NVIRP Landscape Scale Regional Assessments

ENVIRONMENTAL AND GROUNDWATER ASSESSMENTS

- Final v4e
- 25 March 2011

NVIRP Landscape Scale Regional Assessments

ENVIRONMENTAL AND GROUNDWATER ASSESSMENTS

- Final v4e
- 25 March 2011

Sinclair Knight Merz
ABN 37 001 024 095
590 Orrong Road, Armadale 3143
PO Box 2500
Malvern VIC 3144 Australia
Tel: +61 3 9248 3100
Fax: +61 3 9500 1180
Web: www.skmconsulting.com

Executive summary

The Northern Victoria Irrigation Renewal Project (NVIRP) aims to modernise the irrigation delivery infrastructure within the Goulburn Murray Irrigation District (GMID). In doing so, it will generate water savings through improved efficiency in water delivery that will be split between the environment, irrigators and Melbourne (adapted from NVIRP 2010).

In operating the modernised system there will be changes in the water regimes of wetlands and waterways and also changes in groundwater levels and salinity. These changes will occur as a result of reductions in gross water diversions, irrigation channel outfalls, evaporation, bank leakage and seepage, and changes to lateral groundwater flows. The potential environmental impacts associated with these changes have been considered, as required under Victorian and Commonwealth legislation.

Most of the environmental assessments conducted to date have focused on matters of national environmental significance, species of high conservation significance at the state or national level and specific 'at risk' sites that support those values. However, a broad assessment of landscape related issues has not been undertaken. This report presents the results of a regional assessment of the cumulative impacts of NVIRP across the GMID. NVIRP's Water Change Management Framework requires the preparation of a regional environmental assessment and a groundwater assessment. NVIRP has decided that both assessments use similar information and so the assessments have been undertaken together and presented in this report.

The specific habitat types, groups of biota and landscape scale ecosystem functions that are most likely to be affected by the hydrological changes that are predicted to occur as a result of NVIRP have been assessed at a regional scale. The combined assessment does not focus on individual sites, but considers the abundance and distribution of affected habitat types, biota and functions. Cumulative effects of any changes across the landscape and potential mitigation measures are considered.

Overall, the combined assessment indicates that the regional scale threat associated with NVIRP is likely to be small, particularly when considered in the broader context of climate change and natural variability. Most of the aquatic habitats in the landscape and nearly all of the terrestrial habitats and the ecosystem functions they perform will not be affected by the hydrological changes expected as a result of NVIRP. Moreover, the conceptual models used in this report suggest that NVIRP will have little effect on most of the biological indicators considered. The cumulative effects of NVIRP are considered to be minimal.

However, the combined assessment has determined that small waterways and shallow wetlands that receive outfalls from the irrigation system and areas that receive water from bank leakage are the habitat types that are most likely to be affected by NVIRP. Specific changes in these habitats include lower water levels, shorter periods of inundation and less frequent and smaller freshening flows.

Where risk assessments indicate that NVIRP may have an effect on identified values, the risk management tools implemented by NVIRP, including the Water Change Management Framework (WCMF), provide an adequate means of addressing risks. No additional management and mitigation measures are currently required.

The cumulative impacts of NVIRP on the high environmental value waterways and wetlands of the region are considered to be minimal.

The tables below summarise the key project findings in relation to the requirements of the WCMF.

.

Evaluation against Regional Environmental Assessment (REA) requirements

REA requirements	Evaluation - summary	Response to requirements	Relevant section
The Regional Environmental Assessment should address:			
▪ Potential effects of the implementation of NVIRP on aquatic ecosystems and functions including effects on listed species and communities, and listed migratory species;	The GMID and its ecosystem values and water-dependent habitats are described at the regional scale. Biological indicator groups (fish, birds and vegetation) and conceptual models were used to assess the impacts of NVIRP on specific components of the water regime that are critical to the survival of plants and animals across the landscape. The GMID contains significant ecological landscape values. These values include a range of habitat types, biota and ecosystem functions that may be affected by changes to surface water and groundwater hydrology caused by NVIRP. Landscape scale values and ecological functions are a function of the distribution of different habitat types across the region and the wetting and drying regime experienced by these habitat types. Values include presence of plant and animal species, communities of conservation significance and landscape scale ecosystem functions such as connectivity between habitats for biota and hydro-geochemical processing (i.e. nutrient processing and energy dynamics). Wetlands that have either direct or indirect connections to the irrigation system are likely to become drier as a result of NVIRP and in some cases there may be a permanent shift to a drier wetland type. However, in the context of other risks (e.g. climate change), NVIRP provides a low risk to	Shallow wetlands (freshwater meadows and shallow freshwater marshes) and small rivers and creeks that receive direct outfalls from irrigation channels and drains are most at risk from NVIRP. While some impacts may occur at individual sites, the overall landscape scale impact is expected to be small because these systems appear evenly spatially distributed across the GMID, both within and outside of specific irrigation areas.	3, 4.44.6

REA requirements	Evaluation - summary	Response to requirements	Relevant section
	the water regimes of water-dependent habitats that support ecological values in the landscape.		
▪ Effects on regional groundwater and surface water resources	The hydrological impacts of NVIRP on surface water and groundwater across the region are described in detail in the Public Environment Report (PER) and are summarised in this report.	Changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable. Changes in groundwater levels and flows are assessed as negligible. The additional impact over and above that predicted due to climate change is considered to be insignificant.	4.1.2
▪ Effects on salinity	The effects of NVIRP on surface water, groundwater and salinity across the region are described in detail in the PER and are summarised in this report..	Changes in river salinities are likely to be very small.	4.1.2.4 and 4.1.2.4
• Following the completion of the Environmental Watering Plans (EWPs) for the relevant program of works, NVIRP will review the EWPs as a whole and consider:	EWPs have been reviewed as a whole.		5.4, 5.5
• the cumulative effects of the impact of NVIRP on high environmental value waterways and wetlands	Cumulative effects of the impact of NVIRP have been assessed by: • undertaking a risk assessment of the potential impacts of NVIRP to aquatic habitat types and biotic indicators • reviewing residual risk after implementation of available NVIRP risk management options • reviewing EWPs as a whole	The cumulative impacts of NVIRP on the environmental values of waterways and wetlands and on the waterways and wetlands requiring EWPs will be minimal because: • the spatial impact of NVIRP on waterways and wetlands is limited Only nine of 1,019 wetlands identified in the GMID have been assessed as being at risk and requiring preparation of a NVIRP wetland EWP • the impact of NVIRP on the water regime of wetlands (indicated by wetland type) and waterways for which EWPs have been prepared	5.11

REA requirements	Evaluation - summary	Response to requirements	Relevant section
	• reviewing changes to wetland classification pre and post NVIRP • considering the number of waterways and wetlands potentially affected by NVIRP • considering NVIRP's process for identifying potentially 'at risk' waterways and wetlands.	is limited • of sixteen waterways identified as potentially 'at risk', only three NVIRP waterway EWPs have been required to be prepared and only one of these has recommended that mitigation water be provided • risk assessment shows NVIRP's mitigation measures address likely impacts • the shortlisting processes rigorously assessed values and potential impacts • the hydrological and hydrogeological changes due to NVIRP are very small and are unlikely to have any effect on biota or other environmental values.	
• whether any additional management and mitigation measures are required (to be implemented through Environmental Watering Plans.	For sites where specific risks have already been identified, Environmental Water Plans have been developed in accordance with the NVIRP Water Change Management Framework. This framework provides the process for mitigating water-related risks of NVIRP at other sites that might be identified in the future. NVIRP's Environmental Infrastructure Register and Local Groundwater Assessment ensure that all wetlands potentially at risk from NVIRP are assessed and impacts mitigated if required.	Review of EWPs indicates that relevant impacts of NVIRP have been identified and mitigated. No additional management and mitigation measures are required.	5.12
• NVIRP will prepare a Regional Environmental Assessment Report summarising the	This combined assessment report has been prepared.		

REA requirements	Evaluation - summary	Response to requirements	Relevant section
assessment and conclusions. The report will be reviewed and approved as set out in Table 12 of the WCMF.			
• Where regional high environmental values will be adversely affected by the operation of the modified GMID, an appropriate management and mitigation plan will be developed consistent with other policies and programs in the region.	NVIRP presents risk to some aquatic habitats and biotic indicators. NVIRP has a range of processes covering risk assessment and risk management that identify risks to aquatic habitats and biotic indicators. NVIRP's processes are adequate to identify and assess potential sites at risk NVIRP's processes are adaptive and subject to review and refinement NVIRP has a number of risk mitigation options that can be implemented to reduce risks to acceptable ratings. Relevant risk management options are identified through the preparation of EWPs. Risk assessment shows NVIRP's mitigation measures address likely impacts.	Measures additional to the WCMF to address adverse impacts of NVIRP on regional high environmental values are not required to be developed.	5.12

Evaluation against Groundwater Assessment (GA) requirements

GA requirements (from WCMF)	Evaluation - summary	Response to requirements	Relevant section
The Groundwater Assessment Report is to identify and assess the potential changes to regional groundwater as a result of reduced channel outfalls, channel seepage and channel leakage associated with the implementation of NVIRP.	This report has summarised the detailed groundwater assessment prepared for the Public Environment Report.	Overall, changes due to NVIRP are relatively modest compared to changes caused by other factors such as groundwater pumping, drought and climate change.	4.1.2
The report will identify and describe the processes that may change the groundwater regime as a result of the implementation of NVIRP, taking particular account of:	Processes that may change the groundwater regime were identified in the detailed groundwater assessment prepared for the Public Environment Report. These are summarised in this report.	One of the aims of NVIRP is to reduce channel seepage and bank leakage. Upgrades to irrigation infrastructure are expected to reduce recharge to the groundwater system, and as a result, regional watertables in the shallow groundwater system (Shepparton Formation) will fall.	4.1.2
• the likely impact on wetland/lunette groups, waterways and groundwater-dependent ecosystems (GDEs) at a regional and sub-regional scale	The likely impact on wetland/lunette groups, waterways and groundwater-dependent ecosystems (GDEs) at a regional and sub-regional scale has been assessed using aquatic habitat categories and biotic indicators.	Wetlands that have either direct or indirect connections to the irrigation system are likely to become drier as a result of NVIRP and in some cases there may be a permanent shift to a drier wetland type. However, in the context of other risks (e.g. climate change), NVIRP provides a low risk to the water regimes of water-dependent habitats that support ecological values in the landscape. Shallow wetlands (freshwater meadows and shallow freshwater marshes) and small rivers and creeks that receive direct outfalls from irrigation channels and drains are most at risk from NVIRP. This is because even small magnitude reductions in outfalls could have consequences for the water regime and associated values in these small systems. While some impacts may occur at individual sites the overall landscape scale impact is expected to be small because these systems appear evenly spatially distributed across the GMID, both within and outside of specific irrigation areas.	4

GA requirements (from WCMF)	Evaluation - summary	Response to requirements	Relevant section
		At a regional scale, NVIRP presents a low risk to all these indicator groups. Where NVIRP-related hydrological changes occur in their relevant habitats, the water regime components impacted are either of low importance to the life-cycle or habitat required by the indicator group, or the effects will be minor at a regional scale. The one exception is submerged vegetation, where it is conceivable that NVIRP may contribute to a regional shift from submerged vegetation communities to more amphibious communities due to less pooled water in the landscape. This applies mostly to shallow wetlands (freshwater meadows and shallow freshwater marshes) where even small reductions in volume could impact on water regimes. However, as indicated above, these systems are well distributed across the GMID and while localised impacts may occur at specific sites, the landscape impact is likely to be small.	
• each of the types of connections (between irrigation infrastructure and wetlands) listed in Table 8.3 of the desktop assessment (SKM 2008a)	Connection types have been correlated with aquatic habitat categories, described above.	See above	4
• those actions such as channel lining and channel rationalisation designed in part or principally to address seepage and leakage of irrigation water.		Channel seepage is likely to have increased the level of the watertable above natural levels over large areas. This is likely to have been detrimental to ecological values in areas with shallow saline groundwater by bringing saline water close to the surface, where it damages plants and intersect low lying wetlands. Reductions in near-channel groundwater levels by NVIRP channel lining and channel rationalisation may therefore be beneficial.	4.1.2

GA requirements (from WCMF)	**Evaluation - summary**	**Response to requirements**	**Relevant section**
The report will: • review the management and mitigation measures implemented or proposed by NVIRP, particularly the Environmental Watering Plans in respect to actions designed to minimise and mitigate groundwater and salinity related impacts	Environmental Watering Plans have been reviewed Local groundwater impacts of NVIRP are assessed and, if necessary, mitigated by the preparation of Local Groundwater Assessments.	All wetland EWPs and two of three waterway EWPs addressed these groundwater and surface water interactions from the perspective of how they might affect achievement of the wetland or waterway management. No measures were identified as being required to address risks associated with salinity and groundwater.	5.8
• recommend additional management and mitigation measures which may be required, consistent with the principles and commitments of this WCMF.		No additional measures are required.	5.12
The report will assess the cumulative impacts of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID	The hydrological impacts of NVIRP on surface water and groundwater across the region are described in detail in the PER and are summarised in this report. Changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable and no impact on significant environmental values are expected. Changes in groundwater levels and flows across the region are negligible. Changes in river salinities will be too small to have any effect on ecological values. The additional impact over and above that predicted due to climate change is considered to be insignificant.	The cumulative impacts of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID are minimal.	5.11

GA requirements (from WCMF)	Evaluation - summary	Response to requirements	Relevant section
	NVIRP will not affect any of the biological values that currently occur at the assessed sites.		
The report will assess the cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring Environmental Watering Plans (i.e. ‘at risk’).	EWPs were reviewed. All wetland EWPs and two of three waterway EWPs addressed these groundwater and surface water interactions from the perspective of how they might affect achievement of the wetland or waterway management. No measures were identified as being required to address risks associated with salinity and groundwater.	The cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring Environmental Watering Plans (i.e. ‘at risk’) are minimal.	5.8

Contents

Document history and status

Revision	Date issued	Reviewed by	Approved by	Date approved	Revision type
R01	1/11/10	A.Sharpe	A.Sharpe	28/10/10	Technical Review
R02	1/11/10	P.Boon/P. Cunningham	A. Sharpe	10/11/10	Technical Review
R02	29/10/10	P.Feehan, ERP, TAC	A.Sharpe	10/11/10	Client Review
Final	16/11/10	S Treadwell	S Treadwell	16/11/10	Technical review
Final v2	19/1/11	S Treadwell	S Treadwell	19/1/11	Technical review to incorporate ERP comments
Draft v3	8/2/2011				Working draft created after ERP meeting 7/2/2011
Draft v4a	28/2/2011				Working draft
Final v4c	3/3/2011				Finalised document after TAC and ERP review
Final v4d	14/3/2011				Typos corrected. Minor amendments
Final v4e	25/3/2011				Incorporate editor's comments

Distribution of copies

Revision	Copy no	Quantity	Issued to
R02	1xword	1	Pat Feehan, Jacqui Credaro
Final	1xword	1	Pat Feehan, ERP, Carla Evans, Ross Plunkett
Final v2	1xword	1	Pat Feehan, ERP, Carla Evans, Ross Plunkett
Final v4d	1xWord	1	Ross Plunkett
Final v4e	1xWord	1	Ross Plunkett

Printed:	25 March 2011
Last saved:	29 March 2011 12:09 PM
File name:	I:\VWES\Projects\VW05183\Deliverables\Reports\Final report\R06_BB_Stand alone Landscape assessment_Final v2.doc
Author:	Andrew Sharpe, Bonnie Bonneville
Project manager:	Andrew Sharpe
Name of organisation:	NVIRP
Name of project:	Landscape Scale Regional Assessments
Name of document:	Ecological Assessment
Document version:	Final v4e
Project number:	VW05183

Glossary

ASS	Acid sulfate soils
BVT	Broad vegetation type
CEMF	Construction environmental management framework
DSE	Department of Sustainability and Environment
EES	Environment effect statement
EPBC Act	Environment Protection and Biodiversity Conservation Act
ERP	Expert Review Panel
EWP	Environmental watering plan
GDE	Groundwater dependent ecosystem
GMID	Goulburn Murray Irrigation District
G-MW	Goulburn-Murray Water
LTCE	Long term cap equivalent
MNES	Matter of national environmental significance
NVIRP	Northern Victoria Irrigation Renewal Project
PER	Public environment report
PFG	Plant functional groups
VEFMAP	Victorian environmental flow monitoring assessment program
WCMF	Water change management framework

1. Introduction

1.1. Background

The Northern Victoria Irrigation Renewal Project (NVIRP) aims to modernise the irrigation delivery infrastructure in Northern Victoria, specifically within the Goulburn Murray Irrigation District (GMID). In doing so, it will generate water savings through improved efficiency in water delivery that will be split between the environment, irrigators and Melbourne (NVIRP 2010).

In undertaking the modernisation works there will be changes in the water regimes of wetlands and waterways, and changes in groundwater levels and salinity. These changes will occur as a result of reductions in gross water diversions, irrigation channel outfalls, evaporation, bank leakage and seepage, and changes to lateral groundwater flows. The potential environmental impacts associated with these changes have been considered, as required under Victorian and Commonwealth legislation.

The Victorian Minister for Planning determined that an Environmental Effects Statement was not required for NVIRP, subject to conditions as summarised below:

1. Prior to commencing works NVIRP must prepare a framework for environmental management of works (Construction Environmental Management Framework)

2. Appoint an Expert Review Panel to provide advice on hydrological and related ecological changes due to NVIRP

3. Before operation of works, NVIRP must prepare a framework for protection of aquatic and riparian ecological values (Water Change Management Framework)

4. Prepare an assessment report on the ecological changes arising from implementation of NVIRP for the River Murray, the Goulburn River and the Barmah Ramsar Site

5. Before operation of relevant works commences, an approved Environmental Watering Plan (EWP) is required for 'at risk' waterways and wetlands

6. Final advice from the Expert Review Panel (ERP) on the environmental framework (#3 above), the assessment report (#4 above) and individual Environmental Watering Plans (#5 above) is to be made publically available.

The Minister for Planning also included reasons for the decision (reproduced in part below):

> *Any impacts of modified hydrological regimes on aquatic and riparian ecosystems are unlikely to be amenable to detailed, predictive studies (such as might form part of an EES), but are*

instead suited to mitigation through adaptive management of water flows to maintain ecological values. Refinement of risks to individual waterways and wetlands by the proponent will enable effective targeting of efforts for development and implementation of environmental watering plans, which can then be monitored and refined over time.

The Victorian Government's commitment to allocate a large part of the water savings from the operation of the project to environmental flows provides a high measure of assurance that any potential or actual risk to aquatic and riparian ecosystems from reduced flows (due to more efficient supply infrastructure) can be mitigated through environmental watering plans or otherwise rectified through adaptive management. While the potential implications of reduced seasonal inflows to the Goulburn and Murray Rivers and the Barmah Forest Ramsar site warrant further investigation and clarity of management responses, this can be achieved through a focussed investigation without requiring an EES.

Conditions 1, 2, 3 and 5 have been satisfied and Condition 6 has been satisfied as it relates to Conditions 3 and 5. A report addressing Condition 4 has been prepared. A Water Change Management Framework (WCMF) has been prepared. Twelve EWPs have also been prepared to better assess and, where required, mitigate threats in high value waterways and wetlands where NVIRP is most likely to have a significant effect.

NVIRP has also prepared a Public Environment Report (PER) (NVIRP 2010) for the Commonwealth Minister for Environment Protection, Heritage and Arts (DEWHA) for the assessment and approval of an action that may have an impact upon matters of national environmental significance (MNES) under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Minister approved NVIRP's application subject to a number of conditions on 10 May 2010. The approved action must be undertaken in accord with the WCMF (NVIRP 2009c) which also addresses Condition 3 of the Victorian Minister for Planning's decision that an EES is not required.

The PER includes a number of reports that have been used as the basis of this NVIRP Landscape Scale Regional Assessment report.

The WCMF describes the means by which NVIRP will protect aquatic and riparian ecological values through management of water allocations and flows that may be impacted by implementation of NVIRP within the modernised GMID (NVIRP 2010). The WCMF outlines procedures for monitoring, reporting and auditing changes in hydrological conditions in relevant wetlands or waterways associated with the project's operation. It provides the environmental commitments, processes and methods for the relevant operations of the modified system.

Various documents (see Table 1-1) prepared under the WCMF aim to identify potential impacts associated with NVIRP and recommend suitable mitigating actions. This report presents the Regional Environmental Assessment and the Groundwater Assessment.

1.2. Regional Environmental Assessment

The WCMF (Sec 17) (NVIRP 2010) states that the Regional Environmental Assessment should address:

- potential effects of the implementation of NVIRP on aquatic ecosystems and functions including effects on listed species and communities, and listed migratory species
- effects on regional groundwater and surface water resources
- effects on salinity.

Where regional high environmental values will be adversely affected by the operation of the modified GMID, an appropriate management and mitigation plan will be developed consistent with other policies and programs in the region.

Table 1-1: Water Change Management Framework (WCMF) documents. (NVIRP 2010).

Document	Description
Short-listing Reports for Environmental Watering Plans	Short-list of wetlands or waterways that require an Environmental Watering Plan, including specification of whether 'at risk' waterways and wetlands listed in Attachment A of the Minister's conditions require an Environmental Watering Plan or not. Provides rationale for waterways and wetlands requiring Environmental Watering Plans. Includes schedule for development of EWPs, in relation to implementation of NVIRP's program of works.
Environmental Watering Plans	Provides an appropriate water supply protocol to protect the high environmental values of a wetland or waterway, which would otherwise be adversely affected without the additional management and mitigation measures set out in the Environmental Watering Plan.
Regional Environmental Assessment Report	Report setting out: • the cumulative effects of the impact of NVIRP on the high environmental values of waterways and wetlands • any additional management and mitigation measures required to be implemented through Environmental Watering Plans.
Groundwater Assessment Report	Report setting out: • the cumulative impacts of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID • the cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring Environmental Watering Plans (i.e. 'at risk').
Environmental Infrastructure Register	Register setting out infrastructure: • required to be maintained to deliver environmental water • risk assessment of infrastructure alteration • enhancement, voluntarily agreed to by NVIRP.

The WCMF (Sec 17) also states that:

“Following the completion of the EWPs for the relevant program of works, NVIRP will review the EWPs as a whole and consider:

- the cumulative effects of the impact of NVIRP on the high environmental value waterways and wetlands
- whether any additional management and mitigation measures are required.

NVIRP will prepare a Regional Environmental Assessment Report summarising the assessment and conclusions. The report will be reviewed and approved as set out in Table 12 of the WCMF”. (This is reproduced as Table 1-2 below).

1.3. Groundwater Assessment

The Groundwater Assessment is to identify and assess the potential changes to regional groundwater as a result of the reduced channel outfalls, channel seepage and channel leakage associated with the implementation of NVIRP.

The assessment will:

- identify and describe the processes that may change the groundwater regime as a result of the implementation of NVIRP , taking particular account of:
  - those actions such as channel lining and channel rationalisation designed in part or principally to address seepage and leakage of irrigation water
  - each of the types of connections (between irrigation infrastructure and wetlands) listed in Table 8.3 of the desktop assessment (SKM 2008a)
  - the likely impact on wetland/lunette groups, waterways and groundwater-dependent ecosystems (GDEs) at a regional and sub-regional scale
- review the management and mitigation measures implemented or proposed by NVIRP, particularly the EWPs in respect to actions designed to minimise and mitigate groundwater and salinity related impacts
- recommend additional management and mitigation measures which may be required, consistent with the principles and commitments of this WCMF.

Impacts of actions such as channel lining and channel rationalisation have been considered in the documentation associated with the PER (SKM 2009b) and are summarised in Section 4 of this report.

Processes that may change the groundwater regime as a result of the implementation of NVIRP, taking particular account of each of the types of connections (between irrigation infrastructure and wetlands) listed in Table 8.3 of the desktop assessment (SKM 2008a) are considered in Section 4, as is the likely impact on wetland/lunette groups, waterways and groundwater-dependent ecosystems (GDEs) at a regional and sub-regional scale.

The Groundwater Assessment Report will be reviewed and approved as set out in Table 12 of the WCMF (reproduced below as Table 1-2).

Table 1-2: Review and approval of environmental documentation (from WCMF Table 12)

Document	Expert Review Panel	Approval	Timing
Regional Environmental Assessment Report	Final advice to Secretary, DSE to be made publicly available Review of NVIRP draft documentation and feedback or comment	Secretary, DSE following advice from the Expert Review Panel	Following completion of relevant EWPs To be completed on handover of works from NVIRP to G-MW
Groundwater Assessment Report	Final advice to Secretary, DSE to be made publicly available Review of NVIRP draft documentation and feedback or comment	Secretary, DSE following advice from the Expert Review Panel	Before 31 December 2010 or such later time as determined by the Secretary DSE (Extension approved to end of March 2011)

1.4. Combined assessment

NVIRP has decided that the Regional Environmental Assessment and the Groundwater Assessment use similar information, and that the assessments should be undertaken together and presented in this report, the NVIRP Landscape Scale Regional Assessments Report. Therefore, there will not be separate reports forwarded to the Secretary, DSE for approval as required in the WCMF. Instead, the NVIRP Landscape Scale Regional Assessments Report, incorporating the two assessments, will be provided to the Secretary, DSE.

1.5. Assessing cumulative effects

Cumulative effects are the total or combined impacts that may result from a number of activities interacting with the environment in a region. The nature and scale of these effects can vary significantly, depending on factors such as the type of activity performed, the proximity of activities to each other and the characteristics of the surrounding natural, social and economic environments (Brereton, Moran et al 2008). They may also be caused by the combined or sum of the individual effects being greater than the individual effects alone. Cumulative effects are often thought of as the consequences of a large number of small effects.

The approach to assessing cumulative effects of NVIRP in this report has been to:

1. consider impacts that can be attributed to implementation of NVIRP (changes in water supply and flows) (Section 4.1, 4.3)
2. consider the effects of the impact of NVIRP on the environmental values of wetlands and waterways at a landscape scale (Sections 4.5 – 4.8)
3. review management and mitigation measures and consider whether any additional management and mitigation measures are required (Section 5).

The approach considers surface water, groundwater and salinity (Section 4) and excludes impacts that cannot be attributed to NVIRP (e.g. G-MW operational changes, and water trade).

2. Approach

The combined assessment has considered how NVIRP is likely to affect native flora and fauna, their habitats and ecological functions such as nutrient cycling, access to breeding habitats and food, and connectivity between habitats. In all cases the combined assessment has considered how expected changes in hydrology (surface and sub-surface) are likely to affect biota, habitats and functions throughout the GMID region. Impacts associated with NVIRP construction works are dealt with separately under the Construction Environmental Management Framework (NVIRP 2010).

Once potential impacts are identified, the processes NVIRP has in place to mitigate these impacts are assessed at a regional scale. Finally, an analysis of the cumulative effects of any changes across the landscape is undertaken.

The approach has been divided into specific steps, which are summarised in Table 2-1 and described below. The steps address the requirements of the Regional Environmental Assessment and Groundwater Assessment as shown in Section 1-2 and 1-3.

Table 2-1: Summary of project steps showing how each task relates to the WCMF requirements.

Step	Description of step	Link to WCMF assessment requirement.		
		Regional Environment Assessment	Groundwater Assessment	Reference
1	**Regional Description** What are the regional landscape values and functions that NVIRP might impact on? (Include terrestrial and aquatic). Describe the ecological character of the region. This will be done by using various indicators: • habitats/processes • conceptual models. The task will take a 'helicopter' view of the region and will use existing information.			3.1, 4.1
2(a)	**Regional Response to NVIRP** NVIRP is dewatering the landscape – what might happen? Use existing information to describe the expected changes resulting from NVIRP: • generally • specifically on habitat types or groups of biota	Effects on regional groundwater and surface water resources, and effects on salinity.	The report will identify and describe the processes that may change the groundwater regime as a result of the implementation of NVIRP, taking particular account of: • the likely impact on wetland/lunette groups, waterways and groundwater-dependent ecosystems (GDEs) at a regional and sub-regional scale • each of the types of connections (between irrigation infrastructure and wetlands) listed in Table 8.3 of the desktop assessment (SKM 2008a) • those actions such as channel lining and channel rationalisation designed in part or principally to address seepage and leakage of irrigation water The cumulative impacts of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID.	4

Step	Description of step	Link to WCMF assessment requirement. Regional Environment Assessment	Groundwater Assessment	Reference
2 (b)	**Assess impacts** Using the information from 1 & 2(a) describe and asses the risks posed by NVIRP (to these values).	Potential effects of the implementation of NVIRP on aquatic ecosystems and functions including on listed species and communities, and listed migratory species.		4.5- to 4.8
3(a)	**Review mitigation measures** What process (mitigation measures) does NVIRP have in place to address risks?	Potential effects of the implementation of NVIRP on aquatic ecosystems and functions including on listed species and communities, and listed migratory species.	The cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring EWPs. Review the management and mitigation measures implemented or proposed by NVIRP, particularly the Environmental Watering Plans in respect to actions designed to minimise and mitigate groundwater and salinity related impacts.	5.1, 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.11
3(b)	**Review mitigation measures** Are these processes adequate? If not, what else is needed? Also consider other NVIRP benefits • 175 GL • legacy of NVIRP and how it helps with the ecological character of the region and allows redeployment of water.	Following the completion of the EWPs for the relevant program of works, NVIRP will review the EWPs as a whole and consider: • the cumulative effects of the impact of NVIRP on the high environmental value waterways and wetlands • whether any additional management and mitigation measures are required. Consider whether any additional management and mitigation measures are required. Where regional high environmental values will be adversely affected by the operation of the modified GMID, an appropriate management and mitigation plan will be developed consistent with other policies and programs in the region.	Recommend additional management and mitigation measures that may be required, consistent with the principles and commitments of this WCMF.	5.9, 5.10, 5,12

Step 1 – Regional description

The first part of Step 1 describes the GMID region and the specific types of habitat that make up the landscape. An overview of the distribution of specific habitat types is provided.

Step 2 – Regional response to NVIRP and risk assessment

The first part of this step sets the context for the risk assessment. The general surface water and groundwater changes that are predicted to occur throughout the GMID as a result of NVIRP are described. These descriptions are a summary of the hydrological (surface and groundwater) assessments that were used to inform the PER (NVIRP 2010, SKM 2009a, SKM 2009b). Specific changes to particular habitat types and/or particular parts of the GMID are highlighted. These changes are also discussed in the context of hydrological changes that have already occurred as a result of the drought and changes that are predicted to continue as a result of climate change.

The second part of this step is a risk assessment. The various types of habitats that typify the GMID and the physical pathways by which they receive water from the existing irrigation system are described. Using the hydrological changes described in the first part of this step and conceptual models, the risk that NVIRP poses to each habitat type and to ecological functions that may be affected by hydrological changes in that habitat type is assessed. These risks are based on qualitative estimates of the likelihood that NVIRP will result in some sort of hydrological change in that habitat type and the consequence of such a change should it occur. Criteria for likelihood and consequence are shown in Tables 2-2 and 2-3 respectively. The assigned levels of likelihood and consequence are combined to determine the overall level of risk as shown in Table 2-4.

The level of risk is assessed for each habitat type before mitigation actions are considered.

The main ecological values throughout the GMID include various species and communities of plants, fish, birds and frogs. The PER and its supporting documents have already assessed and where necessary addressed the threat that NVIRP poses to significant flora and fauna. However, a regional assessment of potential impacts should more broadly consider threats to any type of biota regardless of their level of conservation significance.

All plants, freshwater fish, and waterbirds can be divided into groups based on their particular water and flow requirements. For example, plants can be divided into terrestrial, amphibious or submerged categories depending on their tolerance to and requirement for inundation. Fish can also be divided into different groups based on their reliance on high flows to trigger spawning or migration, and the particular habitats they prefer. Existing conceptual models are used to describe the relationship between hydrology and specific ecological processes, and determine which groups of plants, fish and birds are likely to be most affected by NVIRP. For each group of biota the type of habitat (from step 2) that they are most commonly associated with is described. For each model there is consideration of how different flow components or elements of the water regime affect particular biological indicators. The hydrological analyses presented in the PER (and summarised in step 2) are used to determine the likelihood of NVIRP affecting those flow components. The regional significance of threatened processes and indicators is discussed.

Potential impacts to ecological processes and indicators due to NVIRP are discussed in the context of other hydrological changes in the region such as drought and climate change.

Table 2-2: Risk assessment likelihood criteria

Likelihood	Criteria
Almost certain	Water regime component is expected to change in most circumstances (50-100% of time)
Likely	Water regime component will probably change in most circumstances (25-50% of time)
Possible	Water regime component should change in some circumstances (5-25% of time)
Unlikely	Water regime component could change in some circumstances (1-5% of time)
Rare	Water regime component is likely to change only in exceptional circumstances (<1% of time)

Table 2-3: Criteria for assessing consequences associated with altered flow, groundwater or salinity on ecological indicators

Consequence	Criteria
Catastrophic	Widespread habitat destruction, irreversible damage, potential loss of species/functional groups/guilds, catastrophic shift in ecosystem processes. Ecosystem is unable to recover and rehabilitation to previous condition is not possible.
Major	Moderate, but widespread (i.e. > 20 per cent of areas with designated habitat type or >20 per cent of relevant biota in region affected) environmental stress observed with short-term disruption to breeding cycles and ecological processes. Or Major, long-term or irreversible damage to environment at a limited number of locations (i.e. < 20 per cent of areas with designated habitat type or <20 per cent of relevant biota in region affected). Potential loss of species/functional groups/guilds, significant shift in ecosystem processes at affected areas. Ecosystem resilience is significantly reduced. Full ecosystem recovery may be possible but would require very difficult and expensive rehabilitation.
Moderate	Minor, short-term and widespread (i.e. > 20 per cent of areas with designated habitat type or >20 per cent of relevant biota in region affected) stress on the environment with rapid recovery, no disruption to breeding cycles or shift in ecosystem processes. Or Moderate environmental stress observed at a limited number of locations (i.e. < 20 per cent of areas with designated habitat type or <20 per cent of relevant biota in region affected), short-term disruption to breeding cycles and ecological processes. Ecosystem resilience is reduced and moderately difficult or expensive rehabilitation is required.
Minor	Minor, short-term stress on the environment at limited number of locations (i.e. < 20per cent of areas with designated habitat type or <20 per cent of relevant biota in region affected) with rapid recovery, no disruption to breeding cycles or shift in ecosystem processes. Simple, low cost rehabilitation required.
Negligible	Negligible effect on the environment. Ecosystem processes and community structure/functional groups remain largely unchanged.

Table 2-4: Risk assessment matrix

Likelihood	Consequence				
	Catastrophic (C)	Major (M)	Moderate (Mo)	Minor (Mi)	Negligible
Almost certain (AC)	Extreme	Very High	High	Medium	Insignificant
Likely (L)	Very High	Very High	Medium	Low	Insignificant
Possible (P)	Very High	High	Medium	Low	Insignificant
Unlikely (U)	High	Medium	Low	Low	Insignificant
Rare (R)	Medium	Medium	Low	Insignificant	Insignificant

Step 3 Review mitigation measures

This step reviews tools available to mitigate potential impacts of NVIRP and to manage the risks identified in Step 2. It also considers the cumulative effects of the impact of NVIRP on the high environmental value wetlands and waterways of the region. Residual risk post mitigation is assessed. Areas of uncertainty in the analysis (for example uncertainty regarding a particular hydrological change or the ecological response to a hydrological change) are flagged. Cumulative impacts are assessed and the need for further management and mitigation measures is considered.

3. Regional description

This section provides a regional scale description of the GMID, the ecosystem values and functions present across the water-dependant habitats in the region and a summary of the hydrological impacts of NVIRP to both surface water and groundwater across the region.

3.1. Description of the GMID, environmental values and ecosystem functions

The GMID is situated in Northern Victoria, in the southern part of the Murray Darling Basin. It is bordered to the north by the River Murray and extends east to west from the Goulburn/Broken to the Loddon River (see Figure 3-1) covering an area of approximately 9,000 square kilometres (km^2). It is known as Victoria's 'food bowl', producing 26 per cent of the nation's milk, nearly 95 per cent of Victoria's tomatoes, 75 per cent of Victoria's stone fruit and 95 per cent of Victoria's grapes, by irrigated agriculture and horticulture on the productive soils of the Southern Riverine Plains (NVIRP 2010).

3.1.1. Victorian Riverina Bioregion

The GMID is located within the Victorian Riverina bioregion. The following is drawn from DSE's description of this bioregion (DSE 2011).

The bioregion covers approximately 24,000 km^2 of the northern Victorian riverine plain, from Rutherglen in the east to Swan Hill and the Avoca River in the west. The southern and eastern boundary of the bioregion occurs at an elevation of about 150 metres. Rainfall ranges from 350 millimetres (mm) per year in the west to an average of 600 mm per year in the east.

The majority of the Victorian Riverina bioregion falls within the riverine plains land system, which is characterised by flat to gently undulating land on recent unconsolidated sediments with evidence of former stream channels. Additional land systems include wide floodplain areas associated with major river systems including the Avoca, Loddon, Campaspe, Goulburn, Ovens and Murray rivers. Isolated areas of low hills also occur within the region, predominantly east of the Goulburn River and south of the Broken Creek.

Grasslands and Grassy Woodlands once covered much of the Riverina but are now restricted to small but significant areas of public and private land. Major environmental features include the Barmah and Gunbower forests, the Kerang Lakes and Corop Lakes systems and the River Murray environment including the Gunbower Creek. These areas also comprise the major public land blocks within the region and provide a range of values for fauna, flora, recreation and tourism. Agriculture is the dominant land use with approximately 90 per cent of the land in private ownership. Major irrigation areas have been developed. Major townships in the area include Shepparton, Swan Hill, Kerang and Echuca – with Shepparton being the largest centre.

3.1.1.1. Broad vegetation types

Plains Grassy Woodland Complexes, Grassland Complexes and Riverine Grassy Woodland Complexes are the three dominant broad vegetation types (BVTs) in the bioregion. The Plains and Riverine Grassy Woodland Complexes are characterised by low-density tree cover dominated by River Red Gum, Black Box, other box eucalypt species and/or Buloke and Callitris pines. The shrubby layer, when present, included species such as Lightwood, Golden Wattle, Gold-dust Wattle and saltbushes. The Grassland BVT is dominated by Wallaby and Spear grasses with a mixture of herbs from the daisy, saltbush and pea families. Grassland Complexes and Grassy Woodland Complexes originally dominated much of the Riverina but are now largely fragmented. Since European settlement in the bioregion, these communities have been severely degraded and now only small remnant areas remain, with little protected on public land.

The bioregion supports numerous rare or threatened vertebrate species, and over 800 species of native vascular plants, of which more than 70 are rare or threatened. Numbers of invertebrate fauna and non-vascular plants are not known.

3.1.1.2. Land management themes

The open grassland plains and Grassy Woodlands in the Victorian Riverina Bioregion were settled and developed early. After the 1860s vast areas of land were cleared or modified to make way for cropping and pasture development. Later, around the turn of the century, large-scale irrigation schemes for the production of fodder crops, cereals and fruits were established on the Campaspe, Goulburn, Loddon and Murray rivers.

Problems of salinity and waterlogging were evident soon after irrigation began in the Kerang area. Vegetation clearance in the south has also had salinity impacts, contributing to rising watertables and saline discharge areas. Irrigation activities have resulted in increased salinity levels in the River Murray, due to the export of salt to the river. Much of this intensive management of agricultural land has also resulted in increased nutrients in wetlands and rivers and tree decline through waterlogging, salinisation and insect attack.

Fertile soils coupled with a secure water supply made most of the area suitable for intensive agriculture. As a consequence, there is very little public land within the bioregion. Extensive strips of public land adjacent to rivers still exist – regular flooding meant that they were not suitable for intensive farming, though much of this area is grazed.

The larger River Red Gum forest blocks found in the Barmah, Gunbower and the Goulburn river areas have been intensively harvested since early settlement for timber products including sleepers, sawlogs and firewood. The composition and structure of the vegetation within these forest blocks has been substantially altered, resulting in a much younger, and in places, denser forest. These structural and age class changes have dramatically affected the diversity and abundance of faunal species, particularly those that are hollow-dependent. Changed flooding regimes and grazing in these areas has also modified the vegetation structure and composition.

All natural ecosystems in the Victorian Riverina have been depleted or highly modified, with only isolated vegetation patches remaining. Grasslands have been the most severely degraded with less than 1 per cent remaining, much of which is found on freehold land. Wetland systems within the bioregion have been altered due to changes in their hydrological cycle (restricted natural wetting and drying phases) and land management practices.

3.1.2. Wetlands

Some high quality environmental assets remain within the GMID, including Ramsar-listed wetlands and waterways of significance for threatened species (NVIRP 2010).

NVIRP aims to generate water savings through modernising the irrigation system to achieve 85 per cent efficiency in its water delivery. In some cases, the watering regimes of rivers and wetlands have been modified due to altered river hydrology, construction of levee banks, diversions and agricultural practices. Many wetlands and waterways now depend on their connection to the irrigation network for water to sustain their environmental values, particularly in dry periods. It is these wetlands and waterways that may be inadvertently impacted by hydrological changes due to NVIRP.

Wetlands are classified by their watering regime, depth of water and salinity (DSE 1994). Permanent waterways and wetlands provide habitat for fish and macroinvertebrates. Freshwater and saline open water wetlands, with shallow mud-flats, provide excellent foraging habitat for waterbirds (Table 3-1). Wetlands with high levels of vegetative cover also provide a safe haven for nesting and breeding for birds and habitat for frogs and macroinvertebrates.

There are 1,019[1] distinct wetlands in the GMID (BL&A 2010). Of these, 961 are freshwater wetlands and 58 are saline wetlands. The major river systems within the GMID are characterised by broad floodplains consisting of the main river channels, anabranches and flood runners that flow during high river flows, and adjacent wetlands that fill when overbank flows occur. Away from the floodplain wetlands, depressions in the landscape and shallow drainage lines contain wetlands that

[1] In an earlier study, SKM (2008a) identified 1137 wetlands in the GMID, 573 of which were identified as having high ecological values. The totals in BL&A (2010) differ slightly because this analysis has amalgamated different mapped wetland areas if they are clearly part of the one wetland basin. The earlier analysis did not distinguish mapped wetland areas that were part of the same wetland basin (BL&A 2010). Unless the figures from the SKM (2008a) report are being specifically quoted, this report will use the BL&A (2010) figures.

are inundated by rainfall and local runoff, or through interactions with local groundwater (i.e. saline lakes in the Kerang Region). Table 3-1 describes the characteristics of the various wetland types across the region. Freshwater meadows (37 per cent) are the most common wetland type, followed by shallow freshwater marsh (28 per cent), permanent open freshwater wetlands (20 per cent) and deep freshwater marsh (10 per cent). Semi-permanent saline (4 per cent) and permanent saline (1 per cent) wetlands are the least common.

An examination of the distribution of wetlands across the region (see Figure 3-1) indicates that shallow and deep freshwater marshes tend to be associated with the floodplains of major rivers and drainage lines. For example, the lower Goulburn, Barmah Forest and Gunbower Forest floodplain systems and also major drainage depressions between Stanhope and Rochester (known locally as the Wanalta Creek Wetlands) are all associated with major rivers and drainage lines. This association suggests a high degree of connectivity is likely between river channels and these wetlands, which include billabongs and flood runners that receive water via direct connection with river channels.

Freshwater meadows are often associated with floodplain forests (e.g. Barmah and Gunbower), but are also distributed more broadly across the region, especially in the eastern half of the GMID. Their broad distribution across the landscape suggests that some of these shallow freshwater meadows are also likely to receive water from direct rainfall and local catchment runoff.

A number of large, permanent open water lakes are present in the region. In fact, the number and area of permanent lakes has increased as a result of irrigation development (GBCMA 2006). These include lakes in the Corop region west of Stanhope (Greens Lake and Lake Cooper), Kow Swamp west of Gunbower and a number of lakes in the Kerang Lakes complex.

Permanent and semi-permanent saline lakes and wetlands are restricted to lower reaches of the Loddon and Avoca catchment in the north west part of the GMID. These wetlands are located in an area with high groundwater salinity (see Section 4.1.2.3). Their water source is saline groundwater, saline drainage water and/or drainage water concentrated by evaporation from the surrounding irrigation areas.

Table 3-1: Wetland types, their dominance, associated values and function and examples in GMID (Corrick and Norman 1980; Heron and Joyce 2008; SKM 2008; BL&A 2010) (* indicates preparation of an NVIRP EWP)

Wetland type (based on Corrick and Norman 1980)	Definition	Number and percentage of total	Associated values	Associated ecosystem functions	Examples in GMID
Freshwater meadows	Temporary wetlands often less than 30 cm deep and inundated for less than 4 months	380 (37%)	Waterbirds (e.g. Brolga, Latham's Snipe) Vegetation (e.g. Common Spike Rush) Frogs (e.g. Spotted Marsh Frog)	Wetting and drying cycles are important for releasing carbon and nutrients that promote subsequent growth by algae, bacteria, plants and animals. Opportunistically used by frogs and other biota when they are wet.	Bray's Swamp Black Box Swamp Merrigum Swamp Dunn's Swamp
Shallow freshwater marsh	Seasonal wetlands with a depth up to 50 cm, flooded for less than 1 year	285 (28%)	Vegetation (e.g. Typha, Red River Gums) Waterbirds, waterfowl Frogs (e.g. Spotted Marsh Frog)	Wetting and drying cycles are important for releasing carbon and nutrients that promote subsequent growth by algae, bacteria, plants and animals. Opportunistically used by frogs and other biota when they are wet.	Hunt's Swamp Thunder Swamp Little Wallenjoe Swamp Kanyapella Basin McDonald Swamp[2]*
Deep freshwater marsh	Semi-permanent wetlands up to 2 m deep	97 (10%)	Diverse vegetation (e.g. Moira Grass, River Red Gums, Giant Rush) Waterbird breeding Small native fish (e.g. gudgeons) Turtles (e.g. Eastern Snake Neck) Frogs (e.g. Banjo Frog)	Provide important breeding habitat for colonial nesting birds and waterfowl following floods. Because of longer inundation times, may also provide habitat for fish and plants and important refuge and watering points in dry years.	Johnson Swamp* Lake Yando* Lake Murphy* Little Lake Boort*
Permanent open freshwater	Deep freshwater wetlands (> 2 m) that hold water on a permanent basis	199 (20%)	Native fish Waterbirds, colonial nesting breeding sites, waterfowl Turtles	Permanent habitat for fish and refuge habitat and watering points during dry years. Provide important waterbird breeding habitats after floods.	Murphy's Swamp Lake Leaghur* Lake Meran* Richardson's Lagoon
Semi-permanent saline wetlands	Dry out each year and are less than 2 m deep	45 (4%)	Migratory wading birds	Wetting and drying cycles are important for releasing carbon and nutrients that promote	Lake Cooper

[2] Also referred to as McDonalds or McDonald's Swamp

				subsequent growth of algae, bacteria, plants and animals. Support large numbers of invertebrates when wet and provide important foraging habitat for wading birds as they dry out.	
Permanent saline wetlands	Permanent wetlands with salinities greater than 4,400 µS/cm	13 (1%)	Migratory wading birds Vegetation (e.g. Ruppia) Native fish (e.g. Murray Hardyhead)	Populations of brine shrimp and other salt-tolerant invertebrates are an important food source for fish and wading birds.	Round Lake* Lake Elizabeth* Tresco Lake

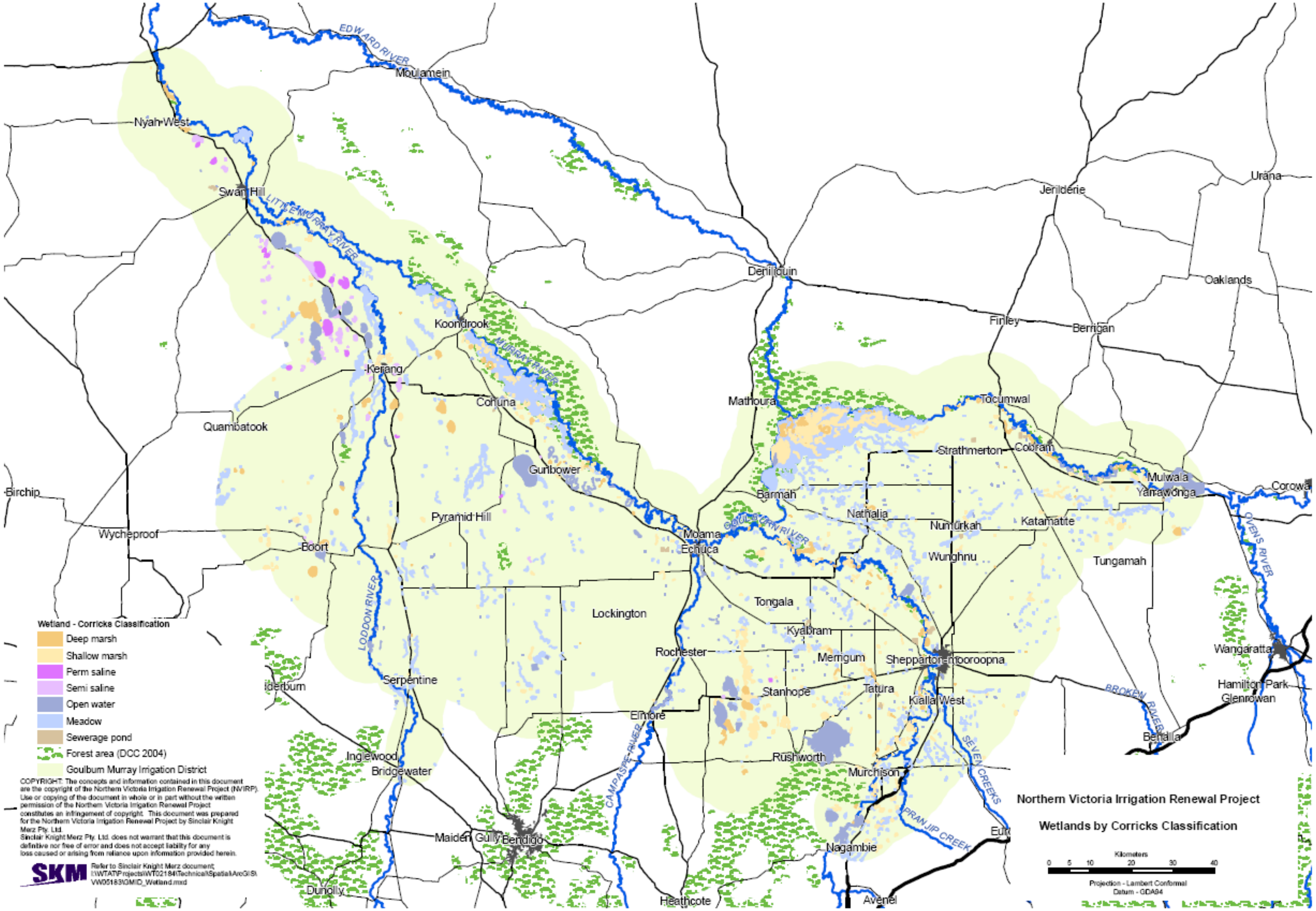

Figure 3-1: Distribution of major wetland types in the GMID based on the Corrick and Norman classification

The mosaic of wetland types and waterways in the landscape are significant environmental and aesthetic values in their own right. This mosaic of wetland types and waterways also supports a diverse range of plant and animal species and perform a range of ecosystem functions and processes. In the GMID, 75 EPBC Act listed species utilise wetland and waterway habitats, in an otherwise semi-arid and highly modified environment. Some species are quite specific to certain wetland types, whereas others are more general and can inhabit a range of wetland types (Heron and Joyce 2008). Wetlands perform ecosystem services that support the health of the environment as a whole. They help to maintain water quality in rivers by trapping sediments and using and storing nutrients before they reach the waterways (Lloyd *et al*. 1992). Wetlands are highly productive environments and support extensive and complex food webs through the carbon and nutrient inputs they receive. Wetlands can provide flood mitigation and if they are connected to the groundwater table can also recharge groundwater supplies. Across the GMID, wetlands, rivers and irrigation infrastructure also provide a water source in an otherwise semi arid landscape for terrestrial biota, including birds, mammals and reptiles. Groundwater adjacent to river channels (and more broadly across the landscape) provides a potential water source for vegetation depending on the depth to the watertable and season.

On a landscape scale, connectivity between wetted habitats and between aquatic and terrestrial habitats is an important value for the natural movement of species for foraging, breeding, migration and dispersal purposes. Habitat fragmentation poses a threat of habitat degradation and biodiversity loss, because it reduces the resilience of species populations, habitats and ecosystems. Changes in species diversity, abundance and composition due to fragmentation may have cascading impacts on the structure and functioning of habitats and ecosystems, and therefore the provision of ecosystem services (Kettunen *et al*. 2007).

This assessment considers at a regional scale the specific habitat types and groups of biota that are most likely to be affected by hydrological changes that are likely to occur as a result of NVIRP. The regional assessment does not focus on individual sites, but does consider the abundance and distribution of affected habitat types and biota.

4. Risk assessment

This section documents an assessment of the risks of implementation of NVIRP to aquatic ecosystems and functions and selected biotic indicators. To provide context, surface water and groundwater changes resulting from implementation of NVIRP are described and risks are then assessed.

4.1. Summary of surface water and groundwater changes

4.1.1. Surface water changes

Across the GMID, some wetlands and waterways benefit from their connection or proximity to the current irrigation system. This is because the water provided via the irrigation delivery network partly compensates for water lost as a result of river regulation and changes to local drainage patterns. The Public Environment Report (NVIRP 2010) noted that the works associated with NVIRP may affect wetlands and waterways in the landscape in four ways:

a) reduction in gross water diversions to irrigation areas due to reduced need to supply losses
b) reduction in outfall contributions to river flows and wetlands due to improved technology and system operations
c) potential reduction in harvesting of flows during storing/spilling mode periods[3]
d) reduction in bank leakage.

The predicted hydrological changes to waterways and wetland types are summarised in the following sections. Specific information is provided about some individual wetlands and river

---

[3] The operation of the GMID works in two different modes: 'supplying' and 'storing/spilling' modes. Any changes in water management, mitigation water and savings due to NVIRP depend on which mode is operating. These modes are described below:

'Supplying' mode

- Supplying mode conditions exist when demands in the system are greater than the volume of tributary inflow available for diversions. System operators are required to release water from storages such as Hume Reservoir and Eildon Reservoir to meet demand. Supplying mode conditions most commonly occur over the summer and autumn irrigation season, but may also occur at times during the May–August (non-irrigation) period to meet minimum passing flow requirements, for environmental watering or for flood pre-releases to protect assets.

'Storing or spilling' modes

The two main occasions when rivers are in storing or spilling mode are:

- When demands in the system from irrigation, for passing flows, for urban water supplies and for environmental watering are less than the volume of tributary inflows. These conditions are most likely to occur outside of the irrigation season (i.e. mid May–mid August) and during traditionally high inflow months of September to November.
- When storages are filled to maximum capacity. In this instance, any inflows originating upstream of storages pass through the storages and flow downstream as the water storages 'spill'. At these times, there are usually high tributary inflows also flowing into the rivers downstream of the storages.

reaches to describe patterns or emphasise the range of changes that may be expected throughout the GMID, but the focus remains on the habitat type rather than individual sites. Further information can be obtained from the Public Environment Report (NVIRP 2010). Site-specific information for wetlands and waterways where significant hydrological changes are expected can be found in the EWPs (see Table 5-1).

4.1.1.1. River channels used as delivery systems

Water savings due to NVIRP are expected to reduce the amount of water that needs to be delivered to irrigation areas, which could result in small reductions in water levels in rivers used as delivery systems, but is not expected to affect winter low flows or high flow events at any time of the year (SKM 2009a). The reduction in gross diversions is likely to occur at a relatively constant rate over the irrigation season.

The river reaches that may be affected by lower water levels due to reduced diversions are the Goulburn River upstream of Goulburn Weir and the River Murray upstream of Torrumbarry Weir. The River Murray between the confluence with Broken Creek and Torrumbarry Weir is also expected to be affected by a reduction in outfalls (Section 4.1.1.3). The magnitude of the reduction in an average year for these river reaches is given below (NVIRP 2010):

- Goulburn River upstream of Goulburn Weir – average reduction in level of 67 mm which represents a 5 per cent reduction in water level
- River Murray between Hume Weir and Yarrawonga Weir – average reduction in level of 14 mm which represents less than a 1per cent reduction in water level.

4.1.1.2. River channels downstream of diversions

River channels downstream of diversions (e.g. Goulburn River downstream of Goulburn Weir and Murray River downstream of Torrumbarry Weir) will not be affected by changes in surface water hydrology due to NVIRP. However, these rivers may be affected by the reduction in outfalls (see Section 4.1.1.3).

4.1.1.3. River channels that receive outfalls

For waterways that have historically received contributions from channel outfalls, the reduction in outfall volume may affect low flows in the waterway over summer and autumn (due to the reduction in operational outfalls) as well as fresh events over summer and autumn (due to the reduction in rainfall rejection outfalls). Larger flow events are not likely to be affected, nor are winter or spring flows. The extent of the impact for each waterway will vary depending on which outfalls have historically contributed to the flows and the NVIRP works proposed for those particular outfalls.

4.1.1.3.1. Major regulated waterways (Goulburn and Murray Rivers)

For the major regulated rivers (Goulburn and Murray Rivers) the reduction in outfalls during supplying mode periods will be compensated by releases from storage (to meet downstream irrigation demands and passing flow requirements), resulting in no net impact on river flows or levels (SKM 2009a in NVIRP 2010). The only exceptions are the outfalls received by the Goulburn River downstream of McCoys Bridge and the River Murray between the confluence of Broken Creek and Torrumbarry Weir (NVIRP 2010), which are expected to be affected by a reduction in gross diversions (see Section 4.1.1.1). The magnitude of the reduction in an average year for two of these river reaches is given below (NVIRP 2010).

Goulburn River downstream of McCoys Bridge:

- average reduction in level of 3 mm over the supplying mode period (note, this reduction in level is due to the combined impact of the reduction in outfalls and backtrade (reduction) of inter-valley transfers to supply Melbourne from savings of the River Murray)
- average reduction in level of 12 mm over the storing or spilling mode period which represents a 1 per cent reduction in water level.

River Murray downstream of Broken Creek confluence:

- the magnitude of the reduction is expected to increase with distance downstream as outfall reductions from an increasing area impact on the river
- downstream of Torrumbarry Weir where the impact is greatest, there is expected to be an average reduction in level of 9 mm, which represents less than a 1per cent reduction in water level.

4.1.1.3.2. Other waterways

For waterways that have historically received contributions from outfalls, the reduction in outfalls may affect low flows over summer and autumn (due to the reduction in operational outfalls) and fresh events over summer and autumn (due to the reduction in rainfall rejection outfalls). Larger events are not expected to be impacted, nor are winter or spring flows. The extent of the impact for each waterway will vary depending on the extent to which outfalls have historically contributed to the water regime in the waterway and the extent to which NVIRP is likely to reduce the magnitude of these specific outfalls. Reductions in outfall contributions may induce environmental stress in some waterways, but may be beneficial in other waterways by shifting the system towards a more natural flow regime.

The variability of impacts to natural waterways associated with reduced channel outfalls is illustrated by comparing effects in the lower Loddon and Campaspe Rivers. The historical outfall contribution (documented in the EWPs (NCCMA 2010a and 2010c)) ranged from 1per cent of total flow over the irrigation season for Reach 3 of the Campaspe River to 24per cent of total flow over the irrigation season for Reach 4 of the Loddon River. Reductions in channel outfalls are therefore expected to have a greater effect in Reach 4 of the Loddon River compared to Reach 3 of the Campaspe River.

4.1.1.4. Irrigation channels (irrigation channels that will <u>not</u> be decommissioned)

Irrigation channels can be considered to operate as a series of weir pools, in that they are generally maintained at constant levels throughout the irrigation season. NVIRP will lead to a reduction in flow through some irrigation channels and may also affect the levels at which irrigation channels are held. Levels may be reduced by up to 150 mm, but more commonly by around 100 mm (M. Poole NVIRP, 2011, *pers. comm.*).

4.1.1.5. Weir pools (i.e. Goulburn Weir pool)

Irrigation system weir pools servicing the GMID (such as Goulburn Weir, Yarrawonga Weir and Torrumbarry Weir) are generally maintained at a constant level (at or near full supply level) throughout the irrigation season. Such operating policies are not expected to change as a result of NVIRP. As such, weir pools are not expected to be impacted by NVIRP.

4.1.1.6. Saline and freshwater wetlands (that <u>do not</u> receive outfalls)

Wetlands (saline and freshwater) that do not receive outfalls will not be affected by changes in surface water hydrology due to NVIRP.

4.1.1.7. Wetlands (that <u>do</u> receive outfalls)

NVIRP may reduce the volume of water held within (or the permanency of) wetlands that have historically received contributions from outfalls. The extent of the impact for each wetland will vary depending on which outfalls have historically discharged to the wetland, the extent to which NVIRP will affect these particular outfalls and the relative contribution these outfalls made to the total water regime of the wetland.

4.1.1.8. Bank leakage

Reductions in bank leakage will lead to 132.6 gigalitres (GL) of savings (long-term cap equivalent (LTCE)) which represents 31 per cent of the total savings volume and is the largest category of water savings.

4.1.2. Groundwater changes

An overview of the hydrogeology of the GMID and potential groundwater changes due to the operation of NVIRP is provided in NVIRP (2010) and is also summarised in NVIRP's Condition 4 Report (NVIRP 2011).

Changes to the depth to groundwater have been assessed primarily through a simulation modelling approach (SKM 2009b). The outputs of the model/models were supported by independent lines of evidence drawn from reports and studies relevant to the GMID prepared over many years. Many of these reports are consistent with the Basin Salinity Management Strategy and discuss the potential effects on surface-water-fed wetlands of falling groundwater levels.

The potential impact of the implementation of NVIRP on salt loads reaching major rivers and the consequent impact on river salinity levels was assessed (see 4.1.2.4).

4.1.2.1. Predicted regional watertable changes

One of the aims of NVIRP is to reduce channel seepage and bank leakage. Upgrades to irrigation infrastructure are expected to reduce recharge to the groundwater system, and as a result regional watertables in the shallow groundwater system (Shepparton Formation) will fall (SKM 2009b). Predicted watertable drops as a result of the operation of NVIRP are from less than 1 to greater than 5 metres (m) depending on location. Predicted watertable depth changes due to NVIRP across the region are also presented graphically in Figure 4-1.

4.1.2.2. Relative effect on groundwater levels

Compared to the effect of drought and climate change on the watertable depth, the changes due to NVIRP are relatively modest. Other factors, such as groundwater pumping that increases depth to watertable, and irrigation intensity that increase or decreases the depth to watertable, can also cause significant changes irrespective of NVIRP.

4.1.2.3. Effects of watertable reductions on regional ecological assets

Areas in the vicinity of high watertables (e.g. within two metres of the ground surface) can be affected by waterlogging, and over time, salinisation of the root zone (SKM 2009). Lower elevations in the landscape tend to be more vulnerable to high watertables. A large proportion of macrophytes and macroinvertebrates are sensitive to quite low levels of salinisation with adverse effects being reported at salinity levels as low as 800 mg/L (1300 µS/cm) (Cant et al. 2003). Adult fish appear to be quite tolerant of salinity levels greater than 8,800 mg/L (14,500 µS/cm). Many of the riparian plants associated with wetlands and lowland rivers are salt sensitive: at 13,500–27,000 mg/L (22,500–45,000 µS/cm) sensitive plants are likely to experience sub-lethal effects, with mortality occurring at 27,000–54,500 mg/L (45,000–90,000 µS/cm). Over 54,500 mg/L (90,000 µS/cm) severe effects are seen and at 110,000 mg/L (180,000 µS/cm) there is likely loss of even the most tolerant plants (Cant et al. 2003). The salinity of sea water is approximately 35,000 mg/L or 58,000 µS/cm.

The particular ecological features that will benefit from lower watertables will be:

- vegetation across the plains, particularly deep-rooted long-established trees
- vegetation surrounding wetlands.

West of the Terrick Terrick Hills, groundwater salinity in the Upper Shepparton Formation is generally saline – up to 50,000 µS/cm. A reduction in the watertable level will reduce the proximity of this saline groundwater to wetlands and areas used for agriculture. The impact will be beneficial, with less intrusion of saline groundwater into the wetlands and less salinisation damage to the vegetation around the wetlands.

Groundwater levels east of the Terrick Terrick Hills are projected to drop between less than 1 m to over 5 m. While the groundwater salinity in the Upper Shepparton Formation east of the Terrick Terrick Hills is much lower than the levels in the west, the salinity levels are still high enough to pose a threat to agricultural production and environmental values. Consequently, a general reduction in the watertable is likely to be beneficial as it will mean less intrusion of saline groundwater into the wetlands and less salinisation damage to the vegetation around the wetlands. The exception would be areas very close to channels that may support wetlands with MNES.

4.1.2.3.1. Near-channel effects

Channel water that seeps into groundwater may create a localised area of relatively fresh groundwater on top of a more saline underlying groundwater. Thus wetlands close to irrigation channels may experience slightly fresher groundwater than wetlands that are further away.

Channel seepage is likely to increase the level of the watertable above natural levels over large areas. These effects are likely to be detrimental to ecological values in areas with shallow saline groundwater because saline water is brought close to the surface where it can damage plants and intersect low lying wetlands. In areas with relatively fresh groundwater, waterlogging may cause damage to ecological values.

Channel seepage will be reduced by NVIRP channel lining and channel rationalisation activities.

4.1.2.3.2. Groundwater effects on rivers and floodplain wetlands

Operation of NVIRP is expected to lead to reduced groundwater levels and hence reductions in groundwater discharge to rivers (SKM 2009b). Across the region this impact is very small in terms of flow in the major rivers, but may be significant for smaller systems like the Broken Creek and Campaspe River during low flow periods.

Modelling results indicate that NVIRP will not alter the watertable levels beneath the Barmah Forest. Given this, it is highly unlikely that there would be any transmission of NVIRP effects further north into the Millewa Forest on the NSW side of the River Murray. Modelling results also suggest that NVIRP will have no effect on watertable levels beneath the Gunbower Forest and even less chance of transmission of NVIRP effects further to the north into the Koondrook-Perricoota Forest.

Even with the changes due to NVIRP there would still be overall gradients of groundwater flow towards the River Murray and associated floodplain forests from nearby irrigation areas. This is because the watertable elevations in the irrigation areas are much higher than the forests. Therefore it is not plausible that fresh groundwater could be drawn out from under the floodplain forest by the actions of NVIRP.

4.1.2.4. River salinity

NVIRP is expected to reduce the total salt load flowing towards rivers and floodplain forests by 6,105 tonnes per year (SKM 2009b). The overall effect of NVIRP on salt loads is relatively small and represents only a 5 per cent reduction in total annual groundwater salt contributions to these environments.

Other assessments indicated that NVIRP will decrease river salinities by up to 5 µS/cm, particularly in the River Murray downstream of Swan Hill during the supplying mode (SKM 2009b). Salinity in the Goulburn River at McCoys Bridge was also predicted to fall by up to 5 µS/cm during the supplying mode, but either remain unchanged or increase by up to 2 µS/cm during the storing/spilling mode (groundwater inflows were assumed to be negligible) (SKM 2009b). Overall these changes are very small in comparison with background salinity regimes (~200 µS/cm) and are not likely to have any effect on biota or other environmental values.

4.1. Climate change

Climate change is expected to have a significant impact on river flows across northern Victoria. Dry flow conditions used in the modelling of the impacts of NVIRP are analogous to conditions expected under a climate change future. Under both average and dry flow conditions modelling indicates that NVIRP is predicted to result in only a small change to river levels (NVIRP 2010). Hence the additional impact of NVIRP over and above that predicted due to climate change is considered insignificant.

As noted above, in Section 4.1.2.2, compared to the effect of drought and climate change on the watertable depth, the changes due to NVIRP are relatively modest. Other factors, such as groundwater pumping that increases depth to watertable, and irrigation intensity that decreases the depth to watertable, can also cause significant changes irrespective of NVIRP.

Changes to river salinity levels are discussed in Section 4.1.2.4.

.

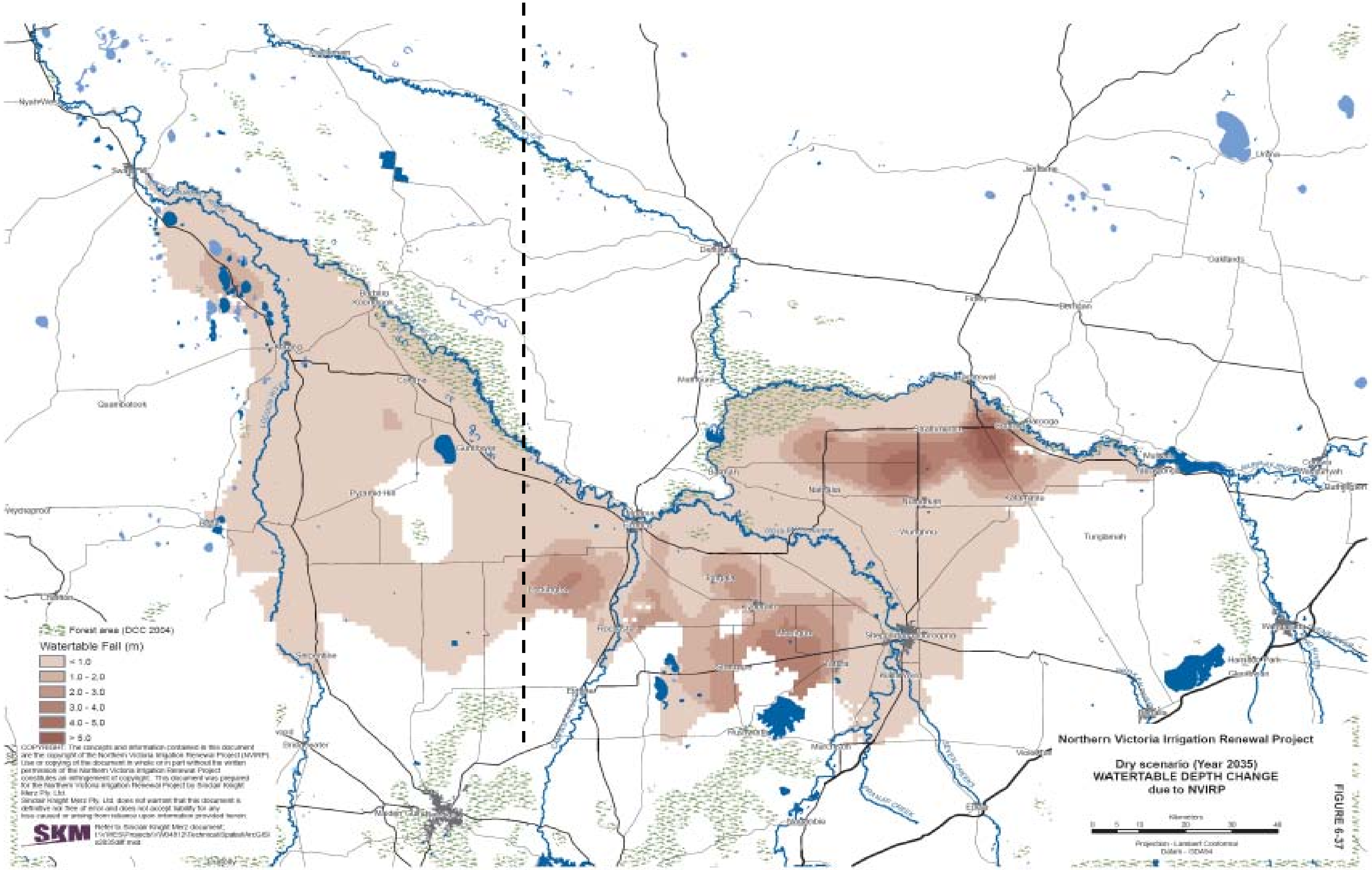

Figure 4-1: Watertable depth change due to NVIRP (dry scenario until Year 2035) (NVIRP 2010). The broken line indicates the east-west delineation at Terrick Terrick Hills

4.2. Groundwater and salinity effects

The effect of NVIRP on watertable reductions and changes in salinity was assessed for the PER (NVIRP 2010). These effects have been summarised in Table 4-1: Summary of NVIRP groundwater and salinity changes and associated ecological effects

Table 4-1: Summary of NVIRP groundwater and salinity changes and associated ecological effects

NVIRP effect	Associated ecological effect
Regional watertable reductions	Increased depth to watertable due to implementation of NVIRP can be beneficial for local and regional ecology by reducing the potential for waterlogging and salinisation. The particular ecological features that will benefit from lower watertables will be: ▪ vegetation across the plains, particularly deep-rooted long-established trees ▪ vegetation surrounding wetlands. Changes due to NVIRP are relatively modest compared to changes caused by other factors such as groundwater pumping, drought and climate change.
Near-channel	Channel seepage is likely to increase the level of the watertable above natural levels over large areas. These effects are likely to be detrimental to ecological values in areas with shallow saline groundwater because saline water is brought close to the surface, where it can damage plants and intersect low lying wetlands or cause waterlogging. Reductions in near-channel groundwater levels by NVIRP channel lining and channel rationalisation may therefore be beneficial.
Groundwater effects on rivers and floodplain wetlands	NVIRP implementation is expected to lead to reduced groundwater levels and hence reductions in groundwater discharge to rivers (SKM 2009b). Across the region this impact is very small in terms of flow in the major rivers, but may be significant for smaller systems like the Broken Creek and Campaspe River during low flow periods. NVIRP is not expected to alter the watertable levels beneath the Barmah Forest. NVIRP is not expected to have an effect on watertable levels beneath the Gunbower Forest. It is not plausible that fresh groundwater could be drawn out from under the floodplain forest by the actions of NVIRP.
River salinity	Changes due to NVIRP are very small in comparison with background salinity regimes (~200 µS/cm) and are not likely to have any effect on biota or other environmental values. NVIRP is expected to reduce the total salt load flowing towards rivers and floodplain forests by 6,105 tonnes (t) per year (SKM 2009b). However, the overall effect of NVIRP on salt loads is relatively small and represents only a 5 per cent reduction in total annual groundwater salt contributions to these environments.

4.3. Overview of groundwater-dependent and aquatic habitats

The GMID landscape consists of a diverse range of habitat types with different levels of water dependency. These include terrestrial, groundwater-dependent, permanent aquatic and ephemeral aquatic habitats. This section considers how the current irrigation system provides water to these habitat types and how NVIRP may change the watering regime of these habitats at a conceptual, landscape scale.

The groundwater-dependent, permanent and seasonally inundated aquatic habitats have been divided into specific categories for the assessment:

1. rivers
    a. used as irrigation systems
    b. downstream of diversions
    c. that receive outfalls
2. irrigation and drainage network
    a. irrigation and drainage channels
    b. weir pools
3. wetlands that do not receive outfalls
    a. river connected wetlands
    b. depressions
    c. groundwater-fed wetlands
        i. Saline wetlands
        ii. Freshwater wetlands
4. wetlands that do receive outfalls
5. bank and service point leakage
6. near-surface groundwater.

A conceptual model of these habitat types in the landscape is provided in Figure 4-2.

Terrestrial habitats that are not directly watered or affected by the irrigation system have not been included in this assessment. Some flora and fauna associated with terrestrial habitats may be indirectly affected by NVIRP because they rely on aquatic habitats as part of their lifecycle, move through them or visit them to drink or feed. These effects are discussed in the context of groundwater-dependent, permanent and ephemeral aquatic systems.

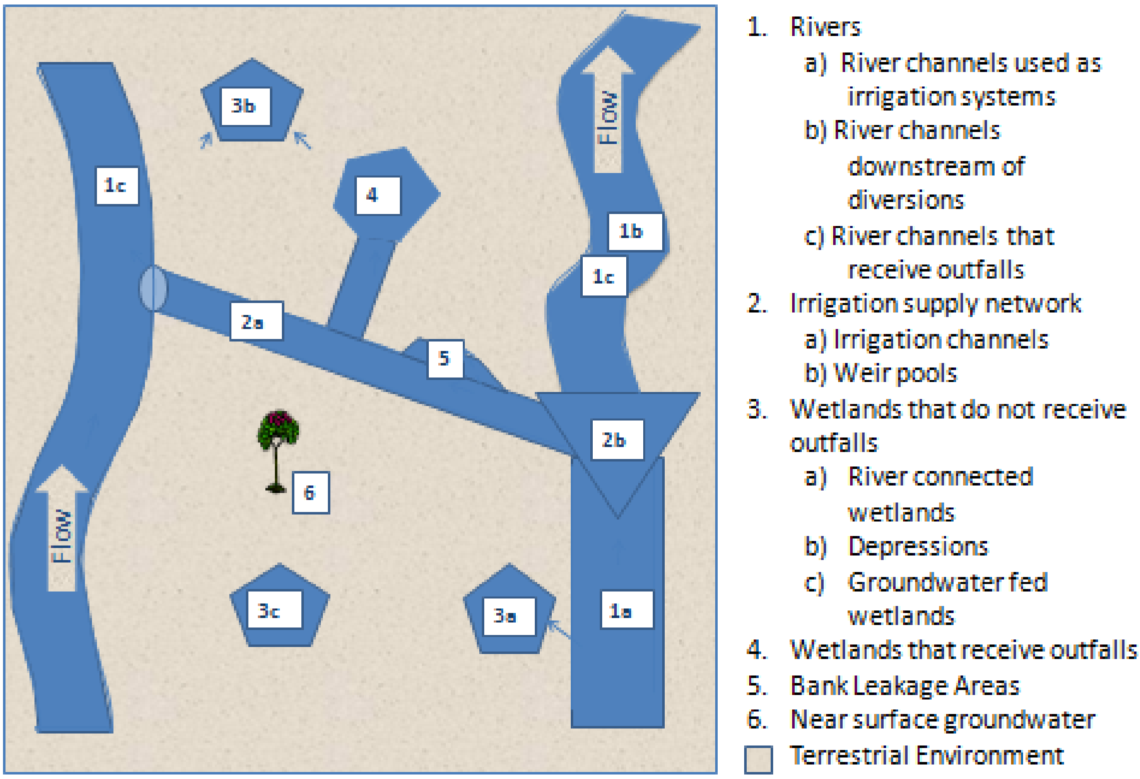

Figure 4-2: Schematic representation of the six types of water-dependent habitats that may be affected by NVIRP

The Public Environment Report (ref. Section 6.4.4.) considered the effect of NVIRP on habitat types under the categories of saline wetlands, freshwater wetlands and waterways, floodplain forests and terrestrial vegetation. The point of difference with this study is that the watering mechanisms provided by the current irrigation system to these habitat types have been specifically considered. The hydrological changes predicted to occur in these habitat types as a result of NVIRP were considered in the context of the watering requirements of the biota residing in these habitats and the ecosystem functions associated with such habitats. This study specifically considered wetlands and waterways present in the landscape that receive water either directly (i.e. outfalls or diversions) or indirectly (i.e. groundwater) from the current irrigation system.

The connection types considered in the desktop assessment (SKM 2008a) are listed in Table 4-2 (the WCMF (Sec 17.2.2) requires consideration of these connection types).

Table 4-3 correlates these connection types with the categories of groundwater-dependent, permanent and seasonally inundated aquatic habitats that have been described for this regional assessment as well as the wetland types described in Table 3-1.

The fourth column of Table 4-3 describes relevant biota and ecological processes. This description can be utilised to make the link to relevant conceptual models (Figure 4-15, Figure 4-16, Figure 4-17 and Figure 4-18). All the connection types described in the desktop assessment are covered by the categories used here. It is therefore expected that the assessments undertaken for this regional assessment will adequately cover the needs of the groundwater assessment.

Table 4-2: Description of connection type (from SKM 2008a)

Connection type (SKM 2008a)	Description
Channel outfall	Wetlands that receive direct outflows from an irrigation channel. The water regime in these wetlands may have been substantially altered by the operation of the existing irrigation system. They receive extra water during the irrigation season. River regulation and construction of levees/ drains may have substantially reduced winter and spring inflows to these wetlands.
Drain	Wetlands that receive water from irrigation drains. These wetlands currently receive more water during the irrigation season, but the drains also carry local catchment runoff and therefore possibly receive higher inflows during natural rain events throughout the year.
On-line	Wetlands that are used to store, treat or transfer water for the irrigation system.
Groundwater/seepage	These wetlands are fed by groundwater, and in some cases where channels are perched nearby in sandy soils there may be some direct channel seepage.
Local catchment	These wetlands are not directly connected to channels or drains, but do receive water from local catchment runoff, which comes from natural rainfall events and the application of irrigation water.
Floodplain	These wetlands primarily receive water when rivers flood. The operation of the irrigation system has altered the flood frequency in many rivers, and levee banks have altered the frequency and duration of inundation events.

Table 4-3: Correlation of aquatic habitat categorisation used in this assessment with connection type used in SKM (2008a), Corrick and Norman wetland type and relevant biota and ecological processes.

Aquatic habitat categorisation used in this assessment	Correlation with connection type used in SKM 2008a	Correlation with wetland type based on Corrick and Norman	Relevant biota and ecological processes
1. Rivers			
a. used as irrigation systems	N/A because not a wetland (on-line is most appropriate)	N/A	Permanent habitat for fish and aquatic vegetation.
b. downstream of diversions	N/A because not a wetland (but may receive outfall water so channel outfall and drain may be relevant)	N/A	Permanent habitat for fish and aquatic vegetation.
c. that receive outfalls	N/A because not a wetland (but channel outfall may be relevant)	N/A	Habitat for fish and aquatic vegetation.
2. Irrigation and drainage network			
a. Irrigation and drainage channels	On line	N/A	Some habitat for fish and aquatic vegetation.
b. Weir pools	On line	Permanent Open Freshwater	Permanent habitat for fish and aquatic vegetation.
3. Wetlands that do not receive outfalls			
a. River connected wetlands	Floodplain	Shallow Freshwater Marshes, Deep Freshwater Marshes, Permanent Open Freshwater	Permanent wetlands provide habitat for fish. Temporary wetlands may provide habitat for fish breeding. Habitat for all vegetation types. Important bird breeding habitat when flooded. Wetting and drying cycles are important for carbon and nutrient cycling.

Aquatic habitat categorisation used in this assessment	Correlation with connection type used in SKM 2008a	Correlation with wetland type based on Corrick and Norman	Relevant biota and ecological processes
b. Depressions	Local catchment	Freshwater Meadows and Shallow Freshwater Marshes	Habitat for amphibious and terrestrial vegetation and bird foraging habitat.
c. Groundwater-fed wetlands			
i. Saline wetlands	Groundwater or seepage	Semi-permanent saline wetlands, Permanent saline wetlands (shallow and deep)	Habitat for some salt tolerant vegetation types and foraging habitat for waterbirds. Permanent wetlands provide habitat for salt tolerant fish species.
ii. Freshwater wetlands	Groundwater or seepage	Shallow and Deep freshwater Marshes	Habitat for all vegetation types and foraging habitat for birds.
4. Wetlands that do receive outfalls	Channel outfall Drain (may also be floodplain and local catchment)	Shallow Freshwater Marsh, Deep Freshwater Marsh, Permanent Open Freshwater, Semi-permanent Saline Wetlands, Permanent Saline Wetlands	Permanent wetlands provide habitat for fish. Temporary wetlands that are connected to river channels may provide habitat for fish breeding. Habitat for all vegetation types. May provide important bird breeding habitat when flooded. Wetting and drying cycles are important for carbon and nutrient cycling.
5. Bank and service point leakage	Groundwater/seepage	Freshwater Meadows, Shallow Freshwater Marshes	Habitat for amphibious vegetation and foraging habitat for birds.
6. Near-surface groundwater	Groundwater/ seepage	N/A because no water at surface	Provide water for terrestrial vegetation.

Similarly, the assessment of wetland/lunette groups, waterways and groundwater-dependent ecosystems, as required by the WCMF (Sec 17.2.2) is adequately addressed by the aquatic habitat categorisation used in this report.

4.4. Risk assessment of groundwater-dependent and aquatic habitats, associated values and ecosystem functions.

This section provides a regional assessment of the impacts of NVIRP on groundwater-dependant and aquatic habitats, their associated values and ecosystem functions. Although a regional assessment is required, data are most commonly available at a site scale, so some aspects of the assessment are made at a site scale but then interpreted at the landscape scale. This regional interpretation occurs in Section 5.

The following sections contain a detailed description of the hydrological and ecological changes expected for each water-dependent habitat type with NVIRP. The sections conclude with a summary of the habitat types and an assessment of the regional significance of any risks posed to these habitats.

4.4.1. Rivers

River channels support many ecological values in the landscape, such as fish, macroinvertebrates and aquatic plants, which are adapted to various flow components (e.g. low flows, high flows, freshening flows and bankfull flows) and rely on the habitat and connectivity provided by rivers for all or part of their life cycles. Different flow components also support or facilitate important ecosystem processes. For example, summer low flows affect the quality and quantity of permanent aquatic habitats and refuges. Freshes and high flows trigger and facilitate fish movement and influence riparian vegetation zones. Bankfull and overbank flows connect the river to floodplain wetlands and transport carbon sources and nutrients between the floodplain and river banks and the river channel.

Rivers may be directly affected by NVIRP through:

- a reduction in irrigation supply flows because less gross water diversions are required for irrigation areas due to reduced need to supply losses
- a reduction in direct channel and drain outfalls to rivers due to improved technology and system operations
- a drop in groundwater levels which may reduce base flows in the river – with the benefit of reduced salinity.

The specific effect of NVIRP on individual rivers or river reaches will depend on the extent to which they are connected to, or are influenced by, the existing irrigation system. Three types of river systems are considered in the following sections:

a. river channels used as delivery systems
b. river channels downstream of major diversions
c. river channels that receive outfalls.

4.4.1.1. River channels used as delivery systems (1a)

River channels that are used to deliver irrigation water throughout the GMID usually have a regulated water regime. Summer and autumn flows in these channels are often much higher (but less variable) than natural due to the delivery of irrigation water from upstream storages to downstream irrigation areas. Conversely, winter and spring flows are generally lower and less variable than natural because tributary inflows higher in the catchment are captured and stored in upstream dams and reservoirs. Despite the regulated flow, these rivers support a range of values and ecosystem functions. Values include the presence of threatened species and communities (e.g. native fish). Ecosystem functions include longitudinal and lateral connectivity and processing and transport of nutrients and energy. However, most regulated rivers in the GMID also contain weirs and dams that pose barriers to the downstream transport of nutrients and organic material (Bunn and Arthington 2002) and also to the movement of fish (Koehn et al. 2004) and possibly plant propagules (e.g. Merritt and Wohl 2006).

NVIRP will generate water savings through improved efficiency in water delivery, meaning that less water will be supplied to major irrigation offtake points within the GMID during the supplying mode (SKM 2009a). This is expected to reduce the magnitude of summer and autumn flows in river channels used as delivery systems (SKM 2009a), but it is not expected to affect the timing of specific flow components during that period. The reduction in water level is expected to be very minor – on average less than 50 mm in systems greater than 1.4 m deep (a change of < 4 per cent), as outlined in NVIRP (2010). NVIRP is not expected to affect low flows during the storing and spilling mode (i.e. during winter and spring) or affect high flows and bankfull flows at any time of the year. Furthermore, NVIRP will not result in the construction of additional barriers to streamflow and hence will not result in any further impact on transport of nutrients, energy or biota.

In river reaches such as the Goulburn River between Eildon Dam and Goulburn Weir, current supply flows may be large enough to raise water levels to such an extent that they engage flood runners or secondary channels, which in turn connect the channel to floodplain wetlands (Figure 4-3). Depending on the commence to fill level of wetlands along the river, a reduction in water level during the irrigation supply season could reduce the frequency and duration of river connection and therefore alter the wetting and drying regime of these wetlands (this is dealt with in more detail in Section 4.4.3.1.1).

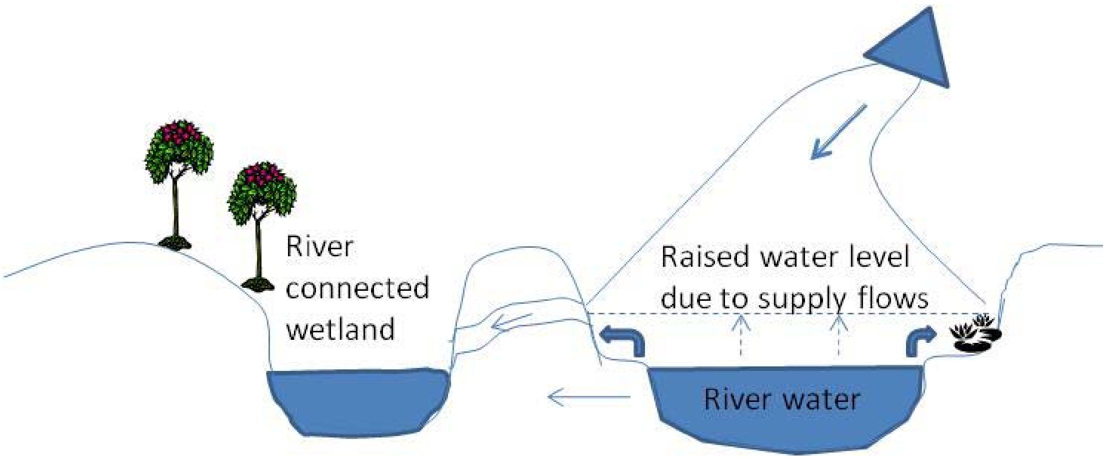

Figure 4-3: Conceptual model showing water sources and pathways for delivery systems

Conclusion

It is *Likely* that river channels used as delivery systems will experience a small drop in water level (< 4 per cent) during the irrigation supply season as a result of NVIRP because less water will be supplied to key irrigation offtake points. In many cases, flows in rivers used as delivery systems are higher than natural during the irrigation season, although some current values may have adapted to or be sustained by higher than natural flows. The reduction in flow in these river channels is expected to be very low and in most cases is probably much less than the natural variation that would occur. The flow changes are definitely not expected to be large enough to alter connections to any floodplain wetlands, nor alter any instream aquatic habitats. As a result NVIRP is expected to have *Negligible* or only *Minor* consequences on ecological values and ecosystem functions in the river channel.

Therefore, NVIRP represents a *Low* to *Insignificant* risk to ecological values and ecosystem functions in river channels used as delivery systems.

4.4.1.2. River channels downstream of diversions (1b)

Rivers downstream of major diversions (e.g. Goulburn River downstream of Goulburn Weir and the River Murray downstream of Torrumbarry) experience a reduction in flow magnitudes all year round due to upstream storage and diversion as part of the current irrigation system. Low water levels and low variability in the flow regime can reduce habitat for fish and cause sedimentation of the river channel (Metzeling *et al*. 1995). Irrigation diversions may result in the loss of fish (particularly drifting eggs, larvae and juveniles) from river systems (King and O'Connor 2007). Export of nutrients and energy from river systems is also possible, which could 'starve' downstream reaches.

NVIRP will not affect the hydrology of river channels downstream of diversions due to changes in the volume of water being diverted – because although the volume of water that needs to be diverted from the river to irrigators will be lower, the difference will be managed by changing the amount of water released from upstream storages. Flow in the river channel downstream of diversion points should therefore not be affected. These river sections may be affected by the reduction in outfalls, but this is discussed separately in Section 4.4.1.3.

Conclusion

NVIRP will *Rarely* affect the flow components of river channels downstream of diversions because the current operation of these river sections will not change. As there are no anticipated changes, there will be a *Negligible* effect on the environment.

NVIRP is not expected to alter the flow regime in river channels downstream of diversion points and therefore represents an *Insignificant* risk to ecological values and functions in such waterways.

4.4.1.3. River channels that receive outfalls (1c)

Channel outfalls and drains contribute water to rivers during the irrigation season (Figure 4-4) due to rainfall rejections by irrigators or for operational reasons. Channel outfall flows help to maintain water in some ephemeral river systems and can increase the frequency and magnitude of freshening flows (Table 4-4).

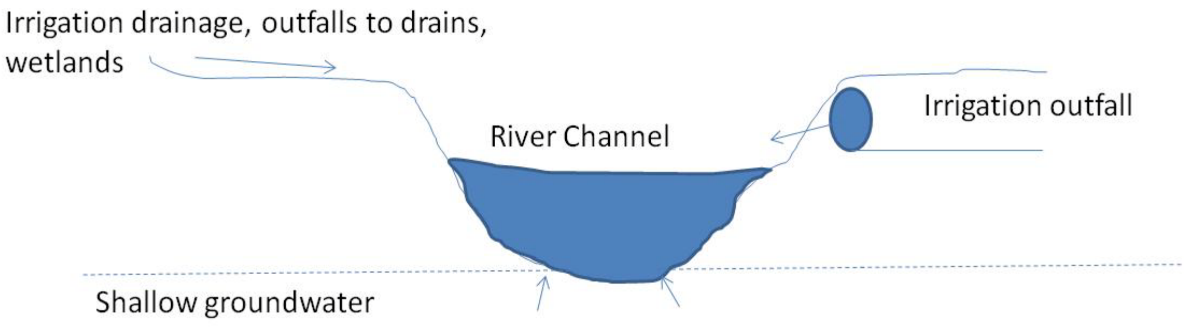

Figure 4-4: Conceptual model showing water sources and pathways for rivers

For the major regulated rivers in the GMID (i.e. Goulburn and Murray Rivers), the reduction in outfalls during supplying mode periods will be compensated for by releases from storage to meet downstream irrigation demands and passing environmental flow requirements (SKM 2009a). If existing outfall contributions exceed those requirements then they will not be compensated. The exception to that situation is where outfalls flow into rivers downstream of compliance points (e.g. Goulburn River downstream of McCoys Bridge).

Outfall contributions to unregulated rivers are unlikely to be automatically compensated because there is no downstream consumptive demand or requirement for minimum passing flows (SKM 2009a). If NVIRP leads to a reduction in these outfalls then it could reduce water levels in the receiving rivers; the extent of the change will depend on the relative contribution that outfalls made to river flows prior to NVIRP.

For small to medium sized waterways (e.g. the lower Loddon River) a reduction in outfalls from NVIRP may affect the magnitude of low flows over summer and autumn due to the reduction in operational outfalls. It may also reduce the magnitude and frequency of freshes over summer and autumn due to the reduction in rainfall rejection outfalls (Table 4-4). Cease-to-flow events may become more frequent or last longer due to the outfall reduction in small unregulated streams in dry years. Larger events are not expected to be impacted, nor are winter or spring flows (SKM 2009a).

The extent of the impact for each waterway will vary depending on the outfall volumes that have historically contributed to the river and the works proposed in the contributing systems. For example, the historical outfall contribution for reaches of the lower Loddon River and Campaspe River ranged from 1 per cent of total flow over the irrigation season for Reach 3 of the Campaspe River to 24 per cent of total flow over the irrigation season for Reach 4 of the Loddon River (documented in the EWPs (NCCMA 2010a; NCCMA 2010c)).

The consequences to ecosystem function of a reduction in the magnitude of low flows and /or an increase in the duration of low flows or cease-to-flows is summarised in Table 4-4. No river systems in Northern Victoria are so dependent on irrigation outfalls that NVIRP would cause the river to change from perennial to ephemeral. However, a reduction in outfalls along with a reduction in groundwater level could increase the frequency or duration of cease-to-flow events in small streams. In extreme cases, such a change may reduce the quality, quantity and permanency of refuge pools and may mean that some biota will be lost during dry periods. Fish are likely to be most susceptible to these changes because the quality or quantity of their habitat will be reduced and opportunities to move between suitable habitats may be more limited. More extensive drying of the bed may also allow terrestrial vegetation to colonise the lower parts of the channel and could increase the risk of acid sulfate soils (ASS). Upon rewetting, these dried sediments are likely to release nutrients. A reduction in the magnitude and frequency of summer freshes may allow terrestrial vegetation to become established near the bottom of the channel and may also allow more organic material to accumulate on the banks and stream bed, which may increase the risk of blackwater events upon rewetting.

Table 4-4: Likely changes to flow components in rivers that receive outfalls from NVIRP and possible consequences for ecosystem values and functions

Flow component	Ecosystem functions performed by flow component	Impact of NVIRP on components of flow regime				Consequence for ecosystem function
		Magnitude	Frequency	Duration	Timing	
Low flow summer	▪ disturb lower channel features by exposing and drying banks and benches ▪ allow accumulation and drying of organic matter in the dry areas of the channel such as benches ▪ maintain permanent pools with an adequate depth of water to provide habitat for aquatic biota.	May decrease due to: -reduced supply flows upstream of offtake points -reduced outfall contributions to low flows -Reduced groundwater contributions to baseflow.	No effect	Decrease in ephemeral systems that may dry more frequently with reduced outfall contributions to low flows.	No effect	▪ reduction in available habitat for aquatic biota ▪ increased disturbance/drying of bed and banks ▪ increased accumulation of organic material/reduction in summer processing and entrainment ▪ increased risk of poor water quality due to stratification.
Low flow winter	▪ sustained longitudinal connectivity for fish movement ▪ sustained inundation of riffles and lower benches to maintain habitat for emergent and marginal aquatic vegetation ▪ cause die back of terrestrial vegetation that has encroached down the bank during the summer low flow period ▪ increase habitat area for instream flora and fauna including access to large woody debris and overhanging banks.	No effect	No effect	No effect	No effect	▪ no effect on ecosystem function.
Summer freshes	▪ provide flow variability to maintain species diversity of emergent and marginal aquatic vegetation and to drive zonation patterns across the channel ▪ maintain emergent and marginal aquatic vegetation by wetting lower channel banks and benches ▪ improve water quality by flushing and turning over any stratified pools ▪ temporary increase in longitudinal connectivity between pools to allow fish movement.	Decrease primarily due to a reduction in rainfall rejections.	Decrease because contributions from rainfall rejections are expected to be reduced.	Decrease because less rainfall rejections could reduce the rate rise and fall of freshening flows.	No effect	▪ increased accumulation of organic material/reduction in summer processing and entrainment ▪ reduction in summer watering of littoral vegetation ▪ increased risk of poor water quality due to reduced flushing.

High flow	▪ entrain terrestrial organic matter that has accumulated on benches ▪ provide sediment transport (sediment entrainment and deposition with no, or limited, net change in channel form) ▪ provide flow variability to maintain species diversity of emergent and marginal aquatic vegetation and to drive zonation patterns on the banks.	No effect	No effect	No effect	No effect	▪ no effect on ecosystem function.
Bankfull / overbank flows	▪ disturbance and resetting of aquatic and riparian vegetation communities ▪ transport sediment that has accumulated in pools ▪ transport of organic matter that has accumulated in the upper channel ▪ removal of aquatic and riparian vegetation through scouring ▪ engage floodrunners and wetlands connected around bankfull.	No effect	No effect	No effect	No effect	▪ no effect on ecosystem function.
Cease to flow	▪ disturb lower channel features by exposing and drying sediment and bed material ▪ promote successional change in community composition through disturbance ▪ maintain a diversity of ecological processes through wetting and drying.	N/A	Small increase as reduced outfalls may cause the channel to dry out more frequently.	An increase as reduced outfalls may shorten duration of water persistence in channel.	No effect	▪ reduction in available habitat for aquatic biota ▪ increased disturbance/drying of bed and banks ▪ increased accumulation of organic material/reduction in summer processing and entrainment ▪ increased risk of poor water quality due to stratification.

<u>Conclusion</u>

It is *Likely* that reductions in outfalls to river channels from NVIRP will affect the flow regime during the irrigation supply season by:

- lowering the magnitude of summer low flows
- decreasing the frequency and duration of summer freshes and/or
- increasing the frequency and duration of cease-to-flow components.

These changes to the flow regime will be most evident in unregulated rivers that will not receive compensation water.

The magnitude of flow changes in rivers due to reduced channel outfalls will vary considerably depending on the size of the river channel and the relative contribution that channel outfalls have historically made to the flow regime. In most cases, channel outfalls contribute very little to the flow regime of rivers. However, in some small river channels, the contributions can be up to 24 per cent or higher. Reducing channel outfall contributions to those particular river channels could alter the quality and quantity of instream habitat and cause short-term disruption to breeding cycles and ecological processes. Impacts may be particularly evident during prolonged droughts when outfalls may otherwise help to maintain the quality and quantity of refuge habitats for aquatic biota. Significant flow regime changes due to reduced channel outfalls are not expected to occur in more than 20 per cent of rivers and streams throughout the GMID, and therefore the consequence to values and ecological processes is considered to be *Moderate*.

Overall, there is a *Medium* risk to ecological values and ecosystem functions in river channels that receive outfalls.

4.4.2. Irrigation supply network

The irrigation supply network consists of irrigation channels and weir pools that may provide habitat for emergent and submerged vegetation and aquatic biota (Figure 4-5). Irrigation channels are assumed to be artificial, low-value habitats; however, weir pools can have high ecosystem and environmental values and are likely to provide important refuge habitats when other parts of the river are dry (SKM 2009a). NVIRP is not expected to substantially change the water regime in irrigation channels and weir pools (SKM 2009a), but lining the channels with plastic will significantly reduce plant growth. These issues are discussed separately for irrigation channels and weir pools in the following sections.

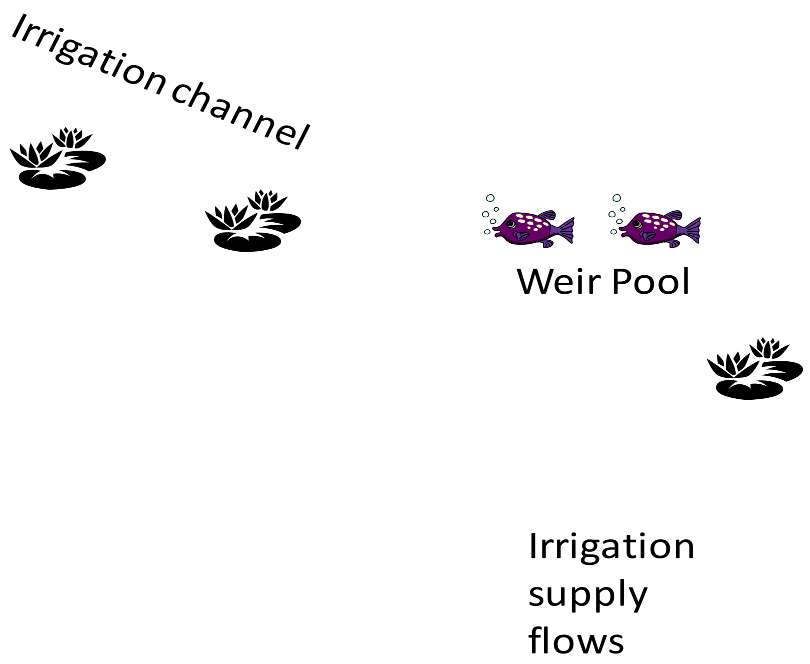

Figure 4-5: Conceptual model showing different habitat features that support vegetation and fish in irrigation channels and weir pools

4.4.2.1. Irrigation and drainage channels (2a)

Irrigation and drainage channels in the GMID are generally understood to be artificial, low value habitats that are not considered as a high ecological asset in themselves. Channels represent a disturbed environment which would not generally support diverse indigenous plant assemblages and are most likely to support generalist species. The channels may be considered as low diversity habitats populated by common and generalist species and are generally poor habitat for species that are sensitive to disturbances of dredging, the use of herbicides and physical removal of plant matter (NVIRP 2010).

Channels can function as a connection between water systems, particularly for native fish but only in a downstream direction due to the presence of regulating structures. Irrigation channels may provide watering points for terrestrial fauna, but most mobile species would be able to access other water sources in the landscape if the irrigation channels were not present. Channel lining may further reduce the effectiveness of channels as fish habitat, but may still offer fish passage depending on the channel length and connectivity to natural waterways.

Irrigation channels are maintained at a constant level throughout the irrigation season. These channels are full during summer and autumn, but are allowed to drain and dry out in winter and early spring. This water regime contrasts with the water regime to which many aquatic plants of the region are adapted and is one reason why only a few species (e.g. *Typha*) prosper in these environments (NVIRP 2010). Channel maintenance activities such as spraying and physical removal are often implemented to control the spread of *Typha* and *Phragmites* (NVIRP 2010). Channel decommissioning, lining and other NVIRP related measures to reduce losses within the channels will mean that less water will need to be delivered through the irrigation channels over the course of the irrigation season to meet existing irrigation demand. However, with the exception of channel decommissioning works in some areas, water levels and general hydrological conditions in individual channels and drains are not expected to change as a result of NVIRP (NVIRP 2010).

Conclusion

With the exception of channel decommissioning works in some areas, water levels and the hydrological regime of channels and drains will *Rarely* change as a result of NVIRP. Any changes would have *Minor* consequences resulting from minor, short-term stress at a limited number of locations because these habitats are of low ecological value and do not support significant ecological functions.

Therefore, NVIRP represents an *Insignificant* risk to ecological values and ecosystem functions in irrigation channels and drains.

4.4.2.2. Weir pools (2b)

Weir pools serve to raise water levels to enable diversion of irrigation water to storages and irrigation channels. Most weir pools throughout the GMID are maintained at a constant level (generally full supply level) throughout the irrigation season. In many cases, weir pools can provide good fish habitat and support aquatic and fringing vegetation that might otherwise have a limited distribution in a relatively dry environment. They also provide watering points for many terrestrial animals. Weir pools have higher environmental values than irrigation channels because they are situated on natural rivers and provide refuge habitat during particularly dry periods. For example, weir pools on the Loddon River and Campaspe River have been recognised as possibly the only habitats that have supported native fish populations through the recent drought (Cottingham *et al*. 2009). Weir pools in other rivers are likely to serve similar functions and are likely to be important sources of colonisers when flows return. Weir pools also contain a range of deep and shallow habitats, with submerged and emergent vegetation that may provide important breeding habitat for native fish. The relatively stable water levels in weir pools mean that they are not likely to be important sites for nutrient and carbon cycling.

Maintenance of stable weir pool levels is not expected to be impacted by NVIRP (NVIRP 2010). As such, NVIRP is not expected to change the water regime in weir pools and therefore values within them are not likely to be affected.

<u>Conclusion</u>

The water levels and the operation of irrigation system weir pools will *Rarely* change as a result of NVIRP. As there are no anticipated changes, there will be a *Negligible* effect on the ecological values and ecosystem functions associated with these habitats.

NVIRP represents an *Insignificant* risk to ecological values and ecosystem functions in irrigation system weir pools.

4.4.3. Wetlands

Floodplain wetlands provide habitat for a range of vegetation communities and can support abundant birdlife, macroinvertebrates, frogs and fish (if there is permanent water). Ephemeral wetlands in particular serve an important function in carbon and nutrient cycling during the drying and rewetting phases. The release of nutrients when wetlands are rewetted drives booms in the growth of bacteria, algae, plankton and invertebrates, which in turn provide food for fish, birds and other species higher up the food chain. The boom in invertebrates is a particularly significant factor in the successful breeding of colonial nesting waterbirds, frogs and fish after flood events (Boulton and Brock 1999; Overton 2009). As water levels recede and wetlands begin to dry, aquatic plants germinate or develop and wading birds and other predators feed on macroinvertebrates at the shallow margins. Having a mosaic of wetlands in the landscape at different depths and stages of drying ensures a good supply of food for wading birds, many of which have high conservation significance. Wetlands also provide important watering points for terrestrial fauna, and the distribution of inundated wetlands can influence the extent to which terrestrial and mobile aquatic fauna are able to move throughout the landscape at any given point in time.

Wetlands may be watered by a combination of high or overbank river flows, groundwater, local surface runoff, outfall from irrigation channels and local drainage. The following sections describe how NVIRP is likely to affect the water regime of wetlands that are watered via these different pathways.

4.4.3.1. Wetlands that <u>do not</u> receive outfalls

4.4.3.1.1. River-connected wetlands (3a)

River-connected wetlands (typically deep and shallow freshwater marshes) rely on anabranches, flood runners or drainage lines to carry river water to them during periods of high flow in the river.

Few, if any, such wetlands receive water directly from irrigation channel outfalls or drains and rely on high, bankfull and/or overbank flows in the river to fill (Figure 4-6). They may also have groundwater connections that either maintain a base water level or provide water for plant root-systems (Figure 4-6). Any threat to these wetlands from NVIRP would come through the following two pathways:

1. NVIRP affecting the height and duration of high flow components in the river
2. NVIRP lowering groundwater levels (if there is a connection) – see Section 4.4.3.1.3.

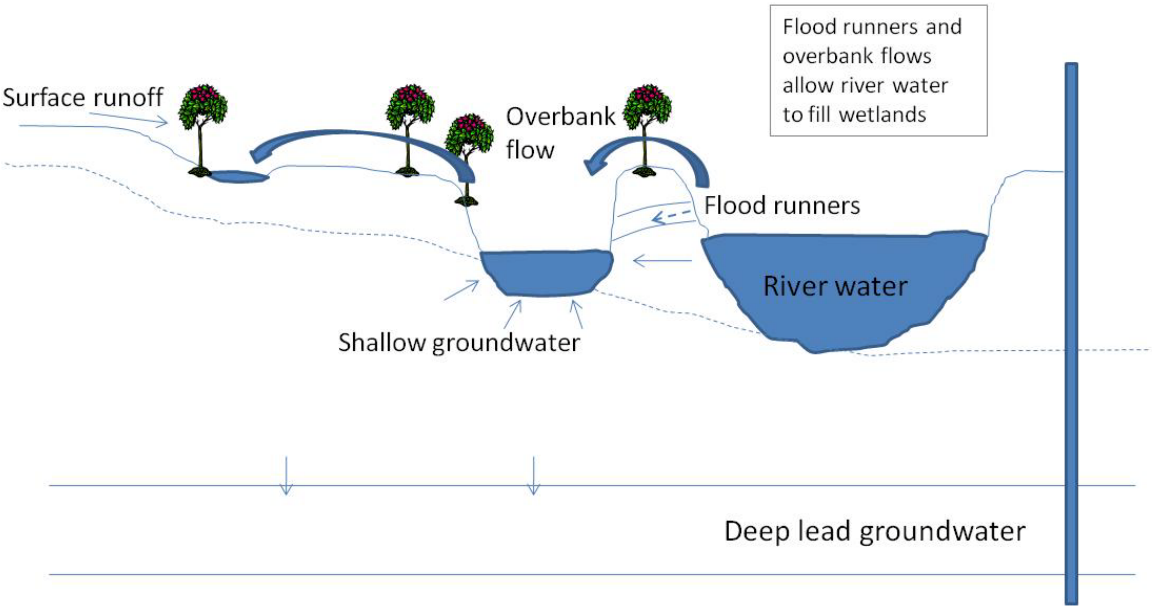

Figure 4-6: Conceptual model for river-connected wetlands. Arrows indicate water pathways that influence the water regime in the wetland

NVIRP will not affect the high, bankfull and overbank flow components in rivers that are required to fill river-connected wetlands in the majority of river systems in the GMID (NVIRP 2010). The only possible exception is for rivers that operate as part of the delivery system, such as the Goulburn and Murray Rivers (see also Section 4.4.1.1). Irrigation supply flows in those river channels may in some cases be high enough to transfer water into wetlands via anabranches or flood runners. NVIRP is expected to reduce the magnitude of supply flows in river channels, but these reductions are expected to have only a small effect on water levels in the river channel (i.e. average drop generally less than 50 mm) and therefore are not expected to affect river contributions to these wetlands (SKM 2009a). In fact, the potential for a reduction in the water level during the supply period may benefit some river-connected wetlands if it results in a reduction in the duration of wetland inundation and provides a more natural drying cycle during the summer period.

Wetting and drying is an important process that drives wetland function such as hydrogeochemical dynamics, nutrient processing and energy dynamics. These in turn influence food webs and overall wetland productivity (Boulton and Brock 1999).

River-connected wetlands in the GMID can also be supported by groundwater and surface water runoff. The exact balance between surface water and groundwater sources is an area of uncertainty for most wetlands in the region (NVIRP 2010). The effects of NVIRP on surface water runoff and groundwater are discussed in Sections 4.4.3.1.2 and 4.4.3.1.3.

<u>Conclusion</u>

NVIRP will not affect the high, bankfull and overbank flow components in rivers that fill river-connected wetlands. The only possible exception is river-connected wetlands that are filled by rivers operated as delivery systems. However, the expected water level changes due to NVIRP in rivers that are used to deliver irrigation water is small and therefore hydrological changes in wetlands that are connected to those river channels are *Unlikely* to occur. In the event that some hydrological changes do occur, the magnitude is expected to be small (i.e. only a slight change in the duration or extent of inundation), which may at worst lead to some short-term stress at a limited number of locations. Therefore the ecological consequences of any hydrological changes should be *Minor*. Based on that assessment, NVIRP represents a *Low* risk to ecological values and ecosystem functions in river-connected wetlands.

4.4.3.1.2. Depressions in the landscape (3b)

Depressions in the landscape (e.g. shallow freshwater meadows) are wetlands that receive water from local surface water runoff following rainfall (Figure 4-7). These wetlands are not directly connected to river channels via flood runners and have no groundwater connection (some wetlands may have groundwater connection, but these are considered separately in Section 4.4.3.1.3). Some of these wetlands may have high conservation significance in their own right. For example the Plains Grassy Wetland Ecological Vegetation Class (EVC 125) occurs in shallow depressions throughout the Goulburn Broken Catchment and is listed as endangered (GBCMA 2006).

These wetlands can be supported by low-salinity soil water overlying saline groundwater, such as fresh water stored in the soil from previous rainfall, or localised flooding. For example, Holland et al. (2006) identified deep soil water, rather than saline groundwater, as the water source for a healthy vegetation community of Black Box (*Eucalyptus largiflorens)* in the lower River Murray region. Infiltration of rainfall and floodwaters through cracking clays and sandy soils are likely to be important for trees growing in small depressions and at the break of slopes (Holland et al. 2006). Bank recharge is also important for trees growing within ~200 m of permanent and ephemeral water bodies, such as rivers and irrigation channels (Holland et al. 2006). The root zone of trees and other species present in these depressions may also access groundwater (this is considered separately in Section 4.4.3.1.3).

The types of depressions considered here do not receive any water from irrigation channel outfalls and are not connected to drainage infrastructure, and therefore NVIRP is not expected to have a direct effect on their water regime. However, bank leakage from irrigation channels and irrigation drainage may indirectly recharge these wetlands. NVIRP will reduce bank leakage and seepage (see Section 4.4.4) and could possibly reduce the sub-surface lateral movement of freshwater to wetlands that are within ~200 m of irrigation channels. Wetlands that receive most of their water from bank leakage or channel seepage are described in Section 4.4.4.

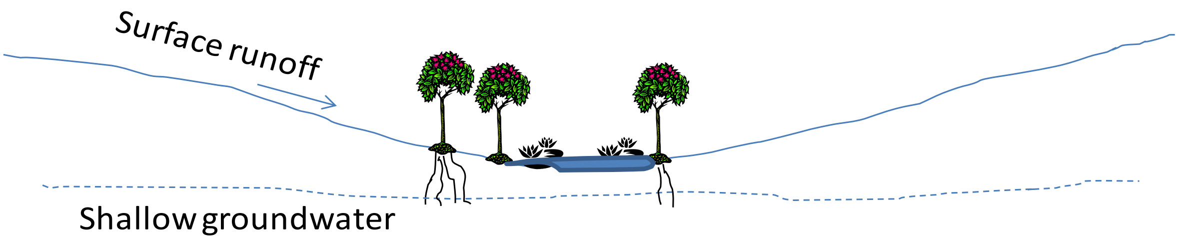

Figure 4-7: Conceptual model for landscape depressions showing that these areas only receive water from local surface run-off

<u>Conclusion</u>

It is *Possible* that NVIRP may change the watering regime of depressions in the landscape through a reduction in bank seepage from irrigation channels. The consequences of such changes are expected to be *Minor*, because only a small proportion of the depressions in the GMID will be affected (i.e. only those within 200 m of irrigation channels) and because the contribution of water from bank leakage and seepage is rarely the only or main water source for such wetlands. Based on that assessment NVIRP represents a *Low* risk to the ecological values and ecosystem functions that are supported by shallow depressions throughout the GMID.

4.4.3.1.3. Groundwater-fed wetlands (3c)

Groundwater-fed wetlands by definition must intersect the underlying groundwater table (Figure 4-8). Groundwater may support both freshwater and saline wetlands in the GMID, depending on the level of connection and the salinity of the underlying aquifer.

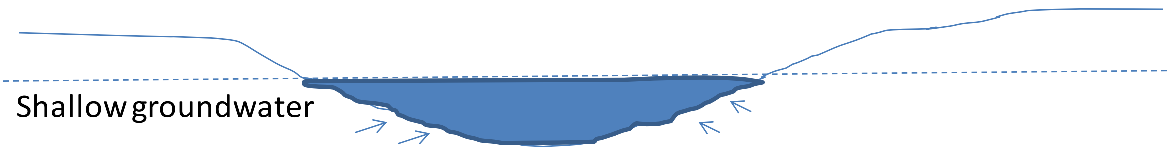

Figure 4-8: Conceptual model for groundwater-fed wetlands showing intersection with shallow groundwater tables

Freshwater wetlands

Freshwater wetlands have been defined for the Public Environment Report as has having salinities below 10,000 µS/cm (BL&A 2010). However, salinities around 5,000 µS/cm differentiates fresh from saline wetlands in the 1994 DSE wetlands layer (DSE 1994). Freshwater wetlands can be categorised as freshwater meadows, shallow freshwater marshes, deep freshwater marshes or permanent open freshwater wetlands depending on the water depth and the wetting and drying regimes. Freshwater wetlands in the GMID can be fed by surface water runoff (see Section 4.4.3.1.2) and/or groundwater. The exact balance between these two water sources is an area of uncertainty for most wetlands in the region (BL&A 2010).

Throughout most of the GMID, the depth to groundwater exceeds three metres, so wetlands up to two metres deep are unlikely to be influenced by groundwater (BL&A 2010). Following that logic, deep freshwater marshes and permanent open freshwater wetlands are the only wetland types that are likely to be influenced by groundwater, and only in areas where groundwater depth is less than three metres.

None of the wetlands in the Shepparton, Murray Valley and Rochester Irrigation Districts are considered to be influenced by groundwater (BL&A 2010). The only freshwater wetlands of known groundwater influence in the GMID are two wetlands in the Central Goulburn Irrigation District (Lake Cooper and Mansfield Swamp), three wetlands in the Pyramid-Boort Irrigation District (Lake Lyngder, Lake Boort and Lake Yando) and several lakes in the Kerang Lakes[4] complex in the Torrumbarry Irrigation district (BL&A 2010).

Groundwater influence in freshwater wetlands is considered to pose a salinity threat across the GMID. A number of freshwater wetlands have experienced rising salinities due to historically rising groundwater levels in parts of the GMID, particularly in the Kerang Lakes region (BL&A 2010).

[4] Note the Kerang Lakes are not specifically included in this regional assessment project.

NVIRP is expected to lower groundwater levels throughout the GMID (see Section 4.1.2.1), but the change is modest compared with the effects of drought (see Section 4.1.2.1) and other influences such as changes in agricultural practices and deep-lead pumping. Although the change is predicted to be small, lower watertables in areas where the groundwater intrusions are highly saline may be of some benefit to freshwater wetlands by reducing salinity. Declines in salinity through reduced groundwater contributions will benefit birds and frog species that use these freshwater wetlands (for instance, the Growling Grass Frog is unable to breed successfully in saline habitat (SKM 2008)).

<u>Conclusion</u>

Reductions in groundwater level due to NVIRP are *Likely* to affect the water regime in a small number of freshwater wetlands that currently intersect the underlying watertable. However, the magnitude of any hydrological change will be small and well within the range of variation that normally occurs between seasons and years. At worst, these small changes will have only a M*inor* impact on ecological values and ecosystem functions that rely on freshwater wetlands throughout the GMID. In fact, it is possible that reductions in groundwater level could provide some benefit to ecological values in freshwater wetlands by reducing salinity. Overall, any reductions in groundwater level due to NVIRP represent a *Low* risk to the ecological values and ecosystem functions that are supported by freshwater wetlands throughout the GMID.

Saline Wetlands

Saline wetlands range in salinity from 10,000 to 100,000 µS/cm. They are characterised by extensive areas of open mudflats when water levels decline over summer. Permanent saline wetlands can still be productive and maintain ecological values, such as the threatened Murray Hardyhead (Ellis 2005). Along with semi-permanent saline wetlands, they can provide foraging habitat for wading birds (Kingsford et al. 2010) and habitat for salt-tolerant plants such as Samphire (Saintilan 2009).

Saline wetlands in the GMID are concentrated around the Kerang region in the Torrumbarry Irrigation Area. Semi-permanent saline wetlands in this area are likely to be surface-water-dependent, whilst permanent saline wetlands are likely to be groundwater dependent (BL&A 2010).

The number of saline wetlands in the GMID has increased since European settlement due to rising groundwater tables and irrigation drainage disposal practices (DSE 2004; BL&A 2010). There are currently 13 permanent saline wetlands and 45 semi-permanent saline wetlands present across the GMID, however not all of these are influenced by groundwater (BL&A 2010). Shallow, semi-permanent saline wetlands are unlikely to be in contact with local groundwater, and their salinity is more likely to be influenced by high levels of surface water evaporation (BL&A 2010). Some wetlands in the Kerang Lakes (e.g. Lake Tutchewop) have been converted to saline wetlands through their use as irrigation drainage evaporation pans.

In the western districts of the GMID, groundwater levels are predicted to drop by 0.2 to 1.3 m due to NVIRP, which is within the seasonal variability of groundwater levels (Sec 4.1.2.1). The expected changes in groundwater levels due to NVIRP are not likely to be large enough to affect the permanency of deep groundwater-fed wetlands. However, some shallow wetlands may experience a drop in water level or a change in state if the NVIRP-induced reductions in groundwater levels are compounded by simultaneous declines in groundwater due to drought or climate change (see Table 4-8).

A drop in water level or the drying out of wetlands may pose a threat of development of acid sulfate soils (ASS). Sulfate-rich groundwater discharge is one of the key risk factors for ASS and high salinity areas are good indicators of high sulfide concentrations (Thomas et al. 2009).

Field observations and chemical analysis have confirmed the presence of both sulfuric materials (pH < 4) and sulfidic materials (high sulfide concentrations and pH < 4) in the GMID region – for example in the lower Loddon River (Thomas et al. 2009). Low pH conditions may occur when sulfur-rich sediments are exposed to the air (through drying), and then subsequently rewet (Baldwin and Fraser 2009). The hypothesis is that the action of rewetting sulfur-rich sediments releases a pulse of sulfuric acid. It is uncertain where and if a drop in watertable level will expose ASS in wetlands.

The distribution, size, locality and trend of ASS symptoms in wetlands and waterways in the Murray Darling Basin are being addressed through research coordinated by the Murray-Darling Basin Authority (MDBA). Phase 1 of the project has identified sites across northern Victoria where ASS symptoms are observed. Some sites are within or adjacent to GMID. Preliminary information provided by MDBA shows that all sites relevant to NVIRP are small and appear to be associated with highly saline and acidic groundwater discharge (J Cooke DSE 2010, *Pers. Comm*.).

MDBA has advised DSE that the identification of priority sites for Phase 2 assessments (more detailed laboratory analysis of samples collected in Phase 1) is underway but was not completed prior to this report. It follows that the incidence of ASS sites within or adjacent to GMID and the impact of NVIRP on these sites cannot be assessed further at this time.

Conclusion

Changes in groundwater levels due to NVIRP are *Likely* to affect water levels in some deep permanent saline wetlands throughout the GMID. However, the magnitude of any change is likely to be within the range that occurs as part of normal seasonal variation and is not expected to have more than a *Minor*, short-term effect on ecological values and ecosystem functions in a small number of wetlands. Groundwater reductions due to NVIRP may compound groundwater level reductions due to severe drought or climate change, but the relative effect of NVIRP in such circumstances will be small and will not of its own cause a shift in state in any wetland. Based on that assessment, groundwater reductions due to NVIRP represent a *Low* risk to saline wetlands throughout the GMID.

NVIRP is unlikely to increase the risk associated with ASS formation throughout the GMID because the predicted reductions in groundwater will not be large enough to completely dry out any wetlands where ASS could occur.

4.4.3.2. Wetlands that do receive outfalls (4)

NVIRP aims to reduce the volume discharged from irrigation channel outfalls by approximately 85 per cent throughout the GMID. Channel outfalls episodically contribute water to wetlands due to rainfall rejections by irrigators (cancelled irrigation orders) or for operational reasons during the irrigation season. Contributions from irrigation channel outfalls, whilst small in volume, may maintain shallow areas of permanent or near-permanent water in some wetlands (Figure 4-9). Irrigation outfalls are delivered sporadically over the summer period, which is not the ideal time for water delivery, but the outfalls may be important for maintaining some submerged plants and other aquatic biota in these wetlands.

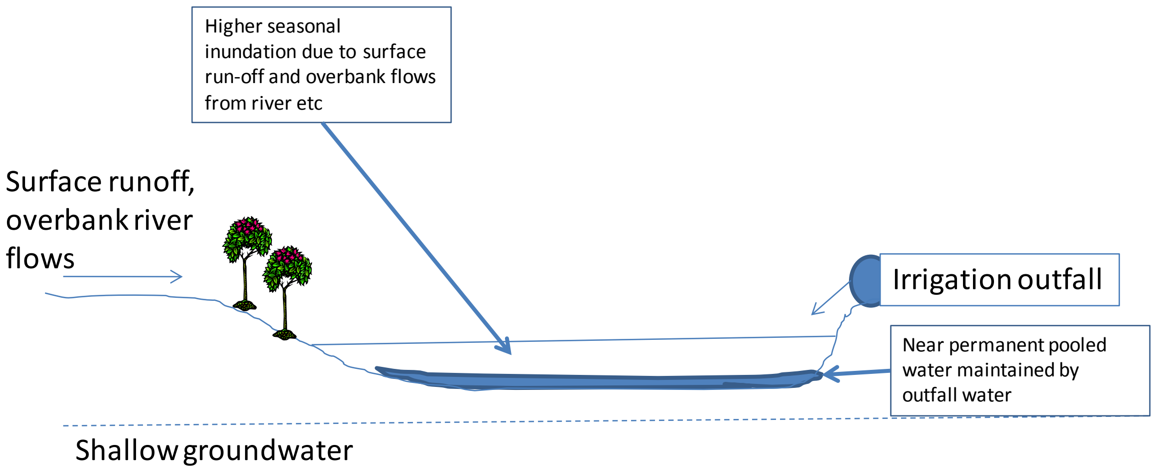

Figure 4-9: Conceptual model for wetlands that receive irrigation outfalls

The likely effect of NVIRP on each wetland will depend on the extent to which outfalls contribute to the wetland watering regime. There are no wetlands in the GMID that receive all of their water from irrigation outfalls. For example, Johnson Swamp received a total of 92.5 ML during the

2004/05 baseline year from outfalls over the irrigation season from September to May. This represents only 5 per cent of the 1,783 ML required to fill the wetland to the target level (1 m deep). The EWP determined that a reduction in the volume of outfall water that entered Johnson Swamp would not have any significant effect on existing environmental values and concluded that mitigation water would not be required (NCCMA 2009).

For Lake Elizabeth, however, outfalls have a much greater influence on the watering regime. A mean long-term annual volume of 556 ML is required to fill Lake Elizabeth to 73.5 m AHD one in three years. During 2004/05, which was considered the baseline year for the NVIRP hydrological assessments, channel outfalls contributed 401 ML between September and May. The ecological values in Lake Elizabeth have become reliant on outfalls and the EWP determined that mitigation water of 267 ML/year should be delivered to the wetland (which is 67 per cent of the original outfall volume) to contribute to achievement of the stated management objectives for this wetland (NCCMA 2010b).

In general, the effect of reduced outfalls may be to lower the water level in deep freshwater marshes and permanent freshwater and saline lakes, but is not expected to be significant enough to cause any permanent wetlands to dry out. In shallow, ephemeral wetlands (such as freshwater meadows and marshes), a reduction in channel outfalls may alter the frequency, timing and duration of wetting and drying phases (Table 4-5). There may also be changes to the timing and rates of rise and fall in these wetlands (Table 4-5).

Table 4-5: An example of the changes in the watering regime during the dry and wet phases due to NVIRP

	Depth	Frequency	Timing	Rise/fall rates	Duration
Dry phase	No change	Increased frequency of dry phases due to less water.	The dry phase may occur earlier depending on outfall.	More rapid onset of dry phase.	Increased duration
Wet phase	Reduced water level as outfalls normally compensate for evaporation and top up water during rain rejections.	Reduced frequency of wetting due to less rainfall rejections.	Wet phase is likely to start later and end earlier because outfall contributions would normally provide water during the warmer months when contributions from other sources of water are lower.	Increased rate of water level decline and decreased rate of rise (rainfall rejections currently funnel large volumes more quickly to the wetland).	Reduced duration

The consequence to ecosystem function of a change in water regime is variable. In some cases reduced outfalls will restore a more natural wetting and drying regime, but in other cases the ecological values and ecosystem functions that currently rely on outfalls may be compromised because they have established as a consequence of the current, artificial regime. At a landscape scale, the return to a more natural wetting and drying regime is likely to be beneficial, but at a site-specific scale could result in the loss of some site-specific values and functions.

Conclusion

Reductions in channel outfalls are *Almost certain* to affect the water regime in wetlands where these contributions currently represent a significant proportion of the total water volume that is delivered in a year or a particular season. The total number of wetlands throughout the GMID that are likely to be affected by reduced channel outfalls is relatively small (the short-listing process has to date only identified 10 out of 573 wetlands with known ecological values that are likely to be significantly affected by reduced outfalls – see NVIRP 2009a) and therefore consequences to ecological values and ecosystem functions throughout the region are expected to be *Moderate*. Based on that assessment, NVIRP represents a *High* risk to ecological values and ecosystem functions that rely on wetlands that receive channel outfalls throughout the GMID. Because only a small proportion of wetlands are likely to be affected, the regional risk will probably be best mitigated by addressing threats at individual sites.

4.4.4. Local bank and service point leakage (5)

Shallow artificial wetlands have formed around some irrigation channels and service points. These wetlands receive local bank seepage and leakage from irrigation channels and service points and/or local surface runoff (Figure 4-10). Seepage is the slow, steady movement of the channel water through the pores of the soil forming the bed and banks of the channel. Seepage enters the watertable directly beneath the channel. Leakage is the escape of water through cracks and defects in the banks of the channel, and also by overtopping of low areas in the tops of the banks. The leakage water tends to pool in low areas beside the channels, with the result that these areas are often wet during the irrigation season (August to May). The wetlands may dry out over winter, or may be maintained by surface water runoff. Although these wetlands have been artificially maintained, some are likely to support frogs, birds and snakes and provide refuge habitat for water-dependent biota when other parts of the landscape dry out. Terrestrial animals are likely to drink from these wetlands, but given the presence of other water sources throughout the landscape (including the nearby irrigation channels), such use is likely to be opportunistic and these habitats are not likely to be main congregating areas. There is some uncertainty around the value of these types of wetlands, their extent and connectivity in the landscape, especially given their close proximity to the more reliable water source provided by irrigation channels. At best, these areas may serve as shallow refugia in extreme dry conditions, but they are not considered high-value ecological assets.

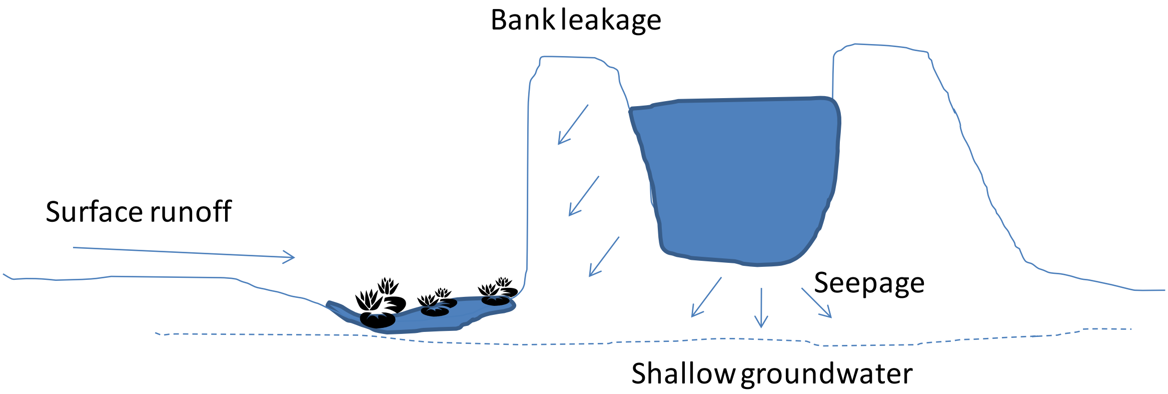

Figure 4-10: Conceptual model for wetlands maintained by local bank leakage

NVIRP will reduce channel seepage and leakage by lining the channels and upgrading infrastructure at service points. Rationalisation of parts of the channel system whereby channel decommissioning occurs is also possible. Reductions in bank leakage will lead to 132.6 GL of savings (long-term cap equivalent (LTCE)) which represents 31 per cent of the total savings volume. This is the largest category of water savings (Table 4-6) and as such these developments are likely to reduce the amount of water that the wetlands receive during the irrigation season. It is therefore likely that many of these artificially inundated habitats near channels will dry out over summer.

Table 4-6: Breakdown of bank leakage savings by location – LTCE

Irrigation Region	Indicative LTCE bank leakage saving (GL)
Shepparton	0.0
Central Goulburn 1 – 4	4.5
Central Goulburn 5 – 9	36.1
Rochester	11.1
Pyramid-Boort	5.0
Murray Valley	32.9
Torrumbarry	43.0
Total	132.6

Conclusion

Efforts to reduce bank leakage and channel seepage will *Almost certainly* cause many of the small depressions and wetlands immediately adjacent to irrigation channels to partially or completely dry out during the irrigation season. Detailed biological surveys have not been conducted in these artificially watered habitats; however, while these habitats are likely to be used opportunistically by some mobile fauna, they are not thought to support high ecological values or ecosystem functions that could not readily use other nearby aquatic habitats. As a result the consequence to ecological values and ecosystem functions throughout the GMID region is considered *Minor*. Based on that assessment, NVIRP represents a *Medium* risk to ecological values and ecosystem functions that are associated with artificially watered habitats beside irrigation channels.

4.4.5. Near-surface groundwater (6)

Near-surface groundwater may support remnant vegetation that is not necessarily associated with a specific wetland. For example, individual trees or patches of vegetation in the landscape may be sustained by their rootzone having access to groundwater. However, the value of this groundwater resource is likely to be determined by its salinity (Figure 4-11). Fresh near-surface groundwater is likely to sustain healthy and diverse stands of vegetation, while saline near-surface groundwater can kill trees whose roots intersect the watertable (Figure 4-11).

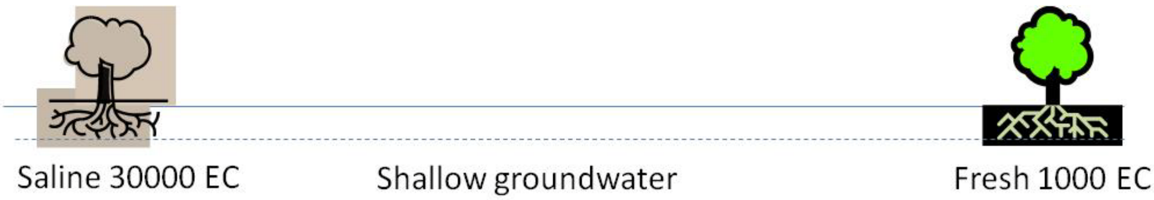

Figure 4-11: Conceptual model for groundwater-dependent vegetation. Trees that have access to fresh groundwater are likely to thrive, while vegetation that only has access to saline groundwater may be stressed. Across the region groundwater salinity is lowest in the east and highest in the west (see Section 4.1.2.3)

This section considers trees in the landscape that may use groundwater to survive in dry periods. Groundwater salinity varies throughout the region. The general trend is saline to the west (i.e. Campaspe, Loddon Regions) and fresher to the east (i.e. Murray-Valley Region, see Section 4.1.2.3). Different tree species have different tolerances to salinities and waterlogging of soils. River Red Gums can tolerate moderately saline conditions, with an upper limit generally around 20,000 µS/cm (MDBC 2003), and some waterlogging, but tree growth is better in non-saline conditions (Benyon et al. 1999). Black Box is salt-tolerant up to a limit of 55,000 µS/cm, but its growth decreases at moderate salinities, especially where the watertable is high (Overton and Jolly 2003). If NVIRP reduces groundwater levels in areas of high salinity it is likely to improve the condition of these vegetation communities. In the western parts of the GMID, groundwater levels are predicted to drop by 0.2 to 1.3 m due to NVIRP. Although the change is predicted to be small, lower watertables in areas where the groundwater intrusions are highly saline may be of some benefit to near-surface groundwater wetlands by reducing the salinity.

Groundwater may support some trees and other plants in the depressions from which they can access the watertable and where the groundwater is relatively fresh (e.g. around Cobram). NVIRP is predicted to lower groundwater levels between 1 and 5 m in the fresher eastern region of the GMID (see Section 4.1.2.1). Any reduction in groundwater levels in these areas due to NVIRP may represent a threat to vegetation, particularly during dry periods. There is uncertainty regarding the role that groundwater plays in supporting native vegetation throughout the GMID. Historically the groundwater levels throughout the GMID were much lower and have only over the last 100 years been raised by increased groundwater recharge associated with land clearance and irrigation (BL&A 2010). Drought and the threat of climate change means that vegetation may become more reliant on groundwater as rainfall is reduced. Note however, that drought and climate change may also lower watertable levels more than NVIRP will (see Section 4.1.2.2).

Conclusion

NVIRP is *Likely* to reduce groundwater levels throughout the GMID. The magnitude of reductions varies across the region, but in most cases is within the range of normal seasonal and annual variation. Groundwater tables are generally quite deep and the extent to which specific plant communities access this water in different parts of the GMID is unknown. In areas where the near-surface groundwater is saline, any reduction in level is likely to benefit the plants that access it. In the eastern part of the GMID (where groundwater is fresher) the watertable is already far below the surface and it is unlikely that many plants would be affected by a further reduction due to NVIRP. On balance, the consequence of groundwater reductions due to NVIRP on plant communities throughout the GMID region is considered *Minor* and therefore the overall risk is considered *Low*.

4.5. Regional assessment of risks to water-dependent habitats

The previous sections considered how the current irrigation system provides water to groundwater-dependent and aquatic habitat types, how NVIRP will change the watering regime of these habitats, and what (if any) effect such changes are likely to have on environmental values and ecosystem processes that are associated with these habitat types. It is concluded that NVIRP represents a low risk to the water regimes of most habitat types throughout the GMID. It is also reasoned that if

NVIRP does not affect the hydrology of these habitats, then it will not affect the environmental values or ecosystem processes that are associated with them.

The only habitat types that are likely to experience significant hydrological changes are rivers and wetlands that receive a substantial proportion of their total annual water volume directly from channel outfalls, and areas next to channels that are artificially watered by bank leakage and bed seepage (Table 4-7). This does not mean that all examples of these habitat types will be affected. Detailed assessments have already considered potential impacts to wetlands and waterways that are known to support significant ecological values such as EPBC and Flora and Fauna Guarantee Act (FFG) listed species. These assessments identified ten wetlands and five waterways where NVIRP was likely to represent a threat. Most of these sites are located in the Pyramid Boort and Torrumbarry Irrigation Districts (see Figure 4-12) and, where needed, EWPs have been developed to address the identified threats.

Table 4-7: Risks to water-dependent habitats (the risk cells have been colour coded to match the colours shown in Table 2-4)

No.	Wetland in conceptual model	Values present	Ecosystem functions	NVIRP Changes to flow regime	Risk on a regional scale
1a	River channels used as delivery systems	Fish Macro-invertebrates Aquatic and riparian vegetation Water quality	Permanent and refuge habitat for aquatic biota. Flows facilitate vegetation zonation, fish movement and longitudinal connectivity. Higher flows transport carbon and nutrients downstream and allow exchange with floodplain.	Lower water levels during the supply season.	The risk to ecological values and ecosystem functions in river channels used as delivery systems is low because the hydrological changes due to NVIRP are likely to occur in summer and autumn and the magnitude of the changes (<50 mm) and ecological consequences will be minor.
1b	River channels downstream of diversions	Fish Macro-invertebrates Aquatic and riparian vegetation Water quality	Permanent and refuge habitat for aquatic biota. Flows facilitate vegetation zonation, fish movement and longitudinal connectivity. Higher flows transport carbon and nutrients downstream and allow exchange with floodplain.	No changes (except where river receives outfalls – see 1c below).	The risk to ecological values and ecosystem functions in river channels downstream of diversions is insignificant as there are no expected hydrological changes due to NVIRP.
1c	River channels that receive outfalls	Fish Macro-invertebrates Aquatic and riparian vegetation Water quality	Permanent and refuge habitat for aquatic biota. Flows facilitate vegetation zonation, fish movement and longitudinal connectivity. Higher flows transport carbon and nutrients downstream and allow exchange with floodplain.	Lower magnitude summer low flows and lower magnitude and frequency of summer freshes and possibly more frequent or extended cease-to-flow periods.	The risk to ecological values in river channels that receive outfalls is medium as NVIRP is likely to reduce outfall contributions to low flow components, which may represent a moderate impact to the values sustained by these flows. A reduction in low flows may reduce the quality and quantity of permanent or refuge habitats and may also allow terrestrial plants to become established closer to the bottom of the channel. Values and functions that rely on higher flow components will not be affected by NVIRP.

No.	Wetland in conceptual model	Values present	Ecosystem functions	NVIRP Changes to flow regime	Risk on a regional scale
2a	Irrigation and drainage channels	Low value habitat	Limited	No changes to water regime Vegetation cannot grow due to channel linings.	The risk to ecological values and ecosystem functions in irrigation channels is insignificant because – except for channels that will be decommissioned – hydrological changes in irrigation channels will be rare. Moreover, irrigation channels support few significant values and therefore any effects would probably be minor.
2b	Weir pools	May provide important refuge habitat and permanent habitat for native fish, vegetation and water birds	Potential refuge habitat and breeding habitat for fish and other aquatic biota.	No changes	The risk to ecological values and ecosystem functions in weir pools is insignificant because there are no expected hydrological changes due to NVIRP.
3a	River-connected wetlands	Landscape connectivity to floodplain and river, vegetation	Carbon and nutrient cycling. Boom in plankton and invertebrates associated with wetting and drying that provide food for fish, birds, frogs and other biota and facilitate vertebrate breeding events. Drying wetlands provide food for wading birds and stimulate plant germination or growth.	No changes, as NVIRP will generally not affect high/overbank flows.	The risk to ecological values and ecosystem functions in river-connected wetlands is low because NVIRP is unlikely to affect higher flows that determine the frequency and duration of connections between the river and floodplain wetlands. Any hydrological changes that do occur will be very small and have a minor effect on values and functions.
3b	Depressions	Amphibious vegetation	Habitat for amphibious vegetation and potentially some carbon and nutrient cycling.	No direct changes, indirect changes associated with lateral flow of channel seepage within 50 m.	The risk to ecological values in depressions is low as it is unlikely that any hydrological changes due to NVIRP will directly impacts on these areas. It is possible that NVIRP may indirectly impact on these wetlands through reducing bank seepage, but any impact on ecological values or ecosystem functions is expected to be minor.
3c	Groundwater-fed wetland	Breeding and foraging habitat for waterbirds	Potentially permanent habitat for waterbirds and fish. Saline wetlands provide an abundance of invertebrates for wading birds and drive	Reduced groundwater levels Climate change and drought have a more	Changes in groundwater levels are likely as a result of NVIRP, but the magnitude of change is likely to be relatively small and within the range of normal seasonal and annual variability. Impacts on ecological values and ecosystem functions are therefore expected to be minor and the

No.	Wetland in conceptual model	Values present	Ecosystem functions	NVIRP Changes to flow regime	Risk on a regional scale
			food chains.	significant effect than NVIRP.	overall risk is low.
4	Wetlands that receive outfalls	Vegetation Frogs, birds Fish (if permanent)	Carbon and nutrient cycling. Boom in plankton and invertebrates associated with wetting and drying that provide food for fish, birds, frogs and other biota and facilitate vertebrate breeding events. Drying wetlands provide food for wading birds and stimulate plant germination or growth.	Threat of reduced water levels and change in ecosystem state for these wetlands due to NVIRP.	NVIRP is almost certain to alter the water regime in some wetlands where channel outfalls currently account for a significant proportion of the total volume of water received during a year or a particular season. Impacts in particular wetlands may be relatively severe, but given only a relatively small proportion of wetlands throughout the GMID are likely to be affected the overall consequence to ecological values and ecosystem functions is moderate. Increased terrestrialisation at the margins of some of these wetlands may occur and there may be less permanent habitat for aquatic biota. Carbon and nutrient cycling may change depending on extent and frequency of wetting and drying patterns. The overall risk of reduced outfalls to wetlands is considered high and should be mitigated. The potential for ASS is currently not known.
5	Local bank and service point leakage	May support vegetation, frogs	Local habitat for plants and frogs. Some connectivity in the landscape. Potential watering points for terrestrial fauna.	Reduced bank leakage due to channel linings are likely to dry up these wet areas.	The risk to ecological values in areas of local bank leakage is medium because NVIRP is almost certain to dry up these wetted areas during summer through lining or decommissioning channels. This presents a minor impact because it is low-value habitat, but these wetted areas may provide habitat in dry periods or increase landscape connectivity. Changes to these habitats are unlikely to reduce connectivity between aquatic habitats or access to water in the landscape because these habitats are adjacent to irrigation channels that are a reliable source of water.
6	Near-surface groundwater	Amphibious vegetation	Support vegetation communities particularly during prolonged dry periods.	Reduced groundwater levels may reduce the extent to which vegetation can access groundwater during dry periods,	The risk to near-surface groundwater ranges from low detrimental risk to medium benefit because, although NVIRP is likely to cause a reduction in groundwater levels the extent to which plants currently rely on that groundwater varies throughout the GMID. In areas with saline groundwater, lower watertables will benefit terrestrial species through less exposure to saline groundwater

No.	Wetland in conceptual model	Values present	Ecosystem functions	NVIRP Changes to flow regime	Risk on a regional scale
				which may lead to a loss of condition.	(NVIRP 2010). Fresher groundwater tables are generally further from the surface and are possibly less accessible to trees. The overall consequence of reduced groundwater levels is, on balance, considered to be minor and the overall risk is therefore considered to be low.
	Terrestrial habitats	Terrestrial Flora Terrestrial Fauna	Feeding and refuge habitat for terrestrial fauna.	No change	Insignificant risk (However potential risks are managed via the Construction Environmental Management Framework).

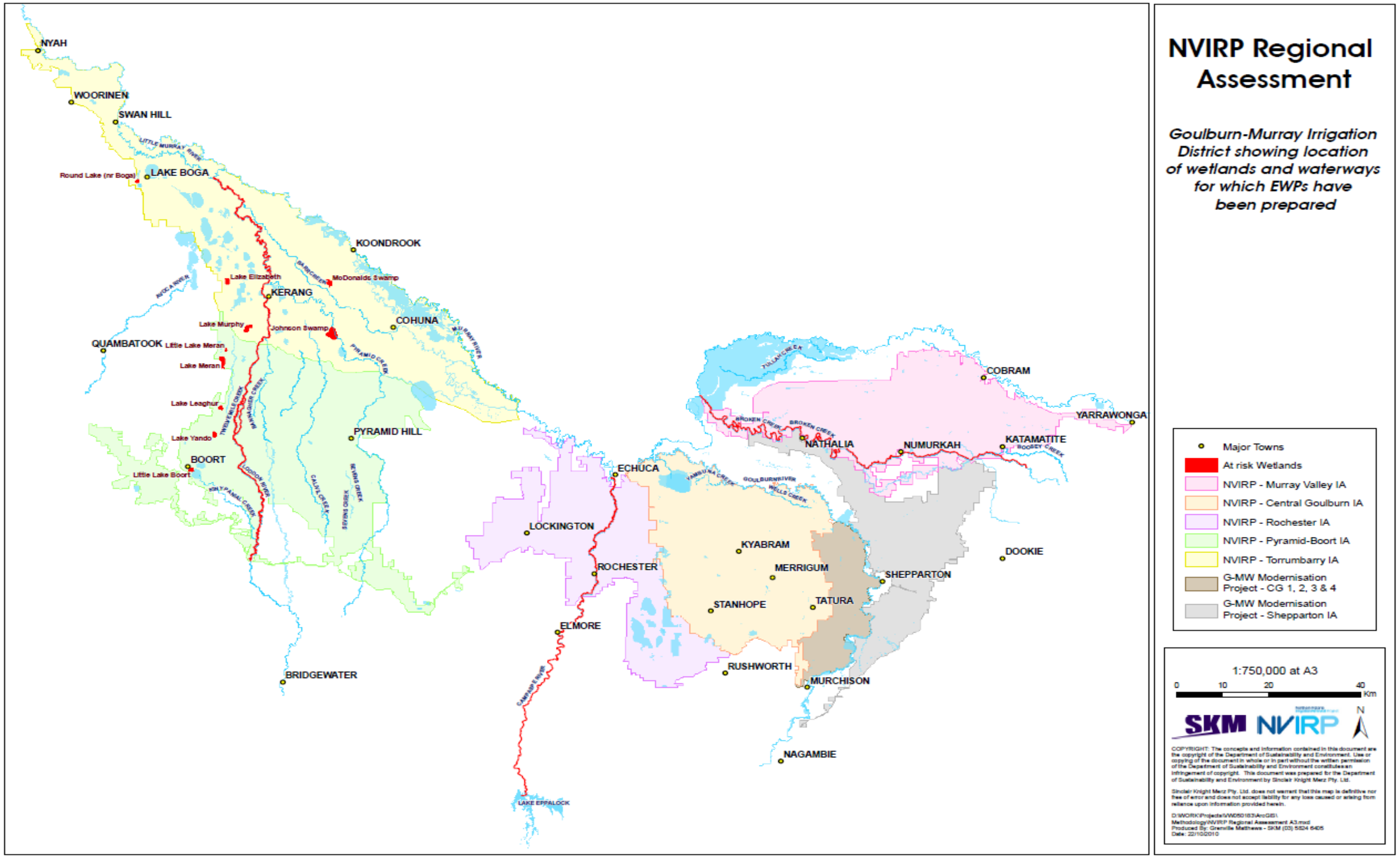

Figure 4-12: Goulburn-Murray Irrigation District showing location of wetlands and waterways with EWPs

At a regional scale, the presence of a mosaic of wetland types is a landscape value in itself, which can be over and above the individual value of wetlands. Waterways and wetlands that do not have high ecological values may have regional significance in terms of the connectivity they provide through the landscape. For example, small wetted areas maintained by bank leakage are vulnerable to the changes in regional hydrology because relatively small changes in the volume of water delivered to these wetlands can have a substantial effect on the overall water regime. While these habitats may have low ecological value individually, they may have greater regional significance by supporting water-dependent plants and animals in dry periods and allowing biota to move between higher value aquatic habitats.

Some types of wetland have suffered from a decline in condition due to land use practices and changes to the regional hydrology. For example, shallow-marsh wetlands have declined by 59 per cent in the GMID since European settlement and deep-marsh wetlands by 64 per cent (GBCMA 2006; NCCMA 2008). NVIRP may cause a further decline in condition of some wetland types at a regional scale through a change in state (Table 4-8), particularly if the wetland is already experiencing water stress, or the wetland's water regime means that it is near the threshold that defines different wetland types. Wetlands that have either direct or indirect connections to the irrigation system could become drier as a result of NVIRP and in some cases this may cause a permanent shift to a drier wetland type as described below:

- permanent wetlands may shift to deep freshwater marshes
- deep freshwater marsh wetlands may shift to shallow freshwater marshes
- shallow freshwater marshes may shift to freshwater meadows
- freshwater meadows may become terrestrial habitats.

A reduction in freshwater contributions from channel outfalls may increase salinities in freshwater wetlands with saline groundwater interactions. Alternatively, lower groundwater levels due to NVIRP may reduce groundwater interactions and saline wetlands may become fresher or less permanent.

A small change in water level (<0.3 m) is likely to occur in some wetlands due to reduced channel outfalls from NVIRP. This will not change the state of permanent or deep freshwater marshes. However, it may cause shallow freshwater marshes to transition towards meadows, or cause meadows to become more terrestrial (Table 4-8). A large change in water level (>1 m) is unlikely to be caused by NVIRP; however, if such a change in water level were to occur then many types of freshwater wetlands in the affected area could shift to completely terrestrial habitats (Table 4-8).

Table 4-8: Changes in wetland state from different reductions in water level possible from NVIRP. Solid arrows indicate likely transitions, broken arrows indicate possible transitions

Water level change due to NVIRP	Likelihood of changes from NVIRP	Permanent	Deep Freshwater Marsh	Shallow Freshwater Marsh	Meadow	Terrestrial
		>2m	<2m	<0.5	<0.3	No water
Very small (<0.1)	Certain	No change	No change	- - - - →	- - - - - - - - →	
Small (<0.3)	Likely	No change	No change	- - - - →	————→	
Medium (<0.6)	Possible	No change	- - - - →	————→		
Large (>1m)	Unlikely	- - - - →	————→			

The abundance and distribution of affected habitats is of most interest for this regional assessment. The above analysis suggests that freshwater meadows and shallow freshwater marshes are most vulnerable to changes in state due to their shallow depth. A map of wetland distribution across the region indicates that freshwater meadows and shallow freshwater marshes are relatively widely distributed across the GMID (Figure 3-1). These wetland types occur both within and outside of the major irrigation areas where NVIRP activities will occur. Hence at a regional landscape scale it is likely that the number of affected wetlands and waterways is relatively small compared to the total number of wetlands in the region (Table 3-1). Given the even distribution, the regional significance is likely to be low. However, if many wetlands and waterways are likely to be affected, or the affected wetlands are all of the same type (e.g. Freshwater Meadow) and are clustered in a particular part of the GMID, then the regional significance will be higher. Such an impact could reduce the abundance of particular species (regardless of whether they have high conservation significance) in the GMID or could disrupt ecosystem functions in a particular part of the GMID, which may have more widespread repercussions.

4.6. Assessment of biological indicators

The main ecological values throughout the GMID include various species and communities of plants, fish, birds and frogs. The PER and its supporting documents have already assessed and, where necessary, addressed the threat that NVIRP poses to significant flora and fauna. However, a regional assessment of potential impacts should more broadly consider threats to any type of biota regardless of their level of conservation significance.

This section aims to identify the biological indicators that are likely to be most threatened by NVIRP across the region. The biological indicators considered are:

1. vegetation
2. birds
3. fish.

For each biological indicator group, the types of water-dependent habitats that support them and the implications of changes to such habitats from NVIRP for each group were considered. Conceptual models (Appendix A) were used to identify the likely threats to particular groups of indicators as a result of NVIRP. Using each model, the effect of different flow components on each indicator group was considered and the likelihood of NVIRP affecting particular flow components across the region was reviewed.

4.6.1. Vegetation

Vegetation communities will be present in all groundwater-dependent and aquatic habitats discussed earlier. For the purposes of the ecological analysis, vegetation has been considered in the context of plant functional groups (PFGs): submerged, amphibious and terrestrial vegetation (Appendix 1 Brock and Casanova (2000)). Submerged vegetation will be most abundant in the more permanently inundated habitat types, such as rivers and permanent wetlands, although short-lived annual species will occur in ephemeral wetlands that are inundated for sufficient periods. Amphibious vegetation is the most versatile of the groups and will be present in most habitat types depending on water regime at a given time. Terrestrial vegetation will be present on the floodplain and across the landscape, but not in permanently or even chronically inundated environments.

Two conceptual models were used to describe the relationships between hydrology and three broad PFGs –submerged, amphibious and terrestrial. Figure 4-13 is a generalised model that shows a classification of PFGs based on an implied relationship to the water regime, taken from the Victorian Environmental Flow Monitoring Assessment Program (VEFMAP) (Chee, Webb et al. 2006). It describes the importance of specific flow components in river channels. There are no comparable models for wetland vegetation, but the effects of NVIRP on wetlands can be inferred by the changes to the permanency of water to the different functional groups.

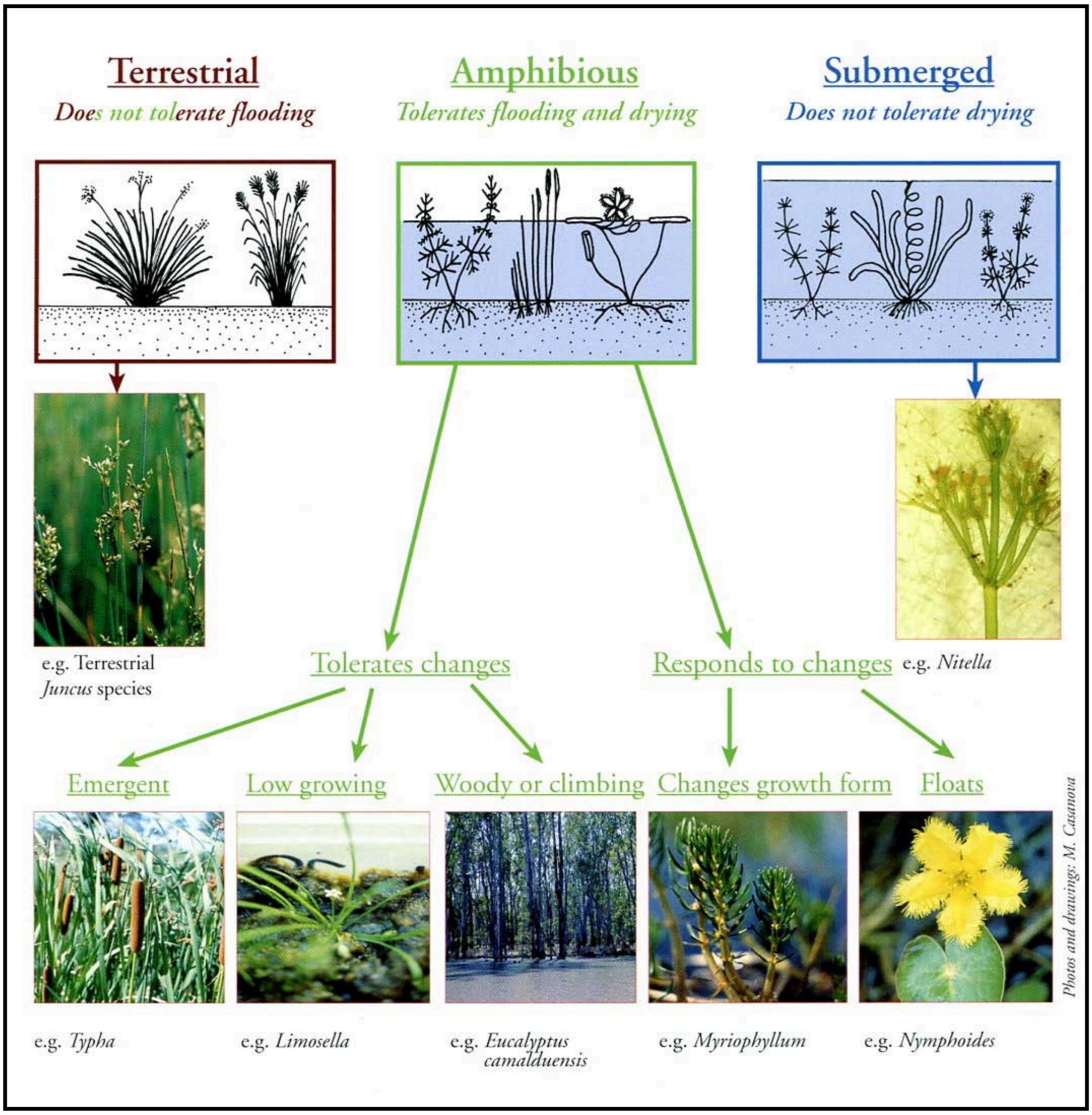

Figure 4-13: Generalised response of different plant functional groups to altered water regime (Source: Brock and Casanova 2000, page 4)

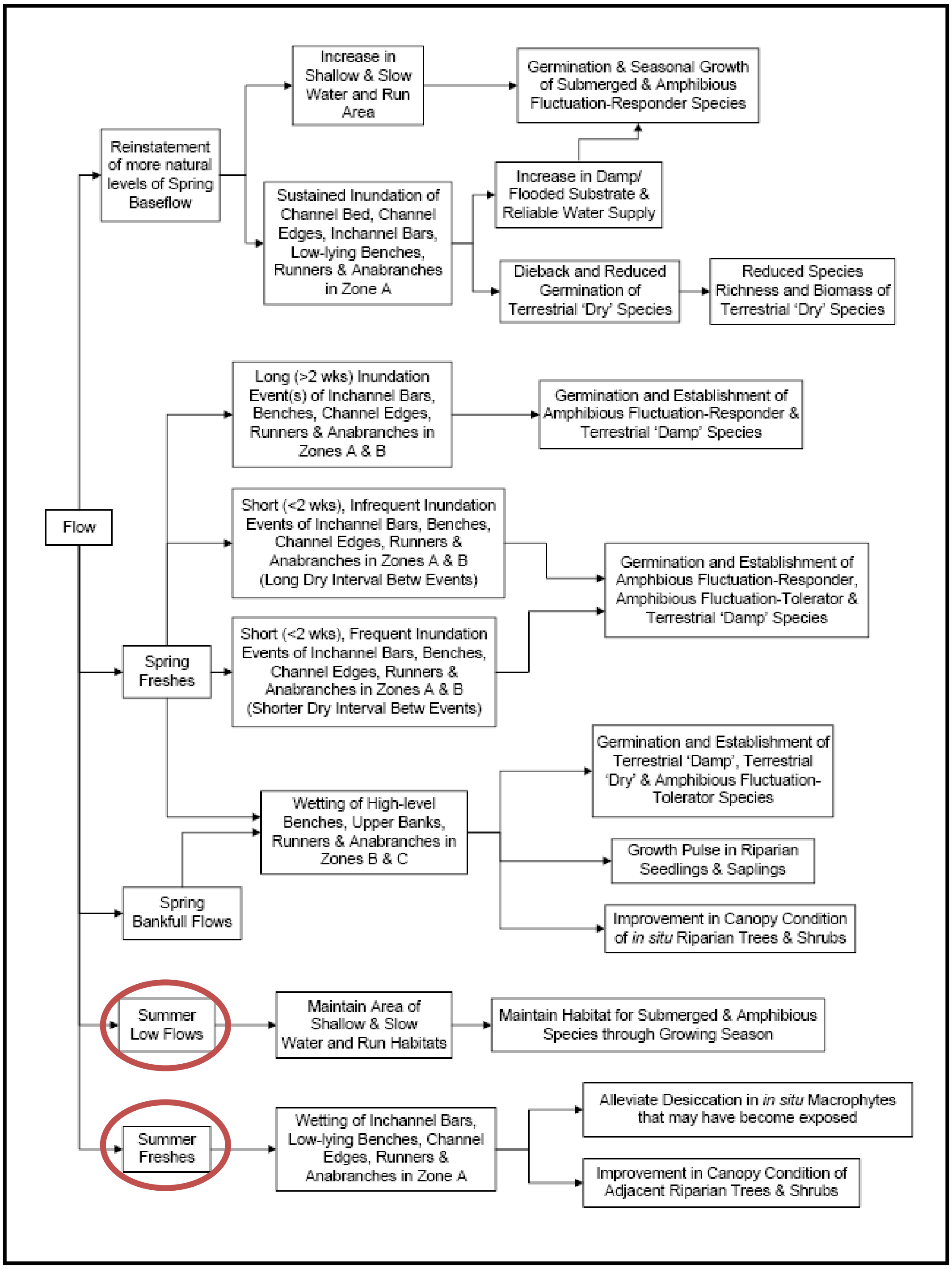

Figure 4-14: Conceptual model of detailed response of different plant functional groups to altered water regime (Source: Chee, Webb et al. 2006, page 29). Red ovals highlight flow components that are most likely to be affected by NVIRP

NVIRP will not affect high or overbank flows in rivers, nor will it affect the frequency of wetland filling. However, it could affect low flows and freshes in river channels and the extent of shallow permanent water in some wetlands that receive outfalls. In the conceptual models, the two flow components most likely to be affected by NVIRP are summer low flows and summer freshes (Figure 4-14). Each of these flow components is considered below in terms of the effects of NVIRP on rivers and wetlands:

Summer low flows

The summer low flow component of the conceptual model may be interpreted as summer water level to be more relevant for wetlands, as the relationships in terms of depth and duration of inundation are the same. NVIRP may directly reduce the water level in rivers and wetlands during the irrigation season by reducing channel outfalls and diversions, and indirectly through reduced bank leakage and lower regional groundwater tables. Reductions in surface and/or groundwater levels could reduce the area of shallow and slow water (in-channel) habitats, which are important for submerged and amphibious plant species through the growing season (Figure 4-14). If some rivers experience cease-to-flows or if wetlands dry out for long periods, submerged plant species that require permanent inundation will most likely be replaced by shorter lived submerged species and amphibious species that can better tolerate fluctuating water levels. Water level changes in large regulated rivers such as the Goulburn and Murray Rivers are predicted to be very minor – on average less than 50 mm in systems greater than 1.4 m deep (see Section 4.4.1.1) – and therefore impacts to vegetation communities in such systems are expected to be negligible. However, hydrological changes and associated effects on submerged and amphibious plant species could be more substantial in smaller rivers, such as the lower Loddon River, and in some wetlands where channel outfalls make a greater contribution to summer low flows and summer water levels (see Section 4.4.1.3). Groundwater-dependent wetlands may also experience a drop in water level from a decline in regional watertables due to NVIRP.

Summer freshes

A reduction in the magnitude and frequency of summer freshes is likely for rivers and wetlands that receive irrigation outfalls (NCCMA 2010a; NCCMA 2010b). Rainfall rejection flows typically occur a day or so after a rainfall event and can instigate or contribute to summer freshes in the receiving rivers. If catchment runoff is low, then rainfall rejections can be solely responsible for summer freshes. Smaller and less frequent freshes will reduce the frequency of watering of amphibious vegetation species that are present in the littoral zone and on in-channel bars and benches (Figure 4-14). Reduced watering will cause stress to this vegetation type and could potentially reduce the diversity of amphibious species present. The impact may be significant in outfall-dependent rivers and wetlands.

Based on the earlier analysis, the types of habitats that may have an altered watering regime due to NVIRP are: small river channels and shallow wetlands that receive outfalls, areas of pooled local bank leakage, and groundwater-dependent ecosystems. Submerged plant species will be most affected if there is less permanent water, particularly during summer. It is conceivable that NVIRP may contribute to a regional shift from long-lived submerged vegetation communities to more amphibious communities with some shorter-lived or annual submerged species (Table 4-9). These changes are more likely to occur in wetland environments than in rivers and streams, because NVIRP is not expected to significantly increase the cease-to-flow period in many rivers (SKM 2009b). A change from amphibious to terrestrial plant communities is not very likely because it would require an elimination of all water from a particular wetland or waterbody.

Table 4-9: Plant functional groups and NVIRP effects. Solid arrows indicate likely transitions, broken arrows indicate possible transitions

Functional group	Submerged	Amphibious	Terrestrial
Direction of threat	⟶	- - - - - - - ➝	No change
Regional scale threats	• Channel outfalls do not keep any systems permanently ponded, but they may ensure that some parts of wetlands remain wet throughout the irrigation season. The only permanent systems are rivers, lakes and weirpools on irrigation supply systems. Therefore channel outfalls are only likely to be providing top-up water (not primary source of water) to submerged vegetation in the majority of systems • NVIRP may dry out some areas more frequently. Any increased drying from NVIRP presents an increased threat of losing submerged vegetation or a conversion from perennial to annual species • Occasional drying for a few months in winter every few years will not have an impact as some aquatic plant species can persist through winter drying.	• Some change in specific species but no loss as a functional group. At a landscape scale, NVIRP could increase the area and species diversity/mosaic of habitat types.	• Increased drying could expand this group. But decreased groundwater in the east region could also affect large trees utilising groundwater (e.g. Black Box).

Conclusion

NVIRP is *Likely* to reduce the magnitude of summer low flows in some river channels and the duration and extent of inundation in some wetlands by such an amount that will cause a shift from long-lived submerged plant communities to communities that are dominated by shorter-lived aquatic species and amphibious plant species. However, these effects will be restricted to a small number of wetlands and river reaches that currently receive a large proportion of their water from irrigation channel outfalls. The ecological consequence is therefore considered to be *Moderate* and the overall risk to submerged vegetation communities throughout the GMID is *Medium*.

The hydrological changes to rivers and wetlands due to NVIRP are not expected to have an adverse effect on amphibious or terrestrial plant communities (consequence is *Minor-Negligible*) and therefore the risk to these vegetation types is *Low* to *Insignificant*.

4.6.2. Birds

Water birds, many of which respond rapidly to flooding, are likely to occur in permanent open water habitat such as saline and freshwater wetlands. Three groups of birds (colonial nesting waterbirds, waterfowl and grebes and waders) were considered.

Detailed conceptual models that explicitly describe the relationship between these three groups of waterbirds and hydrology have not been developed and empirically tested, but Reid et al. (2009) described six main conceptual links between sustainable waterbird communities and water regimes. These links are listed below and described in Figure 4-15:

- Waterbird assemblages are dynamic due to individual's (varying) mobility – hence they are open systems.
- Lateral connectivity is important – there are numerous connections (flow paths) between the river and its floodplains and wetlands.
- The most productive (feeding) wetlands are shallow and recently dry – fluctuating water levels increase productivity.
- A broad range of physical wetland and vegetation types is required to maximise assemblage diversity and provide nesting habitat for most species.
- For successful fledging of most nesting waterbird species to occur, a shifting spatiotemporal mosaic of wetland inundation patterns needs to occur over a lengthy period (e.g. 4-5 months) and at the appropriate time of year (i.e. spring for wetlands in the Southern MDB).
- These wetland mosaics need to be sufficiently large to a) support populations of a diverse range of waterbirds and b) sustain successful recruitment of most species in large floods.

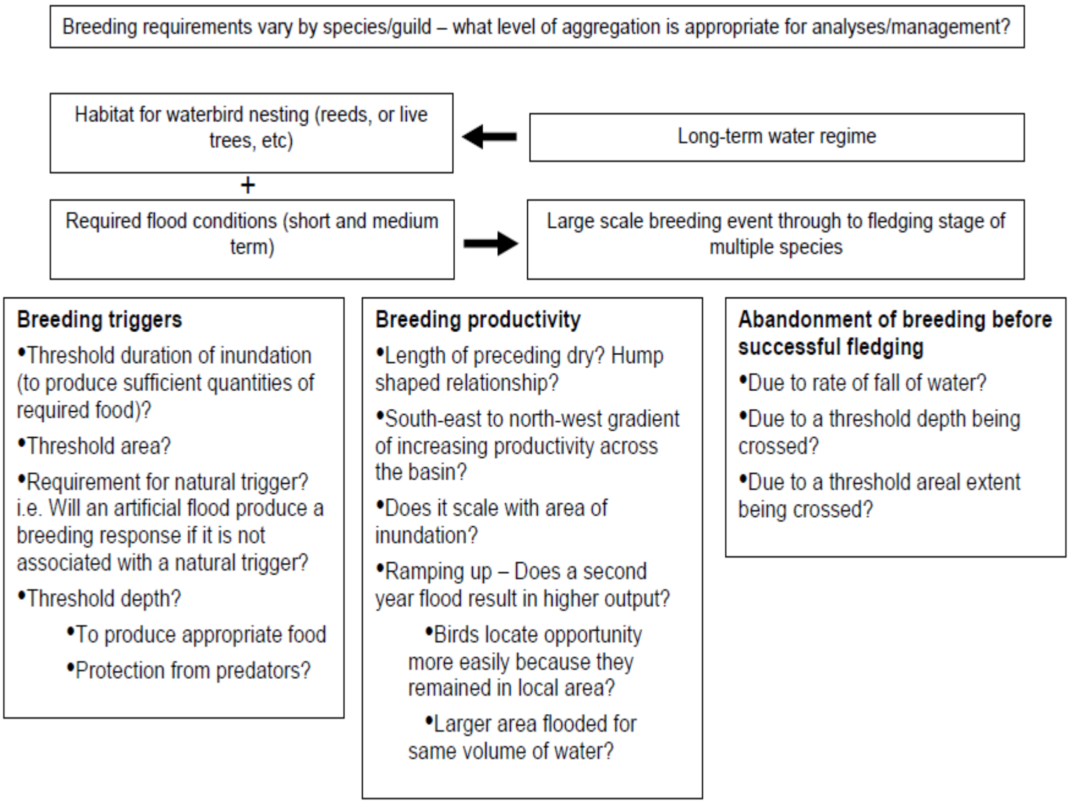

Figure 4-15: Hypothetical relationships between breeding responses and flow regimes for colonial nesting waterbirds (Source: Reid et al. 2009, page 126)

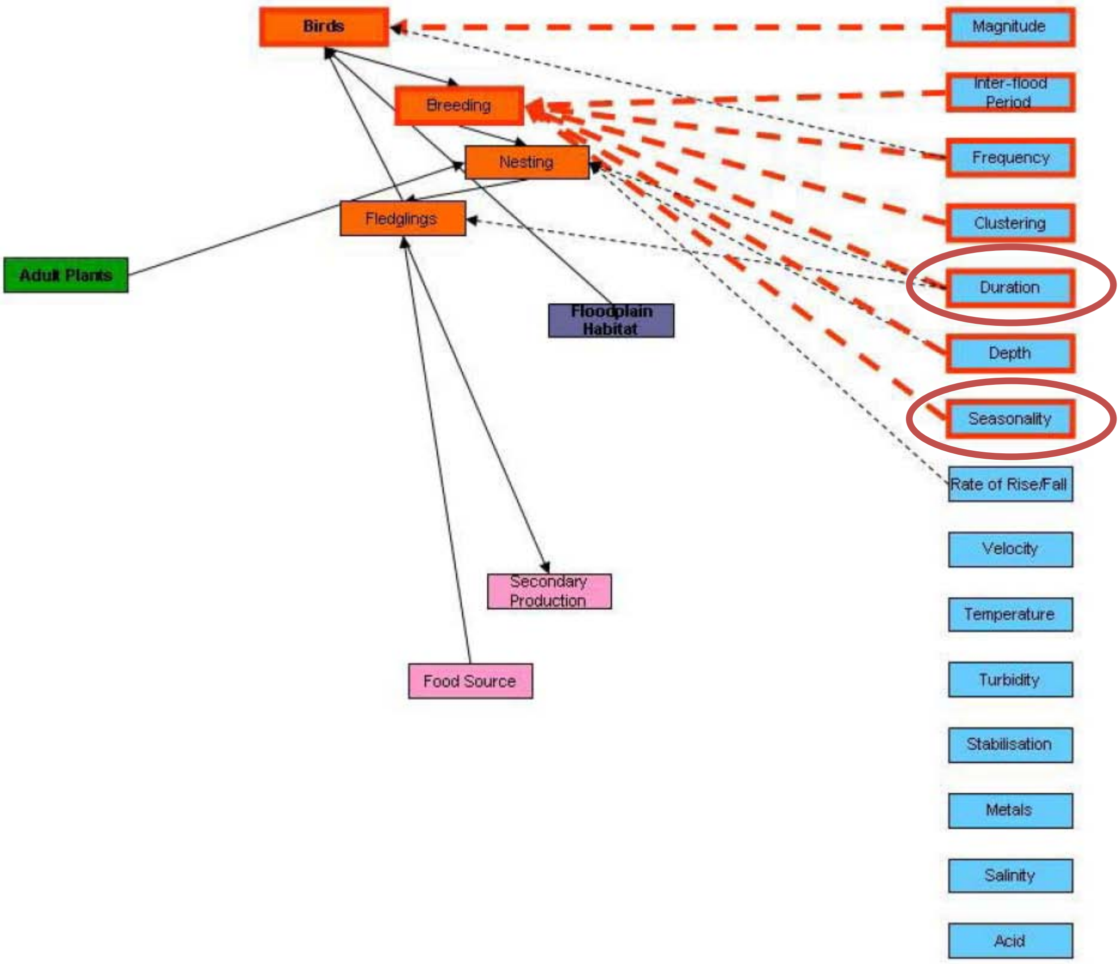

Figure 4-16: Conceptual model of the major components of waterbird life stages that relate to aspects of flow regime. (Source: Overton et al. 2009, page 403). Red ovals highlight flow components that are most likely to be affected by NVIRP

The breeding success of colonial nesting water birds in any habitat in any particular year is primarily determined by the timing and duration of floods (see Figure 4-15 and Figure 4-16). NVIRP is not likely to alter the magnitude, duration or frequency of floods and is therefore not expected to affect the breeding success of this guild (NVIRP 2010).

Water fowl and grebes require permanent open water habitat (Figure 4-15). Permanent open water habitats are not likely to be affected on a regional scale by NVIRP, except where there is a significant outfall contribution and/or groundwater component. There are a small number of wetlands that could become significantly drier as a result of NVIRP, but the high mobility of waterfowl and grebes means that individual birds can move to other permanent waterbodies. Therefore at a regional scale the threat to this guild is low.

Shallow mudflats and semi saline wetlands provide good foraging habitat for waders. This productive habitat is supported through fluctuating water levels, which may be affected by NVIRP through the reduction in outfalls in summer and a decline in regional groundwater levels. However, a return to a more natural wetting and drying regime in some wetlands may increase the mosaic of wetlands at different stages of drying at any given time throughout the GMID region, which may actually increase the abundance and diversity of food for wading birds.

Conclusion

NVIRP will not alter the magnitude, duration or frequency of floods (likelihood is *Rare*) and therefore is not expected to affect the breeding success of colonial nesting waterbirds (consequence is *Negligible*). Therefore the risk to this guild of birds is *Insignificant*.

Permanent open water habitats for foraging are U*nlikely* to be affected on a regional scale by NVIRP, but a small number of wetlands and sections of small rivers are likely to become drier. Given the high mobility of birds and the high likelihood that most waterbodies in the landscape will not have altered hydrology, the ecological consequences for these birds will be *Minor* and the overall risk will be *Low*.

NVIRP is *Likely* to change the water regime in some shallow freshwater and semi-saline wetlands. However, at a regional scale, these changes may actually increase the diversity of wetlands at different stages of drying at any given time. A mosaic of habitats at different drying stages is likely to be beneficial to wading birds that rely on drying wetlands for food, and therefore the ecological consequence to these birds is *Negligible*. The overall risk at a regional scale is considered to be *Insignificant*.

4.6.3. Fish

Permanent rivers and streams in the GMID are important habitat for native fish species such as Murray Cod, Trout Cod and Macquarie Perch that are listed under the EPBC Act. Permanent saline wetlands provide habitat for the EPBC Act listed Murray Hardyhead (King and Tonkin 2009). Other groundwater-dependent and aquatic habitat types may be used opportunistically by some fish species – for example, river-connected wetlands can become important spawning and nursery habitats during floods.

King (2002) recognised six broad categories of fish in the Murray-Darling Basin:

- flood specialists (e.g. Golden Perch, Silver Perch)

- flood opportunists (e.g. Carp)
- low-flow specialists (e.g. Carp Gudgeon, Mosquito Fish)
- generalists (e.g. Australian Smelt, Flathead Gudgeon)
- main-channel specialists (e.g. Murray Cod, Trout Cod, River Blackfish)
- wetland specialists (e.g. Carp Gudgeon, Australian Smelt, Southern Pygmy Perch).

Two conceptual models describe the relationship between specific flow components and these six categories of fish species; however, the models relate more to rivers than to wetlands. It is assumed that current wetland species will persist unless wetlands shift from being permanently inundated to ephemeral.

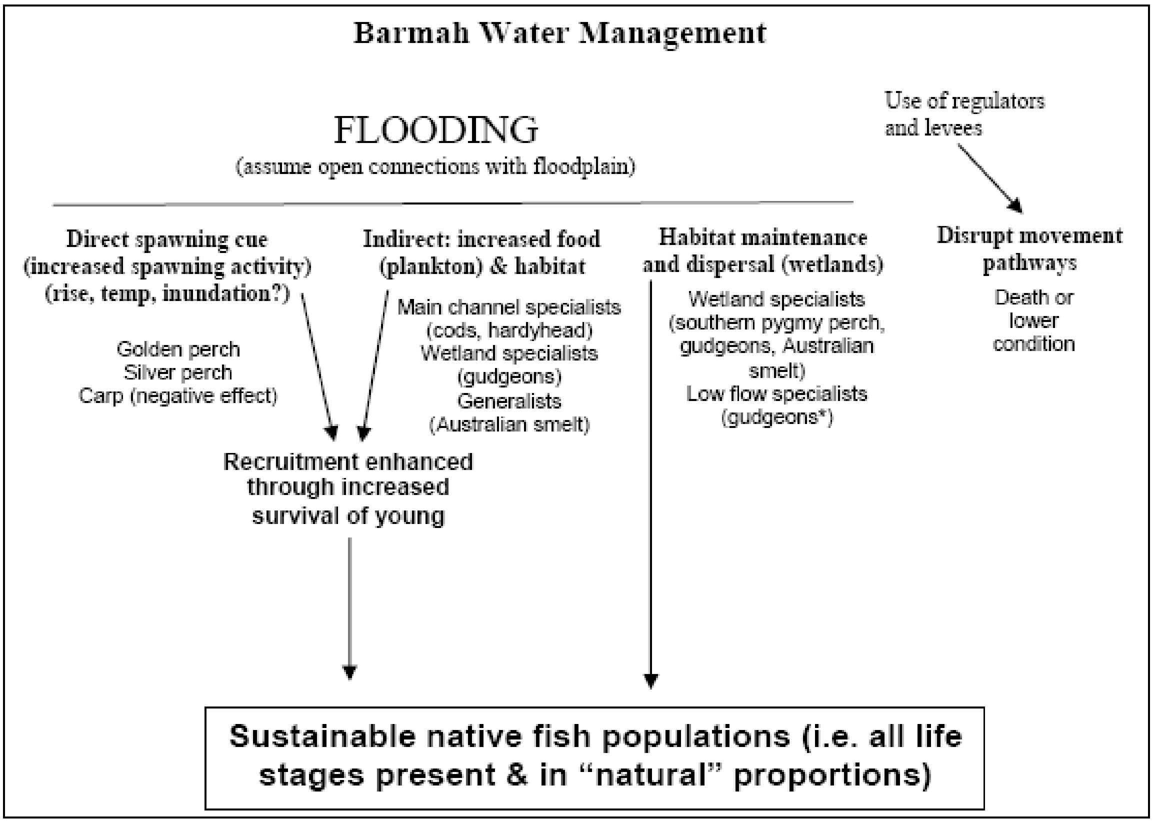

Figure 4-17: Conceptual model of impact of flow on fish communities in the Barmah Forest (Source: McCarthy et al. 2006, page 16)

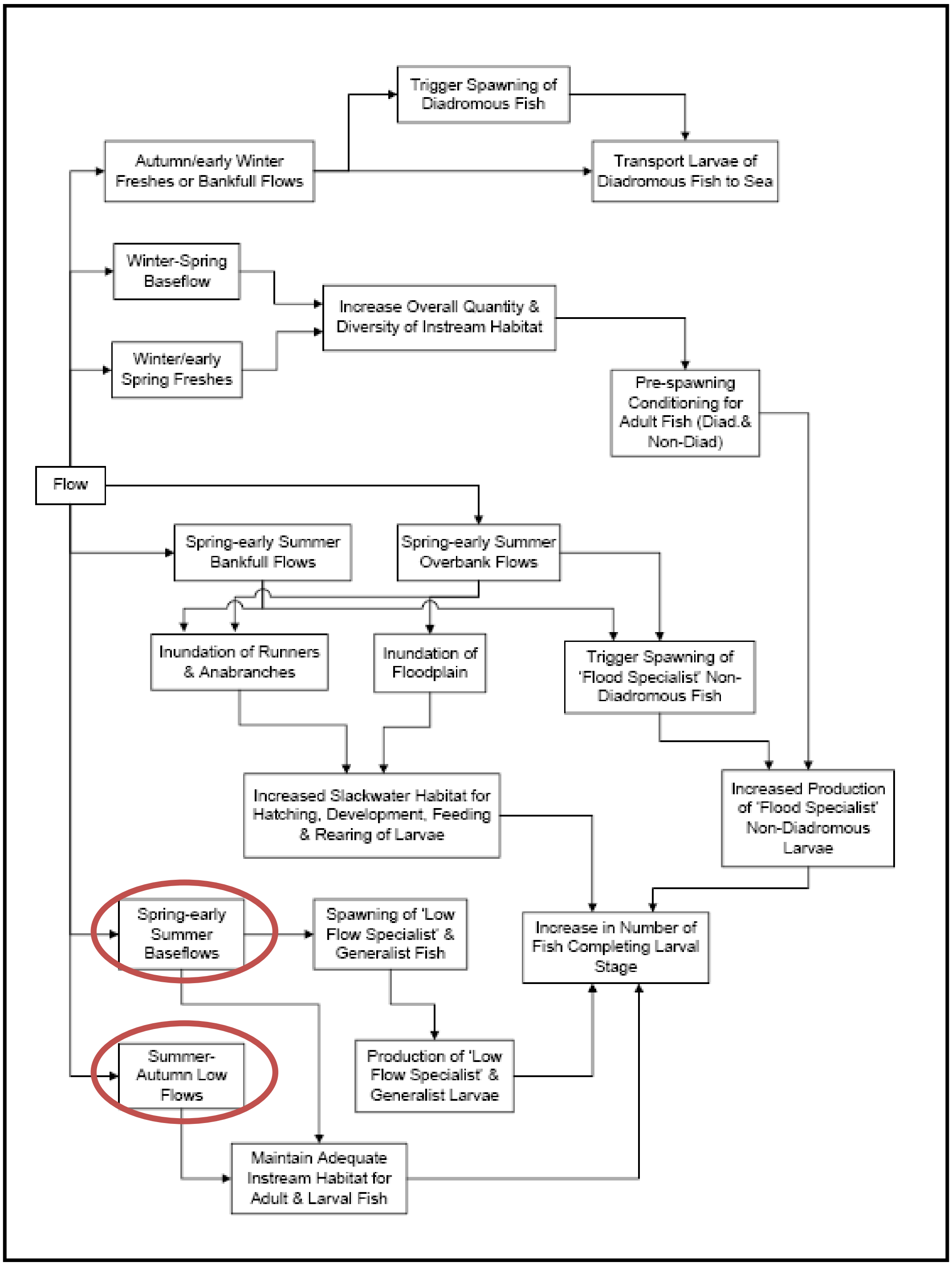

Figure 4-18: Conceptual model for effect of flow on fish spawning and recruitment (Source: Chee et al. 2006, page 34). Red ovals highlight flow components that are most likely to be affected by NVIRP

NVIRP will not influence high flows, winter freshes, bankfull or overbank flows that are important for flood specialists (e.g. Golden Perch, Silver Perch) and flood opportunists (e.g. Carp). The two major flow components to be affected by NVIRP in rivers are summer low flows and summer freshes (documented in waterway EWPs (NCCMA 2010a; NCCMA 2010c). Each of these flow components are considered below in terms of their importance to fish communities and the threat posed by NVIRP:

Summer low flows

Summer low flows are important for providing instream habitat (particularly the extent of shallow vegetated patches and backwaters) for adult and larval fish, as well as connectivity and fish passage along a river channel. The magnitude of summer low flows in some river reaches decline due to reduced channel outfalls. This decline is likely to be relatively small in large regulated rivers (e.g. Goulburn River), but may be more substantial in smaller rivers such as the lower Loddon River, where channel outfalls account for a relatively larger proportion of flow during the warmer months. A decline in regional groundwater levels may reduce the water level of permanent saline wetlands, but this decline is not expected to affect the permanency of the wetlands. A reduction in the magnitude of summer low flows and outfalls to wetlands means that water levels could fall in both rivers and wetland systems. Littoral vegetation may become stranded, which may reduce the quality and extent of fish spawning habitat and refuge habitat for juvenile fish and fish larvae (see Figure 4-18). Such an outcome may threaten the recruitment of low-flow specialists and generalists. Over time, littoral vegetation may respond to a change in water level by colonising lower sections of the bank. However, in the short-term, refuge habitat and breeding habitat for low-flow specialists will be less abundant (Figure 4-18). While the effects of reduced low flows due to NVIRP may be significant at a small number of sites or river reaches, most waterways will not be substantially affected and therefore the consequence to fish across the region will be minor. The overall effect of NVIRP on summer water levels in rivers and wetlands is likely to be small in comparison to other landscape scale threats such as climate change and drought, and the regional risk to native fish communities is considered to be low.

Summer freshes

The conceptual models that were developed for VEFMAP (see Figure 4-18) did not identify summer freshes as a significant flow component for native fish, but such flows could be important in intermittent streams for topping up refuge pools and providing opportunities for localised movement between habitats. NVIRP may cause a reduction in the magnitude and frequency of summer freshes. The magnitude of change is likely to be similar to that described for summer low flows (i.e. small in regulated rivers, medium in larger outfall-dependent rivers and high in small systems). Outfalls from rainfall rejections typically occur a day or so following a rainfall event. They can instigate or contribute to summer freshes in the river. If catchment runoff is low during summer, then rainfall rejections can be solely responsible for summer freshes.

Conclusion

NVIRP will not affect high flows in river channels or flooding frequency in floodplain wetlands; therefore it is not expected to have any effect on flood specialist or flood generalist fish species.

NVIRP is *Likely* to affect the magnitude of summer low flows and freshes in some relatively small river channels and may influence the extent and duration of inundation in a small number of wetlands. These changes may reduce the quality and quantity of refuge habitats in affected waterbodies, however given most rivers and wetlands will be unaffected, the consequence to fish communities at a regional scale is only *Minor*. The overall risk to fish communities as a result of NVIRP is therefore *Low*.

4.7. Regional assessment of risks to biological indicators

This section has identified the biological indicators that are likely to be most threatened by NVIRP across the region (Table 4-10). NVIRP is most likely to affect low flows and freshes in rivers, and the duration, timing and dilution of pooled water in wetlands (NVIRP 2010). Therefore, this analysis has focused on the biological indicators that rely on those watering components.

Vegetation, bird and fish communities in the GMID are of high regional significance, with a number of EPBC-Act-listed species in all indicator groups (NVIRP 2010). At a regional scale, NVIRP presents a low risk to all these indicator groups. Where NVIRP related hydrological changes occur in their relevant habitats, the flow components impacted are either of low importance to the life-cycle or habitat required by the indicator group, or the effects will be restricted to a small number of locations and will therefore be minor at a regional scale. The one exception is submerged vegetation, where it is conceivable that NVIRP may contribute to a regional shift from long-lived submerged vegetation communities to annual submerged plant communities and amphibious plant communities that are less reliant on permanent pooled water in the landscape.

Table 4-10: Summary of NVIRP risks to biological indicators (the risk cells have been colour coded to match the colours shown in Table 2-4)

Biological indicator	Sub-groups	Regional significance	NVIRP changes to flows	Risk on a regional scale
Vegetation	Submerged Vegetation * Amphibious Vegetation Terrestrial Vegetation	High	NVIRP could affect low flows and freshes in river channels and the extent of shallow permanent water in some wetlands.	Submerged vegetation communities are at medium risk from NVIRP due to potential reductions in outfalls that maintain water in wetlands over the dry summer period. Annual submerged vegetation species may have an advantage over perennials, or they may be overtaken by amphibious species.
Birds	Colonial nesting birds Waterfowls and grebes Waders	High	NVIRP is most likely to affect low flows and possibly freshes in rivers and the duration and timing of pooled water in wetlands.	NVIRP presents a low or insignificant risk to birds, as they respond to large flow events that are not affected by NVIRP. NVIRP may have a minor benefit to wading birds if more varied wetland water regimes occur throughout the region creating a larger mosaic of foraging habitats as wetlands dry at different rates.
Fish	Flood specialists Flood opportunists Low flow specialists * Generalists * Main channel specialists Wetland specialists *	High	Reduced magnitudes of low flows from reductions in outfalls may reduce instream habitat for fish species and reduce fish passage. Lower frequency and magnitude summer freshes may reduce topping up refuge pools and reduce local movement opportunities.	NVIRP is not expected to have a widespread effect on low flows and freshes in a large number of rivers and streams throughout the GMID. While fish communities in some individual rivers and wetlands may be affected, the risk to fish communities across the whole region is low.

* Indicates groups that may be affected by NVIRP.

5. Risk management

Previous sections have assessed risks and shown that there are some levels of risk to aquatic habitats and biological indicators.

Risk management (or risk treatment) follows risk assessment and involves the development of strategies to minimise, monitor, and control the probability and/or impact of adverse events.

NVIRP has developed a number of risk management measures. These are discussed below.

5.1. NVIRP risk management tools

5.1.1. Water change management framework

The WCMF is a requirement of the Victorian Minister for Planning and was approved by the Victorian Minister for Water on 14 August 2009.

The WCMF describes the means by which NVIRP will protect aquatic and riparian ecological values through management of water allocations and flows that may be impacted by implementation of NVIRP within the modernised GMID (NVIRP 2010). The WCMF outlines procedures for monitoring, reporting and auditing changes in hydrological conditions in relevant wetlands or waterways associated with the project's operation. It provides the environmental commitments, processes and methods for the relevant operations of the modified system. The WCMF includes review and approval processes that will contribute to implementation of an adaptive management approach.

Various documents (see Table 1-1) prepared under the WCMF aim to identify potential impacts associated with NVIRP and recommend suitable mitigating actions.

5.1.2. Environmental watering plans

EWPs describe an appropriate water supply protocol to protect the high environmental values of a wetland or waterway, which would otherwise be adversely affected without the additional management and mitigation measures set out in the EWP.

The WCMF (Attachment E) sets out the minimum content requirements of EWPs. This includes:

- wetland/waterway description including environmental values
- consultation
- management objectives

- hydrology
- opportunities to deliver water
- potential risks or adverse impacts
- on-going management and governance arrangements
- adaptive management framework.

The WCMF (Sec 17) states that following the completion of the EWPs for the relevant program of works, NVIRP will review the EWPs as a whole and consider:

- the cumulative effects of the impact of NVIRP on high environmental value waterways and wetlands
- whether any additional management and mitigation measures are required.

5.1.2.1. Assessment process for identifying wetlands and waterways with localised impacts

NVIRP commissioned an initial desktop environmental assessment (SKM 2008a) of the potential effects of NVIRP as part of the referral submitted to the Minister for Planning under the *Environment Effects Act 1978* (Vic). The assessment process focused on the potential effects to wetlands, waterways and groundwater, and their associated values. The main effects were considered to be the 85 per cent reduction in channel outfalls throughout the irrigation system and expected changes to bulk water delivery in the Goulburn, Broken, Campaspe, Loddon and Murray Rivers. The desktop assessment process:

- identified 1,137 wetlands[5] in the GMID
- identified 573 of these as having high environmental values (including MNES)
- determined type of connection (if any) to the irrigation system, with 78 being found to be in some way connected
- determined relative contribution of irrigation water to wetland/waterway water regime, with 23 being found to be potentially benefited by outfalls and other incidental water
- identified 229 outfalls to 25 waterways in the GMID

[5] See Footnote 1.

- assessed flow changes due to reductions in outfalls and environmental values in waterways where flow regime may be affected
- identified 16 waterways for investigation for EWPs.

Wetlands and waterways with high environmental values were identified from existing databases maintained by Commonwealth, state, and regional authorities and by drawing on local knowledge and expertise.

The output of the assessment was a preliminary list of wetlands/waterways with high environmental values:

- whose water regime is likely to be altered by implementation of NVIRP
- where insufficient data is available to determine whether its water regime is likely to be altered by implementation of NVIRP
- wetlands and waterways where insufficient data is available to assess environmental values.

The identification of sites for further investigation adopted both a precautionary and an adaptive approach. For example, if there was insufficient information regarding a particular site, then it remained on the preliminary list for further investigation. This included the eight unnamed wetlands on the list, which were identified by SKM (2008a) as being within 100 m of a channel, with a low hydraulic gradient between the channel and the wetland, and therefore possibly connected to the irrigation distribution system via groundwater and/or seepage. To provide certainty, the Groundwater Hydrology Report (NVIRP 2010 Appendix 19) considered the potential localised hydrological effects on these wetlands of any upgraded (lined) channels in the immediate vicinity.

5.1.2.2. Shortlisting reports for wetlands and waterways

Consistent with the WCMF, and further to the Environmental Assessment Report for referral under the Victorian Environment Effects Act, a shortlisting process was then undertaken to determine which wetlands and waterways on the initial desktop assessment (and those identified in the Minister for Planning's decision) may be at risk of localised hydrological effects. The shortlisted sites then required the development of an EWP. The shortlisting process is as follows:

- confirm environmental values of wetland/waterway, where relevant
- confirm source of water supply to wetland/waterway through:

  - site inspections
  - data collection, where relevant

- determine whether existing water supply is sourced from incidental irrigation water. If yes, determine whether implementation of NVIRP and resulting change to the water regime would adversely affect this water supply
- if yes, recommend that a EWP be developed.

The process for validation was undertaken by suitably qualified and experienced consultants and reviewed by the Technical Advisory Committee and the Expert Review Panel.

Where there was any uncertainty in the validation process, an interim EWP was prepared to ascertain the materiality of any potential effects and, if necessary, develop mitigation measures.

Ten wetlands were identified for EWPs, together with four waterways, with further consideration to be given to Nine Mile Creek.

5.1.2.3. Preparation of EWPs

EWPs (Table 5-1) have been prepared for all but Little Lake Meran and Nine Mile Creek which were not determined to require a EWP. Preparation of an EWP for Twelve Mile Creek was incorporated with the Loddon River EWP.

EWPs were reviewed by the Expert Review Panel (ERP) and have been approved by the Victorian Minister for Water and the Federal Minister for Environment Protection, Heritage and the Arts (Sustainability, Environment, Water, Population and Communities).

Table 5-1: Wetlands and waterways with an NVIRP EWP

Wetland	Reference	Waterway	Reference
Johnson Swamp	NCCMA (2009).	Campaspe River	NCCMA (2010a).
Lake Elizabeth	NCCMA (2010b).	Loddon River (including Twelve Mile Creek)	NCCMA (2010c)
Lake Murphy	NCCMA (2010f).	Lower Broken Creek and Nine Mile Creek (tributaries of the Broken River)	Water Technology (2010)
McDonald Swamp	NCCMA (2010i).		
Lake Leaghur	NCCMA (2010d).		
Lake Yando	NCCMA (2010g).		
Little Lake Boort	NCCMA (2010h).		
Lake Meran	NCCMA (2010e).		
Round Lake	NCCMA (2010j).		

5.1.2.4. Technical underpinnings and additional desktop validation

Further to the initial desktop assessment and the shortlisting process described above, an assessment was undertaken by BL&A (2010) using more recent data on fauna distribution to determine if there were any additional wetlands of significance for MNES that should be added to the original shortlisted wetlands (SKM 2008a; Feehan 2009; Hydro Environmental 2009a). This included a significant body of additional information on MNES occurrence (notably the large number of records from the Birds Australia Atlas of Australian Birds).

Occurrences of the original shortlisted sites (SKM 2008) were compared with the map of wetlands and waterways within 400 m of irrigation channels (considered to be the ‘development footprint’) (BL&A 2010).

All wetlands listed by this means were found to have been part of the original SKM (2008) list of wetlands with high environmental values. For this reason, the shortlisting reports (SKM 2008a; Feehan 2009; Hydro Environmental 2009a) are considered to be a valid basis for identifying wetlands where there are likely to be localised impacts.

In addition to these reports, a number of technical assessments (Table 5-2) were undertaken as part of the preparation of the Public Environment Report (PER) to accompany NVIRP's application for project approval under the EPBC Act.

Table 5-2: Technical assessments undertaken for Public Environment Report (PER) (full list)

Issue	Report Title	Reference
Aquatic fauna	Operational impact assessment on aquatic fauna.	(King et al. 2009)
Flora	Assessment of impacts on flora issues of national environmental significance.	(Ecological Associates 2009)
Groundwater	Assessment of hydrological changes from the operation of the NVIRP modernised GMID – groundwater hydrology.	(SKM 2009a)
Ramsar wetlands	Operation impact assessment on wetlands of international importance (Ramsar wetlands),	(Hale 2009)
Surface water	Assessment of hydrological changes from the operation of the NVIRP modernised GMID – surface water hydrology.	(SKM 2009b)
Terrestrial fauna	Operational impact assessment – terrestrial vertebrate fauna.	(BL&A 2010)

5.1.3. Mitigation water

NVIRP has developed a set of principles and environmental commitments in relation to managing the ecological consequences of hydrological changes arising from implementation of NVIRP – including avoiding any contribution to diminishing ecological values in waterways and wetlands. The major mitigation activity undertaken by NVIRP is the provision of mitigation water.

The WCMF requires that mitigation water is provided through the development and implementation of EWPs for sites supporting high environmental values where incidental irrigation water currently has beneficial effects. A key Government requirement governing NVIRP is that the water savings resulting from NVIRP are 'net savings'. This means that mitigation water is provided in advance of any calculation of formal water savings from the project and must be provided as an obligation of NVIRP, providing assurance that significant impacts on MNES will be avoided irrespective of the level of water savings achieved. NVIRP is confident of achieving up to 425 GL of water savings.

The WCMF (Section 9) sets out the criteria for assessing the need for mitigation water. Assessment of the need for, and quantities of, mitigation water was undertaken in the preparation of NVIRP EWPs. Determination of volumes of mitigation water is based on outfall water volumes recorded in the NVIRP baseline year (generally 2004–05). In the majority of cases, actual outfall volumes will be less than what is required to support all water-dependent environmental values of a particular wetland or waterway. The outfall water only forms part of the overall volume required to provide the water regime of the wetland and therefore provision of mitigation water will only provide for part of the water regime of the wetland or waterway.

Mitigation water can be a combination of the project's gross water savings, unregulated flows, drainage flows, existing passing flow requirements as specified in bulk entitlements or obligations on the loss provision as specified in bulk entitlements.

Requirements for mitigation water, as determined by EWPs, are shown in Table 5-4.

5.1.4. Other WCMF requirements

5.1.4.1. Environmental infrastructure register

An environmental infrastructure register has been developed of irrigation infrastructure which is used, or could be used, to deliver environmental water to wetlands or waterways.

NVIRP's environmental infrastructure register (NVIRP 2009b) identifies all wetlands connected to irrigation systems. This is to address the risk that channels that are not included in the backbone but provide water access to significant environmental assets could be decommissioned without regard to the need to retain capability to undertake environmental watering.

The Register requires NVIRP to monitor the connection. If the wetland has been identified as receiving outfall water, NVIRP will undertake a risk assessment and determine appropriate mitigation measures (normally expected to be an EWP).

5.1.4.2. Local Groundwater Assessments

NVIRP undertakes local groundwater assessments (e.g. HydroEnvironmental 2010), as required by the WCMF (Section 17.2.3), to:

- assess whether or not a reduction in channel recharge groundwater is likely to significantly impact on high environmental values associated with the wetland, including matters of national environmental significance
- recommend for EWPs to be prepared where significant impacts on high environmental values associated with a wetland will (or are likely to) occur.

These local groundwater assessments address Condition 5 of NVIRP's approval under the EPBC Act which states that:

- where a wetland that supports or is likely to support Matters of National Environmental Significance (MNES) occurs within 200 metres of a channel for which decommissioning or lining is considered, the person taking the action must ensure that:

    a) qualitative and quantitative impacts of the consequent loss of groundwater on that wetland are assessed

    and

    b) if significant impacts are expected or considered likely, an environmental watering plan for that wetland is prepared, or plans to decommission or line the channel abandoned (DEWHA 2010).

Any assessment to meet this condition also addresses the requirements under the State Minister for Planning's exemption from requiring an Environmental Effects Statement, NVIRP's WCMF, and its obligations under Victorian legislation to minimise impacts on State protected matters.

A method for quantitatively assessing the hydrological effects of modernisation on nearby wetlands is described in NVIRP's water change management framework (Sec 17.3.2); Section 5.4.2.1 of the PER; and its supporting documentation provided to the Commonwealth Government as part of NVIRP's submission for approval under the EPBC Act .

5.2. Construction environmental management framework (CEMF)

NVIRP prepared a construction environmental management framework (CEMF). The CEMF contains a statement of environmental commitments and performance requirements, which includes compliance with applicable Regional River Health Strategies, relevant Regional Catchment Strategies and Victoria's Native Vegetation Framework, together with processes and methodologies for assessing potential impacts on native vegetation and listed flora and fauna. The CEMF was approved by the Minister for Planning in May 2009.

The CEMF contains the following strategies, plans and protocols:

- native vegetation management strategy, describing how NVIRP will manage and control the potential impacts on native vegetation from capital works. The native vegetation offset management strategy and associated plans are subsidiary to this strategy

- flora and fauna management strategy, describing how NVIRP will manage and control the potential impacts on Commonwealth and state listed flora and fauna from capital works

- cultural heritage management strategy, describing how NVIRP will manage and control the potential impacts on Aboriginal cultural heritage from capital works
- capital works environmental management plans, setting out the specific management controls for a particular program of modernisation
- connections protocol, describing how potential environmental impacts will be indentified and how landholders and their contractors will be guided in managing the environmental approvals for the connections program
- communication and consultation protocol.

NVIRP conducts internal audits against the requirements of the CEMF. In addition, an independent environmental audit of the activities and outcomes of each program of modernisation is conducted annually. The Secretary DSE (or delegate) and the Minister for Planning (or delegate) are consulted in confirming the detailed scope of the audit. The appointment of the independent auditor is agreed with the Secretary, DSE. The audit findings are provided to DSE and the Department of Planning and Community Development.

The CEMF provides another assurance that any unforeseen impacts of NVIRP are detected and managed.

5.3. Other processes

The Victorian Government's commitment to allocate a large part of the water savings from the operation of NVIRP to environmental flows provides a high measure of assurance that any potential or actual risk to aquatic and riparian ecosystems from reduced flows (due to more efficient supply infrastructure) can be mitigated through EWPs or otherwise rectified through adaptive management.

Victoria has well developed processes for assessing and managing the salinity impacts of works and activities in line with the provisions of the Basin Salinity Management Strategy (MDBC 2001). In addition, regional processes involving CMAs and relevant agencies support these activities. For example, both the Goulburn Broken and North Central CMAs are implementing projects assessing the potential impacts of recent rainfall events on groundwater levels.

Any potential salinity and groundwater impacts of the use of environmental water entitlements should be managed via these existing processes.

5.4. EWP assessment - wetlands

Table 3-1 lists the type and number of wetlands in the GMID and also notes where NVIRP wetland EWPs have been prepared. Preparation of an NVIRP EWP indicates that there may be an impact associated with the operation of NVIRP and that the impact has been assessed and, where necessary, mitigated via the preparation of an EWP.

Based on numbers of wetlands alone (Table 5-3) it can be seen that NVIRP may have an impact on only a small number of wetlands across the GMID, with permanently saline wetlands being potentially the most affected (two of 13 wetlands). For other wetland types NVIRP EWPs have been prepared for only a few per cent of the total number, indicating the NVIRP's impact on most wetland types across the region is very limited.

In addition, analysis in Section 4.5 suggests that freshwater meadows and shallow freshwater marshes are most vulnerable to changes in state due to their shallow depth. A map of wetland distribution across the region indicates that freshwater meadows and shallow freshwater marshes are relatively widely distributed across the GMID (Figure 3-1). These wetland types occur both within and outside of the major irrigation areas where NVIRP activities will occur. Hence at a regional landscape scale it is likely that the number of affected wetlands and waterways is relatively small compared to the total number of wetlands in the region (Table 3-1 and Table 5-3), and given the even distribution, the regional significance is likely to be low.

Table 5-4 lists wetland classification pre and post NVIRP. This information has been extracted from the NVIRP EWPs which note the pre 1788, current and management objective classification of the wetland. It indicates that, with two exceptions, the wetland classification will not change after the implementation of NVIRP. Six of these NVIRP wetland EWPs identified the requirement for mitigation water.

Table 5-3: NVIRP EWPs by wetland type

Wetland type (based on Corrick and Norman 1980)	Definition	Number and percentage of total	Number and percentage of NVIRP EWPs prepared (by wetland type)
Freshwater meadows	Temporary wetlands often less than 30 cm deep and inundated for less than 4 months.	380 (37%)	0 (0%)
Shallow freshwater marsh	Seasonal wetlands with a depth up to 50 cm, flooded for less than 1 year.	285 (28%)	1 (<1%)
Deep freshwater marsh	Semi-permanent wetlands up to 2 m deep.	97 (10%)	4 (4%)
Permanent open freshwater	Deep freshwater wetlands (> 2m) that hold water on a permanent basis.	199 (20%)	2 (1%)
Semi-permanent saline wetlands	Dry out each year and are less than 2 m deep.	45 (4%)	0 (0%)
Permanent saline wetlands	Permanent wetlands with salinities greater than 4400 µS/cm.	13 (1%)	2 (15%)

Table 5-4 also shows, for each wetland, the mean long-term annual controlled inflow[6] and the volume of mitigation water required to mitigate NVIRP impacts (annualised baseline mitigation water). The ratio of mitigation water to the long-term controlled inflow required varies from 0 per cent to 55 per cent, with four wetlands varying from 9 per cent to 15 per cent and two around 50 per cent. There is no consistent pattern (e.g. wetland type) to this ratio. This indicates that the impacts of NVIRP on most wetlands are relatively modest (as indicated by a small proportion on mitigation water requirement), but even where the impact may be high, the volume of mitigation water to be provided should substantially mitigate NVIRP's impact.

However, it should be noted that full implementation of the EWP will often be dependent on factors other than mitigation of NVIRP impacts. For example, implementation and achievement of management objectives may require provision of NVIRP mitigation water as well as environmental water from other sources (for example, Lake Elizabeth EWP (NCCMA 2010b)).

The two wetlands where current and post NVIRP wetland classification changes are Lake Elizabeth and Lake Leaghur.

---

[6] The total amount of water to be put into the wetland annually in a controlled fashion to achieve the specified level and the desired regime (excluding natural inflows from rainfall and local catchment runoff). This is the average volume over the modelled period).

Table 5-4: Wetland classification pre and post NVIRP (wetlands for which an EWP has been prepared) (MLTACIR = mean long-term annual controlled inflow required to provide desired water regime; ABMW = annualised baseline mitigation water)

Wetland EWP (MLTACIR ML/yr)	Mitigation Water determination (ABMW ML)	Pre 1788 wetland classification	Wetland classification pre NVIRP	Expected wetland classification after EWP implementation
Johnson Swamp (814)	N (0)	Shallow freshwater marsh	Deep freshwater marsh	Deep freshwater marsh (but with extended drying phases)
Lake Elizabeth (556)	Y (267)	Permanent open freshwater	Permanent saline	Semi-permanent saline
Lake Murphy (1157)	N (0)	Shallow freshwater marsh	Deep freshwater marsh	Deep freshwater marsh
McDonald Swamp (1298)	Y (121)	Shallow freshwater marsh	Shallow freshwater marsh	Shallow freshwater marsh
Lake Leaghur (447)	Y (447)	Deep freshwater marsh	Permanent open freshwater	Deep freshwater marsh
Lake Yando (284)	N (0)	Deep freshwater marsh	Deep freshwater marsh	Deep freshwater marsh
Little Lake Boort (645)	Y (96)	Permanent open freshwater	Deep freshwater marsh	Deep freshwater marsh
Lake Meran (1440)	Y (147)	Permanent open freshwater	Permanent open freshwater	Permanent open freshwater
Round Lake (475)	Y (262)	Deep freshwater marsh	Permanent saline	Permanent saline

Lake Elizabeth is expected to change from permanent saline to semi-permanent saline. The goal for Lake Elizabeth recommends a drier operating regime and hence differs from previous management goals, which focused on maintaining the values of a permanent lake. The process for determining the goal involved assessing the values the wetland has historically supported and the likely values it could support into the future considering climate change. It was determined that the goal needed to be achievable and that the water regime needed to support the values in the long-term (i.e. ensure viability of species and habitats in into the future) (NCCMA 2010b).

Lake Leaghur has been managed as a water supply reserve with the primary objective of storing and distributing water for irrigation and domestic purposes. Ecological objectives and hydrological requirements have been identified in determining a desired water regime to support high environmental values supported by Lake Leaghur. This desired water regime, and hence wetland classification, is different to that which has applied in the recent past but is consistent with its pre 1788 classification (NCCMA 2010d).

Overall, this assessment of NVIRP wetland EWPs shows that NVIRP will have minimal impact on wetlands, wetland classifications and their aquatic habitat value across the wetlands for which an EWP has been prepared. The numbers of wetlands assessed via the shortlisting process as requiring EWPs and mitigation water is small compared to the total number of wetlands across the region. The ratio of mitigation water to annual water requirement is small in most cases and there appears to be no consistent pattern in this ratio. This demonstrates that at a regional scale NVIRP can be expected to have little effect on the values of these wetlands.

5.5. EWP assessment – waterways

Of the 16 waterways assessed in the desktop assessment as being potentially at risk from NVIRP, field inspection and outfall analysis identified that only four required preparation of an NVIRP waterway EWP (Feehan 2009). NVIRP waterway EWPs have been prepared for:

- Lower Broken Creek and Nine Mile Creek (downstream of Katamatite) (Water Technology 2010)
- Campaspe River (downstream of Campaspe Weir) (NCCMA 2010a)
- Loddon River (downstream of Loddon Weir) including Twelve Mile Creek (NCCMA 2010c).

Table 5-5 summarises the outcomes of these waterway EWPs. NVIRP may lower water levels and the magnitude and frequency of summer freshes in some rivers and streams that receive outfalls. This is consistent with the assessment of risks to river channels and water-dependent habitats (Table 4-7) and Table 4-10). Individual EWPs have been developed for the river systems with known high values and the impact of NVIRP has only been significant enough in one system (Lower Loddon) to justify the delivery of mitigation water.

SINCLAIR KNIGHT MERZ
SKM

Table 5-5: Summary Outcomes of NVIRP waterway EWPs

NVIRP Waterway EWP	Outcomes of assessment
Lower Broken Creek and Nine Mile Creek (downstream of Katamatite) (Water Technology 2010)	
Flow component affected by NVIRP	Implementation of NVIRP will have negligible impact on any flow component.
Mitigation water assessment	The hydrologic assessment indicates that the vast majority of inflows to the creek system come through channel outfall structures that connect directly to the creeks A reduction in outfalls in excess of orders by 85 per cent is expected to reduce monthly inflows by less than 4 per cent in the creek system based on the 2004/05 base case. This is equivalent to approximately 6.6 ML/day along a waterway that is 196 km long and is not expected to impact on its high value environmental assets, and in particular Murray Cod and Golden Perch habitat and passage. Therefore, mitigation water is not required to protect the environmental assets. However, due to the ongoing dependency of the environmental values on ordered inflows, the delivery of water through the irrigation areas (e.g. River Murray Water passed through the Murray Valley Irrigation Area) to the Broken Creek should continue. Mitigation water was assessed as not required.
Campaspe River (downstream of Campaspe Weir) Reaches 3 and 4 (NCCMA 2010a)	
Flow components affected by NVIRP	*Reach 3* - Based on the recent conditions assessment indicates a 1per cent reduction in both low (25^{th} percentile, 430 ML/month pre-NVIRP) and high (75th percentile, 1,020 ML/month pre-NVIRP) flows. Overall, the results show that based on both the long-term and recent conditions assessment, the reduction in Reach 3 outfalls due to NVIRP is expected to have a limited impact on flow (less than 5 per cent) at Rochester. *Reach 4* - the recent conditions assessment of the impact over the irrigation season (August to April) indicates that low flows will be most affected, though high flows will still be slightly affected.
Mitigation water assessment	Due to the low volumes of outfall water supplied to Reach 3 over the past 10 years in comparison to the volumes required to support the Reach 3 environmental values, it is reasoned that outfalls are not supporting high environmental values at the waterway. Mitigation Water assessment demonstrates that the outfall water does not provide benefit to Campaspe River Reach 3. Therefore mitigation water is not required to maintain the environmental values of the waterway. Mitigation water assessment demonstrates that the outfall water does not provide benefit to Campaspe River Reach 4. Therefore mitigation water is not required to maintain the environmental values of the waterway. Reducing channel outfalls for Reach 4 is not likely to increase the risk to environmental values within Reach 4, due to: • the low volumes of outfall water supplied to the Reach 4 over the past 10 years in comparison to the volumes required to support the Reach 4 environmental values

NVIRP Waterway EWP	Outcomes of assessment
	• pattern of outfall water is generally small and influenced by irrigation demand and less influenced by rainfall • reduction in outfall volumes is likely to have an insignificant impact on the saline pools of the Lower Campaspe River.
Loddon River (downstream of Loddon Weir) (NCCMA 2010c)	
Flow components affected by NVIRP	*Loddon River Reach 4* **–** reduction in Loddon River Reach 4 outfalls due to NVIRP is expected to lead to a reduction in irrigation season flows at Appin South over the whole flow range. *Twelve Mile Creek* – overall the contribution of channel outfalls to the flow in the Twelve Mile Creek is very small. *Loddon River Reach 5* **–** outfalls have historically been supporting the base or low flow components of the flow regime at relatively low outfall volumes, and that higher flows are relatively rare.
Mitigation water assessment	*Loddon River Reach 4* Assessment demonstrates that the outfall water provides benefit to Loddon River Reach 4 and that the provision of mitigation water is warranted if it is managed for environmental purposes because: • flows over the irrigation season will be affected over the whole flow range and particularly the low and average flows • the occurrence of summer cease-to-flow conditions will also be increased by the reduction in outfalls due to NVIRP from 2 per cent of months pre-NVIRP to 18 per cent of months post-NVIRP • the desired flow regime required based on revised environmental flow recommendations is to meet summer fresh and summer base-flows and operate the reach as a permanently flowing stream to maintain aquatic habitat and water quality • significant species including Murray Cod, Silver and Golden Perch are likely to be impacted by a significant reduction in flows including increasing cease to flow from 2 per cent to 18 per cent. An annualised baseline mitigation water volume of 624 ML/yr was calculated. ***Twelve Mile Creek*** Assessment demonstrates that the outfall water does not provide benefit to Twelve Mile Creek. Therefore, mitigation water is not required to maintain the environmental values of the waterway. ***Loddon River Reach 5*** Assessment demonstrates that the outfall water provides benefit to Loddon River Reach 5 and that the provision of mitigation water is warranted if it is managed for environmental purposes because: • flows over the irrigation season will be affected over the whole flow range and particularly the low flows • the desired flow regime required based on revised environmental flow recommendations includes meeting summer fresh and summer

NVIRP Waterway EWP	Outcomes of assessment
	base-flows. Reach 5 will be operated as a permanently flowing waterway to rehabilitate and maintain the native fish community, other aquatic habitat and water quality • Loddon River Reach 5 is very important for native fish by providing habitat and as an important corridor for fish movement between the Murray River and the Loddon River • significant species including Murray Cod, Silver and Golden Perch will be impacted by a reduction in flows, particularly low flows. For example, reduced low flows will impact on water quality and persistence in permanent pools and therefore impact on fish species. An annualised baseline mitigation water volume of 1814 ML/yr was calculated.

Assessment of the outcomes of NVIRP waterway EWPs indicates that NVIRP impacts are variable and should be assessed at a waterway or reach scale if required.

5.6. Assessment of impacts on Goulburn and Murray Rivers

Assessment of the impacts of NVIRP on the Goulburn and Murray Rivers has been undertaken as part of the PER (NVIRP 2010) and to meet the conditions of the Victorian Planning Minister's decision not to require an EES. This assessment concluded:

- changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable and that no impact on significant environmental values are expected
- changes in groundwater levels and flows are negligible
- changes in river salinities would be too small to have any effect on ecological values
- the additional impact over and above that predicted due to climate change is considered to be insignificant
- NVIRP will not affect any of the current biological values at the assessed sites.

5.7. Groundwater assessment

The WCMF calls for preparation of a report setting out:

- the cumulative impacts of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID

- the cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring EWPs (i.e. ‘at risk’).

Information presented in Section 3 indicates that:

- changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable and that no impact on significant environmental values are expected
- changes in groundwater levels and flows across the region are negligible
- changes in river salinities would be too small to have any effect on ecological values
- the additional impact over and above that predicted due to climate change is considered to be insignificant
- NVIRP will not affect any of the current biological values at the assessed sites.

This suggests that the cumulative impact of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology at a regional scale of the GMID and in the context of seasonal variation is minimal. Hence the approach taken of addressing NVIRP impact of works (e.g. channel lining and regulator gate and meter installation) at a site by site level and focusing the consequence locally though EWP preparation, is sound.

5.8. Salinity and groundwater impacts of NVIRP mitigation measures

The WCMF (Sec 17.2) calls for the groundwater assessment to review the management and mitigation measures implemented or proposed by NVIRP, particularly the EWPs in respect to actions designed to minimise and mitigate groundwater and salinity related impacts.

All wetland EWPs and two of three waterway EWPs addressed these groundwater and surface water interactions from the perspective of how they might affect achievement of the wetland or waterway management objectives (summarised in Table 5-6).

No measures were identified as necessary to address risks associated with salinity and groundwater.

This suggests the cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring EWPs (i.e. ‘at risk’) is minimal and that no additional management and mitigation measures are required.

Table 5-6: Summary of EWP assessment of salinity and groundwater issues

Wetland EWP	How the EWP assessed salinity and groundwater issues (summarised from EWPs)
Johnson Swamp	Previous recommendations for management of Johnson Swamp were based on managing the risk of groundwater (with a salinity of 30-40,000 µS/cm) intrusion. If Johnson Swamp is left in a dry (or predominantly dry) state, it may accumulate and retain relatively high salt levels without sufficient water to flush these into the groundwater system, and hence may impact on plant species composition/health. It is expected that subsequent periodic environmental watering of Johnson Swamp will have some temporary impact on the watertable locally and will assist in moving salt away from the lake without causing significant risk to adjacent areas, provided the watering is not too frequent (e.g. once every two or three years).
Lake Elizabeth	There is significant interaction between the surface water in Lake Elizabeth and the underlying groundwater table (which has historically recorded salinity levels of between 30,000 and 40,000 µS/cm). Lack of data and the very recent and previously unrecorded low lake level (and lack of certainty about the accuracy of the current AHD lake level) makes it difficult to predict with much confidence how the local groundwater configuration will alter.
Lake Murphy	The hydrograph record shows a history of dynamic groundwater behaviour with watertable levels in the vicinity of Lake Murphy corresponding well to wetland levels. It is expected that subsequent environmental water delivery to Lake Murphy will have some temporary impact on the watertable locally and assist in moving salt away from the wetland without causing significant risk to adjacent areas.
McDonald Swamp	Prior to 2002, the groundwater levels were higher than the wetland bed (74.70 m AHD), nearing the surface water level. The data also illustrates seasonal fluctuations in response to recharge and evapotranspiration. However, since 2002, groundwater levels have declined dramatically and are now approximately 2 m below the bed. Bores within the vicinity of McDonald Swamp show extremely high, fluctuating EC levels in excess of 40,000 µS/cm. If regional groundwater levels rise and McDonald Swamp is dry, there is a risk of saline groundwater discharge into the wetland.
Lake Leaghur	The monitoring record shows a surface water level consistently higher than the groundwater level. Therefore, when Lake Leaghur is inundated, it would be a source of groundwater recharge. Bores within the vicinity of Lake Leaghur show fluctuating EC levels with mean values ranging from 5,289 µS/cm to 33,681 µS/cm in the northwest. Intermittent watering of Lake Leaghur is likely to result in localised groundwater mounding.
Lake Yando	Groundwater levels within close proximity to Lake Yando have fluctuated over time. Data from bores within the vicinity of Lake Yando show fluctuating EC levels. Intermittently inundating Lake Yando is likely to result in a local temporary impact on watertable level. However, as groundwater levels are currently >3 m deep there is no significant risk of adverse impact on the

Wetland EWP	How the EWP assessed salinity and groundwater issues (summarised from EWPs)
	wetland or neighbouring land through watertable rise.
Little Lake Boort	There are no groundwater bores at Little Lake Boort; currently, there is no evidence of groundwater discharge into the wetland. The data suggests that as the water levels decline in Little Lake Boort, salinity increases through evaporation.
Lake Meran	The monitoring record shows a downward hydraulic gradient beneath Lake Meran which indicates groundwater recharge. Based on limited data, current groundwater levels appear to be below the bed level with no significant groundwater discharge currently occurring at the wetland edge or floor; however, bores further from Lake Meran show regional groundwater levels above the bed level. Intermittent watering of Lake Meran is likely to result in localised groundwater mounding; however, as it appears that groundwater is currently below the bed of the wetland there is no significant risk of adverse impact on the wetland or adjacent land through watertable rise.
Round Lake	At present, there is a strong downward hydraulic gradient beneath Round Lake, which has increased in strength in conjunction with regional groundwater declines and high manipulated surface water levels. Salinity levels within Round Lake have been steadily falling since 2004.
Broken Creek	Changes in surface water/groundwater interaction as a result of the NVIRP have potential impacts on the identified environmental assets. The impacts of NVIRP on regional groundwater, with resultant local impact on waterways are documented in other studies (SKM 2008) prepared in support of the NVIRP approvals process and are not specifically considered in this EWP.
Campaspe River	Campaspe Reach 4 is also influenced by saline groundwater with saline pool stratification occurring in the reach. Reduction in outfall volumes is likely to have an insignificant impact on the saline pools of the Lower Campaspe River.
Loddon River	Not assessed.

NB - the starting point for the assessment is taken to be before the recent rise in groundwater levels as a consequence of recent rain and flood events. It is a reasonable assumption that the groundwater levels and salinity have adjusted dramatically as a consequence of the floods.

5.9. Assessment of residual risk

Residual risk is the risk remaining after risk treatment (Standards Australia 2009). This Section assesses residual risk based on the risks identified in Section 4 and the application of the risk management tools discussed above.

This assessment only considers risks with ratings greater than or equal to medium. Risks with ratings of low or insignificant are not considered to need treatment since they are either not impacted by NVIRP (i.e. Likelihood is *Unlikely* or *Rare*) or their consequences are *Minor* or *Negligible* and are therefore considered acceptable.

Tables 5-7A and B present the outcomes of this assessment. In summary, all risks are reduced to acceptable ratings (i.e. low) by the application of NVIRP risk management measures.

Table 5-7A: Wetlands - Summary of risk, risk management and residual risk (L = likelihood; C = consequence; L(R) = likelihood after risk management; C(R) = consequence after risk management; R(R) = residual risk after risk management; classification and ratings from Tables 2-2, 2-3 and 2-4)

No.	Wetland in conceptual model	L	C	Risk on a regional scale (from Table 4-7)	NVIRP Risk Management	L (R)	C (R)	R (R)	Comment/uncertainty
1c	River channels that receive outfalls	*L*	*Mo*	The risk to ecological values in river channels that receive outfalls is medium as NVIRP is likely to reduce outfall contributions to low flow components, which may represent a moderate impact to the values sustained by these flows. A reduction in low flows may reduce the quality and quantity of permanent or refuge habitats and may also allow terrestrial plants to become established closer to the bottom of the channel. Values and functions that rely on higher flow components will not be affected by NVIRP.	• shortlisting assessments and reports • desktop validation • preparation of EWPs for potentially ‘at risk’ waterways • River Murray and Goulburn River assessments • provision of mitigation water as required • environmental Infrastructure Register • other processes o salinity management o environmental water management.	*U*	*Mo*	*L*	Assumes hydrological and hydrogeological modelling of impacts is adequate. Relies on assumptions about ecosystem response.
4	Wetlands that receive outfalls	*AC*	*Mo*	NVIRP is almost certain to alter the water regime in some wetlands where channel outfalls currently account for a significant proportion of the total volume of water received during a year or a particular season. Impacts in particular wetlands may be relatively severe, but given only a relatively small proportion of wetlands throughout the GMID are likely to be affected the overall consequence to ecological values and ecosystem functions is moderate. Increased terrestrialisation at the margins of some of these wetlands may occur and there may be less permanent habitat for aquatic biota. Carbon and nutrient cycling may change depending on	• shortlisting assessments and reports • desktop validation • preparation of EWPs for potentially ‘at risk’ waterways • provision of mitigation water as required • environmental infrastructure register	*U*	*Mo*	*L*	Assumes that all wetlands are assessed. Relies on assumptions about ecosystem response.

No.	Wetland in conceptual model	L	C	Risk on a regional scale (from Table 4-7)	NVIRP Risk Management	L (R)	C (R)	R (R)	Comment/uncertainty
				extent and frequency of wetting and drying patterns. The overall risk of reduced outfalls to wetlands is considered high and should be mitigated.	• other processes: o salinity management o environmental water management.				
		?	?	The potential for ASS not known.		-	-		Highly uncertain – reassess after MDBA study completed
5	Local bank and service point leakage	*AC*	*Mi*	The risk to ecological values in areas of local bank leakage is medium because NVIRP is almost certain to dry up these wetted areas during summer through lining or decommissioning channels. This presents a minor impact because it is low value habitat, but these wetted areas may provide habitat in dry periods or increase landscape connectivity. Changes to these habitats are unlikely to reduce connectivity between aquatic habitats or access to water in the landscape because these habitats are adjacent to irrigation channels that are a reliable source of water.	• local groundwater assessments • if required, o EWP preparation o provision of mitigation water.	*U*	*Mi*	*L*	Assumes all relevant wetlands are assessed.

Table 5-7B: Biological indicators - Summary of risk, risk management and residual risk (L = likelihood; C = consequence; L(R) = likelihood after risk management; C(R) = consequence after risk management; R(R) = residual risk after risk management. Classification and ratings from Tables 2-2, 2-3 and 2-4)

Biological indicator	Sub-groups	L	C	Risk on a regional scale (from Table 4-10)	NVIRP Risk Management	L(R)	C(R)	R(R)	Comment/uncertainty
Vegetation	Submerged vegetation * Amphibious vegetation Terrestrial vegetation	*L*	*Mo*	Submerged vegetation communities are at medium risk from NVIRP due to potential reductions in outfalls that maintain water in wetlands over the dry summer period. Annual submerged vegetation species may have an advantage over perennials, or they may be overtaken by amphibious species.	• shortlisting assessments and reports • desktop validation • preparation of EWPs for potentially 'at risk' waterways • provision of mitigation water as required • environmental Infrastructure Register • other processes: o salinity management o environmental water management.	*U*	*Mo*	*L*	Residual likelihood could range from unlikely to possible – some uncertainty associated the residual risk rating.

5.10. Residual uncertainty

There are two main sources of uncertainty associated with this regional assessment. Firstly, previous site-specific assessments have only considered wetlands that are known to support species of high conservation significance. Secondly, the hydrological and conceptual models used to inform the assessment rely on some untested assumptions or may not have been verified in the GMID region. These issues are discussed below.

5.10.1. Omissions from previous assessments

There are 1,137 distinct wetlands[7] that have been identified throughout the GMID (SKM 2008a). Of these, 573 were identified as having potentially significant environmental values (SKM 2008a). These 573 wetlands were further assessed to determine whether reduced channel outfalls were likely to represent a threat to EPBC Act listed values. It was concluded that the hydrological changes associated with NVIRP were likely to represent a threat to values in only 10 out of the 573 wetlands (NVIRP 2009a). Additional desktop assessment undertaken by BL&A (2010) validated the original SKM (2008a) assessment, indicating no additional wetlands with significant occurrences of MNES were likely to be affected.

Assessment of the potential impacts of NVIRP on all waterways in the region that receive outfalls was undertaken during the desktop assessment (SKM 2008a) and shortlisting process (Feehan Consulting 2009). There is no uncertainty about waterway assessments.

Some of the remaining 564 wetlands, as well as any additional unmapped or un named wetlands, that may rely on channel outfalls to support their ecological values and ecosystem functions may have been overlooked in the assessments to date because their ecological values are unknown, or they do not support any EPBC-Act-listed species. Bank leakage areas near channels were also excluded because they were not named or natural wetlands. The wetlands that have not been assessed to date are likely to include many relatively small, shallow waterbodies, which are widely distributed across the GMID but typically lack available information to support site-specific assessments. As already noted, these types of wetlands are probably most vulnerable to the hydrological changes associated with NVIRP.

Given the large number and wide distribution of freshwater meadows and shallow marshes across the GMID, it is not surprising that there is a lack of information on the specific values of these habitats. While they may or may not support species listed under EPBC or FFG Acts, the presence of numerous small wetlands throughout the region may be of high environmental value at a landscape scale because of the connectivity they provide for the movement of flora and fauna.

---

[7] See Footnote 1

Frequent wetting and drying patterns in these wetlands are also important for carbon and nutrient cycling – when wet, these habitats can support large numbers of macroinvertebrates, which provide food for other vertebrates.

In addition to wetlands that may be supported by outfalls, bank leakage from channels has the potential to support localised wetlands across the landscape. It is reasonable to assume that channel lining or decommissioning will ultimately result in a drying out of these habitat types. The extent to which they support ecological values and ecosystem functions is also not known; however, it is likely that they provide some habitat for birds, frogs and reptiles on some occasions. At a site scale the drying of these sites is unlikely to represent a significant risk to landscape scale values, but collectively could result in a cumulative drying across the landscape that does result in a reduction in suitable habitat for some biota. The number and distribution of these habitat types across the landscape is not known, hence it is difficult to provide further assessment. Mitigation for these habitats may be needed at a local scale once specific locations are identified during planning for works.

This uncertainty associated with omissions from previous assessments is addressed by NVIRP:

- undertaking local groundwater assessments (Section 5.1.4.2)
- maintaining an environmental infrastructure register (Section 5.1.4.1)
- implementing the construction environment management framework (Section 5.2).

Overall the uncertainty associated with omissions from previous assessments is adequately addressed by NVRIP's assessment processes and the Environmental Infrastructure Register. This uncertainty would not affect the conclusions of this report.

5.10.2. Hydrological and hydrogeological modelling

There is also uncertainty around the modelling of hydrological and hydrogeological impacts. Data from specific gauge locations is used to infer a hydrological response across a river reach, which could be tens to hundreds of kilometres long. The impact of NVIRP, as modelled at gauge locations, is assumed to be representative of the impacts across the broader reach that is represented by that gauge. Other assumptions around the volumes of outfalls, patterns of water distribution and operational complexity also exist. Uncertainty in the hydrogeological analysis exists regarding the assumptions made for seepage and leakage rates, the distribution of and salinity of groundwater across the GMID, flux rates etc. All these areas of uncertainty in the hydrological and hydrogeological analysis, and associated implications for the assessment, are presented in documents supporting the PER (i.e. SKM 2009a and SKM 2009b).

On balance, because the hydrological changes associated with NVIRP are predicted to be small there are no areas of significant uncertainty that would affect confidence in the overall conclusions raised in this report.

5.10.3. Ecosystem response

There is a certain level of uncertainty in the expected ecosystem response to changes in flow and water level and also uncertainty in what constitutes a significant change in water level (i.e. threshold change) from an ecological response perspective.

5.10.4. Acid sulfate soils

A noted in Section 4.4.3.1.3 the incidence of ASS within or adjacent to the GMID and the impact of NVIRP on these sites cannot be assessed further at this time.

Once this information becomes available NVIRP should undertake an assessment using the WCMF as the appropriate framework to determine any possible impacts, and if necessary devise mitigation measures.

5.10.5. Uncertainty summary

Overall, the uncertainty associated with omissions from previous assessments is adequately addressed by NVRIP's assessment processes and the Environmental Infrastructure Register. This uncertainty would not affect the conclusions of this report.

The models used for the hydrological assessments and the analyses of ecological impacts do provide a good indication of the likely changes, but may not accurately predict outcomes at individual locations. However, they are based on the best information available at the time of assessment and are considered fit for purpose. They are adequate for the purposes of assessing potential impacts at the scale of this assessment. In future, it will be important to monitor hydrological and ecological changes throughout the GMID and adaptively manage any threats that are identified.

Once relevant information becomes available, hazards associated with the implementation of NVIRP and ASS should be assessed. Unacceptable risks will be addressed by application of the adaptive management framework of the WCMF.

5.11. Cumulative effects

Based on the above discussion it is concluded that the cumulative impacts of NVIRP on the environmental values of waterways and wetlands and on the waterways and wetlands requiring EWPs are minimal because:

- the spatial impact of NVIRP on waterways and wetlands is limited (indicated by the numbers of these features affected by NVIRP). Only nine of 1,019 wetlands identified in the GMID have been assessed as being at risk and requiring preparation of an NVIRP wetland EWP
- the impact of NVIRP on the water regime of wetlands (indicated by wetland type) and waterways for which EWPs have been prepared is limited. The outcomes of the PER and the Murray, Goulburn and Barmah assessments confirm this. This demonstrates that at a regional scale NVIRP can be expected to have little effect on the values of these wetlands
- of sixteen waterways identified as potentially at risk, only three NVIRP waterway EWPs have been required to be prepared and only one of these has recommended that mitigation water be provided, indicating that the waterway impacts of NVIRP are limited at a regional scale
- risk assessment shows NVIRP's mitigation measures address likely impacts
- the shortlisting processes rigorously assessed values and potential impacts
- the impacts of NVIRP works and their implementation on the hydrology and hydrogeology of the GMID are minimal because the hydrological and hydrogeological changes due to NVIRP are very small and are unlikely to have any effect on biota or other environmental values.

It has been determined that the combined or sum of the individual effects is not greater than the individual effects alone and that NVIRP's environmental impact assessment approach of focusing of the individual effects is sound and fit for purpose.

5.12. Additional management and mitigation measures

From the information presented above is concluded that the current NVIRP management and mitigation measures are adequate to address potential risks of NVIRP to aquatic habitats and biotic indicators. These processes are adaptive and include regular review and reporting. It can be assumed that any unforeseen risks can be managed using these processes.

No additional management and mitigation measures are currently required.

SKM
SINCLAIR KNIGHT MERZ

6. Conclusion and evaluation against WCMF requirements

6.1. Conclusion

From the information presented above it can be concluded:

- NVIRP presents risk to some aquatic habitats and biotic indicators
- NVIRP has a range of processes, covering risk assessment and risk management that identify risks to aquatic habitats and biotic indicators
- NVIRP's processes are adequate to identify and assess potential sites at risk because:
    - NVIRP has implemented a rigorous process for identifying potential 'at risk' waterways and wetlands
    - For sites identified 'at risk' a further rigorous process for assessing NVIRP impacts and determining the need for mitigation has been implemented
    - Sites deemed to be not at risk from NVIRP impacts but which might become 'at risk', are identified via the Environmental Infrastructure Register or Local Groundwater Assessments
- NVIRP's processes are adaptive and subject to review and refinement
- NVIRP has a number of risk mitigation options that can be implemented to reduce risks to acceptable ratings. Relevant risk management options are identified through the preparation of EWPs
- The cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring EWPs (i.e. 'at risk') is minimal
- The cumulative impacts of NVIRP work (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID are considered to be minimal
- The cumulative impacts of NVIRP on the high environmental value waterways and wetlands are considered to be minimal
- No additional management and mitigation measures are required.

These conclusions support the reasons for the Minister's decision to not require an EES, particularly the need to apply an adaptive approach to mitigation.

6.2. Legacy of NVIRP

Apart from the provision of environmental water recovered via NVIRP there are, or will be, a number of benefits resulting from NVIRP implementation that can be considered as NVIRP's environmental water management legacy. This legacy includes:

- the development of the WCMF and associated practices that can provide the basis for enhanced and adaptive environmental management of waterways and wetlands across northern Victoria
- higher level understanding of the environment of the GMID via the preparation of WCMF assessments and document and the preparation of the EPBC Public Environment Report. This information will be essential in making future management decisions
- enhanced environmental management capability of agency staff involved in wetland and waterway management via involvement in WCMF processes
- enhanced capacity to undertake environmental watering through a modernised system.

6.3. Evaluation against WCMF requirements

Tables 6-1 and 6-2 present short summaries of project findings against the requirements of the WCMF (Sec 1-2, 1-3 and Table 2-1).

Table 6-1: Evaluation against Regional Environmental Assessment requirements

REA requirements	Evaluation - summary	Response to requirements	Relevant section
The Regional Environmental Assessment should address:			
▪ Potential effects of the implementation of NVIRP on aquatic ecosystems and functions including effects on listed species and communities, and listed migratory species;	The GMID and its ecosystem values and water-dependent habitats are described at the regional scale. Biological indicator groups (fish, birds and vegetation) and conceptual models were used to assess the impacts of NVIRP on specific components of the water regime that are critical to the survival of plants and animals across the landscape. The GMID contains significant ecological landscape values. These values include a range of habitat types, biota and ecosystem functions that may be affected by changes to surface water and groundwater hydrology caused by NVIRP. Landscape scale values and ecological functions are a function of the distribution of different habitat types across the region and the wetting and drying regime experienced by these habitat types. Values include presence of plant and animal species, communities of conservation significance and landscape scale ecosystem functions such as connectivity between habitats for biota and hydro-geochemical processing (i.e. nutrient processing and energy dynamics). Wetlands that have either direct or indirect connections to the irrigation system are likely to become drier as a result of NVIRP and in some cases there may be a permanent shift to a drier wetland type. However, in the context of other risks	Shallow wetlands (freshwater meadows and shallow freshwater marshes) and small rivers and creeks that receive direct outfalls from irrigation channels and drains are most at risk from NVIRP. While some impacts may occur at individual sites, the overall landscape scale impact is expected to be small because these systems appear evenly spatially distributed across the GMID, both within and outside of specific irrigation areas.	3, 4.44.6

REA requirements	Evaluation - summary	Response to requirements	Relevant section
	(e.g. climate change), NVIRP provides a low risk to the water regimes of water-dependent habitats that support ecological values in the landscape.		
▪ Effects on regional groundwater and surface water resources	The hydrological impacts of NVIRP on surface water and groundwater across the region are described in detail in the Public Environment Report (PER) and are summarised in this report.	Changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable. Changes in groundwater levels and flows are assessed as negligible. The additional impact over and above that predicted due to climate change is considered to be insignificant.	4.1.2
▪ Effects on salinity	The effects of NVIRP on surface water, groundwater and salinity across the region are described in detail in the PER and are summarised in this report..	Changes in river salinities are likely to be very small.	4.1.2.4 and 4.1.2.4
• Following the completion of the Environmental Watering Plans (EWPs) for the relevant program of works, NVIRP will review the EWPs as a whole and consider:	EWPs have been reviewed as a whole.		5.4, 5.5
• the cumulative effects of the impact of NVIRP on high environmental value waterways and wetlands	Cumulative effects of the impact of NVIRP have been assessed by: • undertaking a risk assessment of the potential impacts of NVIRP to aquatic habitat types and biotic indicators • reviewing residual risk after implementation of available NVIRP risk management options	The cumulative impacts of NVIRP on the environmental values of waterways and wetlands and on the waterways and wetlands requiring EWPs will be minimal because: • the spatial impact of NVIRP on waterways and wetlands is limited Only nine of 1,019 wetlands identified in the GMID have been assessed as being at risk and requiring preparation of a NVIRP wetland EWP • the impact of NVIRP on the water regime of	5.11

REA requirements	Evaluation - summary	Response to requirements	Relevant section
	• reviewing EWPs as a whole • reviewing changes to wetland classification pre and post NVIRP • considering the number of waterways and wetlands potentially affected by NVIRP • considering NVIRP's process for identifying potentially 'at risk' waterways and wetlands.	wetlands (indicated by wetland type) and waterways for which EWPs have been prepared is limited • of sixteen waterways identified as potentially 'at risk', only three NVIRP waterway EWPs have been required to be prepared and only one of these has recommended that mitigation water be provided • risk assessment shows NVIRP's mitigation measures address likely impacts • the shortlisting processes rigorously assessed values and potential impacts • the hydrological and hydrogeological changes due to NVIRP are very small and are unlikely to have any effect on biota or other environmental values.	
• whether any additional management and mitigation measures are required (to be implemented through Environmental Watering Plans.	For sites where specific risks have already been identified, Environmental Water Plans have been developed in accordance with the NVIRP Water Change Management Framework. This framework provides the process for mitigating water-related risks of NVIRP at other sites that might be identified in the future. NVIRP's Environmental Infrastructure Register and Local Groundwater Assessment ensure that all wetlands potentially at risk from NVIRP are assessed and impacts mitigated if required.	Review of EWPs indicates that relevant impacts of NVIRP have been identified and mitigated. No additional management and mitigation measures are required.	5.12

REA requirements	Evaluation - summary	Response to requirements	Relevant section
• NVIRP will prepare a Regional Environmental Assessment Report summarising the assessment and conclusions. The report will be reviewed and approved as set out in Table 12 of the WCMF.	This combined assessment report has been prepared.		
• Where regional high environmental values will be adversely affected by the operation of the modified GMID, an appropriate management and mitigation plan will be developed consistent with other policies and programs in the region.	NVIRP presents risk to some aquatic habitats and biotic indicators. NVIRP has a range of processes covering risk assessment and risk management that identify risks to aquatic habitats and biotic indicators. NVIRP's processes are adequate to identify and assess potential sites at risk NVIRP's processes are adaptive and subject to review and refinement NVIRP has a number of risk mitigation options that can be implemented to reduce risks to acceptable ratings. Relevant risk management options are identified through the preparation of EWPs. Risk assessment shows NVIRP's mitigation measures address likely impacts.	Measures additional to the WCMF to address adverse impacts of NVIRP on regional high environmental values are not required to be developed.	5.12

Table 6-2: Evaluation against Groundwater Assessment (GA) requirements

GA requirements (from WCMF)	Evaluation - summary	Response to requirements	Relevant section
The Groundwater Assessment Report is to identify and assess the potential changes to regional groundwater as a result of reduced channel outfalls, channel seepage and channel leakage associated with the implementation of NVIRP.	This report has summarised the detailed groundwater assessment prepared for the Public Environment Report.	Overall, changes due to NVIRP are relatively modest compared to changes caused by other factors such as groundwater pumping, drought and climate change.	4.1.2
The report will identify and describe the processes that may change the groundwater regime as a result of the implementation of NVIRP, taking particular account of:	Processes that may change the groundwater regime were identified in the detailed groundwater assessment prepared for the Public Environment Report. These are summarised in this report.	One of the aims of NVIRP is to reduce channel seepage and bank leakage. Upgrades to irrigation infrastructure are expected to reduce recharge to the groundwater system, and as a result, regional watertables in the shallow groundwater system (Shepparton Formation) will fall.	4.1.2
• the likely impact on wetland/lunette groups, waterways and groundwater-dependent ecosystems (GDEs) at a regional and sub-regional scale	The likely impact on wetland/lunette groups, waterways and groundwater-dependent ecosystems (GDEs) at a regional and sub-regional scale has been assessed using aquatic habitat categories and biotic indicators.	Wetlands that have either direct or indirect connections to the irrigation system are likely to become drier as a result of NVIRP and in some cases there may be a permanent shift to a drier wetland type. However, in the context of other risks (e.g. climate change), NVIRP provides a low risk to the water regimes of water-dependent habitats that support ecological values in the landscape. Shallow wetlands (freshwater meadows and shallow freshwater marshes) and small rivers and creeks that receive direct outfalls from irrigation channels and drains are most at risk from NVIRP. This is because even small magnitude reductions in outfalls could have consequences for the water regime and associated values in these small systems. While some impacts may occur at individual sites the overall landscape scale impact is expected to be small because these systems appear evenly spatially distributed across the GMID,	4

GA requirements (from WCMF)	Evaluation - summary	Response to requirements	Relevant section
		both within and outside of specific irrigation areas. At a regional scale, NVIRP presents a low risk to all these indicator groups. Where NVIRP-related hydrological changes occur in their relevant habitats, the water regime components impacted are either of low importance to the life-cycle or habitat required by the indicator group, or the effects will be minor at a regional scale. The one exception is submerged vegetation, where it is conceivable that NVIRP may contribute to a regional shift from submerged vegetation communities to more amphibious communities due to less pooled water in the landscape. This applies mostly to shallow wetlands (freshwater meadows and shallow freshwater marshes) where even small reductions in volume could impact on water regimes. However, as indicated above, these systems are well distributed across the GMID and while localised impacts may occur at specific sites, the landscape impact is likely to be small.	
• each of the types of connections (between irrigation infrastructure and wetlands) listed in Table 8.3 of the desktop assessment (SKM 2008a)	Connection types have been correlated with aquatic habitat categories, described above.	See above	4
• those actions such as channel lining and channel rationalisation designed in part or principally to address seepage and leakage of irrigation water.		Channel seepage is likely to have increased the level of the watertable above natural levels over large areas. This is likely to have been detrimental to ecological values in areas with shallow saline groundwater by bringing saline water close to the surface, where it damages plants and intersect low lying wetlands. Reductions in near-channel groundwater levels by	4.1.2

GA requirements (from WCMF)	Evaluation - summary	Response to requirements	Relevant section
		NVIRP channel lining and channel rationalisation may therefore be beneficial.	
The report will: • review the management and mitigation measures implemented or proposed by NVIRP, particularly the Environmental Watering Plans in respect to actions designed to minimise and mitigate groundwater and salinity related impacts • recommend additional management and mitigation measures which may be required, consistent with the principles and commitments of this WCMF.	Environmental Watering Plans have been reviewed Local groundwater impacts of NVIRP are assessed and, if necessary, mitigated by the preparation of Local Groundwater Assessments.	All wetland EWPs and two of three waterway EWPs addressed these groundwater and surface water interactions from the perspective of how they might affect achievement of the wetland or waterway management. No measures were identified as being required to address risks associated with salinity and groundwater. No additional measures are required.	5.8 5.12
The report will assess the cumulative impacts of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID	The hydrological impacts of NVIRP on surface water and groundwater across the region are described in detail in the PER and are summarised in this report. Changes in river levels as a consequence of NVIRP are considered so small as to be virtually undetectable and no impact on significant environmental values are expected. Changes in groundwater levels and flows across the region are negligible. Changes in river salinities will be too small to have	The cumulative impacts of NVIRP works (capital works and connections) and their implementation on the hydrology and hydrogeology of the GMID are minimal.	5.11

GA requirements (from WCMF)	Evaluation - summary	Response to requirements	Relevant section
	any effect on ecological values. The additional impact over and above that predicted due to climate change is considered to be insignificant. NVIRP will not affect any of the biological values that currently occur at the assessed sites.		
The report will assess the cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring Environmental Watering Plans (i.e. 'at risk').	EWPs were reviewed. All wetland EWPs and two of three waterway EWPs addressed these groundwater and surface water interactions from the perspective of how they might affect achievement of the wetland or waterway management. No measures were identified as being required to address risks associated with salinity and groundwater.	The cumulative impacts of NVIRP actions on the hydrology and hydrogeology of the waterways and wetlands requiring Environmental Watering Plans (i.e. 'at risk') are minimal.	5.8

7. References

Baldwin, D. and Fraser, M. (2009). Rehabilitation options for inland waterways impacted by sulfidic sediments - A synthesis. *Journal of Environmental Management* **91**(2): 311-319.

Benyon, R.G., Marcar, N.E., Crawford, D.F. & Nicholson, A.T. (1999) Growth and water use of E*ucalyptus camaldulensis* and *E. occidentalis* on a saline discharge site near Wellington, NSW, Australia. *Agricultural Water Management*, **39,** 229-244.

BL&A (2010). NVIRP Operational Impact Assessment Terrestrial Vertebrate Fauna, A report prepared by Brett Lane & Associates for NVIRP.

Boulton, A.J. and Brock, M.A. (1999) *Australian freshwater ecology: processes and management,* Gleneagles Publishing, Glen Osmond.

Brereton, D., C. Moran, et al. (2008). Assessing the cumulative impacts of mining on regional communities: An exploratory study on coal mining in the Muswellbrook area of New South Wales Brisbane: CSRM and CWiMI, Australian Coal Association Research Program, University of Queensland. http://www.csrm.uq.edu.au/docs/C14047.pdf

Brock, M.A. and Casanova, M.T. (1997). *Plant life at the edge of wetlands: ecological responses to wetting and drying patterns*. pp 181-192. In Frontiers in Ecology: Building the Links. (Eds Klomp N. and Lunt, I.). Elsevier, Oxford.

Brock, M. A. and M. T. Casanova (2000). *Are there plants in your wetland?* Canberra, Land and Water R&D Corporation.

Bunn, S.E. and Arthington, A.H. (2002) Basic principles and ecological consequences of altered flow regimes for aquatic biodiversity. *Environmental Management,* **30,** 492-507.

Cant B., James K. and Ryan T. (2003). Salt impact model - strategic framework and information to indicate biodiversity thresholds to salinity. DSE 2003.

Chee, Y.E., Webb, A., Cottingham, P. and Stewardson, M. (2006). *Victorian environmental flows monitoring and assessment program. Monitoring and evaluation of environmental flow release in the Campaspe River*, eWater CRC, Canberra

Corrick, A.H. and Norman, F.I. (1980). Wetlands of Victoria 1. Wetlands and waterbirds of the Snowy River and Gippsland Lakes Catchment. *Proceedings of the Royal Society of Victoria* **91**: 1-15.

Cottingham, P., Doeg, T., et al. (2009). *Summary of ecosystem implications of the continued qualification to Bulk Entitlements for the regulated Loddon and Campaspe River systems.*

CSIRO (2008). *Water availability in the Murray-Darling Basin*. A report from CSIRO to the Australian Government, CSIRO Murray-Darling Basin Sustainable Yields Project**:** 67. CSIRO, Australia.

DSE (1994). Wetland_1994 GIS layer, Department of Sustainability and Environment.

DSE (2003). Advisory list of threatened vertebrate fauna in Victoria. Melbourne, Department of Sustainability and Environment.

DSE (2003). Barmah Forest Ramsar Site: Strategic Management Plan. Melbourne, Victoria, Department of Sustainability and Environment.

DSE (2004). Kerang wetlands Ramsar site Strategic Managment Plan. Melbourne, Victoria, Department of Sustainability and Environment.

DSE (2009). *Northern Region Sustainable Water Strategy*. Department of Sustainability and Environment, East Melbourne.

DSE. (2011). "Victorian Riverina Bioregion." Retrieved 23 Feb 2011, from http://www.land.vic.gov.au/DSE/nrence.nsf/LinkView/FDA265C2B14C0F24CA256EEC000E6E97C302ABD71868C04CCA256EE70007AA53

Ecological Associates (2009). Northern Victorian Irrigation Renewal Project: Assessment of Impacts on Flora Issues of National Environmental Significance.

Ellis, I. (2005) *Ecology of the Murray hardyhead* Craterocephalus fluviatilis *(McCulloch), family Atherinidae*. Murray-Darling Freshwater Research Centre, Lower Basin Laboratory. Report prepared for the Mallee Catchment Management Authority

Feehan Consulting (2009). NVIRP Waterway Short-Listing Report, A report prepared for the Northern Victoria Irrigation Renewal Project.

GBCMA (2006). Priority Wetlands in Goulburn Broken Catchment Shepparton, Victoria., Goulburn Broken Catchment Management Authority.

Hale (2009). Northern Victoria Irrigation Renewal Project: Operation Impact Assessment on Wetlands of International Importance (Ramsar Wetlands), Report to Hydro Environmental, Jennifer Hale, Kinglake. .

Heron, S. and Joyce, A. (2008). Report prepared for Department of Sustainability and Environment.

Holland, K.L., Tyerman, S.D., Mensforth, L.J. and Walker, G.R. (2006). Tree water sources over shallow, saline groundwater in the lower River Murray, south-eastern Australia: implications for groundwater recharge mechanisms. *Australian Journal of Botany* **54**: 193-205.

HydroEnvironmental (2010). Localised Groundwater Impact Assessment Report for 2010 Channel Remediation Works, Northern Victoria Irrigation Renewal Project.

Kettunen, M.A., Terry, A., Tucker, G. and Jones, A. (2007). *Guidance on the maintenance of landscape features of major importance for wild flora and fauna - Guidance on the implementation of Article 3 of the Birds Directive (79/409/EEC) and Article 10 of the Habitats Directive (92/43/EEC)*. Brussels, Institute for European Environmental Policy (IEEP)**:** 114.

King, A.J. (2002). *Recruitment ecology of fish in floodplain rivers of the southern Murray-Darling Basin, Australia*. Department of Biological Sciences. Clayton, Victoria, Monash University.

King, A.J. (2005). Fish in the Barmah-Millewa Forest - history, status and management challenges. *Proceedings of the Royal Society of Victoria* **11**: 117-126.

King, A.J. and O'Connor, J.P. (2007). Native fish entrapment in irrigation systems: A step towards understanding the significance of the problem. *Ecological Management and Restoration*, **8,** 32-37.

King, A.J. and Tonkin, Z. (2009). *Northern Victoria Irrigation Renewal Project: Operational impact assessment on aquatic faun*a. Arthur Rylah Institute for Environmental Research. Department of Sustainability and Environment, Heidelberg.

Kingsford, R.T., Roshier, D.A. and Porter, J.L. (2010) Australian waterbirds - time and space travellers in dynamic desert landscapes. *Marine and Freshwater Research*, **61,** 875-884.

Koehn, J., Stuart, I. and Crook, D. (2004). *Linking ecological importance of downstream fish movements to management of Murray-Darling Basin fish populations.* In: Downstream movement of fish in the Murray-Darling Basin - Workshop held in Canberra, 3-4 June 2003: Statement, recommendations and supporting papers. (Eds. Lintermans, M. and Phillips, B.), pp. 67-78. Murray Darling Basin Commission, Canberra.

Leck, M.A. and Brock, M.A. (2000). Ecological and evolutionary trends in wetlands: Evidence from seeds and seed banks in New South Wales, Australia and New Jersey, USA. *Plant Species Biology* **15**: 97-112.

Lloyd, L.N., Atkins, B. Boon, P., Jacobs, T. & Roberts, J. (1992). *Natural Processes within Murray-Darling Floodplain Wetlands*. In Murray-Darling Basin Floodplain Wetlands Management. (Ed. Sharley, T.). Murray-Darling Basin Commission, Canberra.

McCarthy, B., Nielsen, D., Baldwin, D., Meredith, S., Roberts, J., King, A., Reid, J. and Ward, K. (2006). *Barmah wetland system environmental monitoring program. Part B: Monitoring program*. Murray Darling Freshwater Research Centre, Albury.

MDBC (2003). P*reliminary investigations into observed River redgum decline along the River Murray below Euston*. Technical Report 03/03, Report prepared for the River Murray Environmental Manager, Murray Darling Basin Commission, Canberra, ACT.

MDBC (2005). *The Living Murray Foundation Report on the significant ecological assets targeted in the first step decision*. Murray Darling Basin Commission Publication no. 09/05.

Merritt, D.M. and Wohl, E.E. (2006) Plant dispersal along rivers fragmented by dams. *River Research and Applications,* **22,** 1-26.

Metzeling, L., Doeg, T. and O'Connor W. (1995). *The impact of salinization and sedimentation on aquatic biota*. pp 126-136 In Conserving biodiversity: threats and solution. (Eds Bradstock, R.A., Auld, T.D., Keith, D.A., Kingsford, R.T., Lunney, D. and Sivertsen, D.P.). Beatty and Sons, Surrey.

NCCMA (2008). North Central Regional Wetland Strategy. North Central Catchment Management Authority, Huntly, Victoria.

NCCMA (2009). J*ohnson Swamp Environmental Watering Plan.* Prepared for the Northern Victorian Irrigation Renewal Project by North Central CMA, Huntly, Victoria.

NCCMA (2010a). *Campaspe River Environmental Watering Plan.* Prepared for the Northern Victorian Irrigation Renewal Project by North Central CMA, Huntly, Victoria.

NCCMA (2010b). *Lake Elizabeth Environmental Watering Plan*. Prepared for the Northern Victorian Irrigation Renewal Project by North Central CMA, Huntly, Victoria.

NCCMA (2010c). *Loddon River Environmental Watering Plan*. Prepared for the Northern Victorian Irrigation Renewal Project by North Central CMA, Huntly, Victoria.

NCCMA (2010d). Lake Leaghur Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project by North Central Catchment Management Authority.

NC CMA (2010e). "Lake Meran Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project by North Central Catchment Management Authority."

NC CMA (2010f). "Lake Murphy Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project by North Central Catchment Management Authority."

NC CMA (2010g). "Lake Yando Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project by North Central Catchment Management Authority."

NC CMA (2010h). "Little Lake Boort Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project by North Central Catchment Management Authority."

NC CMA (2010i). "McDonald Swamp Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project by North Central Catchment Management Authority."

NC CMA (2010j). "Round Lake Environmental Watering Plan. Prepared for the Northern Victoria Irrigation Renewal Project by North Central Catchment Management Authority."

NVIRP (2009a). *Northern Victoria Irrigation Renewal Project Waterway Shortlisting Report.* A report prepared by Feehan Consulting for NVIRP.

NVIRP (2009b). W*ater Change Management Framewor*k. Northern Victorian Irrigation Renewal Project, Shepparton.

NVIRP (2010). P*ublic Environment Report*. Northern Victorian Irrigation Renewal Project (NVIRP), Shepparton.

NVIRP (2011). NVIRP Regional Scale Assessments - Condition 4 Assessment. Report prepared by SKM for Northern Victoria Infrastructure Renewal Project.

Overton, I. C., Colloff, M.J., Doody, T.M., Henderson, B. and Cuddy, S.M. (editors) (2009). *Ecological Outcomes of Flow Regimes in the Murray-Darling Basin*. Report prepared for the National Water Commission by CSIRO Water for a Healthy Country Flagship. CSIRO, Canberra.

Overton, I.C. and Jolly, I.D. (2003). I*nvestigation of floodplain and groundwater interactions on Chowilla*. South Australian Department of Water, Land and Biodiversity Conservation and CSIRO Land and Water

Reid, J., Arthur, T., McGinness, H. (2009). *Waterbirds*. pp 120-161 In Ecological Outcomes of Flow Regimes in the Murray-Darling Basin. (Eds Overton, I.C., Colloff, M.J., Doody, T.M., Henderson, B. and Cuddy, S.M.). Report prepared for the National Water Commission by CSIRO Water for a Healthy Country Flagship. CSIRO, Canberra.

Saintilan, N. (editor.) (2009) *Australian saltmarsh ecology*. CSIRO Publishing, Melbourne.

SKM (2008a). *Food Bowl Modernisation Project - Environmental Referrals.* A report prepared by Sinclair Knight Merz for Department of Sustainability and Environment.

SKM (2008b). *Northern Victoria Irrigation Renewal Project - Stage 1: Preliminary determination of groundwater effects.* A report prepared by SKM for NVIRP.

SKM (2009a). *Assessment of hydrological changes from the operation of the NVIRP modernised GMID- surface water hydrology*. Prepared by Sinclair Knight Merz for NVIRP.

SKM (2009b). *Assessment of hydrological changes from the operation of the NVIRP modernised GMID: Groundwater Hydrology*. Prepared by Sinclair Knight Merz for NVIRP.

SKM (2009c). B*armah-Millewa Forest Icon Site: Condition Monitoring Plan.*

SKM (2009d). *Monitoring response to environmental flows in the Loddon and Campaspe Rivers 2008/09.* A report prepared by Sinclair Knight Merz for North Central CMA.

SKM (2010). *Preparation of NVIRP regional assessments - Method report*. A report prepared by Sinclair Knight Merz for NVIRP

Smith, Ough, Scroggie, Schreiber and Kohout (2009). "Assessing changes in macrophyte assemblages with salinity in non-riverine wetlands: A Bayesian approach." Aquatic Botany 90(2): 137-142.

Standards Australia (2009). AS/NZS ISO 31000:2009 Risk Management - Principles and guidelines.

Thomas, B.P., Merry, R.H., Creeper, N.L., Fitzpatrick, R., Shand, P., Raven, M.D. and Jayalath, N. (2009). *Acid Sulfate Soil Assessment of the lower Loddon River and Burnt Creek, Central Victoria* CSIRO Land and Water Science Report 18/09.

Water Technology (2010). Lower Broken Creek and Nine Mile Creek Environmental Watering Plan, Goulburn Broken CMA on behalf of NVIRP.

Young, W.J., Scott, A.C., Cuddy, S.M. and Rennie, B.A. (2003). *Murray flow assessment tool. A technical description (based on version 1.4)*. CSIRO Land and Water.

Appendix A Biological indicators and conceptual models

The Public Environment Report (NVIRP 2010) has considered the impacts of NVIRP at site specific locations and developed mitigation actions through the implementation of the Water Change Management Framework (NVIRP 2090) for areas identified as being at risk. The changes in surface-water hydrology and groundwater levels and salinity can be considered at a broader regional scale by relating the predicted changes to a likely ecological response.

A range of ecological indicators were reviewed to determine whether they were suitable for assessing regional impacts of NVIRP operations on ecological processes and beneficial uses of aquatic systems in the study area and a number of indicators which can be suitably used in the regional assessment are recommended. Details of the approach and justification for indicator selection have been provided in an earlier report for this project (SKM 2010). In summary, to be useful, an indicator had to meet most (preferably all) of the following criteria:

- refer to an important ecological process or component, rather than merely ecological structure (i.e. not be based on taxonomic grounds alone)
- be supported by a conceptual model with explicit links to altered hydrology, which could be used to guide the prediction of likely impacts arising from NVIRP operations. If there was also a robust and readily available literature on ecological responses to a given hydrological perturbation, so much the better
- be able to be applied across a range of spatial scales, but especially at the regional scale required for this investigation, and via a desk-top risk analysis able to be undertaken with currently existing information
- where possible, complement prior investigations undertaken in NVIRP studies, as well as be linked with and inform on other components of the current investigation
- be consistent with general approaches or specific methods commonly used in ecological studies, and with existing inventories and classification systems.

The review of indicators and conceptual models has identified biotic and ecosystem/habitat indictors suitable for assessment where changes in hydrology can be related to changes in ecological condition. These indicators and the conceptual models that describe how each indicator is likely to be affected by hydrological changes are summarised below. Most of the conceptual models presented in this report describe links between a range of flow components and indicators. NVIRP will not necessarily affect all of the flow components described in these models and the regional assessment will only focus on the specific flow components and processes that are likely to be affected by NVIRP. More details about the selection of individual indicators and conceptual models are presented in the *Preparation of NVIRP regional assessments – method report* (SKM 2010).

A.1 Biotic Indicators

A.1.1 Vegetation as plant functional groups

The method proposed for the current project is to analyse possible effects of NVIRP operations on vegetation in the study region in terms of large-scale vegetation groups that closely reflect ecological processes rather than the discrete taxonomic categories used in the earlier investigations. The recommended typology for the establishment of these broad vegetation units is the plant functional group (PFG) classification initially proposed by Brock and Casanova (1997) and revised by Leck and Brock (2000). Table 7-1 shows the range of PFGs in the Leck and Brock schema. For the purposes of this project, only the three broadest groups will be considered, which include terrestrial, amphibious and submerged plants.

Table 7-1: Description of plant functional groups according to Leck and Brock (2000).

Functional group and abbreviation	Description
Terrestrial	**Species that do not tolerate flooding**
Dry species	Germination, growth and reproduction occur in the absence of surface water and where the watertable is below the surface.
Damp species	Germination, growth and reproduction occur on saturated soil.
Amphibious	**Species that tolerate flooding and drying**
Fluctuation tolerator	Germination under damp or flooded conditions
Emergent	Basal portions under water and reproduction out of water
Low growing	Low growing and tolerate complete submersion
Vines	Vines
Trees and shrubs	Woody plants
Fluctuation responders	Germination under flooded conditions, growth in flooded and damp conditions, and reproduction out of water
Morphologically plastic	Heterophylly in response to water level variation
Floating leaves	Floating leaves when plant inundated
Submerged	**Species that do not tolerate drying**

There are two conceptual models that describe the relationships between hydrology and each of the three broad PFGs and are suitable for use in the proposed risk assessments. Figure 7-1 shows a generalised model to inform the basics of the subsequent risk analysis, and Figure 7-2 shows the detailed assessment. Note that Figure 7-2 is taken from the Victorian Environmental Flow Monitoring Assessment Program (VEFMAP) report for the Campaspe River (Chee et al. 2006).

Only parts of the conceptual model shown in Figure 7-2 are relevant to NVIRP operations (e.g. for those hydrological components expected to change), but the whole model is shown for completeness.

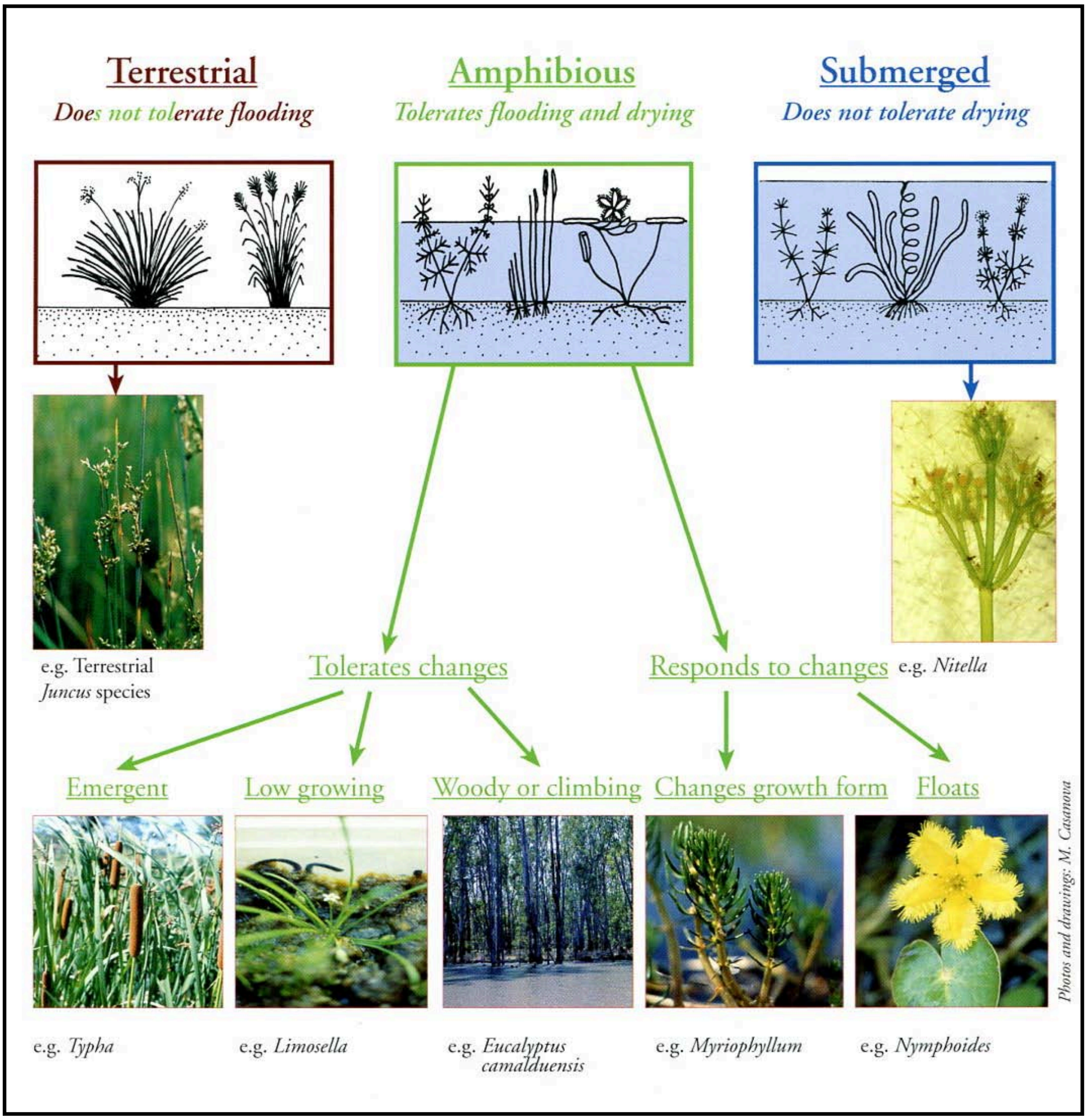

Figure 7-1: Generalised response of different plant functional groups to altered water regime (Source: Brock and Casanova 2000, page 4)

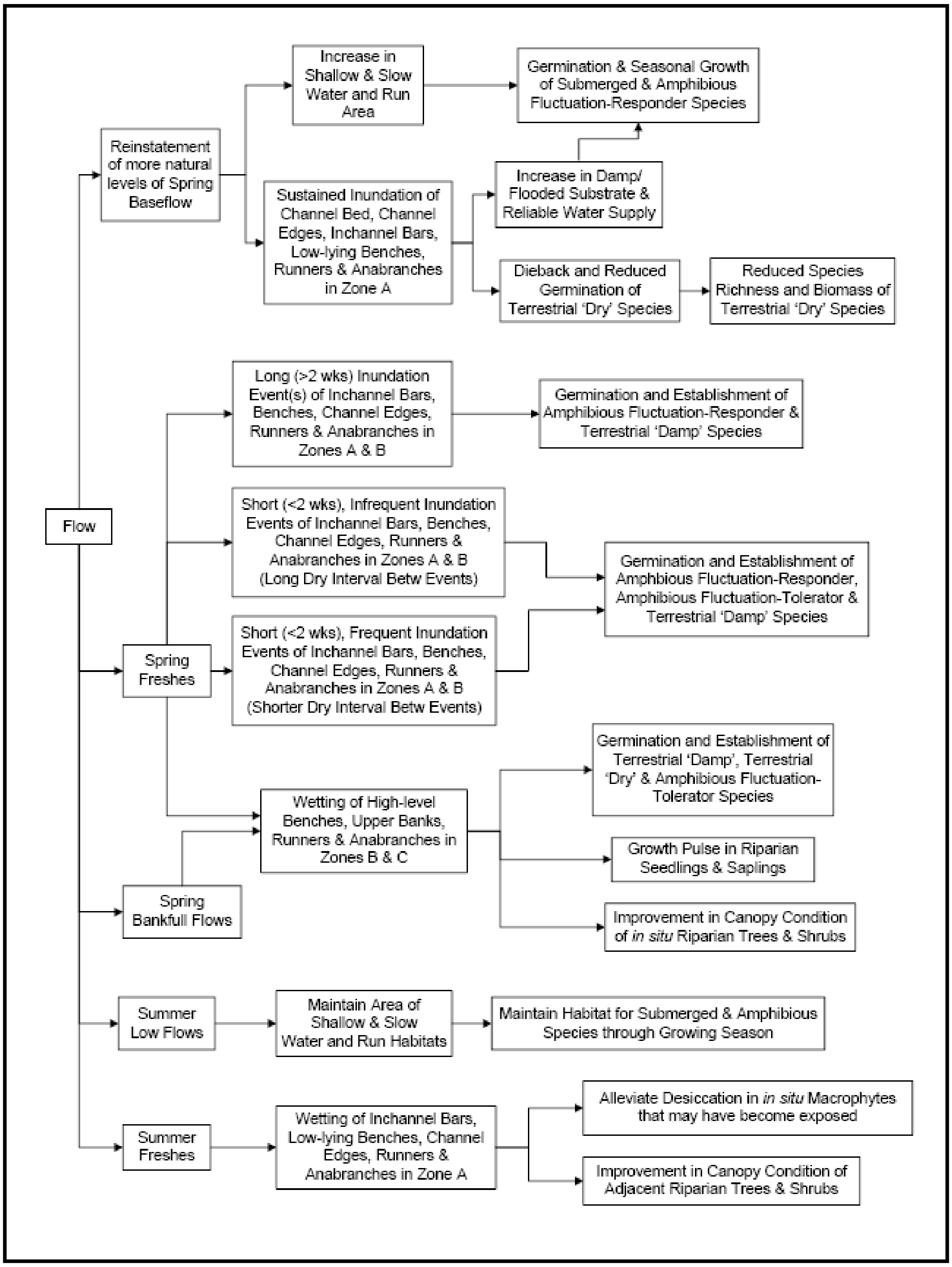

Figure 7-2: Conceptual model of detailed response of different plant functional groups to altered water regime (Source: Chee et al. 2006, page 29)

The risk assessment will use the conceptual models to consider whether the expected hydrological changes associated with NVIRP are likely to adversely affect or benefit terrestrial, amphibious or submerged plant groups in any of the waterways, wetlands or complexes of interest. The assessment can be conducted at any spatial scale that is relevant to the project (e.g. individual wetland, river reach or wetland complex) and can consider whether NVIRP operations are likely to result in a shift across PFGs at a given spatial scale.

The use of these conceptual models allows predictions, which may be used as a foundation for future monitoring. For example, if NVIRP operations were predicted to decrease fluctuations in water level, the PFG approach would predict a decrease in the relative abundance of Amphibious *Fluctuation Responder* plants. If a permanently inundated wetland was expected to dry out for some of the time as a result of NVIRP, then submerged plants would be predicted to disappear or contract to small areas that remain damp.

A.1.2 Birds

There are a number of ways to group bird taxa into broad groups that could be used in the current investigation. For the purposes of the current project, it is recommended that the simple two-way classification employed in the Murray Flow Assessment Tool (MFAT) be used. In this schema, the two groups of interest are i) colonial nesting waterbirds; and ii) waterfowl and grebes. Colonial nesting waterbirds include taxa such as ibis, egrets, herons and spoonbills. They are common throughout south-east Australia and are an important component of the Ramsar listing of many wetlands sites. Waterfowl and grebes include teal, duck, shoveler and grebe. Many birds respond rapidly to flooding. In both cases, there is good information on their responses to altered water regimes (e.g. see Young et al. 2003).

Detailed conceptual models that explicitly describe the relationship between these two groups of waterbirds and hydrology have not been developed and empirically tested, but Reid et al. (2009) described six main links between sustainable waterbird communities and water regimes:

- waterbird assemblages are dynamic due to individual's (varying) mobility – hence they are open systems
- lateral connectivity is important – there are numerous connections (flow paths) between the river and its floodplains and wetlands
- the most productive (feeding) wetlands are shallow and recently dry – fluctuating water levels increase productivity
- a broad range of physical wetland and vegetation types is required to maximise assemblage diversity and provide nesting habitat for most species

- for successful fledgling of most nesting waterbird species to occur, a shifting spatiotemporal mosaic of wetland inundation patterns needs to occur over a lengthy period, e.g. 4-5 months (and occur at the appropriate time of year, i.e. spring for wetlands in the Southern MDB)
- these wetland mosaics need to be sufficiently large to a) support populations of a diverse range of waterbirds and b) sustain successful recruitment of most species in large floods.

These relationships are summarised in Figure 7-3 and Figure 7-4. There is also some excellent quantitative information on the likely response of both groups of waterbirds to changes in water regime[8] and McCarthy et al. (2006) provides useful and spatially relevant information on water-regime requirements of colonial nesting waterbirds for the Barmah forest.

[8] see http://www2.mdbc.gov.au/subs/information.mfat.waterbirds/zb_waterfowl.htm, internet resource viewed 9 March 2010.

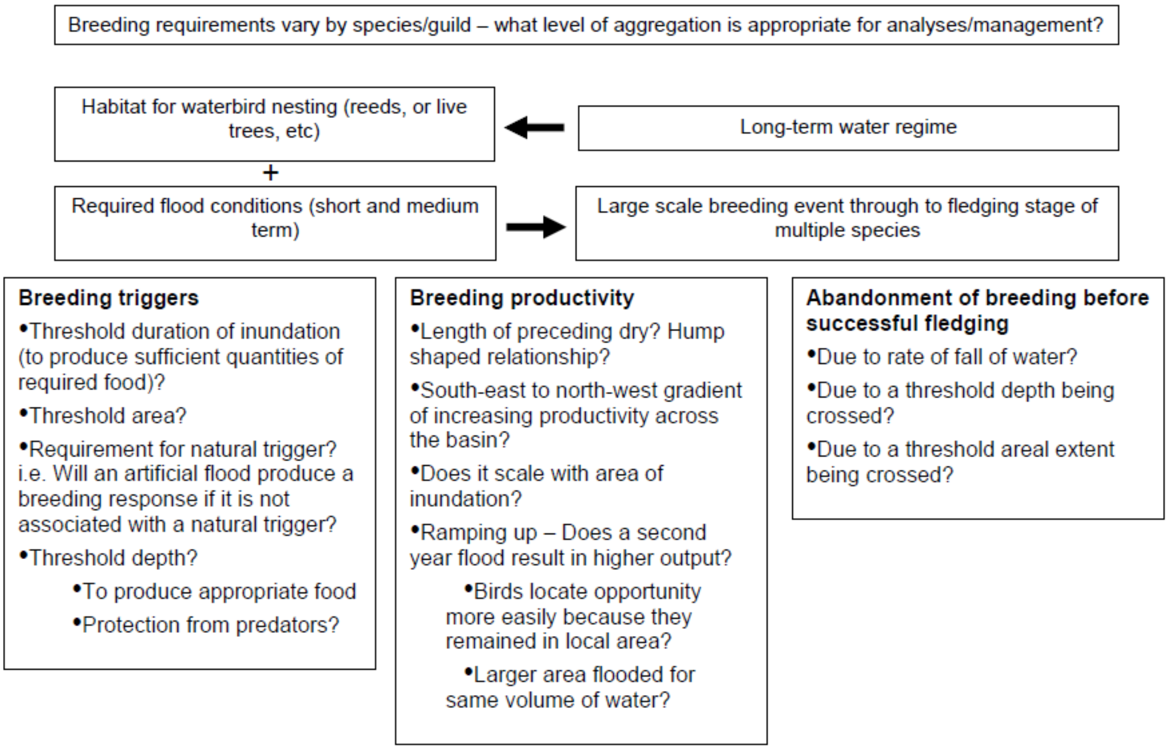

Figure 7-3: Hypothetical relationships between breeding responses and flow regimes for colonial nesting waterbirds (Source: Reid et al. 2009, page 126)

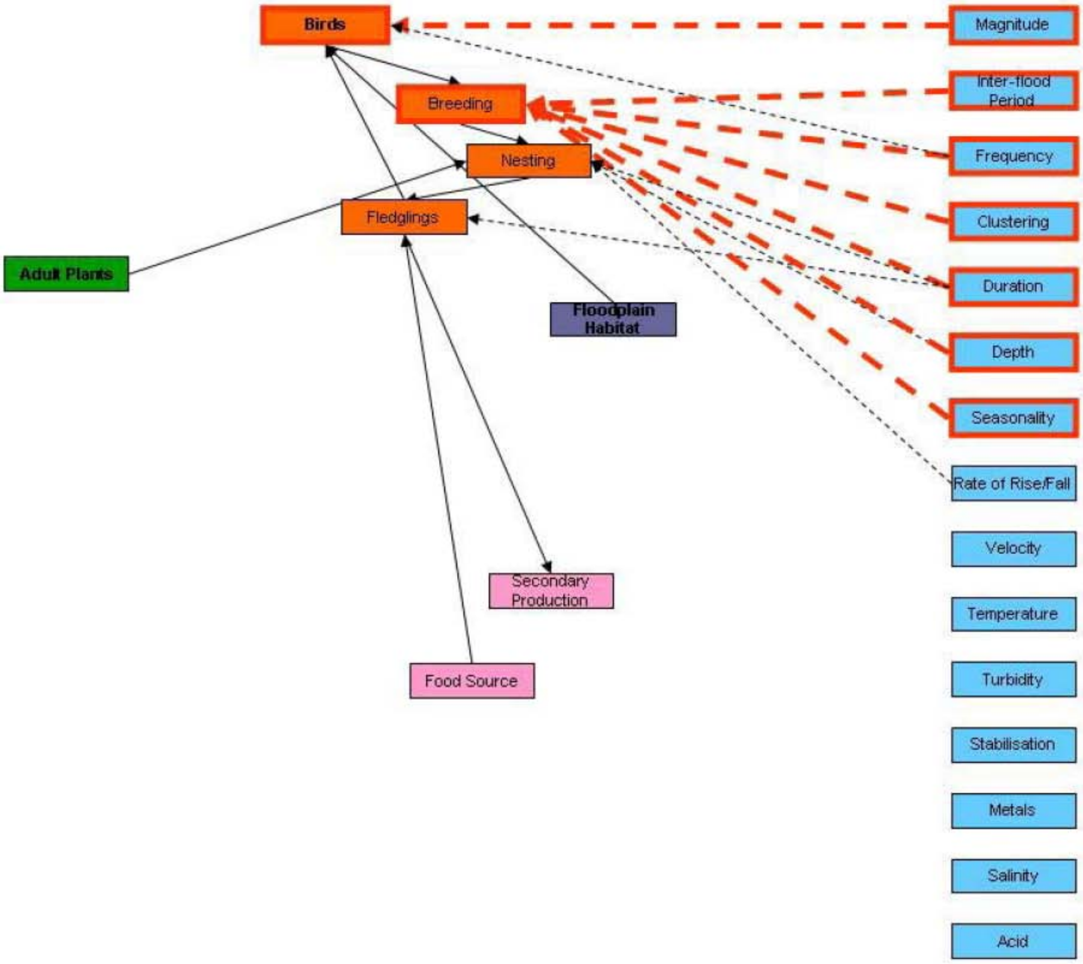

Figure 7-4: Conceptual model of the major components of waterbird life stages that relate to aspects of flow regime (Source: Overton et al. 2009, page 403)

A.1.3 Fish

As with vegetation and birds, it is inappropriate to undertake the regional analysis of the effect that NVIRP is likely to have on fish on a species-by-species basis. Instead, fish will need to be categorised into a manageable number of groups, and likely impacts on those groups examined. King (2002) recognized six broad categories of fish in the Murray-Darling Basin:

- flood specialists (e.g. Golden Perch, Silver Perch)
- flood opportunists (e.g. Carp)
- low-flow specialists (e.g. Carp Gudgeons, Mosquito Fish)

- generalists (e.g. Australian Smelt, Flathead Gudgeon)
- main-channel specialists (e.g. Murray Cod, Trout Cod, River Blackfish)
- wetland specialists (e.g. Carp Gudgeons, Australian Smelt, Southern Pygmy Perch).

McCarthy et al. (2006) presented a simple conceptual model that describes potential hydrological impacts on these six categories of fish (Figure 4-17). Chee et al. (2006) developed a more detailed conceptual model that describes the response of some of these fish categories to changes in specific flow components (Figure 4-18).

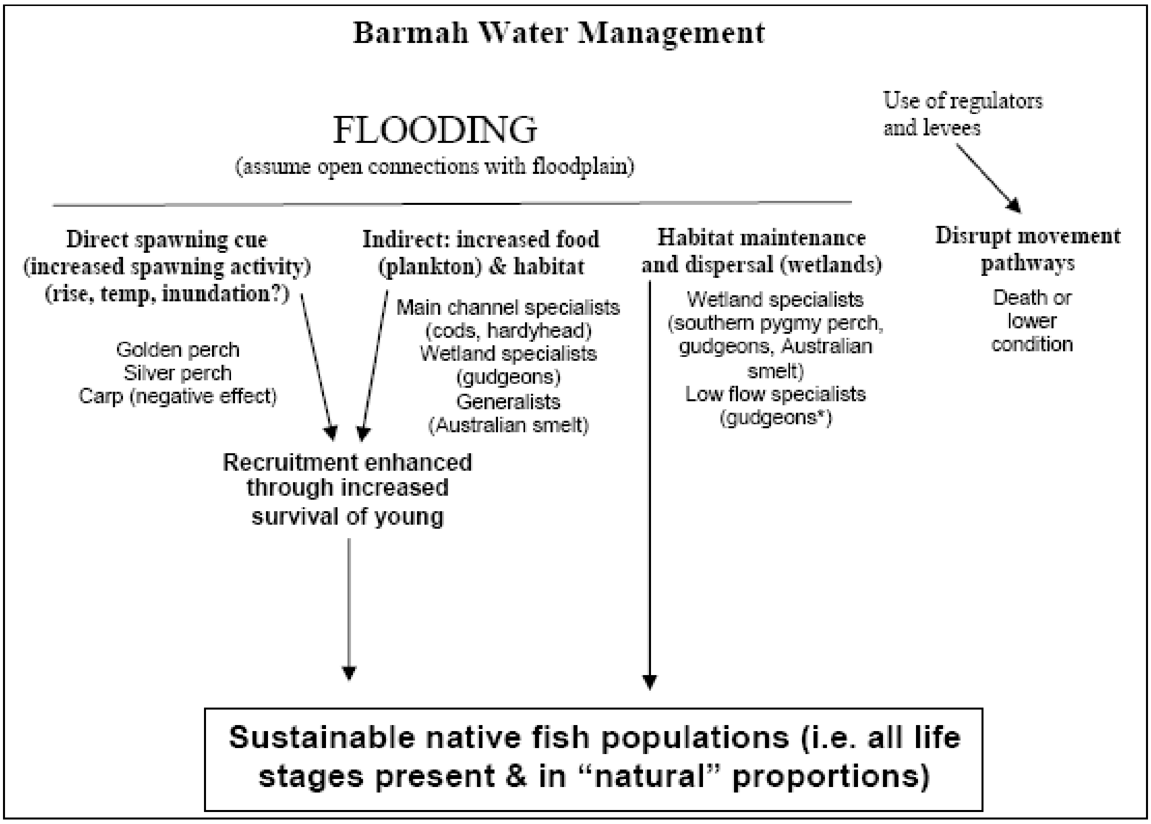

Figure 7-5: Conceptual model of impact of flow on fish communities in the Barmah Forest (Source: McCarthy et al. 2006, page 16)

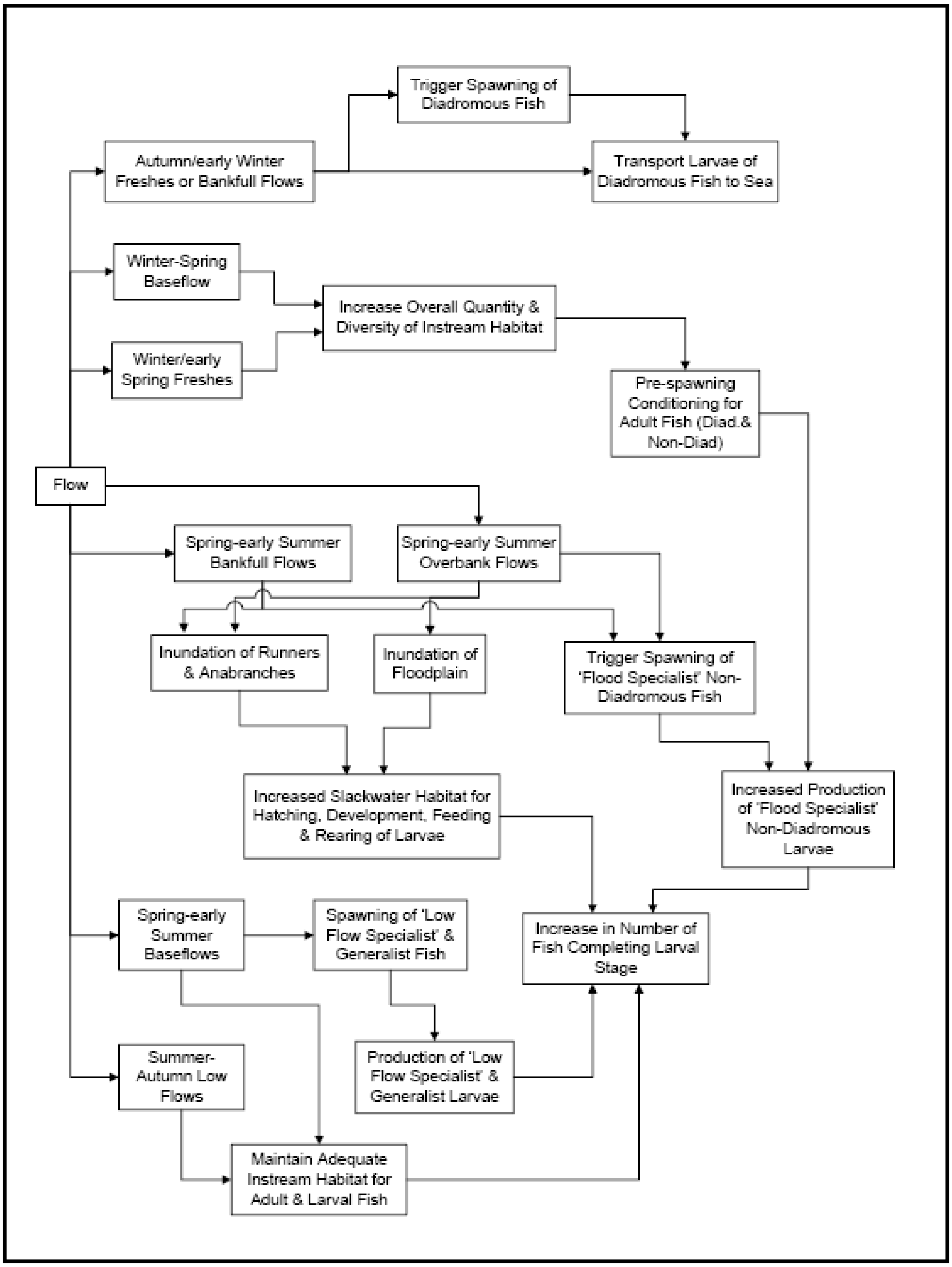

Figure 7-6: Conceptual model for effect of flow on fish spawning and recruitment (Source: Chee et al. 2006, page 34)