Attachment 2 – REG B Report

Regional Evaluation Group Assessment of reference point flow scenarios for zone B of the River Murray System (Hume Dam to Yarrawonga Weir)

Living Murray Regional Evaluation Group B
(Hume Dam to Yarrawonga Weir)

Final Report

20th June 2003

[with minor revisions in October 2003]

REG B Members: Darren Baldwin (Coordinator), Bruce Campbell, Judy Frankenberg, Terry Hillman, Alison King, John Koehn and Keith Ward.

1. Summary

1. Floodplain Vegetation Habitat Condition is substantially improved relative to the CURRENT flow regime, with increasing flows. The best increases in habitat condition occurred for the 1500 GL – B, 750 GL –C and 1500GL – C scenarios.
2. Overall, increasing flow will have a positive effect on Wetland Vegetation Habitat Condition; but only at the highest flows (1500 GL –B, 750 GL – C and 1500 GL-C). In particular, increased flows will improve the condition of vegetation in wetlands higher up on the floodplain.
3. Changing flows will only have a small effect on Waterbirds Habitat Condition.
4. Native fish are being impeded by other factors, including thermal pollution. Changes to the flow regime have little overall effect on Native Fish Habitat Condition. For a net improvement for Native Fish Habitat Condition in this reach it will be necessary to implement structural and operational changes to mitigate thermal pollution, re-snagging and the restoration of fish passage.

Based on the outputs of the MFAT model, of the flow regimes tested the 1500 GL – B and 1500 GL – C scenarios would appear to deliver the best ecological outcomes for this reach of the Murray River.

2. Introduction

The Hume to Yarrawonga reach of the River Murray is heavily impacted by flow regulation. This reach features Hume Dam at the upstream end, which is the most important regulating structure for water supply in the River Murray system (River Murray Water pers. comm.). At the downstream end of the reach is Yarrawonga Weir, which ponds water in Lake Mulwala, to allow gravity diversion to the major irrigation districts served by Mulwala Canal (NSW) and Yarrawonga Main Channel (Vic). Approximately half of the water extracted for irrigation from the River Murray in NSW and Victoria is diverted from Lake Mulwala.

Hume Dam is operated as a key component of the water supply infrastructure of the River Murray system. The River Murray system is operated in accordance with water conservation principles designed primarily to maximise the yield of the system for water supply (with some minor exceptions, including the existing 100 GL/year Barmah-Millewa Entitlement).

As a result of the operation of Hume Reservoir, significant hydrologic change has been experienced in this reach. A substantial reduction in flooding in winter-spring has occurred, due to flows being harvested in Hume Reservoir and other upstream storages (Dartmouth Reservoir and the Snowy Mountains Scheme storages). In addition, Hume Dam provides a secondary function in flood mitigation through pre-releases prior to a spill from the Dam. In addition to reduced flooding downstream of Hume Dam, the Hume to Yarrawonga reach distributes additional inflows diverted from the Snowy River catchment via the Snowy Mountains Hydro-Electric Scheme. The current mean annual flow passing Hume Dam exceeds natural by approximately 600 GL/annum.

The Hume to Yarrawonga reach is a naturally “braided” stream, consisting of a complex network of anabranches in addition to the main stem. It is naturally an actively eroding stream. However, erosion rates resulting from a combination of hydrologic change and clearing and grazing practices now exceed natural rates. The hydrologic changes in this reach now result in an increased proportion of flow within the main stem and anabranch channels, which has contributed to significant alterations in channel profile and bed morphology. The component of flow occurring as flood flows across the floodplain has reduced to about half of the natural proportion.

The Hume to Yarrawonga reach acts as a delivery conduit for regulated flows. This has caused significant hydrologic change. Thoms et al (2000) identified 5 environmental problems in the reach downstream of Hume Dam that could be specifically attributed to river regulation:

* Constant Flow Levels, both during high summer irrigation-flows and low winter base flows, leading to bank erosion, changes to bed morphology and a reduction in in-stream habitat.

* Unseasonably high flows during summer and early autumn. These flows connect low level wetlands to the river at a time when they normally would be in a drying phase.

*A reduction in flooding. Although not designed for the purpose, Hume Dam is currently used for flood mitigation through the use of pre-releases.

*Reduced linkages between the higher floodplain, floodplain wetlands and the river channel.

* Significant decreases in summer and autumn water temperatures as a result of water release from Lake Hume from low-level off-takes.

3. Methodology

3.1. Choice of Localities.

The river zone between Hume Dam and Yarrawonga Weir can be divided into 5 sub-zones based on current river management, hydrology and river morphology (Table 1- but c.f. Rutherford (1991) who described 4 zones based on river morphology alone). In choosing sites representative of the reach, it was felt that it would be impossible to model all flows in sub-zone 1 using modelled flows at Doctors Point gauge and therefore it was agreed not to choose localities within this sub-zone. Similarly, the influence of Lake Mulwala on sub-zone 5 would be difficult to incorporate into the model and were not included.

3.1.1 Floodplain and Wetland Vegetation Models.
REG B does not contain any sites of international importance as listed in the *Convention on Wetlands of International Importance Especially as Waterfowl Habitat (the Ramsar Convention)* therefore we attempted to select localities that were representative of the zone as a whole. We chose one site in sub-zone 2A/B (Quatt Quatta State Forest) and a one site from sub-zone 3 (Croppers Lagoon/Lake Moodemere) to run both the floodplain and vegetation models - Table 2. In order to better reflect changes to flow regime on different wetland types, we chose to run the Wetland Vegetation Habitat Condition Model at localities with quite different commence-to-flows. The locality at which we chose to run the Wetland Vegetation Model (Quatt Quatta) site had a commence to flow of about 11,000 ML/day, (i.e. less than current summer irrigation flows) while the locality at which we chose to run the Wetland Vegetation Habitat Condition model (Croppers Lagoon Site) had a commence to flow of 32,000 ML/day (i.e. at minor-to-moderate flood height).

3.1.2 Waterbird Model.
Only three areas of any importance to waterbirds were identified in our reach (K. Ward pers. comm.)

- An egret and ibis rookery directly below Hume Dam
- A cormorant rookery on St Leonard's Bend.
- A duck breeding ground near Lake Moodemere.

As discussed above, the site near Lake Hume was considered too difficult to model, so it was decided to run the waterbird model at St Leonard's Bend and Lake Moodemere.

3.1.3 Fish Model.
The principal impacts on fish in the Murray River in this reach are considered to be cold water pollution and de-snagging (Thoms et al 2000); with the downstream section of the Reach in slightly better condition than the upstream section. Therefore it was felt that the fish model should be run at two localities, one closer to Lake Hume (Richardson's Bend) and one closer to Lake Mulwala (Cropper Lagoon/ Lake Moodemere).

3.1.4 Algal Model .
The algal model was not run in this reach

3.2. Populating the Model

3.2.1 Configuring Floodplain Hydrology.
All commence to flow data used in the floodplain configurations were supplied by the Murray Wetlands Working Group. (Wetlands are named in the model using the MWWG numbering systems.) Volume/area relationships for all wetlands and floodplains were calculated using the spreadsheet supplied by the SRP. If average depth for a wetland was unknown it was assumed to be 1 metre. Floodplain inundation relationships were estimated according to SRP directions assuming a bank-full flow of about 25,000 ML/day (Thome st al 2000) and maximum flood volume of about 120,000 ML/day (corresponding to the 1956 flood).

3.2.2 Floodplain Vegetation Model.
River red gum forest is the dominant vegetation type and was the only assessment undertaken at the two floodplain vegetation localities. SRP default preference curve were used at both sites with the exception of *Inundation Duration*. Following SRP recommendations that *Inundation Duration* may vary with local condition, the index was set to 1 at 30 days rather than 100 days based on expert opinion. In particular, it was felt that the impact of the relatively high rainfall in the region on River red gum health should be taken into account.

3.2.3 Wetland Vegetation Model.
Based on personal observation by REG members on wetland plant distribution, all the plant groups were run at the Croppers Lagoon Locality, but only *Phragmites australis*, giant rush rushland and ribbon weed herbland at the Quatt Quatta locality. All default preference curves were used in the model, however, the weighting between *Adult Habitat Maintenance Condition and Recruitment Habitat Condition* were set to 0.9/0.1 rather than 0.5/0.5 suggested by the SRP for *Phragmites sp.,* as this best reflected the relative importance of recruitment for this species given that it's principle form of recruitment is vegetative.

3.2.4 Waterbird model.
The waterbird model was run at both waterbird localities using SRP preference curves for both Colonial Nesting Waterbirds and Waterfowl &Grebes. While neither were necessarily found at both sites, nevertheless the Regional Evaluation Group felt that the two Localities were representative of the wetland/floodplain habitat where both groups could potentially occur.

3.2.5 Native Fish Model.
The native fish model was run at the two localities using all 7 fish groups represented in the model. Although Macquarie Perch (Group 2) and catfish (Group 4) are no longer found in this reach of the Murray River, they have both previously been reported here

(Walker and Hillman 1977). As suggested by the SRP the *Spawning Timing* for each group was adjusted to take into account the effects of thermal pollution for all scenarios except NATURAL, Changes were made by comparing measured water temperature data at Doctor's Point (near Albury) and Corowa (Tom Ryan, DSE, unpublished Data) with known temperature limits for spawning for each fish group (Koehn and O'Conner, 1990) – see Table 3. Similarly, *Adult Habitat Condition* for all flow scenarios except NATURAL, were modified to reflect river condition. For the upstream locality (Richardson's bend), *Woody Debris* was set to Few Woody Debris, *Water Temperature* was set to High Thermal Pollution and *Fish Passage* was set to 100000 ML/day to account for the impassability of Yarrawonga Weir and Hume Dam in the reach. For the lower locality (Croppers/Moodemere) *Woody Debris* was set to Moderate Level of Woody Debris, *Thermal Pollution* was set to Moderate Thermal Pollution and *Fish Passage* was set to 100,000 ML/day.

3.2.6 Structural and operational improvements.

To model structural and operational improvements to the reach, regulators were placed on all pipes to wetlands with a commence-to-flow of less than bank-full flow (about 25,000ML/day) – a total of seven regulators. *Thermal Pollution* was decreased to Moderate and Minor for the upstream and downstream sites respectively; Woody debris was set to Moderate and Numerous respectively and *Fish Passage* was set to 1000 ML/day. Spawning timing was adjusted to reflect changes to river temperatures under thermal pollution mitigation – they were set to be intermediate between the default and CURRENT conditions for the upstream Locality, and set to the SRP default for the downstream Locality (Table 3). An additional assessment was also conducted on the Native Fish Habitat Condition model at Richardson bend only. The first setting is only with *Thermal Pollution* switched to Moderate and Spawning times adjusted to account for the decrease in thermal pollution (as above) but with no other changes. In the second *Thermal Pollution* was set to Natural, *Spawning Times* set to the default SRP values, but no other changes.

When assessing structural and operational changes, the CURRENT Scenario was run without any structural or operational changes.

3.3 Model Analyses.

The Living Murray Initiative is based on the assumption that there is a need to improve the condition of the River relative to its present state. Therefore, as well as examining any changes against REFERENCE and NATURAL, REG B chose specifically to examine the impacts of the various flow regimes against the CURRENT Scenario in greater detail. Notwithstanding any potential benefits from additional flows, we felt that it was important to firstly determine whether or not a given flow regime actually resulted in a deterioration from the CURRENT condition, remembering that most of the water allocated for environmental flows for the lower reaches must first pass through this reach. To further explore the extent of improvement over the CURRENT conditions we have constructed tables that compare the test scenario to the CURRENT condition. In constructing the table all the years where the Index in the Test Scenario year is at least

10% better than the index under the CURRENT Scenario have been arbitrarily defined as At Least Marginally Better (and of course includes those years that are either moderately or substantially better than the CURRENT Scenario). An At Least Moderately Better year is one where the index for the Scenario is at least 1.5 times that of the CURRENT Scenario. A Substantially better year is arbitrarily defined as one when the index for the scenario was twice that of the CURRENT Scenario. Similarly, an At least Marginally Worse year is one where the value of the test scenario is at least 10% less than the CURRENT Year, At least Moderately Worse is defined as one where the value is less than ¾ of the CURRENT year and a substantially worse year is one where the Yearly index is half of that of the index under the CURRENT Scenario.

3.4 Additional Analysis - Geomorphology

MFAT does not currently include an assessment of geomorphic impacts resulting from changed hydrology. However, the highly altered hydrology in this reach has caused significant geomorphic change. A simple manual assessment of the geomorphic responses to the modelled scenarios has been undertaken. This assessment is based on a simple interpretation of the proportion of flow passed below certain thresholds, which indicate a change in the potential for erosion.

4. Model Outputs

4.1 Floodplain Vegetation Habitat Condition Model

4.1.1 No Structural or Operational Changes.
Additional water clearly improves the floodplain vegetation condition relative to the CURRENT scenario (Table 4). An extra 1500 GL improves the Floodplain Vegetation index substantially in between 15 to 30% of years, with little or no detrimental effects (Table 5); with the 1500 GL –B and 1500 GL-C flow scenarios delivering greater benefit than the 1500 GL-Cap scenario.

Figure 1 shows the average monthly area of floodplain inundated at three regimes, NATURAL, CURRENT and 1500 GL-C at the Quatt Quatta floodplain locality. While the extra water does not approach the NATURAL scenario, a substantially greater area of the floodplain is inundated under the 1500 GL-C scenario than under CURRENT. It is suggested that the improvement in Floodplain Vegetation Habitat Condition index under the higher flows scenario is a consequence of delivering more water to the floodplain.

Interestingly, Table 5 shows that the NATURAL condition was substantially worse than CURRENT in about 20% of years. Similarly Table 4 shows that the median S/N ratio's for 1500 GL -B and –C scenarios are greater than 1. A cursory year by year comparison between the NATURAL, 1500 GL – B and 1500GL –C scenarios suggests that this is a consequence of the extra water delivered to the floodplain in what would naturally have been dry spells - particularly at the turn of last century and during the 1940's.

4.1.2. With Operational and Structural Changes.
The structural and operational changes made to this zone did not alter the way water was delivered to the floodplain. Therefore, as would be expected, the changes incorporated into the model had no affect on the Floodplain Vegetation indices (Data not shown)

4.2. Wetland Vegetation Model

4.2.1 No Structural or Operational Changes .
Overall, the outputs from the model suggest that additional water above the CURRENT scenario does not manifestly improve the overall Wetland Vegetation Habitat Condition (Table 6). Indeed a comparison of test scenarios to CURRENT shows that only 1500 GL – B, 750 GL-C and 1500 GL–C scenarios show a moderate improvement - and then only in about 10-20% of years (Table 7). An analysis of each of the two localities goes some way to explaining this question. At the "Quatt Quatta" locality, which had a commence-to-flow of 11,000 ML/day, the extra water did not lead to any substantial change over the CURRENT scenario, indeed, the index was moderately or even substantially lower in a few years (Fig. 2). Conversely, for the "Croppers" locality, which had a commence-to-flow of 32,000 ML/Day, about 30% of years were substantially better than CURRENT with the extra flow. Curiously the median values for S/R and S/C are all close to 1. This also may reflect the different response to the two wetlands to flow. As Figure 2 shows, in most years the Quatt Quatta wetland does not respond to increases in flows, while the wetland at the Croppers Lagoon Locality does respond to flow but only in some exceptional years. Therefore, in at least 50% of years the index will not be substantially different between the CURRENT or REFERENCE scenarios hence a median close to 1.

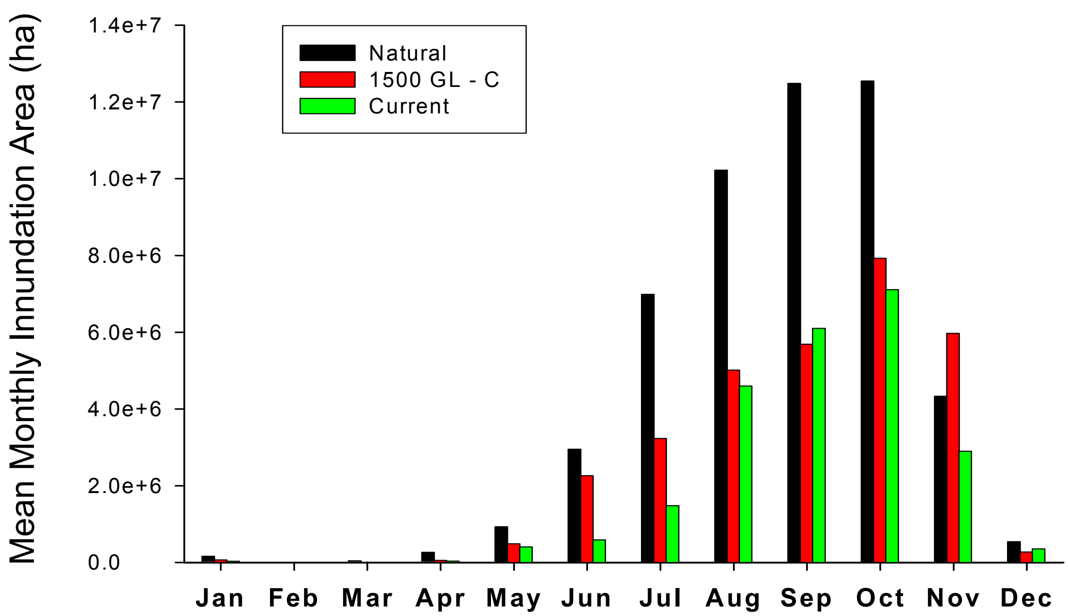

Figure 1 – Mean monthly cumulative inundation area at Quatt Quatta Floodplain locality under NATURAL, CURRENT and 1500 GL – C Scenario.

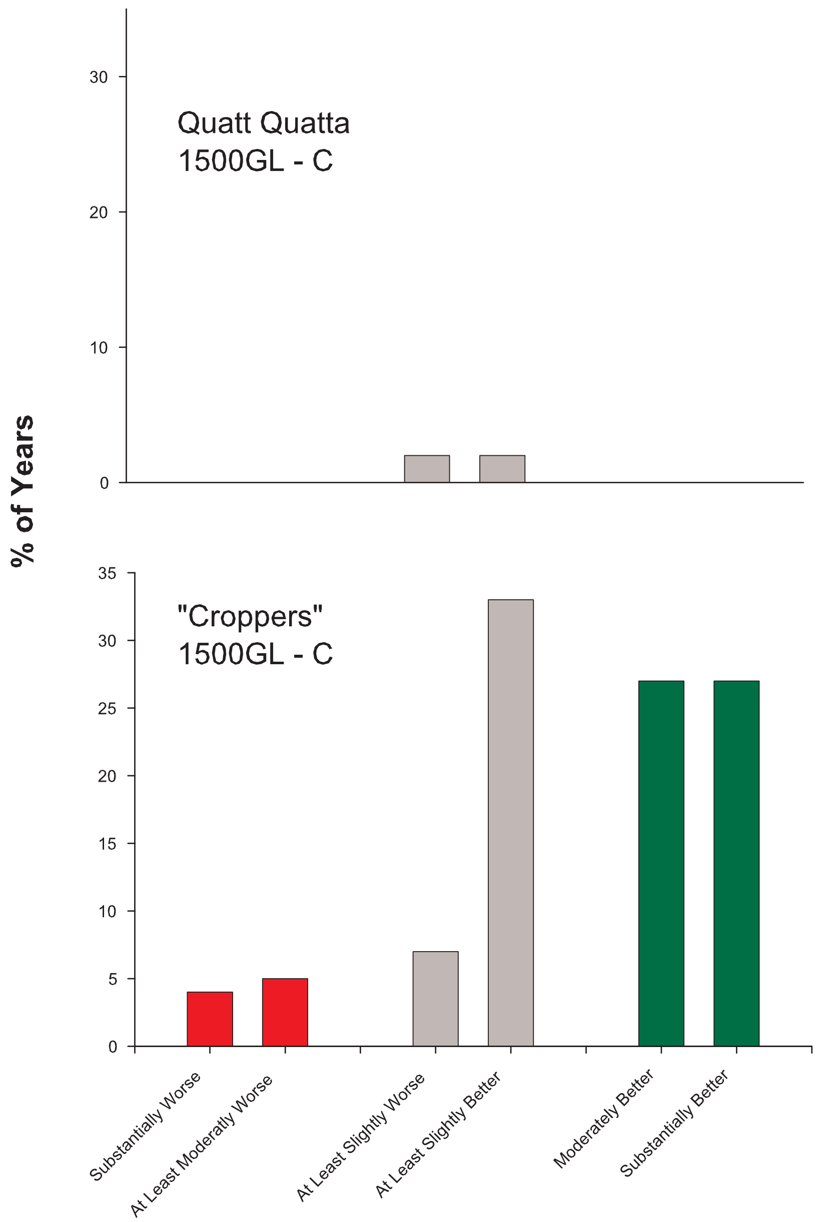

Figure 2 – Improvements in Wetland Vegetation Condition with 1500 GL – C flow Scenario relative to CURRENT for the two wetland vegetation localities.

4.2.2. Structural and Operational Changes
Overall there is a slight decrease in wetland habitat condition with the imposition of structural changes (in this case the installation of regulators) (Table 6 and 8). While this is unexpected, the Wetland Vegetation Habitat Condition index for the Quatt Quatta locality was relative high (about 0.7 for most scenarios) without the addition of a regulator to the model and, the effects of each regulator was not optimised for each wetland, rather a choice of regulator closing and opening times was based on the most common practice in this reach. More judicious choice of regulator operating periods may indeed have increased this value.

4.3 Waterbird Habitat Condition Model

4.3.1 No Structural or Operational Changes.
WHC did not vary substantially between the various flow scenarios. The median S/C and S/R ratio's for all scenarios except for NATURAL are close to 1. When the impact of each scenario was compared with the CURRENT Scenario (Table 10) it can be seen that, while increasing flow can lead to at least a slight improvement in up to 30% of years, none of the flow scenarios resulted in either moderate or substantial improvements over the CURRENT condition.

A Spell analysis was conducted to examine if any of the Scenarios could result in substantial harm to the bird populations through a number of successive bad years. For the analysis a 'bad' year was arbitrarily defined as having a waterbird Habitat Condition Index of less than 0.25. None of the scenarios gave an index of less than 0.25 for more than one year. As for the Floodplain Vegetation Habitat Model, generally speaking the worst years were actually under the NATURAL scenario during the drought periods at the turn of last century and during the 1940's.

4.3.2 Structural and Operational Changes.
The outputs from the Waterbird Habitat Condition model with structural improvements are presented in Table 11. Like, wetland vegetation, the structural improvements lead to a slight decrease in the mean Waterbird Habitat Condition Index (Table 11) for all scenarios. It is probable that the reasons for this are the same (see above).

4.4 Native Fish Habitat Condition Model

4.4.1 Without Structural and Operational changes.
The most noticeable output from running the Native Fish Habitat Condition Model was that all Scenarios had considerably lower index scores than NATURAL (Table 12). Indeed the lowest Native Fish Habitat Index under the NATURAL scenario was at least 0.25 units higher than the highest index value for any other scenario.

Although, the index scores for all Scenarios were considerably lower than NATURAL, changing flows did lead to at least some slight improvements over the CURRENT scenario (Table 13). For example, the Native Fish Habitat Condition index was slightly better under the 1500 GL-Cap scenario than CURRENT scenario in 34% of years.

4.4.2 Murray Cod/Trout cod (Group 6) and Macquarie Perch (Group 2).
As with the overall Native Fish Habitat Condition index, both Group 6 and Group 2 species index scores were lower than NATURAL for all scenarios (Table 14 (a) and (b)) However under some flow regimes, the model predicts that Murray cod and Trout cod should fare better than under CURRENT condition (Table 15 (a)). For example, the table shows that under the 1500 GL – Cap and 1500GL – B scenarios, the Habitat Condition Index is moderately better than the CURRENT scenario in 25% and 10% of years respectively. Indeed, under the 1500GL – Cap scenario the index is substantially better than CURRENT in about 1 year in 10.

Changes to the flow regime from CURRENT had less an effect on Macquarie Perch, with no given flow regime creating moderate or substantially better years than CURRENT.

4.4.3 With Structural and Operational Changes.
The outputs from the Native Fish Habitat Condition model following structural and operational changes (decreasing the impact of thermal pollution, re-snagging and restoring fish passage at Yarrawonga Weir) are presented in Table 16 (a). Overall the Native Fish Habitat Condition Index improved relative to scenarios without structural change (Table 14 and 16); however, all flow scenarios showed similar levels of improvement.

An additional assessment was conducted on the mean Native Fish Habitat Condition Index for Richardson's Bend (the most thermally polluted site) - under four conditions (Figure 3):

1. With no structural or operational changes,
2. With water temperature decreased from High Thermal Pollution to Moderate Thermal Pollution only.
3. As for 2 but with some re-snagging and free Fish passage (i.e the requested SRP changes) and,
4. With no thermal pollution, but without fish passage or any re-snagging.

From the graph it is clear that moderating thermal pollution will have a substantial impact on the overall Native Fish Habitat Condition index.

It is also important to note that in all the scenarios being assessed, with the obvious exception of the NATURAL Scenario, seasonal reversal of flows still occurs (Figure 4). Such seasonal should also impact on the condition of native fish in this region.

4.4.4 Murray Cod/Trout cod (Group 6) and Macquarie Perch (Group 2) with Structural and Operational Changes.
The effects on structural and operational changes on Cod & Trout Cod (Group 6) and Macquarie Perch (Group 2) are presented in Tables 16 (a) & (b). The median S/R values remained close to 1, but the S/C values were usually much greater than 1 for both groups, with the structural changes improving the Cod more so than the Macquarie Perch.

(Remembering the CURRENT scenario had no structural or operational changes while the REFERENCE scenario did.)

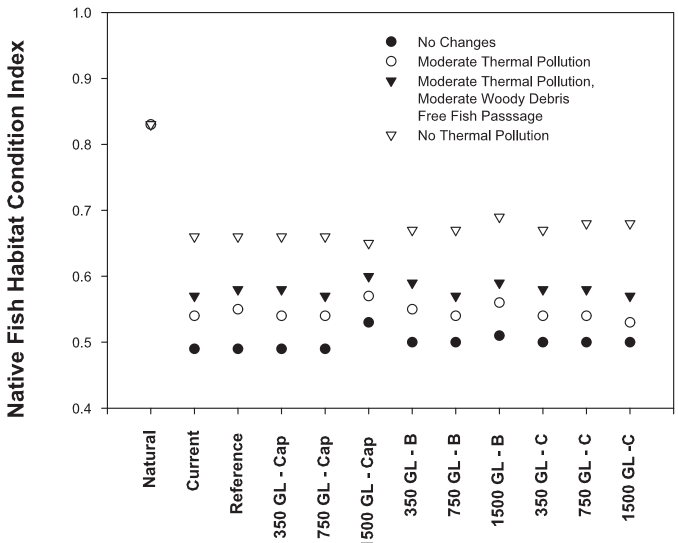

Figure 3 – Changes to the overall fish habitat index with changes to the thermal regime.

4.5 Assessment of Overall River Health.

4.5.1 River Health Index.

The Overall River Health Index for the Murray River between Hume Dam and Yarrawonga Weir under the various flow scenarios are is presented in Table 17. The table clearly shows that the Overall River Health Condition is better under NATURAL conditions compared with the other scenarios. However, increasing flows can have a positive effect on the condition of the reach (Table 17). In particular the mean value of the ORH index was about 20% higher under the 1500 GL – B scenario than under the CURRENT scenario.

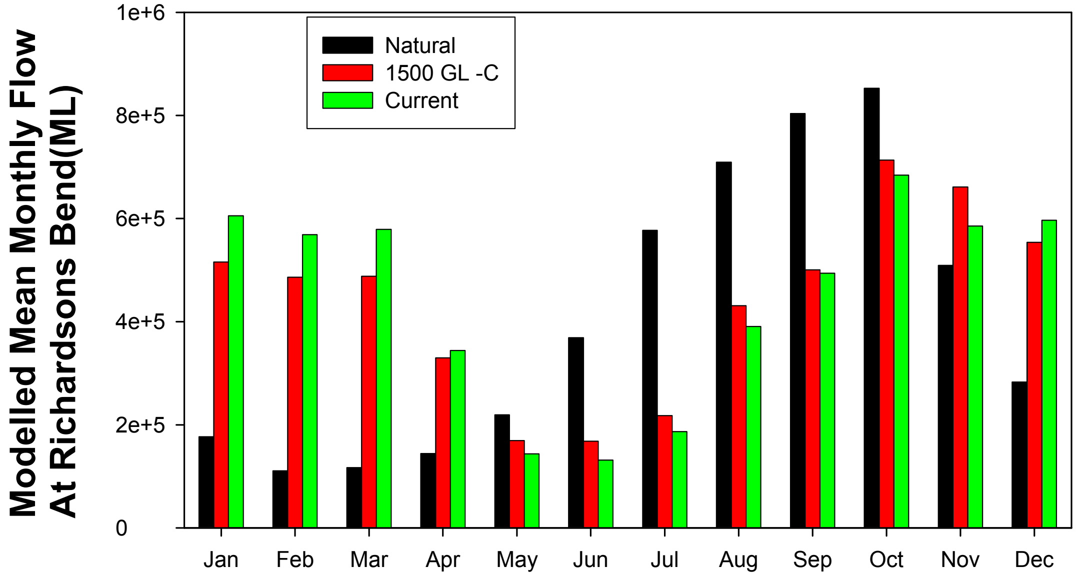

Figure 4 – Modelled mean monthly flow at Richardson's Bend under NATURAL, 1500GL - C and CURRENT scenarios.

A comparison of all the scenarios to the CURRENT condition (Table 18) shows that changing to the 1500GL – B flow scenario would at least slightly improve the overall river index in nearly 70% of years relative to the CURRENT condition, and moderately improve the index in 6% of years. For the 1500GL - C scenario the increases are about 50% and 7% respectively. This conclusion is based on the assumption that each of the 4 Habitat indices (Floodplain Vegetation, Wetland Vegetation, Waterbirds and Native Fish) contribute equally to the Overall River Condition –the default weighting. In the previous section we suggested that the poor condition of native fish in the reach had little to do with flow *per se*, but was more a consequence of thermal pollution. Therefore, inclusion of the Native Fish Habitat index in the overall Reach assessment may 'dilutes' the impact of changing flow conditions. As an exercise we discounted the weight attributable to the Native Fish Habitat Condition Index to overall Reach index to 10% of the other 3 components (that is set its weight to 0.1, while keeping the other indices at 1.0). If Native fish Habitat Condition is discounted within the overall assessment, the model suggests that changing the flow regime to the 1500 GL – B scenario will result in at least moderate improvement to the Overall River Index in nearly 25% of years (Table 19).

5. Other Analyses - Geomorphology

River regulation is an important factor in river channel changes in the Hume to Yarrawonga reach. It is the most important factor in accelerated channel widening, and is the most likely cause of bed degradation (ID&A 1993). Under current conditions, both total flow volume and the proportion passed within bank full capacity are significantly higher than natural conditions.

Table 20 details a range of flow statistics for the River Murray at Doctors Point. A analysis of changes in the proportion of flow at Doctors Point downstream of the Kiewa River junction has been undertaken. (Note however this is a preliminary analysis and is subject to further refinement. Note that comparisons are to Reference conditions rather than Current conditions due to configuration of data provided by MDBC.

1. In-Channel Low Flows (less than 10,000 ML/day)
Natural Conditions - 51.9% of daily flow volume
Reference Conditions - 53.8% of daily flow volume
Reference conditions show a 2% increase in low flows compared to Natural. All scenarios show increases in low flows as water recovery volumes increase. Differences are slight, ranging from 53% (all 350 GL cases) to about 54% for 1500 GL cases.

2. In-Channel High Flows (10,000-25,000 ML/day)
Natural Conditions - 28.9% of daily flow volume
Reference Conditions - 39.3% of daily flow volume
All scenarios show a reduction in in-channel high flows compared to Reference conditions. Generally, the magnitude of the reduction increases in proportion to volumes of water recovered, as expected, indicating a reduction in flow regulation at high flow rates. However, all scenarios continue to maintain a higher proportion of flow in this range than Natural conditions, varying from an average of about 9.1% more for the three 350 GL scenarios to an average of 6.6% more for the three 1500 GL scenarios.

3. Flood Flows (>25,000 ML/day)
Natural Conditions - 19.1% of daily flow volume
Reference Conditions - 6.8% of daily flow volume
Broadly speaking, an increase in the proportion of flow passed across the floodplain instead of in the channel will result in a reduced risk of erosion within the channel. However, the risk of channel avulsion could increase.

All scenarios show an increase in the volume of flows exceeding bank full flow rate, increasing in proportion to the volume of water recovered. However, all scenarios remain well under the Natural flood flow volume.

6. Conclusions

Based on our assessment of the outputs of MFAT, and preliminary geomorphic analysis we can come to the following conclusions

1. All the assessments indicate that Floodplain Vegetation Habitat Condition, Wetland Vegetation Habitat Condition, Waterbird Habitat, Condition, Nativefish Habitat Condition, and Overall River Health Condition would be better, and in most cases considerably better, under NATURAL flow conditions than those

currently in place.

2. Floodplain Vegetation Habitat Condition is substantially improved relative to the CURRENT flow regime, with increasing flows. The best increases in habitat condition occurred for the 1500 GL – B, 750 GL –C and 1500GL – C scenarios.

3. Overall, increasing flow will have a positive effect on Wetland Vegetation Habitat Condition; but only at the highest flows (1500 GL –B, 750 GL – C and 1500 GL-C). In particular, increased flows will improve the condition of vegetation in wetlands higher up on the floodplain.

4. Changing flows will only have a small effect on Waterbirds Habitat Condition.

5. Native Fish are being impeded by other factors, including thermal pollution. Changes to the flow regime have little overall effect on Native Fish Condition. For a net improvement for Native Fish habitat Condition in this reach it will be necessary to implement structural and operational changes to mitigate thermal pollution, re-snagging and the restoration of fish passage.

6. None of the modelled flow scenarios would lead to a substantial net deterioration in overall river health relative to the CURRENT condition.

7. Changes in the proposed flow regime are generally small. The potential for accelerated erosion caused by flow regulation does not appear to be significantly reduced by any of the flow scenarios.

8. Overall changing the flow in the reach to follow scenarios 1500 GL-B or 1500GL – C will lead to a moderate improvement in the condition of this river reach in at least some years.

9. We didn't have the opportunity to fully examine the effects of changing flow regime on other aspects of riverine function, in particular in-channel productivity, material and energy transfers between the river channel and the floodplain (Junk et al 1989) or, the consequence of maintaining anti-drought conditions (high flows during periods that naturally would be dry) in the river (Humphries and Baldwin 2003).

Acknowledgments

Members of REG B would like to thank the Murray-Wetlands Working Group, and in particular Ms Trish Alexander, for supplying, images and commence-to-flow data for all the wetlands in this study. We would also like to thank Ms Jessica McGregor for initial Arcview analysis for floodplain areas.

References.

Convention on Wetlands of International Importance Especially as Waterfowl Habitat (Ramsar), 1971 U.N.T.S. No. 14583, vol. 996 (1976), p. 243.

P. Humphries and D. S. Baldwin (2003). Drought and aquatic ecosystems: an introduction. *Freshwater Biology*. **48**, 1141-1147.

W.J. Junk, P.B. Bayley and R.E. Spark (1989) The flood-pulse concept in river-floodplain systems. *Canadian Special Publications in Fisheries and Aquatic Sciences.* **106,** 110-127.

J. D. Koehn, and W. G. O'Connor, 1990. *Biological Information for Management of Native Freshwater Fish in Victoria*. Government Printer, Melbourne.

I. Rutherford, (1991) *The Geomorphology of the River Murray*. Monash University, Clayton, Victoria.

M. Thoms, P. Suter, J. Roberts, J. Koehn, G. Jones, T. Hillman and A. Close (2000) *Report of the River Murray Scientific Panel on Environmental Flows: River Murray – Dartmouth to Wellington and the Lower Darling River.* Murray-Darling Basin Commission, Canberra.

K.F. Walker and T. J. Hillman (1977). *Limnological Survey of the River Murray in Relation to Albury-Wodonga, 1973-1976.* Albury-Wodonga Development Corporation, Albury NSW.

Table 1 – Sub-zones identified in the Hume-Yarrawonga zone.

Sub-Zone	Location	Features
1	Upstream of the Kiewa River Junction to Hume Dam	Statutory requirement for a minimum flow of 600 Ml/day at Heywood's Bridge and 1200 Ml/day downstream of the Kiewa River Junction. During winter/early spring it is possible that the flow entering the Murray from the Kiewa River far exceeds the 600 Ml/day required to augment the 600 Ml/day released from Hume Dam to meet the flow requirements at Heywood's Bridge
2A	Upstream from the Parlour Creek Junction with the Murray River (near Howlong) to the Kiewa River Junction	Characterised by significant anabranches and billabongs associated with the main river channel
2B	Upstream of the Corowa Throat to the Parlour Ck Junction	This is similar morphologically to Zone 2A except anabranches are not as important. The sub-zone still has a significant number of billabongs.
4	Upstream of the influence of Lake Mulwala (Snake Island) to the Corowa throat.	This sub- zone has significantly fewer billabongs and anabranches than the two zones upstream. The floodplain contains the two largest floodplain lakes in the whole Reach – Lake Moodemere and Croppers Lagoon.
5	Downstream of Snake Island	This sub-zone can come under the influence of Lake Mulwala when the Dam is close to capacity.

Table 2 – Localities and models used in the MFAT Models. * All Wetlands are named using the Murray Wetland Working Group numbering system.

Locality Name in MFAT	Corresponding to :	Ecological Model Applied	Assessments Undertaken
Quatt Quatta Forest - floodplain	Floodplain in Gooramadda State Forest	Floodplain Vegetation Habitat Condition	River Red Gum forest
Croppers Floodplain	Floodplain adjacent to Lake Moodemere	Floodplain Vegetation Habitat Condition	River Red Gum forest
Quatt Quatta Forest - Wetland	Wetlands 7312 & 7313*	Wetland Vegetation Habitat Condition	*Phragmites australis*, giant rush rushlands and ribbon weed herb land
Croppers Lagoon	Wetlands 7978 & 8111*	Wetland Vegetation Habitat Condition	All groups
Quatt Quatta Forest Complex	Wetlands 7312 and 7313* and floodplain in Gooramadda State Forest	Waterbird Habitat Condition	All groups
St Leonard's Bend Complex	Floodplain adjacent to St Leonard's Bend and wetlands 7392, 7399, 7423, 7429, 7439, 7441, 7459, 7481, 8759*	Waterbird Habitat Condition	All groups
Richardson's Bend River Section	River reach immediately downstream of Albury	Native Fish Habitat Condition	All groups
Cropper's Lagoon-Lake Moodemere	River Reach immediately downstream of Corowa	Native Fish habitat Condition	All groups

Table 3 – Optimal Fish Spawning Periods entered into MFAT to account for thermal pollution. Months listed in the table were assigned the value of 1 all others months were assigned a value of zero.

Fish Group	Breeding Period Richardson Bend		Breeding Period Croppers Lagoon/ lake Moodemere	
	Without Structural and Operational Changes	With Structural and Operational Changes	Without Structural and Operational Changes	With Structural and Operational Changes
Group 1	None	Jan to Feb	Jan to Feb	SRP Default
Group 2	Dec to Jan	SRP Default	SRP Default	SRP Default
Group 3	Not Applicable	Not Applicable	Not Applicable	Not Applicable
Group 4	None	Jan to Feb	Jan to Feb	SRP Default
Group 5	Nov to Feb	SRP Default	SRP Default	SRP Default
Group 6	Dec to Jan	Dec to Feb	Dec to Feb	SRP Default
Group 7	SRP Default	SRP Default	SRP Default	SRP Default

.

Table 4 – Outputs from the Floodplain Habitat Vegetation Condition model without structural changes Threshold is the percentage of years where the index was at least 50% of the absolute maximum index found for the natural condition.

Scenario	Mean	Median	Threshold (%)	Median S/R	Median S/C	Median S/N
Natural	0.42	0.48	53	1.12	1.09	N/A
Current	0.35	0.35	43	1.02	N/A	0.90
Reference	0.32	0.32	36	N/A	0.98	0.85
350Gl – Cap	0.34	0.35	42	1.00	1.00	0.91
750 GL - Cap	0.37	0.39	48	1.05	1.02	0.99
1500 GL- Cap	0.4	0.43	50	1.08	1.05	1.00
350 GL - B	0.48	0.55	64	1.22	1.19	1.13
750 GL - B	0.5	0.57	65	1.26	1.22	1.14
1500 GL - B	0.6	0.58	81	1.66	1.46	1.28
350 GL - C	0.48	0.55	62	1.24	1.21	1.10
750 GL - C	0.56	0.57	76	1.57	1.42	1.120
1500 GL - C	0.59	0.57	82	1.67	1.52	1.26

Table 5 – Percentage of years when the overall Floodplain Vegetation Index was better or worse than the CURRENT Scenario. See text for definitions.

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	22	30	44	50	35	27
Reference	10	17	21	12	6	3
350Gl -Cap	3	5	8	6	2	2
750 GL - Cap	1	5	9	19	7	4
1500 GL- Cap	7	12	14	35	20	15
350 GL - B	3	6	6	64	25	15
750 GL - B	5	6	8	71	28	20
1500 GL - B	2	3	4	87	48	37
350 Gl - C	5	5	10	66	30	20
750 GL - C	2	4	10	81	45	35
1500 GL - C	2	3	9	84	51	34

Table 6 – Outputs from the Wetland Vegetation Habitat Condition model without structural changes. Threshold is the percentage of years where the index was at least 50% of the absolute maximum index found for the natural condition.

Scenario	Mean	Median	Threshold (%)	Median S/R	Median S/C	Median S/N
Natural	0.63	0.71	81	1.13	1.15	N/A
Current	0.5	0.39	37	1.00	1.00	0.89
Reference	0.48	0.39	35	1.00	1.00	0.86
350Gl -Cap	0.51	0.39	38	1.00	1.00	0.89
750 GL - Cap	0.51	0.39	41	1.00	1.00	0.90
1500 GL- Cap	0.52	0.39	46	1.00	1.00	0.93
350 GL - B	0.52	0.39	48	1.00	1.01	0.92
750 GL - B	0.53	0.39	48	1.00	1.01	0.92
1500 GL - B	0.56	0.63	63	1.01	1.02	0.95
350 GL - C	0.5	0.39	41	1.00	1.00	0.90
750 GL - C	0.53	0.41	51	1.00	1.01	0.92
1500 GL - C	0.56	0.63	61	1.00	1.01	0.95

Table 7 – Percentage of years when the overall Wetland Vegetation Index was better or worse than the CURRENT Scenario. See text for definitions.

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	0	2	4	52	35	6
Reference	0	6	8	2	0	0
350Gl -Cap	0	0	0	0	0	0
750 GL - Cap	0	0	0	3	0	0
1500 GL- Cap	0	0	1	13	0	0
350 GL - B	0	0	1	10	0	0
750 GL - B	0	0	1	12	0	0
1500 GL - B	0	0	0	27	16	0
350 Gl - C	0	5	5	4	3	0
750 GL - C	0	4	6	16	13	0
1500 GL - C	0	4	5	25	22	0

Table 8 – Outputs from the Wetland Habitat Vegetation Condition model with structural changes. Threshold is the percentage of years where the index was at least 50% of the absolute maximum index found for the natural condition. *The Current Scenario in this analysis was run without regulators on any of the wetlands.

Scenario	Mean	Median	Threshold	Median S/R	Median S/C*	Median S/N
Natural	0.63	0.69	83	1.23	1.11	N/A
Current*	0.5	0.39	52	1.00	N/A	1.00
Reference	0.45	0.38	37	N/A	0.93	0.88
350Gl -Cap	0.48	0.38	41	1.00	0.97	0.81
750 GL - Cap	0.49	0.38	43	1.01	0.98	0.90
1500 GL- Cap	0.51	0.39	48	1.03	0.97	0.90
350 GL - B	0.5	0.38	46	1.01	0.98	0.93
750 GL - B	0.5	0.39	49	1.02	1.00	0.90
1500 GL - B	0.53	0.57	61	1.04	0.96	0.90
350 GL - C	0.48	0.38	42	1.01	0.97	0.95
750 GL - C	0.5	0.4	50	1.01	0.99	0.86
1500 GL - C	0.52	0.57	58	1.04	0.98	0.91

Table 9 – Outputs from the Waterbird Habitat Vegetation Condition model without structural changes. Threshold is the percentage of years where the index was at least 50% of the absolute maximum index found for the natural condition.

Scenario	Mean	Median	Threshold (%)	Median S/R	Median S/C	Median S/N
Natural	0.60	0.69	84	1.24	1.23	N/A
Current	0.46	0.38	35	1.00	N/A	0.81
Reference	0.44	0.38	31	1.00	1.00	0.8
350Gl -Cap	0.47	0.38	36	1.00	1.01	0.8
750 GL - Cap	0.47	0.38	38	1.00	1.01	0.82
1500 GL- Cap	0.48	0.38	44	1.02	1.01	0.84
350 GL - B	0.47	0.4	47	1.01	1.02	0.8
750 GL - B	0.47	0.4	46	1.02	1.02	0.85
1500 GL - B	0.48	0.43	61	1.05	1.03	0.83
350 GL - C	0.45	0.39	39	1.01	1.01	0.81
750 GL - C	0.46	0.4	48	1.01	1.01	0.81
1500 GL - C	0.46	0.42	51	1.01	1.01	0.81

Table 10 – Percentage of years when the overall Waterbird Habitat Index was better or worse than the CURRENT Scenario.   See text for definitions

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	4	5	6	79	6	3
Reference	0	5	17	4	0	0
350Gl -Cap	0	0	1	3	0	0
750 GL - Cap	0	0	3	7	0	0
1500 GL- Cap	0	0	4	20	2	0
350 GL - B	0	2	7	20	0	0
750 GL - B	0	1	6	16	0	0
1500 GL - B	0	0	9	30	0	0
350 Gl - C	0	6	14	12	0	0
750 GL - C	0	6	17	22	0	0
1500 GL - C	0	8	17	25	0	0

Table 11 – Outputs from the Waterbird Habitat Vegetation Condition model with structural changes. Threshold is the percentage of years where the index was at least 50% of the absolute maximum index found for the natural condition. *The Current Scenario in this analysis was run without regulators on any wetlands.

Scenario	Mean	Median	Threshold	Median S/R	Median S/C*	Median S/N
Natural	0.6	0.69	81	1.64	1.23	N/A
Current*	0.38	0.35	37	1.00	N/A	0.71
Reference	0.35	0.33	31	N/A	0.8	0.56
350Gl -Cap	0.39	0.35	39	1.01	0.97	0.74
750 GL - Cap	0.4	0.36	39	1.05	1.0	0.80
1500 GL- Cap	0.44	0.37	47	1.14	1.07	0.86
350 GL - B	0.37	0.36	39	1.01	0.95	0.66
750 GL - B	0.38	0.37	46	1.03	0.96	0.71
1500 GL - B	0.4	0.38	49	1.07	1.02	0.77
350 GL - C	0.38	0.36	37	1.02	0.89	0.64
750 GL - C	0.39	0.36	39	1.04	0.93	0.63
1500 GL - C	0.38	0.38	40	1.06	0.96	0.64

Table 12 – Outputs from the Native Fish Habitat Condition model without structural changes. Threshold is the percentage of years where the index was at least 50% of the absolute maximum index found for the natural condition.

Scenario	Mean	Median	Threshold	Median S/R	Median S/C	Median S/N
Natural	0.85	0.85	100	1.60	1.64	N/A
Current	0.52	0.52	94	1.00	N/A	0.61
Reference	0.53	0.53	94	N/A	1.00	0.63
350Gl -Cap	0.53	0.52	93	1.00	1.00	0.61
750 GL - Cap	0.52	0.52	92	1.00	1.00	0.61
1500 GL- Cap	0.55	0.56	98	1.04	1.04	0.66
350 GL - B	0.53	0.53	95	1.01	1.01	0.63
750 GL - B	0.52	0.52	90	1.00	1.00	0.61
1500 GL - B	0.54	0.54	95	1.02	1.03	0.64
350 GL - C	0.53	0.53	91	1.01	1.01	0.62
750 GL - C	0.53	0.52	94	1.01	1.01	0.62
1500 GL - C	0.53	0.52	92	1.00	1.00	0.62

Table 13 – Percentage of years when the overall Native Fish Habitat Condition Index was better or worse than the CURRENT Scenario. See text for definitions.

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	0	0	0	100	73	0
Reference	0	0	2	6	0	0
350Gl -Cap	0	0	1	1	0	0
750 GL - Cap	0	1	1	8	0	0
1500 GL- Cap	0	0	5	34	0	0
350 GL - B	0	0	0	7	0	0
750 GL - B	0	0	3	7	0	0
1500 GL - B	0	0	5	18	0	0
350 Gl - C	0	0	2	2	0	0
750 GL - C	0	0	1	7	0	0
1500 GL - C	0	1	10	13	0	0

Table 14 (a) – Outputs from the Native Fish Habitat Condition model for Murray cod (Group 6) only.

Scenario	Mean	Median	Median S/R	Median S/C	Median S/N
Natural	0.89	0.9	2.00	2.00	N/A
Current	0.40	0.36	1.00	N/A	0.39
Reference	0.41	0.37	N/A	1.00	0.41
350Gl -Cap	0.41	0.36	1.00	1.00	0.40
750 GL - Cap	0.41	0.36	1.00	1.00	0.40
1500 GL- Cap	0.47	0.46	1.07	1.09	0.53
350 GL - B	0.41	0.37	1.00	1.02	0.41
750 GL - B	0.40	0.36	0.98	0.99	0.40
1500 GL - B	0.43	0.38	1.02	1.02	0.42
350 GL - C	0.40	0.36	1.00	1.01	0.40
750 GL - C	0.41	0.37	1.01	1.01	0.41
1500 GL - C	0.42	0.37	1.01	1.01	0.41

Table 14 (b) – Outputs from the Native Fish Habitat Condition model for Macquarie Perch (Group 2) only.

Scenario	Mean	Median	Median S/R	Median S/C	Median S/N
Natural	0.72	0.72	1.36	1.38	N/A
Current	0.52	0.51	1.00	1.00	0.72
Reference	0.52	0.51	1.00	1.00	0.73
350Gl -Cap	0.52	0.51	1.00	1.00	0.73
750 GL - Cap	0.52	0.51	1.00	1.00	0.73
1500 GL- Cap	0.53	0.51	1.00	1.00	0.74
350 GL - B	0.52	0.51	1.00	1.00	0.72
750 GL - B	0.52	0.51	1.00	1.00	0.73
1500 GL - B	0.54	0.52	1.01	1.01	0.74
350 GL - C	0.52	0.51	1.00	1.00	0.73
750 GL - C	0.53	0.51	1.00	1.00	0.73
1500 GL - C	0.54	0.52	1.01	1.01	0.74

Table 15 (a) – Percent of years when the Murray cod (Group 6) Habitat Condition Index was better or worse than the CURRENT Scenario. See text for definitions.

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	0	0	0	100	91	79
Reference	0	3	13	17	1	0
350Gl -Cap	1	3	4	11	0	0
750 GL - Cap	1	5	9	18	2	0
1500 GL- Cap	1	5	9	51	25	11
350 GL - B	0	2	5	22	1	0
750 GL - B	0	6	13	21	1	0
1500 GL - B	4	5	13	38	10	1
350 Gl - C	0	4	8	12	1	0
750 GL - C	1	4	11	13	4	0
1500 GL - C	2	11	25	28	5	0

Table 15 (b) – Percentage of years when the Macquarie Perch (Group 2) Habitat Condition Index was better or worse than the CURRENT Scenario.
See text for definitions.

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	0	0	0	0	25	0
Reference	0	0	1	5	0	0
350Gl -Cap	0	0	0	1	0	0
750 GL - Cap	0	0	4	7	0	0
1500 GL- Cap	0	0	4	12	0	0
350 GL - B	0	0	0	7	0	0
750 GL - B	0	0	3	10	0	0
1500 GL - B	0	0	2	23	0	0
350 Gl - C	0	0	2	7	0	0
750 GL - C	0	0	3	12	0	0
1500 GL - C	0	0	3	26	0	0

Table 16 (a) – Native Fish Habitat assessment with structural and operational changes. *The CURRENT Scenario was run without any structural or operational changes.

Scenario	Mean	Median	Median S/R	Median S/C*	Median S/N
Natural	0.84	0.85	1.32	1.60	N/A
Current*	0.53	0.53	0.83	N/A	0.62
Reference	0.64	0.64	1.00	1.20	0.75
350Gl -Cap	0.64	0.64	1.00	1.20	0.76
750 GL - Cap	0.64	0.63	0.99	1.19	0.75
1500 GL- Cap	0.65	0.65	1.00	1.21	0.76
350 GL - B	0.64	0.64	1.00	1.20	0.76
750 GL - B	0.64	0.64	1.00	1.20	0.75
1500 GL - B	0.65	0.65	1.02	1.21	0.78
350 GL - C	0.64	0.63	1.00	1.19	0.76
750 GL - C	0.64	0.64	1.01	1.21	0.76
1500 GL - C	0.64	0.64	1.00	1.20	0.76

Table 16 (b) – Murray Cod (Group 6) Fish Habitat assessment with structural and operational changes. *The CURRENT Scenario was run without any structural operational changes.

Scenario	Mean	Median	Median S/R	Median S/C*	Median S/N
Natural	0.89	0.90	1.36	2.00	1.00
Current*	0.41	0.37	0.61	N/A	0.39
Reference	0.63	0.66	N/A	1.63	0.73
350Gl -Cap	0.62	0.63	1.00	1.62	0.69
750 GL - Cap	0.61	0.61	0.99	1.59	0.67
1500 GL- Cap	0.66	0.69	1.00	1.71	0.75
350 GL - B	0.63	0.66	1.00	1.65	0.72
750 GL - B	0.62	0.65	1.00	1.59	0.70
1500 GL - B	0.63	0.68	1.00	1.62	0.73
350 GL - C	0.61	0.62	1.00	1.61	0.69
750 GL - C	0.62	0.64	1.01	1.58	0.70
1500 GL - C	0.59	0.55	0.99	1.50	0.62

Table 16 (c) – Macquarie Perch (Group 2) Fish Habitat assessment with structural and operational changes. *The CURRENT Scenario was run without any structural operational changes.

Scenario	Mean	Median	Median S/R	Median S/C*	Median S/N
Natural	0.72	0.72	1.17	1.38	N/A
Current*	0.52	0.51	0.88	N/A	0.72
Reference	0.60	0.58	N/A	1.13	0.85
350Gl -Cap	0.60	0.57	1.00	1.13	0.85
750 GL - Cap	0.60	0.57	1.00	1.13	0.86
1500 GL- Cap	0.61	0.58	1.00	1.14	0.88
350 GL - B	0.61	0.58	1.00	1.13	0.86
750 GL - B	0.61	0.58	1.00	1.14	0.86
1500 GL - B	0.65	0.63	1.03	1.21	0.89
350 GL - C	0.61	0.58	1.00	1.13	0.85
750 GL - C	0.62	0.58	1.00	1.15	0.86
1500 GL - C	0.65	0.63	1.03	1.21	0.88

Table 17 – Overall river zone health

Scenario	Mean	Median	Threshold	Median S/R	Median S/C	Median S/N
Natural	0.62	0.63	97	1.40	1.30	N/A
Current*	0.46	0.44	65	1.00	N/A	0.77
Reference	0.44	0.43	61	N/A	1.00	0.71
350Gl -Cap	0.46	0.44	64	1.01	1.00	0.77
750 GL - Cap	0.47	0.45	67	1.02	1.01	0.78
1500 GL- Cap	0.49	0.47	80	1.05	1.04	0.81
350 GL - B	0.50	0.48	79	1.08	1.07	0.83
750 GL - B	0.50	0.47	81	1.08	1.07	0.82
1500 GL - B	0.55	0.52	94	1.26	1.16	0.88
350 GL - C	0.49	0.46	77	1.07	1.06	0.80
750 GL - C	0.52	0.48	89	1.17	1.10	0.85
1500 GL - C	0.53	0.51	93	1.20	1.16	0.86

Table 18 – Percentage of years when the overall River Habitat Condition Index was better or worse than the CURRENT Scenario. See text for definitions

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	0	0	1	82	35	8
Reference	0	5	17	4	0	0
350Gl -Cap	0	1	3	4	0	0
750 GL - Cap	0	0	3	7	0	0
1500 GL- Cap	0	0	6	23	3	0
350 GL - B	0	0	3	37	0	0
750 GL - B	0	1	3	37	0	0
1500 GL - B	0	0	2	67	6	0
350 Gl - C	0	2	7	37	0	0
750 GL - C	0	2	7	36	2	0
1500 GL - C	0	0	0	52	7	0

Table 19 – Percentage of years when the overall River Habitat Condition Index was better or worse than the CURRENT Scenario after first discounting the role of flow on improving native fish habitat condition. See text for definitions

Scenario	Substantially Worse (S/C <0.5)	At Least Moderately Worse (S/C <0.75)	At Least Marginally Worse (S/C <0.9)	At Least Marginally Better (S/C >1.1)	At Least Moderately Better (S/C >1.5)	Substantially Better (S/C >1.99)
Natural	0	1	13	63	35	8
Reference	0	8	20	8	0	0
350Gl -Cap	0	2	4	5	0	0
750 GL - Cap	0	0	4	10	0	0
1500 GL- Cap	0	3	8	25	9	1
350 GL - B	0	0	3	46	5	0
750 GL - B	0	2	3	47	8	0
1500 GL - B	0	1	3	72	21	2
350 Gl - C	0	4	8	44	4	0
750 GL - C	0	3	7	60	15	2
1500 GL - C	0	4	7	68	24	2

Table 20 – Flow Distribution for River Murray at Doctors Point (Albury)

		NATURAL	REFERENCE	Current	350-b	350-c	350-a (cap)	750-b	750-c	750-a (cap)	1500-b	1500-c	1500-a (cap)
		5327000	5347000	5348000	5576000	5583000	5440000	5593000	5598000	5433000	5607000	5617000	5434000
TITLE		Natural Conditions Run 20-12-02	Cap Conditions - 100GL Barmah-Millewa Forest Use - Metro Adel 93/94 diversions	Current operating rules with NSW and Vic demand at 1993/94 levels	350 GL REF PT - Snowy 282 GL + 5% pro rata tribs + barrages 5399 + mitta 5557 + dshume 5411 + BM reduce spill +inc 3yr event	350 GL REF PT 2 - 5% pro rata tribs +mitta (5449 &5557) +dshume (5396 & 5411&BMsome spill) +flowSA 5457 +barrages 5399 +anabranch5547	350 GL Reference Point - 4% Reduction on Murray + 5% pro rata reductn on tribs	750 GL REF PT 1 -Snowy 5620 +10% modelled tribs +Mitta 5562 +dshume 5412 +BMnospill +flowSA 5457 +barrages 5399 + SAVcapcut	750 GL REF PT 2 - 10%modelled tribs +mitta(5560 &5557) +dshume(5396 &5411 &BMnospill) +flowSA5455 +barrages5399 +anabranch5547& 5588	750 GL Reference Point - 7% reductn on Murray + 10% model reductn on tribs	1500GL REF PT 1 - Snowy5620 +20%modtribs +SVN17% +Mitta5562&5557 +dshume 5412 +BMnospill+upfl size +flowSA5457&5455 +barrages 5399&5400	1500GLREFPT2 - 20%tribs +SVN16% +mitta(5560&5557 &5453) +dshume(5396&5411&BMspillup) +flowSA5455&5457 +barr5399&5482 +darl5582&5588&5409	1500 GL Reference Point - 17% reductn on Murray + 20% model reductn on tribs
SCENARIO NUMBER		1	3	2	7	10	4	8	11	5	9	12	6
Environment *Hume to Yarrawonga*		Absolute	Absolute	**Change is defined as Difference from Reference Run**									
Spill from Hume excluding Pre-Release (ave GL/year)	Absolute	4173	854	982	939	799	1049	962	772	1082	1019	815	1313
	Change	3319		128	85	-55	195	108	-82	228.3	164.8	-39.1	459.4
Area flooded - Hume to Yarrawonga (ave ha/year)	Absolute	7590	3470	3971	3915	3650	4179	4264	3785	4279	4585	4152	4731
	Change	4121		501	445	180	710	795	316	808.8	1115.4	682.2	1260.9
Mean Annual Doctors Point Flow (GL/year)	Absolute	4860	5307	5299	5230	5300	5297	5222	5301	5294	5220	5298	5278
	Change	-447		-7	-77	-7	-9	-84	-6	-12.2	-86.3	-8.7	-28.1
Mean Summer Doctors Point Flow, Nov-Mar (GL/year)	Absolute	1194	2966	2933	2882	2912	2881	2799	2906	2822	2703	2828	2586
	Change	-1772		-33	-83	-54	-85	-167	-59	-144.2	-263.2	-137.9	-379.5
Median Summer Doctors Point Flow, Nov-Mar (GL/year)	Absolute	1022	3062	3012	2934	2981	2942	2879	3017	2868	2697	2863	2592
	Change	-2040		-51	-128	-81	-121	-183	-46	-194.2	-365.1	-199.8	-470.8
Mean daily change in Albury level (Jun-Sept) cm/day	Absolute	10	6	6	7	6	6	7	6	7	7	7	7
	Change	4		0	0	0	0	1	0	0.2	0.6	0.3	0.8
Percentage of daily flow @ Doctors Point < 10,000 ML/d	Absolute	51.9%	53.8%	52.9%	53.0%	53.0%	53.0%	53.6%	53.0%	53.5%	54.1%	53.9%	54.4%
	Change	-2%		-0.9%	-0.8%	-0.8%	-0.8%	-0.2%	-0.9%	-0.4%	0.2%	0.1%	0.5%
Percentage of daily flow @ Doctors Point between 10,000-25,000 ML/d	Absolute	28.9%	39.3%	39.1%	37.5%	38.3%	38.4%	36.6%	38.3%	37.7%	35.2%	36.3%	35.2%
	Change	-10%		-0.3%	-1.8%	-1.0%	-0.9%	-2.7%	-1.0%	-1.6%	-4.1%	-3.0%	-4.1%
Percentage of daily flow @ Doctors Point between 25,000-45,000 ML/d	Absolute	12.8%	4.5%	5.3%	7.0%	6.5%	5.6%	7.2%	6.7%	5.8%	8.1%	7.5%	7.0%
	Change	8%		0.8%	2.5%	2.0%	1.1%	2.7%	2.1%	1.3%	3.6%	3.0%	2.4%
Percentage of daily flow @ Doctors Point between 45,000-72,000 ML/d	Absolute	4.7%	1.8%	2.0%	1.8%	1.6%	2.2%	1.9%	1.6%	2.2%	2.0%	1.7%	2.6%
	Change	3%		0.2%	0.1%	-0.2%	0.4%	0.1%	-0.2%	0.5%	0.2%	-0.1%	0.8%
Percentage of daily flow @ Doctors Point > 10,000 ML/d	Absolute	48.1%	46.2%	47.1%	47.0%	47.0%	47.0%	46.4%	47.0%	46.5%	45.9%	46.1%	45.6%
	Change	2%		0.9%	0.8%	0.8%	0.8%	0.2%	0.9%	0.4%	-0.2%	-0.1%	-0.5%
Percentage of daily flow @ Doctors Point > 25,000 ML/d	Absolute	19.1%	6.8%	8.0%	9.5%	8.6%	8.6%	9.8%	8.7%	8.9%	10.7%	9.8%	10.4%
	Change	12%		1.2%	2.7%	1.8%	1.8%	2.9%	1.9%	2.0%	3.9%	2.9%	3.6%
Percentage of daily flow @ Doctors Point > 45,000 ML/d	Absolute	6.4%	2.3%	2.7%	2.4%	2.1%	2.9%	2.5%	2.1%	3.0%	2.6%	2.2%	3.4%
	Change	4%		0.4%	0.1%	-0.2%	0.6%	0.2%	-0.2%	0.7%	0.3%	-0.1%	1.1%
Percentage of daily flow @ Doctors Point > 72,000 ML/d	Absolute	1.6%	0.5%	0.7%	0.6%	0.5%	0.7%	0.6%	0.5%	0.8%	0.7%	0.6%	0.9%
	Change	1%		0.1%	0.1%	0.0%	0.2%	0.1%	0.0%	0.2%	0.1%	0.0%	0.3%

Appendix A: Hydrological description of scenarios assessed

Comment on Specific Operational Changes for the Hume to Yarrawonga Reach of the River Murray

Table A1 provides summary comments on each of the measures included in the various hydrological scenarios applicable to the Hume to Yarrawonga Reach, including their overall objective and a short analysis of whether this objective is likely to have been met effectively.

Table A1 – Comment on Specific Operational Changes for the Hume to Yarrawonga Reach of the River Murray

Run Identifier	Description	Included in Scenarios No.	Identifier	Comment
5396	**Boost releases from Hume when Natural Albury Flow > 32,000 ML/day by 10,000 ML/day (but do not exceed 42,000 ML/day). Increase channel capacity for Pre-Releases and Environmental Releases to 42,000 ML/day.**	**10** **11** **12**	**350C** **750C** **1500C**	This option will boost releases from Hume by a maximum of 10,000 ML/day when Natural inflows to the Upper Murray (U/S Hume Dam) and Kiewa Rivers are high. Releases will overlap with Ovens River inflows to provide benefits downstream of Yarrawonga in many cases, although benefit downstream of Barmah will be small. This option reduces the harvesting function of Hume for small to medium events and has the potential for small benefits to the lower floodplain in this reach. Outcomes (measure in isolation, compared to Reference):- • Mean annual spill reduces by 40 GL - boost is a regulated flow and is defined as a pre-release (pre release increases by average 73 GL). By deduction, boost is equivalent to 40 GL/year, delivered over a minimum of 4 days. • Annual average of 240 Ha of additional floodplain inundated.
5410	**Reduce Albury channel capacity to 20,000 ML/day for irrigation releases.**	**8** **9**	**750B** **1500B**	Possibly included to reduce pre-release volumes in an attempt to increase peak spill flow. Possibly also included in an attempt to mitigate geomorphic pressures in Hume to Yarrawonga reach. A reduction in diversions of this scale is likely to proportionally reduce opportunistic annual cropping more than high value horticulture. A shift to a higher proportion of horticulture may not reduce demand requirements sufficiently to justify a reduction in channel capacity. Geomorphic pressures are not likely to be significantly different at 20,000 ML/day compared to 25,000 ML/day. *(cont)*

Run Identifier	Description	Included in Scenarios No.	Identifier	Comment
				Outcomes (measure in isolation, compared to Reference):- • Mean annual spill increases by 195 GL. Most of this is as a result of irrigation demand being constrained by channel capacity. This is confirmed by the average Nov-Mar Albury flow, which reduces by 183 GL. • Pre-release volume reduces by annual average of 24 GL. • Annual average of 703 Ha of additional floodplain inundated.
5411	**Increase Albury channel capacity to 42,000 ML/day for environmental releases and pre-releases.**	**7** **8** **9** **10** **11** **12**	**350B** **750B** **1500B** **350C** **750C** **1500C**	Allows greater capacity to deliver environmental allocations downstream. Will provide greater benefit to lower floodplain in Hume-Yarrawonga reach, although it will trade-off flood flows above minor flood level. Outcomes (measure in isolation, compared to Reference):- • Mean annual spill increases by 30 GL – an obvious reason for this has not been identified. • Pre-release increases by 75 GL. Again, the threshold for pre-release is redefined from 25,000 to 42,000 ML/day. This may indicate more effective delivery of existing environmental entitlements (B-M Entitlement modelled as 100 GL release in July under reference case, but this may be being constrained in some years). • Annual average of 520 Ha of additional floodplain inundated.