CHIMNEY HILL DAM

AQUATIC BIOTA AND ENVIRONMENTAL FLOW ASSESSMENT REPORT

REPORT TO WATER DEVELOPMENT BRANCH, DPIWE

PE DAVIES AND LSJ COOK

JUNE 2003
# Table of Contents

1. Introduction .................................................................................................................. 3

2. Study Methods ............................................................................................................... 5  
   2.1 Instream biota survey ............................................................................................. 5  
   2.2 Macrinovertebrate habitat sampling ....................................................................... 6  
   2.3 Macrophyte habitat sampling ................................................................................ 10  
   2.4 Environmental Flow Assessment ........................................................................... 11  
   2.5 Data analysis ......................................................................................................... 18

3. Aquatic Ecological values ............................................................................................ 19  
   3.1 Aquatic Biota of the Elizabeth River ..................................................................... 19  
   3.2 Macrophyte-macroinvertebrate associations ....................................................... 30  
   3.3 Plant habitat associations ..................................................................................... 36

4. Impact of the Chimney Hill Dam ............................................................................... 42  
   4.1 Hydrology and geomorphology .......................................................................... 42  
   4.2 Instream biota ....................................................................................................... 50  
   4.3 Overall assessment ............................................................................................... 54

5. Mitigation ..................................................................................................................... 57  
   5.1 Mitigation needs and options .............................................................................. 57  
   5.2 Specific mitigation measures ............................................................................... 57

6. Environmental flow regime ......................................................................................... 59  
   6.1 Environmental flow requirements for riparian vegetation .................................. 59  
   6.2 Environmental flow requirements for macrophytes ............................................. 60  
   6.3 Environmental Flow Regime and Recommendations ......................................... 65

7. Summary ....................................................................................................................... 68

References ....................................................................................................................... 69

Appendix 1. ......................................................................................................................... 70
Executive Summary

A survey and assessment of the status of the instream flora and fauna of the Elizabeth River was conducted. The biota are highly modified by the historical effects of the operations of Lake Leake, the modification of the river channel and the introduction of exotic species. The fish community is in a degraded condition. However, key biological values remain, in particular the extensive aquatic plant (macrophyte) communities and their highly diverse and abundant macroinvertebrate fauna, as well as the riparian vegetation which is in particularly good condition.

Risks to the instream biota are explored and mitigation requirements identified. A minimum environmental flow regime and operating rules have been developed. Provided the macrophyte assemblages are maintained through appropriate environmental flow management, there are no significant risks to the aquatic biological values of the Elizabeth River from the proposed dam.

Key recommendations include:

- implementation of a specific minimum environmental flow regime;
- integration of management of Lake Leake and the proposed Chimney Hill Dam;
- ongoing monitoring of the aquatic biological, water quality and geomorphological condition of the river and storage;
- no major changes to operation of either storage without formal review, especially with regard to potential changes to high/flood flow regime.
1. Introduction

This report documents aquatic biological environmental issues associated with the Chimney Hill Dam proposal for the Elizabeth River downstream of Lake Leake. The environmental context of the Elizabeth River is described for instream biological components of the riverine ecosystem, issues and risks to aquatic biota associated with the dam are identified, and recommendations for mitigation activities including an environmental flow regime are describe.

The Chimney Hill dam assessment required information on:

- geomorphology of the river and associated issues;
- riparian vegetation of the river;
- instream biological values (fauna and flora);
- water quality issues;
- mitigation options and recommendations for an environmental flow regime.

Little or no information was available on these subjects, and survey work was conducted to provide basic data for interpretation of the core values of the river system. A conceptual meeting was held in December 2002 by all participants in the aquatic and riparian environmental assessment of the Chimney Hill dam proposal study to allow liaison between specialists and a degree of integration of the individual assessments.
The riparian vegetation, water quality, and geomorphology of the Elizabeth River are described in detail elsewhere (Barker 2003, Koehnken 2003 and Koehnken et al. 2003), but relevant results and conclusions in relation to environmental flows are described in this report.

Little is known about the current ecological condition of the Elizabeth River system. This report therefore provides an overview of the current ecological condition of the Elizabeth River. The status of the riverine ecosystem is described, key values identified and environmental issues and risks from the proposed dam development explored. Mitigation needs are identified, and an environmental flow regime is proposed.

A survey of instream aquatic fauna and flora is described. Inter-relationships between two key biological components (macroinvertebrates and macrophytes) are explored, and habitat associations of the macrophytes are evaluated. Flow-habitat relationships are then used to assess the implications of changes in the flow regime resulting from the proposed dam. These are used as the basis for identifying a minimum environmental flow regime for the river downstream of the proposed dam.
2. Study Methods

2.1 Instream biota survey

A number of sites were sampled in the Elizabeth River between upper Harrimount Marsh and Campbelltown for aquatic biota (Table 2.1) in mid to late February 2003. Sites shown in Table 2.1 and Figure 2.1 were surveyed for fish, macrophytes and macroinvertebrates.

Fish were sampled semi-quantitatively by one-pass of a Smith-Root 240v backpack electroshocker operated by two people. At each site, all habitats were actively fished, for a total of 20 min of battery on-time. All fish caught were identified, counted and measured before being returned to the stream.

Macroinvertebrates were sampled semi-quantitatively using the AUSRIVAS rapid biological assessment (RBA) kick sampling technique in riffle habitats and edgewater habitats. RBA sampling of snags was also conducted by hand and brush scrubbing and picking of 10 pieces of submerged wood with live–picking of residue for 30 minutes.

In addition, a subset of sites (sites 6 – 10) were sampled quantitatively for macroinvertebrates using standard 500 micron mesh net surber samplers, with 10 30 x 30 cm quadrat sample units taken (by hand disturbance of substrate to a depth of ca 10 cm within the quadrat upstream of the sampling net) at each site, at locations sited randomly across the channel. All 10 surber sample units were pooled to from a composite sample at each site. These samples were taken as the basis for future monitoring. A suite of habitat variables were also assessed on each site visit.

All quantitative macroinvertebrate samples were preserved in 10% neutral buffered formalin prior to laboratory processing. Preserved samples were washed over a 500 micron sieve, elutriated with a saturated calcium chloride solution prior to sub-sampling to 20% using a Marchant box sub-sampler (Marchant 1989). One subsample from each sample was hand-sorted under magnification, and all macroinvertebrates counted and identified to family level (for all taxa except Acarina, Oligochaetae,
Copepoda, Turbellaria, Nematoda, Hirudinea, Collembola and Chironomidae, the latter being identified to sub-family level).

All RBA samples were live-picked on-site, following the Tasmanian AUSRIVAS protocol, with all picked macroinvertebrates being preserved in 90% ethanol prior to enumeration and identification to family level as above.

2.2 Macroinvertebrate habitat sampling

A total of 60 additional quantitative (surber) macroinvertebrate samples were collected from two sites – Staircase Gorge (site 6) and downstream of the dam, site 7 (30 samples from each site). Sample sites were selected to cover all possible combinations of depth, substrate type and dominant macrophyte, with data on depth, mean water column velocity, distance from the nearest bank, channel width, macrophyte cover and dominant macrophyte species being recorded for each sampling location. These quantitative samples were processed as described above.
Table 2.1. Details of sites surveyed for instream aquatic biota in the Elizabeth River for the Chimney Hill Dam assessment.

<table>
<thead>
<tr>
<th>Site</th>
<th>Name</th>
<th>Easting</th>
<th>Northing</th>
<th>Distance to Macquarie River, km</th>
<th>Catchment Area (km²)</th>
<th>Altitude (m ASL)</th>
<th>Channel slope</th>
<th>Bankfull Width (m)</th>
<th>Wetted Width (m)</th>
<th>% Riffle</th>
<th>% Pool</th>
<th>% Run</th>
<th>% Snag</th>
<th>Macro-invertebrates</th>
<th>Fish</th>
<th>Macro-phytes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elizabeth River</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Upstream of Campbelltown</td>
<td>541980</td>
<td>5357277</td>
<td>10</td>
<td>330</td>
<td>191</td>
<td>0.0040</td>
<td>8</td>
<td>5</td>
<td>20</td>
<td>0</td>
<td>80</td>
<td>5</td>
<td>RAP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Devil's Elbow</td>
<td>546751</td>
<td>5358815</td>
<td>17</td>
<td>250</td>
<td>232</td>
<td>0.0090</td>
<td>30</td>
<td>20</td>
<td>30</td>
<td>20</td>
<td>50</td>
<td>5</td>
<td>RAP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Downstream of Gorge</td>
<td>548800</td>
<td>5360750</td>
<td>21</td>
<td>247</td>
<td>290</td>
<td>0.0200</td>
<td>25</td>
<td>5</td>
<td>50</td>
<td>0</td>
<td>50</td>
<td>2</td>
<td>RAP, X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Staircase Gorge</td>
<td>550445</td>
<td>5360753</td>
<td>23</td>
<td>243.5</td>
<td>345</td>
<td>0.0200</td>
<td>40</td>
<td>8</td>
<td>15</td>
<td>15</td>
<td>70</td>
<td>0</td>
<td>RAP, X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Upstream of Gorge</td>
<td>551050</td>
<td>5361450</td>
<td>24</td>
<td>236.5</td>
<td>356</td>
<td>0.0114</td>
<td>20</td>
<td>6</td>
<td>30</td>
<td>20</td>
<td>50</td>
<td>0</td>
<td>RAP, X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Ginger Marsh</td>
<td>556800</td>
<td>5357550</td>
<td>34</td>
<td>171.5</td>
<td>506</td>
<td>0.0028</td>
<td>7</td>
<td>5</td>
<td>10</td>
<td>0</td>
<td>90</td>
<td>20</td>
<td>RAP, Surf X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Bridge downstream of Dam</td>
<td>560150</td>
<td>5358074</td>
<td>38</td>
<td>160</td>
<td>528</td>
<td>0.0059</td>
<td>10</td>
<td>6</td>
<td>80</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>RAP, Surf X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>At Dam site</td>
<td>560230</td>
<td>5357550</td>
<td>40</td>
<td>146</td>
<td>537</td>
<td>0.0053</td>
<td>16</td>
<td>15</td>
<td>60</td>
<td>10</td>
<td>30</td>
<td>20</td>
<td>RAP, Surf X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Bridge upstream of Dam</td>
<td>561168</td>
<td>5355992</td>
<td>42.5</td>
<td>118</td>
<td>545</td>
<td>0.0025</td>
<td>10</td>
<td>8</td>
<td>20</td>
<td>0</td>
<td>80</td>
<td>5</td>
<td>RAP, Surf X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Harrimount Marsh</td>
<td>562900</td>
<td>5355350</td>
<td>45</td>
<td>94</td>
<td>552</td>
<td>0.0013</td>
<td>5</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>100</td>
<td>2</td>
<td>RAP, Surf X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tributaries</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Black Snake Marsh</td>
<td>590500</td>
<td>5359500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Harrimount Marsh</td>
<td>564700</td>
<td>5359500</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harrimount Marsh trib</td>
<td>563450</td>
<td>5358150</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hortons Creek</td>
<td>560400</td>
<td>5953380</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hortons Creek trib</td>
<td>559150</td>
<td>5354450</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 2.1. Map of Elizabeth River catchment showing location of survey sites (numbered filled circles), Lake Leake, the proposed dam (light grey polygon), main features and catchment boundary (dashed line). See Table 2.1 for site details.
Figure 2.2. Location of survey sites (filled grey circles) along the Elizabeth River profile.
2.3 *Macrophyte habitat sampling*

A total of 321 observations were made of macrophyte species - habitat associations within the Elizabeth River, across five sites (Table 2.1). Each observation consisted of recording of the dominant macrophyte species, the depth, the mean water column water velocity and the distance from the nearest channel bank.

Accordingly, a total of 107 individual observations of depth, substrate and mean water column velocities were made in two environmental flow study reaches (see below, Section 2.4) for a total of nine plant species (or genera), using a 1 x 1 m quadrat. These observations were made at selected locations at which substantial cover of each species was evident. In addition, all observations of macrophytes derived during transects surveys were also used. These latter observations were screened to include only those for which macrophyte cover was >5%, in order to ensure observations were representative of suitable habitat conditions for each species. This resulted in a total of 142 observations (76 at GM and 66 at DB).

The combined data set contained 249 quadrat observations. For several quadrats, species were co-dominant (eg ca 50% of cover of two species), and these were used as separate observations for each of the co-dominant species. A final data set containing 321 species-habitat records was used to derive a set of habitat preference curves in a standard manner (Bovee 1986, Stalnaker et al. 1995, Humphries et al. 1996), one for each plant species. The number of observations per species/genus is shown in Table 2.2.

**Table 2.2 Number of habitat observations made in the Elizabeth River by plant species or genus (* indicates exotic species).**

<table>
<thead>
<tr>
<th>Species</th>
<th>N Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carex sp.</td>
<td>36</td>
</tr>
<tr>
<td>Juncus procerus</td>
<td>16</td>
</tr>
<tr>
<td>Myriophyllum sp.</td>
<td>81</td>
</tr>
<tr>
<td>Triglochin procera</td>
<td>35</td>
</tr>
<tr>
<td>Potamogeton tricarinatus</td>
<td>36</td>
</tr>
<tr>
<td>Isolepis fluitans</td>
<td>74</td>
</tr>
<tr>
<td>Eleocharis sphacelata</td>
<td>18</td>
</tr>
<tr>
<td>Nymphoides exigua</td>
<td>15</td>
</tr>
<tr>
<td>Aponogeton distachyon*</td>
<td>10</td>
</tr>
</tbody>
</table>
2.4 Environmental Flow Assessment

2.4.1 Hydraulic data

Two representative reaches were selected in the Elizabeth River for hydraulic assessment of instream habitat. One site (site 7, Table 2.1) was selected to represent typical partially-constrained transport channel conditions in the river downstream of the dam site. The other was selected to represent a channel-marsh system (historically a ‘chain-of-ponds’ system, see Koehnken et al. 2003), located at Ginger Marsh (site 6, Table 2.1). Detailed hydraulic and habitat data were collected from the two representative survey reaches. Site maps are shown in Figures 2.3 and 2.4.

Four transects were established at Ginger Marsh, spanning a total distance of 360 m of stream length, and representative of ca 520 m of stream. Five transects were established in the Chimney Hill reach, spanning a total distance of 387 m of stream length, and representative of ca 480 m of stream. The transects were sited to represent the dominant mesohabitats in the reach, as follows (Table 2.3).

Each transect was established with a steel ‘head’ peg on the bank as a local datum from which all water surface elevations (stage) were measured. Each site was rated on two occasions, with stage and discharge measured over a range of low to moderate flows. No high flow gaugings were possible due to sustained low flows during the study.

<table>
<thead>
<tr>
<th>Chimney Hill (site 7) reach</th>
<th>Ginger Marsh (site 6) reach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transect Number</td>
<td>Mesohabitat</td>
</tr>
<tr>
<td>1 (D5)</td>
<td>riffle</td>
</tr>
<tr>
<td>2 (D4)</td>
<td>glide</td>
</tr>
<tr>
<td>3 (D3)</td>
<td>riffle</td>
</tr>
<tr>
<td>4 (D2)</td>
<td>glide</td>
</tr>
<tr>
<td>5 (D1)</td>
<td>glide-pool</td>
</tr>
</tbody>
</table>

Table 2.3. Mesohabitats covered by transects at two representative reaches in the Elizabeth River. G1 and D5 are at the downstream end of each study reach.
Figure 2.3. Location of survey transects for channel profile and hydraulic modeling, site 7, downstream of proposed dam, Elizabeth River. See Table 2.1 and Figure 2.1 for site location.
Figure 2.4. Location of survey transects for channel profile and hydraulic modelling, site 6, at Ginger Marsh, Elizabeth River. See Table 2.1 and Figure 2.1 for site location.
Only low flows occurred during the study period and high flow ratings were estimated from ratings and Mannings’ equations (see below).

At each site, the channel profile was surveyed, and velocities and depths measured at ca. 0.5 - 1 m intervals from the head peg across the full width of the channel (mean intervals of 0.9 and 0.8 m for the site 6 and 7 reaches, respectively). At each interval, substrate composition was recorded (as % of the following grain size classes/types – silt (<1 mm), sand (1 - 4 mm), gravel (4 - 16 mm), pebble (16 - 64 mm), cobble (64 - 256 mm), boulder (>256 mm), bedrock, as well as the area and dominant species of aquatic vegetation.

2.4.2 Habitat-preference curves
Following analysis of the macroinvertebrate-macrophyte relationships (see Section 3.2), it was decided to focus the risk assessment on macrophytes. Thus, habitat preference data were only required for the dominant macrophyte species (and associated assemblages) observed in the Elizabeth, as well as for platypus. The latter data were obtained from existing information (Davies and Cook 2001), and the former from field observations.

Habitat preference data for macrophytes had to be derived from instream observations. The final data set of 321 species-habitat records described in Section 2.3 was used to derive a set of habitat preference curves in a standard manner (Bovee 1986, Stalnaker et al. 1995, Humphries et al. 1996), one for each dominant plant species. The species and number of observations are shown in Table 2.2.

2.4.3 Habitat-flow analysis
Habitat-discharge (WUA-Q) curves were developed for all macrophyte species for the two study sites. Hydraulic simulation was conducted over the flow ranges 0 – 5 cumec using the RHYHAB simulation package. Dry conditions prevented collection of high flow ratings necessary for simulation to higher discharges. The range of flows for which simulations could be conducted was sufficient, however, to include all monthly reference discharges.
Stage at zero flow (SZF) values were calculated from lowest point in each transect for all transects which were riffles and glides (see raw data sheet for transects descriptions). Pool transect SZFs were estimated by survey of the nearest downstream riffle crest (low flow hydraulic control).

2.4.4 Minimum flow risk analysis

In order to derive a minimum environmental flow regime for both rivers, the risk-assessment approach described by Davies and Humphries (1996) was used. This involved a risk assessment of habitat loss for the key macrophyte taxa, relative to a reference flow for each month of the year.

A ‘reference’ flow was required against which to assess changes in habitat and hence risks to biota. Two reference flows were explored initially – ‘historical’ and ‘natural’. However, the ability to model natural (pre-Lake Leake) flows was severely limited by poor understanding of flow performance in the original marsh-river complex between Lake Leake and Staircase Gorge, and was abandoned. In addition, the assessment conducted here was based on the desire to maintain existing riverine values, which have changed significantly since the establishment of the Lake Leake storage. Natural reference flows are of little relevance in this context.

With the aim of maintaining instream habitat under the current Lake Leake operating conditions, a reference discharge was selected which represented median habitat conditions occurring over the last 100 years. A grand median mean daily flow was calculated for each month, derived from the historical flow record, for the period 03/1901 to 12/1999. This seasonal, monthly set of flows was taken as representing the ‘typical’ historical flow condition. In addition, the use of the ‘post-dam’ flow record was explored in relation to the forecast adjustment in channel width under the new irrigation releases (see Section 4 and Koehnken et al 2003).

Average monthly flows unduly bias reference flows upwards and distort the analysis, therefore the median of mean daily flows were used to assess ‘median’ reference flows.
In addition to using a reference flow describing the ‘median’ historical flow condition, an assessment of minimum environmental flow requirements for dry or drought condition years was conducted. This recognizes the need to provide minimum environmental flows which recognise the natural variability in low flows associated with dry conditions. The 20\textsuperscript{th} percentile of mean daily flows for each month over the same period of record (1901-1999) was used to derive a reference flow regime for dry conditions. The use of the 20\textsuperscript{th} percentile (as opposed to a smaller percentile) recognises the need to reduce baseflows in response to moderate rather than extreme dry conditions.

Using the approach described by Davies and Humphries (1996), the following analysis was conducted for the two Elizabeth River sites:

1) Reference flow selection
The ‘historical’ and/or ‘post-dam’ reference flow was selected for each month (Table 9.2).

2) Habitat change
A series of nominal flows at between 0 and 2 cumec intervals were selected for simulation.

The % deviation of habitat availability (WUA) at the nominal flow from the WUA at the reference flow for that month was then calculated using the following formula:

$$\% \text{DelHA} = 100 \times \left( \frac{\text{WUAQ}_{\text{nom}}}{\text{WUAQ}_{\text{ref}}} \right)$$

where $\text{WUAQ}_{\text{nom}} = \text{WUA}$ at the nominal discharge and $\text{WUAQ}_{\text{ref}} = \text{WUA}$ at the reference flow.

This was done for all dominant macrophyte species, as well as platypus.

Separate sets of $\% \text{DelHA}$ values were calculated for each month.

3) Risk categories
Each value of habitat deviation ($\% \text{DelHA}$) was converted to a risk category according to the criteria originally established by Davies and Humphries (1996), as shown in
Table 2.4. For this analysis, the risk being assessed is the risk of failure to maintain biota due to loss of habitat availability relative to reference flow conditions. Results for individual macrophyte taxa were kept separate. The same risk criteria were used for all biological values.

Table 2.4. Risk categories for all biological values in the Elizabeth River and corresponding values (criteria) for \%DelHA i.e. \% remaining WUA under nominal flow of reference flow.

<table>
<thead>
<tr>
<th>Value</th>
<th>Risk Category</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal risk or beneficial</td>
<td>Moderate risk</td>
<td>High risk</td>
<td>Very high risk</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Habitat for macrophytes and platypus.</td>
<td>&gt; 85% of habitat under reference flow</td>
<td>60 – 85% of habitat under reference flow</td>
<td>30 - 60% of habitat under reference flow</td>
<td>&lt; 30% of habitat under reference flow</td>
<td></td>
</tr>
</tbody>
</table>

4) Overall risks and recommended minimum flows

A final risk assessment for each nominal discharge was conducted by taking the lowest risk score (lowest value of \%DelHA, across all species) as the overall risk across all flows below the reference flow, for each month of the year.

This is a deliberately conservative approach in order to minimise risk to the instream biota. All taxa were treated equally in this approach.

The lowest discharge associated with Risk Band I (minimal risk) is generally recommended as the minimum mean daily flow in each month. This recognizes both:

- the desire for no additional environmental risk over and above the existing impacts from current levels of water abstraction and land use; and
- the recognition that actual flows fall below this level in some years.

However, where the values associated with increasing risk at flows close to the reference flow are not deemed of particularly high value, consideration may be given to recommending flows that fall within Risk Band II (moderate risk). Results for
severe or extreme risk (Bands III and IV) are not reported, as they are not considered appropriate for recommendation as minimum environmental flows due to the high risk of negative environmental impacts on the existing instream biota.

2.4.5 Upper limits on minimum environmental flows

The approach described above was also used to develop minimum environmental flow thresholds (or caps) considered to prevent significant harm occurring to the riverine fauna and flora due to sustained high baseflows. Minimum environmental flows are relevant when considering abstractions or flow reductions in river systems. Irrigation flow management in the Elizabeth River, however, uses the river channel as a means of delivering irrigation flows to downstream users. This raises the issue of what are the maximum rates of flow delivery which can be supported without causing harm to the ecosystem. This recognizes the fact that there are both lower and upper limits to the magnitude of minimum flows within which a river ecosystem can be maintained in a sustainable state.

This issue was not explored further, as there were no significant differences in the forecast high flows during the irrigation season (e.g. 80 percentile flows, see section 4), and irrigation flows are limited by the size of the proposed discharge valve. These flows are unlikely to ever approach or exceed bankfull discharge (ca 2 cumec), and so capping of the magnitude of irrigation flows is not apparently required.

2.5 Data analysis

Data analysis of the survey data was conducted using MDS ordination based on Bray Curtis similarities, analysis of similarities (ANOSIM), principal components analysis (PCA) in the Primer E-5 and SYSTAT v 10 packages. Differences between plant groups were assessed using the Kruskal Wallis test.

All rating curve analysis, hydraulic simulation and habitat modelling was conducted using the RHYHAB package (Jowett 1997).
3. Aquatic Ecological values

3.1 Aquatic Biota of the Elizabeth River

3.1.1 Fish

Numbers and species fish caught in the survey are shown in Table 3.1. There were few native fish species recorded, with only the shortfin eel (*Anguilla australis*) widespread throughout the river between Campbelltown and Harrimount Marsh, and the blackfish (*Gadopsis marmoratus*) being recorded in the lower reaches in geomorphological Zone 8. Both these species have been recorded from the lower Elizabeth River before. The highly migratory *A. australis* is known to have occurred in Lake Leake for over 50 years, and widespread throughout the South Esk River (though undoubtedly to a much reduced extent since the construction of the Trevallyn Dam). This species is the subject of an extensive commercial fishery and has been actively stocked (and harvested) in Lake Leake since the 1960’s, with some minor stocking and supplementation of stock by transfer at Trevallyn Dam. Eel lengths ranged from 120 to 650 mm (Figure 3.1), indicating recent recruitment to the population from stocked or migrating elvers. Older eels (550 to 650 mm) tended to be more abundant in the river upstream of the Ginger Marsh. Eels were also observed in the dam (the only remaining water in February) in Harrimount Marsh.

The blackfish is generally regarded as being restricted in natural distribution to catchments of the northern coast of Tasmania, and is believed to have been absent from the South Esk basin. Its occurrence in the lower Elizabeth may be due to translocation early during European settlement or in the first part of the 20th century. The species has not been recorded from the middle Macquarie River, and this Elizabeth River population is likely to be isolated, in part due to the absence of suitable instream snag habitat elsewhere in the immediate Macquarie River system. Its absence further up the Elizabeth is not surprising, as steeper, bedrock dominated stream or shallow, snag-poor macrophyte rich channels are not suitable habitat for this species.

The remaining two species of fish observed in the Elizabeth River were the exotic brown trout (*Salmo trutta*) and redfin perch (*Perca fluviatilis*). Both of these species are widespread throughout the Macquarie River catchment and South Esk basin, and
both have been known to occur in Lake Leake since early in the 20th century. Redfin perch is prevalent in the reach between Ginger Marsh and the damsite, and is favoured by the combination of macrophyte cover and sustained flows during summer. There is a small, but not significant, recreational fishery for brown trout in the Elizabeth River, mainly concentrate din the reaches adjacent to Campbelltown, with a more significant fishery in Lake Leake. There is little fishing for brown trout in the Elizabeth River upstream of the Devils Elbow.

Brown trout ages ranged from 0+ (young of the year) to mature fish of 3 – 4+ years of age, suggesting a self-sustaining population. The survey found evidence of recruitment occurring in the reaches of the Elizabeth between the lower end of Staircase Gorge and Devils Elbow (the upper reaches of Zone 8, Figure 3.2), sites where suitable gravel substrate for spawning was also observed. The mean age and size of fish tended to increase with distance upstream, suggesting that recruitment to upstream populations was restricted and is probably dependent on movement of fish from the lower reaches, and potentially from the reaches immediately downstream of Lake Leake, whose suitability as spawning habitat is unknown.

Five tributary sites were also surveyed for fish, in the Blacksnake and Harrimount Marsh and Hortons Creek catchments, with all but two being dry at the time of survey, with no fish observed. We consider the likelihood of the existence of a remnant population of native galaxiids, possibly *Galaxias fontanus*, in the Elizabeth River catchment to be very low.

Overall, the fish assemblage in the Elizabeth River is in poor condition – dominated numerically by alien species favoured by the modified stream environment and by eels whose population levels are likely to be in large part a result of stocking and restricted upstream migration from the Tamar estuary. The only other native fish species is likely to have been artificially stocked. The se populations of the four species are not of particular conservation significance.

Other native fish species were likely to have been present prior to European development of the catchment (galaxiids in particular), but the presence of brown trout, combined with the loss of the original ‘chain of ponds’ marsh-stream habitats is likely to have been instrumental in their demise.
Table 3.1. Numbers and species of fish caught at sites in the Elizabeth River in February 2003 (numbers are per 20 min battery on-time of fishing effort).

<table>
<thead>
<tr>
<th>Site</th>
<th>Anguilla australis</th>
<th>Salmo trutta</th>
<th>Perca fluviatilis</th>
<th>Gadopsis marmoratus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campbelltown</td>
<td>8</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Devils' Elbow</td>
<td>3</td>
<td>8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D/s Gorge</td>
<td>3</td>
<td>16</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>U/s Gorge</td>
<td>7</td>
<td>9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ginger Marsh</td>
<td>3</td>
<td>1</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Bridge D/s Dam</td>
<td>9</td>
<td>5</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Dam</td>
<td>10</td>
<td>6</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Bridge U/s Dam</td>
<td>11</td>
<td>6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Harrimount Marsh (dam)</td>
<td>7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3.1. Length frequency distribution of all eels caught in the Elizabeth River.
Figure 3.2. Length frequency distribution of all brown trout caught in the Elizabeth River, showing ages associated with major size class groups.

Figure 3.3. Mean age and number of young of the year (0+ age) of brown trout caught at sites in the Elizabeth River, showing area dominated by 0+ and greater mean age in upper reaches.
Table 3.2 shows the composition of macroinvertebrate assemblages derived from quantitative (surber) sampling of the main channel bed at sites 6 to 10.

### Table 3.2. Abundance and overall % representation for all macroinvertebrate taxa observed in quantitative benthic samples from the Elizabeth River in February 2003. Bold numbers indicate dominant taxa.

<table>
<thead>
<tr>
<th>Class</th>
<th>Order</th>
<th>Family</th>
<th>Site Location</th>
<th>6 U/S Gorge</th>
<th>7 Ginger Marsh</th>
<th>8 Bridge d/s Dam</th>
<th>9 Harrimount Marsh</th>
<th>10 Upper Harrimount Marsh</th>
<th>% overall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cnidaria</td>
<td>Hydrozoa</td>
<td></td>
<td>2</td>
<td>15</td>
<td>3</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>0.11</td>
</tr>
<tr>
<td>Platyhelminthes</td>
<td>Turbellaria</td>
<td></td>
<td>60</td>
<td>2</td>
<td>13</td>
<td>2</td>
<td>1</td>
<td>0.10</td>
<td>1.26</td>
</tr>
<tr>
<td>Nematoda</td>
<td></td>
<td></td>
<td>17</td>
<td>98</td>
<td>204</td>
<td>302</td>
<td>719</td>
<td>0.20</td>
<td>1.20</td>
</tr>
<tr>
<td>Mollusca</td>
<td>Bivalvia</td>
<td>Sphaeriidae</td>
<td>2</td>
<td>6</td>
<td>5</td>
<td>41</td>
<td>0.76</td>
<td>0.01</td>
<td>1.14</td>
</tr>
<tr>
<td></td>
<td>Gastropoda</td>
<td>Hydrobiidae</td>
<td>18</td>
<td>70</td>
<td>116</td>
<td>127</td>
<td>452</td>
<td>0.13</td>
<td>1.32</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Planorbididae</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.11</td>
<td>0.03</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ancyliidae</td>
<td>2</td>
<td>8</td>
<td>17</td>
<td>6</td>
<td>1</td>
<td>0.20</td>
<td>0.26</td>
</tr>
<tr>
<td>Annelida</td>
<td>Hirudinea</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td>Oligochaeta</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td>Arachnida</td>
<td>Acarina</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td>Crustacea</td>
<td>Amphipoda</td>
<td>Paramelitidae</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Copepoda</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Isopoda</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ostracoda</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annelida</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Arachnida</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Crustacea</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diptera</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Trichoptera</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td>Coleoptera</td>
<td>Elmidae</td>
<td>(Adult)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(Larval)</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nematomorpha</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>0.36</td>
<td>0.01</td>
<td>0.24</td>
</tr>
<tr>
<td></td>
<td></td>
<td>N Taxa</td>
<td>30</td>
<td>41</td>
<td>36</td>
<td>40</td>
<td>40</td>
<td>0.21</td>
<td>0.21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Total abundance</td>
<td>543</td>
<td>1337</td>
<td>1387</td>
<td>1440</td>
<td>2465</td>
<td>0.21</td>
<td>0.21</td>
</tr>
</tbody>
</table>

3.1.2 Macroinvertebrates
The macroinvertebrates at these sites are highly diverse (even at family level) and highly abundant. A wide range of families are represented, and their composition suggests a high quality environment (in terms of water quality and habitat integrity). All RBA samples, when analysed using the AUSRIVAS bioassessment model (for autumn on riffle and edge habitats), indicated that all sites fell into the A or X bands, ie communities that were highly diverse and/or in reference condition.

The macroinvertebrate community in this section of the river is dominated by Hydrobiid snails (mainly from the genus *Austropyrgus*), worms (Oligochaeta), riffle beetles (family Elmidae), midges (chironomids), amphipods (family Paramelitidae) and mayflies (family Leptophlebiidae), which together comprised 68% of the overall abundance. The strong dominance by hydrobiids (19%), worms, amphipods and chironomids was largely a product of the presence of macrophytes and associated algal/silt material. The presence of abundant riffle beetles and leptophlebiid mayflies was also indicative of the presence of abundant cobble substrate with good quality water.

Differences between sites 7 to 10 were slight, and could not be related to any differences in general site characteristics. This is not surprising, as the overall channel form and habitat type and complexity across these four sites is fairly similar. Site 6 had a significantly lower overall abundance and diversity, and was somewhat different in community composition, with greater relative dominance of the stoneflies of the family gripopterygidae. This is probably related to the greater overall area of organic detrital habitat, combined with a relatively high (20%) cover of woody debris. These habitats, in fast flowing, clean water streams, tend to favour the organic-shredding gripopterygids. The differences in community composition at this site are shown clearly in the ordination plot in Figure 3.4.

RBA samples of macroinvertebrates from riffles, edges and snags have a different community composition from quantitative samples, being influenced by the biases inherent in on-site live-picking. However, they do illustrate changes between the site characteristics in the Elizabeth. None of the three sample sets showed any upstream-downstream gradient in composition. However, steeper rocky sites were clearly distinguished from macrophyte-dominated sites either upstream or downstream of
Staircase Gorge in faunal composition (see Figure 3.4). These differences were highly significant by analysis of similarities (ANOSIM, $p < 0.01$). The presence of macrophytes appears to have a strong controlling influence on macroinvertebrate assemblages.
Figure 3.4. MDS ordination of macroinvertebrate samples from sites in the upper Elizabeth River. Top plot = RBA samples from all sites (riffle habitat). Bottom plot = quantitative (surber) samples taken from sites 6 to 10. Ordinations were derived from a Bray Curtis similarity matrix using square root transformed macroinvertebrate abundance data.

Note: 1. The distinction between rock- and macrophyte-dominated sites (ellipse 1 and 2, respectively) in top plot).
2. the distinctiveness of the Ginger Marsh site (site 6) in bottom plot.
3.1.3 Macrophytes

Macrophytes are a dominant aquatic ecological feature and value of the Elizabeth River.

Barker (2003) suggested that there are three broad types of aquatic macrophyte communities in the Elizabeth:

1. Floating vegetation in deep runs - *Triglochin procera*, *Villarsia reniformis* aquatic herbland
2. Submerged vegetation in shallow faster runs - *Isolepis fluitans*, *Myriophyllum salsugineum*, *Myriophyllum simulans* aquatic herblands and *Potamogeton* spp. aquatic herbfields

Barker did not map the extent of these communities.

Our field observations indicated that the most extensive assemblages are those dominated by:

- *Myriophyllum* and *Isolepis*, generally associated with shallower, fast flowing water in riddles and runs, often associated with cobble substrate with local pockets of silt;
- *Potamogeton tricarinatus* in slightly deeper slower flowing mid-channel areas than above;
- *Eleocharis* generally slower flowing shallow water, often on inner channel margins and in backwaters or eddies, and frequently adjacent to *Nymphoides exigua*;
- *Carex*, *Lepidosperma* and *Juncus*, generally associated with very shallow water, often still or slow flowing, on the channel margins or in floodways.

Distribution of these assemblages is highly site-specific and is determined by local hydraulic and sediment characteristics, dictated largely by slope and geomorphology. No attempt was made to map plant distributions in detail at each site, due to limited resources.
Dense growths of filamentous and characeous algae were observed throughout the channel in sites upstream of Ginger Marsh. The former were often associated with mid-channel stands of *Myriophyllum* and *Isolepis*, and were indicative of the high light conditions and sustained flows. Aquatic mosses were observed in small isolated patches and were nowhere dominant.

*Aponogeton distachyon* was the only exotic macrophyte species observed in any quantity in the Elizabeth, and was present mid-channel in runs, distinguished by its prominent scented white flower spikes. This species was probably introduced to Lake Leake and has spread downstream. It is not a significant weed, and is rarely dense in cover. *Elodea canadiensis*, Canadian pondweed, is known from Lake Leake but was not observed in any high densities in the Elizabeth.

The macrophyte assemblages of the Elizabeth River are particularly well developed. They represent an unusually high diversity and density relative to other streams of this type in Tasmania. While macrophyte densities tend to be higher in streams of the Eastern and North eastern tiers and coast, the Elizabeth River assemblages are particularly rich.

It is our opinion that this reflects the original nature of the stream channel, particularly upstream of Staircase Gorge, typified as it was by complex of marshes, ‘chains-of-ponds’ and intermittent and complex channels (see Koehnken et al 2003). The existing plant assemblages within the current modified channel from are also definitely sustained by irrigation release from Lake Leake, and facilitated by the clearer water discharged from that storage. However, they represent the legacy of the original wetland-river system which would have been highly biodiverse, and particularly in terms of its aquatic plants. The existing macrophyte assemblages are therefore a significant ecological value in their own right and management should focus on maintaining them.

### 3.1.3 Threatened species

There are no listed fish species in the Elizabeth River or its tributaries associated with the proposed dam.
No listed macroinvertebrate species were found in the RBA and surber samples, and this suggests that there are no significant threatened macro invertebrate species issues in the Elizabeth.

Barker et al. (2003) did not report any threatened aquatic plant species in the Elizabeth River, although he did report listed species associated with the riparian zone (e.g. Acacia axillaris).

### 3.2 Macrophyte-macroinvertebrate associations

Macrophyte assemblages were associated with distinct macroinvertebrate assemblages, suggesting that macrophyte assemblages could be used as a surrogate for their macroinvertebrate fauna. Community compositional differences between areas of stream bed with and without plants were significant by ANOSIM (at p = 0.01), as were differences between areas with *Myriophyllum-Isolepis* dominant and other plant species dominant (again by ANOSIM, with p = 0.01). Total abundance and diversity of macroinvertebrates was significantly higher on macrophytes than rocky (gravel, cobble, boulder or bedrock) substrates (both p < 0.001 by Kruskal Wallis test, see Figure 3.5), as were the abundances of all macroinvertebrate families (all p < 0.05 by Kruskal Wallis test), with the single exception of the Psephenidae, for which mean abundances were essentially equal. These differences typically ranged between 1.15 and 3.33 fold, i.e., a 15 to 233% higher abundance on macroinvertebrates than rocky substrates. All taxa were significantly more abundant on the *Myriophyllum-Isolepis* dominated aquatic plant assemblages (all p < 0.05 by Kruskal Wallis test) than on other plant assemblages.

Figure 3.6 shows the plant assemblages superimposed on an MDS ordination of their macroinvertebrate communities. Rocky substrate communities are clearly differentiated from macrophyte-dwelling communities. Their higher diversity is illustrated in Figure 3.7. Similarly, the *Myriophyllum-Isolepis* dominated aquatic plant assemblages have a macroinvertebrate community distinctive from the other macrophyte assemblages sampled. For example, leptophlebiid mayflies and hydrobiid snails are 8 to 10 times more abundant on *Myriophyllum-Isolepis* than on all other macrophyte species (see Figure 3.8), while caenid mayflies and copepods are more
abundant on the other macrophyte species than on *Myriophyllum-Isolepis* (Figure 3.9). This reflects the known preferences of these macroinvertebrate groups for higher and lower velocity water, respectively.

All sites had high proportions of leptophlebiid mayflies, elmid beetles, hydrobiid snails, gripopterygid stoneflies and freshwater worms in their macroinvertebrate communities, but differed substantially in the absolute abundance of these taxa.

Overall, the abundance, diversity and community composition of macroinvertebrates in the Elizabeth River is strongly related to, or controlled by, the presence and type of macrophytes. The management and conservation of macroinvertebrate communities is therefore dependent on the management and conservation of macrophytes.
Figure 3.5. Box plot of total abundance (top) and number of taxa (bottom) of macroinvertebrates on substrate with no plants, *Myriophyllum-Isolepis*, and other dominant plant species.
Figure 3.6. MDS ordination of macroinvertebrates from the Elizabeth River, showing macrophyte status, with 3 = no macrophytes (mainly rocky substrate), 2 = Myriophyllum-Isolepis dominant macrophytes, 1 = other macrophyte species dominant. Note the limited overlap between these three cases.

Figure 3.7. MDS ordination as above. Bubbles are proportional to the
number of macroinvertebrate taxa present. Note higher diversity on macrophytes (samples 1 and 2) compared with rocky substrates (3).

Figure 3.8. MDS ordination as in Figure 3.6. Bubbles are proportional to the abundance of leptophlebiid mayflies (top plot) and Hydrobiid snails (bottom plot). Note strong association between these groups families and *Myriophyllum-Isolepis* dominant macrophyte assemblages (number 2).
Figure 3.9. MDS ordination as in Figure 3.6. Bubbles are proportional to the abundance of copepods (top plot) and caenid mayflies (bottom plot). Note strong association between these groups families and macrophyte assemblages dominated by *Potamogeton*, *Triglochin*, *Chara* or *Nymphoides* (samples indicated by 1).
3.3 Plant habitat associations

Habitat preference curves were developed for eight plant species, based on the 321 spot observations of velocity, depth and dominant substrate composition taken during February to March 2003 in the Elizabeth River. These curves are shown in Figures 3.10 to 3.13.

Both *Myriophyllum* and *Isolepis* were observed to dominate higher velocities, gravel and cobble substrates over a range of depths across the channel. *Eleocharis* and *Nymphoides* both favour shallow to moderate depths, silt-sand substrates at low velocities close to or on the channel margin. *Potamogeton tricarinatus* was observed to favour moderate velocities at intermediate depths on coarse substrates.

*Triglochin procera* was observed at greater depths across a wide range of substrate sizes, but at low to intermediate velocities. *Carex gaudichanianana* was strongly limited to shallow depths and low water velocities in fine substrates on the outer wetted channel margin, behind *Eleocharis*. The exotic species *Aponogeton distachyon* was observed in deep water (> 1m) at low water velocities, typically among boulder substrates, in pools toward the channel centre.

Overall, the habitat preferences of the nine species assessed can be grouped into four ‘types’ (described in Table 3.3):

1. extreme channel margin,
2. channel margin adjacent to deeper water,
3. across channel in riffles and runs,
4. across channel in pools.

The habitat preference curves developed here were used to assess changes in habitat availability for these key taxa in the Elizabeth River with baseflow (or irrigation release) discharge.
Figure 3.10. Habitat preference plots for *Myriophyllum* spp. and *Isolepis* *fluitans* in the Elizabeth River. Substrate coding: 2 = silt, 3 = sand, 4 = fine gravel, 5 = gravel, 6 = cobble, 7 = boulder, 8 = bedrock.
Figure 3.11. Habitat preference plots for *Eleocharis sphacelata* and *Nymphoides exigua* in the Elizabeth River. Substrate coding as in Figure 3.10.
Figure 3.12. Habitat preference plots for *Potamogeton tricarinatus* and *Triglochin procera* in the Elizabeth River. Substrate coding as in Figure 3.10.
Figure 3.13. Habitat preference plots for *Carex gaudichaniana* and *Aponogeton distachyon* in the Elizabeth River. Substrate coding as in Figure 3.10.
Table 3.3. Summary of habitat preferences of Elizabeth R macrophytes.

<table>
<thead>
<tr>
<th>Type</th>
<th>Species</th>
<th>Depth</th>
<th>Velocity</th>
<th>Substrate</th>
<th>Position</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carex gaudichaniana</td>
<td>Shallow</td>
<td>Low</td>
<td>Fine</td>
<td>Outer channel margin</td>
</tr>
<tr>
<td></td>
<td>Juncus procerus</td>
<td>Shallow</td>
<td>Low</td>
<td>Fine</td>
<td>Outer channel margin</td>
</tr>
<tr>
<td>2</td>
<td>Eleocharis sphacelata</td>
<td>Moderate</td>
<td>Low</td>
<td>Fine</td>
<td>Channel margin</td>
</tr>
<tr>
<td></td>
<td>Nymphoides exigua</td>
<td>Moderate</td>
<td>Low</td>
<td>Fine</td>
<td>Channel margin</td>
</tr>
<tr>
<td>3</td>
<td>Myriophyllum sp.</td>
<td>Generalist</td>
<td>Moderate to high</td>
<td>Gravel-cobble</td>
<td>Across channel</td>
</tr>
<tr>
<td></td>
<td>Isolepis fluitans</td>
<td>Generalist</td>
<td>Moderate to high</td>
<td>Gravel-cobble</td>
<td>Across channel</td>
</tr>
<tr>
<td></td>
<td>Potamogeton tricarinatus</td>
<td>Moderate</td>
<td>Moderate</td>
<td>Gravel-cobble</td>
<td>Across channel</td>
</tr>
<tr>
<td>4</td>
<td>Triglochin proceras</td>
<td>Deep</td>
<td>Slow</td>
<td>Generalist</td>
<td>Across channel, pools</td>
</tr>
<tr>
<td></td>
<td>Aponogeton distachyon*</td>
<td>Deep</td>
<td>Low</td>
<td>Coarse</td>
<td>Across channel, pools</td>
</tr>
</tbody>
</table>
4. Impact of the Chimney Hill Dam

4.1 Hydrology and geomorphology

The nature of the historical flow regime in the Elizabeth River and its likely changes with operation of the proposed Chimney Hill Dam have been described in detail by Koehnken et al. (2003).

The Elizabeth River has experienced significant changes in river geomorphology as a result of the operation of Lake Leake. This was primarily a result of changes in the pattern of flows resulting from Lake Leake releases, coupled with changes in sediment budget from the upper catchment due to the presence of the Lake Leake storage. Local changes in channel form, and hence hydrology and hydraulics, have also resulted from drainage and channelisation of the Elizabeth River and associated marshes and tributaries. Some degree of hydrological change may also have resulted from a degree of vegetation clearing, though this is probably a minor issue.

Currently, summers are characterised by flows of about 0.5 m$^3$/s corresponding to the irrigation release from Lake Leake, with higher winter flows occurring as short duration high flow storm events. High flows can occur at anytime of year, with two of the three largest flows on record during summer. Currently, high flow events tend to have steep rising limbs, with more gradual falling limbs due to the onset of spilling from Lake Leake, and attenuation of high flows through the lake. The primary changes to the natural hydrology of the Elizabeth River have therefore been:

- maintenance of a constant summer flow of the order of 0.5 cumec;
- reduction in the frequency and intensity of some floods due to storage/attenuation in Lake Leake;
- more rapid rates of rise in flood peaks from dam spill events.

The result of the historical changes in form and flow regime in the Elizabeth has been:

- loss of natural complex habitats associated with the ‘chain of ponds’ - marsh systems in the catchment upstream of Staircase Gorge.
- establishment of simplified, channelised stream sections upstream of Staircase Gorge, still linked to marshes under flood conditions, though less frequently and intimately;
- a degree of erosion associated with channel adjustment to the new flow regime, mainly of fine materials;
- establishment of conditions favouring prolific macrophyte growth in the main river channel, and a probably loss of macrophyte habitat in pond/pool/marsh habitats;
- establishment of conditions favouring exotic fish species;
- likely reduction in natural aquatic biodiversity of macroinvertebrates and native fish.

Plots of monthly medians of mean daily flows are shown in Figure 4.1 for the pre-dam and post-dam (modelled) scenarios. See Koehnken et al (2003) for the assumptions made when post-dam flows have been modelled. The most notable change is the rise in irrigation season (November to April) median and 20 percentile flows. The other significant feature is a reduction in median flows for the May-July period, due to the occurrence of prolonged near-zero releases during filling of the Chimney Hill dam (see Table 4.1), with a doubling in the number of days with zero discharge at the dam site per year. There are few other changes, and the 80 percentile flows are essentially unchanged post-dam, as large flows > 2 cumec experience little change (Figure 4.2).

Koehnken et al. (2003) summarised the likely changes in hydrology resulting from the operation of the proposed Chimney Hill Dam as:

- A period of very low or no flow in early winter under both flow regimes (beginning in summer during dry years) but being extended post-dam;
- A post-dam increase in irrigation flow from ~0.5 m$^3$/s to ~1 m$^3$/s during the summer months;
- Delayed onset of high winter flows (spills) under the post-dam regime (presumably due to filling of the Chimney Hill impoundment);
- Little change in flows >2 m$^3$/s, which represents spill from Chimney Hill in the post-dam hydrographs.
Figure 4.1. Monthly patterns of medians and 20 percentiles of mean daily flows at Chimney Hill pre-dam (historical from 1902 to 1999) and post-dam (modelled flows, assuming no environmental flow releases).
Figure 4.2. Monthly patterns of 80 percentiles of mean daily flows at Chimney Hill pre-dam (historical from 1902 to 1999) and post-dam (modelled flows, assuming no environmental flow releases).

Table 4.1. Number of days of extremely low flow (near zero discharge) and of flows less than the absolute environmental minimum (22 ML/day – see Section 6) under historical (pre-dam) and modelled post-dam conditions. Note increase in number of near-zero flow days between pre-dam and post-dam in May-September, but absence of further increase in absolute minimum flows.
Hydraulic modelling of surveyed channel sections in two reaches - Ginger Marsh and downstream of the proposed dam (sites 6 and 7, Figure 2.1) was conducted using the RHYHAB package. The modelling was based on field data on river channel sections (profiles, depth and velocity distributions), with 4 and 5 transects surveyed at each site respectively, as well as field measured stage-discharge ratings. The results indicate that a shift from a dominant irrigation release of ca 0.5 (m$^3$/s, or cumec) to around 1.0 cumec will result in increasing the wetted width of the channel by between ca 0.7 and 3.5 m in both of the surveyed sections (Figure 4.1).

These forecast wetted width changes from the increase in irrigation release are shown in Table 4.2. Flows up to ca 1.5 cumec generally stay within the existing channel, while flows > 2 cumec spill into the riparian zone and flood-plain and flood runners at both sites. An overall mean increase of 1.4 and 1.8 m is expected between 0.5 and 1 cumec, with increases ranging up to 3 – 3.5 m at specific sections in both sites.

These increases in wetted width under the proposed irrigation releases are expected to result in adjustments in the physical width of the channel of the same order, since proposed irrigation flow velocities are sufficient to erode and/or transport fine materials which bind bank materials (see Koehnken et al. 2003).

Thus, the numbers presented in Table 4.1 are the best estimate of the likely increase in channel width in the Elizabeth downstream of the dam (and upstream of Staircase Gorge) following prolonged irrigation season flows of the order of 1 cumec (86 ML/day).

A period of adjustment of several years is likely before the channel widens to its final position.
Table 4.2. Forecast increases in wetted width, and ultimately, channel width at study sections in Ginger Marsh and downstream of the proposed dam (in metres).

<table>
<thead>
<tr>
<th></th>
<th>Q (cumec) :</th>
<th>0.5</th>
<th>1</th>
<th>Diff (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ginger Marsh (site 6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G1</td>
<td>9.71</td>
<td>10.36</td>
<td></td>
<td>0.65</td>
</tr>
<tr>
<td>G2</td>
<td>13.13</td>
<td>13.84</td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td>G3</td>
<td>8.23</td>
<td>9.15</td>
<td></td>
<td>0.93</td>
</tr>
<tr>
<td>G4</td>
<td>8.84</td>
<td>12.13</td>
<td></td>
<td>3.29</td>
</tr>
<tr>
<td>Mean difference</td>
<td></td>
<td></td>
<td></td>
<td><strong>1.39</strong></td>
</tr>
<tr>
<td>Downstream of dam (site 7)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DB1</td>
<td>15.09</td>
<td>15.94</td>
<td></td>
<td>0.84</td>
</tr>
<tr>
<td>DB2</td>
<td>10.12</td>
<td>13.58</td>
<td></td>
<td>3.47</td>
</tr>
<tr>
<td>DB3</td>
<td>14.94</td>
<td>15.69</td>
<td></td>
<td>0.75</td>
</tr>
<tr>
<td>DB4</td>
<td>16.30</td>
<td>19.30</td>
<td></td>
<td>3.01</td>
</tr>
<tr>
<td>DB5</td>
<td>16.06</td>
<td>16.89</td>
<td></td>
<td>0.83</td>
</tr>
<tr>
<td>Mean difference</td>
<td></td>
<td></td>
<td></td>
<td><strong>1.78</strong></td>
</tr>
</tbody>
</table>
Figure 4.1. Representative model output from flow modelling, showing channel, flow velocity and water level for a calibration flow and flows ranging from 0.5 to 2.0 m³/s. Graphs are from two channel cross-sections (transects D1 and D3) at site 7.
Figure 4.2. Representative model output from flow modelling, showing channel, flow velocity and water level for a calibration flow and flows ranging from 0.5 to 2.0 m$^3$/s. Graphs are from two channel cross-sections (transects G1 and G3) at Ginger Marsh, Zone 6.
4.2 Instream biota

Key issues for the instream biota during dam construction and commissioning will be:
- sedimentation and/or erosion associated with dam construction works;
- lack of flow while dam fills;
- sedimentation from new roads or associated sites;
- pollution from oil/hydraulic fluid or other waste spillages or seepage.

Key issues for the instream biota following commencement of operations of the Chimney Hill Dam will be:
- the magnitude of the irrigation release and any minimum and maximum environmental flows during that period;
- the occurrence of rapid, short-term variations in flow during the irrigation season;
- the occurrence of any zero-flow or cease-to-flow events;
- whether flows cease during filling of Chimney Hill Dam in autumn/early winter.

The increase in channel width due to enhanced irrigation season flows will:
- initially result in localised erosion and bank instability, with some loss of riparian vegetation (including some vegetation collapse into the stream channel), and enhanced sediment transport downstream;
- result in changes in the area of habitat available for instream macrophytes (and associated fauna).

Koehnken (2003) describes the issues and risks associated with water quality resulting from the proposed Chimney Hill Dam. Issues pertinent to the aquatic biota are:
- declines in temperature of releases form the proposed dam, especially if stratification occurs during summer;
- decreases in dissolved oxygen in releases associated with summer releases, especially during the first few years following impoundment;
- potential for increases in turbidity of downstream flows during summer;
- toxic effects of any blue-green algal blooms which may occur in the dam.
We believe that the primary aquatic biological asset in the Elizabeth River is the macrophytes (and their associated macroinvertebrate fauna), and this assessment is therefore mainly focussed on assessing risks to macrophytes.

4.2.1 Impacts on macrophytes (and associated fauna)

The primary impact of the proposed dam on macrophytes is going to be from the combination of changes in the flow regime (magnitude of the flows, their seasonal pattern, and the risk of higher short term variability) and associated channel adjustment, resulting in changes in habitat suitability and availability. Changes in water quality (DO, temperature and turbidity) are likely to be only of secondary importance (though potentially significant for the instream fauna).

In order to assess the likely change in habitat availability to macrophytes, the hydraulic modelling conducted using survey channel data was repeated, but with channel profiles adjusted by the forecast increase in width. Ratings were then re-calculated assuming adjustment in water depth, and only slight adjustment in at-point water velocities. Substrate composition was assumed to be similar following channel adjustment to that occurring now (as there is little change in flood regime and overall sediment transport characteristics – see Koehnken et al. 2003).

The results are summarised in Table 4.2. Increases in suitable habitat area are substantial for species associated with or adjacent to the bank zone – for example Eleocharis and Nymphoides. This is largely a result of an increase in the area of shallower, slow to moderate velocity water adjacent to the channel margins. Modelling also indicated significant increases in the area of Carex and Juncus habitat. However, the response of these species is also affected by shifts in terrestrial and riparian vegetation, which cannot be modelled in the same manner. It is likely that these two species will not experience a major increase in habitat area, unless adjacent floodways are more frequently filled, which is unlikely. Barker (2003) assumes no change in extent of this vegetation.

Overall, this analysis suggests that the changes in habitat suitability with the adjustment resulting from enhanced irrigation flows and channel widening will, in the
long term not be detrimental to the macrophytes of the Elizabeth River, and may be partially beneficial. This increase in habitat area for macrophytes should, of course be offset against any losses of habitat for riparian plants such as *Acacia axillaris*, addressed by Barker (2003).

It is assumed here that changes in habitat area for macrophytes will result in a proportional adjustment in the relative areas of macrophyte assemblages, and that associated macroinvertebrate communities will adjust accordingly.

It should be noted that this analysis assumes that channel adjustment is complete and that the riparian (bank) zone achieves stability in form and vegetation community in a manner similar to that observed under existing conditions. These changes will not be achieved if there is ongoing fluctuation in river level during the irrigation season at a frequency significantly greater than occurs at present. Maintaining a stable flow environment is critical to minimising negative impacts on the macrophyte community and dependent aquatic biota in the Elizabeth River.

Table 4.2. % change in habitat area suitable for seven macrophyte species in the upper Elizabeth River as a result of a change in irrigation discharge combined with channel adjustment following commencement of operations of Chimney Hill Dam.

<table>
<thead>
<tr>
<th></th>
<th>Myriophyllum</th>
<th>Isolepis</th>
<th>Eleocharis</th>
<th>Nymphoides</th>
<th>Potamogeton</th>
<th>Triglochin</th>
<th>Aponogeton</th>
</tr>
</thead>
<tbody>
<tr>
<td>Downstream of dam</td>
<td>19.46</td>
<td>6.51</td>
<td>49.41</td>
<td>44.83</td>
<td>36.00</td>
<td>45.17</td>
<td>-14.29</td>
</tr>
<tr>
<td>Ginger Marsh</td>
<td>27.49</td>
<td>21.44</td>
<td>63.94</td>
<td>113.79</td>
<td>34.03</td>
<td>36.81</td>
<td>50.00</td>
</tr>
<tr>
<td>Mean</td>
<td>23.47</td>
<td>13.97</td>
<td>56.68</td>
<td>79.31</td>
<td>35.01</td>
<td>40.99</td>
<td>17.86</td>
</tr>
</tbody>
</table>

4.2.2 Impacts on other aquatic fauna

No other significant impacts on aquatic fauna are envisaged. Habitat availability and suitability are unlikely to change significantly provided adequate environmental flows are instituted for fish, macroinvertebrates, platypus or frogs.

4.2.3 Fish and platypus passage

Construction of dams on streams often results in blocking free passage of aquatic fauna upstream and downstream. This is particularly important for Tasmanian freshwater fish, most of which must migrate within the stream system to complete
their life history. A degree of free movement is also important for maintaining platypus populations.

The status of fish populations in the Elizabeth River is sufficiently degraded so as to essentially eliminate the requirement for fish passage at the proposed dam. The brown trout population does not support a substantial recreational fishery. A degree of adult recruitment to the upper Elizabeth is likely to occur due to downstream movement of fish from Lake Leake, and this would also include redfin perch and shortfin eels. There is therefore no compelling argument for a fish ladder.

Provided adequate landscaping (with the advice of a platypus specialist) occurs in the vicinity of the dam wall, platypus movement should not be severely hindered.

4.2.3 Recreational fishery

The establishment of a stocked or intensively managed brown trout fishery in the new storage is not advised. While it will attract a small degree of interest from anglers, the storage will have only limited potential long term potential as a fishery, primarily due to the large fluctuations in level during the irrigation season. A degree of natural stocking will occur from the resident population in the upper Elizabeth (as well as from fish moving downstream from Lake Leake especially following spills). Stocking will only increase the potential for further exotic fish translocations into the catchment, and should not be considered. In addition, the fishery should not be promoted unless it is to be actively managed, as it would encourage littering, degrading of tracks and increased potential for wildfires.
4.3 Overall assessment

The results of this assessment can be summarised by using a risk assessment in a manner consistent with the Australian Standard for Risk Management guidelines AS/NZS 4360: 1999. The issues evaluated above are listed in Table 4.3 for relevant locations and timeframes, and the magnitude of their risks assessed using their likelihood and consequence. Issues with medium to high risks are highlighted as requiring mitigation measures.

Key issues resulting from the proposed development are:

- the immediate impact of construction and road development on sediment inputs to the Elizabeth River with negative consequences for instream biota;
- a period of enhanced erosion associated with channel adjustment to enhanced irrigation releases, with local impacts on macrophytes and associated fauna;
- a long term adjustment in channel dimensions with consequent increases in area of instream macroinvertebrate and macrophyte habitat, particularly between the dam site and Staircase Gorge, though at risk from short term fluctuations in irrigation releases;
- risk of negative impacts on instream biota from prolonged periods of zero discharge from Chimney Hill Dam during filling.

The overall impact of the proposed dam development on aquatic ecological values is not likely to be substantial, especially in the context of the historically modified nature of the Elizabeth River system. The Elizabeth does still have some significant aquatic and riparian conservation values however – most notably the macrophytes and vulnerable riparian plant species (for the latter see Barker 2003). The risks identified here all require some form of mitigation.

Note that an assessment of impacts of the proposed dam on water quality is reported separately (Koehnken 2003).
Table 4.3. Risk evaluation for aquatic ecological issues assessed for the proposed construction and management of dam.
<table>
<thead>
<tr>
<th>Issue</th>
<th>Where</th>
<th>When</th>
<th>Response</th>
<th>Likelihood</th>
<th>Consequence</th>
<th>Risk</th>
<th>Mitigation required?</th>
<th>Mitigation strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macrophytes</td>
<td>Dam storage area</td>
<td>Short term</td>
<td>Loss</td>
<td>Likely</td>
<td>Negligible</td>
<td>Low</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Macrophytes</td>
<td>Dam storage area</td>
<td>Short term</td>
<td>Loss</td>
<td>Likely</td>
<td>Negligible</td>
<td>Low</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td>Dam site</td>
<td>Immediate</td>
<td>Passage blocked</td>
<td>Likely</td>
<td>Negligible</td>
<td>Low</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Fish</td>
<td>Dam site</td>
<td>Immediate</td>
<td>Passage blocked</td>
<td>Likely</td>
<td>Negligible</td>
<td>Low</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Platypus</td>
<td>Dam site</td>
<td>Immediate</td>
<td>Passage blocked</td>
<td>Likely</td>
<td>Negligible</td>
<td>Low</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Macroinvertebrates</td>
<td>Dam to Staircase Gorge</td>
<td>Construction period</td>
<td>Decline from impacts of construction and roading</td>
<td>Possible</td>
<td>Moderate</td>
<td>Medium</td>
<td>Yes</td>
<td>Sediment control at construction sites and road crossings</td>
</tr>
<tr>
<td>Fish</td>
<td>Dam to Staircase Gorge</td>
<td>Construction period</td>
<td>Decline from impacts of construction and roading</td>
<td>Possible</td>
<td>Moderate</td>
<td>Medium</td>
<td>Yes</td>
<td>Sediment control at construction sites and road crossings</td>
</tr>
<tr>
<td>Fish</td>
<td>Staircase Gorge</td>
<td>Long term</td>
<td>Adjustment by increase in habitat area, provided flows stable and Eflows operational</td>
<td>Likely</td>
<td>Moderate</td>
<td>High</td>
<td>Yes</td>
<td>Eflow regime and rules adopted</td>
</tr>
<tr>
<td>Fish</td>
<td>Staircase Gorge</td>
<td>Long term</td>
<td>Adjustment by increase in habitat area, provided flows stable and Eflows operational</td>
<td>Likely</td>
<td>Minor</td>
<td>Medium</td>
<td>Yes</td>
<td>Eflow regime and rules adopted</td>
</tr>
<tr>
<td>Fish</td>
<td>Below Staircase Gorge</td>
<td>Long term</td>
<td>Adjustment by increase in habitat area, provided flows stable and Eflows operational</td>
<td>Likely</td>
<td>Negligible</td>
<td>Low</td>
<td>No</td>
<td></td>
</tr>
</tbody>
</table>
5. Mitigation

5.1 Mitigation needs and options

Mitigation needs for the proposed Chimney Hill Dam are:

- sediment and erosion management during construction and on roads.
- provision of landscaping at the damsite to facilitate platypus passage.
- ensure dam releases are above 5 mg/l in dissolved oxygen.
- ensure dam releases are from upper part of water column (unless blue-green algal bloom develops).
- restriction of access to dam foreshore.
- provide a recommended environmental flow regime (minimum and maximum irrigation flows, high flow management, plus rules relating to short flow variation in flows and zero flow events).

5.2 Specific mitigation measures

The following mitigation measures are to be employed, in addition to those indicated by Koehnken (2003) in relation to water quality, Koehnken et al. (2003) in relation to geomorphology, and Barker et al. (2003) in relation to riparian vegetation.

5.2.1 Sediment control

Provision of adequate and actively managed sediment control during all phases of construction at all high risk construction sites and new roads and road crossings (including provision of adequate road drainage and stream crossings).

5.2.2 Landscaping

Adequate landscaping to be conducted on undeveloped side of dam wall to facilitate platypus passage up and downstream (advice from platypus specialist to be sought).

5.2.3 Dam release DO content

A short section of aeration channel to be built immediately downstream of outlet valve to maximise re-aeration of outflowing water.
5.2.4 Dam release temperature
Multiple level offtakes to be installed. Offtakes to high in water column during summer, unless in advent of blue-green algal bloom.

5.2.5 Stock and vehicle access to storage
Stock and vehicle access to storage foreshore and exposed bed to be prevented. Recreational fishing to be discouraged.

5.2.6 Environmental Flow regime
See Section 6 of this report.
6. Environmental flow regime

The derivation of an environmental flow regime for this river system has several key constraints:

- the river is already high regulated;
- the channel and biological values present have already been affected by the regulated flow regime as well as channel modification and adjustment;
- the presence of the new dam and a further modified flow regime will lead to further channel adjustment.

These constraints prevent the use of the typical approach to deriving an environmental flow regime used in other studies in the state. Instead, any environmental flow regime will be derived recognising:

- the need to maintain the present key environmental values in the river system – in particular the aquatic macrophytes (and their associated fauna), the riparian and floodplain vegetation;
- that the proposed dam will not significantly affect the pattern and type of floods (or in fact most flows above 2 cumec).

6.1 Environmental flow requirements for riparian vegetation

Issues associated with bank inundation, channel adjustment and loss of some riparian vegetation have been discussed by Koehnken et al. (2003) and Barker (2003). Maintenance of the remaining riparian vegetation will be dependent on:

- maintaining an overall seasonal pattern of baseflows that is broadly similar to that occurring under present conditions;
- maintaining the magnitude and frequency of disturbance from floods to be broadly similar to that occurring under present conditions.

Examination of the pre- and post-flow regimes indicates that both of these conditions will be satisfied, with the exception of an extended period of near zero flows during May-June during filling of the new dam. This issue will be discussed in detail below. Provided this is managed properly, there are no specific environmental flow requirements for riparian vegetation.
6.2 Environmental flow requirements for macrophytes

Habitat area for the dominant species of macrophytes is plotted against discharge for the two study reaches in Ginger Marsh and downstream of the dam (sites 6 and 7), with the channel widened according the forecast adjustments. The focus of this analysis is on flows between zero discharge and bankfull, which encompasses the range of historical and proposed irrigation flows.

These plots show a flat response for *Myriophyllum* and *Isolepis* to changing discharge over the range 0.5 to 2 cumec, and a generally flat response for *Eleocharis, Carex, Juncus, Nymphoides* and the introduced *Aponogeton* over the range 0.25 to 1.5 cumec. *Juncus* and *Carex* increase. Increases in suitable habitat area are forecast at flows above 1.5 cumec for *Juncus* and *Carex*, with *Eleocharis, Nymphoides* and *Aponogeton* showing no substantial change in habitat area at these higher flows. The habitat area responses of *Potamogeton tricarinatus* and *Triglochin procera* are steep, and in the case of *Triglochin*, unimodal. Thus, habitat area for these two species is forecast to increase sharply between 0 and 1 cumec, with habitat area declining for *Potamogeton* at higher discharges.

All species show marked declines in habitat area at flows between 0.25 and 0 cumec, with *Myriophyllum* and *Isolepis* showing declines at flows below 0.5 cumec.

Three results emerge from this assessment:

- flows below 0.25 cumec are likely to cause substantial loss of habitat area for all plant species under the proposed irrigation regime;
- habitat area for most species does not respond strongly to changes in discharge between 0.5 and 1 cumec;
- *Potamogeton tricarinatus* and *Triglochin procera* show the most sensitive responses in habitat area to changes in discharge.

Firstly, it is apparent that an absolute minimum flow required to sustain adequate macrophyte habitat in the Elizabeth downstream of the proposed dam is 0.25 cumec (21 ML/day).
Figure 6.1. Changes in habitat area (as WUA in m²/m of river length) for dominant macrophyte species in Ginger Marsh, Elizabeth River, in the channel following adjustment to the proposed irrigation flow regime.
Figure 6.2. Changes in habitat area (as WUA in m²/m of river length) for dominant macrophyte species downstream of the proposed dam (site 7), Elizabeth River, in the channel following adjustment to the proposed irrigation flow regime.
Secondly, the primary responses to changes in baseflow above 0.5 cumec are likely to be seen in Potamogeton and Triglochin i.e. these are the species whose habitat availability will be most sensitive to changes in baseflow post-dam. While Triglochin does not constitute a major part of the macrophyte assemblages in the Elizabeth, Potamogeton does. Provision of minimum environmental flows which maintain Potamogeton habitat in the Elizabeth will also maintain the other dominant species.

The standard habitat-flow based risk assessment methodology for assessing minimum environmental flows in Tasmanian rivers, developed by Davies and Humphries (1996) and adopted by DPIWE was used to assess the minimum flow requirements for the Elizabeth River macrophytes. This risk assessment uses a reference flow regime to evaluate the risk of habitat loss for each month of the year in order to identify an acceptable minimum mean daily flow for each month. All habitat-flow modelling has been conducted using the modified, or adjusted, channel profile forecast to occur post-dam (see Section 4 and Koehnken et al. 2003). There is little relevance, therefore in using the historical flows as reference flows during the irrigation season, as these would not result in the forecast habitat-flow relationships.

The modelled post-dam flows were therefore used as reference flows for the risk analysis in the irrigation season (November to April) and July to October, with the pre-dam historical flows used for the months of May-June. The pre-dam flows did not differ significantly from the post-dam flows for the months of July to October (as Chimney Hill Dam will not significantly affect flows during these months), but are significantly higher for the months of May-June, as Chimney Hill Dam is predicted to fill during this period.

As expected, Potamogeton tricarinatus was the species whose habitat-flow response dominated the risk assessment. Values for the reference flows and the flows representing the lowest bound of the level I Risk band are shown for each month in Table 6.1. They are also plotted along with the recommended absolute minimum flow in Figure 6.2. It should be noted that the final values for the post-dam median and 20 percentile flows will increase for the period May to August once the minimum environmental flows are included in flow modelling. Thus, there should be no period in which the environmental flows exceed the forecast flows.
Table 6.1. Reference flows and resulting average minimum environmental flows for risk band I for each month.

<table>
<thead>
<tr>
<th>Month</th>
<th>Reference flows</th>
<th>Minimum environmental flow (Risk band I)</th>
<th>Absolute minimum flow</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Record</td>
<td>Mean from both sites</td>
<td>Absolute Min Eflow</td>
</tr>
<tr>
<td></td>
<td>Monthly Median</td>
<td>cumec</td>
<td>ML/day</td>
</tr>
<tr>
<td>Jan</td>
<td>Post dam Q 0.87</td>
<td>0.35</td>
<td>48</td>
</tr>
<tr>
<td>Feb</td>
<td>Post dam Q 0.77</td>
<td>0.50</td>
<td>43</td>
</tr>
<tr>
<td>Mar</td>
<td>Post dam Q 0.59</td>
<td>0.45</td>
<td>39</td>
</tr>
<tr>
<td>Apr</td>
<td>Post dam Q 0.45</td>
<td>0.35</td>
<td>35</td>
</tr>
<tr>
<td>May</td>
<td>Pre Dam Q 0.55</td>
<td>0.42</td>
<td>35</td>
</tr>
<tr>
<td>Jun</td>
<td>Pre Dam Q 1.06</td>
<td>0.56</td>
<td>48</td>
</tr>
<tr>
<td>Jul</td>
<td>Post dam Q 1.22</td>
<td>0.55</td>
<td>48</td>
</tr>
<tr>
<td>Aug</td>
<td>Post dam Q 1.60</td>
<td>0.52</td>
<td>45</td>
</tr>
<tr>
<td>Sep</td>
<td>Post dam Q 2.42</td>
<td>0.36</td>
<td>35</td>
</tr>
<tr>
<td>Oct</td>
<td>Post dam Q 1.78</td>
<td>0.45</td>
<td>40</td>
</tr>
<tr>
<td>Nov</td>
<td>Post dam Q 1.12</td>
<td>0.56</td>
<td>48</td>
</tr>
<tr>
<td>Dec</td>
<td>Post dam Q 1.01</td>
<td>0.56</td>
<td>48</td>
</tr>
</tbody>
</table>

Figure 6.3. Plot of monthly mean daily flows for the Elizabeth River post-dam, showing the recommended minimum environmental flows and the absolute minimum flow. Note that the final plots of the median and 20 percentile flows post-dam will change (rise) for the period May to August once the minimum environmental flows are included in post-dam flow modelling.
6.3 Environmental Flow Regime and Recommendations

6.3.1 Environmental Flow Regime: Recommendations and Conclusions

Recommendations reading the environmental flow management regime are as follows:

1. flows are to be maintained, as a matter of course, at or above the recommended mean daily minimum environmental flows shown in Table 6.1;

2. an absolute minimum flow of 0.25 cumec (21.6 cumec) is to be maintained when the above flows cannot be maintained:
   - during dam filling;
   - during dam/valve maintenance/outages;
   - when inflows to the dam fall below the recommended minimum environmental flow.

3. no zero discharge events are to be permitted, as this will significantly reverse the environmental benefits gained from the above environmental flow rules.

No specific prescriptions are made in relation to high/flood flows, as the post-dam operations are unlikely to have any significant impact on flows at bankfull or greater in magnitude. However it is strongly recommended that any operational changes at either the Chimney Hill or Lake Leake storages be reviewed in relation to impacts on high/flood flow magnitude, frequency or timing. Any significant change in the pattern of high/flood flows will have substantial impacts on the channel morphology, erosion rates, water quality and instream biota. Any future alteration to the high/flood flow regime must take into account the minimal requirements of the riverine ecosystem for these events (see Appendix 1).

Two further recommendations are therefore made:

4. no further changes are to be made to the operation of Lake Leake of Chimney Hill Dam that may affect high/flood flows without detailed review of environmental consequences.

5. Lake Leake and Chimney Hill Dam should be managed under the one operational plan, and possibly by a single operator/management body (in line with recommendations by Koehnken 2003 with regard to water quality issues).
The success of the environmental flow regime at maintaining the instream aquatic values will dependent on stable flow delivery. Rapid or frequent short term variation in baseflow will have significant detrimental impacts on instream and riparian values by enhancing or extending the erosional adjustment expected by the channel, and de-watering and/or stranding instream and riparian flora and fauna. The following recommendation is therefore also made:

6. That no rapid increases or decreases in flows are made when increasing or decreasing irrigation supply, or when switching between the minimum environmental flow and the absolute minimum flow. Care must be taken to ensure the stability of the flow regime over and above the level of variation experienced under recent historical conditions.

It is unlikely that these recommendations will severely affect the viability of the Chimney Hill dam proposal. The requirement for a dry season minimum flow was not pursued since the above minimum flow rules should be compatible with dry year scenarios, unless otherwise demonstrated.

The main impact of these recommendations will be in relation to the requirement for a continuous release during dam filling, which will delay the onset of dam filling, possibly by as much as one month.

The minimum environmental flow requirement is likely to be complied with from irrigation releases and/or dam spills in most years, and will generally not require any additional releases. Storage of ‘environmental water’ (ca 500 ML) may be required to comply with the absolute minimum flow requirement during events where cease-to-flow conditions would otherwise occur due to flow management for dam filling etc. It should be noted that the post-dam flow modelling has already taken into account the requirement for ca 400ML of such storage (see Koehnken 2003).

The main environmental benefits of this environmental flow requirement is to minimise the impact on the aquatic biota and maintain water quality during dam filling periods.
The overall benefit of the environmental flow regime will be to maintain the core aquatic environmental values of the Elizabeth River – the macrophytes (and associated fauna) and riparian vegetation.

6.3.2 Other Recommendations and Conclusions

Timing and management of flows should also comply with the recommendations made by Koehnken (2003) with regard to water quality of the storage and downstream releases. Those recommendations apply to both drinking water and environmental water quality.

Ongoing monitoring of the biological, water quality and geomorphological status of the river downstream of the proposed dam should be implemented under licence conditions.

Monitoring should take the form of periodic sampling (initially annual, then reducing) of macroinvertebrates using the same methods reported here for the five sites (sites 6 to 10) upstream of Staircase Gorge. In addition, macrophytes should be monitored by mapping (of dominant species distributions) of four sections at sites 2, 6, 7 and 10. Monitoring of channel width and profiles should be conducted immediately post dam then every 2-3 years, by re-survey of the transects surveyed for this report at sites 6 and 7.

Monitoring of the water quality conditions in the storage is also recommended (see Koehnken 2003).

Any problems highlighted with monitoring should then be formally addressed through periodic review of water licence conditions.

Monitoring/auditing of compliance of releases with the environmental flow regime should also be conducted, initially on an annual basis, reducing to 3-5 yearly.
7. Summary

The aquatic biota of the Elizabeth River was found to be in a modified state, with no threatened species and limited faunal conservation value. The aquatic flora, while in a modified state due to changes inflow regime and channel form, represents a significant conservation value, along with the riparian vegetation (reported on by Barker 2003).

Management should focus on minimising flow-derived impacts on river flora (and associated macroinvertebrate fauna) by introducing a relatively stable minimum environment flow regime which mimics and/or enhances the relative stability in flows experienced historically as a result of Lake Leake releases.

A number of risks to the aquatic ecosystem have been identified with associated mitigation actions. We believe that these are not onerous enough to significantly impact on the viability of the proposed dam.
References


APPENDIX 1.

Guidelines for future management of environmental high/flood flows in the Elizabeth River

To maintain key environmental attributes of the Elizabeth River we recommend maintaining a minimum pattern of high/flood flow events, with each event designed to perform specific ecosystem functions. We recommend four major types of high flow/ flood events, each with a different role, and all of which are considered essential for the maintenance of the riverine ecosystem (Table A1).

Table A1. Key potential environmental roles of four high flows/flood event types in the Elizabeth River.

<table>
<thead>
<tr>
<th>Flood Type</th>
<th>Ecosystem Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median flood</td>
<td>Channel and floodplain/marsh vegetation maintenance, sediment transport.</td>
</tr>
<tr>
<td>Annual flood</td>
<td>Channel and floodplain/marsh maintenance, sediment and LWD transport within river, sediment and nutrient transport.</td>
</tr>
<tr>
<td>Freshes</td>
<td>Maintain riparian/semiaquatic vegetation; flushing of algae and fine organic material; aquatic and riparian plant dispersal and germination. Periodic pool-pool connection and salt flushing.</td>
</tr>
</tbody>
</table>

For these guidelines, median floods are those floods with a 1 in 2 year average return interval, while annual floods are the average annual maximum floods. Both of these flood sizes play key roles in maintaining channel form, primarily though sediment transport, as well as key processes like meander migration and sediment delivery to and from marsh/floodplain complexes. Annual floods also play a role in the transport of large woody debris (LWD). ‘Trigger’ high flows are flows considered essential for triggering key biological events. These flows are required in these rivers to initiate downstream migration of native fish for spawning (in autumn-early winter) and brown trout, as well as upstream migration of native fish juveniles (e.g. elvers – typically in spring). Trigger flows are also likely to play key short term roles in the transport of coarse organic material (CPOM) in river channels. Smaller, more regular
'freshes' are required for several purposes, most notably maintenance of riparian and instream vegetation, local transport of fine particulate organic matter (FPOM) and flushing of algal biofilms.