as the net water diverted for the full range of water products. Net diversion is the sum of the diversions minus the return flows. It should be noted, however, there are no return flows in the Gilbert IQQM. Net diversions are used to reflect the change in mass balance of the system. They do not consider the difference in water quality that may exist between diversions and returns.

Level of use is presented in two ways for this region. The first approach is the same as presented in the Murray-Darling Basin Sustainable Yields Project: the ratio of total use to total surface water availability (Table SE-18). The second is to present a transect of level of use at each main river gauge, which compares the cumulative diversions up to the gauge (including use on effluents and tributaries) with the average annual river flow at the gauge. This approach shows the spatial variation of use (Figure SE-44).

The level of use throughout the Gilbert region is low with 1 percent of the available surface water resource diverted for use. As use is low in the region, demands are able to be met under various climate scenarios. In Table SE-18 the total use is lowest under Scenario Cdry for the reasons outlined in the above section on diversions.

Current utilisation of licences is estimated by considering the unallocated water reserves from the *Gulf Draft Resource Operations Plan* (DNRW, 2008) and the volumetric limits. For the Gilbert catchment the long-term allowable diversions are 42 GL/year (Table SE-13), and the unallocated reserves are reported to be 10 GL/year. Based on these values it is estimated that current usage is approximately 32 GL/year. Allowable usage or total average diversions from IQQM are for the historical period (1930 to 2007) and therefore may differ to the volumes used to develop the resource operations plan.

Table SE-18. Relative level of surface water use in the South-East Gulf system under Scenario A and scenarios B and C relative to Scenario A

	A	B	Cwet	Cmid	Cdry
	GL/y				
Total surface water availability	3724	3143	4570	4001	3184
Streamflow use					
Total net diversions	29	29	29	29	28
Total use	**29**	**29**	**29**	**29**	**28**
	percent				
Relative level of use	1%	1%	1%	1%	1%

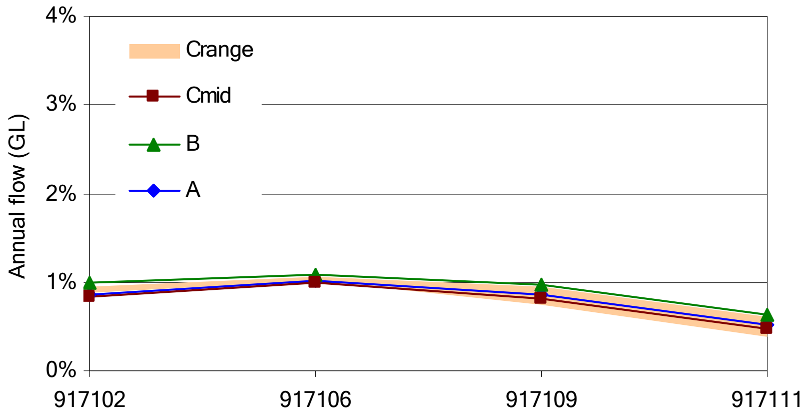


Figure SE-44. Transect of relative level of surface water use in the South-East Gulf region under scenarios A, B and C

Use during dry periods

Table SE-19 shows the average annual diversions, as well as the annual diversions for the lowest 1-, 3- and 5-year periods under Scenario A and the percentage change from Scenario A under each other scenario.

Table SE-19. Indicators of diversions during dry periods in the South-East Gulf system under Scenario A and under scenarios B and C relative to Scenario A

Annual diversion	A	B	Cwet	Cmid	Cdry
	GL/y	percent change from Scenario A			
Lowest 1-year period	10	-1%	1%	1%	-8%
Lowest 3-year period	19	-3%	-4%	-3%	-8%
Lowest 5-year period	20	-2%	-2%	-2%	-6%
Average	29	-1%	0%	0%	-3%

Reliability

The average reliability of water products can be indicated by the ratio of total diversions to the volumetric limit. For the Gilbert region, high security use is compared against licence volume; volumetric limits for town water supply, mining and other uses are compared against a reference demand that is associated with a fixed demand pattern; and agricultural usage is compared against maximum area planted by an application rate or a specified licence capacity. Table SE-20 shows the average reliability under Scenario A and the percent change under scenarios B and C. Results indicate that generally reliability is good for all water products.

Table SE-20. Average reliability of water products in the South-East Gulf system under Scenario A and under scenarios B and C relative to Scenario A

	A			B	Cwet	Cmid	Cdry
	Volumetric limit	Mean annual diversions	Fraction diverted per 1ML allocated				
	GL/y			percent change from Scenario A			
Licensed private usage							
Town water supply							
Unsupplemented	0.1	0.0	0.00				
Mining							
High security	7.3	6.6	0.90	0%	1%	0%	-2%
Unsupplemented	0.4	0.4	1.00	0%	8%	4%	-9%
Agriculture							
General security	4.0	3.0	0.75	0%	0%	0%	-2%
Unsupplemented	29.9	18.7	0.63	-2%	0%	1%	-4%
Other demands							
Unsupplemented	0.3	0.2	0.67	-1%	1%	0%	-1%

There is a difference in most systems between the water that is available for use, as modelled in the Gilbert IQQM as full entitlements are modelled, and the water that is actually diverted for use. These differences may be due to a range of factors including underutilisation of licences, unallocated water reserves and water being provided from other sources such as rainfall. The difference between available and diverted water will vary considerably across water products and time.

SE-3.6.6 River flow behaviour

There are many ways of considering the flow characteristics in river systems. For this report three different indicators are provided: daily flow exceedance, seasonal plot and daily event frequency. These are considered at the end-of-system. Figure SE-45(a) shows the flow exceedance curve.

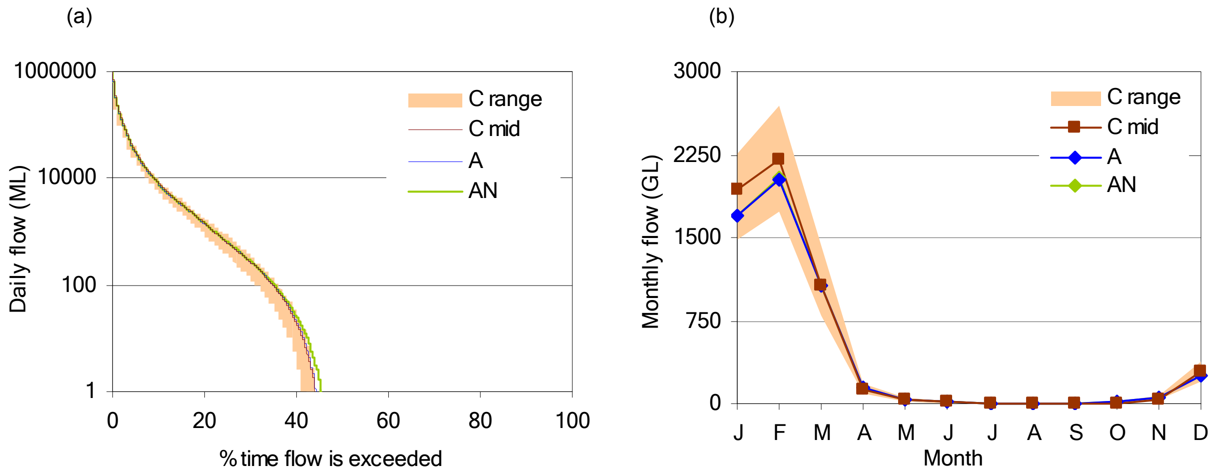


Figure SE-45. (a) Daily flow exceedance curves and (b) mean monthly modelled flow for the South-East Gulf end-of-system under scenarios AN, A and C

Figure SE-45(b) gives the mean monthly flow under scenarios AN, A and C at the end-of-system. There is a strong seasonality at the end-of-system gauge reflecting the wet and dry seasons. This figure also shows minimal change in the seasonality at the end-of-system compared to without-development conditions under all scenarios. The percentage of time that flow is greater than 1 ML/day under these scenarios is presented in Table SE-21. Under climate scenarios there is not a large impact to low flow at the end-of-system.

Table SE-21. Percentage of time modelled flow at the South-East Gulf end-of-system is greater than 1 ML/day under scenarios AN, A, B and C

Catchment	AN	A	B	Cwet	Cmid	Cdry
Gilbert	65%	64%	63%	65%	64%	60%

SE-3.6.7 Share of water resource

Non-diverted water shares

There are several ways of considering the relative level of impact on non-diverted water. Table SE-22 presents two indicators for:

- the average annual non-diverted water as a proportion of the available water
- average annual non-diverted water under each scenario compared with average annual non-diverted water under Scenario A.

Table SE-22. Relative level of non-diverted water in the South-East Gulf system under scenarios A, B and C

Gilbert	A	B	Cwet	Cmid	Cdry
Non-diverted water as a percentage of total available water	99%	99%	99%	99%	99%
Non-diverted share relative to Scenario A non-diverted share	100%	84%	123%	107%	85%

Most water in the Gilbert river basin is not diverted (99 percent), therefore the comparison between scenarios relative to Sceanrio A predominately reflects changes due to climate.

Combined water shares

Figure SE-46 combines the results from water availability, level of development and non-diverted water. The size of the bars indicates total water availability and the subdivision of the bars indicates the diverted and non-diverted fractions. It should be noted, however, that water availability is based on the mean annual volume of water at the last gauge in the system. For the reasons discussed in SE-3.6.3 it is unlikely that this volume of water is accessible for consumptive use.

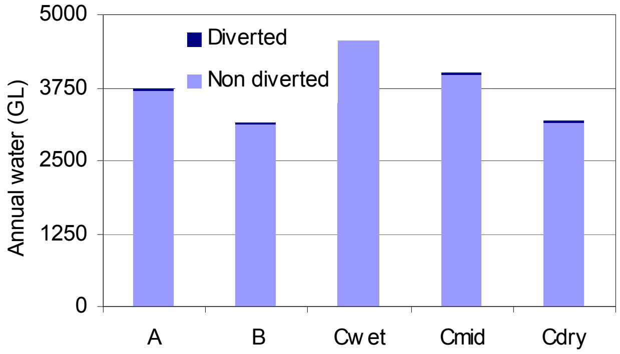


Figure SE-46. Comparison of diverted and non-diverted shares of water in the South-East Gulf system under scenarios A, B and C

SE-3.7 Changes to flow regime at environmental assets

Section 1.3 of the division-level Chapter 1 describes how environmental assets were shortlisted for assessment by this project. Three environmental assets have been shortlisted in the South-East Gulf region: Dorunda Lakes Area, Smithburne–Gilbert Fan Aggregation, and Southern Gulf Aggregation. The locations of these assets are shown in Figure SE-1 and these assets are characterised in Chapter SE-2.

This section presents the assessment of these shortlisted assets and reports metrics for those assets which have sufficient confidence in the modelled streamflow to enable analysis. Confidence in results for low flows and high flows was calculated separately on a scale of 1 to 5, with 1 indicating results with the highest confidence (as described in Section 2.2.6 of the division-level Chapter 2). Hydrological regime metrics (as defined in Section 2.5 of the division-level Chapter 2) for either low flows or high flows are reported only where confidence levels are 1, 2 or 3. If confidence levels in the low flows or high flows are ranked 4 or 5, results are not reported and are labelled NR (not reported).

Some of the assets in this region have multiple nodes at which streamflow modelling results are available. When reporting hydrological regime metrics for such assets a single node was selected. The selected node was that with the highest streamflow confidence level and the largest proportion of streamflow to the asset. Results for all nodes are presented in McJannet et al. (2009).

In the absence of site-specific metrics for the South-East Gulf region a set of standard metrics related to high and low flows have been utilised. However the conversion of these metrics into environmental impacts still requires development of quantitative relationships between flow and ecology.

SE-3.7.1 Standard metrics

Dorunda Lakes Area

The surface water flow confidence level for this asset is considered unreliable (4 or 5) for both wet season and dry season flows which is too unreliable to allow environmental flow metrics to be calculated for this asset.

Smithburne – Gilbert Fan Aggregation

The surface water flow confidence level for this asset is considered unreliable (4 or 5) for both wet season and dry season flows which is too unreliable to allow environmental flow metrics to be calculated for this asset.

Southern Gulf Aggregation

The surface water flow confidence level for this asset is considered unreliable (4 or 5) for both wet season and dry season flows which is too unreliable to allow environmental flow metrics to be calculated for this asset.

SE-3.8 References

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About the project

The Northern Australia Sustainable Yields (NASY) Project has assessed the water resources of northern Australia. The project modelled and quantified, within the limits of available data, the changes to water resources under four scenarios: historical climate; recent climate; future climate considering current water use and future climate with potential future water demand. The project identified regions that may come under increased, or decreased, stress due to climate change and increased water use.

The assessments made in this project provide key information for further investigations carried out through the Australian Government's Northern Australia Water Futures Assessment. This initiative aims to develop a knowledge base so that any development proceeds in an ecologically, culturally and economically sustainable way.

The NASY project was commissioned by the National Water Commission in consultation with the Australian Government Department of the Environment, Water, Heritage and the Arts. This followed a March 2008 agreement by the Council of Australian Governments to undertake comprehensive scientific assessments of water yield in all major water systems across the country and provide a consistent analytical framework for water policy decisions across the nation. CSIRO is also undertaking assessments in south-west Western Australia and Tasmania.

The NASY project was reviewed by a Steering Committee and a Technical Reference Panel. Both include representation from federal and state governments, as well as independent experts.

For further information:

Water for a Healthy Country Flagship
Project Leader
Dr Richard Cresswell
Phone: 07 3214 2767
Email: Richard.Cresswell@csiro.au
Web: www.csiro.au/partnerships/NASY

Northern Australia Water Futures Assessment
Department of the Environment, Water, Heritage and the Arts
Phone: 02 6274 1111
Email: northern.assessment@environment.gov.au
Web: http://www.environment.gov.au/nawfa

Contact Us
Phone: 1300 363 400
+61 3 9545 2176
Email: enquiries@csiro.au
Web: www.csiro.au/flagships