Dear Sallyanne/William

1 Introduction

This memorandum has been prepared for the purposes of responding to a request from Mr Hugh Middlemis, received by GHD care of Clayton Utz, for the following information:

- Bore logs for the two Melbourne Water bores referenced within Technical Report N that are located in the wetland project to the south of the Bolin Bolin Billabong, together with time series plots of groundwater data collected from these bores.
- A map of groundwater bores within a 1 km radius of the Bolin Bolin Billabong.
- Relevant water levels of the Bolin Bolin Billabong including the location of the gauges where the levels were taken.

The information contained in this letter has been sourced from:

- Coffey (2012) report titled *Bolin Bolin Billabong Wetland Project Geotechnical Investigation*, provided by Manningham City Council.
- Raw data of groundwater levels recorded in the two monitoring bores, provided by Melbourne Water.

The Jacobs memorandum and the groundwater data were provided by Melbourne Water and were not prepared specifically for the purposes of the EES.

Relevant information, including borehole logs and falling head tests, have been extracted from the Coffey (2012) report and is included as Attachment A. A copy of the Jacobs (2018) memorandum is also included as Attachment B.
2 Summary of additional hydrogeological information

2.1 Bore locations and borehole logs

Table 1 summarises the information regarding the two Melbourne Water bores, which are the same two groundwater bores referred to in section 6.10.6 of Technical Report N to the EES for North East Link. The borehole logs for these two bores are included in Attachment A, including a plan showing their location.

Table 1 Summary of MW information – nearest bores

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Location</th>
<th>Source</th>
<th>Elevation (TOC) m AHD</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2</td>
<td>-37.77086</td>
<td>MW</td>
<td>10.7</td>
<td>Coffey (2012)</td>
</tr>
<tr>
<td>B6</td>
<td>-37.770248</td>
<td>MW</td>
<td>12.15</td>
<td>Coffey (2012)</td>
</tr>
</tbody>
</table>

Note: Jacobs (2018) report that bore B2 is screened 5.5 m to 10 m and bore B6 is screened from 3.0 m to 8 m (total bore depth of 12.45 m).
2.2 Bolin Bolin Billabong and Yarra River monitoring points

Figure 1 is an extract from Jacobs (2018), showing the Bolin Bolin Billabong measuring point during the environmental watering trial. Included in the figure is also the location of monitoring bores B2 and B6.

Figure 2 shows the location of the Banksia Street gauge station, 229135A, as obtained from the Bureau of Meteorology Water Data Online portal. The location is latitude: -37.76, longitude: 145.08. The Yarra River levels are reported to the station datum, which has a gauge zero of 5.77 m AHD according to the SES (2016)\(^1\) flood intelligence card.

![Figure 1 Banksia Street Gauge Location](image)

2.2 Melbourne Water monitoring information

Melbourne Water provided time series monitoring information as summarised in Table 2. Data up to May 2018 was presented in the EES Groundwater Technical Report, however, further data to June 2019 has been supplied by Melbourne Water.

The data has been obtained during and after the environmental watering trial completed by Melbourne Water, including an unregulated flow event that occurred late 2017.

---

### Table 2  Summary of MW Monitoring information

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Unit</th>
<th>Data</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water level in bore B2</td>
<td>m AHD</td>
<td>From 22/9/2017 To 26/5/2019</td>
<td></td>
</tr>
<tr>
<td>Water level in bore B6</td>
<td>m AHD</td>
<td>From 22/9/2017 To 26/5/2019</td>
<td></td>
</tr>
<tr>
<td>Bolin Billabong level</td>
<td>m</td>
<td>From 13/10/2017 To 20/4/2018</td>
<td></td>
</tr>
<tr>
<td>Gauge 229135A Level</td>
<td>m</td>
<td>From 1/8/2017 To 31/3/2019</td>
<td></td>
</tr>
<tr>
<td>Gauge 229135A Discharge</td>
<td>ML/day</td>
<td>From 1/8/2017 To 31/3/2019</td>
<td></td>
</tr>
<tr>
<td>Bolin Bolin Billabong Dissolved Oxygen</td>
<td>mg/L</td>
<td>From 13/10/2017 To 20/4/2018</td>
<td></td>
</tr>
<tr>
<td>Bolin Bolin Billabong Temperature</td>
<td>°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bolin Bolin Billabong Conductivity</td>
<td>µS/cm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Time series plots are shown in the following figures:

- **Figure 3 Melbourne Water Water Level Monitoring Data**
  - Water level elevation of monitoring bores B2 and B6 (m AHD)
  - Yarra River level at Banksia Street gauge (m AHD)
  - Bolin Bolin Billabong level (m – datum not surveyed)

- **Figure 4 Melbourne Water Water Quality Monitoring Data**
  - Bolin Bolin Billabong level (m – datum not surveyed)
  - Bolin Bolin Billabong electrical conductivity (µS/cm)
  - Bolin Bolin Billabong dissolved oxygen (mg/L)
  - Bolin Bolin Billabong temperature (°C) from two instruments.
Figure 2  Melbourne Water Water Level Monitoring Data

Figure 3  Melbourne Water Water Quality Monitoring Data
2.3 Other drilling data

A review of the Victorian Government’s WMIS was undertaken on 4 July 2019, using a 1 km search radius centred on the deep pool of Bolin Bolin Billabong. The search area is shown in Figure 5.

Fifteen bores were identified within the 1 km radius, of which twelve were installed after 2017 and represent the NEL monitoring bores. The nearest two bores are summarised in Table 3.

Table 3 Summary of WMIS information – nearest bores

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Zone 55 AMG</th>
<th>Date completed</th>
<th>Use</th>
<th>Total Depth (m)</th>
<th>Screen (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Easting</td>
<td>Northing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>WRK061579</td>
<td>330533</td>
<td>5817901</td>
<td>5/05/2011</td>
<td>Observation</td>
<td>10</td>
</tr>
<tr>
<td>WRK061580</td>
<td>330535</td>
<td>5817905</td>
<td>5/05/2011</td>
<td>Observation</td>
<td>10</td>
</tr>
</tbody>
</table>

The construction date and lithological information from WRK061579 (refer Table 4) suggest that these bores are likely to be the same as those installed by Coffey in 2011. A lithological log for bore WRK061580 was not available on the WMIS.

Note that is it not unusual for bores to plot inaccurately on the WMIS. There was no water level or water quality information available on the WMIS.
Table 4  Lithological log of bore WRK061579 from WMIS

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Lithological description</th>
</tr>
</thead>
<tbody>
<tr>
<td>From</td>
<td>To</td>
</tr>
<tr>
<td>0</td>
<td>1.5</td>
</tr>
<tr>
<td>1.5</td>
<td>8.3</td>
</tr>
<tr>
<td>8.3</td>
<td>10</td>
</tr>
</tbody>
</table>

2.4  North East Link drilling data

There are a significant number of NEL project bores within a 1 km radius of Bolin Bolin Billabong, which are shown in Figure 6. The nearest NEL project bore is around 110 m east of Bolin Bolin Billabong.
Figure 5  NEL Project bores

3  Clarification on reference datum

Figure 6-9 in the Groundwater Technical Report shows the water levels of Bolin Bolin Billabong and the Yarra River in m AHD. Please note that this is incorrect. The water levels shown for Bolin Bolin Billabong are measured relative to a datum that is not AHD. Jacobs (2018) indicates that the measurements during the environmental watering trial was taken relative to a pre-test level, when the deep pool was approximately 1.9 m deep at the deepest point. Whilst this level has not been surveyed, the LIDAR and Melbourne Water survey data indicate that it could be around 6 m AHD. Similarly, the water levels for the Yarra River are measured relative to a gauge zero elevation which, for the Banksia Street gauge (229135A), is 5.77 m AHD.

Please note that this is simple mislabelling of data on the chart and has no influence on the groundwater assessments completed to date. Groundwater modelling has relied on accurate LIDAR elevation data, verified against the Bolin Bolin Billabong survey data provided by Melbourne Water, and the river water levels calculated relative to spot measurements of river bed bathymetry. In other words, the water levels used in the modelling have been defined correctly in m AHD.
4 Closure

We trust the information provided in this letter meets your requirements. If you have any questions, please do not hesitate to contact us.
Attachment A
Extracts from Coffey (2012)
### Engineering Log - Borehole

**Client:** Manningham City Council  
**Principal:** Bolin Bolin Billabong Wetland Project  
**Borehole Location:** Refer to Figure 1

<table>
<thead>
<tr>
<th>Method</th>
<th>Support</th>
<th>Water</th>
<th>Notes, Samples, Tests</th>
<th>Material</th>
<th>Graphic Log Classification</th>
<th>Moisture Condition</th>
<th>Density Index</th>
<th>Structure and Additional Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADV</td>
<td>C</td>
<td></td>
<td></td>
<td>CLAY: low plasticity, dark brown, trace of free roots</td>
<td></td>
<td>M</td>
<td>F</td>
<td>TOPSOIL</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CLAY: Low plasticity, dark brown. with some fine grained sand</td>
<td></td>
<td></td>
<td></td>
<td>ALLUVIAL DEPOSITS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>CLAYEY SAND: fine grained, brown, low plasticity clay, with some low liquid limit silt</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 0.5m = 115ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SILTY SAND: fine grained, brown and yellow-brown, low liquid limit silt with some clay</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 1.0m = 107ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>gradate to coarse grained sand</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 1.5m = 18.7ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>becoming brown, trace of fine grained gravel</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 2.0m = 9.1ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>SAND: fine to coarse grained, brown and grey-brown, with some low liquid limit silt</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 2.5m = 6.0ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace of fine to medium grained gravel</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 3.0m = 10.6ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace of fine to medium grained gravel</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 3.5m = 11.1ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>becoming dark grey, trace of medium grained gravel</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 4.0m = 6.4ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace of peats</td>
<td></td>
<td></td>
<td></td>
<td>PID @ 4.5m = 12.2ppm</td>
</tr>
</tbody>
</table>

**Borehole B1 terminated at 9.45m**

- **Borehole No.:** B1  
- **Sheet:** 1 of 1  
- **Project No.:** GEOTABTF08475AA  
- **Date started:** 3.5.2011  
- **Date completed:** 3.5.2011  
- **Logged by:** VSS  
- **Checked by:** 

---

**Legend:**
- **AS:** auger screening
- **AD:** auger drilling
- **RR:** reamer/reamer
- **W:** washbore
- **CT:** core tool
- **DT:** disturbed
- **B:** bulk test
- **V:** vane shear
- **T:** TC test
- **ADT:** auger/reamer test

**Notation:**
- **E:** End of hole
- **U**:** Undisturbed sample
- **D:** Disturbed sample
- **N:** Standard penetration test (SPT)
- **B:** Bulk sample
- **E:** Environmental sample
- **R:** Refusal

**Soil Description:**
- **VS:** very soft
- **S:** soft
- **F:** firm
- **St:** stiff
- **VS:** very stiff
- **H:** hard
- **Fb:** friable
- **W:** wet
- **VL:** very loose
- **L:** loose
- **Wp:** plastic limit
- **D:** dense
- **WL:** liquid limit
- **MD:** medium dense
- **VD:** very dense
# Engineering Log - Borehole

**Client:** Manningham City Council  
**Principal:**  
**Project:** Bolin Bolin Billabong Wetland Project  
**Borehole Location:** Refer to Figure 1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>hole diameter: 110 mm</td>
<td>Northing 591859</td>
<td>bearing:</td>
<td>datum: AHD</td>
</tr>
</tbody>
</table>

## Drilling Information

<table>
<thead>
<tr>
<th>method</th>
<th>support</th>
<th>notes, samples, tests</th>
<th>material</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADV</td>
<td>C</td>
<td>E E E E E E E Usub E Usub E Usub E Usub E Usub E</td>
<td>CLAY: low plasticity, dark brown and brown with some fine grained sand, trace of tree roots. CLAY: Low plasticity, dark brown and brown, with some fine grained sand. CLAY: low to medium plasticity, brown. becoming brown and yellow brown. with some fine grained sand. becoming yellow brown with some fine grained sand.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT</td>
<td>1.23</td>
<td>N=5</td>
<td>SC: CLAYEY SAND: fine grained, grey, yellow-brown, low plasticity clay. becoming yellow brown. becoming dark grey and grey.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT</td>
<td>3.14</td>
<td>N=7</td>
<td>GM: SAND: fine to coarse grained, gray and white-grey, with some fine grained gravel. grades to coarse grained sand</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT</td>
<td>0.00</td>
<td>N=0</td>
<td>CH: CLAY: medium to high plasticity, grey and pale-grey, with some fine grained sand.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Borehole B2 terminated at 10m</td>
</tr>
</tbody>
</table>

## Classification Symbols and Soil Description

<table>
<thead>
<tr>
<th>soil type</th>
<th>plasticity or particle characteristics, colour, secondary and minor components.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAY</td>
<td>low plasticity, dark brown and brown with some fine grained sand, trace of tree roots.</td>
</tr>
<tr>
<td>CLAY</td>
<td>Low plasticity, dark brown and brown, with some fine grained sand.</td>
</tr>
<tr>
<td>CLAY</td>
<td>low to medium plasticity, brown. becoming brown and yellow brown. with some fine grained sand.</td>
</tr>
<tr>
<td>CLAY</td>
<td>becoming yellow brown with some fine grained sand.</td>
</tr>
<tr>
<td>GM</td>
<td>SAND: fine to coarse grained, gray and white-grey, with some fine grained gravel. grades to coarse grained sand</td>
</tr>
<tr>
<td>CH</td>
<td>CLAY: medium to high plasticity, grey and pale-grey, with some fine grained sand.</td>
</tr>
</tbody>
</table>

## Additional Observations

<table>
<thead>
<tr>
<th>moisture condition</th>
<th>consistency index</th>
<th>density index</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOPSOIL</td>
<td>M</td>
<td>P</td>
</tr>
<tr>
<td>ALLUVIAL DEPOSITS</td>
<td>VSt</td>
<td>MD</td>
</tr>
<tr>
<td>PID @ 0.5m = 0.49m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 1.2m = 1.0pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 1.5m = 0.59m</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 2.0m = 2.19pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 2.5m = 3.09pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 3.5m = 6.29pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 3.5m = 10.49pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 4.0m = 10.59pm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PID @ 4.5m = 17.19pm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* trace of dead tree root (peat)
Engineering Log - Borehole

Borehole No: B3
Client: Manningham City Council
Principal: Bolin Bolin Billabong Wetland Project
Borehole Location: Refer to Figure 1

Drill model and mounting: DB 520 Track
Hole diameter: 110 mm

Drilling information

<table>
<thead>
<tr>
<th>Method</th>
<th>Support</th>
<th>Notes, Tests, Etc.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADV</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Material Substance

<table>
<thead>
<tr>
<th>Material</th>
<th>Soil Type</th>
<th>Plasticity or Particle Characteristics, Colour, Secondary and Minor Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLAY</td>
<td>Low to medium plasticity, dark brown with some fine to coarse grained sand, trace of tree roots</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLAY: Low to medium plasticity, dark brown, with some fine to coarse grained sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CLAY: Low plasticity, brown</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Trace of fine grained sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clayey Sand: Fine grained, brown, grey brown, low plasticity clay</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Belty Sand: Fine grained, brown, red-brown and grey</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clayey Sand: Fine grained, grey, brown, yellow brown patches, low plasticity clay, with some medium grained sand</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Clayey Sand: Fine grained, grey and brown, trace of fine grained gravels</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gravelly Sand: Fine to coarse grained sand, grey, white-grey and brown, fine to medium grained gravel</td>
<td></td>
</tr>
</tbody>
</table>

Hole terminated at 7.95m

Consistency/Density Index

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Volvo</th>
<th>Silt</th>
<th>Wet</th>
<th>Very Wet</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>F</td>
<td>F</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>M</td>
<td>M</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>V</td>
<td>V</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>W</td>
<td>W</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>L</td>
<td>L</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>MD</td>
<td>MD</td>
</tr>
<tr>
<td>D</td>
<td>F</td>
<td>F</td>
<td>DD</td>
<td>DD</td>
</tr>
</tbody>
</table>

Additional Observations

- Topsoil
- Alluvial Deposits
- PVD @ 0.5m = 134ppm
- Trace of tree roots
- PVD @ 1.0m = 134ppm
- PVD @ 1.5m = 80.4ppm
- PVD @ 2.0m = 97.4ppm
- PVD @ 2.5m = 120ppm
- PVD @ 3.0m = 142ppm

SPT drops under hammer weight
Trace of peat
# Engineering Log - Borehole

**Client:** Manningham City Council  
**Principal:**  
**Project:** Bolin Bolin Billabong Wetland Project  
**Borehole Location:** Refer to Figure 1

### Drilling Information and Material Substance

<table>
<thead>
<tr>
<th>Method</th>
<th>Support</th>
<th>Notes, Samples, Tests</th>
<th>Classification</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>ADV</td>
<td>C</td>
<td>M, N</td>
<td>CLAY, CLAYEY SAND</td>
<td>ALLUVIAL DEPOSITS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 0.5m = 3.4ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 1.0m = 4.7ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 1.5m = 3.7ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 2.0m = 1.7ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 2.5m = 0.8ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 3.0m = 0.8ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 3.5m = 0.6ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 4.0m = 2.7ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>PID @ 4.5m = 2.7ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace of sea shells</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace of peat</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>trace of sea shells</td>
</tr>
</tbody>
</table>

**Drill Model and Mounting:** DB 520 Track  
**Easting:** 300555  
**Northing:** 5817886  
**Slope:** 90°  
**R.L. Surface:** 11.75

**Datum:** AHD

<table>
<thead>
<tr>
<th>Drilling Information</th>
<th>Material Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil Type: Plasticity or Particle Characteristics, Colour, Secondary and Minor Components.</td>
<td></td>
</tr>
<tr>
<td>Equipment:</td>
<td>PID @ 0.5m = 3.4ppm</td>
</tr>
<tr>
<td>Size:</td>
<td>PID @ 1.0m = 4.7ppm</td>
</tr>
<tr>
<td>Depth:</td>
<td>PID @ 1.5m = 3.7ppm</td>
</tr>
<tr>
<td>Diameter:</td>
<td>PID @ 2.0m = 1.7ppm</td>
</tr>
<tr>
<td>Material:</td>
<td>PID @ 2.5m = 0.8ppm</td>
</tr>
<tr>
<td>Soil:</td>
<td>PID @ 3.0m = 0.8ppm</td>
</tr>
<tr>
<td>Properties:</td>
<td>PID @ 3.5m = 0.6ppm</td>
</tr>
<tr>
<td>Quality:</td>
<td>PID @ 4.0m = 2.7ppm</td>
</tr>
<tr>
<td>Condition:</td>
<td>PID @ 4.5m = 2.7ppm</td>
</tr>
<tr>
<td>Additional Observations: trace of sea shells, trace of peat, trace of sea shells</td>
<td></td>
</tr>
</tbody>
</table>

---

**Borehole B4 terminated at 0.45m**
### Engineering Log - Borehole

**Client:** Manningham City Council  
**Project:** Bolin Bolin Billabong Wetland Project  
**Borehole Location:** Refer to Figure 1

<table>
<thead>
<tr>
<th>Hole Diameter</th>
<th>RL</th>
<th>Bearing</th>
<th>Slope</th>
<th>Datum</th>
<th>Surface</th>
<th>R.L.</th>
<th>Hole Diameter</th>
<th>Notes, Samples, Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 mm</td>
<td>330755</td>
<td>-90°</td>
<td></td>
<td></td>
<td>11.1</td>
<td>5817868</td>
<td>110 mm</td>
<td></td>
</tr>
</tbody>
</table>

#### Drilling Information

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Material Substances</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>CLAY: low to medium plasticity, dark brown, with some fine to coarse grained sand, trace of tree roots</td>
</tr>
<tr>
<td>2-4</td>
<td>becoming low plasticity, grey brown and brown, with some fine grained sand</td>
</tr>
<tr>
<td>4-6</td>
<td>becoming brown, orange-brown and grey, trace of fine grained sand</td>
</tr>
<tr>
<td>6-8</td>
<td>with some fine grained sand</td>
</tr>
<tr>
<td>8-10</td>
<td>CLAYEY SAND: fine grained, grey and grey-brown, low plasticity clay</td>
</tr>
<tr>
<td>10-12</td>
<td>SILTY SAND: fine grained, grey, low liquid limit silt</td>
</tr>
<tr>
<td>12-14</td>
<td>with some coarse grained sand</td>
</tr>
<tr>
<td>14-16</td>
<td>SAND: fine grained, grey, with some fine grained gravel</td>
</tr>
<tr>
<td>16-18</td>
<td>GRAVELLY SAND: fine grained sand, grey and white grey, fine to medium grained gravel</td>
</tr>
</tbody>
</table>

**Borehole B5 terminated at 7.95m**
### Engineering Log - Borehole

**Client:** Manningham City Council  
**Principal:** Bolin Bolin Billabong Wetland Project

**Borehole Location:** Refer to Figure 1

<table>
<thead>
<tr>
<th>Method</th>
<th>Support</th>
<th>Notes, Samples, Tests</th>
<th>Material</th>
<th>Moisture Content</th>
<th>Density</th>
<th>Additional Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>W-ADV</td>
<td>C</td>
<td></td>
<td>CLAY: low plasticity, dark brown, with some fine grained sand, trace of low liquid limit silt and tree roots. CLAY: low plasticity, dark brown, with some fine grained sand, with a trace of low liquid limit silt.</td>
<td>M, F</td>
<td>TOPSOIL</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SANDY CLAY: low plasticity, brown, fine grained sand, with some low limit silt</td>
<td>VS</td>
<td>ALLUVIAL DEPOSITS</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>CLAYEY SAND: fine grained, brown and grey-brown</td>
<td>MD</td>
<td>PID @ 0.5m = 0.8mpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>SAND: fine to coarse grained, brown and grey-brown</td>
<td>W</td>
<td>PID @ 1.0m = 0.8mpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>becoming grey-brown, grades to coarse grained sand and becoming grey and brown</td>
<td>L</td>
<td>PID @ 1.5m = 1.1mpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>grades to coarse grained sand</td>
<td>MD</td>
<td>PID @ 2.0m = 1.4mpm</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>trace of core tree roots ash (black)</td>
<td>L</td>
<td>PID @ 2.5m = 1.5mpm</td>
<td></td>
</tr>
<tr>
<td>SPT</td>
<td>1,13</td>
<td></td>
<td>SAND: coarse grained, grey with some shells</td>
<td>S</td>
<td>trace of peat and dead tree fragments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>N=3</td>
<td></td>
<td>GRAVELLY SAND: fine to coarse grained sand, grey and brown, fine to medium grained gravel</td>
<td>L</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>becoming dark grey with some low plasticity clay</td>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>L</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Additional Notes:**
- 10/11/86 water level on date shown  
- Water inflow
- Water outflow

**Classification Symbols and Soil Description:**
- Based on unified classification system
- Moisture: D - dry, M - moist, W - wet
- Plasticity: Wp - plastic limit, Wi - liquid limit
- Consistency/density index: VS - very soft, S - soft, F - firm, St - stiff, VS - very stiff, H - hard, Fb - failing, Vf - very loose, L - loose, Md - medium dense, D - dense, VD - very dense
# Engineering Log - Borehole

**Client:** Manningham City Council  
**Project:** Bolin Bolin Billabong Wetland Project  
**Borehole Location:** Refer to Figure 1  

<table>
<thead>
<tr>
<th>drill model and mounting:</th>
<th>DB 528 Track</th>
<th>Easting:</th>
<th>330747</th>
<th>slope:</th>
<th>-90°</th>
<th>R.L. Surface:</th>
<th>12.15</th>
</tr>
</thead>
<tbody>
<tr>
<td>hole diameter:</td>
<td>110 mm</td>
<td>Northing</td>
<td>581798</td>
<td>bearing:</td>
<td></td>
<td>datum:</td>
<td>AHD</td>
</tr>
</tbody>
</table>

## Drilling Information

<table>
<thead>
<tr>
<th>method</th>
<th>support</th>
<th>notes, samples, etc</th>
<th>material classification</th>
<th>material description</th>
<th>moisture content</th>
<th>consistency/density index</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPT</td>
<td></td>
<td></td>
<td>SC</td>
<td>CLAYEY SAND: fine-grained, dark grey, low plasticity clay with some low liquid limit silt.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Borehole B6 terminated at 12.45m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Peizometer Installation

- **Standpipe:**
  - 0.5m-0.0m: Free stand steel casing  
  - 0.0m-3.0m: Solid 50mm PVC  
  - 3.0m-8.0m: Machine slotted 50mm PVC  
- **Backfill:**
  - 0m-2.0m: Concrete and cement grout  
  - 2.0m-8.0m: Well graded sand  
  - 8.0m-12.0m: Drill cuttings

---

Form: GEO 5.5, Issue 3, Rev. 1

<table>
<thead>
<tr>
<th>method</th>
<th>support</th>
<th>notes, samples, etc</th>
<th>classification symbols and soil description based on unified classification system</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS</td>
<td>auger screwing*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>AD</td>
<td>auger drilling*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RR</td>
<td>roller auger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>washboard</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CT</td>
<td>cable tool</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HA</td>
<td>hand auger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DT</td>
<td>dialoue</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>blank bit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Vite</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>TC bit</td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g.</td>
<td>AODT</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*bit shown by suffix e.g. AODT (AD = auger drilling)
### Engineering Log - Borehole

**Client:** Manningham City Council  
**Principal:** Bolin Bolin Billabong Wetland Project  
**Borehole Location:** Refer to Figure 1

#### Drilling Information
- **Method:** ADV
- **Support:** Not Observed
- **Notes:** Samples, tests, etc.
- **RL:** Not Observed
- **Depth:** Not Observed

#### Material Substance
- **Material:** Silty Clay
  - **Classification:** CL
  - **Soil Type:** Plasticity or particle characteristics, colour, secondary and minor components.

#### Additional Observations
- **Top Soil:**
  - **ID:** PIDs: 1.4ppm
  - **Note:** SPT tank 350mm under self weight, water clipping after SPT
- **Graingly Sand:**
  - **ID:** PIDs: 1.6ppm
  - **Note:** SPT with solid cone
- **Silt:**
  - **ID:** PIDs: 1.7ppm
- **Gravelly Sand:**
  - **ID:** PIDs: 1.4ppm
  - **Note:** Hole starting to collapse, piece of woodlame rod on SPT sample

---

**Table:**

<table>
<thead>
<tr>
<th>Method</th>
<th>Support</th>
<th>Notes, Samples, Tests</th>
<th>Classification Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>AS</td>
<td>mud</td>
<td>undisturbed sample 50mm diameter</td>
<td>VS, very soft</td>
</tr>
<tr>
<td>AD</td>
<td>auger drilling*</td>
<td>undisturbed sample 63mm diameter</td>
<td>S, soft</td>
</tr>
<tr>
<td>CT</td>
<td>cable tool</td>
<td>disturbed sample</td>
<td>F, firm</td>
</tr>
<tr>
<td>DT</td>
<td>hand auger</td>
<td>N, SPT - sample recovered</td>
<td>Stiff</td>
</tr>
<tr>
<td>V</td>
<td>void test</td>
<td>SPT - with solid cone</td>
<td>VS, very stiff</td>
</tr>
<tr>
<td>T</td>
<td>TC bit</td>
<td>Vane shear (kPa)</td>
<td>H, hard</td>
</tr>
<tr>
<td>e.g.</td>
<td>AOT</td>
<td>Penetrometer</td>
<td>F, firm</td>
</tr>
</tbody>
</table>

**Notes:**
- **50mm diameter:**
- **63mm diameter:**
- **SPT:** Standard penetration test (SPT)
- **Vane shear:** Vane shear (kPa)
- **Penetrometer:** Penetrometer
- **Penetration:** Penetration test (SPT)
- **Vane shear:** Vane shear (kPa)
- **Penetrometer:** Penetrometer
- **Access:** Access to borehole
- **Water:** Water level

---

**Consistency/Density Index:**

<table>
<thead>
<tr>
<th>Moisture</th>
<th>Dry</th>
<th>Medium Dense</th>
<th>Very Dense</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>M</td>
<td>W</td>
<td>L</td>
</tr>
<tr>
<td>F</td>
<td>L</td>
<td>VL</td>
<td>LC</td>
</tr>
<tr>
<td>V</td>
<td>VL</td>
<td>VD</td>
<td>VD</td>
</tr>
<tr>
<td>S</td>
<td>F</td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>Stiff</td>
<td>VS</td>
<td>VS</td>
<td>VS</td>
</tr>
</tbody>
</table>

---

**Legend:**

- **CL:** Clay
- **ML:** Clayey Silt
- **SP:** Sand
- **DI:** Depth
- **E:** Easting
- **N:** Northing
- **R:** R.L.
- **D:** Depth
- **H:** Height
- **R:** R.L.
- **Z:** Zone
- **B:** Bearing
- **P:** Pressure
- **D:** Density
## Engineering Log - Borehole

**Client:** Manningham City Council  
**Principal:**  
**Project:** Bolin Bolin Billabong Wetland Project  
**Borehole Location:** Refer to Figure 1

### Borehole Information
- **Borehole No.:** BH2  
- **Date started:** 23.6.2011  
- **Date completed:** 23.6.2011  
- **Logged by:** DA  
- **Checked by:** 🍀

### Drilling Information
- **Drill model and mounting:** DB 800 Track  
- **Easting:** 336554  
- **Slope:** -90°  
- **R.L. Surface:** 11.2

### Material Substance

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Soil Type</th>
<th>Moisture Condition</th>
<th>Permeability Index</th>
<th>Additional Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>CL</td>
<td>M</td>
<td>ST</td>
<td>TOPSOIL</td>
</tr>
<tr>
<td>2.3</td>
<td>CL</td>
<td>F/ST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.6</td>
<td>ML</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.8</td>
<td>SM</td>
<td>W</td>
<td>MO</td>
<td></td>
</tr>
<tr>
<td>8.2</td>
<td>SP</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**  
- Alluvial Deposits
- Possible SILT CLAY
- SPT CPT 100mm under self weight
- SPT 100mm under self weight
- SILT CLAY and CLAYEY SILT
- Terrestrial layer on top of sand

---

**Legend:**  
- **CL:** Clay  
- **ML:** Mud  
- **SM:** Silt  
- **SP:** Sand  
- **AD:** Auger drilling  
- **AS:** Auger screwing  
- **AT:** ADT  
- **CT:** Cable tool  
- **DT:** Disturbance

---

**Key:**  
- **U:** Undisturbed  
- **D:** Disturbed  
- **N:** Normalized  
- **S:** Special  
- **V:** Vane shear  
- **P:** Pressuremeter  
- **R:** Refusal  
- **ADT:** Auger Diamond Tool  
- **W:** Water level

---

**Notes:**  
- Undisturbed sample 50mm diameter  
- Disturbed sample 50mm diameter  
- Standard penetration test (SPT)  
- SPT - sample recovered  
- SPT with solid cone  
- Vane shear  
- Pressuremeter  
- Environmental sample  
- Refusal

---

**Consistency/Density Index:**  
- VS: Very soft  
- S: Soft  
- F: Firm  
- SI: Stiff  
- VS: Very stiff  
- H: Hard  
- FS: Fail  
- VL: Very loose  
- L: Loose  
- MD: Medium dense  
- D: Dense  
- VO: Very dense
**Engineering Log - Borehole**

Client: Manningham City Council

Principal: Bolin Bolin Billabong Wetland Project

Borehole Location: Refer to Figure 1

<table>
<thead>
<tr>
<th>Drilling Information</th>
<th>Material Substance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Drill method</strong></td>
<td><strong>Material</strong></td>
</tr>
<tr>
<td>ADV</td>
<td>SILTY CLAY: medium plasticity, brown, trace of mica flakes</td>
</tr>
<tr>
<td></td>
<td>CL</td>
</tr>
<tr>
<td></td>
<td>ML</td>
</tr>
<tr>
<td></td>
<td>SP</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Borehole BH3 terminated at 8m**

**Additional Observations**

- TOPSOIL
- ALLUVIAL DEPOSITS
- PIDS: 1.1ppm
- PIDS: 1.6ppm
- PIDS: 2.6ppm
- moisture content increasing
- 1ppm
- TENDING TO SILTY CLAY
- PIDS: 2.1ppm
- PIDS: 2.0ppm
- PIDS: 1.3ppm
- PIDS: 1.3ppm
- PIDS: 0.6ppm
- PIDS: 0.6ppm
- PIDS: 1.1ppm
- PIDS: 1.1ppm
- SPT sunk 150mm under self weight
- PIDS: 2.3ppm
- PIDS: 2.6ppm
- PIDS: 1.1ppm
HYDRAULIC CONDUCTIVITY
ABOVE WATER TABLE - CASED - OPEN
Variable Head

Client: Nanningham City Council
Principal: Bolin Bolin Billebong Wetland Project
Test Location: Refer to Figure 1

Test Method: Janvis 1949
Page 284 is USGW 1977

Test Fluid: Town Supply Water
Height of Datum, HD: 1.10 m

Hole Radius, R: 0.055 m
Hole Depth, D: 4.95 m
Casing Radius, r: 0.055 m
Casing Depth, d: 2.40 m

Test Length, L: 2.55 m
L / R: 46.4
sinh⁻¹ (L/R): 4.63

Depth to Water Table, w: 4.8 m
date & time: 23-Jun-96 7:00 AM

where c = 0.5 sinh⁻¹ (L/R) ln (2 h₁ - L) - ln (2 h₂ - L h₁) / (2h₁ - L) h₁ (2h₂ - L h₂)

<table>
<thead>
<tr>
<th>Reading No.</th>
<th>Elapsed Time (hrs)</th>
<th>Depth to Water (m)</th>
<th>Height of Water (m)</th>
<th>Water Head Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
<td>2.39</td>
<td>3.66</td>
<td>1.00</td>
</tr>
<tr>
<td>1</td>
<td>0.5</td>
<td>2.40</td>
<td>3.65</td>
<td>1.00</td>
</tr>
<tr>
<td>2</td>
<td>1.0</td>
<td>2.42</td>
<td>3.63</td>
<td>0.99</td>
</tr>
<tr>
<td>3</td>
<td>2.0</td>
<td>2.44</td>
<td>3.61</td>
<td>0.99</td>
</tr>
<tr>
<td>4</td>
<td>3.0</td>
<td>2.47</td>
<td>3.58</td>
<td>0.98</td>
</tr>
<tr>
<td>5</td>
<td>5.0</td>
<td>2.50</td>
<td>3.55</td>
<td>0.97</td>
</tr>
<tr>
<td>6</td>
<td>10.0</td>
<td>2.57</td>
<td>3.48</td>
<td>0.95</td>
</tr>
<tr>
<td>7</td>
<td>15.0</td>
<td>2.62</td>
<td>3.42</td>
<td>0.94</td>
</tr>
<tr>
<td>8</td>
<td>20.0</td>
<td>2.65</td>
<td>3.40</td>
<td>0.93</td>
</tr>
<tr>
<td>9</td>
<td>30.0</td>
<td>2.70</td>
<td>3.36</td>
<td>0.92</td>
</tr>
<tr>
<td>10</td>
<td>45.0</td>
<td>2.75</td>
<td>3.30</td>
<td>0.90</td>
</tr>
<tr>
<td>11</td>
<td>60.0</td>
<td>2.78</td>
<td>3.27</td>
<td>0.89</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes:

Sketch of site conditions (not to scale)

Water Table

Height of Water versus Time

(r₂, h₂, h₁) = (1) 0.5 3.35
(r₁, h₁, h₂) = (3) 2.0 3.31

C = 0.033

Hydraulic Conductivity, K = r² C / 2 L (h₂ - h₁)
= 2.1E-07 m/sec
= 0.019 m/day
HYDRAULIC CONDUCTIVITY
ABOVE WATER TABLE - CASED - OPEN
Variable Head

Client: Manningham City Council
Principal: Ekin Bollin Billabong Wetland Project
Project: Refer to Figure 1
Test Location: Toongabbie Wetland Project

Test Method: Jarvis 1949
Page 284 is USGWM 1977

Test Fluid: Groundwater
Height of Datum, HD: 0.50 m

Hole Radius, R: 0.025 m
Hole Depth, D: 10.00 m
Casing Radius, r: 0.060 m
Casing Depth, d: 5.50 m

Test Length, L: 4.50 m
L / R: 180.0
sinh⁻¹(L/R): 5.89

Depth to Water
Table, w (if known): 1.7 m
- date & time: 1/6/2011 3:30 PM

where c = \( \frac{0.5 \text{ sinh}^{-1}(L/R) \ln \left( \frac{2h_1L}{L_h} \right) - \ln \left( \frac{2h_1L}{L_h} - L_h \right)}{(2h_1L - L_h)} \)

---

<table>
<thead>
<tr>
<th>Reading No.</th>
<th>Elapsed Time (s)</th>
<th>Depth to Water (m)</th>
<th>Height of Water (m)</th>
<th>Water Head Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.0</td>
<td>1.64</td>
<td>8.86</td>
<td>1.00</td>
</tr>
<tr>
<td>1</td>
<td>0.2</td>
<td>2.17</td>
<td>8.33</td>
<td>0.94</td>
</tr>
<tr>
<td>2</td>
<td>0.3</td>
<td>2.19</td>
<td>8.31</td>
<td>0.94</td>
</tr>
<tr>
<td>3</td>
<td>0.5</td>
<td>2.19</td>
<td>8.31</td>
<td>0.94</td>
</tr>
<tr>
<td>4</td>
<td>1.5</td>
<td>2.20</td>
<td>8.31</td>
<td>0.94</td>
</tr>
<tr>
<td>5</td>
<td>3.0</td>
<td>2.20</td>
<td>8.30</td>
<td>0.94</td>
</tr>
<tr>
<td>6</td>
<td>4.0</td>
<td>2.20</td>
<td>8.30</td>
<td>0.94</td>
</tr>
</tbody>
</table>

---

Height of Water versus Time

\( (r, n, t, h_1) = \left( \begin{array}{c} 1 \ 0.2 \ 8.33 \\ 2 \ 0.3 \ 8.31 \end{array} \right) \)

\( C = 0.009 \)

Hydraulic Conductivity, \( K = \frac{r^2C}{2L(t_2 - t_1)} \)

\( = \frac{2.4E-07}{2} \text{ m/sec} \)

\( = 0.021 \text{ m/ds} \)
Attachment B
Jacobs (2018)
1. Introduction

1.1 Background

Bolin Bolin Billabong lies on the floodplain of the Yarra River in the Melbourne suburb of Bulleen (Figure 1-1). The changed hydrology of the Yarra River system due to development of water resources and local land use change has significantly altered Bolin Bolin Billabong from its pre-European state.

Melbourne Water has applied a framework for determining and implementing wetland water regime objectives. The overarching framework was originally developed to guide the design and operation of environmentally friendly wetland regulators for the Murray Darling Basin Commission in 2005. The framework is divided into four stages:

Figure 1-1 Map showing location of Bolin Bolin Billabong
1. Management objectives

This stage involves the assessment of wetland values and the development of wetland management objectives.

2. Water regime requirements

This stage involves the identification of wetland water requirements, linked to management objectives. As part of this step it is necessary to determine how water requirements could best be delivered (i.e. via operational changes, regulators, other).

3. Water regime delivery – regulator design

This stage involves the delivery of the appropriate water regime though the design, construction and operation of regulating structures that are designed to deliver the management objectives.

4. Monitoring, evaluation and adaptive management

This stage represents the implementation of the desired water regime and the monitoring and assessment required to support an adaptive management process (SKM, 2005).

A flow chart showing these four stages and consistent input throughout the process from technical studies and stakeholder input is show in Figure 1-2. This report is part of Stage two of the overall framework.

Figure 1-2 Flow chart describing the four key stages of the overarching framework for determining and implementing wetland water regime management.
Previous projects undertaken on Bolin Bolin Billabong have focused on the identification of key ecological values present at Bolin Bolin Billabong and the key threats to these values (part of Stage one of the framework). Specific management objectives have been developed based on this value and threat information. A preferred water regime for the billabong has also been identified (part of Stage two of the framework) to meet these management objectives and enhance the ecological values of the site. Cultural heritage and social values have also been investigated through previous projects, however the management objective developed did not capture these values.

During the development of the water regime requirements, it was acknowledged that a gap in data existed in terms of ecological response to watering. In order to address this information gap a trial environmental watering event was undertaken to improve the understanding of the current water regime (e.g. seepage rates and the volume of water required to fill the billabong) and the ecological responses to the watering. Water level loggers, groundwater monitoring bores and timelapse cameras were all used to capture the response of the billabong to the trial environmental watering. Vegetation assessments were undertaken prior to the watering event and water quality analysis was undertaken during and following the event. This watering event commenced in October 2017.

The objective of this project is to review the data from the trial watering and update the existing conceptualisation, management objectives, including a greater focus on cultural values, and preferred water regime for Bolin Bolin Billabong to support the values of the site. Based on this information, the project will recommend an environmental watering solution that could enable the preferred water regime to be delivered. A workshop with key project stakeholders was held on 14 June 2018 and this document incorporates some of the discussion from that workshop. Melbourne Water are now seeking feedback from stakeholders involved in the management of Bolin Bolin Billabong prior to finalising the watering regime and environmental watering solution prior to developing a detailed design for the preferred environmental watering solution. The progress of the Bolin Bolin Billabong project against the overarching framework for determining and implementing management of the wetland water regime is shown in Figure 1-3.

![Figure 1-3 Current status of project](image_url)
1.2 Bolin Bolin Billabong

Site values

A previous study has been undertaken to determine the water requirements of the Bolin Bolin Billabong (Dodo Environmental, 2010). As part of this study, the key ecological values of the billabong were established.

Two dominant Ecological Vegetation Communities exist at Bolin Bolin Billabong; EVC 172 Floodplain Wetland Aggregate in the deepest parts of the billabong; and EVC 56 Floodplain Riparian Woodland surrounding the billabong.

Two native fish have been recorded in Bolin Bolin Billabong, Short finned eel and Flat headed gudgeon and five exotic species have been recorded (Goldfish, Carp, Mosquitofish, Weatherloach and Redfin perch) (Mitchell et al. 1996). It is likely that the species poor native fish community may be a function of water regime or predation and habitat degradation by exotic species (e.g. Carp).

The key hydrological features of Bolin Bolin Billabong are illustrated in Figure 1-4. The main areas targeted by the trial environmental watering event were the permanent pool and the wet-dry arms.

Figure 1-4 Map showing key hydrological features of Bolin Bolin Billabong
Topographic and pool survey

A topographic survey of the billabong was undertaken prior to the trial environmental watering event to further characterise the variation in depth across the wet-dry arms and permanent pool of the billabong, and to inform the depths to be targeted by the trial environmental watering event. A map of the billabong and the locations of the survey data collected are show in Figure 1-5. The mapped outputs from the longitudinal section surveys of the wet-dry arms are show in Figure 1-6 and Figure 1-7. These outputs from the survey show the variation in bed level throughout the billabong and were used to inform the target depth required to connect along the full length of the northern and southern arms of the billabong. One of the mapped outputs of the cross sections of the permanent pool is shown in Figure 1-8. This was used to help determine the depth that would be achieved within the permanent pool from the trial environmental watering event.

Figure 1-5 Mapped output of the topographic survey undertaken consisting of a longitudinal survey of the wet-dry arms. The points surveyed are shown by the dark blue lines. The location of one of five cross sections taken across the permanent pool using a ‘Q-Boat’ is shown by the green line.
Memorandum
Review of trial environmental watering and unregulated flow event

Figure 1-6 Longitudinal sections showing the elevation profile of the northern arm of Bolin Billabong shown by the blue line in Figure 1-5.

Figure 1-7 Longitudinal section showing the elevation profile of the southern arm of Bolin Billabong shown by the blue line in Figure 1-5.

Figure 1-8 Surveyed cross section of permanent pool shown by the green line in Figure 1-5.
2. Trial environmental watering

In October 2017, Melbourne Water undertook a trial watering event at Bolin Bolin Billabong to investigate the hydrological, hydrogeological and ecological response of inundation events in the billabong. The trial environmental watering event aimed to reach a depth of 0.3 m in the wet-dry arms with an equivalent increase in depth in the permanent pool of the billabong. Water was pumped directly from the Yarra River between 19th October and 27th October and utilised around 60 ML of water from the Yarra River Environmental Entitlement managed by the Victorian Environmental Water Holder. The watering of the Bolin Bolin Billabong coincided with a spring fresh environmental flow release down the Yarra River and so the river level was higher than it would have been in the absence of the environmental flow release.

Monitoring was undertaken prior to, during and after the trial watering event to monitor the response of surface and groundwater levels, water quality and vegetation in the billabong. Monitoring data collected includes:

- Surface water level measurements
- Groundwater level measurements
- Continuous water quality measurements
- Spot water quality measurements
- Timelapse camera images
- Photos prior to, during and after the watering event
- Vegetation assessment prior to the watering event
- Frog assessment
- Fish survey

Figure 2-1 shows the locations of the monitoring data collection sites.
Memorandum

Review of trial environmental watering and unregulated flow event

Figure 2-1 Aerial photograph of Bolin Bolin Billabong showing key features and monitoring data collection sites

2.1 Hydrological response

A review of the surface water level monitoring data (Figure 2-3) was undertaken. The main findings from the review include:

- The permanent pool part of the billabong was filled to a depth of 2.499 m (from an initial level of 0.03 m local datum). The initial depth of the pool in its deepest part was around 1.9m
- The total volume pumped was approximately 60 ML
- It took nine days to reach the 2.499 m level (19/10/2017 to 27/10/2017), although no pumping occurred on the weekend (21-22/10/2017) and the pumping rates dropped when the Yarra River levels fell after an environmental water event was delivered down the river, exposing the suction lines and impacting the efficiency of the pumps. The pumps were removed from site on 31/10/2017.
- The billabong water level drew down 0.955 m to reach a depth of 1.544 m on 30/11/2017 before an unregulated flow event entered the billabong, resulting in the billabong filling again.
- The average rate of drawdown was 0.029 m/day between the end of the pumping and the unregulated filling of Bolin Bolin Billabong.
Photos in Figure 2-2 show the Billabong prior to and following the trial environmental watering event.

Figure 2-2 Bolin Bolin Billabong prior to watering in July 2017 (left) and following watering in October 2017 (right)

Figure 2-3 Water levels in Bolin Bolin Billabong showing times that pumps were on and off or at variable rates (billabong level is not relative to the river level as the surface level gauge has not been surveyed to AHD). The spring fresh environmental watering event in the Yarra River took place between 16 and 28 October 2017. It can be seen that after the Yarra River level dropped on 25 October as this event neared completion and the pumping became much less effective due to the exposure of the suction lines.

2.2 Groundwater response

A review of the groundwater level monitoring data collected during the trial environmental watering event (Figure 2-4) was undertaken. The location of the bores (B2 and B6) in relation to the billabong and Yarra River can be seen in Figure 2-1. Bore construction details are show in Table 2-1.
Memorandum

Review of trial environmental watering and unregulated flow event

Table 2-1 Bore construction details for B2 and B6 used to monitor Bolin Bolin groundwater levels (Coffey, 2012)

<table>
<thead>
<tr>
<th>Bore ID</th>
<th>Latitude</th>
<th>Longitude</th>
<th>Depth (m)</th>
<th>Screened depth (m)</th>
<th>Screened medium</th>
<th>Construction date</th>
</tr>
</thead>
<tbody>
<tr>
<td>B2</td>
<td>-37.77093</td>
<td>145.07695</td>
<td>10.00</td>
<td>5.5-10.0</td>
<td>Sand/Gravelly</td>
<td>2 May 2011</td>
</tr>
<tr>
<td>B6</td>
<td>-37.77054</td>
<td>145.07829</td>
<td>12.45</td>
<td>3.0-8.0</td>
<td>Sand/Gravelly</td>
<td>2 May 2011</td>
</tr>
</tbody>
</table>

The groundwater level trends illustration in Figure 2-4 show a small response to the trial environmental watering event. Groundwater levels increased by approximately 0.15 m in the two weeks following the pumping event before drawing down by the same amount in the following two weeks. This response in groundwater level could also be due to the influence of the spring fresh environmental watering in the Yarra River.

The surface water level in the billabong was drawing down at a rate of approximately 0.02 m/day for the month following the trial environmental watering, a corresponding increase in groundwater levels from surface water discharge from the billabong to groundwater was not observed which suggests the groundwater response could be more closely linked to conditions in the river rather than the billabong.

![Figure 2-4](image)

Figure 2-4 Billabong water level (billabong level is not relative to the river level as the surface level gauge has not been surveyed to AHD), Yarra River level adjacent to Bolin Bolin Billabong and nearby groundwater levels during the trial environmental watering event.

3. Unregulated flow event

In early December 2017, heavy rain was experienced across the Yarra River catchment for approximately 1.5 days. The rain gauge at the Upper Yarra Dam recorded 88.4 mm on 1 December 2017. Water levels in the Yarra River rose in response to this event, the Heidelberg gauge (229135A) recorded a maximum river level of 5.870 m on 3 December 2017 which corresponded to a flow of 9,378.4 ML/d. The last time flows of this magnitude were recorded was in June 2013 when the Heidelberg gauge recorded a flow of 11,383.0 ML/d (Jacobs, 2018).

During this high flow event, Bolin Bolin Billabong was inundated through the inlet on the southern arm of the billabong, this inlet is represented by the green line in Figure 2-1. The whole billabong was filled, with the southern arm draining within a week and the northern arm holding water for an extended period of time (Jacobs, 2018).
Figure 3-1 Bolin Bolin Billabong during the December 2017 unregulated flow event. Images show water rushing into the southern arm as the river levels rose (top left); the inlet point to Bolin Bolin Billabong following the peak of the event (top right); and the permanent pool after the inundation event (bottom).

3.1 Hydrological response

The high flow event in Bolin Bolin Billabong resulted in water levels in the billabong to increase from 1.544 m to 3.694 m as floodwaters from the Yarra River entered the billabong through the inlet channel on the southern arm, see images in Figure 3-1 and graph in Figure 3-2. It can be seen from Figure 3-1 that the water level reached by this event coincides with the base of mature River Red Gum trees lining the edges of the billabong. This indicates that the billabong has regularly filled to this level in the past and delineates the zone of terrestrial vegetation of the higher floodplain from the zone of aquatic and semi-aquatic vegetation of the billabong. The billabong then proceeded to draw down again following this event at an average rate of 0.018 m/day, slower than the 0.029 m/day rate of recession observed following the trial environmental watering event. This change in draw down rate is likely due to the groundwater levels and the subsurface connection of the billabong to the Yarra River, this is discussed further in Section 3.2.
3.2 Groundwater response

Bores B2 and B6 described in Section 2.2 also collected data during the unregulated flow event in December 2017. Figure 3-3 and Figure 3-4 show the groundwater response during the unregulated flow event compared with Yarra River levels and the Bolin Bolin Billabong water level.

It can be seen that groundwater levels in both observation bores showed a much stronger response to the unregulated flow event than they did during the spring fresh environmental watering event in the Yarra River and the trial Bolin Bolin environmental watering pumped event.

During the unregulated flow event groundwater levels in both bores showed an immediate increase of approximately 0.5 m in the first few days and continued to increase at a slower rate in the following weeks, increasing by approximately 0.04 m over the next 12 days. From 21 January to 17 April 2018 both observation bores showed a slow recession in groundwater level at a rate of 0.012 m/day (Figure 3-3 and Figure 3-4). It can also be seen that groundwater levels continued to respond to several small peaks in the Yarra River, the clearest example of this was the small peak on the 24 March 2018.

Figure 3-3 Yarra River level and nearby groundwater levels during the trial environmental watering event in October 2017 and subsequent unregulated flow event in December 2017.
Memorandum

Review of trial environmental watering and unregulated flow event

Figure 3-4 Bolin Bolin Billabong level (billabong level is not relative to the river level as the surface level gauge has not been surveyed to AHD) and nearby groundwater levels during the trial environmental watering event in October 2017 and subsequent unregulated flow event in December 2017

Two conceptual diagrams showing groundwater and surface water interaction have been provided below showing the groundwater response observed following the trial environmental watering and unregulated flow event, see Figure 3-5 and Figure 3-6. Figure 3-5 shows the unregulated flow event in the Yarra River recharging the groundwater via subsurface flow as well as entering the billabong through the inlet channel. The water levels in the billabong increase and are maintained by the high water table in the gravel lens underlying the billabong. Figure 3-6 shows the billabong in the weeks and months following the unregulated flow event. It can be seen that subsurface flows reverse and return back to the Yarra River, lowering the water table. The water level in the billabong decreases but the permanent pool is maintained through its permanent connection to the Yarra River.

Figure 3-5 Conceptual diagram showing the unregulated flow event in the Yarra River recharging the groundwater via subsurface flow
Figure 3-6 Conceptual diagram showing the draw-down of the billabong and subsurface flow returning to the Yarra River following the recession of flood waters.

4. Water quality response

Continuous water quality data was captured at the surface water monitoring site in Bolin Bolin Billabong's permanent pool installed by ALS. Results for dissolved oxygen, water temperature and conductivity can be seen in Figure 4-1. The conductivity levels in the permanent pool showed that the water was relatively saline prior to the pumped environmental watering event which is consistent with our conceptual understanding that the permanent pool is maintained by groundwater in the absence of surface water inflows. Salinity then decreased as fresh water was pumped into the billabong during the trial environmental watering event. Following the pumped event, the salinity increased likely as evaporation occurred from the water surface and there was possibly some inflow from groundwater during this period despite the overall water level in the billabong decreasing. A similar freshening effect was not observed during the unregulated flow event. There are several periods where the conductivity probe was not functioning correctly and these results have been omitted from the graph show in Figure 4-1.

It can also be seen from Figure 4-1 that the dissolved oxygen level was around 7 mg/L prior to the pumped watering event. The probe was installed on the 14th October and may have taken a few days to start functioning correctly as it appears the dissolved oxygen levels were continuously decreasing for several days before the pumping trial started on the 19th October. Dissolved oxygen levels increased slightly on the first day of pumping however the levels quickly dropped off to 0 mg/L as pumping progressed and during the drawdown period. This could be because leaf litter that had accumulated within the wet/dry arms of the billabong since the last inundation event was washed into the permanent pool during the trial environmental watering event and dissolved oxygen levels decreased as this organic material was consumed by bacteria. There was no freshening effect observed with the natural inundation event in December 2017.
Memorandum

Review of trial environmental watering and unregulated flow event

Spot water quality measurements were also undertaken by ALS, Jacobs and the Wurundjeri Land and Compensation Cultural Heritage Council Aboriginal Corporation’s Narrap team during the study period. The measurements are consistent with the trends described above and are further detailed in Jacobs (2018).

5. Ecological response

5.1 Vegetation

Melbourne Water undertook vegetation monitoring in Bolin Bolin Billabong prior to the trial environmental watering event in August 2017 and again following the environmental watering and unregulated flow events in May 2018. The transect used for the vegetation monitoring is represented by the yellow line in Figure 2-1. The full results of this survey are documented in Melbourne Water’s (2018a) report, however the key findings were:

- Prior to environmental watering the vegetation monitoring transect showed indigenous vegetation coverage of 65%
- The main indigenous species reported included Slender Knotweed (*Perscaria decipiens*), Tall Sedge (*Carex appressa*) and Pale Rush (*Juncus pallidus*)
- The main exotic species reported included: Creeping Buttercup (*Ranunculus repens*), Yorkshire Fog (*Holcus lanatus*) and Cocksfoot (*Dactylis glomerata*).
- Following the trial environmental watering and unregulated flooding events the monitoring transect showed an expansion in Slender Knotweed and a contraction in Tall Sedge. There was also an expansion of weeds into the transect from the higher parts of the billabong
- Follow up monitoring is planned for September 2018 to establish whether further encroachment of weeds occurs into the lower parts of the billabong.

Photos taken at the photo points also highlight the change in vegetation pre and post the watering event (Figure 5-1). A graphical representation of the results obtained prior to the watering events and following the watering events can be found in Figure 5-2. Follow up surveys will be undertaken to
monitor the progress of the regeneration of native species in the lagoon and any changes in exotic species to inform weed control.

Figure 5-1 Photo point comparison of before the environmental watering in August 2017 (left) and post the environmental watering and unregulated flow event in May 2018 (right) (Melbourne Water, 2018a)

Figure 5-2 Maps showing the vegetation monitoring transect and vegetation quality scores for each plot. Areas of green indicate highest quality vegetation, orange is medium and red is the poorest quality. A comparison of the results of the pre-watering survey (left) with the post watering survey (right) show an improvement in the vegetation quality in the lowest and deepens part of the billabong however an issue has emerged with the encroachment of weeds from the higher terraces following the drying of the billabong (Melbourne Water, 2018a).

5.2 Fish

Ecology Australia undertook two fish surveys in Bolin Bolin Billabong, one prior to environmental watering and one post the environmental watering and unregulated high flow event on 1 June 2018 (Ecology Australia, 2018). The key findings from the fish monitoring included:

- The pre-watering survey showed that the fish community in Bolin Bolin Billabong was dominated by Short-finned Eels (Anguilla australis). Moderate numbers of exotic species Eastern Gambusia (Gambusia holbrooki) and low numbers of Oriental Weatherloach (Misgurnus anguillicaudatus) were also captured during the survey.
Although not part of the fish monitoring by Ecology Australia, observations were made during the unregulated flow event of large adult carp entering Bolin Bolin Billabong.

Following the unregulated flow event around 20 adult carp died in the billabong and were removed in April 2018 (S Gaskill, pers comm).

The follow up survey on 1 June 2018 showed the fish community in the billabong to be dominated by young of year carp suggesting that adult carp entering the billabong during the flooding event were able to spawn.

Large numbers of the exotic Eastern Gambusia were also detected during the second survey.

Native Short-finned Eels were detected during the follow up survey in moderate abundance however it seems some eels may have migrated out of the billabong during the unregulated flow event.

Further analysis on the eel length data will provide information on the population dynamics within the wetland however these results were not available at the time of writing.

5.3 Frogs

Frog monitoring was undertaken using acoustic recorders before and after the trial environmental watering event in October 2017. An infographic diagram was produced showing the species recorded before and after the pumping event. It can be seen that only one species was recorded in Bolin Bolin Billabong prior to environmental watering, Eastern Common Froglet (*Crinia signifera*). The follow up monitoring showed a total of four species using the billabong in addition to the Eastern Common Froglet including Southern Brown Tree Frog (*Litoria ewingii*), Striped Marsh Frog (*Limnodynastes peronii*) and Spotted Marsh Frog (*Limnodynastes tasmaniensis*).
6. Management objectives

Previous work undertaken to determine the water requirements of the Bolin Bolin Billabong also identified potential management objectives (Dodo Environmental, 2010). The broad management objective identified was:

*Bolin Bolin Billabong should be rehabilitated as far as possible to reflect its ecological condition before European colonisation.*

Complete restoration was determined as unrealistic due to the presence of weeds in the floodplain flora, the likely continuous infestation with exotic fish, and on-going presence of feral animals such as deer, cats and dogs (Dodo Environmental, 2010). This management objective was discussed and agreed on during a stakeholder site visit undertaken on 22nd December 2016. Stakeholders included Melbourne Water, Parks Victoria, and Manningham City Council.

This management objective has a strong ecological focus and doesn’t take into specific consideration the social, amenity and cultural heritage values of the site. This was discussed during the more recent stakeholder workshop held on 14 June 2018. Melbourne Water are now planning to hold further talks with stakeholders including Wurundjeri Traditional Owners to ensure the management objectives for Bolin Bolin Billabong are fit for purpose, take into account a holistic range of values and align with the broader vision for the Yarra River and its floodplain.

An updated approach to determining objectives for billabong management both at a landscape scale and at an individual site scale was discussed during the stakeholder workshop. The main elements of this approach are highlighted in Figure 6-1.
Memorandum

Review of trial environmental watering and unregulated flow event

Figure 6-1 Melbourne Water’s updated approach to determining objectives and implementing a management regime for billabongs as discussed at the stakeholder workshop on 14 June 2018.

Jacobs held an internal workshop on 9 July 2018 to develop suggestions around the broad overarching ‘individual billabong objective’ and the ‘component objectives’ shown in Figure 6-1. The updated Healthy Waterways Strategy (2018b) describes Bolin Bolin Billabong as being part of a highly significant cultural and ecological landscape of billabongs, wetlands and floodplains. An individual billabong vision/objective for Bolin Bolin Billabong could be:

*Bolin Bolin Billabong should be rehabilitated as far as possible to safeguard its future contribution to the vibrant landscape of culturally and ecologically significant billabongs and wetlands situated on the Yarra River floodplain.*

The draft component objectives developed during the workshop are show in Table 6-1 below.

**Table 6-1 Draft component objectives for Bolin Bolin Billabong**

<table>
<thead>
<tr>
<th>Component</th>
<th>Objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecological</td>
<td>To rehabilitate native plant and animal communities and ecosystem processes that are typical of a healthy floodplain billabong</td>
</tr>
<tr>
<td>Cultural</td>
<td>To protect and enhance values associated with a healthy floodplain billabong that are important to Wurundjeri, who are the Traditional Owners of Bolin Bolin Billabong</td>
</tr>
<tr>
<td>Liveability</td>
<td>To promote community connection, amenity and nature-based recreational opportunities associated with a healthy floodplain billabong</td>
</tr>
</tbody>
</table>

At the stakeholder workshop held on 14 June 2018 a variety of notes and questions were raised by Aunty Alice Kolasa from Wurundjeri. These were later provided to Melbourne Water and are included in Appendix A. Some of the notes and questions pertain to the water management regime of Bolin
Bolin Billabong such as the impact of leaf litter on water quality during environmental watering, allocations of environmental water for the billabong, the seasonality of the water regime and revegetation of wetland plants. The issues and concerns raised by Aunty Alice Kolasa during the stakeholder meeting are well aligned with Melbourne Water’s approach to the ecological management of the billabong through providing the preferred environmental flow regime described in Section 7. Other issues were also raised in relation to the broader management of the site including access, car parking and increased urban pressure, however these issues have not been addressed by this project and therefore should be included in the broader management approach for the site.

The individual billabong objective/vision and the component objectives should be further considered by Melbourne Water and the project stakeholders in the context of water management regime and broader management of the billabong prior to finalisation.

7. Preferred water regime

As detailed in Jacobs (2017), based on the high value of Bolin Bolin Billabong and the agreed management objective detailed in Section 6, a preferred water regime for the billabong was developed:

1. Maintain the permanent pool and restore its condition:
   a. Expand zone of permanent pool
   b. Restore macrophyte community
   c. Restore small bodied fish populations

2. Reinstate variable water regime within the wet-dry arms, with an inundation frequency of two in every three years:
   a. Prevent terrestrialisation
   b. Restore seasonal wetland community

The environmental watering solution required to deliver this preferred management regime would also require the management of weeds, exotic fish infestation (Carp control) and feral animals.

Based on the trial watering and unregulated flow event data it is considered likely that this preferred water regime could be achieved in wet conditions, but unlikely to be achieved in dry conditions due to river levels in the Yarra River not high enough to achieve an inundation event. This is discussed further in Section 8.

8. Current water regime

Up until the mid-late 1990s Bolin Bolin Billabong filled regularly with flood waters from the Yarra River. Inundation events during this time occurred at least once a year on average and rarely would the billabong go for successive years without being wetted with floodwaters (Dodo Environmental, 2010). In more recent years there have been long periods between inundation events. The potential reasons for this change in water regime include lower rainfall, river regulation and extraction, and the alienating effects of the levee that separates the billabong from the Yarra River (Dodo Environmental, 2010).

A simple water balance model of the site has previously been developed (Jacobs 2017), using local rainfall, evaporation, streamflow data, and terrain data. This model was extended to include data up to 01/06/2018. The model was calibrated to reproduce historic wet and dry periods, identified from aerial
imagery and historical observations. The model initially adopted an inflow threshold of 11,300 ML/d to calibrate the model to the historic imagery and observations required, however based on the December unregulated flow event, the water balance now can now be updated to:

- reflect a lower inflow threshold of 9,340 ML/day (approximate inflow level in the Yarra River at Bolin Bolin is 9.50m AHD)
- a seepage of 12 mm/d

Figure 8-1 presents the updated water balance including modelled volume of water in the billabong (blue line), along with the Yarra River streamflow (red line), and aerial imagery and historical observations showing wet or dry conditions (orange and green shading).

**Figure 8-1: Bolin Bolin Billabong water balance results**

This update of the water balance continues to generally represent observed wet periods including the December 2017 event. The model suggests that since 2004 Bolin Bolin Billabong has experienced nine inundation events from the Yarra River. Once the billabong fills up it takes a number of months to drawdown again, although there is a small permanent pool at the eastern end of the billabong, which is maintained through a groundwater/subsurface connection with the Yarra River.

The water balance in Figure 8-1 clearly shows two different climate scenarios, a wet period where the billabong is inundated almost annually and a dry period where the billabong does not receive any inundations. The current water regime therefore differs significantly between the two climate scenarios. Two representative periods since 2004 were selected to analyse the different water regimes:

- Wet period - 01/03/2010 – 28/02/2014.
- Dry period - 01/03/2006 – 28/02/2010. It should be noted that another dry period has also occurred between 29/02/2014 and 29/11/2017.

Figure 8-2 displays the time series of streamflow at Heidelberg for the wet and dry years that have been analysed and clearly shows a reduction in streamflow in the dry period, impacting inundation events from the Yarra River.

In the wet period, Bolin Bolin Billabong was inundated 7 times in the four year period, therefore providing an annual inundation. During the dry period, no inundation events occur and therefore the billabong was dry during this period, with exception of the permanent pool.
This difference in water regime during the different climate periods highlights the need for different watering objectives during the different climate periods. During the dry period, when there are no inundation events the watering objectives are around protecting or maintaining the ecological values at the billabong, whereas during the wet period when there are high flows and increased inundation events the ecological objectives will be associated with recovering and enhancing the ecological objectives (Figure 8-3).

As described in Section 8, our current understanding is that Bolin Bolin Billabong commences to flow once Yarra River flows reach 9,340 ML/day measured at the Heidelberg gauge. The simple water balance model was updated to run a range of scenarios in which the inflow threshold was adjusted, which reflects lowering the inlet level of the billabong which is one of the watering solutions identified in Jacobs (2017). The updated simple water balance model enables different inlet level scenarios to be modelled to show how the hydrology of the billabong could be changed if works were carried out to lower the inlet level.

Initial results from modelling different inlet level scenarios are shown in Table 8-1. It can be seen that lowering the inlet from 0.5 to 1 m would allow some additional events to enter the billabong during wet years however in dry years the inlet level would need to be lowered by more than 1.7 m to allow...
additional events to enter the billabong and would possibly keep the billabong too wet during wet years to meet the desired water regime.

It is likely that a combination of lowering the inlet with pumping at certain intervals during dry years may be the best option to achieve the desired watering regime for Bolin Bolin Billabong. Additional hydrological modelling is currently underway which will determine the optimal inlet level for Bolin Bolin Billabong.

Table 8-1 Results from the water balance model of different inlet levels

<table>
<thead>
<tr>
<th>Scenario Number</th>
<th>Inflow Threshold, Flow at Heidelberg Gauge (ML)</th>
<th>Inflow Level at Bolin Bolin Billabong (m AHD)</th>
<th>Number of Inundation Events - Wet Years</th>
<th>Number of Inundation Events - Dry Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11,300</td>
<td>9.97</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>9,340</td>
<td>9.50</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>7,500</td>
<td>9.00</td>
<td>12</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>6,000</td>
<td>8.54</td>
<td>18</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>5,112</td>
<td>8.24</td>
<td>21</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>4,000</td>
<td>7.63</td>
<td>29</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>3,500</td>
<td>7.63</td>
<td>37</td>
<td>3</td>
</tr>
</tbody>
</table>

Environmental Water availability

Also investigated as part of this review was the demand and availability of environmental water for different water management solutions at Bolin Bolin such as pumping or lowering the inlet to the billabong. Pumping water from the Yarra River into the billabong requires the use of an entitlement, during the trial environmental watering event 300 ML was approved by the Victorian Environmental Water Holder from the Yarra Environmental Entitlement 2006 for this purpose.

It is likely that diverting additional water into the billabong by lowering the inlet level will not require use of an entitlement. Work has been undertaken at Spadonis Billabong in Yering which is another billabong adjacent to the Yarra River to lower the inlet to allow additional inflows to enter the billabong. A decision was made by Melbourne Water and the Department of Environment, Land, Water and Planning (DELWP) that an entitlement would not be needed for this purpose as it is a non-consumptive use which will re-enter the Yarra River over time via sub-surface flow. Melbourne Water are again consulting with DELWP to see if a similar arrangement would apply to Bolin Bolin Billabong if lowering the inlet level was to be undertaken.

Next steps

- Further hydrological and hydraulic analysis is currently underway to determine an optimal inlet level to Bolin Bolin Billabong
- Following this further analysis a preferred option will be determined which is likely to be either formalising the inlet channel with some erosion control and access works, or a similar solution with a lowered inlet level.
- Carp screens to assist with pest animal control and options to ensure the billabong doesn’t drain too quickly following an inundation event will also be explored prior to finalisation of the design.
Memorandum

Review of trial environmental watering and unregulated flow event

- Once the design is optimised a series of concept drawings will be produced for the purposes of stakeholder engagement around the potential modifications at the billabong.

- Once these drawings are completed Melbourne Water may want to convene another stakeholder meeting to present the drawings and to confirm the management objectives for Bolin Bolin Billabong. This meeting may involve a field visit to Bolin Bolin billabong and/or Spadonis Billabong. This meeting is beyond the scope of the current project.

11. References


Appendix A – Notes from Aunty Alice Kolasa

‘Bolin was once much more than just what remains. The Yarra River connected Bolin to the other local billabongs of Bulleen and Kew region. The annual cycle of flooding and drying rapidly changed after the arrival of European settlers in the Yarra River catchment. The flow changes started early with the building of Yan Yean in 1857. The changes were dramatic and unprecedented in the local and regional vegetation. Changes in soil sample composition taken from Bolin Billabong suggest that catchment erosion led to a massive input of sediments to Bolin.

The Billabong complex was once much larger than is currently recognised. A map of 1863 shows the two parts of Bolin Billabong connected to each other and to the Yarra River. The second arm of the Billabong and wasn’t until the 1940s that another section of the billabong was covered in. That second area used by the Trinity Grammar as sport fields. Separated by Bulleen road there is still active and connected groundwater.

River Red Gums (Beal in Woi Wurrung) dominated the over-storey species historically within the area, there was also swampy species like Melaleuca, Pomedaris and Callistemon. The area also once contained numerous wetland and seasonal species that had value as food and medicine for Wurundjeri people. These include Water Ribbons, Reeds (Typha) and very likely some Old Man Weed.’

‘Questions for Melbourne Water

- To reduce the impact of the leaf litter on the water quality will there be burning prior to any input of water?
- Will there be a yearly allocation of water for Bolin?
- Will it be a flat amount or will the value vary depending upon rainfall and amount of water in catchments?
- Is this going to be an attempt to recreate the filling and drying of the Billabong that once occurred?
- When will flooding occur and how big will the floods be?
- Has a full management plan been done for Bolin?
- Will the billabong undergo revegetation with wetland species?
- Will the rest of the property undergo revegetation?
- Is there an on-going budget line for the Narrap Team?
- Will the access and parking for visitors and people working at Bolin be improved?

The increased urban pressure on this area will require ongoing works, how can this work continue especially when we have had investment in the area in that past which ended. The previous projects managed to do a lot of work and manage weeds within the reserve but cuts to funding and support meant that the area returned to being weedy and over run.’