



**Technical report: Vegetation extent and condition
mapping of the Macquarie Marshes and floodplains
1991, 2008, 2013**



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Cover photos: Red Gum woodland in Wilgara Private Ramsar Site 2012 (Credit S. Bowen) River cooba lignum in Zoo Paddock 2008, (Credit S. Bowen) Former water couch meadows in the Southern Nature Reserve 2008 (Credit S. Bowen); River Red Gum forest Macquarie Marshes Nature Reserve surveyed during Autumn spring 2013 (Credit: S. Bowen).

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1. Background

1.1 Report purpose

This report is intended to accompany the Vegetation Communities of the Macquarie Marshes 1991, 2008, 2013 mapping products (SEED Dataset VIS_IDs 4890, 4891, 4892; <https://datasets.seed.nsw.gov.au/dataset/vegetation-communities-of-the-macquarie-marshes-in-2013>). The mapping products in the SEED Portal provide maps of the distribution and condition of vegetation communities in the Macquarie Marshes over decadal time periods. This report details the mapping methodology and provides some examples of vegetation change during the mapped period. The report does not evaluate the effect of water delivery to vegetation communities.

1.2 The Macquarie Marshes

The Macquarie Marshes are a complex floodplain wetland system covering an area of approximately 200,000 ha (Kingsford and Thomas 1995). The Marshes are in the lower floodplain of the Macquarie Catchment, approximately 60 km north of Warren in Central Western NSW (Figure 1). Parts of the Marshes are managed by NSW OEH as NSW National Park estate (Macquarie Marshes Nature Reserve). The Marshes are recognised nationally and internationally for their importance as waterbird habitat, with at least 76 waterbird species (44 breeding) recorded using the wetlands (Kingsford and Auld 2005). The Macquarie Marshes Ramsar site covers 19,850 hectares (OEH 2017a), comprising the Macquarie Marshes Nature Reserve (19,078 ha), and parts of the properties 'Wilgara' (Wilgara Wetland, 583 ha, listed in 2000) and 'The Mole' (U-block, 189 ha, listed in 2012). The Macquarie Marshes are also listed in the Directory of Important Wetlands (EA 2001, Anon 2017).

There have been major changes to the natural flow regime of the Macquarie River since the construction of Burrendong Dam in 1967 (Kingsford and Thomas 1995, Thomas et al. 2011). These changes have affected waterbird populations (Kingsford and Thomas 1995, Kingsford and Johnson 1998, Kingsford 2000, Kingsford and Auld 2005) and the extent of semi-permanent wetland vegetation (Bowen and Simpson 2010, Thomas et al. 2010). Previous studies have examined the vegetation communities of the Macquarie Marshes (Brander 1987, Brereton et al. 2000, Shelly 2005). Mapping has been undertaken by Pajmams (1981) who discriminated 40,000 ha of semi-permanent wetlands within 250,000 ha of the greater floodplain. Further, DLWC (2000) identified changes (particularly contraction of Black Box populations) in the distribution of nine tree species in the Macquarie Marshes between 1949 and 1991.

1.3 Wetland and floodplain vegetation as indicators of wetland condition

Flood-dependent vegetation communities are plant communities that occur on floodplains or in wetlands, in which the dominant species depend on moist conditions to complete their lifecycle (DECCW 2010b). Periodic mapping of the extent and condition of wetland and floodplain vegetation communities allows land managers to monitor vegetation response to conservation actions. The Basin-wide environmental watering strategy (MDBA 2014) advocates for an evidence-based prioritisation of the ecological condition of biological assets through monitoring. The mapping product described here provides one of several mechanisms to achieve this monitoring objective.

Hydrologic regime is a key variable influencing the structure and function of flood-dependent plant communities (Mitsch and Gosselink 2000). Water-plants respond to patterns of water presence over time and their continued survival can provide an indication of the historical water regime, or the flow and availability of water in the site during the lifetime of the plants (Casanova 2011). Much research has been conducted on the links between hydrology and plant community dynamics (e.g. Brander 1987, Bren 1988, Driver and Knight 2007, Thomas et al. 2010, Bino et al. 2015) and vegetation is a

sensitive measure of anthropogenic impacts to wetland ecosystems (U.S.EPA 2002). Many human-related alterations to the environment that act to degrade wetland ecosystems cause shifts in plant community composition that can be quantified (Chesterfield 1986, U.S.EPA 2002).

Flood-dependent vegetation communities have been shown to change in response to hydrologic alterations, with increased hydrological connectivity (increased inundation frequency and duration) driving the structure and composition towards more flood-dependent species, while increased drying promotes establishment of more terrestrial species (Thomas et al. 2010, Bino et al. 2015, Wassens et al. 2017). Changes are expected to be slow for communities dominated by long-lived woody species (e.g. River Red Gum, Black Box), compared to communities dominated by herbaceous species (e.g. Common Reed, Water Couch), where changes can occur relatively quickly (Bino et al. 2015). There are likely to be considerable ecological consequences when the natural flow regime is significantly disrupted by upstream river regulation and abstraction (Kingsford 2000).

The current report acknowledges that wetland vegetation boundaries are in flux because they are dependent on seasonal and flood conditions (DLWC 2000). Mapped boundaries cannot be considered static over time.

2. Mapping methodology

2.1 Mapping vegetation community extent

In this study, previous vegetation maps from 1991 and 2008 were used for comparison purposes, and a new vegetation map for 2013 was created to estimate changes in extent of vegetation communities and condition classes.

The 1991 (Wilson 1992) map of the vegetation communities of the Marshes was created by manual aerial photo interpretation (API) of 1:50,000 scale black and white aerial photographs and classification of vegetation communities, calibrated by ground surveys. Vegetation communities in 1991 were determined by dominant species and structural characteristics such as growth form, and density (Johnson et al. 1992). The 1991 mapping product was revisited on two occasions.

In 2008, the 1991 map was scanned and ortho-rectified to create a digital shapefile that was then interrogated for vegetation spatial area and type (Bowen and Simpson 2010). The original mapping units of Wilson (1992) were renamed to reflect the then current classification of vegetation communities in NSW. In 2008 the same spatial area of the Macquarie Marshes was remapped under the NSW Wetland Recovery Program (WRP) (Bowen and Simpson 2010, DECCW 2010a). The spatial extent of vegetation communities in 2008 was delineated by manual API of high-resolution (30 cm) digital colour aerial photographs captured in July 2008. Field surveys were conducted in May, October and November 2008 to provide a reference for the mapping units, verify their extent and to quantitatively assess vegetation condition. Results of the changes in vegetation based on these two maps products between 1991 and 2008 are provided in Bowen and Simpson (2010).

In 2015, the 1991 map was again substantially reworked and revised by manual API using digital versions of scanned and ortho-rectified black and white aerial photography, first captured in January 1991 and viewed on screen to a resolution of 1:1000. This improved product enabled comparisons to be made with subsequent map updates. Co-incident georeferenced on-ground survey data, stored in the NSW OEH Vegetation Information System (VIS) Flora Module, was analysed for vegetation type and condition.

Finally, the Macquarie Marshes vegetation communities were remapped between 2013 and 2014 using manual API of high-resolution (50 cm) ADS40 digital colour aerial photographs captured in September 2013. Field survey data from April 2014 were used to calibrate condition categories and to train observers in the visual signature (texture, colour etc.) of vegetation communities. The 2013 mapping exercise followed the approach in 2008 (Bowen and Simpson 2010). An additional 1893 hectares to the west of the Warren-Carinda Rd were added to the map in all three (3) time captures (1991, 2008, 2013) to provide better coverage of the Macquarie Marshes.

Vegetation community mapping units in all three maps (revised 1991, 2008 and 2013) were converted to NSW OEH Plant Community Types (PCTs) identified in the NSW OEH VIS Classification Module (OEH 2017b). Within the NSW VIS, a PCT is based on structural-growth form (physiognomic) systems (Specht 1970, Walker and Hopkins 1990) and the floristic composition following the vegetation classifications of Benson (2006) and Keith (2004). Descriptions of these PCTs are contained in the NSW OEH VIS Classification (OEH 2017b).

Bowen and Simpson (2010) defined several Hydro-ecological Functional Groups (HFGs) as a floodplain specific classification system for the PCTs mapped in the Marshes. HFGs are based on the structure, watering and life history requirements of the dominant species in the vegetation community (Roberts and Marston 2011, OEH 2017b). All mapped PCTs were assigned to HFGs listed in **Table 1** to provide a higher order grouping for comparing changes in extent and condition. Land use types that were not vegetation communities were allocated to a “Cleared” map unit.

For this study we compared the total areas of the mapped HFGs and PCTs in the Macquarie Marshes at three points in time (1991, 2008 and 2013) to address differences in the extent of flood-dependent and floodplain vegetation communities.

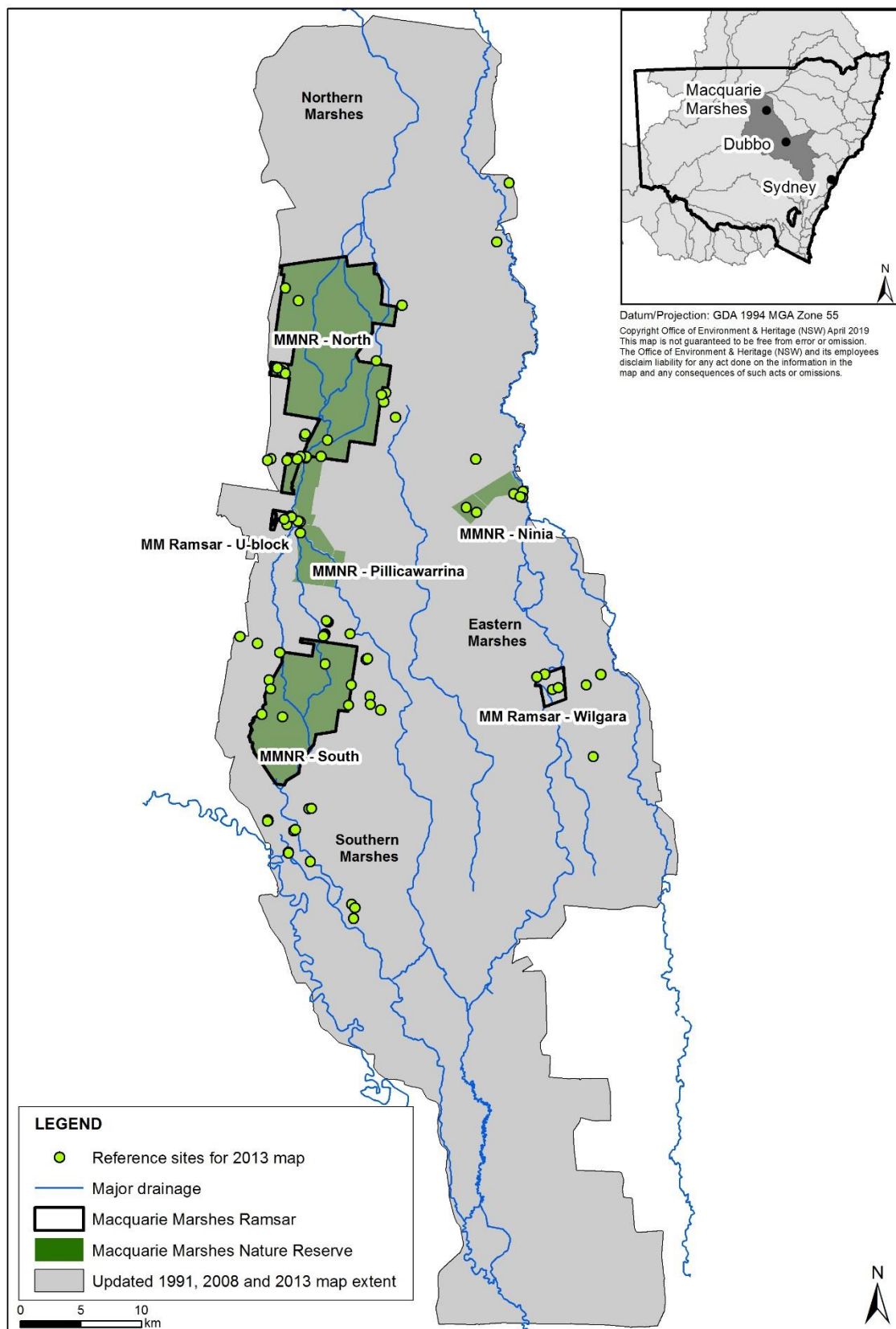


Figure 1: Study area in the Macquarie Marshes showing map extent.

Table 1: Hydro-ecological Functional Groups and their corresponding Plant Community Types
(Bowen and Simpson 2010)

Hydro-ecological Functional Groups / Map Unit	Plant Community Type ID No.	Plant Community Type name
Semi-permanent wetland	181	Common Reed-Bush groundsel aquatic tall reedland grassland wetland
	182	Cumbungi Rushland wetland of shallow semi-permanent water bodies and inland watercourses
	204	Water Couch marsh grassland wetland
	53	Shallow freshwater wetland sedgeland
Lagoons	238	Permanent and semi-permanent freshwater lagoons
River Red Gum open forest	36	River Red Gum tall to very tall open forest (wetland)
River Red Gum woodland	36a	River Red Gum tall woodland (wetland)
River Red Gum grassy woodland	454	River Red Gum grassy chenopod open tall woodland (wetland)
Flood-dependent shrubland wetland	241	River Coobah - lignum swamp wetland
	247	Lignum Shrubland wetland
Flood dependent woodland	37	Black Box woodland wetland
	40	Coolibah open woodland wetland
Non flood-dependent floodplain vegetation	144	Leopardwood low woodland
	145	Western Rosewood - Wilga - Belah low woodland
	158	Old man Saltbush-mixed chenopod shrubland
	206	Dirty Gum-White Cypress Pine tall woodland
	212	Chenopod low open shrubland
	250	Derived tussock grassland
	27	Weeping Myall open woodland
	332	Tumbledown Red Gum - Black Cypress Pine - Red Stringybark woodland
	55	Belah Woodland
	70	White Cypress Pine woodland
	98	Poplar Box - White Cypress Pine - Wilga woodland
Invasive native terrestrial shrubland	Baradine Red Gum	Baradine Red Gum
	Invasive native terrestrial shrubland	Invasive native terrestrial shrubland

2.2 Mapping vegetation community condition

Aerial photography can effectively identify changes in riparian and wetland vegetation (Knapp et al. 1990, Tickle et al. 2006, Yang 2007). API has also been effective in determining tree canopy health measures (e.g. canopy cover, foliage cover, canopy density) to map the spatial distribution of condition classes (Armstrong et al. 2009, Blackwood 2009, McCosker 2009, Bowen et al. 2011). We used API to map the condition of River Red Gum and flood-dependent woodland HFGs at three points in time (1991, 2008 and 2013). In the absence of clearing, the long-lived species that dominate these communities are more likely to respond with changes in their condition before changes in their extent occurs. Under the NSW Environmental Water Management Program (EWMP), the condition of flood-dependent vegetation communities in the Marshes is determined annually from plot-based surveys, using measures of tree canopy health, structural diversity and species composition (Bowen 2016). These measures include estimates of canopy cover, canopy extent and dead canopy in 20 x 50m plots. The survey data from 2014 were analysed for condition class and the survey sites were georeferenced on screen for use as reference sites to standardise signature recognition during manual API.

We viewed high resolution aerial photography in false colour infrared to allow for textural signatures of foliage reflectance to be separated from reflectance from boughs, limbs and other tree surfaces. Shadows cast on the ground by canopies were also useful in assessing the delineation of crowns in mid dense stands. The percentage of dead or extremely stressed trees (trees with denuded boughs and limbs) was assessed within randomly generated 100 x 100 m (1 ha) squares for all polygons and compared to the field surveyed reference sites. An average of two x 1 ha squares per 20 ha were sampled. Polygons were split where necessary to delineate differences in tree canopy condition. One in 20 squares was re-sampled to check for consistency of attribution. Polygons were attributed with one of the condition classes in **Table 2**.

Table 2: Descriptions of condition classes for River Red Gum and Flood-dependent woodland Hydro-ecological Functional Groups (Bowen and Simpson 2010).

Condition class	Description
Good	0 < 10 % dead canopy
Intermediate	11-40 % dead canopy
Intermediate/poor	41-80 % dead canopy
Poor	>80 % dead canopy

2.3 Accuracy assessment of vegetation community extent and condition

Map accuracy reflects how well the mapped features match the on-ground distribution of features. Accuracy assessments may follow qualitative or quantitative approaches (Keith and Simpson 2008). Quantitative methods rely on a large number of random and stratified field observations to estimate accuracy. These field requirements exceeded available resources for the current mapping exercise. The mapping therefore used a qualitative approach to infer accuracy.

Map creation depended on expert knowledge of the system along with field survey of representative vegetation communities and conditions prior to manual interpretation. The authors have extensive on-ground knowledge of the Macquarie Marshes: members of the team have conducted annual field survey within the study area since 2008. In addition, high spatial resolution of mapped features improved interpretation. The 50 cm resolution 3D aerial photography facilitated detailed understanding of vegetation components such as texture and landscape context. The median polygon size for the 2013 map was 5.3 ha.

2.4 Calculating extent and condition of vegetation communities

We calculated the extent in hectares (ha) for each HFG and PCT at each time interval (reworked 1991, 2008 and 2013 maps). We also determined the extents of condition classes (Table 2), but condition was only applied to woodland HFGs. Changes in condition for treeless communities are more likely to reflect change in their species composition and thus a change in their community extent.

3. Trends in vegetation extent and condition in the Macquarie Marshes across the mapped years (1991, 2008, 2013)

This report highlights overall trends in vegetation change across the mapped years (1991, 2008, 2013). Refer to the mapping product for specific spatial and temporal patterns.

The extents for both Plant Community Types (Figure 2; Table 3) and Hydro-ecological Functional Group map units (Figure 3; Table 3) are presented across years. There appeared to be a contraction in semi-permanent wetland vegetation communities from 1991 to 2008 and then expansion in their extent from 2008 to 2013. Simultaneously, there appeared to be an expansion in non flood-dependent floodplain vegetation in 2008 relative to 1991 and a subsequent contraction in 2013.

The distribution of condition classes for woodland communities appeared to change over the mapped time periods (Figure 4; Table 4). Woodland condition appeared to decrease in some areas from 1991 to 2008. Subsequently, there appeared to be an improvement in condition for some areas from 2008 to 2013.

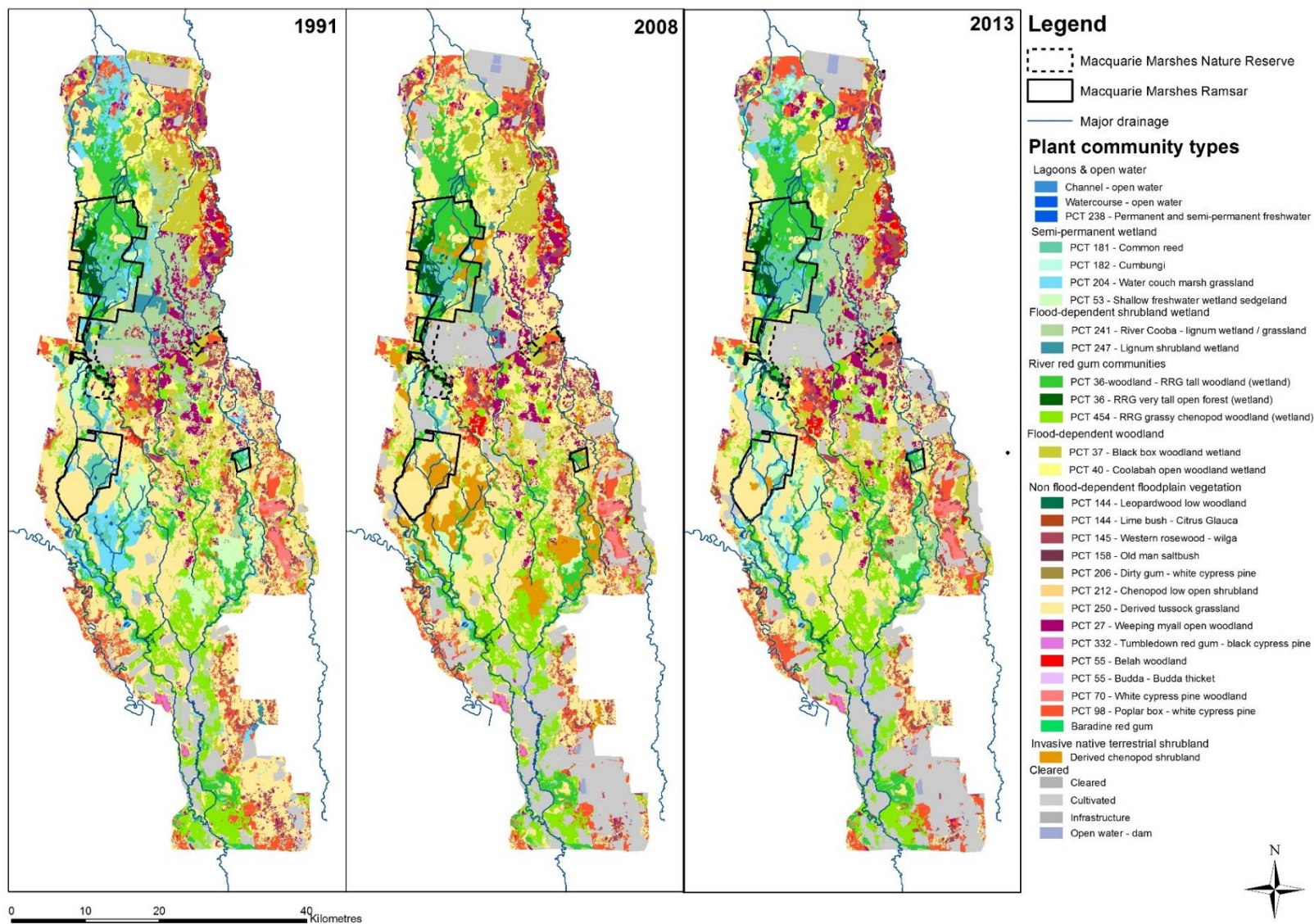


Figure 2: Spatial extent of Plant Community Types mapped in the Macquarie Marshes in 1991, 2008 and 2013.

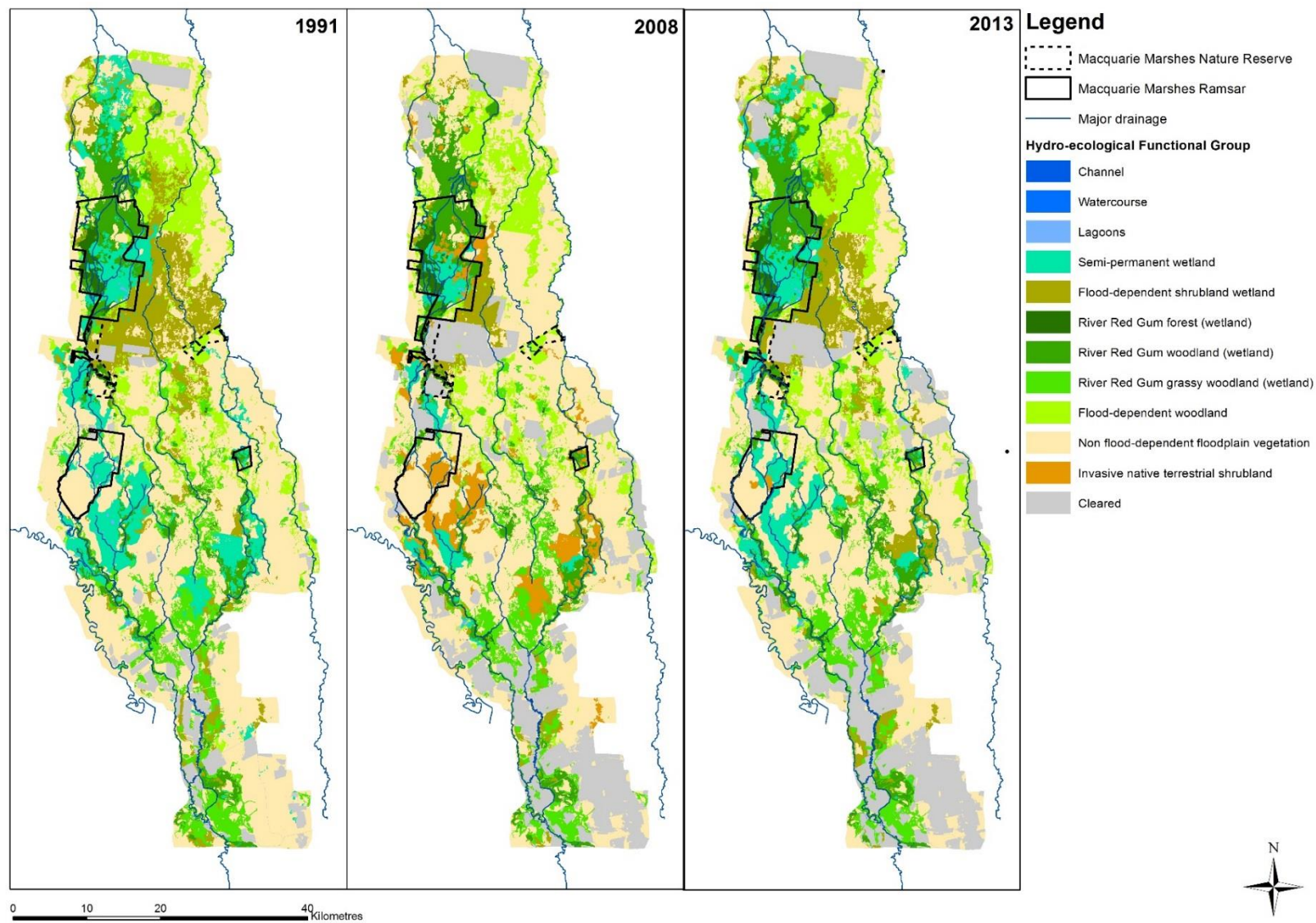


Figure 3: Spatial extent of Hydro-ecological Functional Group map units for the Macquarie Marshes in 1991, 2008 and 2013

Table 3: Extent (in hectares) of Hydro-ecological Functional Groups and Plant Community Types for the mapped area of the Macquarie Marshes in 1991, 2008 and 2013.

Hydro-ecological Functional Groups/ Map Unit	Plant Community Type ID No.	Plant Community Type Name	Area mapped in hectares (ha)		
			1991	2008	2013
Semi-permanent wetland			26712	6758	18230
	181	Common Reed-Bush groundsel aquatic tall reedland grassland wetland	5458	2317	4864
	182	Cumbungi rushland wetland of shallow semi-permanent water bodies and inland watercourses	457	0	1534
	204	Water Couch marsh grassland wetland	12918	912	5354
	53	Shallow freshwater wetland sedgeland	7878	3528	6476
Lagoons	238	Permanent and semi-permanent freshwater lagoons	420	124	396
Channel		Channel - open water	95	138	138
Watercourse		Watercourse - open water	129	127	128
River Red Gum (combined)			40139	39689	41859
River Red Gum open forest	36	River Red Gum tall to very tall open forest (wetland)	2676	2711	2527
River Red Gum woodland	36a	River Red Gum tall woodland (wetland)	17694	18171	20798
River Red Gum grassy woodland	454	River Red Gum grassy chenopod open tall woodland (wetland)	19769	18808	18534
Flood-dependent shrubland wetland			24653	7234	20954
	241	River coobah - lignum swamp wetland	20258	5727	19512
	247	Lignum shrubland wetland	4395	1507	1442
Flood-dependent woodland			26492	24489	27387

Hydro-ecological Functional Groups/ Map Unit	Plant Community Type ID No.	Plant Community Type Name	Area mapped in hectares (ha)		
			1991	2008	2013
Non flood-dependent floodplain vegetation	37	Black Box woodland wetland	17700	16169	18713
	40	Coolibah open woodland wetland	8792	8320	8645
			114036	109397	92090
	144	Leopardwood low woodland	806	736	808
	144 - Lime bush	Lime bush (Citrus glauca) thickets	111	75	77
	145	Western Rosewood - Wilga - Belah low woodland	9245	8568	8594
	158	Old man Saltbush-mixed chenopod shrubland	25	25	25
	206	Dirty Gum-White Cypress Pine tall woodland	29	29	30
	Baradine Red Gum	Baradine Red Gum	20	20	20
	212	Chenopod low open shrubland	716	774	871
	250	Derived tussock grassland	75932	74429	54966
	27	Weeping Myall open woodland	9126	8005	8534
	332	Tumbledown Red Gum - Black Cypress Pine - Red Stringybark woodland	330	323	323
	55	Belah Woodland	1526	1901	1852
	55 - Budda	Budda thicket	4	3	3
	70	White Cypress Pine woodland	1754	1418	1439
	98	Poplar Box - White Cypress Pine - Wilga woodland	14412	13090	14547

Hydro-ecological Functional Groups/ Map Unit	Plant Community Type ID No.	Plant Community Type Name	Area mapped in hectares (ha)		
			1991	2008	2013
Invasive native terrestrial shrubland	Invasive native terrestrial shrubland	Invasive native terrestrial shrubland	4	14847	313
Cleared		Including Infrastructure, cultivated land, Open water – Dam	13111	42988	44296

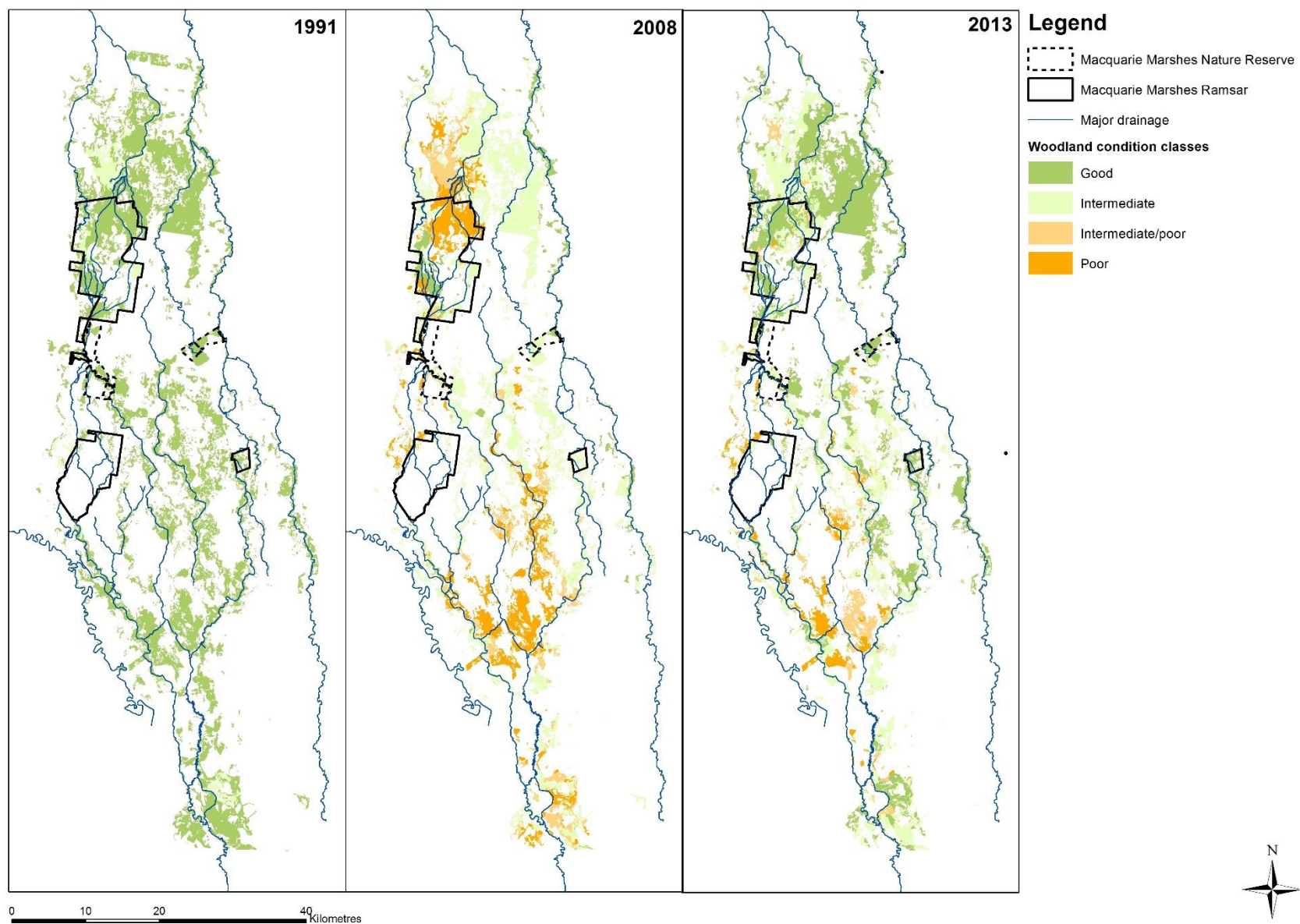


Figure 4: Spatial extent of the condition classes mapped in the Macquarie Marshes for River Red Gum and flood-dependent woodland Hydro-ecological Functional Groups in 1991, 2008 and 2013.

Table 4: Extent of condition classes for River Red Gum and Flood-dependent woodland Hydro-ecological Functional Groups in the Macquarie Marshes mapped area in 1991, 2008 and 2013.

Hydro-ecological Functional Groups / Map Unit	Plant Community Type ID No.		Plant Community Type Name	Condition class	Area in ha		
					1991	2008	2013
River Red Gum (combined)				Good	36350	2179	12843
				Intermediate	3748	13401	19232
				Intermediate/poor	41	8513	5342
				Poor	0	15595	4442
River Red Gum open forest	36	River Red Gum tall to very tall open forest (wetland)	Good	2264	1476	1868	
			Intermediate	413	1028	495	
			Intermediate/poor	0	112	103	
			Poor	0	95	61	
River Red Gum woodland	36 - woodland	River Red Gum tall woodland (wetland)	Good	15011	506	8428	
			Intermediate	2683	7201	10599	
			Intermediate/poor	0	4033	1234	
			Poor	0	6431	538	
River Red Gum grassy woodland	454	River Red Gum grassy chenopod open tall woodland (wetland)	Good	19076	197	2548	
			Intermediate	652	5172	8139	
			Intermediate/poor	41	4369	4005	
			Poor	0	9069	3843	
Flood-dependent woodland				Good	26147	2970	19933
				Intermediate	345	21492	7288

Hydro-ecological Functional Groups / Map Unit	Plant Community Type ID No.	Plant Community Type Name	Condition class	Area in ha		
				1991	2008	2013
			Poor	0	27	137
	37	Black Box woodland wetland	Good	17700	2390	14402
			Intermediate	0	13777	4215
			Poor	0	2	96
	40	Coolibah open woodland wetland	Good	8447	580	5531
			Intermediate	345	7715	3073
			Poor	0	25	41

4. Mapping recommendations

Periodic update of the vegetation extent and condition mapping allows ongoing monitoring of vegetation change in the Macquarie Marshes. We make the following recommendations for the next iteration of the mapping product:

- Undertake a quantitative accuracy assessment using a large number of field observations that are randomly distributed and stratified between vegetation communities (Keith and Simpson 2008)
- Use the quantitative accuracy assessment to determine suitability of mapping semi-permanent wetland vegetation communities when mapping intervals are greater than a single year (DLWC 2000)
- Evaluate the effectiveness of management interventions by relating the mapped vegetation extent and condition to environmental predictors such as climatic and inundation regime data.

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