Dock Lake FLOWS Study

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Contributions to the Dock Lake FLOWS Study

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- Greg Fletcher (Wimmera CMA)

Important note about your report

The sole purpose of this report and the associated services performed by Jacobs is to assess the environmental water requirements of Dock Lake in accordance with the scope of services set out in the contract between Jacobs and the Wimmera Catchment Management Authority. That scope of services, as described in this report, was developed with the Wimmera CMA.

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Contents

Executive Summary

The Boga Lakes (Dock Lake, Green Lake, Taylors Lake and Pine Lake) are located near Horsham in western Victoria. Dock Lake and Green Lake, the westernmost lakes, are separated by only about 300 m with Dock Lake's only inflows coming via Green Lake (up to 100 ML/day via a channel/pipeline). When Dock Lake contained water it was considered by local residents to be of high environmental value for a range of species and communities, particularly for native vegetation and waterbirds.

Dock Lake was used as water storage from 1932 to supply the Riverside Irrigation District, however, the construction of the Wimmera-Mallee Pipeline in 2010 and the purchase of the irrigation entitlement by the Commonwealth Environmental Water Holder (CEWH) have meant that Dock Lake is no longer needed to manage water resources. Although Dock Lake has only recently been removed from the water supply system, it has been dry since the late 1990s due to drought conditions. Aside from short periods of ponding following heavy rainfall, the lake has remained dry since that time.

Aim of the current study

The Wimmera CMA wants to know what values Dock Lake is likely to support if rewetted and what water regime is needed to support those values. That information could then be used to determine whether it is feasible to use available environmental water allocations and enhance current infrastructure to meet the water requirements of the lake and to determine whether Dock Lake should be prioritised for environmental watering from the Wimmera and Glenelg Rivers Environmental Entitlement. The purpose of the current project is to identify the environmental values that Dock Lake could support if rewetted and to determine the inundation regime that would be required to support those values.

Modified FLOWS method

The environmental watering requirements of Dock Lake were determined by broadly following the FLOWS method (Department of Environment and Primary Industries 2013a). Although the FLOWS method was developed to determine environmental flow requirements for regulated rivers and streams, its general approach can be applied to lakes and wetlands. For the current study, as there is no distinct river channel and flow path, LiDAR data were used to describe the morphology and depth profile of the lake. These data, along with estimates of seepage and evaporation, were used to construct a stand-alone, EXCEL based model (the *Environmental Water Retention Model*) to determine the volume of water required to fill Dock Lake to specified levels for specified durations. As in a standard FLOWS study, for the current project we established an Environmental FLOWS Technical Panel (EFTP), made up of specialists in aquatic ecology, birds, aquatic and riparian flora, water quality, hydrology and hydraulic modelling to determine the watering recommendations for the lake.

Review of ecological values and environmental watering objectives

A review of the fauna and flora species and communities that could be supported by Dock Lake was conducted by consulting with local landholders and specialists, databases, reports and academic texts. Based on this review it was determined that the best outcome for the lake would be gained by using environmental water to mimic a 'natural' watering regime, characterised by periodic inundation followed by slow drawdown and then periods when the lake completely dries. In comparison to holding the lake at a relatively deep level permanently (such as Green Lake) which would benefit relatively few species, a more 'natural' wetting/drying would lead to greater floristic diversity at the lake and increased habitat and foraging resources for range of taxa, especially waterbirds.

This 'natural' water regime, characterised by distinct wetting and drying phases, is similar to that proposed for other northern Victoria wetlands. For example, Johnson Swamp, south-east of Kerang, is similarly managed to support a mosaic of plant communities and a diverse range of habitats for waterbirds (North Central CMA 2009).

It is not recommended that Dock Lake be managed as a put and take fishery. A productive fishery would require near permanent, deep inundation, which is incompatible with the objectives for waterbirds and vegetation. The lake could be an opportunistic fishery during periods of inundation.

Environmental watering recommendations

The EFTP defined a set of water regime elements which would constitute a 'natural' wetting/drying regime for Dock Lake and these elements provide the broad scale recommendations which should govern the delivery of environmental water to Dock Lake. Based on the bathymetric analysis and the results of the Environmental Water Retention Model it was determined that between 271 ML (model Scenario 16) and 973 ML (model Scenario 26) should be delivered for each wetting event. We do not make firm recommendations for dry, average and wet climatic conditions because the wetting/drying regime should retain some variability (within the bounds identified by the EFTP). We do however recommend that the frequency of wetting be based on the environmental conditions. The environmental water recommendations for Dock Lake are outlined in Table E1.

Table E1 Environmental watering recommendations for Dock Lake under wet, average and dry climate conditions.

Climate Conditions	Environmental Water Recommendations
All Provide under all climate conditions	Fill to between 271 ML (Scenario 16) and 973 ML (Scenario 26) (vary the final volume over wetting events so that across multiple wetting events, the full range of volumes between these scenarios is delivered.) Commence filling between May and September. Inundation period should last at least 3-4 months (but could be as long as 12-14 months). Dry periods (between wetting events) should last for at least 6, but preferably 12 months.
Wet (Annual net evap: 805 mm) (Representative year: 1915)	Wetting events should occur on average five times a decade (once every two years)
Average (Annual net evap: 1004 mm) (Representative year: 1976)	Wetting events should occur on average three times a decade (once every three to four years)
Dry (Annual net evap: 1236 mm) (Representative year: 1965)	Wetting events should occur on average twice a decade (once every five years)
Extended extreme drought conditions	No watering recommended. A long period between inundation events (less than twice per decade) is likely to result in a serious decline in ecological condition.

Consequences of environmental watering and monitoring program

The proposed watering recommendations have been designed to provide a high quality wetland habitat that is likely to support a diverse range of flora and fauna species and communities. There are a number of unknowns, however, for example related to the existence of a suitable seed bank at the lake to allow revegetation. In addition, there are a number of risks associated with providing the lake with environmental water. One of the major risks comes from the rapid growth of nuisance grass species when the lake dries. The growth of nuisance grass is a particular concern as similar conditions in the past have led to devastating fires. The major knowledge gaps and risks have been identified and a monitoring program has been designed to build our understanding of lake processes and to help in the management of risks.

Prioritisation of environmental water for Dock Lake

The environmental watering recommendations for Dock Lake, presented in this report, have been developed without considering the other environmental water needs in the Wimmera Region. The recommendations should not therefore be taken as an argument for delivering environmental water to Dock Lake. Rather this report describes what could be achieved if environmental water was to be used at Dock Lake. Environmental water allocations are limited, particularly in dry periods and the Wimmera CMA, Victorian Environmental Water Holder (VEWH), Grampians Wimmera Mallee Water (GWMWater) and other stakeholders will need to consider the relative merits of delivering environmental water to Dock Lake and potential implications on other waterways that may have to cope with less water as a result.

1. Introduction

The Boga Lakes (Dock Lake, Green Lake, Taylors Lake and Pine Lake) are located near Horsham in western Victoria. Dock Lake and Green Lake are the western most lakes and are separated by about 300 m, with the Western Highway passing between the two lakes. Dock Lake would have historically (before human intervention) received water when Green Lake filled and overflowed following significant inflows from Diggers Creek and Mibus Creek.

Dock Lake was used as water storage from 1932 to supply the Riverside Irrigation District. Water quality issues, particularly high salinity, meant that water from the lake was often unsuitable for irrigation supply. The construction of the Wimmera-Mallee Pipeline, which was finished in 2010, meant that Dock Lake was no longer required as part of the system. In reality, however, the lake had not been used for some time, having dried out in the late 1990s (Figure 1-1). Aside from short periods of ponding following heavy rainfall, the lake has remained dry ever since.

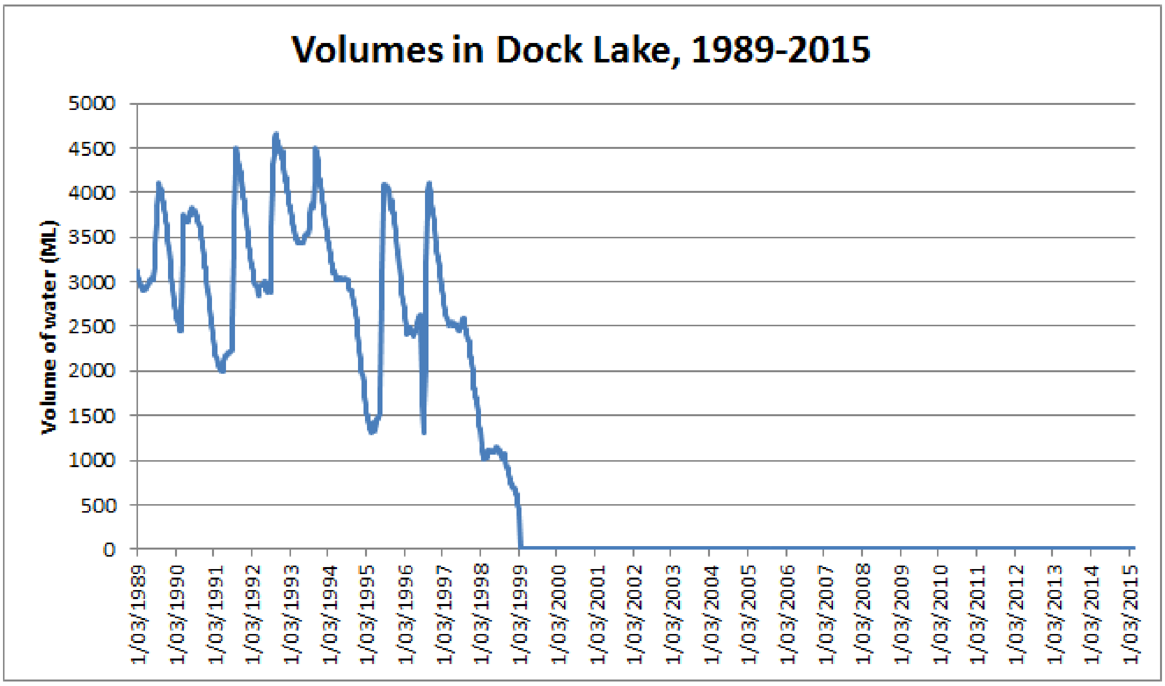


Figure 1-1 Volume of water (ML) in Dock Lake, 1989-2015.

The construction of the Wimmera-Mallee Pipeline and the purchase of the irrigation entitlement by the Commonwealth Environmental Water Holder (CEWH) have meant that Dock Lake is not needed to manage water resources. A review of the system operating rules has led to changes regarding Green Lake, with channel pickup now available to supplement natural catchment inflows and regulated supplies from Grampians Wimmera Mallee Water's (GWMWater) consumptive allocation. Based on estimates from historic inflows, Green Lake is now expected to be filled 70% of the time. As Dock Lake can only be filled from Green Lake, the increased filling of Green Lake increases the opportunity for water to be directed into Dock Lake if that water is likely to meet ecological or social objectives.

Currently, up to approximately 100 ML/day of water can be transferred from Green Lake to Dock Lake via a channel/pipeline and related infrastructure that would require repair/de-silting (Figure 1-2). A small channel (capacity less than 5 ML/day) was constructed in 2013/2014 to allow water to outfall from Dock Lake to Burnt Creek when the lake contains significant volumes (Figure 1-2). The comparatively high salinity of water retained in Dock Lake is, however, a potential risk to the ecological values of Burnt Creek should water be passed through this structure.

Figure 1-2 Left: Regulator structure at the inflow pipe from Green Lake to Dock Lake. Right: Regulator on the outfall channel from Dock Lake to Burnt Creek.

Despite the historically high salinity and the long period it has been dry, when Dock Lake contains water it is considered by local residents to be of high environmental value for native vegetation and for waterbirds. The lake may temporarily support populations of common native small-bodied fish when it is wet, but the lake's variable hydrology probably makes it unsuitable for large-bodied native fish. When holding water, the lake would also provide valuable habitat for frog species.

1.1 Aim of the current study

The Wimmera CMA wants to know what values Dock Lake is likely to support if rewetted and what water regime is needed to support those values. That information could then be used to determine whether it is feasible to use available environmental water allocations and enhance current infrastructure to meet the water requirements of the lake and to determine whether Dock Lake should be prioritised for environmental watering from the Wimmera and Glenelg Rivers Environmental Entitlement or the former irrigation entitlement purchased for environmental watering.

The purpose of the current project is to identify the environmental values that Dock Lake could support if rewetted and to determine the inundation regime that would be required to support those values. The increased understanding resulting from this investigation will enable the organisations responsible for allocating and delivering environmental water in the area (i.e. the Wimmera Catchment Management Authority (Wimmera CMA), Victorian Environmental Water Holder (VEWH), GWMWater and the Commonwealth Environmental Water Holder (CEWH)), to improve decision making regarding water allocations and planning for environmental water in the region.

1.1.1 Modified FLOWS method

The environmental watering requirements of Dock Lake were determined by broadly following the FLOWS method (Department of Environment and Primary Industries 2013a). Although the FLOWS method was developed to determine environmental flow requirements for regulated rivers and streams, its general approach can be applied to lakes and wetlands. The main aspects of the FLOWS method relevant to the current study are i) use of available literature and a field assessment to identify current and historical values; ii) the setting of environmental watering objectives; and iii) the use of literature, hydrological data, hydraulic models and expert opinion to recommend a water regime that should, subject to ancillary actions being implemented, achieve those objectives.

In a standard environmental FLOWS study in rivers, channel cross-sections are surveyed and hydraulic models built to quantify the river flow that is required to inundate particular channel features or generate particular stream velocities or shear forces. The situation with lentic waters bodies, such as lakes and wetlands, differs in as much as the water regime is defined by the timing, frequency and duration of inundation and drying, and the rates at which water levels rise and fall.

For the current study, as there is no distinct river channel and flow path, LiDAR data were used to describe the morphology and depth profile of the lake. These data, along with estimates of seepage and evaporation, were used to determine the volume of water required to fill Dock Lake to specified levels for specified durations. The Wimmera Mallee headworks REALM model also provided a correlation between surface area and volume in the lake, which was linked to the LiDAR.

As in a standard FLOWS study, for the current project we have established an Environmental FLOWS Technical Panel (EFTP), made up of specialists in aquatic ecology, aquatic and riparian flora, water quality, hydrology and hydraulic modelling to determine the watering recommendations for the lake. The members of the EFTP and their technical specialties are outlined in Table 1-1.

Table 1-1 Environmental FLOWS Technical Panel (EFTP)

Name	Organisation	Discipline
Professor Paul Boon	Dodo Environmental	Aquatic and riparian vegetation
Dr Stuart Cooney	EcoLink Consulting	Birds
Dr Andrew Sharpe	Jacobs	Macroinvertebrate and fish ecology and water quality
Dr Josh Hale	Jacobs	Frogs
Amanda Woodman	Jacobs	Hydrology and hydraulic analysis

1.2 Structure of this report

The current report is divided into 13 main parts.

- Following this introduction, Section 2 describes the geographic setting, hydrology and current condition of Dock Lake.
- Sections 3 to 8 identify the environmental values that could be supported by Dock Lake (categorised by environmental value class, i.e. vegetation, birds, frogs, fish, turtles and macroinvertebrates). The habitats likely to be used by the species and communities supported by Dock Lake and the broad water requirements of each of the values are reviewed.
- Based on the review of values and their broad water requirements (Sections 3 to 8), Section 9 enunciates the ecological objectives for the lake. A broad objective for the lake is described as well as specific objectives for vegetation, birds, frogs, fish, turtles and macroinvertebrates.
- Section 10 presents the method used for determining the specific watering recommendations for the lake (inundation volumes, extents and frequency).
- The watering recommendations for the lake are outlined in Section 11. Watering recommendations are provided for wet, average and dry climate conditions (and the definition of these climatic conditions is discussed).
- Section 12 discusses the consequences of the proposed environmental watering regime for the values of Dock Lake. An important part of this discussion is a consideration of the potential risk from providing environmental water to the lake. The major risks, related to each environmental value class (i.e. vegetation, birds, etc.), are described.

- With a system such as Dock Lake, which has been dry for some time, it is critical that monitoring is undertaken during and following inundation so that we can understand how the lake is functioning. This is important not only to manage risks, but also to demonstrate benefits of environmental watering. Therefore, Section 13 describes a monitoring program that should be carried out to determine the impact of environmental watering at Dock Lake.

2. Dock Lake

According to Barlow (1987) Dock Lake has a capacity of 5,900 ML and covers an area of 215 ha (Figure 2-2). The storage management rules, however, indicate that the effective full supply level is 4,420 ML and covers 215 ha (GWMWater 2014). The discrepancy between the lake capacity and the effective full supply level was, according to Barlow (1987), to prevent erosion impacts on an adjacent road (however, it should be noted that Barlow (1987) suggested that the level to avoid damage to the road was 3,850 ML). Depth surveys conducted at the full supply level by the Rural Water Commission in 1990 showed at its deepest (along the eastern bank) that the lake was about 2.2 m deep (McIlvena 2007).

Since its removal from the Wimmera Mallee Headworks system, and the construction of the Wimmera Mallee Pipeline, Dock Lake has not received inflows. Dock Lake is downstream of Green Lake, and would have naturally filled when Green Lake filled and overflowed. Green Lake receives its water via a channel system from Rocklands Reservoir and Burnt Creek and also receives local catchment inflows from Diggers Creek and Mibus Creek. The inlet from Green Lake has silted up, and therefore Dock Lake cannot be expected to receive inflows, unless this inlet is un-silted, the level in Green Lake gets very high or an extreme overland flow event occurs.

2.1 Site assessment

Photos were taken of Dock Lake during the EFTP assessment conducted on 2 March 2015. The bank on the eastern side of the lake is steep with a narrow riparian zone consisting primarily of scattered River Red Gums (*Eucalyptus camaldulensis*; Figure 2-1). The eastern side of the lake is flatter and with little woody vegetation (Figure 2-3).

Figure 2-1 Dock Lake. Photos taken from eastern bank looking west.

The northern bank is much less steep, with mature River Red Gums lining what would have been the riparian zone at the full supply level. A number of dead trees are located along the northern bank. About half way along the northern bank is the outlet channel to Burnt Creek (Figure 2-3).

There are many standing dead trees in the western part of the lake, particularly near the edge. A section of the northern-western bank has a nearly vertical wall, with exposed sandstone bedrock (see Figure 2-3).

The outlet from Green Lake passes under the Western Highway and joins Dock Lake in the southern bank (Figure 2-3). The beach on the northern side of Green Lake is a popular recreational area (Figure 2-4).

Figure 2-2 Aerial view of Dock Lake.

Figure 2-3 Dock Lake. Top Left: Eastern side of the lake. Top Right: Dead trees along the northern bank, with mature River Red Gums in the background. Middle Left: Outlet channel to Burnt Creek on the northern bank of Dock Lake. Middle Right: Dead trees along the western side of the lake. Bottom Left: Rock wall on the western side of the lake. Bottom Right: Inlet channel from Green Lake looking toward the Western Highway and Green Lake.

Figure 2-4 Left: Regulator at Green Lake looking toward the Western Highway. Left: Beach at northern end of Green Lake.

3. Vegetation

3.1 Species and communities supported by Dock Lake

The vegetation community in Dock Lake is heavily influenced by the water regime and the limited information available suggests it has undergone three major shifts in the last century. These shifts relate to i) the period before it was converted to an irrigation water storage (i.e. pre-1932), ii) the period when it was operated as an active water storage (i.e. 1930s − 1999), and iii) the period that followed its decommissioning as an irrigation supply, including that of the most recent drought (i.e. after 1999).

3.1.1 Vegetation community prior to the operation as an irrigation water storage

To our knowledge there is no quantitative information on the aquatic and fringing vegetation present in Dock Lake before it was converted to an irrigation water storage in 1932. Given its position in the landscape and the regional climate, it is likely that it was an intermittent or seasonal wetland (*sensu* Boulton and Brock 1999) inundated most or every year in wet periods and less frequently in dry periods. When it was inundated it would likely have supported a range of floating, submerged, floating-leafed, and emergent vegetation. Floating plants would likely have included the floating ferns *Azolla* and *Lemna* spp. Submerged and floating leaved vegetation may have included Water Ribbons (*Triglochin procerum*), pondweeds (*Potamogeton* spp.), milfoils (*Myriophyllum* spp.) and Eelgrass (*Vallisneria australis*). Fringing emergent vegetation probably included rushes, sedges and reeds (e.g. *Cyperus* and *Juncus* spp. and *Phragmites australis*) as well as groundcover species such as docks (*Rumex* spp.), knotweeds (*Persicaria* spp.), and Nardoo (*Marsilea drummondii*). River Red Gum would have been the dominant canopy-forming tree around the lake, and probably had an understorey of Lignum (*Muehlenbeckia florulenta*) and various chenopod (saltbush) species.

The presence of large dead adult trees towards the edge of the inundated extent lake suggests the lake also supported River Red Gum of various ages that drowned as a result of near-permanent water when the lake was converted to a water storage (Figure 3-1). There are, however, large living River Red Gums outside the inundated extent of the lake.

Figure 3-1 Remnant (dead) River Red Gum at Dock Lake (right photograph Paul I. Boon).

3.1.2 Vegetation community during the period as an irrigation water storage

Based on the 1981 report of the Land Conservation Council (LCC), Ecological Associates (2009) reported that before the mid-1990s Dock Lake was a permanent, open, freshwater wetland with a sandy bottom. This description presumably refers to the conditions after 1932. Following its integration into the irrigation supply system, the lake was used also for recreational activities, including angling and duck shooting. It had been actively stocked with up to four species of introduced fish and was recognised for its Redfin Perch (*Perca fluviatilis*), Rainbow Trout (*Oncorhynchus mykiss*), Brown Trout (*Salmo trutta*) and Tench (*Tinca tinca*) angling. The Land Conservation Council rated the lake as having very high value for waterbirds, as it was used as a feeding area, for breeding, and as drought refuge (Ecological Associates 2009).

There appear to be no description of the aquatic vegetation in the lake when it was used as a water storage. It is known, however that at full supply level the maximum depth was ~2.5 m, a depth that would allow the development of many if not all of the species of submerged and floating-leaved taxa that probably occurred before 1932, at least around the edges. The fringes may have continued to support some emergent species, but the introduction of higher and more constant water levels probably decreased the floristic diversity of these fringing communities. It is difficult to determine without detailed field investigations the species that would been lost, but it is likely that emergent vegetation such as rushes, sedges and reeds (e.g. *Cyperus*, *Juncus* spp and *Bolboschoenus*) would have been among them. Common Reed (*Phragmites australis*), with its wide hydrological niche, is likely to have been one of the few species to be still supported. Floating plants such as *Azolla* and *Lemna* probably continued to be present, at least episodically.

3.1.3 Vegetation community after its operation as an irrigation water storage (i.e. current)

The change in operating practices that followed the construction of the Wimmera-Mallee pipeline in 2010, combined with the recent prolonged drought, mean that Dock Lake has been dry almost constantly since the mid-to-late 1990s. Ecological Associates (2009) reported that when it was dry (i.e. conditions at present) the lake held none of the recreational values identified by the LCC 1981 report, but still contained some of the few remaining native habitat fragments in the area. A site visit undertaken in April 2009 by Ecological Associates indicated that EVC 636 (Lake Aggregate) was no longer present on the lakebed, a result not surprising given that the inspection was undertaken during the millennium drought. Ecological Associates reported that on the northern side of the lake there were areas of River Red Gum, present as both adults and juveniles, and dense patches of Lignum. The presence of these two species was interpreted as possibly constituting a remnant of EVC 636. Similar fringing vegetation was present in our field inspection of early March 2015 (Figure 3-2).

Figure 3-2 Fringing vegetation around Dock Lake (photograph Paul I. Boon).

Ecological Associates (2009) reported also that introduced grasses and weeds then (i.e. 2009) dominated lake bed vegetation, with small patches of native grass (e.g. *Austrodanthonia* and *Austrostipa*), reed and sedges present. The exotic Curly Dock (**Rumex crispus*) was abundant on the lake bed during the March 2015 field inspection (Figure 3-3).

Figure 3-3 Dry Curly Dock on the lake bed of Dock Lake (photograph Paul I. Boon).

3.1.4 Potential to rehabilitate or improve the vegetation values of Dock Lake

In its present condition, Dock Lake supports only terrestrial vegetation types dominated by introduced grasses and other taxa, many of them weeds. The fringes, however, have ecologically valuable River Red Gum and Lignum communities and their associated habitats for terrestrial and aquatic organisms. There is significant potential for rehabilitation, perhaps even restoration, of the aquatic and fringing vegetation should a more natural wetting and drying regime be implemented. From the perspective of native vegetation, the most appropriate water regime would mimic the one that existed before 1932, and would involve periodic wetting and drying of the lake bed. The following section outlines the broad principles involved in establishing those hydrological conditions.

3.2 Broad water requirements of the vegetation species and communities at Dock Lake

Wetlands and floodplains across much of the semi-arid zone of south-eastern Australia would, under pre-European conditions, experience alternating periods when they were inundated to various depths and periods when they were completely dry. The biota of floodplain wetlands are well adapted to changeable hydrological conditions. Figure 3-4 shows three broad plant responses to different wetting and drying regimes in intermittent or seasonal wetlands: i) terrestrial taxa intolerant of flooding; ii) amphibious taxa tolerant of flooding; and iii) submerged taxa, intolerant of desiccation.

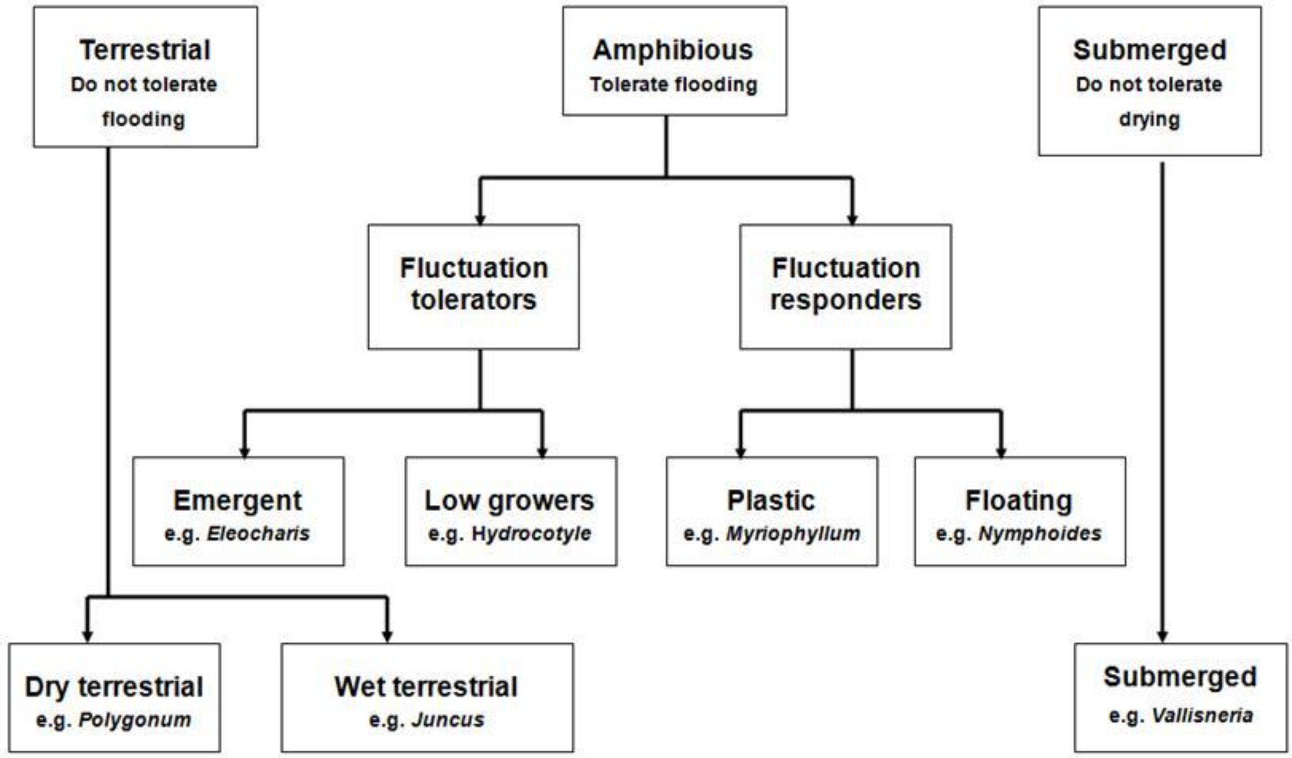


Figure 3-4 Structural-functional grouping of wetland plants according to responses to wetting and drying and changes in water level. (Source: Brock and Casanova 2000, Table 1).

A set of general principles for ecologically-appropriate water regimes in wetlands of the semi-arid parts of south-eastern Australia can be devised from existing information on the known responses of wetland biota and ecosystem-scale processes to wetting and drying. Briggs (1988) attempted such a task over 25 years ago, when she devised generic guidelines for wetlands in inland New South Wales. Gippel (1996) also made some general recommendations for the hydrology of freshwater wetlands in Victoria. More recently, Boon *et al.* (2005) and Boon *et al.* (2009) devised an updated set of guidelines. Similar heuristics have been developed to inform the environmental watering of many wetlands in north and western Victoria including, for example, for Johnson Swamp by the North Central Catchment Management Authority (2009). The following are principles that seem broadly applicable to the reintroduction of more natural wetting and drying regimes in Dock Lake in order to allow the re-establishment of a floristically and structurally diverse aquatic and fringing vegetation.

- **Principle 1 - Maintaining stable, high water levels is generally incompatible with the maintenance of high ecological values.**
  Its corollary, Principle 2 provides an explanation as to why.

  Principle 2 – Water levels need to fluctuate seasonally
  Fluctuating water levels allow a wide range of vegetation types to develop, as rising and falling water alternately exposes and inundates different parts of the shoreline. The well-established ‘intermediate disturbance hypothesis’ (Connell 1978) posits that under environmentally constant conditions one or a few well-adapted and competitively superior species will eventually become dominant, but that fluctuating conditions will allow a diverse range of plants to exist in a spatial and temporal mosaic. Management goals for environmentally watered wetlands often include the objective of supporting a mosaic of structurally and floristically complex plants species (e.g. Johnsons Swamp; North Central CMA 2009) and fluctuating water levels is a critical process in achieving those objectives.

  Fluctuating water levels also facilitate the creation of shallow fringing areas, which allow wading birds to feed, and submerged aquatic plants to maintain their photosynthetic organs in the photic zone.

  What depths should water levels fluctuate over? Water deeper than ~ 2m will not support the growth of emergent macrophytes such as rushes, reeds and sedges. Water this deep overwhelms these plants' ability to aerate their roots and rhizomes. For submerged plants, the maximum water depth is set by water clarity. Water that contains large amounts of suspended clays will be too turbid for submerged plants to photosynthesis and maintain a positive carbon balance. Water that is too shallow may get too warm over summer months, or be insufficient to give the plants enough room to grow. Depths in the open-water sections of wetlands of 0.3−0.7 m are often recommended to facilitate the growth of submerged plants. Floating plants of course are not affected by water depth.

- **Principle 3 - Wetlands require periodic drawdown of water levels and complete drying.**
  See discussion in its corollary - Principle 4

  Principle 4 - Ephemeral wetlands require periodic inundation.
  Since most floodplain wetlands in south-eastern Australia experience a strongly seasonal climate and drought is not uncommon, the biota are well adapted to episodic and even prolonged desiccation. Three to four years seems to be about the maximum period that ephemeral wetlands can be kept fully inundated without ecological degradation becoming apparent, especially to amphibious and emergent plant communities. The most appropriate duration of wet and dry periods, however, varies with the type of vegetation supported by the wetland and with broader management objectives. Intermittent wetlands in arid or semi-arid zones with a dominant Black Box/Lignum vegetation require shorter periods of inundation − and longer dry periods − than do River Red Gum dominated systems. For wetlands with significant River Red Gum components, approx. 18–24 months seems to be the longest period of inundation before adult trees die *en masse*. The loss of structurally important taxa, especially canopy trees such as River Red Gum, can have serious adverse impacts on waterbird breeding. Ellis and Meredith (2005) recommended a dry phase for two wetlands near Wentworth in south-western New South Wales, on the basis that it would improve the likelihood of successful waterbird breeding, increase fish recruitment and macroinvertebrate productivity, lower water-column turbidity and provide productive habitats for terrestrial and amphibious fauna. In contrast, Black Box/Lignum dominated systems require less frequent inundation, and a wetting period that lasts only a few months (e.g. Johnsons Swamp; see North Central Catchment Management Authority 2009).

  In general it is thought that shallow or ephemeral wetlands should be drained for at least 6 months, in order to allow soils to dry fully and biogeochemical processes to attain their end points (Boon 2006, Boon *et al.* 2005, 2009). Drying should occur over the summer to autumn period, when the wetlands would naturally experience the high temperatures and high evaporative losses typical of summers in south-eastern Australia with a temperate or Mediterranean-type of climate. Complete desiccation may be required to control noxious fish species, such as Carp. Such regimes generally seek to mimic natural wetting and drying cycles, which was one of the first recommendations made by Gippel (1996) for managing water regimes in high-value wetlands in Victoria: ‘Ideally, reinstate the natural hydrological regime by removing disturbing factors’ (Gippel 1996, page 136).

If a drying phase is instigated, it is important that it be long enough to generate the desired ecological outcomes. There are ecological risks associated with the dry period that is too short and, for floodplain wetlands on the Murray River around Barmera and Renmark South Australia Tucker *et al.* (2003) recommended dry periods of at least 3 months but no more than 6 months duration. The upper limit was set on the basis of the risk of saline intrusions and excessive growth of terrestrial vegetation on the wetland floor.

A risk with near-annual flooding of floodplain wetlands is excessive regrowth of River Red Gums. Briggs and Thornton (1995) argued that River Red Gum-dominated wetlands often needed to be managed, for example by thinning saplings, to ensure the trees produced good spreading branches that would allow birds to nest. Conversely, ephemeral wetlands that are kept chronically dry progressively lose their ecological value and will eventually convert into fully terrestrial environments. Walker (2006, page 266) argued that '…wetlands subjected to drying for too long may not produce a pulse of high productivity when floods occur'.

In addition to increasing plant biodiversity and maintaining critical ecosystem-scale ecological processes such as nutrient cycling and organic-matter degradation, there are a few other specific management benefits that could accrue from implementing a more natural wetting and drying regime in floodplain wetlands:
- Control of noxious fish species, such as Carp.
- Control of undesirable plant species, such as Cumbungi (*Typha* spp.).
- A completely dry and consolidated substratum wouldn't flocculate on subsequent wetting with positive impacts for water quality.
- Cracks that open up on the dry lake bed would provide habitat for terrestrial faunal species (e.g. lizards, insects) and propagation sites for vegetation.

Principle 5 - Wetlands should be flooded in late winter or early spring, and remain inundated for at least three to eight months.
Floodplain wetlands in south-eastern Australia usually flood in late winter or early spring. This flooding regime follows seasonal patterns in rainfall and stream flow, and the subsequent duration of inundation ensures that waterbirds can breed successfully and aquatic plants and macroinvertebrates can complete their life cycle and, where required, lay down resistant egg and seed banks. It is assumed that a similar timing is required for non-floodplain wetlands.

Most environmental watering plans for wetlands in south-western New South Wales, north and western Victoria and relevant sections of South Australia explicitly state that inundation should commence in winter/spring. An example is provided by the environmental watering plan developed for Johnson Swamp by the North Central Catchment Management Authority (2009). Since 1989 eight watering plans have been proposed for this wetland, of which six explicitly stated that watering was to start in winter or spring. The regime outlined in the 2009 synthesis report similarly recommended inundation in winter/spring.

Consistent with these recommendations for Johnson Swamp, a Victorian semi-arid zone wetland, D'Santos (2006) recommended that ephemeral floodplain wetlands associated with various rivers of the mid-Murray region in central New South Wales should commence to fill before the end of September. Water inputs should cease no later than the end of November, with the expectation that they will be dry by February the following year. Thus if a wetland is flooded in early September and dry by the end of February, it will have remained inundated for about six months. Wet periods of as short as 3 months may be sufficient for some taxa of aquatic plants and rapidly-breeding birds such as ducks (Briggs and Thornton 1999), but longer periods are required for other species of waterbird, such as the cormorants, pelicans and herons, so that they may complete breeding and young birds can fledge (Briggs 1997).

There are significant risks of wasting water without achieving appreciable ecological outcomes if floodplain wetlands are inundated for too short a period. Roberts and Marston (2014), for example, noted that floods of short duration (30–45 days) in the Millewa Forest of New South Wales were effective in wetting the sub-soil of areas close to flood runners but not of River Red Gums ~40 m away. In contrast, longer floods (60–80 days) gave no evidence of this distance effect and the ecological benefits of inundation were more widespread.

- **Principle 6 – Rates of inundation and drawdown need to be controlled.**
There are few data sources on optimum rise times for the inundation (flooding) phase of wetlands. If the rate of inundation is too fast, plants can be overtopped and drowned. Similarly, the rate at which a wetland dries out can have serious impacts on wetland structure and function. An accelerated drawdown mediated by engineering structures may eliminate salt from a wetland, whereas a slow evaporation-driven drawdown will lead to the retention of salt. Rates of fall that are too rapid will strand fish, interfere with waterbird breeding, contribute to bank slumping, and possibly add to water-column turbidity.

  In one of the few studies on the topic, Blanch *et al.* (1996) reported that *Vallisneria spiralis* (now *V. australis*) could extend its leaves at rates of up to 2 cm/day to reach into the upper levels of the water where light was still readily available. Jensen and Turner (2002) recommended a filling rate of less than 1 cm/day to allow submerged plants to grow in floodplain wetlands of the Riverland in South Australia. Tucker *et al.* (2003) proposed that rapid filling (>3 cm/ day) was likely to limit germination and the survival of submerged aquatic plants in floodplain wetlands. Jensen and Turner (2002) proposed that drawdown rates of greater than 10 cm/week (equal to about 1.5 cm/day) resulted in a rapid transition to dry vegetation on the bed of a drawing-down wetland.

- **Principle 7 - Multiple wetting-drying cycles may be required for environmental rehabilitation.**
Hydrological intervention over a single year may be unlikely to result in long-term improvements in the biodiversity and environmental values of degraded wetlands, and multiple wetting and drying cycles may be needed to achieve ecological rehabilitation. There is little information on the number of cycles that are required for effective rehabilitation. Pillai and McGarry (1999) concluded that 3–9 alternating wet and dry cycles were required to repair swelling-clay soils in chronically grazed wetlands in the arid zone of inland Australia.

- **Principle 8 - Ecological connectivity among wetlands should be acknowledged and maximised**
Wetlands are often strongly interconnected by the movement of mobile fauna (such as birds and fish) and the translocation of plant fragments and propagules. Thus biodiversity opportunities are maximized when movements are allowed to take place. Wetlands thus should not be managed as single biodiversity 'hot spots' in the environment, but as members of a landscape-scale mosaic of aquatic and terrestrial systems.

4. Birds

4.1 Species supported by Dock Lake

Although no systematic surveys of Dock Lake have been undertaken, 82 bird species have been recorded at Dock Lake between 1982 and 1999 (Department of Environment Land Water and Planning 2015a). These species belong to a range of foraging guilds, including waterfowl, migratory waders and woodland birds. It is unlikely that all of these species would occur at the same time, instead, these lists reflect the dynamic nature of the lake and only a subset of these species would be found at the lake at any given time, depending on the vegetation and water levels at the lake (discussed further below).

Of the 82 species recorded at Dock Lake, 15 are considered threatened or near threatened in Victoria (Table 4-1) (Department of Sustainability and Environment 2013b). This includes six species that are listed in the *Flora and Fauna Guarantee Act (1988)* Vic and two, Australasian Bittern (*Botaurus poiciloptilus*) and Curlew Sandpiper (*Calidris ferruginea*), that are listed as nationally Endangered under the *Environment Protection and Biodiversity Conservation (EPBC) Act (1999)* Cth. Two introduced species, House Sparrow (*Passer domesticus*) and Common Starling (*Sturnus vulgaris*), have also been recorded at the lake (Department of Environment Land Water and Planning 2015a).

Table 4-1 Threatened species previously recorded at Dock Lake, Victoria. Threat Status relates to the *Advisory List of Threatened Vertebrate Fauna in Victoria* (Department of Sustainability and Environment 2013b). FFG Act = Flora and Fauna Guarantee Act (1988); EPBC Act = Environment Protection and Biodiversity Conservation (EPBC) Act (1999). Source: Victorian Biodiversity Atlas (Department of Environment Land Water and Planning 2015a).

Common Name	Specific Name	Threat Status	FFG Act	EPBC Act
Magpie Goose	*Anseranas semipalmata*	Near threatened	Listed	
Australasian Shoveler	*Anas rhynchotis*	Vulnerable	-	
Freckled Duck	*Stictonetta naevosa*	Endangered	Listed	
Hardhead	*Aythya australis*	Vulnerable	-	
Blue-billed Duck	*Oxyura australis*	Endangered	Listed	
Musk Duck	*Biziura lobata*	Vulnerable	-	
Pied Cormorant	*Phalacrocorax varius*	Near threatened	-	
Royal Spoonbill	*Platalea regia*	Near threatened	-	
Eastern Great Egret	*Ardea modesta*	Vulnerable	Listed	
Australasian Bittern	*Botaurus poiciloptilus*	Endangered	Listed	Endangered
Common Greenshank	*Tringa nebularia*	Vulnerable	-	
Curlew Sandpiper	*Calidris ferruginea*	Endangered	-	
Pectoral Sandpiper	*Calidris melanotos*	Near threatened	-	
Latham's Snipe	*Gallinago hardwickii*	Near threatened	-	
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	Vulnerable	Listed	

Systematic surveys at nearby Taylors Lake recorded 119 bird species (T. Mintern *In Lit*. 5 March 2015) and a search of historical records from the lakes surrounding Dock Lake returns 104 species that are found in the wider landscape. The list includes 11 threatened species that have not previously been recorded at Dock Lake, including one species, Swift Parrot (*Lathamus discolour*), that is listed as nationally Endangered under the EPBC Act (Table 4-2). All of these species have the potential to occur at Dock Lake when the habitat is suitable

Table 4-2 Threatened species not previously recorded at Dock Lake, but recorded at nearby Taylors Lake, Victoria. Threat Status relates to the *Advisory List of Threatened Vertebrate Fauna in Victoria* (Department of Sustainability and Environment 2013b). FFG Act = Flora and Fauna Guarantee Act (1988); EPBC Act = Environment Protection and Biodiversity Conservation (EPBC) Act (1999). Source: Victorian Biodiversity Atlas (Department of Environment Land Water and Planning 2015a).

Common Name	Specific Name	Threat Status	FFG Act	EPBC Act
Glossy Ibis	*Plegadis falcinellus*	Near threatened	-	
Little Egret	*Egretta garzetta nigripes*	Endangered	Listed	
Nankeen Night Heron	*Nycticorax caledonicus hillii*	Near threatened	-	
Pectoral Sandpiper	*Calidris melanotos*	Near threatened	-	
Australian Pratincole	*Stiltia isabella*	Near threatened	-	
Brolga	*Grus rubicunda*	Vulnerable	Listed	
Black Falcon	*Falco subniger*	Vulnerable	-	
Spotted Harrier	*Circus assimilis*	Near threatened	-	
Whiskered Tern	*Chlidonias hybridus javanicus*	Near threatened	-	
Swift Parrot	*Lathamus discolor*	Endangered	Listed	Endangered
Brown Treecreeper (south-eastern subspecies)	*Climacteris picumnus victoriae*	Near threatened	-	

4.2 Habitat use at Dock Lake

Dock Lake has the potential to support a wide range of avian species that exploit a range of habitat niches. The precise composition of the bird assemblage will naturally vary over time in response to changes in water levels, both within the lake and in the wider landscape; and the corresponding change in vegetation composition and structure.

When the lake is near capacity it has the potential to provide habitat for a wide range of waterbirds. The margins will provide foraging habitat for species included probing and stabbing piscivores such as the Eastern Great Egret (*Ardea alba*) Little Egret (*Egretta garzetta*), White-faced Heron (*Egretta novaehollandiae*), White-necked Heron (*Ardea pacifica*), sifting piscivores/insectarivores like the Royal Spoonbill (*Platalea regia*), Yellow-billed Spoonbill (*Platalea flavipes*) and dabbling ducks, Pacific Black Duck (*Anas superciliosus*), Grey Teal (*Anas castanea*) and Pink-eared Duck (*Malacorhynchus membranaceus*). Deeper parts of the lake will provide habitat for swimming piscivores like the Little Pied Cormorant (*Microcarbo melanoleucos*), Little Black Cormorant (*Phalacrocorax sulcirostris*), Great Cormorant (*Phalacrocorax carbo*) and grebes such as the Australasian Grebe (*Tachybaptus novaehollandiae*) and the Hoary-headed Grebe (*Poliocephalus poliocephalus*). The open and unvegetated middle of the lake, where water exceeds approximately 1-1.5 metres deep, would provide habitat to diving ducks such as Hardhead (*Aythya australis*), Musk Duck (*Biziura lobata*) and Blue-billed Duck (*Oxyura australis*). Deep water will also provide habitat for diving piscivores, such as Australasian Darter (*Anhinga novaehollandiae*) and Great Crested Grebe (*Podiceps cristatus*) and hawking piscivores such as Whiskered Tern (*Chlidonias hybrid*) and White-winged Tern (*Chlidonias leucopterus*). Many of these species are reliant on the natural introduction of fish to the lake following extended periods without water. This happens during flood years when waterbodies are connected and when birds fishing on other waterbodies carry fish to the lake. This natural process can be disrupted by the introduction of exotic fish such as Eastern Gambusia (*Gambusia holbrooki*) that predate on the usually small native fish, or change the natural habitat of the lake (e.g. European Carp (*Cyprinus carpio*) that destroy aquatic vegetation through pugging).

As the lake dries, exposed mudflats and shallow water would provide habitat to a range of waders. This includes species that are resident to Australia; Red-kneed Dotterel (*Erythrogonys cinctus*), Black-fronted Dotterel (*Elseyornis melanops*), Red-capped Plover (*Charadrius ruficapillus*), Black-winged Stilt (*Himantopus leucocephalus*), Red-necked Avocet (*Recurvirostra novaehollandiae*), as well as migratory waders such as Curlew Sandpiper, Red-necked Stint (*Calidris ruficollis*), Sharp-tailed Sandpiper (*Calidris acuminate*), Marsh

Sandpiper (*Tringa stagnatilis*) and Common Greenshank (*Tringa nebularia*). These species arrive during the austral summer (approximately September-October) before departing for Northern Hemisphere breeding grounds in March-April (Higgins and Davies 1996). During their time in Australia these birds forage for invertebrates on exposed mudflats and areas of shallow water (less than 10 cm deep). Many of these species are threatened taxa and most are protected under either or both of the China–Australia Migratory Bird Agreement (CAMBA) and Japan–Australia Migratory Bird Agreement (JAMBA), which are treaties between the countries to minimise harm to migratory shorebirds which migrate between them and the habitats that these birds rely on.

When the lake is completely dry, the waterbirds and water-dependent birds will leave for other areas that support more suitable habitat. As colonising terrestrial vegetation replaces the aquatic vegetation and exposed mud, a different suite of birds will return. This includes species such as Brown Quail (*Coturnix ypsilophora*), Australasian Pipit (*Anthus australis*) and the introduced Eurasian Skylark (*Alauda arvensis*) as well as species that have adapted to the agricultural practices introduced by European settlement, including Australian Magpie (*Gymnorhina tibicen*), Magpie-lark (*Grallina cyanoleuca*) and Australian Raven (*Corvus coronoides*).

Areas of emergent and fringing aquatic vegetation, including stands of *Typha* sp. and *Juncus* sp., provide foraging habitat for a range of skulking crakes and rails; Australian Spotted Crake (*Porzana fluminea*), Spotless Crake (*Porzana tabuensis*), Baillon's Crake (*Porzana pusilla*), Buff-banded Rail (*Gallirallus philippensis*) and Lewin's Rail (*Lewinia pectoralis*). Larger areas of this vegetation would provide foraging and nesting habitat for bitterns, such as the Little Bittern (*Ixobrychus dubius*) and Australasian Bittern (*Botaurus poiciloptilus*) as well as non-waterbirds such as the small, reed dependent Golden-headed Cisticola (*Cisticola exilis*), Australian Reed Warbler (*Acrocephalus australis*) and Little Grassbird (*Megalurus gramineus*). Fringing these areas, and in sections that are less densely vegetated, larger rails like the Purple Swamphen (*Porphyrio porphyria*), Dusky Moorhen (*Gallinula tenebrosa*) and more terrestrial ducks such as the Australian Wood Duck (*Chenonetta jubata*) are likely to be found. These areas may also support the cryptic and threatened Latham's Snipe (*Gallinago hardwickii*) and Australian Painted-snipe (*Rostratula australis*).

The riparian vegetation and floodplain woodland are likely to support a range of woodland birds, including resident species such as Yellow-rumped Thornbill (*Acanthiza pusilla*) and Striated Pardalote (*Pardalotus striatus*), nomadic species such as Olive-backed Oriole (*Oriolus sagittatus*) and seasonal migrants such as Sacred Kingfisher (*Todiramphus sanctus*) and Rufous Whistler (*Pachycephala rufiventris*). Of particular importance in this vegetation community is the role of River Red Gums in providing nesting habitat for hollow dependent species, including cockatoos; Sulphur-crested Cockatoo (*Cacatua galerita*), Galah (*Eolophus roseicapilla*), Long-billed Corella (*Cacatua tenuirostris*), parrots; Red-rumped Parrot (*Psephotus haematonotus*), Eastern Rosella (*Platycercus eximius*) and some threatened species, including Brown Treecreepers (*Climacteris picumnus*). Stands of Lignum provide refuge for smaller birds such as Superb Fairy-wren (*Malurus cyaneus*) and Zebra Finch (*Taeniopygia guttata*).

It is likely that the natural water regime of Dock Lake resulted in a variable amount of each of the habitat types described above, at any given time. This process of wetting and drying would maximise the species diversity within the lake. It is less clear what would maximise overall abundance of individuals, however, given the ability of most waterbirds to travel large distances to exploit the most favourable conditions, this is likely to reflect local and national wetland conditions and not just the condition of Dock Lake. Similarly, managing the lake to maximise breeding success of birds in general is difficult. Different species have different requirements and managing the lake to encourage breeding of one species is likely to preclude breeding of another. While waterbird breeding has been recorded at Dock Lake, it is not known for providing significant breeding habitat for any species in recent history. It is also likely that if the water regime recommended herein is adopted, breeding of some species will occur when conditions suit at both Dock Lake and in the wider landscape. Given the conditions beyond Dock Lake cannot be controlled, it is recommended that the Lake be managed to maximise species diversity, rather than absolute abundance or breeding of any particular species.

4.3 Broad water requirements of birds at Dock Lake

To maximise species diversity at Dock Lake the water level of the lake needs to vary over time. A variable amount of water in the lake and intermittent periods of drying, favour greater floristic diversity (see Section 3), and this enhances the habitat quality for most of the birds that will use the lake. This is likely to be true even for birds that are not directly exploiting the flora of the lake, such as the deep diving ducks. Given the lake is naturally shallow, a water regime that ensures that some areas of open water are maintained, to the exclusion of plants, will enable these duck species to colonise the lake at various times. Conversely, drying periods will expose mud and encourage growth of plants around the edges of the lake, and this will provide habitat for the mud-feeders and species that require dense fringing and emergent vegetation. This approach has been applied to the water management regime at Johnson Swamp (North Central CMA), which is highly regarded for its waterbird diversity and its role as a waterbird refuge within north-eastern Victoria.

The literature is silent on what constitutes deep water in relation to the preferences of the diving ducks. Species such as Blue-billed Ducks and Musk Ducks are known to dive to depths of three metres (Marchant and Higgins 1990), however it would be expected that both deeper and shallower waters would nonetheless provide habitat for these species. These species also require open areas of water, free from visual obstruction, which deeper water tends to provide (Marchant and Higgins 1990). A fill volume where approximately 50% of the inundated extent of the lake is at a depth of near one metre, is likely to provide enough open water for the diving ducks over a period of time that is long enough to enable discovery of the lake and colonisation for these species.

As the water recedes, or at the shallow margins, the bird assemblage will have changed from supporting diving and dabbling ducks, grebes and other piscivores, to being dominated by stalking and sifting predators such as egrets, herons and spoonbills. Very shallow waters and exposed mud-flats will provide foraging habitat to the migratory and non-migratory waders and plovers. Ideally shallow water and exposed mud flats would occur during the summer months in the majority of years in which water is provided to the lake to coincide with the presence of the migratory waders.

As the lake dries even more, depending on the length of time that water persists as well as the speed at which it dries, areas of dense, semi-aquatic vegetation are likely to encroach onto the lake bed. These conditions favour the crakes, rails, bitterns and snipe that feed in the puddles and mud beneath the reeds and dense vegetation. The death of these plants, when water returns to the lake, will also provide nutrients for the macroinvertebrates that provide an important food source for a range of birds and their prey (such as frogs and fish). Drying out is also likely to be an important management tool for the control of some exotic fish that predate on the native fish and tadpoles that a range of waterbirds also depend on.

Should waterbirds breed at Dock Lake, it is important that the water level of the lake does not fluctuate rapidly or be significantly different to what might be expected through natural evaporation or rainfall events. Rapid changes in the water level may drown nests or leave chicks exposed to predation if water levels drop. To minimise the risk of this occurring, it is recommended that the lake be monitored and water levels managed to respond to breeding events.

Large volumes which would mean that much of the lake is covered by relatively deep water would benefit some species (like ducks) but the habitat that would be created would be relatively uniform, reducing the diversity of birds that could use the lake. The greatest species diversity is likely to be achieved with intermediate volumes which provide some deeper open habitat but also a variety of depths with some fringing mudflats.

5. Frogs

5.1 Species supported by Dock Lake

The frog communities that could be supported by Dock Lake were reviewed by assessing records on the Victorian Biodiversity Atlas (VBA; Department of Environment Land Water and Planning 2015a) and recent surveys of the area east of the lake by Ecology and Heritage Partners (2015). No frog species are recorded on the VBA as occurring at Dock Lake, but the Growling Grass Frog (*Litoria raniformis*), the Pobblebonk (*Limnodynastes dumerilii*) and the Common Spadefoot Toad (*Neobatrachus sudelli*) have been recorded in the broader Boga Lakes area (i.e. Green, Pine and Taylors Lakes) and therefore these species could occur at Dock Lake when conditions are suitable.

The Common Froglet (*Crinia signifera*) and the Common Spadefoot Toad were recorded by Ecology and Heritage Partners from the area to the east of the lake, an area which included Pine and Taylors Lakes and a number of smaller waterbodies.

The distribution and known habitat preferences for Victorian frog species were also reviewed to determine any other species that are likely to use Dock Lake or the surrounding area when it is inundated. Based on that review it was concluded that three other species: the Southern Brown Tree Frog (*Litoria ewingii*), Plains Froglet (*Crinia parinsignifera*) and Spotted Marsh Frog (*Limnodynastes tasmaniensis*) could also use Dock Lake.

There are no records of Peron's Tree Frog (*Litoria peronii*) on the VBA from the area and Dock Lake is marginally outside the previously presumed distribution of this species (Cogger 2000). Recently however, Peron's Tree Frog has been recorded from Burnt Creek, near Dock Lake (G. Fletcher Wimmera CMA, pers. comm.).

Of the frog species that have been identified as potentially occurring at Dock Lake, only one, the Growling Grass Frog, is protected under state or federal legislation. The Growling Grass frog is considered Endangered under the EPBC Act, listed under the FFG Act and rated as Endangered under the Victorian Government's *Advisory List of Threatened Vertebrate Fauna in Victoria* (Department of Sustainability and Environment 2013a). All other species identified above are common in Victoria.

5.2 Habitat use at Dock Lake

Although Dock Lake is currently dry and therefore would not support breeding populations of frogs, the lake may be recolonised and support some species following inundation.

Growling Grass Frog

Growling Grass Frogs are usually associated with deep pools with open water (i.e. not marshlands) in still or slow flowing streams, lakes, swamps and billabongs (Pyke 2002). They are usually found in areas with extensive fringing vegetation, which provide foraging and calling stages for adult frogs and attachment points for eggs. Growling Grass Frogs could have used the vegetated margins of Dock Lake when the lake held water.

Growling Grass Frogs breed in spring to summer, with tadpoles metamorphosing after approximately two to three months on average (Heard *et al.* 2010). Recruitment (based on studies near the Murray River) is highest when hydroperiod is longer than 6 months (Wassens 2011).

Dock Lake has historically had relatively high salinity for irrigation use (up to 3,000 µS/cm, but typically around 1,200 – 1,500 µS/cm), however, the salinity levels recorded in Dock Lake are not likely to exclude Growling Grass Frogs. The salinity tolerance of adult Growling Grass Frogs is estimated to be approximately 10,000 µS/cm (Smith *et al.* 2008).

Growling Grass Frogs are likely to be impacted heavily from predation by non-native fish species, particularly Carp and Eastern Gambusia, which are known to eat frog eggs and tadpoles. Both of these fish species are likely to have been present in Dock Lake when it was inundated and therefore it is unlikely that the lake would have represented optimal habitat for Growling Grass Frogs.

As Dock Lake has been dry for more than 15 years it is unlikely that any Growling Grass Frog populations persist in the immediate area. The nearest recent records of Growling Grass Frogs are at Murtoa, which is approximately 25 km away (Nicholson *et al.* 2013). The Murtoa population is not considered secure, as changes to the water supply system in that area (replacement of dams with tanks) may threaten the regular water supply to important breeding sites.

To our knowledge there are no known Growling Grass Frog populations between Murtoa and Dock Lake and therefore, while it is possible that the species could recolonise Dock Lake if it is inundated (and has suitable fringing vegetation and water quality), the long distance to potential source populations makes colonisation unlikely. If wet conditions filled drainage lines and natural depressions across the landscape, which would provide 'stepping stone' habitats and dispersal corridors between existing populations and Dock Lake, then colonisation may occur.

Translocation of Growling Grass Frogs has been attempted occasionally in the past (Koehler *et al.* 2015), but they are rarely successful. Translocation from even nearby populations is not likely to be a viable option in this instance given the potentially marginal habitat value of Dock Lake for Growling Grass Frogs.

Southern Brown Tree Frog

The Southern Brown Tree Frog is most commonly recorded calling from the fringes of relatively deep (≥0.5 m), open water, but can breed in a variety of habitats including small rain-filled depressions. They can breed at any time of the year, although primarily in winter/spring. At Dock Lake this species is likely to have used the vegetated margins of the lake.

There are records on the VBA of Southern Brown Tree Frogs from the Barrabool Flora and Fauna Reserve/Wimmera River Marma Streamside Reserve (Department of Environment Land Water and Planning 2015a), which is about 12 km from Dock Lake. As this species is able to use a variety of habitats, they are also likely to occur closer to Dock Lake, for example in farm dams and other permanent water sources such as Green Lake. It is likely that Southern Brown Tree Frogs will recolonise Dock Lake if it is regularly inundated and the water engages suitable vegetation (i.e. vegetation which provides cover from predators and attachment points for eggs).

Peron's Tree Frog

Peron's Tree Frogs are often found reasonably long distances from water, sometimes high in trees (Cogger 2000). They most commonly breed in depressions that are filled by summer rain, but are likely to breed in more permanent waterbodies as well.

There are no formal records of Peron's Tree Frogs from the region, but they have been recently recorded by local landholders calling from very close to the lake by (Greg Fletcher, Wimmera CMA, pers. comm.). It is not clear how many frogs are present in the landscape (Dock Lake is at the margin of the species' distribution), however, if there is a self-sustaining population nearby, Peron's Tree Frog is likely to rapidly colonise the lake once it is inundated.

Froglets

The Common Froglet and the Plains Froglet are very common species and can breed in a variety of waterbodies, from small rain-fed depressions and marshes, to the margins of large rivers (Wassens 2011). They call and breed throughout the year and can quickly colonise habitats that have been dry for many years. These species have also been recorded from the Barrabool Flora and Fauna Reserve/Wimmera River Marma

Streamside Reserve (Department of Environment Land Water and Planning 2015a) and are likely to occur in other nearby habitats. The froglets would likely colonise Dock Lake quickly (within a year) if water was provided that engaged suitable habitat (i.e. vegetation to allow cover from predators).

Marsh Frogs

The Pobblebonk and Spotted Marsh Frog most commonly call from within dense aquatic vegetation at the margins of permanent pools and from shallow marshlands (Cogger 2000). Pobblebonks breed in late-winter to autumn and are commonly active after rain. The Spotted Marsh Frog can breed nearly all year, except in the middle of winter (Cogger 2000).

Both of these species are common and widespread in Victoria and would likely use habitat at Dock Lake soon after inundation, provided that suitable marshy vegetation was present at the margin of the lake.

Common Spadefoot Toad

The Common Spadefoot Toad is a burrowing species, which is usually observed in marshy habitats after heavy rains. As this species relies on the inundation of depressions and soaks following rainfall, it would be unlikely to be benefited by the broad inundation of Dock Lake. This would especially be the case if the wetting of the lake was separated from other environmental conditions, such as heavy rainfall, that likely act as important biological cues for this species.

5.3 Broad water requirements of frogs at Dock Lake

Most Victorian frog species require surface water for foraging and/or breeding habitat at some stage during their life cycle. Specific inundation events (either lake filling or local rainfall that fills depressions) are needed to trigger frogs to breed, but water regime alone is not sufficient to ensure successful frog breeding. Suitable fringing and riparian vegetation and adequate food must also be present.

Different frog species can breed in a variety of water bodies ranging from rain-fed ponds and small depressions to rivers, wetlands and lakes. However, all breeding water bodies must satisfy three broad requirements:

1) Surface water must be available at the right time of year (i.e. during the breeding season). This is because the majority of Victorian frog species amplex (mate) in water and lay their eggs near, or attached to, fringing vegetation.

2) The water body (pool, pond, wetland or lake) needs to hold water long enough to allow tadpoles to develop into adult frogs (metamorphose). The required hydroperiod varies between species; it can be as short as 6 weeks for small, fast developing species (e.g. Common Froglet) and more than 6 months for larger species (e.g. Pobblebonks) Wassens 2011). The required hydroperiod for a particular species can also vary due to water temperature, food availability and predation pressure (Anstis 2007).

   Hydroperiod is particularly important for Growling Grass Frogs. Recruitment (based on studies near the Murray River) is generally highest when hydroperiod is longer than 6 months (Wassens 2011). Heard *et al.* (2010) demonstrated a strong negative relationship between wetland hydroperiod and extinction probability (i.e. wetlands with short hydroperiod are more likely to be unoccupied than permanent wetlands).

3) Although not the case for Dock Lake, in flowing systems it is also important that still or very slow flowing conditions are maintained for as long as tadpoles are present in the waterbody. Tadpoles are not strong swimmers and can easily be washed out of suitable habitats if high flows occur at the wrong time (Wassens 2011).

The frogs that are known to occur, or that are likely to occur, at Dock Lake would use the vegetated margins of the lake and fringing marshy areas. Provided that this habitat is inundated or engaged for sufficient time to allow successful reproduction and tadpole development, Dock Lake is likely to support a range of frog species. Colonisation from nearby habitats is probable for most species except Growling Grass Frogs. Growling Grass Frogs are unlikely to colonise Dock Lake in the short, or even medium term, unless suitable source populations (which are not currently known) exist within a few kilometres of the lake.

6. Fish

6.1 Species supported by Dock Lake

Dock Lake has been effectively dry for more than 15 years and does not currently support any fish. However, the VBA shows that two native species: Australian Smelt (*Retropinna semoni*) and the River Blackfish (*Gadopsis marmoratus*); and four introduced species: Redfin Perch (*Perca fluviatilis*), Goldfish (*Carassius auratus*), Rainbow Trout (*Oncorhynchus mykiss*) and Brown Trout (*Salmo trutta*) have historically been recorded in Dock Lake (Department of Environment Land Water and Planning 2015a). It should be noted that the VBA only includes records that have been submitted for inclusion and therefore the VBA records may not therefore accurately reflect the actual species present.

The Victorian Government's Inland Angling Guide outlines the fishing spots in the Wimmera area and indicates that when inundated, Dock Lake supported Redfin Perch to 2 kg, Trout to 3 kg and Tench (*Tinca tinca*) to 1.7 kg (Department of Environment Land Water and Planning 2015b).

An analysis of fish data for all the Boga Lakes indicates that four other native species: Murray Cod (*Maccullochella peelii*), Golden Perch (*Macquaria ambigua*), Macquarie Perch (*Macquaria australasica*) and Flat-headed Gudgeon (*Philypnodon grandiceps*) and two other introduced species: Carp (*Cyprinus carpio*) and Chinook Salmon (*Oncorhynchus tshawytscha*) have been recorded in the region (Department of Environment Land Water and Planning 2015a). Macquarie Perch have not been recorded in the catchment for many years, however, the other larger bodied native species, Murray Cod and Golden Perch, have been stocked from other catchments (Ecological Associates 2009). Any of these recorded species could potentially colonise or be stocked in Dock Lake if it is more permanently inundated.

As part of Ecology and Heritage Partners' (2015) survey of the Pine and Taylors Lakes area, aquatic surveys were undertaken at a number of locations both within the lakes and the surrounding waterbodies. In Pine Lake, Carp Gudgeon (*Hypseleotris* spp.), Flathead Gudgeon and Redfin Perch were recorded. Australian Smelt, Flathead Gudgeon, Common Carp, Goldfish (*Carrassius auratus*) and Redfin Perch. A number of other waterbodies were also surveyed, and in addition to the above species, Common Galaxias (*Galaxias maculatus*) and Obscure Galaxias (*Galaxias* sp. 1.) were also recorded.

Silver Perch (*Bidyanus bidyanus*) have been stocked in the area recently (G. Fletcher, Wimmera CMA, pers. comm.) but we know of no formal records of the species from the area.

6.2 Habitat use at Dock Lake

There is limited woody debris or structure in Dock Lake (Figure 6-1) and therefore the majority of the habitat for fish would come from inundated and fringing vegetation. Given the limited habitat available at the lake, it is unlikely that the larger bodied native species that are known from the other Boga Lakes (Murray Cod, Golden Perch, Macquarie Perch) would have been supported by Dock Lake when it was inundated. It is more likely that the majority of the large bodied fish community in Dock Lake would have been introduced species like Redfin Perch, Goldfish, Rainbow Trout, Brown Trout, Carp and Tench. Small bodied native species such as Flat-headed Gudgeon, Carp Gudgeon and Australian Smelt could however have been supported.

Figure 6-1 Dock Lake showing the woody habitat features towards the fringe of the lake. Large woody riparian zone is evident to the right of the picture.

6.3 Broad water requirements of fish at Dock Lake

The water requirements of the native species that may have been supported in Dock Lake are reviewed below.

River Blackfish are predominantly a river species that prefer pool habitats with overhanging vegetation, abundant woody debris and areas with low velocity flow (Jackson *et al.* 1996). They generally need some flow to flush silt from submerged hollow logs or snags that they use as nest sites. Moreover, it is generally considered that salinity levels would need to be below 6,000 mg/L (i.e. approximately 10,000 µS/cm), which is the assumed tolerance for River Blackfish larvae and juveniles (Bacher and Garnham 1992). However, despite presumably not representing ideal habitat for River Blackfish, there are historical records showing they were present in Dock Lake at least prior to 1963. As the lake was probably never high quality habitat, it is unlikely that River Blackfish would recolonise Dock Lake in significant numbers even if permanently inundated and would need to be stocked.

Australian Smelt are a pelagic species, meaning they spend most of their time swimming in the middle and upper layers of the water column, rather than near the bottom or the shore (Lintermans 2007). Dock Lake would need areas of relatively deep, open water to support populations of Australian Smelt.

Golden Perch and Murray Cod either need to migrate or need large flows to trigger spawning and successful breeding. They are unlikely to naturally colonise or breed in Dock Lake, but stocked individuals could persist if the lake is permanently inundated and water quality is adequate (anecdotal reports suggest that Murray Cod were present in Green Lake historically, G. Fletcher, Wimmera CMA, pers. comm.). Under those circumstances, the main limiting factor for large-bodied native species will be the low density of submerged wood and complex emergent fringing vegetation that can provide habitat.

It should be noted that given the uncertainty around supply, it is unlikely that Dock Lake would be a suitable candidate for stocking of native species. Furthermore, the deep inundation required to support large bodied species is incompatible with the water regimes required to support other values (e.g. vegetation and birds, see Section 9).

If Dock Lake is inundated, it is most likely to provide suitable habitat for small-bodied native fish such as Flat-headed Gudgeon, which could easily colonise the lake from the channel that connects it to Green Lake. Flat-headed Gudgeon is often found in shallow, muddy or weedy areas of lakes and feed on a range of taxa including macroinvertebrates, tadpoles, crustaceans and other small fish (Lintermans 2007).

Trout may be stocked in Dock Lake if it is full, but as outlined above, given uncertainty around the duration it would contain water, the lake is probably a low priority for the stocking of even exotic species. Some people may also try and introduce Redfin Perch, although such introductions would not be authorised. Environmental water is generally not used in lakes to support stocked populations of exotic fish that are primarily used to sustain recreational angling.

According to the Victorian Government's Inland Angling Guide, Green Lake supported Redfin Perch, Tench, Golden Perch and Murray Cod and a low number of River Blackfish (Department of Environment Land Water and Planning 2015b). Currently, however, Green Lake is thought to only support Redfin Perch in high numbers (Greg Fletcher; Wimmera CMA pers. comm.), although it is highly likely that Carp also occur. While it is theoretically possible that any of the species currently supported by Green Lake could move into Dock Lake during filling, in reality it is probable that Redfin Perch and Carp would be the only species that could colonise Dock Lake in any significant numbers.

7. Turtles

7.1 Species supported by Dock Lake

Only one turtle species the Common Long-necked Turtle (*Chelodina longicollis*) has been recorded from Dock Lake. No other turtle species are likely to be present in the area (Cogger 2000).

7.2 Habitat use at Dock Lake

The Long-necked Turtle is able to use a variety of habitats, from slow flowing rivers and lakes to small, ephemeral ponds and pools (Chessman 1988). It is able to aestivate to avoid desiccation and is able to make large overland migrations (Cogger 2000) meaning that it is tolerant of a range of conditions. Generally Common Long-necked Turtles lay their eggs in holes dug on the bank of the lake, swamp or river in early summer (Cogger 2000).

7.3 Broad water requirements of turtles at Dock Lake

Turtles feed on molluscs, tadpoles, small fish and crustaceans. Provided that the habitat provided at Dock Lake is suitable for these organisms, turtles are likely to be supported also.

8. Macroinvertebrates and microinvertebrates

8.1 Communities supported by Dock Lake

When inundated, the macroinvertebrate communities of Dock Lake would likely have been characterised by species that prefer permanent, still water. Insect larvae, such as dragonflies, caddisflies and mayflies whose adults could readily lay eggs in the lake when it is inundated, would likely have been supported. The lake could also support large numbers of aquatic beetles and true bugs that can fly from one water body to another. The lake would also have supported large populations of freshwater shrimps (*Parataya australiensis* and *Macrobrachium* sp.).

Microinvertebrates (e.g. rotifers, ostracods) would have played an important part in the food web of Dock Lake when it was inundated.

The lake is also known to have supported Yabbies (J. McGuire pers. comm.).

8.2 Habitat use at Dock Lake

The majority of macroinvertebrate habitat at Dock Lake would be provided by the woody substrates along the northern bank and the western side of the lake and any submerged or emergent vegetation. Microinvertebrates would have been distributed throughout the lake, including within the water column, within sediments and detritus and associated with plant material.

8.3 Broad water requirements of the macroinvertebrate communities at Dock Lake

If Dock Lake was inundated, it is likely that a reasonably diverse and abundant macroinvertebrate community would establish quickly. Many macroinvertebrate taxa have winged adult stages that can disperse easily. Given that Green, Taylors and Pine Lakes are all nearby, and are likely to support good macroinvertebrate communities, Dock Lake is likely to be colonised by aerial dispersal shortly following inundation.

The macroinvertebrate communities of Green Lake are likely influenced by inflows from the MacKenzie River/ Burnt Creek system. Colonisation of Dock Lake by macroinvertebrates from Green Lake may also occur as the lake is filled. Freshwater Shrimp (*Parataya australiensis* and *Macrobrachium* sp.) would likely be transferred from Green Lake to Dock Lake during filling.

Rotifers, one of the most common microinvertebrate taxa, hatch from eggs that are resistant to desiccation and which can lay dormant in dry lake beds for many years (Walsh 2015). Rotifers can then reproduce quickly following inundation, forming an important part of the food web for other microinvertebrates and higher order consumers. It is likely that a range of microinvertebrate taxa (such as rotifers) are currently lying dormant at Dock Lake and would increase in abundance quickly following any inundation.

Yabbies can dig very deep burrows (up to 2 m deep) where they can aestivate for up to several years during dry conditions (Withnall 2000). It is possible that some Yabbies are still present at Dock Lake and would therefore become active following inundation. Yabbies would also likely rapidly colonise Dock Lake from Green Lake following (and possibly during) filling.

9. Environmental watering objectives

We have used the review of values and their associated water regime requirements presented in the preceding five chapters as a basis for determining a set of environmental objectives for Dock Lake. In the following section, we describe a broad environmental objective for the lake and then articulate specific objectives for each category of environmental value. It is important to note that the objectives presented do not consider the amount of environmental water available for use at Dock Lake or more broadly throughout the Wimmera region. Rather the objectives focus on what could be achieved if particular water regimes were provided.

9.1 Broad objective

Environmental water could be used at Dock Lake in a range of ways and to achieve a range of environmental objectives. At one end of the spectrum, sufficient water could be provided to the lake to inundate it permanently to near the full supply level (similar to how the lake was operated prior to 1999; see Figure 1-1). In contrast, water could be used to mimic a more ‘natural’ wetting regime, which would include periodic inundation, followed by slow drawdown and then periods when the lake completely dries. The ecological consequences of the two water regimes are described conceptually below.

If Dock Lake was permanently inundated, near the full supply level, it would result in relatively deep, but uniform, habitat across much of the lake. A few species would benefit from such a water regime, including fish species (most likely Redfin Perch and Carp, but also trout provided that they establish in the lake) and piscivorous (fish eating) birds such as ducks. Shallow water and mudflats would be relatively rare under this filling scenario and therefore species that rely on these habitats for foraging (wading species such as dotterels, plovers and sandpipers) would not benefit.

A deep, permanently inundated lake would provide little habitat heterogeneity for macrophytes. The floristic diversity at the lake would likely be limited to only a small number of species such as Common Reed, and then only around the margins of the lake (and River Red Gums in the riparian zone).

The low diversity and limited extent of fringing and submerged macrophytes may reduce the suitability of the lake for many frog species, which require vegetation for cover and for egg attachment sites.

A conceptual diagram of the lake with a deep, permanent water regime is presented in Figure 9-1. The conceptual diagram is not intended to represent exactly the species and communities that would be supported by Dock Lake if it was inundated permanently. It is instead designed to illustrate the relative homogeneity of habitat that is provided when the water level in the lake is deep and to show how a relatively low number of species are benefitted.

In contrast to a permanent water regime, environmental water could be provided to Dock Lake to mimic a more natural wetting/drying cycle. Under this scenario, a lower volume of water would be provided to the lake and then would be allowed to dry. As is illustrated in Figure 9-1, the deep, open water habitat is still provided at the lake, but there is less than under the deeper scenario. Fish from Green Lake are likely to colonise Dock Lake, but as the lake is not permanently inundated, populations are likely to be smaller. Fish in the lake would attract piscivorous birds (as in the permanent filling scenario) however the provision of shallow habitats and mudflats at the edge of the lake (and as the lake dries), would also attract wading birds.

With greater water level variability at the lake, including more light penetrating the water column, the floristic diversity would also increase with a range of floating, submerged, floating-leafed, and emergent vegetation all likely to be present. Floating plants may include *Azolla* and *Lemna* spp and the submerged and floating leaved vegetation may include Water Ribbons, pondweeds, milfoils and Eelgrass. The exact species that would colonise the lake would be determined by the seed bank that is still present at the lake (see Section 11.3) and by those species that could colonise from outside the system.

Frogs would benefit from the range of habitats provided by the emergent and submerged macrophytes under the 'natural' wetting/drying regime, particularly if the edges of the inundated extent of the lake formed a marshy habitat. Frogs would also benefit from a smaller fish population. As the lake would dry regularly, colonisation of fish from Green Lake would have to occur with each wetting event.

As the lake dries, the shallow, mudflat habitats would increase, benefitting the wading waterbirds. Deep water would retract however, likely reducing the lake's suitability for fish and piscivorous diving bird species (Figure 9-1).

When completely dry, critical ecosystem-scale ecological processes such as nutrient cycling and organic-matter degradation will occur. Over time the wetland vegetation will be replaced by terrestrial species. The dry period will help control fish species, such as Carp, and plant species such Cumbungi (*Typha* spp.). Provided that the dry period is long enough the substratum will dry completely, opening up cracks which can form important habitat for terrestrial faunal species (e.g. lizards, insects) and propagation sites for vegetation (Figure 9-1).

As illustrated by the conceptual diagrams, providing a variable wetting/drying cycle increases the biodiversity that can be supported by the lake. It is our assessment that this is preferable to providing a uniform habitat that supports only a small number of species, such as under the permanent inundation scenario.

The habitats around Dock Lake were also considered when it was decided to adopt a 'natural' wetting/drying regime, rather than a permanently inundate lake. If Dock Lake was inundated permanently, it would not provide any diversity of habitat over that which is already present at nearby Green Lake. Green Lake is near permanently inundated and replicating this at Dock Lake would not lead to an overall increase in the species that could be supported in the region.

The rest of this section presents the specific ecological objectives for the species and communities that could be supported by the lake.

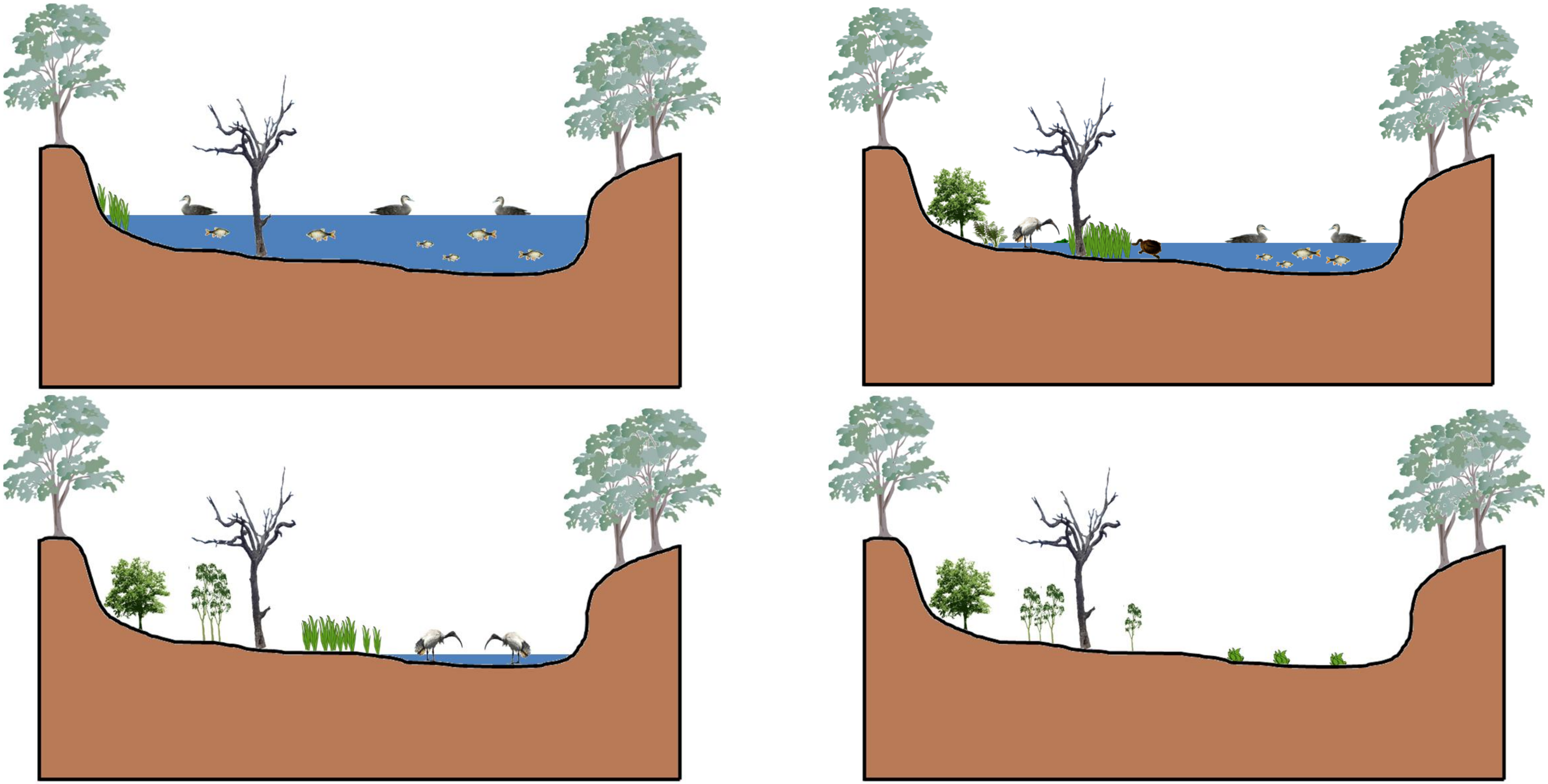


Figure 9-1 Conceptual model of the lake, showing possible consequences of different filling levels. Top left: Relatively high fill volume and permanent inundation providing homogenous habitat which benefits a few species. Top right: A lower fill volume, showing the diversity of habitat provided and species that can be supported. Bottom Left: As the lake dries, more shallow habitat opens up, benefitting wading bird species and resulting in a change in vegetation composition and location in the lake. Bottom Right: When the lake is dry, over time wetland vegetation and birds will be replaced by more terrestrial species.

9.2 Vegetation

The environmental watering objective for vegetation in Dock Lake, is to return a seasonal or an intermittent wetting and drying cycle to the wetland to encourage the establishment and maintenance of structurally and floristically diverse native vegetation.

9.3 Birds

The watering objective for birds is to provide diverse habitat and foraging resources to a suite of birds by varying the water level in the lake over time. The lake will support different species at different of the wetting/drying cycle. A variable amount of water in the lake and intermittent periods of drying also favours greater floristic diversity (as described above). This floristic diversity will maximise waterbird diversity and positively influence waterbird abundance by creating a range of micro-habitats and supporting a range of foraging resources for birds to exploit.

9.4 Frogs

It is unlikely that Dock Lake will support Growling Grass Frogs in the future due to the distance from viable populations and the marginal habitat for this species at the lake. The lake is, however, likely to provide secondary habitat for a range of common frog species. The environmental watering objective for frogs is to encourage the use of Dock Lake by common species at times of inundation, not only benefitting the local populations of these species, but also providing an important food resource for birds.

9.5 Fish

There is no specific environmental watering objective for fish as the lake is not likely to be inundated long enough to allow populations to establish. Fish (native or exotic species) that colonise Dock Lake from Green Lake during inundation would provide a valuable food resource for birds. Fish should not therefore be excluded from entering Dock Lake from Green Lake during the filling stage.

9.6 Turtles

There is only one turtle species that is likely to be present in the area; the abundant and widespread Common Long-necked Turtle. A more permanent inundation regime would likely benefit turtles more than one characterised by wetting and drying, however turtles are still likely to be supported by Dock Lake whenever it is inundated.

9.7 Macroinvertebrates and microinvertebrates

The environmental water objective for macroinvertebrates and microinvertebrates would be to engage suitable habitats to attract and support an abundant and diverse community. Macroinvertebrates and microinvertebrates provide an important part of the food web for many taxa, including fish, frogs and birds.

10. Bathymetric model and Environmental Water Retention Model

The specific environmental water regime proposed for Dock Lake (i.e. timing of inundation, length of inundation, fill volume) was determined by the development of a stand-alone water retention model in Microsoft Excel (the Environmental Water Retention Model). The Environmental Water Retention Model was used to test the filling extent and rate of draw down associated with different water regimes. Specifically, the model was used to determine:

1. The volume of water required to fill the lake to particular water levels.

2. The rate at which water would leave the lake through seepage and evaporation.

The following section describes the inputs to the model, how the model was tested and how the model was used to quantify environmental water recommendations for Dock Lake.

10.1 Stage 1: Bathymetry assessment

A gridded bathymetry model of Dock Lake (produced from LiDAR) of 2 m grid resolution was used for the analysis. The bathymetry model was 'filled' with water to specified heights identified by the EFTP to determine the volume of water required to achieve particular ecological outcomes. The water heights modelled ranged from an empty lake to a full lake in 5 cm increments, producing 96 scenarios in total. The outputs of this analysis were rating curves of volume, surface area and depth and a GIS based output showing the depth profiles and inundation extents of each of the 96 scenarios.

To assist the EFTP in determining the most suitable water regime for the lake, maps showing the depth and inundation extents of 10 of the filling scenarios (Scenario 6, 16, 26, etc. to 96) were produced (see Appendix B). The EFTP's preliminary assessment determined that Scenarios 16 and 26 would provide appropriate depths sufficient to meet the watering objectives outlined in Section 9.

Scenario 16 inundates an area of approximately 115 ha to a maximum depth of 0.8 m and an average depth of 0.2m. Scenario 16 equates to a volume of 271 ML (Figure 10-1). Scenario 26 inundates about 155 ha, with a maximum depth of 1.3 m and an average depth of 0.6 m. Scenario 26 equates to a volume of 973 ML.

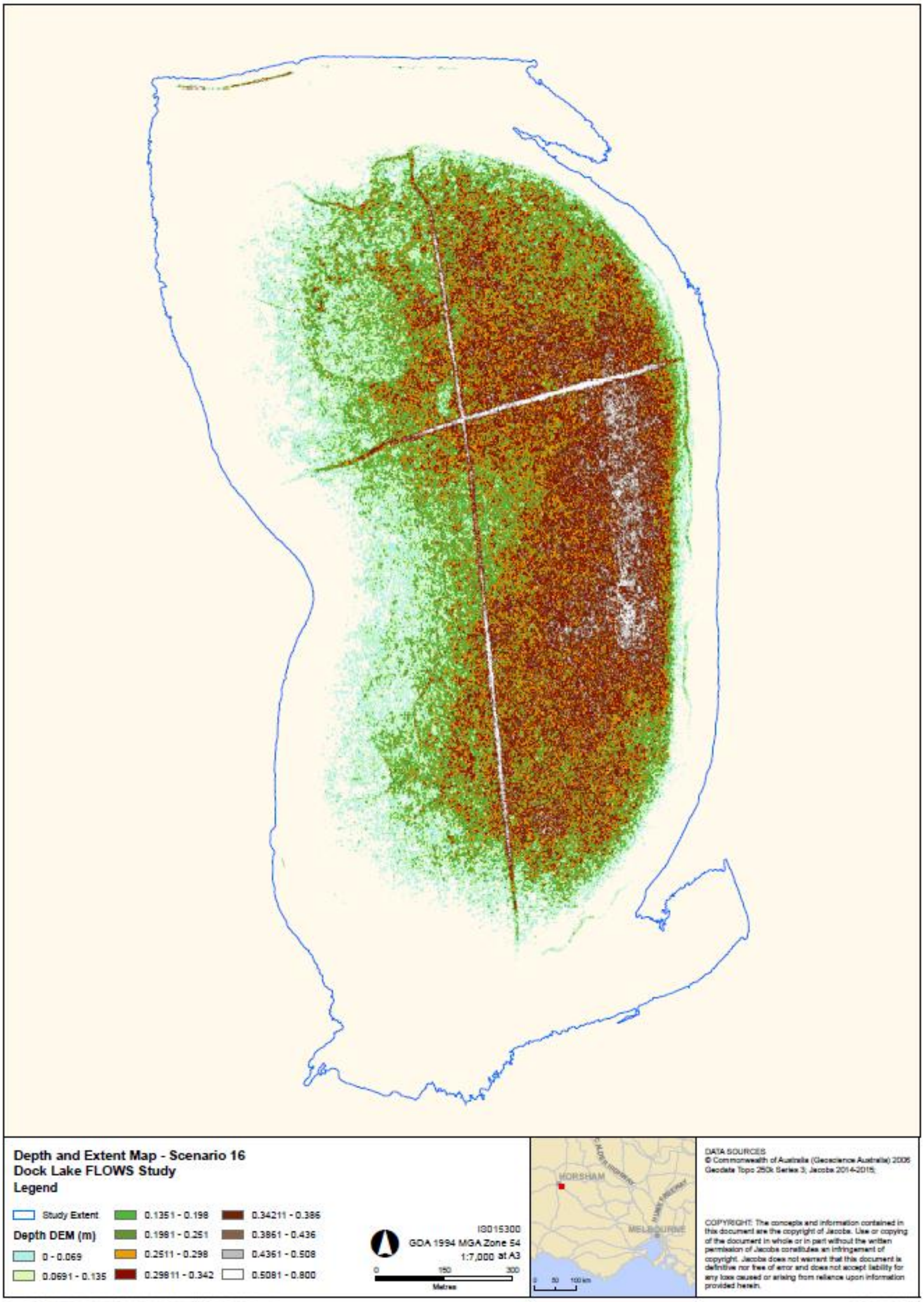


Figure 10-1 Dock Lake Filling Scenario 16.

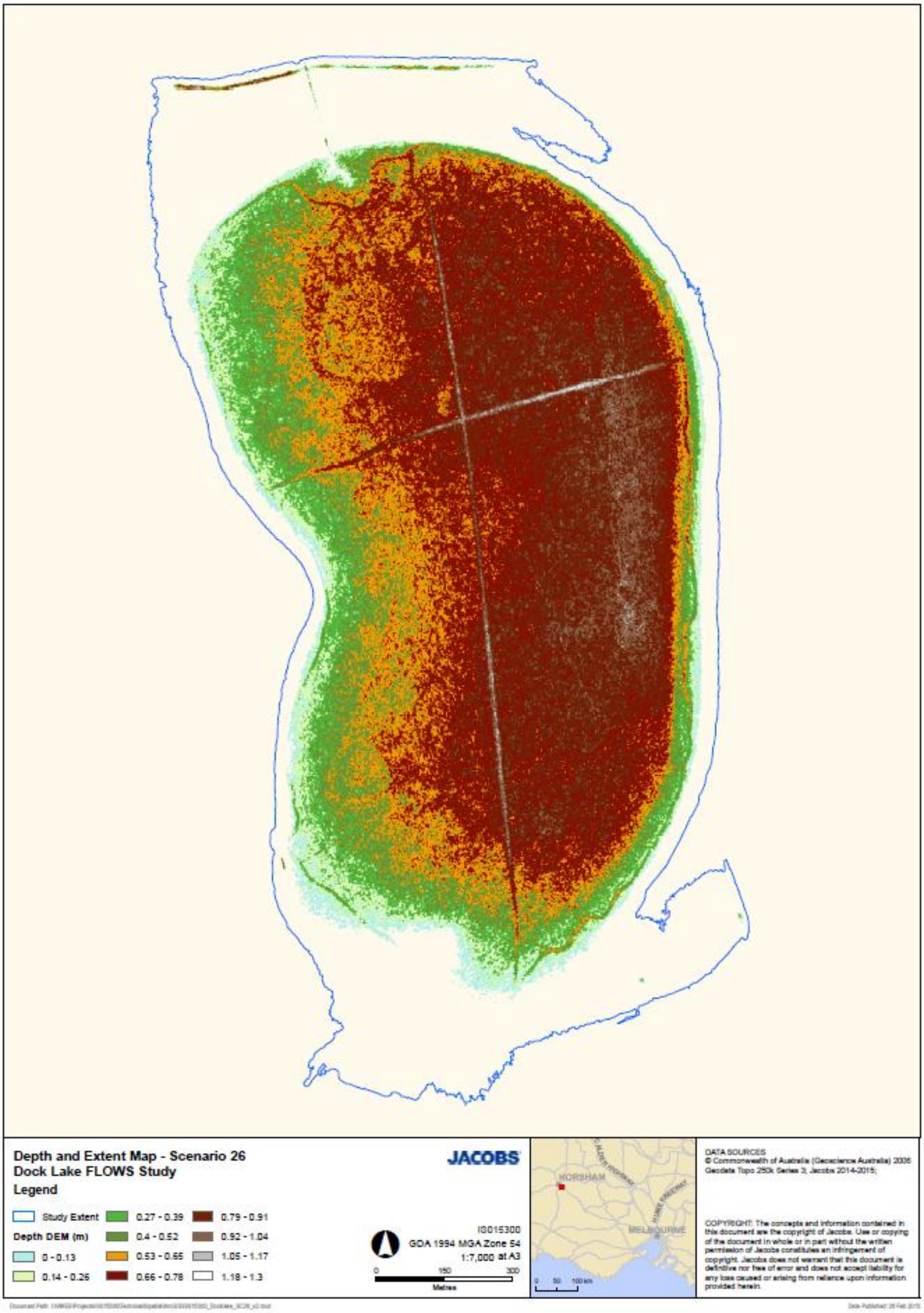


Figure 10-2 Dock Lake Filling Scenario 26.

10.2 Stage 2: Environmental Water Retention Model

Environmental water would need to be pumped into Dock Lake from Green Lake, or Green Lake would need to be filled to a volume which would allow the gravity feed outlet to be inundated. A Microsoft Excel based Environmental Water Retention Model was created to represent the water retention rates in Dock Lake when environmental water is added to the lake. The model accounts for the volume added, net evaporation, seepage; and allows the user to add additional water at any point during the drawdown; based on the following equation:

$$Water\ Volume = Water\ Volume\ Prev\ Day - Net\ Evaporation - Seepage + Water\ Added$$

Each of these elements is discussed further below.

10.2.1 Water volume

The rating table, which links water height, volume and surface area (established as part of Stage 1) was used to quantify the water balance. The REALM model adopts a rating curve which was developed based on 12 surveyed points, whereas the rating table developed from the LiDAR was based on gridded data. The LiDAR based model is therefore presumed to be of higher accuracy than the REALM model.

The rating tables for the LiDAR and REALM model were compared for volume-height (Figure 10-3) and volume-surface-area (Figure 10-4). These figures show that low volumes present the largest variation from the REALM rating table; but that the shapes are generally consistent.

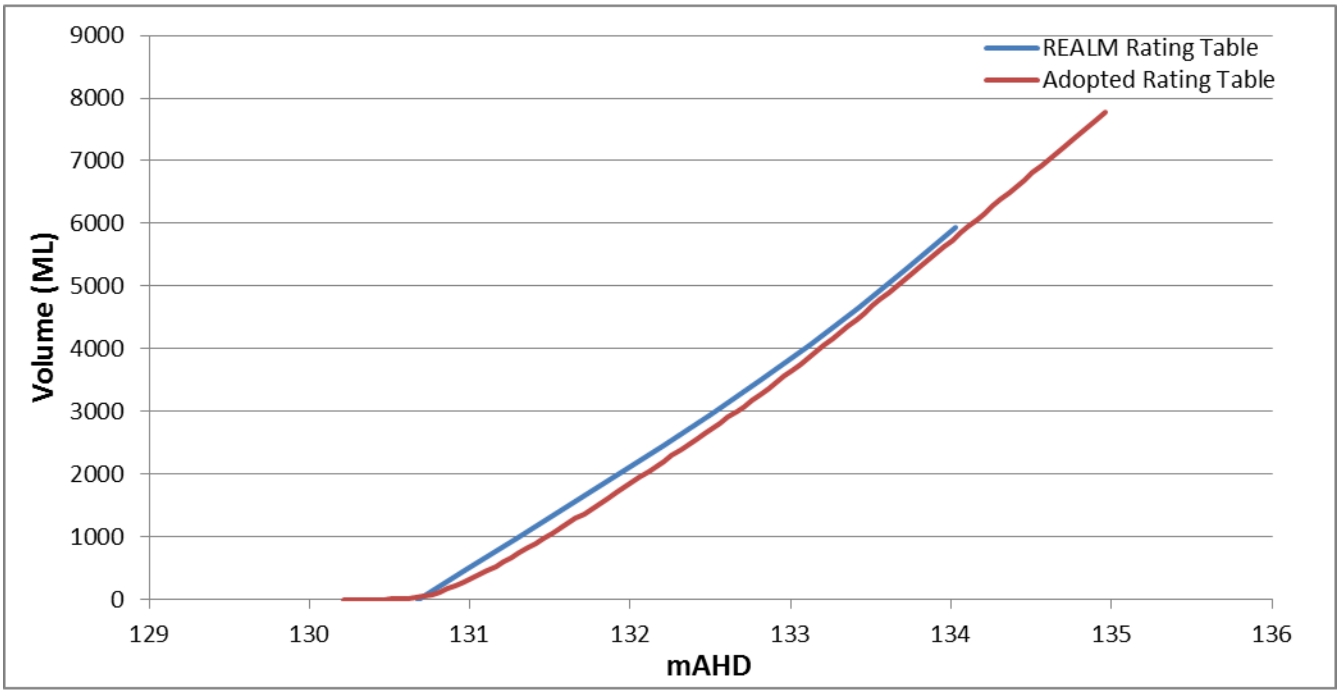


Figure 10-3 Volume-Height Rating Table

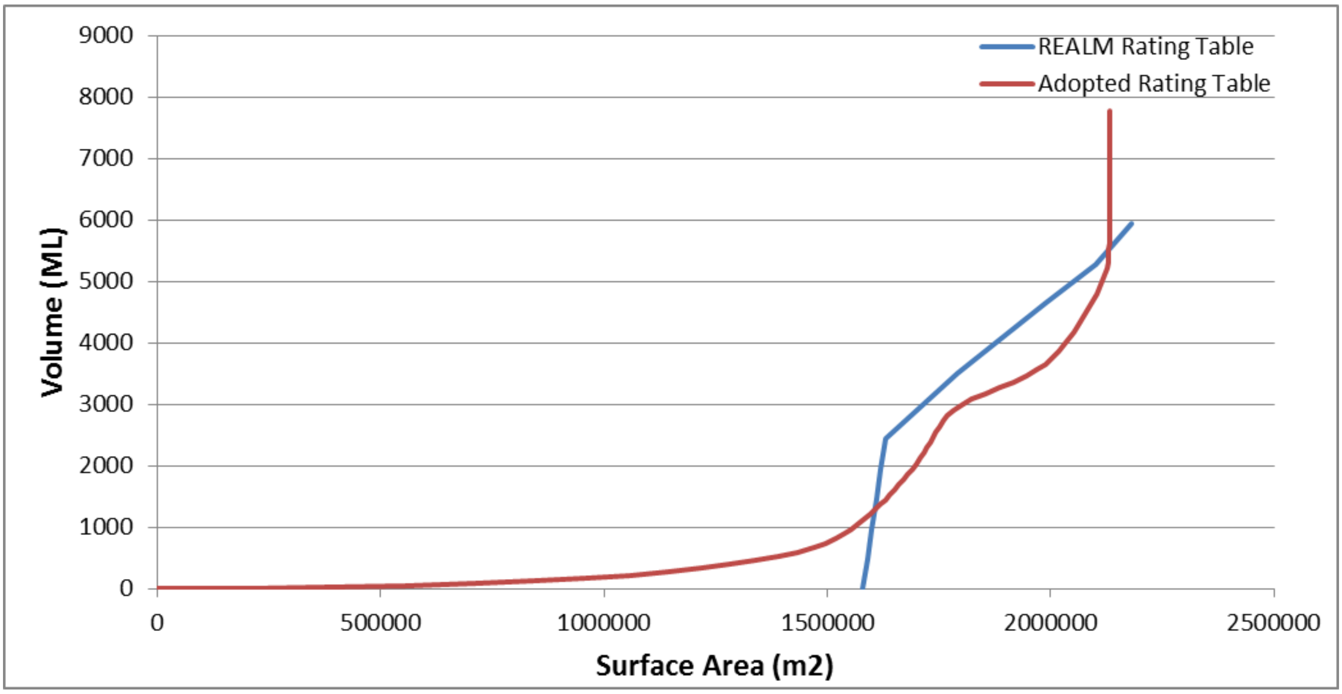


Figure 10-4 Volume-Surface Area Rating Table

10.2.2 Net Evaporation

Net evaporation is represented in our Environmental Water Retention Model as daily evaporation minus rainfall. Daily evaporation was adopted at Tottington (St Arnaud) (Gauge 079079); which was infilled and factored by 1.024, to match the evaporation to Dock Lake; a pan factor of 0.8 was also adopted to the evaporation data. This method is consistent with the daily method applied in the Derivation of Daily Inputs for the Wimmera-Mallee REALM model in 2005 by SKM, prior to the monthly model being adopted. Daily rainfall was adopted from Polkemmet (Gauge 079023), which was infilled.

Four years were selected as representative years, one each for a wet year, a dry year, an average year and the driest year. These years were selected by determining the annual net evaporation and sorting to determine where each year sat in the middle of one third of the record. The years adopted are presented Table 10-1.

Table 10-1 Representative climate years

Climate Conditions	Representative Year	Annual Net Evaporation
Driest Year	1982	1619 mm
Dry	1965	1236 mm
Average	1976	1004 mm
Wet	1915	805 mm

Net evaporation was then applied to the surface area of the lake associated with the level and volume of the lake.

10.2.3 Seepage (geology and hydrogeology)

Seepage from the lake was determined by examining the underlying geology and hydrogeology of Dock Lake. Surface geology maps show that Dock Lake lies upon or within Quaternary aged lake deposits. These lake deposits are described as being comprised of carbonaceous clay and silt, and, fine to coarse grained sand and gravel. Underlying Dock Lake are Tertiary aged fluvial and marine sediments. Dock Lake is near to the boundary of the incursion of marine sediments and the exact nature of the sediments at depth is not well described.

State wide aquifer mapping (the Victorian aquifer framework) indicates that at Dock Lake the lake deposits are underlain by an approximately 30 m thick Parilla Sand aquifer, which is the watertable aquifer. Beneath the watertable aquifer is the Renmark Group aquifer, which is about 75 m thick in this area. The resolution of the State-wide mapping is not fine enough to determine the thickness of the lake bed deposits. Based on anecdotal evidence and prior knowledge of the area, the lake sediments beneath Dock Lake are estimated to be 0.5 m thick. These sediments are finer grained than the Parilla Sand and as a result are assumed to have lower permeability. Thus it is conceptualised that Dock Lake lies on a thin, fine grained sediment base that provides some separation from the underlying watertable.

Groundwater level has been collected in this area over a number of years, but there have been changes in the location and frequency of monitoring at different times. There are few long term records close to the lake. The closest long term measurements location that has recent data on the watertable elevation is 5.5 km north east of Dock Lake. Observation bores 61454 and 61453 record groundwater levels for the Parilla Sand aquifer and the Renmark Group aquifer, respectively. Figure 10-5 shows the recorded groundwater measurements for these bores. Analysis of these readings has led to the following conclusions:

- Current groundwater level in the watertable aquifer (Parilla Sand aquifer) is approximately 4 m below ground surface.
- Current groundwater pressure level in the Renmark group aquifer is about 3 m below the surface.
- An upward hydraulic gradient (of between one to one and a half metres) has been maintained over the past two decades.
- Separation of the hydraulic head between the aquifers indicates that fine grained sediments exist between the two aquifers, and these probably maintain pressure separation.
- Groundwater levels in the watertable aquifer respond to longer term weather conditions.
- Groundwater levels in the watertable declined during the millennium drought.
- Groundwater levels in the watertable responded to the high rainfall period in 2010/2011.
- Groundwater levels in the Renmark Group aquifer follow a similar pattern to that in the watertable, indicating that the recharge area for the Renmark Group is likely to be nearby.

Depth to groundwater measurements from observation bores close to Dock Lake are consistent with regional depth to groundwater mapping for Victoria, which indicates groundwater is less than 5 m below the ground surface (refer Visualising Victoria's Groundwater web site) at the bore site. On this basis, the State-wide mapping has been used to identify the depth to groundwater in the immediate vicinity of Dock Lake. Depth to watertable is also mapped within 5 m of the ground surface. Specifically, the depth to groundwater at Dock Lake from State-wide mapping is estimated to be 4 m below the ground surface.

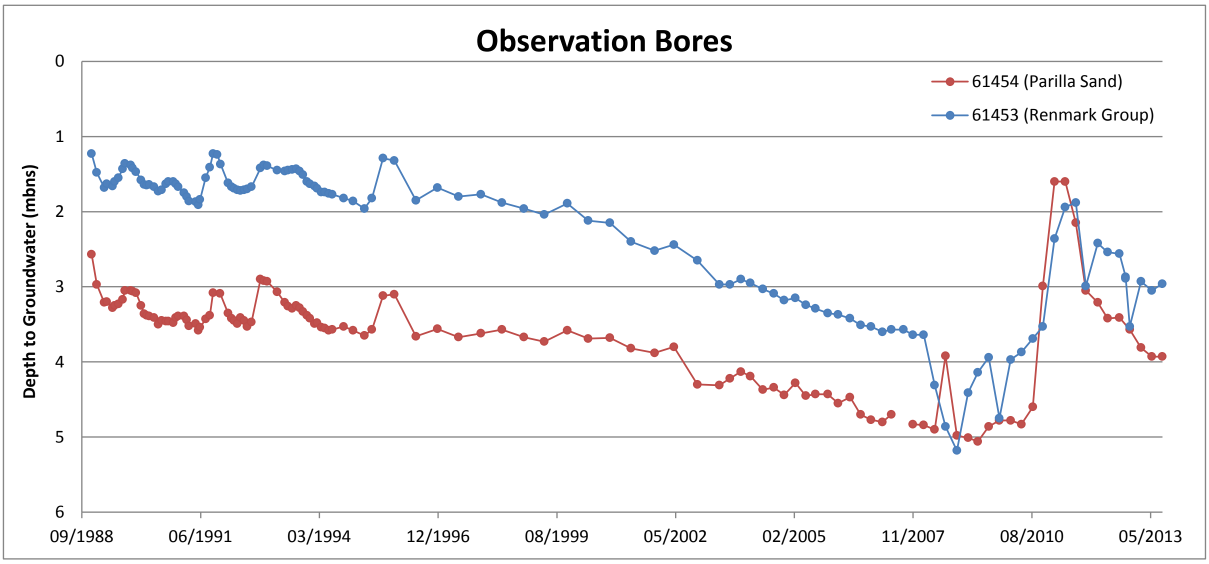


Figure 10-5 Depth to groundwater for the watertable aquifer and deep aquifer, approximately 5.5 km northeast of Dock Lake.

Dock Lake is conceptualised to have negligible inflow from groundwater, due to the watertable in this area being sufficiently below ground surface. This is supported by the fact that Dock Lake does not retain water during low rainfall periods (i.e. it is not likely to be maintained by groundwater discharge).

Dock Lake is presumed to lie upon a low permeability bed of sediments, underlain by the Parilla Sand aquifer, which is estimated to be unsaturated up to a depth of 4 m below ground level. Dock Lake is likely to lose water through the low permeability base, to the unsaturated zone of the Parilla Sand aquifer. Seepage from the lake is expected to eventually reach the watertable at a depth of 4 m. Lateral flow in the Parilla Sand aquifer is then expected to carry the water away, to the north.

The conceptual model for Dock Lake is provided in Figure 10-6.

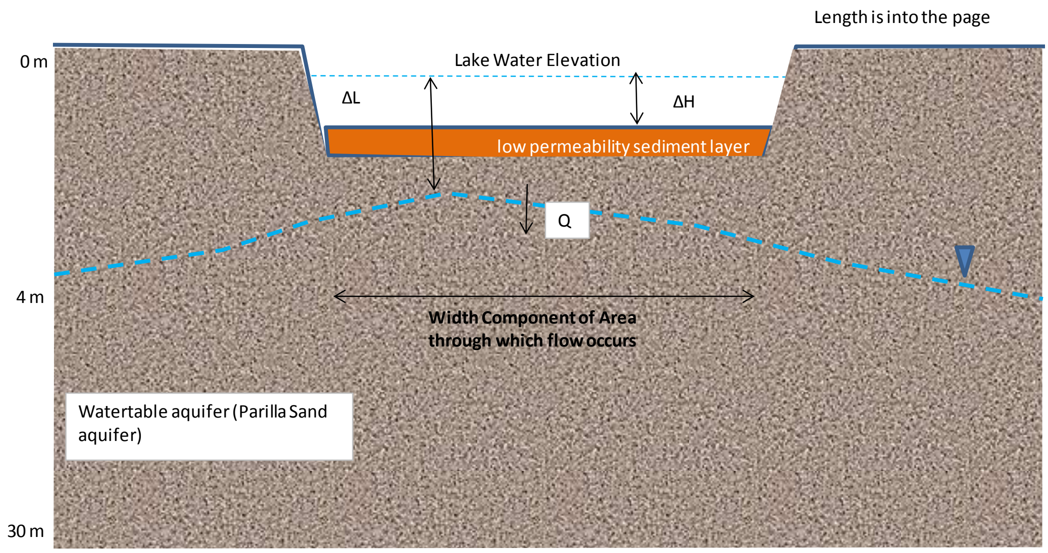


Figure 10-6 Conceptual model for lake seepage from Dock Lake.

Seepage loss from the lake has been estimated using Darcy's law for flow, which is expressed in the following form:

$Q = k\ i\ A$

where:

- Q = seepage through an area (m^3/day).
- k = the limiting saturated hydraulic conductivity in the vertical flow path (m/day).
- i = hydraulic gradient ($\Delta H/\Delta L$).
    - ΔH - the difference in elevation of the water surface of the lake compared with groundwater.
    - ΔL – the length of the flow path to the watertable.
- A = area through which flow occurs (m^2).

We have had to make multiple assumptions for these calculations because there is limited site specific data. The inputs to the seepage estimate, including the hydraulic conductivity value and the depth to the watertable under the lake have all been estimated using our experience in Victorian lakes and wetlands. Site specific data would greatly improve the reliability of the seepage calculation.

A range of seepage rates have been calculated. Estimates have been prepared for Scenario 26 and Scenario 16 lake fill conditions. The range of estimates has been bracketed to represent variation in the assumed length through which seepage occurs, from 1 m to 4 m. This range represents the uncertainty in the depth to groundwater beneath the lake and encompasses shallow groundwater conditions and deeper groundwater conditions.

Seepage rates are estimated at:

- Scenario 26 (lake volume of 972 ML) would lose water through seepage at rates ranging from 0.5 ML/day to 2 ML/day.
- Scenario 16 (lake volume of 271 ML) would empty at a rate ranging from 0.2 ML/day to 0.9 ML/day.

Given the uncertainty in the inputs to the seepage calculation, the seepage rates were crossed checked against available real-time lake volume information to confirm the estimates seepage rates were within the correct order of magnitude.

Water levels in Dock Lake were provided for the period 1994 to 1996. In this period there was 6 months (April 1994 to October 1994) when there were no recorded inflows. We compared the rate of drop of the lake with estimated rainfall and evaporation over the same period.

The measured loss of lake volume was 1,570 ML. Allowing for evaporation loss (estimate obtained from the REALM model) plus rainfall gain (gauge 79010), with the balance being ascribed to seepage, seepage loss was estimated at approximately 1 ML/day. This compares favourably with the calculated seepage values given above.

The Environmental Water Retention Model allows the user to toggle between the minimum or maximum seepage rates for each scenario; which allows for a range of draw down scenarios to be considered.

10.2.4 Assumptions of the Environmental Water Retention Model

The following assumptions should be noted about the Environmental Water Retention Model:

- Representative climate data (rainfall and evaporation) are applied, and therefore retention rates for future periods are indicative and will vary with climate.

- Start month of water has an effect on the length of time that water is maintained in the storage.

- Seepage contributes largely to the rate of retention of water in the basin and is not varied as water level varies (in reality seepage rate would vary with water level).

- Care needs to be taken when adopting the model. Applying a daily model to the lake will seemingly provide greater accuracy, however, the results should be assessed broadly in terms of the length of time water is retained, rather than assessing change in storage rates over a daily time scale.

11. Environmental watering recommendations

11.1 Elements of a 'natural' wetting/drying regime at Dock Lake

The EFTP defined the following water regime elements which would represent a 'natural regime' for Dock Lake:

1. The maximum water level and inundation duration should vary between filling events.

2. Drawdown and drying should occur slowly and take place over the summer months.

3. Filling should occur in winter to early spring (between May and September) to mimic the timing of wetting events naturally. If filling in winter, when there is likely to be limited vegetation growth, filling can occur rapidly (over a few days). If filling the lake in spring, when vegetation will be growing, fill rate should ideally not exceed 3 cm a day (Blanch *et al.* 1996, see Section 3.2) to avoid overtopping and drowning vegetation.

4. Dock Lake should be filled to between Scenarios 16 and 26 (Appendix B) during each watering event to maximise the diversity of habitat provided at the lake. Dock Lake does not need to be watered every year and therefore if there is not enough water to meet the requirements of Scenario 16 in a particular year, then no water should be delivered to the lake. The full range of volumes between Scenario 16 and Scenario 26 should be delivered over multiple watering events (i.e. over multiple years) (which would mimic 'natural' events and would avoid erosional impacts from consistently filling to the same water level.

5. Dry periods should last for at least 6 months and preferably up to 12 months between wetting events to allow the lake bed to dry fully and to allow biogeochemical processes to attain their end points.

6. The inundation period should extend for at least 3-4 months and up to 12-14 months.

7. The frequency of inundation should vary during different climatic conditions (See Table 10-1 for a discussion of wet, average and dry climatic conditions at Dock Lake). In wet climatic conditions (high rainfall periods), inundation should occur on average five times per decade (once every two years). In average climatic conditions (average rainfall periods), inundation should occur on average three times per decade (once every three to four years). In dry climatic conditions (low rainfall periods), inundation should occur on average twice per decade (once every five years).

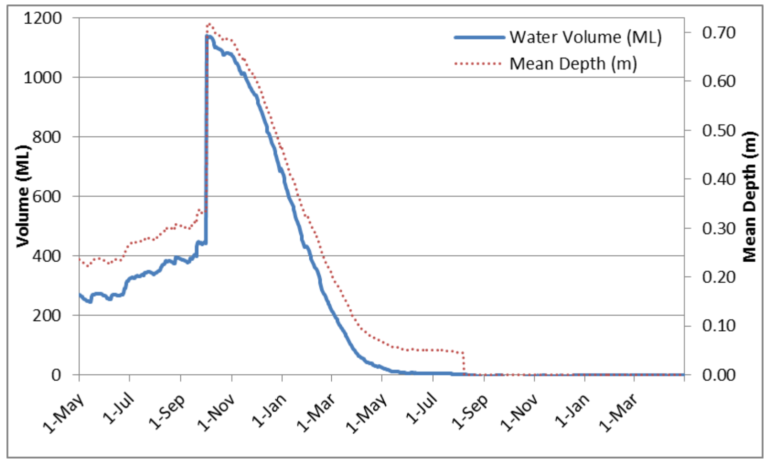
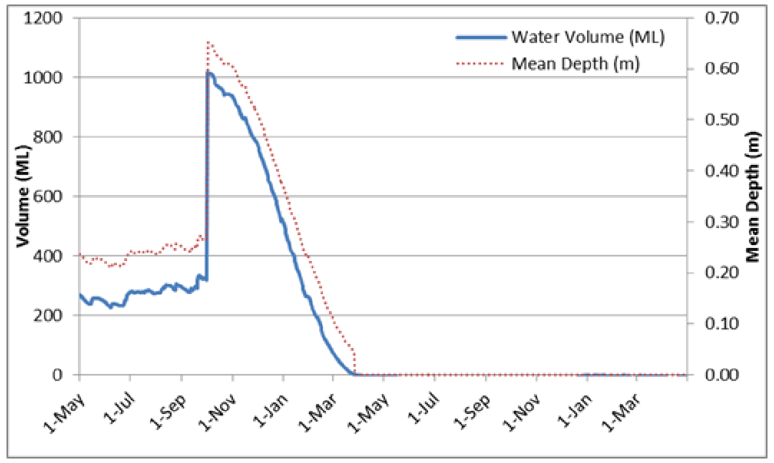
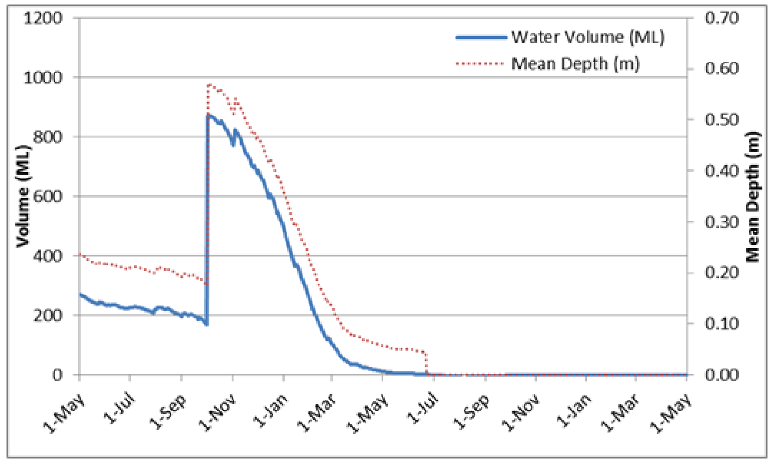
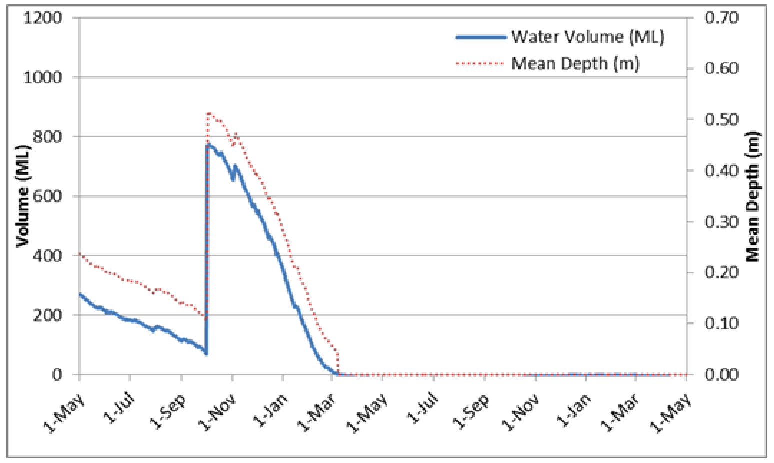
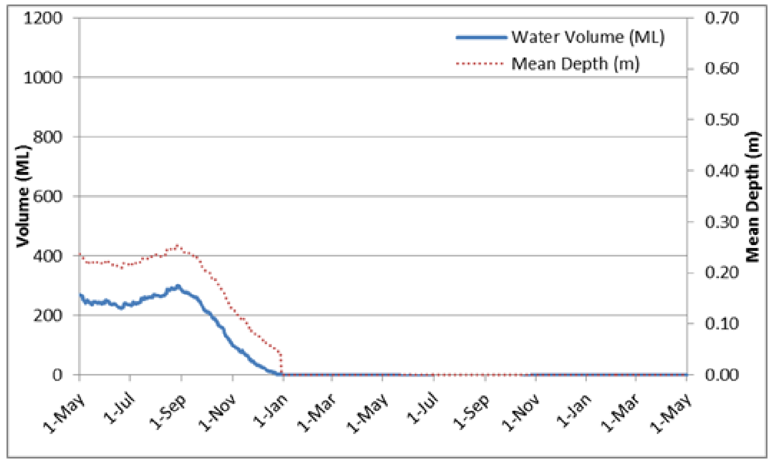
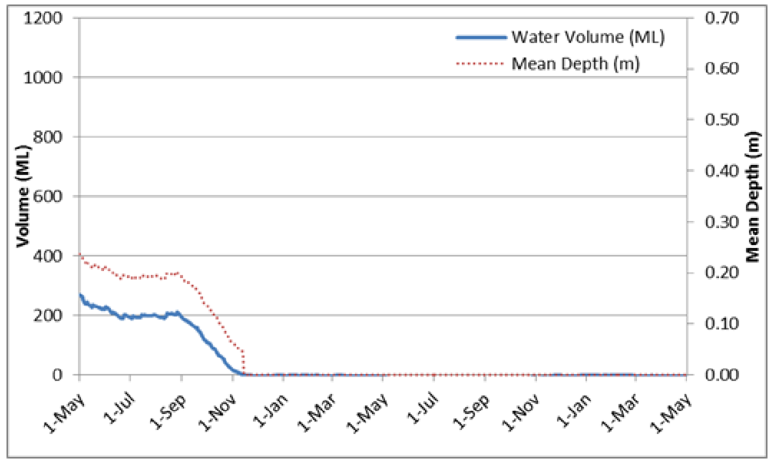
8. Water does not need to be provided to the lake all in one event. For example, the lake could be filled to a certain volume in early winter to wet the soil and then additional water could be provided in late winter/early spring, prior to the main vegetation growing phase, to reach the desired end water level.

11.2 Results of the Environmental Water Retention Model

Using the water regime elements outlined in Section 11.1, the Environmental Water Retention Model was run for several scenarios, including varying climate conditions and expected seepage rates. These runs were undertaken with a combination of Scenarios 16 and 26 and under the high and low seepage estimations for each scenario (the seepage estimations could be refined over time based on observations during wetting events). Some general model run observations are summarised below and example watering scenarios are presented in Table 11-1.

- The fastest loss of water occurs during summer months with very limited drawdown observed over winter. Therefore adding water in late autumn (May) provides the longest water retention.
- Scenarios looking at filling in late autumn and then topping up in late winter were examined (Table 11-1). When water is topped up in October, the volume assumed is the difference between Scenario 26 and Scenario 16, which equates to a volume of 702 ML.
- The inlet capacity is 100 ML/d. The model assumes that the whole volume is added in one day (rather than over a number of days to achieve the volume required). Filling over one day is not recommended from an ecological standpoint, however, from a modelling perspective this will have minimal impact on the losses and retention rates.
- There is no allowance in the model for the possible losses associated with filling a dry lake bed. As the lake has been dry for a number of years, the impact on the modelled results may be important. This should be monitored at least during the first filling event and maybe during subsequent events (see Section 13.1).
- Under wet climate conditions, it can be expected that water will be retained in the lake for between 11 and 16 months (depending on the actual seepage rate). Under average conditions, water is expected to be retained in the lake for between 10 and 14 months. Finally, under dry conditions, in which a lower volume of water is transferred into the lake, water is expected to be retained for between 7 and 8 months.

Table 11-1 Environmental watering scenarios for wet, average and dry climate conditions

Climate type	Description	Duration of water retained	
		Low seepage	High seepage
Wet climate	Fill to scenario 16 in May, then top up to scenario 26 in October, then let dry. This scenario inundates to a depth of about 0.8 m in some locations throughout the lake, with an average depth of 0.6 m throughout the lake. Frequency: five times a decade (once every two years). Ensure 12 months drying between filling events.	 **16 months inundation**	 **11 months inundation**
Average climate	Fill to scenario 16 in May, then top up to scenario 12 in October, then let dry. This scenario inundates to a depth of about 0.8 m in some locations throughout the lake, with an average depth of 0.6 m throughout the lake. Frequency: three times per decade (once every three to four years). Ensure 12 months drying between filling events.	 **14 months inundation**	 **10 months inundation**
Dry climate	Fill to scenario 16 in May, then let dry. This scenario inundates to a maximum depth of about 0.8m in only a few locations, with an average depth of 0.2 m throughout the lake. Frequency: at least twice per decade (once every five years). Ensure 12 months drying between filling events.	 **8 months inundation**	 **7 months inundation**

11.3 Summary of environmental water recommendations

The 'natural' water regime elements, identified by the EFTP and summarised in Section 11.1, provide the broad scale recommendations which should govern the delivery of environmental water to Dock Lake. We do not make firm recommendations for dry, average and wet climatic conditions because the wetting/drying regime should retain some variability (within the bounds outlined in Section 11.1). We instead provide some recommended bounds for water delivery in different climatic conditions and those are summarised in Table 11-2.

During dry conditions it is likely that smaller volumes of environmental water will be available than during wet conditions. During dry times, therefore, it is likely that volumes in the lower end of the range between Scenario 16 and 26 could be delivered to Dock Lake. As long as sufficient volume to achieve Scenario 16 is provided, then water should be delivered to the lake. Variability of final fill volume across wetting events should be aimed for wherever possible (i.e. in dry conditions, if sufficient volume to greater than Scenario 26 is available, this should be provided to achieve variability over wetting events).

Under extended extreme drought conditions, when very limited water is present in the system, environmental water provision will need to be balanced out against competing priorities. During these conditions it is highly unlikely that environmental water will be available to provide to Dock Lake. It should be noted that if the lake is not provided with water at least two times per decade that a significant decline in ecological condition is likely.

Table 11-2 Environmental watering recommendations for Dock Lake under wet, average and dry climate conditions.

Climate Conditions	Environmental Water Recommendations
All Provide under all climate conditions	Fill to between 271 ML (Scenario 16) and 973 ML (Scenario 26) (vary the final volume over wetting events so that across multiple wetting events, the full range of volumes between these scenarios is delivered.) Commence filling between May and September. Inundation period should last at least 3-4 months (but could be as long as 12-14 months). Dry periods (between wetting events) should last for at least 6, but preferably 12 months.
Wet (Annual net evap: 805 mm) (Representative year: 1915)	Wetting events should occur on average five times a decade (once every two years)
Average (Annual net evap: 1004 mm) (Representative year: 1976)	Wetting events should occur on average three times a decade (once every three to four years)
Dry (Annual net evap: 1236 mm) (Representative year: 1965)	Wetting events should occur on average twice a decade (once every five years)
Extended extreme drought conditions	No watering recommended. A long period between inundation events (less than twice per decade) is likely to result in a serious decline in ecological condition.

12. Consequences of watering recommendations

The following section summarises the consequences of the proposed watering regime for the ecological values identified above and the objectives described in Section 9.

12.1 Consequences of watering recommendations for water quality

It is assumed that, all else being equal, the water provided from Green Lake to inundate Dock Lake would be of suitable quality to support the range of ecological objectives identified in Section 9. Once the water is provided to Dock Lake, however, particularly for the first time after more than 15 years of being dry, a range of water quality issues may result:

1. Large amounts of vegetation have grown up on the dry lake bed and this material will commence to decompose when the lake is rewetted. The decomposition will fuel bacterial growth, which in turn will support a zooplankton-driven food web and carbon and nutrients will eventually feed into higher trophic levels. The initial surge in microbial productivity is often considered a desirable outcome when previously dry wetlands or shallow lakes are rewetted after a lengthy dry spell (e.g. Briggs *et al.* 1985). If, however, bacteria, zooplankton and other microbes grow more quickly than oxygen can diffuse from the atmosphere into the water column, anoxia could develop. This could result in localised animal kills and, under the worst conditions, the development of noxious tastes and odours.

2. Over longer periods, the microbial-zooplankton food web will result in the regeneration of the nutrients that were previously tied-up in the dead plant material. The liberation of these nutrients could fuel the excessive growth of algae. If aquatic macrophytes establish quickly enough following inundation, they will provide strong competition for nutrients and light with the algae. The effects of nutrient enrichment and of removing aquatic plants on phytoplankton blooms and the development of poor water quality have been described for a shallow lake near Shepparton (Morris *et al.* 2003 a, b, 2004, 2006) and lessons learnt from that investigation may be applicable to the Dock Lake situation.

3. Salinity has been an issue in the lake in the past, reducing its suitability as an irrigation water storage. While our understanding is that the salinity levels recorded in the lake historically may not be such an issue for biota, if may be a risk during inundation. Salinity should therefore be monitored closely as the lake is filled and during the inundation peiod.

12.2 Consequences of watering recommendations for vegetation

There are likely to be significant advantages in re-introducing a more natural wetting and drying regime into Dock Lake. A floristically and structurally diverse plant community should develop (if propagules are available), and this vegetation would provide food and critical habitat to a wide range of animals. Submerged plant communities, some with floating leaves, would probably develop, as would a wide fringe of emergent rushes, reeds and sedges. These vegetation types would complement the existing River Red Gum and Lignum communities that currently border the lake.

There are two possible risks to vegetation associated with the proposed watering regime:

1. First, there may be insufficient plant propagules (in terms of abundance or diversity) in the lake-bed sediments to allow native aquatic vegetation to re-establish following the first inundation. The near-permanent flooding of the lake since 1932 would likely have resulted in the death of much of the original soil-based seed bank; the prolonged period over the recent drought, coinciding with the lake's decommissioning as a water supply, probably also resulted in the remaining seed bank becoming smaller and less diverse. With little or no viable seed bank to allow plants to return following inundation, it is not clear that a desirable vegetation response will occur, at least not for the first few years. It is recommended that a series of pre-inundation trials be undertaken to determine the size and

composition of the soil-based seed bank. Brock *et al.* (1997) provide protocols for undertaking these trials, which could be done by local community or school groups. Such trials would also help build a sense of community ownership in the rehabilitation of the lake.

It is worth noting that animals (particularly waterbirds) taking advantage of water in the rewetted lake will probably introduce plant propagules into the water body too. They could do this via seeds caught on their feet or feathers, which then germinate and establish; or via small fragments of living plant being brought into the wetland which subsequently establish and spread by asexual (clonal) means. Given the highly stochastic nature of these processes, it is not possible to predict whether they will occur. Over the longer-term, they are, however, likely.

2. Second, the rapid growth of plants as the lake dries and in the subsequent dry phase may pose a fire risk. Blown Grass (*Agrostis avenacea*) is known to be present around Dock Lake and build-ups of dead material have in the past been responsible for damaging fires. Consideration will have to be given to the best way to manage any accumulation of terrestrial vegetation on the lake bed during the dry phase. This management would involve consultation with the land manager of Dock Lake (GWMWater) and local DELWP and CFA.

   It is strongly recommended that a Fire Management Plan be developed in consultation with all the relevant stakeholders. This plan should incorporate weed management and any fuel reduction carried out in the lake should be done in accordance with best practice plant and vehicle hygiene protocols to prevent the spread of weeds.

   While fire management and prevention is a major concern, unless the terrestrial vegetation is identified as a fire risk, it should be left to grow in the lake bed. Any vegetation that grows during the dry phase does perform a useful ecological function when the lake is re-inundated; it decays rapidly and provides food for the zooplankton that emerge from the sediments upon re-wetting.

12.3 Consequences of watering recommendations for birds

There are likely to be significant advantages to local bird populations in re-introducing a more natural wetting and drying regime into Dock Lake. Regardless of the successful recolonization of the lake by native plants, the changes in the varying the water level will increase the heterogeneity of the lake’s flora which is likely to increase the diversity of bird species using the lake. Should poor water quality emerge as a result of nutrient release and algal blooms some species of waterbird may find the habitat at the lake unsuitable, especially during the peak of any such bloom, however this is only likely to be a short term issue.

Some birds can become pests to agriculture, including waterbirds such as Australian Wood Ducks (*Chenonetta jubata*) (Marchant and Higgins 1990). Given the limited size of Dock Lake and introduction of variable water levels it is unlikely that a population of ducks or any single other species will increase in numbers to represent a risk to nearby agriculture, especially considering the types of common land uses in the vicinity of Dock Lake (i.e. grazing and wheat farming). Ducks are also common at the nearby Boga Lakes and if they were likely to cause issue to nearby agriculture, it would probably have already occurred.

Other minor risks associated with an increased abundance of birds at Dock Lake include:

1. An increased risk of vehicle collisions with low flying and young birds.
2. An increase in the number of predatory species in the area. These are likely to be introduced predators such as Red Fox (*Vulpes vulpes*) and Feral Cats (*Felis domesticus*).
3. Damage to local area from increased visitation to the lake by game hunters (if permitted) and bird watchers.

12.4 Consequences of watering recommendations for frogs

Dock Lake, once inundated, is likely to provide habitat for common species that are already resident in the local area. Inundation in late winter/spring, provided that it persists for at least a few months, may allow breeding to occur. Unless Dock Lake is inundated each year, it is only ever likely to provide secondary habitat for frogs (i.e. the lake would not support long-term, self-sustaining breeding populations). Despite only providing secondary habitat, use of the lake by frogs would not only benefit the local populations of these species, it would also provide an important food resource for birds. The common frog species that would probably use the lake are likely to be tolerant of a range of water quality conditions.

There are only minor risks associated with the inundation of Dock Lake for frogs:

1. If the inundation period does not extend long enough to allow tadpoles to complete development, widespread tadpole death may occur (which would be a frequent occurrence in natural populations).

2. An increase in road mortality may occur as frogs attempt to access Dock Lake from other habitats (e.g. Green Lake). Little is known of the size of the frog populations in Green Lake, but if they are large, road mortality is probably already common (although probably not frequently recorded) on the Western Highway.

12.5 Consequences of watering recommendations for fish

Reports from when the lake was used as a water storage indicates that the fish assemblage was dominated by stocked exotic species (trout, Redfin Perch) although some small bodied native species (Australian Smelt, River Blackfish) were probably also supported.

The proposed watering regime, which recommends relatively long periods with no standing water, would not support self-sustaining fish populations in Dock Lake. Fish could access Dock Lake from Green Lake during filling. Some fish in Dock Lake would benefit birds by providing a food resource.

There are some minor risks from inundating Dock Lake in terms of fish:

1. The conditions in the lake following inundation may be very suitable for Carp breeding (they are known to breed in floodplain habitats). Carp are widespread throughout the Wimmera and have been recorded recently in Burnt Creek (G. Fletcher, Wimmera CMA pers. comm.), however, increased abundance following breeding in Dock Lake could have negative consequences for the biota of Burnt Creek. The proposed filling scenarios (16 and 26) have a final water level well below the sill height of the Burnt Creek (see Appendix B) and therefore it is unlikely that Carp could access Burnt Creek during environmental wetting events. However, if a large natural event occurs following environmental watering then it could occur. The installation of a temporary Carp screen could mitigate this risk in these situations. Fish surveys undertaken during inundation would also provide more information on this risk.

2. Fish may be stranded as the lake dries. It is highly likely that birds and other fauna will eat these fish, however, if this does not happen then the fish carcasses may be a minor aesthetic nuisance.

12.6 Consequences of watering recommendations for turtles

Once inundated, Dock Lake would be suitable for use by Common Long-necked Turtles. Common Long-necked Turtles are able to migrate overland and would likely colonise an inundated Dock Lake from Green Lake, either during the filling or potentially overland. The provision of additional habitat would likely benefit turtles, but as there is permanent habitat in the nearby area (primarily Green Lake) a periodically inundated Dock Lake would likely only provide secondary habitat. Once the lake begins drying, turtles would migrate to other permanent habitat.

There are minor risks from inundating Dock Lake:

1. Mortality due to road strike may increase as turtles travel overland to access Dock Lake once it is inundated, or to return to other habitats after it dries.

12.7 Consequences of watering recommendations for macroinvertebrates and microinvertebrates

Dock Lake, once inundated, is likely to attract a diverse and abundant macroinvertebrate community, either by aerial dispersal from nearby habitat, or by colonisation from Green Lake during filling. Microinvertebrates eggs are likely still present in the system (as dormant, desiccation tolerant eggs) which would hatch following inundation. There are no major risks from a macroinvertebrate and microinvertebrate perspective from the filling of Dock Lake.

13. Proposed monitoring program

Dock Lake has been dry since the late-1990s, and while we have estimated the potential consequences of watering, there are many unknowns and risks (outlined in Section 11.3). To ensure that environmental watering achieves the objectives outlined in Section 9 and to ensure risks are managed as far as possible, it is important that monitoring be conducted in Dock Lake, especially during and following the initial inundation.

The following section briefly outlines a monitoring program for the lake. The monitoring program is tiered, some monitoring activities are proposed to occur immediately following and during inundation, while other monitoring techniques could be added to assess second order affects.

On the establishment of the monitoring program, appropriate sites will need to be determined. This would be best done during the first filling event which will allow habitats to be identified. These sites should also be reviewed after subsequent filling events as habitats are improved.

Based on the results of this monitoring program, the watering recommendations proposed here should be reviewed and if required, amended, to either reduce the risks of watering or to improve the achievement of the ecological objectives.

13.1 Water quality and water depth

Water quality should be monitored during and following the filling stage, ideally as part of each wetting event. Monitoring is particularly important during the initial filling, which will track the consequences of the predicted trophic upsurge as the existing terrestrial vegetation is wetted and decomposes. Specifically:

1. Standard, *in situ* water quality variables (pH, turbidity, electrical conductivity, temperature, dissolved oxygen) should be measured in Dock Lake routinely (weekly to begin with until stable levels are recorded and then monthly). Samples should be taken from at least 5 locations in the lake, preferably at least some from the near the centre of the wetted extent (i.e. do not take all samples from the bank).

   Dissolved oxygen levels are should be monitored closely to determine if bacteria, zooplankton and other microbes are growing more quickly than oxygen can diffuse from the atmosphere into the water column and therefore causing the lake to become anoxic.

   Salinity should also be a focus of monitoring. The water in Dock Lake may become more saline over time, a factor that reduced the lake’s effectiveness as a water storage for irrigation. Although the salinity was not typically high enough historically to be an issue to aquatic biota, the concentrations in the lake should still be monitored over time to increase understanding of lake processes.

2. Following initial filling, the microbial-zooplankton food web will likely liberate nutrients from the dead plant material and the nutrients may then fuel excessive algal growth. Algal growth should be monitored by examining Chlorophyll A levels and Blue Green Algae (BGA) counts. To provide further insight into the pathway, nutrient (nitrogen and phosphorus) concentrations should also be monitored. For simplicity, this monitoring should be carried out at the same time and at the same sites as the other water quality monitoring.

3. Water depth should be measured once the recommended volume has been delivered to verify modelling outputs of the current study. This could be done using fixed staff gauges or data loggers, depending on the capacity of the CMA to visit the lake to obtain the level data. Modelled depth could also be verified by conducting a simple depth survey (i.e. measure depth from a boat at a number of points in the lake) shortly following the delivery of the water (i.e. when the volume corresponding to a particular filling scenario is delivered).

4. Water loss during filling as water 'wets' the lake margins is unknown. This is likely to be worst during the first filling due to the current long dry period of the lake, but may also be high if the lake lies dry for more than a couple of years. Monitoring of the volume lost should be undertaken to determine whether additional water is required to meet objectives in future years. This can be undertaken by assessing water level and therefore volume in the lake in the days following filling using data loggers. Monitoring the volume lost will also allow the seepage estimates, used as part of the Environmental Water Retention Model, to be updated to improve the accuracy of the model.

13.2 Macroinvertebrates and microinvertebrates

The trophic upsurge immediately following the inundation of the lake will be important for attracting fauna (birds, frogs) to the lake. Although unlikely, if the macroinvertebrate or microinvertebrate communities fail to establish, or decline following the upsurge, then higher order consumers may not be supported by the lake. As a consequence, understanding the macroinvertebrate and microinvertebrate biomass response will be important to determining the effectiveness of environmental watering.

Ideally, macroinvertebrate and microinvertebrate biomass will be tracked from shortly following the filling of the lake, through the first inundation period. To build up a semi-quantitative estimate of macroinvertebrate abundance, it is recommended that standard macroinvertebrate samples (kick or sweep sample) be taken at four locations around the lake. These samples could be roughly standardised by timing each sampling method (e.g. ten minutes) and estimating abundance using a standard subsampling method in the laboratory. Identification to family would be sufficient, as we are most interested in the abundance of macroinvertebrates (although a high level understanding of diversity would be interesting). Monitoring ideally would take place twice during the filling event, once shortly following inundation (within the first month to observe the trophic upsurge) and another a few months later (once communities are likely to have stabilised).

Microinvertebrates can be sampled by analysing water samples taken at the same times and location as the macroinvertebrate monitoring. A high level measure of abundance and diversity is all that would be required, and could likely be undertaken by the same suppliers completing the macroinvertebrate monitoring. Tracking this biomass through the second wetting event is also likely to be very informative (the trophic upsurge following the first and second wetting event is likely to be very different).

13.3 Vegetation

Some vegetation responses may become apparent during the first watering event, while some species/communities may take a number of wetting/drying cycles to respond. Understanding how the vegetation changes is important, as second order responses (particularly the use of the lake by birds but also fish and frogs) will be determined in large part by the vegetation.

It is proposed that the vegetation species and communities present at approximately ten repeated transects around the lake be described qualitatively. These transects should be oriented perpendicular to the water's edge and extend from outside the riparian zone and into the water as far as practical. The vegetation responses are likely to be large and so qualitative descriptions of the extent and condition of the vegetation communities and species along the transect should be sufficient to determine the consequence and effectiveness of the environmental watering.

It is recommended that this monitoring take place one month, three months and sixth months after the first inundation period. The first filling period may be quite different to subsequent wetted periods and so there is value in extending this monitoring into at least the second inundation event and beyond.

13.4 Birds

Changes in bird populations following wetting of the lake is an example of a second order response that could be monitored once it has been determined that the watering is demonstrating effects in other variables (primarily vegetation). Bi-annual bird surveys (during wetted periods) could be completed, based on defined search areas and durations (e.g. a repeated survey transect or a timed search). Species and abundance should be assessed, which as a standardised method is proposed, would allow comparison over wetting events.

One of the two surveys each year should be carried out in the breeding season (i.e. spring). While we do not expect that the lake will represent high quality breeding habitat for a range of species, some species may breed opportunistically. Confirmation of breeding, particularly if successful, would be a clear demonstration of the value of the environmental watering.

Ideally local ornithological societies would be engaged to assist, or even complete entirely, these surveys. Local groups would already have a good understanding of the area and would be able to complete the surveys efficiently and would provide a valuable way to engage the local community.

13.5 Fish

Like the bird monitoring, an assessment of the fish using Dock Lake could be conducted at a later stage, perhaps in the second or third wetting event. As it is likely that primarily exotic species will use the lake, fish surveys are of primary interest as they allow the development of a more detailed understanding of how the ecosystem of the lake is functioning.

Ideally, a repeated survey method would be employed using boat-electrofishing. One day boat-electrofishing and night setting fyke nets (fine and coarse meshed) and bait traps in potential fish habitat would likely be sufficient to survey the fish community of the lake. The aim would be to determine the species that are using the lake, with a simple measure of relative abundance sufficient. Caught fish should be weighed and their length measured which would provide information on the age classes of the fish using the lake and may also allow a determination of whether recruitment is occurring in the lake.

13.6 Frogs

Frog surveys could be completed during future wetting events. Estimating frog abundance is extremely difficult and labour intensive and therefore surveys should concentrate on determining the species assemblages using various areas of the lake. The simplest way to do this would be to fix call recorders (such as a *SongMeter*) at locations around the lake (four to six sites should be sufficient) which would be suitable for frogs (e.g. shallow areas with fringing and/or emergent macrophytes). The call recorders can be programmed to record overnight and calls can be used to easily identify the species that made them. Determining the frog species that are supported by the lake during wet periods will increase understanding of how the wetland is functioning and provide a simple demonstration of the value of environmental water.

13.7 Turtles

If turtles are using Dock Lake, they are likely to be caught in the fyke nets which will be used as part of fish surveys. It is not recommended that specific turtle surveys be carried out. Like frogs and birds, monitoring to confirm the use of the lake by turtles would provide a simple yet powerful demonstration of the value of environmental water for the lake.

14. Prioritisation of environmental water for Dock Lake

The environmental watering recommendations for Dock Lake, presented in this report, have been developed without considering the other environmental water needs in the Wimmera Region. The recommendations should not therefore be taken as an argument for delivering environmental water to Dock Lake. Rather this report describes what could be achieved if environmental water was to be used at Dock Lake. Environmental water allocations are limited, particularly in dry periods and the Wimmera CMA, VEWH and other stakeholders will need to consider the relative merits of delivering environmental water to Dock Lake and potential implications on other waterways that may have to cope with less water as a result.

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Appendix A. Avian Records in the vicinity of Dock Lake

Avian species recorded at, or in the vicinity of, Dock Lake, Victoria. * denotes introduced species. Source: Victorian Biodiversity Atlas (Department of Environment Land Water and Planning 2015), Alcorn data *In Litt DATE* and Tim Mintern *In Litt.* 5 March 2015.

Common Name	Specific Name	Previous records
Australasian Bittern	*Botaurus poiciloptilus*	Dock Lake
Australasian Grebe	*Tachybaptus novaehollandiae*	Dock Lake
Australasian Pipit	*Anthus novaeseelandiae*	Boga Lakes
Australasian Shoveler	*Anas rhynchotis*	Dock Lake
Australian Hobby	*Falco longipennis*	Taylors Lake only
Australian Magpie	*Gymnorhina tibicen*	Dock Lake
Australian Pelican	*Pelecanus conspicillatus*	Dock Lake
Australian Pratincole	*Stiltia isabella*	Boga Lakes
Australian Raven	*Corvus coronoides*	Boga Lakes
Australian Shelduck	*Tadorna tadornoides*	Dock Lake
Australian White Ibis	*Threskiornis molucca*	Dock Lake
Australian Wood Duck	*Chenonetta jubata*	Dock Lake
Banded Stilt	*Cladorhynchus leucocephalus*	Taylors Lake only
Black Falcon	*Falco subniger*	Boga Lakes
Black Kite	*Milvus migrans*	Taylors Lake only
Black Swan	*Cygnus atratus*	Dock Lake
Black-chinned Honeyeater	*Melithreptus gularis*	Boga Lakes
Black-faced Cuckoo-shrike	*Coracina novaehollandiae*	Dock Lake
Black-fronted Dotterel	*Elseyornis melanops*	Dock Lake
Black-shouldered Kite	*Elanus axillaris*	Dock Lake
Black-tailed Native-hen	*Gallinula ventralis*	Dock Lake
Black-winged Stilt	*Himantopus himantopus*	Dock Lake
Blue-billed Duck	*Oxyura australis*	Dock Lake
Bluebonnet	*Northiella haematogaster*	Taylors Lake only
Blue-winged Parrot	*Neophema chrysostoma*	Boga Lakes
Brolga	*Grus rubicunda*	Boga Lakes
Brown Falcon	*Falco berigora*	Dock Lake
Brown Goshawk	*Accipiter fasciatus*	Taylors Lake only
Brown Quail	*Coturnix ypsilophora*	Taylors Lake only
Brown Songlark	*Cincloramphus cruralis*	Boga Lakes
Brown Treecreeper	*Climacteris picumnus*	Taylors Lake only
Chestnut Teal	*Anas castanea*	Dock Lake
Clamorous Reed Warbler	*Acrocephalus stentoreus*	Dock Lake
Cockatiel	*Nymphicus hollandicus*	Dock Lake
* Common Blackbird	*Turdus merula*	Taylors Lake only
Common Bronzewing	*Phaps chalcoptera*	Taylors Lake only
Common Greenshank	*Tringa nebularia*	Dock Lake

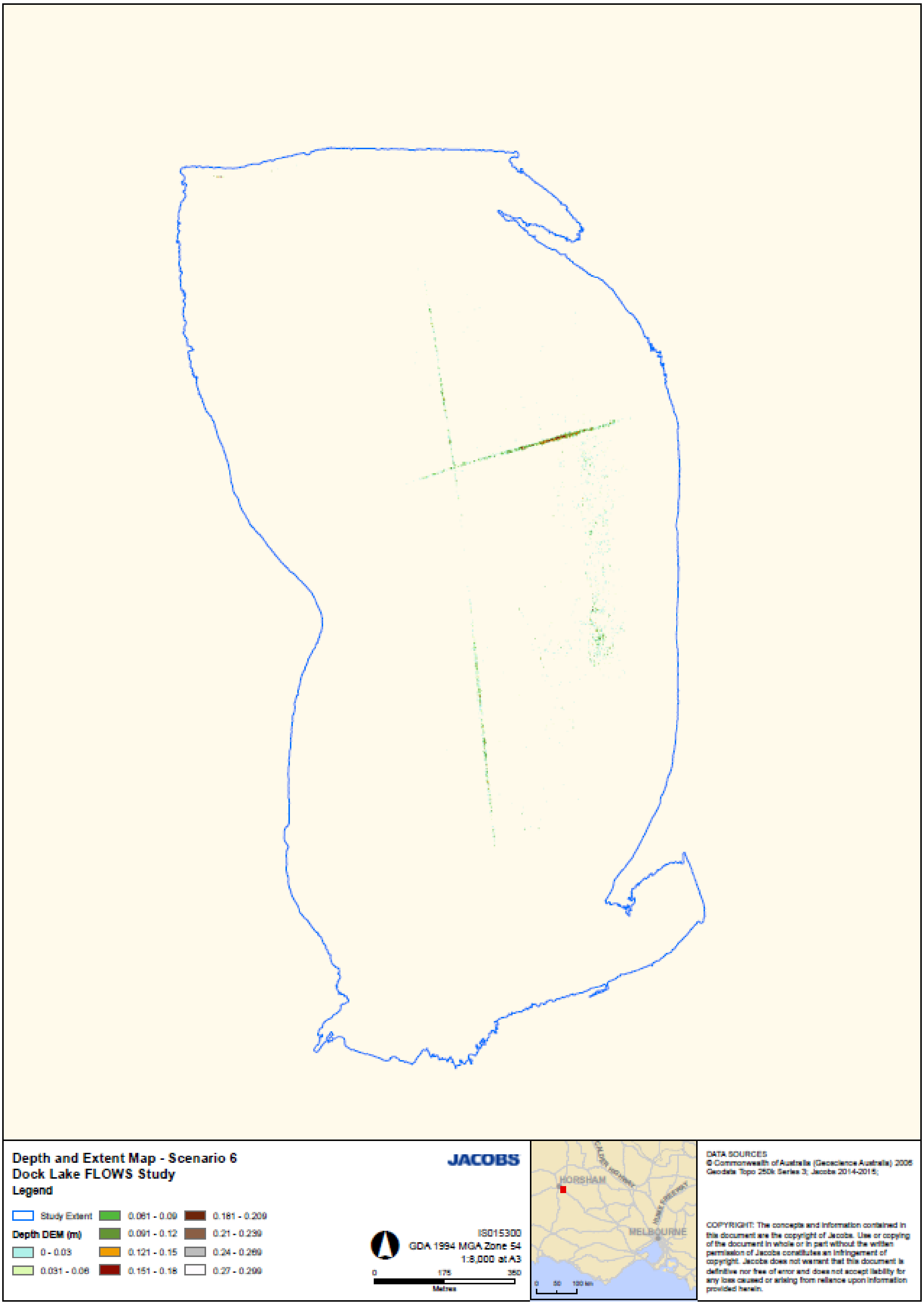
Common Name	Specific Name	Previous records
* Common Starling	*Sturnus vulgaris*	Dock Lake
Curlew Sandpiper	*Calidris ferruginea*	Dock Lake
Crested Pigeon	*Ocyphaps lophotes*	Dock Lake
Crested Shrike-tit	*Falcunculus frontatus*	Boga Lakes
Crimson Rosella	*Platycercus elegans*	Boga Lakes
Darter	*Anhinga novaehollandiae*	Dock Lake
Double-banded Plover	*Charadrius bicinctus*	Dock Lake
Dusky Moorhen	*Gallinula tenebrosa*	Dock Lake
Dusky Woodswallow	*Artamus cyanopterus*	Dock Lake
Eastern Great Egret	*Ardea modesta*	Dock Lake
Eastern Rosella	*Platycercus eximius*	Taylors Lake only
Eurasian Coot	*Fulica atra*	Dock Lake
* European Goldfinch	*Carduelis carduelis*	Taylors Lake only
* European Skylark	*Alauda arvensis*	Boga Lakes
Fairy Martin	*Petrochelidon ariel*	Taylors Lake only
Flame Robin	*Petroica phoenicea*	Taylors Lake only
Freckled Duck	*Stictonetta naevosa*	Dock Lake
Galah	*Eolophus roseicapilla*	Dock Lake
Glossy Ibis	*Plegadis falcinellus*	Boga Lakes
Golden Whistler	*Pachycephala pectoralis*	Boga Lakes
Golden-headed Cisticola	*Cisticola exilis*	Taylors Lake only
Great Cormorant	*Phalacrocorax carbo*	Dock Lake
Great Crested Grebe	*Podiceps cristatus*	Dock Lake
Grey Fantail	*Rhipidura albiscarpa*	Boga Lakes
Grey Shrike-thrush	*Colluricincla harmonica*	Dock Lake
Grey Teal	*Anas gracilis*	Dock Lake
Hardhead	*Aythya australis*	Dock Lake
Hoary-headed Grebe	*Poliocephalus poliocephalus*	Dock Lake
* House Sparrow	*Passer domesticus*	Dock Lake
Latham's Snipe	*Gallinago hardwickii*	Dock Lake
Laughing Kookaburra	*Dacelo navaeguinea*	Dock Lake
Little Black Cormorant	*Phalacrocorax sulcirostris*	Dock Lake
Little Eagle	*Hieraaetus morphnoides*	Dock Lake
Little Egret	*Egretta garzetta nigripes*	Boga Lakes
Little Grassbird	*Megalurus gramineus*	Taylors Lake only
Little Pied Cormorant	*Microcarbo melanoleucos*	Dock Lake
Little Raven	*Corvus mellori*	Boga Lakes
Long-billed Corella	*Cacatua tenuirostris*	Dock Lake
Magpie Goose	*Anseranas semipalmata*	Dock Lake
Magpie-lark	*Grallina cyanoleuca*	Dock Lake
Masked Lapwing	*Vanellus miles*	Dock Lake
Masked Woodswallow	*Artamus personatus*	Boga Lakes

Common Name	Specific Name	Previous records
Musk Duck	*Biziura lobata*	Dock Lake
Musk Lorikeet	*Glossopsitta concinna*	Boga Lakes
Nankeen Kestrel	*Falco cenchroides*	Boga Lakes
Nankeen Night Heron	*Nycticorax caledonicus hillii*	Boga Lakes
New Holland Honeyeater	*Phylidonyris novaehollandiae*	Boga Lakes
Noisy Miner	*Manorina melanocephala*	Dock Lake
Olive-backed Oriole	*Oriolus sagittatus*	Taylors Lake only
Pacific Barn Owl	*Tyto javanica*	Boga Lakes
Pacific Black Duck	*Anas superciliosa*	Dock Lake
Pectoral Sandpiper	*Calidris melanotos*	Dock Lake
Peregrine Falcon	*Falco peregrinus*	Dock Lake
Pied Cormorant	*Phalacrocorax varius*	Dock Lake
Pink-eared Duck	*Malacorhynchus membranaceus*	Dock Lake
Purple Swamphen	*Porphyrio porphyrio*	Dock Lake
Purple-crowned Lorikeet	*Glossopsitta porphyrocephala*	Taylors Lake only
Rainbow Lorikeet	*Trichoglossus haematodus*	Boga Lakes
Red Wattlebird	*Anthochaera carunculata*	Boga Lakes
Red-capped Plover	*Charadrius ruficapillus*	Dock Lake
Red-kneed Dotterel	*Erythrogonys cinctus*	Dock Lake
Red-necked Avocet	*Recurvirostra novaehollandiae*	Dock Lake
Red-necked Stint	*Calidris ruficollis*	Dock Lake
Red-rumped Parrot	*Psephotus haematonotus*	Dock Lake
Restless Flycatcher	*Myiagra inquieta*	Taylors Lake only
* Rock Dove	*Columba livia*	Boga Lakes
Royal Spoonbill	*Platalea regia*	Dock Lake
Rufous Songlark	*Cincloramphus mathewsi*	Dock Lake
Sacred Kingfisher	*Todiramphus sanctus*	Dock Lake
Sharp-tailed Sandpiper	*Calidris acuminata*	Taylors Lake only
Silver Gull	*Chroicocephalus novaehollandiae*	Dock Lake
Silvereye	*Zosterops lateralis*	Boga Lakes
Singing Bushlark	*Mirafra javanica*	Taylors Lake only
Singing Honeyeater	*Lichenostomus virescens*	Taylors Lake only
Spotted Harrier	*Circus assimilis*	Taylors Lake only
Spotted Pardalote	*Pardalotus punctatus*	Taylors Lake only
Straw-necked Ibis	*Threskiornis spinicollis*	Dock Lake
Striated Pardalote	*Pardalotus striatus*	Dock Lake
Stubble Quail	*Coturnix pectoralis*	Taylors Lake only
Sulphur-crested Cockatoo	*Cacatua galerita*	Boga Lakes
Superb Fairywren	*Malurus cyaneus*	Taylors Lake only
Swamp Harrier	*Circus approximans*	Dock Lake
Swift Parrot	*Lathamus discolor*	Boga Lakes
Tree Martin	*Petrochelidon nigricans*	Dock Lake

Common Name	Specific Name	Previous records
Wedge-tailed Eagle	*Aquila audax*	Taylors Lake only
Weebill	*Smicrornis brevirostris*	Taylors Lake only
Welcome Swallow	*Petrochelidon neoxena*	Dock Lake
Whiskered Tern	*Chlidonias hybrida*	Dock Lake
Whistling Kite	*Haliastur sphenurus*	Dock Lake
White-bellied Sea-Eagle	*Haliaeetus leucogaster*	Dock Lake
White-breasted Woodswallow	*Artamus leucorynchus*	Dock Lake
White-browed Woodswallow	*Artamus superciliosus*	Taylors Lake only
White-faced Heron	*Egretta novaehollandiae*	Dock Lake
White-fronted Chat	*Epthianura albifrons*	Dock Lake
White-fronted Honeyeater	*Sterna striata*	Taylors Lake only
White-necked Heron	*Ardea pacifica*	Dock Lake
White-plumed Honeyeater	*Lichenostomus penicillatus*	Dock Lake
White-winged Chough	*Corcorax melanorhamphos*	Taylors Lake only
White-winged Triller	*Lalage tricolor*	Taylors Lake only
Willie Wagtail	*Rhipidura leucophrys*	Dock Lake
Yellow Thornbill	*Acanthiza nana*	Boga Lakes
Yellow-billed Spoonbill	*Platalea flavipes*	Dock Lake
Yellow-rumped Thornbill	*Acanthiza chrysorrhoa*	Dock Lake
Yellow-tailed Black-Cockatoo	*Calyptorhynchus funereus*	Dock Lake
Zebra Finch	*Taeniopygia guttata*	Boga Lakes

Appendix B. Filling scenario depth and inundation extent maps

The maps showing the inundation extents and depth profiles of ten of the filling scenarios are presented. The water heights modelled ranged from an empty lake to a full lake in 5cm increments, producing 96 scenarios in total (Scenario 0 = an empty lake (i.e. no water) to Scenario 96 = inundation to 4.8 m above empty).


Depth and Extent Map - Scenario 6
Dock Lake FLOWS Study
Legend
Study Extent
Depth DEM (m)
0 - 0.03
0.031 - 0.06
0.061 - 0.09
0.091 - 0.12
0.121 - 0.15
0.151 - 0.18
0.181 - 0.209
0.21 - 0.239
0.24 - 0.269
0.27 - 0.299
JACOBS
IS015300
GDA 1994 MGA Zone 54
1:8,000 at A3
0
175
350
Metres
HORSHAM
MELBOURNE
DATA SOURCES
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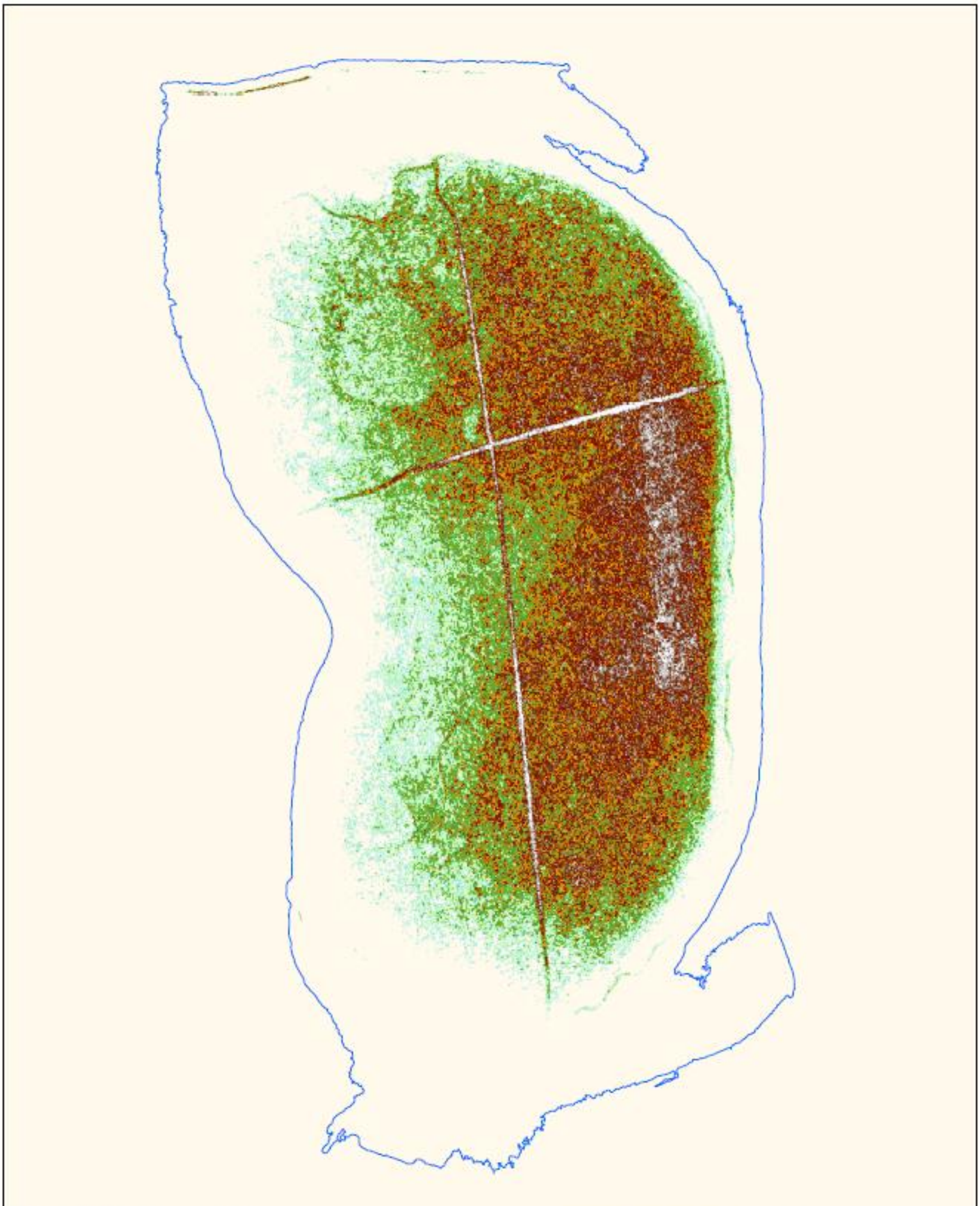

Depth and Extent Map - Scenario 16
Dock Lake FLOWS Study
Legend

Study Extent	0.1351 - 0.198	0.34211 - 0.386
Depth DEM (m)	0.1981 - 0.251	0.3861 - 0.436
0 - 0.069	0.2511 - 0.298	0.4361 - 0.508
0.0691 - 0.135	0.29811 - 0.342	0.5081 - 0.800

IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0 150 300
Metres

DATA SOURCES
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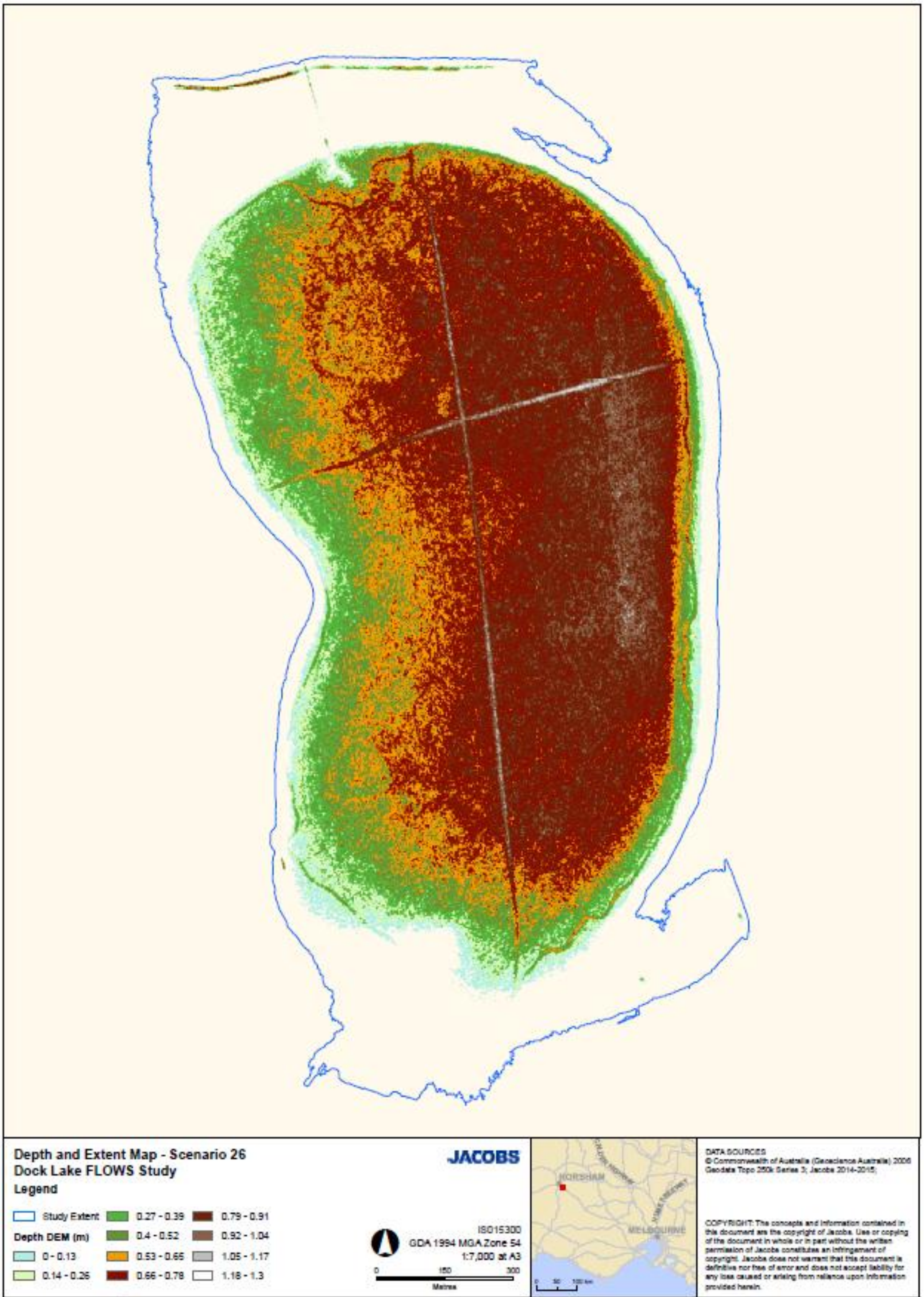
Depth and Extent Map - Scenario 26
Dock Lake FLOWS Study
Legend
Study Extent
Depth DEM (m)
0 - 0.13
0.14 - 0.26
0.27 - 0.39
0.4 - 0.52
0.53 - 0.65
0.66 - 0.78
0.79 - 0.91
0.92 - 1.04
1.05 - 1.17
1.18 - 1.3
JACOBS
IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0
150
300
Metres
HORSHAM
MELBOURNE
0
50
100 km
DATA SOURCES
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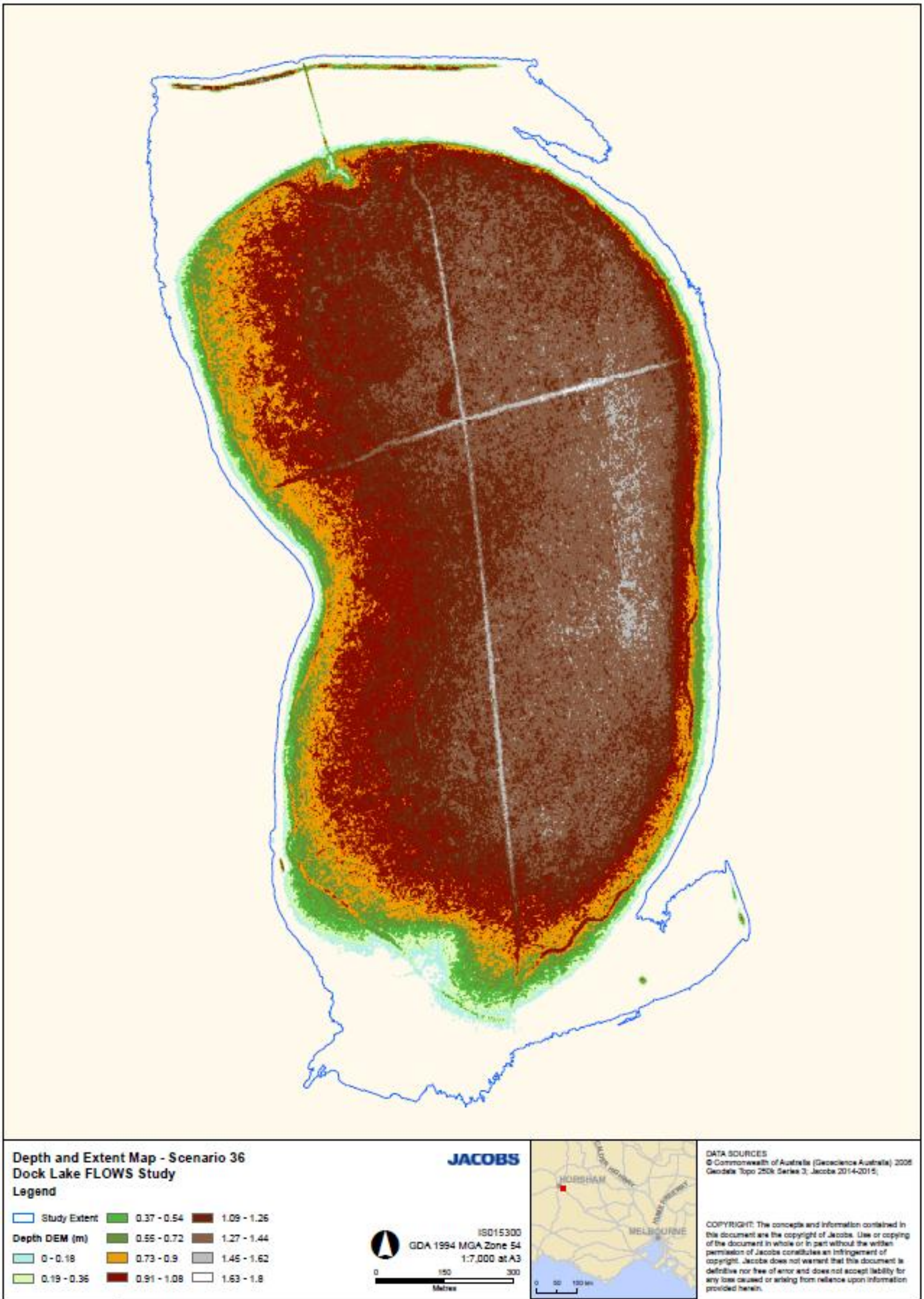
297 x 420 mm



Depth and Extent Map - Scenario 36
Dock Lake FLOWS Study
Legend
Study Extent
Depth DEM (m)
0 - 0.18
0.19 - 0.36
0.37 - 0.54
0.55 - 0.72
0.73 - 0.9
0.91 - 1.08
1.09 - 1.26
1.27 - 1.44
1.45 - 1.62
1.63 - 1.8
JACOBS
IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0
150
300
Metres
HORSHAM
MELBOURNE
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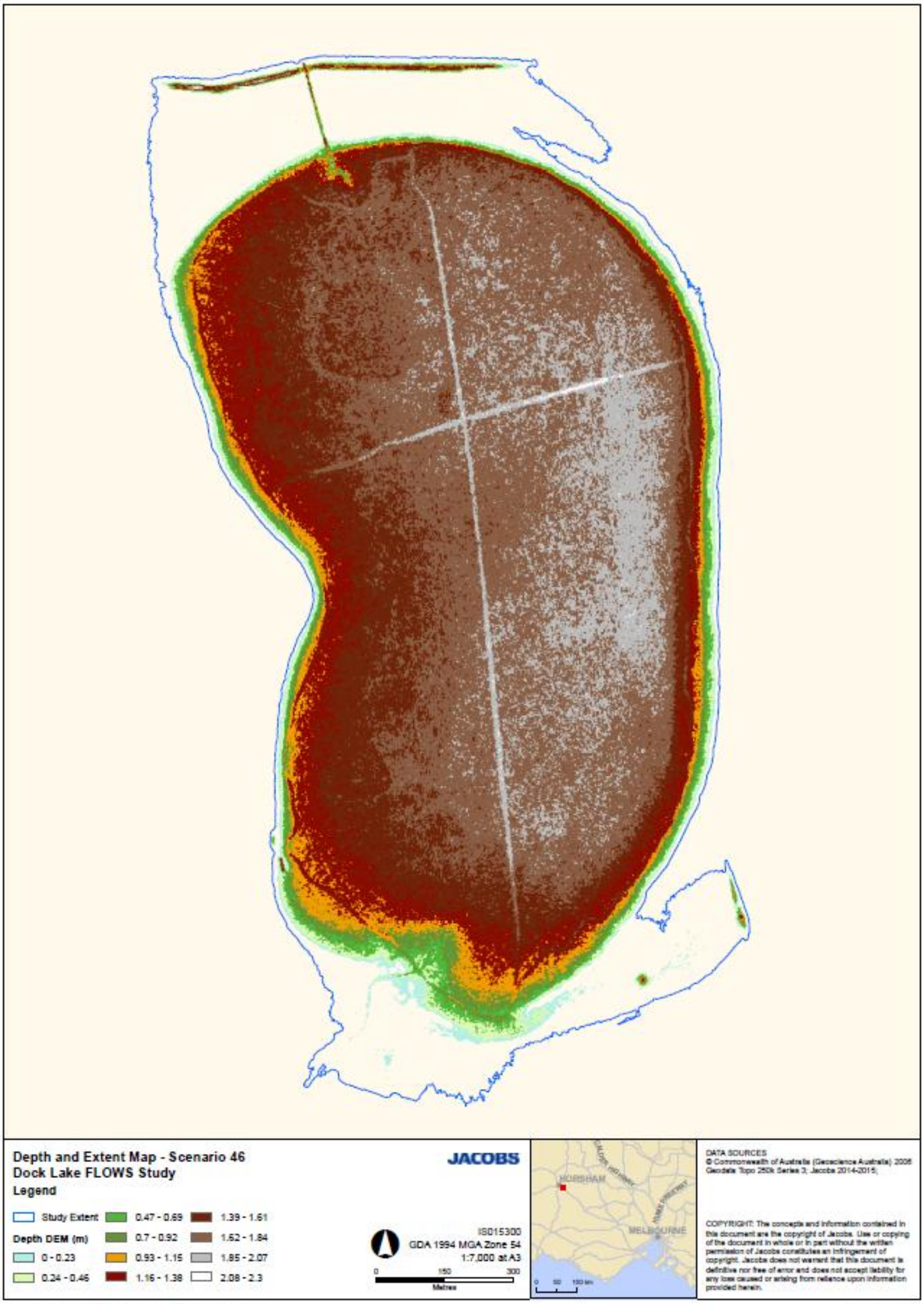
297 x 420 mm


Depth and Extent Map - Scenario 46
Dock Lake FLOWS Study
Legend
Study Extent
Depth DEM (m)
0 - 0.23
0.24 - 0.46
0.47 - 0.69
0.7 - 0.92
0.93 - 1.15
1.16 - 1.38
1.39 - 1.61
1.62 - 1.84
1.85 - 2.07
2.08 - 2.3
IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0
150
300
Metres
HORSHAM
MELBOURNE
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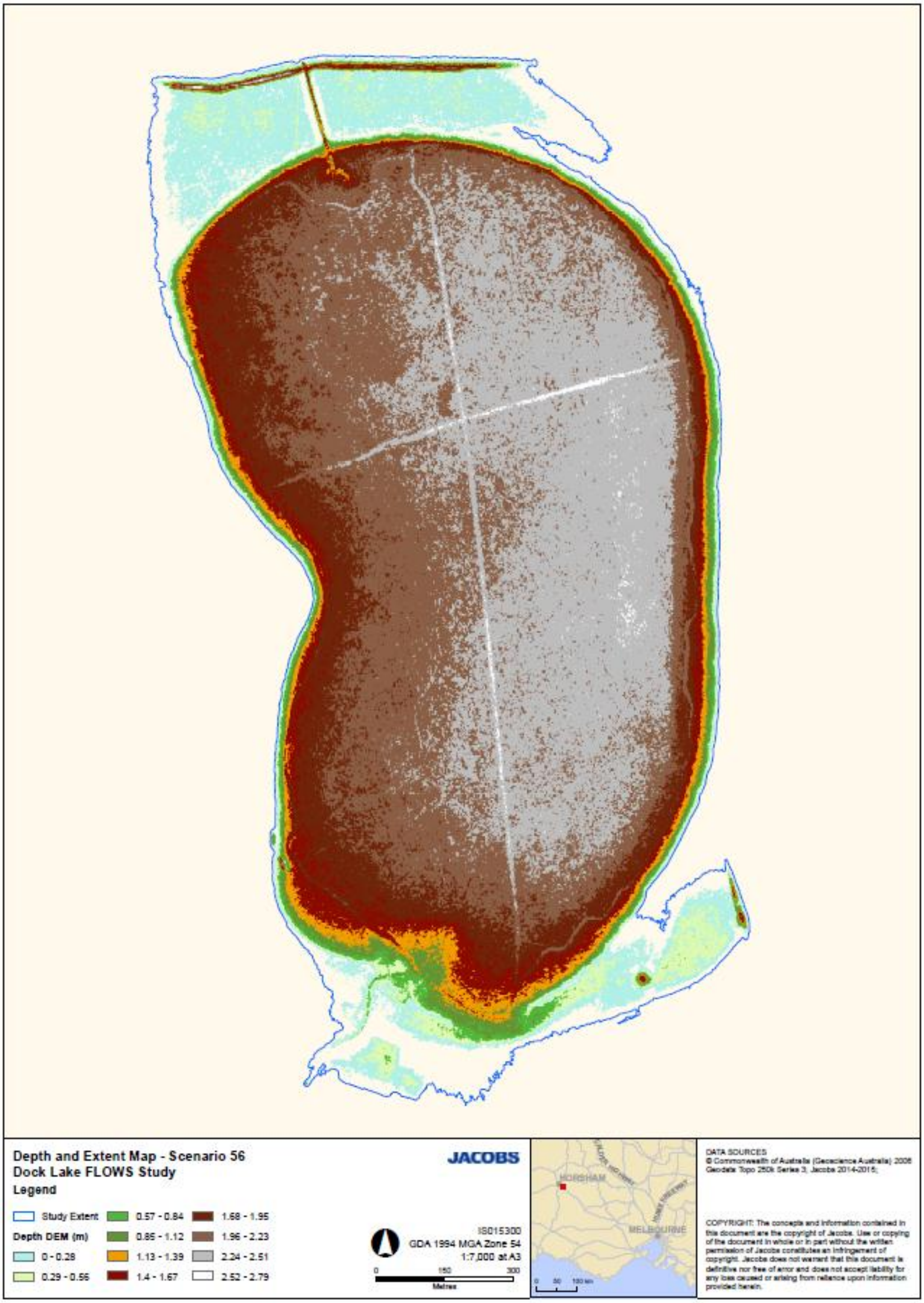
Depth and Extent Map - Scenario 56
Dock Lake FLOWS Study
Legend
Study Extent
Depth DEM (m)
0 - 0.28
0.29 - 0.56
0.57 - 0.84
0.85 - 1.12
1.13 - 1.39
1.4 - 1.67
1.68 - 1.95
1.96 - 2.23
2.24 - 2.51
2.52 - 2.79
JACOBS
IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0
150
300
Metres
HORSHAM
MELBOURNE
0
50
100 km
DATA SOURCES
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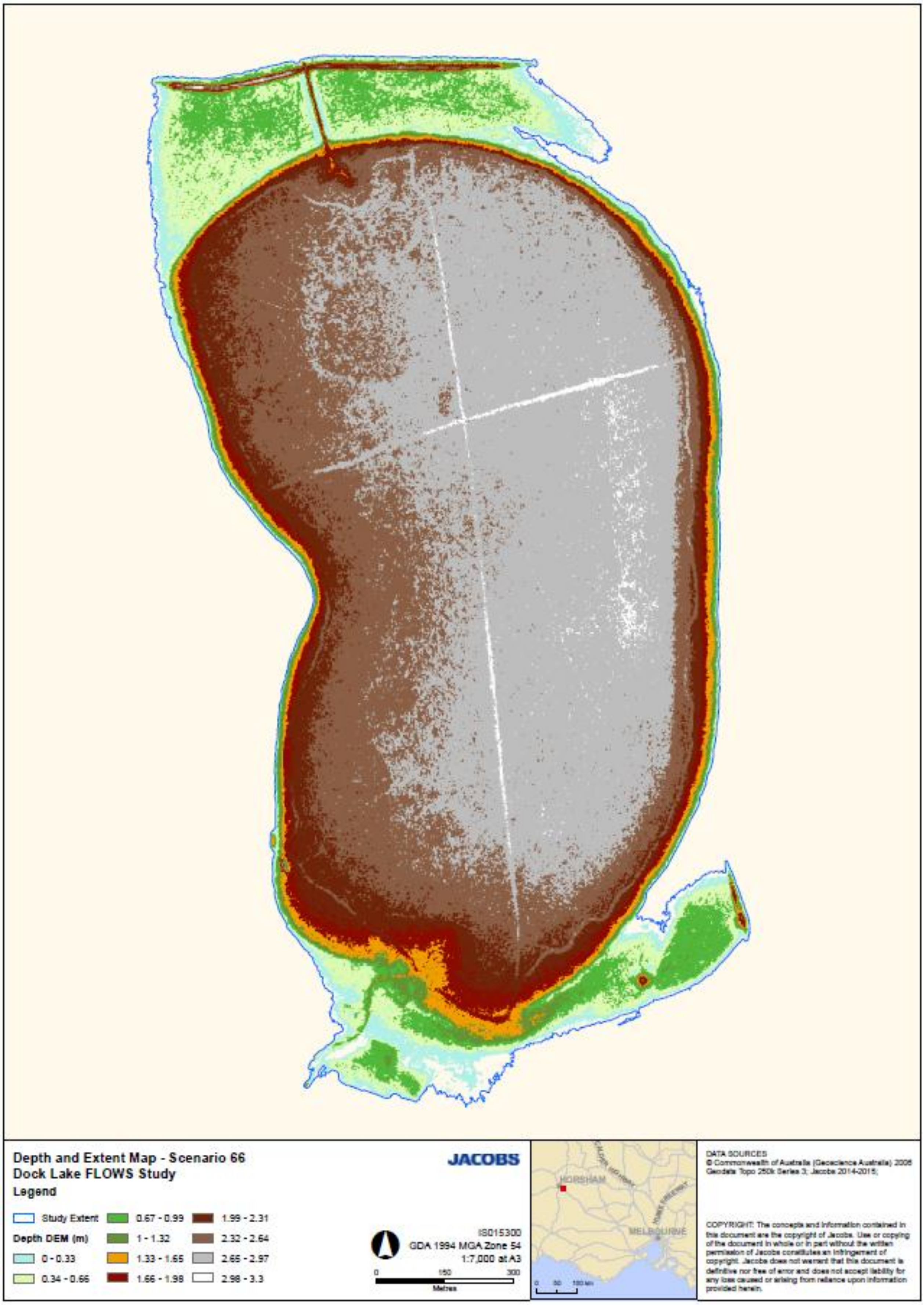
Depth and Extent Map - Scenario 66
Dock Lake FLOWS Study
Legend
Study Extent
Depth DEM (m)
0 - 0.33
0.34 - 0.66
0.67 - 0.99
1 - 1.32
1.33 - 1.65
1.66 - 1.98
1.99 - 2.31
2.32 - 2.64
2.65 - 2.97
2.98 - 3.3
JACOBS
IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0
150
300
Metres
HORSHAM
MELBOURNE
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Depth and Extent Map - Scenario 76
Dock Lake FLOWS Study
Legend

Study Extent

Depth DEM (m)

- 0 - 0.38
- 0.39 - 0.76
- 0.77 - 1.14
- 1.15 - 1.52
- 1.53 - 1.9
- 1.91 - 2.28
- 2.29 - 2.66
- 2.67 - 3.04
- 3.05 - 3.42
- 3.43 - 3.8

JACOBS

IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0 150 300
Metres

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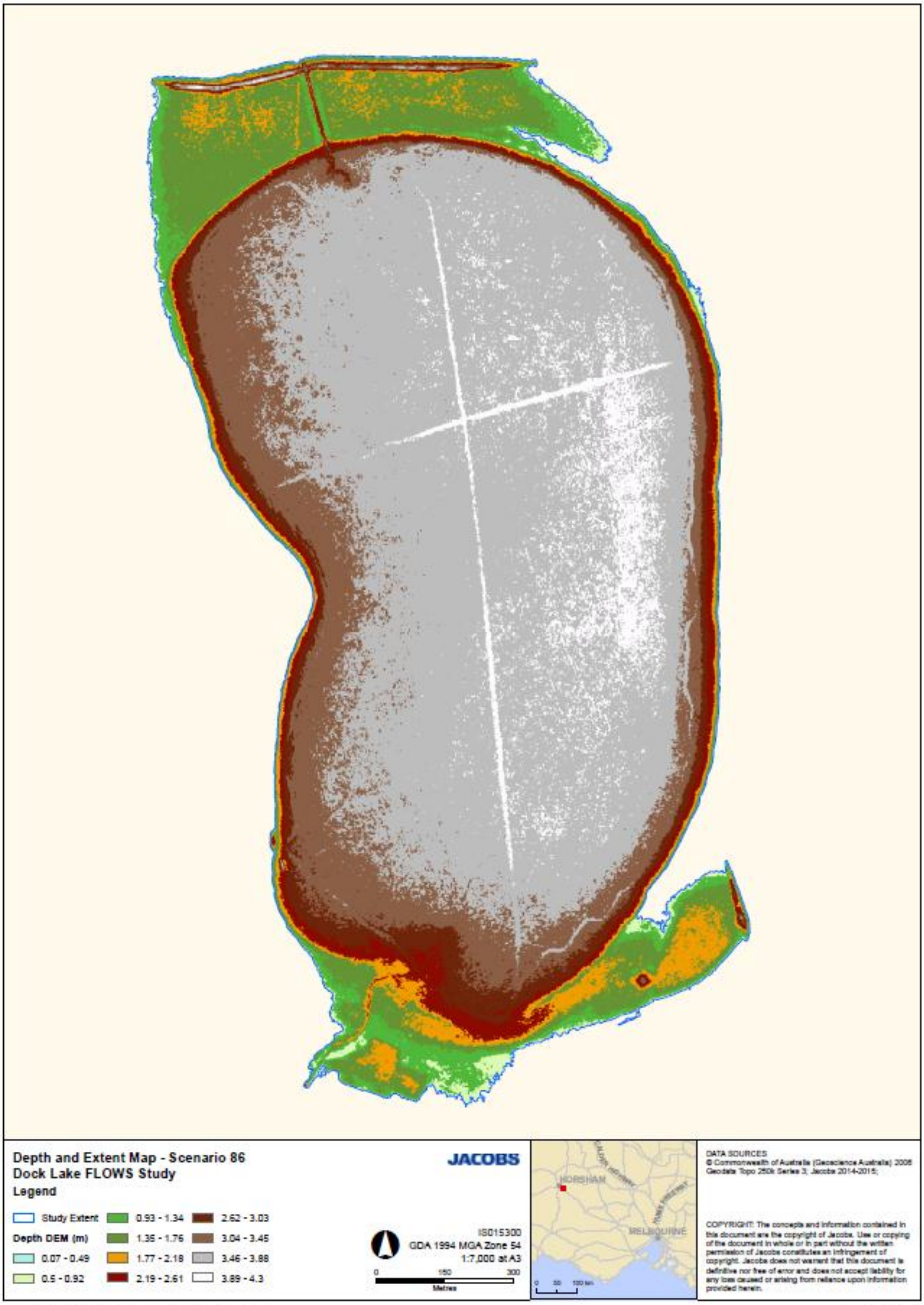
Depth and Extent Map - Scenario 86
Dock Lake FLOWS Study
Legend
Study Extent
Depth DEM (m)
0.07 - 0.49
0.5 - 0.92
0.93 - 1.34
1.35 - 1.76
1.77 - 2.18
2.19 - 2.61
2.62 - 3.03
3.04 - 3.45
3.46 - 3.88
3.89 - 4.3
JACOBS
IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0
150
300
Metres
HORSHAM
MELBOURNE
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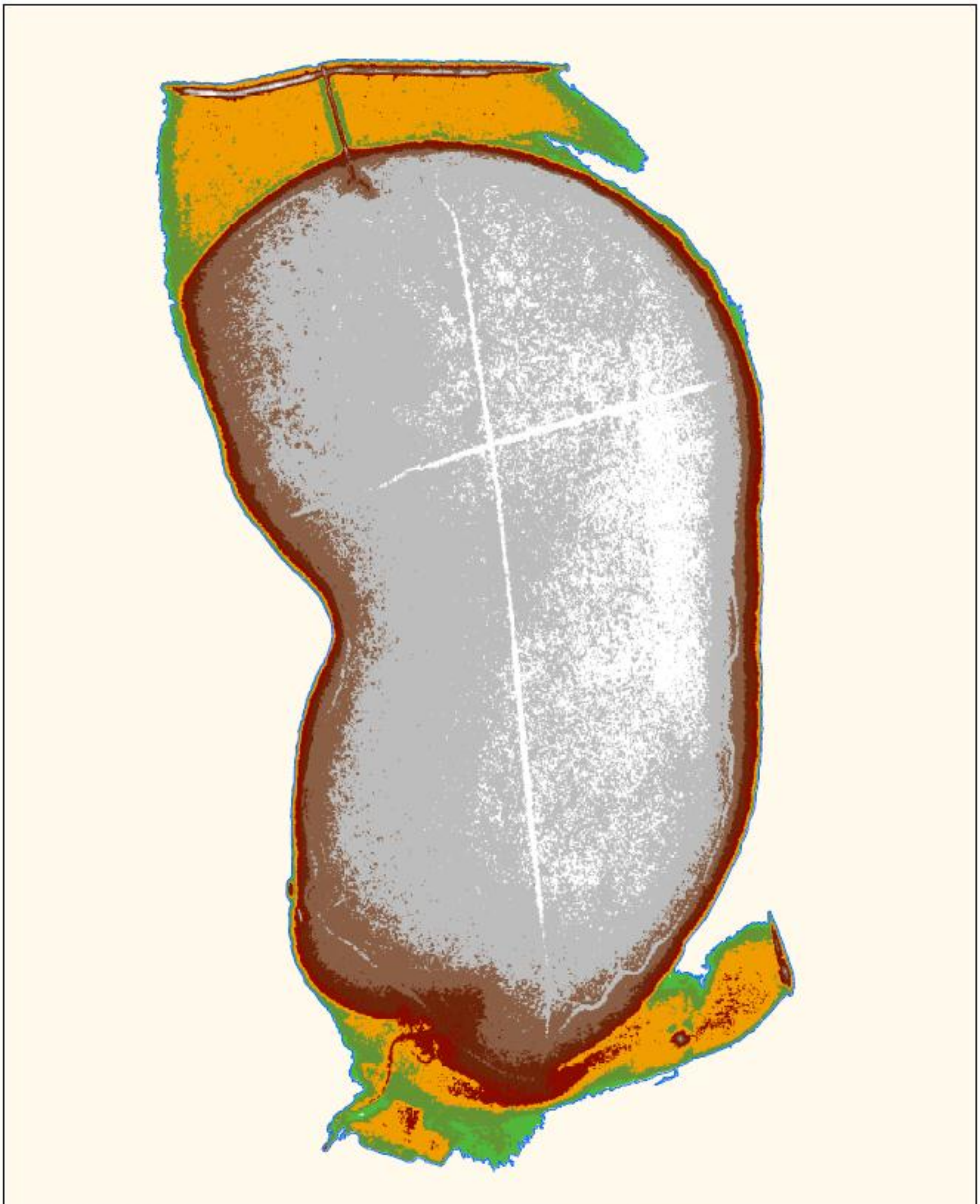

Depth and Extent Map - Scenario 96
Dock Lake FLOWS Study

Legend

Study Extent	1.01 - 1.48	2.91 - 3.38
Depth DEM (m)	1.49 - 1.96	3.39 - 3.85
0.05 - 0.53	1.96 - 2.43	3.86 - 4.33
0.54 - 1	2.44 - 2.9	4.34 - 4.8

IS015300
GDA 1994 MGA Zone 54
1:7,000 at A3
0 150 300
Metres

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