Baseline Synthesis of Ecohydrological Data for the Taratap and Tilley Swamp Watercourses, South East of South Australia

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Melaleuca halmaturorum fringing Yeulba Swamp, Taratap Watercourse
All photos taken by J. Tuck unless otherwise stated.

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EXECUTIVE SUMMARY

The Taratap and Tilley Swamp Watercourses extend across more than 60 km of inter-dune flats between Salt Creek and Kingston SE, in the Upper South East of South Australia. Covering an expanse of approximately 12,700 ha of wetland habitat and consisting of 60 % native vegetation in a largely drained and cleared landscape, the watercourses represent an extensive, regionally important area of native wetland and terrestrial vegetation.

The watercourses have undergone dramatic change, beginning after European settlement of the area (with drainage activities commencing in the 1860s) and accelerating dramatically after the Second World War, with local and regional drainage and vegetation clearance having profound impacts on hydrology and the quantity and character of wetland vegetation and associated fauna.

A major water management project in the region – the South East Flows Restoration Project (SEFRP) – is expected to trigger significant changes in hydrological conditions within the watercourses after completion in late 2018. The SEFRP aims to deliver freshwater inflows to the Coorong from the South East drainage network for the purposes of salinity management, and with its design also routing water through the Taratap and Tilley Swamp Watercourses, significant hydrological restoration of wetland habitats within Tilley Swamp is anticipated. Hence the project is aiming to recover some of the ecological values that would once have been associated with such a large, reliable, continuous area of wetland habitat, situated in close proximity to other significant wetlands in the region (such as the Coorong and the terminal wetlands of the northern Bakers Range Watercourse).

This document presents both a review and baseline of ecohydrological information for the Taratap and Tilley Swamp Watercourses, with a focus on wetland habitats within the SEFRP study area. It incorporates historical information about the natural history of the area, the sequence of drainage, environmental change and historic flora and fauna records. Historic satellite imagery is used to map surface water and recreate historical hydrographs for three key wetlands within the watercourses since 1987. Historic aerial imagery is also analysed to broadly track vegetation response across the watercourses since 1954.

Previous ecohydrological monitoring is summarised, with a focus on SEFRP-initiated ecological monitoring of vegetation, fish, frogs and waterbirds. Broad trends are identified, and to track the impacts of the SEFRP, previous ecohydrological monitoring is summarised and monitoring recommendations are presented.

The current ecological state is that of an altered but ecologically valuable area, incorporating large areas of remnant vegetation and wetlands, and retaining significant vegetation communities and flora and fauna species. Analysis of satellite (Landsat) imagery shows decreased inundation of wetlands since 1987. There have been marked changes in vegetation communities, with invasion of terrestrial species into wetland basins, visible in analysis of historic aerial imagery and verified in on-ground wetland monitoring.

Most notably, the wetland has dramatically shifted in hydrological character. Tilley Swamp was originally a large, relatively deep and (once full) mostly static waterbody, where much of the inland

surface waters of South East accumulated (behind high sill levels at Morella Basin and Martins Washpool) prior to periodically overflowing, when full, into the Coorong via Salt Creek. When this occurred, a vast sheet of water several tens of kilometres long was formed; stretching south from Morella Basin and providing a wide range of highly connected aquatic habitats that supported a diversity of species of flora and fauna. This wetland was complementary to the nearby Coorong which is more saline in character and does not provide the same breeding opportunities for many species.

However as a result of artificial drainage, both via artificial deepening of Salt Creek and within Tilley Swamp itself, combined with the gradual upstream diversion of inflows, in recent decades most of the SEFRP study area has experienced ongoing water stress. Hence, the key findings of this review include:

- A long term drying trend, confirmed by analysis of surface water.
- A vegetation response has been detected in response to those drier conditions in wetlands within the study area, with terrestrial vegetation communities moving down the elevation gradient of wetlands and displacing residual open aquatic habitats and wetland vegetation.
- More deeply inundated conditions at Morella Basin after the Upper South East Dryland Salinity and Flood Management Program (USE Program) began diverting and holding some saline groundwater drainage inflows in the basin have largely reversed the terrestrialisation process in that sole wetland feature, providing an indication of the potential response of those wetlands anticipated to receive greater inundation post-SEFRP.
- Recent improvement of fish populations across the SEFRP area, noting that there is an absence of detailed fish monitoring data prior to the year 2000, which means that no data on the original (pre-drainage) fish assemblages of the study area are available for comparative analysis.
- As for fish, frog records in the post-drainage era are sparse, but indicate salinities in parts of the watercourses to be unsuited to common freshwater frogs. However, records may also be influenced by the timing of ecological surveys, which have generally occurred late in the year, but also decades after major freshwater flows from the lower South East into the study area were interrupted.
- Waterbird presence across inundated wetlands is expected to increase over time, with improved wetland hydrology (i.e. increased depth and duration of inundation) post-SEFRP, however waterbirds are largely responsive to wider environmental conditions in south-eastern Australia which are likely to significantly influence survey results in any given year.

With this context in mind, and although the SEFRP will not precisely replicate historical conditions (e.g. water quality), it will greatly improve on the modern ecohydrological regime of the northern end of Tilley Swamp (in particular) within the SEFRP study area. Assuming that Tilley Swamp regularly fills to its restored design elevation of 5.4 m AHD, which is recommended, it will almost match the original watercourse sill (5.5 m AHD at Martins Washpool), providing a 'cease to flow' depth, extent and duration of inundation in the northern watercourse broadly similar to pre-development conditions.

The information in this report is intended to provide a comprehensive baseline that future ecohydrological changes, in response to the new watercourse conditions, can be measured against. In turn, this will inform future management and provide an objective set of parameters for eventual evaluation of project success.

TABLE OF CONTENTS

1. Project context

1.1. *Project background*

The Taratap and Tilley Swamp Watercourses are located in the Upper South East of South Australia, between Taratap Road in the south and Salt Creek in the north. The watercourses feature approximately 12,700 ha of wetland habitat, all of which is reliant upon inflows of fresh-brackish water from the South East drainage network to maintain ecological values. The watercourses flow in a north-westerly direction and typically occur on the western side of flats bound by low, parallel ranges to the east and west. The two names essentially describe the continuation of the same watercourse (also historically called Reedy Creek) with the name Taratap Watercourse given to the section between Taratap Road and Henry Creek Road, and Tilley Swamp Watercourse used from Henry Creek Road to Salt Creek.

1.1.1 Hydrology

Prior to European colonisation, the watercourse received surface runoff from a catchment comprising a large portion of the South East of South Australia and extending into western Victoria (SEDB 1980). Regular, extensive and, in some locations, deep inundation occurred and the vegetation and ecological character of the watercourse reflected that water regime. Typically for the South East, the low gradient of the watercourse meant that no clearly defined river-style channels existed across much of the region, with the exception of a few locations through ranges like Blackford and Henry Creek, and at the terminus of Tilley Swamp into the Coorong at Salt Creek. Instead, water mostly moved slowly through extensive, shallow wetlands which filled and spilled in sequence, frequently causing extensive inundation of associated floodplains in the process. Surface flows into the Coorong occurred via Salt Creek when water levels exceeded natural sills at the northern end of Morella Basin (see Section 3.1). Although historic Salt Creek inflow volumes have not been accurately quantified to date, it is clear from the evidence presented (referenced in Section 3.1) that they were highly variable and episodic.

From the 1860s onwards, engineered drainage at the regional and local scale, undertaken to improve the agricultural viability of the country, profoundly changed the hydrology of the watercourse. Regional scale drainage greatly reduced the size of the catchment and consequently reduced the volumes of water entering the watercourse. In more recent decades, flows entering the watercourse at the south were directed to sea by the Blackford Drain, completed in 1964 (SEDB 1980). Local scale drainage also affected watercourse flows. The Taratap and Tilley Swamp Drains were completed in 2006 and 2000 respectively as part of the USE Program. The drains are located to the east of the watercourse and intercept both surface and groundwater that would otherwise enter the watercourse from flats to the east, taking this water north into Morella Basin, the terminal wetland of the system, where it has since been released (below the historic sill level) into the Coorong via Salt Creek. The USE Program provided the capacity to maintain some runoff and direct local drain flows into the Taratap Watercourse for ecological purposes, and wetlands in this area have received regular inundation since 2006, albeit much reduced from pre-drainage water levels. However, no such capacity was provided for the Tilley Swamp Watercourse downstream of Tilley Swamp Conservation Park, and consequently the greater part of the Tilley Swamp Watercourse has been almost permanently dry since 2000 (see Section 4.2).

1.1.2 Vegetation

Vegetation clearance for agriculture has been extensive in the South East, with 87% of the region's native vegetation cleared (Croft et al. 1999). In this regard, the Tilley Swamp Watercourse is exceptional in that it remains largely undeveloped and lies adjacent to large remnant areas of uncleared terrestrial vegetation, that in some cases are also in close proximity to other large remnants. This area of high remnancy was recognised as a "Key Biodiversity Area" and referred to as the North West District in the *Biodiversity Plan for the South East of South Australia* (Croft et al. 1999).

Despite the intactness of surrounding terrestrial habitats, the vegetation of the Tilley Swamp Watercourse has changed dramatically as a consequence of reduced frequency, depth, duration and extent of inundation. In particular, open herblands, that supported extensive beds of aquatic plants when inundated, have been displaced by *Melaleuca halmaturorum* shrublands that are less tolerant of inundation, a process referred to as terrestrialisation. While *M. halmaturorum* shrublands are native and support other native species, their encroachment into wetlands represents a substantial loss of feeding and breeding habitat for waterbirds, including migratory shorebirds and waterfowl, and a loss of habitat for aquatic biota generally.

1.1.3 South East Flows Restoration Project

The Millennium Drought (1996 – 2010) contributed to reduced flows in the Murray-Darling Basin and a period of no flow from the River Murray into the Coorong between 2006 and 2010. With freshwater inputs limited to the relatively small inflows from the South East via Salt Creek and direct rainfall, evaporative loss from the surface of the Coorong was replaced largely by seawater via reverse flows at the Murray Mouth (sensu Webster 2005). As a consequence, salinity in the Coorong increased dramatically. At its peak in 2009, salinity exceeded 170 g/L across the entire South Lagoon and exceeded 200 g/L in some locations (Mosley et al. 2017), greatly exceeding the tolerances of many species important to the ecological character of this Ramsar site (Lester et al. 2011, Phillips and Muller 2006). In response, the ecosystem of the Coorong, and of the South Lagoon in particular, is now considered to be highly degraded (e.g. Kingsford et al. 2011, Paton 2010).

One management response, commencing in 2007, was to investigate the potential for increased freshwater inflows to the Coorong from the South East drainage network. The project, which became known as the South East Flows Restoration Project (SEFRP), went through extensive feasibility, community and Traditional Owner engagement, business case development, and design and construction phases and was due for completion in late 2018. The SEFRP will enable flows in the Blackford Drain to be diverted into a new floodway, connecting to the existing Taratap and Tilley Swamp Drains, to ultimately be delivered to the Coorong via Salt Creek. Modelling indicates the SEFRP will increase the volume of water available for release into the Coorong, if required for salinity management, from 29.4 to 55.3 GL/yr (average, historic climate) (Whiting 2017).

Under the SEFRP, issues surrounding the ability to pass flows through the Tilley Swamp Watercourse *en route* to the Coorong have been resolved. Thus, in addition to the Taratap Watercourse, diversions into the Tilley Swamp Watercourse will be possible. Watercourse flows will be prioritised over flows in the upgraded Tilley Swamp drain when salinity reduction in the Coorong South Lagoon is not an immediate priority. Thus, the SEFRP is anticipated to achieve a degree of hydrological restoration of the Tilley Swamp Watercourse, with consequent ecological recovery likely. Inflows to the Taratap Watercourse are also anticipated to increase.

1.1.4 The need for an ecohydrological baseline

While increased water availability for the Coorong is the primary objective of the SEFRP, the provision of ecohydrological benefits for the *en route* wetland habitats of the Taratap and Tilley Swamp Watercourses is an important secondary objective, and was one of the reasons that this alignment was originally chosen for the project (as per Farrington 2010). A reversal of terrestrialisation and an improvement to the condition of aquatic habitats is anticipated. Increased diversity and abundance of wetland-dependent biota is likely. A pre-SEFRP baseline ecohydrological characterisation is therefore required to enable future progress towards this objective, and deviation from its current ecological state, to be accurately measured.

1.2. *Scope of this report*

This baseline synthesis characterises the ecology of the Taratap and Tilley Swamp Watercourses with an emphasis on vegetation, waterbirds, fish and frogs. Previously collected monitoring data have been used to provide a quantitative baseline against which to compare future changes at representative locations. A broader scale description of the area and long-term trends relating to vegetation and inundation has been obtained by review of relevant previous studies and interpretation of historic aerial photography and satellite imagery. The resultant ecological characterisation of the study area will form an important baseline against which to compare future changes anticipated under the SEFRP.

Specifically, this report:

- Summarises quantitative vegetation, waterbird, fish and frog data collected in the Taratap and Tilley Swamp Watercourses in 2011, 2012, 2016 and 2017.
- Reviews previous reports to provide a comprehensive list of flora and fauna species, including introduced species, currently present in the Taratap and Tilley Swamp Watercourses. A summary of the distribution and abundance of vertebrate fauna species within the study area is also included.
- Provides maps of the vegetation of a 19,500 ha area of the Taratap and Tilley Swamp Watercourses (Figure 1), currently and historically, and identifies trends in broad vegetation types. Ortho-rectified historical aerial imagery from 1954, 1966, 1978, 1987, 1999 and 2013 has been interpreted for this purpose.
- Provides commentary on long-term inundation trends in watercourse areas based upon mapping of inundation from remotely sensed imagery (Landsat satellites) via the Australian continental scale Water Observations from Space (WOfS).
- Makes recommendations relating to the detection of future ecological changes, particularly for vegetation, waterbirds, fish and frogs, in the context of the completion of the SEFRP.

1.3. ***Study area***

The SEFRP study area covers the Taratap and Tilley Swamp Watercourses, roughly between Taratap Road in the south and Salt Creek in the north (Figure 1), approximately 60 km in length and between 1.4 km and 5.5 km in width, and covering 19,514 ha in total (Figure 1).

Figure 1 – SEFRP study area

2. Description of Tilley Swamp

2.1. *Geology, soils and climate*

The Taratap and Tilley Swamp Watercourses are situated within the Naracoorte Coastal Plain bioregion, a distinctively flat coastal plain formed over limestone deposits laid down when the area was subject to inundation by the ocean. Consolidated sand dunes were formed by a gradual uplift of the coastal plain that elevated and left isolated coastal barriers from successive sea level maximums (Bourman et al. 2016).

These stranded dunes run parallel to the coast and prevent easy passage of water to the ocean. Prior to drainage, up to 45 % of the South East was subject to permanent or seasonal flooding (Harding 2007), largely attributable to the lack of any significant rivers or creeks running to the ocean despite high rainfall and large amounts of standing water. Instead, slow-moving flows move north-west along a shallow gradient via surface flows and groundwater expression or movement, inundating wetland and floodplain habitat along the way, and reaching their natural terminus at Salt Creek.

Elevation variations are low, ranging from roughly sea level in wetland basins up to approximately 50 metres at the highest point. In the Tilley Swamp Watercourse, calcarenite dunes form barriers to the east and west, with soils comprising shallow loamy sands to loams over calcrete, or deep sands. The soils of the flats and wetlands range from shallow to moderately deep calcareous sandy loams to loams, overlying calcrete and the clays of the swamps (DEWNR 2018). The Taratap Watercourse shares the same consolidated dune barriers to the east and west, while soils on the flats and lagoons are mostly black to clay loams over calcreted limestone. Wet saline and sodic soils have been considered problematic for agricultural activities after development and drainage occurred throughout both watercourses (DEWNR 2018, Merry and Fitzpatrick 2005).

The study area experiences a Mediterranean climate, with warm, dry summers and cool wet winters and a mean annual rainfall of just under 500mm (BoM 2018). The nearest reliable long-term weather data is from Meningie (Figure 2).

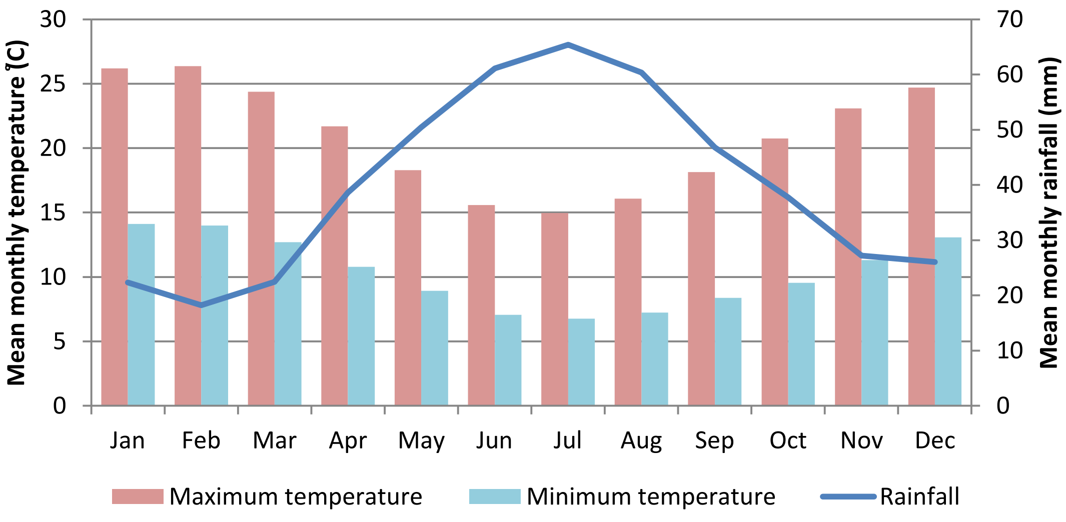


Figure 2 – Mean monthly temperature and rainfall at Meningie, 1987-2017 (Bureau of Meteorology)

2.2. *Current land use and land cover*

Alongside extensive artificial drainage, the South East of SA has also been largely cleared for agriculture (Croft et al. 1999). In the Taratap and Tilley Swamp Watercourses, higher areas and well-drained flats are generally cleared and grazed, but many areas more prone to inundation and/or with inherent elevated levels of soil and groundwater salinity, were left partially or fully intact (Figure 3).

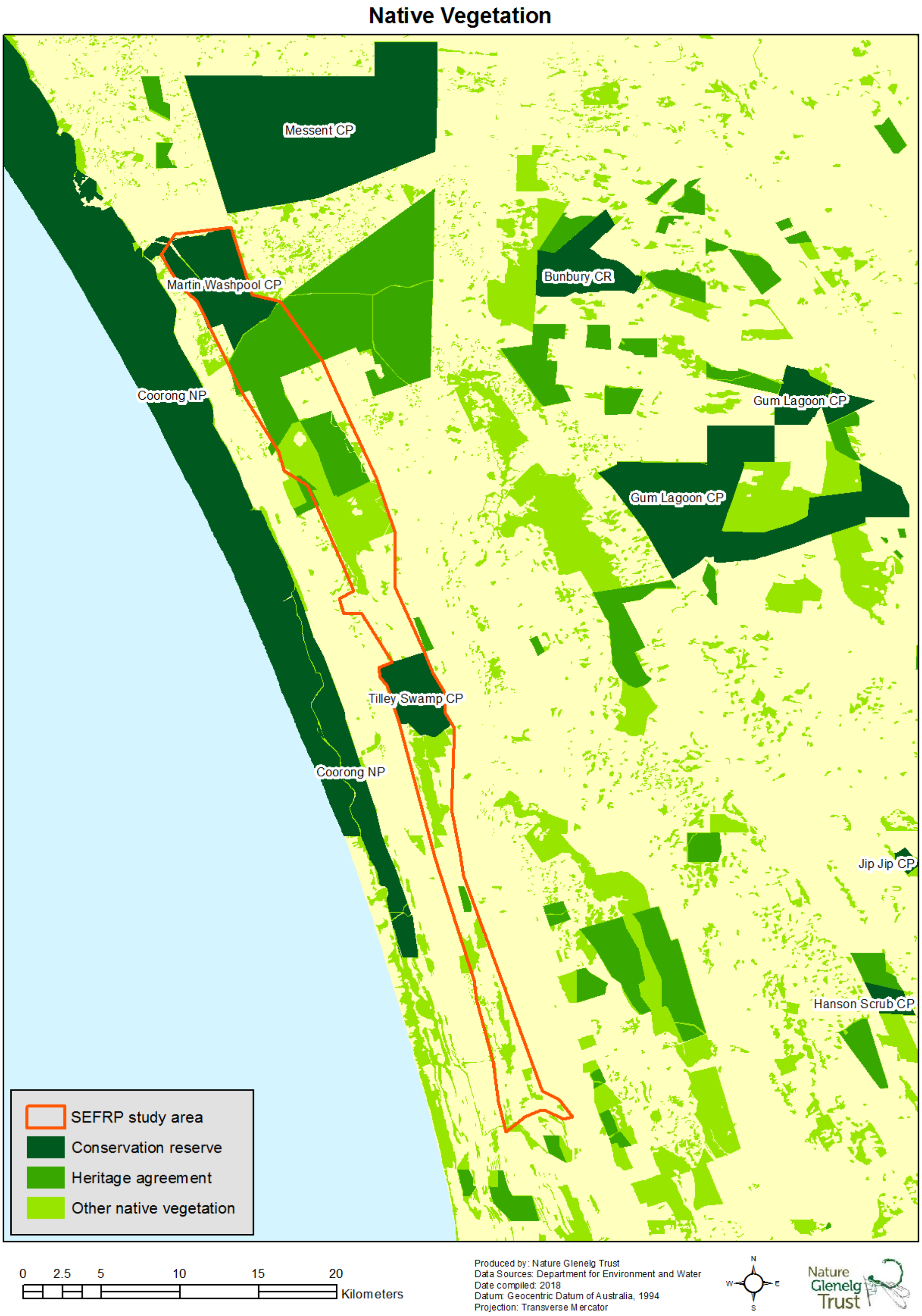


Figure 3 – Conservation status and native vegetation cover

As a result, a large proportion of remnant native vegetation remains, with conservation parks, Heritage Agreements and other native vegetation totalling approximately 60 % of the SEFRP study area (Table 1), which is one of the highest levels of remnancy for any drained watercourse in the South East. The remaining cleared land is sparsely populated and mostly used for agriculture, with easements (drainage channels and roads) also being a significant land-cover category (Jacobs and DEWNR 2016).

Table 1 – SEFRP study area land use

Land use	Area (ha)	% of study area
Conservation park	4,336.8	22.2
Heritage agreement	3,784.3	19.4
Other native vegetation	3,645.7	18.7
Cleared (agriculture/infrastructure)	7,747,1	39.7
Total	**19,513.9**	**100**

2.2.1 Native vegetation

Today, the Taratap and Tilley Swamp Watercourses contain large areas of remnant terrestrial native vegetation where it was not cleared for agriculture, including Tilley Swamp Conservation Park, Martin Washpool Conservation Park and other large Heritage Agreements and patches of vegetation. Remnant vegetation has typically been subject to varying levels of disturbance or degradation, or change in character as a result of drainage, noting that most areas were previously also utilised to varying degrees for pastoral grazing activities for a period after the 1840s.

Tilley Swamp Conservation Park (1,515 ha)

In roughly the middle of the study area, Tilley Swamp Conservation Park encompasses a large wetland (a 1,077 ha deeper area within the formerly more extensive and continuous Tilley Swamp), along with smaller wetlands and remnant terrestrial vegetation. The land on which Tilley Swamp Conservation Park now lies was previously used for seasonal grazing, before a clearance permit application by the owner was refused in the 1980s. Under the compensation provisions of the legislation in place at the time (*Native Vegetation Management Act 1985*), this prompted its private registration as a Heritage Agreement and later led to its purchase by the government and designation as a Conservation Park in 1993 to 'conserve remnant vegetation associations' (DEHAA 1999).

Martin Washpool Conservation Park (2,851 ha)

At the northern end of the study area, Martin Washpool Conservation Park encompasses a large wetland (Morella Basin – 858 ha), numerous smaller wetlands, and remnant and recently revegetated terrestrial vegetation. The first (eastern – 1800 ha) portion of the Park was dedicated in 1969, and an additional portion of Morella Basin was strategically purchased as part of the USE program in 1998, before being incorporated into Martin Washpool Conservation Park in 2005. The basin, which had been significantly altered from its pre-European state since the first cutting into Salt Creek in 1864, now receives saline groundwater collected by the Tilley Swamp drain from other parts of the Upper South East network, and allows flows to be held before release into the Coorong via Salt Creek (Bachmann 2014).

Heritage Agreements

A large area of land is protected under various Heritage Agreements and date from the era (under legislation from 1985-1991, the *Native Vegetation Management Act 1985*) when native vegetation laws came into effect and areas refused for clearance could be set aside with compensated agreements. These are mostly situated north of Henry Creek Road. Significant Heritage Agreements include the stations of Stoneleigh Park, Banff and Safari, situated in the area between Tilley Swamp CP and Martin Washpool CP. South of Tilley Swamp CP and within the SEFRP study area, only one 83 hectare area is protected under Heritage Agreement, in the Taratap Watercourse.

Other native vegetation

The watercourses retain significant patches of native vegetation that are outside the formal Protected Area system. Notable areas include more than 2,000 ha of relatively intact terrestrial vegetation and wetland immediately north of Cantara Road, around 650 ha of extensive but degraded native vegetation between Tilley Swamp and Henry Creek Road, and patches of variable quality vegetation covering more than 700 ha, adjacent to Pataenbury, Varcoe, Englands and Yeulba swamps on the Taratap Watercourse. Other patches of native vegetation – often degraded *Melaleuca* shrubland – remain scattered through the watercourse.

Revegetation

Over the past 15 years, more than 500 ha of terrestrial and wetland fringe vegetation has been planted to the north and west of Morella Basin in Martin Washpool CP, across public and private land. The private land component is owned by Wetlands and Wildlife. This bolsters habitat connectivity between the Coorong NP, Martin Washpool CP and remnant vegetation to its south and east, including Heritage Agreements and Messent CP.

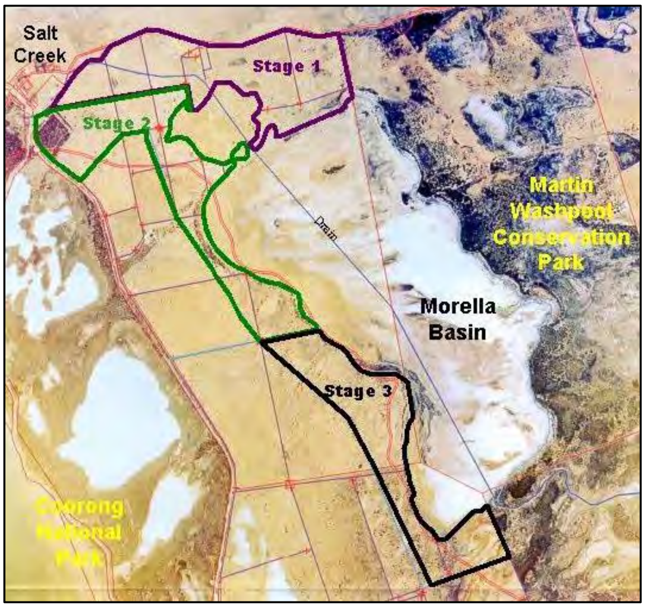


Figure 4 – Before and after images of the 535 hectare area around Morella Basin revegetated in three 'Stages' – Stage 1 in 2001, Stage 2 in 2002 and Stage 3 in 2003. Additional areas revegetated by Wetlands and Wildlife are situated in the area between Stage 2 and 3 and the Coorong National Park. Image left from Stokes (2008), image right from Google Earth (taken 16th Nov 2018).

Surrounding native vegetation

The vegetation in the watercourses forms an important component of a large remnant area that also takes in the Coorong National Park (48,975 ha), 500 metres to the west of the study area, Messent Conservation Park (11,583 ha) less than 1 km to the north east, and Gum Lagoon Conservation Park (8906 ha) and Bunbury CR (1,944 ha), both within 15 km to the east. Large Heritage Agreements are also adjacent, with the Bonneys Camp Heritage Agreement (7,021 ha) contiguous with Martin Washpool CP. Additional substantial tracts of native vegetation remain on private land in the West Avenue and Bakers Range Watercourses. Combined, the area retains one of the largest areas of remnant vegetation in the Upper South East, identified as one of five priority remnant areas in the *Biodiversity Plan for the South East of South Australia* (Croft et al. 1999).

2.2.2 Wetlands

Prior to drainage, all of the low-lying land on the Taratap and Tilley Swamp watercourses was subject to inundation (Figure 5), noting that on the Taratap flats, this DEW mapping significantly underestimates the original wetland extent on the flats to the east of the project area. Seventy-six wetlands have been mapped within or partially within the SEFRP study area (Table 2), with a pre-European coverage of approximately 12,700 ha. However, as will be explored in later section, the entire system could function as a contiguous wetland feature in major inundation events, noting that modern mapping in very flat systems like this is often simply shaped by landscape modifications or artificial features that separate polygons such as drains or roads.

Table 2 – Summary of wetland sizes in study area, based on current DEW mapping

Wetland size (ha)	No. of wetlands
0-10	36
10-50	18
50-100	7
100-500	7
500-1500	8
Total	**76**

Wetland condition is variable and is largely influenced by drainage, vegetation clearance and agricultural practices. The current ecological value of many wetlands – including all 500-1500 ha wetlands – has been assessed by DEW (section 5.1.1). Wetlands across both watercourses have been subject to a long-term terrestrialisation process due to changes in hydrology; these changes in wetland vegetation density over time are quantified through analysis of historical imagery in Section 4.1.

Figure 5 – Pre-European wetland extent

2.2.3 Agriculture

Cleared agricultural land is dominated by cattle and sheep grazing, while plantation forestry, irrigated agriculture and cropping – large components of land use in other areas of the South East – are minimal. This is a reflection of lower natural productive capacity of the land, reflected in the soil types and saline groundwater, and its propensity (even in the presence of drains) to experience seasonal brackish inundation.

3. Tilley Swamp ecohydrology prior to 1954

3.1. *Indigenous occupation*

Prior to European occupation, the Ngarrindjeri people inhabited an area that stretched from Cape Jervis to Lacepede Bay (near Kingston SE), including the Taratap and Tilley Swamp watercourses (O'Connor 1994, Tindale 1974). The effect of colonialisation on indigenous life in the South East roughly followed patterns seen in other parts of Australia, including conflict between Aborigines and colonialists, displacement and dispossession and the erosion of traditional ways, documented in a number of sources, including those listed in Clarke (2015a).

Ngarrindjeri native title has been recognised for part of the land stretching from just north of Morella Basin, all the way north west to Cape Jervis, including both coastal and inland areas and encompassing the Lower Lakes and Murray Mouth; another native title claim further south encompasses almost the entirety of the land containing the SEFRP study area, but has yet to be determined (Department of the Premier and Cabinet 2019).

A lack of detailed studies on indigenous life in the South East limit current understanding of how the watercourses were used, however it is generally recognised that wetlands and watercourses strongly influenced subsistence strategies in the region (Clarke 2015b). Water stretched across the flats of the Upper South East through the wetter months and restricted camp locations to higher ground, from which food resources such as fish, waterfowl and bulrush (*Typha* sp.) rhizomes could be exploited (Pretty et al. 1983). Wetlands also provided materials for construction of tools, with rushes heavily utilized for weaving fish and other animal traps and constructing baskets for transportation of food. As a result of the abundant resources found in wetland areas, Indigenous people could remain in a smaller geographic area across the year, compared to more nomadic strategies in arid districts (Clarke 2015b).

While sparse records of indigenous usage of wetlands exist for the region, some specific locations are recorded, such as the northern end of Rushy Swamp just north of Kingston, where Aboriginal people set basketware traps along the Reedy Creek watercourse to catch fish as it left the swamp (Tindale, cited in Clarke (2015a)).

Although outside the scope of this project, it is strongly recommended that further work be completed to capture the indigenous stories and ecological knowledge of the project area, including the collection and synthesis of oral histories. Such a body of work would strongly complement the eco-hydrological and scientific information from other sources presented in this report.

3.2. *European history of Tilley Swamp and Reedy Creek*

Tilley Swamp is named after William Tilley, who took out the first pastoral occupation licence for the area first known as 'Miserable Creek' (an early name for Henry Creek) on 22 April 1847. Later, on 1 July 1851, this became pastoral lease no. 199, which he called 'Tilley's Swamp'. William Tilley sold the lease in 1854, which was held by a succession of different lease holders until eventually being resumed by the government for closer settlement in approximately the late 1870s.

This lease however did not encompass what we consider Tilley Swamp today, as shown in Figure 6.

Figure 6 – Map of the pastoral runs north of Kingston (Lacepede) from the 1850s and 1860s. William Tilley's original lease (199), covered the Taratap Flat between Blackford Creek and Henry Creek. Lease 493 and 778, held by James Foot(e), covered the stretch between Henry Creek and Salt Creek.

What soon became known as Tilley Swamp, the northern portion of the immense sheet of largely static water that (when full or overflowing) extended all the way from Salt Creek in the north to the Henry Creek crossing in the south (and, while receiving inflows, often for several months of the year, to Blackford Creek and beyond), fell largely within the leases of James Foot(e).

William Tilley established the first accommodation house for overland travellers in the area near where the two runs met, on the West Avenue Range at the Henry Creek crossing, later replaced by Batten's/Batton's Accommodation House nearby, on the opposite (western or coastal) side of Tilley Swamp.

Before exploring the early maps and accounts in more detail, it is worth noting that the names of geographical locations have evolved over time for what we now describe as Tilley Swamp and the Taratap Watercourse.

Prior to artificial drainage, early accounts considered Tilley Swamp to simply be the continuation or terminus of the Reedy Creek Watercourse, which commenced in the lower South East, and found its way into Tilley Swamp via the Blackford Creek.

As can be seen in Figure 7, Reedy Creek is for much of its length (in the lower South East) a narrow flat bounded by the Reedy Creek Range to its west and the West Avenue Range to its east.

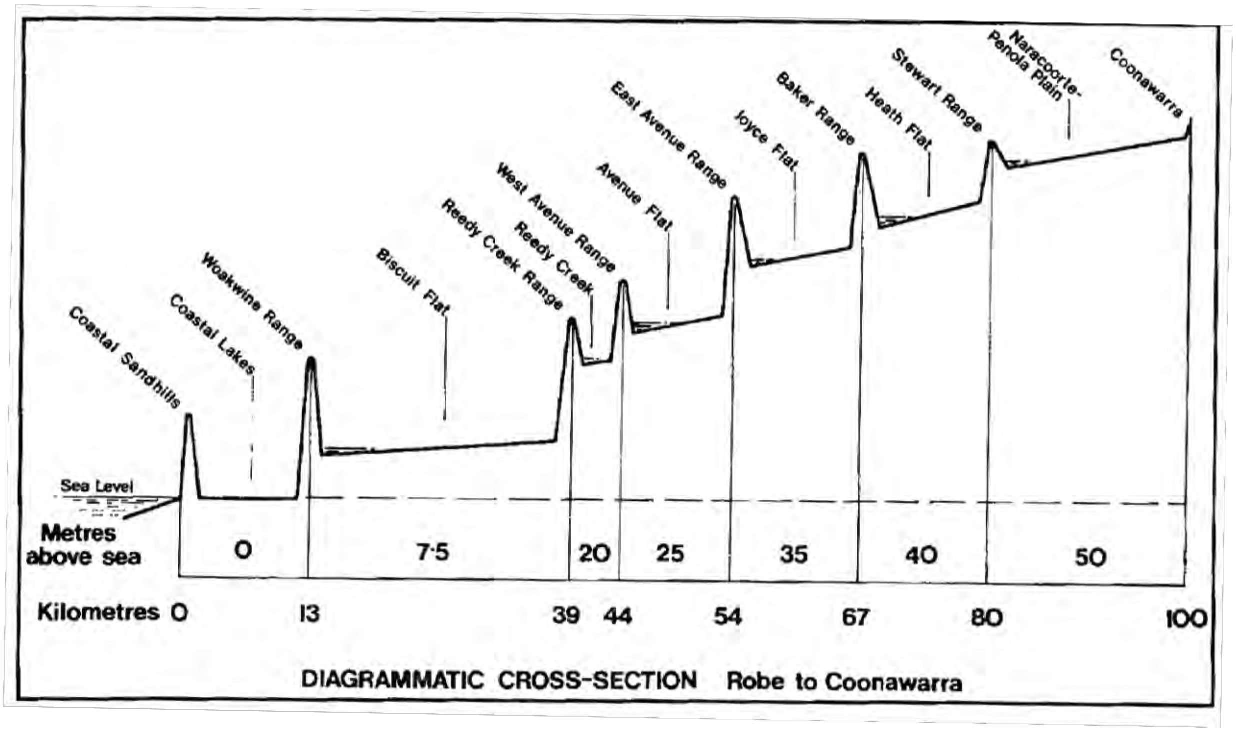


Figure 7 – Vertically exaggerated cross-section from Robe to Coonawarra showing the location of Reedy Creek (from Turner and Carter (1989))

Fed by multiple sources, including local rainfall, accumulated flows from its catchment to the south (in the vicinity of Mount Graham and Mount Burr) and discharging shallow groundwater (as a result of wetlands ponding against the West Avenue Range), Reedy Creek was originally considered the main arterial waterway in the South East.

Julian Tenison-Woods, who arrived in the South East in 1857 and was highly observant, compiled many useful observations of the region in his book 'Geological Observations in South Australia: Principally in the District South-East of Adelaide' (Tenison-Woods 1862).

Noting that many of his regional observations appear to correspond with either a period of below average rainfall in the late 1850s or later (drier) seasonal conditions in the summer or autumn, significantly impacting on the volumes of water he observed, he nevertheless described the origin, direction of flow and course of Reedy Creek as follows:

> *"At the foot of Mount Graham, about forty-five miles from Guichen Bay, there is a large morass of very deep black mud. This trends away along the east side of a range of hills, in*

a north-westerly direction, until it becomes, in a mile or so, a perfect channel, about half a mile wide, containing little or no water, but very boggy, and covered with reeds. It continues on in the same width for many miles, until it becomes a stream, which empties itself into the Salt Creek and thence into the Coorong. In winter, a small amount of water drains off in the centre of the morass after the first five or six miles, and the stream becomes more copious as it proceeds farther, but the general character of the creek is a great morass, many miles in length, and varying in width from half a mile to 200 yards, and running for its whole length at the foot of the range."

During wetter times, areas that he simply describes as being muddy or boggy would have been more deeply inundated. However, consistent with other early accounts, this reference highlights that Reedy Creek was considered to be the region's main inland waterway from the earliest days of settlement, a factor that significantly influenced early approaches to regional artificial drainage enhancement. The final subsequent stretch of Reedy Creek (now called the Taratap Watercourse) before it reached Tilley Swamp, after passing through the range at Blackford, is shown in the 1906 map in Figure 8.

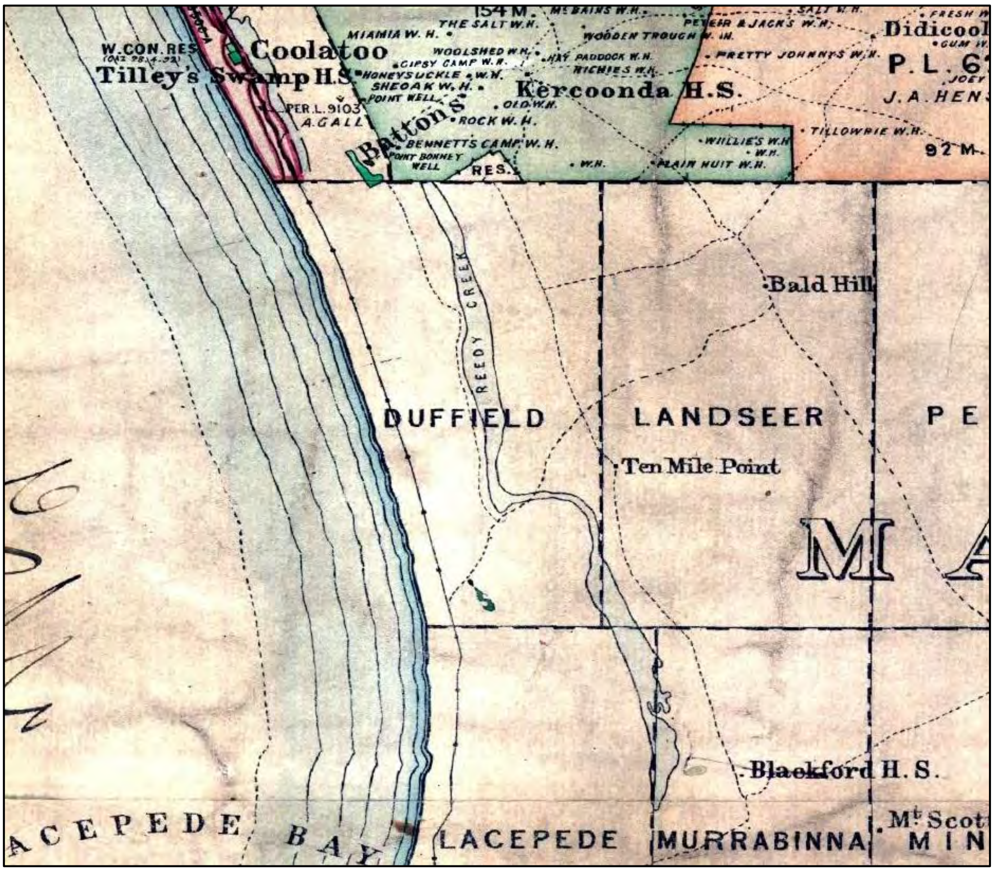


Figure 8 – Map from 1906, showing the last stretch of Reedy Creek between Blackford and Tilley Swamp, but after the creation of Goyder's Bank which forced all the flows northwards from Murrabinna. Goyder's Bank is not shown, but is situated at the southern tip of the mapped watercourse, just above the 'M' in Murrabinna.

It should be noted that the map in Figure 8 is dated after many of the early government drainage works were already completed and influenced the direction of flows in this area. The precise nature and impact of these works will be expanded on later, but included the construction of banks and artificial drains that 'forced' Reedy Creek to continue along the route that was perceived to be the main flowpath, as described by Tenison-Woods, and illustrated (in red) on the 1980 South Eastern Drainage Board map shown in Figure 9.

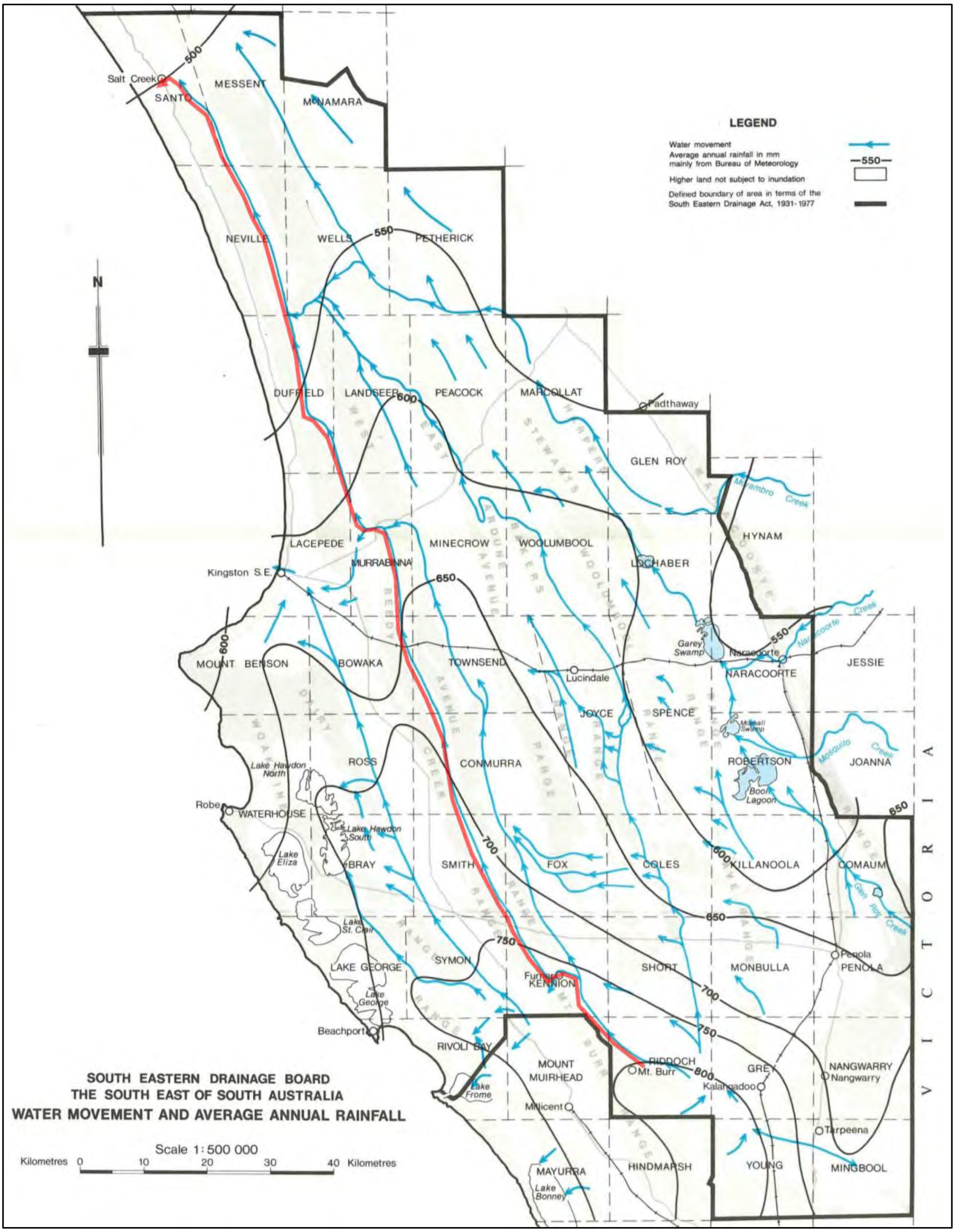


Figure 9 – Map from the report by the South Eastern Drainage Board (1980), showing the original direction of flows in the South East, and with the original length of the Reedy Creek Watercourse highlighted here in red.

However, as a result of the extremely flat terrain in the South East, seasonal, climatic and other variable weather influences (such as fetch caused by wind), along with the impact of those early drainage and banking works, the truth about the direction and magnitude of Reedy Creek flows is a little more complex than at first glance.

In the wet decade of the 1860s, with transport and communication routes regularly interrupted or slowed for long periods, there was great pressure from colonists and settlers in the South East to improve the speed of freight, mail and human movement between Mt Gambier and Adelaide. Talk of the South East of South Australia joining Victoria, which was more readily and quickly accessible overland than its own capital of Adelaide, or seceding and forming a new colony in partnership with neighbouring areas of western Victoria (proposed to be called Princeland) flourished briefly in this era. Likewise, so did talk of schemes that would seek to harness the waters of the region and turn them into an asset for communication and transport. It was during this period, before major drainage works had commenced, that several gentlemen strongly advocated publicly (via newspaper submissions) for the state government to invest in a European-style solution, where canals, using locks and weirs, would be constructed and managed both for transport (by flat-bottomed steamboats) and to facilitate drainage and development of adjacent land for agriculture, rather than simply seeing more water drained directly to the sea without being put to practical use. This submission in the Border Watch (1864) by Mr W. J. Browne of Moorak, explains and justifies the scheme as follows. He stated:

> *"The Reedy Creek is naturally a canal for several months in the year. Consequently, it would require but little clearing or deepening to render it navigable during the whole year. By a single lock you could retain as much of the Reedy Creek water as you required, the surplus water that you must get clear of, combined with the natural drainage of the swamps lying between the Reedy Creek and Lacepede Bay, would furnish sufficient water to supply a cutting from the Reedy Creek to Maria Creek and the Coorong. This canal would recover a large quantity of good land and drain an immense tract of country. It is the emptying of Reedy Creek that makes Tilley's Swamp; consequently, that water would be conveyed into the canal…*
>
> *…A combined system of navigation by means of the Coorong and Reedy Creek would be of very great advantage to the South-East and would retain for Adelaide the trade of the district, which Adelaide is now rapidly losing. It would facilitate the making of roads east and west, the land running north and south being the main highway. It would bring not only the produce and trade of our own country to our own ports, but also some of that of Victoria.*
>
> *Mr Palmer says he thinks the Coorong and Reedy Creek can be easily connected by a navigable canal and continually rendered so by directing the drainage of the surrounding waters into these two channels. The Coorong should receive the drainage of Maria Creek. The sea mouth of the Maria Creek, if necessary, might be blocked up and a channel cut through the pipe-clay flat to the Coorong. Tilley's swamp should be also drained into the Coorong by deepening its natural outlet through the Salt Creek.*
>
> *I have seen the water so deep on several occasions that a boat could have been taken from the Coorong to near Mount Muirhead."*

Browne and others envisaged a regulated canal for transport running the entire length of the Coorong and through the Ephemeral Lakes, from Lake Alexandrina to Kingston and then turning inland up a new channel constructed from Maria Creek to Blackford, and then following the length of Reedy Creek south to Mt Muirhead, near Millicent.

While the practicalities of such as a scheme do not appear to have been taken seriously by government, this submission does give a unique insight into the frustration being caused by inundation and its impact on early transport and communication. It is also important to understand that such sentiments were widespread, and a key precursor to Surveyor-General George Goyder's eventual heavy involvement in drainage matters in the South East, which led to major government investment from the 1860s onwards. This began to address the concerns of a South East regional population which felt neglected and overlooked for infrastructure investment by its capital in Adelaide, a situation that was greatly aggravated by community awareness of the region's financial contribution to state coffers.

Of particular relevance to the question of Reedy Creek flows, in the same submission, Mr W. J. Browne (Border Watch 1864) also went on to state:

> *"I would connect the Maria Creek and the Coorong with the Reedy Creek, at Blackford's. The Reedy Creek is there hemmed into a narrow channel, through which it flows on to a flat,* ***the main body going towards Tilley's Swamp; but a portion turning southward passes through a low range by Murrabinna****; from thence to the Maria Creek Swamp."*

Although (as he confessed elsewhere in his submission) his opinions were formed by observation alone after regularly passing through the area when wet and needed 'checking with the level', Browne felt that the majority of Reedy Creek water at Blackford went north into Tilley Swamp. However, a later, more lengthy and comprehensive assessment by Goyder himself (1883), after many visits to the region, disagreed:

> *"There is one valley of natural drainage through the district, known as the Reedy Creek. Commencing at Mount McIntyre, wending west north-west, and gradually forming a channel between two of the ridges above referred to, and finding its way in a northerly direction into Tilley's Swamp by the creek at Blackford, and by Henry's Creek further north into swamps leading towards Salt Creek.* ***At Blackford the greater portion of the water floods the Murrabinna flat and flows to lower lands towards the lighthouse buildings on the beach, and also spreads over the flat east of Kingston, and drains into the sea by Maria Creek, or into the Coorong, forming in dry weather a series of lagoons between the heart of the Coorong and the Kingston and Naracoorte railway****."*

The lighthouse buildings referred to by Goyder were cottages near the beach at Cape Jaffa – originally known as "King's Camp" (Rob England, pers. comm. 2019). The extensive flats in this wider general area, which were collectively known at that time as Maria Swamp or Maria Creek Swamp, originally also received any combined surplus waters flowing north from the Millicent flats, filling the Wangolina flats and Butchers Gap.

Despite Goyder's likely accurate indication that the "the greater portion" of water from Blackford Creek flowed south over the Murrabinna flats, contrary to the observations of Browne, precisely what proportion of the flows would have discharged in each of the different potential directions of flow is difficult to ascertain today. This is because it was also unlikely to have been consistent on any given day when the system was flowing and the flats already fully inundated with water. Instead it was likey to be quite variable and driven by factors such as:

(1) how much water was already ponded downstream in Tilley Swamp, which typically has a very gently sloped natural gradient, once water passed over the Taratap Ridge;
(2) how much water was entering Tilley Swamp from Henry Creek, contributing to a significant downstream flow constriction even if Tilley Swamp itself was not full;
(3) how much water was pushing up from the Millicent and Biscuit Flats and already filling the Maria Swamp from this vast, reliable catchment in the lower South East; and/or
(4) lastly, but crucially, the effect of prevailing wind direction on water movement and elevation (i.e. fetch) in all the waterbodies involved.

Hence, it can be ascertained from the early observations that because the South East is so flat, and given that water could pond on the flats regularly in winter and spring anywhere from 1 to 6 feet (or more) in depth, it is not simply a matter of looking at the current lowest points in the landscape and assuming that all the water flowed in a single direction. While that may have been the case in drier times or at the end of a seasonal flow, as when it appears Tenison-Woods made his observations, or on days with no wind, that was certainly not the case on other occasions, when during floods water could be observed as being relatively static over large areas, or flowing in multiple directions, over various intermediate and higher watercourse sills, not just simply following the lowest points of relief.

Hence the 1980 Drainage Board map in Figure 9 doesn't fully illustrate all the directions of flow as described by Goyder; in particular flows making their way towards the Coorong via the Ephemeral Lakes. These are shown more clearly on the inset of this area shown in Figure 10, which more accurately depicts the water reaching the Murrabinna flats via Blackford Creek (blue arrow) and either:

(A) flowing north into Tilley Swamp, or
(B) flowing south towards Maria Creek at Kingston, and/or
(C) subsequently spilling north towards the Coorong Ephemeral Lakes, (as described by Goyder).

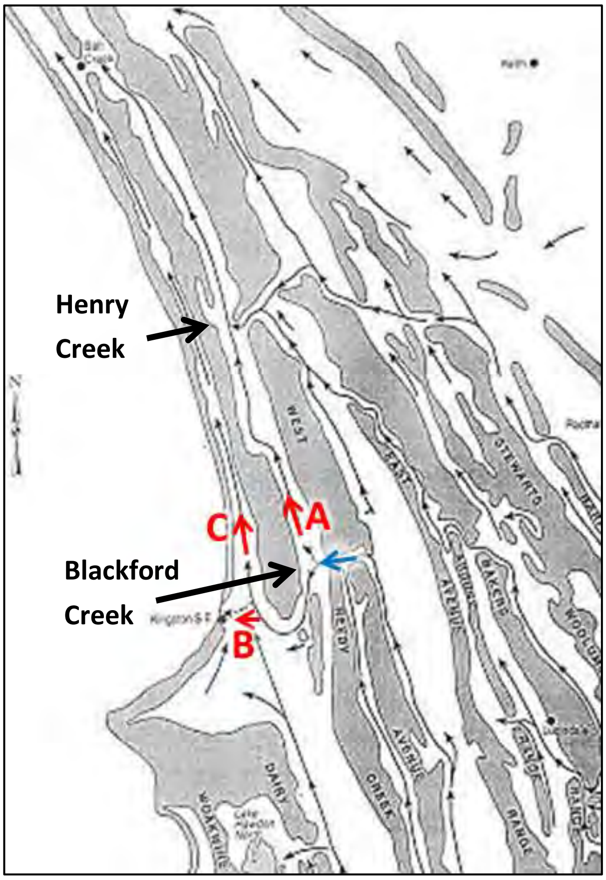


Figure 10 – Inset map of original flow paths in the vicinity of Kingston SE, highlighting the three potential directions of surface flow from the Reedy Creek at Blackford/Murrabinna, as described by Goyder in 1883. The blue arrow indicates the location where Reedy Creek and surplus Avenue Flat flows passed through the Reedy Creek Range at Blackford Creek. From there flows could either discharge (A) north towards Tilley Swamp, or south via Murrabinna towards Maria Creek Swamp, where water could either (B) discharge into the sea at Kingston or (C) flow north into the south lagoon of the Coorong via the Ephemeral Lakes.

What therefore appears clear from the various early descriptions that exist, by those who witnessed and recorded them prior to artificial drainage works, is that water from Blackford could and did flow in all of these directions. When Tilley Swamp was full and already running into the Coorong at Salt Creek, or if Blackford Swamp was not yet full enough (or there was insufficient wind fetch) to breach the Taratap Ridge, water from Blackford Creek would preferentially flow south via Murrabinna and then west towards Kingston. However, with a driving head of flows (possibly assisted by south-westerly winds) from the Millicent direction feeding Maria Creek Swamp during wetter times, the only other potential destination for these flows (again, if Tilley Swamp was full) was along the Coorong Ephemeral Lakes, eventually discharging into the South Lagoon of the Coorong. Again, based on the gentle gradients involved, such flows would have been mostly broad and sluggish, consistent with all the watercourses of the South East, as each wetland filled and spilled in the sequence along this path. The presence of a seasonal historic flowpath via the Coorong Ephemeral Lakes is also supported by the traditional knowledge of Ngarrindjeri people (Coombe 1993, England 1993, Hemming and Rigney 2008a, Hemming and Rigney 2008b).

This account of regional hydrology is also supported by a wide range of early independent accounts and observations, and is also reinforced by some of the key initial strategic decisions made by the SA Government surveyors when artificial drainage commenced in the 1860s. One of those key decisions, the construction of Goyder's Bank at Murrabinna in 1886, to prevent Reedy/Blackford Creek water from reaching Maria Creek Swamp and the Coorong Ephemeral Lakes, will be explored in Section 3.4. The variable extremes of inundation and flows observed in the early years of European settlement, depending on the prevailing climatic conditions at the time, will also be revisited in Section 3.3.

To help paint a picture of the original sluggish nature of the watercourses of the South East, which filled, back-flooded and spilled as they flowed from south to north, Goyder (1883) also noted that:

> *"Reedy Creek is also intersected by a series of low banks, which help to retain the water up to a certain height; after this is attained the flow is resumed, though large areas are inundated during its progress."*

It is perhaps not surprising then that the very first attempts at improving the trafficability and agricultural productivity of the South East largely focused on improving the ability of Reedy Creek, as well as the East Avenue and Avenue Water Courses, to carry more water, more efficiently along their naturally impeded flow paths.

The reason for this is explained by Goyder (1870):

> *"On first considering the subject of drainage in the South-East, I thought it best that one grand scheme, embracing the whole area from the natural northern outlet at Salt Creek into the Coorong to that at the south end of Lake Bonney, should be matured, and all operations and expenditure carried on and incurred tend towards the development of such scheme; but at the suggestion of the Hon. Mr. Milne this system was departed from, and the work divided into two distinct branches, having equally distinct ends in view, namely:—The drainage of the southern portion into Lakes Bonney and Frome, such portion being mostly of good character and fit for tillage; and the drainage of all the country lying north of a line from Penola to the north end of Rivoli Bay into the Coorong via Henry's Creek, Tilley's Swamp, and Salt Creek, the land in the northern portion being mostly of a character only adapted to grazing purposes, and the object sought to be attained being*

> *the improvement of the vegetation and consequent increased grazing capacity and value to the country."*

To achieve this outcome in the north of the region, Goyder (as recorded by Ward (1869)) envisaged:

> *"two outlets at the northern end of the district, one at Lacepede Bay into Maria Creek, which will drain the Maria Creek Swamp, and all the Biscuit Flat north of the Mount Benson range; and another into the Coorong at Salt Creek, which will drain the whole extent of the Avenue Flats lying to the eastward of the Maria Creek Swamp, and uniting with several other flats at Reedy Creek, and falling thence to Salt Creek, as others do from Blackford to Maria Creek. Thus these two points, the Salt Creek having an outlet into the Coorong, and Maria Creek having an outlet 50 miles further south to Lacepede Bay will, in fact, tap the whole waters of the northern end of the district."*

As a result of this initial approach:

1. very early cuttings were made from 1863-67:
    a. in the lower South East through the Woakwine Range at Narrow Neck (to Lake Frome) and English's and Milne's Gaps (to Lake Bonney), after which the intensive drainage scheme on the Millicent peat flats commenced.
    b. in the mid-South East formalising an artificial drainage outlet via the natural (but subsequently modified) outlet at Maria Creek, to the sea at Kingston, and
    c. in the Upper South East into Salt Creek from Morella Basin to enable the Tilley Swamp to discharge more regularly and efficiently into the Coorong.
2. Reedy Creek was also progressively channelised from 1881, when in-stream ridges or impediments to flow were breached, and additional private drains directed water into it, as a main arterial route for directing waters (from across the region, outside the Millicent flats) more efficiently into the northern drainage area, *en route* to the Coorong.

In terms of Reedy Creek specifically, Goyder noted in 1883 that at that time the SA Government were:

> *"now conducting works with the view to relieve other localities and confine the water to the channel of Reedy Creek, down the valley of which large drains are being formed, the main drain being 60 feet wide and 5 feet deep."*

These early changes from the 1860s altered the nature of flows both reaching and passing through Tilley Swamp. However, to understand the impact of the change in hydrological condition in Tilley Swamp, it is necessary to gain a clearer understanding of what Tilley Swamp was like before drainage.

3.3. *Early accounts of Salt Creek and Tilley Swamp*

One of the very first detailed European descriptions of Tilley Swamp and Salt Creek include Hawdon's account of his overland journey from Port Phillip to Adelaide, when he travelled from the Coorong Ephemeral Lakes, across to Tilley Swamp and north to Henry Creek on the 5th of August, 1839. This part of his journey is recorded as follows (with descriptive notes added in brackets and <u>underlined</u> to clarify key locations or times):

> *"The sand hillocks bounding the coast getting more precipitous, we crossed a narrow pass between two lakes* (<u>two of the Coorong Ephemeral Lakes</u>) *and proceeded up the eastern*

> *side, the country still being of a barren description. Towards the eastward I rode inland about ten miles* (along and over the West Range)*, when I observed another chain of lakes extending to the southeast, parallel to those nearer the coast we had been skirting* (wetlands of Tilley Swamp)*. I met with an old native, and as we were both unarmed we soon became friends. He told me that the waters of these lakes were salt* (confirming the pre-European brackish character of Tilley Swamp, at least during that year)*. On my overtaking the party we proceeded to the freshwater stream* (Salt Creek) *discovered by the men left by Mr Bonney in his last expedition* (Bonney's party travelled through several months earlier in March-April 1839)*, after he had gone forward to Lake Alexandrina. This stream rises from underneath a mass of limestone. The water is somewhat brackish; the stream is sufficient to turn a mill; but after running for half a mile it enters the lake* (the Coorong)*. In this part of the lake, which is perfectly salt, we observed about half a foot of rise in the tide."* (Hawdon 1839)

Interestingly, the country was very dry and the bulk of coastal swamps easily traversed by Bonney's party when travelling through a few months earlier, but by August of that year Tilley Swamp was clearly filling, and was described as a 'chain of lakes'. During both of these 1839 visits to Salt Creek, the steady fresh-brackish flow down the creek was apparently being driven by groundwater springs/seepage, because a surface flow from Morella Basin was not evident at that time.

The next reference that has emerged is from June 1842, when the SA Government were describing the boundaries of newly established Counties, Salt Creek was used as one of the boundary markers as follows. The new boundary followed:

> *"the coastline, from the sea outlet of the Murray to a spot opposite where the Salt Creek empties itself into the Coorong."* (Southern Australian 1842)

The boundary then followed *"this creek to the Rocky Ridge at its source…"* (Southern Australian 1842). Again, springs at the rocky ridge upstream were considered to be the 'source' of Salt Creek, indicating that on the basis of climatic trends at that time, overland surface flows from Tilley Swamp via Morella Basin may not have yet been understood or observed.

An apparent lack of understanding about just how wet the South East could become, and its detrimental impact on transport, continued with Governor Grey's journey to the South East in the autumn of 1844, when he was accompanied by a number of people including his newly appointed Commissioner of Public Lands, Charles Bonney (referred to above), surveyor Thomas Burr and artist George French Angas.

In his letter to Lord Stanley (dated June 22, 1844; cited in Dutton (1846)), Governor Grey stated that:

> *"as this country lies immediately between New South Wales and South Australia, and forms an almost continuous link of good country between the rivers Murray and Glenelg, and* ***can, in its natural state, be traversed in nearly all directions by drays and carts without the slightest difficulty****, there can be but little doubt that in the course of the next few years an uninterrupted line of settlements will exist between Adelaide and Port Phillip : indeed the squatters from New South Wales have already begun to occupy the most extreme south-eastern portion of this new country with sheep and cattle stations."*

Despite the fact that they travelled through during the driest time of year (autumn) clearly this was a drier than average phase, and Governor Grey didn't perceive how just wet the 'easily traversable flats' could become.

More detailed observations of Salt Creek and Tilley Swamp were made in the journals of Grey's companions. Firstly (Angas 1847) recalled that on April 22nd 1844:

> *"This day's journey brought us to the Salt Creek; a river of salt water flowing out of the Coorong, and running through the desert to the eastward. Open green flats, skirted with she-oaks and a few gum-trees, occur along its margin, and tolerable feed for the cattle was found about our camping-place. Luxuriant tea-trees embower this sluggish stream, the vile waters of which are covered with a green scum. About a quarter of a mile up the creek we found a well of clear fresh water, beneath a projecting ledge of rock : it was surrounded by moss and flowers ; and the recent foot-prints of the emu and kangaroo, showed that these creatures of the wilderness had been slaking their thirst there during the heat of the afternoon. We called it "Bonney's Well."*

Despite the fact that it was already understood that Salt Creek flowed *into* the Coorong (based on the earlier references), and was already being called by this name by 1842, Angas nevertheless either misunderstood what he was seeing, and due to a northerly wind, must have observed saline Coorong water flowing upstream – or alternatively may have simply made an error in his notes. It also appears that this erroneous description may have led to at least one map that inaccurately represented the direction of flow, catchment and/or physical extent of Salt Creek, produced around the same time, as shown in Figure 11.

Figure 11 – Map of the Coorong from Dutton (1846) with an inaccurate impression of Salt Creek continuing a considerable distance inland, but showing how it was used to mark the boundary of the County of Russell.

However, interestingly and of some significance, Angas went on the say that:

> *"Conglomerate masses of recent shells, cemented together by lime, with a small portion of sand, occurred for some way along the bed or ravine of the Salt Creek ; and in other places recent shells lay in immense numbers upon the plains that we crossed, at a distance of three or four miles from the water." (Angas 1847)*

Based on this description, it seems highly likely that he followed Salt Creek upstream into its connecting flowpaths with Morella Basin, which were dry at that time, and this description strongly implies relatively recent immersion and/or flows along the creek bed and swamps upstream of the inundated section. The increase in elevation he would have experienced following the Creek upstream makes it seem even stranger that he misinterpreted the flow direction, making a simple transcription error in his notes the more likely explanation for his description of flow direction.

When recording events on the same day at Salt Creek, Thomas Burr in his journal said:

> *"His Excellency, accompanied by Messrs Bonney, Gisborne, and myself, walked up the Creek for about two miles, when we came to a large hole containing salt water. On walking round this hole, it was observed that the native dogs had been there recently, and at several places had scratched away the earth. At one place a small hole had been made by them, only removed by a ridge of earth about six inches across, and half an inch in height above the water in the large hole, on tasting the water in this small hollow, made by the native dogs, it was discovered to be perfectly fresh!"* (Burr 1844)

The author of this section of this Baseline Synthesis report (Mark Bachmann) has personally observed the exact same phenomenon in the springs along Henry Creek, where the main in-stream pools in the section of the creek passing through the West Avenue Range were brackish, but small seeps in pools immediately adjacent (but slightly up-slope) were comparatively fresh.

After travelling a little further south, Thomas Burr's account from the 24th of April 1844 described travelling inland to explore the ranges and swamps inland of the Coorong, as follows:

> *"Having dispatched the drays, his Excellency proceeded to a range (Wombat Range)* (now called the West Range) *about two miles to the north of the road, and from a point on that range we proceeded ten miles in a N.E. direction, when we came of a low scrubby range, beyond which, to the N.N.E. and E. were apparently a succession of low barren ranges, with wide valleys between them; to the S.E. there were some distant ranges, which appeared to be wooded. From this range we struck off S.E. and crossed a low swampy ground that must be subject to periodical inundations of fresh water, for there were numerous fresh water shells (particularly Bulimus) on the surface* (this description, and the distances travelled, is a likely match for the Cortina Lakes (Rob England, pers. comm. 2019). *This swamp continues from where we were to the Salt Creek. The soil is rotten, but good; and there are upon it many small sand hills, well wooded, and grassed, which, from the range, have much the appearance of islands."*

Thomas Burr's account was accompanied by a map that appears to have been prepared by him (as Deputy Surveyor General) in 1844, as shown in Figure 12 (as supported by Coombe (2018)). An inset of the key area of interest from that journey is reproduced in Figure 13.

Figure 12 – Map by Burr (1844) showing the route and features encountered by Governor Grey's party

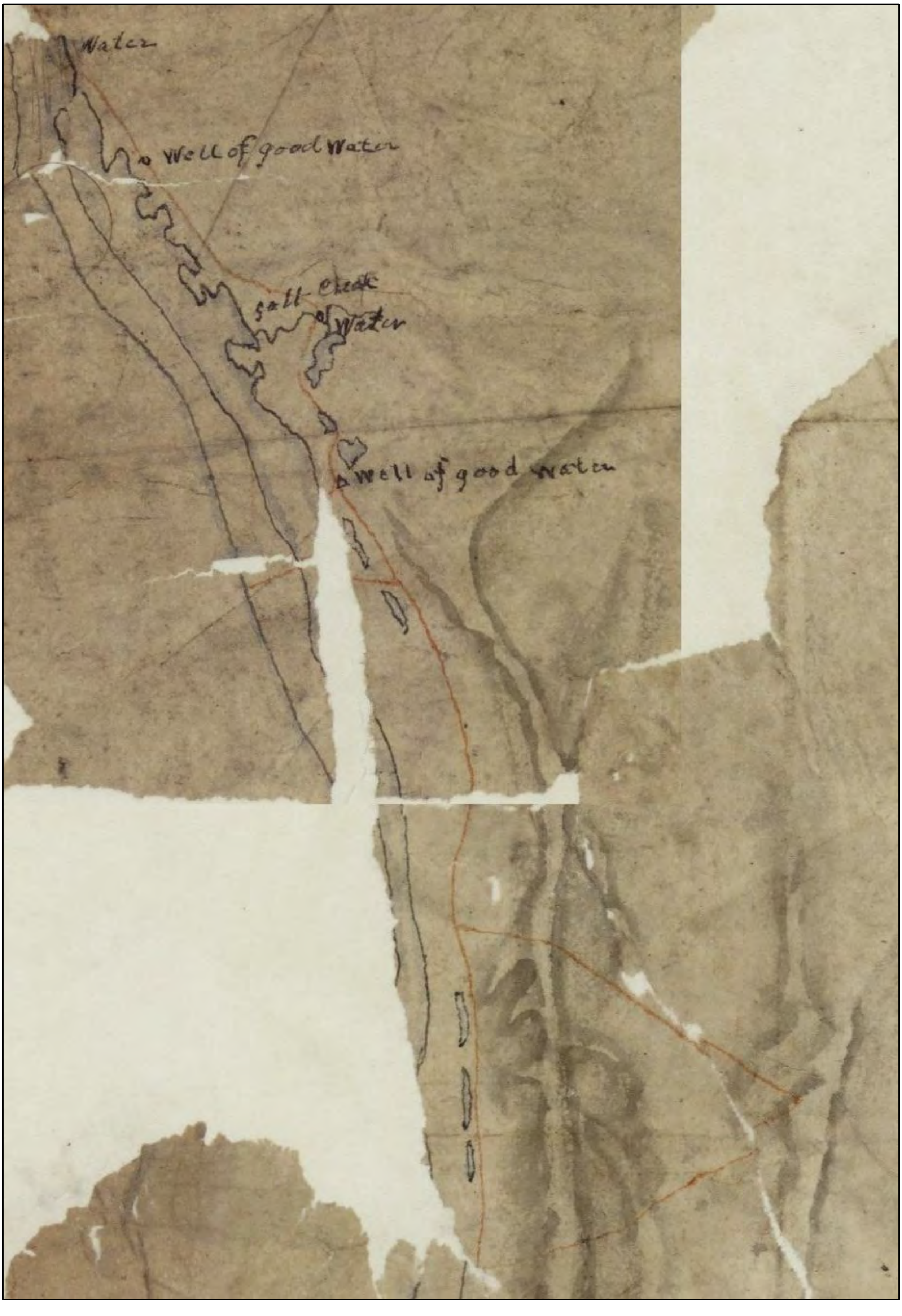


Figure 13 – Inset of map by Burr (1844) showing a more accurate representation of Salt Creek, plus the deepest part of Morella Basin holding water (which he didn't describe in his journal), and the route they took across Tilley Swamp further south (to Kercoonda), where open water was clearly not encountered.

On closer inspection, the map in Figure 13 indicates that Governor Grey's party sighted Morella Basin, and that it retained a reasonable amount of water at the time of their visit – based on its size relative to the other wetland features mapped during their journey. This is informative, because it indicates that despite the relative general dryness of the landscape at that time, Morella Basin retained permanent inundation. This is itself also helps to explain the presence of spring-fed baseflows in Salt Creek, driven by the elevated groundwater beneath Morella Basin and Tilley Swamp.

However, in complete contrast these earlier accounts, we only have to look forward to 1847 to hear a very different impression of Salt Creek.

In his memoirs, Tolmer (1882) recounted how he:

> *"started from Adelaide on or about the 7th July, 1847, with Police-trooper Dewson and a pack-horse, and upon reaching the **Salt Creek** I camped for the night on the north side of the creek, which **was much swollen and impassable on account of the heavy rains which had fallen**.*
>
> *Early the following morning we started up the creek, thinking a better crossing would be obtained, instead of which **the whole of the flat was one continuous sheet of water**; and if the reader will refer to the map of the district he will perceive that my course from the Salt Creek to Lake Mundy (which is near Kilbride) was southeast; and as the whole distance consists of alternate flats intersected by well-timbered ridges running north and south, he will at once perceive that to keep the said course necessitated travelling obliquely across the flats, which were all submerged, and the water so deep in many places that our horses had to swim."*

In explaining the position of the road he helped to define on the return journey, that went on to be used for decades to come, he said:

> *"Old colonists will doubtless remember that the winter of 1847 was one of the most severe and wettest ever experienced in the colony. After undergoing incredible hardships, and narrowly escaping with our lives, through the horses tumbling into holes and rolling over us, we nevertheless successfully reached Mr. Watson's station (Kilbride), where we were received with the greatest kindness and hospitality; and after resting a few days, and finding of course that the line I had taken was impracticable, I then examined and ran down several of the ridges referred to, and was rewarded by finding that there was a good practicable road for horses or vehicles along the base of one of these ridges, from Mount Muirhead to near the Salt Creek, with plenty of water and feed for horses; which having reported as being practicable winter and summer, was at once adopted by the Government, and for many years afterwards was used by the police in carrying the mail, until it was contracted for by private individuals."* (Tolmer 1882)

It took almost a decade, but the true nature of the South East had revealed itself.

Noting that in this account, it was only the month of July when Salt Creek was already flowing, with Morella Basin and Tilley Swamp full and overflowing, the winter and spring of 1847 must have been an extremely significant year for inundation in the South East and flows into the south lagoon of the Coorong.

The next confirmed flow event at Salt Creek based on a search of historic accounts was in 1852, when it was reported in the South Australian Register on Friday 17th September that:

> *"Inspector Rose is of opinion that for some time to come the road by the Coorong will not be practicable, as a great portion of it must still be swampy, and he was informed by the mailman that* ***Salt Creek was so swollen, as to be almost impassable****. As yet, the Hundred-mile Scrub is the best route, but as the season advances, the feed, which is already growing scarce there, and the surface water, will disappear."* (South Australian Register 1852)

The same event in September 1852, was also noted by a Mr Livingstone of Mount Gambier (Livingstone 1852); in the South Australian Register, Monday 20th September 1852), who advised other travellers on the condition of the Coorong overland route to Adelaide:

> *"The road by the Coorong is in good condition, but that travellers* ***must strike inland to avoid the Salt Creek, and Tilley's Flat, now inundated****. He crossed Tilley's (i.e. Henry) Creek a short distance above the Station, the water there not being more than four feet deep. Mr Livingstone also advises travellers to keep on the inland side of the range after crossing the creek."*

In 1852, the creek was still running in late November, with the following account by Mr P. B. Coombe, who was in a travelling party of people who were shipwrecked on the *Margaret Brock* travelling back to Adelaide by foot, appearing in the South Australian Register on the 1st of December 1852:

> *"After walking 46 miles the first day, we succeeded in reaching the Salt Creek, at half past 10 o'clock at night. The next morning* (Sat 27th November 1852) *I induced Mr. Robinson, who keeps a public-house, to cross the Creek with his horse and cart, with provisions, which he did, though* ***there was a considerable stream of water running at the time****. The following day he returned with the females in the cart, and the rest of the party arrived in safety the same evening."* (Coglin 1852)

Another early account (Kruse 1864), stated that Tilley Swamp reached sufficient depth for Salt Creek to naturally run in 1854 and again for five months in 1863.

These early references indicate that, despite being fed by permanent springs generating a modest baseflow, Salt Creek did not run with surface flows every year, but when it did, crossing the creek became difficult, because the alternative upstream crossing used by Grey's party (between Salt Creek and Morella Basin) available to travellers during the drier times was completely flooded. These events (in at least 1847, 1852, 1854 and 1863) were dependent upon sufficient rainfall and flows generated from across the region to occasionally fill Tilley Swamp and Morella Basin to above its original full capacity (noting that the original capacity of the wetland will be addressed in Section 3.4).

Crucially however, these observations confirm recorded outflows occurred before the often reported flows that are known to have occurred into the Coorong via Salt Creek **after** drainage enhancement works commenced, which includes at least nine events recorded by the South Eastern Drainage Board between 1891 and 1956 (see listed on page 78, in Jensen et al. (1983); note that this document is also commonly referred to as the 'Cardwell Buckingham report'). Curiously, this report does not include reference to the flows that were immediately released into Salt Creek as a result of the completion of drainage cutting works in 1864/65 (see referenced later in this section), and probably again in 1884 and 1886. This makes it seem extremely likely that additional flow events between 1865 and 1891 would have occurred but were simply not officially reported or recorded.

In addition to these minimum of ten (but probably several more) recorded flow events after drainage, the chance observational accounts of Tolmer, Rose, Livingstone, Coglin and Kruse provide clear evidence that Salt Creek did indeed receive overland surface flows from Tilley Swamp on an occasional, episodic basis **before** any works took place, in addition to the apparent groundwater spring discharges that fed gentle baseflows down Salt Creek (as a result of the impounded wetlands in Tilley Swamp driving lateral movement of groundwater through the permeable limestone substrate, as is commonly observed elsewhere in the region).

Considering the extreme remoteness of Salt Creek in the earliest days of European settlement, and the lack of written observational records available to scrutinise, it is probable that there were also additional pre-drainage surface flows that went unreported and are simply missing from the historical record.

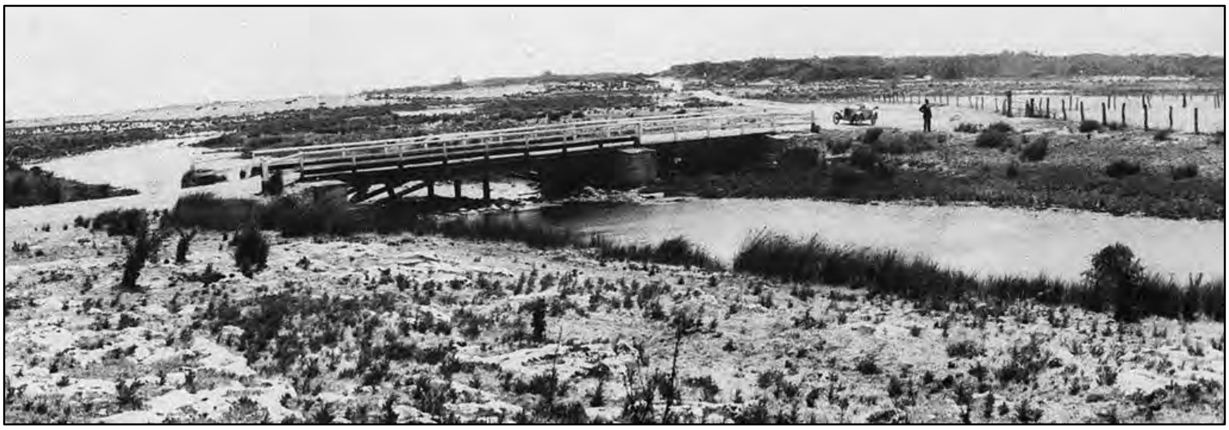
This fresh assessment of early accounts supports the findings of the very useful and detailed historic analysis undertaken by Rob England in his self-published work 'The Cry of the Coorong' (England 1993). The key assertion in his work was that the Coorong was historically capable of becoming much fresher on occasions (ranging from fresh to estuarine and marine) and that the Cardwell Buckingham report (by Jensen et al. (1983)) was being too dismissive of the likely historic significance of ground and surface water contributions to the Coorong from the historic catchments of Salt Creek and the Maria Creek Swamp, across the lower and mid-South East, prior to comprehensive drainage of those flows to the sea.

Events that have transpired since that time, including the adoption of the SEFR project, the outcomes of other studies (see Tomlinson (1996); Von der Borch (1994)) and the findings of this additional detailed review into the historic condition of Tilley Swamp, tend to support the majority of his hypotheses and evidence presented to describe historic hydrological conditions in the Upper South East. The most recent scientific study using diatom analysis within sediments to reconstruct a timeline through the entire Coorong (Gell and Haynes 2005) confirmed that salinity in the southern lagoon of the Coorong was highly variable, and capable of being temporarily freshened (long before European settlement) as a result of surface flows from the South East via Salt Creek. The historic observational accounts reviewed as part of this Baseline Synthesis report are consistent with the findings in (Gell and Haynes 2005).

A comprehensive search of historic Coorong observations has not been undertaken, as it is outside the scope of this report, but it is noteworthy that during the verified era of semi-regular fresh-brackish flows into the Coorong via Salt Creek that it is not difficult to find records of a very different system to that which we see today. Here are just a few examples:

> *"**FISH IN THE COORONG**. The Inspector of Fisheries (Mr. MacIntosh) has forwarded a report to the Commissioner of Crown Lands with respect to fishing in the Coorong. Accompanied by Inspector Ewens, he sailed down the Coorong, as far as Salt Creek, a distance of over 70 miles from Goolwa. At present no fishing boats venture farther down the Coorong than the Needles, a narrow neck of water, 50 miles from Goolwa, across*

which there is a dangerous reef of rocks. The only passage does not exceed 20 ft. in width, and is difficult to find. In consequence of the absence of fishing boats from the Needles to Salt Creek the water there is much better stocked with fish than at the other end of the Coorong, and with a short net Mr. Macintosh secured nine dozen fine fish at one haul. He found that pelicans and cormorants bred annually in thousand on these islands about seven miles from Salt Creek, and this gave further proof of the plentiful supply of fish in the vicinity. Mr. MacIntosh believes that the drainage of South-Eastern waters into the lower end of the Coorong is the attraction for the shoals of bream that frequent it. At present 45 licensed fishermen are working either in the Coorong or on the adjacent inland waters, and Mr. MacIntosh suggests that it would be a great advantage to them if the lower end of the Coorong were made more easily available to them by improving the entrance channel. A low draught oil launch would then be able to run fairly regularly from Goolwa to Salt Creek, picking up fish and game for market en route." (Border Watch 1906)



Salt Creek c. 1927 – A significant natural channel. Image courtesy of the State Library of SA

*"**TO MOUNT GAMBIER AND BACK BY MOTOR….** About four miles further on we came to Salt Creek, which flows into the Coorong. At this point a cafe has recently been erected, and most motorists pull up there. We stayed an hour and enjoyed an excellent lunch of fish, which had been caught in the Coorong. Fish may also be caught in Salt Creek, some of the holes in which are of a good depth… …. The night before we arrived they had caught something like 300 fish in the Coorong, and by mid-day the lot had been sold."*

(Kapunda Herald 1928)

*"**THE MIGRATORY WILD FOWL.** Recently the game laws in South Australia have been so altered that there is now no fear of game diminishing to any serious extent. It is just as plentiful as it was 50 years ago. About the year 1923 the Coorong for its whole length was literally black with game of all kinds. They rose in clouds, thousands at a time would fly 200 or 300 yards, and resettle, so that the water appeared to lie covered with living patchwork. This was about three weeks before the season opened. About a week later rain fell in the interior, and in a few days the millions of ducks had dwindled down to a small isolated flock here and there… …That season, from a sportsman's point of view, was a failure on the Coorong, but when there is a prolonged drought in the interior and the birds*

> *have nowhere else to go, they have a very bad time all over the southern part of the colony and not only in South Australia."* (Observer 1928)

Outside of the impact of surface flows via Salt Creek into the Coorong, it is also evident that Tilley Swamp itself, as the ultimate destination of much of the surface flows across the South East, held a significant amount of water every year, and in some seasons "formed an inland sea broken only by a few bars which stretched from Salt Creek in the north to a point 8 miles (13 km) south of Maria Creek, overall a distance of 56 miles (90 km)" (Turner and Carter 1989).

To illustrate just how much water would find its way into and be held within Tilley Swamp, in November 1861, Hanson (Hanson and Coulthard 1863) stated that:

> *"Henry's creek, near Tilley's Old Accommodation House, which takes the accumulated waters of many of the swamps into Tilley's Swamp, is in winter a very dangerous crossing; in November I crossed it with a strong current over the axle of the cart, and then, but for the hut-keeper at the Old Accommodation House to show the place of crossing, could not have crossed with safety at all; something ought certainly, if the road is to be used, to be done here.*
>
> *Soon after leaving the Old Accommodation House, and between this and Batten's, Tilley's Swamp has to be crossed; in November 1861, this was nearly up to the axle of the cart.*
>
> *At present, there being no exit for the water on Tilley's Swamp by the Salt Creek, there is no current, the depth of water is the only difficulty. Were an outlet made, as I am sure there ought to be, for the water from Tilley's Swamp by the Salt Creek, this outfall, if effectual for the general drainage, as it would eventually be, would establish a current, and would render necessary a raided causeway, and flood culverts. After crossing Tilley's Swamp, Batten's Accommodation House is soon reached."*

Coulthard also gave a description of this country to Parliament in September 1864, where he stated that opposite Battens (near Henry Creek) the swamp had "not been dry for 4 years". At the overland route crossing there was 4 feet (1.2 metres) of water "at the present time" and the swamp at Henry's Creek was 2 ½ miles (4 km) wide. Near Salt Creek there were two large swamps separated by a bar. The larger of the swamps was 5 miles long by 1 mile wide (Morella Basin). The second swamp led into a gorge with from 10 feet to 12 feet (3-4 m) depth of water. From this point Coulthard said Tilley Swamp began in earnest *'spreading over an immense tract of country, and further than the eye can reach in a southerly direction, with a chain of islands running through the centre of the swamp'* (Turner and Carter 1989).

As a result of its character and depth, early authors considered Tilley Swamp as just one in the chain of major wetlands that characterised the South East coastal district (SA Register 1883):

> *"The lowest country, running parallel with the seacoast, consists of long chains of swamps, deepening very frequently into lakes, many of them fresh water, some brackish, and other salt. Thus we have Lakes Alexandrina, Albert, Coorong, Tilley's Swamp, Lakes Hawdon, Eliza, St. Clair, George, Frome, Coonunda Swamp, and Lake Bonney, all of considerable length."*

Another earlier observation by Hanson (Chief Engineer) and Coulthard (Assistant Engineer) recorded during January 1863, paved the way for what was soon to follow.

Hanson stated:

> *"The Salt Creek and Tilley Swamp being then the outlet of the water over so large an extent of country, it became necessary to examine, the ground at this place, and see whether there was anything which prevented the exit of the water, and whether, if so, the outfall could be improved. At the time of examination, although there was a considerable amount of water in the lower or north end of the swamp, there was no communication between the swamp and the creek, otherwise than that which might arise from soakage, to which a small current in the creek appeared to be due; but in times of flood there appeared to be two channels by which the overflow gets into Salt Creek* (Figure 14)*. Two small rises exist, one in each of these channels, by which the water is pounded in the Swamp until it gets (it is said) to be nine feet deep. When this is the case tidewater flows over the rise, and a stream, or rather two streams run into the Salt Creek. From this it would, appear that a short cutting of about nine feet deep would lower the water in winter time on Tilley's Swamp by about nine feet, and entirely drain the upper part of the swamp at all times. This is a statement made from judging by the eye only. It is however now being tested by the level, so that the feasibility and cost of the scheme may be known."*

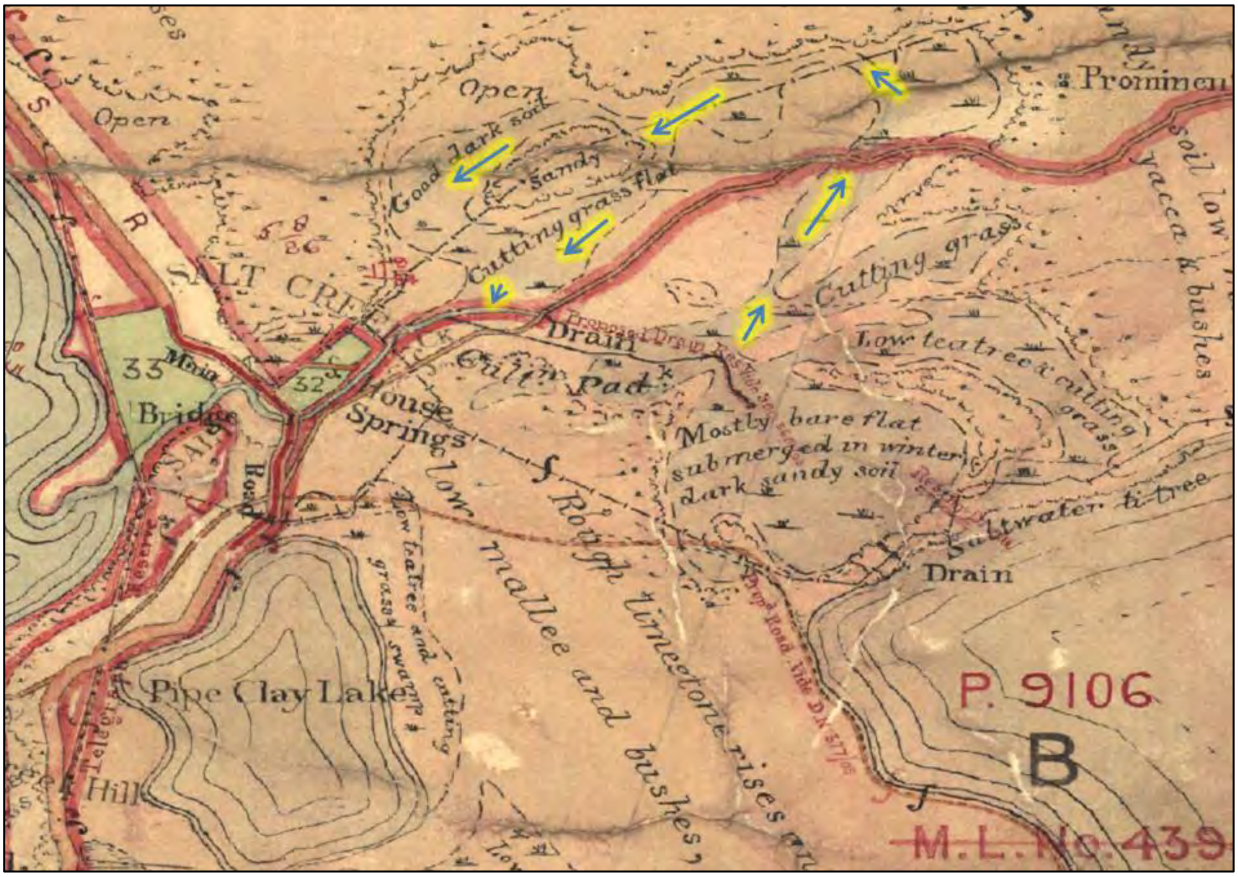


Figure 14 – Portion of the Surveyor General's annotated map of the Hundred of Santo from 1896 showing the natural section of Salt Creek, the original dual flowpaths along a 'a circuit of more than two miles' (see blue arrows, added by author) from Morella Basin and Tilley Swamp.

3.4. *Artificial drainage of Tilley Swamp and the Upper South East*

On the 8th of January 1863, while travelling south towards Mt Gambier, William Milne (Commissioner of Public Works) noted in his diary:

> *"We went up the Salt Creek a short distance and, turning up a rise on the right, had a fine view of Tilleys Swamp, which had the appearance of a long lake. We discussed the practicability of draining it by cutting a trench through two saddles of low hills onto the Salt Creek."* (Milne 1863, cited in Turner and Carter (1989))

In late 1864, works on the first drain from Tilley Swamp into Salt Creek commenced, with the goal of completely bypassing the original winding, dual watercourse, as shown in Figure 15. This was the shortest route between the swamp and the steeper gully section of Salt Creek.

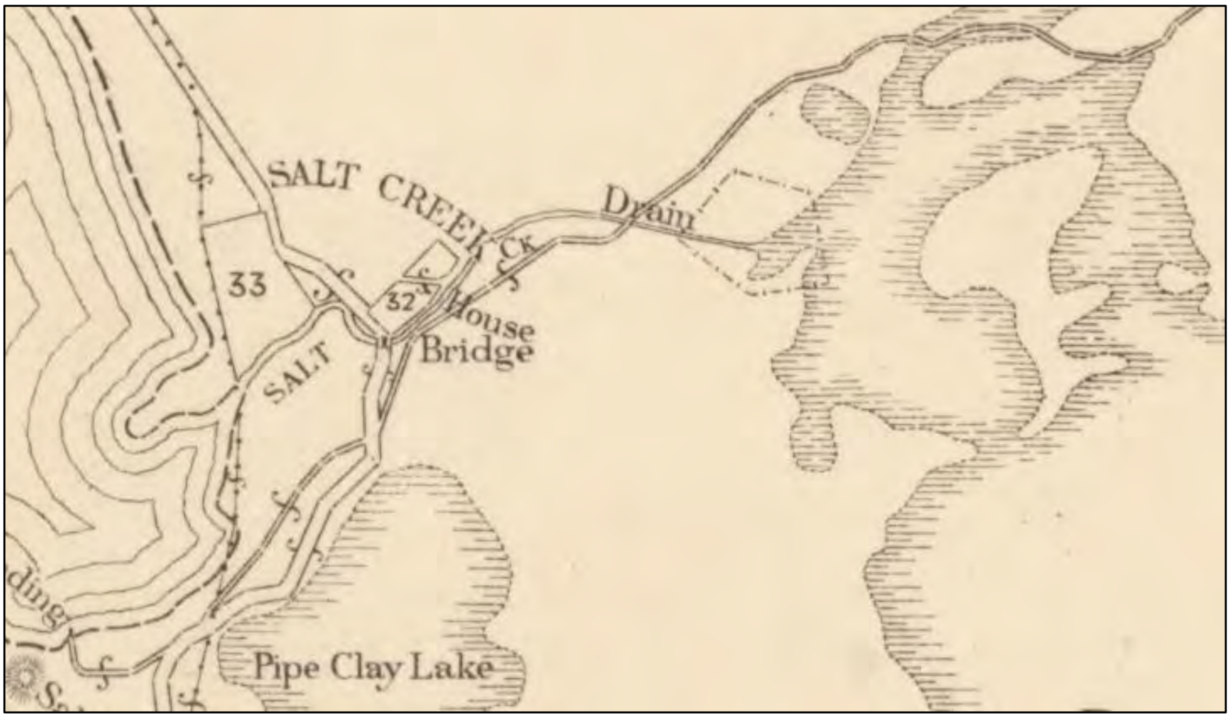


Figure 15 – Portion of a Hundred of Santo map from 1896 showing first artificial cutting between Tilley Swamp (Morella Basin - right) and the Coorong (left) via Salt Creek.

A review of the works, and their impacts, were reported in the Adelaide Observer in February 1865, after a site visit in January 1864:

> *"Having had an opportunity lately of seeing the works which have just been concluded in this (to you) out of the way place, and knowing that you take an interest in the whole South-Eastem District, I may, as one of your correspondents, give you a few remarks relative to what I have seen. The works here, which Mr. Coulthard, the Assistant Engineer, has been carrying on for some months; consist of a bridge over the creek and a cutting from the upper part of the creek, across by a short cut to Tilley's Swamp*.
>
> *Formerly the water from the immense swamp came round by a circuit of more than two miles and by the watercourse just made the distance a little over one quarter of a mile* (as shown in Figure 14)*. This cutting in some places appears to be over twelve feet deep, and the shallowest parts about four feet, down which the water appears to be running at*

the-rate, of about four miles per hour, sixteen to twenty inches deep, and nearly twenty feet broad. Such an outlet must carry off an immense body of water, the depth of the present cutting must take about three feet at least off the swamps, and if the Assistant Engineer continues the drainage next season further on (and it is to be hoped he will) the forty miles and upwards of water above will be completely drained off, and thousands of acres will be available for pasture. Part of the Creek too, has been widened and deepened, by which the water gets away with more ease than formerly. About half a mile below the drainage works was the old general summer crossing (and a rough crossing it was) a very handsome and substantial bridge has been placed, the abutments, which are very strong, are built of stone, the remainder is apparently of Oregon timber…" (Adelaide Observer 1865)

This initial report dated from mid-January was followed by an immediate update in the same newspaper edition:

"The water in Tilley's Swamp has already been lowered 3 feet by the cutting lately made by the Assistant Engineer. It is still running off rapidly, the current being strong and 8 inches deep." (Adelaide Observer 1865)

Considering that these reports are in late summer, the quantity of water still being held in Tilley Swamp at that time must have been substantial. However, those earliest drainage works were soon to expose the fact that a number of other physical impediments to efficient drainage (i.e. ridges of higher ground) existed within Tilley Swamp itself, contributing to immense backwaters for several tens of kilometres up the Tilley Swamp flat. Hence, additional works were planned and carried out over subsequent decades (including the cuttings from Martins Washpool in 1884 and 1886, as shown in Figure 16) to help lower levels further and convey flows.

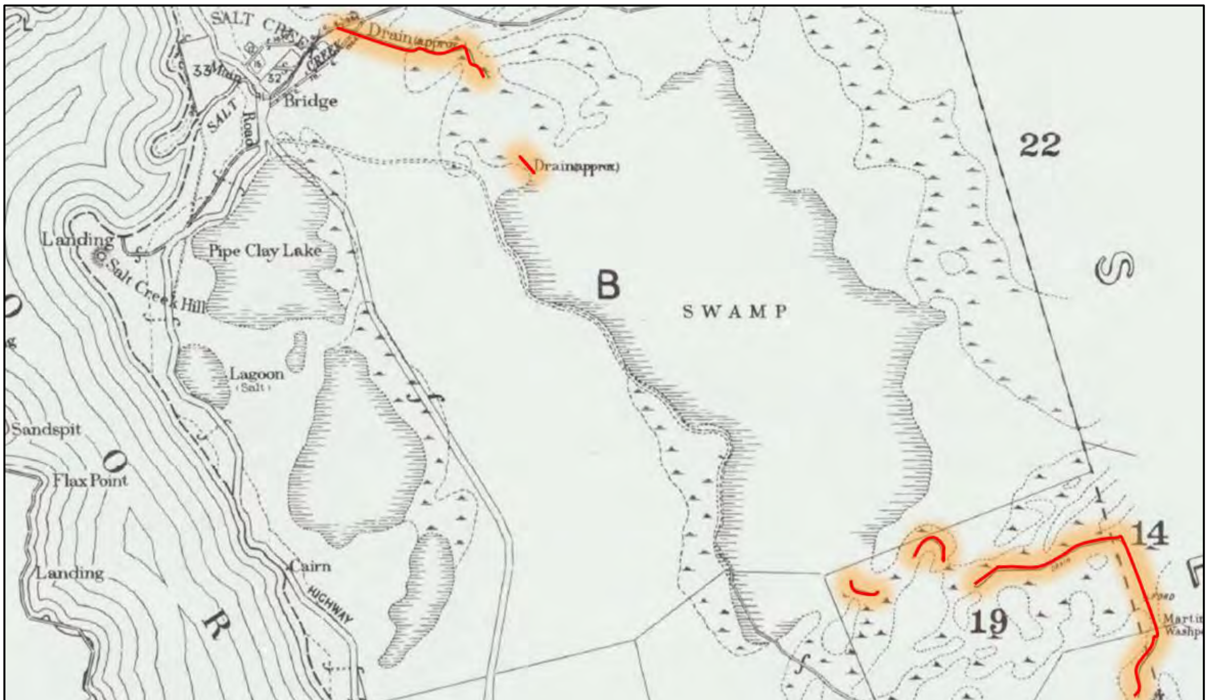


Figure 16 – The additional cuttings made in Tilley Swamp to facilitate its drainage into the Coorong. The Martins Washpool sills were breached in the bottom right of the image.

This approach aimed to improve the ability for Tilley Swamp to convey flows, and drainage activities around the region were therefore undertaken with a view to enhancing the movement of water in a north-westerly direction towards Tilley Swamp, en route to the Coorong via Salt Creek.

But the increased flows to the north were being felt elsewhere in the region, with concerns being expressed by residents in the vicinity of Maria Creek Swamp surrounding Kingston about additional flooding (despite the 1860s drainage work at Maria Creek), as a result of the discharge of water south-west towards the coast via Murrabinna from the Reedy Creek at Blackford:

> *"A petition bearing twenty-seven signatures of residents in and around Kingston, was presented to the House of Assembly by Mr. Hardy on Wednesday. The petitioners asked that the Government would take steps to carry off the surplus water of the Maria Creek swamp, and other drainage works in the neighborhood of Kingston.*
>
> ***The natural flow of water towards the coast had been greatly increased by*** *the railway cuttings and* ***the drainage operations in bringing the flood waters from Lucindale to Reedy Creek****, resulting in excessive floods, during the last two years; and the cutting of bars, &c, at Salt Creek, would not have the effect of draining to any appreciable extent the land around Kingston and towards Robe."*
>
> (South Australian Weekly Chronicle 1884)

The pressure continued over the next couple of years, up to an including the time when works were undertaken. In resisting further political intervention before the impact of the works were known, Goyder made the following report to the Commissioner of Crown Lands, which was placed before the Parliament:

> *"I am anxious to ascertain before any further vote is considered the effect of the closing operations now in hand as approved by the Commissioner, and which by clearing the channels of Reedy Creek and Tilley's Swamp of the main bars obstructing the flow of water towards Salt Creek, and the construction of embankments preventing portions of the combined waters of Biscuit Flat and Blackford (*i.e. Reedy*) Creek flooding the Kingston Flats by way of a south channel passing to the east of Murrabinna and other minor channels whose natural outlets are these flats….*
>
> *…These formerly flowed by a channel and passed to the north and south of Murrabinna Station, and spread thence in a south-west, west, and north-westerly direction over Kingston Flat. They have been obstructed, however, by the embankments, and the waters directed by Tilley's Swamp in the direction of Salt Creek, where the waters are discharged into the Coorong by a continuous channel from Mount MacIntyre Flat by Reedy Creek and Blackford…*
>
> *….The nature of these embankments which have just been completed, and of which the Kingston residents are doubtless unaware, are known to the Hon. Commissioner, and I wish to see the result before reporting further upon the subject…*
>
> (Goyder 1886)

As previously described, the water from Reedy Creek could originally flow in either direction from Blackford after discharging through the range at Blackford, and flows had increased to this location (Goyder (1883) observed that "the greater portion" flowed south to the Murrabinna flats). The remedy Goyder referred to above specifically consisted of the following:

> *"By November 1885, 50 miles of continuous drain... along Reedy Creek watercourse and, in 1886, the Blackford embankment, also known as Goyder's Bank, was constructed. These banks were placed strategically in the path of Reedy Creek waters from Blackford to Maria Creek, and diverted all waters northwards towards Tilley Swamp."*
>
> (Turner and Carter 1989)

Some of those strategic works appear on the Hundred of Murrabinna map from the 1880s, as shown in Figure 17.

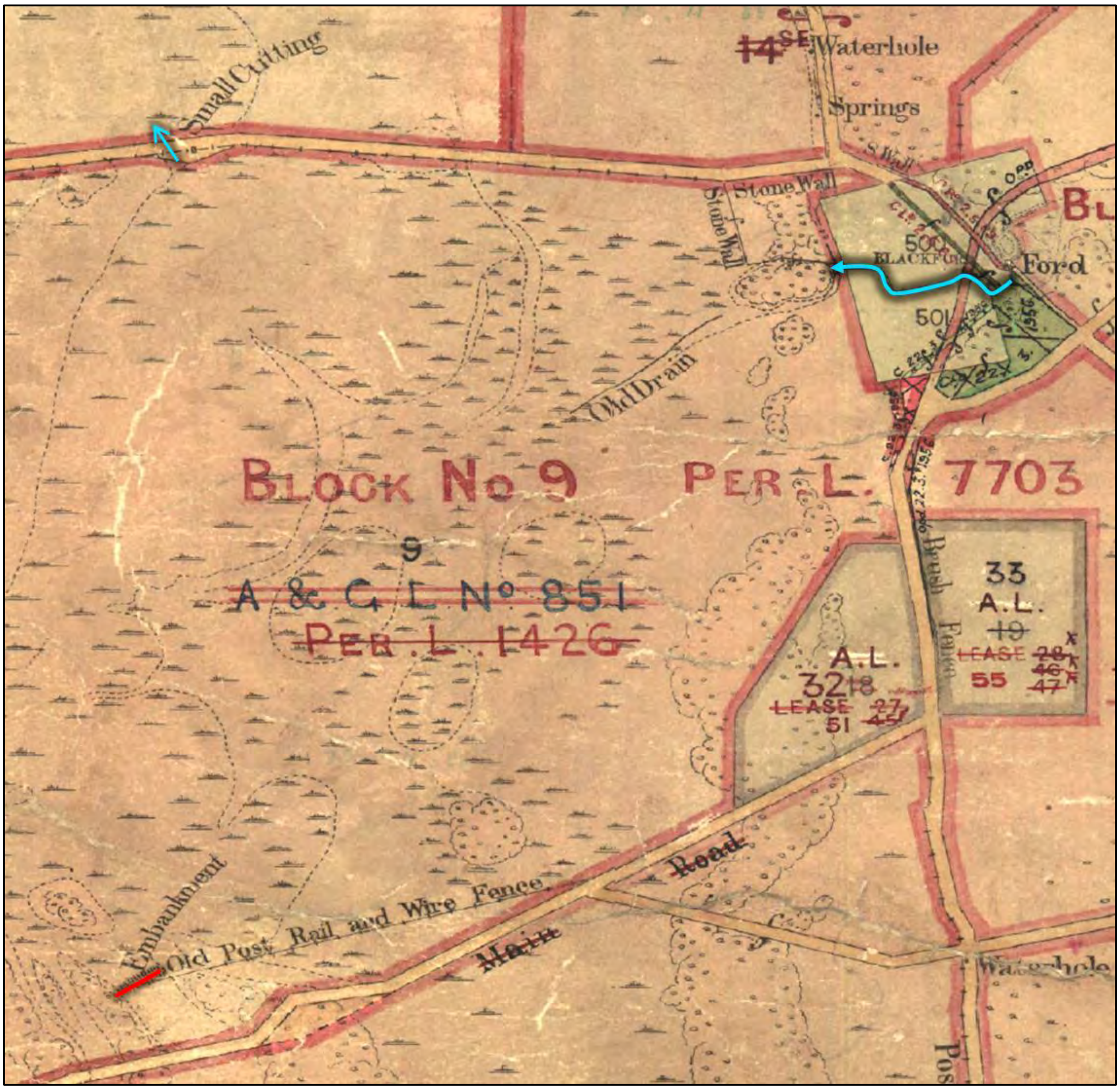


Figure 17 – The Blackford embankment or Goyder's Bank works (red line in bottom left corner) along with a small cutting (top left) made in 1886, encouraged the now enhanced flows from the upgraded and channelised Reedy Creek watercourse, to <u>only</u> find their way into Tilley Swamp, after flowing through Blackford Creek (top right) and filling Blackford Swamp (left portion of image, marked as swamp).

The impacts of the works were immediate; however, as has often been the case in the South East when it comes to the politics of water, pleasing one group of landholders often resulted in new difficulties for others:

> *"The lessees of land recently allotted in the hundreds of Murrabinna and Duffield, and the lessees of pastoral lands at and near Tilley's Swamp, complained that the embankments made by this office stopped the waters from flooding the Kingston flats as formerly, and flooded lands now held by them. They suggested that the embankment should be removed and the waters passing from Reedy Creek via Blackford conducted by the channel now obstructed by the embankment complained of and taken to the sea by an enlarged drain along the main road, and leading to Maria Creek."* (Goyder 1890)

Consistent with some of the historic accounts previously provided, significant flows continued to discharge into Tilley Swamp further north at Henry Creek, which also conveyed (and also later supplemented, through drainage enhancement) large quantities of water directly into Tilley Swamp. Henry Creek was the most northern place where surface flows naturally breached the range into Tilley Swamp, and conveyed water from both the Avenue flats, which were a reliable source of flows, and a portion of the northern Bakers Range Watercourse flows.

Available evidence suggests that the northern Bakers Range Watercourse flows probably increased substantially in volume on some occasions, caused by the back-water inundation impact during wetter periods, when the downstream terminal wetlands in that watercourse were filling or full, or due to in-stream impediments to flow (Bachmann 2015).

In summary, the period of early drainage from the 1860s to 1910:

- caused a major reduction in the sill level of Tilley Swamp as a result of the cuttings at Salt Creek and Martins Washpool;
- forced additional water into Tilley Swamp, with the construction of Goyder's Bank at Murrabinna preventing any of the Reedy/Blackford Creek water finding its way into Maria Swamp or the southern Ephemeral Lakes of the Coorong. The impact of this change was also enhanced via artificial drainage works in the vicinity of Kingston at Maria Creek, lowering the levels of the Maria Swamp, and reducing the original northerly watercourse flows along the Ephemeral Lagoons of the Coorong.
- enhanced the flow of water from the mid and lower South East towards Tilley Swamp via Reedy Creek and Henry Creek.

However, outside of these specific changes, early drainage works did not significantly alter the prevailing direction of surface flows across the bulk of the region. As a result, Tilley Swamp actually received an additional volume of water from across the South East, more quickly, which also were drained more rapidly into the Coorong via the enhance cuttings at Martins Washpool and Salt Creek. But all of that was set to change with a major change in the philosophy of drainage from 1910.

The natural gradient of the South East from south to north is so slight that the natural watercourses were incapable of conveying water efficiently enough to satisfy the demands of landholders. Hence, after ongoing petitions and eventual agreement between landholders and the government, a more comprehensive drainage scheme was adopted, and construction commenced in 1912. This was the era when the first major east-west cuttings through the ranges would begin, building on the prior success of early cuttings made through the Woakwine Range at Narrowneck, Milne's and English's Gaps, and assisted by the advent of steam powered excavation equipment (Turner and Carter 1989).

However, the scheme during this time had a dual objective. As well as directing water westwards to the ocean in the lower South East, via the large cuttings made through the Woakwine Range for Drain L and Drain M, some additional measures (in the form of cuttings and stop-banks) were taken to control how flows were conveyed for the waters that still reached the Upper South East.

Those of relevance to Tilley Swamp are illustrated in Figure 18.

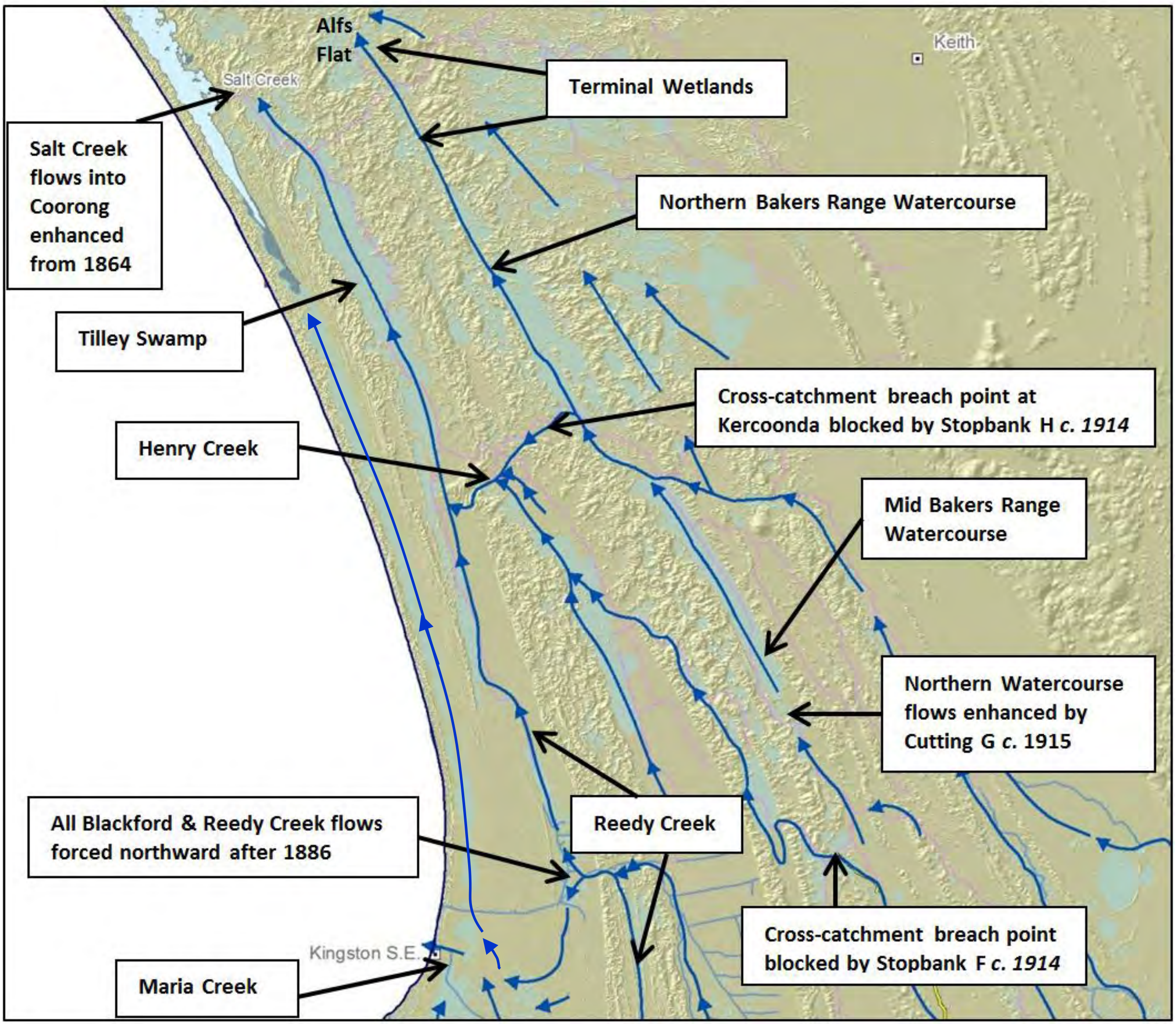


Figure 18 – Historic flow direction of surface water (dark blue arrows) in the Upper South East, with notes of key watercourses and modifications to flow. (Adapted from Bachmann 2015)

The objective of these measures was to increase both the amount and regularity of flows into the northern Bakers Range Watercourse, and to reduce the amount discharged into Tilley Swamp. At the time this vast area of undeveloped scrub and wetlands (inland of Salt Creek) was seen as wasteland – part of the 'scrub desert' country in the South East of little grazing or agricultural value.

The impact of these works is evident in an account from 1918 by two Adelaide businessmen, who saw vast amounts of water in the vicinity of Alf Flat, at the northern extremity of the Bakers Range Watercourse (as recounted in Smith and Foale (1998)). They said that:

> *"We found the whole country inundated with water, huge arms of channels stretching away in all directions… All the gullies and valleys have been filled with water leaving here and there islands and peninsulas of land. The most astonishing fact is that the water is pure drinking water…"*

Foale and Smith hypothesised that this immense body of water has been caused by the wet year of 1917 which, as a result of the relatively new stopbanks to the south, retained vast amounts of additional water in the Bakers Range Watercourse and enabled increased flows to reach this location. Ordinarily a large portion of these flows would have breached the ranges at the locations of the stopbanks and found their way into Tilley Swamp. It is from this period that old word-of-mouth reports emerge that suggest that Alf Flat was "flooded to depths up to 6 metres and stayed flooded for years with no further recharge" (SEDB 1980).

This is how the region largely functioned until the post-war period, when comprehensive drainage of the South East was proposed. The Anderson Scheme, of 1950-1972, enlarged the earlier east-west drains (such as Drain M) and constructed new ones, including the Blackford Drain which was constructed over several years from 1958 until the mid-1960s (Turner and Carter 1989). This had a major impact on Tilley Swamp, which has rarely held water for any significant length of time ever since.

One of the last major floods that preceded comprehensive drainage where lower South East fresh surface flows reached the Upper South East is captured in aerial imagery from 1956. Significant volumes of water have not reached Alf Flat since the floods of 1963 (Nitschke 1983).

1956 **Present**

Figure 19 – The wetlands in a portion of the Northern Bakers Range Watercourse (Cortina Lake – left of image)

By comparison, after the floods of 1981 there was only a small amount of water present on the flats from local run-off (Nitschke 1983).

At that time, local resident Mr. Hawke stated that in 1956, which was a very wet year, before Drain M cut off the Bakers Range Watercourse, the water was about 9 metres deep in Alf Flat on the western side against the range and extended over a large area into Messent Conservation Park. The average depth was about 1.2 metres over 1000 hectares. There was still a large amount of water present in 1960, but the level continued to fall until 1963, when further intakes resulted in the water again reaching about the 1956 level (Nitschke 1983). Levels then began falling again until the early 1970s, and Mr. Hawke reported that the decline in the groundwater levels caused the wedge hole in the base of Alf Flat in Messent Conservation Park to go dry for the first time in living memory in 1972 (Rob England, pers. comm. 2019).

As a result of the Anderson and the Blackford Scheme Drainage Schemes from the late 1960s, up until 1983, the quantity, quality and regularity of flows reaching the wetlands of the Upper South East generally diminished, causing the drastic changes in ecology which have followed (and are still unfolding in many areas) that will be explored in greater detail throughout this report.

The loss of that regular inundation, along with changes in agricultural technology and political pressures from outside the region, also precipitated a new wave of development that led to agricultural rather than pastoral use of the land. The result was massive scale native vegetation clearance and conversion to improved pasture across the Upper South East (as visible in Figure 19), a process that accelerated from the 1950s to the early 1980s and only ended with the introduction of Australia's first native vegetation clearance laws in South Australia in 1983.

This development was also accompanied by a wave of associated private drainage works, which were dramatically increased when a major private landholder in the region (Mr. Tom Brinkworth) made it known that he would welcome all the water possible to be diverted to the Watervalley Wetlands. Thus, the entire area of the Watervalley Wetlands – which had continued to dry – was suddenly filled again in the early 1980s. During a major flow event in 1983, the Drainage Board decided to open a constriction in the Bakers Range Watercourse known as "the Mouse Hole", and let the water flood again into Bonneys Camp, and through to the Messent Conservation Park wetlands. This (by then) unusual inundation event was also facilitated by the Stop Banks indicated in Figure 18, which, prior to their construction and as previously described, would have allowed the surplus waters of the Bakers Range Watercourse to escape west through these low points in the ranges, towards Tilley Swamp.

However, the new promise of much of the area that has been developed in the Upper South East was short-lived, when the inherent salinity of the shallow groundwater table that underlies all the flats became apparent during the 1980s. It was then that the elevated water tables beneath the soils of the broad saline flats – after a string of above average rainfall years, and no longer shaded by (and cleared of) their deep rooted perennial native vegetation – began to cause problems for farmers. Whether through evapo-concentration as a result of surface inundation, or salts drawn to the bared surface through capillary rise of shallow groundwater, the end result was the characteristic salt scolds and loss of pastures typically associated with dryland salinity.

But it is clear that this inundation in the 1980s was not unusual; indeed, as we have explored in detail, it would have been relatively minor by historic standards. Significantly however, it was the first extended wetter phase since much of the Upper South East had been cleared and developed for more intensive forms of agriculture. The watercourse country was already known to consist of formerly brackish to saline flats, floodplains and wetlands, where inherent soil salinity and shallow groundwater had always existed – albeit semi-regularly freshened by major surface flows from the lower South East. Prior to development these conditions had not presented any issues for the land in its original state covered with native vegetation (or indeed bare ground on some of the flats), and a pastoral use for grazing, as 'station country'.

But it turns out that the evidence of salt was there for all to see, as indicated by the composition of the original salt-tolerant vegetation, and as recorded in the notes of the early surveyors and agricultural advisors – which also included reference to bare, salt scolds in many locations. Indeed the latter, CSIRO agricultural scientists, gave repeated warnings in the 1930s about the high proportion of the Upper South East that exhibited prevailing characteristics of waterlogging and salinity.

However, as can been seen in Figure 20, and on the basis of the subsequent phase of development that resulted in the majority of native vegetation cover being lost over large areas of the Upper South East, their warnings were not heeded. This was a time when the land was still used for low-intensity pastoral purposes, where fire to manage regrowth was the land management tool of choice by graziers, but the country was otherwise in its natural state.

For more information see the summary about the work of Taylor in 1933, and Melville and Martin in 1936, in Smith and Foale (1998).

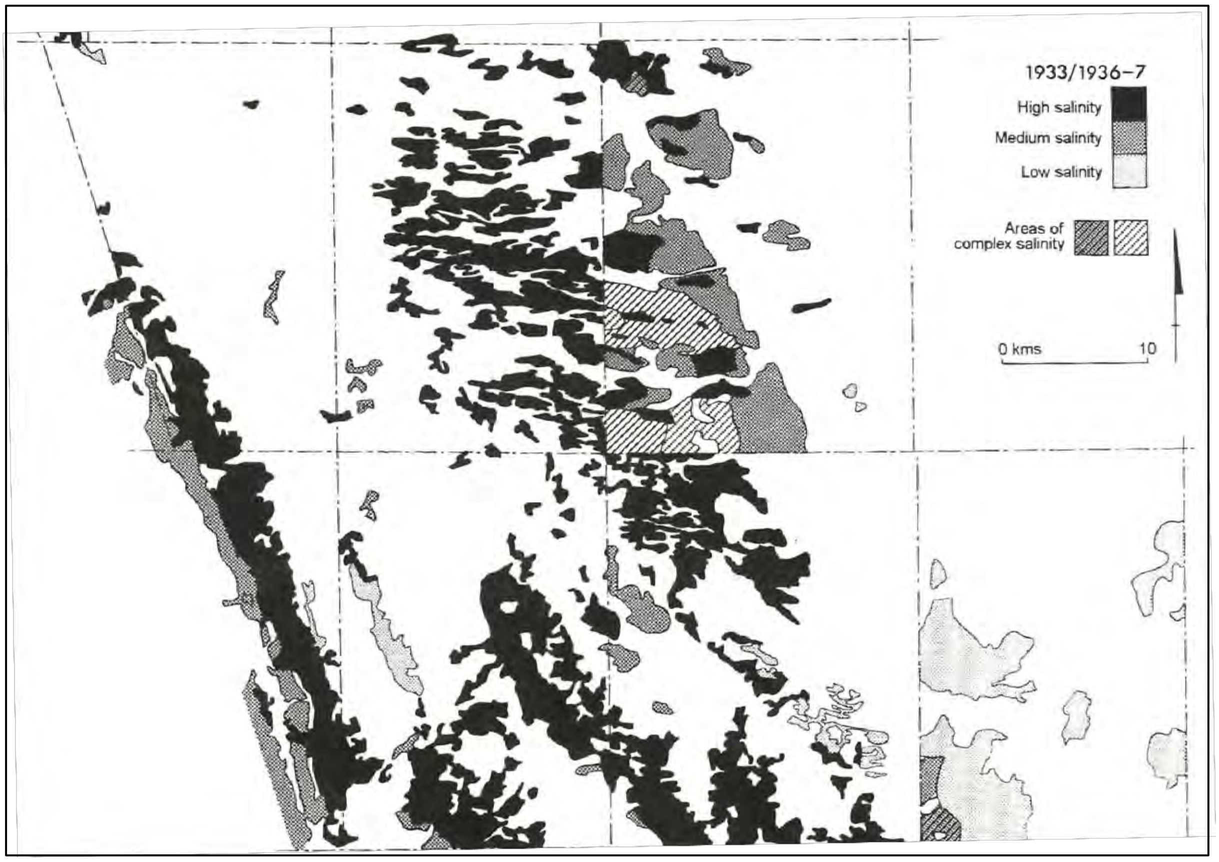


Figure 20 – Areas of the Upper South East considered to be at risk from salinity after two CSIRO studies in the mid-1930s (from Smith and Foale (1998)), which includes the majority of the wetlands and floodplains. Tilley Swamp is at the far left.

Hence, by the 1980s and after decades of intensive development, both the land use and the production expectations of landholders had dramatically changed. The recent emphasis had been agricultural rather than pastoral, a transition that had been encouraged (and in fact incentivised) by previous government policy and investment schemes (e.g. AMP).

With surface salinisation an increasing concern, some private landholders began more drastic (deeper) forms of drainage work on their own properties. A more coordinated approach was eventually agreed to and acted upon by the state government, resulting in the development of the Upper South East (USE) program (from the 1990s to 2011), which incorporated both existing private drainage works and constructed new drains. The program combined shallow drains for removal of seasonal surface water, a major new network (650 km) of deeper drains to manage shallow saline groundwater, and floodways to manage environmental flows into en route wetlands.

As part of this most recent program, and despite concerns very clearly articulated by many individuals, organisations and agencies during the first consultation period about ecological impacts (see "Part B: Submissions" in the Upper South East Dryland Salinity and Flood Management Plan Supplement; NRC, 1993), including within a major detailed review of the Plan by the Semeniuk Research Group (Semeniuk 1993), surface flows through most of the remaining wetlands in the Upper South East were soon being significantly altered via the construction of deep groundwater drains (from 1998-2011).

Groundwater drains have been found to not only intercept surface flows, but in lowering naturally shallow water tables, they also make the landscape itself less likely to inundate and produce surface runoff, or capable of retaining water in wetlands after inundation, given their dependence on and interaction with shallow groundwater.

Three major drains in particular impacted flows reaching the Taratap Watercourse and Tilley Swamp.

The **Fairview Drain** was constructed in 1998, and immediately prevented water that otherwise used to enter the East and West Avenue Range Watercourses south of Rowney Road from flowing north. This caused an immediate and now ongoing reduction in the amount of surface water that reaches Henry Creek, with no surface (i.e. natural overland) flows generated by either of the Avenue Watercourses reaching Henry Creek since that time, and no longitudinal surface flows from the West Avenue Range Watercourse into Henry Creek at all recorded since 2000.

The **Taratap Drain** was constructed between 2004 and 2006 to provide flood mitigation for cleared former floodplains of the Taratap Flat, with the additional role of delivering some additional flows to wetlands in the central catchment with excess flows forwarded to the Tilley Swamp Drain. Historic flows from south of the Watercourse were intercepted by the Blackford Drain and Murrabinna-Blackford Drain system, completed in 1965 and 1966 respectively, however inflows from the local catchment under normal or higher rainfall conditions have been deemed sufficient to maintain what were deemed "key" wetlands along the Watercourse (DFW 2011).

The **Tilley Swamp Drain** was constructed between 1999 and 2000, channelling water north from the Henry Creek drain at Henry Creek Rd through private land, along the eastern boundary of Tilley Swamp CP, and via the eastern edge of the Tilley Swamp Watercourse through private land, before cutting its way through Martin Washpool CP and flowing into Morella Basin. Regional drainage had removed much of the historic overland flows that fed the Watercourse from its extensive catchment to the south, and inflows are now primarily sourced from the local catchment west of the drain. Under high rainfall conditions, surface water flows from floodplain to the east that previously flowed naturally into the Watercourse are now intercepted by the Tilley Swamp drain. Local catchment inflows are insufficient to meet the needs of the wetlands and large floodplain, and can be supplemented by excess flows from the West Avenue and Bakers Range catchments and the Taratap Watercourse when available, using control structures at Henry Creek Rd and Petherick Rd (DFW 2011). An outlet regulator controls flows out of the Tilley Swamp Watercourse into Morella Basin and onward to the South Lagoon of the Coorong.

A portion of Morella Basin was strategically purchased as part of the Upper South East Program (USEP) in 1998 and later incorporated into Martin Washpool Conservation Park (in 2005). Since this time, the basin has been used to hold saline groundwater drainage discharge emanating from the Upper South East network (rather than fresher surface flows from much further afield, as was previously the case), but at a much redued depth than its original historical (i.e. pre-1864) full-supply level. Morella Basin is a prominent exception to the drying trend not only observed throughout the rest of Tilley Swamp, but also witnessed across most of the Upper South East; with the recent phase of comprehensive groundwater drainage substantially and further altering inundation patterns across the majority of the Upper South East. In conjunction with an extended period of mostly below average rainfall over the past two decades, this coincides with a significant decline in the character and condition of a large number of wetlands in the affected area.

In response to this trend however, recent modifications to the drainage system in the Upper South East have increasingly considered environmental requirements, with efforts to manipulate water levels in wetlands to maintain or enhance ecological values, and even to maximise the habitat values of the artificial drains themselves.

Major projects include the REFlows program (2003 to 2006), which aimed to return historic freshwater flows to wetlands of the Upper South East from Drain M at Callendale, and the South East Flows Restoration Project (2014 to 2018). As described earlier, the SEFR project proposes to significantly alter the hydrology of Tilley Swamp by increasing the outlet sill level into Salt Creek and restoring an increased volume and frequency of flows, which in turn will result in significant increases in the depth and duration of inundation throughout the wetland system.

Prior to the SEFRP, the various government endorsed drainage works in the Upper South East had resulted in the construction of 714 km of drains and floodways, alongside the 1875 km of drains in the lower South East (Plowman 2014). Artificial drainage has facilitated the conversion of land to agriculture and been the primary contributing factor in detrimentally modifying the hydrology of wetlands and floodplains across the watercourses, triggering significant changes in vegetation structure and composition, as will be discussed in the following sections.

A timeline summary of some of the key events capable of altering in hydrological conditions in Tilley Swamp is summarised in Table 3. Note that this is not intended to provide a comprehensive summary, just a general overview of some of the key events and their likely impacts on the eco-hydrology Tilley Swamp.

Table 3 – Descriptive summary of general, relative changes in the hydrology of Tilley Swamp over time

Time Period	Flows and salinity	Depth
Pre-European natural conditions **Prior to 1864**	Seasonally variable, but capable of receiving high flows. Presumed relatively fresh temporarily in high flows, grading to brackish/saline in low flows, and highly saline later in the season through evapo-concentration.	Very deep at Morella Basin and Martins Washpool, where semi-permanent wetlands occur, and cause a backwater inundation gradient for several tens of kilometres to the south.
1864 to 1886	1864 works increased regularity of flows into Coorong, due to Salt Creek cutting, and 1880s works increased flows from Reedy Creek in lower South East. No change in salinity.	Reduced depth in Morella Basin, but little change elsewhere upstream, due to significant other impediments to drainage within Tilley Swamp (ridges at Martins Washpool).
1886 to 1912	1886 works increased flows from Reedy Creek (Goyder's bank) and reduced sills within Tilley Swamp, but some lower SE water is later cut off. Increase in regularity / volume of surface flows into the Coorong. Likely short-term freshening of Tilley Swamp.	Despite the increase in flows, the depth and duration in Tilley Swamp is reduced as a result of the in-stream sills being breached at Morella Basin and Martins Washpool. Tilley Swamp likely to be less permanent.
1912 to 1965	Stop-banks (F, H) hold more water in the Bakers Range Watercourse and additional works on drains to the sea in the lower SE, reduce flows reaching Tilley Swamp and hence the Coorong. Likely increases in swamp salinity due to reduced flow.	With sills breached and less water arriving in Tilley Swamp, depth and duration further reduced. Conversely, and at the same time, as a result of the changes, the nearby northern Bakers Range Watercourse and Alf Flat received greater volumes of water for a longer duration than previously.
1965 to 1998	Major loss of flows to Tilley Swamp as a result of comprehensive drainage in the lower and mid SE, with the exception of local runoff and modest discharges from Henry Creek. Increased salinity.	Local private drainage within the watercourse leads to a further reduction in depth and duration of inundation.
1998 to 2018	Loss of natural fresh surface flows via Henry Creek due to Fairview Drain, but upper SE groundwater drains generate saline flows from multiple new catchments to Morella Basin (Northern Outlet and Kercoonda S-Bend Drains). Tilley Swamp itself is almost totally and comprehensively drained by a new groundwater drain, except for a small area in Tilley Swamp CP temporarily hydrated when Kercoonda Drain flows available. General further salinity increase.	Morella Basin is partially restored to hold water prior to discharge into the Coorong, but the bulk of Tilley Swamp is totally dry. Only small areas subject to minor temporary incidental inundation as a result of diversions and/or the limited capacity of the Tilley Swamp groundwater drain to cope with regional inflows.
Post SEFR Project	Flows from the lower Blackford drain catchment will be redirected to Tilley Swamp for the first time since the 1960s, along a new floodway/drain alignment. High to moderate flows are likely to be brackish and not tap into the original catchments of the lower South East, meaning Tilley Swamp will definitely be more saline than it was originally (pre-1864).	Agreement to hold water to 5.4M AHD in Morella Basin and Tilley Swamp will see the wetland further restored, almost to its original depth (under 'cease-to-flow' conditions). When it fills to this depth, increased areas at the northern end of the wetland will likely be semi-permanent again, with groundwater mounding expected to have a carryover effect between years and potentially reactivate springs in the Coorong.

The original sill levels that were breached in the 1860s and 1880s, at Morella Basin and Martins Washpool respectively, were accurately surveyed by experienced SEWCDB staff (Brenton Puddy and Michael Talanskas) in the early 1990s. At this time there had been some debate and confusion about whether the existing drainage outlet into Salt Creek had been placed at the original 'breach point'. However, as outlined earlier in this report, it is clear that this higher point (6.9 m AHD) on the edge of Morella Basin was chosen for the outlet drain location simply because it was the shortest route between the edge of the main swamp and the creek, despite the fact that this resulted in the need for a deeper cutting. The ground survey (see Figure 21) confirmed this fact, establishing that the high point at Martins Washpool (5.5 m AHD) was indeed the true determinant of static water levels throughout the bulk of Tilley Swamp, and that the sill level via the natural winding outflow path from Morella Basin to Salt Creek was actually slightly lower (4.9 m AHD).

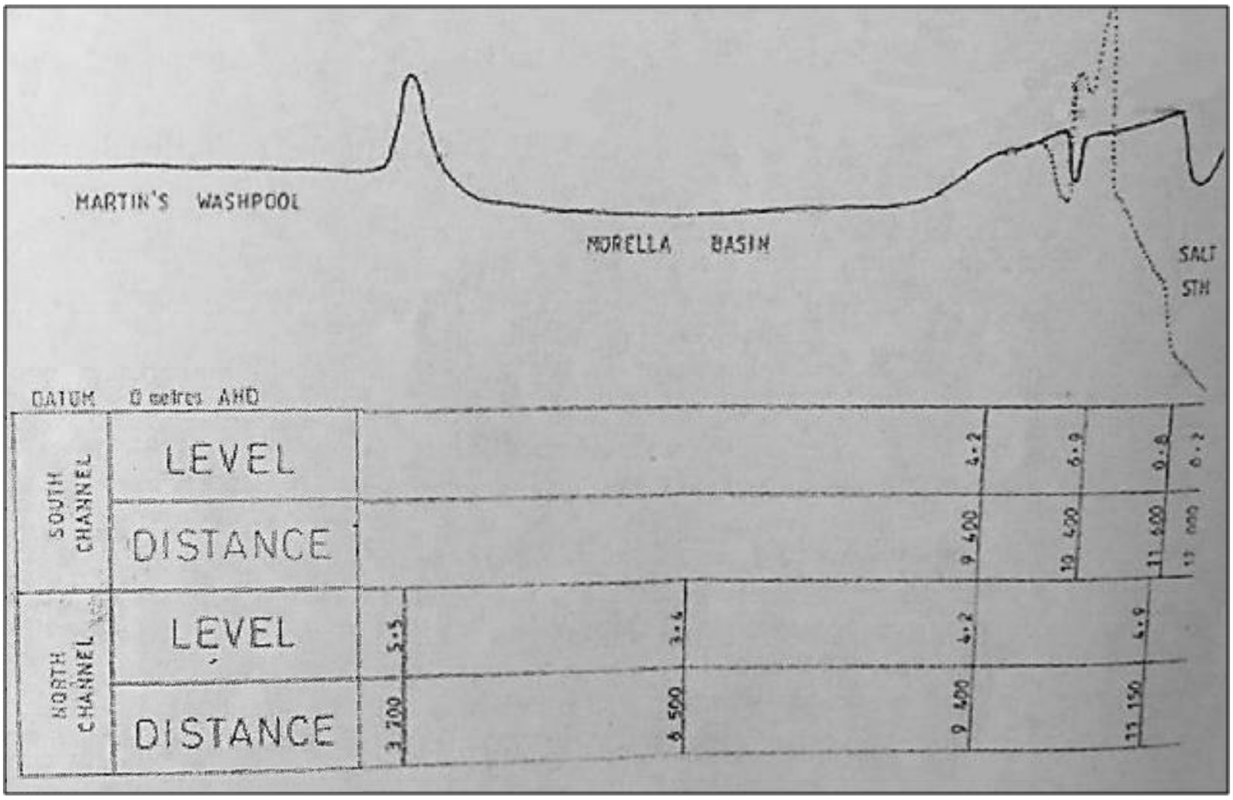


Figure 21 – The survey undertaken by the SEWCDB of the original sill levels of Martins Washpool and Morella Basin (indicated by the rows marked 'north channel') and the levels along the artificial cutting (dashed profile line) that was first constructed between Morella Basin and Salt Creek in 1864 (here called 'south channel').
[Note: it was erroneously considered the 'south channel' because there was speculation that the 1864 drain cutting had itself followed a natural flowpath. This assumption is incorrect, as it is just a drain cutting along the shortest route, and the 'dual flowpaths' observed prior to drainage were in fact (as demonstrated in this report) both found within what is labelled here as the 'north channel'.]

Consistent with the historic records reconstructed earlier in this section, this explains why the cutting in 1864 resulted in the drainage of Morella Basin, but made little difference to static water levels in Tilley Swamp upstream of Martins Washpool until additional works were undertaken in the 1880s. This earlier ground-based survey work has also been run through a brief validation exercise by NGT using LiDAR-derived Digital Elevation Model data, to make sure that levels we are now relying on for modelling purposes are broadly consistent with those accurately surveyed on the ground. The elevations of several narrow points on the northern edge of Morella Basin and along the circuitous original northern flowpath to Salt Creek were checked, and the results are marked on the original map of this area, shown in Figure 22.

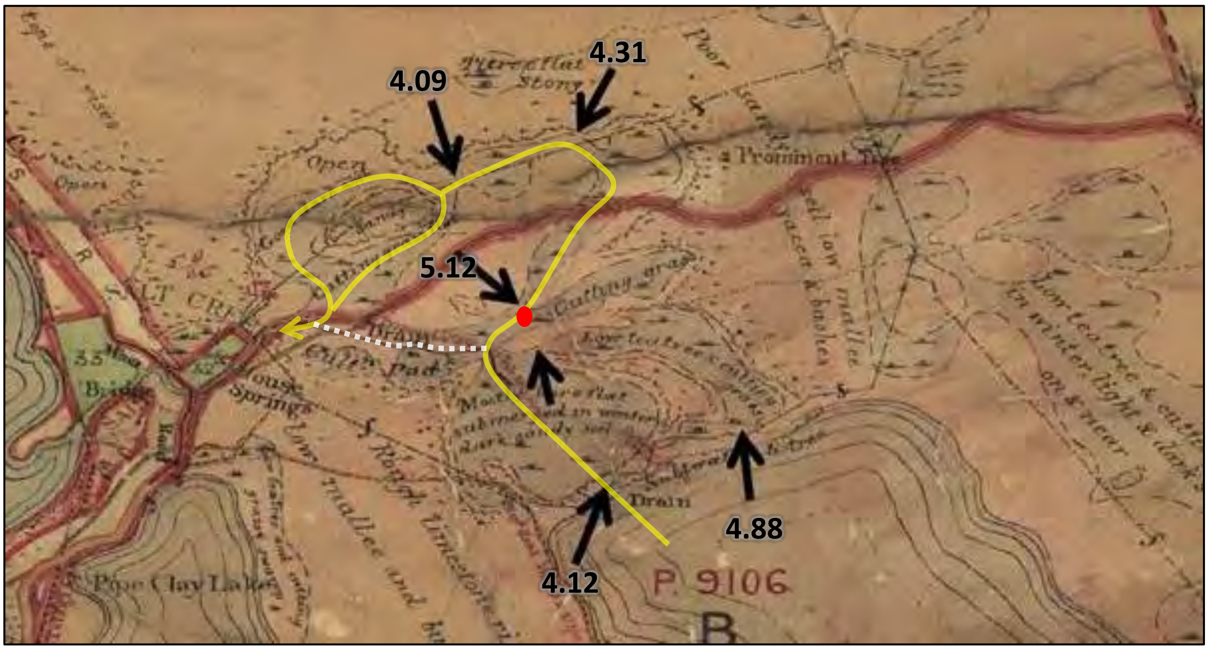


Figure 22 – Marked up original map showing elevations derived from modern Digital Elevation Model data. Red dot indicates likely location of the original 4.9 m AHD sill, the location that shows up on the DEM as approximately 5.12 m AHD. Yellow lines show the preferential direction of natural flows prior to 1864 based on the natural surface levels. The artificial cutting made in 1864 is dashed white.

Considering the potential error margin of this data (due to false ground readings caused by vegetation cover), and the fact that only several points were randomly checked, it is broadly consistent with and validated by the SEWCDB survey. The location marked with the elevation '5.12 m AHD' would appear to be the site that corresponds with the likely original sill level, and is within 22 cm of the ground-based survey-identified sill. This is further validated by the fact that none of the fringing mature River Red-gums around Morella Basin are growing below this elevation, indicating a match for this being close to a former high-water mark. After reaching this height, flows spilled unrestrained down the winding dual flowpath to Salt Creek and into the Coorong.

Checking the original levels of Morella Basin and Martins Washpool is extremely helpful for reconstructing how Tilley Swamp would have functioned and for developing a picture of its inundation extent prior to European settlement. Using a combination of this data, vegetation patterns, early survey maps and the accounts of inundation depth and extent in the early European accounts, we have developed a coarse map to give an impression of what inundation extent would have looked like at times when Tilley Swamp was full, under flowing conditions (Figure 23).

Further, thanks to modern GIS tools, earlier descriptions and the timeline in Table 3 can be broadly illustrated using a LiDAR derived Digital Elevation Model data, to run predicative inundation scenarios of estimated change to the inundation extent in Tilley Swamp through time. Figure 24 illustrates the direct impact that the different sill levels at Morella Basin and Martins Washpool have had on static inundation potential of Tilley Swamp under cease to flow conditions over the past 160 years. Please note that these maps do not represent inundation extent accurately in any given inundation event, given that flooding regularly used to (and in some cases – e.g. Taratap wetlands – still can and does) occur outside these areas, as per the estimated original floodplain extent in Figure 23. It is simply conveying the impact that the outlet sills have on Tilley Swamp inundation and its change over time.

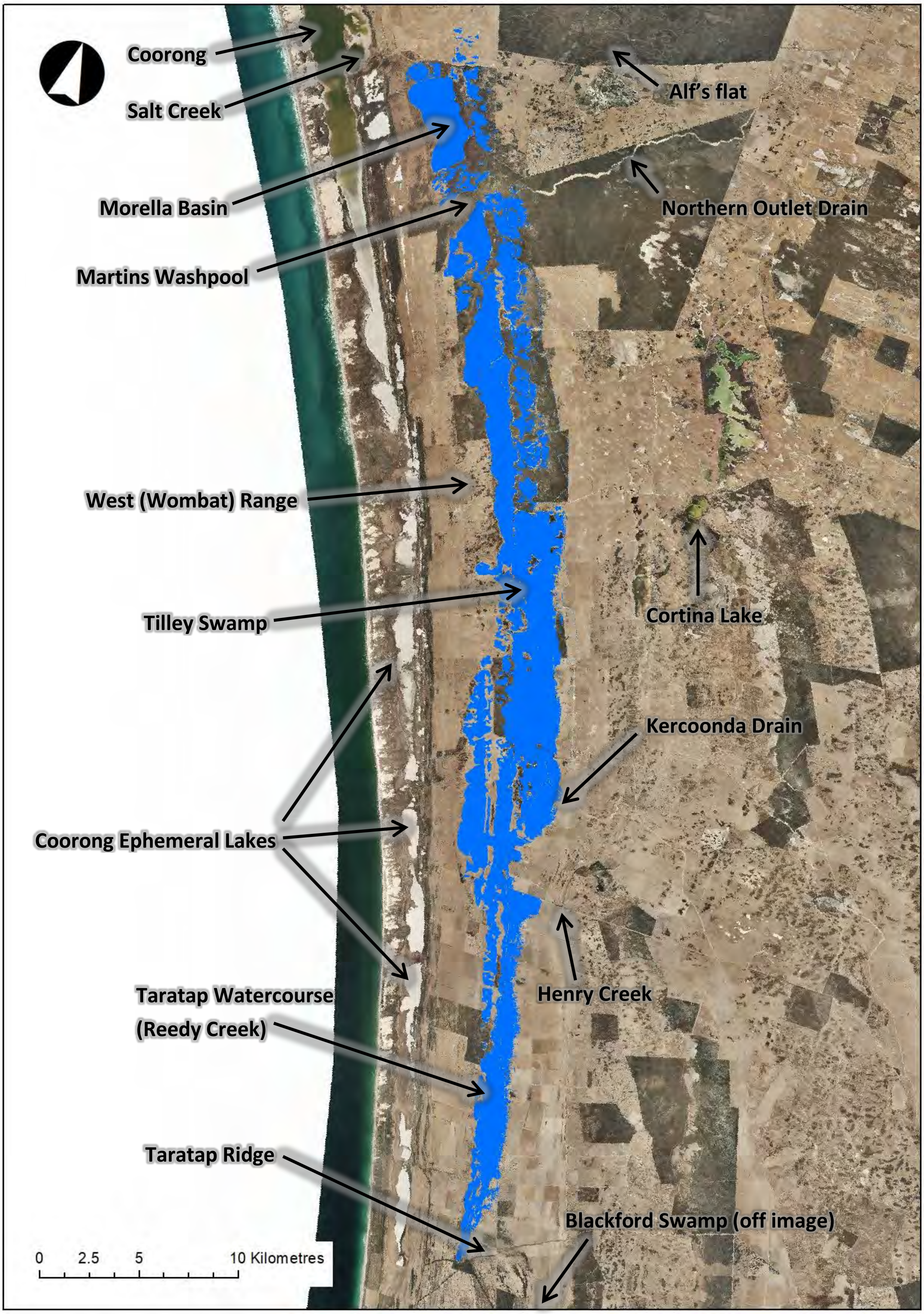
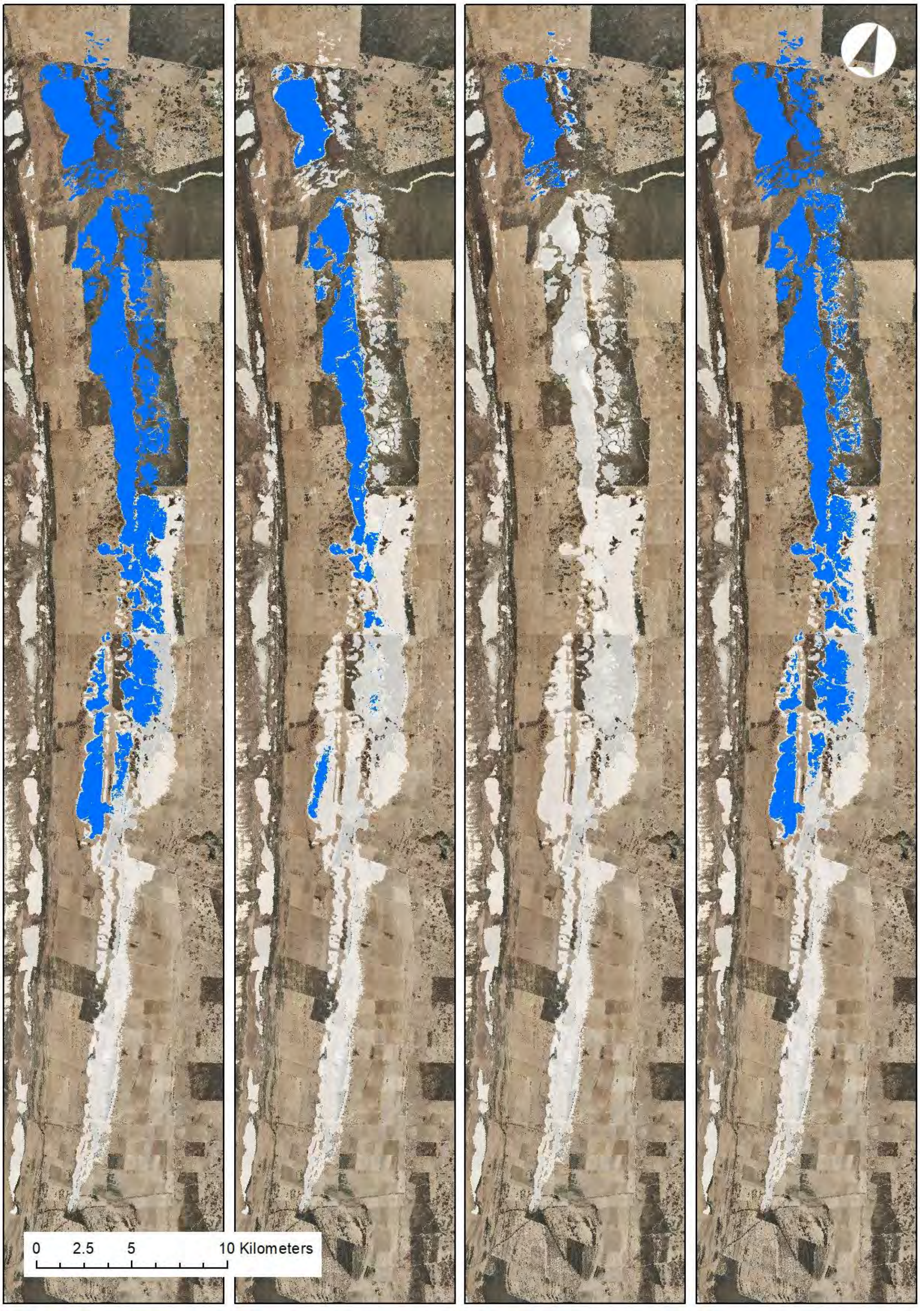


Figure 23 – Estimated inundation extent of Tilley Swamp during wetter phases, at full supply level and during flowing conditions. Total Wetland Area = 12,835 ha; Total Volume at this extent = 96.02 GL. Figures are approximate. Key locations referenced in this section as marked. Map by Ben Taylor.



Pre-drainage sills	***1864/1886-1998***	***Post-1998***	***Post-2018 (Post-SEFRP)***
Morella 4.9m AHD	*Morella 3.9m AHD*	*Morella 4.5m AHD*	*Morella 5.4m AHD*
Tilley Swamp 5.5m AHD	*Tilley Swamp 5.0m AHD*	*Tilley Swamp drained*	*Tilley Swamp 5.4 m AHD*
7372 ha; 44.2 GL	*3286 ha; 12.7 GL*	*1000 ha; 10.4 GL*	*6825 ha; 44.4 GL*

Figure 24 – The maximum static inundation potential of Tilley Swamp based only on broad changes to outlet sills at Morella Basin and Tilley Swamp over time. Note that inundation can/does occur outside these areas, indicated by the full original floodplain extent (as per Figure 23) – shaded white. Maps by Ben Taylor.

This clearly indicates how the major restoration works now being undertaken at Tilley Swamp are likely to achieve wetland inundation impacts (area, depth and duration) in Tilley Swamp broadly consistent with original conditions. This new water regime will be super-imposed upon, and managed in conjunction with, a complex pre and post-SEFR project drainage network (shown in Figure 25) that resulted from the extensive history of development previously described.

Figure 25 – Drainage network and the SEFRP study area (Taratap and Tilley Swamp drains highlighted)

A conceptual diagram is shown in Figure 26, as an alternative way of illustrating the information presented in the previous Figures, especially the inundation scenario maps in Figure 24.

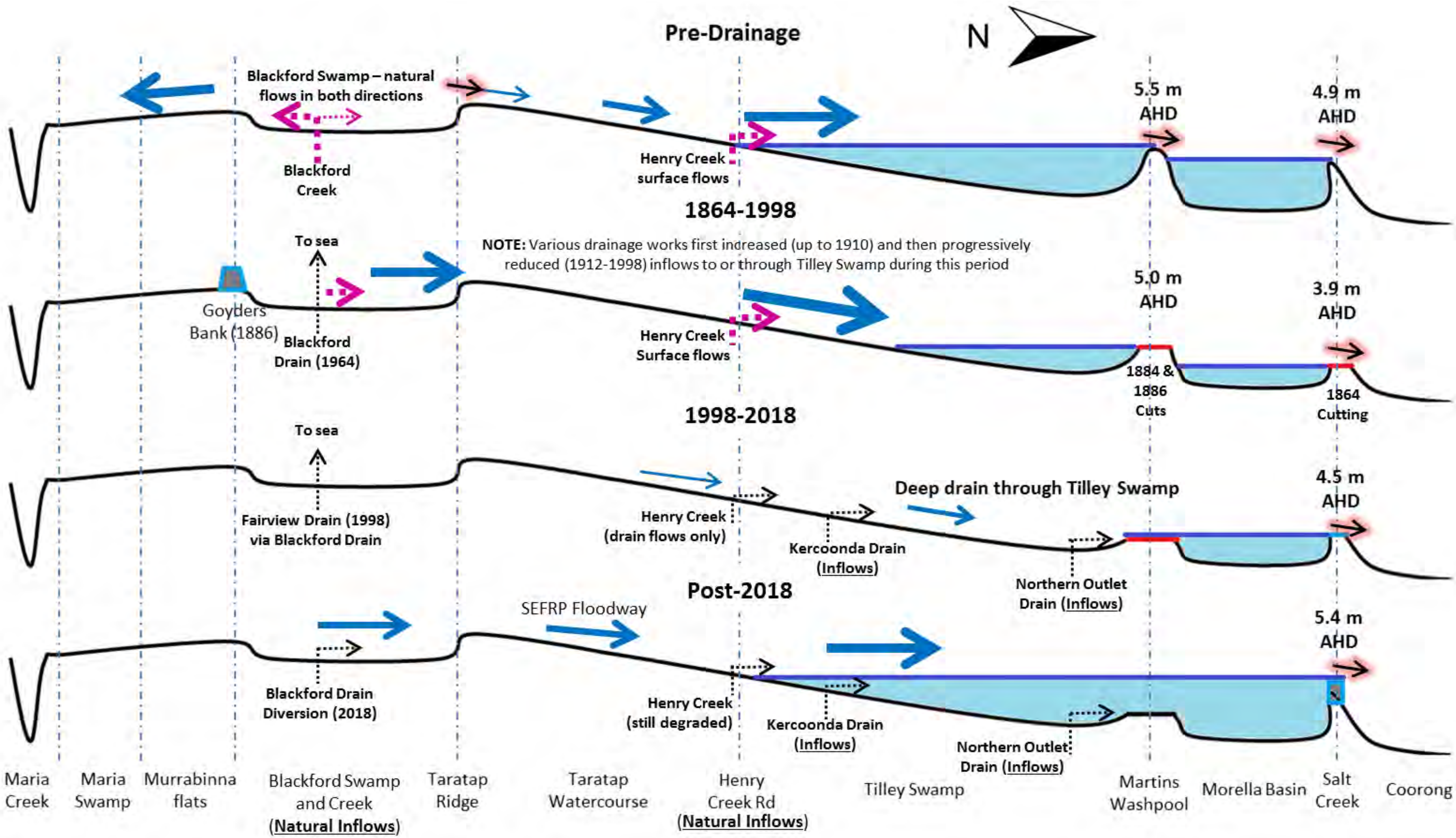


Figure 26 – This vertically exaggerated 100 km long axis between Kingston and Salt Creek shows key features represented as a conceptual north-south longitudinal cross section. Although not illustrated here, this entire cross-section was wetlands and floodplains, and could go under water for several months or longer. Note that only static 'cease-to-flow' levels of inundation in Tilley Swamp caused by the sills at Martins Washpool and Morella Basin are shown here. Diagram by Mark Bachmann.

***KEY:** **Blue arrows** are flow direction, where **size** of arrow indicates relative volume. **Purple dashed arrows** are natural surface inflows. **Black dashed arrows** are artificial drains. **Black/shaded red** arrows are natural (or now regulated) overflow sills. Original and altered sills are marked as indicated in **m AHD**.*

3.5. *Native vegetation of Tilley Swamp prior to 1954*

The best evidence available to reconstruct the original ecological character of Tilley Swamp is through assessing changes in its native vegetation. The source material in this era, which pre-dates aerial photography, is first-hand written accounts and the notations made by the early surveyors on some of their plans. From this we can gain a significant insight into the early character of the land and how this information interacts with, and potentially helps to express the hydrological story of the previous section.

One of the very first, albeit brief, European accounts of the wetlands of the Upper South East was recorded by George French Angas in autumn 1844 (Angas 1847), when he decided to head inland from the southern Coorong – in a location between present day Salt Creek and Kingston (his route is shown as mapped by Thomas Burr in Figure 12) – to see what the interior of the region was like:

> *"We struck out to the east and north-east, across the desert ranges, to examine the country in that direction. Passing through a barren and dreary region of scrub, rendered more cheerless by the dark clouds that were gathering all round the horizon, after about seven miles we ascended a limestone ridge, from the summit of which we descried extensive swamps to the eastward. Further on we crossed several of these swamps, which consisted of loose, black, rotten, vegetable matter and sand: they are occasionally flooded during the rainy season, and at the time of our visit were covered very thickly with the dead shells of a reverse bullimus. We regained the shores of the Coorong, which here terminates in a series of salt-lagoons, after passing successive swamps intersected by belts of grassy soil and low hills, scattered over with casuarina and a variety of smaller shrubs. Wombat holes were very numerous, and traces of these animals occurred in every direction. Emus were also abundant in the neighbourhood of the swamps."*

Burr's description of the same day appears earlier in this report on page 24.

Coulthard gave a description of the country to Parliament in September 1864, where he stated that the swamp changed character at Henry Creek. North, the water was deeper, the swamps were rush-covered and dotted with islands; while to the south, the swamps were shallower, narrower and covered with thatching grass (which is *Gahnia filum*). Near Salt Creek there were two large open water swamps separated by a bar (Turner and Carter 1989). In 1864, Goyder also made notes on the vegetation of the Tilley Swamp run, the southern portion of the area of interest for this report, as previously shown in Figure 6. In terms of swamp vegetation, as he travelled across the run, he predominantly recorded cutting grass, rushes, bushes, tea-tree, herbs, a few reeds, water still in places, and grass and herbs around margins of swamps (Goyder 1864, cited in McArthur (2007)).

By twenty years later, from the 1880s, surveys for closer settlement give some early insights into a more detailed picture of the likely original native vegetation in the area – albeit after 30-40 years of grazing – but after only the first phase of hydrological change (i.e. the 1864 cutting at Salt Creek, the 1884-86 enhancement of the Salt Creek outlet works around Morella Basin and building of Goyder's Bank in 1886).

We'll review the descriptions by assessing a number of sites from south to north.

Firstly, the Reedy Creek discharge site via Blackford, was described (as shown below in Figure 27) in March 1887 in the following ways:

- "Large swamp with very thick and high rushes, containing water nearly all the year round". In the survey notes it says that the "large swamp is wet all the year round".
- "Open flat with cutting grass and rushes with watercourses flowing through it – dark clayey soil."
- "Open flat with very high cutting grass and small rushes – dark sandy soil."
- "Scattered honeysuckle, well grassed flat."

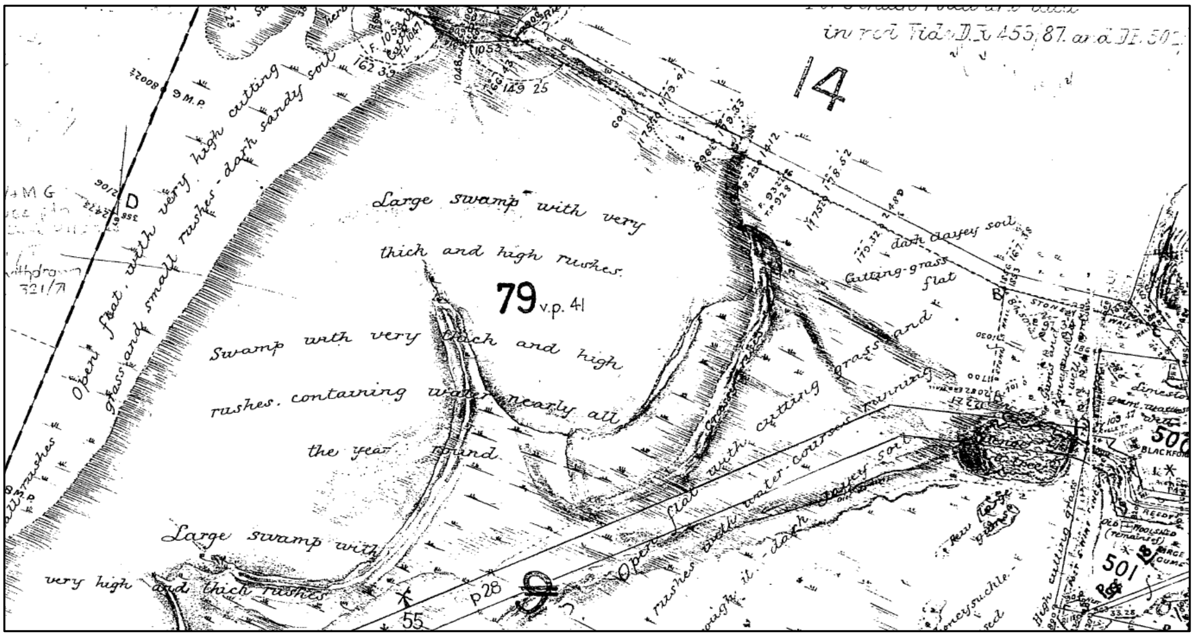


Figure 27 – Survey plan of the swamp on Reedy Creek in 1887, immediately downstream of Blackford

This is also consistent with how this particular area was described several decades later by Blackburn (1964), as shown in Figure 28. Being in the otherwise brackish to saline Upper South East, he mapped the majority of the Reedy Creek and the Tilley Swamp flat between Henry Creek and Blackford Creek as permanent rushy peat swamp (along Reedy Creek itself – see areas marked as swamp on Figure 28), saline swamp (Ro) or groundwater rendzina (Hy) soils. He also mapped the narrow band of freshwater seepage at the 'break of slope' along the eastern flank of the flat, where remnant patches of *Leptospermum lanigerum* and *Gahnia trifida* can still be seen today. This threatened vegetation community associated with freshwater springs, and usually occurring over peat soils, is near the edge of its range in this part of the region, with only Henry Creek to the north preserving remnant *Leptospermum lanigerum* anywhere beyond this point.

When describing the character of "Salt Swamps" in the Blackford area, Blackburn said:

> *"These have high concentrations of soluble salts, mainly sodium chloride and lime carbonate. Samphire is generally the dominant plant, but on some swamps the vegetation in rushes and the soil is peaty, as on the Reedy Creek watercourse near Blackford."*

In making this comment, as useful as it is for confirming of the vegetation type of the location, it is not clear if Blackburn understood precisely what he was describing and the impact of recent hydrological change. In the case of Reedy Creek downstream of Blackford (i.e. what we now refer to as the Taratap Watercourse), it was an area that had increasingly had its previously reliable southern flows from Reedy Creek in the lower South East interrupted. It is those fresher flows from further afield which would have led to the development of the dense rushy vegetation reliant upon, and representative of, such conditions. Hence for a reliable discharge location, also sustained from beneath by elevated groundwater, the formation of peaty soil was the logical result. However, it now goes without saying that this process, given subsequent waves of artificial drainage, has been further and now permanently disrupted.

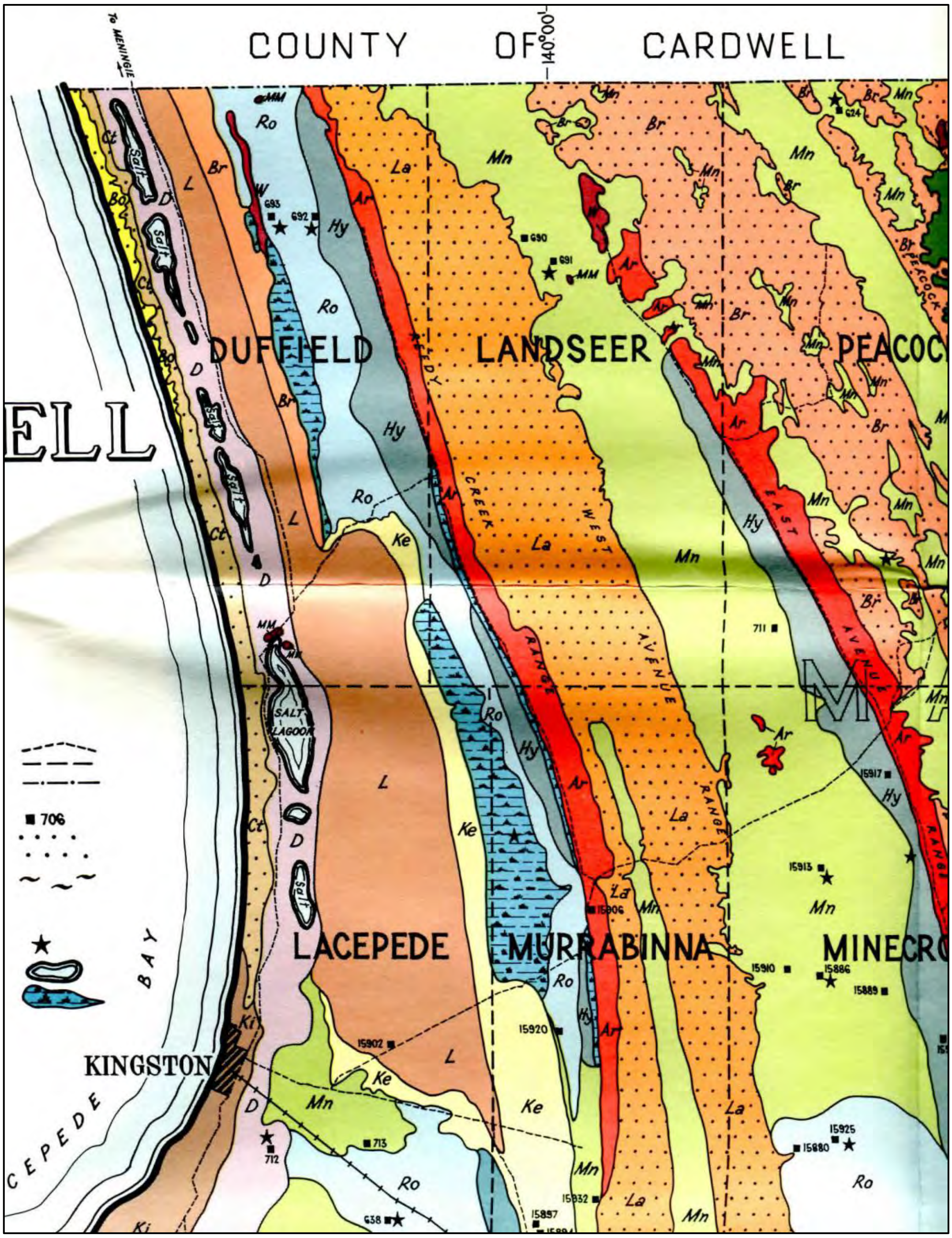


Figure 28 – Blackburn's 1964 soil map of Reedy Creek (i.e. Taratap), immediately downstream of Blackford – the peat area in the vicinity of Murrabinna (marked blue) broadly represents the extent of Blackford Swamp.

A short distance further down the Reedy Creek Watercourse to the north, where the formal beginning of the study area (for the purposes of this report) starts, in what is now called the Taratap Watercourse, the following descriptions are from the survey diagrams from 1889 (Figure 29):

- "Reedy Creek Watercourse" which is noted as having "rushes" along the deepest part of the flat, along which the majority of the flows from the creek at Blackford were conveyed northwards towards Tilley Swamp. A portion of this area is mapped as a rushy, peaty swamp by Blackburn (1964).
- The narrower connecting channel from the east is noted to consist of "rushes and cutting grass".
- The flats to the east were described as "Lowlying dark clayey soil with cutting grass tussocks". These areas are considered saline flats by Blackburn, transitioning from saline swamp (Ro) to groundwater rendzina (Hy) soils from west to east across the flat.

The defined line demarcating the watercourse implies semi-permanence of water along this section.

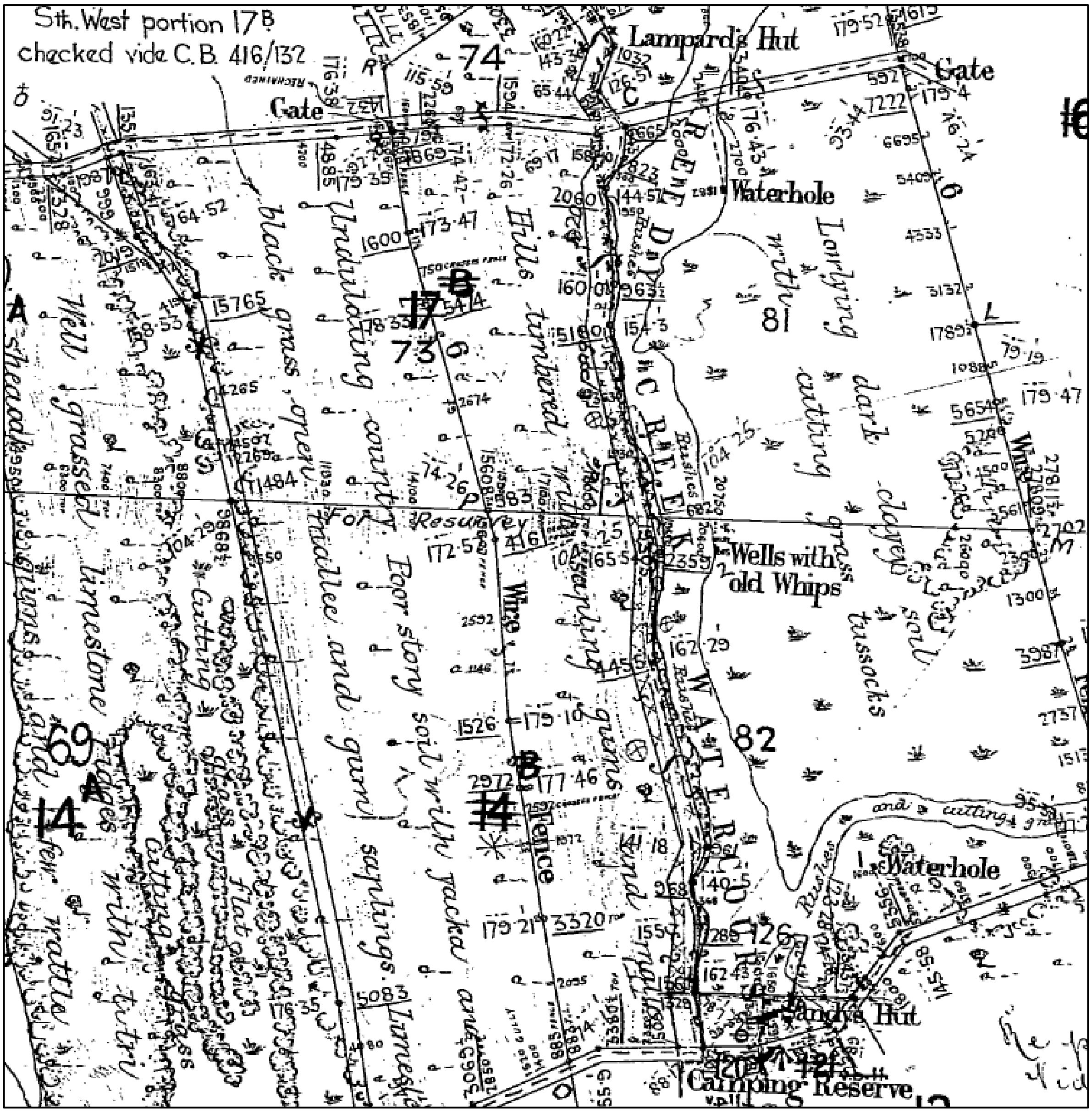


Figure 29 – Survey plan of Reedy Creek and the Taratap Flats from 1889, north-west of Blackford

Immediately east of the previous image, Figure 30 helps us to gain an appreciation of the transition across the flats from west to east, and the complexity and diversity of vegetation types – as well as the inherent salinity of the area. From west to east, the vegetation was described as follows:

- "Scattered tea-tree and cutting grass" and "low-lying dark clayey soil with cutting grass" adjacent to the watercourse"
- "Open ti-tree, dark clayey soil with cutting grass and samphire" in the centre of the flat. This is consistent with Blackburn (1964) who also went on to say when describing "salt swamps", that:

  "Alternatively there are situations where the ground cover is mainly samphire with occasional salt-water tea-tree"

- "Low lying open flat. Good dark clayey soil with cutting grass and patches of dwarf ti-tree" across the majority of the eastern portion of the flat.
- "Scattered banksia" on the slightly more elevated, but still wet, eastern portion of the flat.
- Then on the range to the east "hills timbered with banksia, gums, shea-oak and ti-tree. Fairly grassed sandy soil with patches of limestone."

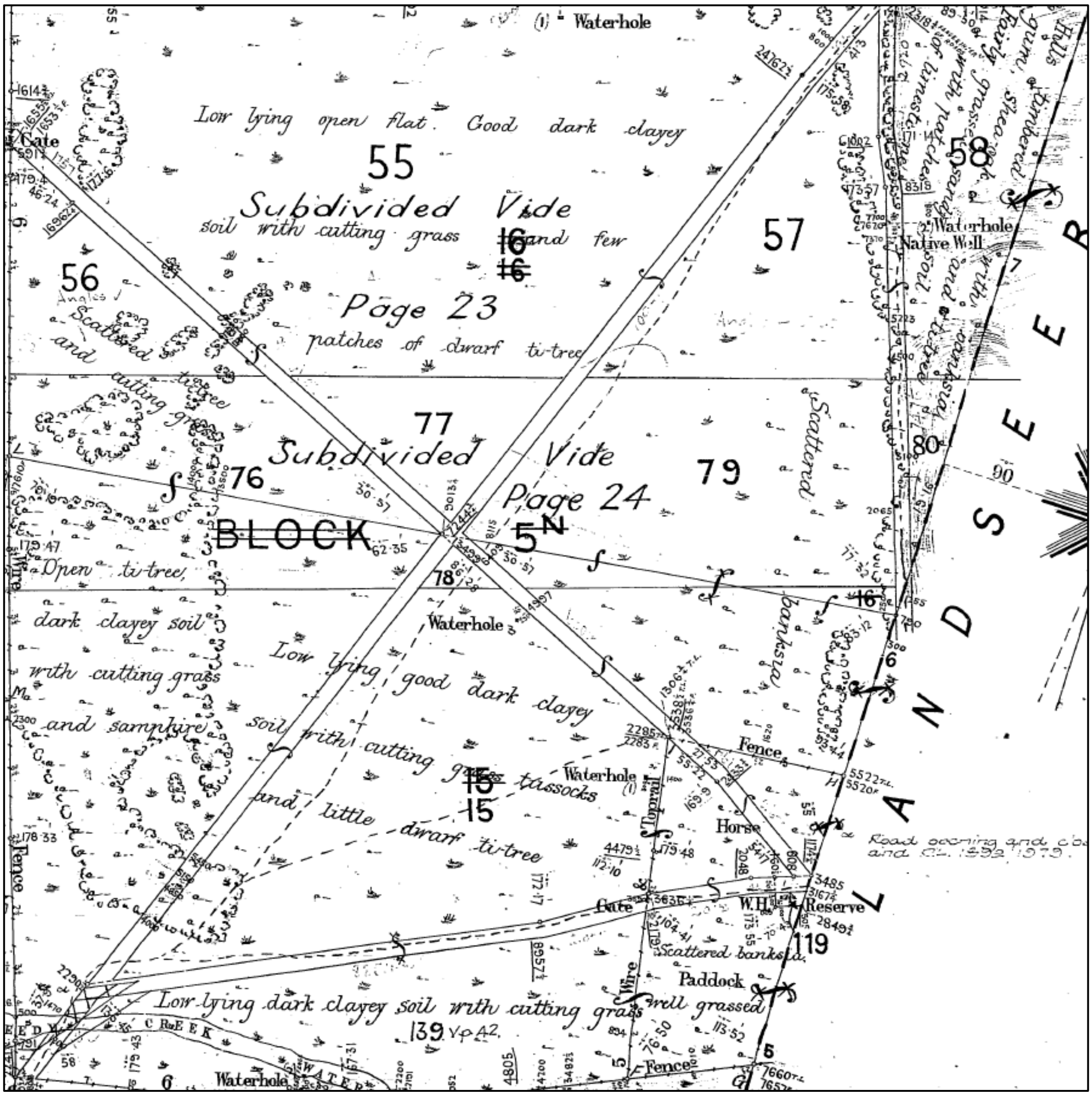


Figure 30 – Survey plan of the Taratap Flat from 1889, immediately east of Figure 29

Figure 29 and Figure 30 provide an excellent west to east cross section of the Taratap flat – from range to range – after 40 years of pastoral activities but well before mechanical clearance, and certainly prior to any major changes in hydrological regime.

Further to the north along the watercourse, abutting Henry Creek Road, as drawn by the surveyor in January 1887, is shown below in Figure 31.

- The western flank of the watercourse is bounded by a "well grassed stony ridge, gum shea-oak and ti-tree"
- The vegetation of the "Reedy Creek Watercourse" (now called the Taratap Watercourse) is not noted, indicating that it is likely open in character.
- To the east of that is "Light clay with cutting grass" and a large area across the flat that is marked "Fair light clayey soil with limestone about 6 inches from surface with occasional outcrop above surface and mostly covered with cutting grass, with patches of ti-tree heath".
- Also note where dispersed flows are shown to enter the flat from Henry Creek, in the top centre of the image (where highlighted).

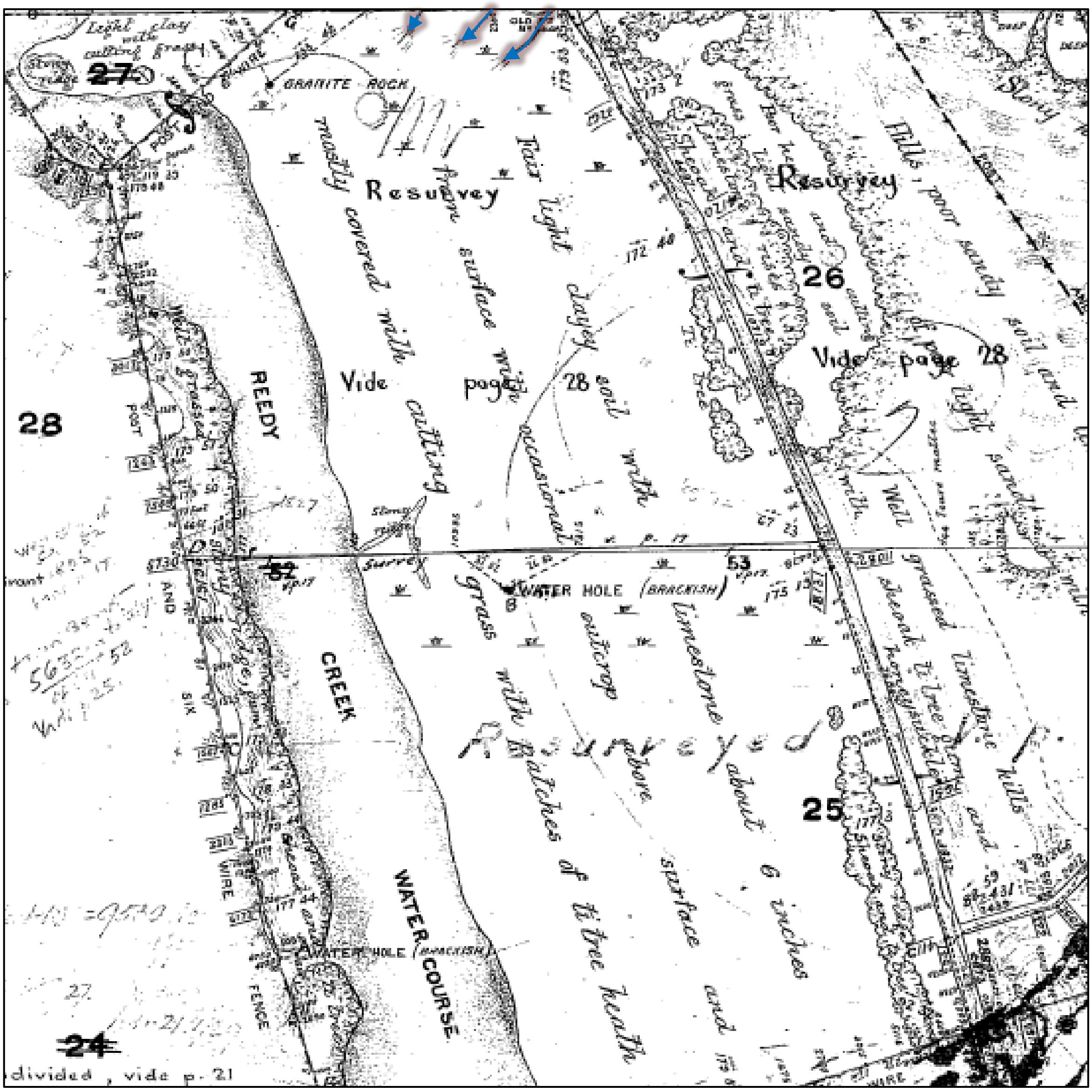


Figure 31 – Survey plan of the Taratap Flat from 1889, immediately south of Henry Creek Road. The blue arrows indicate where Henry Creek discharges into the flat.

To the north beyond this point, the early surveys are scant, because the Hundred of Duffield formed the edge of the surveyed Hundreds for several decades, with the majority of the Upper South East kept for decades longer as station country under pastoral lease. This portion of Tilley Swamp is likely to have been most significantly impacted as a result of the removal of downstream sills (at Morella Basin 1864/5 and 1884, and Martins Washpool in 1886) impacting on the upstream retention of water in the wetland.

The basic outline of the watercourse through the Hundred of Neville was included on the Hundred map of 1941, as shown in Figure 32, but the surveys for this area did not include detailed descriptions.

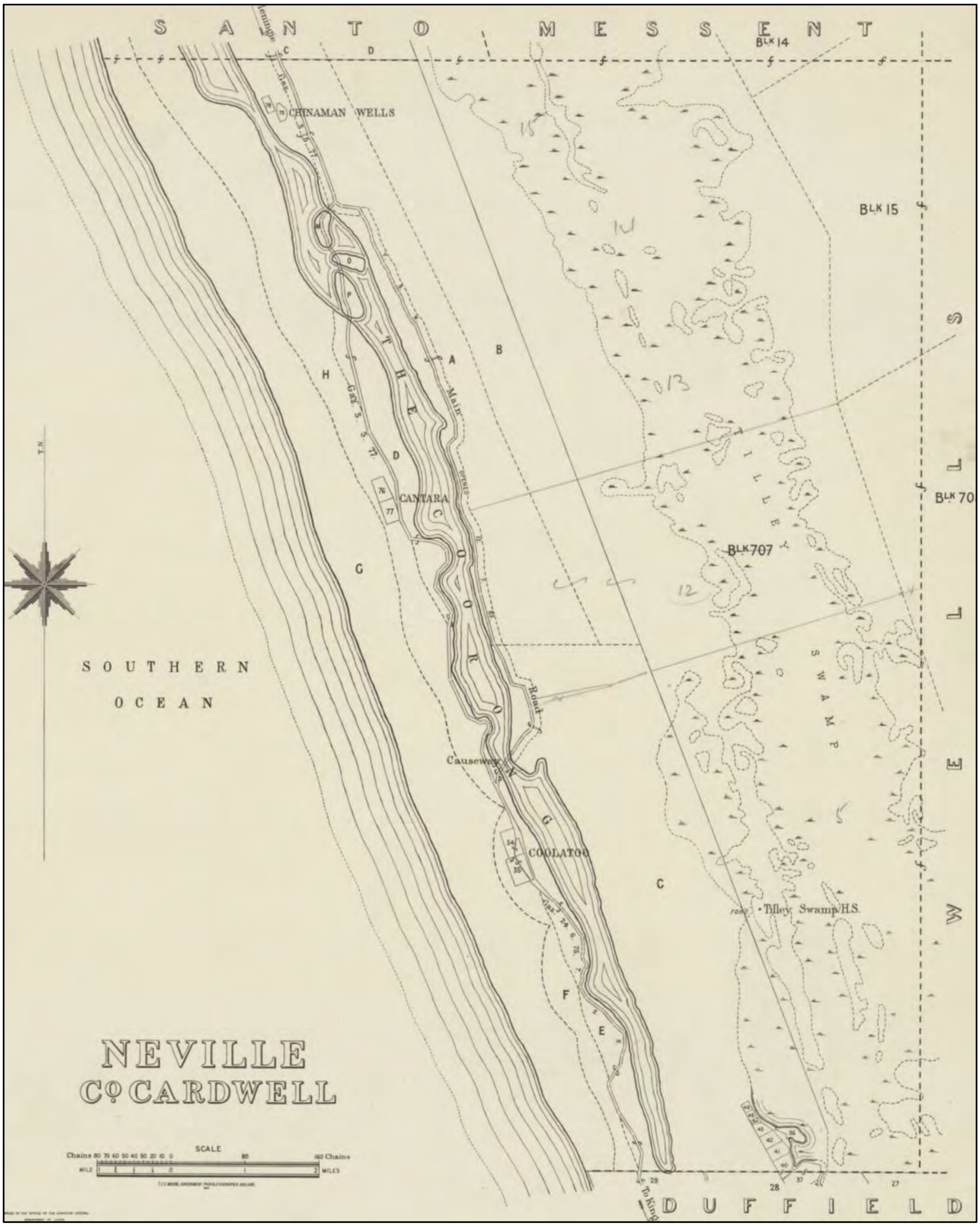


Figure 32 – Map of the Hundred of Neville from 1841, showing the margins of Tilley Swamp

This stretch of country includes the portion of the watercourse where Coulthard, prior to drainage, in December 1864 reported that south of the gorge (in the vicinity of Martins Washpool - about 2 miles (3 km) south of Salt Creek), the water was 4 or 5 feet (1.2 – 1.5 metres) deep "*further than the eye can reach*". That observation was made looking from north to south over the area shown in Figure 32.

At that depth, and consistent with other early observations, Tilley Swamp would have regularly presented a vast sheet of water for several months of the year. The quality of the water is not currently ascertainable, but it is probably that – like many wetlands in the Upper SE – the initial, occasionally large, surface flows reaching this section of the swamp would have had a considerable freshening effect, causing the swamp to be brackish when full, lined with patches or islands of scattered fringing *Melaleuca halmaturorum*. In major flow events, the filling of Morella Basin with relatively freshened water enabled the establishment of a fringe of mature River Red-gums around the basin, which still persist around (and in some cases above) the former high water mark today.

As the watercourse seasonally dried out however and, consistent with its underlying saline soils and groundwater, brackish conditions would have given way to increasingly saline conditions, i.e. samphire flats in the formerly more deeply inundated areas. Specht (1972) noted "very few plants occur in the community: *Wilsonia backhousei*, *Gahnia filum* (thatching grass), and *Salicornia quinqueflora* (samphire) may be found". As this scenario played out with greater regularity after drainage, upstream diversions and development, this section of the watercourse underwent eventual further ecological shifts, which will be explored later.

Beyond the Hundred of Neville, and we are fortunate to be given an early glimpse of the near-original character of Tilley Swamp around Morella Basin (shown in Figure 33). A more detailed map of this area in the Hundred of Santo, was created in 1896, but the information it presents appears to be from surveys in the early 1880s, just prior to the drainage enhancement works of 1884 and 1886.

Figure 33 – Map of the Hundred of Santo from 1896, showing the area around Morella Basin, the original flowpaths to Salt Creek and the early drainage works of 1864

The vegetation is described as follows:

- To the west of Morella Basin are "rough limestone rises and light sandy soil in hollows, low mallee and bushes, yacca and a little grass."
- This grades into an area on the margin of the wetland described as a "patch of better grazing, light red sandy soil, and stony rises, few teatree, sheaoak and bushes, a little grass."
- Interestingly, no mention is made of the scattered River Red Gums that today line this western flank of Morella Basin today. Not being dominant, their omission is not unusual (on the basis of other areas in the Upper South East where they occur and are also omitted in survey plans), as they must have been present at the time.
- The main Morella Basin itself is simply marked as open water "Swamp".
- The connecting basin to the north that links with the original flowpaths was described as a "mostly bare flat, submerged in winter, dark sandy soil".
- The original flowpaths themselves were marked as "good dark soil, cutting grass flat", while a side area connected to this was shown as consisting of "low tea-tree and cutting grass".
- At the northern margin of Morella Basin was a strip specifically marked as fringing "Saltwater ti-tree". This is consistent with areas found at the fringe of semi-permanent wetlands all the way along the South East coast today (from Lakes Eliza (saline) to Bonney (brackish-fresh)). Indeed Specht (1972), described the requirements of the species as follows:

  "The paperbark tea-tree Melaleuca halmaturorum often lines the banks of the brackish streams as far as the tide ascends. The community thus occupies a position equivalent to the mangrove growing downstream in tidal estuaries. The paperbark is restricted in its habitat and never forms a dense community."
- To the east of Morella Basin, a large flank of connected "low tea-tree and cutting grass flats, submerged in winter" also occurs, in part of what later became Martins Washpool Conservation Park.

This description of the area in and around Morella Basin supports the assumed ecological character of the stretch to the south in the Hundred of Neville, down the Henry Creek Road, being the continuation of a largely open water brackish swamp, capable of occasional temporary freshening, with fringing areas of cutting grass in the shallows and patches of saltwater tea-tree around the high water mark. The inundation of this entire area was effectively regulated by the original height of the natural sill at Martins Washpool.

This close to 'pre-development' condition of Tilley Swamp however began to change throughout first half of the 20th century, in response to the sequence of hydrological changes outlined in Table 3.

Indeed, as early as 1952, prior to the first comprehensive aerial photography, Blackburn noted that the "*paperbark had spread rapidly in low-lying parts of the Kingston-Avenue Range Drainage Area of the Lower South East*" (referenced in Specht (1972)). While he hypothesised that man-made drains had increased the salt concentration of these areas (which is also partly true given the loss of precious freshening flows from the lower South East) and was responsible for the change, the reality was much simpler. Drainage had simply opened up new ground for germinating paperbarks (*Melaleuca halmaturorum*) to survive without being drowned. It was a fateful sign of things to come in the post-World War Two era of comprehensive drainage, as will be explored in later sections.

4. A review of Tilley Swamp ecohydrology since 1954

4.1. *Mapped change in vegetation density from historic aerial photography (1954-2013)*

4.1.1 Methodology

To track the recent (post-WWII) change in vegetation communities, approximately decadal aerial photography of the Tilley and Taratap Watercourses was obtained from the Department for Environment and Water (DEW) archives. The aerial photographs were scanned at 800 dpi by DEW and provided as digital files. Images were then georeferenced and ortho-rectified by NGT, then stitched into composite raster datasets, as shown in Appendix 10.2. The characteristics of the imagery varied from date to date (Table 4).

Table 4 – Characteristics of aerial photography

Year of photography	Colour/B&W
1954	B&W
1978	Colour
1987	Colour
1999	Colour
2013	Colour

Changes in vegetation along the Taratap and Tilley Swamp Watercourses from 1954 to 2013 were mapped by expert interpretation of aerial photography. An interpreter was trained to recognise photograph characteristics (colour, intensity, texture and pattern) of known ground classes in one image date, and then applied their understanding of these characteristics to map the classes of interest on other image dates.

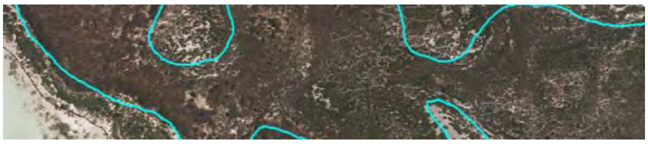
The analyst trained on the 2013 composite raster dataset using a combination of photo interpretation, previous vegetation mapping (AWE 2007) and ground-truthing of preliminary mapping. The most reliable unit for mapping was found to be shrub and tree density, particularly in relation to the lower resolution imagery (less than 1:40,000). Classes of density and criteria used are summarised in Table 5.

Areas of homogenous vegetation density were then mapped from the 1954, 1978, 1988 and 1999 aerial photography, displayed at a scale of 1:5000.

Given the broad uniformity of modern (brackish-saline swamp) vegetation communities across much of the study area, this method was deemed appropriate for the purposes of quantifying broad scale change. This is especially the case between Tilley Swamp CP and Morella Basin, where a relatively simple floristic community (i.e. often a single species of dominant shrub – *M. halmaturorum* – with a strong spectral signature) is now associated with the saline swamp vegetation community that has established in the watercourse since drainage (noting that as described in Section 3.5, a large proportion of this area was originally under the direct influence of the pre-1864 sills at the far northern end of the watercourse (at Morella Basin and Martins Washpool).

Where mapped features showed visible internal boundaries in historical aerial images, polygons were split and reshaped to capture areas that were homogenous in a given time-set. The output was a set of features which measured uniform units of vegetation density over time.

Table 5 – Vegetation densities and corresponding visual keys for types mapped across the Taratap and Tilley Swamp Watercourse areas

Vegetation density	Visual key	Colour and intensity	Texture
Open (O)		Light brown, grey or white with no dark clumps	Smooth
Very sparse (VS)		Light brown or white with very few dark clumps	Mostly smooth
Sparse (S)		Light brown or white with some small dark clumps	Smooth with patchy clumps
Mid-dense (MS)		Light brown or white with several dark clumps	Rough with more spaces than clumps
High (H)		Light brown or white with large dark clumps	Rough with more clumps than spaces
Dense (D)		Dark brown	Smooth

4.1.2 Results

Vegetation density change (1954-2013)

Over the entire study area, the greatest area of both increasing shrub density and reduction of open area was associated with mapped wetlands (Table 6). This was typically associated with an increase in *Melaleuca halmaturorum* recruitment across wetlands which are bisected by drains or have had their water source diverted by drains (Figure 34).

Reduction in vegetation density on the other hand is most typically related to land clearing of high density patches between 1954 and 1978, with some further clearance of moderate density patches occurring between 1978 and 1987 (See Figure 34 and Figure 35).

Table 6 – Changes in vegetation densities across the Taratap and Tilley Swamp Watercourse areas

Density	1954 area and % of total area		1978 area and % of total area		1987 area and % of total area		1999 area and % of total area		2013 area and % of total area	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Wetland polygons according to DEW mapping (of a total of 11,653 ha)										
open	3870	33	↓ 2032	17	1676	14	1597	14	1711	15
very sparse	1327	11	↑ 2503	21	↑ 3375	29	2901	25	2686	23
sparse	2007	17	1523	13	1736	15	↓ 1122	10	824	7
medium	2309	20	2287	20	↓ 1363	12	1524	13	1304	11
high	1921	16	2361	20	2503	21	↑ 3258	28	3490	30
dense	219	2	↑ 948	8	999	9	1251	11	1624	14
revegetation	0	0	0	0	0	0	0	0	13	0
Non-wetland polygons according to DEW mapping (of a total of 7,863 ha)										
open	249	3	253	3	272	3	252	3	309	4
very sparse	1873	24	2680	34	↑ 3301	42	3276	42	3171	40
sparse	586	7	774	10	1021	13	896	11	454	6
medium	1585	20	1355	17	↓ 657	8	646	8	972	12
high	2415	31	↓ 1748	22	1547	20	1633	21	1605	20
dense	1155	15	1053	13	1066	14	1161	15	1230	16
revegetation	0	0	0	0	0	0	0	0	123	2
Overall (of a total of 19,517 ha)										
open	4119	21	↓ 2284	12	1948	10	1849	9	2020	10
very sparse	3201	16	↑ 5183	27	6676	34	6177	32	5857	30
sparse	2593	13	2298	12	2758	14	2017	10	1278	7
medium	3894	20	3642	19	↓ 2020	10	2170	11	2276	12
high	4336	22	4109	21	4051	21	4891	25	5096	26
dense	1374	7	2001	10	2065	11	2412	12	2854	15
revegetation	0	0	0	0	0	0	0	0	136	1

↑ Point of major increase ↓ Point of major decrease

The data in Table 6 demonstrates very clearly the process of terrestrialisation that has been taking place in Tilley Swamp, with:

- A major decrease in the area of open habitat between 1954 and 1978, with a corresponding increase in the other density categories.
- A partial reversal of this trend between 1978 and 1987, driven by a final wave of legal native vegetation clearance.
- However by 1999 and beyond, a further major increase in high density wetland vegetation, in conjunction with a corresponding drop in sparse wetland vegetation.

Table 7 reviews the overall change that has occurred between 1954 and the present. The key data (within the categories where the most dramatic change in wetland character is visually observed) are highlighted in green, indicating that of the wetland area mapped in 1954 in Tilley Swamp:

- Less than half of the original area of bare ground in the swamp remains today.
- Conversely, areas of high density (e.g. *high* or *dense* categories), and indicative of the process of terrestrialisation, have grown significantly, by almost 3000 hectares or a quarter of the total wetland study area assessed.

Table 7 – Total changes in Tilley Swamp vegetation densities from 1954 to 2013 (arrows indicate direction of trends in changing wetland vegetation character)

Density	Overall change 1954 - 2013		
	Area change in 2013 compared to 1954	Change as a % of the total study area total since 1954	Change as a proportion of the 1954 area of this wetland density category
Wetland			
open	2159 ha less	**19 % less**	**44 %: less than half**
very sparse	1359 ha more	**12 % more**	**202 %: double**
sparse	1183 ha less	**10 % less**	**41 %: less than half**
medium	1005 ha less	**9 % less**	**56 %: around half**
high	1569 ha more	**13 % more**	**182 %: almost double**
dense	1405 ha more	**12 % more**	**742 %: over 7 times more**
revegetation	13 ha more	-	-
Non-wetland			
open	60 ha more	**1 % more**	**124 %: a little more than the same**
very sparse	1298 ha more	**17 % more**	**169 %: approaching double**
sparse	132 ha less	**2 % less**	**77 %: around a quarter less**
medium	613 ha less	**8 % less**	**61 %: around a third less**
high	810 ha less	**10 % less**	**66 %: around a third less**
dense	75 ha more	**1 % more**	**106 %: almost the same**
revegetation	123 ha more	-	-
Overall			
open	2099 ha less	**11 % less**	**49 %: half the area**
very sparse	2656 ha more	**14 % more**	**183 %: almost double**
sparse	1315 ha less	**7 % less**	**49 %: half the area**
medium	1618 ha less	**8 % less**	**58 %: just over half**
high	760 ha more	**4 % more**	**118 %: a little more than the same**
dense	1480 ha more	**8 % more**	**208 %: more than double**
revegetation	136 ha more	-	-

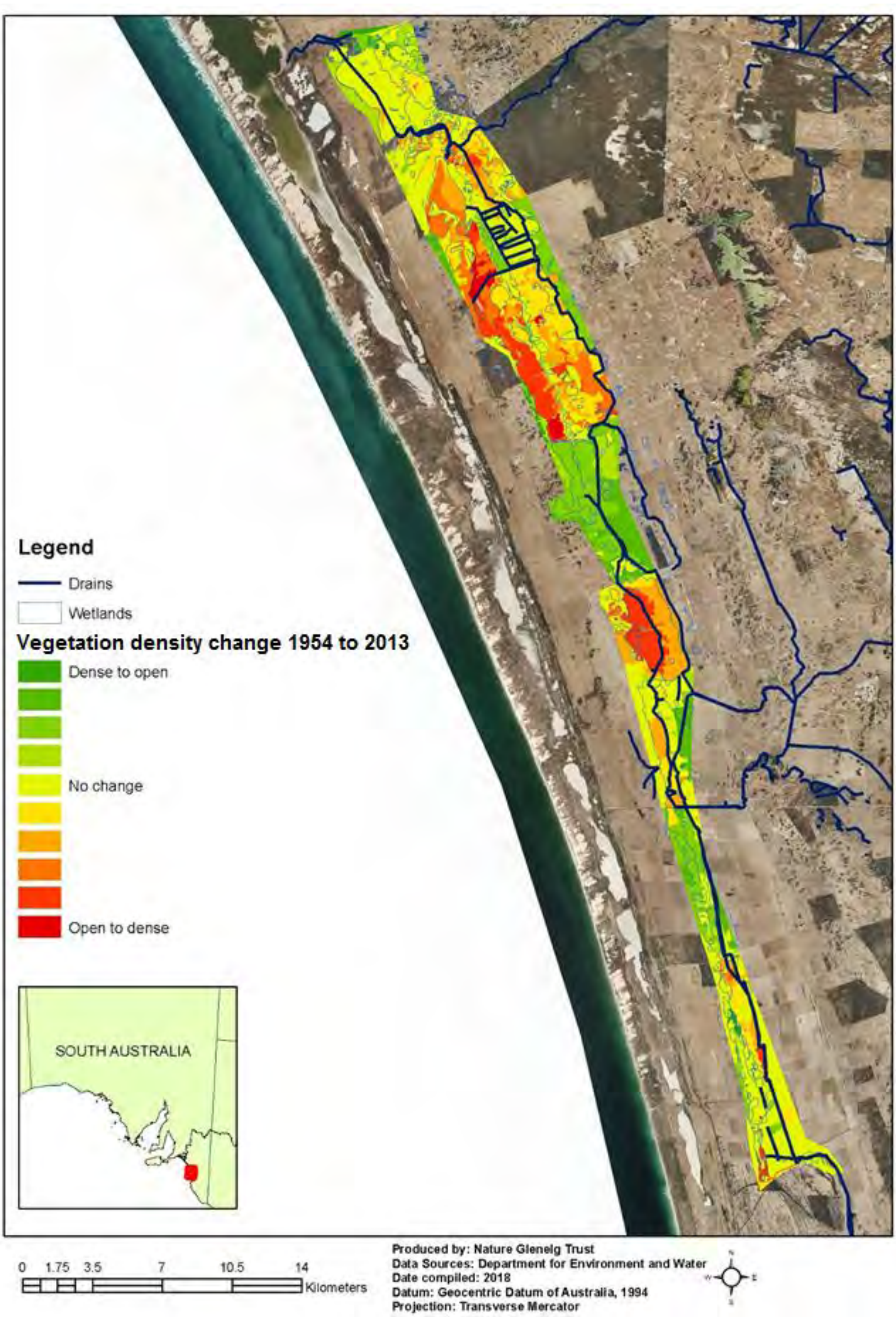


Figure 34 – Vegetation density change - 1954-2013

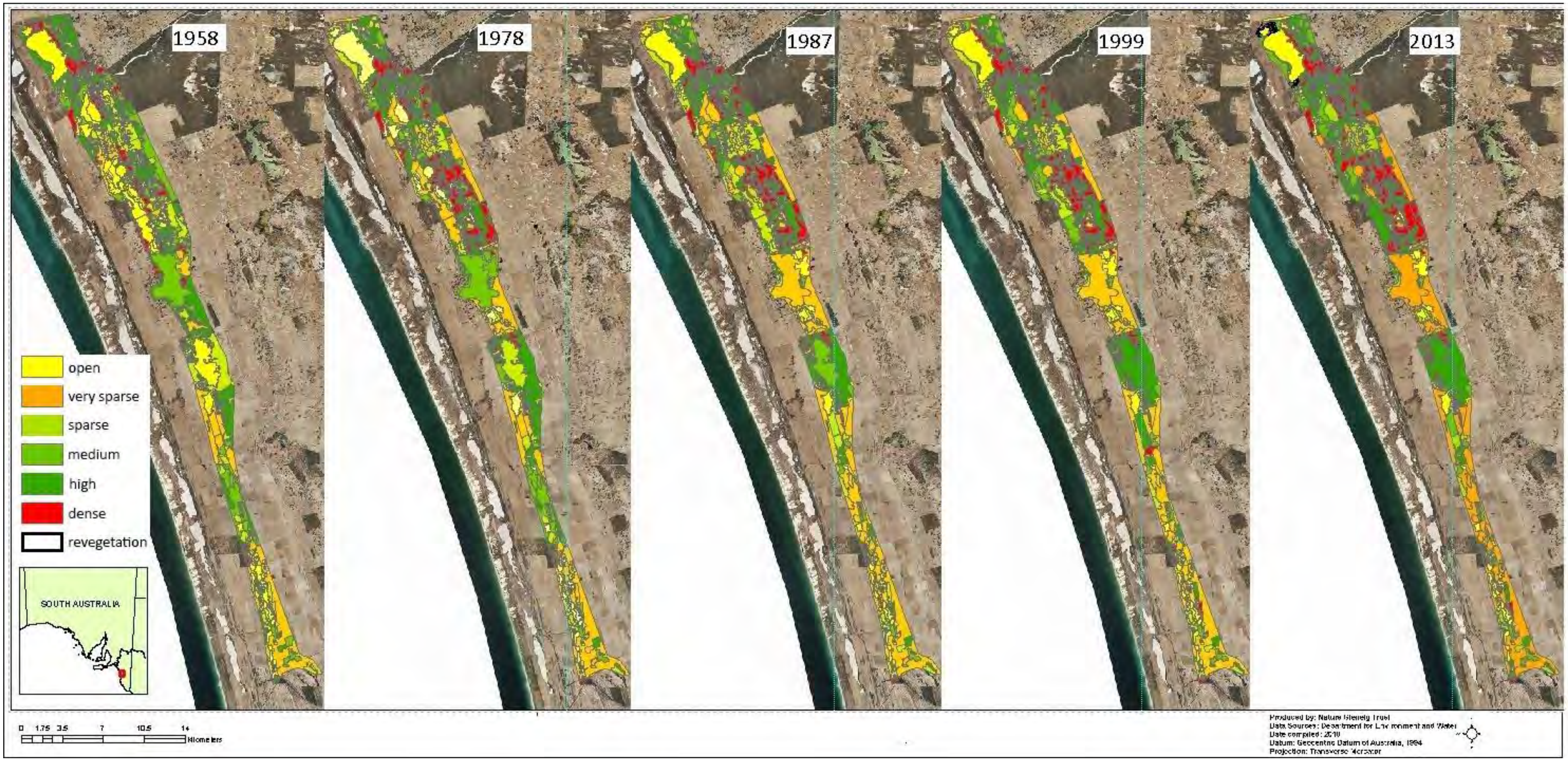


Figure 35 – Changes in vegetation density over time

4.1.3 Discussion

The ongoing terrestrialisation process in wetland basins is clearly visible across historic imagery, with some sections of the Tilley Swamp watercourse undergoing detectable change in the earliest two sets of historic aerial imagery available, from 1954 to 1966. Imagery analysis revealed a reduction in open wetland habitat in 2013 to less than half (44%) of what it was in 1954, with very sparse wetland vegetation more than doubling (202%), indicating the ongoing recruitment of shrubs into previously open ground. Dense vegetation increased more than seven-fold (742%) in that time, demonstrating the scale of the trend. An example of a change from open wetland habitat to dense habitat across a shorter timescale (1978-2013) can be seen in Figure 36.

Figure 36 – Example of terrestrialisation in the northern end of Tilley Swamp CP between 1978 and 2013

Large scale vegetation community change is much more noticeable on the Tilley Swamp Watercourse, as a result of long-term grazing exclusion from areas of publicly or privately reserved land, with vegetation communities shifting wholesale in response to the drying trend. In contrast, the Taratap Watercourse has generally become more open as a result of vegetation clearance for agriculture and subsequent grazing, which suppresses seedlings and provides some artificial control over vegetation structure, in the absence of the type of prolonged inundation that has been interrupted since the 1950s (Dickson et al. 2013). This assessment is consistent with the visual observations previously reported in (Dickson et al. 2013), of what terrestrialisation looks like on the ground in Tilley Swamp (Figure 37).

Figure 37 – M. halmaturorum establishing within former open aquatic habitat zones of Tilley Swamp, showing different age cohorts. Photo by Mark Bachmann

Additionally, terrestrial species are now widely observed within former floodplain habitats across Tilley Swamp (and the Upper South East more broadly), and provide an example of the terrestrialisation of the higher (drier) portions of the floodplain that also occurs as vegetation communities creep “down-slope” in response to the artificially prolonged dry conditions. For examples from Tilley Swamp, see Figure 38.

Figure 38 – Terrestrialisation of the floodplain in Tilley Swamp: (left) coastal wattle (Acacia longifolia var. sophorae) invasion (right) coast-beard heath (Leucopogon parviflorus) recruitment under M. halmaturorum from bird dispersed seed. Photos by Mark Bachmann

While changes in grazing regime (i.e. removal of stock) can certainly play a role in enabling increased *Melaleuca* recruitment in certain situations, it is clear that the predominant factor at play generally across the Upper South East – at the landscape level – is the alteration to wetland hydrology (as explained in detail in Section 3.4), resulting in a long-term drying trend that is independent of climate. This also demonstrates the clear causal link and relationship between wetland hydrology and ecology.

4.2. *Wetland Hydrographs 1987 – 2017*

4.2.1 Methodology and results

Mapping of surface water from remotely sensed imagery (Landsat satellites) via the Australian continental scale Water Observations from Space (WOfS) dataset (Geoscience Australia 2014, Mueller et al. 2016) has previously been used in conjunction with a LiDAR (Light Detection and Ranging) derived Digital Elevation Model (DEM) to re-create historical surface water hydrographs for open water wetlands in the South East (Harding et al. 2018).

Harding and Herpich (2018) used the same approach to re-create historical hydrographs for three wetland basins within the Taratap and Tilley Swamp Watercourses likely to be influenced by the SEFRP: Englands Swamp, Tilley Swamp Conservation Park (CP), and Frostys Swamp (Figure 39).

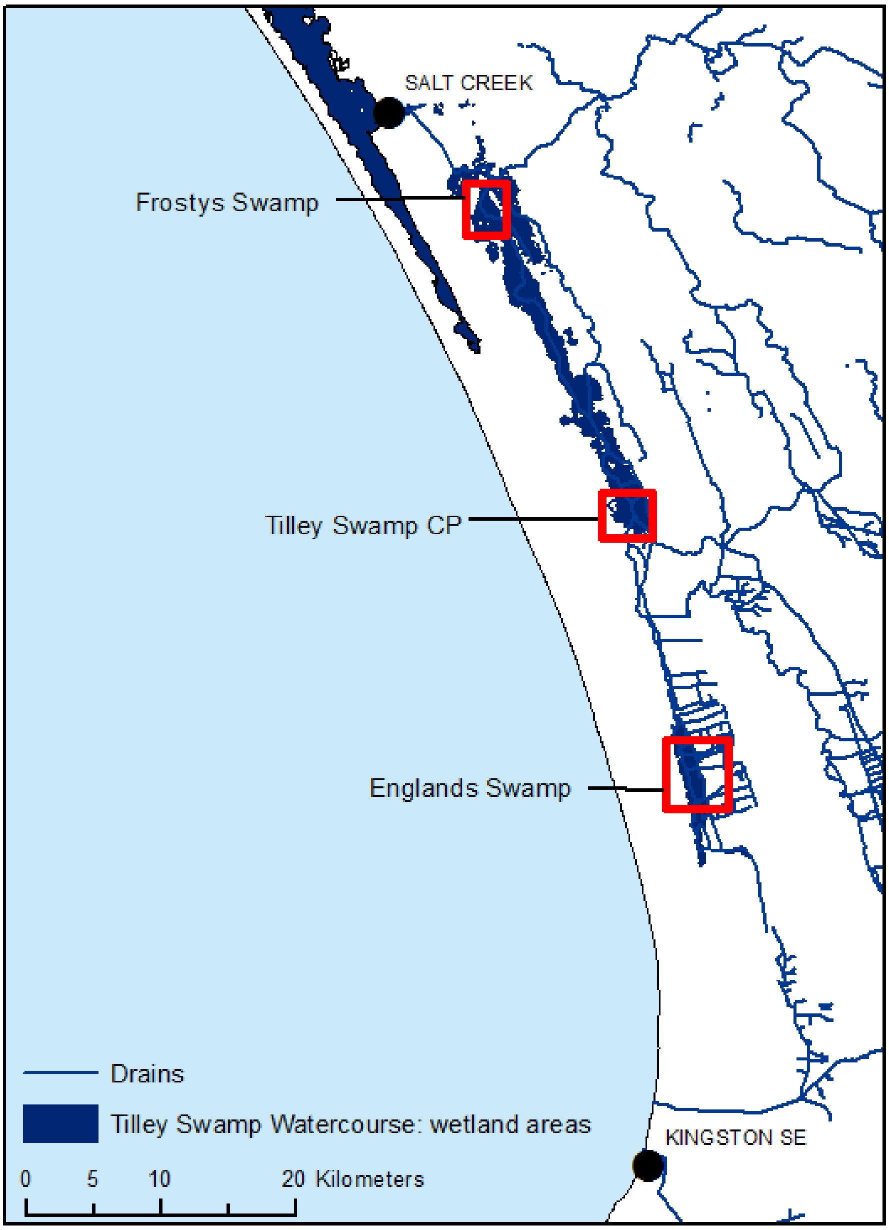


Figure 39 – Location of wetlands selected for WOfS hydrograph analysis (source: Harding and Herpich 2018)

These sites were chosen for their compatibility with the methodology (include sparsely vegetated areas) and broad spatial coverage of the SEFRP study area.

Harding and Herpich (2018) analysed cross-sections of each wetland basin, incorporating deepest and least vegetated sections, and where possible, surface water monitoring equipment (Figure 40).

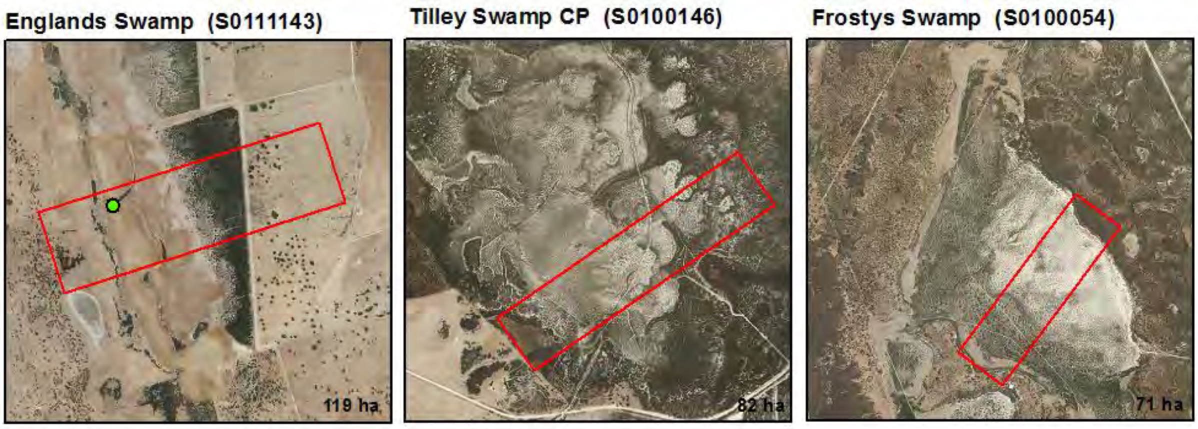


Figure 40 – Location of cross-sections for WOfS hydrograph analysis. Green point represents surface water monitoring infrastructure location (source: Harding and Herpich 2018)

The WOfS derived hydrographs are intended to provide semi-quantitative measures of wetland surface hydrology from 1987 (the launch of Landsat) to the present, providing a baseline hydrology of these sites prior to the influence of the SEFRP. The hydrographs determined by Harding and Herpich (2018) are shown in Figure 41.

Given the ongoing nature of data capture from WOfS, the method could be used to monitor the effectiveness of the SEFRP in delivering surface water flows to the Taratap and Tilley Swamp Watercourses in future years.

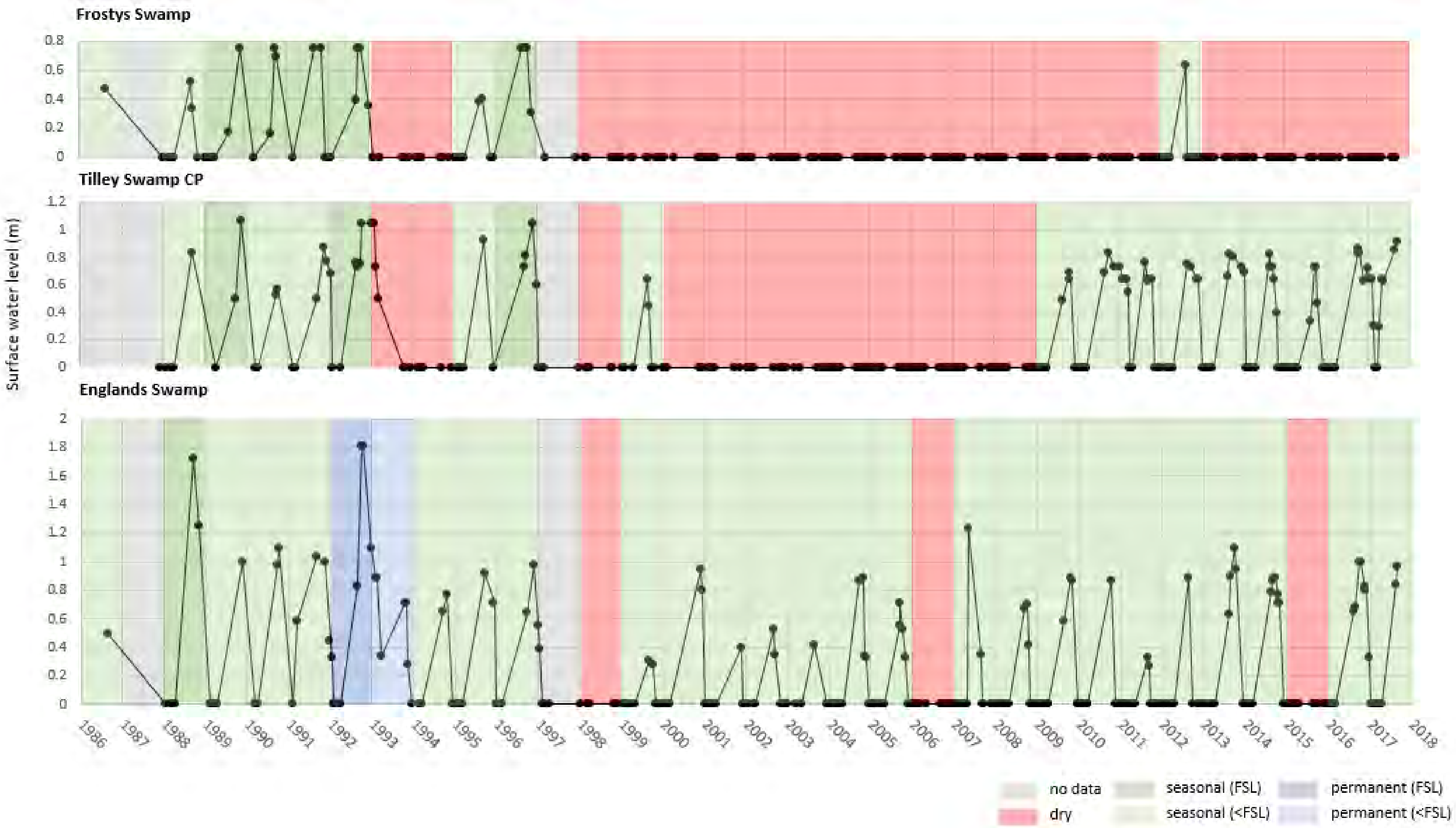


Figure 41 – Surface water hydrographs produced from WOfS and LiDAR DEM analysis for selected wetland basins in the Taratap and Tilley Swamp Watercourses between 1987 and 2018. Permanent (FSL): wetland reached full supply level and at least some area of the wetland remained inundated throughout the entire 12 month period; Permanent (<FSL): at least some area of the wetland remained inundated throughout the entire 12 month period, but did not reach full supply level; Seasonal (FSL): wetland wets and dries, and reached full supply level at some time during the 12 month period; Seasonal (<FSL): wetland wets and dries, but does not reach full supply level during the 12 month period; Dry: wetland did not record any surface water inundation during the 12 month period; no data: no WOfS observations available to determine seasonal high water level (source: Harding and Herpich 2018).

4.2.2 Validation

Surface water logger data (site A2391101) for Englands Swamp allowed for the verification of the WOfS derived hydrograph for this site from 2009 to 2017. Figure 42 provides a comparison of the WOfS derived outputs and surface water logger data, presented as monthly averages, for Englands Swamp. The WOfS hydrograph methodology provides reliable detection of 'dry' observations (91% of observations accurately identified by WOfS) and reliable detection of general trends in surface water levels. The comparison between the two datasets provides some confidence in using the WOfS derived hydrographs for explaining long-term surface water behaviour and trends across a landscape. The WOfS hydrograph methodology was shown to over-estimate actual levels by an average of 0.17m at Englands Swamp between 2009 and 2017, likely due to discrepancies in pixel sizes between the WOfS 25 x 25m pixels and the 2x2m DEM.

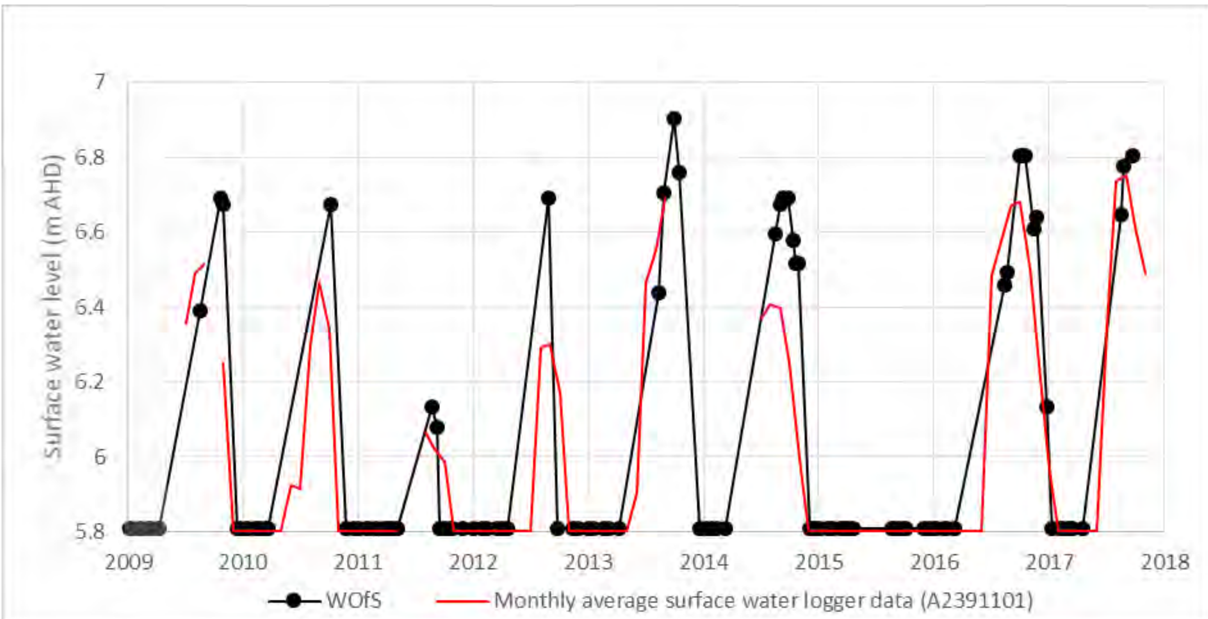


Figure 42 – Comparison of WOfS derived hydrograph data with surface water logger data available from 2009 to 2017 for Englands Swamp (source: Harding and Herpich 2018)

Spatial Representation for 10 Year Epochs

Harding and Herpich (2018) calculated mean spring high (maximum) surface water levels at each wetland for three ten-year epochs (1987-1997, 1997-2007, 2007-2017) over the period of data capture. The epochs were chosen to reflect general changes in hydrology over the 1987-2017 period. Mean spring high surface water levels were displayed spatially in ArcGIS® by converting the surface water levels (in m AHD) to water depths by subtraction of the LiDAR DEM using raster calculator for each of the three basins. Similarly, the highest water level recorded from the WOfS analysis, 1992 for all three wetlands, was also spatially displayed. Results for Englands Swamp are presented in Figure 43, Tilley Swamp CP in Figure 44 and Frostys Swamp in Figure 45.

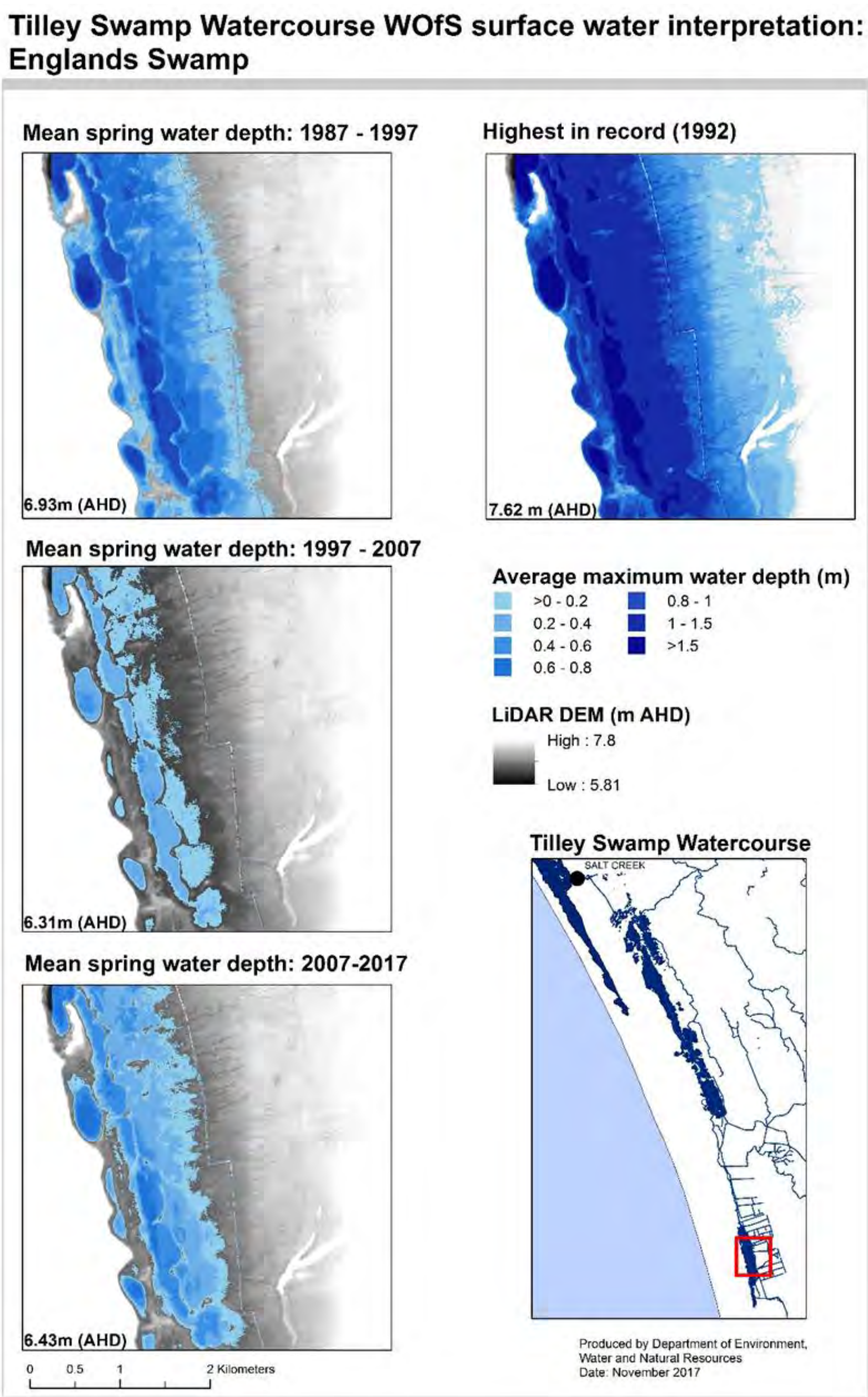


Figure 43 – Spatial representation of mean surface water depth over 10-year epochs and maximum surface water depth on record: Englands Swamp (source: Harding and Herpich 2018)

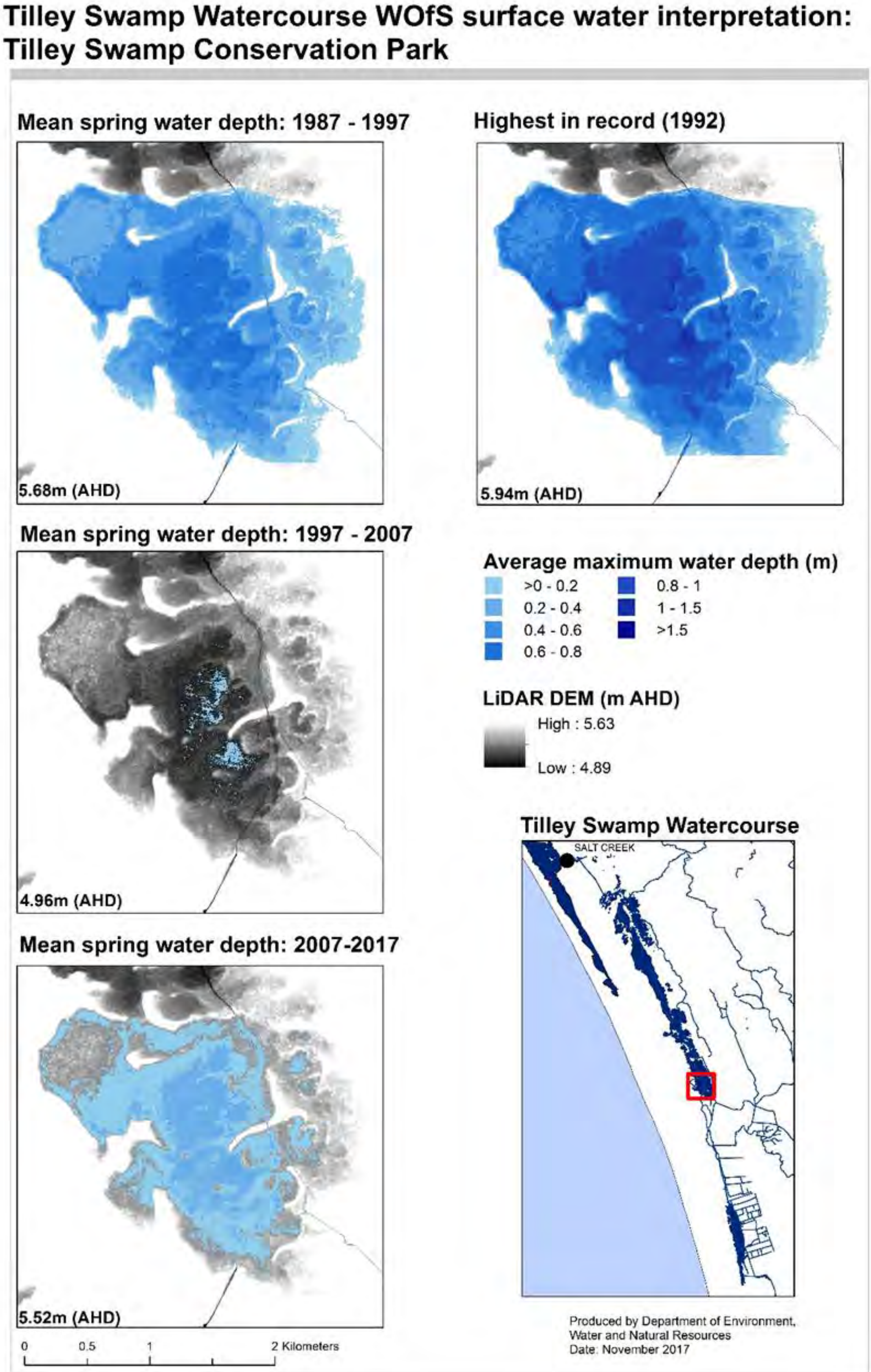


Figure 44 – Spatial representation of mean surface water depth over 10-year epochs and maximum surface water depth on record: Tilley Swamp CP (source: Harding and Herpich 2018)

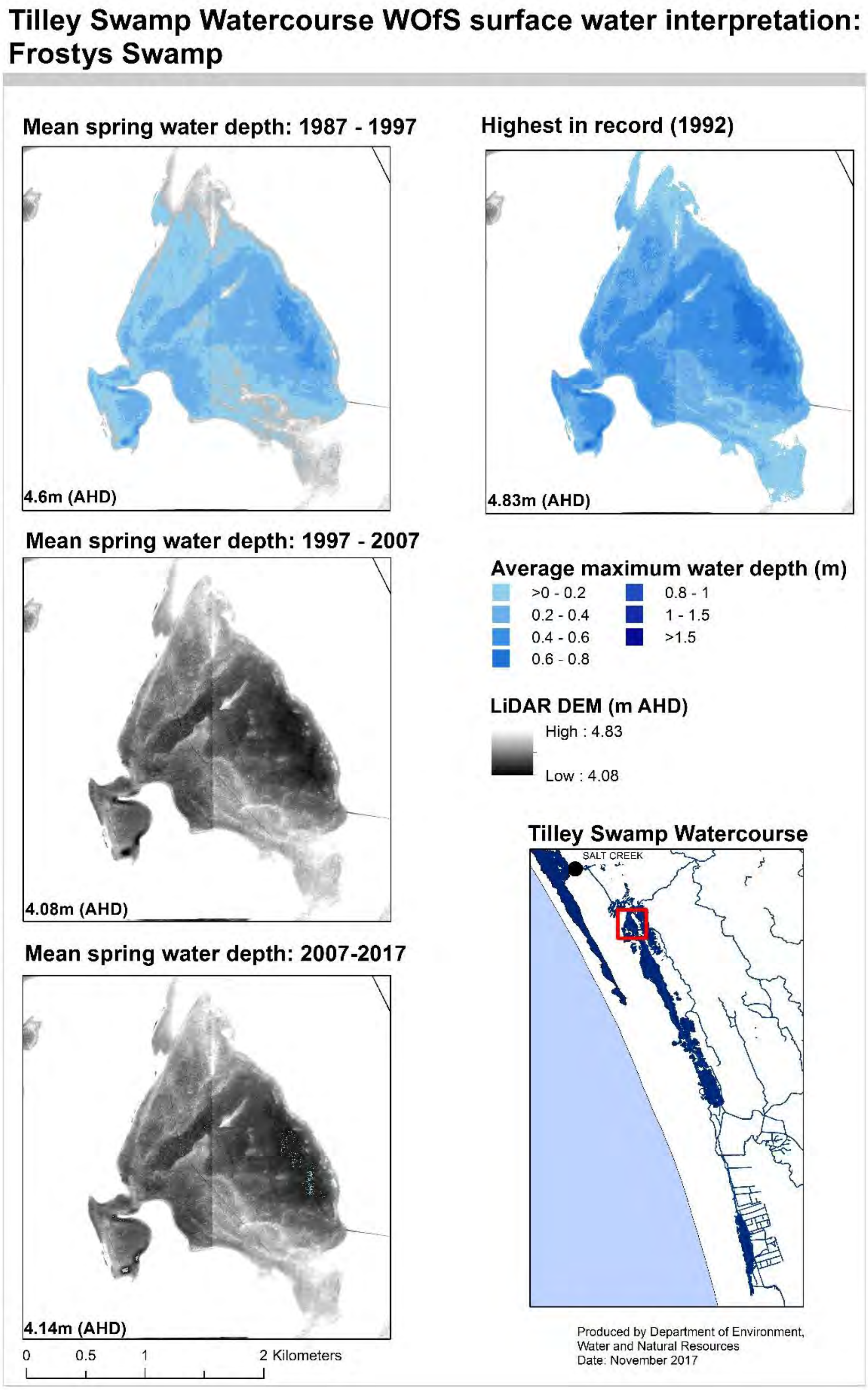


Figure 45 – Spatial representation of mean surface water depth over 10-year epochs and maximum surface water depth on record: Frostys Swamp (source: Harding and Herpich 2018)

4.2.3 Discussion

The WOfS derived hydrographs provide a reliable indication of baseline (pre-SEFRP) hydrology for three representative wetlands of the Taratap and Tilley Swamp Watercourses. The methodology may slightly over-estimate maximum depth, however it indicates periods of inundation and exposure with a high degree of confidence. Comparison of these baseline hydrographs with post-SEFRP hydrographs will enable the effectiveness of the SEFRP at maintaining and restoring *en route* wetland hydrology to be measured quantitatively.

Under the SEFRP, the surface water level logger at Englands Swamp (site A2391101) will continue to operate, allowing both direct measurement of wetland hydrology and a validation tool for future WOfS analysis. A surface water level logger has been installed at Frostys Swamp, providing additional measurement and validation in a wetland where the hydrological restoration effect of the SEFRP is anticipated to be most detectable.

Interpretation of the hydrographs for the three wetlands must account for key events during the 1987-2017 period:

- Construction of the Tilley Swamp Drain, completed in 2000, affecting both Frostys Swamp and Tilley Swamp CP;
- Construction of the Taratap Drain, completed in 2006, affecting Englands Swamp;
- The Millennium Drought, affecting all three wetlands, which in the study area was most severe from approximately 2001-2008; and
- Upstream drains (e.g. Fairview from 1998), diversions (e.g. Reflows) and other catchment influences.

Frostys Swamp

The hydrology of Frostys Swamp changed markedly across the study period. Prior to the construction of the Tilley Swamp Drain in 2000, Frostys Swamp received regular seasonal inundation, with inundation occurring in 8 out of 12 years for which WOfS data are available. After 2000, inundation occurred in only 1 out of 18 such years. The Millennium Drought likely contributed to reduced inundation between 2001 and 2008; however the lack of inundation after 2008, despite improved frequency and extent of inundation at Tilley Swamp CP and Englands Swamp, can be attributed directly to the impact of the Tilley Swamp Drain. The drain very effectively prevented inundation of Frostys Swamp after its construction.

The terrestrialisation of Frostys Swamp (as described in Section 4.1.3) can in part be explained by reduced inundation after 2000. Under the SEFRP, diversions into the Tilley Swamp Watercourse, including Frostys Swamp, will be possible and will be prioritised when the Coorong has no immediate requirement for water from the South East drainage network. Interestingly, the SEFRP will set a new maximum sill elevation for Frostys Swamp (controlled at Morella outlet regulator) of 5.4 mAHD, some 0.57 m higher than the maximum water level detected using the WOfS hydrograph methodology for the study period (4.83 mAHD in 1992). Depending upon the frequency and duration that the post-SEFRP maximum water level is achieved, profound, ecologically desirable changes to the vegetation of Frostys Swamp and surrounding watercourse areas could potentially occur as a result of this new hydrological regime.

Tilley Swamp CP

The hydrograph for Tilley Swamp CP shows regular inundation prior to 2000, with inundation occurring in 8 out of 11 years for which WOfS data are available. Construction of the Tilley Swamp Drain in 2000 included infrastructure facilitating the diversion of flows from the drain into Tilley Swamp CP, and the inlet drain and weir from the Tilley Swamp Drain into the conservation park was installed in 2006. However, no inundation was detected from 2000-2008, corresponding with the Millennium Drought, before regular inundation recommenced in 2009. Inundation occurred in all subsequent years, including some particularly dry years (e.g. 2015). Regular inundation after 2009 corresponds with the end of the Millennium drought (locally) in 2009 and the construction of the Bald Hills Drain in 2010. The latter increased the size of the catchment of the Tilley Swamp Drain upstream of Tilley Swamp CP and improved the reliability of flows by draining groundwater from the Bald Hills flats. However, the WOfS derived hydrographs indicate that the maximum depth and extent of inundation in Tilley Swamp CP was reduced after construction of the Tilley Swamp Drain in 2000. Full supply level, achieved in 1989, 1992 and 1996, has not occurred post 2000 despite some wet years (e.g. 2013, 2016). Under the SEFRP, diversions into Tilley Swamp CP will remain a high priority and therefore the frequency of inundation is anticipated to be maintained. The increased water availability arising from the SEFRP may increase the depth and duration of seasonal inundation, with a maximum water surface elevation of 6.0 mAHD possible with SEFRP infrastructure in place (Taylor et al.(in prep.)).

Englands Swamp

At Englands Swamp, regular seasonal inundation was maintained throughout the 1987-2017 period, with a frequency of 10 out of 10 detectable years from 1986-1997, 8 out of 10 detectable years from 1998-2007, and 9 out of 10 detectable years from 2008-2017. The first two epochs occurred prior to the construction of the Taratap Drain in 2006. The persistence of regular inundation after 2006 may be attributable to the inclusion of infrastructure that enabled Taratap Drain flows and local catchment flows to be diverted into this wetland, unlike the arrangement for Frostys Swamp. However, the operation of the Taratap Drain may have reduced maximum depth at Englands Swamp, with full supply level, achieved in 1988 and 1992, not achieved after 2006 despite some wet years (e.g. 2013, 2016). Under the SEFRP, diversions into Englands Swamp (and the greater Taratap Watercourse) will remain a high priority and local catchment inflows will be maintained. Therefore, the frequency of inundation is anticipated to be maintained. The increased water availability arising from the SEFRP may increase the duration of seasonal inundation, however the restoration of full supply level inundation at this site (as defined above) is unlikely to occur due to the risk of flooding adjacent agricultural land.

Regional scale drainage, particularly the construction of the Blackford Drain in 1964, would have contributed to a major reduced frequency and extent of inundation of all three wetlands examined, however those changes occurred prior to the launch of Landsat and are therefore not able to be examined using the WOfS hydrograph methodology. However, this process of hydrological change (described in Section 3.4) and the terrestrialisation of the entire watercourse (see Section 4.1.3) corresponds with both the regional and local scale ecohydrological changes arising from drainage.

5. Summary of recent ecological knowledge

A number of significant ecological studies have been conducted in the study area; major studies are outlined in Table 8. More detailed discussion of the scope of these and other studies are included in Section 7.1 as part of a broader review of past monitoring efforts, and their relevance to future monitoring needs.

Table 8 – Major ecological monitoring efforts in the Taratap and Tilley Swamp Watercourses

Year	Study	Purpose	Vegetation component	Fauna component					
				Fish	Frogs	Waterbirds	Birds (all)	Mammals	Reptiles
1996	Biological Survey of Tilley Swamp	Broad flora and fauna survey across Tilley Swamp Watercourse as part of the Biological Survey of SE SA	Quadrats		Y		Y	Y	Y
2000-	Aquasave-NGT Fish Monitoring	Aquasave-NGT monitoring sites. Some sites later incorporated into SEFRP-initiated monitoring.	None	Y					
2000-2014	USE Program monitoring	Monitor impacts of Tilley Swamp drain. Some sites later incorporated into SEFRP-initiated monitoring.	Quadrats, transects and vegetation "fan" in Tilley Swamp, Stoneleigh Park and Morella Basin				Y	Y	Y
2011-2016	SEFRP-initiated monitoring	REFLOWS assessment and pre-SEFRP baseline monitoring	Wetland transects and quadrats across Taratap and Tilley Swamp Watercourses	Y	Y	Y			
2015	Corridor Flora & Fauna Study (Jacobs)	Pre-SEFRP clearance corridor assessment	BushRAT plots and vegetation mapping		Y		Y	Y	Y

The following sections collate the various data collected in previous ecological monitoring projects in the study area, with an emphasis on SEFRP-initiated monitoring of vegetation, fish, frogs and waterbirds. Flora and fauna species are outlined, with threatened species from each group (vegetation, fish, frogs, waterbirds, reptiles and mammals) listed. Full species lists for each group are included in Appendix 10.5. Flora and fauna records have been sourced from Biological Databases of South Australia (BDBSA), South Australian Wetland Inventory Database (SAWID), South Australian Research and Development Institute (SARDI), BirdLife, and SA Museum datasets. A 3 km buffer was applied to datasets to capture records in close proximity. On its western edge, this area extends to roughly the edge of the south lagoon of the Coorong, taking in a section of the Coorong National Park, and the south western corner of Messent Conservation Park. It also includes records from the Princes Highway adjacent to the study area. In addition, a small number of project reports contain species records not included in the above datasets, and these were reviewed and incorporated.

A final note of caution is advised when interpreting the information presented in this section. Clearly the most comprehensive ecological research, mapping and data collation has occurred over the past 20 years which, on the basis of previous sections in this report, coincides with the end of an extended period of ecohydrological stress. Hence current knowledge does not represent a reference state, just a moment in time on a very long continuum of ecohydrological change that dates back to 1864.

5.1. *Vegetation summary*

5.1.1 Wetlands

DEW wetland ecological value assessments

76 wetlands have been mapped within or partially within the SEFRP study area. Of these, 29 have been assessed for their ecological value by DEW, with data stored in SAWID. Figures 46 and 47 show the distribution of Very High, High, Moderate and Low value wetlands throughout the watercourses with area summarised in Table 9; additional wetland characteristics are listed in Appendix 10.4 and 10.6.

Table 9 – Ecological value and area of wetlands in the SEFRP study area (source: SAWID)

Ecological Value	Wetlands	Total wetland area *	%
Very high	4	5,222.8	41.2
High	7	2,636.6	20.8
Moderate	12	3,373.2	26.6
Low	6	445.2	3.5
Unrated	47	994.7	7.8
Total	**76**	**12,672.6**	**100**

* Total wetland area, including parts lying outside study area

Based on DEW assessments recorded in SAWID, large, very high value wetlands are mostly located north of Henry Creek Road in the Tilley Swamp Watercourse, and include Morella Basin (858 ha), a large section of wetland to the east of Morella in Martin Washpool CP (249 ha), and the main wetland of Tilley Swamp CP (1078 ha). The Tilley Swamp Floodplain running from Cantara Rd to the southern boundary of Martin Washpool CP represents a large area (>3000 ha) of mostly intact native vegetation that retains very high ecological value, despite its significantly altered hydrology. Some wetlands within the Tilley Swamp Watercourse (i.e. Frostys Swamp) have been severely affected by the combined loss of inflows and drawdown from deep groundwater drainage, leading to vegetation change and a marked deterioration of wetland values, seen in the map.

In the Taratap Watercourse, many wetlands retain a degree of hydrological function despite local drainage and reduced inflows, but have also been heavily affected by vegetation clearance, grazing and increasing salinity. A large area of floodplain wetland on the watercourse still retains high ecological value despite grazing, while most other wetlands of the watercourse are degraded and tend to be of low to moderate value.

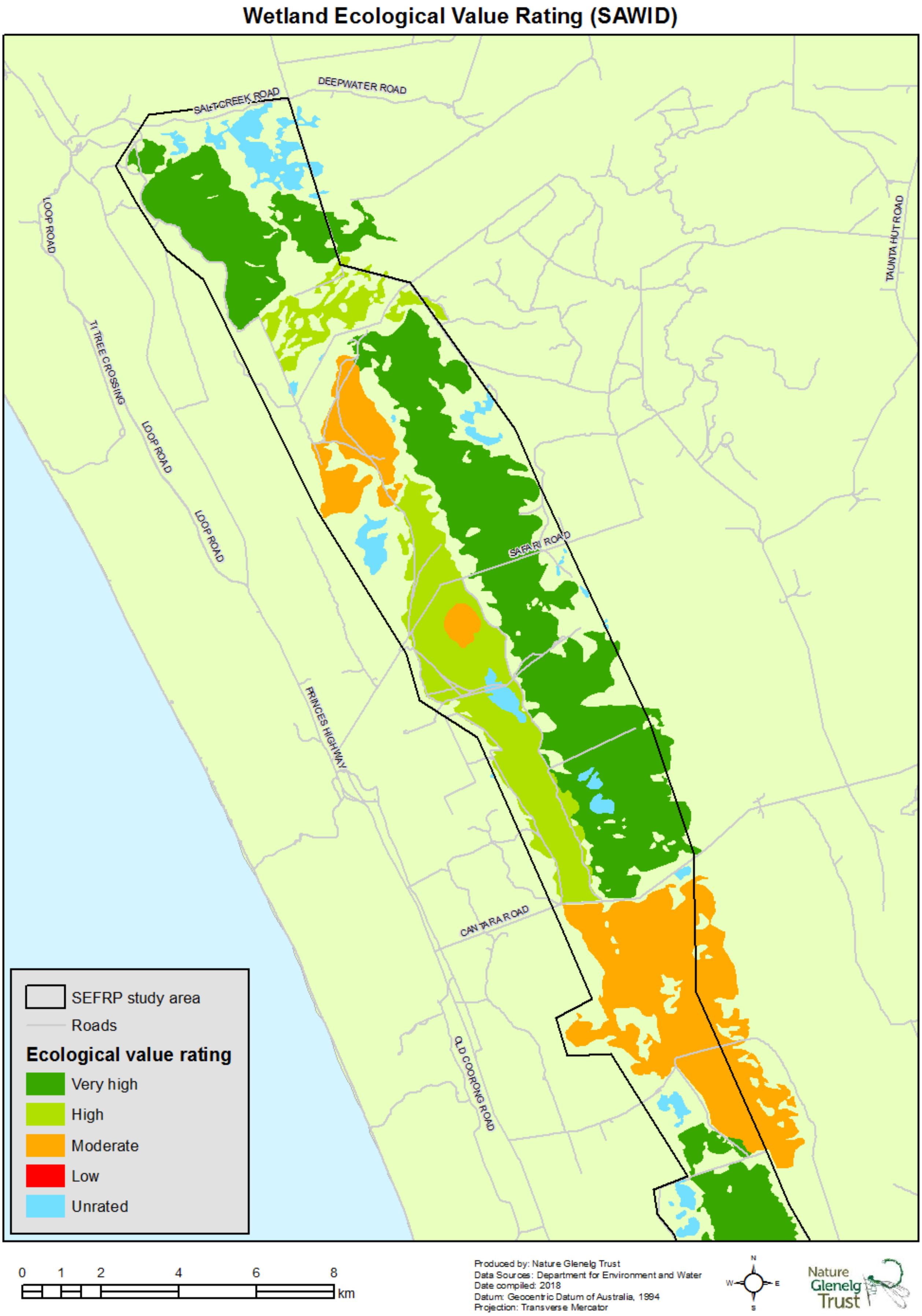


Figure 46 – Wetland Ecological value rating (from SAWID) – north

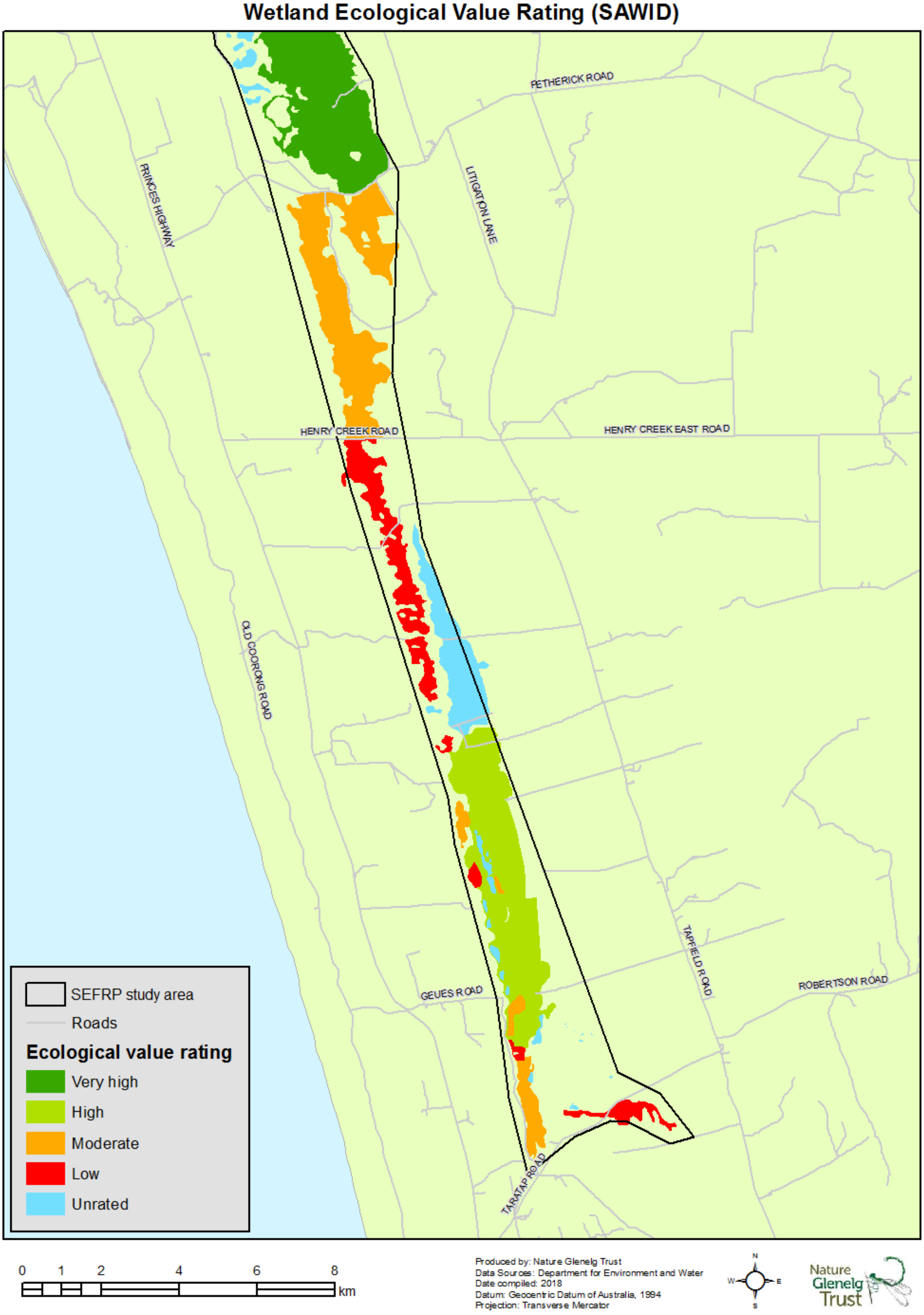


Figure 47 – Wetland ecological value rating (from SAWID) – south

5.1.2 Vegetation communities

5.1.2.1 *Existing vegetation mapping*

A wide range of environmental conditions through the Taratap and Tilley Swamp Watercourses drives high diversity of vegetation communities, from deep open water wetland to elevated woodland. Fine scale vegetation community mapping was conducted for the Stoneleigh Park property and Tilley Swamp CP by Milne and Squire (2001), included in Appendix 10.4, however the same mapping methodology has not been extended across the watercourses.

Mapping of native vegetation communities is held by the Department for Environment and Water (Figures 48 and 49), and while not all vegetation communities present in the area are mapped, an indication of the general character and distribution of vegetation communities through the SEFRP study area is provided. While useful as an overall picture, the distribution and cover of some communities lacks accuracy – an example being *Ruppia* sp. +/- *Wilsonia* sp. submerged herbland, which is underrepresented in DEW mapping despite extensive presence in the Taratap watercourse.

Table 10 – Native vegetation community cover based on DEW mapping

Vegetation community	Mapped area (ha)	%
Allocasuarina verticillata woodland	266.3	2.3
Baumea juncea (mixed) sedgeland	43.9	0.4
Eucalyptus arenacea woodland	10.1	0.1
Eucalyptus diversifolia woodland	1695.0	14.5
Eucalyptus fasciculosa woodland	959.6	8.2
Eucalyptus leucoxylon woodland	11.4	0.1
Eucalyptus fasciculosa/leucoxylon woodland	5.8	0.1
Gahnia filum (mixed) sedgeland	1372.7	11.7
Melaleuca brevifolia shrubland	574.3	4.9
Melaleuca halmaturorum shrubland	5925.8	50.6
Ruppia sp. +/- *Wilsonia* sp. submerged herbland	602.7	5.2
Melaleuca lanceolata woodland	11.4	0.1
Permanent Deep Open Water	127.5	1.1
Selliera radicans, Wilsonia sp. open herbland	93.3	0.8

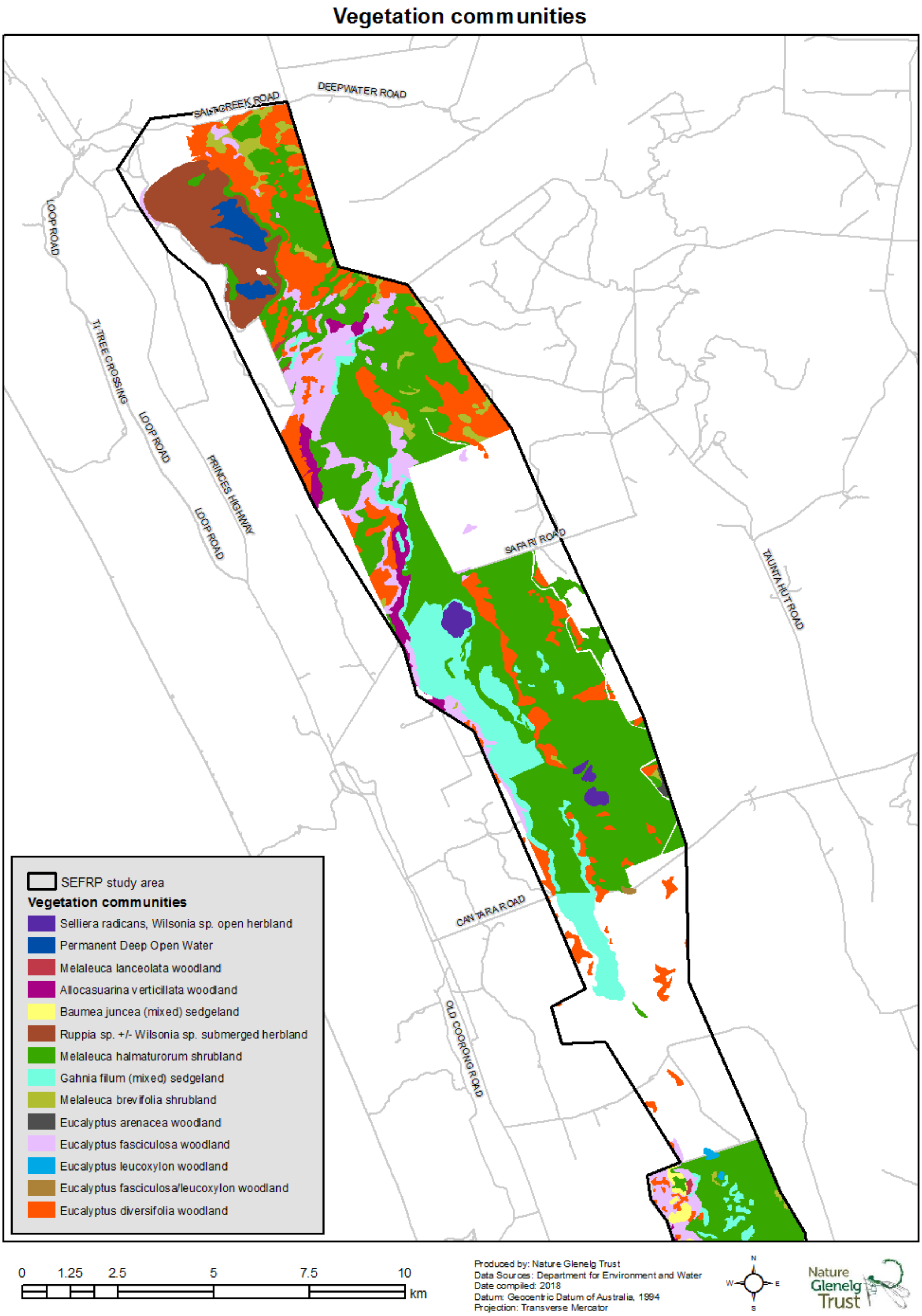


Figure 48 – Mapped vegetation communities (DEW) - north

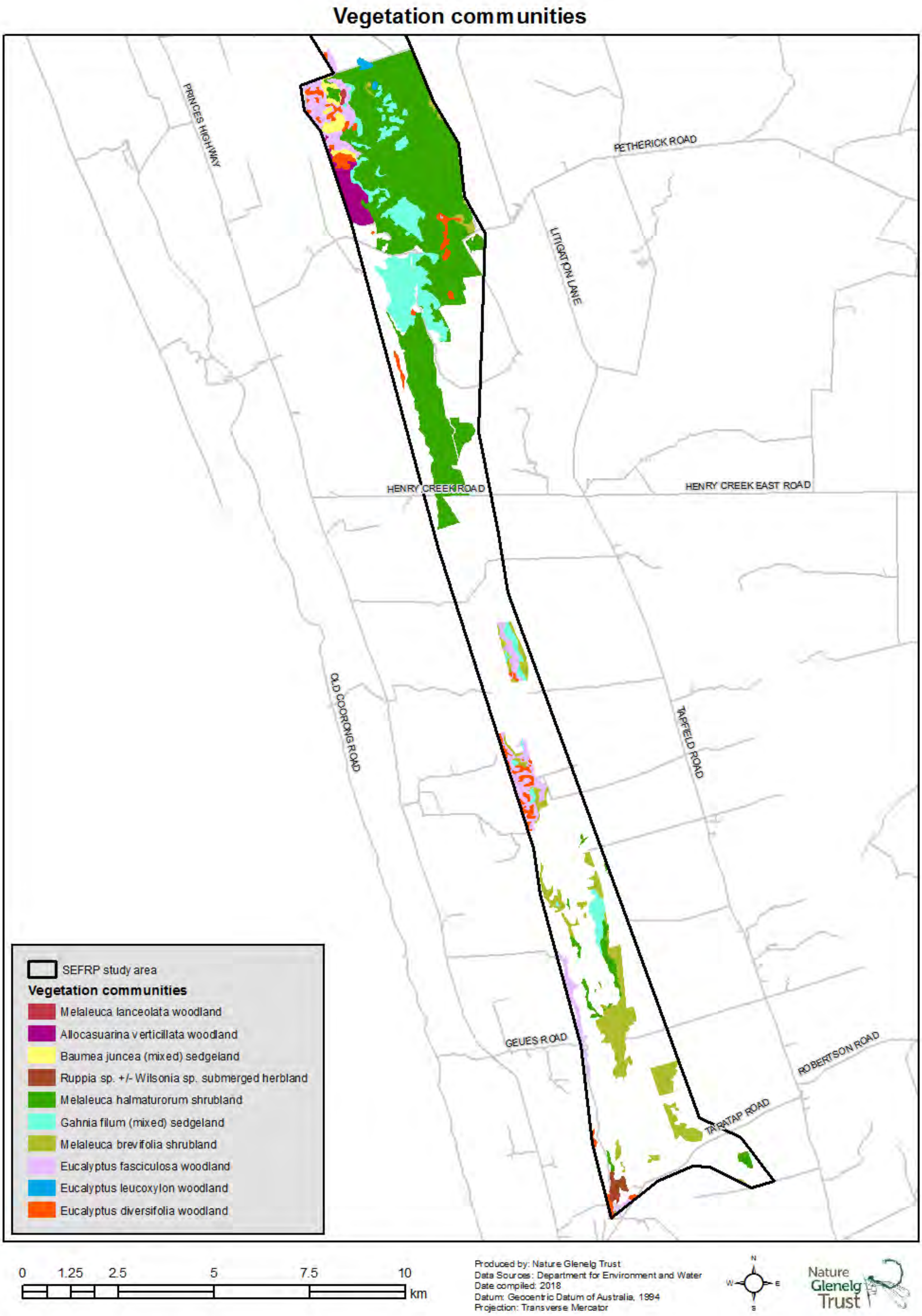


Figure 49 – Mapped vegetation communities (DEW) - south

5.1.2.2 *Vegetation community descriptions*

Recent studies (i.e. Jacobs (2015)) have used variations of these communities to describe the vegetation of the watercourses in more detail, including additional communities not included in DEW mapping. Descriptions of the major vegetation communities present are included below.

The descriptions are derived from multiple sources: Wetland and wetland-associated communities (such as *Eucalyptus camaldulensis* woodland and *Melaleuca halmaturorum* shrubland) are derived from Wetland Vegetation Component (WVC) models (de Jong and Harding 2007, Ecological Associates 2009), while terrestrial descriptions are primarily derived from the South East benchmark communities (Milne and Croft 2012), with reference to the *Biological Survey of Tilley Swamp* (Stewart et al. 1998) and the study by the environmental consultants Jacobs (2015).

Table 11 – SEFRP study area vegetation communities

Community	Vegetation community	BCMM SE community type	WVC model
Wetland communities	Saline samphire low shrubland	6.8 Saline samphire low shrublands	1.12 Samphire low herbland
	Saline herbland	6.7 Saline herblands	1.2 Seasonal brackish aquatic bed
	Gahnia filum sedgeland	6.5 Brackish to saline thatching grass sedgelands	1.8 *Gahnia filum* tussock sedgeland
	Gahnia trifida sedgeland	6.4 Freshwater to brackish cutting grass sedgelands	1.9 *Gahnia trifida* tussock sedgeland
	Seasonal saline low aquatic bed		2.15 Seasonal saline low aquatic bed
Wetland-associated terrestrial communities	*Eucalyptus camaldulensis* open woodland	5.1 Woodlands with a seasonally inundated grass and sedge understorey	1.1 *Eucalyptus camaldulensis* Woodland
	Melaleuca halmaturorum shrubland	6.6 Brackish to saline tall shrublands	1.4 *Melaleuca halmaturorum* Tall Shrubland
	Melaleuca brevifolia shrubland	5.3 Seasonally inundated wet heath shrublands	1.3 *Melaleuca brevifolia* Low Shrubland
Terrestrial vegetation communities	*Eucalyptus fasciculosa/E. leucoxylon* open woodland	2.1 Low woodlands over open sclerophyll shrub understorey on sandy loam soils	
	Eucalyptus arenacea woodland	1.1 Low Woodlands with a dense heath understorey on deep white sands	
	Banksia ornata shrubland	1.2 Shrublands with a dense heath understorey on white sands	
	Eucalyptus diversifolia open mallee	7.5 Coastal mallee with mid-dense shrub and sedge understorey on calcareous dunes	
	Allocasuarina verticillata +/- *Melaleuca lanceolata* open woodland	7.3 Coastal and sub-coastal low woodlands with open grassy understorey	
	Acacia longifolia +/-*Myoporum insulare* shrubland	7.2 Coastal dune shrublands	
Modified communities	In-drain and drain corridor vegetation		
	Revegetation		
	Pasture		

5.1.2.3 *Saline samphire low shrubland*

Vegetation description

A low samphire shrubland found in flats subject to shallow seasonal or intermittent inundation, located on flats between sand dunes, on sandy clay loam to clay loam soils (Figure 50). Ground cover is limited to salt-tolerant species and is dominated by *Sarcocornia quinqueflora* or *Tecticornia* sp. forming a low shrub layer. Other groundcover is usually sparse with bare ground evident, and species diversity is low. Associated species include *Samolus repens*, *Wilsonia* spp. and *Selliera radicans*. *Melaleuca halmaturorum* and *Gahnia filum* may be sparsely present in areas of lower salinity. This vegetation community has been subject to invasion by terrestrial species as a result of drainage, usually evidenced by a marked increase in recruitment of *Melaleuca halmaturorum* and/or *Gahnia filum*.

Fauna associations

Flooded areas can contain aquatic invertebrates that support large numbers of foraging waders and ducks such as Chestnut Teal and Grey Teal. Wetland edges and other waterlogged areas can provide seeds and invertebrates for shorebirds such as Red-necked Stint (Ecological Associates 2009). *Sarcocornia quinqueflora* is a favoured food plant of the nationally critically endangered Orange-bellied Parrot (Orange-Bellied Parrot Recovery Team 2006), although there are no records of the species within the SEFRP study area.

Figure 50 – Saline samphire low shrubland fringing Morella Basin

5.1.2.4 *Saline herbland*

Vegetation description

An open herbland found on saline seasonally-inundated shallow depressions in the floodplain (Figure 51). Characterised by open vegetation that is generally less than 5 cm tall, including species such as *Selliera radicans*, *Samolus repens*, *Wilsonia backhousei, Wilsonia rotundifolia, Schoenus nitens* and *Podolepis canescens.* The palatability of its herbs, forbs and grasses encourage high browsing pressure, maintaining an open structure.

Due to drainage, many areas containing this form of herbland are no longer seasonally inundated and have been subject to encroachment of vegetation communities such as *Melaleuca halmaturorum* and *Melaleuca brevifolia* shrublands (Jacobs and DEWNR 2016). Ecological Associates (2010) suggest that to maintain this habitat and prevent colonisation by more drought tolerant species, inundation for 3-6 months with water of 3,000 to 16,600 $\mu S.cm^{-1}$ is needed at least two years in three.

Fauna associations

This vegetation community is highly productive for fauna, and when inundated for longer periods it can provide shallow water and macrophytes that provide food and shelter for fish, frogs and crustaceans, and in turn, species such as Little Egret, terns and herons, and bats that feed on aerial insects. Shallow open water with semi-emergent macrophytes is the preferred feeding habitat for many waterbirds in the South East, and in the drying cycle it supports grazing by Australian Shelduck, kangaroos and wombats (Ecological Associates 2009, Jacobs 2015).

Figure 51 – Saline herbland

5.1.2.5 *Gahnia filum (mixed) sedgeland*

Vegetation description

An open sedgeland found over semi-saline clay soils in seasonally-inundated depressions, or as regeneration in pasture land (Figure 52). *Gahnia filum* can be a mono-specific stand, or with sub-dominants including *Juncus kraussii* and/or *Gahnia trifida*. There may be an emergent layer of shrubs such as *Melaleuca halmaturorum* and *Melaleuca brevifolia*, and the community frequently merges into *Melaleuca halmaturorum* shrubland, or into samphire shrubland. Lack of inundation often results in invasion of terrestrial vegetation.

The understorey is usually of low diversity and contains salt-tolerant species including smaller sedges, *Tecticornia* sp. and herbs such as *Samolus repens*, *Selliera radicans*, *Wilsonia backhousei* and *Angianthus preissianus*. This vegetation community is now regionally vulnerable, reflecting loss due to regional drainage, clearance for agriculture and invasion by terrestrial species.

Fauna associations

Gahnia filum sedgeland can provide dense cover suited to cryptic species such as Latham's Snipe and Australasian Bittern, and when inundated it can provide nesting sites for waterfowl. Terrestrial species such as Southern Emu-wren, Striated Fieldwren and Clamorous Reed-warbler also use this habitat (Ecological Associates 2009).

Figure 52 – Gahnia filum sedgeland. Photo from Jacobs and DEWNR (2016)

5.1.2.6 *Gahnia trifida sedgeland*

Vegetation description

A dense and low-diversity sedgeland dominated by *Gahnia trifida*, found on clay soils over limestone and typically waterlogged in winter. *Gahnia trifida* is usually dense and can co-dominate with *Melaleuca brevifolia* or *Melaleuca halmaturorum*. This habitat usually occurs in less saline conditions than *Gahnia filum* and where flows decrease or become less saline, that species can become established, with *M. halmaturorum* often invading when inundation is insufficient. The sparse understorey includes smaller sedges such as *Baumea juncea*, *Schoenus nitens* and *Juncus kraussii,* and salt tolerant herbs and grasses.

Fauna associations

The fresher water can support aquatic plants that suit macroinvertebrates and frogs, while the typically dense cover provides shelter and food for cryptic species such as Latham's Snipe and Australasian Bittern. When flooded, it can provide nesting sites for waterfowl, such as the Australasian Shoveler, Chestnut Teal and Pacific Black Duck, and occasional Water-rats. As with *Gahnia filum sedgeland*, resident birds include small passerines such as Striated Fieldwren (Ecological Associates 2009).

Figure 53 – Gahnia trifida sedgeland (photo from Jacobs (2015))

5.1.2.7 *Seasonal saline low aquatic bed*

Vegetation description

A wetland community that occurs at the lowest points of some seasonal wetlands and at the margins of some permanent wetlands. Submerged aquatic species are salinity-tolerant, including *Ruppia* spp., *Lepilaena* spp., *Myriophyllum* spp. and *Potamogeton pectinatus*, and *Crassula helmsii* has been recorded in parts of the Taratap Watercourse. This wetland community is present in the Taratap watercourse and at Morella Basin, currently semi-permanent due to increased inflows. Morella Basin displays some characteristics of the WVC *Semi-permanent Deep / Open Water*, but the higher salinities present likely distinguish it from wetlands of that class.

Unlike other wetland communities on the Taratap and Tilley Swamp Watercourses, this community can lack terrestrial vegetation or sedgelands when the water is dry, due to the frequency and duration of inundation. Dry basins often comprise fine white clay, and when last monitored in 2012, Morella Basin contained *Sarcocornia quinqueflora* and *Wilsonia* sp. Under regular and prolonged inundation, these species may decrease in favour of true aquatics, including Ruppia and charophytes.

Fauna associations

Ecological Associates (2009) list this community as one of the most important in the South East for shorebirds, and shallower waters (<30cm) allow wading for oystercatchers, stilts and avocets. *Ruppia* is an important food source for the Black Swan and migratory waders such as Red-necked stint and Curlew Sandpiper (Rogers and Paton 2009), and *Ruppia* propagules and infauna are easily accessible in the shallows and recently exposed aquatic bed (Ecological Associates 2009). Salinity may limit diversity of native fish, favouring species such as Smallmouth Hardyhead that are tolerant of higher salinities. The fresher character of aquatic habitats in the Taratap Watercourse support fish such as the Southern Pygmy Perch, and frog species including Common Froglet, Banjo Frog and Brown Tree Frog.

Figure 54 - 5.1.2.7 Seasonal saline low aquatic bed (photo from Dickson et al. (2013))

5.1.2.8 *Eucalyptus camaldulensis woodland*

Vegetation description

An open woodland usually found on the heavier soils of the floodplain, ideally alternating between wet and dry. Understorey tends to be sparse, and consists of mostly low grasses and herbs including *Rytidosperma* spp. and *Austrostipa* spp. along with herbaceous lily and *Compositae* species and scattered shrubs. Periodically-inundated areas can also include wetland-associated herbs including *Selliera radicans*, *Samolus repens* and *Wilsonia* spp. When flooded, it can include fringing sedges such as *Juncus* spp., *Isolepis nodosa* and *Cyperus gymnocaulos*.

This habitat is rarely intact due to clearance for agriculture, but modified remnants occur to the south of the study area and scattered around the fringe of Morella Basin. The open understorey and soil fertility invite invasion by exotic pasture grasses and broadleafs, and remaining trees are often in poor health due to decreased inundation and/or frequency of freshening flows, higher salinities, grazing pressure and subsequent lack of recruitment.

Fauna associations

Flooded vegetation provides breeding habitat and shelter for frogs and fish, and feeding opportunities for waterbirds such as Grey Teal, Chestnut Teal and Pacific Black Duck. Mature trees provide hollows for parrots, bats and possums and their fallen timber creates ground habitat for reptiles, while taller mature trees provide invaluable roosting and nesting sites for raptors (Ecological Associates 2009).

Figure 55 – Eucalyptus camaldulensis open woodland. Photo from Jacobs and DEWNR (2016)

5.1.2.9 *Eucalyptus fasciculosa/E. leucoxylon woodland*

Vegetation description

An open woodland community over sandy loam or sandy soils, often on calcrete rises. *E. fasciculosa* is common in the study area, mapped and recorded on sandier soils throughout. It should be noted that the detailed mapping of Tilley Swamp and Stoneleigh Park by Milne and Squire (2001) includes only *Eucalyptus leucoxylon* woodland at those properties, while mapping by DEW and the quadrat monitoring in the Biodiversity Survey of Tilley Swamp record the same areas as mostly *Eucalyptus fasciculosa* woodland, and may be a more reliable guide. The two are considered together here.

This community contains an open overstorey of *Eucalyptus fasciculosa, Eucalyptus leucoxylon*, or both species occurring as co-dominants. *Eucalyptus diversifolia* can be present as a sub-dominant and *Melaleuca lanceolata* may appear in stands or as scattered trees.

Xanthorrhoea caespitosa can form thickets, and shrubs include *Banksia marginata*, *Hibbertia sp.* and *Leucopogon parviflorus.* Understorey tends to be open and may include *Kunzea pomifera* in the form of dominant mats at ground-level and low shrubs such as *Rhagodia candolleana.* Grasses are not usually dominant in the understorey but *Rytidosperma* sp. is commonly scattered.

Fauna associations

This habitat has been noted as a favoured habitat for both the Common Wombat and European Rabbit (Jacobs and DEWNR 2016), and grazing pressure may help to keep the understorey relatively open. It attracts a wide variety of birdlife, including the Superb Fairy-wren and Rufous Whistler, and various species of honeyeater are prominent during flowering periods.

Figure 56 – Eucalyptus fasciculosa/leucoxylon open woodland

5.1.2.10 *Eucalyptus arenacea woodland*

Vegetation description

A low woodland community usually over deep white sands, more common on the higher dunes to the east and sparsely present within the SEFRP study area on the eastern edge of the Tilley Swamp watercourse. In the study area, *Eucalyptus fasciculosa* and *Eucalyptus diversifolia* exist as a sub-dominant.

The midstorey comprises a diverse array of heathy shrubs, with prominent *Banksia ornata* and *Leptospermum myrsinoides* and *Xanthorrhoea caespitosa* cover. Smaller shrubs include *Acacia spinescens*, *Allocasuarina muelleriana* ssp. *muelleriana*, *Correa reflexa* var. *reflexa* and *Hibbertia* sp. Understorey is diverse and can include *Lepidosperma* sp., *Hypolaena fastigiata*, *Stenanthera conostephioides* and *Rytidosperma* sp.

Fauna associations

This vegetation community is associated with a range of woodland birds, including Shy Heathwren, Golden Whistler, Southern Scrub Robin, Spotted Pardalote, and Tawny-crowned Honeyeater. The Biological Survey of Tilley Swamp also recorded the Southern Emu-wren three times in this habitat.

Mammals include the Silky mouse which is associated with *Leptospermum myrsinoides* cover, Little Pygmy-possum and the Short-beaked Echidna. A range of reptiles live in the leaf litter, with common species including the Eastern Three-lined Skink, Bougainville's Skink and Spotted Ctenotus.

5.1.2.11 *Melaleuca halmaturorum shrubland*

Vegetation description

An open to closed shrubland generally found on floodplains and dominated by *Melaleuca halmaturorum,* with *Melaleuca brevifolia* sometimes present as a co-dominant or understorey species. This is the most widespread community in the study area and is often found adjacent to or intergrading with *Melaleuca brevifolia* shrubland. The structure is often dense with heavy vegetative litter, and typically includes a sparse and low-diversity understorey. In damper areas this is usually low and can include *Tecticornia* sp. and *Samolus repens*, while in drier areas the understorey may be taller and include *Rhagodia candolleana* and *Leucopogon parviflorus*, herbs such as *Wilsonia* sp. and *Comesperma volubile*, and sparse grasses. *Gahnia filum* is often a component and can be present under a range of conditions.

Before the construction of the drain network this community was mostly confined to seasonally inundated swamp margins, but it has undergone a large scale expansion downslope into the floodplain and shallow depressions as part of a broader terrestrialisation trend.

Fauna associations

When flooded for an extended period, this shrubland can support roosting and nesting of larger waterbirds such as herons and cormorants. When dry the shrubland can provide habitat for Pygmy Possums, Southern Emu-wren and Malleefowl, and honeyeaters are attracted during flowering periods. Reptiles such as the Tiger Snake are often present at the fringes of wet habitat (Ecological Associates 2009) and Wombats are also common (Jacobs 2015).

Figure 57 – Melaleuca halmaturorum shrubland

5.1.2.12 *Melaleuca brevifolia shrubland*

Vegetation description

A closed shrubland dominated by *Melaleuca brevifolia*, commonly found in seasonally-inundated shallow depressions that are usually subject to lower duration and lower salinity inundation than areas dominated by *Melaleuca halmaturorum*. The shrub layer can be mono-specific, or it may include scattered shrubs such as *Acacia longifolia* ssp. *sophorae*. Understorey is usually sparse due to competition from dense *Melaleuca*, including leaf and bark litter, and in drier areas or in prolonged periods without inundation can include *Eutaxia microphylla*, *Darwinia micropetala*, *Hakea* spp. *and Banksia* spp. (Jacobs and DEWNR 2016). Both *Melaleuca brevifolia* quadrats in the Biological Survey of Tilley Swamp contained the rare *Comesperma polygaloides* (Stewart et al. 1998).

Melaleuca halmaturorum shrubland is often found adjacent or intergrading with this community. Both communities are often found within former wetland areas and can be indicative of terrestrialisation resulting from a change in hydrological regime; however the presence of *Melaleuca brevifolia* shrubland is not necessarily indicative of a long-term drying trend (Jacobs and DEWNR 2016).

Fauna associations

During inundation, the aquatic vegetation and sedges provide habitat for frogs and cryptic waterbirds. Dry shrubland supports ground-dwelling reptiles and a diverse range of birds such as Southern Emu-wren and Beautiful Firetail, while flowering plants attract honeyeaters, a range of invertebrates and the Eastern and Western Pygmy Possums (Ecological Associates 2009).

Figure 58 – Melaleuca brevifolia shrubland (bordering Eucalyptus fasciculosa/leucoxylon woodland)

5.1.2.13 *Banksia ornata shrubland*

Vegetation description

A relatively dense and high-diversity shrubland dominated by a combination of *Banksia ornata*, *Xanthorrhoea caespitosa* and *Leptospermum myrsinoides*, over deep white sand on dunes or sandy plains. Emergent trees may include *Eucalyptus diversifolia*, *Eucalyptus fasciculosa* and *Eucalyptus leucoxylon*. Smaller shrubs include *Correa reflexa*, *Hibbertia* sp., *Calytrix tetragona* and *Adenanthos terminalis*. Understorey may include *Kunzea pomifera* and *Lepidosperma* sp.

Fauna associations

The large *Banksia ornata* flowers provide an important nectar source for honeyeaters and small nectar-feeding mammals such as the Eastern and Western Pygmy Possums and the Silky Mouse. The Common Wombat is often found grazing on groundcover species (Foulkes and Heard 2003).

Figure 59 – Banksia ornata shrubland. Photo from Jacobs and DEWNR (2016)

5.1.2.14 *Allocasuarina verticillata +/- Melaleuca lanceolata open woodland*

Vegetation description

An open woodland commonly found on poorly developed shallow soils over calcrete and on consolidated dunes. It is characterised by an open canopy of *Allocasuarina verticillata*, with *Melaleuca lanceolata* often present as a co-dominant. *Eucalyptus diversifolia* may also be present, and E. diversifolia woodland may be found nearby.

Figure 60 - Allocasuarina verticillata +/- Melaleuca lanceolata open woodland – A. verticillata-dominated overstorey

The shrub layer tends to be very open, with species such as *Acacia longifolia* ssp. *sophorae*, *Leucopogon parviflorus*, *Myoporum insulare* and *Bursaria spinosa*. Groundcover is open and grassy and may include mats of *Kunzea pomifera* and native grasses.

Fauna associations

The open habitat is suited to a variety of common woodland bird species such as wrens and honeyeaters, while native grasses provide a food source for seed-eating birds, and Beautiful Firetail have been observed nesting in mature *Allocasuarina verticillata* (Rogers 2011). Exposed limestone in this habitat can be favoured by skinks and other small reptiles, and Jacobs (2015) found the Common Wombat to be associated with this community, providing habitat for burrow construction.

Figure 61 – Allocasuarina verticillata +/- Melaleuca lanceolata open woodland – Melaleuca lanceolata–dominated overstorey

5.1.2.15 *Acacia longifolia +/- Myoporum insulare shrubland*

Vegetation description

An open shrubland occurring on low dunes and sandy plains near the Coorong South Lagoon (close to Salt Creek) as well as in low dunes in other locations. It is characterised by a low and open shrubby overstorey of *Myoporum insulare* and *Acacia longifolia* var. *sophorae*, along with *Olearia axillaris*.

Mid-storey species include *Rhagodia candolleana* and climbers such as *Tetragonia implexicoma* and *Muehlenbeckia gunnii*, and groundcover is mostly comprised of low shrubs, sedges and herbs including *Kunzea pomifera*, *Ficinia nodosa*, *Cynoglossum australe*, *Senecio* sp. and *Pelargonium* sp. Variations of this vegetation community were recorded by Jacobs in the proposed SEFRP alignment to the north west of Martin Washpool close to Salt Creek Road, and to the north of Frostys Swamp (Jacobs 2015). *Lycium ferocissimum* (African Boxthorn) can be a problematic weed in this vegetation community, being well suited to the free draining soils and relatively open structure (Jacobs 2015, Noble 2013).

It is also worth noting that *Acacia longifolia* is now also considered an aggressive undesirable invader of other vegetation communities in the South East.

Fauna associations

This shrubland is highly associated with the Common Wombat and the Silky Mouse. Birdlife is diverse with some species feeding on the sweet fruit of *Myoporum insulare*. The dense structure of this shrubland is particularly associated with bird species that favour dense cover, including Beautiful Firetail, Southern Emu-wren and Rufous Bristlebird (Foulkes and Heard 2003).

Figure 62 – Acacia longifolia +/- Myoporum insulare shrubland. Photo from Jacobs and DEWNR (2016)

5.1.2.16 *In-drain and drain corridor vegetation*

Vegetation description

Drains frequently contain regrowth of native vegetation, with the vegetation communities present influenced by soils, salinity, hydrological conditions and proximity to other native vegetation. In-drain communities can function as samphire herblands, with species such as *Sarcocornia blackiana* (Figure 63). Other drain communities can resemble open herbland with species such as *Samolus repens*, *Wilsonia backhousei* and *Selliera radicans*, or sedgeland with *Juncus kraussii* over *Samolus repens* and *Wilsonia backhousei*. Some areas are permanently inundated, particularly toward the northern end of the study area, and contain species such as *Myriophyllum* spp., *Potamogeton pectinatus*, *Ruppia* spp. and *Lepilaena cylindrocarpa*.

On the banks of drains, vegetation may include regenerating shrubs including *Melaleuca halmaturorum* and *Melaleuca brevifolia* and sedges such as *Gahnia filum* and *Juncus kraussii*.

Most vegetation within drain corridors was removed during the construction of drains and formed vehicle tracks, and some regeneration of native vegetation has occurred in previously cleared areas and on the spoil heaps containing soil from drain excavation. In 2015, environmental consultants Jacobs mapped spoil heap and other native vegetation within the proposed SEFRP alignment, and found it to generally reflect the adjacent vegetation communities. As drains mostly pass through low, historically wet areas, *Melaleuca halmaturorum* comprised most of the regeneration observed. Species richness was often higher on spoil heaps than adjacent shrubland communities as the more open structure and disturbance has allowed their establishment. For the same reasons, weed species were more commonly recorded on spoil heaps (Jacobs 2015).

Fauna associations

Some drain sections often hold water later into the year or even all year round, and as such can provide habitat and feeding opportunities for waterbirds when other water bodies such as shallow wetlands have dried. Terns are often seen following drains while foraging, and other waterbird records include many of the ducks found in wetlands in the region, and waders such as Banded Stilt. For fish and other aquatic species, drains provide valuable connections between aquatic habitats and deeper pools and can form temporary refuge areas as the surrounding landscape dries. Species recently recorded in drains include Southern Pygmy Perch, Smallmouth Hardyhead and Congolli (Whiterod et al. 2018).

Figure 63 – Example of in-drain vegetation community dominated by Sarcocornia blackiana

Figure 64 - Example of permanently inundated drain habitat, with Myriophyllum caput-medusae in the channel waters and Wilsonia sp. and then Melaleuca halmaturorum lining the channel (from Jacobs and DEWNR (2016))

5.1.2.17 *Revegetation*

Description

Revegetation was planted between 2001 and 2003 in a 535 ha area surrounding Morella Basin (see section 2.2.1 – Revegetation). Revegetation areas were direct seeded with species including *Melaleuca halmaturorum* in wet depressions; sandy and calcrete rises contain *Eucalyptus fasciculosa*, *E. diversifolia*, *E. leucoxylon* and *Allocasuarina verticillata* over *Acacia* sp. and *Dodonaea viscosa*, and *Callistemon rugulosus* is planted on sloping loamy clay (Mercer and Griffin 2009). In 2008, sixteen new species (not in the revegetation mix and not originally at the site) were found to have regenerated in the seven years since stock removal (Stokes 2008).

Figure 65 - Revegetation plantings fringing Morella Basin: aerial view 2013 (image from DEW)

Fauna associations

Revegetation now extends the remnant vegetation of Morella Basin to form what may eventually be an important corridor between the wetland and the vegetation blocks formed by the Coorong NP to the west and a partial corridor to Messent CP to the north east. A study by Mercer and Griffin (2009) recorded 45 native bird species in revegetation areas that were between four and six years old, including the nationally vulnerable Southern Emu-wren.

Figure 66 - Photopoint in the stage 1 revegetation area of Morella Basin prior to planting in June 2001 (left) and the same photopoint in January 2016 (4.5 years old) (right) (from Stokes (2008))

5.1.2.18 *Pasture*

Vegetation description

Large parts of the study area have been cleared of their original vegetation, by machinery, stock, or a combination of both. These areas are mostly of limited habitat value and are dominated by introduced pasture grasses and broadleafs, but pasture can also include scattered native vegetation in the form of remnant vegetation or regrowth. Common regrowth includes *Gahnia filum* on waterlogged soils, and remnant overstorey often includes scattered *Eucalyptus* sp. or *Melaleuca halmaturorum* that have thus far survived clearance and grazing.

Vegetation includes intentionally-planted pasture species as well as common agricultural weeds. These spread readily into nearby native vegetation by a range of vectors, and some desirable agricultural species such as *Ehrharta* sp., *Phalaris aquatica* and *Thinopyrum elongatum* threaten nearby bushland and wetland habitats – particularly those with an open structure or which are partially degraded or otherwise disturbed.

Fauna associations

This vegetation type is mostly associated with sheep and cattle, attracting invertebrates and insectivorous birds. Other bird species including *Neophema* and finches feed on the seeds of pasture grasses and broadleaf weeds such as *Polygonum aviculare* and *Poa annua*, and common species such as Masked and Banded Lapwings, Australian and Little Ravens and Australian Magpie target insects and their larvae. Large numbers of kangaroos graze on open grassy areas and shelter in native vegetation; similarly, wombats will browse exotic grasses close to native vegetation cover.

Figure 67 – Heavily-grazed paddock

Figure 68 – Paddock with browsed Gahnia regeneration and modified Eucalyptus fasciculosa/leucoxylon woodland in background

5.1.3 Threatened flora species

Fifteen flora species have been recorded in the study area or nearby (within 3 km) that are listed as threatened on a national, state, or bio-regional level (Table 12). Amongst these species, there are a small number of nationally-listed plants, with a high representation of orchids. Most threatened orchid records within the study area are from the conservation reserves of Tilley Swamp CP and Martin Washpool CP, where large areas of intact native vegetation remain and flora monitoring intensity has been relatively high. While a number of species have not been seen for some years, it is possible that populations persist undetected where suitable habitat remains – particularly in less-monitored Heritage Agreements.

A number of other species are listed as rare in the region and have been included in the full flora species list in Appendix 10.5.

Table 12 – Summary list of threatened flora species in the SEFRP study area (+3 km)

Species	Common Name	Conservation status		Distribution notes
		EPBC	NPWSA	
Caladenia calcicola	Limestone Spider-orchid	VU	EN	One record (1991) in Martin Washpool CP, south of Morella Basin.
Caladenia dilatata	Late Spider-orchid		EN	One record (2004) in the south-west corner of Tilley Swamp CP.
Clematis aristata	Australian Clematis		VU	One record (1987) in Tilley Swamp CP.
Cuscuta tasmanica	Golden Dodder		VU	4 records (last 2011) around Morella Basin, and one in now cleared land south of Stoneleigh Park.
Lachnagrostis punicea ssp. *filifolia*	Narrow-leaf Blown-grass			3 records (2000) in Tilley Swamp CP.
Leptorhynchos squamatus ssp. *squamatus*	Scaly Buttons			3 records (1996) in the south east corner of Tilley Swamp CP.
Luzula densiflora	Dense Wood-rush			1 record (2002) outside the study area in the south west corner of Messent CP.
Mitrasacme pilosa var. pilosa	Hairy Mitrewort		VU	1 record (1991) in the north west corner of Tilley Swamp CP.
Opercularia ovata	Broad-leaf Stinkweed			2 records (1986) – one just east of Frostys Swamp and one in the heritage agreement to its east.
Ophioglossum lusitanicum	Austral Adder's-tongue			2 records (1991) in the south of Martin Washpool CP.
Pterostylis tasmanica			VU	4 records (1998) in Tilley Swamp CP.
Ranunculus robertsonii	Slender Buttercup			3 records (last 1983) in Tilley Swamp CP.
Thelymitra azurea	Azure Sun-orchid			2 records (last 1967) in now-cleared land south of Tilley Swamp CP and near Salt Creek.
Thelymitra epipactoides	Metallic Sun-orchid	EN	EN	27 records (last 2012) in Tilley Swamp, 3 in Messent CP (last 2005) and 1 in Coorong NP (1992).
Utricularia tenella	Pink Bladderwort			2 records (1998) in Tilley Swamp CP.

EN=Endangered, VU=Vulnerable, NT=Near Threatened

5.1.4 Weed species and distribution

A number of weed species recorded in the study area are listed and controlled at a national (Weeds of National Significance – WONS) or state (Declared under NRM Act 2004) level (Table 13). A full list of exotic flora species is included in Appendix 10.5.1.

Table 13 – Controlled weed species

Species	Common Name	Threat status	
		WONS	NRM Act 2004
Asparagus asparagoides	Bridal Creeper	Y	Y
Chrysanthemoides monilifera	Boneseed	Y	Y
Echium plantagineum	Salvation Jane	Y	Y
Euphorbia terracina	False Caper		Y
Juncus acutus	Spiny Rush		Y
Lycium ferocissimum	African Boxthorn	Y	Y
Marrubium vulgare	Horehound	Y	Y

The recent survey of the SEFRP alignment by the consultants Jacobs (Jacobs and DEWNR 2016) included these species in a list of weeds to be monitored and managed, along with *Euphorbia paralias*, *Phalaris aquatica*, *Senecio pterophorus* and *Thinopyrum elongatum*. Of these species combined, the following can be considered significant threats to remnant vegetation within the Taratap and Tilley Swamp Watercourses:

***Asparagus asparagoides* (Bridal Creeper)** is a major weed of bushland in south eastern Australia, invading undisturbed and disturbed vegetation and threatening low plants and shrubs in a range of habitats. Seed is dispersed by birds and other fauna such as foxes and rabbits, making the containment of populations problematic. In the study area, it is mostly found in woodland habitats and is particularly detrimental to small and sometimes rare native plants, including orchids (Willis 2008).

***Chrysanthemoides monilifera* (Boneseed)** is an aggressive invader of remnant bushland that spreads rapidly – particularly after fire. Seeds are spread by birds, rabbits and foxes, and persist well in soil. Seedlings can become established in a wide range of habitats from *Eucalypt* forest to coastal fringe vegetation and plants are salt-tolerant (CRC for Australian Weed Management 2003), making it a significant threat to a range of habitats in the Taratap and Tilley Swamp Watercourse.

***Juncus acutus* (Spiny Rush)** is an invasive sedge that colonises damp and seasonally inundated areas, with the ability to reach a density that displaces most or all other flora species. Seed is easily dispersed by water and wind and once in a watercourse it has the potential to invade connected saline and brackish to freshwater wetlands (Keighery and Keighery 2006). The species is not currently widespread in the study area, but scattered plants have been observed on the Tilley Swamp drain batters (Mark de Jong, pers.obs) and in the wider drainage system (Ben Taylor, pers. obs.), providing a vector for possible dispersal into restored SEFRP wetlands.

Lycium ferocissimum **(African Boxthorn)** is an invasive weed with the potential to significantly transform open habitats, and can invade denser woodlands. It grows in a broad range of soil types and establishes well on light soils (Noble 2013). Seed is readily dispersed via water, birds and foxes and its branches and spiny foliage can harbor rabbits. Recently it has been controlled in inaccessible areas in the Coorong N.P. by application of granular herbicide from helicopter with some success (Jonathan Tuck, pers. obs.).

Thinopyrum elongatum **(Tall Wheat-grass)** is a highly competitive drought-tolerant tussock grass, planted extensively as a means of managing saline, waterlogged soils – particularly in Victoria. When allowed to run to seed, it can rapidly invade wetlands and become dominant, to the exclusion of native species. Tussocks can become large and dense enough to form a barrier for native fauna and affect surface water flows (Northern & Yorke NRM Board 2011).

5.1.4.1 *Weed status*

The Taratap and Tilley Swamp watercourses are subject to varying levels of historical disturbance and proximity to agricultural land and drains, and weeds are generally present throughout. A number of national and state-listed weed species are found in more highly-disturbed areas and are also sparsely present in remnant vegetation according to records. The increase in weeds noted post-fire in Tilley Swamp CP in 2014 (Dickson and Bachmann 2015) illustrates the ability of some weeds to respond to disturbance in intact native vegetation.

Figure 69 shows the general distribution of records of national and state controlled weeds from the BDBSA and SAWID datasets. It should be noted that weed records are concentrated in areas of greater survey effort or visitation, and as a result many records are concentrated south of Morella Basin in the location of ecological surveys, and nearby on roadsides along the edge of the Coorong.

A 2015 survey by the consultants Jacobs recorded weed presence at 37 sites along the SEFRP alignment, including nationally and state-listed species, detailed maps of which are included in the project report (Jacobs 2015). This gave perhaps the widest geographic coverage of any of the existing weed surveys. However, as the SEFRP alignment runs largely along the existing Taratap and Tilley Swamp drains, survey locations were close to habitat disturbance, and weed presence is likely to be reflective of disturbed edges along the alignment rather than overall weed presence throughout the watercourses. The report notes the general disturbance condition of the SEFRP alignment, finding the area around Salt Creek to be highly modified with high rabbit impact and presence of African Boxthorn, while Tilley Swamp CP had moderate levels of weeds that were more prevalent in areas burnt in 2013, including African Boxthorn, Bridal Creeper and Horehound.

Current knowledge of weed distribution is lacking, and more comprehensive weed surveys would be beneficial for planning coordinated weed control in a more connected landscape under the SEFRP. Landscape connectivity has many benefits for native flora and fauna, but additional landscape linkage by increased flooding of watercourses or by revegetation (i.e. the north-west corner of Martin Washpool to the Coorong) can facilitate movement of weed seed through connected areas via fauna or water.

Amongst the nationally or state-listed weeds, Spiny Rush (*Juncus acutus*) is of particular concern, despite only one BDBSA/SAWID record and the species not being detected during the Jacobs survey in 2015. The species is a serious threat to the wetland and floodplain habitats of the watercourses, having the ability to establish in saline and brackish wetland environments and reach densities that will exclude other native species (Keighery and Keighery 2006). More detailed recommendations regarding weed monitoring – particularly of Spiny Rush – are included in Section 7.3.

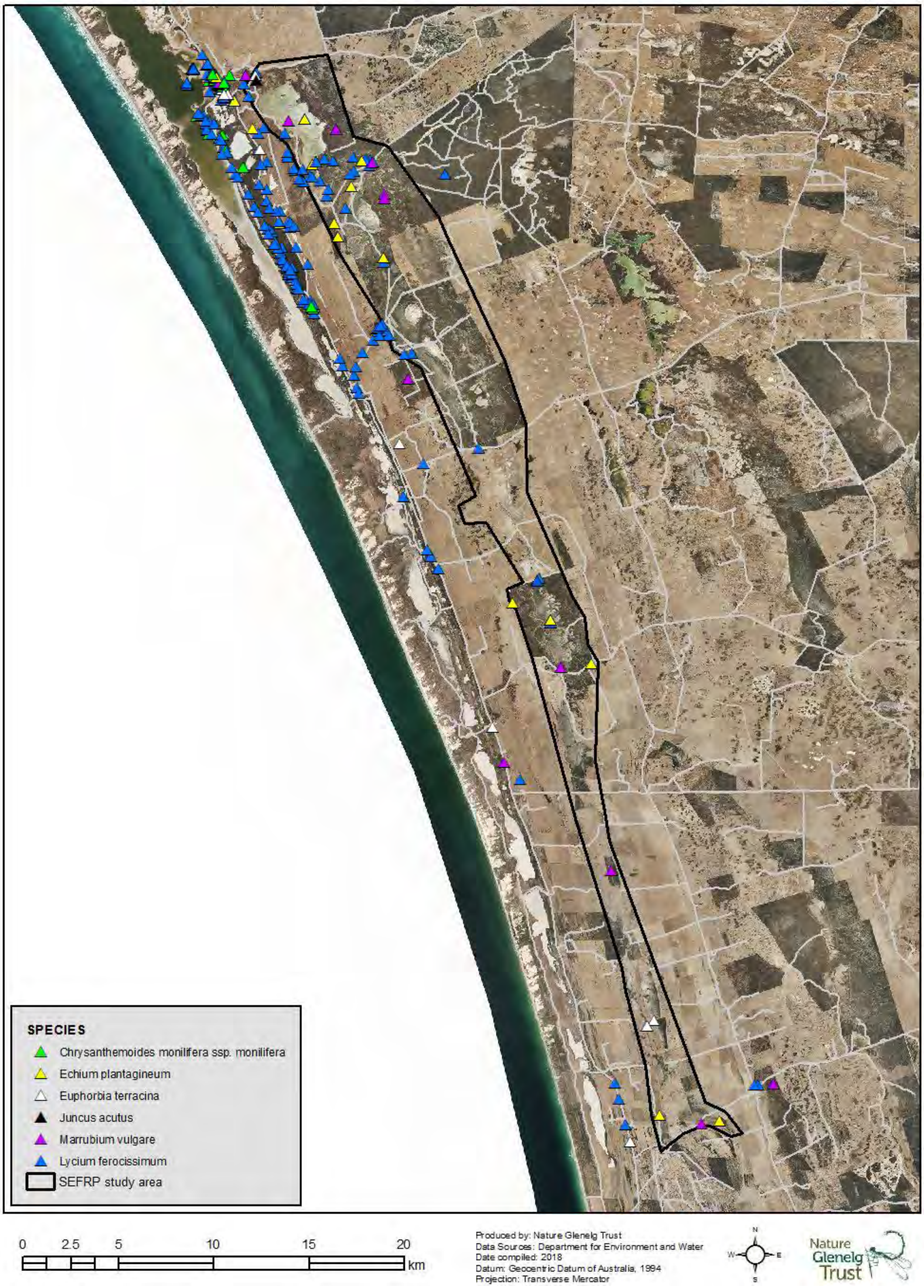


Figure 69 – National/state controlled weed records within 3 km (BDBSA/SAWID datasets)

5.2. *Vegetation monitoring*

5.2.1 Biodiversity Surveys

5.2.1.1 *Biological Survey of Tilley Swamp – vegetation plots (1996)*

In 1996, the Biological Survey of Tilley Swamp in 1996 (Stewart et al. 1998) was the first systematic survey that attempted to characterise flora and fauna in the Tilley Swamp Watercourse. The survey also aimed to inform decision making regarding the drainage options through the wetland that were being considered at the time, which ultimately resulted in the construction of the Tilley Swamp Drain as part of the USE Scheme.

Sixteen 30 x 30m vegetation quadrats were sampled, within which all vascular plants present were recorded, along with life stage, cover/abundance, and vegetation association description. Details of overstorey height, canopy depth and diameter, and canopy cover were also recorded, and a description of the location and physical environment of each quadrat. These quadrats were also used for fauna surveys.

Two hundred and twenty eight (228) flora species were recorded, including 11 that are currently regionally-threatened (Near Threatened or higher - Table 14).

Table 14 – Threatened flora species recorded during the Biological Survey of Tilley Swamp (1996)

Species	Common name	EPBC	NPWSA	Bioregion
Brachyscome cuneifolia	Wedge-leaf Daisy			VU
Centrolepis aristata	Pointed Centrolepis			NT
Centrolepis strigosa ssp. *strigosa*	Hairy Centrolepis			NT
Comesperma polygaloides	Mauve Milkwort			NT
Eucalyptus leucoxylon ssp. *stephaniae*	Scrubby Blue Gum			NT
Eutaxia microphylla	Common Eutaxia			NT
Hydrocotyle medicaginoides	Medic Pennywort			NT
Lachnagrostis billardierei ssp. *billardierei*	Coast Blown-grass			NT
Leptorhynchos squamatus ssp. *squamatus*	Scaly Buttons			VU
Poa sieberiana var. *hirtella*	Grey Tussock Grass			VU
Triglochin mucronata	Prickly Arrowgrass			NT

While the vegetation survey was not intended to be used for longer-term monitoring, the quadrats traverse most of the vegetation communities present in the watercourses, with the exception of saline herbland and deep open water communities.

Of particular interest are seven survey sites located in areas expected to be influenced by the SEFRP (Table 15) and which could provide comparison for vegetation composition change under the SEFRP.

Table 15 - Tilley Swamp biodiversity quadrats - sites relevant to the SEFRP

Quadrat	Vegetation community	Native species	Weed species	Fauna species	Threatened species
TS00101	*Samphire* low shrubland	10	2	17	*Triglochin mucronata* (SE:NT)
TS00201	*Banksia ornata* open heath	34	0	38	
TS00801	*Melaleuca halmaturorum* low open forest	10	24	21	*Lachnagrostis billardierei* ssp. *billardierei* (SE:NT)
TS00802	*Melaleuca halmaturorum* low open forest	11	7	n/a	
TS00901	*Eucalyptus diversifolia* open scrub	48	5	37	*Poa sieberiana* var. *hirtella* (SE:VU) *Eucalyptus leucoxylon* ssp. *stephaniae* (SE:NT)
TS10001	*Melaleuca halmaturorum* shrubland	9	1	24	
TS01101	*Melaleuca halmaturorum* open scrub	2	8	20	*Hydrocotyle medicaginoides* (SE:NT)

5.2.2 Pre-SEFRP wetland monitoring

5.2.2.1 *Tilley Swamp Drain monitoring (2000-2012)*

Prompted by the construction of the Tilley Swamp Drain in 1999-2000, a vegetation monitoring program for Tilley Swamp and the Stoneleigh Park property was established in 2000 focusing on measuring the effects of groundwater drawdown on vegetation close to the drain (Telfer et al. 2000). Four transects were established at 100m, 500m, 850m and 1200m from the drain, with the 1200m drain being beyond the zone of influence from the drain. Monitoring was subsequently conducted to varying levels of completeness in 2000, 2001 and 2002.

The 2000 monitoring did not detect a change in vegetation health with distance from the drain at either site. At Stoneleigh Park, vegetation was dominated by *Melaleuca halmaturorum* with 30 understorey species. Tilley Swamp CP was dominated by *Melaleuca halmaturorum* with some *Melaleuca brevifolia,* and a much more diverse understorey of 52 species.

By the third year of monitoring (2002), it was concluded that the drain had not had a significant impact on plant health to that date, and groundcover composition was not expected to change in response to groundwater drawdown over that time period.

In 2012, monitoring was repeated at Tilley Swamp CP as part of the broader SEFRP-initiated wetland monitoring. Monitoring data confirmed a trend toward drier site conditions since the initial monitoring in 2000, with vegetation within transects responding by becoming more diverse and more densely vegetated, with less bare ground or open areas, and a higher proportion of pasture grasses and other exotic species. This change was most marked in the 500m transect, in which the *Melaleuca halmaturorum* shrubland increased from 6 species recorded in 2000 to 37 species in 2012. This was seen to be a strong indication of a drying trend, and supported by the presence of terrestrial species such as *Acacia longifolia* ssp. *sophorae* and *Leucopogon parviflorus*.

Aquatic vegetation monitoring recorded a significant change in the large middle section of the monitoring area, with a transition from herbland to a drier *M. halmaturorum* shrubland interspersed by small pockets of herbland (Figures 70 and 71).

Figure 70 – Tilley Swamp Conservation Park aquatic vegetation fan photopoint – year 2000. Photo from Telfer et al. (2000).

Figure 71 – Tilley Swamp Conservation Park aquatic vegetation fan photopoint – year 2012. Photo from Dickson and Bachmann (2015).

5.2.2.2 *Tilley Swamp Drain monitoring (2014 – after Tilley Swamp CP fire)*

Site conditions at Tilley Swamp CP were dramatically altered in February 2013 by a bushfire that burnt approximately 90% of the park. Dickson et al. (2013) anticipated a post-fire mass-recruitment event, that could result in development of even denser *M. halmaturorum* in brackish aquatic beds. To capture the change, the Tilley Swamp transects and aquatic fan site visited in previous Stoneleigh Park and Tilley Swamp monitoring were surveyed in November 2014, with the intention of capturing vegetation changes (Dickson and Bachmann 2015).

Basic vegetation communities were unchanged from previous monitoring events, with *Melaleuca brevifolia* shrubland dominant on the transect closest to the drain, and *Melaleuca halmaturorum* shrubland dominant on the remaining three transects.

Thirty-one mostly fire-responsive species were detected in 2014 that were not detected in 2012, including 12 weed species. Notable vegetation changes included mats of brackish herbs dominated by *Wilsonia backhousei* in areas that previously had dense overstorey cover. Other species included the fire-responsive herb *Apalochlamys spectabilis*), stands of *Lawrencia spicatum* outside transects, and increased grass cover in open areas, including *Lachnagrostis filiformis*.

Species diversity in transects largely continued to increase, following the trend observed across monitoring from 2000 to 2012 (Figure 72). However, the cover of the four most dominant species had altered significantly (*Samolus repens, Wilsonia rotundifolia, Selliera radicans* and *Melaleuca halmaturorum*), with the three herb species decreasing from densities of <40% to densities of <5%, sparse or occurrences of 1-10 individuals.

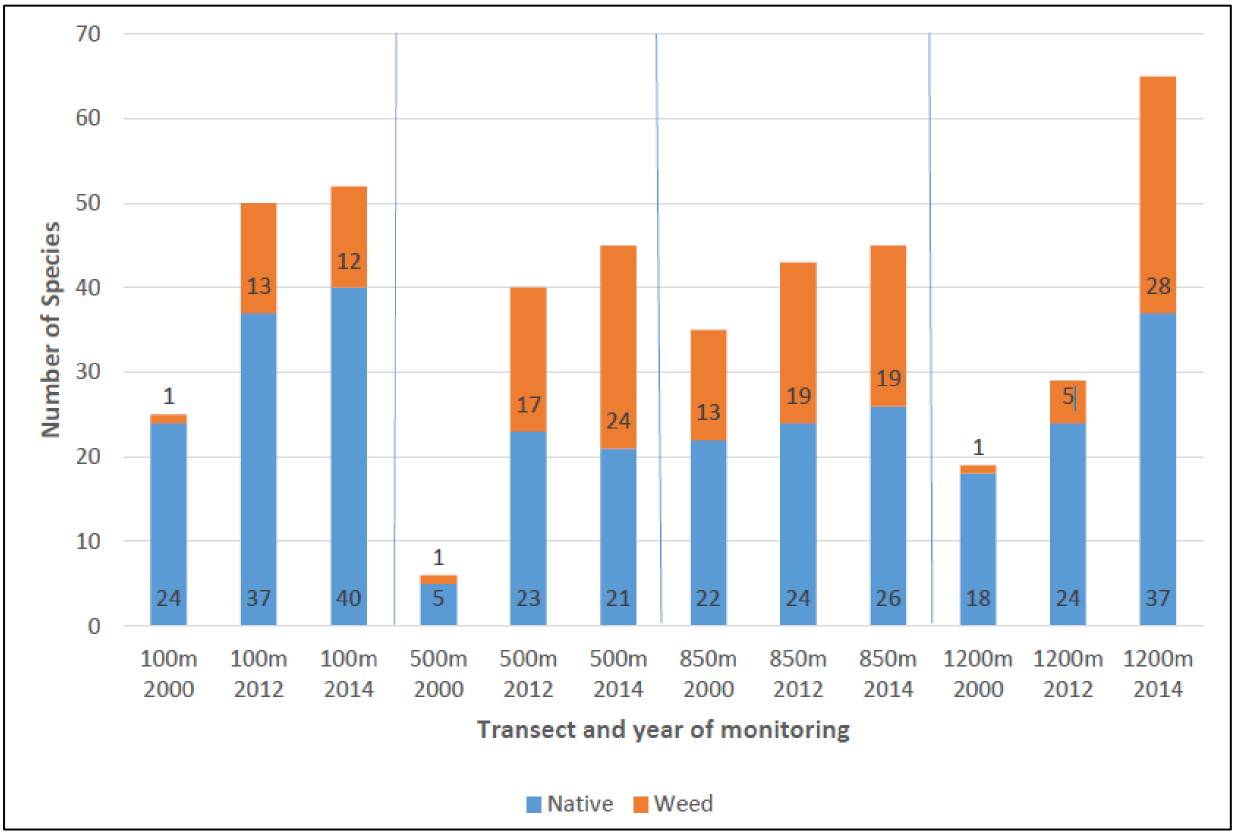


Figure 72 – The number of species recorded along each transect in the year of establishment (2000) and pre-fire 2012 and post-fire 2014 (source: Dickson and Bachmann (2015))

Melaleuca species were rapidly regenerating, with *M. brevifolia* resprouting from the base and mass recruitment of *M. halmaturorum* seedlings observed. Aquatic vegetation monitoring 'fans' for 2012 and 2014 showed *M. halmaturorum* shrubland continuing to increase in density throughout the inundated zones, moving into most potential quadrats and increasing in cover by between 5 to 80% . This had effectively replaced most of the previously open Brackish Herbland (Figure 75).

Overall, the results suggest that the post-fire state in the monitoring area – at least in the near-term – was moving to a dense shrubland over a brackish herbland, accelerating the trend observed in previous monitoring.

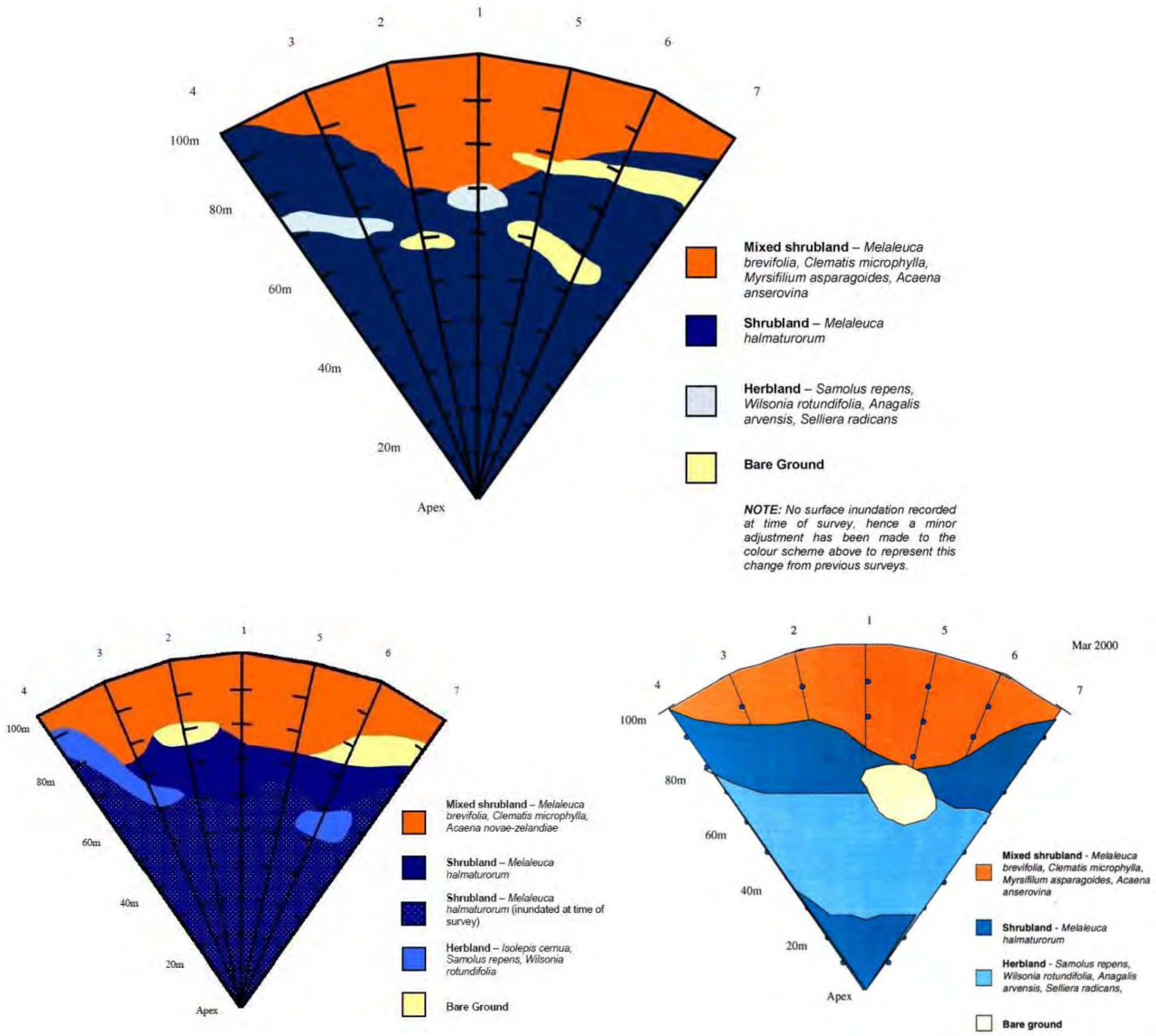


Figure 73 - Aquatic vegetation 'fans' for 2000 (bottom right), 2012 (bottom left) and 2014 (top) (from Dickson and Bachmann (2015))

5.2.2.3 ***SEFRP-initiated monitoring***

SEFRP-initiated vegetation monitoring began in 2012, with a focus on surveying wetland vegetation likely to be influenced by changes in water regime through the Tilley and Taratap Watercourses. The first round of monitoring (January 2012) was part of a broader review of wetlands of both the Upper and Lower South East, and included one site within the SEFRP study area (Morella Basin), and it has been repeated and/or expanded in October-November 2012, 2014 and 2016 (see Table 16).

Table 16 – Locations and monitoring methods for SEFRP-initiated vegetation monitoring sites

Location (listed north to south)	Wetland ID	Site name	Vegetation monitoring method	2000 (Telfer study)	Jan 2012	Oct-Nov 2012	2014	2016
Morella Basin (Tilley Swamp)	S0100038	'MB1' (middle)	• Transect • Quadrats		Y	Y		
		'MB2' (south)			Y	Y		
		'MB3' (north)			Y	Y		
Frostys Swamp (Tilley Swamp)	S0100054	Site 1 (FS1)						Y
		Site 2 (FS2)						Y
Wetlands & Wildlife (Tilley Swamp)	S0104731	W&W North (WW2)						Y
Wetlands & Wildlife (Tilley Swamp)	S0101265	W&W South (WW1)						Y
Pitlochry (Tilley Swamp)	S0100075	Pitlochry						Y
Tilley Swamp (Tilley Swamp)	0100146	USE305	• Monitoring 'fan'	Y		Y	Y	
		USE301	• Transect • Step point analysis			Y	Y	
		USE302				Y	Y	
		USE303				Y	Y	
		USE304				Y	Y	
McBride (Taratap)	-	MU1	• Transect • Quadrats			Y		
Marwood (Taratap)	S0111150	MM1				Y		
		MM2				Y		
Stewarts (Taratap)	S0101573	LS				Y		
Yeulba (Taratap)	S0100227	YS1				Y		
	S0100236	YS2				Y		
Chris Englands (Taratap)	S0111143	CE1				Y		
	S0111150	CE2				Y		
		CE3				Y		

Methods

Under SEFRP-initiated vegetation monitoring, the primary flora survey methodology involved the establishment of line transects and quadrats in wetlands. Transects ran from terrestrial vegetation on the wetland edge, down to its deepest point or where aquatic vegetation becomes consistent.

For the length of the transect, the three most dominant species for each of six strata were recorded, along with the density of each species. The species and densities changed frequently along transects. The transect data was represented in vegetation kite charts (Appendices 10.6.1 to 10.6.3). At the wetland end of each transect, three 2x2m quadrats were monitored to characterise wetland vegetation, recording all species and their relative cover. Sites were also visited for fish, frog and waterbird monitoring, described in section 5.3.

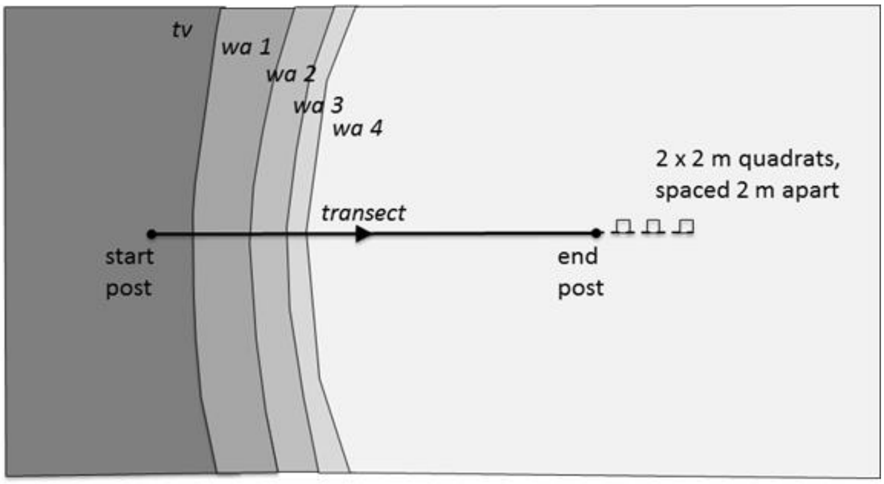


Figure 74 - Vegetation transect and quadrat location (from Dickson et al. (2013))

2012 monitoring

At the onset of monitoring in January 2012, a long-term drying trend was well-established and recorded in monitoring including that of Telfer et al. (2000). The 2012 monitoring took in 13 sites in total, with Morella Basin being the only site monitored in January; the site was revisited in October-November along with 12 new monitoring sites (Dickson et al. 2013).

By the time of monitoring in October-November 2012, wetlands had drawn down significantly with some wetlands totally dry and consisting of a damp herbland. These recently-dried sites generally had higher species diversity than sites that were inundated or significantly drier, and the damper the herbland, generally the more diverse the site was. The sites at Englands, Yeulba and Marwood had a number of co-dominant species that continually fluctuated in dominance along the transect.

The majority of sites traversed wetland beds that had been significantly affected by drainage, and by 2012, many of the sites had developed a herbland on the wetland bed, indicating a lack of frequent and prolonged inundation, and comprising native species such as *Wilsonia rotundifolia*, *Selliera radicans*, *Triglochin striatum* and exotic species such as *Chenopodium glaucum*, *Cirsium vulgare* and *Heliotropium* spp.

The most notable change across the watercourse was the detection of a long-term drying trend, with terrestrial habitat creeping down-slope in response to drier conditions. Illustrating this, young cohorts of *M. halmaturorum* were detected in the edges of the wetland basin at Tilley Swamp, Yeulba Swamp, Englands, Marwoods, McBrides and Morella Basin, appearing within the historic high water mark and clearly marking the drying trend.

The large wetland of Morella Basin formed an outlier in that inundation had actually increased due to drainage inflows, with wetland vegetation observed to be adapting to the new regime. Between monitoring events in January and November 2012, *Melaleuca halmaturorum* had disappeared from sections of the monitoring transect, with the species appearing to have retreated up the elevation gradient in response to more regular inundation. This provides an indication of potential ecological change within the broader Tilley Swamp Watercourse under a more highly inundated scenario (i.e. post-SEFR project).

A number of grazed or recently-grazed sites were included in the 2012 monitoring, and allowed comparison of the effects of grazing between sites and even within the same site. Sites that had been grazed more intensively had a higher proportion of pasture grasses and broadleafs, while those where grazing had recently been removed or reduced had high densities of pasture grasses. Management of grazing timing and intensity was noted to be a possible tool for the management of the process of terrestrialisation seen at many wetlands.

2016 monitoring

In late November 2016, vegetation transects and associated quadrats were monitored at six newly-established sites across five wetlands in the northern half of the study area (Tuck et al. 2017). All but one site (Pitlochry) were dry at the time of monitoring. None of the 2012 sites were repeated; instead, the focus was on wetlands that are expected to receive additional flows subsequent to implementation of SEFRP hydrological works. Detailed transect vegetation data is included as vegetation kite charts in Appendix 10.6.

All sites monitored were dry or almost dry, and all were ringed by *Melaleuca halmaturorum* shrubland at the historic high-water mark. As observed during 2012 monitoring of other sites on the Tilley Watercourse, vegetation transects indicated the continued recruitment of *M. halmaturorum* and other terrestrial species within wetlands, with wetland beds displaying a post-drainage transition toward *M. halmaturorum*-dominated shrubland.

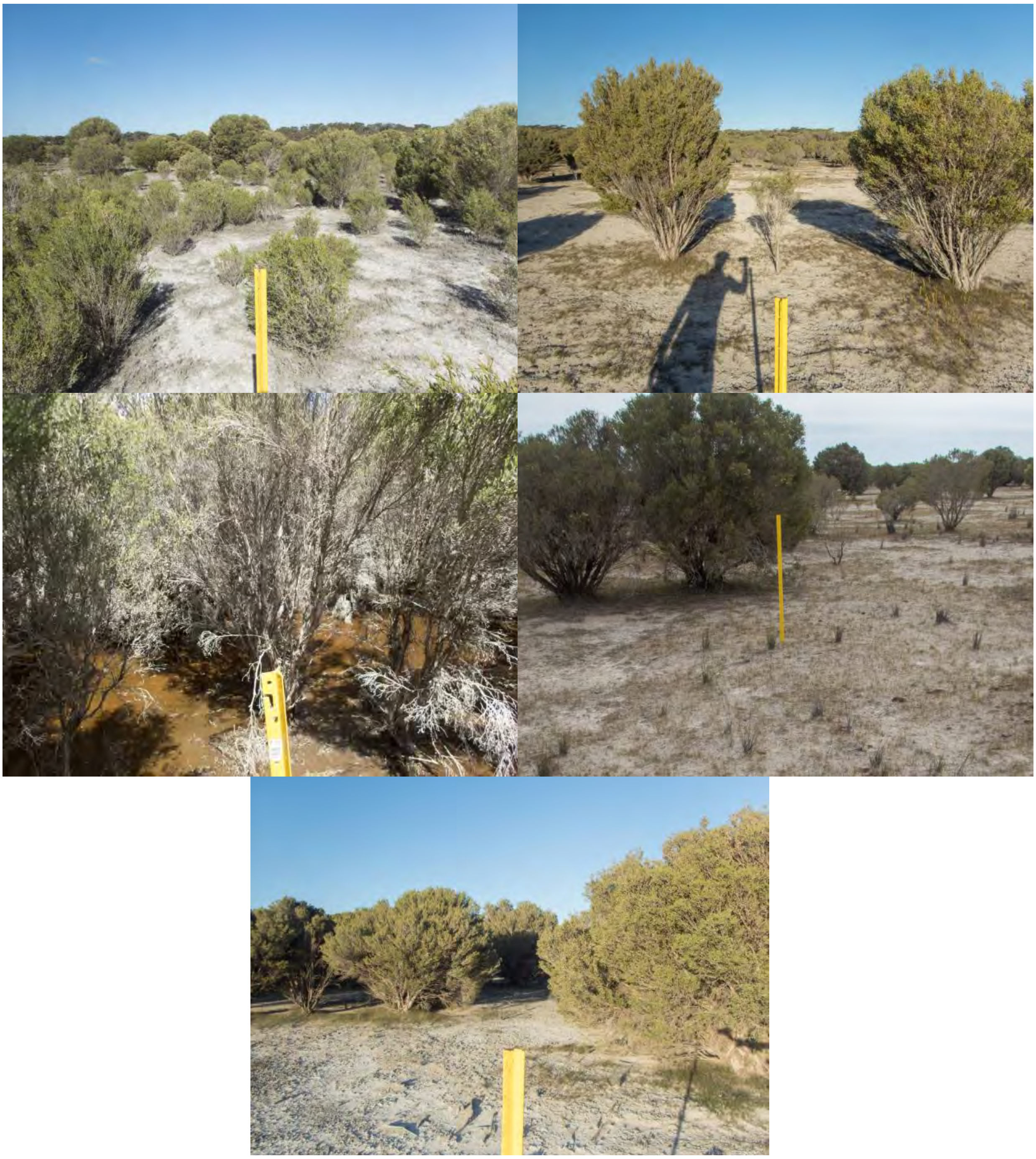


Figure 75 – November 2016 wetland monitoring sites: (from top left) Frostys Swamp east, Frostys Swamp west, Pitlochry, Tilley Swamp Wetlands & Wildlife, Tilley Swamp Brinkworth and Wetlands & WIldlife

Transects were started in terrestrial vegetation adjacent to the wetland and moved down the elevation gradient to the deepest part of the wetland. Two sites – Frostys Swamp and Pitlochry – provided conditions reflective of general trends across the watercourse.

Frostys Swamp

Using site FS1 at Frostys Swamp as a roughly representative example (Figure 76), the transect first moves from terrestrial vegetation (1) into the historic wetland edge (2) dominated by dense 1-3 m *M. halmaturorum* and accompanied by terrestrial shrubs and grasses.

Beyond this initial *M. halmaturorum* stand and further into the wetland, dominant vegetation is sparser and consists largely of scattered *M. halmaturorum* of various age classes (4), often accompanied by *Gahnia filum* and recent recruits of terrestrial species such as *Leucopogon parviflorus* and *Comesperma volubile*. More recent recruitment events (3) are indicated by defined cohorts of younger *M. halmaturorum* from 0.3 to 1m tall. The youngest recruits (<0.3 m tall) are not visible from aerial photography.

At around 100m into the transect, the understorey begins to change from exotic and native grasses and herbs, to brackish to saline native herbland species including *Wilsonia* sp., *Samolus repens* and *Schoenus nitens,* recorded in quadrat monitoring.

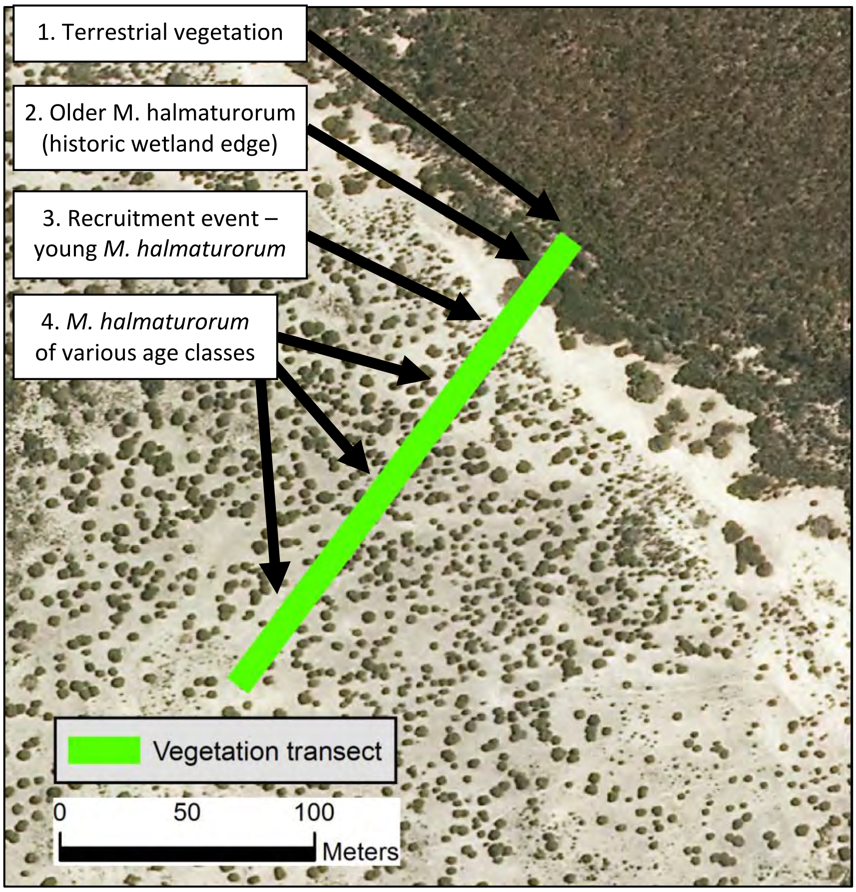


Figure 76 – Frostys Swamp vegetation transect (FS2) – November 2016

Variations of this structural change across the wetland gradient were found across the other 2016 monitoring sites, with dense *Melaleuca halmaturorum* at the historic wetland edge giving way to brackish to saline herbfields or samphire with an emergent overstorey of *M. halmaturorum* that is increasing in density over time.

Pitlochry

While the four northern sites were dry at the time of monitoring and displayed similar vegetation transitions, the Pitlochry site still retained a low level of water. Understorey vegetation was reflective of both intermittent inundation and saline soils, with species including *Sarcocornia quinqueflora*, *Wilsonia humilis*, *Samolus repens* and emergent *Gahnia filum*.

Further along the transect, terrestrialisation was more advanced than at the other sites, with younger *M. halmaturorum* giving way to larger and increasingly dense plants toward the end of the transect. Quadrats were dominated by the *M. halmaturorum* overstorey, and a sparse understorey of *Wilsonia rotundifolia*, *Sarcocornia quinqueflora* and *Gahnia filum*.

Comparison with historic aerial imagery supports the observation of a strong and ongoing terrestrialisation trend within the wetland.

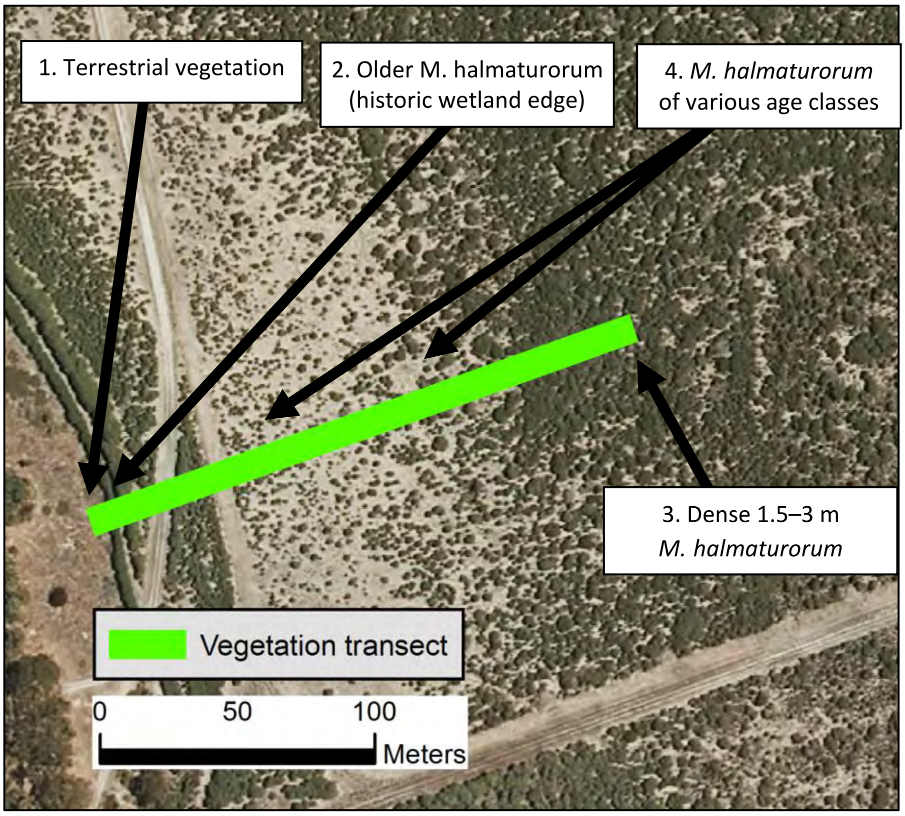


Figure 77 – Pitlochry vegetation transect – November 2016

Figure 78 – Post-fire regeneration at Tilley Swamp Conservation Park in 2018

5.2.3 Other monitoring

5.2.3.1 ***Jacobs pre-clearance monitoring (2015)***

In June 2015, the environmental consultants Jacobs undertook pre-clearance vegetation surveys within the SEFRP alignment, surveying 37 sites using the Bushland Rapid Assessment Technique (BushRAT) developed by the Nature Conservation Society of South Australia (NCSSA) (DEWNR 2013). Most monitoring sites were on the Tilley Swamp watercourse, with five sites around Salt Creek and its interface with the Coorong, three sites on the Taratap watercourse and one site further south, at the Blackford Drain.

Within the monitoring sites, 14 vegetation associations were recorded, aligning to 11 South East benchmark communities (Milne and Croft 2012). *Melaleuca halmaturorum* shrubland was the most frequently recorded association, appearing at 6 of 37 sites, followed by *Allocasuarina verticillata* +/- *Melaleuca lanceolata* open woodland and *Gahnia filum* sedgeland at 5 sites each.

While BushRAT scores are not intended as a quantitative monitoring tool, the assessments still give a general indication of vegetation quality along the SEFRP alignment. The scores from most sites indicated good quality vegetation, with an average BushRAT score of 74 of 100. *Gahnia filum* and *Melaleuca halmaturorum* habitat was generally of high quality, while lower quality vegetation included *Myoporum insulare* shrubland around Salt Creek and *Gahnia trifida* sedgeland on the Taratap watercourse. The lowest scoring site was outside the SEFRP study area at the Blackford Drain, with *Eucalyptus camaldulensis* ssp. *camaldulensis* woodland containing trees in poor condition, with no recruitment noted.

No listed species were recorded at any monitoring sites, other than *Eucalyptus fasciculosa* (SA: rare) which is widespread through the watercourses, but it was noted that the timing of surveys (winter) was unlikely to locate orchids.

5.3. ***Vertebrate fauna monitoring***

Distinct groups of vertebrate fauna (fish, frogs, birds, reptiles and mammals) are summarised separately in the sections below. Several of the recorded species have conservation status at a regional, state, or national level.

5.3.1 Fish

Fish surveys are a relatively recent component of fauna monitoring in the watercourses. Broad studies such as the Biological Survey of Tilley Swamp concentrated mostly on terrestrial fauna, along with easily-observed waterbirds and frogs. The earliest fish records from the area date to 2001, when the Tilley Swamp and Salt Creek drainages were targeted during monitoring as part of the broader South East fish inventory (Hammer 2002). These monitoring locations were incorporated into SEFRP monitoring, and data collected under both projects are summarised in the sections below.

Eight native fish species have been recorded in the Taratap and Tilley Swamp watercourses or near to it (Table 17), with exotic fish species absent to date. Significant species include the threatened native fish Congolli and Southern Pygmy Perch. Details of distributions based on fish sampling are detailed in a summary of SEFRP-initiated fish monitoring below.

A number of drain and creek habitats are connected to the watercourses, and some records of additional species are in close proximity. A population of the Yarra Pygmy Perch persists in Henry Creek, being most recently detected in 2017, while the River Blackfish (*Gadopsis marmoratus*) has not been recorded there since 2002. Dwarf Galaxias (*Galaxiella pusilla*) was previously present at Log Crossing Bridge but has not been recorded during monitoring since 2002. Western Bluespot Goby (*Pseudogobius olorum*) has been recorded in Salt Creek, and is assumed to still be present, with the possibility of expansion into Morella Basin under suitable conditions (Nick Whiterod, pers.comm. 2018).

Table 17 – Native fish species recorded in and around the SEFRP study area

(note: records from additional nearby SEFRP-initiated **fish monitoring** sites included (Henry Creek, Blackford Drain and Big Telowie)

Common Name	Species Name	EPBC	SA Fisheries	2009 Action Plan
Carp Gudgeon	*Hypseleotris* spp.			
Congolli	*Pseudaphritis urvillii*			VU
Flathead Gudgeon	*Philypnodon grandiceps*			
River Blackfish	*Gadopsis marmoratus*		P	EN
Short-finned Eel	*Anguilla australis australis*			RA
Smallmouthed Hardyhead	*Atherinosoma microstoma*			
Western Bluespot Goby	*Pseudogobius olorum*			
Yarra Pygmy Perch	*Nannoperca obscura*	VU	P	CR

CR=Critically Endangered, EN=Endangered, VU=Vulnerable, P=Protected, RA=Rare

5.3.1.1 ***SEFRP-initiated fish monitoring***

SEFRP fish sampling data comprises 14 sites located within and near to the SEFRP alignment. Some sites (i.e. Henry Creek, Blackford Drain) were established in earlier studies and have data dating back approximately 20 years (i.e. Hammer 2002). Additional sites (i.e. Pitlochry, Taratap Brinkworth) have been added more recently with the intent of collecting data relevant to the SEFR project. Sampling sites include wetlands (i.e. Yeulba), drains (i.e. Tilley Swamp Drain) and connected natural creeks (i.e. Henry Creek). Examples of habitat at monitoring sites can be seen in Figures 81 and 82.

Method

All sites were sampled using single-wing fyke nets (3m wing, D entrance, two compartments and 4mm stretch) set overnight across available habitat. All sampled fish were identified to species level (Allen et al. 2002), counted and observed to obtain general biological information (size range, reproductive condition and external disease or parasites). Length-frequency information (as Total Length, TL, mm) was gathered for specific components of catches; namely, more threatened freshwater and diadromous species.

Overall summary

Comparison of fish sampling over the two most recent years, with previous sampling indicates gradual improvement across the SEFRP area (see Table 18). Previously, SEFRP monitoring sites were dominated by the salt-tolerant Smallmouthed Hardyhead, with low numbers of Southern Pygmy Perch (and historically Yarra Pygmy Perch) occurring at Henry Creek and diadromous Congolli at Morella Basin. Fish catches over 2016 and 2017, although still dominated by Smallmouthed Hardyhead, show recent recolonization of Southern Pygmy Perch in the Taratap and Tilley Swamp Watercourses (presumably as a result of sustained inundation and connectivity). The nearby Henry Creek has also seen improvement of populations and persistence of the Yarra Pygmy Perch, although its future viability remains in doubt. The detection of novel regional species (e.g. Short-finned Eel at Blackford Drain) further emphasises the benefits of greater flows.

Site-based observations

Little change across years has been observed at ***Morella Basin***, with two species, the diadromous Congolli and Small Mouthed Hardyhead, recorded during surveys in 2012, 2016 and 2017. These two species are well adapted to the saline conditions of this northern site.

Prior to SEFRP surveys, very few fish had been previously caught in the ***Tilley Swamp Watercourse***, and the only species to be detected during surveys in 2002 at Keith-Cantara Rd and Tilley Swamp CP was the Smallmouthed Hardyhead. In spring 2016, two additional species – Flathead Gudgeon and Southern Pygmy Perch – were detected across the watercourse, with the latter occurring across three of the four sites. Pitlochry was the only site where no fish were detected, owing to the limited aquatic habitat at the site in spring 2016.

Table 18 – Comparison of fish catch recorded during previous surveys (various years) and more recent sampling in spring 2016 and spring 2017. Previous surveys in 2012 and 2014 use comparable fyke netting, while all other previous surveys employed dip netting.

			Previous survey								Spring 2016							Spring 2017						
				FW				DI		ST	FW				DI		ST	FW				DI		ST
	Waterway	**Location**	Year previously sampled	Carp Gudgeon	Flathead Gudgeon	Southern Pygmy Perch	Yarra Pygmy Perch	Congolli	Short-finned Eel	Smallmouthed Hardyhead	Carp Gudgeon	Flathead Gudgeon	Southern Pygmy Perch	Yarra Pygmy Perch	Congolli	Short-finned Eel	Smallmouthed Hardyhead	Carp Gudgeon	Flathead Gudgeon	Southern Pygmy Perch	Yarra Pygmy Perch	Congolli	Short-finned Eel	Smallmouthed Hardyhead
SEFRP study area	Morella Basin	Upstream outlet weir	2012					28		1146					4		412					2		1741
	Tilley Swamp Drain	DS confluence north outlet	-										17				208		1			2		154
	Tilley Swamp	Pitlochry	-																	152				5994
	Tilley Swamp Drain	Keith-Cantara Rd	2002							100			2				1			3		5		69
	Tilley Swamp	Tilley Swamp CP	2002									21	5				459			44				
	Taratap Swamp	Brinkworth property	-																	26				
	Taratap Swamp	Englands property	2008																	3				
	Taratap Swamp	Unnamed Englands	2012														2			57				2
	Taratap Swamp	Yeulba property	-																	2				
Nearby	Big Telowie	Off rock island	2012		3	8				200			13				1			404				339
	Henry Creek	Pool A	2014	2	1	1342				124		27	39	3			1	2	6	108	3			4
	Henry Creek	Pool B	2014	143	103	366	4			69		22	35	4			16	15	29	395	12			3
	Henry Creek	Pool C	2012		2	24					4	49	259	5	3		168		7	466	1			21
	Blackford Drain	Rowney Rd West	2014							3679						2	35							133
										Sub Total	**4**	**119**	**370**	**12**	**7**	**2**	**1303**	**17**	**43**	**1660**	**16**	**9**		**8460**
										TOTAL	**1,817 fish (7 species)**							**10,205 fish (6 species)**						

Fish abundance and species distributions increased in spring 2017, presumably owing to the sustained inundation and connectivity throughout the region's watercourses. Fish were recorded across all four sites and Congolli were detected for the first time, occurring at the two drain sites. Increased numbers of Smallmouthed Hardyhead and Southern Pygmy Perch were also recorded, with the latter species being mainly represented by juveniles (Figure 79).

The ***Taratap Watercourse*** has undergone considerable change across the survey years. Previous monitoring efforts in 2008 at the Englands site and 2012, at the Unnamed Englands site recorded no fish, while surveys in spring 2016 recorded just two Smallmouthed Hardyhead at Unnamed Englands. In spring 2017 however, Southern Pygmy Perch were relatively abundant and occurred across all four monitoring sites, and the Smallmouthed Hardyhead remained present in small numbers. Length frequency distributions for Southern Pygmy Perch show the species was represented exclusively by new recruits (Figure 79). The recolonisation of these sites emphasises the benefits of inundation of wetlands across this section of the SEFRP flowpath.

Outside of the immediate SEFRP study area, the permanent pools at ***Henry Creek*** represent key habitat for numerous native fish species, including the threatened Yarra Pygmy Perch. Historically, the species has shown a declining trend at Henry Creek, which continued in 2012 when no Yarra Pygmy Perch were detected (data not shown). Slight improvements were seen in 2014 surveys, when four individuals were detected in one of the pools. Monitoring in the two most recent years has indicated the species is still persisting, albeit in low numbers. While the species was mainly represented by older fish in 2016 (Figure 80), most recent sampling detected a greater proportion of 1+ and 2+ fish which is encouraging. While numbers of Yarra Pygmy Perch were similarly low in 2016 and 2017, Southern Pygmy Perch were far more abundant at each of the three pools in spring 2017. The high representation of juveniles (i.e. <30 mm total length; Figure 1), indicated recent successful spawning and recruitment. At Big Telowie, few fish were recorded in spring 2016, but following inundation, numbers of both Southern Pygmy Perch and Smallmouthed Hardyhead were greatly higher in spring 2017. Given the high presence of juveniles, the shallow vegetated aquatic habitat at Big Telowie presumably provides ideal substrate for native fish spawning.

Previous surveys of ***Blackford Drain*** in 2014 detected high numbers of a single species, the Smallmouthed Hardyhead. This was also true for earlier (2001, 2002) surveys at the site (data not shown). Across the two most recent sampling years, Smallmouthed Hardyhead were only recorded in low numbers, presumably due to high flows in the drain creating unfavourable conditions for this salt-tolerant species. Yet, the high flows likely facilitated the migration upstream of Short-finned Eel to the site, with two individuals detected in spring 2016. These records are significant as South Australia represents the western extent of the species range.

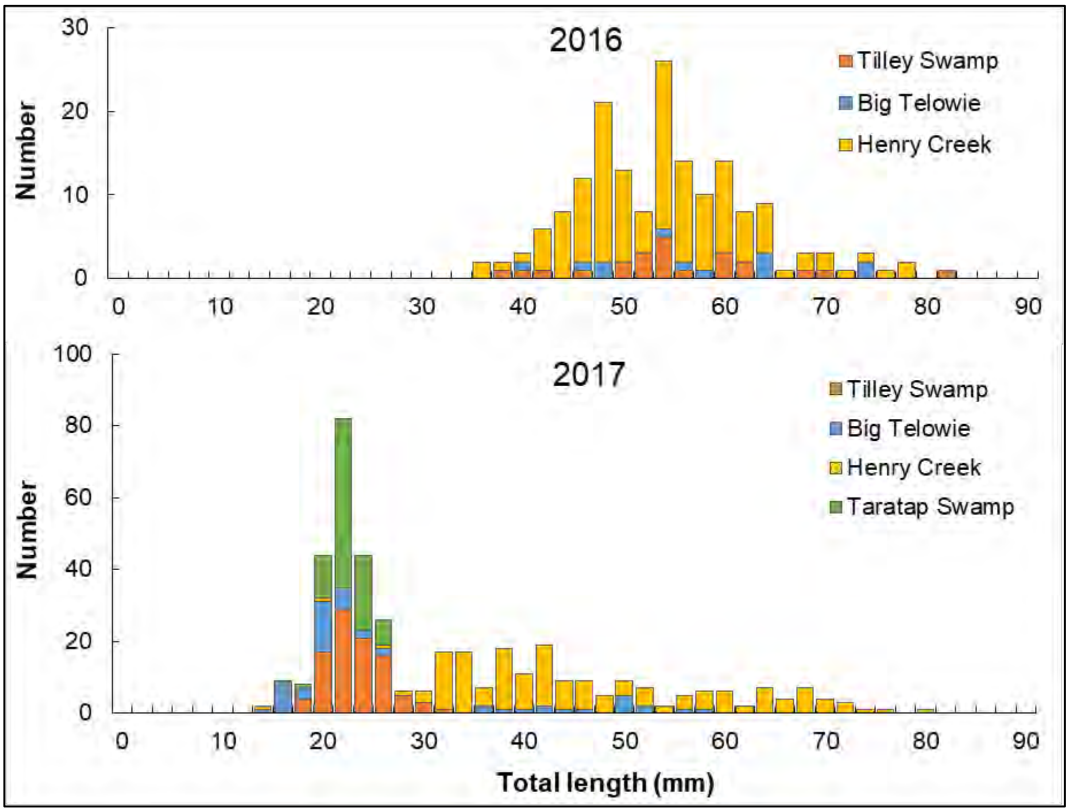


Figure 79 – Length frequency distributions for Southern Pygmy Perch

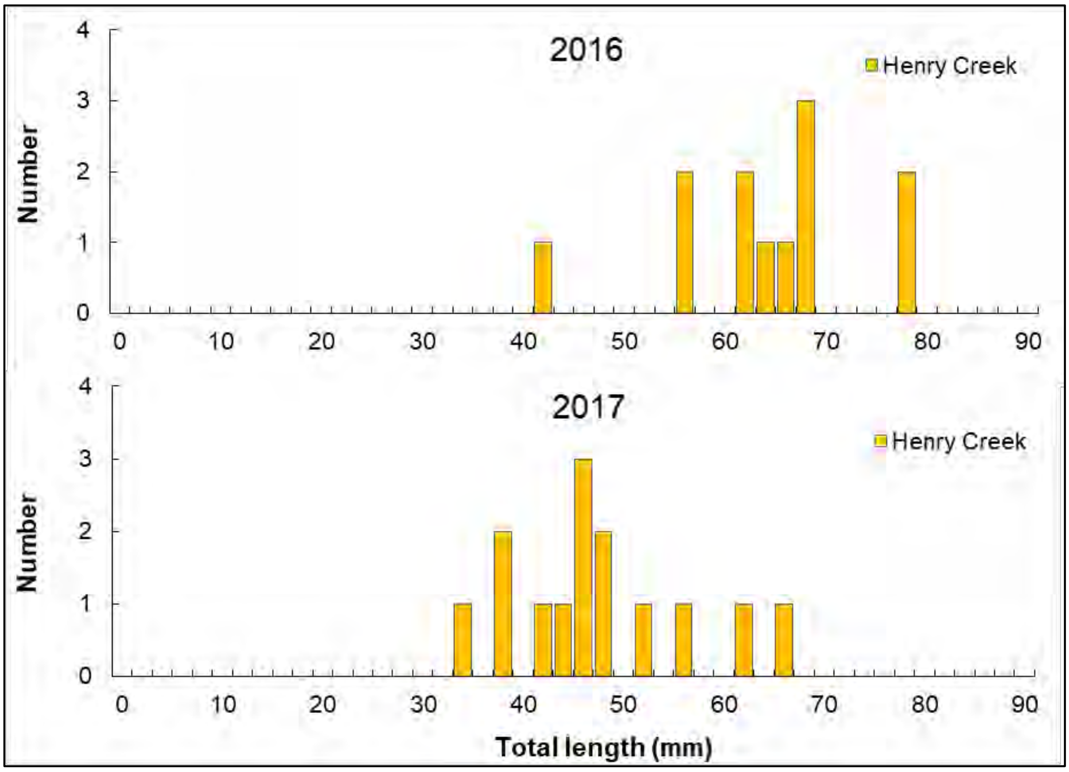


Figure 80 – Length frequency distributions for Yarra Pygmy Perch

Figure 81 – 2016 fish sampling sites (clockwise from top left): Morella Basin, Tilley Swamp Drain - DS confluence, Tilley Swamp Drain – Keith-Cantara Rd, Tilley Swamp CP (drain), Tilley Swamp - Pitlochry, Big Telowie. Photos by Lauren Veale.

Figure 82 – 2016 fish sampling sites (from top left): Henry Creek – Pool C, Henry Creek – Pool A, Taratap – Chris England, Taratap - Unnamed Englands, Taratap – Yeulba, Blackfords Drain. Photos by Lauren Veale.

Figure 83 – Smallmouth hardyhead, flathead gudgeon, congolli, shortfinned eel, and Yarra pygmy perch and southern pygmy perch in breeding condition. Photos by Lauren Veale.

5.3.2 Frogs

Seven frog species – all native – have been recorded in or near to the SEFRP study area (Table 19). Most records are located in and around the northern half of the Taratap and Tilley Swamp Watercourse, and particularly around Tilley Swamp CP, Martin Washpool CP and the heritage agreements to its immediate south, where survey effort has been higher than in other areas of the watercourses.

Targeted frog monitoring is a recent occurrence in the SEFRP study area, and prior to the Biological Survey of Tilley Swamp (Stewart et al. 1998) only one frog species had been recorded in the SEFRP study area: Brown Tree Frog in the south of Tilley Swamp in 1987. Three additional frog species were recorded in the Biological Survey, and other than the very limited records from the recent SEFRP-initiated monitoring, most other recent records are opportunistic. A number of additional frog species have been recorded nearby (Spotted Marsh Frog, Brown Toadlet and Marbled Toadlet), indicating their possible presence in the study area.

Table 19 – Frog species recorded in the SEFRP study area (+ 3 km)

Species	Common name	EPBC	NPWSA
Crinia signifera	Common Froglet		
Limnodynastes dumerilii	Banjo Frog		
Limnodynastes tasmaniensis	Spotted Marsh Frog		
Litoria ewingii	Brown Tree Frog		
Neobatrachus pictus	Burrowing Frog		
Pseudophryne bibronii	Brown Toadlet		RA
Pseudophryne semimarmorata	Marbled Toadlet		VU

VU=Vulnerable, RA=Rare

5.3.2.1 *SEFRP-initiated frog monitoring*

Targeted frog monitoring has been undertaken in the Taratap and Tilley Swamp Watercourses in January 2012 (one site), October-December 2012 (nine sites) and November-December 2016 (16 sites).

Monitoring was undertaken at a selection of SEFRP fish monitoring sites and/or at vegetation transect locations where fish surveys were not required. Location within a wetland was determined using the presence of suitable aquatic and riparian habitat, and call playback was used to stimulate a calling response, recorded as close as possible to dusk over a 25 minute period.

Table 20 – Summary of SEFRP-initiated frog monitoring 2012-16

Location (listed north to south)	Wetland ID	Jan 2012	Oct-Nov 2012	Nov-Dec 2016
Taratap Stewart	S0101573	Not surveyed	Wet - no frogs	Wet - no frogs
Taratap England	S0111143	Not surveyed	Wet - no frogs (1 *N. pictus* and 33 tadpoles during fish sampling)	Wet - no frogs
Taratap Unnamed	S0111150	Not surveyed	Wet - no frogs	Wet - no frogs
Taratap Marwood	S0111150	Not surveyed	Wet - no frogs	Dry – no frogs
Taratap Marwood-England	S0111150	Not surveyed	Wet - no frogs	Wet - no frogs
Taratap Brinkworth	S0111150	Not surveyed	Not surveyed	Wet - no frogs
Tilley Swamp CP 1	S0100146	Not surveyed	Wet - no frogs	Wet - no frogs
Tilley Swamp CP 2	S0100146	Not surveyed	Wet - no frogs	Wet - no frogs
Morella Basin	S0100038	Wet – no frogs	Not surveyed	Wet - no frogs
Wetlands & Wildlife (Brinkworth)	S0101265	Not surveyed	Not surveyed	Dry – no frogs
Wetlands & Wildlife (Brinkworth)	S0104731	Not surveyed	Not surveyed	Dry – no frogs
Pitlochry	S0100075	Not surveyed	Not surveyed	Dry – no frogs
Frostys Swamp 1	S0100054	Not surveyed	Not surveyed	Wet - no frogs
Frostys Swamp 2	S0100054	Not surveyed	Not surveyed	Wet - no frogs
Yeulba 1	S0100236	Not surveyed	Dry – no frogs	Wet - no frogs
Yeulba 2	S0100227	Not surveyed	Dry – no frogs	Wet - no frogs

Frog status

No frogs have been recorded in SEFRP-initiated monitoring in the study area, despite the presence of apparently-suitable habitat. Outside of the regular frog monitoring period, opportunistic records include one Painted Frog (*Neobatrachus pictus*) and 33 tadpoles at Taratap England during fish sampling in 2012; Eastern Banjo Frog and Common Froglet were heard calling at the same site in winter 2012, and brown tree frog have also been recorded on the Taratap Watercourse (Mark De Jong, pers. comm. 2018).

The lack of frog records during monitoring may signal unsuitable aquatic conditions for particular frog species within the Taratap and Tilley Swamp Watercourses late in the year. In Oct-Nov 2012 – the last time water parameters were measured as part of the monitoring – salinities ranged from 6200 to 7800 µS/cm, which may be too high for the freshwater frogs common to the region. Perhaps influenced by this, the Southern Bell Frog (EPBC – vulnerable) has been recorded nearby in the Bakers Range and West Avenue Watercourses, but not in the Taratap or Tilley Swamp Watercourses.

Some of the ground-dwelling frogs also tend to call earlier in the season in response to rainfall and may be missed when monitoring frogs later in the year (Tuck et al. 2017). There may be issues with conducting frog surveys in diverse habitats during a short monitoring period, which increases the likelihood that conditions may be less favourable at some sites or for some species (Dickson et al. 2013). Records collected opportunistically outside of the regular monitoring period should be considered when assessing frog populations.

5.3.3 Birds

The range of habitats in the Taratap and Tilley Swamp Watercourses support a variety of woodland, wetland and shore-dwelling bird species (Table 21). The watercourses are an inland resource for migratory shorebirds and an important breeding ground for waterbirds in the Upper South East, with wetland habitats providing feeding areas and shelter for nesting (Jaensch and Auricht 1989). The area also represents a vital stopover for woodland birds moving between the Lower South East and the Mount Lofty Ranges (Stewart et al. 1998).

Birds are relatively well-represented in historical records than other classes of fauna, with numerous records from the Salt Creek and Tilley Swamp area from the 1930s onward. Prior to the first aerial imagery in 1954, vegetation was largely intact in the Salt Creek and Tilley Swamp region, offering large areas of interconnected habitats. While access to some parts of the Tilley Swamp Watercourse proved difficult, early searches of the Salt Creek district at the top of the SEFRP study area recorded a number of now threatened or rarely seen species, including Grey-crowned Babbler (*Pomatostomus temporalis*), Malleefowl (*Leipoa ocellata*), Fairy Tern (*Sternula nereis*), Hooded Plover (*Charadrius cucullatus*) and Hooded Robin (*Melanodryas cucullata*) (Sutton 1930, Hanks 1930).

Several important data sources exist from the 1980s. A survey of Tilley Swamp during the flood year of 1981 confirmed its importance to waterbirds during such conditions, recording 2750 birds of 19 species, of which five were breeding (Jaensch and Auricht 1989). Bird species were also recorded as part of the native vegetation assessments of Heritage Agreements on Safari Park and Tilley Swamp Conservation Park in 1986 and 1987 respectively.

More recently, the Biological Survey of Tilley Swamp (Stewart et al. 1998) and the SEFRP-initiated waterbird monitoring of 2012-2017, have added to the picture of diverse but depleted avifauna. Stewart recorded 107 species, including one nationally vulnerable species (Malleefowl - *Leipoa ocellata*), and numerous others with state or regional conservation ratings, including Blue-winged Parrot (*Neophema chrysostoma*), Latham's Snipe (*Gallinago hardwickii*), Painted Button-quail (*Turnix varia*) and the Yellow-tailed Black-Cockatoo (*Calyptorhynchus funereus*).

In other studies taking in the SEFRP study area, 52 species were recorded on Taratap Flat in October 2004 (Bachmann et al. 2005), while a study at Morella Basin found birds using revegetation areas at approximately five years since planting, recording 48 species (45 native) across four 2 ha plots (Mercer and Griffin 2009). Surveys by Jacobs along the proposed SEFRP alignment in 2015 also recorded 77 species, including Malleefowl.

Multi-year waterbird monitoring was conducted at Morella Basin as part of the Flora and Fauna monitoring program for the Tilley Swamp Drain from 2000-2002 (Telfer et al. 2000, Milne and Squire 2001, Donohoue et al. 2003). Quarterly waterbird counts were also conducted at Morella Basin from

2001–2008 as part of USE Program monitoring, and another count was undertaken of Morella and Taratap in 2009 by PIRSA Rural solutions. Waterbird counts have also been conducted at Morella Basin as part of Australian Wader Studies Group (AWSG) wader surveys at the Coorong and South East coastal lakes, now administered by BirdLife Australia, with annual counts occurring each summer, with additional winter counts scheduled for at least 2019-23 (Dan Weller, pers. comm. 2019).

SEFRP-initiated waterbird monitoring has taken in a number of repeat sites within the SEFR study area from 2012-2017, discussed in more detail in section 5.3.3.1.

Table 21 – Bird species recorded in the SEFRP study area (+ 3 km)

Species	**Common name**	**EPBC**	**NPWSA**
Acanthagenys rufogularis	Spiny-Cheeked Honeyeater		
Acanthiza apicalis	Inland Thornbill		
Acanthiza chrysorrhoa	Yellow-rumped Thornbill		
Acanthiza iredalei	Slender-billed Thornbill	ssp	ssp
Acanthiza lineata	Striated Thornbill		
Acanthiza iredalei hedleyi	Slender-Billed Thornbill		
Acanthiza lineata clelandi	Striated Thornbill (MLR, SE)		
Acanthiza nana	Yellow Thornbill		
Acanthiza pusilla	Brown Thornbill		
Acanthiza reguloides	Buff-rumped Thornbill		
Acanthorhynchus tenuirostris	Eastern Spinebill		
Accipiter cirrocephalus	Collared Sparrowhawk		
Accipiter fasciatus	Brown Goshawk		
Acridotheres tristis	Common Myna		
Acrocephalus australis	Australian Reed-Warbler		
Acrocephalus stentoreus	Clamorous Reed-Warbler		
Actitis hypoleucos	Common Sandpiper		R
Aegotheles cristatus	Australian Owlet-nightjar		
Alauda arvensis	Eurasian Skylark		
Anas castanea	Chestnut Teal		
Anas gracilis	Grey Teal		
Anas platyrhynchos	Mallard Duck		
Anas rhynchotis	Australasian Shoveler		R
Anas superciliosa	Pacific Black Duck		
Anhinga novaehollandiae	Australasian Darter		R
Anthochaera lunulata	Western Wattlebird		
Anthochaera carunculata	Red Wattlebird		
Anthochaera chrysoptera	Little Wattlebird		
Anthus novaeseelandiae	Australian Pipit		
Anthus richardi	Richard's Pipit		
Aphelocephala leucopsis	Southern Whiteface		
Aphrodroma brevirostris	Kerguelen Petrel		
Apus pacificus	Fork-Tailed Swift		
Aquila audax	Wedge-tailed Eagle		
Ardea ibis	Cattle Egret		R
Ardea alba	Common Egret		
Ardea alba modesta	Great Egret		
Ardea intermedia	Intermediate Egret		R

Species	Common name	EPBC	NPWSA
Ardea pacifica	White-necked Heron		
Ardenna carneipes	Flesh-Footed Shearwater		R
Ardenna tenuirostris	Short-tailed Shearwater		
Ardeotis australis	Australian Bustard		V
Arenaria interpres	Ruddy Turnstone		R
Artamus personatus	Masked Woodswallow		
Artamus cyanopterus	Dusky Woodswallow		
Artamus superciliosus	White-browed Woodswallow		
Aythya australis	Hardhead		
Barnardius zonarius	Australian Ringneck		
Biziura lobata	Musk Duck		R
Bubulcus ibis coromandus	Eastern Cattle Egret		
Cacatua galerita	Sulphur-Crested Cockatoo		
Cacatua sanguinea	Little Corella		
Cacatua tenuirostris	Long-Billed Corella		
Cacomantis flabelliformis	Fan-Tailed Cuckoo		
Cacomantis pallidus	Pallid Cuckoo		
Calamanthus fuliginosus	Striated Fieldwren		
Calamanthus campestris	Rufous Fieldwren		
Calidris acuminata	Sharp-tailed Sandpiper		
Calidris canutus	Red Knot		
Calidris ferruginea	Curlew Sandpiper		
Calidris ruficollis	Red-necked Stint		
Caligavis chrysops	Yellow-faced Honeyeater		
Calyptorhynchus funereus	Yellow-tailed Black Cockatoo		V
Carduelis carduelis	European Goldfinch		
Cereopsis novaehollandiae	Cape Barren Goose		R
Chalcites basalis	Horsfield's Bronze Cuckoo		
Chalcites lucidus	Shining Bronze Cuckoo		
Charadrius bicinctus	Banded Dotterel		
Charadrius ruficapillus	Red-Capped Dotterel		
Charadrius bicinctus	Double-banded Plover		
Charadrius ruficapillus	Red-capped Plover		
Chenonetta jubata	Australian Wood Duck		
Chenonetta jubata	Maned Duck		
Cheramoeca leucosterna	White-Backed Swallow		
Chlidonias hybrida	Whiskered Tern		
Chlidonias leucopterus	White-winged Tern		
Chroicocephalus novaehollandiae	Silver Gull		
Chalcites osculans	Black-Eared Cuckoo		
Cincloramphus mathewsi	Rufous Songlark		
Circus approximans	Swamp Harrier		
Circus assimilis	Spotted Harrier		
Cladorhynchus leucocephalus	Banded Stilt		V
Climacteris picumnus	Brown Treecreeper		
Colluricincla harmonica	Grey Shrikethrush		
Columba livia	Feral Pigeon		
Coracina novaehollandiae	Black-faced Cuckooshrike		

Species	Common name	EPBC	NPWSA
Coracina papuensis	White-bellied Cuckooshrike		R
Corcorax melanorhamphos	White-Winged Chough		R
Cormobates leucophaea	White-Throated Treecreeper		
Corvus coronoides	Australian Raven		
Corvus mellori	Little Raven		
Corvus tasmanicus	Forest Raven		
Coturnix ypsilophora	Brown Quail		V
Coturnix pectoralis	Stubble Quail		
Cracticus tibicen	Australian Magpie		
Cracticus tibicen telonocua	White-backed Magpie		
Cracticus torquatus	Grey Butcherbird		
Cygnus atratus	Black Swan		
Dacelo novaeguineae	Laughing Kookaburra		
Daphoenositta chrysoptera	Varied Sittella		
Dasyornis broadbenti	Rufous Bristlebird		R
Dicaeum hirundinaceum	Mistletoebird		
Diomedea exulans	Wandering Albatross	ssp	V
Dromaius novaehollandiae	Emu		
Drymodes brunneopygia	Southern Scrub Robin		
Egretta garzetta	Little Egret		R
Egretta novaehollandiae	White-Faced Heron		
Elanus axillaris	Black-Shouldered Kite		
Elseyornis melanops	Black-Fronted Dotterel		
Eolophus roseicapillus	Galah		
Eopsaltria australis	Eastern Yellow Robin		
Epthianura albifrons	White-fronted Chat		
Erythrogonys cinctus	Red-kneed Dotterel		
Eurostopodus argus	Spotted Nightjar		
Excalfactoria chinensis	King Quail		E
Falco berigora	Brown Falcon		
Falco cenchroides	Nankeen Kestrel		
Falco longipennis	Australian Hobby		
Falco peregrinus	Peregrine Falcon		R
Falco subniger	Black Falcon		
Fulica atra	Eurasian Coot		
Fulmarus glacialoides	Southern Fulmar		
Gallinago hardwickii	Latham's Snipe		R
Gallinula tenebrosa	Dusky Moorhen		
Gallirallus philippensis mellori	Buff-banded Rail		
Lichenostomus virescens	Singing Honeyeater		
Gelochelidon nilotica	Gull-Billed Tern		
Geopelia cuneata	Diamond Dove		
Geopelia placida	Peaceful Dove		
Glyciphila melanops	Tawny-Crowned Honeyeater		
Glossopsitta concinna	Musk Lorikeet		
Glossopsitta porphyrocephala	Purple-crowned Lorikeet		
Grallina cyanoleuca	Australian Magpie-lark		
Haliaeetus leucogaster	White-bellied Sea Eagle		E

Species	Common name	EPBC	NPWSA
Haliastur sphenurus	Whistling Kite		
Hieraaetus morphnoides	Little Eagle		
Himantopus himantopus	Black-winged Stilt		
Himantopus leucocephalus	White-headed Stilt		
Hirundapus caudacutus	White-throated Needletail		
Hirundo neoxena	Welcome Swallow		
Hydroprogne caspia	Caspian Tern		
Hylacola cauta	Shy Heathwren		
Lalage tricolor	White-winged Triller		
Larus pacificus	Pacific Gull		
Leipoa ocellata	Malleefowl	VU	VU
Lichenostomus cratitius	Purple-Gaped Honeyeater		ssp
Limicola falcinellus	Broad-Billed Sandpiper		
Malacorhynchus membranaceus	Pink-Eared Duck		
Malurus cyaneus	Superb Fairywren		
Malurus cyaneus leggei	Superb Fairywren		
Malurus cyaneus cyanochlamys	Superb Fairywren		
Malurus lamberti	Variegated Fairywren		
Manorina melanocephala	Noisy Miner		
Megalurus cruralis	Brown Songlark		
Megalurus gramineus	Little Grassbird		
Megalurus timoriensis	Tawny Grassbird		
Melanodryas cucullata	Hooded Robin		ssp
Melithreptus brevirostris	Brown-headed Honeyeater		
Melithreptus gularis	Black-chinned Honeyeater		ssp
Melopsittacus undulatus	Budgerigar		
Microcarbo melanoleucos	Little Pied Cormorant		
Microeca fascinans	Jacky Winter		ssp
Milvus migrans	Black Kite		
Mirafra javanica	Horsfield's Bush Lark		
Myiagra inquieta	Restless Flycatcher		R
Neochmia temporalis	Red-browed Finch		
Neophema chrysogaster	Orange-bellied Parrot	CR	E
Neophema chrysostoma	Blue-winged Parrot		V
Neophema elegans	Elegant Parrot		R
Neophema petrophila	Rock Parrot		R
Lichenostomus leucotis	White-Eared Honeyeater		
Nycticorax caledonicus	Nankeen Night-Heron		
Nymphicus hollandicus	Cockatiel		
Ocyphaps lophotes	Crested Pigeon		
Oreoica gutturalis	Crested Bellbird		
Oxyura australis	Blue-Billed Duck		R
Pachycephala pectoralis	Golden Whistler		
Pachycephala rufiventris	Rufous Whistler		
Pachyptila desolata	Antarctic Prion		
Pachyptila turtur	Fairy Prion		
Pardalotus punctatus	Spotted Pardalote		
Pardalotus striatus	Striated Pardalote		

Species	Common name	EPBC	NPWSA
Passer domesticus	House Sparrow		
Pelecanoides urinatrix	Common Diving Petrel		
Pelecanus conspicillatus	Australian Pelican		
Petrochelidon ariel	Fairy Martin		
Petrochelidon nigricans	Tree Martin		
Petroica boodang	Scarlet Robin		ssp
Petroica goodenovii	Red-capped Robin		
Petroica phoenicea	Flame Robin		V
Petroica rosea	Rose Robin		
Phalacrocorax carbo	Great Cormorant		
Phalacrocorax sulcirostris	Little black Cormorant		
Phalacrocorax varius	Great Pied Cormorant		
Phaps chalcoptera	Common Bronzewing		
Phaps elegans	Brush Bronzewing		
Phylidonyris novaehollandiae	New Holland honeyeater		
Platalea flavipes	Yellow-billed Spoonbill		
Platalea regia	Royal Spoonbill		
Platycercus elegans	Crimson Rosella		
Platycercus eximius	Eastern Rosella		
Plectorhyncha lanceolata	Striped Honeyeater		R
Plegadis falcinellus	Glossy Ibis		R
Pluvialis apricaria	European Golden Plover		
Pluvialis squatarola	Grey Plover		
Podargus strigoides	Tawny Frogmouth		
Podiceps cristatus	Great Crested Grebe		R
Poliocephalus poliocephalus	Hoary-Headed Grebe		
Pomatostomus superciliosus	White-browed Babbler		
Porzana fluminea	Australian Spotted Crake		
Porzana pusilla	Baillon's Crake		
Porzana tabuensis	Spotless Crake		R
Psephotus haematonotus	Red-rumped Parrot		
Pterodroma mollis	Soft-Plumaged Petrel	VU	
Lichenostomus fuscus	Fuscous Honeyeater		
Lichenostomus ornatus	Yellow-Plumed Honeyeater		
Lichenostomus penicillatus	White-Plumed Honeyeater		
Puffinus gavia	Fluttering Shearwater		
Purnella albifrons	White-Fronted Honeyeater		
Recurvirostra novaehollandiae	Red-necked Avocet		
Rhipidura albiscapa	Grey Fantail		
Rhipidura leucophrys	Willie Wagtail		
Sericornis frontalis	White-browed Scrubwren		
Smicrornis brevirostris	Weebill		
Spilopelia chinensis	Spotted Dove		
Stagonopleura bella	Beautiful Firetail		R
Stagonopleura bella interposita	Beautiful Firetail (SE)		
Stagonopleura guttata	Diamond Firetail		V
Stercorarius antarcticus	Brown Skua		
Sternula albifrons	Little Tern		E

Species	Common name	EPBC	NPWSA
Sternula nereis	Fairy Tern		E
Stictonetta naevosa	Freckled Duck		V
Stipiturus malachurus	Southern Emu-Wren		
Stipiturus malachurus polionotum	Southern Emu-wren (South East)		R
Strepera graculina	Pied Currawong		ssp
Strepera versicolor	Grey currawong		ssp
Strepera versicolor melanoptera	Black-winged Currawong (SE, MLR, MM)		
Sturnus vulgaris	Common starling		
Tachybaptus novaehollandiae	Australasian Grebe		
Tadorna tadornoides	Australian Shelduck		
Thalassarche chlororhynchos	Yellow-Nosed Albatross		ssp
Thalassarche chrysostoma	Grey-Headed Albatross	VU	V
Thalassarche melanophris	Black-Browed Albatross	VU	V
Thalasseus bergii	Greater Crested Tern		
Thinornis rubricollis	Hooded Plover	VU	V
Threskiornis molucca	Australian White Ibis		
Threskiornis spinicollis	Straw-Necked Ibis		
Todiramphus sanctus	Sacred Kingfisher		
Tribonyx ventralis	Black-Tailed Native-Hen		
Trichoglossus haematodus	Rainbow Lorikeet		
Tringa glareola	Wood Sandpiper		R
Tringa nebularia	Common Greenshank		
Tringa stagnatilis	Marsh Sandpiper		
Turdus merula	Common Blackbird		
Turnix varius	Painted Buttonquail		R
Turnix velox	Little Buttonquail		
Tyto javanica	Eastern Barn Owl		
Tyto delicatula	Eastern Barn Owl		
Vanellus miles	Masked Lapwing		
Vanellus tricolor	Banded Lapwing		
Xenus cinereus	Terek Sandpiper		R
Zosterops lateralis	Silvereye		

5.3.3.1 *SEFRP-initiated waterbird monitoring*

Waterbirds were first included in SEFRP monitoring in late 2012 (Dickson, Whiterod et al. 2013), with further rounds of monitoring in late 2016 and late 2017 (Tuck et al. 2017, Whiterod et al. 2018).

Monitoring focussed on wetland habitats through the Taratap and Tilley Swamp Watercourses, and surveys were mostly conducted in the same wetlands as those for fish, frogs and vegetation. Monitoring assessed the total open water area of smaller (<100ha) wetlands, and most of the open area of the larger (>100ha) wetlands from accessible vantage points. Details recorded included species found, numbers and any evidence of breeding, and the inundation state of each wetland (dry, below capacity, at capacity, flooded).

Results

Most wetlands on the Taratap Watercourse held water at the time of monitoring and supported waterbird populations in all years (see Table 22 and Figure 84). In contrast, the wetlands of the Tilley Swamp Watercourse were mostly dry, with the exception of Morella Basin. Waterbird records were concentrated within these inundated wetlands on the Taratap Watercourse and Morella Basin. Large fluctuations in total abundance were recorded across monitoring years: 2017 had the highest total bird numbers (25,760), which may reflect improving conditions in SEFRP wetlands due to increased flows (noting that 2012 monitoring included less sites than 2016 and 2017 monitoring).

In 2016, despite above-average rainfall leading to greater depth and duration of inundation in wetlands, waterbird numbers were markedly lower (6,782) – an observation which could be attributed to above-average rainfall over northern and eastern Australia (Figure 85) attracting most waterbirds away from the region at the time (Tuck et al. 2017).

It is noted that waterbird surveys occurred later in the year on some occasions, when wetland water levels were low and increasing in salinity, and would have influenced waterbird presence and abundance.

Table 22 – Summary of Taratap and Tilley Swamp waterbird survey data from 2012-2017

Year	Sites monitored	Wetland water level			Total birds	No. of species	Species breeding
		< capacity	at capacity	flooded			
2012	5	5			14,992	32	2
2016	12	2	3	2	6,782	22	5
2017	8	2	6		25,761	25	2
				Total	47,535	41	

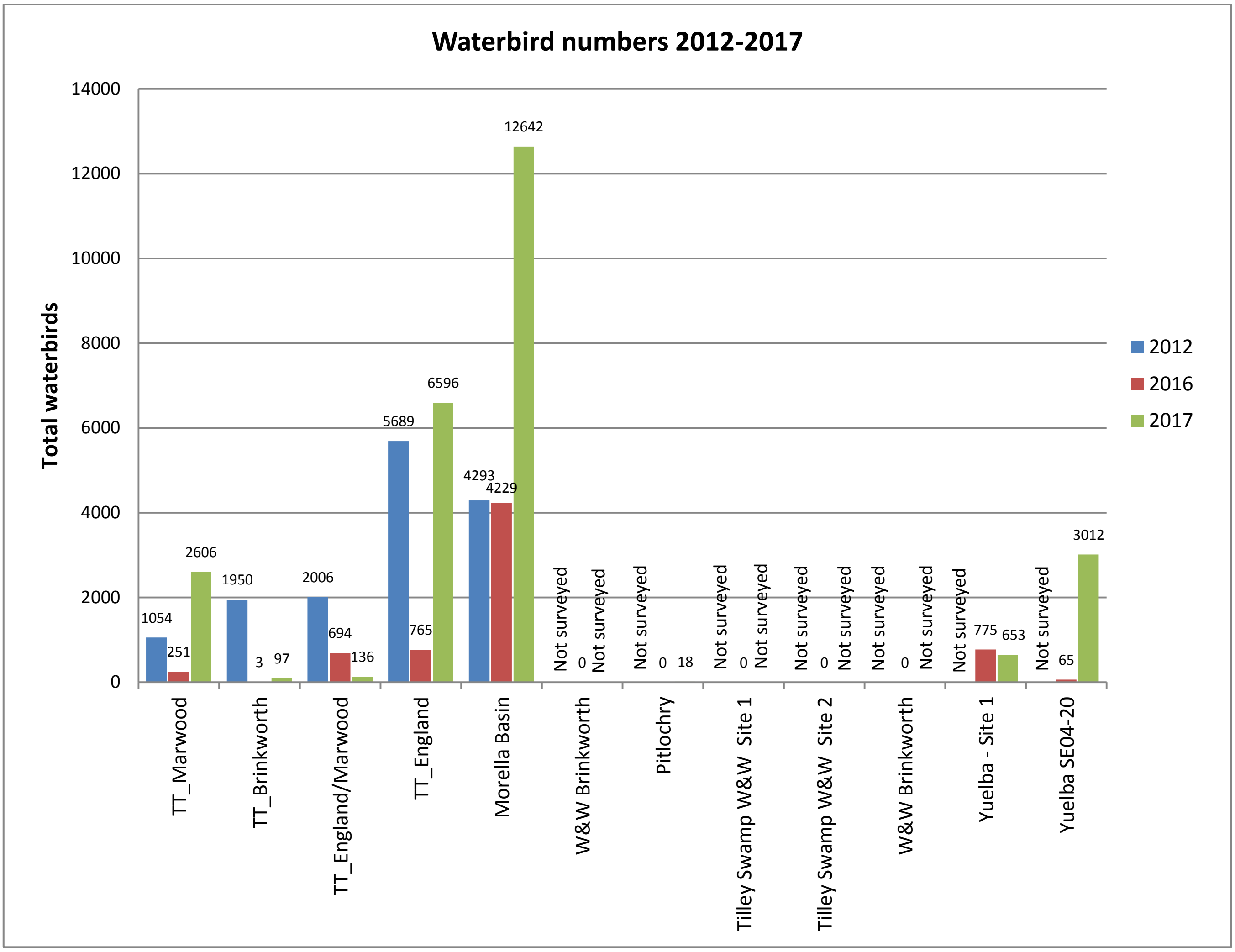


Figure 84 – Waterbird numbers at each site during 2012, 2016 and 2017 monitoring

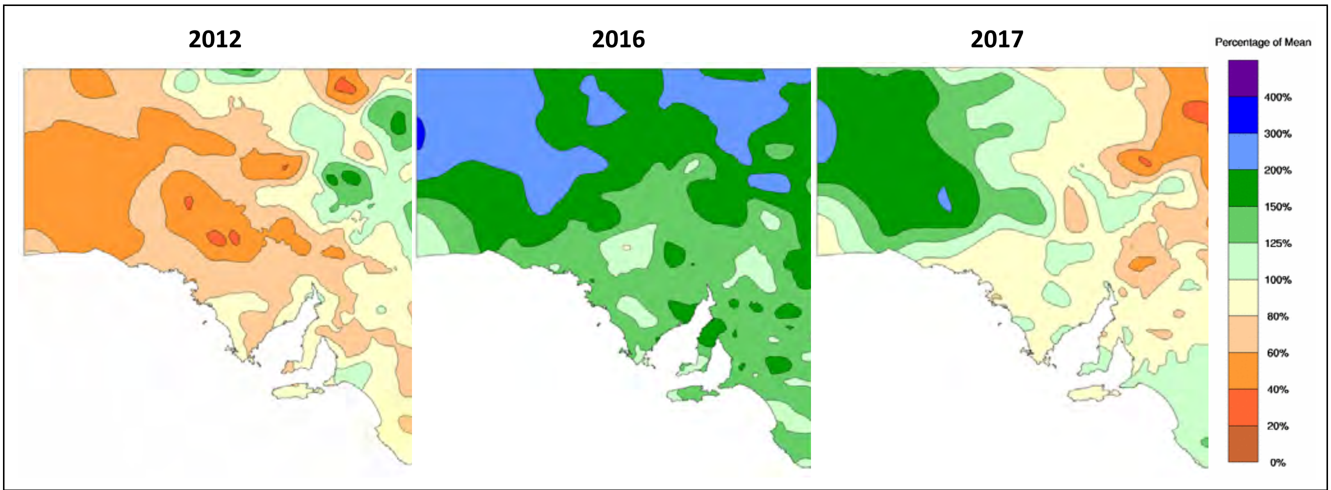


Figure 85 – Annual rainfall percentages for South Australia in waterbird monitoring years

(source: BOM http://www.bom.gov.au/climate/current/annual/sa/archive/2012.summary.shtml)

Species composition/breeding

Forty-one species have been recorded within the SEFRP study area during waterbird monitoring. The most numerically abundant species across all years were Grey Teal (24,947 birds representing 53% of birds across all years), followed by Australian Shelduck (7434 birds, 16%) and Chestnut Teal (2886 birds, 6%). Sites which held the water latest into spring and had the most diverse number of habitats were of the most use to water birds and supported the greatest diversity of species (Dickson, Whiterod et al. 2013).

With the exception of Morella Basin, all wetlands supporting breeding are located on the Taratap Watercourse, with breeding activity observed to be related to the presence of fringing vegetation providing shelter. Waterbirds were observed breeding at seven different wetlands, with Taratap England-Marwood supporting breeding during all monitoring events (Table 23).

Important wetlands

The large wetlands of Morella Basin (500-1000 Ha) and Englands (50-100 Ha) have been the top two wetlands in terms of total waterbird abundance across the three years of monitoring. Morella Basin in particular is subject to more reliable inundation than many of the other wetlands in the watercourse, with regular inflows from the Tilley Swamp drain.

Table 23 – Waterbird monitoring sites with breeding activity

Site	2012					2016					2017				
	Shelduck	Black Swan	Hardhead	Grebe	Black Duck	Shelduck	Black Swan	Hardhead	Grebe	Black Duck	Shelduck	Black Swan	Hardhead	Grebe	Black Duck
Taratap Marwood	Y														
Taratap England-Marwood	Y				Y		Y					Y			
Taratap England	Y						Y								
Morella Basin						Y						Y			
Pitlochry											Y				
Yeulba - Site 1						Y		Y	Y	Y					
Yeulba SE04-20												Y			

5.3.3.2 *Mammals*

Most biological research undertaken in the Taratap and Tilley Swamp Watercourses has concentrated on vegetation or avifauna, and while the recent SEFRP-initiated monitoring also included fish and frogs, mammals were not included. Mammals recorded in the study area are listed in Table 24.

Table 24 - Native mammal species recorded in the SEFRP study area (+3 km)

Species	Common name	EPBC	NPWSA
Native mammals			
Cercartetus concinnus	Western Pygmy-possum		
Cercartetus lepidus	Little Pygmy-possum		
Chalinolobus gouldii	Gould's Wattled Bat		
Chalinolobus morio	Chocolate Wattled Bat		
Macropus fuliginosus	Western Grey Kangaroo		
Macropus giganteus	Eastern Grey Kangaroo		RA
Macropus rufogriseus	Red-necked Wallaby		RA
Mormopterus sp4	Free-tailed bat		
Nyctophilus geoffroyi	Lesser Long-eared Bat		
Pseudomys apodemoides	Silky Mouse		
Tachyglossus aculeatus	Short-beaked Echidna		
Vespadelus regulus	Southern Forest Bat		
Vespadelus vulturnus	Little Forest Bat		
Vombatus ursinus	Common Wombat		RA
Pest mammals			
Axis axis	Chital		
Bos taurus	Cattle		
Capra hircus	Feral Goat		
Cervus dama	Fallow Deer		
Cervus elaphus	Red Deer		
Cervus timorensis	Rusa Deer		
Felis catus	Cat		
Lepus capensis	Brown Hare		
Lepus europaeus	European Brown Hare		
Mus musculus	House Mouse		
Oryctolagus cuniculus	European Rabbit		
Rattus rattus	Black Rat		
Vulpes vulpes	Fox		

Figure 86 – Common Wombat (Vombatus ursinus)

Figure 87 – Western Pygmy-possum (photo B. Haywood)

Pest mammals

The SEFRP study area is mostly bounded by agricultural land and is subject to incursion of the pest mammal species that are common through south-eastern Australia, including the Fox, European Rabbit, Brown Hare, Goats and House Mouse. Stock and game species held on adjacent private property also escape into native vegetation, and deer are known to have established wild populations in Tilley Swamp CP and surrounding areas. The management plan for Tilley Swamp CP notes that European Rabbits were a particular problem in the past – particularly on the western and northern boundaries – and that baiting had decreased the population (DEHAA 1999).

The impacts of feral mammals include over-grazing of open areas, suppression of regenerating seedlings, browsing of sensitive plants, and trampling of vegetation particularly in damp or wetland habitats. Clearance, removal of water through artificial drainage, and the drain corridors themselves also allow predatory species such as foxes to more easily access previously inaccessible areas, and reduce the ability of small mammal and bird species to evade predators (May and Norton 1996).

Monitoring summary and status

The first systematic mammal trapping within the SEFRP study area occurred in 1996, with the Biological Survey of Tilley Swamp, which took in 16 sites in the area from Martin Washpool in the north to Tilley Swamp CP in the south, including a number of sites in between the two (Stewart et al. 1998). The results included 19 mammal species (eight introduced), with notable species including the rare (SA) Common Wombat (*Vombatus ursinus*) and Red-necked Wallaby (*Macropus rufogresius*), and the regionally rare Little Pygmy-possum (*Cercartetus lepidus*) and Western Pygmy-possum (*Cercartetus concinnus*). The Silky Mouse (*Pseudomys apodemoides*) was also recorded on a sand dune.

A biological survey of Messent CP in 1994 had recorded similar species (Owens et al. 1995). Other records in the south west corner of Messent CP close to the SEFRP study area include Western Pygmy-possum in 2017 and 2012, Silky Mouse in most years and Little Pygmy-possum in 2014. Little Pygmy-possum was also recorded during several excursions by the SA Museum between 1983 and 1986.

Bats have been subject to various surveys, with the Tilley Swamp survey recording the Chocolate Wattled Bat (*Chalinolobus morio*), Lesser Long-eared Bat (*Nyctophilus geoffroyi*) and Little Forest Bat (*Vespadelus vulturnus*). Additional surveys at Martin Washpool CP found the Southern Forest Bat (*Vespadelus regulus*) and Little Forest Bat (*Vespadelus vulturnus*). The survey by the consultants Jacobs in 2015 using ANABAT audio recorders detected four bat species recorded on previous surveys: Gould's Wattled Bat, Southern Forest Bat, Little Forest Bat, and Lesser Long-eared Bat, along with new records of the Free-tailed Bat (*Mormopterus* sp.) and an undetermined Forest Bat (*Vespadelus* sp.).

The Tilley Swamp study raised particular concerns about the effects of drain construction on species with poor dispersive abilities, and species prone to predation by exotic species, including small mammals (Stewart et al. 1998). As a result, fauna crossings were included in the design of the subsequent Tilley Swamp drain. Monitoring of crossings in Martin Washpool CP in 2002 (Donohoue et al. 2003) and revisited in 2005 and 2006, resulted in 13 Western Pygmy-possum records, five Little Pygmy-possum records and two Silky Mouse records, with more than half of the records coming from the drain just south of Morella Basin. The authors recommended annual monitoring of fauna crossings; however monitoring sites have not been revisited since 2006.

Many of the bat records also come from the 1996 Biological Survey of Tilley Swamp, which recorded Chocolate Wattled Bat (*Chalinolobus morio*), Lesser Long-eared Bat (*Nyctophilus geoffroyi*) and Little Forest Bat (*Vespadelus vulturnus*).

SEFRP-initiated monitoring

Mammals have not been included in SEFRP-initiated monitoring.

5.3.3.3 *Reptiles*

In total, 22 species of reptile have been recorded in and within 3 km of the study area (Table 25), compared to 49 recorded in the greater South East (Foulkes and Heard 2003).

Table 25 –Reptile species recorded in the SEFRP study area (+3 km)

Species	Common name	EPBC	NPWSA
Amphibolurus norrisi	Mallee Tree-dragon		
Aprasia striolata	Lined Worm-lizard		
Bassiana duperreyi	Eastern Three-Lined Skink		
Chelodina longicollis	Common Long-necked Tortoise		
Ctenotus orientalis	Spotted Ctenotus		
Ctenotus spaldingi	Eastern Striped Skink		
Ctenotus uber	Spotted Ctenotus		
Diplodactylus vittatus	Wood Gecko		
Echiopsis curta	Bardick		RA
Hemiergis peronei	Four-toed Earless Skink		
Lampropholis delicata	Delicate Skink		
Lampropholis guichenoti	Garden Skink		
Lerista bougainvillii	Bougainville's Skink		
Morethia adelaidensis	Adelaide Snake-eye		
Morethia obscura	Mallee Snake-eye		
Pogona barbata	Eastern Bearded Dragon		
Pogona vitticeps	Central Bearded Dragon		
Pseudemoia entrecasteauxii	Southern Grass Skink		
Pseudonaja textilis	Eastern Brown Snake		
Tiliqua rugosa	Sleepy Lizard		
Tiliqua scincoides	Eastern Bluetongue		
Varanus rosenbergi	Heath Goanna		VU

Figure 88 – Lerista bougainvillii

Figure 89 – Varanus rosenbergi

Monitoring summary and status

Prior to the 1996 biological survey of Tilley Swamp, little was known about the herpetofauna of the Tilley Swamp Watercourse, with no species lists compiled for Martin Washpool or Tilley Swamp Conservation Parks and only one specimen from the watercourse lodged with the SA Museum (Stewart et al. 1998). Most other surveys taking in the SEFRP study area since have not specifically targeted reptiles, recording opportunistic observations instead.

The 1996 survey recorded 13 species, working within the limitations of cool, dry conditions, making the most significant addition to reptile data to date. The most abundant species across all records are the small skinks, including Delicate Skink (*Lampropholis delicata*), Mallee Snake-eye (*Morethia obscura*), Four-toed Earless Skink (*Hemiergis peronei*) and Bougainville's Skink (*Lerista bougainvillii*). There have been few records of larger reptiles, but the state-vulnerable and regionally-endangered Rosenberg's Goanna (*Varanus rosenbergi*) – often referred to as the Heath Goanna – has been observed in coastal vegetation around Salt Creek as recently as 2015. The species shelters in burrows, hollow logs and rock crevices (Cogger 2014) and could feasibly be present in parts of the study area.

Snake records comprise the Tiger Snake (*Notechis scutatus*) and the Eastern Brown Snake (*Pseudonaja textilis*) – both common within the region. An unconfirmed sighting of a Bardick (*Echiopsis curta*) was made in the south west corner of Messent CP in 1994, along with a museum record from 1950 just south of Salt Creek. The only aquatic reptile on the list, the Long-necked Tortoise (Aquasave DB), has been recorded nearby (within 3 km) at Salt Creek and at Henry Creek.

SEFRP-initiated monitoring

Reptiles have not been included in SEFRP-initiated monitoring.

6. Summarising the trajectory of ecological change

Prior to SEFRP-initiated monitoring, most ecological data collected on the Taratap and Tilley Swamp Watercourses was from one-off surveys or opportunistic observations, limiting the ability to compare across time. However, general long-term ecological trends seen across the broader South East region appear intact in the watercourses, with declines in diversity and abundance of native species since European settlement, primarily driven by vegetation clearance and altered hydrology as a result of drainage (Stewart et al. 1998). While land clearance had largely ceased by the 1990s, alteration of hydrology has been ongoing, and a multitude of pressures including nearby agricultural practices, weed incursion, feral predators and fire have continued to drive change in ecological communities across the watercourse.

6.1. *Vegetation*

6.1.1 Overall trajectory

The original extent of native vegetation cover across the SEFRP study area has decreased significantly, with approximately 40% of native vegetation now cleared, and some of the remaining vegetation is subject to grazing and fragmentation. Vegetation clearance was made possible by drainage efforts on a local and regional scale, with direct drainage of wetlands and interception of the overland flows that fed the Taratap and Tilley Swamp watercourses. Compounding this, the loss of water from the landscape has led to widescale change in vegetation communities, with a distinct transition in many areas from seasonal brackish aquatic beds to *Melaleuca halmaturorum* shrubland, a process that has continued and accelerated until the present.

Given the scale of clearance and changes in landuse, it is likely that by the time detailed monitoring began in the watercourse a number of flora species had already disappeared from the area. It is notable that – other than orchids – relatively few threatened flora species have been found in the area, although a much larger number of rare species have been recorded. To date, flora searches during optimal detection periods have been limited, particularly in the large Heritage Agreements on private land, and more effort could potentially locate additional populations of threatened flora. The halting of broad-scale clearance in the mid-1980s has helped to safeguard important terrestrial vegetation communities, including rare *Eucalyptus fasciculosa* woodland, but the modification of hydrology has continued, with the Tilley Swamp drain in particular having a strong effect on wetlands of the watercourse.

6.1.2 Terrestrialisation

A notable exception to the lack of longitudinal monitoring data is Tilley Swamp CP, where detailed vegetation monitoring was conducted between 2000 and 2012 with the intent of detecting any effect of the Tilley Swamp groundwater drain constructed in 1999-2000. The study at Tilley Swamp is instructive when interpreting change across the rest of the watercourse, as it confirms the ongoing terrestrialisation process within wetland basins clearly visible at ground level (Figure 90) or when comparing historic aerial images across time (Section 4.1). Repeat monitoring of vegetation transects at Tilley Swamp in 2012 clearly showed terrestrial vegetation communities moving down-slope in response to drier conditions, with *Melaleuca halmaturorum* shrubland dramatically displacing damp herbland even over the relatively short (12 year) timescale (Dickson et al. 2013).

Figure 90 – Ongoing terrestrialisation evidenced by multiple cohorts of Melaleuca halmaturorum in the basin of Frostys Swamp, 2016

This terrestrialisation trend is present across much of the watercourse, with most wetland basins subject to invasion by terrestrial species in areas that were formerly wetland or herbland. In 2016, all five vegetation monitoring sites featured young cohorts of *Melaleuca halmaturorum* in the edges of the wetland basin, while in 2012 the affected sites included Yeulba Swamp, Englands, Marwoods, McBrides, Tilley Swamp and Morella Basin.

The process of terrestrialisation has been a dramatic consequence of the long-term drying trend in the Taratap and Tilley Swamp Watercourses, evident in the WOfS analysis by Harding and Herpich (2018) at three key wetlands (section 4.2). In looking for the contributing factors to this trend over the past 50-60 years and its more recent acceleration, Dickson et al. (2013) identified three probable primary drivers:

1. ***Regional Drainage:*** *With the exception of more recent REFLOWS diversions, the general (long-term) loss of surface flows from southern catchments (e.g. Anderson Scheme/Blackford Drains in the 1950/60s, Fairview Drain in 1998) has reduced the availability of high volume, lower salinity flows of surface water available to Upper South East wetlands.*
2. ***Climate:*** *A 20 year period of below-average rainfall across the South East and western Victoria since the early-mid 1990s is a significant factor helping to drive the current longer-term drying trend and vegetation community shift.*
3. ***Local Groundwater Drainage:*** *Deep groundwater drains constructed over the past 20 years across the Upper South East, are also likely to be contributing to the longer-term drying trend and vegetation shifts currently being observed, in conjunction with the*

preceding two factors. Groundwater drainage is designed to lower the local watertable, to protect agricultural land from upper soil profile salinisation. However groundwater drains are also located within or adjacent to sensitive natural environments (e.g. Tilley Swamp CP). At many locations, in the transmissive soil and substrate types of the Upper South East, the groundwater drains appear to be reducing the ability of the floodplain to hold water and/or generate surface flows.

This report has also highlighted the fact that Tilley Swamp's original outlet sills into the Coorong via Salt Creek have been breached and deepened progressively since 1864, and that this initiated the drying trend long before the subsequent changes began.

The original (2000) design of the Tilley Swamp drain allowed additional flows into Tilley Swamp under the right conditions, but while the drain has helped to increase frequency of inundation to Morella Basin, the maximum extent and duration of inundation across Tilley Swamp has decreased, and full supply level (seen multiple times before drain construction to the modified – i.e. lowered – modern sill level of some wetland features in the watercourse) has not occurred since construction. The drain also effectively cut off Frostys Swamp after construction, with inundation occurring only once in 18 years since construction, compared to 8 out of 12 years before construction (section 4.2).

Without direct intervention to change hydrology and return water to the floodplain and wetlands, the drivers for terrestrialisation are still actively in play.

For the watercourses, the SEFRP design includes delivery of additional flows, providing the possibility that the trend can be slowed or reversed in some areas, if inflows are sufficient.

6.2. *Fauna*

As with vegetation, perceptible changes in fauna assemblages appear mostly linked to clearance and drainage, and appear to reflect those of the wider South East, where an initial drastic decline followed broad-scale drainage, vegetation clearance and the introduction of feral herbivores and predators. It is notable that vegetation clearance in the Taratap and Tilley Swamp Watercourses has occurred relatively recently compared to other areas of South Australia including the Lower South East and the Murray-Darling Basin. As a consequence, the ecological 'debt' is still being paid as flora and fauna populations struggle with habitat loss, small remnant size and loss of connectivity (and associated genetic bottlenecks) (Cooper et al. 2002, Lindenmayer and Fischer 2006).

While fauna records pre-dating the 1996 Biological Survey of Tilley Swamp are few, local extinction of fauna species within the SEFRP study area is suggested by the low abundance and diversity of detected biota. In particular, fish, small mammals and reptiles appear particularly affected, and are all susceptible to habitat fragmentation and vulnerable to introduced predators.

So far, any resultant changes in fauna assemblages would be more easily attributed to the lack of water in wetlands and subsequent absence of aquatic species than to changes in vegetation structure and composition. However, it can be reasonably expected that the transition of vegetation communities has affected the suitability or productivity of habitat for some fauna species – particularly those that are wetland dependent – and altered the behaviour, distribution and spatial habitat use of the species still present.

It is important to note that it is not currently possible to estimate fauna populations and distributions due to limited survey effort, lack of detectability of many species, and inconsistency between surveys in both method and timing. In general, fauna monitoring efforts to date are more useful as an indication or "snapshot" of fauna using an area in a particular time. Fish monitoring may be an exception; due to the limited available habitats, consistency of method and repeat monitoring visits over an extended period of time, there may be some additional confidence that monitoring provides a reasonably accurate representation of fish populations and distribution.

6.2.1 Fish

Fish have been highly impacted by local and regional drainage in the Upper South East, and are now highly restricted in terms of potential habitats, primarily by a combination of lack of inundation of former habitats combined with a lack of connectivity between suitable remaining habitats.

2012 monitoring largely reflected deteriorating conditions for fish at wetlands that didn't receive inflows in monitoring years, as well as limited dispersal opportunities for fish to move into wetlands that filled as a result of localised runoff. However, with increased inundation in recent years, 2017 monitoring detected an increase in total fish abundance, and indicated some limited recovery of fish populations within existing sites.

Additionally, 2017 saw dispersal of native species into a number of wetlands on the floodplain where no fish were detected in 2016 (Taratap Brinkworth, Taratap Englands, Yeulba and Pitlochry), indicating recent dispersal and recolonisation across the SEFRP pathway. Initiatives to further increase flows into en-route wetlands can be expected to continue this trend.

As well as benefitting existing fish populations, the recent increase in inundation and connectivity within the SEFRP alignment provides some potential for other species to move into the floodplain, provided suitable aquatic conditions and dispersal opportunities exist. Salt Creek provides a connection to the Coorong South Lagoon under the right conditions, potentially allowing dispersal of some species between the Coorong and Morella Basin. The Western Bluespot Goby – previously detected in Salt Creek (December 2001) – could be one such species.

This increase in connectivity also poses an element of risk, with a danger of facilitating the expansion of feral fish species such as Eastern Gambusia. Notably, no feral fish have been detected during SEFRP-initiated monitoring, however Eastern Gambusia are now present in the southern section of Drain L (Whiterod and Gannon 2017), highlighting the need to understand potential movements of invasive fish when considering redirection of flows from other catchments (such as Drain L) to augment the SEFRP flowpath.

6.2.2 Frogs

While the recent SEFRP-initiated frog monitoring recorded no frogs in the SEFRP study area during survey periods, Painted Frog, Eastern Banjo Frog and Common Froglet were recorded opportunistically at Englands wetland, prior to monitoring in 2012. Frogs were also recorded in earlier surveys, including four species during the nine-day Biodiversity Survey of Tilley Swamp CP in 1996 (Stewart et al. 1998).

The lack of frogs during SEFRP-initiated monitoring is likely to have been influenced by survey timing, being conducted in a period more suited to the detection of freshwater species that are unlikely to occur in the saline habitats visited, than the detection of burrowing or other terrestrial frogs that will typically call with the onset of rain earlier in the season (Tuck et al. 2017). An interpretation of frog diversity, abundance and distribution is not possible from the collected data; however, given opportunistic records and the apparent suitability of habitat in the floodplain, it is likely that frogs are more widely present and more diverse than detected so far. More recent observations of increased frog presence in the Taratap Watercourse coincide with management of flows to reduce salinity, with 4,500EC now routinely achieved (Mark De Jong, pers. comm. 2018).

While many frog species have the ability to rapidly disperse given appropriate conditions, the projected salinity of future flows into SEFRP en-route wetlands will likely continue to be a limiting factor in the expansion of some aquatic frog species, even under more highly-inundated scenarios.

6.2.3 Waterbirds

In the short-term, waterbirds appear highly responsive to continental-scale climatic conditions that drive wetland conditions in south eastern Australia. In years of widespread high rainfall, waterbirds respond with wider dispersal due to greater availability of habitat, resulting in lower numbers seen in wetlands in south eastern Australia. In drier years, waterbirds concentrate in a more limited number of wetlands, including more reliable wetland regions in the South East of South Australia (DEWNR 2017).

SEFRP-initiated monitoring data can be interpreted as reflecting these broader patterns: high total waterbird abundance was observed in 2012 in a year of high rainfall after drought, while 2016 brought wetter conditions in central and eastern Australia that allowed greater dispersal of waterbirds and lower abundance in south eastern Australia. In 2017, low rainfall in eastern and central Australia meant that key wetland areas such as the Lake Eyre Basin and Cooper Creek were dry (Porter et al. 2017). This had the effect of limiting waterbird dispersal through that area and concentrating waterbirds near the coastal habitats of southern Australia (DEWNR 2017), which may explain the increase in waterbirds during SEFRP waterbird monitoring that year.

The detection of longer-term trends in the Taratap and Tilley Swamp Watercourses is difficult due to patchy monitoring data prior to SEFRP-initiated monitoring. The observations of Jaensch and Auricht (1989) at Tilley Swamp CP in the flood year of 1981 suggest that now-drier parts of the Tilley Swamp Watercourse had the potential to host large populations of birds and may have done so more regularly in the past. In recording 2750 birds at Tilley Swamp, the authors stated that "*In the context of the post-drainage situation in the South-East, wetland conditions clearly were not average or normal in 1981; they more closely resembled pre-drainage conditions*".

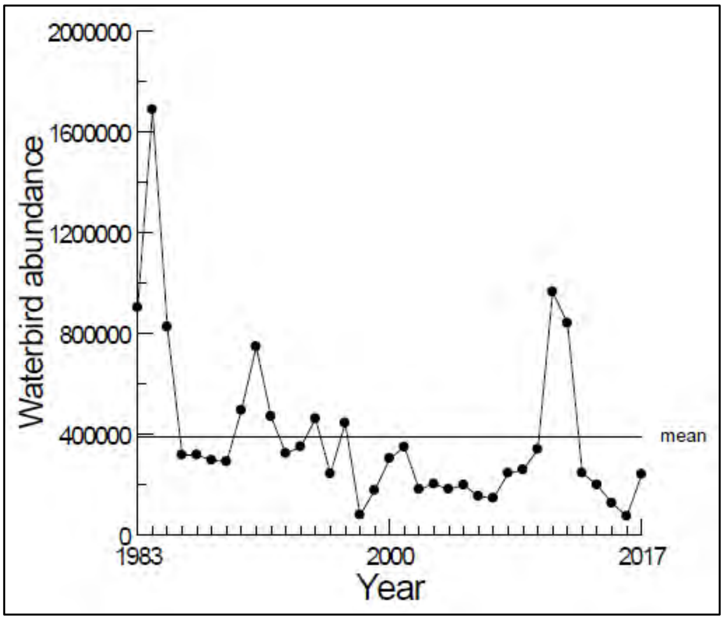


Figure 91 – Total waterbirds across Eastern Australia (fom Porter, et al . 2017)

It can be reasonably expected that the watercourses supported much larger populations of waterbirds prior to drainage of wetlands and vegetation clearance, and that a steady decline has occurred since then.

Despite short-term increases such as those seen in 2017, current waterbird populations in the Taratap and Tilley Swamp Watercourses likely reflect long-term declines as recorded by the Eastern Australian Aerial Waterbird Survey (EAAWS), which has reported a decline in overall waterbird abundance, total wetland area and breeding species richness since monitoring began in 1983 (Porter et al. 2017). However, a more highly-inundated scenario such as that proposed by the SEFRP design could result an increase in available habitat, leading to increased usage by waterbirds.

6.2.4 Mammals

In the South East of SA, mammals have been affected by a number of pressures, including introduction of feral predators, loss of habitat, and the broader effects of habitat fragmentation, resulting in 20% of mammal species now being considered vulnerable, endangered or critically endangered in the region, and a further 9% now considered regionally extinct (Gillam and Urban 2011).

Within and around the Taratap and Tilley Swamp Watercourses, a lack of native mammal diversity and abundance – particularly of small mammals – indicates the declines observed across the South East of SA to be intact in this area. Encouragingly, some of the small mammals such as Pygmy-possums and the Silky Mouse still persist in larger conservation parks such as Martin Washpool, and Common Wombats and Red-necked Wallabies can also be found, whereas in some parts of the South East they are rarely recorded.

In addition to a decline in diversity and abundance, species composition has been altered, with smaller mammals generally decreasing while larger herbivores have adapted to vegetation changes. In particular, many of the open flats and depressions of the floodplain are no longer subject to frequent or prolonged inundation and are favoured by herbivores, with easy access to cleared areas and palatable grasses and forbs. In many parts, terrestrialisation has not yet progressed to the point where it has restricted access for herbivores, and large numbers of kangaroos, wombats and rabbits enact intense grazing pressure.

Changes in inundation regime such as that proposed by the implementation of the SEFRP should not greatly affect mammal species, although some open grazing areas will be inundated more frequently, including herblands in drying wetland basins that are currently favoured by the Common Wombat. There will be other impacts however. As outlined by Stewart et al. (1998) prior to the construction of the Tilley Swamp drain, the construction of additional drainage infrastructure through the watercourses may have a number of detrimental effects – the drains themselves presenting a physical barrier to movement/dispersal for some species being one of the major ongoing concerns.

6.2.5 Reptiles

Overall survey effort for reptiles in the watercourse has been low, with the Tilley Swamp survey forming the main basis for records, and that study itself being limited to 16 quadrats over a week in relatively cool and dry conditions (Stewart et al. 1998). The report of the Biological Survey of the South East of SA noted that the reptile fauna of the region is not known well enough to determine the status of most species with certainty, and that some species that are currently present may be lost to the region before their presence is known (Foulkes and Heard 2003).

As with mammals, the lack of recent, targeted monitoring across the watercourses does not allow definition of clear population trends, other than the general declines seen in native fauna populations. Clearance of habitat and the introduction of feral predators will have had a major impact on herpetofauna, as it has for mammals.

Increased inundation of wetlands within the watercourses does not appear to pose a significant threat to existing reptile populations, and greater wetland area may create more wetland edge habitat, with food sources such as invertebrates and frogs that will favour some species. However, the concerns regarding detrimental effects from construction of further drainage-related infrastructure for mammals (listed above) apply equally to reptiles.

6.3. *Fire and climate change*

The February 2013 fire at Tilley Swamp CP burnt approximately 90% of the park, resulting in significant changes in vegetation structure and composition. Post-fire vegetation monitoring in 2014 saw an increase in species diversity in monitored transects, with most new records being species that will preferentially colonise open areas or are disturbance-responsive, and a significant proportion of these (39%) being weeds (Dickson and Bachmann 2015). While relative species abundance may stabilise somewhat over time, fire can lead to establishment of persistent weed populations, particularly of competitive, fire-responsive species such as Boneseed (*Chrysanthemoides monilifera*).

The most threatening post-fire response was a dramatic change in vegetation character in wetland transects caused by extremely dense regeneration of *Melaleuca halmaturorum* seedlings – recorded at densities of greater than 300 stems/m^2 in some locations. Without adequate inundation in wetlands to drown juvenile plants, concerns were raised that they would become established, resulting in a rapid transition of those areas to dense *Melaleuca halmaturorum* shrubland (Dickson and Bachmann 2015).

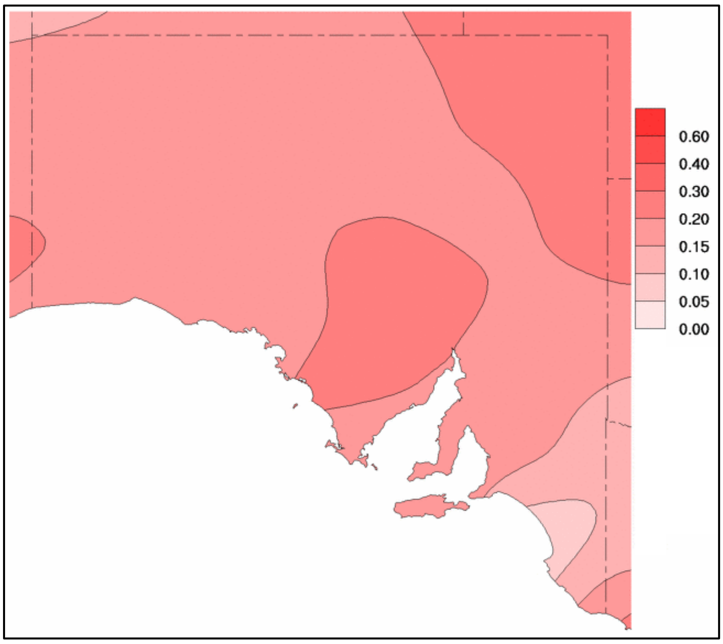


Figure 92 – Map of South Australia showing the trend in mean annual surface temperatures from 1950 to 2016. Source: Bureau of Meteorology
(http://www.bom.gov.au/climate/change/#tabs=Tracker&tracker=timeseries)

Beyond structural and compositional change to vegetation, the ongoing drying of wetland habitats across the Taratap and Tilley Swamp Watercourses increases the susceptibility of remnant vegetation to wildfire. Climate change is projected to increase temperatures and decrease rainfall across the region, resulting in drier conditions and heightened fire risk (Guerin et al. 2018a, CSIRO 2018), further intensifying the impacts of local and regional drainage.

These outcomes highlight the vulnerability of isolated patches of remnant vegetation within the watercourses, isolated by vegetation clearance and modified by changes in hydrology. While the Upper South East has been less affected by climate change since 1950 than other areas of the state, change since the 1950s is detectable and expected to increase in severity. Current modelling by (Guerin et al. 2018b) rates the Upper South East and Murray Mallee region as *Susceptible* – the most vulnerable category in that study.

The ultimate implications for both flora and fauna under a drier and more fire-prone climate include lowered diversity and more uneven allocation of biomass, as an increasingly select set of species able to thrive in the changing conditions increase their dominance (Guerin et al. 2018a). In geographically isolated remnants it is difficult or impossible for some species to re-colonise, meaning that local species extinctions are unlikely to reverse without direct intervention. Possible ecological levers to mitigate this include the planting of vegetation corridors to link large remnants, and modifying hydrology using the drainage network to increase inundation through the watercourses, as proposed by the SEFRP.

7. Review of monitoring needs

7.1. *Summary of previous ecohydrological monitoring*

Several monitoring programs, covering a range of ecohydrological parameters, have been undertaken in the Taratap and Tilley Swamp Watercourses over several decades, as described in more detail in Section 5. Monitoring programs have been initiated for several purposes but all have collected information potentially useful for assessing the outcomes of the SEFRP. A summary is provided below and monitoring locations are shown in figures 93 to 96.

SEFRP-initiated monitoring

Commencing in its feasibility phase, the SEFRP implemented monitoring designed to provide quantitative baseline (pre-SEFRP) data describing the ecology of wetlands likely to be affected by the project, in addition to previous work. All sites have been monitored at least once since 2011, with most monitored twice or more (Dickson et al. 2013, Ecological Associates and Aquasave Consultants 2012, Tuck et al. 2017, Whiterod et al. 2018). Monitoring includes:

- Vegetation transects across 18 wetland elevation gradients throughout the study area. These are designed to detect the response of vegetation to hydrological change. The methodology, which has been revised slightly since initiation of the program, is described by Dickson, Whiterod *et al.* 2013.
- Vegetation quadrats at 18 sites, designed to detect the response of vegetation to hydrological and water quality changes, targeting the most deeply inundated aquatic vegetation present (see Dickson et al. 2013).
- Fish survey at 14 locations, including both drain and wetland habitats. A number of these locations were established for earlier studies (e.g. Hammer 2002) and therefore have data extending back approximately 20 years.
- Waterbird survey, including identification of breeding, at 14 locations; and
- Frog survey at 20 sites.

The data for these surveys are held in Excel databases for which the SEWCDB is custodian, except fish data which are held in an ArcGIS geodatabase for which Aquasave-NGT is custodian. Of all the monitoring programs in place within the Taratap and Tilley Swamp Watercourses, this SEFRP initiated program provides what are likely to be the most sensitive and rapidly responding biological measures of response to the project.

USE Program monitoring (Telfer)

Native vegetation clearance required to construct the Tilley Swamp Drain in 1999-2000, part of the USE Program, was undertaken in accordance with an approved management plan (South Eastern Water Conservation and Drainage Board and Primary Industries and Resources South Australia 1999). Under the management plan, vegetation and fauna monitoring was established to detect the effects of the drain upon adjacent groundwater dependent vegetation and wetland ecohydrology (Telfer et al. 2000). The monitoring consisted of:

- At two locations, Tilley Swamp CP and Stoneleigh Park, four vegetation transects were established parallel with the drain. The transects are each 500 m in length and located 100, 500, 850 and 1200 m from the drain. The objective was to detect changes to vegetation health and plant community composition potentially caused by changes to groundwater.
- The above transects were also used for a quantitative bird survey (see Milne and Squire 2001).
- At four locations, Tilley Swamp CP, Stoneleigh Park, Morella Basin east and Morella Basin west, seven transects were established in a "fan" arrangement from a single apex. The objective was "to monitor changes in aquatic vegetation community composition in response to increased surface water flows" (Milne and Squire 2001). Note that, following baseline surveys, inundation increased at the Morella Basin east and Morella Basin west sites, but declined at the Tilley Swamp CP and Stoneleigh Park sites (see Section 4.2).
- Waterbird monitoring was established at the northern and southern ends of Morella Basin (exact locations unclear) (Donohoue et al. 2003, Milne and Squire 2001).

Telfer's baseline methodology was first applied in March 2000 and was repeated, to varying degrees of completeness, in autumn 2001 (Milne and Squire 2001), 2002 (Donohoue et al. 2003), 2012 (Dickson et al. 2013) and 2014 (Dickson and Bachmann 2015). The methodology provides measures of plant cover and health that are likely to be sensitive to hydrological change. Of the wetland sites featuring the "fan" of transects, the two Morella Basin sites have been strongly influenced since first surveyed by the hydrological restoration of Morella Basin under the USE Program. However, all four wetland sites are likely to be influenced by the SEFRP.

The Stoneleigh Park transects parallel with the Tilley Swamp Drain were illegally cleared some time after the 2002 monitoring (M. De Jong, pers. comm. 2018). Although this area is naturally regenerating, the usefulness of the transects for monitoring the effects of past and future groundwater and hydrological change is likely compromised.

Biological Survey of Tilley Swamp

Stewart *et al.* (1998) undertook a biological survey of the Tilley Swamp Watercourse and surrounding terrestrial vegetation using the standardised biological survey methodology (30 × 30 m quadrats) for flora (Heard and Channon 1997) and vertebrate fauna (mammals, reptiles, amphibians and birds) (Owens 2000). Of the sites surveyed, seven are located in areas likely to be influenced by the SEFRP:

- TS00101, TS00201, TS00801, TS00802 (flora only), TS00901, TS01001 (ecological clearance for SEFRP), TS01101

While the biological survey methodology was not intended as a quantitative monitoring tool, repeating the methodology is likely to reveal changes to flora and fauna communities, particularly where changes have been pronounced. In this regard, site TS01001 may provide important insights as vegetation at this location was cleared for ecological purposes under the SEFRP and pronounced changes are anticipated. In 2001, two of the above sites (TS0201, TS0901) were resurveyed for birds (Milne and Squire 2001).

Aquasave-NGT Fish Monitoring Sites

The SEFRP-initiated Monitoring surveyed fish monitoring sites previously established by Aquasave-NGT within the SEFRP study area. However, there are a small number of long established Aquasave-NGT sites that have not been resurveyed for the SEFRP-initiated monitoring that could potentially provide insights into the effectiveness of the SEFRP. They include sites at Salt Creek (Figure 93) that could measure the effectiveness of the Salt Creek fishway, to be installed as part of the project. There are also sites in Henry Creek, Taratap Watercourse and Blackford Drain that could be resurveyed. However, given that a high number (14) of sites were incorporated in the SEFRP-initiated monitoring, surveying additional sites is a low priority.

Vegetation Mapping

Historic and contemporary mapping of vegetation density, based on interpretation of aerial imagery and the digital elevation model (DEM), has been undertaken for this report (see Section 4.1). Previously, fine scale vegetation mapping of Tilley Swamp CP and the Stoneleigh Park property, describing the vegetation present in 2001, was completed by Milne and Squire (2001). Regular, high resolution aerial imagery of the area is anticipated in the future, which will enable regular vegetation mapping to be undertaken as a useful, broad scale form of monitoring.

Jacobs BushRAT Sites

Environmental consultants Jacobs undertook vegetation assessment and mapping of the SEFRP study area in June 2015 for the SEFRP native vegetation clearance application (Jacobs 2015). The assessment included detailed descriptions of the floristic composition and condition of vegetation using the Bushland Rapid Assessment Technique (BushRAT) developed by DEWNR (2013). There are 7 BushRAT sites (1 ha) located in areas likely to be inundated under the SEFRP that were not cleared for SEFRP construction:

- BR02, BR11, BR22, BR23 (grazed), BR26, BR29 (grazed), BR32.

The data for these sites is contained in the assessment report (Jacobs 2015). While the BushRAT methodology is not intended for use as a quantitative monitoring tool, the future reassessment of these BushRAT sites could provide useful information on vegetation response to the SEFRP. For example, future vegetation mapping could revisit these locations for ground truthing.

Hydrological monitoring infrastructure

The SEWCDB has the following loggers and related infrastructure permanently installed within the SEFRP study area, collecting the following data every hour:

- TARATAP WATERCOURSE AT CHRIS ENGLANDS WETLAND (site A2391101): water level, salinity (EC), pH;
- Taratap Drain at Englands Crossing (site A2391141): flow rate, water level, salinity (EC);
- MORELLA BASIN @ Upstream of Outlet Regulator (site A2391061): water level, salinity (EC); and
- SALT CREEK OUTLET @ Salt Creek (site A2390568): flow rate, water level, salinity (EC).

Data are telemetered and available in real time on the WaterConnect website:

(https://www.waterconnect.sa.gov.au/Systems/RTWD/Pages/Default.aspx). Data custodian is the Department of Environment and Water (DEW). Under the SEFRP these loggers will be maintained (or relocated if necessary) and will provide direct measurement of hydrological and water quality outcomes. Additional loggers are proposed to inform operational decision making within the upgraded system. Three of the proposed new loggers will enable direct measurement of SEFRP hydrological and water quality outcomes:

- Taratap Watercourse upstream of outlet regulator: water level, salinity (EC);
- Tilley Swamp Watercourse at Frostys Swamp: water level, salinity (EC), pH, dissolved oxygen; and
- Tilley Swamp Watercourse upstream of outlet regulator: water level, salinity (EC).

A full list of hydrological monitoring sites relevant to the SEFR project is included in Section 10.7.

Groundwater Monitoring

Commencing in April 2016, monthly monitoring of 15 pre-existing observation wells within the SEFRP study area has been undertaken by DEW. Key parameters are water level and salinity. Varying amounts of historical data are also available for most wells. Data are available on the WaterConnect website. This observation well network provides important baseline information for groundwater. Changes to groundwater depth and/or salinity arising as a consequence of the project could have implications for both ecology and agriculture within the SEFRP study area.

Water Observations from Space (WOfS)

As discussed in Section 4.2, WOfS data for the study area has been collected by the Landsat satellite since 1987 and will continue to be collected in the future. These data provide a spatially comprehensive measure of hydrological change through time or, using the methodology of Harding and Herpich (2018), site-specific hydrographs from 1987 onwards. Future assessment of the hydrological changes arising from the SEFRP will be possible using this approach.

WVC models

Updated WVC models by Harding (REF) describe many of the vegetation communities found on the watercourses, along with their specific hydrological requirements including inundation regimes and water quality parameters. When considered alongside hydrological data including those collected from surface water loggers, groundwater observation wells and during SEFRP-initiated ecological monitoring, WVC models could potentially provide insight into the hydrological drivers for the observed transitions of vegetation communities.

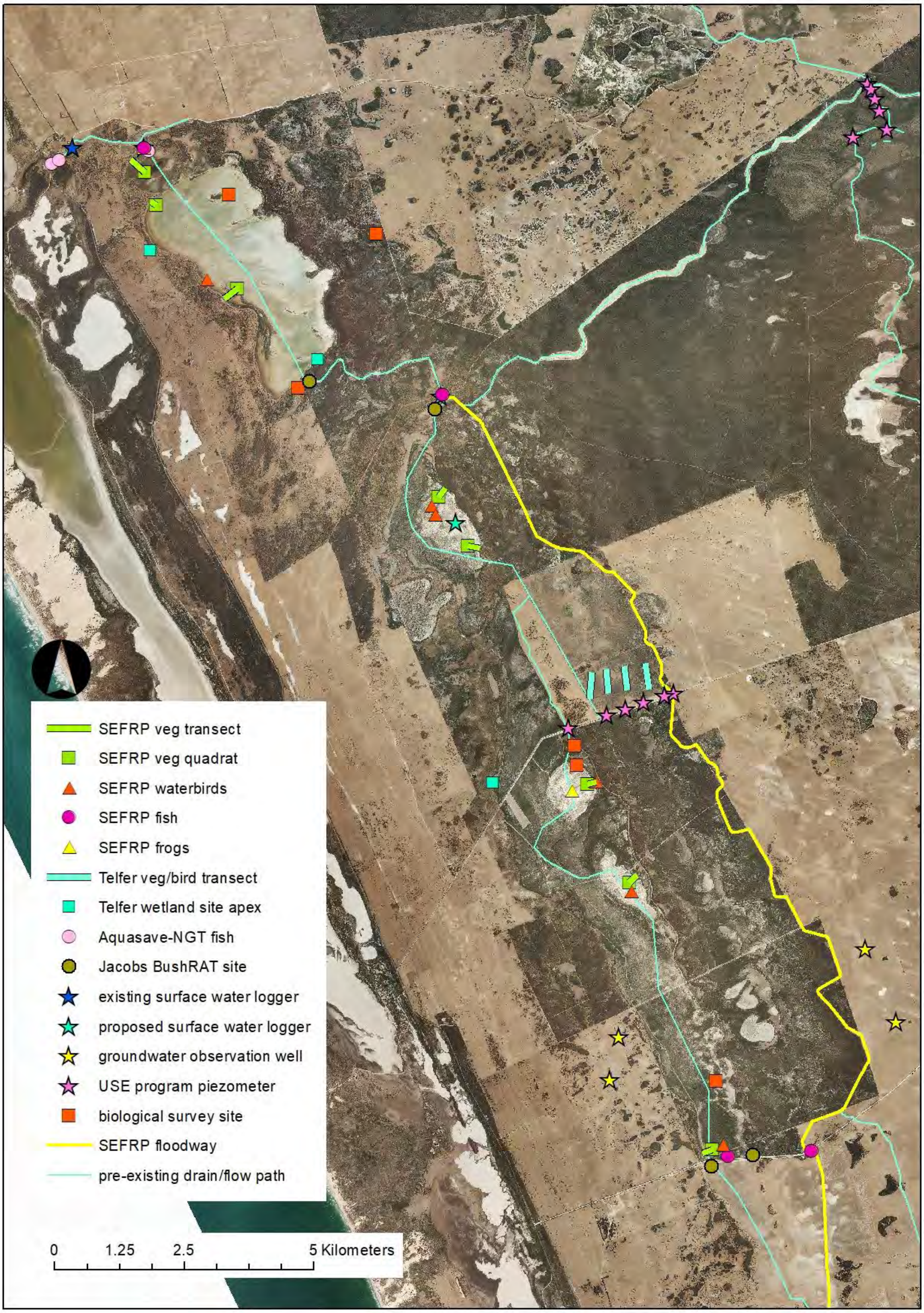


Figure 93 – SEFRP ecohydrological monitoring, Salt Creek to Cantara Road

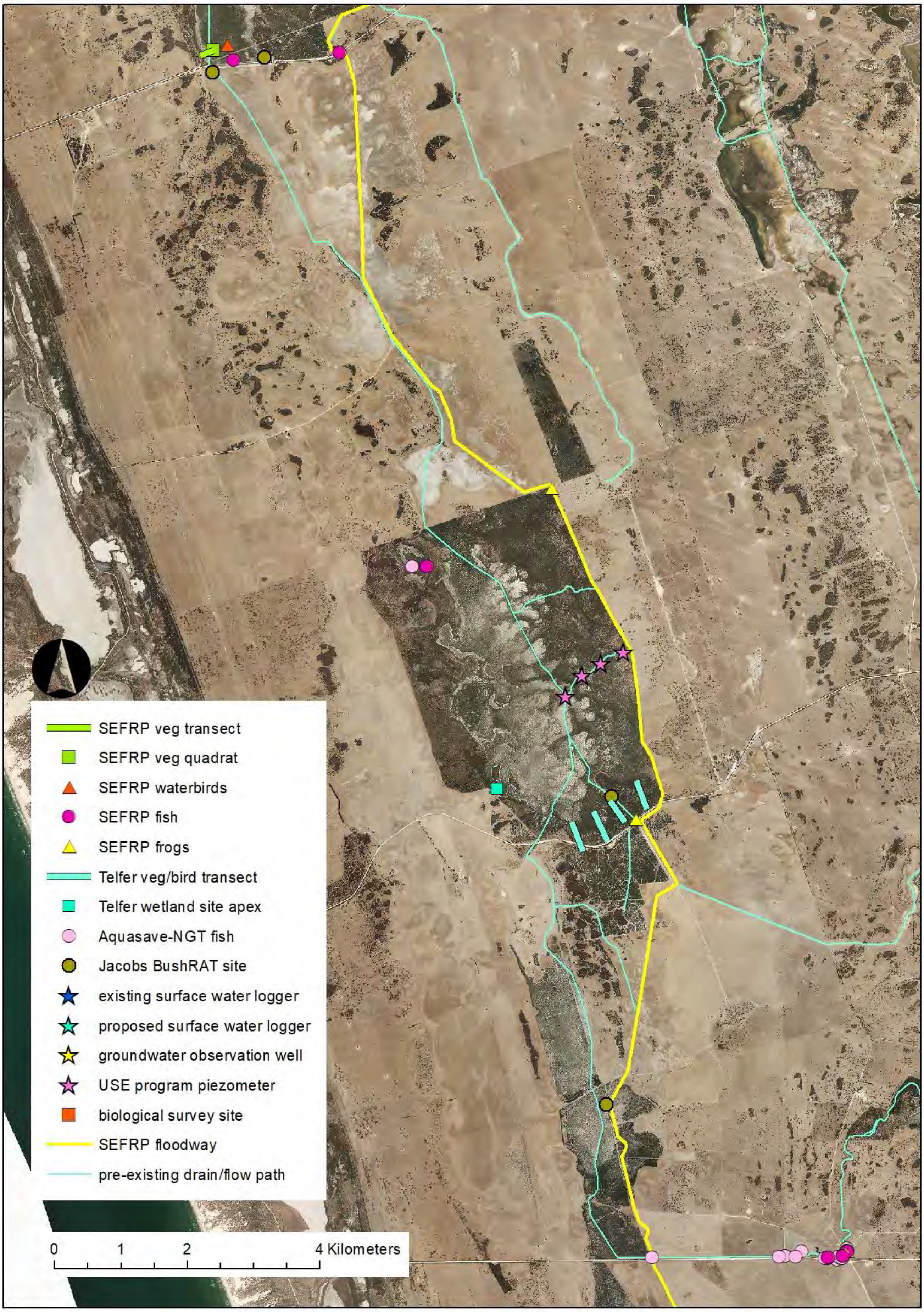


Figure 94 – SEFRP ecohydrological monitoring, Cantara Road to Henry Creek Road

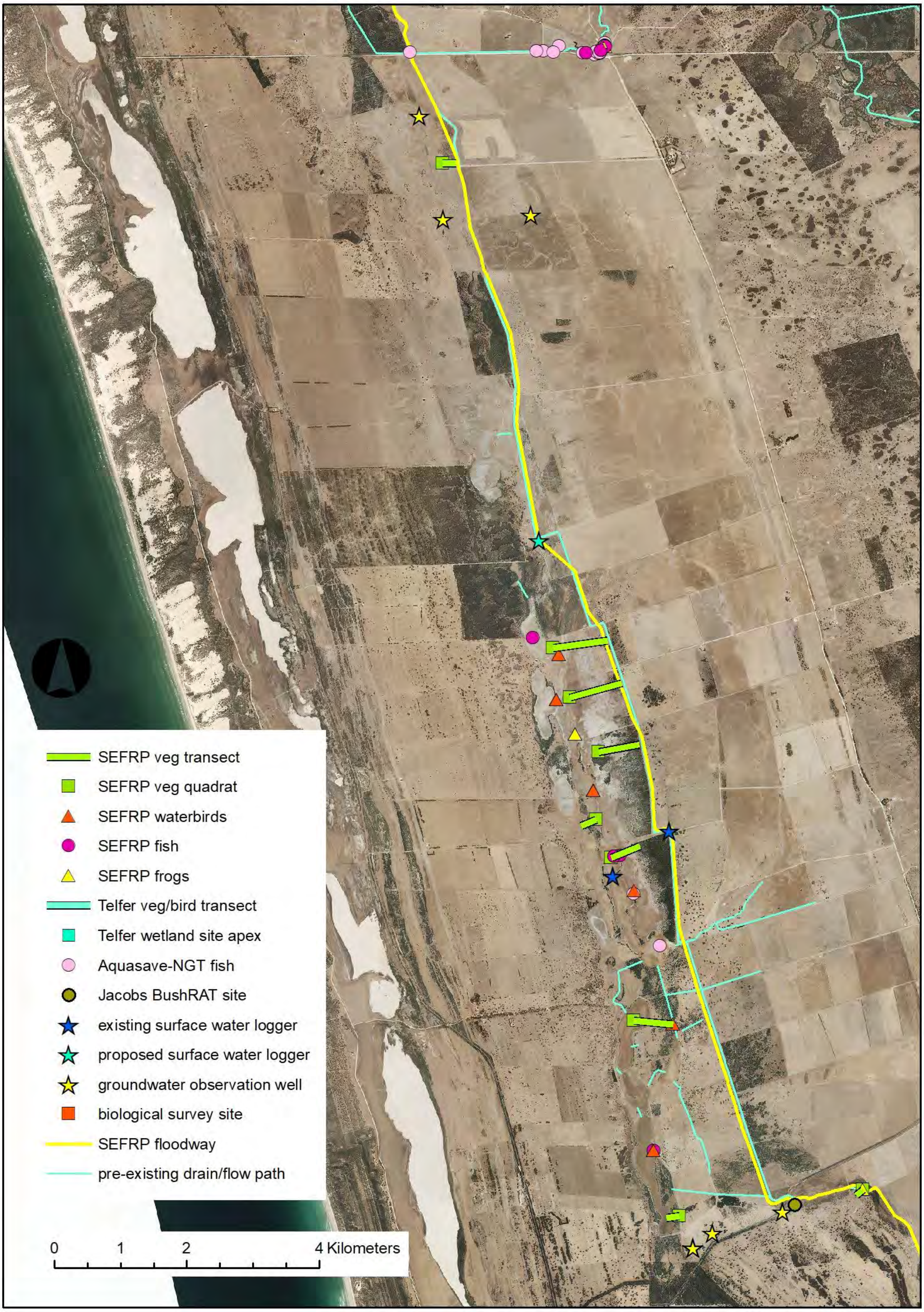


Figure 95 – SEFRP ecohydrological monitoring, Henry Creek Road to Taratap Road

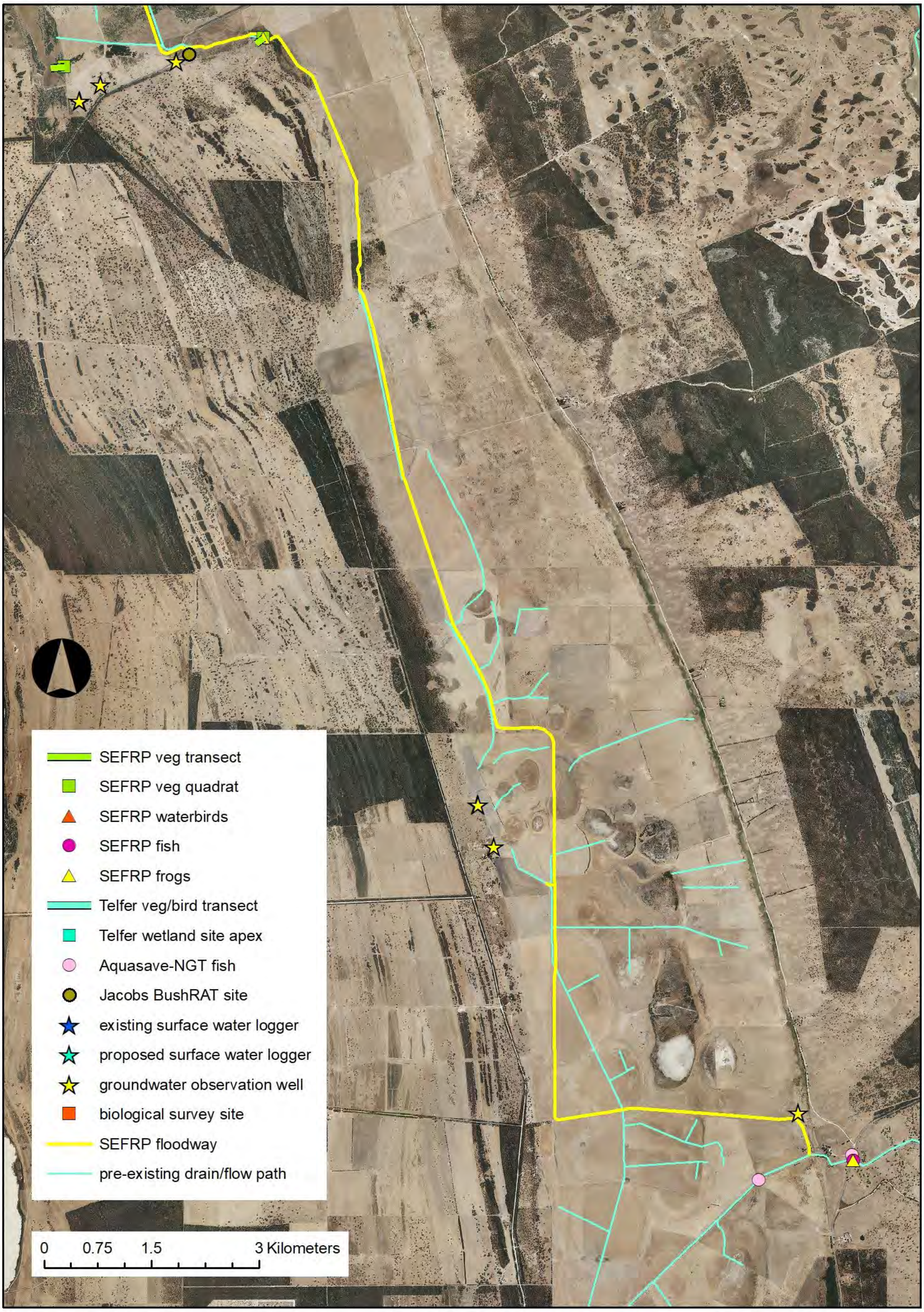


Figure 96 – SEFRP ecohydrological monitoring, Taratap Road to Blackford Drain

7.2. *Monitoring gaps*

The spatial coverage of past, present and proposed ecohydrological monitoring, and the range of parameters covered, provides a sound basis for measuring the outcomes of the SEFRP for *en route* wetlands, provided monitoring continues at an appropriate frequency (see Section 7.3). Relatively minor additions to the monitoring program, discussed below, would fill gaps and provide for a thorough ecohydrological assessment of the project.

7.2.1 Waterbirds - Tilley Swamp Watercourse

Waterbird diversity and abundance is anticipated to increase, particularly in the Tilley Swamp Watercourse, under the SEFRP. Spatial coverage and locations of waterbird monitoring sites is relatively sound but could be improved by the addition of one to two sites in the section between Cantara Road and the northern boundary of Tilley Swamp CP (the Cortina Downs and Hindmarsh Park properties). Although this area is cleared and grazed, and will continue to be, regular inundation is anticipated and waterbird use is likely to increase. The area could provide a valuable comparison of waterbird use between grazed and ungrazed sites further north. The watercourse immediately south of Cantara Rd is of particular interest, as the duration of inundation is likely to increase markedly in this area. Unfortunately, the collection of baseline (pre-SEFRP) data will not be possible.

7.2.2 Wetland S0102503

Wetland S0102503 is located in the south of the SEFRP study area where very limited past and present ecohydrological monitoring has occurred (Figure 97). The wetland is representative of aquatic habitats in the general vicinity, for which monitoring data are lacking. Although not directly influenced by the SEFRP via surface water connection, there is a potential for influence via groundwater. Excavation of the SEFRP floodway just 300 m from the wetland has the potential to affect local groundwater, and thus surface water hydrology and the wetland ecosystem. Permission to establish ecohydrological monitoring in wetland S0102503 has been sought from the landholder previously and not been granted. If access for monitoring is granted in the next one to two years, it is not too late to establish an ecological baseline against which to compare future monitoring and assess any impacts of the SEFRP upon this and adjacent wetlands. The full suite of parameters assessed under the SEFRP-initiated monitoring would be appropriate. If the site remains inaccessible, the area could be examined using the WOfS and vegetation mapping approaches utilised for other parts of the SEFRP study area.

7.2.3 Fishway assessment

The spatial coverage of fish monitoring sites within the SEFRP study area is likely sufficient to detect changes to the fish community of *en route* wetlands and drain habitats arising from the project. However, with the SEFRP installing fishways at the Salt Creek and Morella outlet regulators, improved fish movement between the Coorong and upstream habitats is a secondary objective of the project. When completed and operational, a targeted assessment of the effectiveness of these fishways is warranted. A one-off assessment during a period of fishway flows, ideally in spring when peak fish movement is anticipated, may be sufficient. If the assessment recommends changes to the design and/or operations of the fishways, follow up assessments may be required.

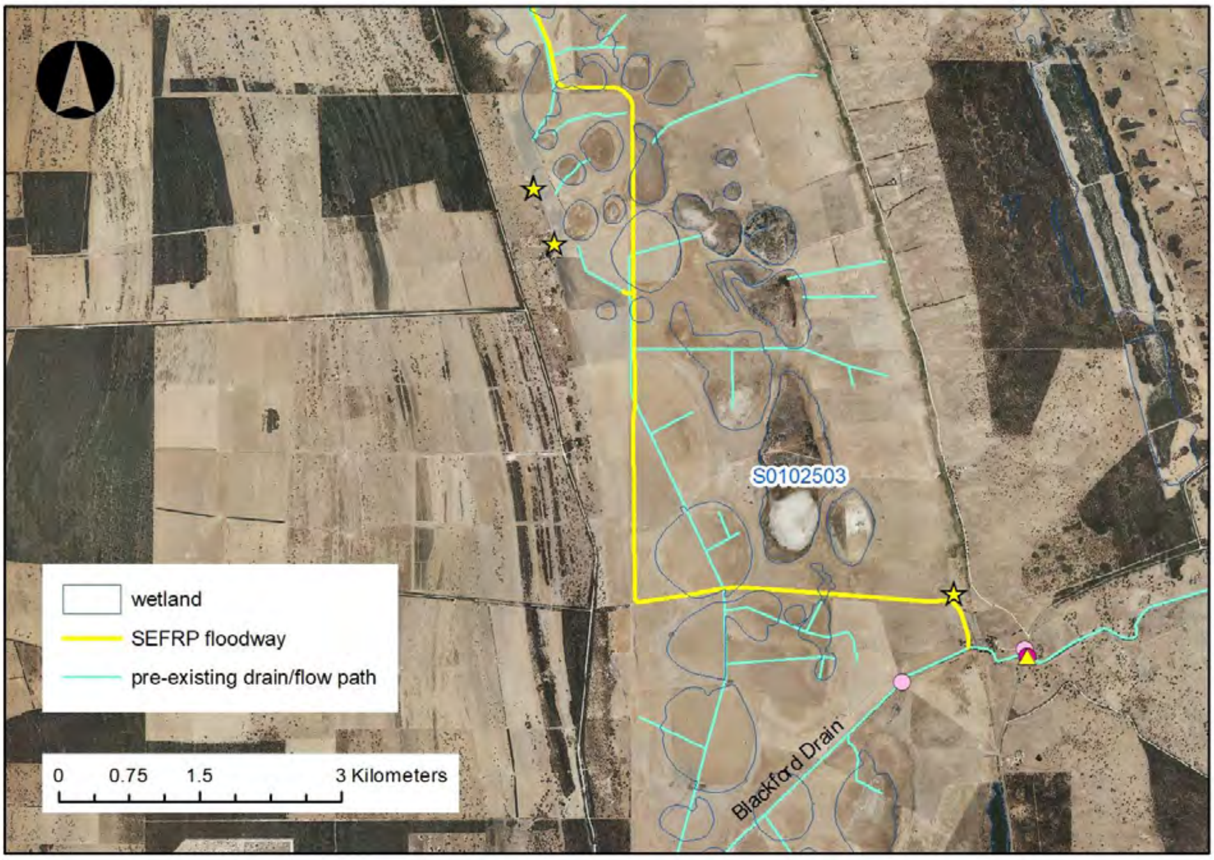


Figure 97 – Location of wetland S0102503. Monitoring parameter symbols are explained in preceding figures.

7.2.4 Weed surveillance

By increasing the catchment area for *en route* wetlands, the SEFRP may increase the risk of weed invasion via waterborne propagules from upstream infestations. Spiny Rush (*Juncus acutus*) is a species of particular concern, although there may be others. On-ground vegetation monitoring, in particular the SEFRP-initiated monitoring of transect and quadrats, but also including other approaches described above, is likely to detect the establishment of new weed species, or the proliferation of existing weeds, within *en route* wetlands should this occur. However, by the time such changes are detected within *en route* wetlands, weed invasion may be well advanced and the window of effective control or eradication may have closed.

Spiny Rush is known to occur within the SEFRP study area (Jacobs 2015) and was observed within the pre-existing Tilley Swamp Drain prior to its upgrade for the SEFRP (B. Taylor, pers. obs.). The species is also known to be present in the Blackford Drain catchment upstream of the SEFRP diversion regulator. The brackish, seasonally inundated *en route* wetlands of the SEFRP study area could provide ideal conditions for the proliferation of Spiny Rush. For this reason, a surveillance and control program is recommended. Surveillance should be prioritised as follows:

1. Channel edges of the SEFRP floodway immediately (0 – 1 km) upstream of diversion locations into *en route* wetlands.
2. Within *en route* wetlands where inlet channels give way to open wetland habitat without a clearly defined channel. Seeds may be deposited at such locations because flow velocity is likely to decrease.

3. The SEFRP floodway generally.
4. The emergent zone of *en route* wetlands generally. Spiny Rush is an emergent sedge that favours wetland margins.

Weed surveillance is recommended as an annually occurring element within the SEFRP monitoring program. Surveillance of *en route* wetlands can be reduced in years when diversions into these sites does not occur. Surveillance should be linked to a control program that targets emerging threats.

7.2.5 Hydrological monitoring infrastructure

The Cantara Road to Henry Creek Road section of the SEFRP study area is lacking surface water monitoring infrastructure within *en route* wetlands (Figure 94). A telemetered water level logger at the lowest point of Tilley Swamp Conservation Park would provide two benefits. Firstly, it would assist with real-time flow management and secondly, it would allow assessment of longer-term outcomes for this wetland reserve.

7.2.6 Groundwater monitoring

The SEFRP utilised 15 pre-existing observation wells to undertake a baseline groundwater monitoring program within the study area. This is an effective and efficient approach given that well installation is expensive and the pre-existing wells had historical data for comparison. However, the Taratap Road to Blackford Drain section of the SEFRP study area has a patchy spatial coverage of observation wells (Figure 96), yet groundwater impacts are possible in this section. Along most of its length the SEFRP floodway was created by widening but not deepening the existing Taratap and Tilley Swamp Drains. Modelling suggests that widening has minimal influence on adjacent groundwater levels, while deepening is more likely to cause groundwater decline (Morgan et al. 2011). Thus the Taratap Road to Blackford Drain section, where both widening and deepening occurred, may be more likely to exhibit groundwater decline than areas further north. Installation of additional observation wells within this section would improve spatial coverage and more effectively measure groundwater impacts, if they occur.

Groundwater data collected during long-term monitoring of these wells under the SEFR project and the previous USE program is currently held at the SEDB office, and represents a highly useful resource when evaluating the response of wetlands to the changes enacted by the SEFR project. Detailed analysis of the dataset could further clarify links between groundwater and wetland inundation in SEFRP en-route wetlands.

7.3. *Monitoring Recommendations*

Program	Parameter	Sites	Frequency	Last Completed	Next Due	Comments	Priority
SEFRP-initiated monitoring	waterbirds	14 existing 2 new (south of Cantara Rd)	Annual	2017	2019	Low cost, high community interest, high likelihood of change due to SEFRP in Tilley Swamp Watercourse, moderately reliable ecological indicator. Includes water depth at time of monitoring.	high
	vegetation transects	18 existing	1 year in 3	2016	2019	Moderate cost, high likelihood of change due to SEFRP in Tilley Swamp Watercourse, very reliable ecological indicator.	high
	vegetation quadrats	18 existing	1 year in 3	2016	2019	Low cost, high likelihood of change due to SEFRP in Tilley Swamp Watercourse, very reliable ecological indicator. Includes water parameters at time of monitoring (depth, EC, pH).	high
	fish	14 existing	1 year in 3	2017	2020	Moderate cost, moderate likelihood of change due to SEFRP, moderately reliable ecological indicator. Includes water parameters at time of monitoring (depth, EC, pH).	moderate
	frogs	20 existing	1 year in 5	2016	2021	Low cost, moderate likelihood of change due to SEFRP, poor-moderately reliable ecological indicator in SEFRP study area (brackish to saline habitat, low natural frog diversity and abundance). Includes water parameters at time of monitoring (depth, EC, pH).	low
USE Program monitoring	vegetation transects (parallel with drain)	Tilley Swamp CP site	1 year in 10	2002	2019	Moderate cost, informative of past effects of Tilley Swamp drain, low-moderate likelihood of change due to SEFRP	low
	bird transects (parallel with drain)	Tilley Swamp CP site	1 year in 10	2002	2019	Moderate cost, informative of past effects of Tilley Swamp drain, low-moderate likelihood of change due to SEFRP. Assesses habitat rarely monitored for birds.	moderate
	Vegetation transects (fans within wetlands)	Stoneleigh Park and Tilley Swamp CP sites	1 year in 3	Stoneleigh Park 2000 Tilley Swamp CP 2014	2019	Moderate cost, high likelihood of change due to SEFRP, very reliable ecological indicator. Complimentary to SEFRP Initiated Monitoring, but with longer-term dataset.	moderate

Program	Parameter	Sites	Frequency	Last Completed	Next Due	Comments	Priority
		Morella Basin east and Morella Basin west	1 year in 10	2000	2019	Moderate cost, moderate likelihood of change due to SEFRP, very reliable ecological indicator. These sites have become more aquatic under the USE Program, but depth and duration of inundation may increase again under the SEFRP. Complimentary to SEFRP Initiated Monitoring, but with longer-term dataset.	moderate
Biological Survey of Tilley Swamp	birds	7 sites	annual	1996	2019	Complementary to SEFRP-initiated monitoring, but with longer-term dataset.	moderate
Vegetation Mapping	vegetation	Entire study area	1 year in 10	2015 (image used in this report)	2025	Moderate cost, moderate to high likelihood of change due to SEFRP, very reliable ecological indicator at appropriate spatial and temporal scales. Could use Biological Survey of Tilley Swamp and Jacobs BushRAT sites for ground truthing.	high
Hydrological Monitoring Infrastructure	Surface water level, flow rate, water quality	4 existing 3+ new Additional in Tilley Swamp CP recommended	hourly	n/a	n/a	High cost, direct measure of hydrological effectiveness of SEFRP. No recommendation required: existing sites will be maintained and new sites will be installed under the SEFRP. Also important for real-time operation.	high
Groundwater Monitoring	Groundwater depth and salinity	15 existing	monthly	ongoing	ongoing	Moderate cost, measure of effect (if any) of SEFRP upon groundwater. Baseline (pre-SEFRP) data collected since April 2016. Should be continued for 2-3 years of SEFRP operation.	high
Water Observations from Space	Surface water extent	Entire study area, with hydrographs determined at 3 sites	1 year in 10 (hydrographs determined)	2018	2028	Low cost, direct measure of hydrological effectiveness of SEFRP at a broad spatial and temporal scale. Partly addressed with greater accuracy by Hydrological Monitoring Infrastructure.	moderate
Fishway Assessment	Fish movement	Salt Creek, Morella Basin	Once-off	n/a	2019	Low cost, once-off assessment of new SEFRP fishways.	high
Weed Surveillance	Key pest plant presence/absence	Entire study area, particularly drains	annual	n/a	2019	Low cost but potentially highly effective measure to protect ecological values of *en route* wetlands.	high

8. Conclusion

The Taratap and Tilley Swamp watercourses represent large and important areas of remnant vegetation and wetlands in a key biodiversity area of the South East of SA (Croft, Carruthers et al. 1999). While the area has undergone significant change since European settlement, it retains high remnancy of vegetation and wetlands – and restoration potential – in a region that has otherwise been extensively drained and cleared.

Many other parts of the South East offer few options for hydrological restoration, however the proximity of drains channelling water from watercourses to the east and south of the Taratap and Tilley Swamp watercourses offers the possibility – via the SEFRP – of delivering a substantial increase in environmental flows to a system that once channelled a large proportion of the surface water that moved slowly northward across the South East.

Although the SEFRP is designed with the primary goal of delivering additional flows to the south lagoon of the Coorong, an important secondary objective is to bring ecohydrological benefits to *en route* wetlands of the Taratap and Tilley Swamp watercourses. Increased frequency, depth and duration of inundation are anticipated to cause a reversal of terrestrialisation in a number of wetlands, ultimately increasing the diversity and abundance of wetland-dependent biota. With significant ecological change on the horizon, this represents a timely opportunity to form a pre-SEFRP baseline.

Data collected to date demonstrate the watercourses to be ecologically complex, with large areas of remnant vegetation and wetland providing habitat for diverse taxa, including a number of threatened species. SEFRP-initiated monitoring has recorded diverse and breeding waterbird populations and habitat for native fish, and the drainage system provides connectivity in a largely drained and fragmented aquatic landscape, offering some opportunity for dispersal under suitable conditions.

Vegetation monitoring has shown the watercourses to be subject to profound drainage-related vegetation change within wetlands, with an ongoing terrestrialisation process in wetland basins that is detectable in the earliest two sets of historic aerial imagery available, from 1954 to 1966. Analysis of historic imagery revealed a reduction in open wetland habitat in 2013 to less than half of what it was in 1954, and the dense vegetation category increased more than seven-fold in that time, demonstrating a progression towards completion of the terrestrialisation process. This trend has been verified on-ground in transect and quadrat-based vegetation monitoring, initiated in 2000 with the long term Tilley Swamp Drain monitoring program (Telfer, de Jong et al. 2000), and expanded in the more recent SEFRP-initiated vegetation monitoring, which takes in other *en route* wetlands such as Frostys Swamp.

Recent analysis of satellite imagery by Harding and Herpich (2018) shows that the hydrological drivers for vegetation change have intensified in parts of the watercourse since the construction of the Tilley Swamp Drain in 1999. In the example of Frostys Swamp, which prior to construction received inundation in 8 out of 12 years for which data are available, the drain has effectively prevented any subsequent inundation. In contrast, the same drain has increased the effective catchment of the Tilley Swamp CP wetland and contributed to it receiving inundation every year since the end of the drought in 2009, although inundation has not been sufficient to reverse terrestrialisation in the wetland basin that was exacerbated by the regeneration process that has occurred since a bushfire in 2014. This highlights the difficulty of reversing terrestrialisation once it has taken hold.

The ecohydrological data recorded across a range of past monitoring projects, including the recent SEFRP-initiated monitoring, represent a sufficient baseline for detecting future change in the watercourses. Maintenance of the current monitoring program, with some minor additions as outlined, would allow a thorough ecohydrological assessment of the SEFRP, and guide future management decisions in order to maximise ecohydrological outcomes.

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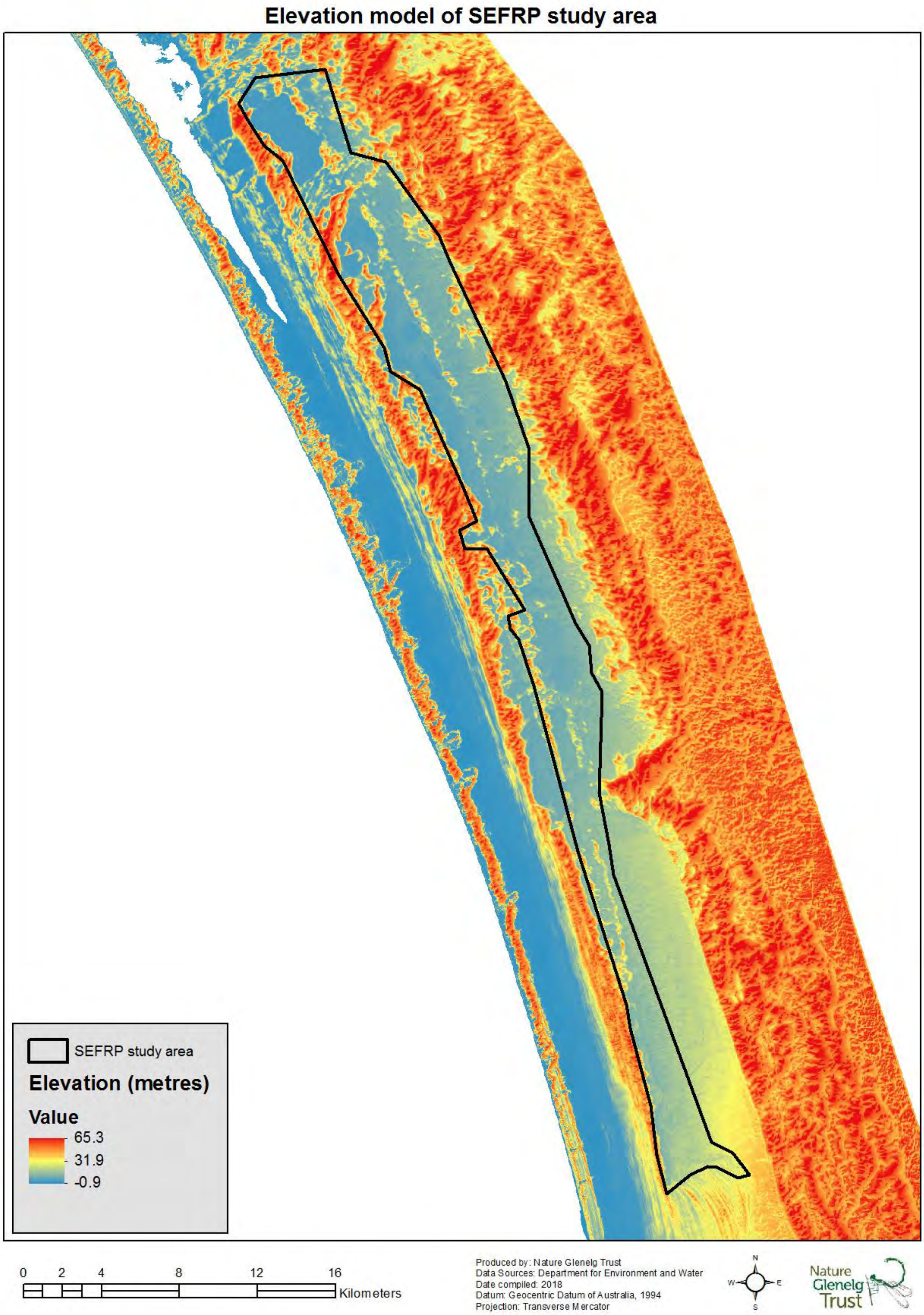
10. Appendices

10.1. *SEFRP study area elevation model*



10.2. *Historic aerial photograph mosaics*

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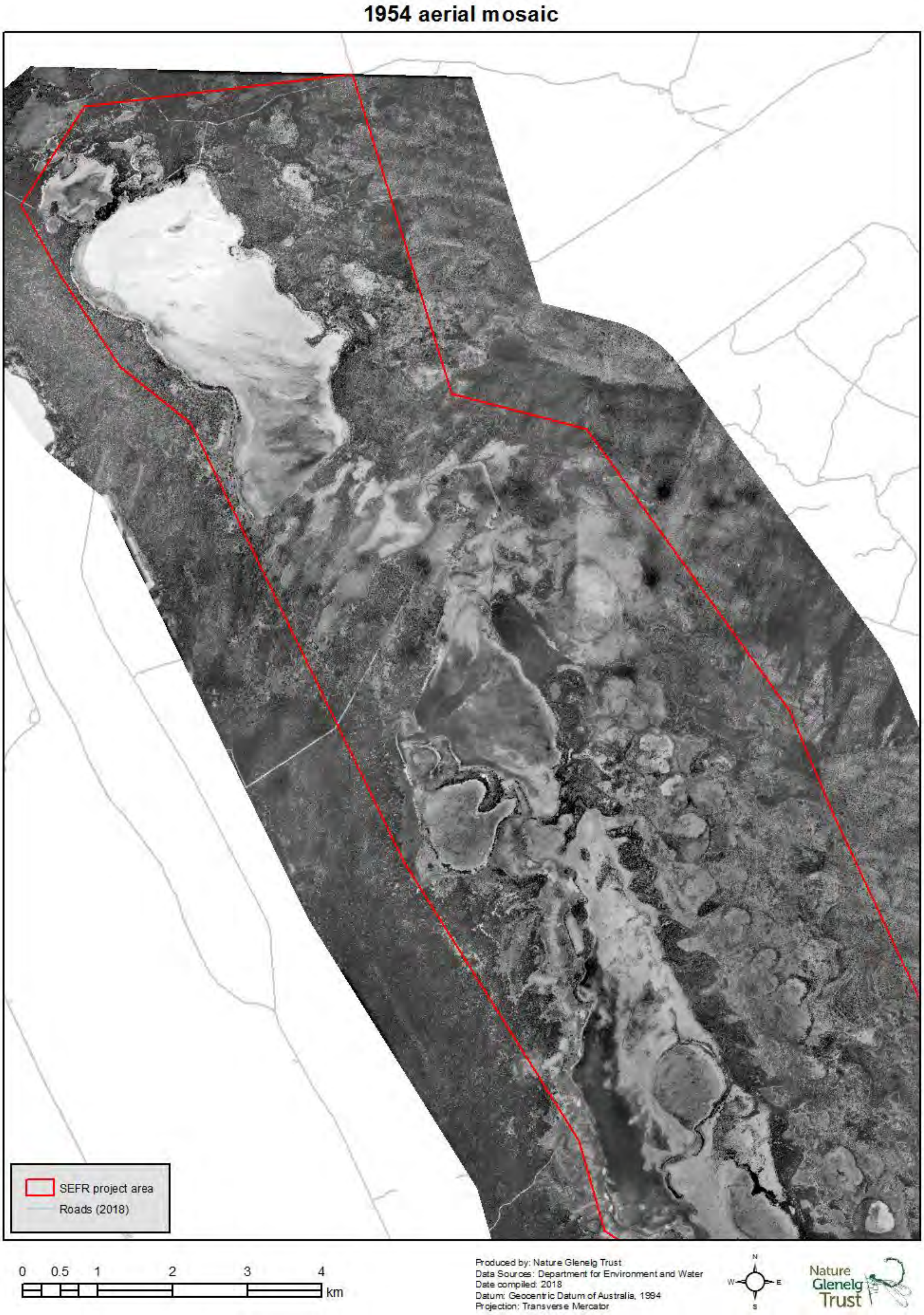

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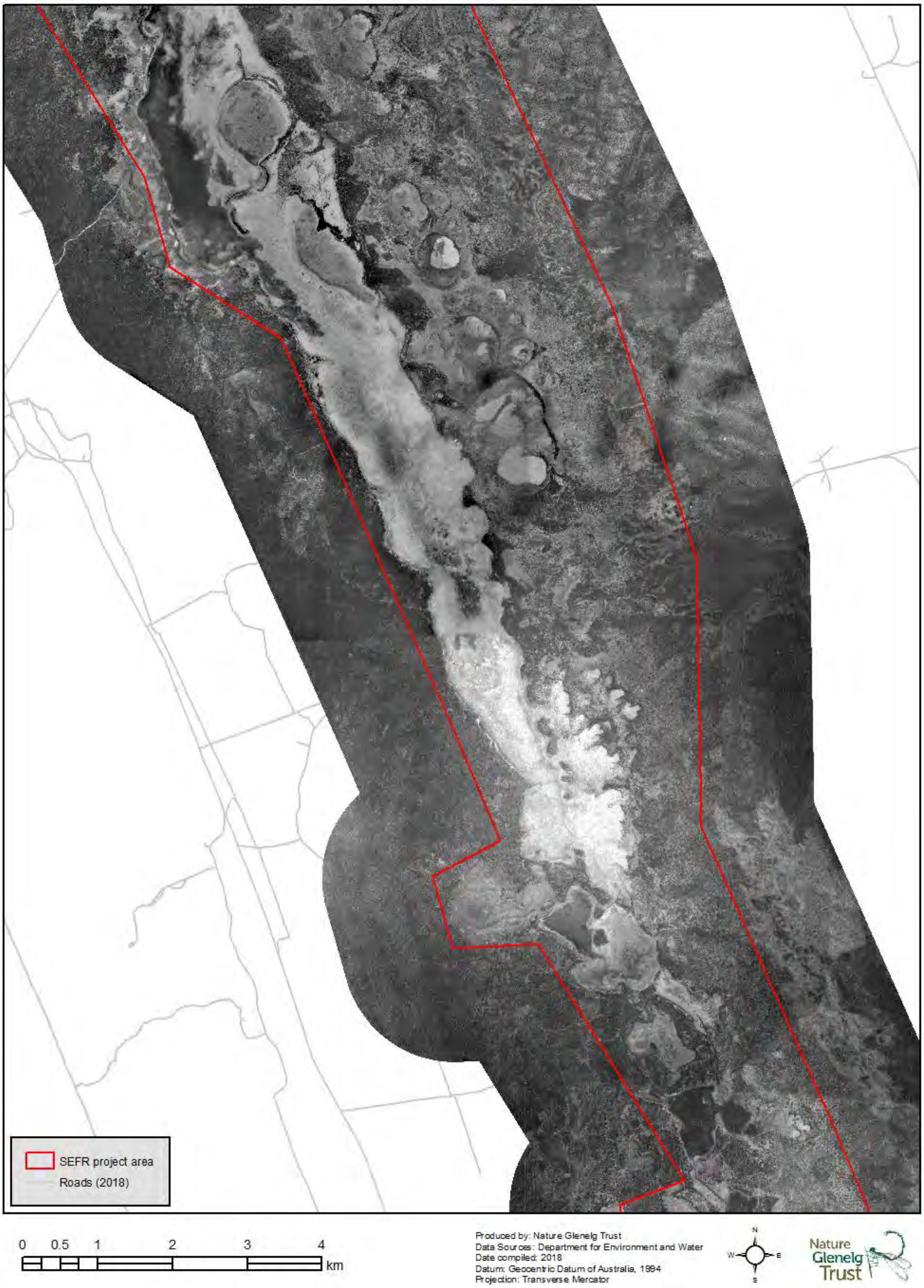
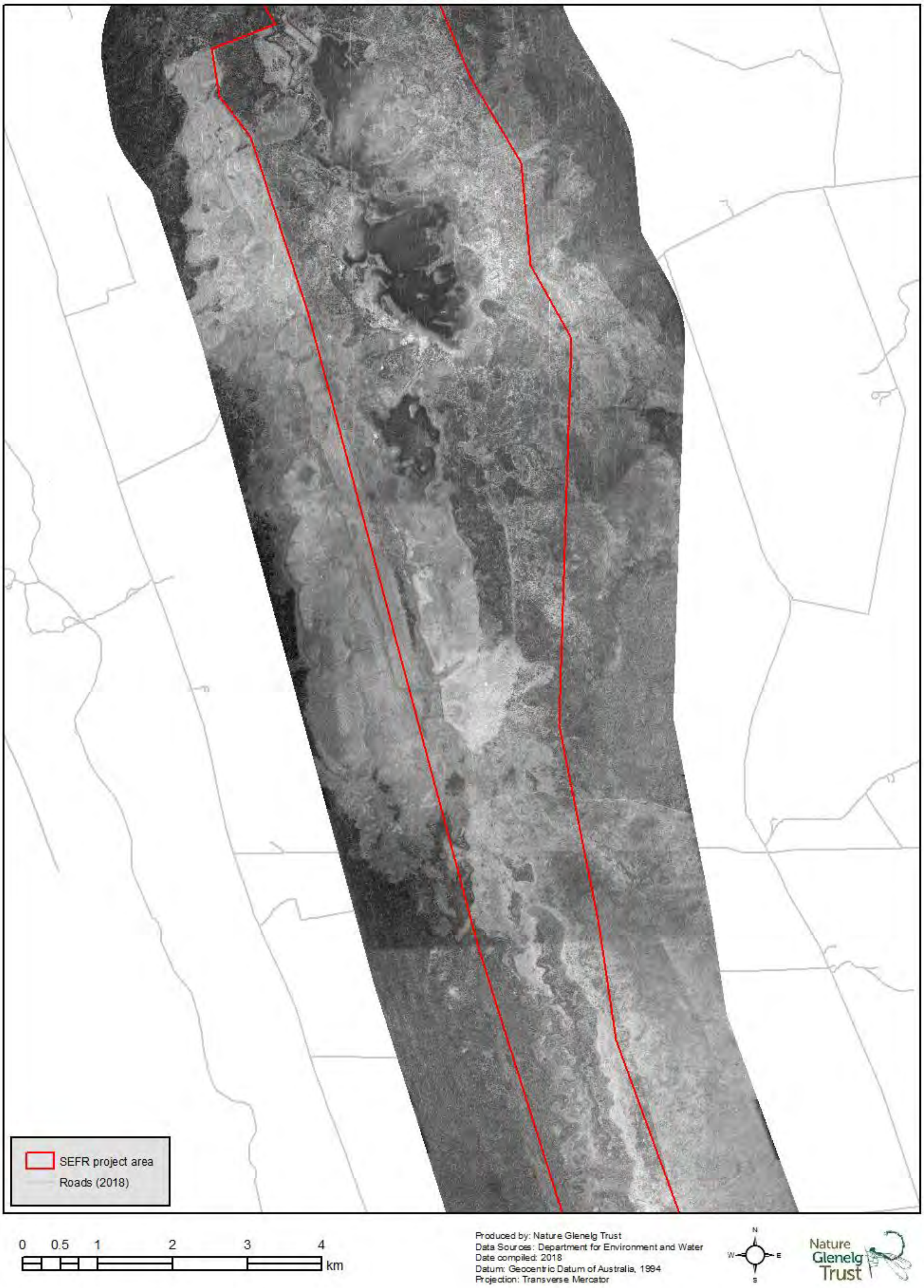


1954 aerial mosaic




1954 aerial mosaic
SEFR project area
Roads (2018)
0 0.5 1 2 3 4
km
Produced by: Nature Glenelg Trust
Data Sources: Department for Environment and Water
Date compiled: 2018
Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
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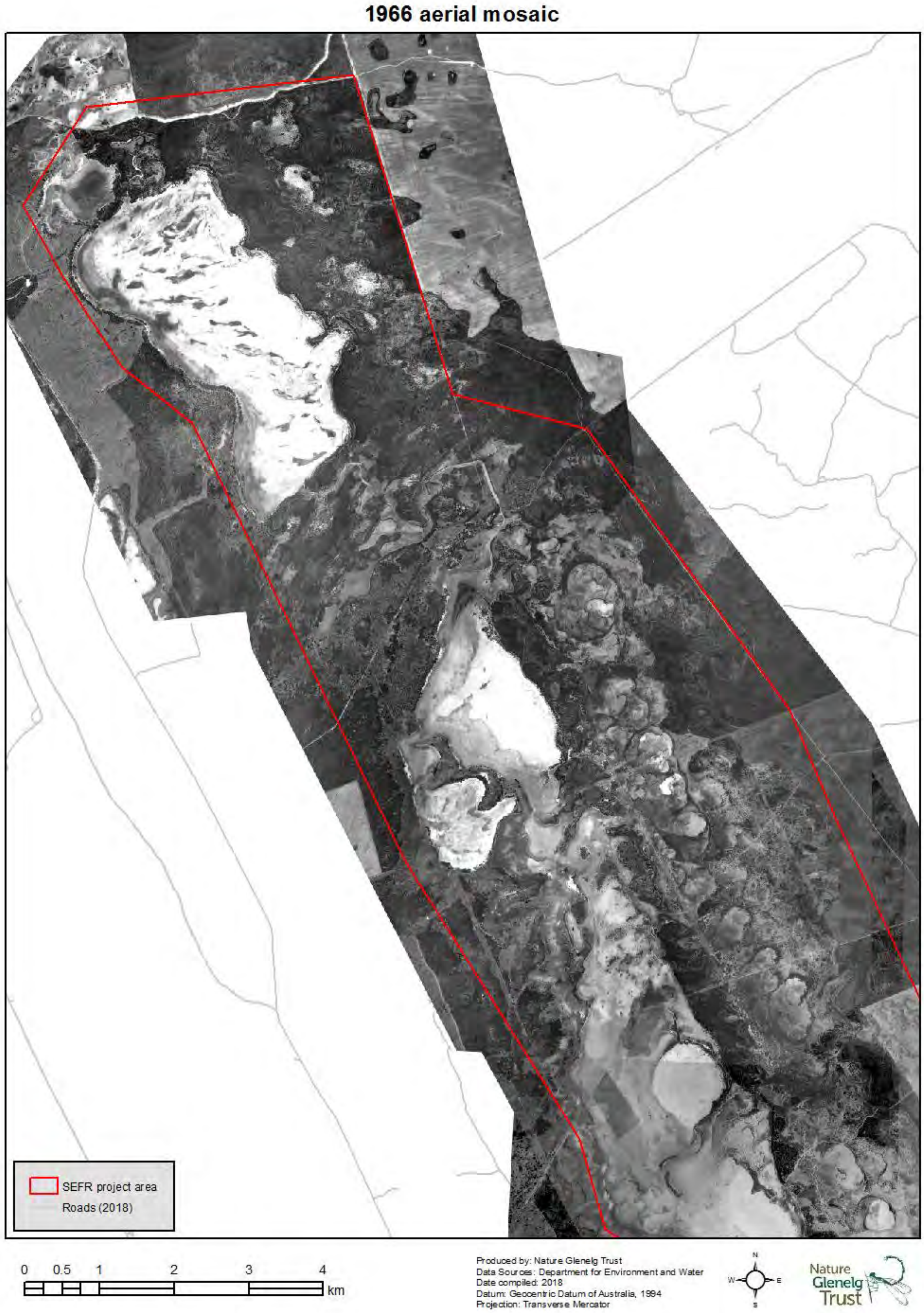
Nature Glenelg Trust

10.2.2 1966


1966 aerial mosaic
SEFR project area
Roads (2018)
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Produced by: Nature Glenelg Trust
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Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
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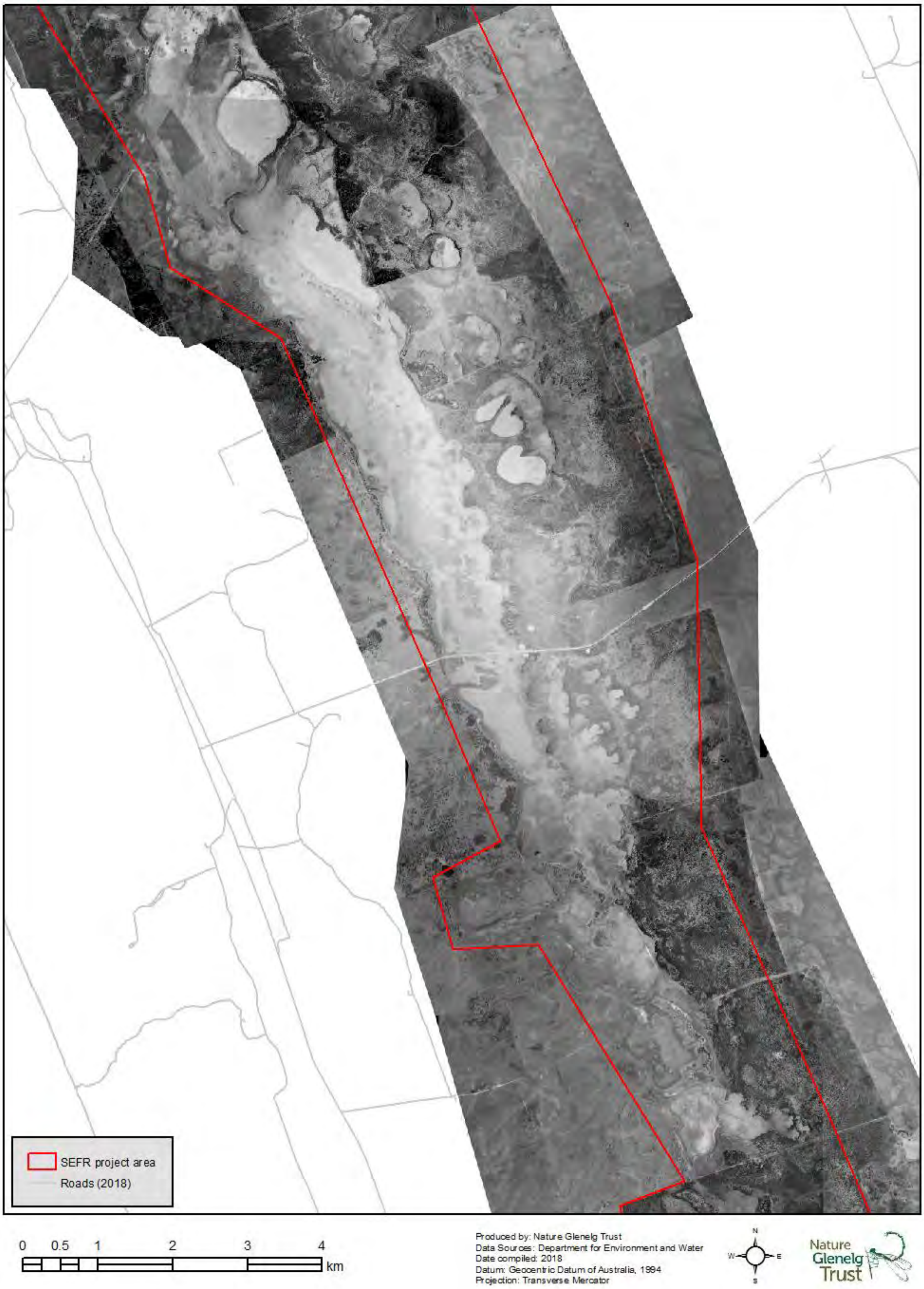
Nature Glenelg Trust

1966 aerial mosaic




1966 aerial mosaic
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Roads (2018)
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Produced by: Nature Glenelg Trust
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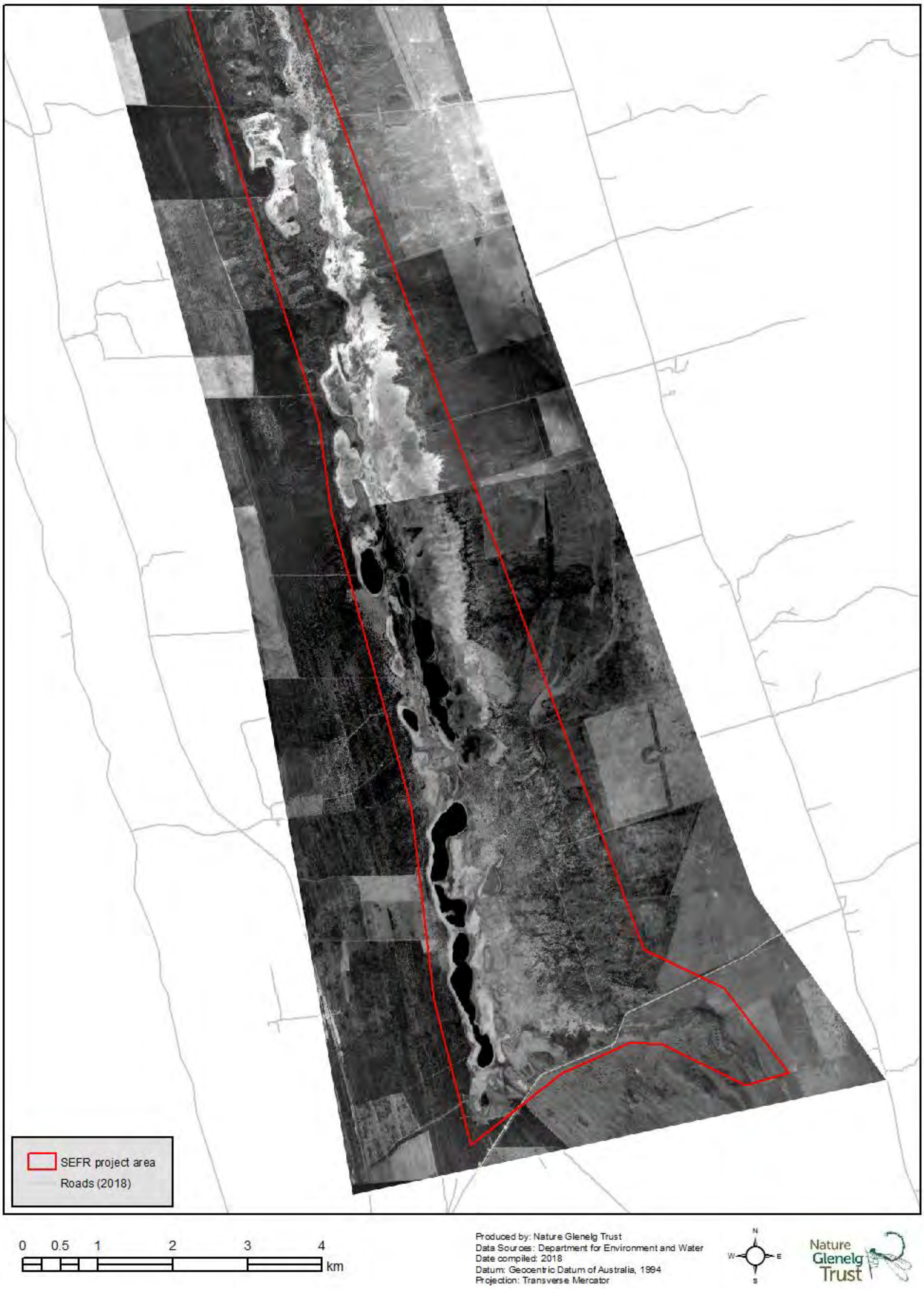
1966 aerial mosaic



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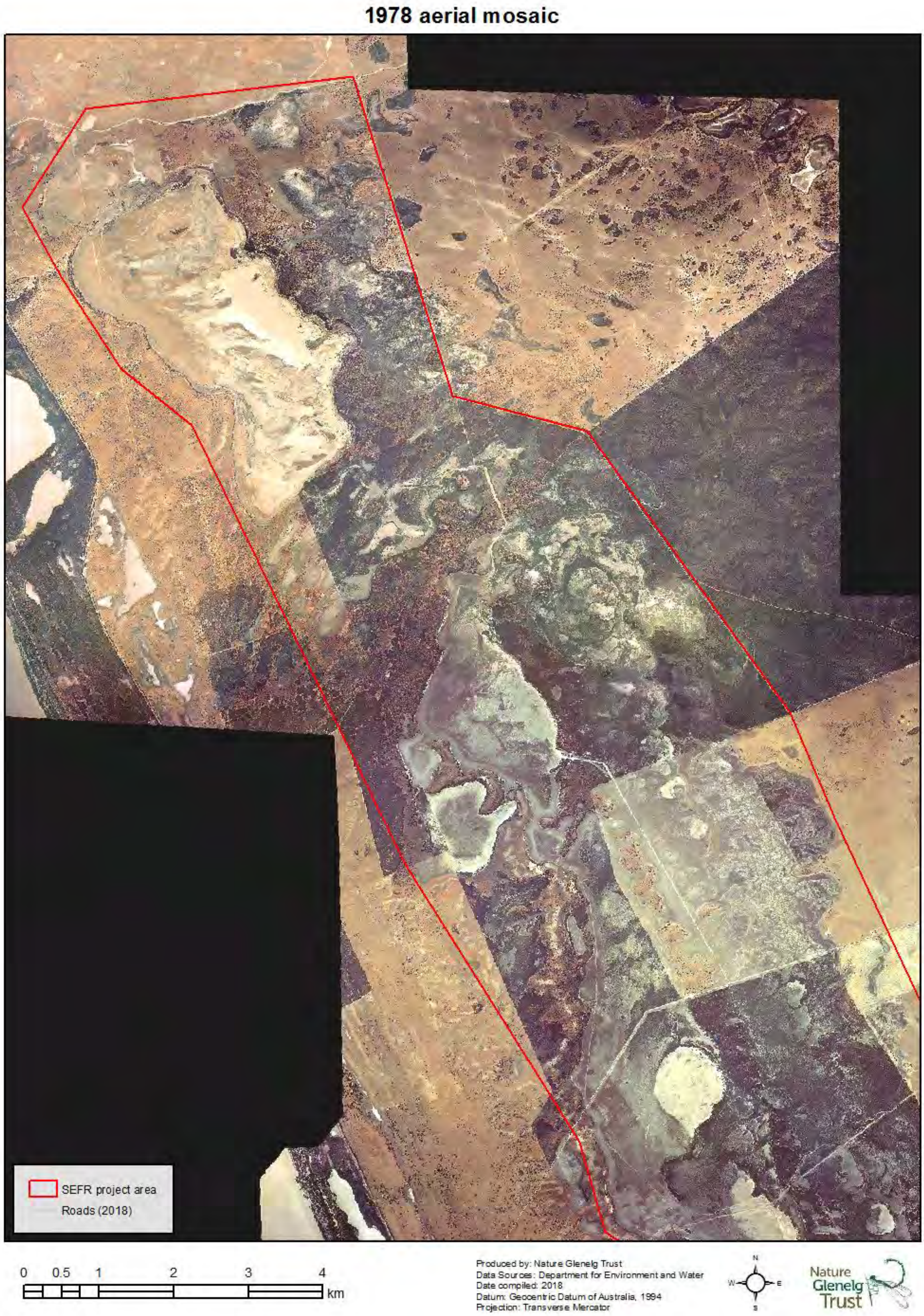
1978 aerial mosaic
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km
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Data Sources: Department for Environment and Water
Date compiled: 2018
Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
Nature Glenelg Trust


1978 aerial mosaic
SEFR project area
Roads (2018)
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km
Produced by: Nature Glenelg Trust
Data Sources: Department for Environment and Water
Date compiled: 2018
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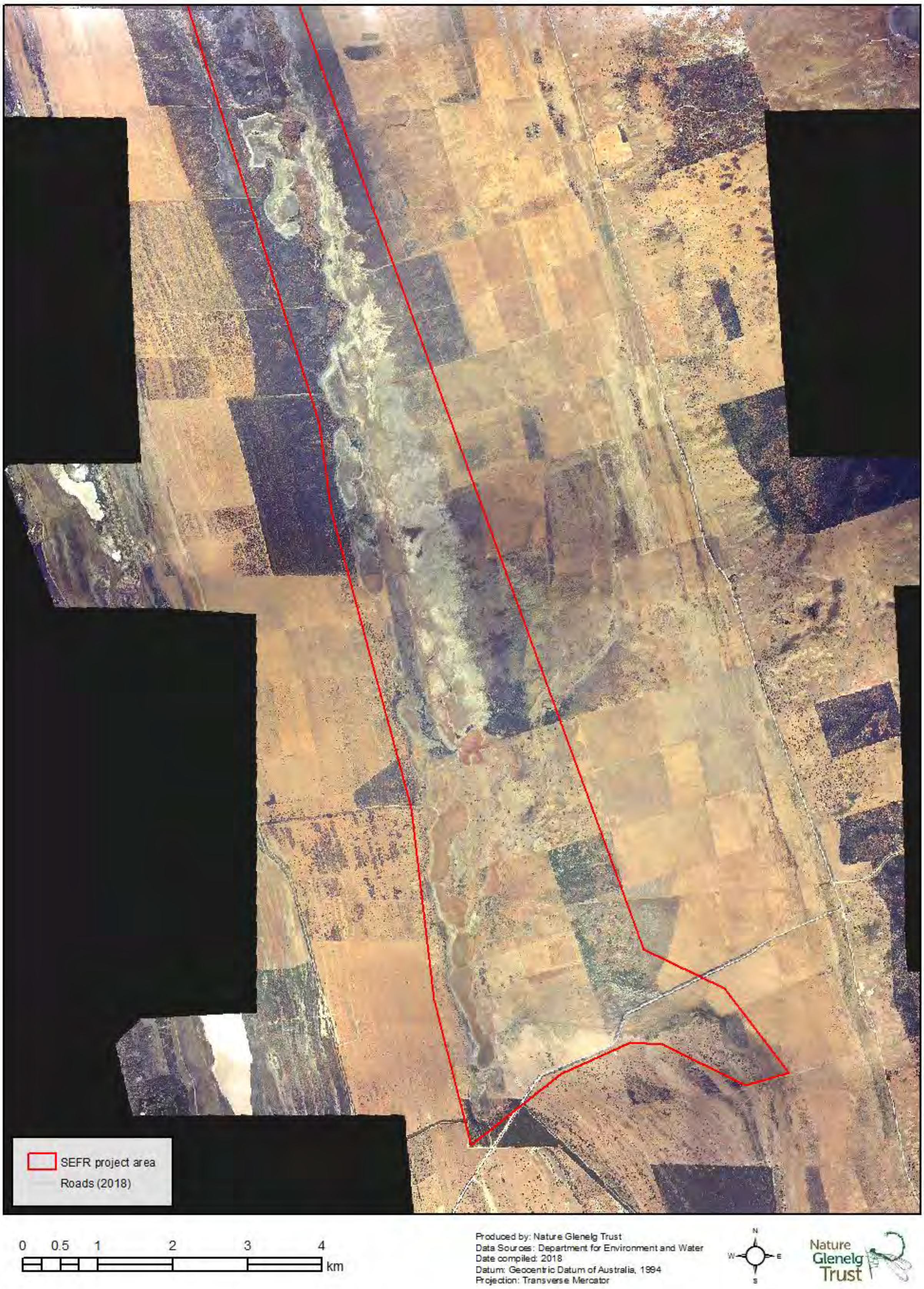
Nature Glenelg Trust

1978 aerial mosaic

1978 aerial mosaic



10.2.4 1987


1987 aerial mosaic
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km
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Data Sources: Department for Environment and Water
Date compiled: 2018
Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
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Nature Glenelg Trust


1987 aerial mosaic
SEFR project area
Roads (2018)
0 0.5 1 2 3 4
km
Produced by: Nature Glenelg Trust
Data Sources: Department for Environment and Water
Date compiled: 2018
Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
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Nature Glenelg Trust


1987 aerial mosaic
SEFR project area
Roads (2018)
0 0.5 1 2 3 4
km
Produced by: Nature Glenelg Trust
Data Sources: Department for Environment and Water
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Projection: Transverse Mercator
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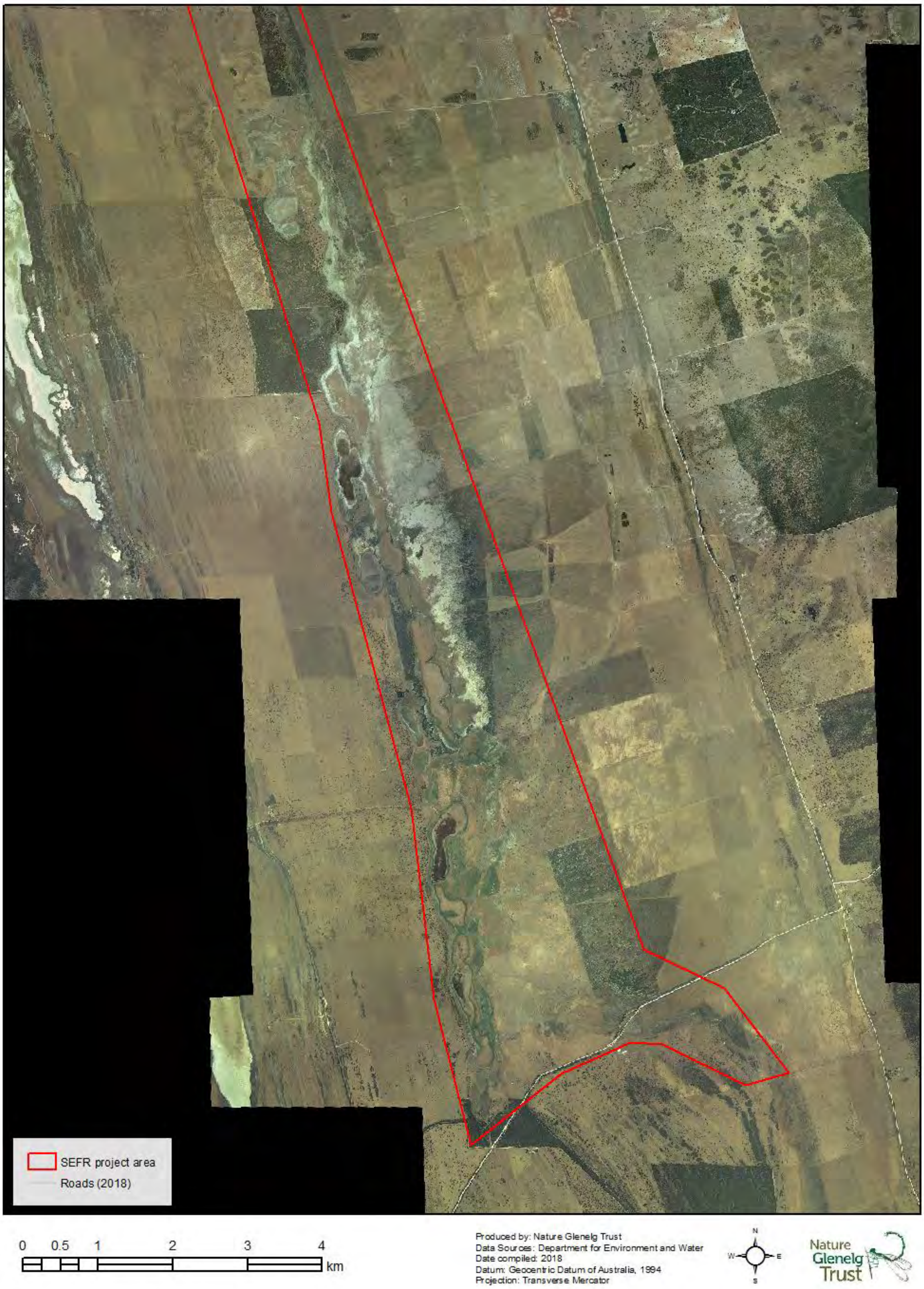
1987 aerial mosaic



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Projection: Transverse Mercator

Nature Glenelg Trust

10.2.5 1999


1999 aerial mosaic
SEFR project area
Roads (2018)
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Produced by: Nature Glenelg Trust
Data Sources: Department for Environment and Water
Date compiled: 2018
Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
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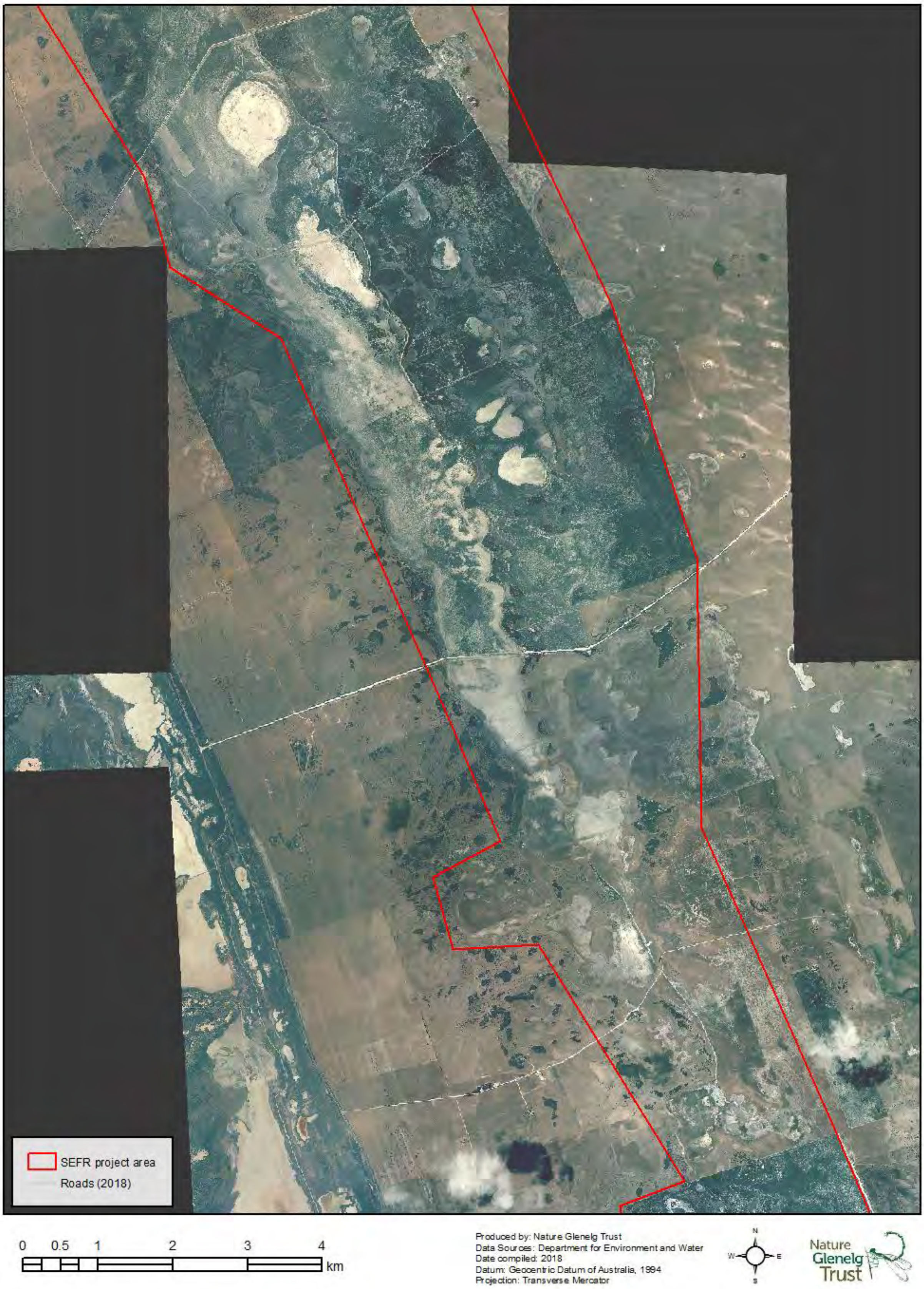
Nature Glenelg Trust

9

1999 aerial mosaic



1999 aerial mosaic

1999 aerial mosaic

10.2.6 2013


2013 aerial mosaic
SEFR project area
Roads (2018)
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km
Produced by: Nature Glenelg Trust
Data Sources: Department for Environment and Water
Date compiled: 2018
Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
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Nature Glenelg Trust

2013 aerial mosaic


2013 aerial mosaic
SEFR project area
Roads (2018)
0 0.5 1 2 3 4
km
Produced by: Nature Glenelg Trust
Data Sources: Department for Environment and Water
Date compiled: 2018
Datum: Geocentric Datum of Australia, 1994
Projection: Transverse Mercator
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Nature Glenelg Trust

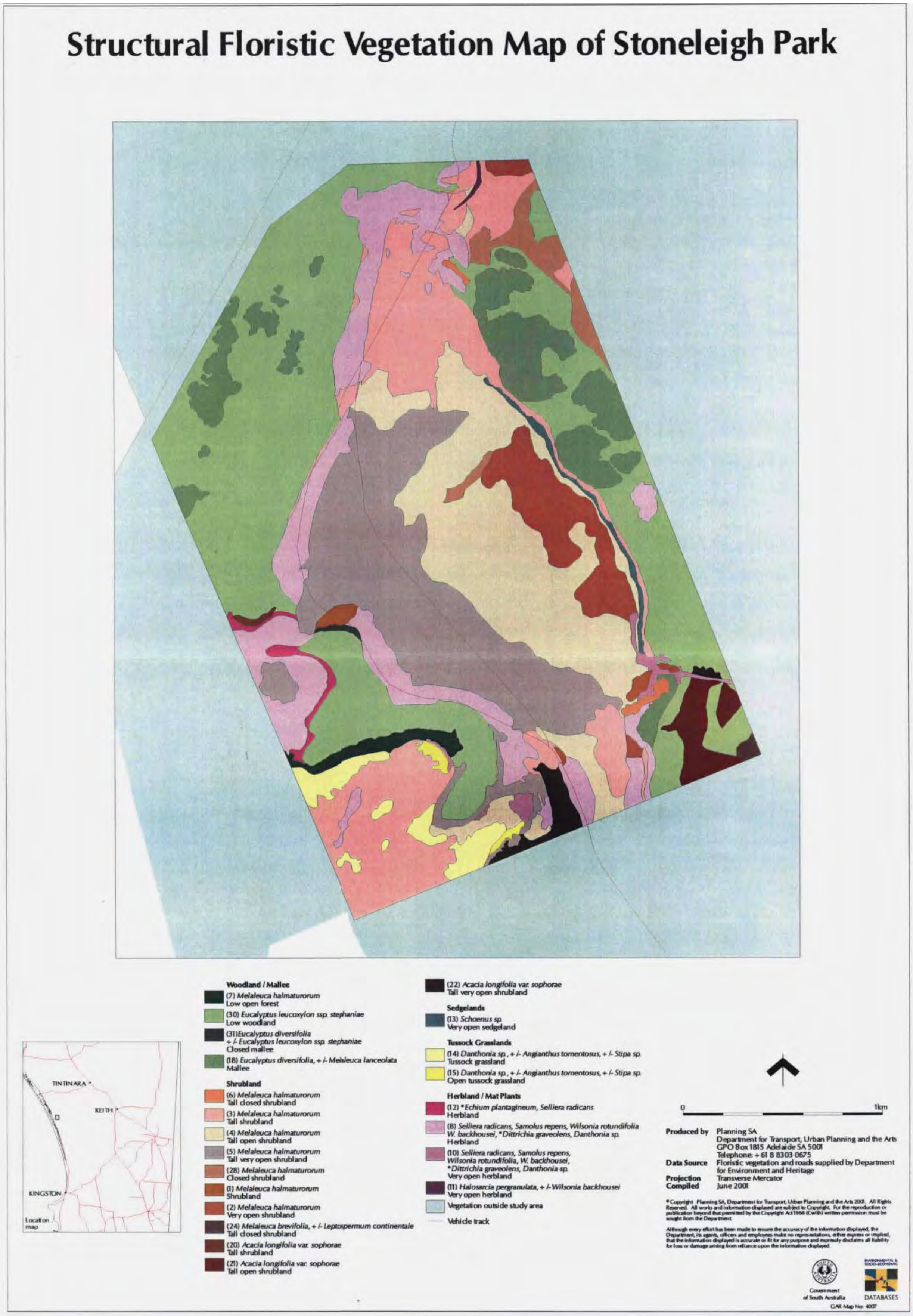
2013 aerial mosaic

10.3. *Rated wetlands within or partially within the SEFRP study area*

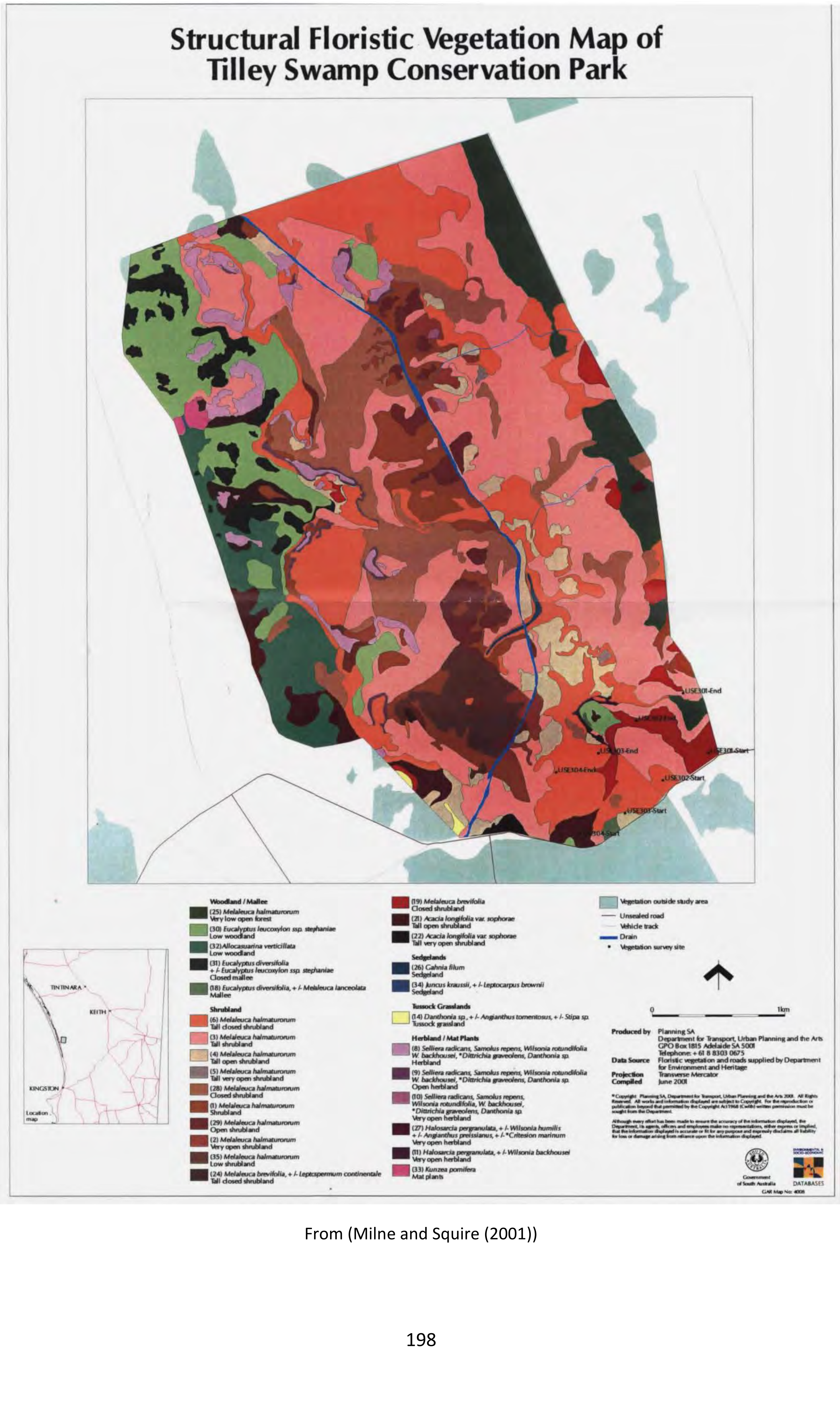
Source: South Australian Wetland Inventory Database (SAWID)

Wetland ID	Name	Complex	Size (Ha)	Inundation regime	Optimum inundation	Water quality / salinity (µs/cm)	Wetland Vegetation Components (WVCs)	Ecological value rating
S0100038	Morella Basin	Morella Basin	858.4	Permanent	8 months inundation	Slightly brackish/saline 2700-20000	1.1, 1.4, 1.12, 2.15	Very high
S0100052	Martin Washpool	Martin Washpool	263.7	Intermittent	6 months inundation	Brackish/saline 2700-20000	1.3, 1.4, 1.8, 1.9	High
S0100054	Tilley Swamp (Frostys Swamp)	Tilley Swamp	503.3	Seasonal	6 months inundation	Brackish/saline 6500-20000	1.3, 1.4, 1.8, 1.9, 1.12	Moderate
S0100075	Tilley Swamp	Tilley Swamp	1440.0	Seasonal	6 months inundation	Brackish/saline 6500-20000	1.3, 1.4, 1.8, 1.12	High
S0100115	Tilley Swamp	Tilley Swamp	417.0	Seasonal	6 months inundation	No data	-	Moderate
S0100146	Tilley Swamp	Tilley Swamp	1077.5	Seasonal	6 months inundation	Brackish/saline 6500-20000		Very high
S0100159	Tilley Swamp CP	Tilley Swamp	554.0	Seasonal	6 months inundation	Brackish/saline 2500-20000	1.3, 1.4, 1.8, 1.12	Moderate
S0100176			274.6	Seasonal	6 months inundation	No data	-	Low
S0100197	Pateanbury Swamp		60.5	Seasonal	< 4 months inundation	No data	-	Low
S0100200			10.1	Seasonal	< 4 months inundation	No data	-	Low
S0100205	Varcoe Wetland		33.1	Seasonal	< 4 months inundation	No data	-	High
S0100209			26.9	Seasonal	< 4 months inundation	No data	-	Moderate
S0100213			15.5	Seasonal	< 4 months inundation	No data	-	Low
S0100227	Yeulba Swamp	Yeulba	24.8	Seasonal	< 4 months inundation	Brackish 2500-10000	-	Moderate
S0100230	Yeulba Swamp	Yeulba	12.1	Seasonal	< 4 months inundation	Brackish 2500-10000	-	Low
S0100236	Yeulba Swamp	Yeulba	35.1	Seasonal	6 months inundation	Brackish 2500-10000	-	Moderate
S0101573			72.5	Artificially dry	6 months inundation	No data	-	Low
S0104731	Tilley Swamp	Tilley Swamp	75.7	Seasonal	No data	No data	1.8, 2.15 (both unverified)	Moderate
S0105053		Martin Washpool	248.6	Intermittent	No data	No data	1.3, 1.4	Very high
S0111141	Sandys Hut Lake		3.6	Seasonal	6 months inundation	Brackish 2500-10000	-	Moderate
S0111143			82.2	Seasonal	No data	Brackish 2500-10000	-	High
S0111144			5.6	Seasonal	No data	Brackish 2500-10000	-	Moderate
S0111148	Reedy Creek Floodplain		57.8	Intermittent	No data	No data	-	Moderate
S0111150	Reedy Creek Floodplain		763.4	Seasonal	6 months inundation	Brackish 2500-10000	-	High
S0111151	Tilley Swamp Floodplain	Tilley Swamp	202.1	Intermittent	No data	No data	-	Moderate
S0111505	Tilley Swamp	Tilley Swamp	1467.4	Artificially dry	No data	No data	-	Moderate
S0111507	Tilley Swamp Floodplain	Tilley Swamp	3038.3	Intermittent	No data	No data	1.4, 1.8	Very high
S0111509	Tilley Swamp	Tilley Swamp	46.2	Intermittent	No data	No data	1.3, 1.4	High
S0111511		Martin Washpool	7.9	Intermittent	No data	No data	-	High

10.4. ***Detailed vegetation maps from previous surveys***



From Milne and Squire (2001)



From (Milne and Squire (2001))

10.5. *Detailed species lists*

10.5.1Flora of the SEFRP study area

Species	Common name	EPBC	NPWSA
Acacia acinacea	Wreath Wattle		
Acacia cupularis	Cup Wattle		
Acacia leiophylla	Coast Golden Wattle		
Acacia ligulata	Umbrella Bush		
Acacia longifolia ssp. *longifolia*	Sallow Wattle		
Acacia longifolia ssp. *sophorae*	Coastal Wattle		
Acacia melanoxylon	Blackwood		
Acacia myrtifolia	Myrtle Wattle		
Acacia paradoxa	Kangaroo Thorn		
Acacia pycnantha	Golden Wattle		
Acacia retinodes var.	Silver Wattle		
Acacia saligna	Golden Wreath Wattle		
Acacia spinescens	Spiny Wattle		
Acacia verticillata ssp. *ovoidea*	Prickly Moses		
Acaena agnipila var.	Downy Sheep's Burr		
Acaena echinata	Sheep's Burr		
Acaena novae-zelandiae	Biddy-biddy		
Acaena ovina var. *velutina*	Downy Sheep's Burr		
Acianthus caudatus	Mayfly Orchid		
Acianthus pusillus	Mosquito Orchid		
Acrotriche affinis	Ridged Ground-berry		
Acrotriche cordata	Blunt-leaf Ground-berry		
Acrotriche patula	Prickly Ground-berry		
Acrotriche serrulata	Cushion Ground-berry		
Actites megalocarpus	Coast Sow-thistle		
Adenanthos terminalis	Yellow Gland-flower		
Adriana klotzschii	Coast Bitter-bush		
Adriana quadripartita	Coast Bitter-bush		
Agrostis avenacea var.	Common Blown-grass		
Agrostis avenacea var. *avenacea*	Common Blown-grass		
Aira caryophyllea	Silvery Hair-grass		
Aira cupaniana	Small Hair-grass		
Aira elegantissima	Delicate Hair-grass		
Ajuga australis	Australian Bugle		
Allium ampeloprasum	Wild Leek		
Allocasuarina luehmannii	Bull Oak		
Allocasuarina mackliniana ssp. *mackliniana*	Macklin's Oak-bush		
Allocasuarina mackliniana ssp. *xerophila*	Macklin's Oak-bush		
Allocasuarina muelleriana ssp. *muelleriana*	Common Oak-bush		
Allocasuarina pusilla	Dwarf Oak-bush		
Allocasuarina verticillata	Drooping Sheoak		

Species	Common name	EPBC	NPWSA
Alopecurus myosuroides	Slender Fox-tail		
Alopecurus pratensis	Meadow Fox-tail		
Althenia cylindrocarpa	Long-fruit Water-mat		
Ammophila arenaria	Marram Grass		
Amphibromus macrorhinus	Long-nosed Swamp Wallaby-grass		
Amyema melaleucae	Tea-tree Mistletoe		
Amyema miquelii	Box Mistletoe		
Amyema pendula ssp. *pendula*	Drooping Mistletoe		
Anagallis arvensis	Pimpernel		
Anchusa arvensis	Bugloss		
Angianthus preissianus	Salt Angianthus		
Angianthus tomentosus	Hairy Angianthus		
Apalochlamys spectabilis	Showy Firebush		
Aphanes australiana	Australian Piert		
Apium annuum	Annual Celery		
Apium prostratum var.	Native Celery		
Apium prostratum var. *filiforme*	Native Celery		
Apium prostratum var. *prostratum*	Native Celery		
Apodasmia brownii	Coarse Twine-rush		
Arctotheca calendula	Cape Weed		
Argentipallium blandowskianum			
Argentipallium obtusifolium	Blunt Everlasting		
Arthropodium fimbriatum	Nodding Vanilla-lily		
Arthropodium strictum	Common Vanilla-lily		
Asparagus asparagoides	Bridal Creeper		
Asparagus asparagoides f. Western Cape (R.Taplin 1133)	Bridal Creeper		
Asphodelus fistulosus	Onion Weed		
Asterella drummondii			
Astroloma conostephioides	Flame Heath		
Astroloma humifusum	Cranberry Heath		
Atriplex paludosa ssp. *cordata*	Marsh Saltbush		
Atriplex paludosa ssp. *paludosa*	Marsh Saltbush		
Austrostipa curticoma	Short-crest Spear-grass		
Austrostipa drummondii	Cottony Spear-grass		
Austrostipa flavescens	Coast Spear-grass		
Austrostipa hemipogon	Half-beard Spear-grass		
Austrostipa macalpinei	Annual Spear-grass		
Austrostipa mollis	Soft Spear-grass		
Austrostipa mollis group	Soft Spear-grass		
Austrostipa mundula	Neat Spear-grass		
Austrostipa scabra ssp. *falcata*	Slender Spear-grass		
Austrostipa sp.	Spear-grass		
Austrostipa stipoides	Coast Spear-grass		
Austrostipa trichophylla			
Avellinia michelii	Avellinia		

Species	Common name	EPBC	NPWSA
Avena barbata	Bearded Oat		
Avena fatua	Wild Oat		
Avena sativa	Cultivated Oat		
Babingtonia behrii	Silver Broombush		
Baeckea crassifolia	Desert Baeckea		
Banksia marginata	Silver Banksia		
Banksia ornata	Desert Banksia		
Bartsia trixago			
Baumea arthrophylla	Swamp Twig-rush		
Baumea juncea	Bare Twig-rush		
Bellardia latifolia	Red Bartsia		
Beyeria lechenaultii	Pale Turpentine Bush		
Billardiera cymosa ssp. *cymosa*	Sweet Apple-berry		
Billardiera scandens var. *scandens*	Eastern Apple-berry		R
Billardiera sericophora	Silky Apple-berry		
Blackstonia perfoliata	Yellow-wort		
Blennospora drummondii	Dwarf Button-flower		
Bolboschoenus caldwellii	Salt Club-rush		
Boronia coerulescens ssp. *coerulescens*	Blue Boronia		
Boronia filifolia	Slender Boronia		
Bossiaea prostrata	Creeping Bossiaea		
Bovista brunnea			
Brachycome debilis	Weak Daisy		
Brachyloma ciliatum	Fringed Brachyloma		
Brachyscome ciliaris var.	Variable Daisy		
Brachyscome cuneifolia	Wedge-leaf Daisy		
Brachyscome debilis	Weak Daisy		
Brachyscome exilis	Slender Daisy		
Brachyscome goniocarpa	Dwarf Daisy		
Brachyscome graminea	Grass Daisy		
Brachyscome lineariloba	Hard-head Daisy		
Brachyscome perpusilla	Tiny Daisy		
Brassica napus	Coleseed		
Brassica tournefortii	Wild Turnip		
Briza minor	Lesser Quaking-grass		
Bromus diandrus	Great Brome		
Bromus hordeaceus ssp. *hordeaceus*	Soft Brome		
Bromus madritensis	Compact Brome		
Bromus rubens	Red Brome		
Brunonia australis	Blue Pincushion		
Bulbine semibarbata	Small Leek-lily		
Bupleurum semicompositum	Hare's Ear		
Burchardia umbellata	Milkmaids		
Bursaria spinosa ssp. *spinosa*	Sweet Bursaria		
Caesia calliantha	Blue Grass-lily		

Species	Common name	EPBC	NPWSA
Cakile maritima ssp. *maritima*	Two-horned Sea Rocket		
Caladenia calcicola	Limestone Spider-orchid	VU	E
Caladenia cardiochila	Heart-lip Spider-orchid		
Caladenia carnea	Pink Fingers		
Caladenia carnea complex	Pink Fingers Caladenia		
Caladenia dilatata	Late Spider-orchid		E
Caladenia latifolia	Pink Caladenia		
Caladenia necrophylla	Late Spider-orchid		R
Caladenia ornata	Ornate Pink Fingers	VU	E
Caladenia patersonii complex	White Spider-orchid		
Caladenia prolata	Shy Caladenia		
Caladenia reticulata	Veined Spider-orchid		
Caladenia richardsiorum	Little Dip Spider-orchid	EN	E
Caladenia X cardiochila x reticulata	Hybrid Spider-orchid		
Calandrinia calyptrata	Pink Purslane		
Calandrinia eremaea	Dryland Purslane		
Calandrinia granulifera	Pigmy Purslane		
Callistemon rugulosus var. *rugulosus*	Scarlet Bottlebrush		
Calytrix alpestris	Snow Heath-myrtle		
Calytrix tetragona	Common Fringe-myrtle		
Carduus tenuiflorus	Slender Thistle		
Carpobrotus modestus	Inland Pigface		
Carpobrotus rossii	Native Pigface		
Carpobrotus sp.	Pigface		
Cassytha glabella f. dispar	Slender Dodder-laurel		
Cassytha melantha	Coarse Dodder-laurel		
Cassytha pubescens	Downy Dodder-laurel		
Caustis pentandra	Thick Twist-rush		
Centaurea melitensis	Malta Thistle		
Centaurea sp.	Centaury		
Centaurium erythraea	Common Centaury		
Centaurium sp.	Centaury		
Centaurium tenuiflorum	Branched Centaury		
Centella cordifolia	Native Centella		
Centrolepis aristata	Pointed Centrolepis		
Centrolepis polygyna	Wiry Centrolepis		
Centrolepis strigosa ssp. *strigosa*	Hairy Centrolepis		
Cerastium balearicum	Chickweed		
Cerastium glomeratum	Common Mouse-ear Chickweed		
Ceratocoma jacksoniae			
Chamaescilla corymbosa var. *corymbosa*	Blue Squill		
Cheilanthes austrotenuifolia	Annual Rock-fern		
Chenopodium glaucum	Glaucous Goosefoot		
Chondrilla juncea	Skeleton Weed		
Choretrum glomeratum	White Sour-bush		

Species	Common name	EPBC	NPWSA
Chrysanthemoides monilifera ssp. *monilifera*	Boneseed		
Chrysocephalum apiculatum	Common Everlasting		
Chrysocephalum baxteri	White Everlasting		
Cicendia filiformis	Slender Cicendia		
Cirsium vulgare	Spear Thistle		
Cladonia cervicornis ssp. *verticillata*			
Cladophora vagabunda			
Clematis aristata	Mountain Clematis		V
Clematis microphylla var. *microphylla*	Old Man's Beard		
Comesperma calymega	Blue-spike Milkwort		
Comesperma polygaloides	Mauve Milkwort		
Comesperma volubile	Love Creeper		
Conium maculatum	Hemlock		
Conospermum patens	Slender Smoke-bush		
Convolvulus angustissimus ssp. *peninsularum*	Narrow-leaf Bindweed		
Convolvulus erubescens	Australian Bindweed		
Convolvulus remotus	Grassy Bindweed		
Conyza bonariensis	Flax-leaf Fleabane		
Coronidium scorpioides			
Correa alba var. *pannosa*			
Correa reflexa var. *reflexa*	Common Correa		
Correa reflexa var. *scabridula*	Common Correa		
Corybas despectans	Coast Helmet-orchid		
Corybas dilatatus	Common Helmet-orchid		
Corybas expansus	Dune Helmet-orchid		V
Corybas incurvus	Slaty Helmet-orchid		
Cotula australis	Common Cotula		
Cotula coronopifolia	Water Buttons		
Cotula vulgaris var. *australasica*	Slender Cotula		
Craspedia glauca	Billy-buttons		
Crassula closiana	Stalked Crassula		
Crassula colligata ssp. *colligata*			
Crassula colligata ssp. *lamprosperma*			
Crassula colorata var.	Dense Crassula		
Crassula colorata var. *acuminata*	Dense Crassula		
Crassula decumbens var. *decumbens*	Spreading Crassula		
Crassula helmsii	Swamp Crassula		
Crassula natans var. *minus*	Water Crassula		
Crassula sieberiana ssp. *tetramera*	Australian Stonecrop		
Cryptandra tomentosa	Heath Cryptandra		
Cucumis myriocarpus	Paddy Melon		
Cuscuta planiflora	Small-seed Alfalfa-dodder		
Cuscuta tasmanica	Tasmanian Dodder		V
Cymbonotus preissianus	Austral Bear's-ear		
Cynodon dactylon	Couch		

Species	Common name	EPBC	NPWSA
Cynodon dactylon var. *dactylon*	Couch		
Cynoglossum australe	Australian Hound's-tongue		
Cynosurus echinatus	Rough Dog's-tail Grass		
Cyperus laevigatus	Bore-drain Sedge		
Cyperus tenellus	Tiny Flat-sedge		
Cyrtostylis reniformis	Small Gnat-orchid		
Cyrtostylis robusta	Robust Gnat-orchid		
Dactylis glomerata	Cocksfoot		
Dampiera rosmarinifolia	Rosemary Dampiera		
Darwinia micropetala	Small Darwinia		
Daucus glochidiatus	Native Carrot		
Daviesia brevifolia	Leafless Bitter-pea		
Daviesia ulicifolia	Gorse Bitter-pea		
Deyeuxia quadriseta	Reed Bent-grass		
Dianella brevicaulis	Short-stem Flax-lily		
Dianella brevicaulis/revoluta var.	Black-anther Flax-lily		
Dianella revoluta var.			
Dianella revoluta var. *revoluta*	Black-anther Flax-lily		
Dichelachne crinita	Long-hair Plume-grass		
Dichondra repens	Kidney Weed		
Dillwynia glaberrima	Smooth Parrot-pea		
Dillwynia hispida	Red Parrot-pea		
Dillwynia sericea	Showy Parrot-pea		
Distichlis distichophylla	Emu-grass		
Dittrichia graveolens	Stinkweed		
Diuris calcicola			
Diuris orientis	Wallflower Donkey-orchid		
Diuris pardina	Spotted Donkey-orchid		
Dodonaea bursariifolia	Small Hop-bush		
Dodonaea humilis	Dwarf Hop-bush		
Dodonaea viscosa ssp.	Sticky Hop-bush		
Dodonaea viscosa ssp. *spatulata*	Sticky Hop-bush		
Drosera aberrans			
Drosera auriculata	Tall Sundew		
Drosera glanduligera	Scarlet Sundew		
Drosera hookeri	Pale Sundew		
Drosera macrantha ssp. *planchonii*	Climbing Sundew		
Drosera peltata	Pale Sundew		
Drosera pygmaea	Tiny Sundew		
Drosera whittakeri	Scented Sundew		
Echium italicum	Italian Bugloss		
Echium plantagineum	Salvation Jane		
Ehrharta calycina	Perennial Veldt Grass		
Ehrharta erecta	Panic Veldt Grass		
Ehrharta longiflora	Annual Veldt Grass		

Species	Common name	EPBC	NPWSA
Eleocharis acuta	Common Spike-rush		
Enchylaena tomentosa var. *tomentosa*	Ruby Saltbush		
Epacris impressa	Common Heath		
Epilobium billardierianum ssp.	Robust Willow-herb		
Epilobium billardierianum ssp. *billardierianum*	Robust Willow-herb		
Epilobium billardierianum ssp. *X intermedium*	Variable Willow-herb		
Eragrostis brownii	Bentham's Love-grass		
Eragrostis cilianensis	Stink Grass		
Eragrostis curvula	African Love-grass		
Eremophila longifolia	Weeping Emubush		
Erigeron bonariense			
Eriochilus cucullatus	Parson's Bands		
Erodium botrys	Long Heron's-bill		
Erodium cicutarium	Cut-leaf Heron's-bill		
Erodium crinitum	Blue Heron's-bill		
Eryngium ovinum	Blue Devil		
Eucalyptus arenacea	Dune Stringybark		
Eucalyptus arenacea/baxteri	Brown Stringybark		
Eucalyptus baxteri	Brown Stringybark		
Eucalyptus camaldulensis var. *camaldulensis*	River Red Gum		
Eucalyptus diversifolia	Coastal White Mallee		
Eucalyptus diversifolia ssp. *diversifolia*	Coastal White Mallee		
Eucalyptus diversifolia subsp. hesperia			
Eucalyptus fasciculosa	Pink Gum		R
Eucalyptus incrassata	Ridge-fruited Mallee		
Eucalyptus leptophylla	Narrow-leaf Red Mallee		
Eucalyptus leucoxylon ssp.	South Australian Blue Gum		
Eucalyptus leucoxylon ssp. *pruinosa*	Inland South Australian Blue Gum		
Eucalyptus leucoxylon ssp. *stephaniae*	Scrubby Blue Gum		
Eucalyptus obliqua	Messmate Stringybark		
Eucalyptus ovata	Swamp Gum		
Eucalyptus rugosa	Coastal White Mallee		
Eucalyptus viminalis ssp. *cygnetensis*	Rough-bark Manna Gum		
Euchiton collinus	Creeping Cudweed		
Euchiton gymnocephalus	Creeping Cudweed		
Euchiton involucratus	Star Cudweed		
Euchiton japonicus	Creeping Cudweed		
Euchiton sphaericus	Annual Cudweed		
Euphorbia exigua	Dwarf Spurge		
Euphorbia paralias	Sea Spurge		
Euphorbia terracina	False Caper		
Euphrasia collina ssp. *tetragona*	Coast Eyebright		
Eutaxia diffusa	Large-leaf Eutaxia		
Eutaxia microphylla	Common Eutaxia		
Eutaxia microphylla var. *microphylla*	Common Eutaxia		

Species	Common name	EPBC	NPWSA
Exocarpos cupressiformis	Native Cherry		
Exocarpos sparteus	Slender Cherry		
Exocarpos syrticola	Coast Cherry		
Festuca arundinacea	Tall Meadow Fescue		
Ficinia nodosa	Knobby Club-rush		
Frankenia pauciflora var.	Southern Sea-heath		
Frankenia pauciflora var. *gunnii*	Southern Sea-heath		
Gahnia deusta	Limestone Saw-sedge		
Gahnia filum	Thatching Grass		
Gahnia lanigera	Black Grass Saw-sedge		
Gahnia trifida	Cutting Grass		
Galerina unicolor			
Galium curvihirtum	Tight Bedstraw		
Galium gaudichaudii	Rough Bedstraw		
Galium murale	Small Bedstraw		
Geranium molle var. *molle*	Soft Geranium		
Geranium potentilloides var. *potentilloides*	Downy Geranium		
Geranium retrorsum	Grassland Geranium		
Geranium solanderi	Austral Geranium		
Geranium solanderi var. *solanderi*	Austral Geranium		
Glischrocaryon behrii	Golden Pennants		
Glossodia major	Purple Cockatoo		
Gnaphalium indutum	Tiny Cudweed		
Gnaphalium indutum ssp. *indutum*	Tiny Cudweed		
Gnaphalium spicatum	Spiked Cudweed		
Gnephosis tenuissima	Dwarf Golden-tip		
Gomphocarpus cancellatus	Broad-leaf Cotton-bush		
Gompholobium ecostatum	Dwarf Wedge-pea		
Gonocarpus tetragynus	Small-leaf Raspwort		
Goodenia blackiana	Native Primrose		
Goodenia geniculata	Bent Goodenia		
Goodenia sp.	Goodenia		
Goodenia varia	Sticky Goodenia		
Goodia medicaginea	Western Golden-tip		
Gramineae sp.	Grass Family		
Grevillea ilicifolia	Holly-leaf Grevillea		
Grevillea ilicifolia complex	Holly-leaf Grevillea		
Grevillea ilicifolia ssp. *ilicifolia*	Holly-leaf Grevillea		
Grevillea lavandulacea ssp. *lavandulacea*	Spider-flower		
Grevillea lavandulacea var. *sericea*	Spider-flower		
Grevillea pauciflora subsp. leptophylla	Narrow-leaf Grevillea		
Gyrostemon australasicus	Buckbush Wheel-fruit		
Hainardia cylindrica	Common Barb-grass		
Hakea mitchellii	Heath Needlebush		
Hakea nodosa	Yellow Hakea		

Species	Common name	EPBC	NPWSA
Hakea repullulans	Furze Hakea		
Hakea rostrata	Beaked Hakea		
Hakea rugosa	Dwarf Hakea		
Hakea vittata	Limestone Needlebush		
Haloragis acutangula f.	Smooth Raspwort		
Haloragis eichleri	Eichler's Raspwort		R
Haloragis heterophylla	Variable Raspwort		
Haloragis myriocarpa			R
Halosarcia sp.	Samphire		
Hardenbergia violacea	Native Lilac		
Helichrysum leucopsideum	Satin Everlasting		
Helichrysum luteoalbum	Jersey Cudweed		
Helichrysum scorpioides	Button Everlasting		
Heliotropium europaeum	Common Heliotrope		
Hemichroa pentandra	Trailing Hemichroa		
Hibbertia devitata	Smooth Guinea-flower		
Hibbertia fasciculata	Bundled Guinea-flower		
Hibbertia riparia	Guinea-flower		
Hibbertia sericea var.	Silky Guinea-flower		
Hibbertia sericea var. *scabrifolia*	Rough-leaf Guinea-flower		
Hibbertia sericea var. *sericea*	Silky Guinea-flower		
Hibbertia stricta var. *stricta*			
Hibbertia virgata	Twiggy Guinea-flower		
Holcus lanatus	Yorkshire Fog		
Hordeum glaucum	Blue Barley-grass		
Hordeum leporinum	Wall Barley-grass		
Hordeum marinum	Sea Barley-grass		
Hornungia procumbens	Oval Purse		
Hyalosperma demissum	Dwarf Sunray		
Hybanthus floribundus ssp. *floribundus*	Shrub Violet		
Hydrocotyle callicarpa	Tiny Pennywort		
Hydrocotyle capillaris			
Hydrocotyle foveolata	Yellow Pennywort		
Hydrocotyle hirta	Hairy Pennywort		
Hydrocotyle laxiflora	Stinking Pennywort		
Hydrocotyle medicaginoides	Medic Pennywort		
Hydrocotyle muscosa	Mossy Pennywort		
Hydrocotyle tripartita	Three-part Pennywort		
Hyparrhenia hirta	Tambookie Grass		
Hypericum gramineum	Small St John's Wort		
Hypnum cupressiforme var. *lacunosum*			
Hypochaeris glabra	Smooth Cat's Ear		
Hypochaeris radicata	Rough Cat's Ear		
Hypolaena fastigiata	Tassel Rope-rush		
Hypoxis glabella var. *glabella*	Tiny Star		

Species	Common name	EPBC	NPWSA
Hypoxis vaginata var. *vaginata*	Yellow Star		
Hysterangium affine			
Hysterobaeckea behrii	Silver Broombush		
Imperata cylindrica	Blady Grass		
Isoetopsis graminifolia	Grass Cushion		
Isolepis cernua	Nodding Club-rush		
Isolepis marginata	Little Club-rush		
Isolepis platycarpa	Flat-fruit Club-rush		
Isopogon ceratophyllus	Horny Cone-bush		
Ixodia achillaeoides ssp. *alata*	Hills Daisy		
Juncus acutus	Sharp Rush		
Juncus articulatus	Jointed Rush		
Juncus bufonius	Toad Rush		
Juncus caespiticius	Grassy Rush		
Juncus capitatus	Dwarf Rush		
Juncus flavidus	Yellow Rush		
Juncus kraussii	Sea Rush		
Juncus kraussii subsp. australiensis			
Juncus pallidus	Pale Rush		
Juncus subsecundus	Finger Rush		
Kennedia prostrata	Scarlet Runner		
Kunzea pomifera	Muntries		
Lachnagrostis billardierei	Coast Blown-grass		
Lachnagrostis billardierei ssp. *billardierei*	Coast Blown-grass		
Lachnagrostis filiformis	Common Blown-grass		
Lachnagrostis punicea ssp. *filifolia*	Narrow-leaf Blown-grass		R
Lachnagrostis robusta	Tall Blown-grass		R
Lagurus ovatus	Hare's Tail Grass		
Lasiopetalum baueri	Slender Velvet-bush		
Lasiopetalum behrii	Pink Velvet-bush		
Lasiopetalum discolor	Coast Velvet-bush		
Lawrencia spicata	Salt Lawrencia		
Lawrencia squamata	Thorny Lawrencia		
Laxmannia orientalis	Dwarf Wire-lily		
Leontodon taraxacoides ssp. *taraxacoides*	Lesser Hawkbit		
Lepidobolus drapetocoleus	Scale Shedder		
Lepidosperma canescens	Hoary Rapier-sedge		
Lepidosperma carphoides	Black Rapier-sedge		
Lepidosperma concavum	Spreading Sword-sedge		
Lepidosperma concavum/congestum/laterale	Sword-sedge		
Lepidosperma congestum	Clustered Sword-sedge		
Lepidosperma curtisiae	Little Sword-sedge		
Lepidosperma laterale	Tall Sword-sedge		
Lepidosperma semiteres	Wire Rapier-sedge		
Lepidosperma sp. Narrow leaf (R.L.Taplin 709)			

Species	Common name	EPBC	NPWSA
Lepidosperma viscidum	Sticky Sword-sedge		
Lepilaena cylindrocarpa	Long-fruit Water-mat		
Lepilaena patentifolia	Spreading Water-mat		
Leporella fimbriata	Fringed Hare-orchid		
Leptinella reptans	Creeping Cotula		
Leptocarpus tenax	Slender Twine-rush		
Leptoceras menziesii	Hare Orchid		
Leptomeria aphylla	Leafless Currant-bush		
Leptorhynchos squamatus ssp. *squamatus*	Scaly Buttons		
Leptospermum continentale	Prickly Tea-tree		
Leptospermum coriaceum	Dune Tea-tree		
Leptospermum myrsinoides	Heath Tea-tree		
Lepyrodia muelleri	Erect Scale-rush		
Leucophyta brownii	Coast Cushion Bush		
Leucopogon clelandii	Cleland's Beard-heath		R
Leucopogon costatus	Twiggy Beard-heath		
Leucopogon ericoides	Pink Beard-heath		
Leucopogon glacialis	Twisted Beard-heath		
Leucopogon affinis	Lance Beard-heath		
Leucopogon parviflorus	Coast Beard-heath		
Leucopogon sp.	Beard-heath		
Leucopogon virgatus var. *virgatus*	Common Beard-heath		
Leucopogon woodsii	Nodding Beard-heath		
Levenhookia dubia	Hairy Stylewort		
Levenhookia pusilla	Tiny Stylewort		
Levenhookia sonderi	Slender Stylewort		
Lilaeopsis polyantha	Australian Lilaeopsis		
Limonium companyonis	Sea-lavender		
Limonium hyblaeum			
Linum marginale	Native Flax		
Lobelia anceps	Angled Lobelia		
Lobelia gibbosa	Tall Lobelia		
Lobelia irrigua	Salt Pratia		
Logania linifolia	Flax-leaf Logania		
Lolium perenne X Lolium rigidum	Hybrid Ryegrass		
Lolium rigidum	Wimmera Ryegrass		
Lomandra collina	Sand Mat-rush		
Lomandra effusa	Scented Mat-rush		
Lomandra juncea			
Lomandra leucocephala ssp. *robusta*	Woolly Mat-rush		
Lomandra micrantha ssp.	Small-flower Mat-rush		
Lomandra micrantha ssp. *micrantha*	Small-flower Mat-rush		
Lomandra nana	Small Mat-rush		
Lomandra sororia	Sword Mat-rush		
Lotus australis	Austral Trefoil		

Species	Common name	EPBC	NPWSA
Luzula densiflora	Dense Wood-rush		
Luzula meridionalis	Common Wood-rush		
Lycium ferocissimum	African Boxthorn		
Lysimachia arvensis	Pimpernel		
Lythrum hyssopifolia	Lesser Loosestrife		
Malva parviflora	Small-flower Marshmallow		
Malva preissiana	Australian Hollyhock		
Marrubium vulgare	Horehound		
Medicago lupulina	Black Medic		
Medicago minima var. *minima*	Little Medic		
Medicago polymorpha var. *polymorpha*	Burr-medic		
Medicago sativa ssp.	Lucerne		
Medicago scutellata	Snail Medic		
Melaleuca brevifolia	Short-leaf Honey-myrtle		
Melaleuca gibbosa	Slender Honey-myrtle		
Melaleuca halmaturorum	Swamp Paper-bark		
Melaleuca halmaturorum			
Melaleuca lanceolata	Dryland Tea-tree		
Melaleuca lanceolata ssp. *lanceolata*	Dryland Tea-tree		
Melilotus indicus	King Island Melilot		
Mentha diemenica	Slender Mint		
Mentha pulegium	Pennyroyal		
Mesembryanthemum crystallinum	Common Iceplant		
Microbryum starckeanum			
Microlaena stipoides var. *stipoides*	Weeping Rice-grass		
Microseris lanceolata	Yam Daisy		
Microtis arenaria	Notched Onion-orchid		
Microtis arenaria			
Microtis unifolia			
Microtis unifolia complex	Onion-orchid		
Millotia muelleri	Common Bow-flower		
Millotia tenuifolia var.	Soft Millotia		
Millotia tenuifolia var. *tenuifolia*	Soft Millotia		
*Minuartia mediterranea**			
Mitrasacme paradoxa	Wiry Mitrewort		
Mitrasacme pilosa var. *pilosa*	Hairy Mitrewort		V
Moenchia erecta	Erect Chickweed		
Monotoca scoparia	Prickly Broom-heath		
Montia australasica	White Purslane		R
Moraea flaccida	One-leaf Cape Tulip		
Muehlenbeckia adpressa	Climbing Lignum		
Muehlenbeckia gunnii	Coastal Climbing Lignum		
Mundulla yellows			
Myoporum insulare	Common Boobialla		
Myoporum montanum	Native Myrtle		

Species	Common name	EPBC	NPWSA
Myoporum parvifolium	Creeping Boobialla		R
Myosotis australis	Austral Forget-me-not		
Myosotis discolor ssp. *discolor*	Yellow-and-blue Forget-me-not		
Myriocephalus rhizocephalus	Woolly-heads		
Myriophyllum amphibium	Broad Milfoil		
Myriophyllum muelleri	Hooded Milfoil		
Myriophyllum sp.	Milfoil		
Neurachne alopecuroidea	Fox-tail Mulga-grass		
Nicotiana glauca	Tree Tobacco		
Oenothera stricta ssp. *stricta*	Common Evening Primrose		
Olearia axillaris	Coast Daisy-bush		
Olearia ciliata var. *ciliata*	Fringed Daisy-bush		
Olearia floribunda	Heath Daisy-bush		
Olearia lanuginosa	Woolly Daisy-bush		
Olearia pannosa ssp. *cardiophylla*	Velvet Daisy-bush		R
Olearia ramulosa	Twiggy Daisy-bush		
Onopordum acanthium	Scotch Thistle		
Opercularia ovata	Broad-leaf Stinkweed		
Opercularia turpis	Twiggy Stinkweed		
Opercularia varia	Variable Stinkweed		
Ophioglossum lusitanicum	Austral Adder's-tongue		
Oxalis corniculata ssp. *corniculata*	Creeping Wood-sorrel		
Oxalis perennans	Native Sorrel		
Oxalis pes-caprae	Soursob		
Ozothamnus ferrugineus	Tree Everlasting		
Ozothamnus turbinatus			
Parapholis incurva	Curly Ryegrass		
Parentucellia latifolia	Red Bartsia		
Parietaria debilis	Smooth-nettle		
Paspalum dilatatum	Paspalum		
Pauridia glabella var. *glabella*	Tiny Star		
Pelargonium australe	Austral Stork's-bill		
Pelargonium littorale	Native Pelargonium		
Pelargonium rodneyanum	Magenta Pelargonium		
Pelargonium sp.	Storks-bill		
Persicaria sp.	Knotweed		
Persoonia juniperina	Prickly Geebung		
Peziza austrogeaster			
Phalaris aquatica	Phalaris		
Phalaris canariensis	Canary-grass		
Phalaris minor	Lesser Canary-grass		
Pheladenia deformis	Bluebeard Orchid		
Phragmites australis	Common Reed		
Phyllangium divergens	Wiry Mitrewort		
Phylloglossum drummondii	Pigmy Clubmoss		

Species	Common name	EPBC	NPWSA
Phyllota pleurandroides	Heathy Phyllota		
Phyllota remota	Slender Phyllota		
Picris squarrosa	Squat Picris		R
Pimelea glauca	Smooth Riceflower		
Pimelea humilis	Low Riceflower		
Pimelea micrantha	Silky Riceflower		
Pimelea octophylla	Woolly Riceflower		
Pimelea phylicoides	Heath Riceflower		
Pimelea serpyllifolia ssp. *serpyllifolia*	Thyme Riceflower		
Pimelea stricta	Erect Riceflower		
Plantago bellardii	Hairy Plantain		
Plantago coronopus ssp.	Bucks-horn Plantain		
Plantago coronopus ssp. *coronopus*	Bucks-horn Plantain		
Plantago lanceolata var.	Ribwort		
Plantago lanceolata var. *lanceolata*	Ribwort		
Plantago sp.	Plantain		
Plantago sp. B (R.Bates 44765)	Little Plantain		
Platylobium obtusangulum	Holly Flat-pea		
Plumatichilos plumosum			
Poa annua	Winter Grass		
Poa billardierei			
Poa crassicaudex	Thick-stem Tussock-grass		
Poa halmaturina	Kangaroo Island Poa		
Poa labillardieri var. *labillardieri*	Common Tussock-grass		
Poa meionectes	Fine-leaf Tussock-grass		
Poa poiformis var. *poiformis*	Coast Tussock-grass		
Poa sieberiana var. *hirtella*	Grey Tussock Grass		
Podolepis aristata ssp. *affinis*	Grey Copper-wire Daisy		
Podolepis canescens	Grey Copper-wire Daisy		
Podolepis canescens			
Podotheca angustifolia	Sticky Long-heads		
Polycarpon tetraphyllum	Four-leaf Allseed		
Polygala myrtifolia	Myrtle-leaf Milkwort		
Polygonum aviculare	Wireweed		
Polypogon maritimus	Coast Beard-grass		
Polypogon monspeliensis	Annual Beard-grass		
Pomaderris obcordata	Wedge-leaf Pomaderris		
Pomaderris paniculosa ssp.			
Pomaderris paniculosa ssp. *paniculosa*	Mallee Pomaderris		
Poranthera microphylla	Small Poranthera		
Poranthera triandra	Three-petal Poranthera		
Potamogeton pectinatus	Fennel Pondweed		
Prasophyllum occidentale	Plains Leek-orchid		
Pratia irrigua	Salt Pratia		
Pseudognaphalium luteoalbum	Jersey Cudweed		

Species	Common name	EPBC	NPWSA
Psilocybe musci			
Pteridium esculentum ssp. *esculentum*			
Pterostylis alata	Tall Shell-orchid		
Pterostylis nana	Dwarf Greenhood		
Pterostylis pedunculata	Maroon-hood		
Pterostylis plumosa	Bearded Greenhood		
Pterostylis robusta	Large Shell-orchid		
Pterostylis sanguinea	Blood Greenhood		
Pterostylis tasmanica	Small Bearded Greenhood		V
Puccinellia fasciculata	Borrer's Saltmarsh-grass		
Puccinia elymi			
Pultenaea acerosa	Bristly Bush-pea		
Pultenaea hispidula	Rusty Bush-pea		
Pultenaea penna	Feather Bush-pea		
Pultenaea prostrata	Silky Bush-pea		
Pultenaea tenuifolia	Narrow-leaf Bush-pea		
Pultenaea vestita	Feather Bush-pea		
Pyrorchis nigricans	Black Fire-orchid		
Quinetia urvillei	Quinetia		
Ranunculus pachycarpus	Thick-fruit Buttercup		
Ranunculus pumilio var. *pumilio*	Ferny Buttercup		
Ranunculus robertsonii	Slender Buttercup		R
Ranunculus sessiliflorus var.	Annual Buttercup		
Ranunculus sessiliflorus var. *sessiliflorus*	Annual Buttercup		
Reichardia tingitana	False Sowthistle		
Reseda alba	White Mignonette		
Reseda luteola	Wild Mignonette		
Restio sp.	Cord-rush		
Rhagodia candolleana ssp.	Sea-berry Saltbush		
Rhagodia candolleana ssp. *candolleana*	Sea-berry Saltbush		
Rhagodia parabolica	Mealy Saltbush		
Rhagodia sp.	Saltbush		
Riccia albida			
Riccia bifurca			
Riccia spongiosula			
Ricinus communis	Castor Oil Plant		
Rinzia orientalis	Desert Heath-myrtle		
Roepera billardierei	Coast Twinleaf		
Romulea rosea var. *australis*	Common Onion-grass		
Romulea rosea var. *australis*	Common Onion-grass		
Rorippa nasturtium-aquaticum	Watercress		
Rosa canina	Dog Rose		
Rosa rubiginosa	Sweet Briar		
Rostraria cristata	Annual Cat's-tail		
Rostraria pumila	Tiny Bristle-grass		

Species	Common name	EPBC	NPWSA
Rubus anglocandicans			
Rubus discolor	Blackberry		
Rumex brownii	Slender Dock		
Rumex conglomeratus	Clustered Dock		
Rumex crispus	Curled Dock		
Ruppia megacarpa	Widgeon Grass		
Ruppia polycarpa	Widgeon Grass		
Ruppia tuberosa	Widgeon Grass		
Rytidosperma caespitosa	Common Wallaby-grass		
Rytidosperma caespitosum	Common Wallaby-grass		
Rytidosperma duttonianum	Brown-back Wallaby-grass		
Rytidosperma fulvum	Leafy Wallaby-grass		
Rytidosperma geniculatum	Kneed Wallaby-grass		
Rytidosperma setacea var. *setacea*	Small-flower Wallaby-grass		
Rytidosperma setaceum	Small-flower Wallaby-grass		
Sagina apetala	Annual Pearlwort		
Sagina maritima	Sea Pearlwort		
Salvia verbenaca var.	Wild Sage		
Salvia verbenaca var. *verbenaca*	Wild Sage		
Salvia verbenaca var. *vernalis*	Wild Sage		
Samolus repens			
Sarcocornia blackiana	Thick-head Samphire		
Sarcocornia quinqueflora	Beaded Samphire		
Scabiosa atropurpurea	Pincushion		
Scaevola aemula	Fairy Fanflower		
Scaevola albida	Pale Fanflower		
Schismus barbatus	Arabian Grass		
Schoenoplectus pungens	Spiky Club-rush		
Schoenus apogon	Common Bog-rush		
Schoenus breviculmis	Matted Bog-rush		
Schoenus deformis	Small Bog-rush		
Schoenus nitens			
Sebaea albidiflora	White Sebaea		
Sebaea ovata			
Selliera radicans	Shiny Swamp-mat		
Senecio biserratus	Jagged Groundsel		
Senecio elegans	Purple Groundsel		
Senecio glomeratus	Swamp Groundsel		
Senecio glomeratus ssp. *longifructus*	Swamp Groundsel		
Senecio hispidissimus	Rough Groundsel		
Senecio laceratus	Cut-leaf Groundsel		
Senecio odoratus	Scented Groundsel		
Senecio odoratus var. *odoratus*	Scented Groundsel		
Senecio picridioides	Purple-leaf Groundsel		
Senecio pinnatifolius	Variable Groundsel		

Species	Common name	EPBC	NPWSA
Senecio pinnatifolius group	Variable Groundsel		
Senecio pterophorus	African Daisy		
Senecio quadridentatus	Cotton Groundsel		
Senecio spanomerus			
Senecio squarrosus	Squarrose Groundsel		
Senecio tenuiflorus	Woodland Groundsel		
Senecio vulgaris	Common Groundsel		
Sherardia arvensis	Field Madder		
Silene nocturna	Mediterranean Catchfly		
Silene vulgaris	Bladder Campion		
Siloxerus multiflorus	Small Wrinklewort		
Silybum marianum	Variegated Thistle		
Sisymbrium irio	London Mustard		
Solanum aviculare	Kangaroo Apple		
Solanum elaeagnifolium	Silver-leaf Nightshade		
Solanum laciniatum	Cut-leaf Kangaroo-apple		
Solanum nigrum	Black Nightshade		
Solanum simile	Kangaroo Apple		
Solanum tuberosum			
Sonchus asper	Rough Sow-thistle		
Sonchus hydrophilus	Native Sow-thistle		
Sonchus oleraceus	Common Sow-thistle		
Spergularia marina	Salt Sand-spurrey		
Spergularia media	Coast Sand-spurrey		
Spergularia tasmanica			
Spinifex sericeus			
Sporobolus virginicus	Salt Couch		
Spyridium nitidum	Shining Spyridium		
Spyridium phylicoides	Narrow-leaf Spyridium		
Spyridium subochreatum var.	Velvet Spyridium		
Spyridium vexilliferum var.	Winged Spyridium		
Spyridium vexilliferum var. *latifolium*	Winged Spyridium		
Spyridium vexilliferum var. *vexilliferum*	Winged Spyridium		
Stackhousia aspericocca ssp.	Bushy Candles		
Stackhousia aspericocca ssp. *Cylindrical inflorescence (W.R.Barker 1418)*	Bushy Candles		
Stackhousia monogyna	Creamy Candles		
Stackhousia spathulata	Coast Candles		
Stellaria caespitosa	Starwort		
Stellaria media	Chickweed		
Stellaria pallida	Lesser Starwort		
Stenanthera conostephioides	Flame Heath		
Stuartina muelleri	Spoon Cudweed		
Stylidium graminifolium	Grass Trigger-plant		
Stylidium perpusillum	Tiny Trigger-plant		

Species	**Common name**	**EPBC**	**NPWSA**
Styphelia exarrhena	Desert Heath		
Suaeda australis	Austral Seablite		
Swainsona lessertiifolia	Coast Swainson-pea		
Tamarix ramosissima	Saltcedar		
Taraxacum cygnorum	Coast Dandelion	VU	
Taraxacum erythrospermum	Red-seed Dandelion		
Taraxacum officinale	Dandelion		
Tecticornia arbuscula	Shrubby Samphire		
Tecticornia halocnemoides ssp. *halocnemoides*	Grey Samphire		
Tecticornia lepidosperma			R
Tecticornia pergranulata ssp. *pergranulata*	Black-seed Samphire		
Tecticornia sp.	Samphire		
Tecticornia tenuis	Slender Samphire		
Tetragonia implexicoma	Bower Spinach		
Tetragonia tetragonioides	New Zealand Spinach		
Tetraria capillaris	Hair Sedge		
Tetratheca pilosa	Hairy Pink-bells		
Tetratheca pilosa ssp. *pilosa*	Hairy Pink-bells		
Thelymitra antennifera	Lemon Sun-orchid		
Thelymitra azurea	Azure Sun-orchid		
Thelymitra benthamiana	Leopard Sun-orchid		
Thelymitra epipactoides	Metallic Sun-orchid	EN	E
Thelymitra flexuosa	Twisted Sun-orchid		
Thelymitra ixioides	Spotted Sun-orchid		
Thelymitra juncifolia	Large-spotted Sun-orchid		
Thelymitra nuda	Scented Sun-orchid		
Thelymitra nuda/pauciflora	Sun-orchid		
Thelymitra pauciflora	Slender Sun-orchid		
Thelymitra rubra	Salmon Sun-orchid		
Themeda triandra	Kangaroo Grass		
Thinopyrum elongatum	Tall Wheat-grass		
Thinopyrum junceiforme	Sea Wheat-grass		
Thomasia petalocalyx	Paper-flower		
Threlkeldia diffusa	Coast Bonefruit		
Thyridia repens	Creeping Monkey-flower		
Thysanotus juncifolius	Rush Fringe-lily		
Thysanotus patersonii	Twining Fringe-lily		
Thysanotus racemoides	Rush Fringe-lily		
Tolypella nidifica			
Torilis nodosa	Knotted Hedge-parsley		
Tribolium acutiflorum			
Tribolium obliterum			
Tricoryne elatior	Yellow Rush-lily		
Tricoryne tenella	Tufted Yellow Rush-lily		
Trifolium angustifolium	Narrow-leaf Clover		

Species	Common name	EPBC	NPWSA
Trifolium arvense var. *arvense*	Hare's-foot Clover		
Trifolium campestre	Hop Clover		
Trifolium dubium	Suckling Clover		
Trifolium fragiferum var.	Strawberry Clover		
Trifolium fragiferum var. *fragiferum*	Strawberry Clover		
Trifolium glomeratum	Cluster Clover		
Trifolium subterraneum	Subterranean Clover		
Trifolium tomentosum	Woolly Clover		
Triglochin centrocarpum	Dwarf Arrowgrass		
Triglochin isingiana	Spurred Arrowgrass		
Triglochin minutissima	Tiny Arrowgrass		
Triglochin mucronata	Prickly Arrowgrass		
Triglochin nana	Dwarf Arrowgrass		
Triglochin striata	Streaked Arrowgrass		
Typha domingensis	Narrow-leaf Bulrush		
Uromyces scaevolae			
Urtica incisa	Scrub Nettle		
Urtica urens	Small Nettle		
Utricularia tenella	Pink Bladderwort		
Vellereophyton dealbatum	White Cudweed		
Verbascum thapsus ssp. *thapsus*	Great Mullein		
Verbascum virgatum	Twiggy Mullein		
Veronica calycina	Hairy Speedwell		
Vicia sativa ssp. *sativa*	Common Vetch		
Vittadinia australasica var.	Sticky New Holland Daisy		
Vittadinia australasica var. *australasica*	Sticky New Holland Daisy		
Vittadinia cuneata var.	Fuzzy New Holland Daisy		
Vittadinia cuneata var. *cuneata*	Fuzzy New Holland Daisy		
Vittadinia dissecta var. *hirta*	Dissected New Holland Daisy		
Vittadinia gracilis	Woolly New Holland Daisy		
Vulpia bromoides	Squirrel-tail Fescue		
Vulpia myuros f. myuros	Rat's-tail Fescue		
Wahlenbergia gracilenta	Annual Bluebell		
Wahlenbergia littoricola	Coast Bluebell		
Wahlenbergia stricta ssp. *stricta*	Tall Bluebell		
Weissia brachycarpa	Small-mouthed Beardless-moss		
Weissia controversa	Green-tufted Stubble-moss		
Wilsonia backhousei	Narrow-leafed Wilsonia		
Wilsonia humilis	Silky Wilsonia		
Wilsonia rotundifolia	Round-leaf Wilsonia		
Wurmbea dioica ssp. *dioica*	Early Nancy		
Xanthorrhoea australis	Austral Grass-tree		
Xanthorrhoea caespitosa	Sand-heath Yacca		
Xanthorrhoea semiplana ssp.	Yacca		
Xanthosia dissecta	Cut-leaf Xanthosia		

Species	Common name	EPBC	NPWSA
Xanthosia huegelii	Hairy Xanthosia		
Xanthosia leiophylla	Cut-leaf Xanthosia		
Zoysia macrantha ssp. *walshii*	Manila Grass		
Zygophyllum billardierei	Coast Twinleaf		

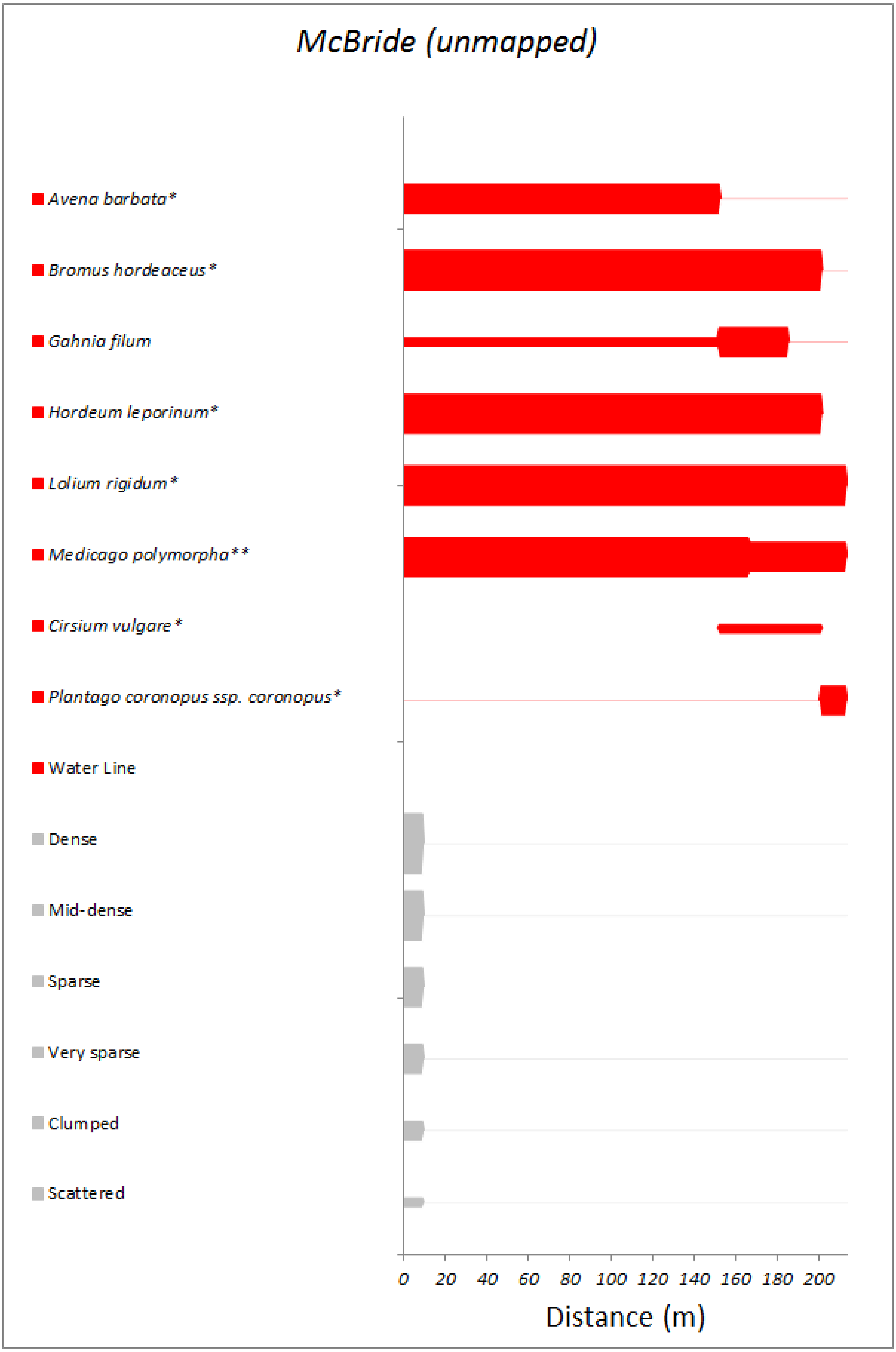
10.6. *Vegetation transect kite charts from the study area*

10.6.1 2012 vegetation transect kite charts


Morella 2
Terrestrial vegetation
Terrestrial vegetation
Chenopodium sp - immature
Hordeum marinum*
Melaleuca halmaturorum
Melaleuca halmaturorum (<0.2 m)
Melaleuca halmaturorum (1-2 m)
Melaleuca halmaturorum (2-3m)
Melaleuca halmaturorum (all dead)
Samolus repens
Sarcocornia quinqueflora
Sarcocornia quinqueflora
Parapholis incurva*
Wilsonia backhousei
Wilsonia rotundifolia
Wilsonia rotundifolia
Water Line (NR)
Water Line
Chara sp.
Chara sp.
Gahnia filum
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300
Distance (m)
Jan 2012
Oct/Nov 2012


Morella 3
Terrestrial vegetation
Terrestrial Vegetation
Hordeum marinum*
Melaleuca halmaturorum
Melaleuca halmaturorum (<1 m)
Melaleuca halmaturorum (1.5 - 2 m)
Melaleuca halmaturorum (1-1.5 m)
Melaleuca halmaturorum (2-3 m)
Melilotus indica*
Limonium companyonis*
Parapholis incurva*
Parapholis incurva*
Distichlis distichophylla
Distichlis distichophylla
Sarcocornia quinqueflora
Sarcocornia quinqueflora
Wilsonia backhousei
Hemichroa pentandra
Wilsonia rotundifolia
Wilsonia rotundifolia
Samolus repens
Wilsonia humilis
Suaeda australis
Water Line (NR)
Water Line (NR)
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
Jan 2012
Oct/Nov 2012
0
20
40
60
80
100
120
140
160
180
200
220
240
Distance (m)


Tilley Swamp
Melaleuca halmaturorum (>2m))
Melaleuca halmaturorum (<1m)
Melaleuca halmaturorum (1-2m)
Isolepis cernua
Wilsonia rotundifolia
Samolus repens
Chara sp.
Lilaeopsis polyantha
Waterline
Centaurium tenuiflorum*
Poaceae sp - juvenile
Microtis uniflora complex
Mixed Shrubland
Leucopogon parviflorus
Tetragonia implexicoma
Anagallis arvensis*
Acaena novae-zelandiae
0
10
20
30
40
50
60
70
80
90
Distance (m)


McBride (unmapped)
Avena barbata*
Bromus hordeaceus*
Gahnia filum
Hordeum leporinum*
Lolium rigidum*
Medicago polymorpha**
Cirsium vulgare*
Plantago coronopus ssp. coronopus*
Water Line
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0 20 40 60 80 100 120 140 160 180 200
Distance (m)

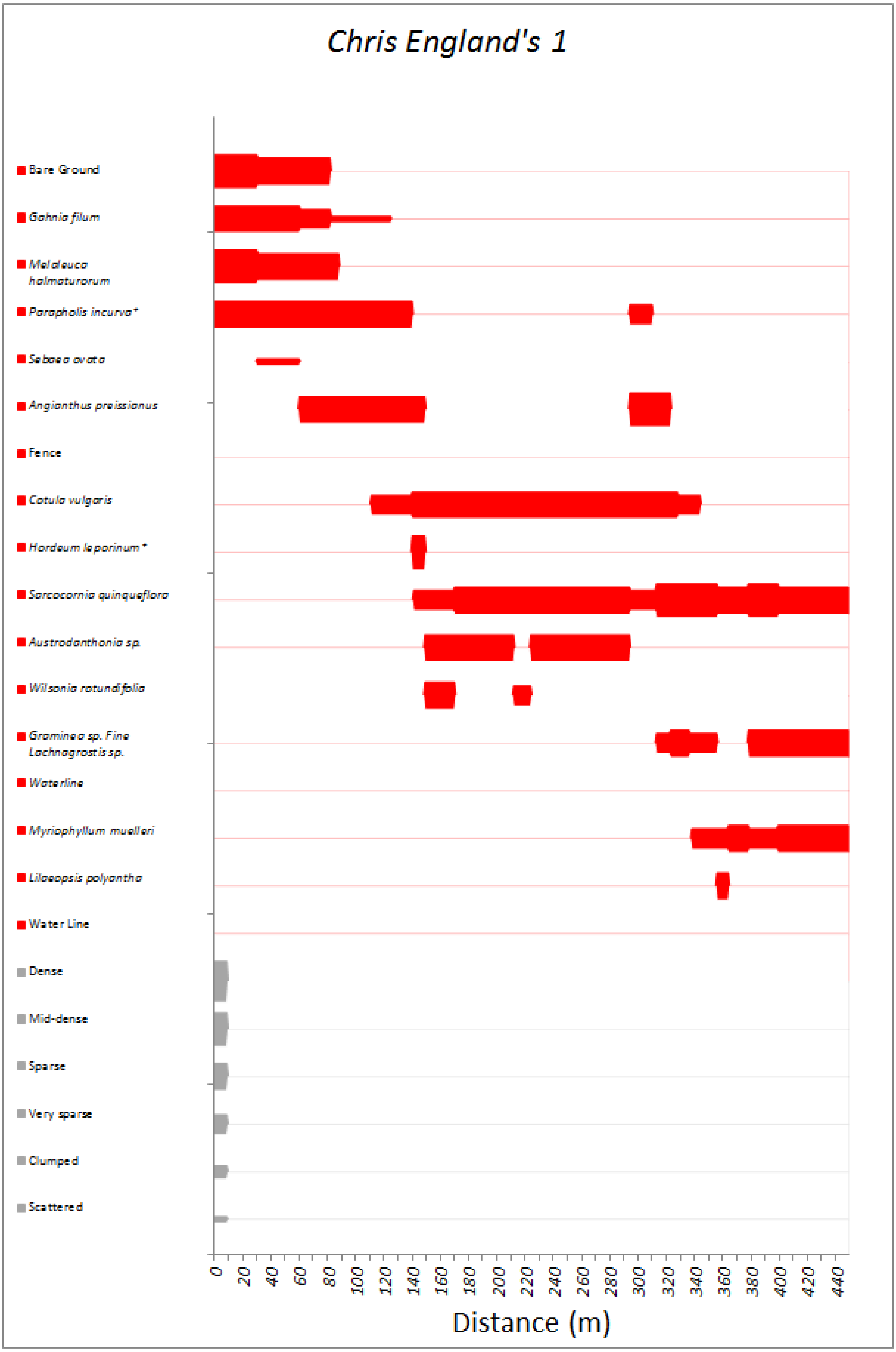

Marwood 1
Melaleuca halmaturorum
Bare ground
Hordeum leporinum*
Lolium rigidum*
Trifolium sp.*
Gahnia filum
Lagurus ovatus*
Melaleuca halmaturorum (<1m)
Parapholis incurva*
Sarcocornia quinqueflora
Bromus hordeaceus*
Medicago polymorpha**
Wilsonia backhousei
Avena barbata*
Romulea rosea*
Gahnia filum (j)
Angianthus preissianus
Pratia irrigua
Sebaea ovata
Selliera radicans
Cotula vulgaris
Wilsonia rotundifolia
Cuscuta planiflora*
Hydrocotyle capillaris
Gahnia filum
Melaleuca halmaturorum (<0.1m)
Isolepis cernua
Graminea sp. Fine Lachnagrostis sp.
Water Line
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance (m)


Marwood 2
Burnt ground
Hordeum leporinum*
Lolium rigidum*
Medicago polymorpha**
Bromus diandrus*
Gahnia filum
Melaleuca halmaturorum (1-3m; Dead)
Melaleuca halmaturorum (1-3m)
Hordeum marinum*
Avena barbata*
Melaleuca halmaturorum (<1m)
Parapholis incurva*
Romulea rosea*
Angianthus preissianus
Gahnia filum (j)
Sebaea ovata
Lachnagrostis filiformis
Melaleuca halmaturorum (<0.1m)
Pratia irrigua
Selliera radicans
Cotula vulgaris
Bare Ground
Triglochin mucronatum
Hemichroa pentandra
Sarcocornia quinqueflora
Wilsonia humilis
Hydrocotyle capillaris
Wilsonia backhousei
Cuscuta planiflora*
Wilsonia rotundifolia
Graminea sp. Fine Lachnagrostis sp.
Myriophyllum muelleri
Waterline
Chara sp.
Lilaeopsis polyantha
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
Distance (m)


L Stewart
Eucalyptus leucoxylon stephaniae
Cirsium vulgare*
Lolium rigidum*
Hordeum marinum*
Medicago polymorpha**
Echium plantagineum*
Gahnia filum
Bromus diandrus*
Distichlis distichophylla
Rumex crispus*
Bromus hordeaceus*
Arctotheca calendula*
Avena barbata*
Trifolium campestre*
Romulea rosea*
Comesperma volubile
Juncus kraussii
Sarcocornia quinqueflora
Puccinellia fasciculata*
Parapholis incurva*
Samolus repens
Wilsonia rotundifolia
Baumea juncea
Waterline
Filamentous algae
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0 10 20 30 40 50 60 70 80 90 100 110 120 130
Distance (m)


Yuelba 1
Melaleuca halmaturorum
Parapholis incurva*
Puccinellia fasciculata*
Samolus repens
Sarcocornia quinqueflora
Gahnia filum
Lolium rigidum*
Avena barbata*
Lolium rigidum*
Medicago polymorpha**
Melaleuca halmaturorum (j)
Bromus sp.*
Hairy Chenopodium shrub
Ozothamnus ferrugineus
Hordeum leporinum*
Persicaria sp.*
Asparagus asparagoides*
Hordeum leporinum*
Wilsonia rotundifolia
Bromus hordeaceus*
Cirsium vulgare*
Austrodanthonia caespitosa
Fence
Water Line
Avena barbata*
Bromus diandrus*
Hordeum marinum*
Eucalyptus diversifolia
Juncus kraussii
Sonchus asper*
Lolium rigidum*
Polypogon monspeliensis*
Triglochin striatum
Lilaeopsis polyantha
Polypogon monspeliensis*
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0 20 40 60 80 100 120 140 160 180 200 220 240 260 280 300 320 340 360 380 400 420 440 460 480 500 520 540 560 580
Distance (m)

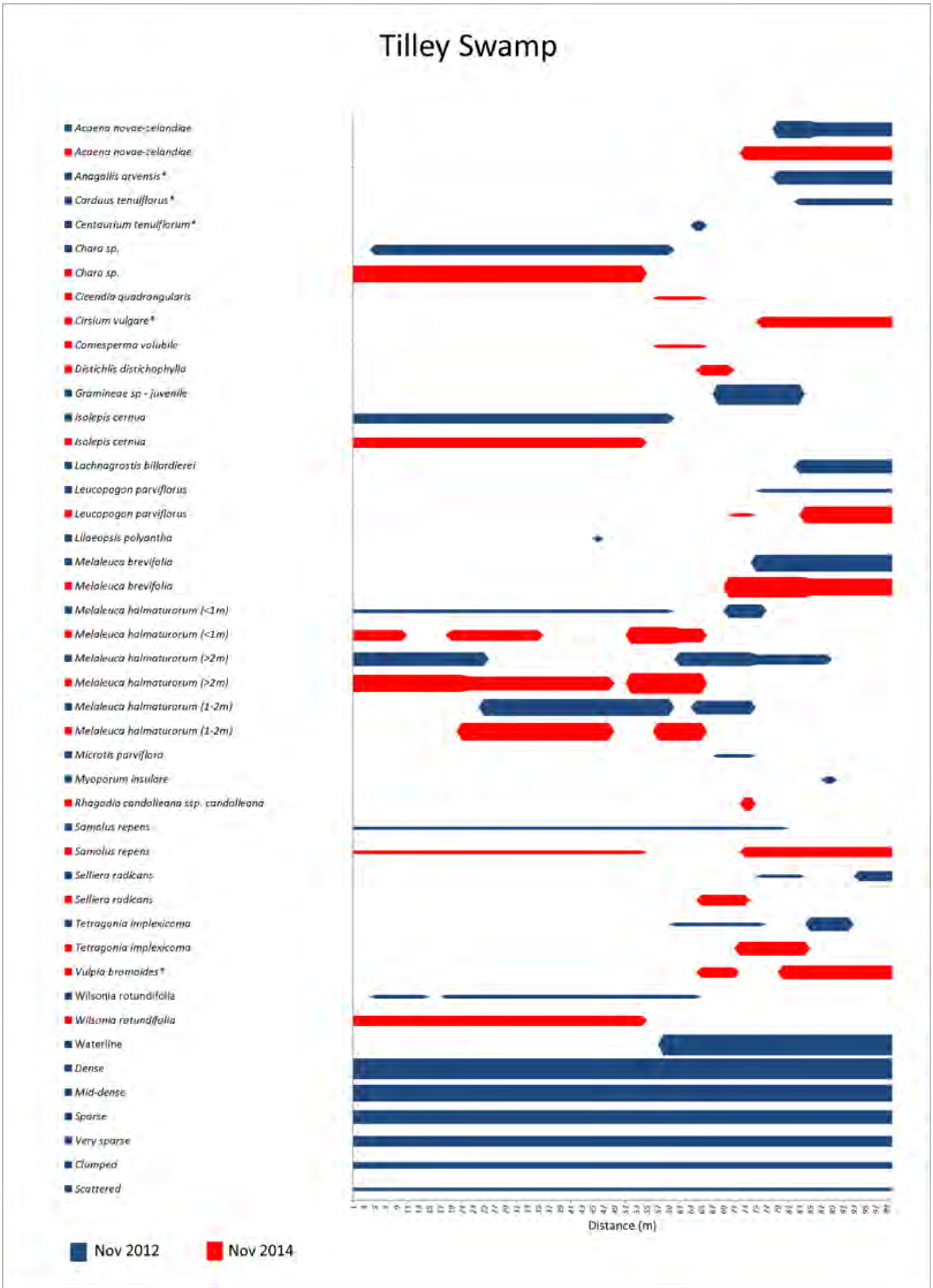

Yuelba 2
Terrestrial Zone
Avena barbata*
Bromus sp.*
Melaleuca halmaturorum
Polypogon monspeliensis*
Medicago polymorpha**
Lolium rigidum*
Sarcocornia quinqueflora
Asparagus asparagoides*
Muehlenbeckia gunnii
Parapholis incurva*
Samolus repens
Hordeum leporinum*
Tetragonia implexicoma
Austrodanthonia sp.
Lilaeopsis polyantha
Wilsonia rotundifolia
Graminea sp fine (no ID features)
Pratia irrigua
Angianthus preissianus
Water Line
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190
Distance (m)


Chris England's 1
Bare Ground
Gahnia filum
Melaleuca halmaturorum
Parapholis incurva*
Sebaea ovata
Angianthus preissianus
Fence
Cotula vulgaris
Hordeum leporinum*
Sarcocornia quinqueflora
Austrodanthonia sp.
Wilsonia rotundifolia
Graminea sp. Fine Lachnagrostis sp.
Waterline
Myriophyllum muelleri
Lilaeopsis polyantha
Water Line
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0
20
40
60
80
100
120
140
160
180
200
220
240
260
280
300
320
340
360
380
400
420
440
Distance (m)

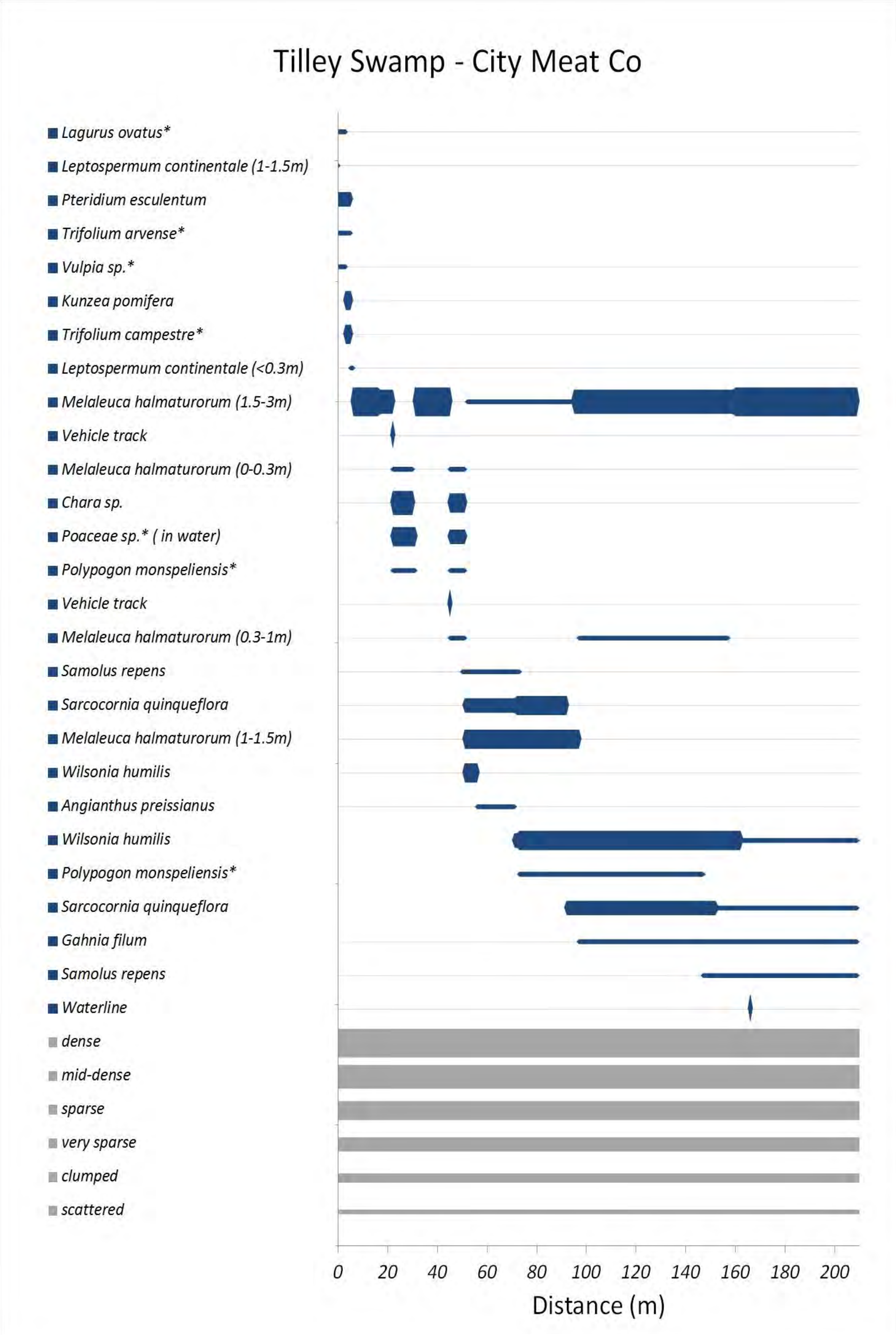

Chris England's 2
Avena barbata*
Bromus hordeaceus*
Hordeum leporinum*
Lagurus ovatus*
Parapholis incurva*
Romulea rosea*
Wilsonia rotundifolia
Bare ground
Gahnia filum
Melaleuca halmaturorum
Sarcocornia quinqueflora
Bromus sp.*
Hordeum leporinum*
Lolium rigidum*
Samolus repens
Sebaea ovata
Graminea sp. Fine Lachnagrostis sp.
Pratia irrigua
Cotula vulgaris
Waterline
Chara sp.
Myriophyllum muelleri
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
220
230
240
Distance (m)

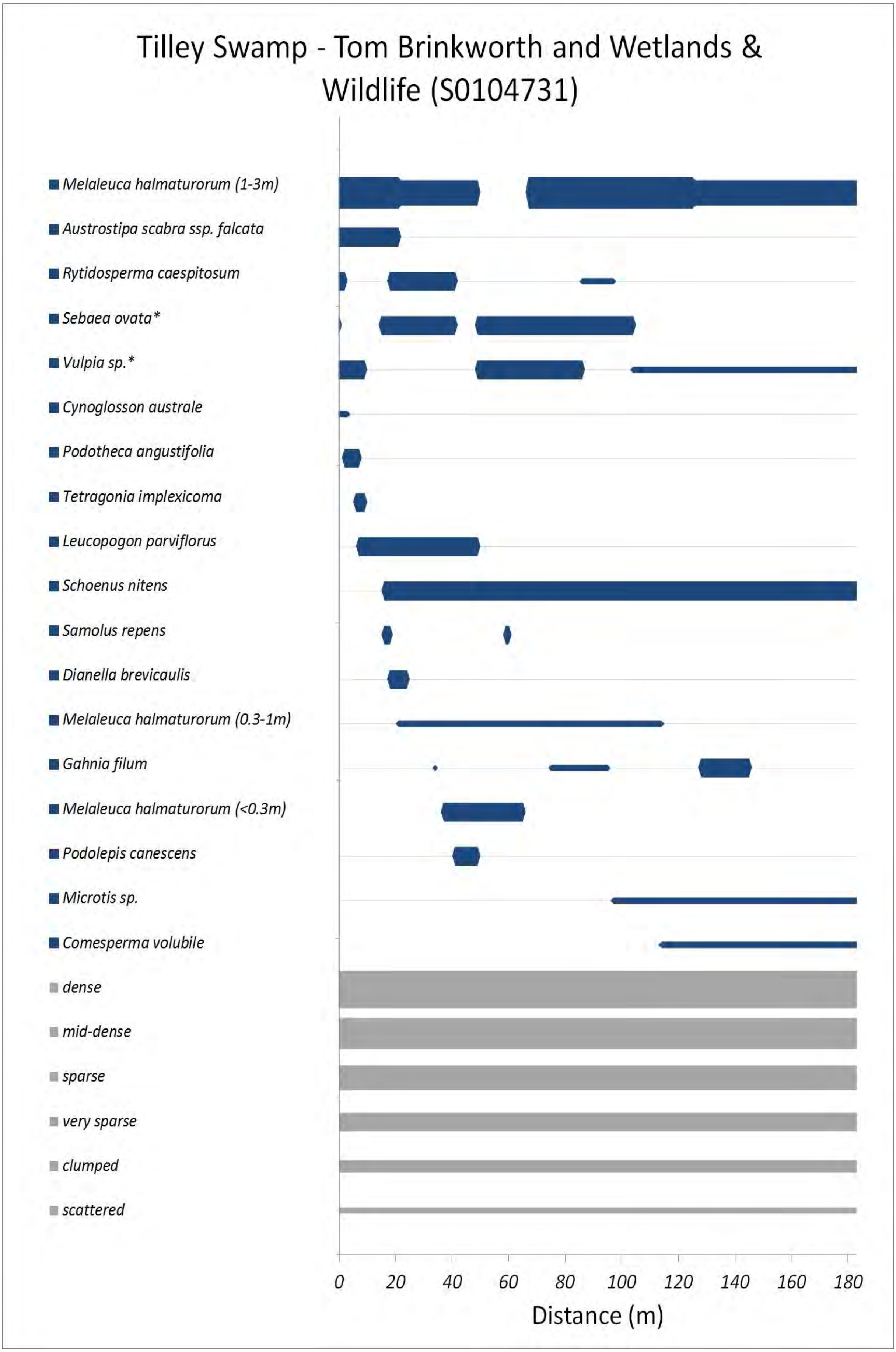

Chris England's 3
Bare Ground
Gahnia filum
Lagurus ovatus*
Melaleuca halmaturorum (>2m)
Melaleuca halmaturorum (0.5-1m)
Hydrocotyle capillaris
Melaleuca halmaturorum (1-2m)
Gahnia filum (j)
Parapholis incurva*
Sebaea ovata
Wilsonia backhousei
Pratia irrigua
Selliera radicans
Graminea sp.
Angianthus preissianus
Cotula vulgaris
Melaleuca halmaturorum (<0.5m)
Austrodanthonia caespitosa
Cirsium vulgare*
Wilsonia rotundifolia
Sarcocornia quinqueflora
Wilsonia humilis
Schoenus nitens
Dense
Mid-dense
Sparse
Very sparse
Clumped
Scattered
0
50
100
150
200
250
300
350
400
450
500
Distance (m)

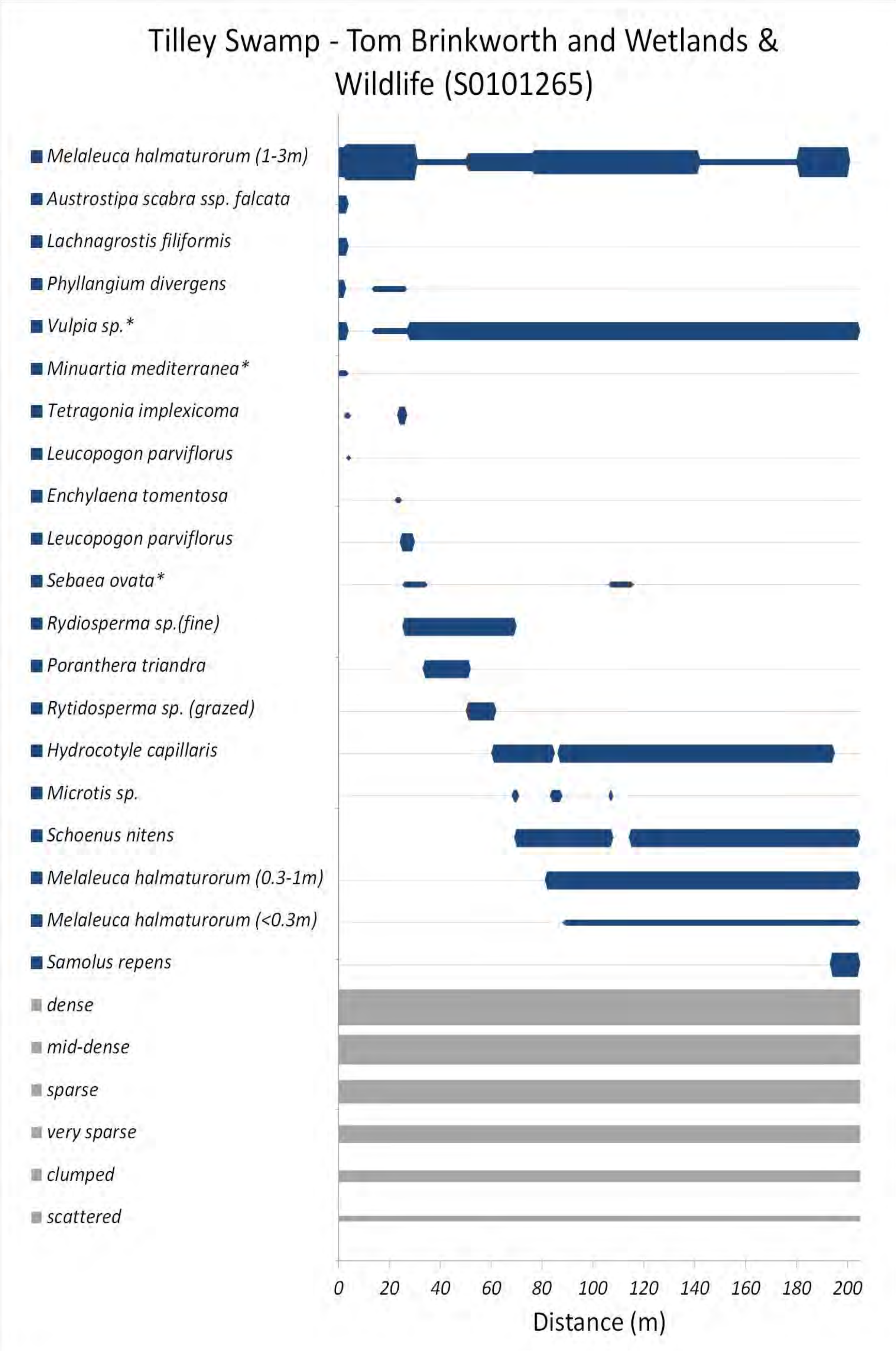
10.6.2 2014 vegetation transect kite charts

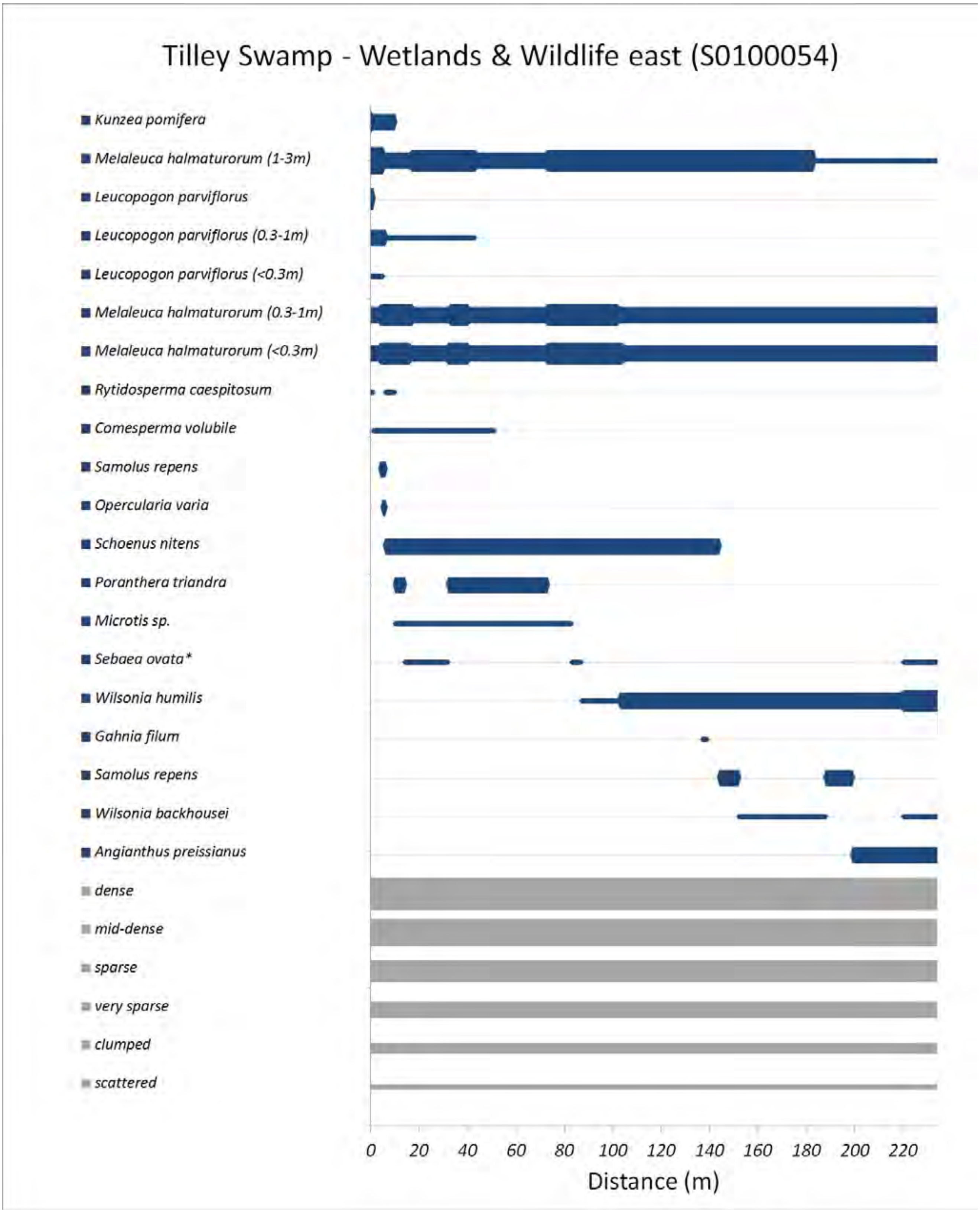


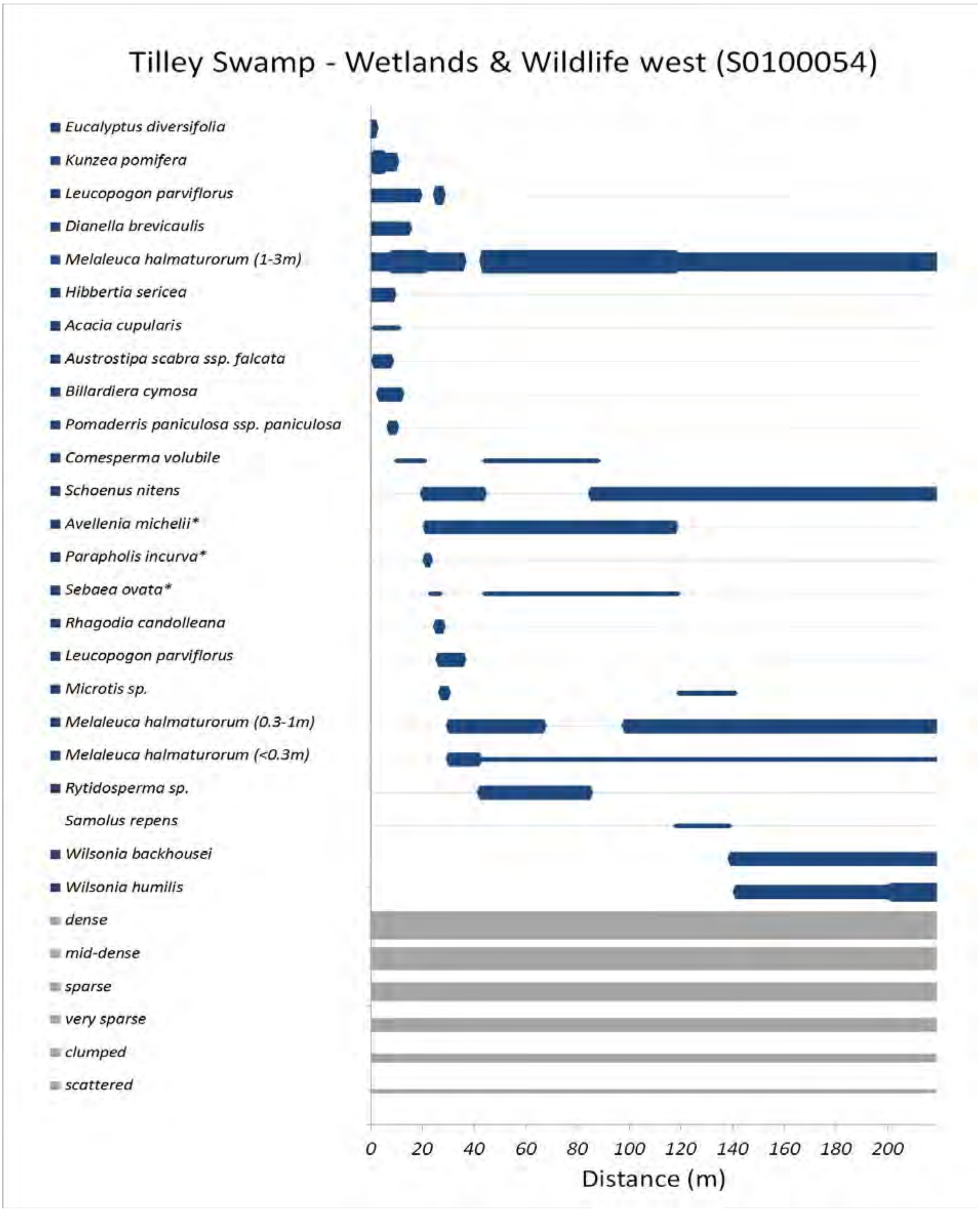
10.6.3 2016 vegetation transect kite charts




Tilley Swamp - Tom Brinkworth and Wetlands & Wildlife (S0104731)
Melaleuca halmaturorum (1-3m)
Austrostipa scabra ssp. falcata
Rytidosperma caespitosum
Sebaea ovata*
Vulpia sp.*
Cynoglosson australe
Podotheca angustifolia
Tetragonia implexicoma
Leucopogon parviflorus
Schoenus nitens
Samolus repens
Dianella brevicaulis
Melaleuca halmaturorum (0.3-1m)
Gahnia filum
Melaleuca halmaturorum (<0.3m)
Podolepis canescens
Microtis sp.
Comesperma volubile
dense
mid-dense
sparse
very sparse
clumped
scattered
0
20
40
60
80
100
120
140
160
180
Distance (m)


Tilley Swamp - Tom Brinkworth and Wetlands & Wildlife (S0101265)
Melaleuca halmaturorum (1-3m)
Austrostipa scabra ssp. falcata
Lachnagrostis filiformis
Phyllangium divergens
Vulpia sp.*
Minuartia mediterranea*
Tetragonia implexicoma
Leucopogon parviflorus
Enchylaena tomentosa
Leucopogon parviflorus
Sebaea ovata*
Rydiosperma sp.(fine)
Poranthera triandra
Rytidosperma sp. (grazed)
Hydrocotyle capillaris
Microtis sp.
Schoenus nitens
Melaleuca halmaturorum (0.3-1m)
Melaleuca halmaturorum (<0.3m)
Samolus repens
dense
mid-dense
sparse
very sparse
clumped
scattered
0
20
40
60
80
100
120
140
160
180
200
Distance (m)


Tilley Swamp - Wetlands & Wildlife east (S0100054)
Kunzea pomifera
Melaleuca halmaturorum (1-3m)
Leucopogon parviflorus
Leucopogon parviflorus (0.3-1m)
Leucopogon parviflorus (<0.3m)
Melaleuca halmaturorum (0.3-1m)
Melaleuca halmaturorum (<0.3m)
Rytidosperma caespitosum
Comesperma volubile
Samolus repens
Opercularia varia
Schoenus nitens
Poranthera triandra
Microtis sp.
Sebaea ovata*
Wilsonia humilis
Gahnia filum
Samolus repens
Wilsonia backhousei
Angianthus preissianus
dense
mid-dense
sparse
very sparse
clumped
scattered
0
20
40
60
80
100
120
140
160
180
200
220
Distance (m)



Tilley Swamp - Wetlands & Wildlife west (S0100054)
Eucalyptus diversifolia
Kunzea pomifera
Leucopogon parviflorus
Dianella brevicaulis
Melaleuca halmaturorum (1-3m)
Hibbertia sericea
Acacia cupularis
Austrostipa scabra ssp. falcata
Billardiera cymosa
Pomaderris paniculosa ssp. paniculosa
Comesperma volubile
Schoenus nitens
Avellenia michelii*
Parapholis incurva*
Sebaea ovata*
Rhagodia candolleana
Leucopogon parviflorus
Microtis sp.
Melaleuca halmaturorum (0.3-1m)
Melaleuca halmaturorum (<0.3m)
Rytidosperma sp.
Samolus repens
Wilsonia backhousei
Wilsonia humilis
dense
mid-dense
sparse
very sparse
clumped
scattered
0
20
40
60
80
100
120
140
160
180
200
Distance (m)

10.7. *Water monitoring stations relevant to the SEFR project*

Monitoring Site	Purpose	Parameters
A2391261 – Blackford Drain upstream of Diversion Regulator	- Measure quality, level and volume of water approaching the Blackford Diversion regulator to inform possible regulator operations	Level, EC, Temp, Flow
A2391262 – Blackford Diversion Regulator	- Measure level and quality of water at the weir pool to inform regulator operations - Monitor AWMA automated gate operations - Allow remote reboot of HMI if required (re-establish remote control)	Level, EC, Temp, Flow
A2391263 – SEF Channel downstream of Diversion Regulator	- Measure quality, level and volume of water being diverted up the SEF channel - Allows comparison with A2391261 and AWMA flow algorithm for total flow heading in either direction from the weir pool	Level, EC, Temp, Flow
A2391264 – Taratap Drain at FS13	- Measure quality and level of water in the SEF channel to inform possible regulator operations at FS15 Yeulba Swamp diversion regulator	Level, EC, Temp
A2391265 – FS13 crossover channel	- Measure quality and level of water passing over the SEF channel and flowing into Yeulba Swamp	Level, EC, Temp
A2391266 – Taratap Drain at TA14	- Measure quality and level of water in the Taratap Drain to inform regulator operations for Taratap Wetland Outfall regulator	Level, EC, Temp
A2391267 – Taratap Wetland Outlet at TA14	- Measure quality and level of water at the wetland outfall point and compare against A2391266 to inform regulator operations	Level, EC, Temp
A2391268 – Tilley Swamp Drain upstream of Petherick Road	- Measure quality, level and volume of water in the Tilley Swamp Drain to inform possible regulator operations at TS01	Level, EC, Temp, Flow
A2391269 – Tilley Swamp Drain at FN17 Diversion Regulator	- Measure quality and level of water in the Tilley Swamp Drain to inform possible regulator operations at Hindmarsh Park Diversion Regulator	Level, EC, Temp
A2391270 – Tilley Swamp Watercourse at Pitlochry	- Measure quality and level of water as it moves through the Tilley Swamp watercourse - Determine travel times for flows moving through the watercourse	Level, EC, Temp, pH/ORP, DO
A2391271 – Frostys Swamp	- Measure quality and level of water in Frostys Swamp - Very early warning of water approaching the outfall point at Martins Washpool	Level, EC, Temp
A2391272 – Tilley Swamp Drain at Martins Washpool	- Measure quality and level of water in the Tilley Swamp Drain - Compare levels with A2391273 to determine when regulator operations at this location are feasible	Level, EC, Temp
A2391273 – Frostys Swamp Outlet	- Measure quality and level of water at the swamp outfall point and compare against A2391272 to inform regulator operations	Level, EC, Temp
A2391274 – Morella Outlet Regulator	- Measure level and quality of water at the terminal end of the Morella Basin to inform regulator operations - Monitor AWMA automated gate operations, including recording flow data from AWMA algorithm - Allow remote reboot of HMI if required (re-establish remote control)	Level, EC, Temp, Flow