TOOLIBIN LAKE TECHNICAL NOTE
LAKE OUTFLOW CONTROL STRUCTURE

INTRODUCTION

Toolibin Lake is seriously threatened by salinisation from both rising groundwater levels and surface water inflows from the catchment. To protect Toolibin Lake and its environs from further salinisation and to reclaim areas already degraded, the Department of Conservation and Land Management (CALM), the community and other government agencies developed the Toolibin Lake Recovery Plan.

The first stage of the recovery program was completed in 1995, with construction of a surface water control scheme which comprised of two projects; improving farm drainage for a subcatchment on the Toolibin Flats, and the construction of a large separator and diversion channel on the western side of the lake. To allow the initial and end of season highly saline, low volume flows to be diverted, while allowing fresher flows to be directed into the lake. Groundwater pumping began in March 1997 and was extended in 1999 and 2001.

As part of continuing work on surface water management, a lake outflow control structure was installed in April 2000. The objective of the outflow control structure is to improve the control of lake salinity and regeneration conditions on the lake bed by providing a method to drain low volume, highly saline pools, and control flooding of the lake floor. The outflow control structure will provide capacity to increase outflows from Toolibin Lake and will enable more frequent flushing of accumulated salt in the lake, thereby reducing the salt load and limiting maximum salinity as the lake dries by evaporation.

This technical note describes the study undertaken to determine the likely effects of the outflow control structure on Toolibin Lake’s salt load, and provides details of its design, construction, and operation.

DESCRIPTION OF TOOLIBIN LAKE

Toolibin Lake lies approximately 45km east of Narrogin, 250 km south-east of Perth at the top of the Northern Arthur River Catchment (Figure 1), which drains into the Blackwood River. The lake is the first in a series of nine lakes and is the only major lake in the chain which has not become saline. It is understood that the occurrence of several dolerite dykes have restricted significant groundwater inflow to the lake from the north.

The lake is an ephemeral wetland located in the middle of a broad valley floor, covering approximately 300 ha. About one in three years it fills and overflows, with a maximum depth of 2m when full. The area receives 375-425 mm in annual rainfall and has 2000 mm annual evaporation. At least 90% of the 45 000 ha catchment has been cleared and the area and severity of dryland salinity continues to increase.

Toolibin Lake and its environs provide an important breeding habitat for a variety of waterbirds, and it is one of the last inland freshwater lakes in the south-west. It is the only lake which has retained a sheoak/melaleuca association across significant parts of the lake floor, and has been classified as a "Wetland of International Importance" under the Ramsar Convention. The nature reserves including and adjoining Toolibin Lake are managed by CALM on behalf of the Conservation Commission of Western Australia.
DEVELOPMENT OF A WATER & SALT BALANCE MODEL

In 1999 CALM commissioned JDA Consultant Hydrologists to assess the impact of constructing an outflow control structure on the salt load in Toolibin Lake (JDA, 1999). This assessment required the development of a daily water and salt balance model for the lake, based on the following equations:

\[ V_i = V_{i-1} + I_i + R_i - E_i - O_i - P_i - D_i \]

\[ SL_i = SL_{i-1} + ISL_i - OSL_i - PSL_i - DSL_i \]

where

- \( V_i \) = Toolibin Lake Storage Volume \((m^3)\) at day \( i \) (current day)
- \( V_{i-1} \) = Toolibin Lake Storage Volume \((m^3)\) at day \( i-1 \) (previous day)
- \( I_i \) = Inflow Volume for day \( i \) \((m^3/day)\)
- \( R_i \) = Rainfall Volume on Lake Surface for day \( i \) \((m^3/day)\)
- \( E_i \) = Evaporation Volume from Lake Surface for day \( i \) \((m^3/day)\)
- \( O_i \) = Overflow from Lake for day \( i \) \((m^3/day)\)
- \( P_i \) = Outflow Control Structure Piped Outflow Volume for day \( i \) \((m^3/day)\)
- \( D_i \) = Existing Channel Diversion of all inflow when inflow salinity greater than 1000 mg/L \((m^3/day)\)
- \( SL_i \) = Toolibin Lake Salt Load at day \( i \) \((kg)\)
- \( SL_{i-1} \) = Toolibin Lake Salt Load at day \( i-1 \) \((kg)\)
- \( ISL_i \) = Inflow Salt Load for day \( i \) \((kg/day)\)
- \( OSL_i \) = Overflow Salt Load for day \( i \) \((kg/day)\)
- \( PSL_i \) = Outflow Control Structure Piped Outflow Salt Load for day \( i \) \((kg/day)\)
- \( DSL_i \) = Existing Channel Diversion Salt Load for day \( i \) for inflow salinity greater than 1000 mg/L \((kg/day)\)

The model assumed that at all times the water within the lake was uniformly mixed and hence had uniform salinity. When the lake was empty it was assumed salt contained in the lake was stored in the bed and mobilised during the next inflow event. Infiltration and groundwater influences were neglected in the model, and the existing diversion channel was modelled assuming all inflow since 1996 with salinity greater than 1000 mg/L would be diverted from Toolibin Lake.

Calibration for the period 1979-1997 using data summarised in Table 1 was found to provide good agreement (to within 20%) of historical levels.

**Table 1: Toolibin Lake Water Balance Model Data**

<table>
<thead>
<tr>
<th>Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inflow Data</strong></td>
<td></td>
</tr>
<tr>
<td>Daily Volume m(^3)/day</td>
<td>Water &amp; Rivers Commission Station No. 609010 Northern Arthur River</td>
</tr>
<tr>
<td>Daily Salinity (mg/L)</td>
<td></td>
</tr>
<tr>
<td><strong>Lake Volume Data</strong></td>
<td></td>
</tr>
<tr>
<td>Daily Water Level (m AHD)</td>
<td>Water &amp; Rivers Commission Station No. 609009</td>
</tr>
<tr>
<td>Storage-Area-Elevation Curve</td>
<td></td>
</tr>
<tr>
<td><strong>Lake Salinity Data</strong></td>
<td></td>
</tr>
<tr>
<td>Lake Salinity Spot Samples (mg/L)</td>
<td>Water &amp; Rivers Commission Station No.'s 609009, 6091024, 6091025, 6091026, 6091027, 6091028</td>
</tr>
<tr>
<td><strong>Rainfall Data</strong></td>
<td></td>
</tr>
<tr>
<td>Daily Rainfall (mm)</td>
<td>Bureau of Meteorology Station No 010 654 Wickepin Post Office</td>
</tr>
<tr>
<td><strong>Evaporation Data</strong></td>
<td></td>
</tr>
<tr>
<td>Average Monthly (mm)</td>
<td>Luke et al (1985) for Narrogin</td>
</tr>
</tbody>
</table>

**EFFECT OF OUTFLOW CONTROL STRUCTURE ON LAKE SALT LOAD**

The effect of an outflow control structure from Toolibin Lake was determined by comparing water balance model results with and without discharge through a piped outflow. A range of different outflow control structures were modelled, including varying pipe diameters and invert levels, to determine the optimum configuration in terms of salt removal from the lake. Modelling results are shown in Figure 2.

The outflow control structure was found to contribute to controlling the rate of salt load increase in Toolibin Lake between flushing events which occur during periods of large relatively fresh inflows. The amount of flow and salt which can be released from the lake every through a small diameter outlet pipe is...
significant. Approximately 3 tonnes/day of salt can be removed by a 300mm outlet pipe flowing full (72 litres/sec) and assuming a discharge salinity of 500 mg/L and a discharge volume of 6220 m³/day.

For the modelled period of 1979-1997, the existing diversion channel together with a single outlet pipe set at 297.0m AHD reduced the salt load contained in the lake by 80%. Of this reduction 60% was due to the impact of the diversion channel with a further 20% reduction as a result of the outflow control structure. The 80% reduction in salt load equated to an estimated 8000 tonne reduction over the 19 year modelling period.

**DESIGN & CONSTRUCTION**

The preferred location of the outlet structure was identified as immediately adjacent to the existing lake overflow area near the south western corner of the lake (Figure 1). This site was recommended based on its proximity to the existing diversion scheme channel, to minimise construction requirements, to provide good access for operation and maintenance, and to maximise the use of existing infrastructure.

Design drawings of the outlet control works are shown in Figure 3. Pre-cast concrete structures were considered to be most suitable in terms of ease of construction and minimising future maintenance costs.

![Diagram showing design details](image)

**Figure 3**: Outflow Design

Key features of the design included:

- A 16m long 450mm diameter outlet pipe (invert 297.0 mAHD) with precast standard headwall units.
- Provision of a 2m x 2m stone pitched apron within the existing diversion channel for scour protection. Discharge velocities through the outlet pipe at pipe full flow conditions will typically be 1.2 m/s.
- Provision of stop boards to prevent back flow of saline water from the diversion channel into the lake during bypass flow events and to regulate releases from the lake to the diversion channel.

The outflow control structure was constructed by Kiam Corporation in April 2000 at a cost of $7000. Feasibility and design fees for the project totalled $14,000.

**OPERATING STRATEGY**

The operating strategy for the outflow control structure is shown in Table 2. This strategy will be periodically reviewed and refined following inflow events based on operating experience.

**Table 2**: Outflow Control Structure Operating Strategy

<table>
<thead>
<tr>
<th>Timing</th>
<th>Operating Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Prior/following inflow event (no flow occurring through the outflow structure)
- Stopboards at downstream end\(^1\) reset to closed position.
- Upstream end\(^1\) stopboards reset to preferred setting.

### At commencement of inflow event while initial inflow to Toolibin Lake is diverted to the bypass channel.
- Stopboards at downstream end reset to remain in closed position to prevent backflow from the channel into the lake.
- Re-adjust upstream end stopboards (if required).

### At closure of bypass channel flow (inflow now diverted into Toolibin Lake).
- When flow in bypass channel has subsided and while lake level is less than upstream stopboard level setting remove stopboards at downstream end to fully open position.

### During an Inflow Event\(^2\)
- If additional discharge is required, wait until water level in lake has reached the level of the current stopboard setting and remove a further single board. Depth of water in lake at this time will be 450mm maximum.

---

1. Upstream end refers to end of outlet pipe within lake. Downstream end refers to end of pipe located in diversion channel.
2. Changing of stopboards generally not required during an inflow event. Stopboards provide operational flexibility if required.

---

### CONCLUSIONS

The salt load within Toolibin Lake has increased markedly from the late 1970’s until today. A driving factor for this increase is that large inflow events to flush the lake are rare and evaporation of inflows leaves salt accumulated in the lake bed. While a large inflow event as experienced in 1983 would result in large scale salt removal from the lake even without any outflow control structure, the piped outlet installed in April 2000 will significantly contribute to controlling the rate of salt load accumulation in Toolibin Lake between flushing events.

For the modelled period of 1979-1997, the existing diversion channel together with a single outlet pipe set at 297.0m AHD reduced the salt load contained in the lake by 80%. Of this reduction 60% was due to the impact of the diversion channel with a further 20% reduction as a result of the outflow control structure. The 80% reduction in salt load equated to an estimated 8000 tonne reduction over the 19 year modelling period.

### REFERENCES

