Black Swamp Flood Regime Determination

PROJECT REPORT

- Final
- 19 October 2007

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1. Introduction

The Black Swamp wetland complex is situated on the floodplain of Nine Mile Creek and is considered to be of bioregional significance. This wetland complex comprises the Black Swamp Wildlife Reserve, Purdies Swamp and an unnamed wetland area located in the adjoining floodplain. The Black Swamp wetlands are generally considered to be in good condition, as reported by the *Broken Boosey and Nine Mile Creeks Wetland Implementation Plan* study conducted for the Goulburn Broken CMA in 2006. However, similar to the majority of Victoria's wetlands, the ecological values of the Black Swamp wetlands are also under threat. The current regulated flow regime in the Nine Mile Creek has resulted in unseasonal and prolonged flooding of the wetlands, reducing the biodiversity and abundance of certain types of biota. This situation has also been exaggerated by the regular, unauthorised manipulation of the wetland regulating structure to provide suitable conditions for waterfowl hunting. The implementation of a more natural wetting and drying cycle is required to protect and enhance the ecological values of this wetland complex.

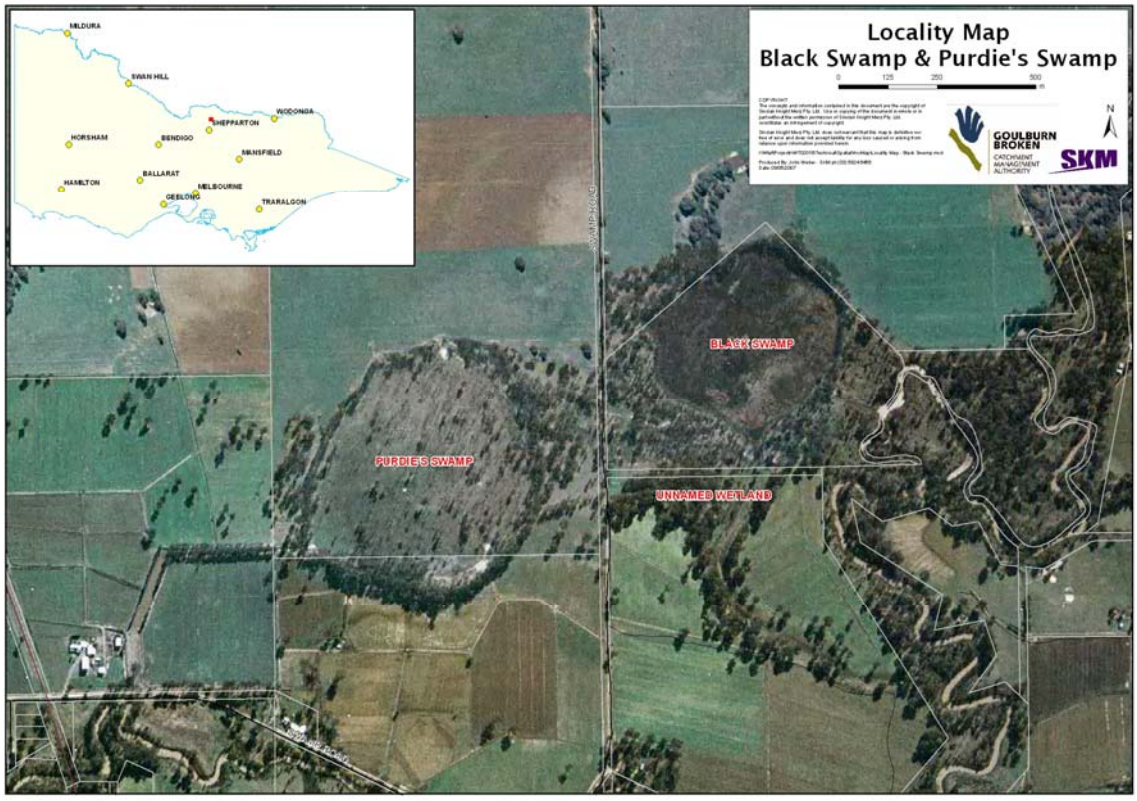
A draft *Interim Management Statement* was prepared for the Black Swamp wetland complex by the then Department of Conservation and Environment in 1991. This document included a description of the ecological values of the wetland, critical levels, a description of the water regime and recommended management actions. Since this time, some of the management actions have been implemented, particularly the construction of a regulating structure to preclude high irrigation flows in summer and autumn. Unfortunately, operation of the regulating structure has not been consistent with the recommended management actions of the *Interim Management Statement* and in many years an unnatural wetting regime for the wetland has occurred and this has impacted on the ecological values of the wetland complex.

This project documents the key ecological values present within the Black Swamp wetland complex and the threats posed to them by the current water regime. Through field assessments, topographic survey work and the development of a hydraulic model, the current water regime was documented and compared to the desired regime required to maintain and enhance the ecological values of the wetland complex. Works and actions required to implement the desired water regime and support the wetland's ecological values are also presented.

2. Background

2.1 Location

The Black Swamp wetland complex (Figure 1) is located on the floodplain of Nine Mile Creek east of Wunghnu and 27 km north of Shepparton.



- **Figure 1 Black Swamp/Purdies Swamp complex location and features.**

The complex is located in the Victorian Riverina bioregion of Victoria (NRE 1997). The Victorian Riverina bioregion occurs on the northern Victorian Riverine Plain, which is characterised by flat to gently undulating land on recent unconsolidated sediments with evidence of former stream channels and includes wide floodplain areas associated with major river systems (NRE 1997). The natural vegetation occurring in this bioregion was Plains Grassy Woodland Complexes, Grassland Complexes, and Riverine Grassy Woodland Complexes (NRE 1997). The Plains and Riverine Grassy Woodland Complexes are characterised by low density tree cover dominated by River Red Gum *Eucalyptus camaldulensis*, Black Box *E. largiflorens*, other box eucalypt species and/or Buloke *Allocasuarina leuhmanii* and native Callitris pines *Callitris* sp.. If a shrub layer is present, species include Lightwood *Acacia implexa*, Golden Wattle *A. pycnantha*, Gold-dust Wattle *A. acinacea* and saltbushes (Family Chenopodaceae). The Grassland complex is dominated by Wallaby grass *Austrodanthonia* spp. and Spear grass *Austrostipa* spp. with a mixture of herbs from

the daisy (Family Asteraceae), saltbush and pea families (Family Fabaceae). Grassland Complexes and Grassy Woodland Complexes originally dominated much of the Riverina but are now largely fragmented (NRE 1997).

Black Swamp is located on public land within the Black Swamp Wildlife Reserve and Purdies Swamp lies adjacent to the reserve on private land. The wildlife reserve is 49 ha, with 27 ha covering Black Swamp itself, Purdies Swamp is 32 ha (DCE 1991) and the entire complex (comprising the associated floodplain and connecting floodways) is 107 ha (Project Brief 2007).

Based on the 1994 DSE wetland categories (DSE 2007a) the Black Swamp/Purdies Swamp complex can be divided into three wetlands: Black Swamp (including a shallow area to the north of Black Swamp following a drainage line), Purdies Swamp and an area connecting Black and Purdies Swamps and extending south towards Nine Mile Creek (see Figure 1). The classification and areas of these wetlands are summarised in Table 1.

Table 1 Wetland classification of the Black Swamp/Purdies Swamp Complex (DSE 2007a).

Wetland	Wetland number	Area (ha)	Classification
Black Swamp	607 991	20.33	Shallow marsh-dead timber
Wetland to the north of Black Swamp	607 991	7.17	Shallow marsh-herb
Purdies Swamp	600 990	31.6	Shallow marsh-Red Gum
Wetland connecting Black and Purdies Swamps	607 988	13.22	Meadow-Red Gum

2.2 Significance

The majority of Victoria's wetlands have been significantly altered, degraded or lost (NRE 1997). The wetlands in the Black Swamp complex are shallow freshwater marshes whilst the low-lying connecting channel is a freshwater meadow (DSE 2007a). Shallow wetlands including freshwater meadows and shallow freshwater marshes have been significantly reduced both in number and size within Victoria, which has particular significance for faunal species that require shallow wetland habitats for breeding or nesting, such as the Brolga (NRE 1997). There is now only 40% of the original area of shallow freshwater marshes remaining in Victoria (NRE 1997). Of the six wetland categories used in Victoria, this category represents the second largest loss of wetland area in Victoria (deep freshwater marshes represent the greatest loss with now only 30% of their original area remaining) (NRE 1997).

Shallow freshwater marshes are the second most common wetland type in the Goulburn Broken Catchment Management Authority (CMA) region (31% of wetlands) following freshwater meadows (38% of wetlands) (GBCMA 2002). Although shallow freshwater marshes are relatively common in the Goulburn Broken CMA region, there has been a significant decrease in shallow freshwater marshes in the region (GBCMA 2002). Although the numbers and areas of these

wetlands are known in the state and region, there is usually no indication of the condition of these wetlands. There are very few large wetlands in the Goulburn Broken CMA region with only 4% of the wetlands in the region being over 100 ha in size (GBCMA 2002).

Shallow freshwater marshes are characterised as wetlands which usually dry out in mid summer and refill with the onset of winter rain (Corrick and Norman 1980, NRE 1997). In these wetlands, the soil is waterlogged throughout the year and surface water to 0.5 m deep may be present for 6-8 months (Corrick and Norman 1980).

In addition to the significance of the wetlands based on their wetland types, the complex is the largest wetland area along Nine Mile Creek (SKM 2005) and is one of the most significant wetland areas within the Middle Broken Creek-Lower Nine Mile Creek system (DCE 1991). The complex is not specifically included in the Broken Creek Directory of Important Wetlands in Australia listing. However, the National Land and Water Resources Audit (NLWRA 2002) listed Black Swamp as bioregionally significant and the complex is considered of regional conservation significance in the draft *Wetlands Conservation Strategy for the Shepparton Irrigation Region* (DCE 1991).

2.3 Management history and uses

Black Swamp occurs within the Black Swamp Wildlife Reserve, which is managed by Parks Victoria. Purdies Swamp occurs on private land that is managed by two separate land holders. The unnamed wetland also occurs on private land.

The 34 ha area identified as the Black Swamp (Nine Mile Creek) site (C19) was described by the Land Conservation Council (LCC 1985) as a shallow, permanent fresh-water wetland in a natural floodway containing rushes and reeds and with a number of dead trees, being the Water Reserve south of allotment 23, Parish of Drumanure. Also, that it was an important Australian White Ibis *Threskiornis molucca* breeding area and that some revegetation works were required.

Black Swamp is managed as part of the Black Swamp Wildlife Reserve. Recommendations made by the LCC in May 1985 (LCC 1985) stated that wildlife reserves be used:

(a) primarily to conserve the habitat of native animals, particularly water birds;
(b) for public recreation and education where this does not conflict with the primary aim;
and that
(c) grazing be permitted at the discretion of the land manager if it does not conflict with the above aims;
and that they be permanently reserved under Section 4 of the *Crown Land (Reserves) Act* 1978 and be managed by the Department of Conservation, Forests and Lands.

Since that time, a draft *Interim Management Statement* has been prepared for Black Swamp (DCE 1991), the 2005 Lower Broken Creek Waterway Management Strategy (GHD 2005) has been implemented which provides for the broader framework for works and activities on the Nine Mile Creek, and the Broken-Boosey State Park (which abuts Black Swamp) has been declared following recommendations in the Environmental Conservation Council's *Box-Ironbark Forests & Woodlands Investigations* Final Report (ECC 2001). A list of past management actions associated with Black Swamp is provided in Table 2. There is little information regarding the past management activities of Purdies Swamp.

Table 2 Past management history of Black Swamp.

Year	Activity	Source
Feb 1884	Temporarily reserved, site affording access to water (Water Reserve).	DSE, Black Swamp internal file
1961	Nine Mile Creek becomes a carrier stream receiving water from the East Goulburn Main Channel, new irrigation licences.	DSE, Black Swamp internal file
1963	Nine Mile Creek is dredged.	DSE, Black Swamp internal file
Feb 1964	Nine Mile Creek is dredged.	DSE, Black Swamp internal file
Sep 1968	State Rivers and Water Supply Commission (SRWSC) agrees to provide water management structures in Nine Mile Creek for Black and Purdies Swamps.	DSE, Black Swamp internal file
Mar 1969	The Minister agrees to provide water management structures in Nine Mile Creek for Black and Purdies Swamps.	DSE, Black Swamp internal file
Nov 1969	Water requirements for Black and Purdies Swamps assumed to be met by unregulated flows in Nine Mile Creek. Water needs to be defined by Fisheries and Wildlife Department (FWD).	DSE, Black Swamp internal file
1971	Channel constructed between Nine Mile Creek and Black Swamp	DCE (1991)
1971	Working bee to move pipes located on the inlet channel.	DSE, Black Swamp internal file
1979	SRWSC seeks indemnity from FWD for possible inundation of Purdies Swamp.	DSE, Black Swamp internal file
May 1979	Pipes eroded.	DSE, Black Swamp internal file
Oct 1979	SRWSC provides design for regulating structure on the inlet channel.	DSE, Black Swamp internal file
Feb 1980	Inlet cleaned by Field and Game Association.	DSE, Black Swamp internal file
Jun 1980	SRWSC legal opinion not able to undertake works.	DSE, Black Swamp internal file
Winter 1981	Control structure on inlet channel damaged by floodwater.	DSE, Black Swamp internal file
Feb 1982	SRWSC reject upgrade of structure on inlet channel, pending amending legislation to permit supply for wildlife purposes.	DSE, Black Swamp internal file
Mar 1989	Temporarily reserved for the management of wildlife (Wildlife Reserve).	DCE (1991)
1991	Draft *Interim Management Statement* written by DCE with recommendations for future water regime.	
1992	Construction of current adjustable regulator on inlet channel to Black Swamp.	Rick Felton, DSE, *pers. Comm.*.
Mar 1994	Arrowhead invasion (dense).	DSE, Black Swamp internal file

The Black Swamp reserve is used for recreation including duck hunting. The wetland is considered to be of state significance for hunting when water is present and hunters travel considerable

distance to the wetland. Illegal off road vehicle use also occurs in the reserve, along with timber harvesting and rubbish dumping. Purdies Swamp occurs on private land and is used for grazing. Duck hunting also occurs on this wetland.

Although an adjustable regulator has been constructed in an attempt to deliver a more desirable water regime to the wetlands, the water regime recommended in the Draft *Interim Management Statement* (DCE 1991) has never been fully implemented and the operation of the structure has been *ad hoc*.

2.4 Historical Modification of Water Regime

The information in this section has been summarised from the draft *Interim Management Statement* for the Black Swamp Wildlife Reserve (DCE 1991). More detailed information regarding the current hydrology follows in Section 3.1.

Naturally the wetlands would have been seasonally inundated River Red Gum dominated wetlands. Both Black Swamp and Purdies Swamp would have received water from Nine Mile Creek when floodwaters broke the banks of the creek and spilled into these wetlands via the un-named wetland to their south. There was also a local catchment of 200 ha to the north of Black Swamp that would have contributed to the wetting of these wetlands.

The natural water regime would have seen flooding of the wetlands during winter-spring and draw down and drying over summer-autumn. It is not clear what the frequency of this flooding would have been; the draft *Interim Management Statement* (DCE 1991) is equivocal stating on one occasion that wetting would occur in most years but on another occasion that wetting would have occurred every second or third year. Other suggestions are that it received water three years in every five (R. Weber, DSE, *pers. comm.*).

In the 1960's, utilisation of Nine Mile Creek for irrigation supply and drainage outfalls commenced This resulted in the creek being changed from a seasonally dry waterway over summer-autumn (with the exception of irregular and intermittent flows during this period) to having a permanent flow over summer-autumn. The increase in flows in the Nine Mile Creek resulted in prolonged inundation of Black Swamp and Purdies Swamp because the regulated flow level in the creek was higher than the commence to fill level of the wetlands.

In the late 1960s dredging of the creek was undertaken to increase the capacity of the Nine Mile Creek. As a result of these works water levels in the Nine Mile Creek were reduced and Black Swamp and Purdies Swamp were no longer permanently inundated.

Excavation of a water supply channel to Black Swamp was undertaken in 1971 to ensure water was present for the duck hunting season. This led to another phase of permanent inundation of the

wetland. Water also flowed more freely into Purdies Swamp. Culverts were installed in the channel to allow some control and vehicle access but they were repeatedly washed out. The water level in Black Swamp fluctuated with the water levels in Nine Mile Creek. The water regime at this time was permanent shallow flooding of the central open area of Black Swamp with winter-spring flooding of the narrow fringing vegetation and the floodway depressions.

An outlet channel from Purdies Swamp to Grass's Dam to the west of the wetland was constructed in the mid 1970s. This has resulted in the ponding level in the wetland being set by the fixed crest level of the dam. At this time Purdies Swamp was flooded more regularly, at greater depths and for longer durations, than under natural conditions. There was the potential for water to enter the wetland over the summer-autumn period when water overflowed from Black Swamp or Grass's Dam. Purdies Swamp had regular winter-spring flooding with ponding until around December and a regular dry period over summer-autumn.

Since 1992 a regulator has been installed on the water supply channel to Black Swamp in an attempt to reduce the inundation of the wetlands as recommended in the draft *Interim Management Statement* (DCE 1991), although this regulator is regularly tampered with in an attempt to allow water into the wetland for the duck hunting season. The current drought has lead to a recent extended dry period in the wetlands.

3. Water regime

The water regime for the Black Swamp complex has been determined through a combination of hydrology in Nine Mile Creek and hydraulic modelling of the relationship between flow in the creek, inflow characteristics of the swamp and a water balance for the swamp complex. Details of the approach used to develop a flow regime for Nine Mile Creek and hydraulic modelling is provided in Appendix A.

The following sections summarise the outcomes of the modelling with respect to the current and natural water regimes.

3.1 Current water regime

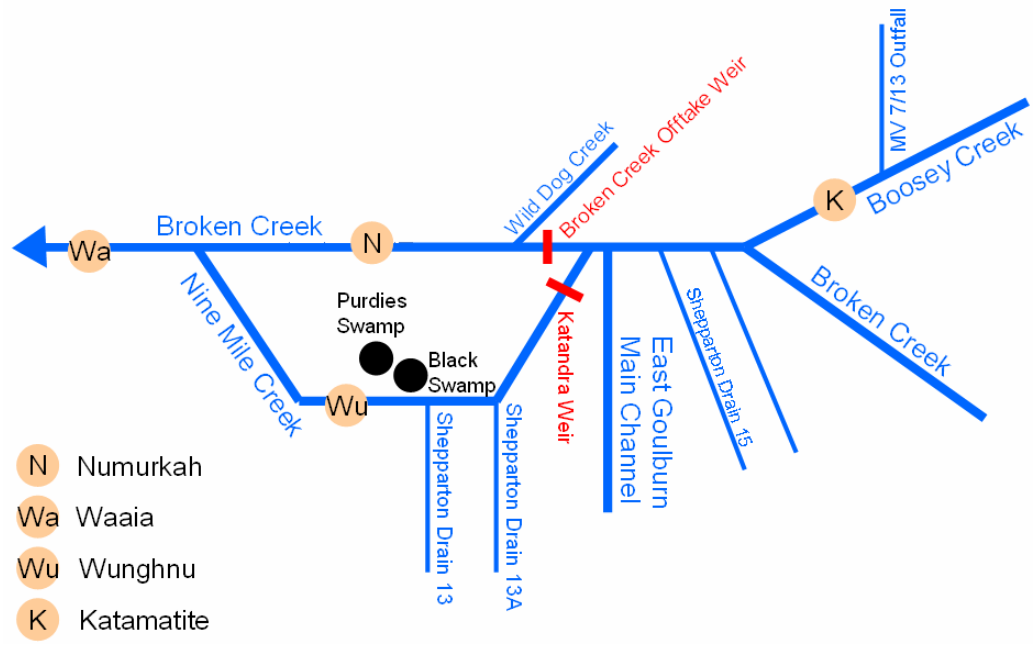
Water enters Black Swamp from Nine Mile Creek, which is an anabranch of the Broken Creek. It begins downstream of the confluence of Boosey Creek and Broken Creek, and rejoins Broken Creek between Numurkah and Waaia (Figure 2).

The following sources of water contribute to flows in Nine Mile Creek:

- Flows from Boosey Creek and the upper Broken Creek,
- Outfalls from the East Goulburn Main Channel (EGM), and
- Drainage from the Murray Valley and Shepparton Irrigation Areas.

Gate structures are located on Broken Creek and Nine Mile Creek at the effluent of Nine Mile Creek. These gates control the division of water between the two waterways. Discussions with Goulburn-Murray Water staff have indicated that the split of flow between the two waterways can be highly variable according to the relative downstream irrigation demands. A range of estimates for the flow split were provided, ranging from a 60%:40% split through to a 75%:25% split. Given this variability it has been assumed that the split of flows between the two waterways is 2/3:1/3 between Nine Mile Creek and Broken Creek which is approximately in the middle of the range 60%:40% and 75%:25%.

Currently, flows in Nine Mile Creek are elevated during the irrigation season by regulated outfalls from the East Goulburn Main Channel (EGM) and drainage inflows and channel outfalls from the Murray Valley and Shepparton Irrigation Areas. A standing order of irrigation water is outfalled from the EGM throughout the irrigation season that is typically 100 ML/d – 300 ML/d, while flows from each drain or channel outfall are generally 1 ML/d – 3 ML/d. Flows in Nine Mile Creek decline in winter when outfalls from the EGM and other G-MW channels reduce to ~0 ML/d.



- **Figure 2 Schematic of the Lower Broken Creek and Nine Mile Creek**

The 'natural' flow path between the Nine Mile Creek and Black and Purdies Swamp has been determined to be via the Unnamed Wetland located to the south of Black Swamp. A range of earthworks have been undertaken on this depression which has resulted in its hydraulic function being compromised. Specifically an earthen levee bank has been constructed across the depression adjacent to the Nine Mile Creek thereby blocking this flow path. Other works on the depression include the excavation of two dams within the depression, the excavation of a drain along most of its length and the general incorporation of these works into the on-farm irrigation and drainage layout of the property.

The artificial inlet channel to Black Swamp is located on a large meander bend in Nine Mile Creek. There is a meander cut-off on this bend that effectively short circuits low flows from the meander. However, modelling shows that under regulated and peak flows the presence of the cut off does not significantly influence levels at the inlet channel to Black Swamp, so all modelling has been undertaken with the cut-off active.

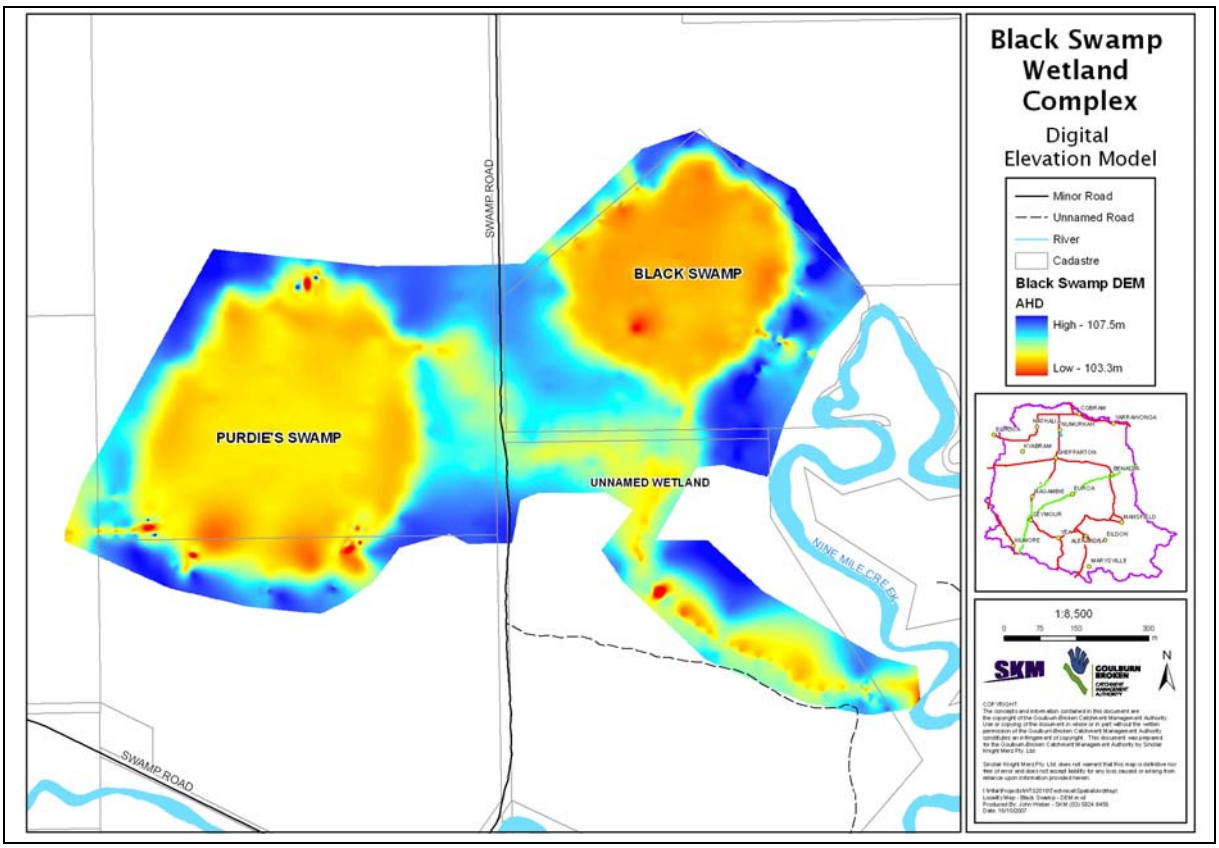
Under the current regulator arrangements between Black Swamp and Nine Mile Creek water enters Black Swamp when flows in Nine Mile Creek are approximately 100 ML/d and Purdies Swamp when flows are approximately 300 ML/d (Table 3).

- **Table 3 Flow in Nine Mile Creek versus flow to Black and Purdies Swamp, under current conditions**

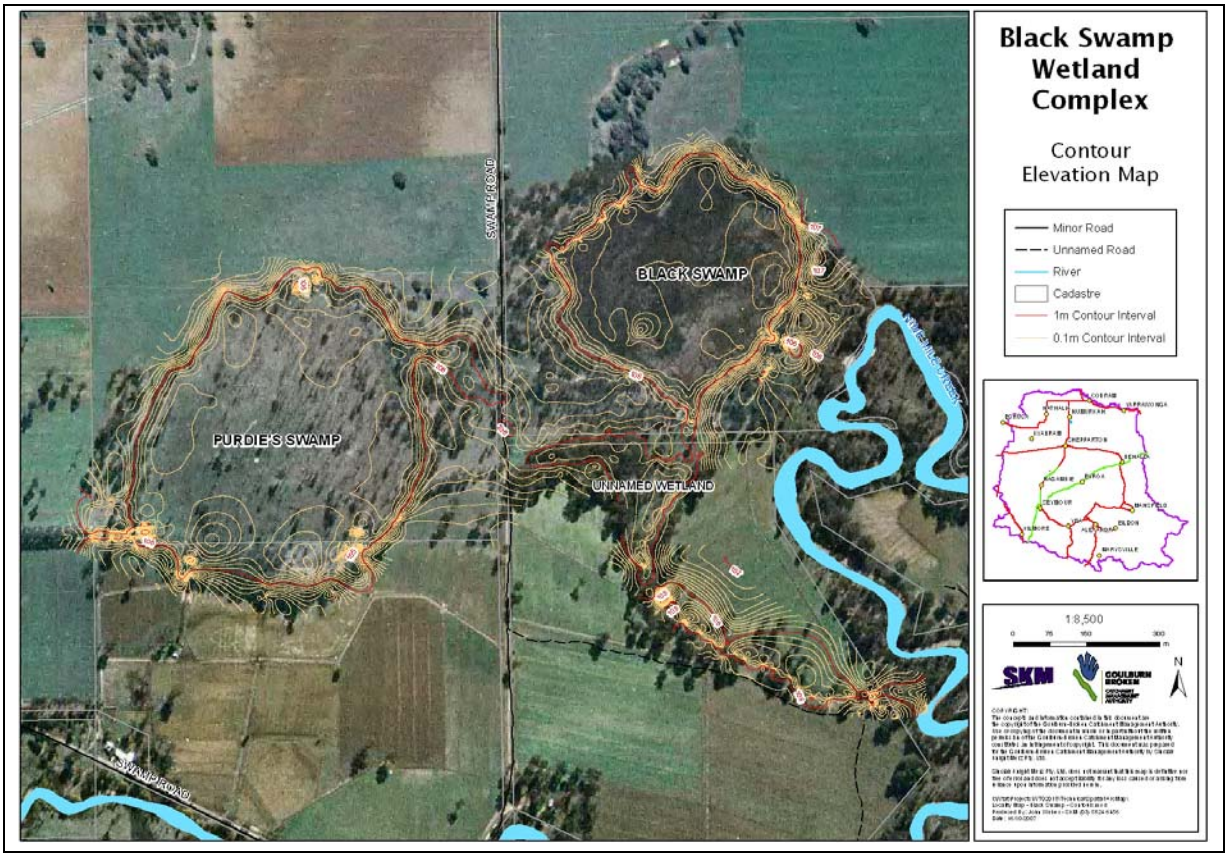
Flow in Nine Mile Creek (ML/d)	Level in Nine Mile Creek (m AHD)	Max. Discharge to Black Swamp (ML/d)	Max. Discharge to Purdies Swamp (ML/d)
86.4		0.0	0.0
95.0	105.612	6.3	0.0

Flow in Nine Mile Creek (ML/d)	Level in Nine Mile Creek (m AHD)	Max. Discharge to Black Swamp (ML/d)	Max. Discharge to Purdies Swamp (ML/d)
172.8	105.776	24.0	0.0
259.2	105.910	54.1	0.0
293.8	105.950	67.0	6.0
345.6	106.020	86.7	27.9
432.0	106.114	119.2	61.4

Therefore, under current conditions, flows in Nine Mile Creek are sufficient to allow water to enter Black Swamp during the regulated flow (irrigation) period, which is typically September through to April (Figure 5). This results in Black Swamp experiencing near permanent inundation (Figure 6; Figure 7) in most years. A Digital Elevation Model and topographic map highlighting the detailed surface levels in the vicinity of the three wetlands and immediate surrounds are shown in Figure 3 and Figure 4. The Digital Elevation Model and contour information was derived from field survey undertake throughout the site.



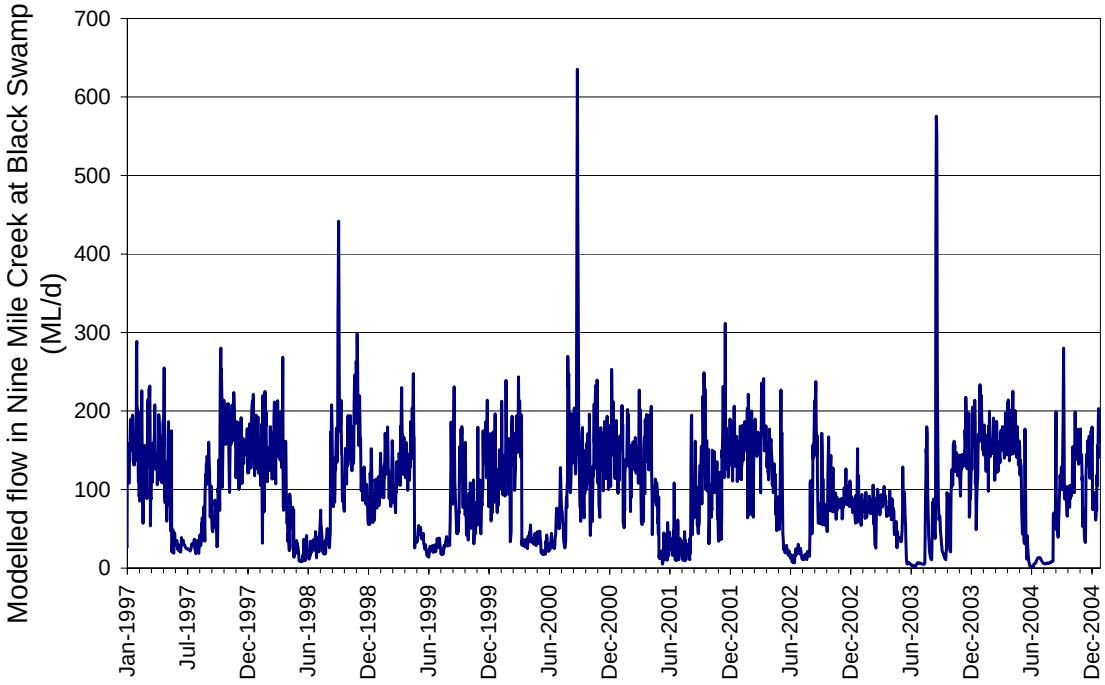
- **Figure 3 Digital Elevation Model of Black Swamp Wetland Complex**



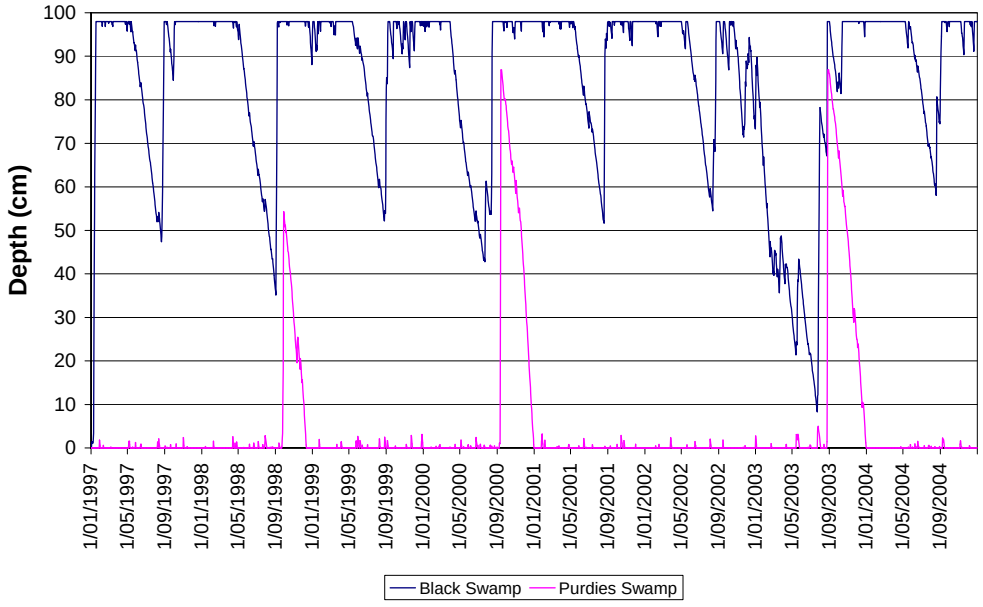
- **Figure 4 Contour Map of Black Swamp Wetland Complex**

In contrast, regulated flows rarely exceed 300 ML/d; the flow that allows water to enter Purdies Swamp (Figure 5). Hence, Purdies Swamp experiences a near natural frequency of wetting and drying (Figure 6; Figure 7). The main feature that impacts on the hydrology of Purdies Swamp is the outlet channel to Grass's dam which is located in the south west of the wetland. The bed level of this drain (105.6 m AHD) approximates the bed level of the wetland and is significantly lower than the natural sill level of the wetland. Initial hydraulic modelling of Purdies Swamp indicated that with this drain in place ponding of water in the wetland did not occur. In order to restore the wetting and drying regime of Purdies Swamp a structure will need to be constructed at this location to restore the natural sill level of the wetland. The crest level of this structure would need to be approximately 106.3 m AHD.

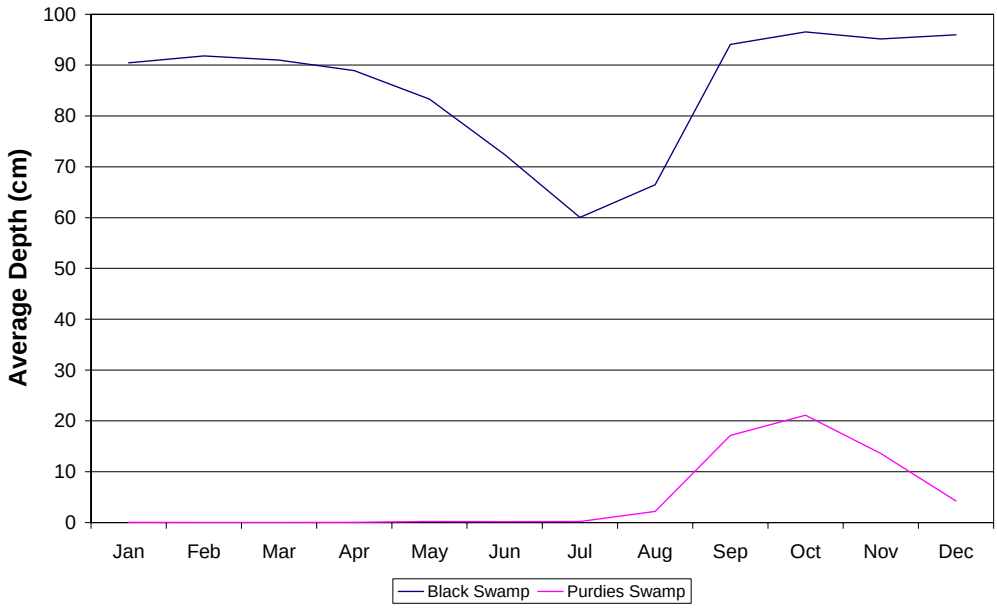
Consequently, for all subsequent hydraulic modelling undertaken for these wetlands it has been assumed that the natural sill level of Purdies Swamp has been restored via the construction of a weir or other structure on this drain.



- **Figure 5 A time series of modelled flow in Nine Mile Creek at the inlet to Black Swamp under current conditions (1997-2004)**



- **Figure 6 A time series of modelled water depth in Black and Purdies Swamp under current conditions (1997-2004), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**



- **Figure 7 The average depth in Black Swamp and Purdies Swamp, under current conditions (1997-2004), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**

3.2 Natural water regime

The current wetting regime for Black Swamp is opposite to the natural regime. Under natural conditions the wetting and drying of Black and Purdies swamp would be determined by the pattern of peak flows in Nine Mile Creek. The following sections describe the modelled natural wetting and drying regime for the swamp complex post and per 1997. Post 1997 relates to conditions experienced under the current drought, compared with pre 1997, which presents a more typical natural regime.

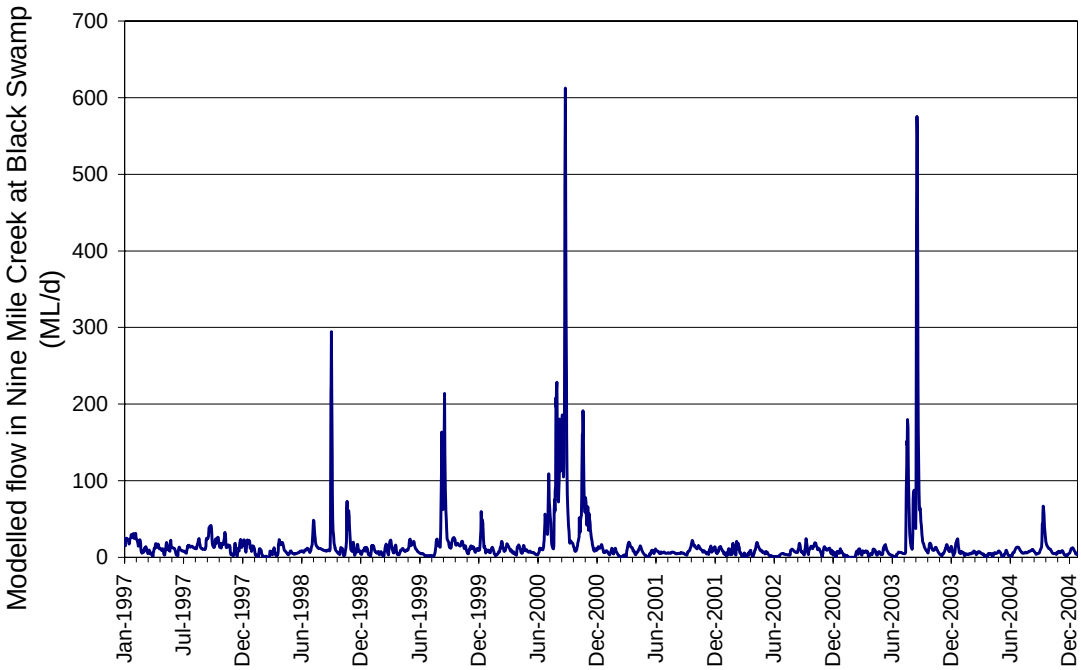
Several runs of the hydraulic model were also undertaken with the embankment which prevents flow along the natural inflow path between the unnamed wetland and Nine Mile Creek removed, and the current offtake to Black Swamp from Nine Mile Creek blocked to a natural sill level of 106.18 m AHD. The intent of this modelling was to establish the natural commence to flow conditions for the wetlands. Under this natural regime Black Swamp begins to fill via this 'natural' depression once flows in Nine Mile Creek reach approximately 400 ML/d. Meaningful flows into the wetlands begin once flows in Nine Mile Creek reach approximately 500 ML/d (Table 4).

- **Table 4. Flow in Nine Mile Creek versus flow to Black and Purdies Swamp, assuming the link between Nine Mile Creek and the unnamed wetland is restored**

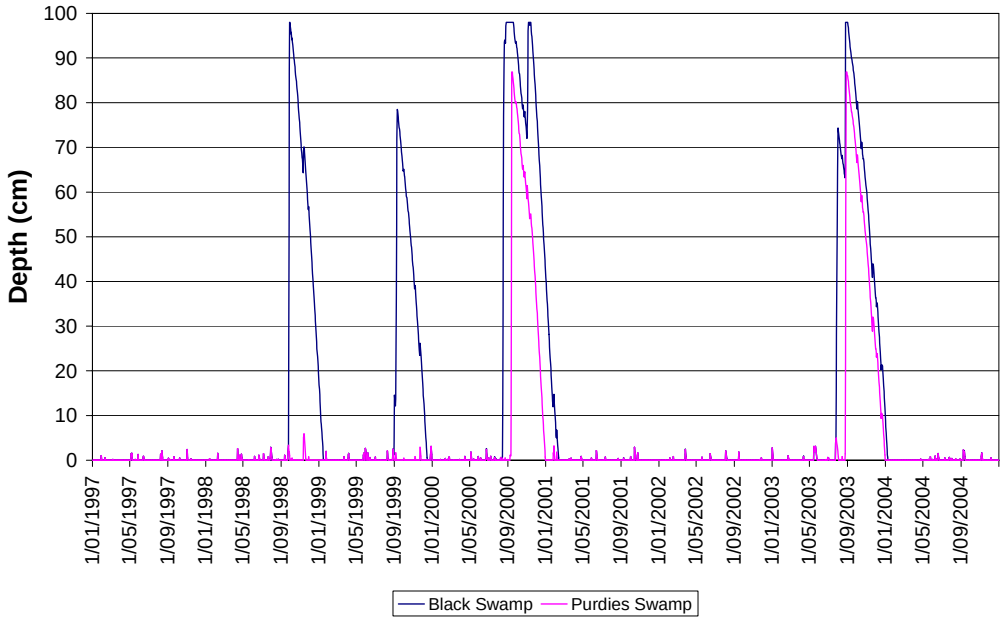
Flow in Nine Mile Creek (ML/d)	Level in Nine Mile Creek (m AHD)*	Max. Discharge to Black Swamp (ML/d)	Max. Discharge to Purdies Swamp (ML/d)
362.9	106.087	2.0	0.0
406.1	106.132	3.6	0.0
457.9	106.181	7.3	0.0
475.2	106.194	16.8	0.0
518.4	106.217	38.0	5.1
570.2	106.273	50.8	24.8
622.1	106.312	63.0	41.6

3.2.1 Post 1997

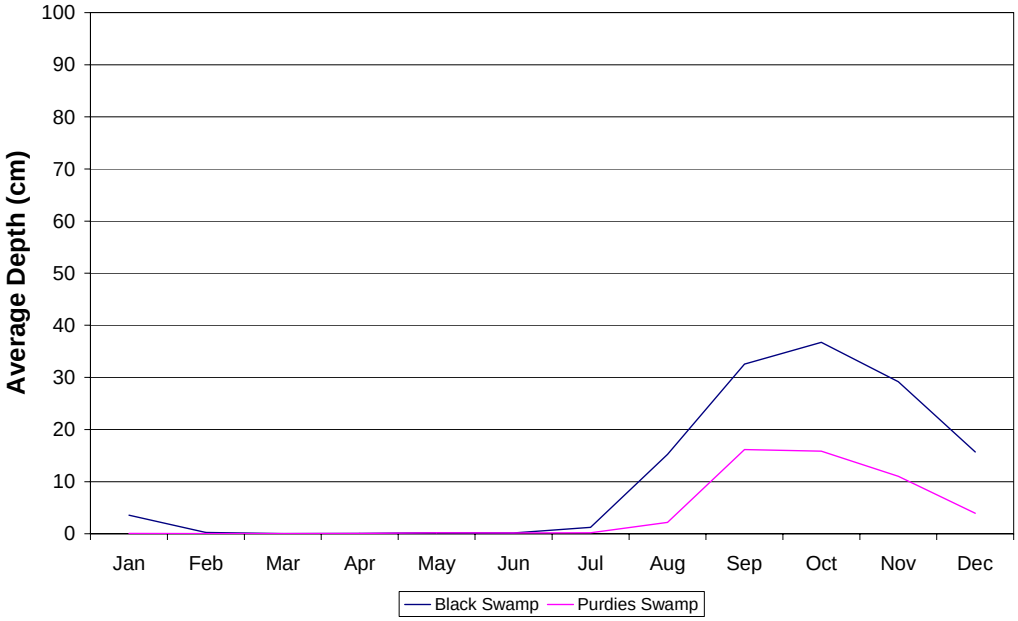
Modelled natural flows in Nine Mile Creek (Figure 8) show only four peak flows between 1997 and 2004 sufficient to inundate Black Swamp, two of these would have also inundated Purdies Swamp (Figure 9). Each inundation event would have occurred in late winter or early spring, with the swamps retaining the water for several months (Figure 10). In contrast to the current regime, Black Swamp would have been dry by the end of every summer post 1997.



- **Figure 8 A time series of modelled flow in Nine Mile Creek at the inlet to Black Swamp under natural conditions (1997-2004)**



- **Figure 9 A time series of modelled water depth in Black and Purdies Swamp under natural conditions (1997-2004), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**



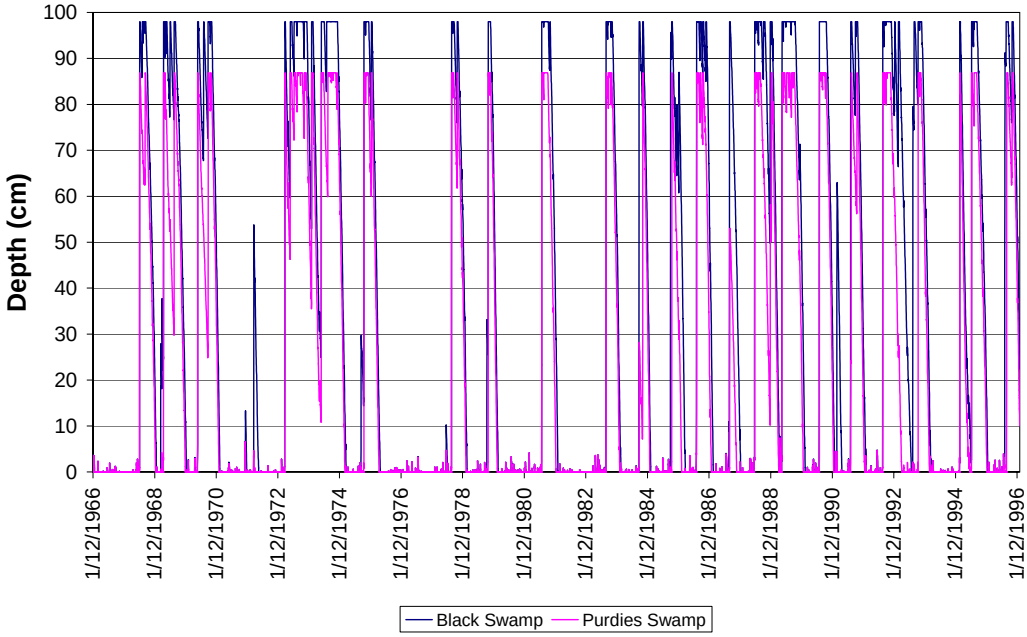
- **Figure 10 The average depth in Black Swamp and Purdies Swamp, under natural conditions (1997-2004), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**

3.2.2 Pre 1997

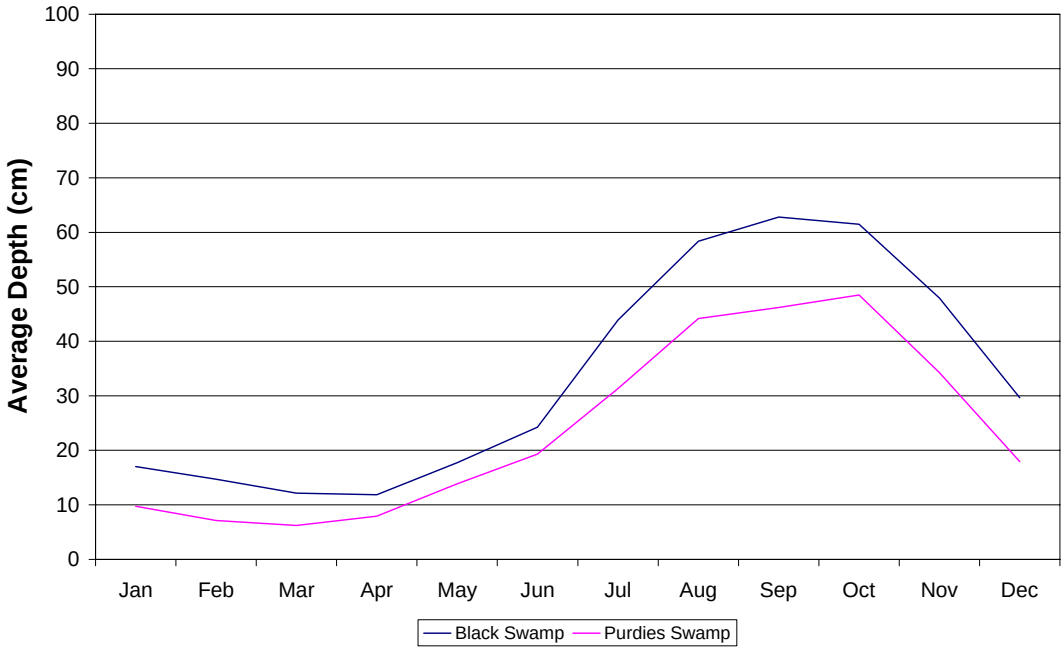
Under natural conditions pre 1997 the inundation of Black and Purdies Swamp would have been a more frequent compared with post 1997 (Figure 11). Pre 1997, it is estimated that under natural conditions Black and Purdies Swamp would have:

- been inundated 8 in every 10 years,
- filled sometime between June and October, and
- retained water for between 3 and 6 months.

The average depth of water in Black and Purdies Swamp under natural conditions would have therefore been much greater pre 1997 compared with post 1997 (Figure 12).



- **Figure 11 A time series of modelled water depth in Black and Purdies Swamp under natural conditions (1966-1996), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**



- **Figure 12 The average depth in Black Swamp and Purdies Swamp, under natural conditions (1966-19996), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**

4. Ecology

4.1 Ecological vegetation classes

There is little vegetation remaining at the wetlands which can be classed as Ecological Vegetation Classes (EVCs). The pre-1750s EVC for Black and Purdies Swamps was River Red Gum Wetland (EVC 292) (DSE 2007a) (Figure 13). The unnamed wetland to the south (607 988) was Plains Grassy Wetland (EVC 125), the surrounding area was Plains Grassy Woodland/Gilgai Wetland Mosaic (EVC 259) and Nine Mile Creek was Creekline Grassy Woodland (EVC 68) (DSE 2007a). All of these EVCs are considered endangered in Victoria (DSE 2007b).

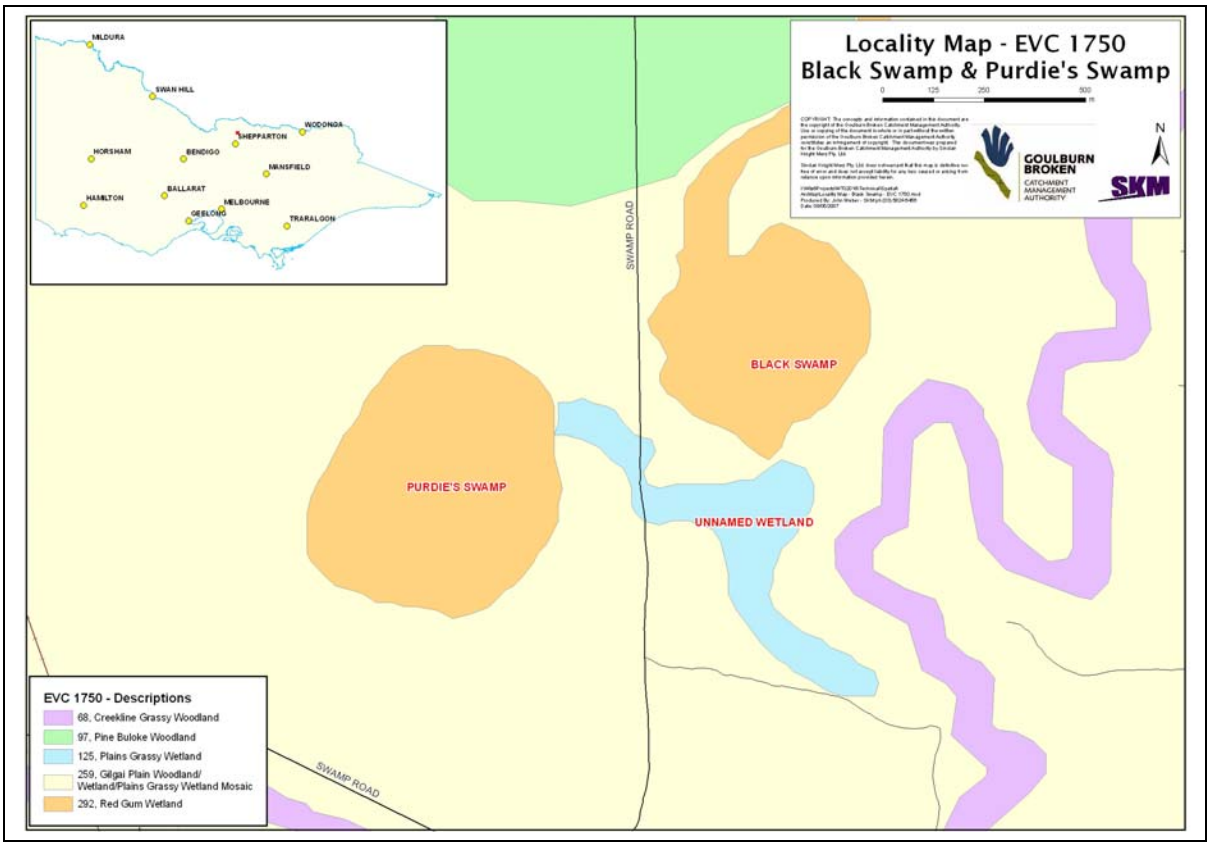
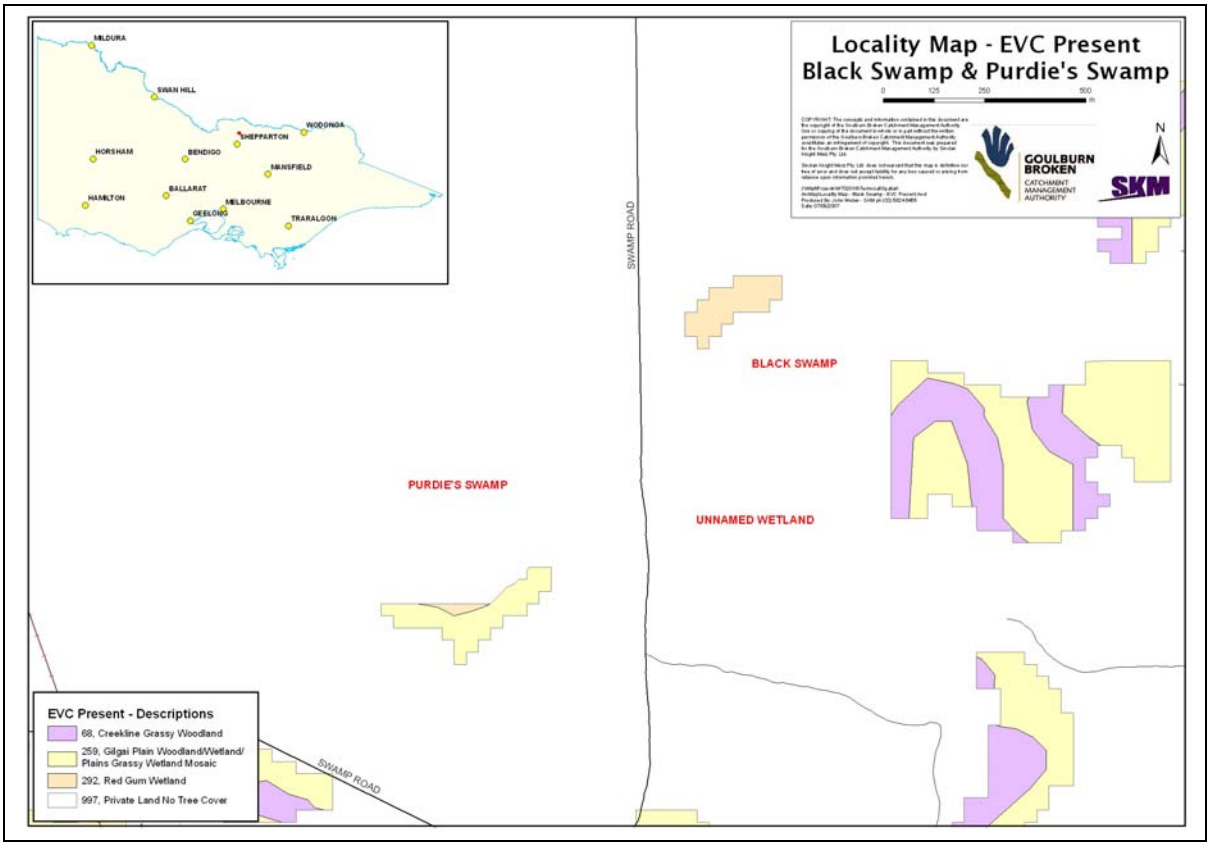


Figure 13 Pre-1750 EVCs – Black Swamp Wetland Complex

The current areas of EVC, based on DSE's mapping, are a small area of River Red Gum Wetland (EVC 292) at both Black (north eastern side) and Purdies Swamps (southern side) and a small area of Plains Grassy Woodland/Gilgai Wetland Mosaic (EVC 259) at Purdies Swamp (southern side) (DSE 2007a) (Figure 14).



- **Figure 14 Current EVCs – Black Swamp Wetland Complex (source DSE 2007a)**

4.2 Flora

4.2.1 Black Swamp

Around 60 plant species (DCE 1991; DSE 2007c; Roberts and Hale 2006) have been recorded at Black Swamp; of these species, approximately 40% are introduced (Appendix B). The most notable of these, from a water regime aspect, is Arrowhead *Sagittaria platyphylla* as it is considered a significant aquatic weed. Approximately 40% of the species recorded from the wetland can be considered water regime dependant and less than 10% of the species are shrub or tree species. Important wetland habitat species include River Red Gum and Tangled Lignum *Muehlenbeckia florulenta.* It is important to note that the lists of species previously recorded are by no means definitive. The records depend on variables such as the person recording the information, the purpose of the study and the time of year. It is fully expected that if more detailed and frequent surveys were undertaken at the wetlands a far more exhaustive list of species would be compiled hence giving a greater understanding of the ecology of the wetlands.

The once seasonal River Red Gum dominated wetland was changed to a permanent wetland as a result of utilising Nine Mile Creek as an irrigation channel in the 1960s and the construction of the water supply channel to the wetland (DCE 1991). This permanent inundation lead to the death of

the River Red Gums in the wetland. Although a regulator has been installed on the supply channel in an attempt to return a more ecologically desirable water regime, it is regularly vandalised to allow a greater flow of water to the wetland in a hope to encourage waterfowl for hunting. In recent years however the wetland has been largely dry, most likely as a combination of improved regulator management and the current drought. It is thought that the original aquatic understorey in the centre of the wetland would have consisted of species such as Spike-rush *Eleocharis* sp., Water Milfoil *Myriophyllum* sp. and Water Ribbons *Triglochin* sp. with fringing vegetation consisting of species such as Rushes *Juncus* sp., Sedges *Carex* sp., Cane Grass *Eragrostis infecunda* and Tangled Lignum (DCE 1991).

Over previous years the near permanent inundation is thought to have led to the replacement of some of the prior plains vegetation with species more tolerant of waterlogging, such as the regeneration of the fringing River Red Gums. This shift in the vegetation community is most evident in the riparian zone and in low-lying areas that have been inundated for long periods of time (SKM 2005). Whilst the water regime was more permanent it had the potential to favour dense growth of algae and species such as Azolla *Azolla* sp. and Cumbungi *Typha* sp. (DCE 1991). In addition, when the wetland experienced long periods of inundation it was thought that dense European Carp *Cyprinus caprio* population may have been responsible for causing high turbidities which restricted growth of desirable submerged and emergent vegetation (DCE 1991).

Significant species

There have been no flora species recorded from Black Swamp which are listed under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act* 1999 (EPBC Act) or Victoria's *Flora and Fauna Guarantee Act* 1988 (FFG Act). Two species have been recorded which are considered of state significance (Victorian Rare or Threatened Species) and one species of regional significance (Table 5). Of these species, Long Eryngium *Eryngium paludosum* and Broughton Pea *Swainsona procumbens* can be considered water regime dependant.

Table 5 Black Swamp significant flora species.

Scientific name	Common name	Conservation Status in Vic.	Regional significance
Eryngium paludosum	Long Eryngium	Vulnerable	
Myoporum montanum	Waterbush	Rare	
Swainsona procumbens	Broughton Pea		Yes

4.2.2 Purdies Swamp

Around 20 plant species have been recorded at Purdies Swamp and, of these species, close to 40% are introduced and approximately 40% can be considered water regime dependant (Appendix B).

River Red Gum is the only recorded shrub or tree species. It is important to note that the lists of species previously recorded are by no means definitive.

Purdies Swamp was previously dominated by River Red Gums but the majority of the trees in the centre of the wetland died in the 1960s (DCE 1991). Extensive regeneration has occurred around the wetland's margin (DCE 1991). When inundated, the centre of the wetland supports species such as Common Spike-sedge *Eleocharis acuta*, Small Spike-sedge *Eleocharis pusilla*, Buttercup *Ranunculus* sp., Rush, Bent Grass *Agrostis* sp. and Wallaby Grass (DCE 1991).

Significant species

There have been no flora species recorded from Purdies Swamp which are listed under the Commonwealth's EPBC Act. or Victoria's FFG Act or considered threatened in Victoria. One recorded species is considered to be of regional significance. However, this species is not considered a water regime dependant species (Table 6).

Table 6 Purdies Swamp significant flora species.

Scientific name	Common name	Regional significance
Pimelea curviflora s.s.	Curved Rice-flower	Yes

4.2.3 Unnamed wetland

The low-lying connecting area between Black Swamp and Purdies Swamp (unnamed wetland 607 988) has supported a greater diversity of species than has been present in either of the two wetlands (DCE 1991). This greater diversity occurred as a result of the regular summer drying compared to the near permanent Black Swamp or the drier Purdies Swamp (DCE 1991). Species previously recorded here include Common Spike-sedge, Water-milfoil, Starworts *Callitriche* sp. and *Stellaria* sp., Wallaby Grass, Water Primrose *Ludwigia peploides* and Wavy Marshwort *Nymphoides crenata*.

4.3 Fauna

4.3.1 Black Swamp

Birds represent the greatest number of fauna records (90%) for Black Swamp (Appendix B). Non-bird species recorded at the wetland include the Red Fox *Canis vulpes*, two frogs (Plains Froglet *Crinia parinsignifera* and Common Froglet *C. signifera*), European Carp and European Rabbit *Oryctolagus cuniculus*. The majority of species recorded at the wetland (92%) are native with the exception of the Fox, Carp, Rabbit and House Sparrow *Passer domesticus*. It is important to note, as is the case with the flora species lists, that the lists of species previously recorded are by no means definitive. In addition, a number of the records on the DSE database (2007d) for the map grid reference associated with Black Swamp have a written description associating them with Purdies Swamp. It therefore makes it difficult to determine which wetland they were actually

present at although it is highly probable that a number of the species could and would move between the wetlands.

When water is present, Black Swamp is utilised by a relatively diverse number of bird species (DCE 1991) and is considered fair for duck hunting in an average year (DSE 2007e). Previously, when Black Swamp was near permanently inundated, it provided a dry season refuge and habitat for a number of species however the productivity of the wetland was considered low due to near permanent flooding (DCE 1991). Species of interest for hunting include Pacific Black Duck *Anas superciliosa*, Grey Teal *Anas gracilis*, Wood Duck *Chenonetta jubata*, Mountain Duck (Australian Shelduck) *Tadorna tadornoides* and Chestnut Teal *Anas castanea* (DSE 2007e). The wetland has also been considered an important White Ibis breeding area in the past (LCC 1985; DCE 1991; DSE 2007e).

Significant species

There have been no fauna species listed under the EPBC Act previously recorded from Black Swamp. Of the significant species previously recorded at Black Swamp (Table 7) five may be considered water regime dependant (the Brown Treecreeper *Climacteris picumnus* being the exception). There are two species which are listed under the FFG Act and one species protected under the international treaties JAMBA (Japan-Australia Migratory Bird Agreement) and CAMBA (China-Australia Migratory Bird Agreement). All six species are considered to have a conservation status in Victoria. These significant species have been infrequently recorded or recorded on a single occurrence in overall low abundance.

Table 7 Black Swamp significant fauna species.

Scientific name	Common name	Conservation status in Vic.	FFG Act listed	Treaty
Anseranas semipalmata	Magpie Goose	Vulnerable		
Ardea alba	Great Egret	Vulnerable	Yes	JAMBA, CAMBA
Ardea intermedia	Intermediate Egret	Critically endangered	Yes	
Aythya australis	Hardhead	Vulnerable		
Climacteris picumnus	Brown Treecreeper	Near threatened		
Platalea regia	Royal Spoonbill	Vulnerable		

4.3.2 Purdies Swamp

Only six fauna species have previously been recorded at Purdies Swamp (Appendix B); all are birds with the exception of one frog species, Common Froglet, and all are native. It is important to note, as is the case with the flora species lists, that the lists of species previously recorded are by no means definitive.

In the past, duck breeding was significantly greater at this wetland than at Black Swamp as the wetland had higher productivity than Black Swamp due to it drying regularly (DCE 1991). This

situation has potentially changed as a result of the drier periods now experienced by Black Swamp. Past habitat values include standing dead trees (stags), live trees, fringing vegetation and clumps of vegetation (DCE 1991).

Significant species

Only one significant species has previously been recorded at Purdies Swamp, Magpie Goose *Anseranas semipalmata* (Table 8), and this is likely to be the same individuals recorded at Black Swamp (*i.e.* same date, recorder and number of birds).

Table 8 Purdies Swamp significant fauna species.

Scientific name	Common name	Conservation status in Vic.
Anseranas semipalmata	Magpie Goose	Vulnerable

4.4 Index of wetland condition

As part of the *Broken Boosey and Nine Mile Creeks Wetland Implementation Plan* (Regional Ecosystem Services 2006) the wetland condition of the Black Swamp complex has been assessed as relatively good (Roberts 2006). In particular, Black Swamp was considered in reference condition and Purdies Swamp and the connecting channel only slightly below reference condition (Table 9).

Table 9 Assessment of wetland condition (Roberts 2006).

Wetland	Condition	EVC benchmark	Values and comments
Black Swamp (607 991)	Reference	EVC 653 Aquatic Herbland	Habitat values are associated with large quantities of leaf litter and several large logs and Lignum as an understorey to River Red Gum. Although the current vegetation and condition rates this wetland as high this wetland has undergone a dramatic change in the past and now has dead stags which was once a woodland of River Red Gum. These River Red Gums would have generated light-shade patterns on the ground, and hence a variable understorey; and fallen timber and litter.
Purdies Swamp (600 990)	Slightly below	EVC 292 Red Gum Wetland and EVC 815 Riverine Swampy Woodland	Potential habitat value as a result of large quantities of fallen branches and standing dead trees.
South flowing channel from Black Swamp (607 988)	Slightly below	EVC 292 Red Gum Swamp and EVC 815 Riverine Swampy Woodland	Presence of an electric fence around wetland (although not complete) will be positive for the wetland, however all fallen timber has been removed.

4.5 Field assessment

SKM ecologists undertook a one day assessment of Black and Purdies Swamps on the 11th April 2007. The assessment involved a visual appraisal of the wetlands to note vegetation species

present, habitat attributes and any other matters relevant to the formulation of the flood regime determination. Species observed during the site inspection are listed in Appendix C.

4.5.1 Black Swamp

The vegetation profile at Black Swamp consists of three zones, the wetland bed, the littoral (or fringe) zone and the terrestrial zone (Figure 15). At the time of the assessment there was no water present in the wetland however, the wetland had received an illegal inflow at the end of 2006. The wetland bed is variable in topography with areas of deeper holes. The vegetation in the wetland bed consisted of a mix of semi-aquatic (Slender Knotweed *Persicaria decipiens* and Water Couch *Paspalum distichium*) (Figure 16) and more terrestrial species (Goosefoot *Chenopodium* spp.) with the deeper holes containing Cumbungi and Tall Spike-rush *Eleocharis sphaecelata*.

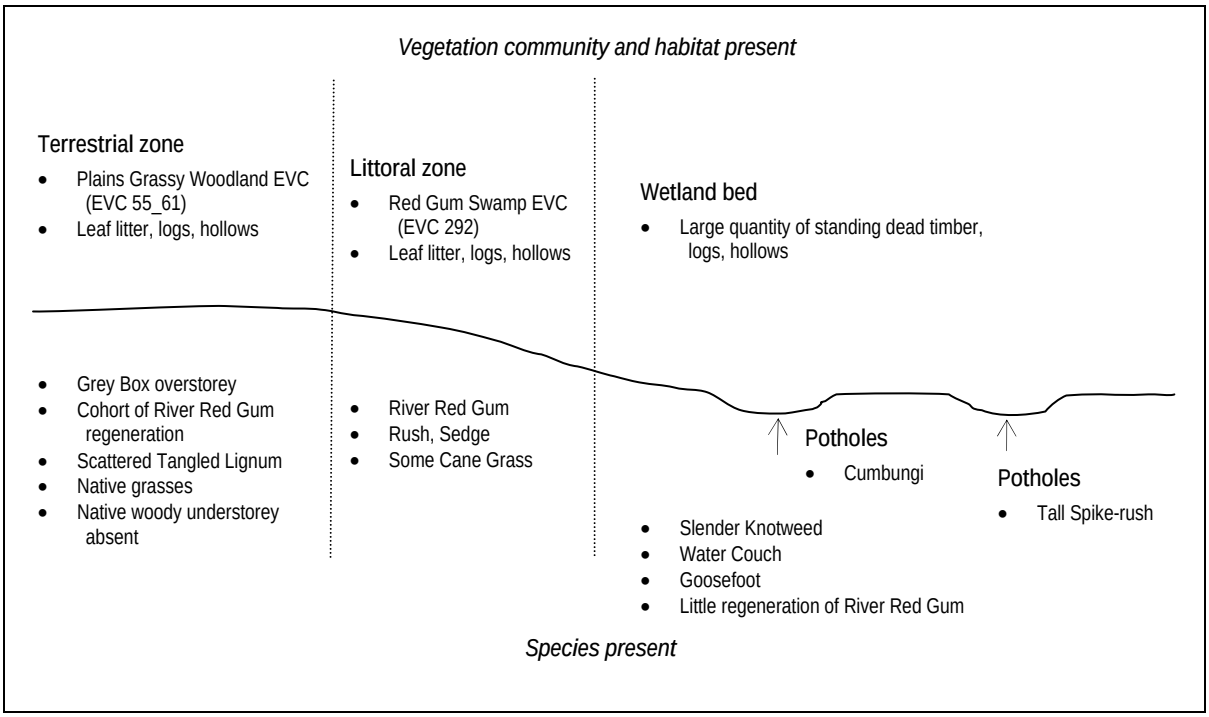


Figure 15 Generalised vegetation profile at Black Swamp (April 2007 when no water was present).

The littoral zone comprised an overstorey of River Red Gum with some Rushes and Sedges as the ground cover (Figure 17). There were scattered stands of Tangled Lignum and Cane Grass but these stands were limited in their distribution and did not form continuous bands of vegetation. There were few understorey plants however, Black-anther Flax-lily *Dianella revoluta* was present on the wetland margins. Further south of the wetland the quality of the remnant vegetation improved with Lemon Beauty-heads *Calocephalus citreus,* Variable Sida *Sida corrugata,* Grey Germander *Teucrium racemosum,* New Holland Daisy *Vittadinia cuneata,* Waterbush *Myoporum montanum,* River Bluebell *Wahlenbergia fluminalis* and Pink Bindweed *Convolvulus erubescens*

also being present. On the northern edge of the wetland the littoral vegetation is located on private land and was degraded due to grazing.

- **Figure 16 Wetland bed of Black Swamp.**

- **Figure 17 Fringing vegetation at Black Swamp.**

The terrestrial zone comprised a Grey Box *E. microcarpa* overstorey with a native ground cover, including Wallaby Grass, Cottonbush *Mariana* spp., Windmill Grass *Chloris truncate* and Variable Sida. The woody shrub layer was absent however, the tree health was good to excellent.

Revegetation works have been undertaken within the reserve. Historically, revegetation was undertaken by the former Lands Department in the south western corner of the reserve and consisted of species which are not necessarily indigenous to the area but did include River Red Gum and Bottlebrush *Callistemon* sp.. More recently, the Goulburn Broken CMA has undertaken some revegetation works in the terrestrial zone comprising indigenous woodland species such as

Golden Wattle, Mallee Wattle *A. montana*, Chinese Scrub *Cassinia arcuata* and Sweet Bursaria *Bursaria spinosa*.

Based on the field inspection, the littoral zone was assessed as Red Gum Wetland EVC (EVC 292) and the terrestrial EVC as Plains Grassy Woodland/Gilgai Wetland Mosaic EVC (EVC 259). The wetland bed was dry at the time of the assessment so the EVC associated with this area could not be determined. This assessment concurs with DSE's EVC mapping (DSE 2007a).

In terms of habitat, leaf litter and fallen timber is present although there is evidence of firewood collection. There are large numbers of hollows in both living and dead trees and scattered patches of Lignum and Cane Grass.

Pest species observed included European Rabbits, Scotch Thistle *Onopordum acanthium*, Cats Ear *Hypochoeris radicata* and Tall Fleabane *Conyza albida*.

4.5.2 Purdies Swamp

Purdies Swamp is shallower than Black Swamp and the bed was dry at the time of the field assessment. The vegetation profile of Purdies Swamp is similar to that at Black Swamp (Figure 15) except that the bed of the wetland is more even without the pot holes that are present in Black Swamp. There are more weeds on the wetland bed at Purdies Swamp as a result of the intensive grazing. The grass and herb species are restricted in distribution and there are large areas of bare ground (Figure 18). There are few aquatic species present with Rushes and Sedges sparsely distributed. There are some moderately aged standing live River Red Gums (60-70 cm dbh) however all the old River Red Gum present are long dead. The trees are not as healthy as those at Black Swamp. There is some fallen timber on the ground. No EVCs were identified during the field inspection, which differs from DSE's EVC mapping (DSE 2007a) which indicated that there is some River Red Gum Wetland (EVC 292) present.

The fringing vegetation consists of less large trees than at Black Swamp and is typically of lesser quality but there is a large amount of regeneration. The fringing vegetation consists of River Red Gum with several age classes and no old trees. It is possible that the wetland may have been cleared in the past. There is fallen timber present and leaf litter (Figure 19). This wetland is heavily grazed and, as a result, there is no native groundcover or understory present and there are a large number of weeds including Scotch Thistle and Bathurst Burr *Xanthium spinosum*.


- **Figure 18 Wetland bed of Purdies Swamp.**


- **Figure 19 Fringing vegetation at Purdies Swamp.**

4.5.3 Unnamed wetland

The areas of this wetland (unnamed wetland 607 988) close to Black and Purdies Swamps were observed during the field inspection with the more southern areas not assessed. This wetland appears to have undergone significant disturbance in the past however it does support a range of ages of River Red Gum. There are some large old trees and many regenerating trees likely to be from a series of floods given the various ages. There is no evidence of groundcovers or shrubs which is likely to be due to the dense cover of regenerating River Red Gums, especially towards the southern and western areas of the wetland.

4.6 Key ecological values

The key ecological values for Black and Purdies Swamps have been identified through consideration of past species lists, the draft *Interim Management Statement* (DCE 1991), other

literature and the field assessment (Table 10 and Table 11). Only the water regime dependant values have been identified as the nature of this document is a flood regime determination for the wetlands.

Table 10. Black Swamp key ecological values.

Value	Reason
Vegetation community	
Red Gum Wetland (EVC 292)	Endangered
Threatened plants	
Long Eryngium	VROTS (Vulnerable)
Broughton Pea	Regional significance
Waterbird community	
Colonial nesting waterbirds and waterfowl	Diversity
Threatened animals	
Magpie Goose	VROTS (Vulnerable)
Great Egret	VROTS (Vulnerable)
Intermediate Egret	VROTS (Critically endangered), FFG Act listed, treaties
Hardhead	VROTS (Vulnerable), FFG Act listed
Royal Spoonbill	VROTS (Near threatened)
Habitat species	
River Red Gum	Habitat for birds, bats, lizards, frogs, invertebrates
Tangled Lignum patches	Habitat for waterbird breeding, roosting
Cumbungi clumps	Habitat for birds

Table 11. Purdies Swamp key ecological values.

Value	Reason
Waterbird community	
Colonial nesting waterbirds and waterfowl	Diversity
Threatened animals	
Magpie Goose	VROTS (Vulnerable)
Habitat species	
River Red Gum	Habitat for birds, bats, lizards, frogs, invertebrates

4.7 Threats to the key ecological values

There are a number of activities and threats occurring at the wetlands which may impact upon the key ecological values of these wetlands. These activities and threats include:

- **Modified hydrology**: an *increase* in ponding time in Black Swamp has lead to the dense growth of Cumbungi, Azolla and algae in the past and death of River Red Gums. Increased ponding of a wetland generally decreases the plant diversity and may increase the abundance of particular species in turn reducing habitat opportunities for animals and impacting on water quality. The potential *decrease* in ponding length at Purdies Swamp due to the drain to the

south-west may potentially turn this wetland into a more terrestrial dominated area than is desired and than it has been in the past.

- **Weeds**: these species include plants that are environmental weeds and declared noxious weeds. There are a number of introduced species that have been observed at the wetlands (see Appendices B.1, B.2 and C.1). Arrowhead is considered a serious environmental weed associated with waterways and wetlands whilst Bathurst Burr and Scotch Thistle are declared noxious (both categorised as regionally controlled weeds) under the *Catchment and Land Protection Act* 1994. Weeds out complete indigenous species and can therefore reduce the floral diversity of an area.

- **Carp**: this species is considered a pest in waterways and wetlands. It is unknown to what extent Carp have an impact on the aquatic environment however they are considered responsible for declining water quality and native fish populations and causing bank erosion. In the context of Black and Purdies Swamps this species is 'controlled' by the regular drying out of the wetlands.

- **Recreation**: illegal off road vehicle use currently occurs at Black Swamp. This activity contributes to soil erosion and vegetation destruction, in turn impacting on habitat availability and suitability.

- **Rubbish dumping**: this activity is occurring at Black Swamp currently. Whilst dumped rubbish is aesthetically unpleasing it may also impact on habitat values and, depending on the nature of the rubbish, be poisonous to the surrounding plants and animals in the area.

- **Timber harvesting**: whilst this activity may be permitted it conflicts with the aim of the Wildlife Reserve which is to protect wildlife. Habitat destruction occurs when timber is removed (this includes standing and fallen and live and dead timber).

- **Grazing**: this currently occurs at Purdies Swamp and is an allowable use of Wildlife Reserves but does not currently occur at Black Swamp. Grazing wetlands reduces the diversity of wetland vegetation and causes destruction to this environment through trampling and pugging. The movement of livestock also has the potential to transport weeds to the wetland area and move them about within that area.

5. Ecological and water regime objectives

5.1 Ecological objective

The ecological objective developed for these wetlands have been formulated following consideration of the key ecological values identified in Section 4.6 and consideration of the draft *Interim Management Statement* (DCE 1991), LCC (1985) recommendations and the current and future constraints associated with obtaining and delivering environmental water. The objective proposed is specifically for the water regime dependant components of the wetlands and as such does not include the terrestrial woodland environment or non-water dependant threatened species. The objective for the wetlands is:

> *To manage for a diverse ecosystem with regular, more natural, wetting and drying, specifically to maintain and encourage a River Red Gum dominated wetland whilst supporting the threatened species and habitat components.*

When setting the objective for the wetlands, consideration of the values and potential for obtaining environmental water was considered. The potential lack of an allocation for the Broken and Nine Mile Creeks and the difference in volume required for implementing a permanent versus seasonal water regime is an issue that will most likely result in small volumes of water potentially being available for the wetlands. In addition, to support and extend the existing vegetation and waterbird communities a water regime which involves both flooding and drying phases will produce a much more diverse ecosystem.

5.2 Water regime requirements

The water regime requirements of the values identified for both Black and Purdies Swamps are presented in the following section. Although for a number of the components little information is available.

5.2.1 Flora

Vegetation community

The EVC, Red Gum Wetland (EVC 292), is characterised as being an open woodland to 15 m tall with a diverse understorey dominated by sedgy or grassy-herbaceous aquatics and species tolerant of intermittent to seasonal inundation with periods of inundation ranging from 2 to 6 months (DSE 2005).

Threatened plants

There is little information available regarding the specific water requirements of the threatened plants (Long Eryngium *Eryngium paludosum* and Broughton Pea *Swainsona procumbens*) present at Black Swamp.

A list of aquatic and riparian flora and fauna considered threatened up until 2002 supplied by the then Department of Natural Resources and Environment (NRE 2002) listed Long Eryngium as being associated with the riparian zone, wetlands and lakes along with swampy, irrigated or flooded areas, depressions on sand, loam, clay and cracking clays (Botanic Gardens Trust 2007). Broughton Pea is considered as growing on heavy soils prone to waterlogging (Botanic Gardens Trust 2007).

Habitat species

The water requirements for the following species have been obtained from Roberts (2001). This reference provides the water requirements for species in both the northern and southern parts of the Murray-Darling Basin. The southern requirements are all that have been included below.

River Red Gum *Eucalyptus camaldulensis*

For the maintenance of River Red Gum an average flood frequency of once every one to two years is preferable. A duration of four to seven months is ideal with a duration of greater than 24 months detrimental to this species. Durations shorter than four to seven months can be tolerated if summer flooding also occurs, however, repeated summer flooding can cause changes in the understorey composition. Preferred timing of inundation is winter-spring. Complete drying between wet phases is desirable so as to enable cracking of the soil for aeration and deep recharge upon rewetting. A large flood is required for regeneration of this species with this flood extending into summer followed by a wet winter-spring or shallow and brief or pulsed winter-spring floods and even brief or shallow summer flooding to improve recruitment success.

Tangled Lignum *Muehlenbeckia florulenta*

To maintain Lignum an average flood frequency of once every two to eight years is required (with preference of the latter in southern areas). Ponding duration of three to five months is preferable with continuous ponding to be avoided. Preferred timing of flooding is spring-summer. Complete dying is desirable to enable cracking of the soil for aeration and deep recharge. For regeneration, summer floods extending into autumn is likely to be required.

Cumbungi *Typha* sp.

For maintenance of Cumbungi a near annual flooding with a duration of seven to nine months is ideal (however six to 12 months is tolerated). If a short duration of flooding occurs then this should be winter-spring to early summer. An inundation depth of 5 cm to 1.5 m is required. Pulsed flooding is tolerated so long as the ground remains saturated in between pulses. Rhizomes are relatively tolerant of drying and can survive one to two years under dry conditions if well established. Mud or shallow water (0-5 cm) is required for germination whilst deeper water (5-15 cm) is required for seedling growth with continuous moist conditions for several months (six months) required until the seedlings become established.

5.2.2 Fauna

Colonial nesting waterbirds and waterfowl

Colonial nesting waterbirds, waterfowl and grebes have similar water regime requirements. Flooding frequency is not important to these groups as these species are generally highly mobile and can travel large distances to find flooded wetlands (Scott 2001). Those species that do not travel long distances tend to require more permanent water (Scott 2001). Spring and early summer is the important period for waterbird breeding in the south of the Murray-Darling Basin (Scott 2001) therefore flooding of floodplain wetlands is important at this time. The productivity of wetlands that periodically flood and then dry, tends to be higher than wetlands that are permanently inundated, therefore a dry period of between six and twelve months is ideal with dry periods longer than this potentially impacting on the survival of some aquatic species (LMSRP 2003). Many Australian species of duck are highly mobile and nomadic as a response of their adaptation to irregular rainfall (Pizzey and Knight 1999).

Threatened animals

All the threatened animals previously recorded within the complex (Magpie Goose, Great Egret, Intermediate Egret, Hardhead and Royal Spoonbill) can be considered colonial nesting waterbirds or waterfowl with the water requirements for this group described above.

5.2.3 Habitat

The vegetation species considered important as habitat components within the complex (River Red Gum, Tangled Lignum and Cumbungi) have been discussed above.

5.3 Water regime objectives

There are a number of components which constitute the water regime of a wetland (Table 12). These components largely determine the processes, species and communities which occur at a wetland. The desired timing, frequency, duration, rate of rise and recession and depth and variability for each of these components at Black and Purdies Swamps have been determined, where possible, based on the water regime requirements of the values (Table 13 and Table 14). These components form the water regime objectives for the wetland.

Table 12 Components of the water regime of wetlands (modified from Bunn *et al.* 1997 and Boulton and Brock 1999).

Component	Definition
Timing	**When water is present**. Within year patterns are most important in seasonal wetlands, whereas among year patterns and variability may be more important in temporary wetlands.
Frequency	**How often filling and drying occur**. Some wetlands permanently contain water whereas others are subjected to wetting and drying cycles at a range of intervals from several times a year, on an annual basis or less frequently.
Duration	**The period of inundation**. Duration of inundation can be as short as days and may extend to years. Duration can also vary within and among wetlands.
Rate of rise and recession	**The rate at which water level rises or falls**. The rate of rise and fall can be critical for species adapted to different conditions or may provide cues for life history stages.
Extent and depth	**The area of inundation and the depth of water**. Area inundated and depth of water will influence the dynamics of a wetland, for example depth affects light penetration. Area and depth can vary within a wetland at different times, thus different processes will occur in the one wetland across a range of temporal and spatial scales.
Variability	**The degree to which the above features change**. All of the above components of the water regime can change at a range of time scales from short to long. Variability is often dramatically altered under management.

Table 13 Black Swamp water regime objectives.

Value	Water regime requirement				
	Component	Timing	Frequency	Duration	Depth
Vegetation community (Red Gum Wetland (EVC 292))	Flooding	Winter-spring	Every 1 to 2 years	4-7 months	Shallow
Threatened plants (Long Eryngium, Broughton Pea)	Flooding	Unknown	Unknown	Unknown	Shallow
Waterbird community and threatened animals	Flooding	Spring to early summer	Not important	6-7 months	Various
Habitat species (River Red Gum)	Flooding	Winter-spring (extending into summer for regeneration with a wet winter-spring following)	Every 1 to 2 years	4-7 months	Shallow
Habitat species (Tangled Lignum patches)	Flooding	Spring-summer (extending into autumn for regeneration)	Every 2 to 8 years	3-5 months	Unknown
Habitat species (Cumbungi clumps)	Flooding	Not applicable	Near annual	7-9 months	5 cm-1.5 m (maintenance), 0-15 cm (regeneration)

- **Table 14 Purdies Swamp water regime objectives.**

Value	Water regime requirement				
	Component	Timing	Frequency	Duration	Depth
Waterbird community and threatened animals	Flooding	Spring to early summer	Not important	6-7 months	Various
Habitat species (River Red Gum)	Flooding	Winter-spring (extending into summer for regeneration with a wet winter-spring following)	Every 1 to 2 years	4-7 months	Shallow

Rate of rise and recession, variability of the water regime and extent of flooding have not been specified as these components being relatively general for most wetland environments. The rate of rise is driven by the hydrology of the adjacent waterway and drawdown is driven by evaporation and seepage. However, artificially rapid draw down of water levels should be avoided because this may leave plant species suddenly without water.

The variability of a wetland is largely a factor of how all the other water regime components change over time. As such, no specific recommendations for variability are made except to stress that the catchment's climatic conditions should be replicated as far as possible in the wetland. That is to say that, when there are periods of drought this should be reflected in the wetland hydrology and when there are a series of wet years this should also be reflected. This assumes that the wetland's desired water regime is being delivered and if other stresses are occurring at the wetland (*e.g.* pressure from predators or undesirable species), then consideration of the water regime independent of the catchment may be necessary.

The extent of wetland flooding is determined by the depth required and the topography of the wetland. If the depth requirements of the values are delivered then the appropriate extent of flooding for the wetland will be delivered also.

The preferred regime to maintain conservation values is for near annual flooding for around six months over the winter/spring period. As Black Swamp is a game reserve, duck hunting is also a value that will continue at the wetland. The duck hunting season typically lasts for 12 weeks from mid March to Mid June. To be suitable for duck hunting the wetland needs to have a water depth of 30 – 50 cm to allow for wading during the hunting season. Under natural conditions the winter/spring period would have been the typical time of inundation. The modified water regime of the wetlands has facilitated duck hunting and is reflected in the classification of Black Swamp as a State Game Reserve. However, the wetland should not be artificially inundated to support hunting. Rather, duck hunting should be allowed to occur if natural flooding during summer or autumn occurs.

6. Water regime recommendation

6.1 Water regime recommendations to support ecological values

It is recommended that Black Swamp and Purdies Swamp be managed primarily for their conservation values (which is consistent with the LCC 1985 recommendations) with an appropriate water regime that provides for near annual inundation of around six months in the winter/spring period (Table 15). Artificial inundation in summer and autumn should be avoided; however, if natural flood events occur during the summer/autumn period then the wetlands should be allowed to fill. Under these circumstances opportunistic duck hunting could occur within the hunting season.

Table 15 Water regime recommendation

Inundation component	Recommendation
Timing	Winter/spring
Frequency	Near annual
Duration	6 months
Depth	Variable depths to 50 cm
Rate of rise and fall	Driven by rate of rising flood and natural evaporation and seepage
Variability	Based on variability in peak natural flows

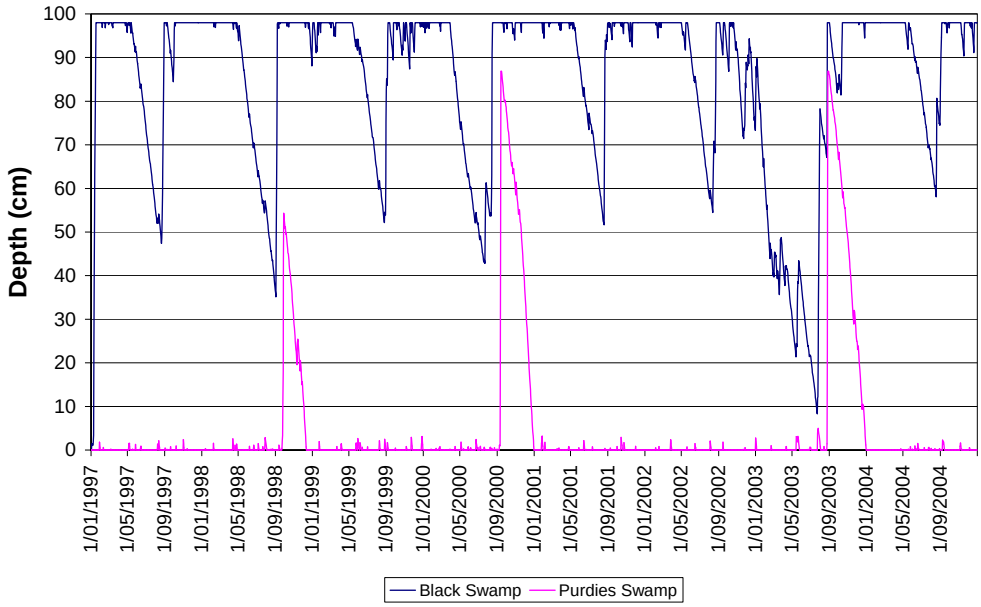
6.2 Differences between the recommended and current water regime

Under the current regulator arrangement with the regulator open, regulated flows in Nine Mile Creek are sufficient to allow water to enter Black Swamp during the regulated flow (irrigation) period, typically September through to April (Figure 20). These flows enter Black Swamp when flow in Nine Mile Creek is around 100 ML/d. The preferred timing for inundation is during winter and/or spring. If the regulator is shut then the regulated flows in the creek are excluded from the wetland. This has largely been the case over the last ten or so years. On occasions the regulator has been tampered with and regulated flows have entered the wetland. In addition, as a result of the recent climatic conditions there have been few peak flows (natural events) that have entered the wetland therefore resulting the in the largely dry period experienced by the wetland.

Assuming the existing regulator is not operated appropriately the presence of regulated flows in Nine Mile Creek results in Black Swamp experiencing, on average, near permanent inundation. Purdies Swamp, however, still experiences a near natural wetting and drying regime as it's commence to fill level is located above the regulated flow level. This allows only the peak natural flow to enter the wetland.

There are a range of depths in each of the wetlands due to variation in the topography. The previously recorded depths (DCE 1991) for the wetlands state that the maximum surcharge depth in Black Swamp is 90 cm (high water mark) and this declines to 40 cm once they hydrograph falls

below the commence to fill level. For Purdies Swamp the maximum surcharge depth 40-50 cm and declines to 33 cm as flows recede. Modelled depths are slightly different to those previously reported. This is because of some inherent uncertainties in modelling and also possible changes in critical levels over time due to on-ground works. However, the differences are relatively minor and of little ecological consequence.

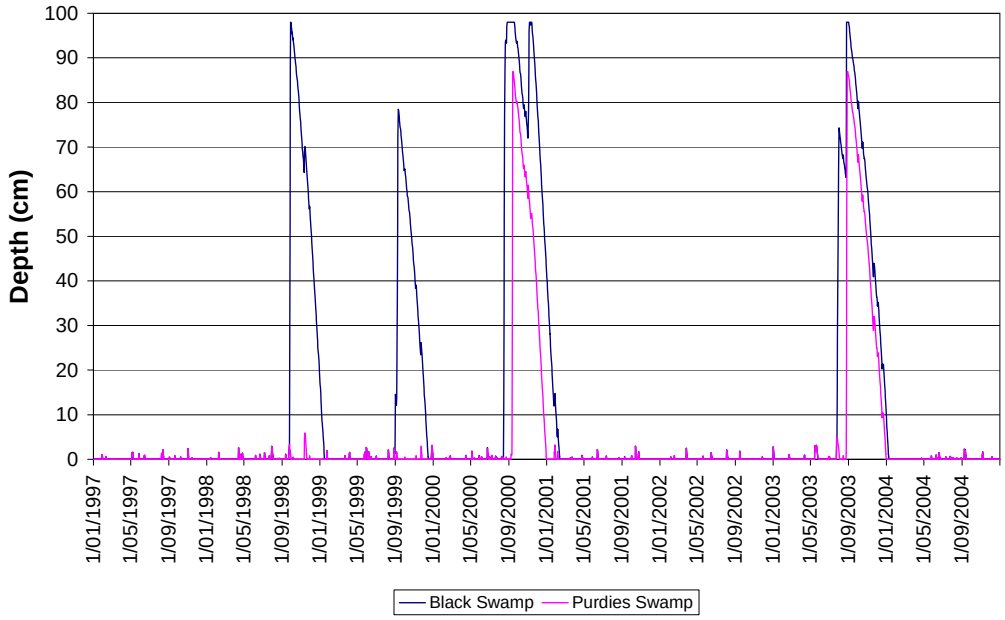


- **Figure 20 A time series of modelled water depth in Black and Purdies Swamp under current conditions (1997-2004), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**

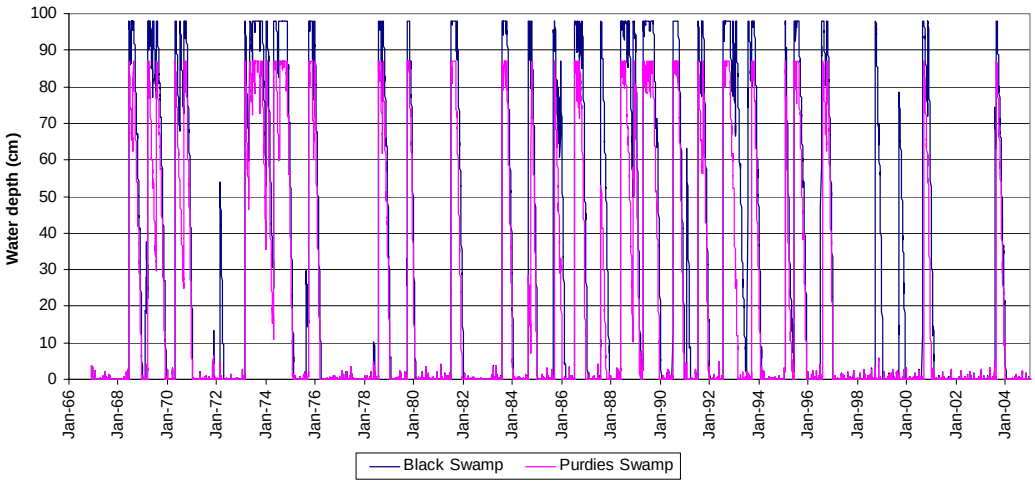
The current wetting regime is opposite to the natural and recommended regime. Under natural conditions the wetting and drying regime of Black and Purdies Swamps is determined by the frequency of the peak annual flow in upper Broken Creek upstream of the Nine Mile Creek effluent. Modelling has indicated under the natural regime for the site Black Swamp begins to fill once flows in Nine Mile Creek reach approximately 400 ML/d. This peak flow typically occurs in winter or spring and is sufficient to inundate the wetlands within one to two days, the wetlands then retain water on average for several months. Prior to 1997 peak annual flows sufficient to inundate both swamps occurred nearly every year, however since 1997 drought conditions have resulted in a reduction in the frequency of peak natural flows sufficient to inundate the swamps (Figure 22).

If the existing regulator was operated to exclude regulated flows during summer then the current flow regime would be more similar to natural. Although regardless of the timing of the peak natural flow if the regulator was not closed until late spring then the wetlands would nearly always

receive water in September when irrigation flows commence. This would reduce the natural variability in the timing of filling.



- **Figure 21 A time series of modelled water depth in Black and Purdies Swamp under natural conditions (1997-2004), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**



- **Figure 22 A time series of modelled water depth in Black and Purdies Swamp under natural conditions (1966-2004), assuming the regulator to Black Swamp is operated to allow water to enter Black and Purdies Swamp, but not drain back to Nine Mile Creek and that the natural sill level of Purdies Swamp has been reinstated**

Table 16 summarises the comparison between the current, natural and recommended water regime for Black Swamp (note, Purdies Swamp currently still receives a near natural regime).

- **Table 16 Summary of water regime in Black Swamp under current, natural and recommended regimes.**

Water regime variable	Current	Natural	Recommended
Frequency of inundation	Annual	8 times per 10 years	Near annual
Start month of inundation	September – April	June - October	Winter - spring
Duration of inundation	12 months if regulator is not closed ~6 months if regulator is closed in November	3 - 6 months	6 months
Depth of inundation	0 - 95 cm (surcharged level)	0 - 65 cm (surcharged level)	Variable to around 50 cm

6.3 Impact on ecological values

As a result of the past water regime and management practices there are limited ecological values present at the wetlands. However, the introduction of a more natural wetting and drying would significant improve the ecological values associated with the wetland complex and enhance overall biodiversity and productivity. The water regime components having the greatest impact on the ecology of these wetlands are the timing and duration of inundation. Inundation at a time of year not suited to the natural ecology of the area disrupts the reproductive cycles of the plants and animals reliant on the water in the wetland. Permanently inundated wetlands result in plants not having a seasonal cue to grow or flower and may result in the seed bank becoming unviable. A permanently inundated wetland has less diversity than a wetland that floods and dries and favours just a few species that are adapted to a permanently wet environment. When a wetland is dry for an extended period it becomes dominated by terrestrial species (and in this case many weed species) and, depending on the length of the dry period, may also result in the seed bank of aquatic or flood dependant species becoming unviable.

The ecological values identified in this report (Table 10 and Table 11) do not include any submerged or amphibious species. This may be a result of the wetland being permanently inundated for a long period and then dry for an extended period. There is some regeneration of River Red Gums at the wetlands as a result of the recent drying of the wetland, with some wet periods, which followed the extended wet period. The Red Gum Wetland (EVC 292) can survive without water however an extended period without water or, conversely, with permanent water will alter the understorey composition, with the potential loss of species and may result in encroachment, retraction or even death of the River Red Gums. The threatened plant species identified at the wetlands, although not observed during the field assessment, like the Red Gum

Wetland community, can survive without inundation for periods but require some flooding to maintain a viable population. It is unclear whether these species are still present at Black Swamp.

Waterbird communities are opportunistic and if conditions are not favourable will move to a more favourable environment. If the wetlands have a drying and wetting regime the productivity of the wetlands would increase and opportunities for breeding and feeding would be restored. Australian White Ibis have previously been recorded as breeding at Black Swamp (LCC 1985) however they are not present currently. Having an extended dry period will have resulted in these birds moving away. The habitat species identified (River Red Gum, Tangled Lignum and Cumbungi) all benefit from a wetting and drying regime and either permanent inundation or extended dry periods will impact on their vigour and extent.

When the wetlands were previously permanently inundated potential threats included the presence of Carp, Sagittaria (and other weeds) and excessive growth of Cumbungi, Azolla and algae. All these species rely on a system of permanent inundation. Although Cumbungi and Azolla are native species and provide habitat and a resource for many native animals a water regime which includes a drying phase will assist in keeping these species in control.

6.4 Summary

Despite the presence of a regulating structure to try and provide a suitable water regime under current conditions problems with the operation of the structure have resulted in the wetland either being too wet or potentially too dry. And while the wetlands are considered to be in relatively good condition, their value could be significantly enhance through the delivery of a more natural water regime. This can be achieved through some modifications to and more effective operation of the existing regulator as outlined in the following section.

7. Water delivery options

7.1 Water delivery options

Several scenarios were considered to reinstate a more natural wetting and drying regime to the wetlands. One option, the reinstatement of the natural flow path to the wetlands via the Unnamed Wetland was considered but was not deemed achievable due to the difficulties associated with the requirement to modify a range of existing private works (drains, dams and banks) that are present within the Unnamed Wetland. Other options considered modification of the existing regulating structure to reinstate a more natural wetting and drying regime for the site.

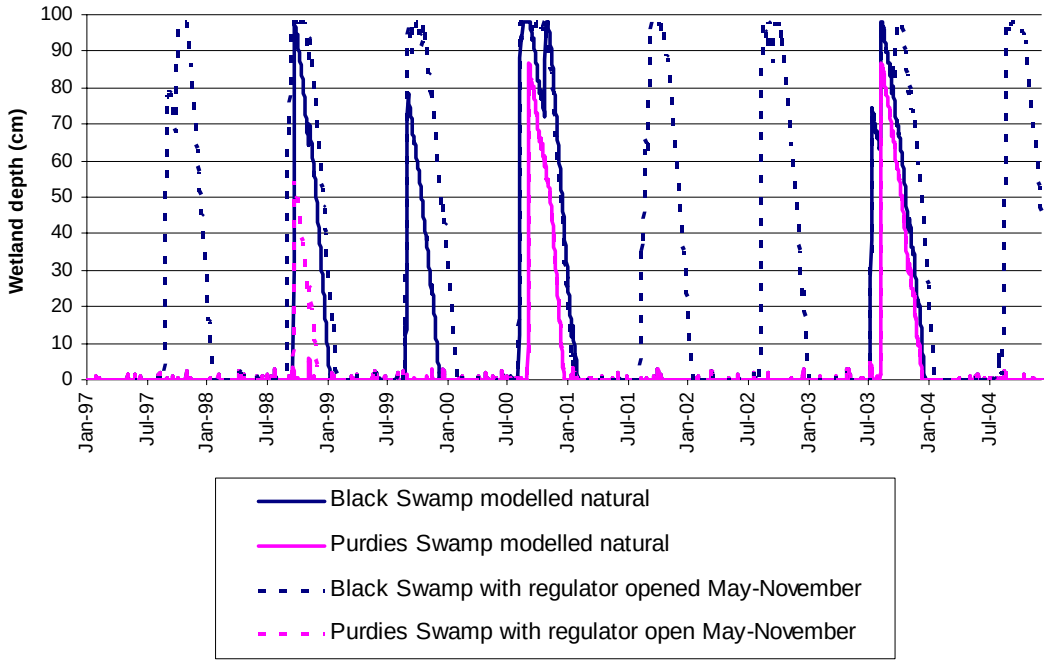
A number of regulator scenarios were modelled to determine the most appropriate scenario that would enable the reinstatement of a more natural wetting and drying regime to the wetland; that is regulator scenarios that enable the peak annual flow to enter the wetlands but which exclude regulated flows from entering Black Swamp. Two options were modelled:

1) opening the Black Swamp regulator in May once regulated flows down Nine Mile Creek have ceased and closing it in November after the natural peak annual flow has passed (i.e more effective operation of the existing structure); and
2) raising the invert level of the flow path between Nine Mile Creek and Black Swamp to exclude regulated flows at any time of the year but still allow peak annual flows to enter the wetland (i.e. modification of the existing structure).

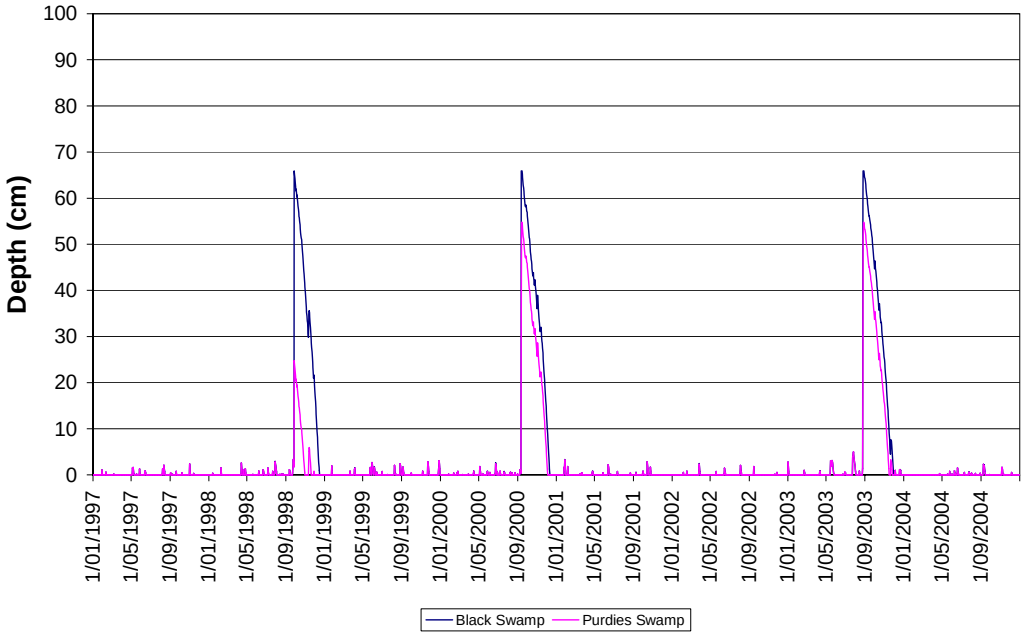
Under Scenario 1), opening the regulator in May allows peak annual flows to enter the wetland, but because regulated flows commence in September, the wetland receives water regardless of whether the peak annual flow has occurred by September or not (
Figure 23). Hence, the wetting regime does not incorporate elements of natural variability because it will invariably receive flows around September every year.

Under Scenario 2), raising the commence to flow level to exclude regulated flows (equivalent to a level to exclude flows less than 400 ML/d) prevents regulated flows from entering the wetland regardless of the time of the year while still enabling the natural peak annual flow to enter the wetland with natural timing and frequency (Figure 24). The comparison between the wetting and drying regimes presented under the two scenarios shows that Scenario 2 better mimics the natural conditions. The benefit of Scenario 2 is that raising the commence-to-fill level eliminates the need to open or close the regulator at different times of the year. It can also enable modifications to the existing regulator to be made that will reduce the chances of the regulator being vandalised. In addition, raising the commence-to-fill level and then allowing water to drain out of the swamp and back to this level once the peak flow has passed creates a depth profile in the two swamps more similar to the recommended depth of around 50 cm.

If Scenario 2 is adopted the regulator should be modified in such a way as to maintain flexibility to allow water into the swamp under regulated flow conditions if required. For example, during a prolonged dry period it may be necessary to artificially inundate the swamp, or prolong the wetting phase in order to help meet a specific objective. This could occur for example, where a bird breeding event occurred and it was desirable from an adaptive management approach to prolong the duration or manipulate the depth of inundation on a case by case basis.



- **Figure 23 Modelled time series of depth in Black Swamp and Purdies Swamp under natural conditions and with regulator operating rules set to open in May and close in November.**



- **Figure 24 Modelled time series of depth in Black Swamp and Purdies Swamp with regulator commence to flow raised to prevent regulated flows (<400 ML/d) entering Black Swamp.**

7.2 Recommended water delivery option

It is recommended that Scenario 2) (raising the commence to flow level of Black Swamp to exclude regulated flows) be implemented. This option prevents regulated flows from entering the wetland regardless of the time of the year while still enabling the natural peak annual flow to enter the wetland with natural timing and frequency. Additionally this option matches the natural commence to flow conditions for the site.

The comparison between the wetting and drying regimes presented under the two scenarios shows that Scenario 2 better mimics the natural conditions. Additionally adopting Scenario 2 eliminates the need to open or close the regulator at different times of the year. It can also enable modifications to the existing regulator to be made that will reduce the chances of the regulator being vandalised. In addition, raising the commence-to-fill level and then allowing water to drain out of the swamp and back to this level once the peak flow has passed creates a depth profile in the two swamps more similar to the recommended depth of around 50 cm.

7.2.1 Works and operating rules required to deliver desired water regime

If Scenario 2 is adopted the regulator should be modified in such a way as to maintain flexibility to still allow water into the swamp under regulated flow conditions if required. For example, during a

prolonged dry period it may be necessary to artificially inundate the swamp, or prolong the wetting phase in order to help meet a specific objective.

8. Assessment of existing Regulating Structure

The exiting water control infrastructure located at the eastern side of Black Swamp consists of two components; a constructed channel and a regulator.

The constructed channel is approximately 175 m long and extends from Nine Mile Creek to Black Swamp. This acts as both an inflow and outflow channel. The channel is well defined and has a depth of about 1.0m below natural ground level and a top width of approximately 5 m.

The regulator structure consists of a 900mm diameter HDPE pipe (Black Brute™) under the access track and a reinforced concrete regulator (Figure 25).

Downstream (wetland) end of regulating structure

Upstream (creek) end of regulating structure

- **Figure 25 Existing Black Swamp Regulating Structure**

The pipe invert and floor of the regulator are depressed 200 to 350 mm below the cease to flow level of the inflow channel. The box structure is equipped with drop bar slots, and manually operated drop bars (some were in place and some were scattered in the channel). The lid of the structure is cast in place concrete and is not designed to be removed. Rock beaching has been placed on the west side of the structure for a distance of 4m to 7 m from the end of the pipe.

The condition of the regulator is reasonably good. There were negligible signs of concrete deterioration. There was no sign of erosion or piping around the culvert except for limited loss of rock beaching at the east headwall. Subsidence of pipe backfill was evidenced by potholes above the pipe.

The operation of the structure is by use of manually place drop boards. Evidence of vandalism is present, as the existing drop bars are scattered in the channel. Locking brackets to fix the drop bars in place were partially in place but not in use. The structure does not meet contemporary standards for safe operation due to the manual drop bar operation and lack of fall protection.

8.1 Functional Requirements

Based on the recommended scenario, the functional requirements of the future regulating structure are to:

1) have simple operating procedures based two positions of control FULLY LOWERED and FULLY RAISED;
2) be easy and safe to operate;
3) be vandal proof;
4) provide appropriate fish passage; and
5) provide an appropriate level of vehicle protection in accordance with the road Authorities requirements.

8.2 Option Development and Assessment

The option considered most suitable for modification of the existing structure would consist of fitting a new gate into the existing regulator structure. A range of other miscellaneous repairs and other improvements would also be required.

A vertical lift gate would be installed in the existing regulator. The base of this gate would be at the level of the current floor of the existing regulator and the top of the gate would be set to the appropriate level to exclude irrigation flows in the Nine Mile Creek from the wetland and match the natural commence to flow conditions for the wetlands. The top of the gate should be set to 106.08 m AHD.

A range of other options could be utilised at this site however the advantages of the above arrangement are its relative simplicity of operation, low likelihood of leakage and lower cost.

A simple vertical lift gate that occupies the full width of the regulator and with the base of the gate at floor level is the preferred option. When in the fully lowered position the top of the gate would represent the commence-to-flow level for the wetland (i.e. act as a fixed crest) and would be set at a level above the normal regulated flow level. The gate would be able to be operated (raised) in exceptional instances where it was determined that irrigation flows should be allowed into the wetland to meet specific ecological objectives

8.3 Recommended Arrangement

This section describes the preferred gate arrangement, ancillary works and how the functional requirements are met.

The vertical lift gate should occupy the full width of the regulator and have a sill at existing floor level. Some obstruction to the inflow area caused by the gate frame is acceptable. The top of the

gate would be set to 106.08 m AHD to exclude irrigation flows in the Nine Mile Creek from Black Swamp and to match the natural commence to flow conditions to the wetland.

The gate would be manually operated using a crank or hand wheel and designed to be lockable. Operation of the gate would only be required in exceptional instances where it was determined that irrigation flows should be allowed into the wetland to meet specific ecological objectives.

Other work to consist of:

- Hand rails to provide fall protection from the concrete regulator headwalls; and
- Filling and grading of the track immediately over the pipe to fix pot holes and subsidence.

Currently no vehicle guardrails are provided at the structure, nor are there any marker posts. It is recommended that the responsible road Authority (in this case Parks Victoria) provide their requirements for the track, and the level of vehicle protection required (if any).

8.4 Fish Passage

The level of fish passage appropriate to the structure has been considered. With the operation rules proposed it is considered that level of fish passage provided is adequate.

When the flow through the culvert is high there may be some limitation on the passage of native fish. However this flow is expected to be in the direction that fish would want to move (ie into the wetland as it is filling and out of the wetland as it is dropping) and so the structure is not likely to constitute a barrier to fish passage.

When the water levels between Black Swamp and Nine Mile Creek have equalised then full fish passage will be provided. The culvert invert is depressed below the bed of the channel which means that at low flows there should not be a significant point increase in velocity and there will be some depth (approximately 200mm) for movement of small fish.

9. Complementary actions to support the key ecological values

A range of complimentary management actions are recommended to support the proposed reintroduction of a natural wetting and drying regime to the wetland via the modifications to the wetland regulating structure. These management actions are summarised in Table 17 with an indication as to whether they are to be implemented in Black Swamp, Purdies Swamp or both.

Table 17 Recommended Complimentary Management Actions to Support Key Ecological Objectives within the Black Swamp Wetland Complex

Management Action	Black Swamp	Purdies Swamp
Construction of a fixed crest weir/spillway on 'Grass's Drain' to reinstate natural wetland sill. The crest level of this structure would need to be approximately 106.3 m AHD.		✓
Implement programs to manage the range of environmental and noxious weeds that are present in and around the wetlands	✓	✓
Encourage private landholders to implement appropriate grazing regime to allow for the regeneration of native species		✓
Discourage the collection of firewood (including standing dead and fallen timber)		✓
Undertake regular patrol and enforcement activities to minimise the extent of illegal firewood collection	✓	
Discourage vehicle use within the bed of the wetland		✓
Undertake regular patrol and enforcement activities to minimise the extent of illegal off road vehicle use	✓	
Undertake regular patrol and enforcement activities to minimise the extent of illegal rubbish dumping	✓	
Undertake a strategic revegetation program with suitable indigenous native species to increase habitat diversity	✓	✓
Implement a regular monitoring program to determine trends with regard to the health of the wetlands – suggested parameters include: ▪ water regime components (timing, frequency, duration, depth) ▪ vegetation (tree health, community composition) ▪ water birds and other fauna ▪ Index of Wetland Condition	✓	✓
Implement a range of community education activities to highlight the environmental values associated with the wetlands	✓	✓

10. Conclusions

The Black Swamp Wetland Complex (Black Swamp, Purdies Swamp and Un-named Wetland) are a bioregionally significant system that is being impacted on by a range of factors including a significant modification to their hydrology.

The primary ecological and water regime objectives for these wetlands are the reintroduction of a more natural water regime of near annual flooding for around six months over the winter/spring period that will encourage a River Red Gum dominated wetland.

Hydraulic modelling has indicated that this regime will be able to be achieved via the implementation of two modifications to existing infrastructure.

Firstly, minor modification of the existing wetland regulating structure will be required in order to raise the existing sill level of this structure such that unseasonal irrigation flows in the Nine Mile Creek are excluded from the Black Swamp and the natural commence to flow conditions were re-instated..

Secondly a fixed crest weir or spillway will be required to be constructed to reinstate the natural sill level of Purdies Swamp and thereby restore the natural depth and duration of inundation of this wetland.

11. Acknowledgments

Person	Organisation/association
Jack Ginnane	Adjacent landholder (Black Swamp)
Max Boase	Landowner (Unnamed Wetland)
Vince Wilson	Landowner (Purdies Swamp)
Norm Newby	Landowner (Purdies Swamp)
Rolf Weber	DSE (Tatura)
Rick Felton	DPI (Wangaratta)
Bruce Wehner	Parks Victoria (Shepparton)
Dave Darby	G-MW (Cobram)
Sam Green	G-MW (Tatura)

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Appendix A Hydrology and hydraulic modelling

The following steps and assumptions were made to derive a daily time-series of water depth in Black Swamp and Purdies Swamp for the period 1/12/1966 – 31/12/2004:

1) Three daily time-series of flow in Nine Mile Creek at Black Swamp were derived by Willam Vlotman:
   - *Natural pre-1997*, which equalled 2/3 of the sum of flows passing gauge 404204 (Boosey Creek at Tungamah) and gauge 404214 (Broken Creek at Katamatite),
   - *Natural post-1997*, which was derived using the same method to estimate the *Natural pre-1997* time-series, and
   - *Current post-1997*, which was derived using gauged, modelled and G-MW estimated flows from Broken Creek, Boosey Creek, the EGM and drainage outfalls.

   The daily time-series are stored in *I:\WTAT\Projects\WT02018\Technical\WTAT02018 Blackswamp Hydrographs\BlackSwampHydrograph.xls*

2) Several runs of the hydraulic model of the study area were undertaken, with and without the cut in the oxbow of Nine Mile Creek adjacent Black Swamp. Results from the hydraulic model were used to construct tables of flow in Nine Mile Creek versus flow to Black and Purdies Swamp (Table A.1. and Table A.2.).

- **Table A.1. Flow in Nine Mile Creek versus flow to Black and Purdies Swamp, assuming the cut in the oxbow of Nine Mile Creek adjacent Black Swamp is present (i.e. existing conditions)**

Flow in Nine Mile Creek (ML/d)	Level in Nine Mile Creek (m AHD)	Max. Discharge to Black Swamp (ML/d)	Max. Discharge to Purdies Swamp (ML/d)
86.4		0.0	0.0
95.0	105.612	6.3	0.0
172.8	105.776	24.0	0.0
259.2	105.910	54.1	0.0
293.8	105.950	67.0	6.0
345.6	106.020	86.7	27.9
432.0	106.114	119.2	61.4

- **Table A.2. Flow in Nine Mile Creek versus flow to Black and Purdies Swamp, assuming the cut in the oxbow of Nine Mile Creek adjacent Black Swamp is absent**

Flow in Nine Mile Creek (ML/d)	Level in Nine Mile Creek (m AHD)	Max. Discharge to Black Swamp (ML/d)	Max. Discharge to Purdies Swamp (ML/d)
51.8		0.4	0.0
112.3		15.5	0.0
181.4		38.2	0.0
250.6		61.9	4.4
337.0		91.2	41.6
432.0		123.4	73.8

3) Using the daily time-series of flow in Nine Mile Creek at Black Swamp, combined with Table A.1. and Table A.2. a time-series of daily flows to Black and Purdies Swamp was developed for 'with cut' and 'no cut' scenarios, assuming either *Natural pre-1997*, *Natural post-1997* or *Current post-1997* flows. The assumptions were:
   a) The relationship between flows in Nine Mile Creek and flows to Black and Purdies Swamp was adequately defined by the maximum discharges to both swamps, given steady-state flow in Nine Mile Creek. This assumption will tend to underestimate (by up to 1 day) the time required to fill Black and Purdies Swamp, because it does not account for the reduction in inflow to the swamps as they approach supply level.
   b) That is, because Black Swamp fills quickly, flow to Purdies Swamp could be based solely on the level (i.e. flows) in Nine Mile Creek,
   c) Linear interpolation of the relationships in Table A.1 and Table A.2 was appropriate for determining flows to Black and Purdies Swamp for the full range of flows in Nine Mile Creek,
   d) The time taken to create a steady-state relationship between flows in Nine Mile Creek and flows to Black and Purdies Swamp was small enough to be ignored, and
   e) The regulator between Nine Mile Creek and Black Swamp would be operated so that,
      - Flow could always enter Black and Purdies Swamp from Nine Mile Creek, but
      - Water could not drain from Black and Purdies Swamp back to Nine Mile Creek.

4) Using the time-series of daily flows to Black and Purdies Swamp, a daily water-balance was derived for the 6 possible combinations of *Natural pre-1997*, *Natural post-1997* and *Current post-1997* flows, under 'with cut' and 'no cut' scenarios. The assumptions were:
   a) Rainfall on and evaporation from Black and Purdies Swamp was adequately represented by rainfall measured at Goorambat (081017) and evaporation measured at Lake Mokoan (081116). Methods and assumptions used to infill and extend these climate series can be found in *I:\WCMS\Projects\WC03657\Technical\Current & Natural Flows\Climate Series*. Net evaporation from Moodies Swamp was modelled using a pan coefficient of 0.8,
   b) Water seeped from Black and Purdies Swamp at a rate of 5 mm/d (Keith Collett, pers. comm.),

c) Black and Purdies Swamp did not have local catchment areas which contributed run-off to the swamps,

d) The proportion of flows to Black and Purdies Swamp from Nine Mile Creek which actually entered the swamps remained 1.0, regardless of how full Black and Purdies Swamp were,

e) Water would only enter Black and Purdies Swamp via the channels connecting Nine Mile Creek to the swamps. That is, contributions from overland flow during floods were ignored,

f) The stage-storage relationship for Black and Purdies Swamp was adequately defined by discharge time-series at cross-sections -12.5 and 805.35 respectively, and level time-series at cross-sections 322.32 and 1074.11 respectively, for the hydraulic model run where flow in Nine Mile Creek was 5 m^3/s and the oxbow cut existed. It was also assumed that linear interpolation could be used to extend both ends of the stage-storage relationship.

g) For the purposes of calculating water depths, the invert levels for Black and Purdies Swamps were 105.420 m AHD and 105.531 respectively, and the FSL level was 106.400 m AHD.

5) To simulate the impact of possible operating rules, the water balances were repeated for the following scenarios (all assuming the oxbow cut was in place):

a) the Purdies Swamp drain was active,

- meaning the FSL level for Black Swamp was 105.939 m AHD (the height of the saddle point between Black and Purdies Swamp), and Purdies Swamp was always dry.

b) the regulator between Nine Mile Creek and Black Swamp was operated so that,

- between June to October inclusive, flow could always enter Black and Purdies Swamp from Nine Mile Creek, but not drain back to Nine Mile Creek, and
- between November to May inclusive, no flow was allowed to enter Black and Purdies Swamp from Nine Mile Creek.

c) a fixed weir (of level 106.079 m AHD) existed between Nine Mile Creek, which prevented flows entering Black Swamp and Purdies Swamp until flows in Nine Mile Creek exceeded 400 ML/d. Table A.1 was not re-derived for this scenario. Rather, it was simply assumed no flow entered Black and Purdies Swamp while flows in Nine Mile Creek were 400 ML/d or less. In addition, for this scenario, it was assumed the FSL level for Black and Purdies Swamp was 106.079 m AHD (i.e. the level of the weir).

Appendix B Previous species lists

Flora species list – data from DCE (1991), DSE (2007c), Roberts and Hale (2006)

Last Year of most recent record

Total Total number of records

Origin Introduced plants/naturalised alien and dual origin (native but some stands may be alien)

* All 'non-native' species.

\# Species classified as having a 'dual origin'.

CST Conservation status in Victoria

x Presumed extinct in Victoria: no post-1950 records from Victoria, in spite of field searches specifically for the plant; or intensive field searches (since 1950) at all known sites have failed to record the plant. The plant's status elsewhere in Australia is not considered in this category.

e Endangered in Victoria: rare and at risk of disappearing from the wild state if present land use and other causal factors continue to operate. The plant's status elsewhere in Australia is not considered in this category.

v Vulnerable in Victoria: rare, not presently endangered but likely to become so soon due to continued depletion; occurring mainly on sites likely to experience changes in landuse which would threaten the survival of the plant in the wild; or taxa where total populations are so low that recovery form a local natural disturbance such as drought, landslip or fire is doubtful. The plant's status elsewhere in Australia is not considered in this category.

r Rare in Victoria but not considered otherwise threatened (the status elsewhere in Australia not being considered). This category does not necessarily imply that the plants are substantially threatened, but merely that there are relatively few known stands.

k Poorly known and suspected, but not definitely known, to belong to any of categories x, e, v or r within Victoria. At present accurate field distribution information is inadequate.

Regional Y Those plants identified by Ryan (2002) as significant within the Goulburn Broken region.

B.1 Black Swamp flora

Scientific name	Common name	Last*	Total	Origin	CST	Regional
Arctotheca calendula	Cape Weed	1986		*		
Aster subulatus	Aster-weed	1986		*		
Austrodanthonia sp.	Wallaby Grass	(1991)				
Avena fatua	Wild Oat	1986		*		
Azolla filiculoides	Pacific Azolla	1986				
Bromus hordeaceus subsp. *hordeaceus*	Soft Brome	1986		*		
Callitris glaucophylla	White Cypress-pine	1993				
Calotis scapigera	Tufted Burr-daisy	1986	2			
Cardamine paucijuga s.l.	Annual Bitter-cress	1986				
Carex inverse	Knob Sedge	1986				
Centipeda cunninghamii	Common Sneezeweed	1986				
Cerastium glomeratum s.l.	Common Mouse-ear Chickweed	1986		*		
Cerastium glomeratum s.s.	Sticky Mouse-ear Chickweed	1985		*		
Cirsium vulgare	Spear Thistle	1986		*		
Chenopodium pumilio	Clammy Goosefoot	(2006)				
Cotula bipinnata	Ferny Cotula	1986		*		
Crassula decumbens var. *decumbens*	Spreading Crassula	1986				
Cynodon dactylon	Couch	1986				

Scientific name	Common name	Last*	Total	Origin	CST	Regional
Cyperus eragrostis	Drain Flat-sedge	1986		*		
Cyperus exaltatus	Tall Flat-sedge	1986	2			
Eleocharis acuta	Common Spike-sedge	1986				
Eleocharis pusilla	Small Spike-sedge	1986	2			
Elymus scaber var. *scaber*	Common Wheat-grass	1986				
Enteropogon acicularis	Spider Grass	1986	2			
Epilobium ciliatum	Glandular Willow-herb	1986		*		
Epilobium hirtigerum	Hairy Willow-herb	1986				
Eragrostis infecunda	Southern Cane-grass	1986				
Eryngium paludosum	Long Eryngium	2002	2		v	
Eucalyptus camaldulensis	River Red Gum	1986				
Euchiton sphaericus	Annual Cudweed	1986				
Hakea tephrosperma	Hooked Needlewood	1993				
Hordeum marinum	Sea Barley-grass	1986		*		
Hordeum murinum s.l.	Barley-grass	1986		*		
Juncus radula	Hoary Rush	1986				
Juncus subsecundus	Finger Rush	1986	2			
Lachnagrostis filiformis	Common Blown-grass	1986				
Lamium amplexicaule	Dead Nettle	1986		*		
Lepidium draba	Hoary Cress	1986		*		
Lobelia concolor	Poison Pratia	1986				
Lolium rigidum	Wimmera Rye-grass	1986		*		
Lythrum hyssopifolia	Small Loosestrife	1986				
Muehlenbeckia florulenta	Tangled Lignum	1986				
Myoporum montanum	Waterbush	1990			r	
Myriophyllum sp.	Water Milfoil	(1991)				
Paspalum sp.	Water Couch	(1991)		*		
Persicaria decipiens	Slender Knotweed	(2006)				
Persicaria hydropiper	Water Pepper	1986				
Persicaria prostrate	Creeping Knotweed	1986				
Poa annua	Annual Meadow-grass	1986		*		
Poa fordeana	Forde Poa	1986				
Ranunculus sessiliflorus	Annual Buttercup	1986				
Rumex brownie	Slender Dock	1986				
Sagittaria platyphylla	Sagittaria (Arrowhead)	1994		*		
Sonchus asper s.l.	Rough Sow-thistle	1986		*		
Sonchus oleraceus	Common Sow-thistle	1986		*		
Stellaria media	Chickweed	1986		*		
Swainsona procumbens	Broughton Pea	1986	2			Y
Trifolium fragiferum var. *fragiferum*	Strawberry Clover	1986		*		
Trifolium subterraneum	Subterranean Clover	1986		*		
Triglochin sp.	Water Ribbons	(1991)				
Typha orientalis	Broad-leaf Cumbungi	1986				
Vulpia muralis	Wall Fescue	1986		*		

* these dates all refer to DSE (2007a) except where indicated by parenthesis. In these instances (1991) relates to DCE (1991) and (2006) to Roberts and Hale (2006).

B.2 Purdies Swamp flora

Scientific name	Common name	Last*	Total	Origin	Regional
Agrostis sp.	Bent Grass	(1991)			
Austrodanthonia sp.	Wallaby Grass	(1991)			
Consolida ajacis	Eastern Larkspur	2001		*	
Cirsium vulgare	Spear Thistle	(2006)		*	
Eleocharis acuta	Common Spike-sedge	(1991)			
Eleocharis pusilla	Small Spike-sedge	(1991)			
Eucalyptus camaldulensis	River Red Gum	(1991)			
Heliotropium sp.	Heliotrope	(2006)			
Hordium sp.	Barley-grass	(2006)		*	
Juncus sp.	Rush	(1991)			
Lolium sp.	Rye-grass	(2006)		*	
Ludwigia peploides	Water Primrose	(1991)			
Myriophyllum sp.	Water Milfoil	(1991)			
Paspalum sp.	Water Couch	(1991)		*	
Phalaris minor	Lesser Canary-grass	1967		*	
Pimelea curviflora s.s.	Curved Rice-flower	1981			Y
Potamogeton tricarinatus	Floating Pondweed	(1991)			
Pseudoraphis spinescens	Moira Grass	(1991)			
Pycnosorus globosus	Drumsticks	1981	2	#	
Ranunculus pumilio var. *pumilio*	Ferny Small-flower Buttercup	1991			
Xanthium spinosum	Bathurst Burr	(2006)		*	

*these dates all refer to DSE (2007a) except where indicated by parenthesis. In these instances (1991) relates to DCE (1991) and (2006) to Roberts and Hale (2006).

B.3 Unnamed wetland flora

Scientific name	Common name	Last*	Total	Origin	Regional
Austrodanthonia sp.	Wallaby Grass	(1991)			
Callitriche sp.	Starwort	(1991)			
Eleocharis acuta	Common Spike-sedge	(1991)			
Ludwigia peploides	Water Primrose	(1991)			
Myriophyllum sp.	Water Milfoil	(1991)			
Nymphoides crenata	Wavy Marshwort	(1991)			
Stellaria sp.	Starwort	(1991)			

* these dates all refer to DCE (1991).

Fauna species list – data from DCE (1991) and DSE (2007d).

Explanation of abbreviations

Last	Year of most recent record	
Total	Total number of records	
Origin	*	Alien
CST	Conservation status in Victoria	
	CR	Critically Endangered
	End	Endangered
	Vul	Vulnerable
	R/R	Rare
	NT	Near Threatened
	R/C	Restricted colonial, breeding or roosting sites
	Ins	Data Deficient, Insufficient data
	Rxt	Regionally extinct
	Ext	Presumed extinct
	Cmp	Comprising several taxa
	Ssp	Sub-species
FFG	Status under the *Flora and Fauna Guarantee Act* 1988	
	L	Listed under FFG
	T	Listed as a threatening process
Treaty	Species listed on an International Treaty	
	C	China Australia Migratory Bird Agreement
	J	Japan Australia Migratory Bird Agreement

B.4 Black Swamp fauna

Scientific name	Common name	Last*	Total	Origin	CST	FFG	Treaty
Acrocephalus stentoreus	Clamorous Reed Warbler	1994	1				
Anas castanea	Chestnut Teal	1991	2				
Anas gracilis	Grey Teal	1995	17				
Anas superciliosa	Pacific Black Duck	1995	16				
Anhinga melanogaster	Darter	1989	1				
Anseranas semipalmata	Magpie Goose	1991	1		Vul		
Ardea alba	Great Egret	1989	2		Vul	L	J, C
Ardea intermedia	Intermediate Egret	1986	1		CR	L	
Ardea pacifica	White-necked Heron	1986	1				
Aythya australis	Hardhead	1991	1		Vul		
Cacatua roseicapilla	Galah	1994	1				
Canis vulpes	Red Fox	1989	1	*	*		
Chenonetta jubata	Australian Wood Duck	1993	8				
Cincloramphus mathewsi	Rufous Songlark	1994	1				
Climacteris picumnus	Brown Treecreeper	1994	1		NT		
Corvus coronoides	Australian Raven	1994	1				
Crinia parinsignifera	Plains Froglet	1989	1				

Scientific name	Common name	Last*	Total	Origin	CST	FFG	Treaty
Crinia signifera	Common Froglet	1989	2				
Cygnus atratus	Black Swan	1995	9				
Cyprinus caprio	Carp	(1991)	1	*			
Egretta novaehollandiae	White-faced Heron	1989	4				
Fulica atra	Eurasian Coot	1995	4				
Gallinula tenebrosa	Dusky Moorhen	1989	1				
Grallina cyanoleuca	Magpie-lark	1994	1				
Gymnorhina tibicen	Australian Magpie	1994	1				
Haliastur sphenurus	Whistling Kite	1994	1				
Himantopus himantopus	Black-winged Stilt	(1991)	1				
Hirundo ariel	Fairy Martin	1994	1				
Hirundo neoxena	Welcome Swallow	1994	1				
Hirundo nigricans	Tree Martin	1994	1				
Larus novaehollandiae	Silver Gull	1990	1				
Lichenostomus penicillatus	White-plumed Honeyeater	1994	1				
Malacorhynchus membranaceus	Pink-eared Duck	1993	2				
Oryctolagus cuniculus	European Rabbit	1994	1	*	*		
Pardalotus striatus	Striated Pardalote	1994	1				
Passer domesticus	House Sparrow	1994	1	*	*		
Pelecanus conspicillatus	Australian Pelican	1990	6				
Phalacrocorax carbo	Great Cormorant	1989	3				
Phalacrocorax melanoleucos	Little Pied Cormorant	1989	1				
Platalea flavipes	Yellow-billed Spoonbill	1989	3				
Platalea regia	Royal Spoonbill	1989	2		Vul		
Platycercus eximius	Eastern Rosella	1994	1				
Porphyrio porphyrio	Purple Swamphen	1995	3				
Psephotus haematonotus	Red-rumped Parrot	1994	1				
Rhipidura leucophrys	Willie Wagtail	1994	1				
Tadorna tadornoides	Australian Shelduck (Mountain Duck)	1994	5				
Threskiornis molucca	Australian White Ibis	1989	6				
Threskiornis spinicollis	Straw-necked Ibis	1989	2				
Todiramphus sanctus	Sacred Kingfisher	1994	1				
Vanellus miles	Masked Lapwing	1986	1				

* these dates all refer to DSE (2007d) except where indicated by parenthesis. In these instances (1991) relates to DCE (1991).

B.5 Purdies Swamp fauna

Scientific name	Common name	Last*	Origin	CST
Anas gracilis	Grey Teal	(1991)		
Anas superciliosa	Pacific Black Duck	(1991)		
Anseranas semipalmata	Magpie Goose	1991		Vul
Ardea sp.*and/or Egretta* sp.	Heron	(1991)		
Chenonetta jubata	Australian Wood Duck	(1991)		

Scientific name	Common name	Last*	Origin	CST
Crinia signifera	Common Froglet	1989		
Cygnus atratus	Black Swan	(1991)		
Crinia parinsignifera	Plains Froglet	1989		
Tadorna tadornoides	Australian Shelduck	(1991)		
Threskiornis sp.	Ibis	(1991)		

* these dates all refer to DSE (2007d) except where indicated by parenthesis. In these instances (1991) relates to DCE (1991).

Appendix C Species observed during the field assessment (April 2007)

C.1 Flora

Scientific name	Common name	Origin	CST
Acacia montana	Mallee Wattle		
Acacia pycnantha	Golden Wattle		
Austrodanthonia spp.	Wallaby Grass		
Bursaria spinosa	Sweet Bursaria		
Callistemon sp.	Bottlebrush		
Calocephalus citreus	Lemon Beauty-heads		
Carex spp.	Sedge		
Cassinia arcuata	Chinese Scrub		
Chenopodium spp.	Goosefoot		
Chloris truncata	Windmill Grass		
Convolvulus erubescens	Pink Bindweed		
Conyza albida	Tall Fleabane	*	
Dianella revoluta	Black-anther Flax-lily		
Eleocharis sphaecelata	Tall Spikerush		
Eragrostis infecunda	Southern Cane-grass		
Eucalyptus camaldulensis	River Red Gum		
Eucalyptus microcarpa	Grey Box		
Hypochoeris radicata	Cats Ear	*	
Juncus spp.	Rush		
Mariana spp.	Cottonbush		
Muehlenbeckia florulenta	Tangled Lignum		
Myoporum montanum	Waterbush		
Onopordum acanthium	Scotch Thistle	*	
Paspalum distichium	Water Couch	*	
Persicaria decipiens	Slender Knotweed		
Sida corrugata	Variable Sida		
Teucrium racemosum	Grey Germander		
Typha spp.	Cumbungi		
Vittadinia cuneata	New Holland Daisy		
Wahlenbergia fluminalis	River Bluebell		
Xanthium spinosum	Bathurst Burr	*	

C.2 Fauna

Scientific name	Common name	Origin	CST
Oryctolagus cuniculus	European Rabbit	*	