# LAKE WARDEN WETLAND SYSTEM: SURFACE WATER QUALITY AND HYDROLOGY REVIEW

Figure 1. Lake Windabout, https://www.bing.com/images/search?view=detailV2&ccid=yHggzHHy&id=B89D61A7B5EE3C1CBAB81111F12CA042AC526C80&thid=OIP.yHggzHHyGX_7CCezUea46wHaE8&mediaurl=https%3a%2f%2fstatic.wixstatic.com%2fmedia%2f3938b5_1c53dfdca2a047208c233a5fc490b2f6

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*Prepared for*

# South Coast Natural Resource Management

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## Introduction

The Lake Warden wetland system, sitting 5km north of Esperance, WA, is an internationally recognised and protected wetland environment that holds exceptional importance. Wetlands are among the most diverse ecosystems in the world, providing essential services for life, and almost all our fresh water (Ramsar, 2020). Under the Ramsar convention for wetlands of international importance the system is recognised for its:

***Biological values – primarily its migratory waterbirds and habitat links***

***Water quality ecosystem functions***

***As a buffer against flood events***

***Indigenous and European heritage***

***Recreation & tourism – walk trails, water sports and amenities***

***Educational purposes – Kepwari Walk Trail Education Pack***

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In previous years, the Lake Warden Catchment was protected under *the "Lake Warden Natural Diversity Recovery Catchment,"* who's key objective was to protect the species richness and abundance of the area. In 2014, this plan was scrapped and replaced by a *"Care and Maintenance,"* phase. This paper gives an in-depth review of the Lake Warden system (including the hydrology of the lakes) and reviews current management practise, providing recommendations to help protect this beautiful wetland into the future.

# Background

## Hydrology

Hydrology is defined as the study of water, including its occurrence, distribution, circulation, and interaction with the environment around it (Britannica 2020). Although the hydrology of the Lake Warden Catchment has been studied for years, our understanding of the area's overall hydrology was still limited.

The Lake Warden catchment is approximately 212 000 ha of which 85% has been cleared for agriculture and other human land use (this is roughly 148 000 ha). Since the town of Esperance has developed around the system, there are many direct and indirect impacts on the catchment from human activity. It consists of eight major lakes and 90 smaller surrounding ones, some extending beyond the Ramsar boundaries. The system is divided into three main hydrological zones:

***Eastern suite***

***Central suite***

***Western suite***

**See figure 2 for the boundaries of Lake Wardens three hydrological zones**

Water moves through these systems in a north to south direction, with much of the water moving underground (termed groundwater).

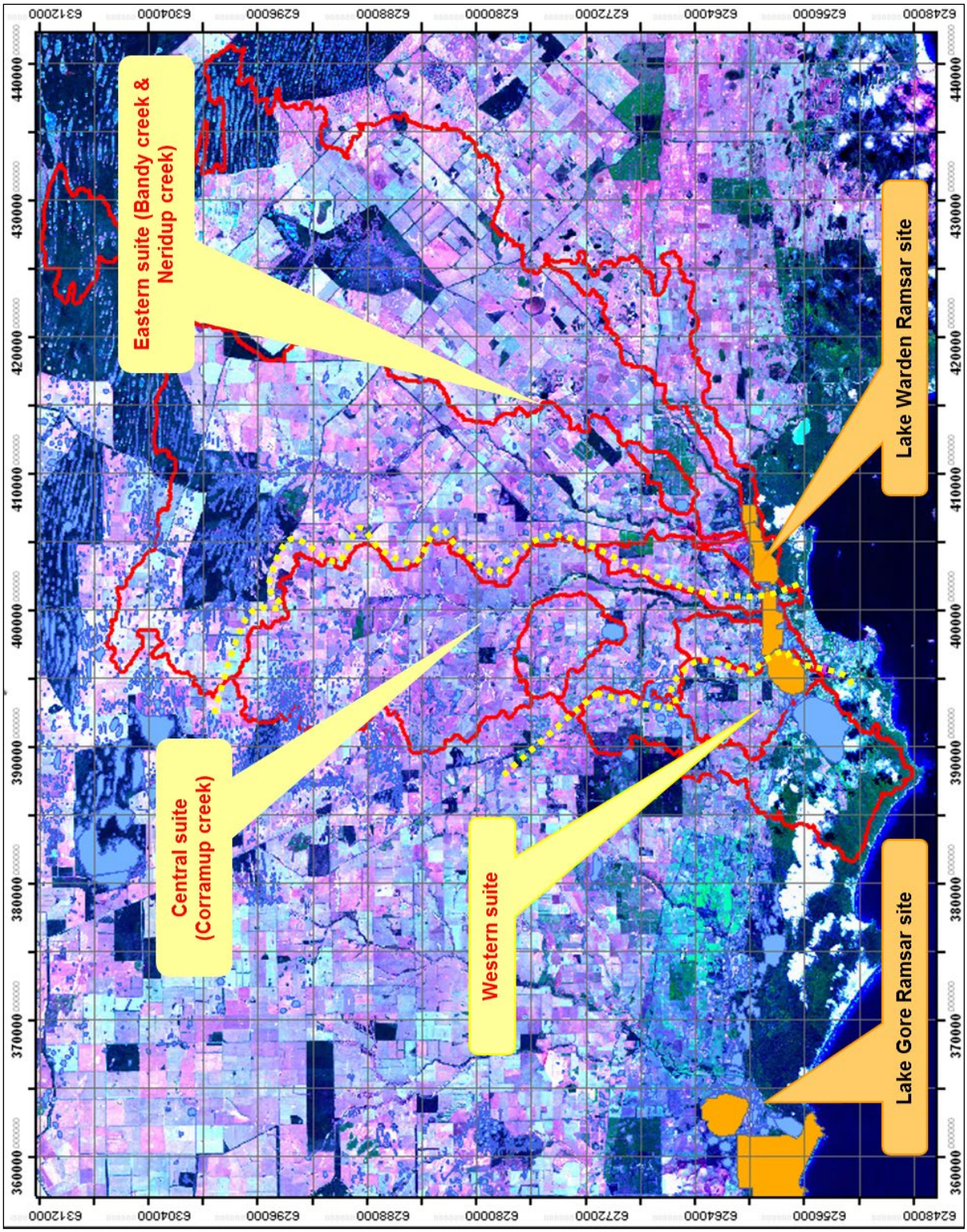


Figure 2. Hydrological Zones of the Lake Warden Catchment, Esperance WA

## The Eastern Suite

Water in the Eastern suite comes from the Neridup and Bandy Creek catchments and is made up of Lakes Ewan's, Mullet, Station and more (figure 3). It was previously thought that Bandy Creek only passed water into Station Lake, although we now know that water in fact flows through Ewan's Lake in its journey between Bandy Creek and Station Lake. Mullet Lake is known as a terminal lake, meaning this is where water will not be passed on, but instead held at Mullet Lake as its "final destination."

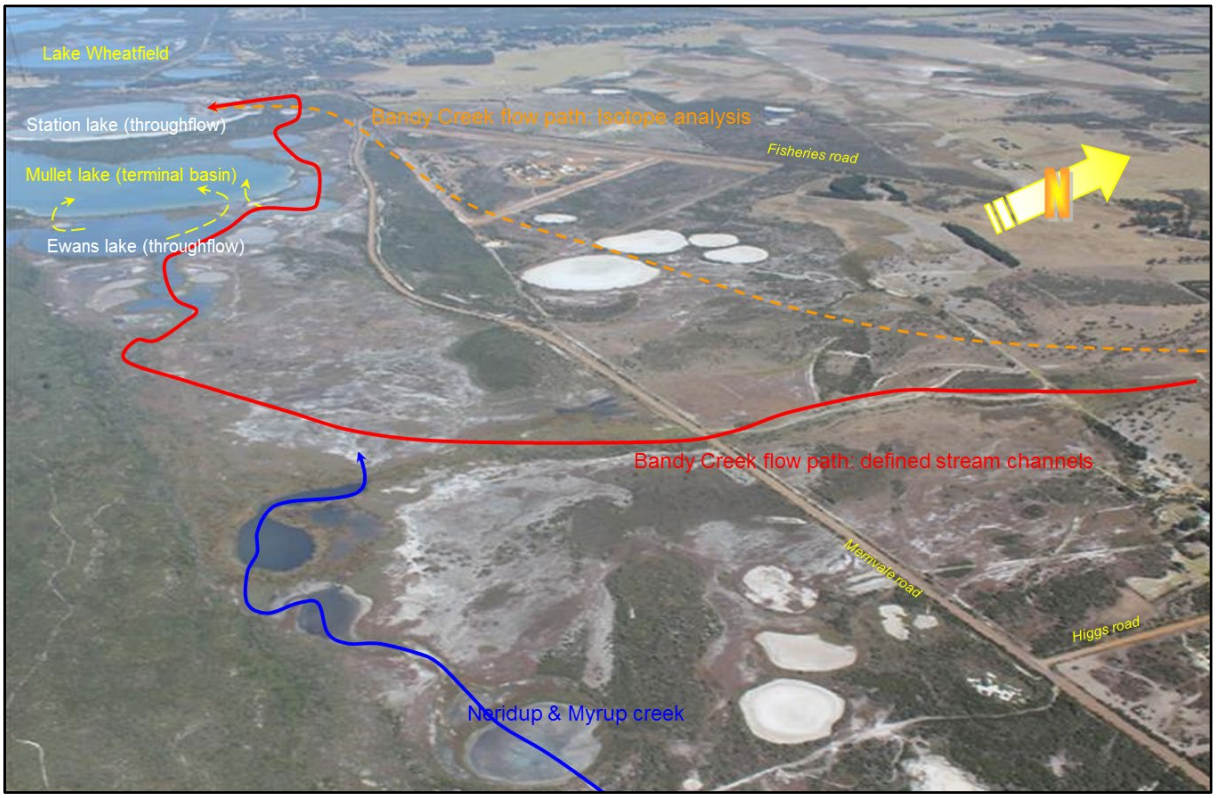


Figure. 3 The Eastern Suite (zone 1) and its flow paths

The Eastern suite is naturally saline and alkaline although it does fluctuate seasonally. Summer months can bring about changes in pH and salinity, that can sometimes lead to algal blooms or hypersaline conditions at times when there has not been a lot of rain. Most of the lakes in the Eastern suite rely on rainfall to keep them full, and in long periods of dry weather, are susceptible to drying out. Only Ewan's and Mullet Lake stay full all year round, as they are fed by groundwater, not rainfall. We call these types of lakes, "perennials," (Whitford W.G. & Duval B.D. 2019).

## The Central Suite

This zone (figure 4) consists of Lakes Wheatfield, Woody, Windabout and more. Water flows to the Central suite from Coramup Creek, which goes directly to Lake Wheatfield. Lake Wheatfield then feeds all the other lakes in the system. This "flowthrough," has been significantly altered by human activity and erosion in the Coramup area, which has resulted in large floods in past years. Human intervention is need in this area to help manage the flow of water and prevent flood events. Recommended intervention like gravity pipelines have already been implemented and have successfully eased the "flowthrough."


Figure 3. The Central Suite (zone 2) and its flow paths

All lakes in the Central Suite are perennial with only the small satellite lakes drying up over summer. Just like the Eastern Suite, pH, salinity, and depth of the lakes change with the weather and can be very different between winter and summer. For example, all the lakes are naturally saline, but can become more saline in summer with less rain providing the required freshwater input. It is also normal for Lake Windabout to be cut off from Lake Woody over the summer months, as the water depth declines.

## The Western Suite

This suite consists of Lake Warden and Pink Lake which are connected by a series of smaller lakes (figure 5). These two lakes are terminal, and there is no real drainage of water here, they are essentially the "sump" of the entire catchment, a place where all the water, nutrients and material end up. Lake Warden and Pink Lake have been disconnected for many years, which has caused a significant impact on the lakes. Primarily, salts received by Pink Lake from the entirety of the Lake Warden Wetland system, are now deposited into Lake Warden, and not received by Pink Lake.

### *Lake Warden –*

*This lake has a catchment of approximately 5600-6800 Ha, and gains groundwater from other, nearby systems. Warden is linked to Pink Lake through a series of smaller lakes, which are thought to create a "chain," that allows water to pass between the two terminal lakes. Warden is highly variable, its salinity and pH can change rapidly, even within just one day. Warden's peak salinity can reach more than 400,000 mg/L at the lakes surface.*

### *Pink Lake –*

*Pink Lake has a catchment of approximately 7000Ha which is supplied directly from rainfall and groundwater seepage only, Pink Lake does not get water from any creeks or streams. The lake has hyper-saline waters from East to West, while the West and South ends tend to be fresh to brackish. Its salinity can vary greatly throughout the seasons peaking at approximately 105,000 – 210, 000mg/L.*

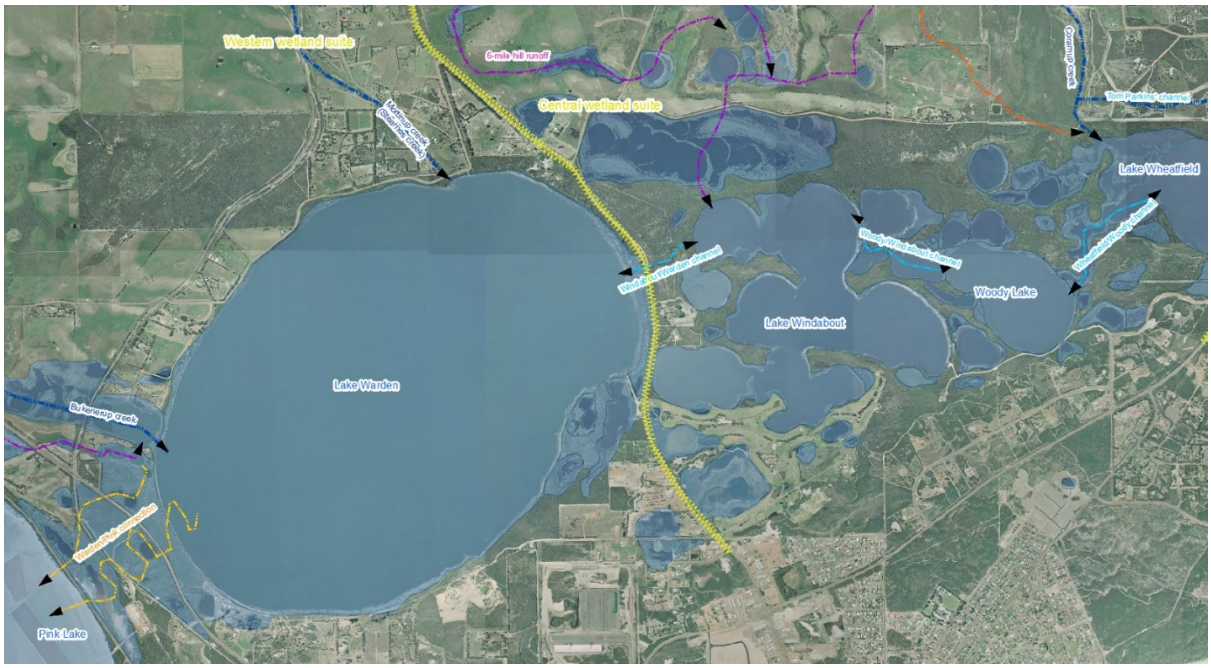


Figure 4. Flow paths of the Western & Central Suite

## The water quality of the lake warden wetland system

The water quality in this wetland system is poorly researched, with most sampling being done for certain lakes in isolation. This means we have very little data that is comparable for the whole system, or that has been recorded continuously over an extended period. Because of this, it is hard to properly understand the relationships and interactions between the lakes.

Some sampling has been undertaken in the years between 2009 – 2016, including major nutrient analysis by Parks and Wildlife Esperance, Parks and Wildlife Perth and the University of Western Australia (UWA). The problem with these samples is their low frequency that will not accurately represent trends in the systems water quality over time.

The need for sampling frequency arises as some reactions in the water will occur over a couple of minutes, while others may take weeks. Current sampling of the area is therefore, only giving us "snapshots," of the system with many missing puzzle pieces. Without frequent, accurate, and consistent monitoring of the system at all scales (from individual lakes, to the whole system) everything we known about the water quality of the Lake Warden Wetland System is based on individual interpretation, local knowledge, and bias.

### Ewans Lake

Ewan's Lake is a very healthy system. It is considered free-draining and perennial, meaning it is full of water all year long. In its water, there are plenty of nitrates and just enough phosphates (two nutrients that assist plants to grow) to support the system without causing algal blooms. (An algal bloom occurs when the wetland has too much nitrate and phosphorus, removing oxygen from the wetland and killing the organisms that live there). The lake is dominated by chloride and sodium and has increased in salinity 18% since 2003.

### Mullet Lake

Much like Ewans, Mullet Lake has plenty of nitrates and just enough phosphorus to support a good, healthy system. At times, there is an excess of these nutrients (often after summer flooding) which causes an increase in plant activity but there is not a lot of data about these changes. Mullet is also dominated by chloride and sodium and its salinity has increased 11% since 2003. Mullet Lake is another terminal lake, however, in high rainfall it can flow through to other areas.

## Station Lake

Station Lake has the same nitrate and phosphorus characteristics as Mullet and Ewans Lake although we see rapid increases in these nutrients following summer floods. More data will need to be collected to understand the effects of the increasing nutrients in this event. chloride and sodium dominate the system and the salinity has increased 5% since 2002. Station Lake is free-draining and ephemeral, meaning the lake is only full for short periods of time during the year, usually after high rainfall events. Overall, this lake is in good health.

## Lake Wheatfield

This lake is quite different to the others with nutrients that have changed greatly over time. Phosphorous has increased since 2014, while nitrates have decreased. There has been more than one incident of fish deaths in the Lake, which could be because of a lack of oxygen, or the increase in ammonium and bromine. To this date there is no sufficient evidence to properly explain the deaths. One phenomenon that occurs in Lake Wheatfield is a sudden disappearance of algal blooms in summer. The cause of the algae's death is not known, but when this occurs, ammonia concentrations rapidly increase to toxic levels. This occurs as algal remove ammonia through intense synthesis, keeping ammonia levels in the water down at non-toxic levels, once the algae die, there is nothing removing excess ammonia in the water.

Salinity at Lake Wheatfield has increased only 5% since 2002 and dropped by 2% when the Lake Wheatfield pipeline was installed in 2009. This lake is perennial and deemed to be in good health.

## Woody Lake

Woody has a healthy supply of nitrates and phosphorus, at times there is an excess of phosphorus which causes an increase in biological activity. Woody Lake is perennial and has only increased in salinity 5% since 2003. The installation of the Lake Wheatfield pipeline also caused Woody to drop in salinity approximately 2%. This is because the lakes are interconnected and operate as one, linked by water flowing between the two for most of the year. This water flow may stop during dry summer months.

Unexplained fish deaths have also occurred in Woody Lake, which require more data to understand, but in general the lake is very healthy.

## Lake Windabout

Windabout has a healthy supply of nitrates and phosphorus, at times there is an excess of phosphorus which causes an increase in biological activity. Salinity has increased 8% since 2003, with the installation of the Lake Wheatfield pipeline having no effect on this increase. The Lake is perennial and connects to Woody Lake via several smaller “Satellite,” lakes that bridge the two major lakes. Some natural barriers exist between Windabout and Woody, including a sandbar that can stop the flow of water between the two. Lake Windabout also suffers from the unexplained fish deaths. Despite this, the Lake is in good health.

## Lake Warden

The installation of the Lake Wheatfield pipeline has reduced the amount of water entering Lake Warden since 2010, it now relies on water from large runoff events i.e. high rainfall or floods to fill the lake. Nutrients and salinity are highly variable at Lake Warden. There is an estimated increase in salinity of 30% since 1980’s Warden’s poor data collection makes it hard to be sure of true nutrient and salinity values.

## Pink Lake

Pink Lake’s salinity and nutrients vary greatly, much like Lake Warden. Data from the Lake is most likely inaccurate and does not give a good representation of the water quality. Given Pink Lakes history of salt mining however, we can accept that salinity has decreased from historical levels following this mining. The lake is ephemeral and dries up most summers. Despite the limited data and declined salinity, the lake appears to be in good health.

# Keeping the system healthy – management targets

## The Western Suite

Lake Warden's optimal depth is between 0.3 – 1.4m, this is where depth is most suitable for waterbirds (Massenbauer 2007). However, returning Lake Warden to this optimal depth level has caused an increase in salinity which may be causing a decline in aquatic invertebrates in the lake, a food source for the waterbirds. Balancing the need to reach this optimal depth, while maintaining low levels of salinity is considered the primary challenge for the Lake Warden wetland system. The compromise is that; to accept high water levels will reduce the salinity of the lake but reduces available shore habitat to between 26 to 48Ha.

Due to infrequent monitoring between 1979 and 2002, our knowledge of salinity, runoff and other parameters is very poor, this creates challenges when trying to understand the data we are seeing today. However, since 2002, monitoring consistency has improved, and we see that salinity levels have increased around 30%. We also know from weekly shorebird counts that because of the salinity increase, there is a disappearance of known waterbirds.

As Lake Warden is a terminal lake, once salt enters this system, there is no natural way for it to be removed. While Lake Warden gets increasingly saline, historic salt mining at Pink Lake has decreased the salinity of the lake enough for it to lose its famous pink hue. The *Pink Lakes Project* suggests that removing salt from Lake Warden and replacing it into Pink Lake will both allow Lake Warden to reduce its salinity and regain its waterbirds, while Pink Lake increases its salt load and goes back to being pink. In the meantime, Lake Warden should be kept between 0.8 – 1.5m for optimum shorebird habitat, meaning that no less than 26ha of exposed shore surrounds the lake, and median summer salinities does not exceed 160 000 mg/l.

## The Central Suite

The central suite is predominantly managed under the Standard Operating Procedure of the Lake Wheatfield Pipeline (table 1) which has proved very successful. It has also helped to reduce water flowing into Lake Warden, helping Warden with its salinity issues as listed above. By controlling water with the pipeline, salinity has reduced in Wheatfield, Woody and Windabout and over the next couple of decades salinity in the central suite may in fact be reversed.

**Table 1. Standard Operating Procedure for Lake Wheatfield Pipeline**

| Standard Operating Procedure for Lake Wheatfield Pipeline |
| --- |
| ***Guideline 1:*** *Pipeline remains closed until water level in Lake Wheatfield exceeds 1.2m.* |
| ***Guideline 2:*** *When water level exceeds 1.2m (or is likely to exceed 1.2m initially) and its predicted that the water level will exceed an overall depth of 1.6m as a result of a large rainfall event or a wet season, the pipeline is opened.* |
| ***Guideline 3:*** *Once the water level has dropped to 1.0m (or is likely to drop by itself because of a dry season), the pipeline is closed. The pipeline can be closed sooner if water level predictions indicate the water level is likely to drop below 0.8m over the summer period to prevent this from happening* |

## The Eastern Suite

Currently, the system is free draining to the Southern Ocean, there is no management in place for this suite. By removing the Bandy Creek Weir, the system has also recovered from flooding. The only cause for concern is increased salinity levels, but this is only directly linked to reduced water levels.

## Maintenance & care

As of 7 October 2014, the Lake Warden Natural Diversity Recovery Program entered a maintenance phase where the very basic obligations regarding the program can be met and maintained. The main factors for these obligations are:

- The systems Ramsar listing (this means there are federal and international reporting requirements)
- Responsibilities for certain infrastructure, such as the Lake Wheatfield pipeline.

There is a current water monitoring program (table 2) however this program is only sufficient for observing trends over time i.e. changes in salinity from 1998 to 2002. To understand changes in the wetlands and why they are happening i.e. the unexplained fish kills, it is important to include more detailed monitoring.

Table 2. Lake Warden Wetland System current Water Monitoring Program

| | **Locations** | **Parameter(s)** | **Frequency** |
|---|---|---|---|
| Surface water quantity | All depth gauged lakes of the LWWS | depth at gauge | monthly |
| Surface water quality | All depth gauged lakes of the LWWS | salinity, pH | monthly |
| | All depth gauged lakes of the LWWS | TN, TP, Orthophosphate, Nitrates and chlorophyll A | quarterly |
| Groundwater quantity | All bores | depth to groundwater | Not monitored |
| Groundwater quality | Shallow bores | salinity, pH and RDO | Not monitored |
| | Deep bores/pisos | salinity, pH and RDO | Not monitored |
| Surface water quality | Lake Wheatfield, Bandy creek at discharge point (B2), Bandy creek at harbour (B3) | Depth at gauge, salinity, pH, TN, TP, Orthophosphate, Nitrates and chlorophyll A | Fortnightly whilst pipeline operating |
| Operation of pipeline | Lake Wheatfield | - | As per SOP |

## Conclusion

The Lake Warden Wetland System is poorly understood, data and monitoring have been sparse and inconsistent over the years. What we can understand is this:

The Eastern Suite appears to be very stable with only small fluctuations in salinity because of nearby clearing. The management of water levels in the central suite is resulting in a possible improvement of water quality and is helping to reduce the salinity of Lakes Windabout and Warden. The Western Suite is by far the largest cause for concern and should be a primary focus of management in this system.

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