Australian Government

MURRAY–DARLING BASIN AUTHORITY

Water resource assessments for without-development and baseline conditions

Supporting information for the preparation of proposed Basin Plan

Murray–Darling Basin Authority technical report 2010/20 Version 2
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Cover image: Water testing at Lake Werta Wert in South Australia which received an environmental water allocation in July 2008. (photo by Arthur Mostead © MDBA)

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ACRONYMS AND TERMS USED

Baseline — modelled scenario representing development and water management conditions at June 2009 (refer Section 2.1)

Basin —the Murray–Darling Basin

CEWH — Commonwealth Environmental Water Holder

DERM —Department of Environment and Resource Management, Queensland

DIPNR — former Department of Infrastructure, Planning and Natural Resources, NSW

DLWC — former Department of Land and Water Conservation, NSW

DNR — former Department of Natural Resources, NSW

DSE — Department of Sustainability and Environment, Victoria

GL/y — gigalitres per year

GS — general security

GSM — Goulburn simulation model

HRWS — high reliability water share

IQQM — integrated quality and quantity model

IRSMF — integrated river system modelling framework

LRWS — low reliability water share

LTCE — long-term Cap equivalent

MDBA — Murray–Darling Basin Authority

MDBSY —the CSIRO's Murray–Darling Basin Sustainable Yields project

MSM — Bigmod — linked monthly simulation model and daily flow and salinity routing model for the River Murray system

NOW — NSW Office of Water, part of the NSW Department of Water and Energy

NSW — New South Wales

QLD — Queensland

REALM — resource allocation model

ROP — resource operations plan

SA — South Australia

SDL — long-term average sustainable diversion limit

TLM — The Living Murray

Water for Rivers — program for water recovery for providing environmental flows for the Snowy River

Without-development — modelled scenario representing near natural river system conditions (refer to Section 2.2)

1 INTRODUCTION

An understanding of the water balance across the Murray–Darling Basin, under various scenarios, is critical information for the development of a Basin Plan. In 2007–2008, the CSIRO Murray–Darling Basin Sustainable Yields (MDBSY) project published a series of reports documenting water availability across the Murray–Darling Basin (the Basin), including an assessment of the likely impacts of climate change to ~2030 on water availability (e.g. CSIRO 2008k). This assessment was the most comprehensive and integrated assessment of water availability in the Basin ever undertaken.

As part of the technical work supporting the development of the proposed Basin Plan, the Murray–Darling Basin Authority (MDBA) (with assistance from CSIRO and its consultants and state governments) has developed Basin-wide modelling capability. It has adopted and enhanced the Integrated River System Modelling Framework (IRSMF) developed by CSIRO (Figure 1). This framework links together 24 individual river valley models that have been developed by state agencies, CSIRO, Snowy Hydro Limited and MDBA over the past four decades for water management and policy development. This report presents the water balances for the Basin, derived from the modelling framework. It includes details of the modelled baseline and without-development scenarios, and the resulting water balances for each valley, including inflows and diversions. The model set-up and the data and time series used as inputs encapsulate modelling assumptions, water management policies and water sharing arrangements, which are all part of the baseline for the proposed Basin Plan. This report only provides an overview of model set-up and key assumptions and other documents with more details have been referenced.

This report has been prepared to explain the origin of data included in Schedule 1 and Schedule 3 of the proposed Basin Plan. It also explains the origin of the estimates for unmodelled diversion and interception data.

This report (version 2, MDBA Technical report 2010/20) has been updated and simplified, relative to version 1, which was prepared to support the release of the Guide to the proposed Basin Plan (MDBA 2010b). This version no longer includes the results of modelled climate change scenarios.

Note that the numbers presented in the water balance tables for some river valleys differ from those in MDBA technical report 2010/20 version 1 due to updates and revision of models and feedback received on the Guide to the proposed Basin Plan (MDBA 2010b).

A related report 'Comparison of water course diversion estimates in the proposed Basin Plan with other published estimates' (MDBA 2011) explains why numbers reported in the water balances in this report may differ from numbers in other previously published reports; including state based water sharing plans in NSW, the Cap for Victorian catchments and resource operations plans (ROP) in Queensland.

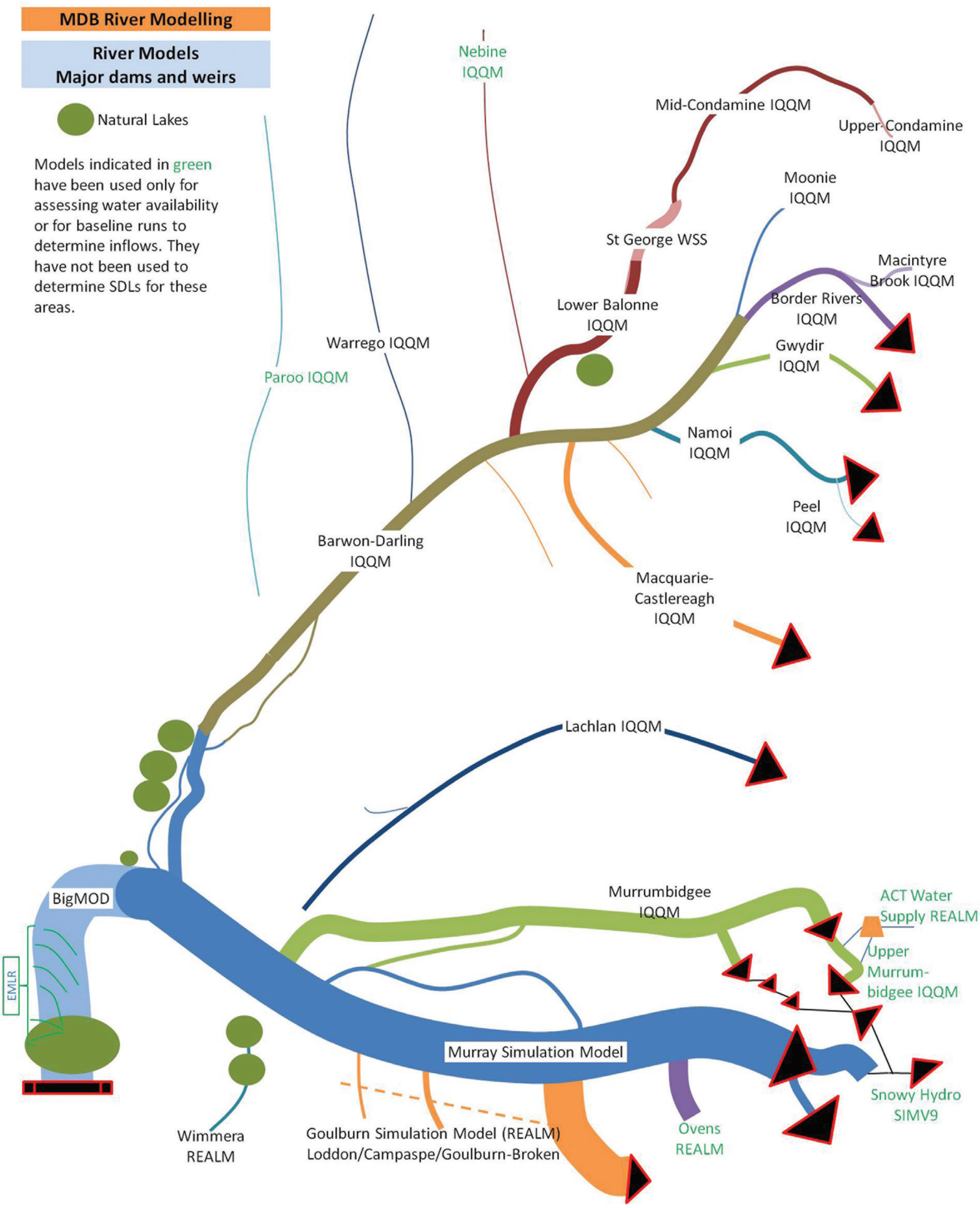

Figure 1 Integrated River system modelling framework used for Basin Plan development

2 SCENARIOS MODELLED

The two scenarios used as starting point for the development of the proposed Basin Plan and for setting environmental water requirements are:

- baseline scenario
- without-development scenario

This report provides an overview of the models used for various catchments and presents resulting water balances for without-development and baseline scenarios under the historic climate, over the period July 1895 to June 2009. These water balances provide best available estimates of annual average inflows, diversions, losses and outflows in the system. Time series analysis of the flow regimes has been used to assess the environmental water requirements for key assets and key ecological functions.

2.1 Baseline scenario

The baseline scenario (model run no. 871) represents the water sharing arrangements and diversions as permitted by the transitional and interim water resource plans, where these were in place as at June 2009. It reflects the Murray–Darling Basin ministerial Cap level of development for all states unless current water sharing arrangements have a usage level lower than the cap level, e.g. the NSW water sharing plans.

The water recovery under The Living Murray (TLM) and Water for Rivers for the Snowy River is included as part of the baseline conditions but water recovery under other programs such as the Commonwealth Government Sustainable Rural Water Use and Infrastructure and Restoring the Balance in the Murray–Darling Basin programs, the NSW Government River Environmental Restoration program and the Northern Victorian Irrigation Renewal Program are not included in the baseline scenario.

Further details of the baseline conditions modelled for each individual valley are discussed in Section 4.

2.2 Without-development scenario

The without-development scenario (model run no. 844) is a near natural condition model run. It is based on the baseline conditions scenario, from which all of the dams, irrigation and environmental works infrastructure and all consumptive users (such as irrigation, town water supply and industrial water uses) are removed from the system. However, these models are not necessarily a representation of pre-European conditions, as inflow estimates have not been corrected for land use changes and on-farm development in the catchments, which are largely included implicitly in the calibration of rainfall-runoff models and measured data used in the models. Moreover, the impact of changes due to levee construction and other in-channel structures on flows in anabranch systems, has not been considered.

3 WATER BALANCE TERMS

In the following sections, water balances are presented for the 18 river systems. The water balance terms have been presented as:

- Change in storage — net change in storage (dams and river channel) between the start of simulation in July 1895 and end of simulation in June 2009
- Inflows — total system inflows from gauged and ungauged tributaries (and where relevant from modelled tributaries)
- Losses — total system losses including evaporation losses, river channel losses and anabranches that do not return to the river or the downstream river system, as such it also includes flow to terminal lakes or wetlands

- Diversions — total diversions from the modelled system, which are accountable under the Murray–Darling Basin Cap (unless specified otherwise)
- Outflows — the end-of-system flow is the flow from the modelled area to a downstream model, or to the sea in the case of the river Murray; for some models, the reported 'total modelled outflows' may include other outflows (e.g. flood breakouts) that need to be taken into account for the calculation of the unattributed flux (or mass balance error).

Appendix 1 summarises the above mentioned water balance terms for all valleys for the without-development and baseline scenarios (whereby the change in storage has been combined with the losses).

The water balances presented in this report provide our best knowledge of the volumes of water that flow into the river systems, volumes used for consumptive use, volumes flowing into floodplain wetlands, volumes lost as recharges to groundwater or evaporation, and the volumes that reach the end of the system. The quality and quantity of available measured flow data varies across the Basin, especially for tributaries and small streams flowing into the main river. Generally, the most reliable measured flow data is available for flow measurements along the key gauging stations on the main river. Based on these flow measurements, it is often not possible to accurately differentiate between inflows to the river between two reliable measurement locations and losses that occur in that river reach. Therefore, often model estimates of unmeasured inflows and river system losses between reliable gauges on the main river may be over or under estimated. However, the confidence in the modelling predictions on the net effect (inflows minus losses) is still reasonably high, because of calibration and validation of the models at the reliable gauges under range of flow conditions.

The MDBA has used the best available information on system water balances for deriving sustainable diversion limits for the proposed Basin Plan.

4 WITHOUT-DEVELOPMENT AND BASELINE SCENARIOS

The following sections present the key features of the individual without-development and baseline models and the water balance results for without-development and baseline scenarios under historical climatic conditions.

Model development, including input data development and model calibration are discussed in greater detail in separate reports for each river system, which have been referenced in this document.

4.1 Paroo

4.1.1 Model description

The Paroo River is an ephemeral river, with most of its catchment located in Queensland. The Paroo region covers less than 4% of the total area of the Murray–Darling Basin, and has less than 0.1% of the Basin's population (CSIRO 2007c).

The Paroo river system is modelled with an Integrated Quantity and Quality Model (IQQM) (DLWC 1995) representing the Paroo River from the Yarronvale gauge (424202) to its inflow into the Darling River. Whilst the Department of Environment and Resource Management, Queensland (DERM) has included diversions and residual inflows into the NSW portions of the Paroo, Warrego, Nebine and Moonie IQQMs, DERM considers these representations to be indicative only and advises they should not be relied upon without further verification by the NSW Office of Water (NOW). The Paroo system rarely flows to the Barwon–Darling system and in absence of enough data to calibrate the river system model, the inflows from Paroo system to the Barwon–Darling system are assumed to be zero.

The baseline conditions for the Paroo system are based on the resource operations plan (ROP) (DERM 2006a). This ROP model version is described in detail in a report prepared by DERM (2006b). No changes have been made to the model for its integration into the MDBA's integrated river systems modelling framework (IRSMF). The model was audited by Bewsher Consulting (2010a) and was recommended for use for setting the Cap and for annual Cap auditing. The audit identified issues with the approximate nature of data available to model overland flows and recommended the submission of a revised model by December 2012.

4.1.2 Results and discussion

The water balances for without-development and baseline conditions for the Paroo system are summarised in Table 1. The Paroo system does not have many flow gauges, and only 8% of the river system inflows are measured. The remaining 92% of inflows are estimated using models. The total mean annual inflow to the Paroo system is estimated at 678.2 GL/y under without-development conditions. The Paroo system has only a very small amount of diversions and is still in pristine condition (0.04% of total inflows).

Table 1 Water balances for the Paroo system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-1.0	-1.0
Inflows		
Directly gauged (not included in water balance)	56.6	56.6
Indirectly gauged	621.5	618.7
Total inflows	678.2	675.4
Diversions		
QLD diversions	-	0.19
NSW diversions	-	0.10
Total modelled water course diversions	-	0.29
Losses		
Net evaporation from storage	126.9	126.9
Natural water bodies	492.4	489.4
Floodplain losses south of Wanaaring	59.4	59.3
Total losses	678.8	675.6
Outflows		
QLD to NSW border flow	475.6	475.4
Total outflow to Barwon–Darling	0	0
Unattributed flux		
Unattributed flux	0.4	0.4

4.2 Warrego

4.2.1 Model description

The Warrego region covers 7% of the Basin and is predominantly located in Queensland at the northern edge of the Basin. It is bounded to the east by the Condamine–Balonne region and by the Paroo region to the west. The region has less than 1% of the Basin's population (CSIRO 2007d).

The Warrego River system is modelled using a daily time step IQQM developed by DERM (2006c). The model simulates the Warrego River system from the Augathella gauge (423204) to three terminal points:

- Ford's Bridge (gauges 423001 and 423002) draining to the Darling system
- Widgeegoara–Noorama Creeks draining to Nebine Creek
- Cuttaburra Creek draining to the Paroo system.

The Warrego system in Queensland crosses the border into NSW at the following points:

- Warrego River at Barringun (gauge 423003)
- Widgeegoara–Noorama Creeks at the border
- Irrara Creek at the border
- Cuttaburra Creek at the border.

Allan Tannock Weir is the only regulated storage in the model. The model assumes that inflows into Allan Tannock Weir up to 300 ML/day will bypass the weir. There is a regulated water supply from Allan Tannock Weir to two irrigation nodes. The water is shared between these users via an annual accounting system.

The without-development and baseline versions of the model provided by DERM were developed for the ROP for the Warrego (DERM 2006a). No changes have been made to the model for its integration into the MDBA's IRSMF, so the model is directly based on the ROP version, which is described in detail in DERM 2006c. This model assumes that the 8 GL of unallocated water entitlement is used within the system. The model was audited by Bewsher Consulting (2010a) and was recommended for use for setting the Cap and for annual Cap auditing. The audit identified issues with the approximate nature of data available to model overland flows and recommended that DERM submit a revised model by December 2012 after suggested improvements to the model are made.

4.2.2 Results and discussion

The water balances for the without-development and baseline scenarios for the Warrego system are summarised in Table 2.

The Warrego system does not have many flow gauges, and only 8% of the inflows are measured. The remaining 82% of inflows are estimated using models. The total inflows to the Warrego system are 616 GL/y, and only a small fraction of these (8%) are diverted from the river system. Under without-development conditions, 15% of the total inflows would reach the Barwon–Darling system. This has decreased to 12% under baseline conditions.

4.3 Nebine

4.3.1 Model description

The Nebine system is a sub-catchment of the Condamine–Balonne system (CSIRO 2008c). The Nebine model is an IQQM representation of the Nebine River from the headwater inflows at Wallam Creek, Mungallala Creek and the Nebine River and includes inflows from the Warrego River through the Widgeegoara and Noorama Creeks near the NSW border. The model ends at the confluence of Nebine and Warrego inflows. The outflows from the Nebine are inflows into the lower Balonne system. The Nebine system is unregulated and has no regulated storages, but the model includes nine storages to model the natural water bodies.

The without-development and baseline version of the models were provided by DERM and were developed for the ROP for the Nebine (DERM 2006a). No changes have been made to the model for its integration in the MDBA's IRSMF, so the Nebine baseline model used is the ROP version of the model, described in detail in DERM (2006e). This model includes a 1.1 GL unallocated water entitlement, which is assumed to be used within the system. The model was audited by Bewsher Consulting (2010a) and accredited for use for setting the cap and annual cap auditing. The audit identified issues with the approximate nature of data available to model overland flows and recommended that DERM submit a revised model by December 2012 after suggested improvements to the model are made.

4.3.2 Results and discussion

The water balances for without-development and baseline conditions for the Nebine system are summarised in Table 3.
The Nebine system does not have any long-term gauges, so all of its inflows are estimated using models. The total inflows in the Nebine system are 94 GL/y. Under without-development conditions, 59% of inflows would reach the lower Balonne system. This has decreased to 52% under baseline conditions, with 7% of total inflows being diverted.

Table 2 Water balances for the Warrego system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-0.4	-0.4
Inflows		
Directly gauged	51.0	51.0
Indirectly gauged	565.1	565.1
Total inflows	616.1	616.1
Diversions		
QLD diversions	-	44.7
NSW diversions	-	6.9
Total modelled water course diversions	-	51.6
Losses		
Total QLD losses	378.0	356.3
Total NSW losses	148.0	132.3
Total losses	526.1	488.7
Outflows		
Fords Bridge – outflow to Barwon-Darling	69.4	58.2
Cuttaburra Creek – outflow to Paroo	17.1	14.3
Norooma & Widgeegoara Creek – outfl. to Nebine	3.9	3.7
Total outflows	90.4	76.2
Unattributed flux		
Unattributed flux	0.02	0.04

Table 3 Water balances for the Nebine system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-0.4	-0.4
Inflows		
Residual catchment (i.e. indirectly gauged)	93.8	93.6
Total inflows	93.8	93.6
Diversions		
QLD diversions	-	6.2
NSW diversions	-	0.0
Total modelled water course diversions	-	6.2
Losses		
Storage evaporation losses	8.5	12.4
River losses	30.9	27.3
Total losses	39.4	39.6
Outflows		
End-of-system outflows to Condamine–Balonne	55.4	48.9
Unattributed flux		
Unattributed flux	-0.6	-0.8

4.4 Condamine–Balonne

4.4.1 Model description

The Condamine–Balonne region (including the Nebine) is predominantly in southern Queensland, extends about 100 km to the south-west into New South Wales and represents 12.8% of the total area of the Basin. It has 9% of the Basin's population (CSIRO 2008c). The Condamine–Balonne system is modelled using four separate models that have been linked together:

- the upper Condamine (UCON) daily time step IQQM model
- the middle Condamine (MCON) daily time step IQQM model
- the St. George (STGE) daily time step capacity share model
- the lower Balonne (LBON) daily time step IQQM model.

The four models have been developed by DERM and are described below.
The baseline models correspond to the ROP for the Condamine–Balonne (DERM, 2010). The models have been submitted for auditing for their accreditation for the Cap implementation, but the auditing has not been completed yet.

Upper Condamine model

The model represents the upper Condamine River from the Condamine headwater inflows into Killarney Weir to the Condamine River at Cecil Plains Weir gauge (422316A) and the North Condamine River at the Lone Pine gauge (422345A). The outflows from the upper Condamine are inflows into the middle Condamine system.

The model includes seven in-stream supply storages; two unregulated (Killarney Weir and Connolly Dam) and five regulated (Leslie Dam, Talgai Weir, Yarramalong Weir, Lemontree Weir and Cecil Plains Weir). In addition, off-stream storages for overland flow diversion are also included in the model.

The modelled water use includes high priority supplemented users, medium priority supplemented users, unsupplemented users, overland flow diversion, high priority town water supplies and high priority stock and domestic users in Queensland. The upper Condamine system is operated under an annual accounting scheme with a maximum allocation level of 100%.

Middle Condamine model

The model represents the middle Condamine system from Cecil Plains Weir and Lone Pine gauge to the Beardmore Dam headwater gauge (422212B), including the Maranoa River. The outflows from middle Condamine are inflows into the lower Balonne model for the without-development scenario and inflows into the St. George model for the baseline scenario.

The model has 15 regulated storages (Tipton Weir, Cooby Dam, Loudon Weir, Bell Town water supply, Jandowae town water supply, Warra Weir, Chinchilla Weir, Condamine Weir, Rileys Weir, Tara town water storage, Freers Weir, Dogwood Creek Weir, Drillham Creek Weir, Surat Weir, and Neil Turner Weir). The model also has off-stream storages for water harvesting and overland flow diversion.

The modelled water use includes high priority supplemented users, medium priority supplemented users, unsupplemented users, overland flow diversion, high priority town water supplies and high priority stock and domestic users in Queensland. The middle Condamine system is operated under two annual accounting schemes, both with a maximum allocation level of 100%.

St. George model

The St. George daily model has been built by DERM to simulate the St. George Water Supply Scheme (WSS). The model covers a section of the Balonne River from Beardmore Dam to the St. George Jack Taylor Weir (JTW) gauge (422201). It receives inflows from the middle Condamine model and provides outflows to the Lower Balonne model.

The St. George water supply scheme consists of Beardmore Dam, which is connected to Moolabah weir and Buckinbah weir by the Thuraggi Channel. The Beardmore Dam and the three weirs (JTW, Moolabah and Buckinbah) have been combined into a single storage in the model. The storage-area-volume curve used for the single storage is adjusted to account for the levels maintained in the weirs during normal operation of the combined storages. The model also includes off-stream storages for water harvesting and overland flow diversion. The system is modelled using a capacity share scheme by modelling individual shares in the storage (CSIRO 2008c).

Lower Balonne model

The lower Balonne model represents the Balonne, Culgoa and Bokhara rivers with inflows from the St. George and Nebine models and including the Narran River and Narran Lakes.

The lower Balonne system is unregulated and there are no regulated storages in the model. However, the model includes 14 storages to model the natural water bodies and two large on-river storages that represent private water users. The model also has storages for water harvesting and overland flow diversion. The modelled water use in Queensland includes unsupplemented users, overland flow diversion, and two town water supplies. NSW water use is modelled for unsupplemented users and three town water supplies.

Table 4 Water balances for the Condamine–Balonne system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-0.2	-0.2
Inflows		
Tributary inflow from Nebine	55.4	48.9
Directly gauged (headwater)	229.5	229.5
Indirectly gauged	1,421.7	1,421.9
Total inflows	1,706.6	1,700.3
Diversions		
QLD diversions	-	713.3
NSW diversions	-	1.1
Total modelled water course diversions	-	714.5
Losses		
River losses	976.2	583.2
Net evaporation from storages	161.1	159.1
Total losses	1,137.2	742.4
Outflows		
Border flows	913.6	380.7
End-of-system total outflows	569.4	241.8
Unattributed flux		
Unattributed flux	0.2	2.9

Note that there is some overlap between the St. George model and the lower Balonne model. The St. George model ends at the bifurcation point downstream of JTW, whereas the lower Balonne model starts from JTW. This overlap is taken into account in the reporting of the results for the Condamine–Balonne system.

The lower Balonne model ends at the following three locations, where it flows into the Barwon–Darling system:

- Culgoa River downstream of Collerina (gauge 422006)
- Bokhara River downstream of Goodwins (gauge 422005)
- Narran Lake outflow downstream of Narran Park (gauge 422029).

The without-development and baseline versions of the models were provided by DERM and were used for the preparation of the ROP for the Condamine–Balonne (DERM, 2010). The Condamine–Balonne baseline model used is the ROP version of the model. However, subsequent to the model runs presented in this report, an updated version of the model has been supplied to MDBA. The Condamine–Balonne models are being audited by Bewsher Consulting for their suitability for setting the Cap and for annual Cap auditing. The diversion estimates for the Condamine will be updated based on recommendations of this audit and any changes made as a consequence.

4.4.2 Results and discussion

The water balances for without-development and baseline conditions for the Condamine–Balonne system are summarised in Table 4. The Condamine–Balonne system has a limited number of flow gauges on contributing tributaries, and only 13% of the inflows are based on gauged data. The remaining 87% of inflows are estimated using models. The total inflows in the Condamine–Balonne system are 1,706 GL/y. Under without-development conditions 33% of the total inflows flows into the Barwon–Darling system. This proportion has decreased to 14% under baseline conditions, whereby 42% of the inflows is diverted.

4.5 Moonie

4.5.1 Model description

The Moonie region is largely in south-eastern Queensland to the east of St. George. It covers 1.4% of the total area of the Murray–Darling Basin. Its population is less than 0.1% of the Basin total (CSIRO 2008i).

The Moonie River system is modelled using IQQM developed by DERM (2006d). The model simulates the Moonie River system from Nindigully (417201) to Gundablouie (417001). The Moonie River crosses the Queensland–NSW border at a point up-stream of Gundablouie.

Table 5 Water balances for the Moonie system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-0.00	-0.01
Inflows		
QLD inflows		
Directly gauged	112.9	112.9
Indirectly gauged	24.2	24.2
Total QLD inflows	137.1	137.1
Total NSW inflows	14.0	14.0
Total inflows	151.1	151.1
Diversions		
QLD diversions	-	33.2
NSW diversions	-	0.8
Total modelled watercourse diversions	-	34.0
Losses		
QLD losses	39.2	34.0
NSW losses	15.6	11.8
Total losses	54.8	45.7
Outflows		
QLD to NSW border flow	97.9	69.9
Gundablouie end-of-system flow to Barwon–Darling	96.3	71.4
Unattributed flux		
Unattributed flux	-0.02	-0.02

The without-development and baseline versions of the models were provided by DERM and were developed for the ROP for the Moonie (DERM, 2008b). No changes have been made to the model for its integration in the MDBA's IRSMF, hence the baseline model used for the Moonie is the ROP version of the model, described in detail in DERM (2006d). The 1.2 GL/y of unallocated water described in the Moonie Water Resource Plan 2003 (DERM, 2008b) is included in the model as a diversion.

The model was audited by Bewsher Consulting (2010a) and was accredited for the implementation and auditing of the Cap. The audit identified issues with the approximate nature of data available to model overland flows and recommended that a revised model be submitted by December 2012.

4.5.2 Results and discussion

The water balances for without-development and baseline conditions for the Moonie system are summarised in Table 5

The Moonie system is well gauged, such that 75% of the river system inflows are based on gauged data. The remaining 25% of inflows are estimated using models. The total inflows in the Moonie system under historical climate are 151 GL/y. Under without-development conditions, the proportion of inflows that reaches the Barwon–Darling system is 64%. Under baseline conditions, this has been reduced to 47%, whereby 22% of total inflows are diverted.

4.6 Border Rivers including Macintyre Brook

4.6.1 Model description

The Border Rivers region straddles the border between NSW and QLD, and covers 4% of the area of the Basin. The region has 2.5% of the total population of the Basin (CSIRO 2007a). The Border Rivers and Macintyre Brook systems are modelled separately using two models.

Macintyre Brook model

The Macintyre Brooke model simulates the Macintyre Brook system from Coolmunda Dam to its confluence with the Dumaresq River. The Macintyre Brooke outflows are the total of two modelled outflows, representing the regulated and unregulated components of flow at the Booba Sands gauge (416415). Coolmunda Dam is the only regulated storage in the model, in addition to two unregulated weirs, i.e. Whetstone and Ben Dor. The model is operated under an annual accounting scheme. Water use as modelled corresponds to Queensland high and medium priority water allocations and town water supplies.

Border Rivers model

The Border Rivers model simulates the Border Rivers system from the headwater inflows of Pike Creek into Glenlyon Dam and the Severn River (NSW) into Pindari Dam. The water use in Queensland is modelled for high and medium priority water allocations, unsupplemented water allocations and town water supplies and in NSW for general security, supplementary access and high security town water supplies. NSW supplementary access is constrained by a 120 GL/y Cap. The model is operated under a continuous account scheme.

The natural weir pools and floodplains along the length of the Border Rivers are modelled as storages. Pindari Dam, Glenlyon Dam, and Boggabilla Weir are the regulated storages in the model. The model also includes unregulated system on-farm storage including overland flow harvesting.

The model includes state sharing of Glenlyon Dam and Boggabilla Weir. There is also state sharing of inflows and surplus flows. Surplus flows are allocated on a state basis and any under-utilised water is accessible to the other state with a payback arrangement in Glenlyon Dam.

The Border Rivers model feeds into the Barwon–Darling system at three locations:

- Mungindi gauge (416001)
- Neeworra on Boomi River (416028)
- the confluence of Little Weir River and the Barwon River.

The baseline model as used by MDBA is the model corresponding to the Inter-Government Agreement (IGA) between NSW and QLD. The Border Rivers Cap model, including model calibrations and validations, is described in more detail in DERM (2008a).

The Border Rivers and Macintyre Brook models are yet to be audited by Bewsher Consulting for accreditation for use for the Cap implementation. Therefore, estimates of diversions reported herein may change as a consequence of recommendations from the independent audit of the model.

4.6.2 Results and discussion

The water balances for without-development and baseline conditions for the Border Rivers system (including the Macintyre Brook system) are summarised in Table 6. The system has a reasonable number of flow gauges on the contributing tributaries with 41% of the river system inflows based on gauged data, and 59%

Table 6 Water balances for the Border Rivers and Macintyre Brook system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	0.13	-0.26
Inflows		
Directly gauged (headwater)	814.4	814.4
Indirectly gauged	1,188.0	1,187.9
Total inflows	2,002.4	2,002.3
Diversions		
QLD diversions	-	217.5
NSW diversions	-	191.3
Total modelled water course diversions	-	408.8
Losses		
River losses	1,191.7	1,038.1
Evaporation from storages	20.7	50.3
Net loss to groundwater	-8.7	-8.7
Total losses	1,203.7	1,079.7
Outflows		
End-of-system in Barwon at Mungindi	539.5	317.0
End-of-system in Boomi at Neewora	215.1	173.4
End-of-system in Little Weir at the confluence	42.8	22.3
Total outflows to Barwon–Darling	797.4	512.6
Unattributed flux		
Unattributed flux	1.1	1.4

estimated using models. The total inflows for both without-development and baseline conditions are 2,002 GL/y.

For the Border Rivers system (including the Macintyre Brook system) 40% of its total inflows would reach the Barwon–Darling system under without-development conditions. This has decreased to 26% under baseline conditions, with 20% of inflows being diverted.

4.7 Gwydir

4.7.1 Model description

The Gwydir region is located in north-eastern NSW and covers 2% of Basin. It has 1.4% of the Basin's population (CSIRO 2008e).

For regulated parts of Gwydir Catchment a daily time step IQQM model has been set up by NOW. The Gwydir model covers the catchments of Gwydir River from Stonybatter gauge (418029) to its confluence with the Barwon River. Towards the lower end of the Gwydir valley, the model covers the floodplains of Mehi River, Mallowa Creek, Moomin Creek and Carole/Gil Gil Creeks. The model provides three end-of-system flows to the Barwon–Darling model, i.e. Gwydir River at Collymongle gauge (418031), Mehi River at Collarenebri gauge (418055) and Gil Gil Creek at Galloway gauge (416052), as well as return flows from the Gingham watercourse. During major floods, the accuracy of measurements of flow at these gauges is poor and it is believed that some floods bypass these

Table 7 Water balances for the Gwydir system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-	-7.4
Inflows		
Directly gauged	755.6	755.6
Indirectly gauged	240.5	240.5
Total inflows	996.1	996.1
Diversions		
Total modelled water course diversions	-	314.0
Losses		
Net evaporation from storage	-	23.1
River losses	480.5	370.7
Effluent losses	1,605.7	1,292.4
Effluent returns	-1,457.6	-1,170.5
Total losses	628.6	515.7
Outflows		
Gil Gil Creek	129.0	79.3
Gwydir River at Collymongle	20.6	4.9
Mehi River at Collarenebri	217.9	89.7
Total outflows to Barwon-Darling	367.5	173.9
Unattributed flux		
Unattributed flux	-0.0	-0.1

gauges; the estimated flow contributions due to these bypass flows are included in the Barwon–Darling model as additional floodplain flows.

The model used for the Basin Plan modelling is the water sharing plan version of the model. There is no separate documentation of this model version, but environmental flow rules and water sharing arrangements in the model correspond to the Gwydir Water Sharing Plan (DIPNR 2004a). However, the Cap model setup is described in detail in DNR (2009) and this report provides information on model calibration and validation details of processes modelled. The Cap version of the model has been reviewed as part of the Cap auditing (Bewsher 2002a) and has been accredited for Cap implementation.

The water sharing plan version of the model does not include water buybacks by the Commonwealth and NSW governments since the start of the water sharing plan.

4.7.2 Results and discussion

The water balances for without-development and baseline conditions for the Gwydir system are summarised in Table 7. The Gwydir system has a good network of gauges on the contributing tributaries and as a consequence, 76% of the river system inflows are based on gauged data and only 24% are estimated using models. The total inflows in the Gwydir system are 996 GL/y. Under without-development conditions, 37% of total inflows reaches the Barwon–Darling system. This has decreased to 17% under baseline conditions, with 32% of inflows being diverted.

4.8 Namoi

4.8.1 Model description

The Namoi region is situated in north-eastern New South Wales. It covers 3.8% of the total area of the Basin and has 4.5% of the Basin's population (CSIRO 2007b).

For the regulated parts of the Namoi and Peel catchments, two separate daily time step IQQM models have been set up by NOW and have been linked in MDBA's IRSMF modelling framework. The Peel model covers sub-catchments of the Peel River from headwater inflows into the Dungowan Dam to its confluence with the Namoi River downstream of the Keepit Dam. There is one end-of-system flow to the Namoi model at the Carroll Gap gauge (419006).

The Namoi model covers the catchments of the Manilla River from its headwater inflows into Split Rock Dam to the confluence with the Namoi River, and the catchments of the Namoi River from the North Cuerindi gauge (419005) to the lower flood plains of Namoi valley covered by Pian Creek and Namoi River and their anabranches. The Namoi River meets the Barwon River near Walgett gauge (419057). There are two end-of-system flows, taken as inflows into the Barwon–Darling model, at the Waminda gauge (419049) in the Pian Creek and the Goangra gauge (419026) in the Namoi River. The flows from Mooki River are included as inflows at Breeza gauge (419027) and flows from Cox's Creek are included at Boggabri gauge (419032) in the model.

The development of the Namoi and Peel Cap models is described in detail in DIPNR (2004d) and DNR (2006c). These models were reviewed as part of the Cap auditing and are accredited for Cap implementation (Bewsher 2005 and 2009).

The models used for estimating baseline diversion limits are the water sharing plan version of models for the Namoi and Peel systems. There is no separate documentation of the water sharing plan version of the model, but environmental flow rules and water sharing arrangements in the model correspond to the Namoi Water Sharing Plan (DIPNR 2004g) and the Peel River Water Sharing Plan (DECCW 2010). The model does not include water buybacks by the Commonwealth and NSW governments since start of the water sharing plan.

4.8.2 Results and discussion

The water balances for without-development and baseline conditions for the Namoi and Peel system are summarised in Table 8. The system has a limited number of gauges on the contributing tributaries and as a consequence only 38% of the river system inflows are based on gauged data. The remaining 62% of inflows are estimated using models. The total inflows are 1,883 GL/y. Under without-development conditions, the proportion of total inflows that reaches the Barwon–Darling system is 44%. This has decreased to 35% under baseline conditions, with 14% of inflows being diverted.

Table 8 Water balances for the Namoi and Peel system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-	-4.7
Inflows		
Directly gauged	723.9	723.9
Indirectly gauged	1,151.8	1,153.3
Groundwater gain	7.5	9.1
Total inflows	1,883.1	1,886.3
Diversions		
Total modelled watercourse diversions	-	265.2
Losses		
River groundwater loss	0.9	6.7
Storage evaporation losses	0.8	51.5
River evaporation losses	18.2	18.2
River losses	1,124.5	972.9
Effluent losses	209.5	319.9
Effluent return flows	-209.5	-319.9
Irrigation drainage returns flows	-	8.2
Losses in supplying Tamworth TWS	-	0.3
Total losses	1,144.4	1,041.4
Outflows		
End-of-system outflows to Barwon–Darling model	828.3	652.5
Total modelled outflows	739.8	584.8
Unattributed flux		
Unattributed flux	-1.1	-0.4

4.9 Macquarie–Castlereagh and Bogan rivers

4.9.1 Model description

The Macquarie–Castlereagh and Bogan region is located in central-west NSW, covers 6.9% of the area of the Basin and has 9% of the total population of the Basin (CSIRO 2008h). The region comprises the Castlereagh, Macquarie and Bogan river basins.

For regulated parts of the Macquarie River and for unregulated parts of the Castlereagh River, a daily time step IQQM model has been developed by NOW. The Castlereagh River is modelled from inflows at Mendooran gauge (420004) to Coonamble gauge (420005). The model covers the Macquarie River from the headwater inflows into Chifley Dam to its confluence with the Barwon River and the Cudgegong River from the headwater inflows into Windamere Dam to its confluence with the Macquarie River at Burrendong Dam. Towards the lower end of valley, the model covers the Bogan River and the floodplain areas between the Macquarie River and the Bogan River.

In the IRSMF modelling framework, flows at the following five gauging stations from the Macquarie-Castlereagh model are used as inflows to the Barwon–Darling Model:

- Castlereagh River at the Coonamble gauge (420005);
- Marthaguy Creek at the Carinda gauge (421011);
- Macquarie River at the Carinda gauge (421012);
- Bogan River at the Gongolgon gauge (421023); and
- Marra Creek at the Billybingbone Bridge gauge (421107).

The development of the Macquarie River Cap model is described in detail in DNR (2006b). This model was reviewed as part of the Cap auditing and is accredited for Cap implementation (Bewsher 2011a).

The water sharing plan versions of the models for Macquarie, Bogan, Marra, Marthaguy and Castlereagh were linked for the MDBSY project and this linked version of the model has been used for the Basin Plan modelling. There is no separate documentation of the water sharing plan version of the model, but environmental flow rules and water sharing arrangements in the model correspond to the water sharing plans for the Macquarie and Cudegong Rivers (DIPNR 2004b) and Castlereagh River (DIPNR, 2004c). The model does not include water buybacks by Commonwealth and NSW government since the start of the water sharing plan.

4.9.2 Results and discussion

The water balances for without-development and baseline conditions for the Macquarie–Castlereagh and Bogan system are summarised in Table 9.

The system has a limited number of gauges on the contributing tributaries and as a consequence only 39% of the river system inflows are based on gauged data. The remaining 61% of inflows are estimated using models. The total inflows in the Macquarie–Castlereagh and Bogan system are 2,859 GL/y. The proportion of inflows that reaches the Barwon–Darling system under without-development conditions is 27%. This has decreased to 22% under baseline conditions, with 14% of total inflows being diverted.

Table 9 Water balances for the Macquarie–Castlereagh and Bogan River system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-	-4.3
Inflows		
Directly gauged	1,104.7	1,104.7
Indirectly gauged	1,754.4	1,523.3
Total inflows	2,859.1	2,628.0
Diversions		
Total modelled water course diversions	-	380.3
Losses		
On-farm evaporation	-	5.0
River losses	1,576.8	1,280.9
Net evaporation from storages	-	54.0
Return flows	928.2	688.3
Macquarie Marshes evaporation	328.0	228.8
River evaporation	16.5	16.7
Effluent losses	939.3	693.0
Total Losses	1,932.4	1,585.1
Outflows		
End-of-system outflows to Barwon–Darling model	760.0	576.9
Total modelled outflows	926.7	667.3
Unattributed flux		
Unattributed flux	0.0	-0.3

4.10 Barwon–Darling

4.10.1 Model description

The Barwon–Darling region is located in north-western NSW and covers 13% of the Basin. The region has 2.5% of the Basin's population. The region contains the Talyawalka wetland system, which is a nationally important wetland located between Wilcannia and Menindee on the Darling Riverine Plains (CSIRO 2008a). For development of management policies and for general regulation of flows, a daily time step IQQM model was developed by NOW. The model receives tributary inflows from the Gwydir, Namoi and Border–Rivers models in the reach of the Barwon River between the Mungindi and Walgett gauges, and from the Warrego, Condamine–Balonne and Macquarie–Castlereagh models in the reach between the Walgett and Louth gauges. The lower end of the model covers the wetlands, lakes and billabongs of the Talyawalka wetland system.

The Barwon–Darling is an unregulated system and in-stream minimum flows are ensured by specifying various flow thresholds for water users with different licence classes. There are three irrigation license classes, i.e. classes A, B and C. There are issues with underestimation of inflows from the tributary models during some of the major floods. Therefore, estimates of additional flows, which may bypass the most downstream gauges of the tributary catchments, are included in the Barwon–Darling model.

The model used for Basin Plan development is at the 2007/08 level of irrigation development and incorporates the Cap accounting rules of July 2007 (i.e. reduced entitlements and continuous carryover). The development of this model is described in detail in DNR (2006a). The model does not include water buybacks by Commonwealth/NSW Governments from the system. The model is yet to be audited for accreditation for setting the Cap and for annual Cap compliance. As a consequence of this audit and its recommendations, the diversion estimate may be revised.

Table 10 Water balances for the Barwon–Darling system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-	-
Inflows		
Warrego	69.4	58.2
Condamine–Balonne	569.4	241.8
Moonie	96.3	71.4
Border Rivers	797.4	512.6
Gwydir	367.5	173.9
Namoi	828.3	652.5
Macquarie–Castlereagh	760.0	576.9
Local Barwon–Darling inflows	913.9	483.2
Total inflows	4,402.3	2,770.6
Diversions		
Total modelled watercourse diversions	-	197.5
Losses		
Evaporation losses from storages		
Warrego	32.3	28.2
Floodplain lakes	79.7	50.1
River evaporation	49.5	48.5
Sub-total storage losses	161.5	126.8
River losses		
Reach losses	1,072.5	678.4
Effluent losses	75.5	43.3
Sub-total river losses	1,148.0	721.8
Total losses	1,309.5	848.6
Outflows		
Menindee Lakes end-of-system flow	3,092.1	1,723.2
Unattributed flux		
Unattributed flux	0.7	1.3

4.10.2 Results and discussion

The water balances for without-development and baseline conditions for the Barwon–Darling system are summarised in Table 10. The Barwon–Darling system gets contributions from various tributaries, which have a gauging station near their confluence with the Barwon–Darling system. However, during flood events significant volumes of water can bypass these gauges and are then only measured at the gauging stations on the Barwon–Darling system. The volume of water that bypasses these tributary gauges can comprise a significant proportion of total Barwon–Darling inflows during high flow periods. This has been accounted for in the water balance as local inflows to the Barwon–Darling system. The total inflows to the Barwon–Darling system are estimated to be 4,402 GL/y under without-development conditions. Under without-development conditions, 70% of the total inflows reach the Menindee Lakes. Under baseline conditions the inflows have decreased to 37% of without-development inflows. The baseline inflows into the Barwon–Darling system are affected by developments in all upstream river valleys; therefore, reductions in end-of-system flows are due to the combined effect of upstream valley developments and developments in the Barwon–Darling system itself.

Under baseline conditions, diversions in the Barwon–Darling system are 7% of its inflows.

4.11 Lachlan

4.11.1 Model description

The Lachlan region is situated in central western New South Wales. It covers 8% of the total area of the Murray–Darling Basin and has 4.7% of the population of the Basin (CSIRO 2008f).

The Lachlan is modelled with a daily timestep IQQM model (Hameed and Podger 2001). The Lachlan River is modelled from its headwater inflows into Wyangala Dam and Belubula River inflows to the Carcoar Dam. The river breaks out into Willandra Creek and eventually runs dry. The model ends at the Great Cumbung Swamp and has no contribution to any of the downstream systems. The model includes key water regulation storages (i.e. Wyangala Dam, Carcoar Dam, Lake Cargelligo, Brewster Weir and Lake Brewster).

The development of the Lachlan Cap model is described in DLWC (2002). The model has been reviewed as part of the Cap auditing and has been accredited for Cap implementation (Bewsher 2002b).

The models used for estimating baseline diversion limits are the water sharing plan version of model. There is no separate documentation of the water sharing plan version of the model, but environmental flow, irrigation demands and environmental flow rules in the model correspond to the Lachlan Water Sharing Plan (DIPNR 2004e). The model does not include water buybacks by the Commonwealth and NSW governments since the start of the water sharing plan.

4.11.2 Results and discussion

The water balances for without-development and baseline conditions for the Lachlan system are summarised in Table 11. The Lachlan system has a good network of gauges on the contributing tributaries and as a consequence 70% of the river system inflows are based on gauged data and 30% are estimated using models. The total inflows into the Lachlan system are 1,424 GL/y. The Lachlan is an isolated system; most of the time water ends in wetlands and billabongs with no contribution to the Barwon–Darling or the River Murray system.

Under the historical climate scenario, diversions are 20% of system inflows.

Table 11 Water balances for the Lachlan system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-	-8.8
Inflows		
Directly gauged	991.8	991.8
Indirectly gauged	432.4	432.4
Total inflows	1,424.3	1,424.3
Diversions		
Total modelled water course diversions	-	286.6
Losses		
Wetland replenishment	-	26.2
Environmental contingency flow	-	5.0
River groundwater loss	-	17.4
Evaporation from public storages	-	67.7
Evaporation from natural water bodies	170.3	84.0
River loss and effluent loss	1,253.9	946.5
Total losses	1,424.3	1,146.8
Outflows		
End-of-system outflows	-	-
Unattributed flux		
Unattributed flux	-0.0	0.4

4.12 Murrumbidgee

4.12.1 Model description

The Murrumbidgee region is located in southern NSW and covers 8.2% of the Basin. The region is home to 27% of the total population of the Basin (CSIRO 2008l). It includes the nationally significant mid-Murrumbidgee wetlands and low Murrumbidgee floodplain, as well as the extensive Murrumbidgee and Colleambally irrigation areas.

The Murrumbidgee modelling suite is comprised of three models: the Snowy scheme (SNAT under without-development conditions, SNOW otherwise); the upper Murrumbidgee model (UBID) which represents the catchment from Tantangara Storage to Burrinjuck Dam; and the Murrumbidgee model (BIDG) which represents the main river from Burrinjuck and Blowering Dams to the ends-of-system at Balranald, Billabong Creek at Darlot and Forest Creek. Flows from the Cotter and Googong storages were provided by ACTEW to represent usage in the ACT. This includes the Murrumbidgee to Googong transfer, an enlarged Cotter Dam and a projected ACT population of 396,000. ACT diversions have been included as 40 GL/y, equal to the Cap. The Cap version of the Murrumbidgee model (BIDG) is described in DWE 2007. The model has been reviewed as part of the Cap auditing and has been accredited for Cap implementation (Bewsher 2010b).

Table 12 Murrumbidgee Water for Rivers purchases

Murrumbidgee Water for Rivers purchases	Entitlement (GL)	LTCE (GL/y)
Infrastructure		
Forest Creek stage 2	23.4	22.2
Forest Creek stage 1 — alternative stock and domestic supply	11.3	10.7
Barren Box Swamp water recovery*	20.0	19.3
Total	**54.7**	**52.2**
Market purchase and infrastructure programs which would lead to reduction in diversions from river		
NSW regulated general security market water purchase	40.4	25.7
On-farm reconfiguration	21.5	13.7
Colleambally Irrigation Co-Op Ltd	3.5	3.4
Hay Private Irrigation District stock and domestic pipeline	1.0	1.0
Total	**66.4**	**43.8**
Sum of infrastructure and market purchases	**121.1**	**96.0**

* This has been incorrectly included in the infrastructure category, but should be part of infrastructure programs that lead to reduction in diversions from the river and thus the baseline diversion limit should be reduced by this amount.

Table 13 Murrumbidgee TLM purchases

The Living Murray	Entitlement (GL)	LTCE (GL/y)
Infrastructure	3.5	2.2
Market purchase	78.4	49.9
TOTAL	**81.9**	**52.1**

Basin Plan modelling for the Murrumbidgee system is based on the water sharing plan (DIPNR 2004f; DWE 2009) version of the model and Snowy inflows are based on the pre-corporatisation version of the Snowy model. There is no documentation available for the water sharing plan version of the model as provided to MDBA. This original model version does not include water recovery for TLM, RiverBank or Water for Rivers for the Snowy Scheme, or water recovered by the Commonwealth Environmental Water Holder (CEWH).

The changes carried out to the Murrumbidgee model as compared to the water sharing plan version before its usage for determining baseline diversion limits were as follows.

- The baseline Murrumbidgee model was linked to the upper Murrumbidgee and Snowy scheme models to get better representation of the ACT and Snowy scheme impacts on the Burrinjuck Dam and Blowering Dam inflows.
- The model has been extended to include the Jounama catchment upstream of Blowering Dam.
- The without-development model is also a new model as compared to the version used by CSIRO for the MDBSY project and was developed by the NOW, based on the baseline model.
- Water recovery for TLM (purchase of 78.4 GL of entitlement) was added to the baseline model by MDBA. Water recovery under the Water for Rivers program is not in the model, but model results have been corrected for this recovery externally to determine baseline diversion limits. Table 12 and Table 13 detail TLM and Water for Rivers purchases to date.

Table 14 Water balances for the Murrumbidgee system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-	-16.8
Inflows		
Directly gauged	3,610.4	4,074.4
Indirectly gauged	625.8	625.8
Transfer from Murray through Finlay's Escape	-	42.1
Total inflows	4,236.3	4,742.3
Diversions		
Net modelled water course diversions	-	2,001.5
Losses		
Net evaporation from NSW storages	-	31.7
Small on-river wetlands	-	0.1
Lowbidgee evaporation total	310.6	213.7
River losses	960.2	773.9
Total losses	1,270.7	1,019.4
Outflows		
Billabong Creek at Darlot (to Murray, via Edward R.)	123.5	320.7
Murrumbidgee River at Balranald (to Murray)	2,724.2	1,224.6
Forest Creek (to floodplain)	29.9	56.8
TLM supply to Murray		34.3
Total outflows	2,877.5	1,636.4
Unattributed flux		
Unattributed flux*	88.0	101.8

* Includes river reach evaporation and change in reach storage.

- The Balranald end-of-system flow demand was updated to include the water sharing plan minimum flow rule which has come in effect from 2008–2009.
- Inputs from the Murray system which affect the Murrumbidgee system (Finlay's Escape, Lake Victoria storage levels and Murray announced allocations for Lowbidgee diversion determination) were updated based on the most recent information produced by the Murray model.

4.12.2 Results and discussion

The water balances for without-development and baseline conditions for the Murrumbidgee system are summarised in Table 14. The system has a reasonable number of gauges on the contributing tributaries, and as a consequence 85% of the river system inflows are based on gauged data, and only 15% are estimated using models. The total inflows to the Murrumbidgee system excluding the Snowy (for without-development conditions) are 4,236 GL/y. The total inflows are higher under baseline conditions (4,742 GL/y) due to the transfer from the Snowy River (included in the directly gauged inflows), inter-valley transfers and the impact of ACT diversions.

For the Murrumbidgee, 67% of its total inflows would reach the Murray system (Balranald plus Darlot) under without-development conditions and this has decreased to 33% under baseline conditions. The total diversions are 42% of baseline inflows.

4.13 Ovens

4.13.1 Model description

The Ovens region is in north-eastern Victoria. It covers 0.7% of the total area of the Murray–Darling Basin and has 2.3% of the total population in the Basin (CSIRO 2008m). The Ovens system is modelled with a weekly REALM model that covers the entire Ovens River from the northern slopes of Mount Hotham and Mount Buffalo through the Ovens valley, passing numerous regional towns. The system is modelled to the confluence with the Murray River upstream of Yarrawonga Weir. The most downstream gauge on the Ovens River is at Peechelba (403241). The Ovens model was developed in 1995 and there have been various reviews and updates since then. The most recent review and recalibration is described in SKM (2008). The Ovens model was received from the Victorian Department of Sustainability and Environment (DSE). The model inputs were last updated to December 2008 by SKM (2009b).

The REALM model of the Ovens River represents the current level of development and water sharing rules as of 2009. The water sharing rules are documented in the relevant bulk entitlements for the Ovens River (DSE 2010). The model has only been updated to December 2008, and does

Table 15 Water balances for the Ovens system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	0.0	0.1
Inflows		
Directly gauged	1319	1,319.0
Indirectly gauged	434.0	434
Total inflows	1,753	1,753
Diversions		
Total modelled water course diversions	-	25.4
Losses		
Net evaporation	-	1.5
Farm dam impact	-	14.0
River losses	17.6	19.4
Total losses	17.6	34.9
Outflows		
End of system flows (Peechelba)	1,735.2	1,692.9
Unattributed flux		
Unattributed flux	0.0	0.0

Water balance is for period from July 1895 to December 2010.

therefore not cover the January 2009 to June 2009 period. The Ovens flows to the Murray system for this period are based on actual (Peechelba flow) data.

The version of the model used in this project explicitly includes small catchment dams (farm dams) and the effects of groundwater pumping. Groundwater pumping is only modelled in the upper Ovens River catchment in an area with a direct hydraulic connection to the river. Other groundwater impacts, which under most flow conditions are small relative to streamflow volumes, are not explicitly modelled.

4.13.2 Results and discussion

The water balances for without-development and baseline conditions for the Ovens system are summarised in Table 15. As mentioned above, the model has been updated to December 2008 and does not cover the whole Basin Plan baseline period (i.e. up to June 2009). Hence, the water balances provided present annual average figures for the period from July 1895 to December 2008.

The inflows to the Ovens model are determined using a range of different methods, including gauged tributary flows that may be factored in to account for the ungauged part of the tributary catchment downstream of the gauge, as well as water balance methods and rainfall–runoff modelling (SKM 2009b). The Ovens catchment has a relatively high number of gauges and 75% of the inflows have been identified as directly gauged. The total inflows into the Ovens system are 1,753 GL/y. For the Ovens system, 99% of inflows would reach the Murray system under without-development conditions, as only 1% of inflows is lost. Under baseline conditions, 97% of inflows still flow into the Murray, which highlights a relatively low level of development in the catchment; only 1.4% of inflows are diverted under baseline conditions and historical climate.

4.14 Goulburn–Broken, Campaspe and Loddon rivers

4.14.1 Model description

The Goulburn–Broken, Campaspe and Loddon regions are situated in northern Victoria. The regions cover 4.8% of the area of the Murray–Darling Basin (including the Avoca region) and have 16% of the Basin's population (CSIRO 2008d; 2008b; 2008g).

The Goulburn–Broken, Campaspe and Loddon river systems are modelled together in the monthly 'Goulburn Simulation Model' (GSM), because they are hydrologically linked. The Broken River flows into the Goulburn River near Shepparton, and the Goulburn, Campaspe and Loddon rivers are all linked via the Waranga Western Channel (WWC), which transfers water from the Goulburn River to the Campaspe and Loddon river catchments. The WWC continues on from the Loddon River catchment through to the Wimmera region. The GSM includes outflows from Casey's Weir to Broken Creek, but does not model Broken Creek. Due to the links between the three different river systems, changes in one part of the GSM can affect flows and reliability of supply in other GSM river systems.

The baseline model being used represents the level of development and water sharing rules as of 2009 with diversions at Cap level less water recoveries for TLM and Water for Rivers, as well as Victorian government water recovery in the Loddon catchment. The water sharing rules are documented in the relevant bulk entitlements for the Goulburn, Broken, Campaspe and Loddon rivers (DSE 2010). The model was provided by the DSE. The configuration of the GSM model and its calibration and validation is described in the Cap report (DSE 2005). This model was audited and accredited for use for annual Cap auditing (Bewsher 2006). The last major model configuration is described in DSE (2007).

Table 16 Environmental water recovery and trade entitlements included in the GSM baseline model

Description	HRWS (GL)	LRWS (GL)	Total (GL)
Goulburn–Broken			
Water recovery for TLM			
Living Murray account reconfiguration	19.2		19.2
Shepparton modernisation[1]	26.0	9.4	35.5
Purchase	5.6		5.6
20% sales water		141.2	141.2
Water for Rivers water recovery			
Normanville	3.9		3.9
IMSVID	10.9		10.9
Strategic Measurement project	0.5		0.5
Water share purchases (incl. Madowla Park)	4.2	17.9	22.1
Inter-valley trade			
Permanent trade	110.2		110.2
Campaspe			
Water recovery for TLM			
Account reconfiguration	0.1		0.1
20% of sales water		5.0	5.0
Inter-valley trade			
Exchange rate trade until June 2007	1.2		1.2
Loddon			
Victorian government water recovery			
Boort Wetlands	2.0		2.0
20% of sales water		2.0	2.0

[1] These numbers represent TLM entitlements as included in the model at the time the Basin Plan scenarios were run. However, these numbers do not exactly represent the TLM entitlements resulting from the Shepparton modernisation and will be corrected in the model to 20.5 GL HRWS and 15.8 GL LRWS for future scenarios.

Water recovery and inter-valley trade included in the model has been summarised in Table 16. Some other key features of the model are as follows.

- It includes Winton Swamp (27 GL capacity), which was previously the site of Lake Mokoan (365 GL capacity) and has now been decommissioned.
- It excludes the 225 GL/y of water savings and infrastructure changes under the Northern Victoria Irrigation Renewal Project (NVIRP). Part of NVIRP is the Sugarloaf Interconnector pipeline to Melbourne, which will deliver up to 75 GL/y from the Goulburn River downstream of Lake Eildon to Melbourne; this is also excluded from the model.
- It excludes the proposed decommissioning of irrigation supplies to the Campaspe Irrigation District (19.5 GL HRWS and 10.2 GL LRWS entitlement).
- It excludes the connection of the town of Axedale to the Bendigo water supply system. The town is assumed to source its 0.1 GL/y from the Campaspe River.

- It excludes the Goldfields Superpipe, which supplies water to Ballarat (up to 18 GL/y) and Bendigo (up to 20 GL/y). The pipe runs from the WWC near Colbinabbin to Sandhurst Reservoir in the Bendigo urban system, then to White Swan Reservoir in the upper reaches of the Barwon River basin in southern Victoria.

4.14.2 Results and discussion

The results for the Goulburn–Broken, Campaspe and Loddon River systems are discussed separately in the following sections.

Goulburn–Broken

The water balances for without-development and baseline conditions for the Goulburn–Broken system are summarised in Table 17.

The inflows to the various river reaches have been estimated using various methods including 'gauged and transposed flows' (in which gauged tributary flows are factored up to include an estimate of the ungauged part of the tributary catchment below the gauges) and water balance methods based on main stream gauges (SKM 2009a). The total inflows in the Goulburn–Broken system under historical climate are 3,378 GL/y. For the Goulburn–Broken system it is estimated that 99.7% of its total inflows would reach the Murray system under without-development conditions, which has been decreased to 49% under baseline conditions, with 46% of inflows being diverted.

The negligible losses being predicted by the without-development conditions model are because the model does not include an estimate of river losses along the Goulburn

Table 17 Water balances for the Goulburn–Broken system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-0.0	-20.5
Inflows		
Total inflows	3,377.6	3,383.6
Diversions		
Broken diversions	-	13.2
Goulburn diversions	-	1,551.6
Total modelled water course diversions	-	1,564.8
Losses		
Irrigation drainage returns	-	-29.1
River losses	2.6	168.3
Net evaporation	7.1	31.4
Total losses	9.7	170.5
Outflows		
End-of-system flow at McCoys Bridge (to Murray model)	3,368.0	1,665.8
Total modelled outflows	3,368.0	1,667.7
Unattributed flux		
Unattributed flux	0.0	1.1

Table 18 Water balances for the Campaspe system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	0.0	-2.5
Inflows		
Total inflows	289.7	289.7
Diversions		
Total modelled water course diversions	-	110.9
Losses		
Net evaporation	-	16.8
Channel losses	8.9	10.5
Total losses	8.9	27.3
Outflows		
End of system flow at Rochester (to Murray model)	280.8	156.8
Total modelled outflows	280.8	154.0
Unattributed flux		
Unattributed flux	0.0	0.1

Table 19 Water balances for the Loddon system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	0.0	-1.3
Inflows		
Total inflows	255.4	255.4
Diversions		
Total consumptive diversions	-	88.6
Environmental diversions (Boort wetlands)	-	2.2
Total modelled water course diversions	-	90.7
Losses		
Net evaporation	-	14.4
Channel losses	16.9	22.2
Total losses	16.9	36.5
Outflows		
End-of-system flow at Appin South (to Murray model)	144.7	67.8
To flood breakouts u/s from Appin South	93.7	61.5
Total outflows	238.5	129.3
Unattributed flux		
Unattributed flux	0.0	0.1

River; the river losses reported in the water balances for the without-development scenario are only for the Broken system. The baseline model only includes an estimate of additional river losses along the upper Goulburn that occur due to river operations. The floodplain losses in the model are included in estimates of flow contribution from catchments downstream of Eildon and partly in the losses between McCoys Bridge and River Murray reach between Yarrawonga and Torrumbarry. The estimation of losses and flows from tributaries downstream of Eildon in the Goulburn model needs to be reviewed to better represent flow contribution vis-a-vis floodplain losses.

Campaspe

The water balances for without-development and baseline conditions for the Campaspe system are summarised in Table 18. River system inflows have been estimated based on a range of different methods (SKM 2009a), including the gauged and transposed flows (described for the Goulburn–Broken system above) and water balance methods. The total inflows to the Campaspe system are currently 290 GL/y. For the Campaspe system, it is estimated that 97% of total inflows would reach the Murray system under without-development conditions. Under baseline conditions this has decreased to 53%, with 38% of inflows being diverted.

Loddon

The water balances for without-development and baseline conditions for the Loddon system are summarised in Table 19. The inflows of the Loddon system are estimated based on regressions using nearby tributary gauges and water balances using mainstream gauges (SKM 2009a). The total inflows to the Loddon system are 255 GL/y. For the Loddon system it is estimated that 93% of total inflows would reach the Murray system under without-development conditions. Under baseline conditions this has decreased to 51%, with 35% of inflows being diverted for consumptive use.

4.15 Wimmera

4.15.2 Model description

The Wimmera region is located in western Victoria. It covers 3% of the total area of the Basin and has 2.5% of the Basin's population (CSIRO 2007e).

The Wimmera model is a monthly REALM representation of the Wimmera River. The baseline model also includes the Glenelg River to downstream of Rocklands Reservoir and the Avon–Richardson rivers. These rivers interact with the Wimmera headworks system, so that transfers can be made from the Glenelg to the Wimmera. Surface water in the Wimmera River is not connected to the River Murray and hence there are no downstream impacts on other reporting regions in the Murray–Darling Basin.

The Cap version of the model has been described by W&D Engineering and Legal Services (W&D 2009). This model has been audited and accredited for use for annual Cap auditing (Bewsher 2011b). The without-development and baseline models used for basin planning have been provided by the DSE.

The baseline model represents the level of development and water sharing rules as of October 2010. The water sharing rules are documented in the relevant bulk entitlements for the Wimmera and Glenelg rivers (DSE 2010). The model includes stages 1 to 7 of the northern Mallee pipeline and includes supply systems 1 to 6 (i.e. all supply systems) of the Wimmera–Mallee pipeline. The savings from these pipeline projects have created new entitlements for the environment and future growth and use of these entitlements has been activated in the model. There is 40.56 GL/y

Table 20 Water balances for the Wimmera system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-7.1	-7.9
Inflows		
Inflows	248.3	248.3
Inflows from Avon and Richardson Rivers[1]	-	22.6
Transfers from other basins (Glenelg)	-	24.6
Total inflows	248.3	295.5
Diversions		
Total consumptive diversions	-	65.7
Wetland diversions	-	0.9
Total modelled diversions	-	66.6
Losses		
Evaporation from lakes	180.6	146.6
Evaporation and loss from headwater storages and channels	-	34.4
River losses	55.3	27.5
Flows to lakes and wetlands	19.3	28.4
Total losses	255.2	236.9
Outflows		
Total end-of-system outflows (to Murray)	0.0	0.0
Unattributed flux		
Unattributed flux	0.1	0.2

1 Not included in the without-development model

of environmental water entitlement in the model, which includes 32.2 GL/y from the northern Mallee pipeline stages 1 to 7 and 8.3 GL/y from the Wimmera–Mallee pipeline supply systems stages 1 to 6. The allocations to these entitlements are managed as a combined volume, which is shared between the Wimmera and Glenelg systems. The model also includes supply to the Horsham Irrigation District (19 GL/y irrigation product and 9 GL/y irrigation loss entitlements).

4.15.2 Results and discussion

The water balances for without-development and baseline conditions for the Wimmera system are summarised in Table 20. The total inflows to the Wimmera system under without-development conditions are 248 GL/y. However, under baseline conditions, inflows are higher due to the 24.6 GL/y transfer from the Glenelg River and the inclusion of the Avon–Richardson inflows. From the Wimmera system there are no outflows into the Murray system and the system ends in terminal lakes, including Lake Hindmarsh, Lake Albacutya and a series of smaller lakes in the Mallee. The flows to these lakes and wetlands have been included in the water balance as losses. Under baseline conditions, 23% of the baseline inflows are diverted.

4.16 Murray

4.16.1 Model description

The Murray region straddles southern New South Wales, northern Victoria and south-eastern South Australia. It represents 19.5% of the total area of the Murray–Darling Basin and has 16% of the Basin's population (CSIRO 2008j).

The Murray and lower Darling systems are modelled using the Murray monthly simulation model (MSM) and a daily routing model (Bigmod). The modelling suite has been used for development and implementation of range of water resource planning and management policies and operating rules including Cap on water use, the basin salinity management strategy, development of optimal operating strategies for major storages, water accounting and resource assessment (MDBC 2002a; MDBC 2007; Bewsher 2008).

The model commences with headwater inflows from the Murray River (about 40 km south of Mt. Kosciuszko) and Darling River inflows into Menindee Lakes, and finishes at the barrages which separate the Lower Lakes from the sea (MDBC 2002b). More recently, a hydraulic model of hydrodynamic behaviours and salinity in the Coorong developed by the CSIRO (Webster 2007) has been included in this modelling suite.

The model receives inflows from the Snowy Mountain Hydro-electric Scheme (SMHS) via releases through the Murray 1 Power Station (WAMC 2002). It also receives inflows from a number of tributaries including:

- Kiewa River at Bandiana
- Ovens River at Peechelba
- Goulburn River at McCoy's Bridge
- Campaspe River at Rochester
- Loddon River at Appin South
- Billabong Creek at Darlot
- Murrumbidgee River at Balranald
- Barwon–Darling rivers at the Menindee Lakes

The model includes the four major storages: Dartmouth Dam on the Mitta Mitta River, Hume Dam on the Murray River, Menindee Lakes on the lower Darling and Lake Victoria (an off-river storage connected to the Murray River). The Menindee Lakes system is modelled as four major lakes: Wetherell, Pamamaroo, Menindee and Cawndilla. In addition, a number of weir pools and natural wetlands and floodplains are included in the model. A number of smaller weirs are not included as they do not impact on monthly operations (MDBC 2007). The model simulates:

- water sharing arrangements between the states, as per the Murray–Darling Basin Agreement (Schedule 1 to the Water Act 2007 (Cwlth))
- water accounting as per the Murray–Darling Basin Agreement
- allocation by states to groups of water users
- irrigation water demands in the key regions throughout the system
- transfers required between storages to ensure that demand can be met
- operation of various dams and structures including orders to meet forecast demand and pre-releases from each storage for flood mitigation.

The baseline conditions of the Murray and lower Darling system that have been used are as follows.

- They are based on the water sharing and management arrangements in place at June 2009, i.e. the water sharing plan for NSW Murray and lower Darling systems and Cap conditions for Victoria and SA with adjustment for water recovery under TLM and the Water for Rivers program (MDBA 2011).
- Water trade within the model includes permanent entitlement trade to June 2009. This level of trade is used for the entire modelling period. This includes increases or decreases in the NSW,

Victorian and SA Cap as result of such permanent trade. The model also includes the ability for Tandou to trade up to 20 GL when required and when Menindee Lakes is in MDBA control. Apart from this, however, no inter-valley temporary trade is modelled.

- Environmental flow provisions included in the baseline model include:
  - additional dilution flows of 3,000 ML/d, if the volume of water stored in Menindee Lakes is more than 1,650 GL in June and July, 1,500 GL in August and 1,300 GL in any other months, and the combined storage of the Hume and Dartmouth dams is more than 2,000 GL
  - Darling Anabranch environmental releases during periods of off-allocation on the Lower Darling
  - environmental water allocation of up to 150 GL/y for the Barmah–Millewa Forest, and the associated watering rules (MDBC 2006a, 2006b).
  - a 500 GL long-term Cap equivalent (LTCE) water recovery for TLM initiative and environmental water delivery of the recovered water (Table 21)
  - recovery of water for Water for Rivers (Table 22) and 70 GL River Murray increased flow from Snowy scheme.
- Calling available water from tributary TLM accounts is managed in the Murray model on an as need basis. To do this, when end-of-system flows at tributaries are transferred to the Murray model and used as inputs to the Murray model, the end-of-system flows are reduced by the volume released from their TLM accounts. This is because the release determined by the tributary models (Goulburn simulation model and Murrumbidgee model) may not be useful for meeting environmental water needs in Murray. Instead, the Murray model maintains these accounts using the announced allocation level of the tributary models and calls water out from the accounts when it is needed. For ensuring deliverability of the TLM water that the Murray can call out, a time series describing the available channel capacity in the Goulburn system is used to limit the maximum TLM water that can be called out.
- TLM works and measures include and are operated as:
  - rostered environmental watering requirements based on pre-defined rules for achieving or maintaining ecological health conditions at TLM icon sites
  - scheduled water delivery from the identified watering requirements within available TLM and River Murray Increased Flows (RMIF) water on a most-needed basis.
- SA restriction policy and carryover provisions are included (MDBA 2009).

4.16.2 Results and discussion

The water balances for without-development and baseline conditions for the Murray and Lower Darling system are summarised in Table 23. The Murray and Lower Darling system is well gauged and only a small fraction (<2%) of its inflows are estimated. The total inflows into the Murray and Lower Darling system under without-development conditions are 16,386 GL/y. The total inflows under baseline conditions have been reduced due to developments in its contributing catchments and are 12,368 GL/y under historical climate. Under without-development conditions, 76% of the total Murray and Lower Darling inflows reach the sea through the Murray Mouth. Under baseline conditions this has decreased to 42% of current inflows, which corresponds to only 31% of the without-development inflows.

Table 21 The Living Murray water recovery projects

Proponent	Project	LTCE (GL)	Entitlement (GL)	Category of entitlement
NSW	Murray Irrigation Limited	17.8	100.0	NSW Murray supplementary water
	Pipe It	0.1	0.2	NSW Murray general security water
	Market purchase measure	115.3	69.2	NSW Murray general security water
			1.1	NSW Murray high security water
			0.5	Lower Darling high security water
			150.0	Lower Darling supplementary water
			76.8	Murrumbidgee general security water
	Tandou Limited	9.3	100.0	Lower Darling supplementary water
	NSW Package B	47.0	47.8	Lower Darling general security water
		9.0	-	Poon Boon Lakes (modelled)
		7.1	3.7	NSW Murray high security water
			3.7	Vic Murray high reliability water share
	Wetland Water Recovery – stage 1	0.6	0.3	NSW Murray high security water
			0.3	Vic Murray high reliability water share

...continued

Table 21 The Living Murray water recovery projects

Proponent	Project	LTCE (GL)	Entitlement (GL)	Category of entitlement
Vic	Sales unbundling	120.0	98.8	Vic Murray low reliability water share
			141.2	Goulburn low reliability water share
			5.1	Campaspe low reliability water share
			3.0	Vic Murray low reliability water share[1]
	Victorian reconfiguration	24.9	5.7	Vic Murray high reliability water share
			19.2	Vic tributaries high reliability water share
	Shepparton modernisation	29.3	20.5	Vic tributaries high reliability water share
			15.8	Vic tributaries low reliability water share
	Lake Mokoan decommis-sioning and Snowy high reliability water share 22 GL	28.1	-	Modelled
SA	SA government held water	35.0	18.9	South Australian River Murray
			12.3	
	Purchase from willing sellers		4.3	
			1.1	
Australian Government	Water efficiency tender	0.2	0.2	NSW Murray general security water

[1] Not included in the model

...continued

Table 21 The Living Murray water recovery projects

Proponent	Project	LTCE (GL)	Entitlement (GL)	Category of entitlement
MDBA	Living Murray water purchase	18.6	7.3	South Australian River Murray
			7.2	Vic Murray high reliability water share
			5.5	Vic tributaries high reliability water share
	Pilot market purchase	13.3	1.9	Vic Murray high reliability water share
			0.02	Vic tributaries high reliability water share
			13.0	NSW Murray general security water
			1.6	Murrumbidgee general security water
	Ricegrowers' on-farm water Efficiency round 1	0.9	1.3	NSW Murray general security water
		0.1	0.2	Murrumbidgee general security water
	Ricegrowers' on-farm water Efficiency round 2	4.2	5.2	NSW Murray general security water
		1.0	1.2	Murrumbidgee general security water
	Sustainable Soils and Farms on-farm reconfiguration	3.0	3.2	Vic Murray high reliability water share

Table 22 Water for Rivers recovery in the Murray

Valley	Project	Entitlement (GL)
NSW Murray	Market purchase (GS)	29.955
	Deniliquin Golf Club (GS)	0.238
	Edward Gulpa wetland evaporation savings	7.0
VIC Murray	Woorinen stock and domestic pipeline (HRWS)	1.5
	IMSVID excluding Normanville and Woorinen (HRWS)	5.488
	Market purchase (HRWS)	5.419
	Market purchase (LRWS)	5.08
	North-east CMA surrender of water share (HRWS)	0.706
	Madowla Park reconfiguration (HRWS)	1.99
	On-farm reconfiguration (LRWS)	0.46

Table 23 Water balances for the Murray system for without-development and baseline scenarios

Water balance (GL/y)	Without-development	Baseline
Storage		
Total change in storage	-13.0	-75.4
Inflows		
Darling (inflow to Menindee Lakes)	3,092.1	1,723.2
Murrumbidgee (Balranald)	2,724.2	1,257.0
Murrumbidgee (Darlot)	123.5	320.7
Catchment managed by Snowy scheme	616.9	1,132.8
Ovens at Peechelba	1,728.2	1,686.0
Goulburn at McCoy's Bridge	3,368.0	1,665.2
Campaspe at Rochester	280.8	151.9
Loddon at Appin South	144.7	67.8
Directly gauged Murray sub-catchments	4,047.1	4,035.9
Indirectly gauged Murray sub-catchments	260.2	327.6
Total inflows	16,385.6	12,368.1
Diversions		
NSW Murray diversions	-	1,680.2
NSW lower Darling diversions	-	54.7
Victorian Murray diversions	-	1,657.0
SA Murray diversions	-	665.0
Total diversions	-	4,056.3
Losses		
Total net evaporation	427.6	611.6
Net groundwater loss	-	47.0
Total loss including SA	3,593.9	2,585.4
Total losses	4,021.4	3,244.0
Outflows		
Barrage outflow	12,377.2	5,142.4
Unattributed flux		
Unattributed flux	0.00	0.02

Under baseline conditions, diversions are 25% of the without-development inflows (or 33% of baseline inflows). The total end-of-system flows are 5,142 GL/y.

5 UNMODELLED DIVERSIONS

In a number of SDL resource units there are some diversions which are not modelled by the river systems models. These could be diversions from the catchments upstream of storages or from catchments upstream of inflow points to these models. In most cases these diversions have been estimated by state agencies as part of reporting for the Cap. The unmodelled diversions in various valleys since the introduction of the Cap are summarised in Table 24. These diversions from unregulated watercourses have been estimated based on crop area surveys and assessed irrigation requirements in NSW (MDBA 2009) and percent adjustment of the modelled component in Victoria (Bewsher 2006).

The unmodelled diversions included in the total watercourse diversions are the average of reported unmodelled diversions for the period 1997/98 to 2009/10 for NSW and Victoria.

6 ACCOUNTING FOR UNMODELLED INFLOWS AND DIVERSIONS FOR PREPARATION OF THE PROPOSED BASIN PLAN

The without-development and baseline model scenarios, as presented above, have been used to make estimates of total inflows and Baseline Diversion Limits (BDLs) presented in the proposed Basin Plan. However, the figures presented in Schedule 1 to the proposed Basin Plan may differ from figures presented in the water balance tables for individual valleys, as various post-processing steps have been applied to account for inflows and diversions not included in the models.

The total inflows estimate provided in Schedule 1 to the proposed Basin Plan are based on the local inflows (i.e. excluding inflows from upstream modelled connected river systems), modelled for without-development conditions. However, these modelled inflows do not include explicit representation of interceptions (e.g. farm dams and plantation forestry) or some unregulated watercourse diversions (see Section 5 of this document). The interception by farm dams and forestry plantations are based on the most recent available estimates of the impact of these interception activities on runoff. Outcomes from studies undertaken by SKM, CSIRO and the Bureau of Rural Sciences (2010) and SKM (2007) have been used for these estimates. However, these studies acknowledge limitations to the accuracy of their results, and MDBA recognises that their application to the Basin Plan needs to keep these limitations in mind.

In the absence of adequate data to correct for these changes over time, it has been assumed that modelled inflows include the full effect of these interceptions and unmodelled watercourse diversions and

Table 24 Diversions not included in Cap/water sharing models (GL/year)

New South Wales	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	Average
Intersecting Streams[1]	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
Border Rivers	13.7	17.7	15.7	15.7	15.7	13.7	18.7	16.7	18.0	14.0	19.2	19.0	13.7	16.3
Gwydir	11.3	11.3	14.3	10.3	12.3	10.3	10.3	12.3	11.4	10.0	10.3	10.3	10.3	11.1
Namoi/Peel	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1	78.1
Macquarie/ Castlereagh/Bogan	38.3	57.3	51.3	56.3	50.3	35.3	44.3	38.8	44.5	35.8	44.3	39.7	35.3	43.9
Barwon–Darling/ lower Darling	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lachlan	16.3	15.9	16.1	15.6	16.7	15.3	15.3	15.3	15.3	15.6	15.3	15.3	15.3	15.7
Murrumbidgee	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4	42.4
Murray	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7	27.7
Total NSW	**231.0**	**253.6**	**248.8**	**249.4**	**246.4**	**226.1**	**240.1**	**234.5**	**240.7**	**226.9**	**240.5**	**235.7**	**226.1**	**238.4**
Victoria	1997–1998	1998–1999	1999–2000	2000–2001	2001–2002	2002–2003	2003–2004	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009	2009–2010	Average
Goulburn/Broken/ Loddon	29.8	34.4	41.8	39.3	23.2	22.5	23.5	39.4	60.6	16.7	12.6	13.6	17.4	28.8
Campaspe	3.7	3.2	2.6	2.5	4.4	1.8	1.3	1.0	0.6	0.4	0.2	0.1	0.1	1.7
Wimmera–Mallee	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.2	0.0	0.8
Murray/Kiewa/ Ovens	0.0	0.0	0.0	0.0	5.7	12.8	9.1	9.2	17.7	6.8	4.1	4.2	2.1	5.5
Total Victoria	**34.4**	**38.5**	**45.3**	**42.7**	**34.2**	**37.9**	**34.8**	**50.5**	**79.7**	**24.8**	**17.7**	**18.1**	**19.7**	**38.2**

[1] Intersecting Streams diversions are partly included in the Queensland models and the estimated diversions have not been reviewed

therefore the estimates of the total inflows (Schedule 1 to the proposed Basin Plan) are obtained by adding interceptions and unmodelled diversions to the modelled inflows (Table 25).

The BDLs are based on the sum of the modelled diversions (as presented in the water balance tables), unmodelled watercourse diversions (Section 5) and interceptions. Estimates of these different components have been included in Schedule 3 to the proposed Basin Plan and are also presented in this document in Table 26.

For some valleys, additional adjustments have been made to the inflows and BDL estimates. These adjustments are shown in Table 25 and Table 26 and are described below.

Queensland valleys and Intersecting Streams

For the Paroo, Warrego, Condamine–Balonne, Nebine and Moonie systems, the modelled diversions reported in Table 26 are based on the total Queensland diversions only. Modelled NSW diversions in these valleys (a total of 9 GL/y) have not been used because of advice from NOW on the questionable accuracy of these estimates. The NSW diversions in these regions are represented by Intersecting Streams, but the modelled diversions have been replaced by a diversions figure of 3 GL/y, which is based on Cap reporting (Table 26).

Murrumbidgee

The Murrumbidgee inflows include a Snowy transfer of 402 GL/y. This is based on a transfer of 498 GL/y, which has been reduced by 96 GL/y to account for water recovery under the Water for Rivers program.

The Murrumbidgee diversions have been adjusted by -44 GL/y (long-term Cap equivalent) to account for water recovery through market purchase mechanisms under the Water for Rivers program.

The ACT diversions figure is based on the current Cap of 40.5 GL/y.

Kiewa

Kiewa inflows under without-development conditions for the modelling period have been derived using flow for Kiewa at Bandiana after correcting them with historical diversions data (MDBC 2002b). Since flows at Bandiana are net of river system losses, total Kiewa inflows have been corrected by 7 GL/y for estimated river system losses.

Kiewa diversions have been estimated by MDBC at the 1993/94 level of development as part of setting up the Cap in various valleys (MDBC 2002b). These diversions are estimated as 11 GL/y.

Murray

The local inflows to the Murray are based on the directly and indirectly gauged Murray sub-catchments and the Snowy Mountain Hydro-electric Scheme releases (Table 23). The indirectly gauged inflows are 260.2 GL/y. The directly gauged inflows are 4,047.1 GL/y, but this figure includes inflows to the Kiewa of 668 GL/y and excludes contribution from the Murray catchment managed by the Snowy scheme estimated as 617 GL/y. The modelled local inflows for the Murray exclude Kiewa inflows, as Kiewa has been reported separately (Table 25). Therefore, Murray local catchment inflows are estimated as 4,256 GL/y (4,047 gauged + 260 ungauged – 668 Kiewa inflows reported separately + 617 Murray catchment managed by the Snowy scheme).

The diversions reported in the water balance table (Table 23) provides total Murray diversions for NSW, Victoria and South Australia. The total Murray diversions in the water balance table (Table 26) also includes the 55 GL/y of lower Darling diversions, separately reported in the proposed Basin Plan.

Ovens

The Ovens model is not implemented in the IRSMF framework and was only updated to the end of December 2008 (SKM 2009b). The modelled annual average outflows for the without-development scenario is 1,735 GL/y for the period July 1895 to December 2008 (Table 15). This time series has been extended to 30 June 2009 using gauged flow data for the Ovens River at Peechelba. The resulting annual average outflows for the whole baseline period of July 1895 to June 2009 is 1,728 GL/y, which is 7 GL/y less than for the modelled period (July 1895 – Dec 2008). It is assumed that the relatively low outflows in the January to June 2009 period result from relatively low inflows in this period. Therefore, the modelled inflows of 1,753 GL/y (Table 15) have also been reduced by 7 GL/y to 1,746 GL/y (Table 25). Modelled diversions were also extended to June 2009 (based on reported annual diversions for the valley), but this did not change the overall annual average of 25.4 GL/y.

Wimmera–Avoca

The without-development inflows for the Wimmera are 248 GL/y (Table 20). As the Avoca model has not been included in the modelling framework, 88 GL/y was added for Avoca inflows (taken from the Murray–Darling Basin Sustainable Yields project, CSIRO 2008g). The estimated transfer of 24.7 GL/y from the Glenelg into the Wimmera catchment has also been included in the total inflows figure, as have 22.6 GL/y of inflows from the Avon and Richardson that have been included in the baseline model, but not in the without-development model. This results in a total adjustment addition of 135 GL/y to the modelled without-development inflows (Table 25).

Table 25 Modelled without-development local inflows and additions/adjustments made to determine total inflows as reported in Schedule 1 to the proposed Basin Plan (GL/y)

SDL resource unit	Modelled inflows (without-development)	Unmodelled diversions	Interceptions	Adjustments	Total inflows
Northern Basin					
Paroo	678		9.7		688
Warrego	616		83		699
Condamine–Balonne	1651		265		1,916
Nebine	94		25		119
Moonie	151		51		202
Intersecting Streams			111		111
Border Rivers (total)[1]	2,002	41	173		2,217
Gwydir	996	11	125		1,131
Namoi	1,883	78	165		2,126
Macquarie–Castlereagh	2,859	44	310		3,213
Barwon–Darling	914				914
Total northern Basin	11,844	174	1,318	0	13,336
Southern Basin					
Ovens	1,753		58	-7	1,804
Goulburn–Broken (total)[2]	3,378	29	152		3,558
Loddon	255		90		346
Campaspe	290	2	40		332
Murrumbidgee (total)	4,236	42	513	402	5,193
Kiewa	668		14	7	689
Lower Darling			5.5		6
Murray (total) [3]	4,256	33	153	527	4,968
EMLR / Marne–Saunders[4]	120[5]				120
Total southern Basin	14,956	106	1,025	929	17,016
Disconnected					
Lachlan	1,424	16	316		1,755
Wimmera–Mallee	248	1	62	135	446
Total disconnected	1,672	17	378	88	2,154
Basin total	**28,465**	**297**	**2,721**	**1,064**	**32,506**

[1] Includes Queensland Border Rivers and NSW Border Rivers SDL resource units

[2] Includes Goulburn and Broken SDL resource units

[3] Includes NSW Murray, Victorian Murray, SA Murray and SA Non-Prescribed Areas SDL resource units

[4] Includes Eastern Mount Lofty Ranges and Marne–Saunders SDL resource units

[5] Not modelled by MDBA, but based on MDBSY water availability estimate (CSIRO 2008k)

Note: Reported total inflows can vary slightly from the sum of numbers in individual columns due to rounding.

Table 26 Modelled diversions, unmodelled diversions and adjustments made to determine the total watercourse diversions and interceptions added to determine final BDL estimates as presented in the proposed Basin Plan (GL/y)

SDL resource unit	Modelled diversions	Unmodelled diversions	Adjustments	Total watercourse diversions	Interceptions	Total BDL
Northern Basin						
Paroo[1]	0.2			0.2	9.7	9.9
Warrego[1]	45			45	83	128
Condamine–Balonne1	713			713	265	978
Nebine[1]	6			6	25	31
Moonie[1]	33			33	51	84
Intersecting Streams	9		-6	3	111	114
Border Rivers — Queensland	218	25		242	78	320
Border Rivers — NSW	191	16		208	95	303
Gwydir	314	11		325	125	450
Namoi	265	78		343	165	508
Macquarie–Castlereagh	380	44		424	310	734
Barwon–Darling	198			198		198
Total northern basin	2,372	174	-6	2,540	1,318	3,858
Southern Basin						
Ovens	25			25	58	83
Goulburn	1,552	29		1,580	109	1,689
Broken	13			13	43	56
Loddon	89			89	90	179
Campaspe	111	2		113	40	153
Murrumbidgee (NSW)	2,002	42	-44	2,000	501	2,501

...continued

Table 26 Modelled diversions, unmodelled diversions and adjustments made to determine the total watercourse diversions and interceptions added to determine final BDL estimates as presented in the proposed Basin Plan (GL/y)

SDL resource unit	Modelled diversions	Unmodelled diversions	Adjustments	Total watercourse diversions	Interceptions	Total BDL
Australian Capital Territory			40.5	40.5	12	53
Kiewa	11			11	14	25
Lower Darling	55			55	5.5	61
Murray — New South Wales	1,680	28		1,708	104	1,812
Murray — Victoria	1,657	6		1,662	45	1,707
Murray — South Australia	665			665		665
SA non-prescribed areas					3.5	3.5
Eastern Mount Lofty Ranges			28.3[2]	28.3		28.3
Marne–Saunders			2.9[3]	2.9		2.9
Total southern Basin	7,858	106	28	7,993	1,025	9,018
Disconnected						
Lachlan	287	16		302	316	618
Wimmera–Mallee	66	1		67	62	129
Total disconnected	352	16	0	368	378	747
Basin total	**10,583**	**297**	**22**	**10,902**	**2,721**	**13,623**

1 Queensland diversions only

2 Data provided by South Australian Department for Water corresponding to full realisation of the draft EMLR water allocation plan which includes 13 GL/y of intercepted water by runoff dams and commercial plantations

3 Intercepted water by runoff dams

7 PUBLISHED NUMBERS

The numbers published in this report for various water balance terms (i.e. diversions, losses, inflows or end-of-system flows) for various catchments may be different to those published previously in reports by MDBA, the Basin states, CSIRO or other consultants for the purposes of the Cap or water sharing plans/ROPs/bulk entitlements. There are number of reasons why these could be different and these reasons vary from valley to valley. The key reasons for the differences are as follows.

- The Basin Plan modelling has been undertaken using the climatic data for the period July 1895 to June 2009. This was the common period for which all 24 river system models had climate data available. Numbers published by MDBA, states, CSIRO or consultants for various river systems are not for this period and usually results are based on the longest period for which data was available for individual river systems.
- Models were updated to include permanent inter- and intra-state water trade.
- Models were updated to include water recovered by TLM and Water for Rivers (for provision of environmental flows to the Snowy and Murray rivers) and its use for the environmental works and measures.
- Any improvements or updating of models carried by the states/MDBA since the development of water sharing plans in NSW, water resource plans/ROPs in Queensland or bulk entitlement in Victoria were adopted in the Basin Plan version of models.
- Best available estimates for the impact of groundwater use on the river system flows at 2030 have been included in the Lachlan (17.4 GL/y), Namoi (11.2 GL/y) and Murray (47 GL/y) models.
- Some model calibrations have been improved since the versions used for the development of various water sharing arrangements in the past and these updated models have been used for the Basin planning purposes.

More details on the differences between previously published numbers and the numbers presented here can be found in a separate report (MDBA 2011).

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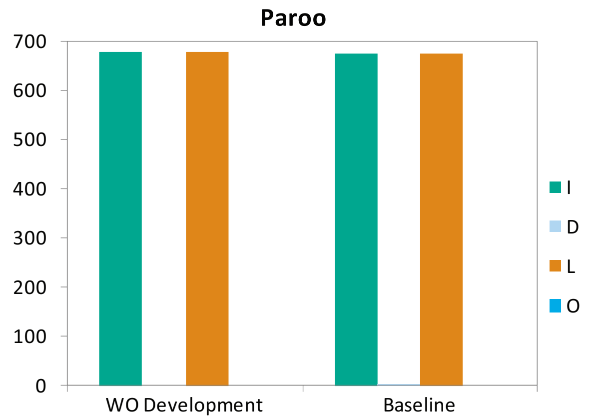
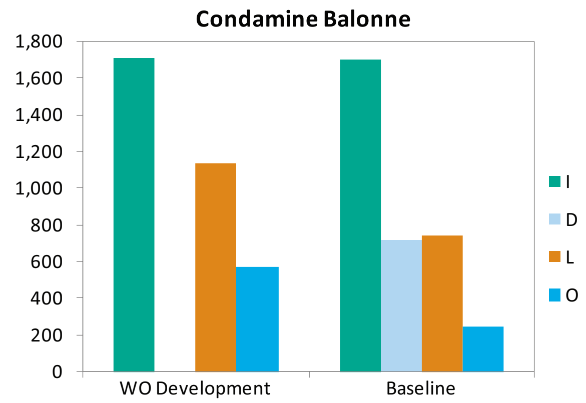
9 APPENDIX

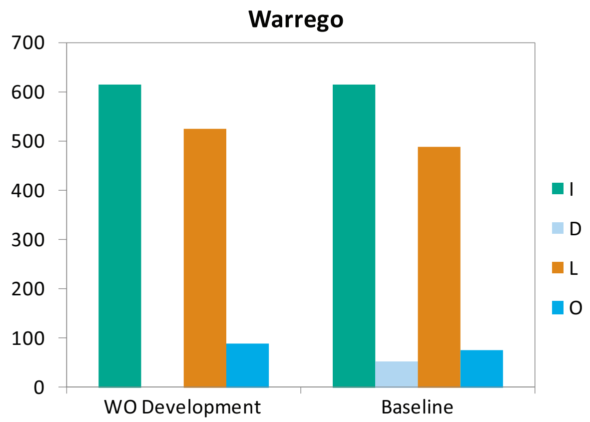
Modelled annual average inflows, diversions, losses (including change in storage) and end-of-system flows (i.e. flow to downstream system) (GL/y) for without-development and baseline scenarios.

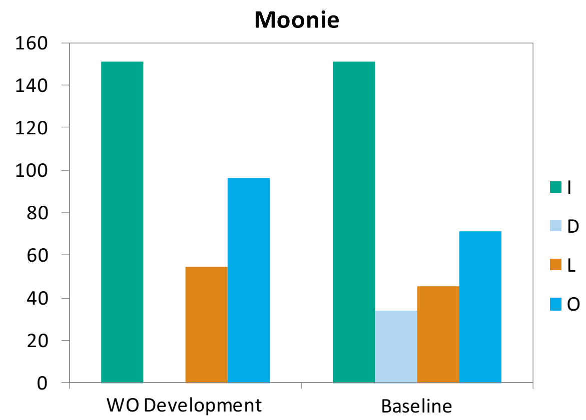
Legend:

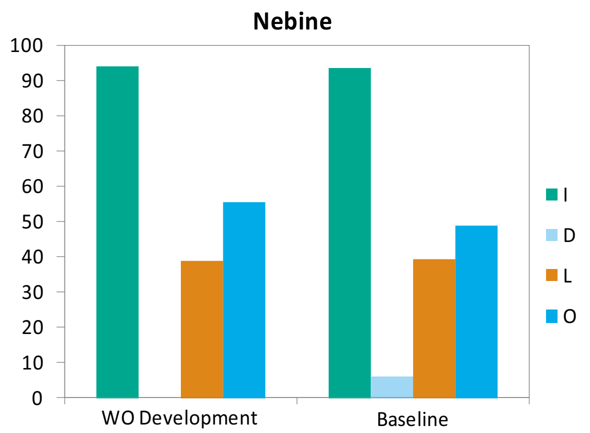
Inflows
Diversions
Losses
End-of-system flow

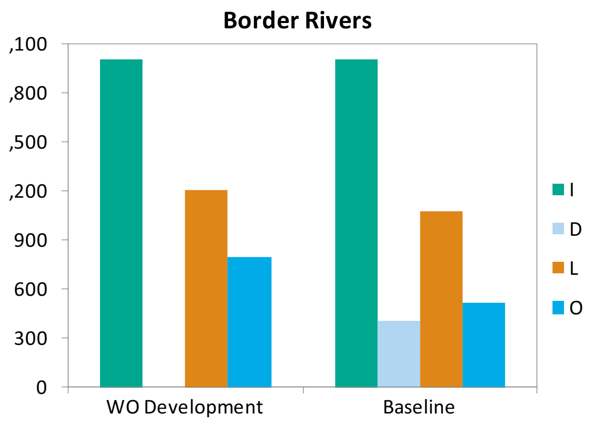


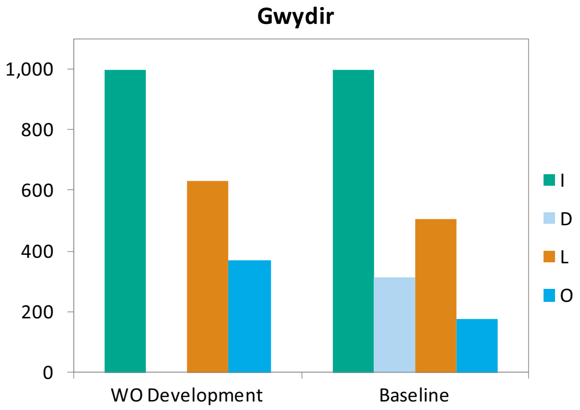


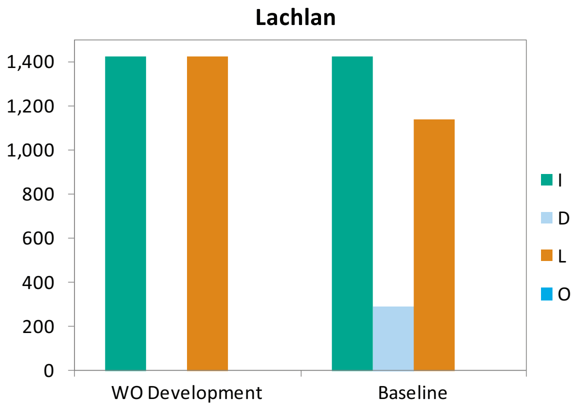









Gwydir
1,000
800
600
400
200
0
WO Development
Baseline
I
D
L
O


Lachlan
1,400
1,200
1,000
800
600
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0
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Baseline
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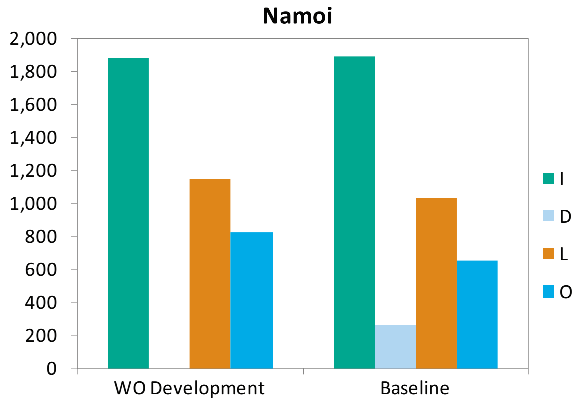
Namoi
2,000
1,800
1,600
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1,200
1,000
800
600
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0
WO Development
Baseline
I
D
L
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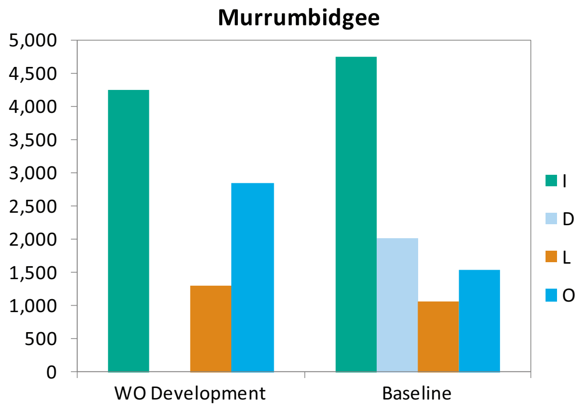
Murrumbidgee
5,000
4,500
4,000
3,500
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2,000
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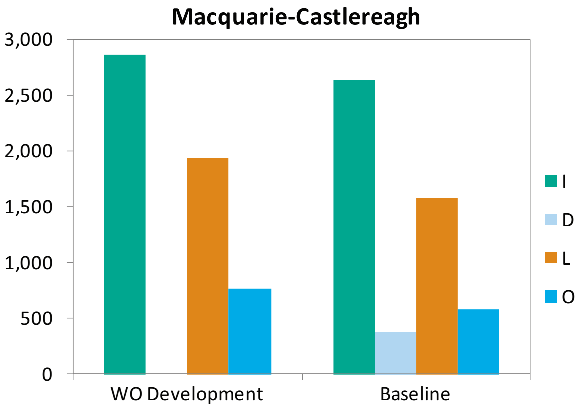
1,000
500
0
WO Development
Baseline
I
D
L
O


Macquarie-Castlereagh
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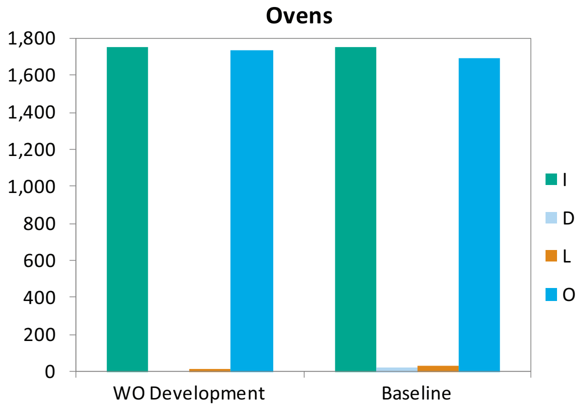
2,500
2,000
1,500
1,000
500
0
WO Development
Baseline
I
D
L
O


Ovens
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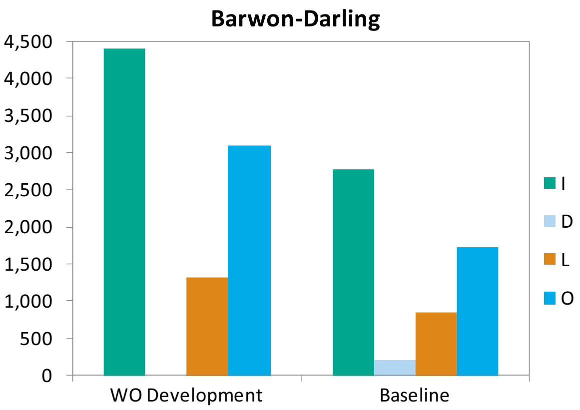
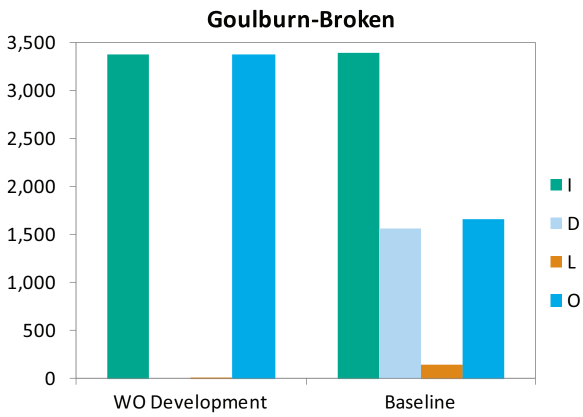
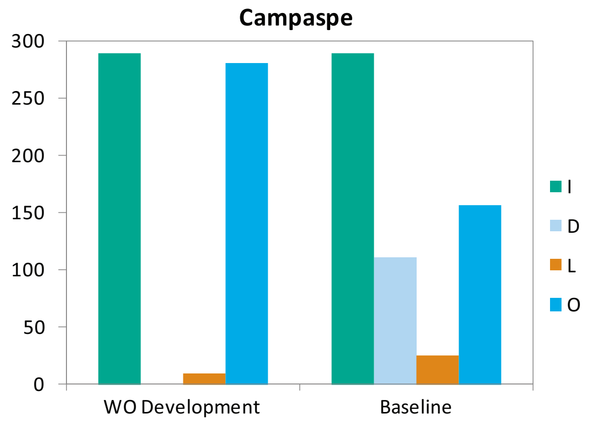
1,000
800
600
400
200
0
WO Development
Baseline
I
D
L
O


Barwon-Darling
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
WO Development
Baseline
I
D
L
O


Goulburn-Broken
3,500
3,000
2,500
2,000
1,500
1,000
500
0
WO Development
Baseline
I
D
L
O


Campaspe
300
250
200
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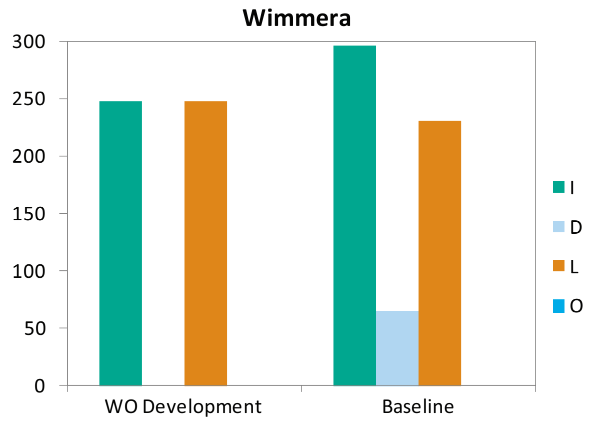
100
50
0
WO Development
Baseline
I
D
L
O


Wimmera
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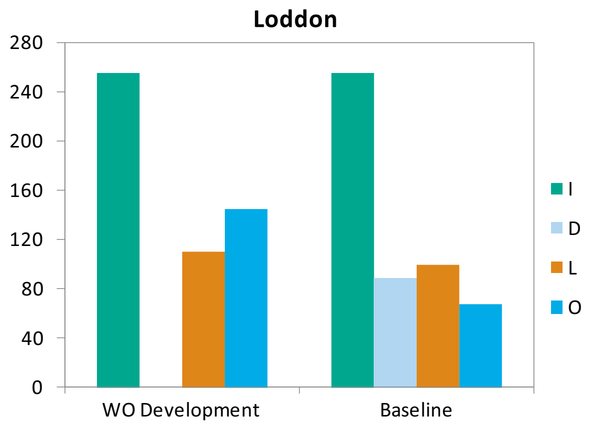
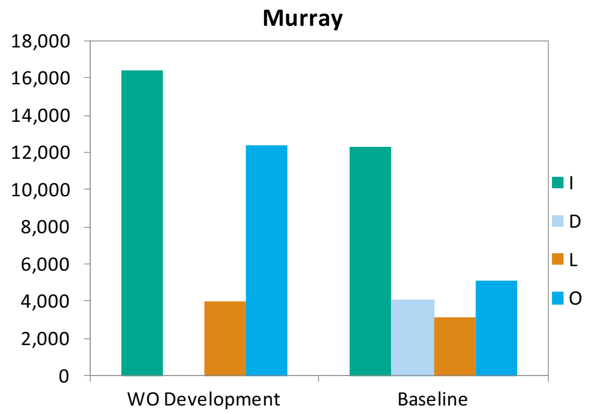
WO Development
Baseline
I
D
L
O


Loddon
280
240
200
160
120
80
40
0
WO Development
Baseline
I
D
L
O


Murray
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
WO Development
Baseline
I
D
L
O

Australian Government

MURRAY–DARLING
BASIN AUTHORITY