Impacts of Rural Drainage on Nature Conservation Values

Nyabing Case Study 2:

Technical-Assessment

Project for Department of Conservation and Land Management

RFQ 46510/99

Prepared by

actis Environmental Services and Regeneration Technology Pty Ltd

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Disclaimer:

The assessment criteria presented in this report are suggestions made by the consultants for consideration. The assessment criteria do not represent the views of CALM or any other organisation. Further more the case study results cannot be used to evaluate the Nyabing Drainage Project, as there was no opportunity for the proponents to review the process or data used. Official Project data may have been subsequently modified after the initial exchange of information.

Technical Assessment

Introduction

The Nyabing Drainage Project is used in this section as a case study example of a technical assessment of the Evaluation of Saline Drainage (*actis* Environmental/Regeneration Technology 2000). The outcome of this case study will not affect the progress of this project, which has already met the requirements the present NOI scheme.

The case study presents the outcomes of TECHNICAL ASSESSMENT process. The technical assessment is based on a more detailed investigation and modelling of the hydrology of the Lake Coyrecup Catchment, as well as some biological investigation of wetland flora and fauna. The SELF ASSESSMENT of Nyabing is presented in a separate document.

The initial investigation of the TECHNICAL ASSESSMENT is an evaluation of the water and salt fluxes in the catchment and Lake Coyrecup specifically. The mass balance was then used to model changes in the hydroperiod, salt load, salt concentration, and area flooded with and without a discharge from the proposed drains in Lake Coyrecup. Speculations on the log term changes in the catchment were made and the changes that may be expected to the Lake by increased discharge scenarios. The results of a brief biological survey complete the TECHNICAL ASSESSMENT.

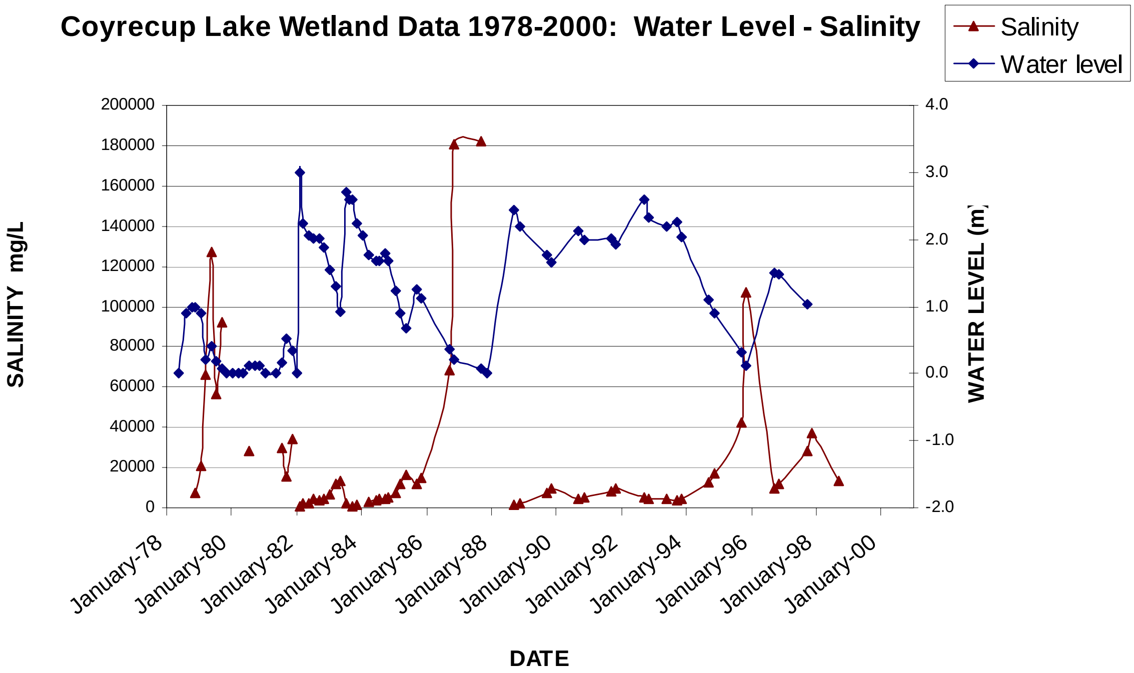
Mass Balance

Water and Salt Balance of Lake Coyrecup

Several attempts were made to model the water balance of Lake Coyrecup. They were not completely successful because the creeks that ultimately feed Coyrecup do not have a defined channel to the lake basin. All creeks deteriorate into shallow discontinuous channels at the *Halosarcia* flats to the east of the Lake. It is expected that the water flow from the creeks recharge the water table in most creek flow cases. Some times the creek water will bypass the Lake to continue onto Dumbleyung Lake, or overland to Lake Coyrecup. The lake volume in Coyrecup is then principally a function of water table levels plus an occasional top up from the overflow. Most models deal with either surface flows or groundwater movements, and it is difficult to estimate the impact of the drain flow on the groundwater levels.

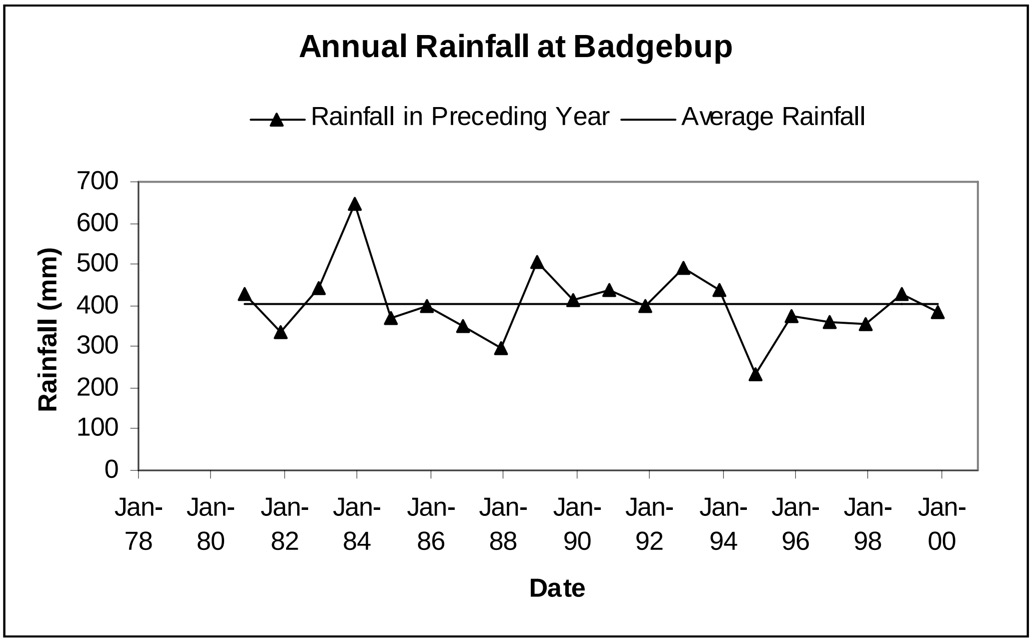
The water and salt balances of Lake Coyrecup have been estimated to provide an indication of the factors which need to be considered when assessing the impact of imposed flow conditions, such as artificial drainage, on the riparian and wetland systems in the wheatbelt of WA. Working with both salt and water balance calculations assists in placing estimates to the numbers required to complete each balance.

Figure 1 Lake Coyrecup Data



Only a snapshot of the salt and water balance is possible given the availability of hydrology and salinity measurements of both rainfall and stream flow in the region is limited to 1996-1999 period.

Figure 2. Catchment Rainfall (Bureau of Meteorology)



There are two major drainage lines forming the catchment above Lake Coyrecup. The northern arm is the Nyabing sub-catchment in which artificial drainage is proposed. The southern arm is the Gnowannullup Gully sub-catchment which is much larger but does not include any rural township. The Lake Coyrecup catchment is headwaters to the Coblinine River and forms one third of the catchment for Dumbleyung Lake.

The long-term (1916-1999) average annual rainfall based on the two rainfall stations in the Nyabing Sub-catchment (Badgebup and Kwobrup) is 416 mm. The rainfall value of 381 mm used in the water and salt balance is for the period 1966-1999 when streamflow data were also available. In the last 20 years the long-term (10 year) moving average has been ≤400 mm.

Annual Indicative Water and Salt Balance

Assumptions Used:

i. Area of the Catchment to Lake Coyrecup = 194,165 ha

ii. Nyabing Sub-catchment = 59,752 ha (WRC figure. Kevin Lyons used 44,200 ha)

iii. Gnowannullup Gully Catchment = 134,413 ha.

iv. Rainfall is the mean of stations #10508 (Badgebup) and #10589 (Kwobrup) for 1996-1999 inclusive.

v. The Bibkin gauging station (609021) where Coblinine River enters Dumbleyung Lake was used for flow estimate. Lake Coyrecup catchment is 34% of this catchment.

vi. Area of Lake Coyrecup is 453 ha (WRC measurement using GIS)

vii. Lake contains water for the 7 months based on recorded streamflow.

viii. There are no piezometer data to indicate hydraulic gradients or water quality. Damp soil immediately below a skin (<2mm) of a dispersed clay layer covering the floor of the lake in February 2000 suggested an upward gradient. A 0.5 m augered hole did not produce free water within 30 minutes. Both these observations suggested the hydraulic head (groundwater level) is within a metre of the soil surface in summer. This generality is supported by data (13/1/00) supplied by Colin Walker (Geo & Hydro Environmental Management P/L) from recent installation of cased holes for shallow water table levels in 5 transects in the Lake Coyrecup Reserve.

ix. One datum for salinity of groundwater at 3.4 m depth in 1998 with salinity at 1930 mS/m (approx. 12.000 mg/L) was provided by Machushla Prasser-Jones (Agriculture WA, Kojonup). Groundwater salinity in alluvium for the Dumbleyung Landcare Zone is given by Cody (1994) at >14,000mg/L.

x. The volumetric capacity of Lake Coyrecup is about 4,530,000 m^3 per metre depth.

xi. Proposed drainage is 78 km excavated open relief drains producing flow of 0.2 L/sec/km, plus 38 km of shallow relief drains, with discharge being continuous for 150 days each year. (K. Lyons).

xii. Lake Coyrecup last overflowed in 1992 when rainfall at Badgebup rainfall station was 491 mm. Since 1950, rainfall has exceeded 490 mm in 1955, 1963, 1964, 1968, 1971, 1974, 1982, 1988, 1992.

Table 1 Lake Water Balance

Parameter	Water Vol m^3	Comments
INPUT		
Rainfall	1,725,900	1996/99 data – mean rainfall is 381 mm
Stream Inflow	3,658,600	1996/99 data based on Bibkin gauging station
Artificial Drainage	202,200	78km drain @ 0.2L/sec for 150 days/year
Groundwater Inflow	275,600	Flux of 0.4mm/day over 5 month period
Total Input	**5,862,300**	
OUTPUT		
Evaporation-Lake	1,929,000	Water in lake for 7 months – 2mm/day evap
Evaporation-Soil	275,600	Evaporation of g/water inflow for 5 months
Surface Outflow	0	No evidence of flow from lake since 1992
Groundwater Recharge	3,858,100	Recharge at 4 mm/day for 7 months required to close the water balance.
Total Output	**6,062,700**	

Table 2 Salt Balance for the Lake

Parameter	Salt Mass tonne	Comments
INPUT		
Rainfall	17	Uses 1996/99 data at 10mg/L salt concentration
Stream Inflow	49,715	1996/99 data based on Bibkin gauging station with flow-weighted salinity of 13,600 mg/L
Artificial Drainage	3,033	Salinity 15,000mg/L for 150 days of flow/year
Groundwater Inflow	4,134	Groundwater salinity 15,000mg/L for 5 months
Total Input	**56,899**	
OUTPUT		
Evaporation-Lake	0	Water in lake for only 7 months
Evaporation-Soil	0	Discharge for only 5 months
Surface Outflow	0	None in 1996-1999 period
Groundwater Recharge	57,871	Lake water salinity for recharge at 15,000mg/L
Total Output	**57,871**	

Conclusions from Water and Salt Balance Estimates

Runoff is generally greater (maybe factor 4 at average rainfall) than the volume of rain falling on lake surface. Surface inflow (3.6 GL) plus rain falling on the lake (1.7 GL) are at least an order of magnitude greater than the additional flow from projected artificial drainage scheme (0.2 GL). The salt inflow by the stream flow into the lake is the dominant source of salt (50,000 tonnes) for the lake being about an order of magnitude greater than from the proposed drainage (3,000 tonne) or from an estimate of groundwater discharge into the lake (4,000 tonne).

What is the potential volume of an artificial drainage system for an integrated salinity management strategy in the Nyabing sub-catchment (59,750 ha)? Assuming that excess recharge beneath agricultural land is about 5% of rainfall, that 75% of the sub-catchment is under arable agriculture, and that 50% of the excess water is managed by appropriate vegetation systems, then the volume of water to be added annually to the lake from an effective drainage system could be about 4 GL. For the whole catchment above Lake Coyrecup the potential drainage water volume is 14 GL annually.

The lake capacity is adequate to store the water received as runoff from years of about average (≈420 mm) or less rainfall. This has certainly been the case since 1992 (based on the current condition of the outflow channel and culvert) when rainfall was about 490 mm. Currently, the channel by which outflow from the lake would occur shows that it has not had flow for a long time. Local advice indicated that the last known outflow was in 1992.

There is sufficient potential evaporation (at ≈0.7 times E_{pan} equivalent to ≈1400mm) to remove the water being received by the lake from stream flow and rainfall. However, this loss of water would need to be demonstrated by the accumulation of about 65,000 tonnes of salt in the lake in each year since 1992. Observation show that this accumulation has not occurred. Quite the opposite was evident in February 2000 as no salt crystals were observed on the surface of soil in the dry lake bed.

To achieve a salt balance, it was found that recharge to the groundwater through the base of the lake needed to be about 4 mm/day for the estimated 7 months when inflow to the lake occurred. This seems a high value, but recharge is the only route out of the lake for salt in years when there is no surface outflow. Groundwater recharge from the lake will occur only when the lake contains water with a hydraulic head that exceeds the head of the groundwater. There was no indication that the hydraulic head of the groundwater beneath the lake was above the floor of lake.

It is not conclusive that groundwater discharge into the lake occurs with any significant magnitude. The estimate used (0.4 mm/day over 4 months) is probably high and may only be as vapour flow when the lake is dry which coincides with the period of high potential evaporation. There is no evidence that there is adequate hydraulic head to cause liquid discharge (seepage) from the groundwater system into the lake. Evaporation, however, will cause salt accumulation in the near surface and contribute to the salt load in the lake. A large error in the estimate of the salinity of the groundwater discharging into the lake does not have a significant bearing on the overall salt balance because of the dominance of the salt load coming with surface inflow to the lake.

The movement of salt out of Lake Coyrecup by groundwater recharge means that the salt load is being transferred to the area of land down-gradient where hydraulic conditions cause that saline water to discharge at the soil surface. These areas are “new” saline wetlands. Where this recharge mechanism applies, it will also carry any additional salt contributed to a lake via artificial drainage systems. However, for the proposed drainage the mass of extra salt is within the error term for this analysis.

For the catchment of Lake Coyrecup the output/input ratio for salt averaged 8 for 1996-1999 period.

Water and Salt Model for Lake Coyrecup

The following figures were generated for Lake Coyrecup using local evaporation, rainfall, calculated runoff and estimated drain flows as inputs. The climate data was sourced from the Bureau of Meteorology's web page, the runoff calculation was provided by Adrian Peck and the modelling by Mark Coleman of `actis` Environmental Services.

The model automatically adjusts evaporation rates with changing salinity. Seepage is assumed to be constant at 1.5mm per day. The period increments for calculations were fortnightly.

Figure 3 Area of Lake Coyrecup

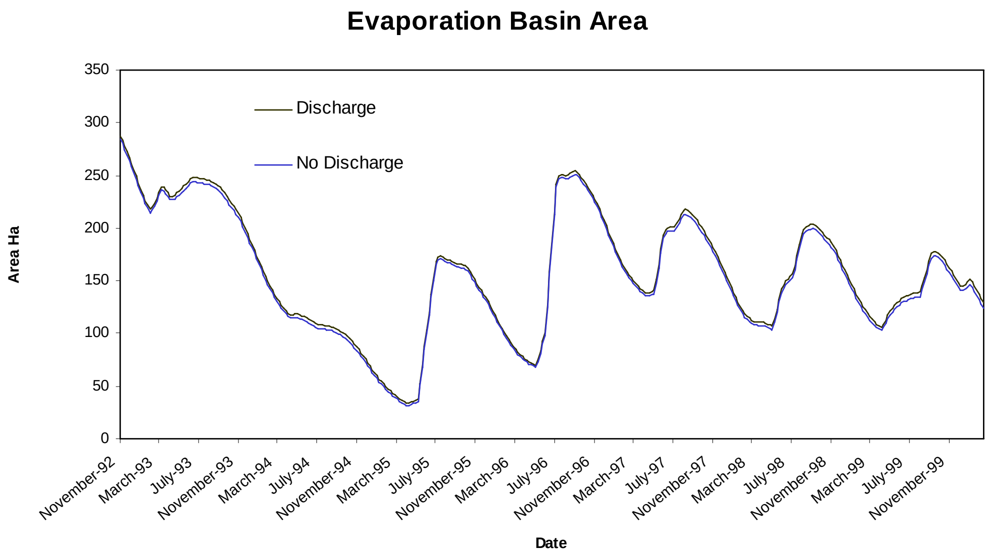


Figure 4 Water Height in Lake Coyrecup

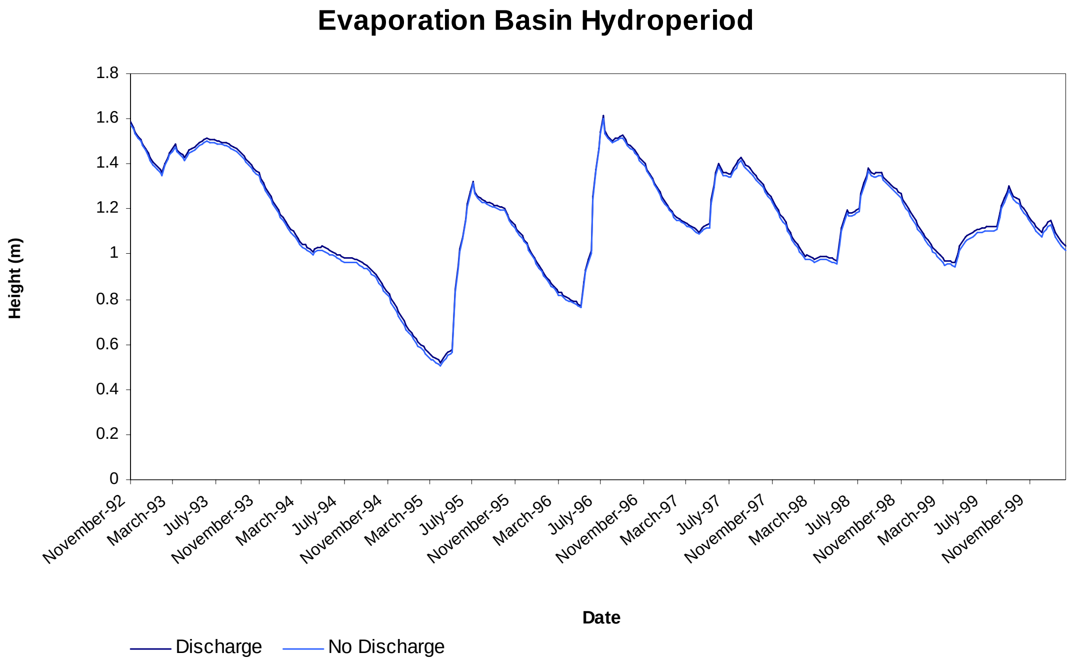


Figure 5 Salt Load in Lake Coyrecup

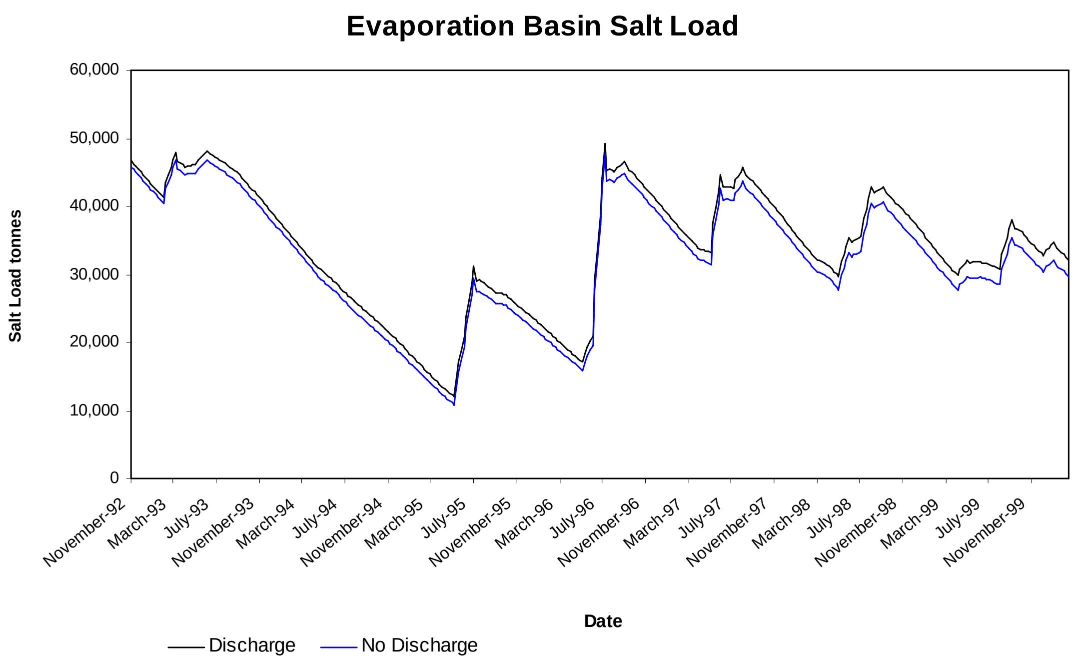


Figure 6 Salt Concentrations in Lake Coyrecup

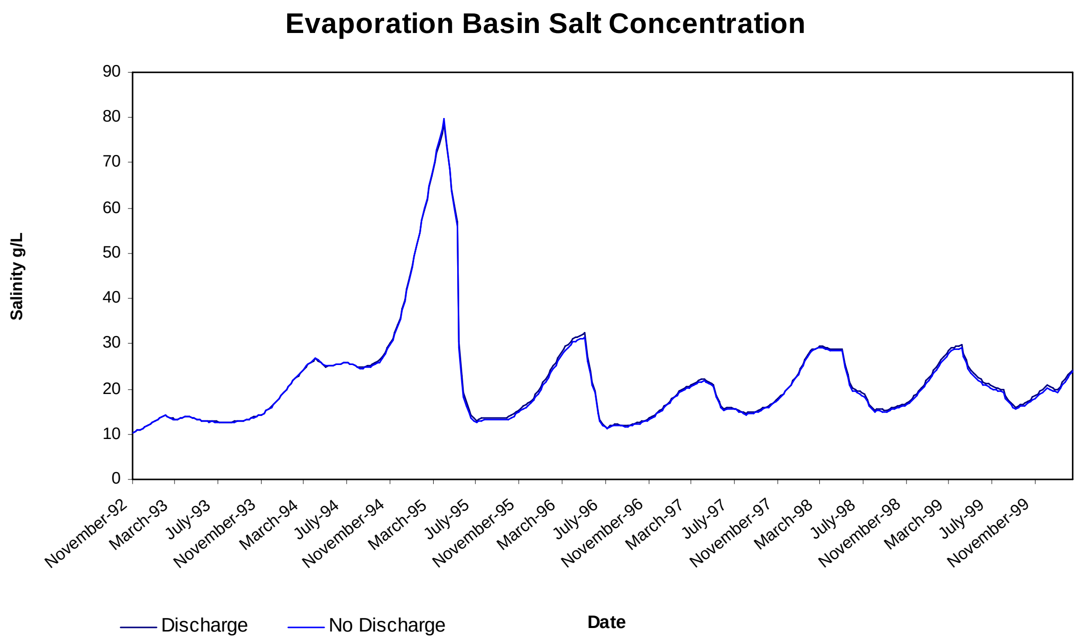
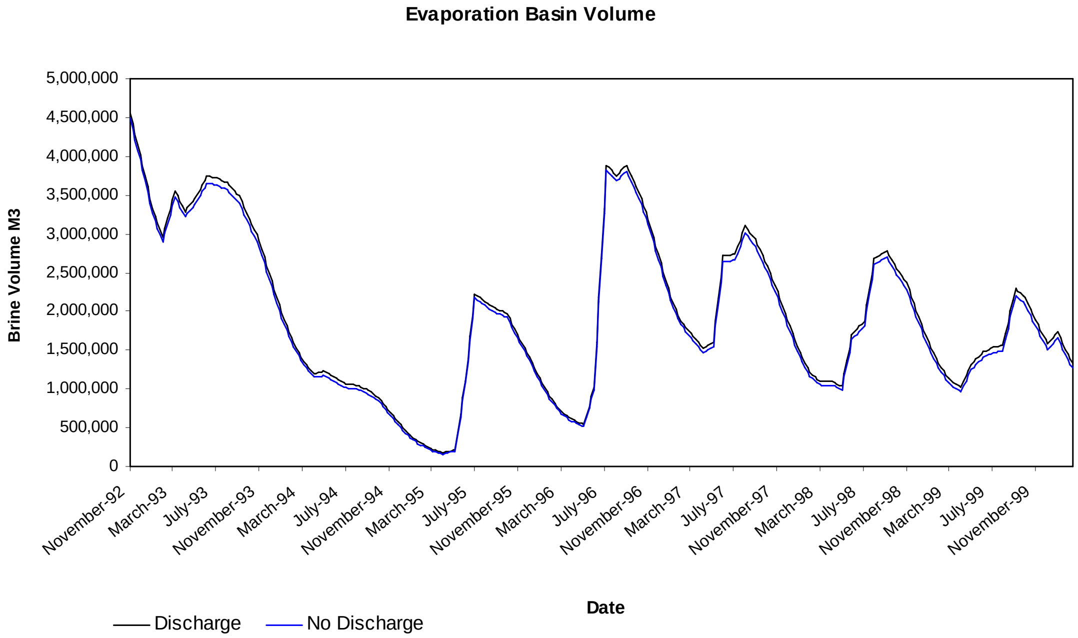


Figure 7 Volume of Lake Coyrecup



The model assumed that Lake Coyrecup had been receiving a discharge similar to that proposed by the Nyabing Project in one scenario while the second assumed that there has been no discharge. The model-generated graphs show that the Lake parameters are similar for the scenario with and without the discharge. The most significant difference was the estimated salt load with drain discharge. Increased salt load was also identified in the SELF ASSESSMENT evaluation guidelines as being a significant factor. The other parameters for the discharge scenario tracked the non-discharge values with small but minor variations.

The major difference between the modelled evaluation and the guidelines as proposed is that the model allows for the removal of salt into the groundwater out of Lake Coyrecup. This was seen as a reasonable inclusion given this is the observed pattern for the catchment, and because the modelled figures would not approach the measured depths in Coyrecup without this allowance. The mass balance of the Lake supported this principle.

The modelled evaluation implies that the SELF ASSESSMENT guidelines are conservative.

As noted before, the models are limited but the necessity to make assumptions and generalisations. This would be the case for most other wetlands as well. The interpretations from the model should be considered within the limitations of this lack of knowledge.

Chemistry

The pH of the Nyabing drain is 1.1 units more than the Lake Coyrecup's residual water. More samples would have been preferred but the results indicate that the discharge from the drain should be passed. For comparison, the Datatine drain has a pH significantly lower than the Lake Coyrecup. The Datatine does not in fact drain into the Coyrecup, but if it did then on site treatments (such as increasing the residual time or flowing over limestone) may be suggested.

Table 3 Major Ion Concentrations

Location	pH #	Conductivity mS/cm	TDS ppm	Salinity mg/l	Na mg/l	K mg/l	Mg mg/l	Ca mg/l	Cl mg/l	SO4 mg/l	Alkalinity mg/l
Lake Coyrecup	7.2	220	130,000	110,000	36,000	62	5,400	2,800	64,000	11,000	280
Nyabing Farm Drain	8.3	770	38,000	36,000	14,000	26	1,200	170	21,000	2,400	380
Datatine Drain	3.4	120	65,000	61,000					35,000	3,800	10

The major ions from a sample from Lake Coyrecup and a farm drain were analysed and expressed as a percentage of standard seawater evaporate. According to the SELF ASSESSMENT criteria, the ionic composition of the discharging brine should be within 20% of the receiving water. This is the case for chloride, potassium and sodium but not calcium, sulphate and magnesium. The criteria does allow for different salinities of the receiving and discharging waters, but if the Nyabing Farm Drain was from a reconstituted brine, such as rain water dissolving crystalline salts, then the difference may be explained. This does not seem a likely explanation and further technical evaluation and sampling would be indicated.

Table 4 Ratio of Major Ions to Standard Seawater Evaporate

Location	Ca	SO4	Mg	Cl	K	Na
Lake Coyrecup	242%	142%	148%	116%	6%	118%
Nyabing Farm Drain	41%	89%	93%	109%	7%	130%
Datatine Drain	0%	87%	0%	112%	0%	0%

The minor ions such as metals and pollutants are all less than or approximately the same as the receiving waters. The discharge would not have a significant effect on the receiving waters.

Table 5 Minor Ion Concentrations

	pH	Al	As	Bo	Cr	Cd	Cu	Fe	Pb	Mn	Ni	St	Zn	Nitrate N	Phosphate
Location	#	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Lake Coyrecup	7.2	0.40	0.001	7.50	0.01	0.013	0.01	0.02	0.01	0.02	0.03	32.00	0.01	0.03	0.14
Nyabing Farm Drain	8.3	0.10	0.003	6.60	0.01	0.002	0.01	0.01	0.01	0.01	0.01	2.90	0.01	0.03	0.16
Datatine Drain	3.4			7.80										0.13	0.08

Long-Term Hydrological Trends

General

Discharge of saline water to natural streams and artificial drains in the South-West and Great Southern districts of WA may change over the next 50 to 100 years as a result of factors that affect the rate of groundwater recharge. These factors include continued clearing of native vegetation, changes in agricultural practices and climate change.

Nyabing Drainage Proposals – Future Scenarios

The hydrological functions of Coyrecup Lake (height, salt load, salt concentration and volume) were modelled using the last nine years evaporation and rainfall data. The runoff into the Lake was modelled from rainfall and catchment size (Adrian Peck personal communication). Groundwater interaction was assumed to be a set rate out of the Lake at 2 mm per day over the area covered by brine. It is also assumed that the drains do not increase the surface runoff.

Three scenarios were modelled, the current Nyabing proposal, two times the drainage volume and three times the drainage volume. It should be pointed out that the current proposal incorporates two thirds of the existing salt scalds in the catchment of Coyrecup Lake and the third scenario is unlikely to be ever realised. The results of the modelling can be seen in Figure 8 to Figure 19.

In summary the following statements can be made.

- The hydroperiod in Coyrecup Lake is unlikely to be significantly affected by increased drainage. There is a noticeable increase in the modelled water height but it is very small compared to the natural variations.

- The salt load will be significantly affected by the increased drainage.

- The salt concentration change will be minor with increased drainage. This observation should be considered with caution, as it is also true that at the same water height in Coyrecup Lake before and after drainage, the salinity will be much higher.

- There will be a moderate increase in Lake volume after increased drainage. The water volume increase is only minor for the present Nyabing proposal. Water volume and hydroperiod are a function of the algorithm used to calculate the basin of Coyrecup Lake.

Potential Hydroperiod Changes

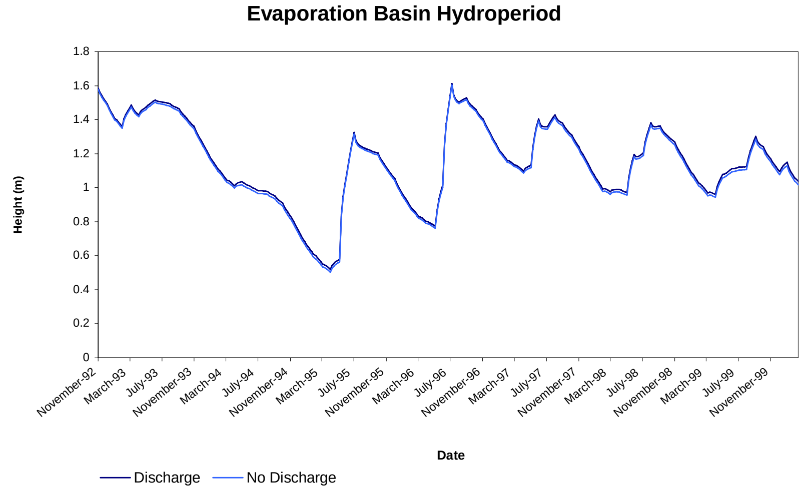


Figure 8 Hydroperiod of Coyrecup Lake with and without discharge at 7.8 L/sec

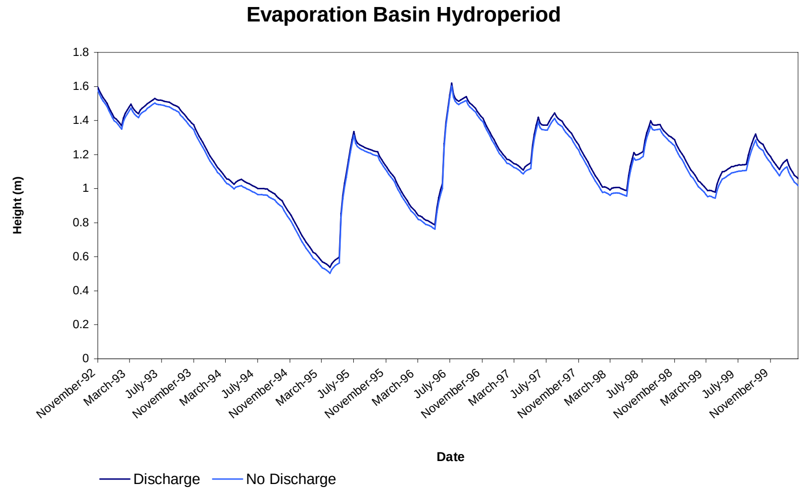


Figure 9 Hydroperiod of Coyrecup Lake with and without discharge at 16.6 L/sec

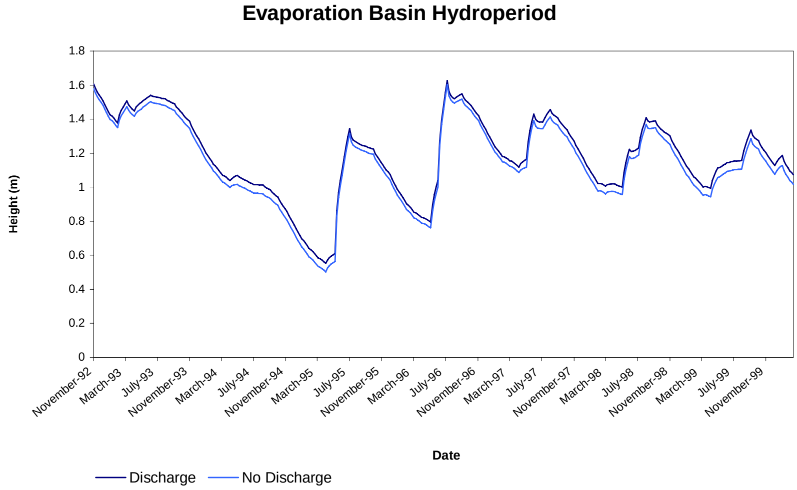


Figure 10 Hydroperiod of Coyrecup Lake with and without discharge at 23.4L/sec

Potential Salt Load Changes

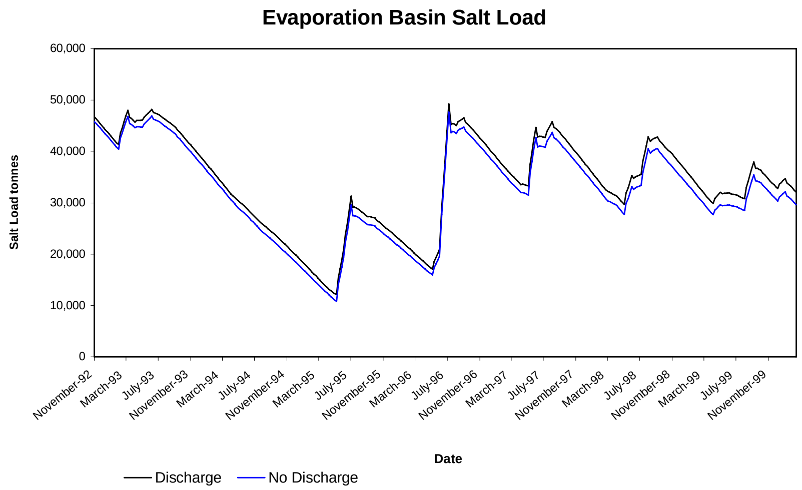


Figure 11 Salt Load of Coyrecup Lake with and without discharge at 7.8 L/sec

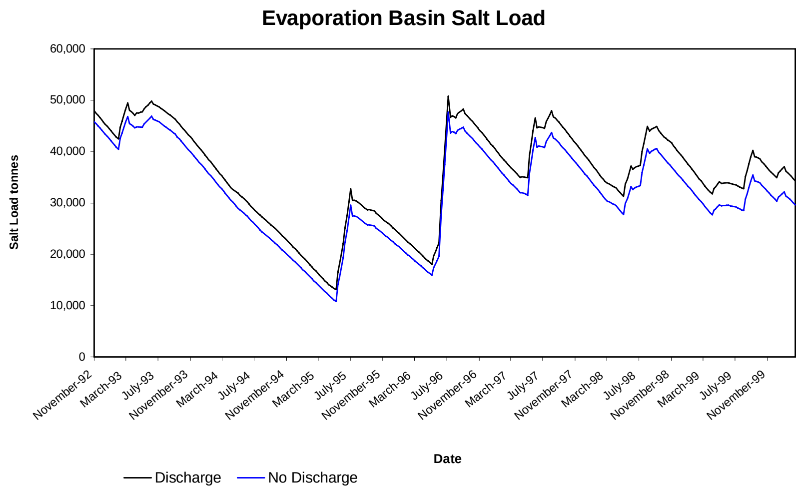


Figure 12 Salt Load of Coyrecup Lake with and without discharge at 15.6 L/sec

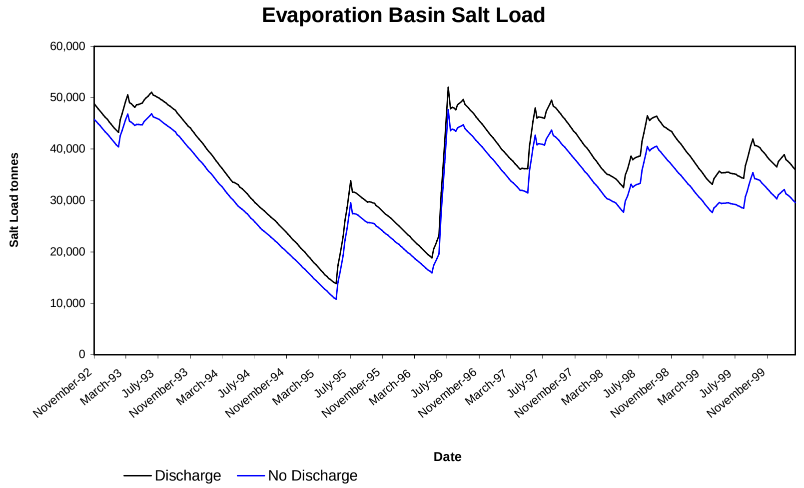


Figure 13 Salt Load of Coyrecup Lake with and without discharge at 23.4 L/sec

Potential Salt Concentration Changes

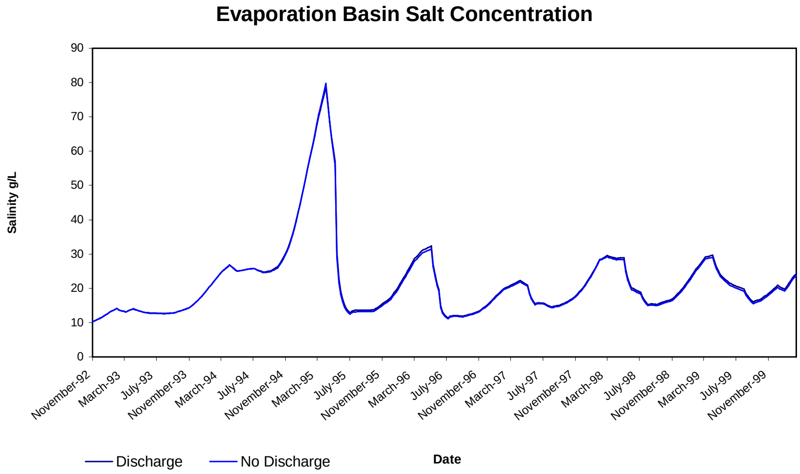


Figure 14 Salt Concentration of Coyrecup Lake with and without discharge at 7.8 L/sec

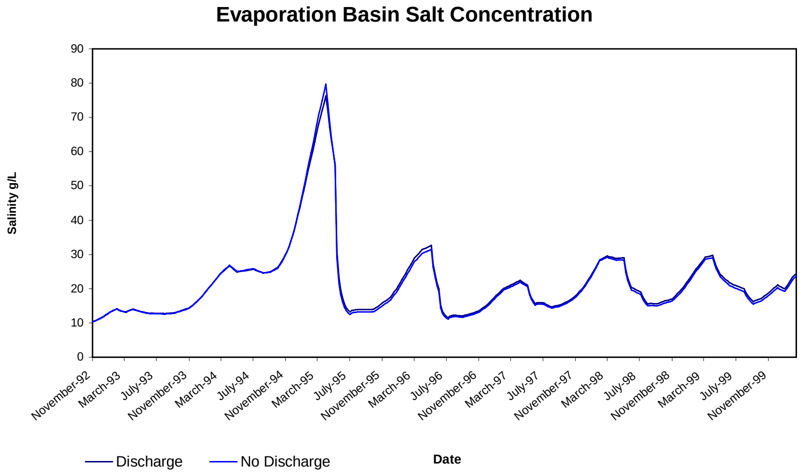


Figure 15 Salt Concentration of Coyrecup Lake with and without discharge at 16.6 L/sec

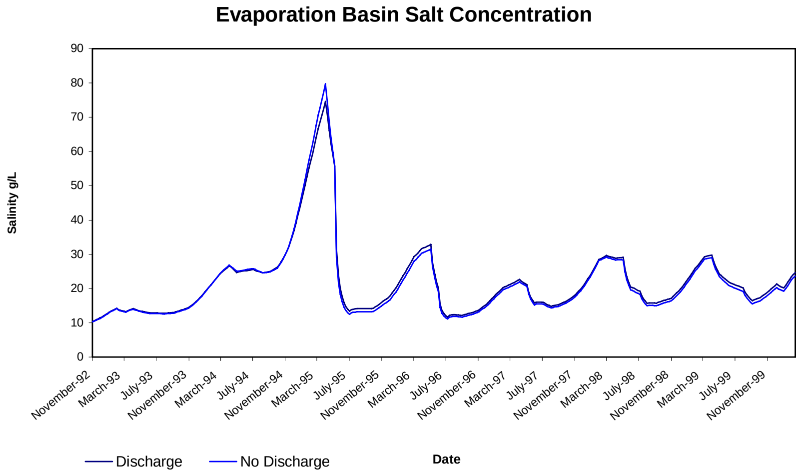


Figure 16 Salt Concentration of Coyrecup Lake with and without discharge at 23.4 L/sec

Potential Changes in Coyrecup Lake Volume

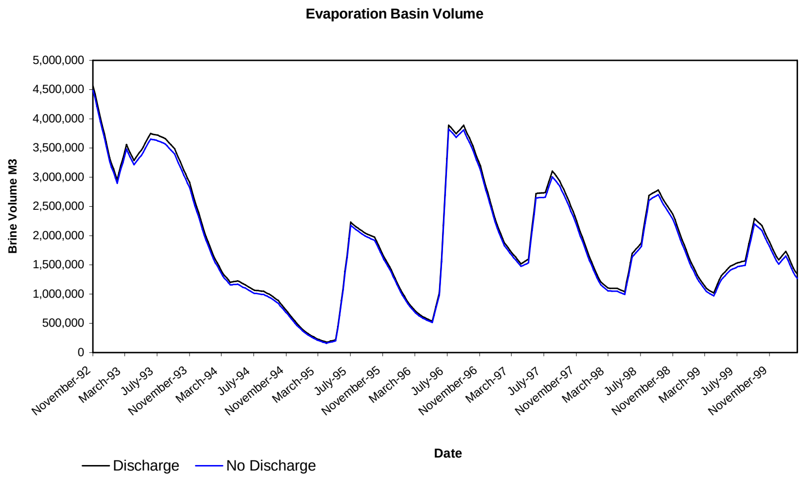


Figure 17 Volume of Coyrecup Lake with and without discharge at 7.8 L/sec

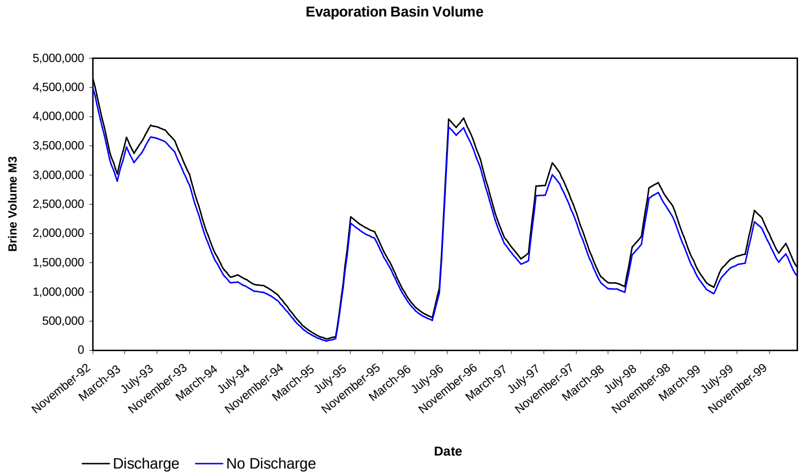


Figure 18 Volume of Coyrecup Lake with and without discharge at 15.6 L/sec

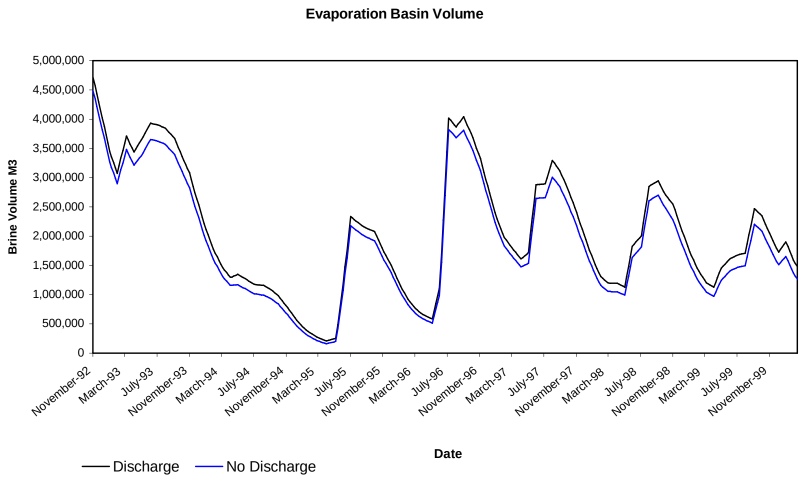


Figure 19 Volume of Coyrecup Lake with and without discharge at 23.4 L/sec

Current Trends of Groundwater Level and their Impact on Streams and Wetlands

There is abundant evidence that groundwater levels are increasing at many locations throughout the southern agricultural areas of WA. The increasing levels are a direct result of the net increase of groundwater recharge beneath areas of land that have been cleared of native vegetation for agriculture and other uses. Whilst groundwater levels can be expected to gradually approach new equilibria in response to past changes of land use, the dynamics of this process are uncertain. Moreover, land use changes are continuing in some areas (e.g. pasture to crop or *vice versa*) and there may be other unforeseen changes over the coming 50 to 100 years.

Experience shows that groundwater systems in these districts respond very slowly to the changes of recharge rate that follow changes of land use. This is a consequence of low rates of groundwater recharge, and characteristics of regolith aquifers (transmissivity, storativity and dimensions).

Increasing groundwater levels are known to affect the environment of natural drainage lines and receiving wetlands in several ways:

1. When the rising water table is within about 2 m of the soil surface, groundwater is lost by evaporation leaving dissolved salts on the soil surface.
2. When the water table intersects the soil surface, groundwater is discharged forming a spring or seepage area, usually along stream banks. Evaporation of the seepage water can result in very high salinity at the soil surface and in the receiving stream.
3. There is less infiltration of rainfall in areas of groundwater evaporation or seepage, resulting in greater runoff and erosion. Infiltration is reduced because of the high water content of the soil, and soil sodicity (excessive sodium relative to other cations adsorbed on clay particle surfaces).
4. The salinity of water in a receiving wetland reflects a balance between amounts of water lost by evaporation and seepage to aquifers beneath the wetland. As the water level in an underlying aquifer rises, the rate of seepage from the wetland decreases and the water becomes more saline on average. In some wetlands the water level in the underlying aquifer has increased to the point where the direction of seepage has reversed resulting in discharge of groundwater to the wetland. This usually results in a very large increase of salinity within the wetland.

The magnitude of these impacts will continue to increase so long as groundwater levels continue to rise.

Evidence from Lake Coyrecup

Salt Balance

WRC has provided data from the Bibkin stream gauging station (#609021) that has been used to calculate the discharge of soluble salts from this catchment. Inputs of soluble salts to the catchment have been calculated from rainfall (Badgebup rainfall station) and analyses of rainfall samples, including geographic data reported by Hingston and Gailitis (1976). Results are summarised in the following table.

Table 6 Estimated Coyrecup Lake Catchment Output/Input Ratio for Salt

Year	**Rainfall (mm)**	**Saltfall (kg)**	**Salt Flow (kg)**	O/I Ratio	O/I Ratio for 30.5 kg/ha input
1996	361	7,009,357	73,990,200	10.6	12.5
1997	352	6,834,608	55,152,800	8.1	9.3
1998	426	8,271,429	39,034,200	4.7	6.6
1999	384	7,455,936	30,683,600	4.1	5.2
Mean Ratio				6.9	8.4

Peck and Hurle (1973) reported salt output to input ratios for 7 partly farmed catchments in the Southwest and Great Southern districts of WA. Ratios ranged from around 4 near the Darling Scarp to around 20 in lower rainfall (Dale and Williams) catchments. On this basis, the Coyrecup Lake catchment appears to have an abnormally low output of soluble salts. It is uncertain why this should be so. One possibility is that water tables in the relatively recently cleared Coyrecup Lake catchment are further from equilibrium with current rates of groundwater recharge. A consequence of this would be that increasing salt yields, and probably increasing salinity of flow from the catchment could be expected for some time into the future, even if there was no further change of land use and the climate was stable.

Water Level and Salinity Data

CALM has provided records of water level and salinity of Lake Coyrecup over the period 1978 to 2000 that were used, together with rainfall records from Badgebup to prepare the attached graphs.

During the period 1978 to 2000, the depth of water in Lake Coyrecup has ranged from 0 to 3 m and the salinity from 900 to 182 000 mg/L. At the highest water levels, it is likely that water flowed from the lake. Clearly the salinity of water remaining in the lake has been very high during periods of low water level (e.g. 1979, 1987 and 1996).

Effect of Increasing Inflow of Saline Water

There was an extended period of above-average rainfall at Badgebup from 1989 to 1994. In this period, the water level remained relatively steady at around 2 m and the salinity was relatively low at around 4000 to 9000 mg/L. The greater inflow of water in this period maintained a higher water level in the lake, and prevented the development of very high salinities that occur with very low water levels.

Therefore, increasing inflow of saline water (that is expected to result from increasing groundwater levels in the catchment area) is expected to maintain slightly higher water levels and reduce the frequency of occurrence of very high lake salinity.

Effect of Increasing Water Level in Aquifers Beneath the Lake

An increasing water level in the shallowest underlying aquifer would reduce the rate of seepage loss from the lake, resulting in a greater water level within the lake. The higher water level would reduce the frequency of very low water levels that result in very high lake salinity. However, when the aquifer water level exceeded the average water level in the lake, there would be a net loss of groundwater and the lake salinity would increase to very high levels. In this situation, the only mechanism for loss of solute from the lake would be surface flow during periods of high rainfall. As the lake would continue to hold water, the loss of solute by ablation would be minimal.

Therefore, an increase of groundwater level beneath the lake (expected as a result of regional impacts of agricultural development) is expected to increase lake water level and reduce the frequency of periods of very high salinity in the short-term. However, an increasing groundwater level beneath the lake would increase the average salinity of water in the lake, which may become very high.

Effects of Rainfall Variation

There was an extended period of above-average rainfall at Badgebup from 1989 to 1994. In this period, the water level remained relatively steady at around 2 m and the salinity was relatively low at around 4000 to 9000 mg/L. The greater inflow of water in this period maintained a higher water level in the lake, and prevented the development of very high salinities that occur with very low water levels.

There have been two periods of below average rainfall at Badgebup whilst water level and salinity was recorded in Lake Coyrecup. In the period 1984 to 1987 there was a cumulative deficit of rainfall (actual less average) of 202 mm resulting in falling water levels and increasing salinity, which was greater than 180 000 mg/L from November 1986 to September 1987. The cumulative deficit over the period 1994 to 1997 was 293 mm. In this period the water level fell more than 2 m, but the lake did not dry completely and the highest salinity recorded was 107 000 mg/L.

Climate Change

Global climate change could affect both rainfall and evaporation in the southern agricultural areas of WA.

CSIRO Atmospheric Research has recently provided a report on predicted trends of climate in the southwest of WA to the WA Government. This report has not been seen. Dr Peter Whetton of CSIRO advises that the current best estimate is that there will be increasing rainfall in this region in winter and spring.

Increased rainfall in these seasons would probably lead to increased groundwater recharge, although this is by no means certain, because of the link of rainfall to temperature and therefore plant development. Moreover, groundwater recharge is dependent on rainfall intensity and distribution, which are secondary effects of climate change.

In an earlier report (CSIRO, 1996, copy attached) changes of precipitation in the Southwest and Great Southern districts of WA varied depending on the structure of the model used. All changes are relative to 1990 levels. Winter rainfall in 2070 was estimated to change by –5 to

+5% (slab models) or –20 to 0% (coupled models). Summer rainfall in 2070 was predicted to change by +4 to +30% (slab models) or-10 to +10% (coupled models).

The range of values and the difference between 1996 and current predictions emphasises uncertainty in climate modelling. This work does not include predictions beyond the year 2070.

Figure 20 Salinity and water height of Lake Coyrecup

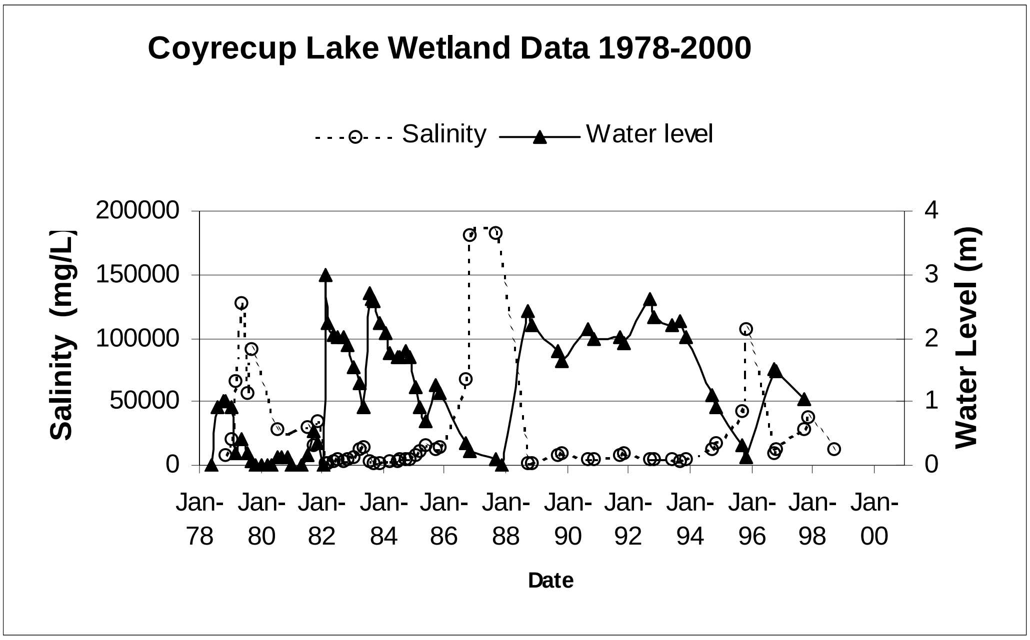
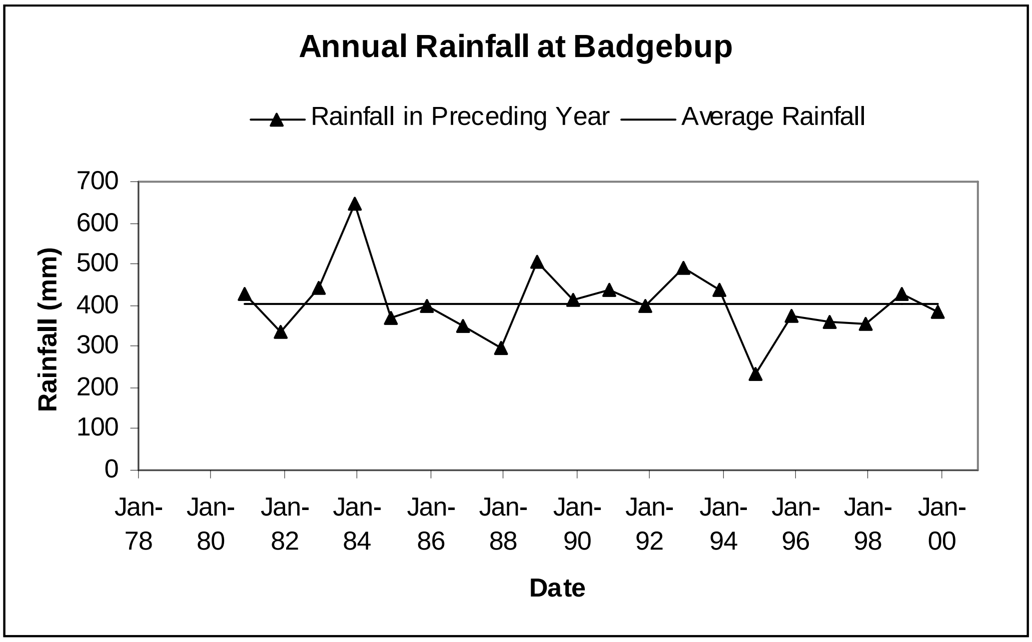


Figure 21 Rainfall at Badgebup



Flora and Fauna

A detailed flora and fauna survey was conducted by Halse and Cale (2000) at Lake Coyrecup, which rates the wetland as having a good waterbird fauna but a low invertebrate diversity compared to other lakes in wheatbelt reserves.

For this study, a site visit was made to identify wetland vegetation and aquatic invertebrates within Lake Coyrecup. This was used as an indicator of the salinity levels within the lake, as well as vegetation condition.

Lake Coyrecup is an oval shaped lake surrounded mainly by *Casuarina* woodland over a *Melaleuca* understorey. The lake bed soil is coarse grey/brown sandy clay over lighter grey, very dense clay with a pH of 9.5. Trees standing in the open water appear to have been dead for some time, however those close to the shoreline have died recently – many still retaining dead leaves. There has been a large recruitment of *Casuarina* up to 18m from the permanent tree line. Elsewhere the lake bed is very sparsely vegetated. It is suspected that the lake vegetation cycles according to high or low rainfall years, massive recruitment occurring in suitable years and massive deaths in very wet years.

The flora and fauna found at Lake Coyrecup are cosmopolitan species. The floral species were indicative of moderately saline (Mesosaline) conditions and seasonal waterlogging. No rare or endangered flora or fauna was sighted. Dotterels were seen nesting on the edge of the lake and several ducks were out on the lake waters.

The main species recorded from this rapid assessment are listed below:

Flora Species List for Lake Coyrecup

Casuarina obesa
Halosarcia lepidosperma
Halosarcia pergranulata
Melaleuca cuticularis
Nitella pencillata (Submergent)
Ruppia sp (Submergent)
Sarcocornia quinqueflora

Fauna Species List for Lake Coyrecup

Gastropod shells (Open water – centre)

Gastropoda – Family: Pomatiopsidae – Genus: *Coxiella* (Submerged macrophytes, open water)

Isopoda – Family Oniscidae (Shallows among trees)

Coleoptera – Family: Hydrophilidae – Species: *Berosus sp* (Inlet)

Coleoptera – Family: Hydrophilidae – Species: *Berosus discolor* (Inlet)

Coleoptera – Family: Dytiscidae – Species: *Necterosoma darwini* (Inlet)

Summary of Technical Review

In general terms the conclusions reached about Lake Coyrecup's water balance were:

- The lake's basin intercepts the groundwater level for most times of the year.
- The lake will recharge when full but discharge when empty.
- The potential evaporation is much larger than the available water for most years (storage).
- There is little evidence that the Lake overflows in anything other than an exceptional year. Lake Coyrecup last overflowed in 1992 when rainfall at Badgebup rainfall station was 491 mm. Since 1950, rainfall has exceeded 490 mm in 1955, 1963, 1964, 1968, 1971, 1974, 1982, 1988, 1992.
- Salt inflow from the catchment is large (200-300 kg per ha).
- Groundwater salinity is about 14 g/L.
- Surface inflow (3.6 GL) plus rain falling on the lake (1.7 GL) are at least an order of magnitude greater than the additional flow from projected artificial drainage scheme (0.2 GL).
- The salt inflow by the stream flow into the lake is the dominant source of salt (50,000 tonnes) for the lake being about an order of magnitude greater than from the proposed drainage (3,000 tonne) or from an estimate of groundwater discharge into the lake (4,000 tonne).
- To achieve a salt balance, it was found that recharge to the groundwater through the base of the lake needed to be about 4 mm/day for the estimated 7 months when inflow to the lake occurred.
- For the catchment of Lake Coyrecup the output/input ratio for salt averaged 8 for 1996-1999 period.
- During periods of above-average rainfall there has been increased streamflow into the lake, higher water levels, and a lower frequency of periods of very high salinity.
- During periods of low rainfall there has been low water level and very high lake salinities have been recorded.

The current proposed discharge was modelled for Lake Coyrecup. The model suggested that there would not be a significant change to the functions of the Lake over and above the natural changes. There is however no clear indication of what is a significant change to the wetland.

The ionic composition of the proposed drain water is slightly different from the samples taken from Lake Coyrecup. The differences do not indicate that there will be large change in the chemistry of the Lake water. This is particularly so because the discharge is a distance from the Lake and will be modified by the sediment in the Creek.

Over the coming 50 to 100-years, it is expected that there will be increased streamflow carrying an increased salt load into Lake Coyrecup, and the water level in aquifers beneath the lake will rise. In addition, there may be a small increase or decrease of rainfall as a result of increasing atmospheric CO_2 and other ‘greenhouse’ gasses.

It is thought that the future trends will be an increased water flow into Lake Coyrecup from rainfall and increasing groundwater. Concurrently there will be an increased salt load from runoff and evaporation of groundwater. Higher water levels in the lake would reduce peak salinity, but the higher salt load into the lake would increase average lake salinity. That is it will be saltier for the same water height in the present time. Ultimately, however, an increasing groundwater level beneath the lake could increase the average salinity of water in the lake to a very high level in the interim between irregular flushing of the lake by very large flow events.

The effects of small changes of rainfall due to the ‘Greenhouse Effect’ are not readily predicted, because net groundwater recharge is dependent of rainfall distribution and intensity, and the response of plants to temperature change.

If the drain flow into the receiving wetland was to increase by a factor of two or three over and above what is proposed, it is expected that:

- The hydroperiod in Coyrecup Lake is unlikely to be significantly affected by increased drainage. There is a noticeable increase in the modelled water height but it is very small compared to the natural variations.
- The salt load will be significantly affected by the increased drainage.
- The salt concentration change will be minor with increased drainage. This observation should be considered with caution, as it is also true that at the same water height in Coyrecup Lake before and after drainage, the salinity will be much higher.
- There will be a moderate increase in Lake volume after increased drainage. The water volume increase is only minor for the present Nyabing proposal..

The flora and fauna found at Lake Coyrecup are cosmopolitan species. The floral species were indicative of moderately saline (Mesosaline) conditions and seasonal waterlogging. No rare or endangered flora or fauna was sighted.

Implications for the Drainage Management Guidelines.

1. Data indicating water volume and salt loads for rainfall, catchment runoff and projected volume of artificial drainage need to be established to guide decisions about the impact of changes to the catchment hydrology on lakes and wetlands.
2. The dynamic operation of lakes and wetlands, including the interactions between surface and groundwater, need to be quantified as part of the evaluation process.
3. Where adequate data are not available (which may be a common factor) appropriate monitoring should be established as even one year of data can be quite indicative of the dominant functions in water and salt movement or accumulation. For example, the changes in water level and salinity of a lake over a 12 month period can be used to understand the dynamics of the flow systems associated with the lake. One nest of piezometers can indicate the hydrology and salinity of the groundwater system as it responds to the presence or absence of water in the lake. Continuation of monitoring once drainage has been established will assist strategic management.
4. Groundwater is the source of salt in flow systems of catchments. Rainfall, and associated surface runoff, is the primary source of water. Secondary sources would principally be artificial drainage of aquifers with the potential volume of water and mass of salt greater than surface runoff.
5. Recharge and discharge systems in lakes can transmit significant quantities of water and salt.
6. Annual salt and water balance analyses are the appropriate method to identify the principal volume and mass of movements of water and salt in the environment. The use of both salt and water balances provides the means to test the reasonableness of estimated values inevitably required in the analysis. The provision of hydrogeological information and groundwater data is as important as the surface hydrological monitoring where groundwater recharge and discharge contribute significant quantities to the movement of water and salt in managed landscapes.
7. Monitoring systems should be a requirement for all projects that aim to modify the hydrology in catchments, where possible obtaining base-case measurements to provide comparative analyses following changes in management activities. Measurements needed are quantity (volume or level) and quality of rainfall, streamflow, drainage water, to and from the wetland and associated groundwater system.
8. Complete water and salt balance analyses should be an integral part of management activities affecting any modification to the catchment hydrology. The relative magnitude of each component provides a guide to the priority for management.

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