REPORT ON HYDROLOGICAL & ENGINEERING ISSUES

PARADISE DAM FISHWAYS

BURNETT RIVER, QLD

Prepared for:

The Federal Court of Australia

Prepared by:

M.F Winders

22 June 2009

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1.0 INTRODUCTION

1.1 Background to the Report

The Burnett River Dam on the Burnett River was constructed for Burnett Water Pty.Ltd, subject to a final design developed out of environmental impact studies and public consultation and having regard to the recommendations of a Technical Advisory Panel to the drafting of the *Water Resource Plan (Burnett Basin) 2000* (**Reference 1**). The Burnett River Dam, which became operational in November 2005, is now known as Paradise Dam.

Construction of the dam was initially constrained by two conditions of approval under the *Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)*. Following the 2003 listing of the lungfish under the *EPBC Act* as being "vulnerable to extinction", further approval conditions were imposed, including the following which are relevant to this report:

> *3. Burnett Water Pty.Ltd. must install a fish transfer device on the Burnett River Dam suitable for lungfish. The fishway will commence when the dam becomes operational.*
>
> *4. Burnett Water Pty.Ltd. must adhere to the environmental flow requirements specified in the Water Resource Plan (Burnett Basin) 2000* (**Reference 2**) and the *Resource Operation Plan (Burnett Basin) 2003* and the *Burnett River Dam Flow Strategy for Lungfish* dated 22 May 2003 (**Reference 3**)

The Queensland Department of Primary Industries and Fisheries subsequently issued a *Waterway Barrier Works Approval & Notification to Build Fishways*, dated November 2003, and issued under State law (**Reference 4**) - a copy of the relevant section of which is included as **Attachment 1**.

The fish transfer device ultimately consisted of three devices, viz. an upstream fish lift, a downstream fishway and a flume to transport lungfish from near the spillway to the entrance to the downstream fishway, the details of which are described later in this report.

The final design of the fishway devices evolved from the conceptual stage to the as-constructed stage in response to the recommendations of several reports and reviews.

Wet testing of the upstream fishway has been completed and some monitoring of its performance has been undertaken and reported upon but there appears to have been only a few successful upstream transfers of lungfish to date.

While wet testing of the downstream fishway was unable to be undertaken until after the dam recently filled to a level sufficient for the downstream fishway to become operable, there has only been a quite limited amount of monitoring data available for its effectiveness to be assessed at this stage.

The water level in the dam has yet to reach a point where an incipient flow over the spillway has occurred or where the water level has reached the flume constructed to transfer fish from the right hand side of the spillway to the downstream fishway. Thus there has been no wet-testing to date of the flows in the flume from inside the spillway to the downstream fishway entrance chamber, nor of its effectiveness in attracting lungfish away from the spillway.

Wide Bay Burnett Conservation Council Inc. (WBBCC) claims that the devices are not suitable for the transfer upstream and downstream of lungfish and contravene Condition 3 of the approval under the *EPBC Act.*.

WBBCC is now in litigation in the Federal Court of Australia in relation to an alleged failure by Burnett Water Pty.Ltd. to construct and operate the fishways in accordance with the above conditions and has requested the author to prepare a report to the Federal Court relating to the relevant hydrological and engineering issues which demonstrate such non-compliance.

A copy of the first and second letters of instruction from WBBCC's solicitors is included as **Attachment 2.**

1.2 Material Relied Upon to Prepare this Report

The material relied upon in the production of this report has been obtained by reference to the reports obtained by WBBCC's solicitors under Discovery and other material available to the author of this report, as listed in the report's References in Section 10.0.

The author was able to discuss ecological aspects of the fish transfer devices with environmental scientist, Mr Jim Tait and to review his report to the Court (**Reference 5**).

On 16 June 2009, the author was able to visit the site, inspect the fish transfer devices, the dam spillway, stilling basin, intake works, discharge works and the waters upstream and downstream of the dam.

On that date access to the operating manuals for the dam and fishways held in the dam control room was denied to the author and the author was unable to inspect the log sheets completed by the control room operators. For this reason, comments made in this report upon operating procedures and the site-specific data that might be used to assess the results of the DPI&F fishway monitoring reports are based solely upon what appear to be draft manuals obtained under Discovery.

1.3 Statement to the Court

This report has been prepared for the assistance of the Federal Court of Australia in the matter, *Wide Bay Burnett Conservation Council inc. v. Burnett Water Pty.Ltd.* No. QUD 319/08.

I am a consulting engineer and am the principal of the environmental consultancy Max Winders & Associates Pty.Ltd., trading as MWA Environmental. My curriculum vitae, (**Attachment 3**) detail my qualifications and experience in mechanical engineering, water engineering and environmental impact assessment.

I have made all the enquiries I consider desirable and appropriate and no matters of significance that I regard to be relevant to the proceedings have, to my knowledge, been withheld from the Court. The factual matters raised in this report are true to the best of my knowledge and the opinions stated in it are genuinely held by me.

I understand my duty to the Court in these proceedings is to assist the Court and I believe that I have complied with this duty to the best of my ability.

Signed: ______________________ Date: 22 June 2009

M.F. Winders, B.E. (Hons), F.I.E.Aust., C.P. Eng., R.P.E.Q.

2.0 BACKGROUND HYDROLOGICAL ISSUES

2.1 Explanation of water releases from the Paradise Dam

The fishways installed on the Paradise Dam require flowing water to operate and to be efficient and practicable, the use of water to operate the fishways should be integrated into the overall operation of the dam. To be able to integrate the fishways into the overall operation of the dam, it is necessary to understand the purposes for which water is released from the dam, how these releases occur, and their timing.

Water is released from the Paradise Dam for two main purposes:

- **Human-use** for irrigation of agricultural crops, urban water supply, and industrial use.

- **Environmental flows** to maintain the ecosystems associated with the Burnett River, including, in part, lungfish.

In this context, note that dam operators and water regulators typically measure water releases in megalitres (ML). An Olympic sized swimming pool holds 2,500,000 litres or 2.5 megalitres.

The Paradise Dam has a main water outlet through which water can be released via two mechanisms (Anon 2002, BUR.002.001.0978):

- a low level outlet that can release up to 1550 ML/per day; and

- a high level outlet that can release up to 10,400 ML/day.

Operating together, the main water outlet can release up to 12,000 ML/day, which is a considerable amount of water and is equivalent to flood conditions in the Burnett River. Figure 5 shows pre and post-dam flows on the Burnett River. It indicates that flows exceeding 12,000 ML/day are relatively rare and are exceeded only around 5% of the time. However, floods in the Burnett River can exceed flows of 100,000 ML/day. The maximum instantaneous flow recorded in the Burnett River was 1,413,681 ML/day at Walla Gauging Station in January 1890 and peak flows of 250,000 ML/day are expected to occur every 10 years on average (**Reference 6**).

The closest gauging station to the dam is Figtree, 12 km downstream of the dam wall. Average daily flow at Figtree with the construction of dam was expected to range between 12,523 ML/day in February to 615 ML/day in August (**Reference 6**). Prior to the dam average annual flows at Figtree were 1,233,484 ML/year (**Reference 6**). Following construction of the dam average annual flows at Figtree were expected to be 1,199,999 ML/year (**Reference 7**).

When constructed the dam was expected to yield around 130,000 ML/year for human uses, which is around 10% of the mean flow. The difference between the mean flow and the yield for human use is due to most water released from the dam ultimately forming environmental flows to maintain downstream ecosystem functions such as wetlands and estuaries at the mouth of the Burnett River. Some water is also lost from the dam due to evaporation and seepage. Annual releases from the dam (including for human use and environmental flows) are expected to average around 1,199,999 ML per annum, with minimum releases of 96,834 ML per annum and maximum releases of 12,607,200 per annum (**Reference 6**).

The dam reservoir has a storage capacity of 300,000 ML. When the dam is full the water level in the dam reservoir reaches EL 67.6 m. When water in the dam exceeds the full supply level, it is released over a stepped spillway constructed as an integral part of the dam and discussed further below (see Figures 1, 2(a), 2(b) and 15(b)).

Water can also be released from the Paradise Dam through the upstream and downstream fishways, although in relatively much smaller volumes. Between February and April 2009 the logs of releases via the upstream fishway indicated that around 30 ML/day was required to operate it for 24 hours. For the same period the downstream fishway operated with releases around 20 ML/day. To operate both fishways, therefore, releases around 50 ML/day, although this amount can be varied. If both fishways were operated each day releasing 50 ML/day in total, the annual releases from the fishways would be around 18,250 ML, which is a very small fraction of the amount of water that is released from the dam each year.

In summary, water can be released from the dam for either human-uses or environmental flows in any of five ways via the:

- Downstream fishway – requiring around 20 ML/day to operate based on operational logs for February to April 2009;
- Upstream fishway – requiring around 30 ML/day to operate based on operational logs for February to April 2009;
- Low level outlet (irrigation release) up to 1550 ML/day;
- High level outlet (environmental release) up to 10,4000 ML/day;
- Stepped spillway for flows exceeding 12,000 ML/day (or lower if for some reason the main water outlets are not operated at capacity).

As a general rule, the dam operator releases water from the dam in two circumstances, either:

- when it is required by downstream users (i.e. the water is sold and released downstream for delivery to purchasers); or
- as required by law to satisfy environmental flow requirements.

It is important to realise that downstream human users of water from the dam can be supplied with water via the fishways and, therefore, water released through the fishways can serve both a normal operating (i.e. commercial) purpose and an environmental purpose. If water is scare, such as in the recent time of drought, it makes operational sense if any releases are made through the fishways to serve these dual purposes. It is inefficient to see releases via the fishways as only “environmental flows” when they can serve to deliver water for downstream human-users perfectly well if only small amounts of water are required or the water can be delivered over an extended period.

Water released from the dam flows downstream to the Ned Churchward Weir, where it can be held before release to the major human-users downstream in Bundaberg and its surrounding agricultural areas. As the Ned Churchward Weir provides further potential to control water released downstream from the Paradise Dam, there is no reason in principle why the relatively small releases via the fishways cannot be used to deliver water for human uses over an extended period in preference to “slugs” of water being released via the low or high level water outlets. For this reason, it is sensible to use the fishways to release as much water as they require for optimal operation when the dam operator wishes to deliver water for downstream commercial users.

2.2 Relevant Commonwealth and Queensland laws

The dam operator is constrained not only by the conditions of the EPBC Act approval, noting that condition 4 requires environmental flows to be released, but also by Queensland law controlling water management.

The relevant Queensland laws, plans and licences controlling water management applying to the Paradise Dam are structured in the following hierarchy:

- The *Water Act 2000* (Qld) provides overarching legislation controlling water management in the State, including water infrastructure and planning;

- The *Water Resource (Burnett Basin) Plan 2007*, which replaced the *Water Resource (Burnett Basin) Plan 2000*, provides a plan for sustainable water management and establishing water allocations in the Burnett Basin;

- The *Burnett Basin Resource Operations Plan 2008*, which replaced the *Burnett Basin Resource Operations Plan 2003*, provides detail for implementing the *Water Resource Plan*, including infrastructure operating rules and monitoring requirements;

- A Resource Operations Licence issued under the *Water Act 2000* provides specific authority for the holder to interfere with the flow of water to operate the Paradise Dam.

It is not my role to examine the legal issues surrounding the relationship between the Commonwealth and Queensland laws controlling the operation of the Paradise Dam. However, I will summarise the relevant provisions of the Queensland laws as I understand them to explain the how they affect water releases from the dam. As a preliminary issue, however, reference needs to be made to IQQM modelling, which forms the scientific basis for water planning in the Burnett Basin.

2.3 Environmental Flows & Their Description Using IQQM Modelling

The matters which address the conditions of approval of the Paradise Dam and its fishways refer to the concepts of "environmental flows", "hydrological models" and the "IQQM model". Brief descriptions of these terms are given below to assist in the understanding of references to these terms in the hydrological assessments described later in this report.

At a 2007 Brisbane International River Symposium *environmental flows* were defined as "describing the quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihoods and well-being that depend on these ecosystems". In this instance the lungfish population of the Burnett River is an important component of the freshwater ecosystem, as are the waters upstream and downstream of the dam.

A *hydrological model* is a computer program that simulates the stream flow in a freshwater river system and creates a daily water budget for the whole length of the stream.

The *IQQM model* of the Burnett River basin is a hydrological model and associated statistical analysis and reporting software that simulates ...*daily streamflows, flow management, storages, releases, instream infrastructure, water diversions, water demands and other hydrologic events in the plan area.* A summary description of the Burnett River IQQM model, as extracted from **Reference 5**, is included as **Attachment 4**.

The software is recognised for its ability to model environmental flow conditions ... *including the maintenance of riparian flows and transfers between reservoirs constrained by environmental flows and fish passage requirements* (**Reference 4**).

2.4 Approval Conditions Relevant to the Assessment of Environmental Flows

The 2003 approval under the *EPBC Act* required:

> *Burnett Water Pty.Ltd. must adhere to the environmental flow requirements specified in the Water Resource Plan (Burnett Basin) 2000 and the Resource Operations Plan (Burnett Basin) 2003 and the Burnett River Dam Flow Strategy for Lungfish dated 22 May 2003.*

2.5 Relevant Sections of the Water Resource Plan (Burnett Basin) 2000 (Reference 1)

Extracts from the WRP relevant to the matter are included as Attachment 5.

The WRP of 2000 may be regarded as the basis for the location, design and mode of operation of the dam and its associated structures.

As such, it is considered that the following extracts from the WRP are relevant to the transfer of lungfish upstream and downstream at the dam:

- General Outcome (e) of the WRP required water to be managed and allocated to provide for community aspirations about matters which included ….*(iii) protecting species of significant conservation value, including, for example, lungfish and turtles.*

- The Ecological Outcomes for the WRP area required that water …. *is to be managed and allocated –*

  (a) to maintain pool habitats, and native plants and animals associated with the habitats, in watercourses; and

  (b) to maintain long term water quality suitable for riverine and estuarine ecosystems; and

  (c) to provide flow regimes that favour plants and animals associated with water courses and riparian zones; and

  (d) to provide wet season flow to benefit native plants and animals, including, for example, fish and prawns, in estuaries; and

  (e) to improve stream flow conditions to assist the movement of fish along water courses.

- *The IQQM computer program's simulation for the simulation period for surface water is used to assess consistency with the environmental flow objectives…..*

  (In this case the simulation period extends from 01/01/1890 to 30/06/1997)

The WRP refers to the concepts of "water project areas", "subcatchment areas" and "nodes", in which a node is defined as ….*a place on a watercourse in the plan area….*

For the purposes of the WRP, the nearest “node” to the Paradise Dam is Node 2, described in Schedule 4 as …*Burnett River at Figtree gauging station (AMTD 119 km)..*at a point approximately 12 km downstream from what is now the dam site.

Division 2 of the WRP lists the following relevant environmental flow objectives for the various nodes in Schedule 5 of the WRP, in which it is stated for Node 2 :

(1) *….the percentage of the total number of days in the simulation period when the daily flow is less than 2 ML should be between the minimum and maximum percentages ….2% min. and 20% max.*

(2) *….the 50% daily flow exceedance stated for each month for the node should be equalled or exceeded between 32% and 68% of the total number of days in the month in the simulation period…..*varying from 101 ML/day in September to 976 ML/day in January in the case of Node 2.

The WRP also sets “medium to high flow objectives” to be achieved in developing the Resource Operations Plan. It is considered that the nature of the parameters so defined, being related only to relative changes either to long term annual average flows or to minor flood flows, are not particularly relevant to the fishway issue because the matters of ecological importance are the timing and duration of flows and water levels on a daily, monthly or seasonal basis rather than gross percentiles calculated for the 107 year simulation period.

It is surprising then that these “medium to high flow objectives” are the only key indicators referred to in the *Burnett River – Flow Strategy for Lungfish.*

2.6 Relevant Sections of the Resource Operations Plan (Burnett Basin) 2003 (Ref. 2)

The ROP was issued in 2003. Extracts from the ROP relevant to this matter are included as **Attachment 6**.

Attachment 3.1 of the ROP …*shows the linkages prescribed by the WRP and the relevant ROP rules that are to achieve the outcomes and also lists examples of monitoring that will be undertaken to assess if the outcomes are being achieved, e.g.*

> *6(e)(iii): protecting species of significant conservation value, including, for example, lungfish and turtles.*
>
> > *ROP Rules: Operating rules require releases to be made in a way that supports a more natural flow regime.*
> >
> > *Monitoring: Ecological outcome monitoring will support assessment of this outcome.*
>
> *7(f): Water is to be managed and allocated to improve stream flow conditions to assist the movement of fish along water courses*
>
> > *ROP Rules: Operating rules state the requirements for the meeting of EFOs and the operation of fishways.*
> >
> > *Monitoring: Records detailing periods of fishway operation will help assess if fishways are being operated at the appropriate time of year and long enough for fish to move upstream. Fish community structure monitoring will help determine if the movement of fish is occurring throughout the basin.*
>
> *11(2): Water in the Burnett River is to be managed and allocated to provide for lungfish habitat in the river particularly lungfish habitats downstream of Gayndah at AMTD 200 km*

> *ROP Rules: Operating rules for Ned Churchward Weir require that water levels suitable to promote aquatic vegetation (macrophytes) survival are maintained, so that they are available for lungfish breeding.*
>
> *Monitoring: The extent of aquatic vegetation (macrophytes) in the ponded area of Ned Churchward Weir will be measured. The water level in Ned Churchward Weir will be recorded daily.*

Attachment 3.3 of the ROP deals with the monitoring of natural ecosystems. There is no specific requirement for monitoring lungfish, except as included as "fish", the ROP requiring collection of fish data annually at specified sites which include:

- Gayndah (AMTD 203)
- Figtree Creek (AMTD 119) and
- Ned Churchward Weir Tailwater (AMTD 74.1)

2.7 Review of the Burnett River Dam Flow Strategy for Lungfish (Ref.4)

A copy of the Strategy is included for reference as **Attachment 7.**

The strategy merely adopts those environmental flow objectives of the WRP which are related more towards allowing the post-development medium to high flow regime to differ from the "natural" flow regime by an empirically determined, small but significant percentage when considered against the life cycle of a lungfish.

The criteria are exactly the same (see **Table 1** below).

Table 1: Comparison of Environmental Flow Objectives

Flow Objective (> or =Pre-dev.value)	WRP 2000	Lungfish Flow Strategy
Mean Annual Flow	81%	81%
Annual Proportional Flow Deviation	2.1	2.1
1.5 yr ARI daily flow volume	74%	74%
5 yr ARI daily flow volume	71%	71%
20 yr ARI daily flow volume	82%	82%
Flow Regime Class	Late Summer	Late Summer

The explanation of the *Strategy* makes no reference to how it avoids potential impacts on the life cycle of individual lungfish, the population dynamics upstream or downstream of the dam, nor the survival of a sustainable genetic pool.

The nature of the objectives embodied in the *Strategy* indicates that Burnett Water, by merely copying the geomorphological environmental flow objectives of the WRP and not identifying ecological objectives appropriate to the survival of the lungfish, has failed to recognize the submissions made under the *EPBC Act* and the conditions which were subsequently applied.

A June 2000 report to the Department of Natural Resources (**Reference 7**) detailed how proposed environmental flow measures should be assessed. It referred to "medium and high flow indicators" as well as to "low flow indicators". Significantly, it is noted in the report (p.10) that:

> *The impact ratings used in the development of the environmental flow performance measures do not take into account any special conservation values of particular river or stream reaches. In the case of reaches which have high conservation values, it may be appropriate to set higher environmental flow limits than the basin-wide limits.*

It is considered that this qualification is one that should have been considered when setting the environmental flow objectives for the *Strategy* as this would have identified the flow constraints to the successful operation of both the upstream and downstream fishways at the Dam and the extent to which spillway flows might create mortalities.

It will be shown later how the available IQQM modelling could have been used to develop the *Strategy* into a form in which appropriate design rules for the fishways would have been provided, while the results of subsequent monitoring of lungfish movements could have been used to modify the operating rules governing flow releases such that the future operation of the fishways would achieve the expectations of the approval conditions.

2.8 General Comments Regarding Validity of Hydrological Data

Two sets of hydrological data are available for review in assessing the potential and actual hydrological impacts of the fishways, viz:

- actual flow data at stream gauging stations on the Burnett River, particularly those at Figtree some 12 km downstream of the Paradise Dam (see **Attachment 8**)

- simulated dam water levels and flows at the dam site and downstream at Figtree obtained by IQQM modelling over the period 1890 – 1996, as discussed later in this report.

While the stream gauging information allows comparisons to be made with the stream flow regime prior to the dam's construction over a quite lengthy period there is only a relatively short period since the dam has been constructed and for its flow release strategies to be consolidated for comparison with the results of monitoring of lungfish movements to be assessed and reported upon.

The currently available reports upon monitoring the performance of each fishway (**References 7-10**) have been considered principally upon irrigation release outflows of less than 100 ML/day whereas the IQQM modelling for environmental flow performance monitoring has been based principally on flows in the range 1000 ML/day up to 100,000 ML/day.

This brings into the consideration the validation of the IQQM model against pre-dam stream flow monitoring which has been reported upon in an independent review of the IQQM modelling (**Reference 5**) and which shows the model to be poorly calibrated when flows at the Walla stream gauge are less than 100 ML/day (ref. Appendix 2 of **Reference 5**).

3.0 THE PARADISE DAM & ASSOCIATED POTENTIAL HYDROLOGICAL IMPACTS

3.1 Relevant Details of the Paradise Dam and its Upstream and Downstream Reaches

3.1.1 Dam Site & Construction Details

Paradise Dam, formerly known as Burnett River Dam, has been constructed at 131.2 km AMTD, approximately 80 km southwest of Bundaberg and 35 km north-west of Biggenden.

Details of the construction of the dam and its water management structural details, as provided by others, are included as **Attachment 9** of this report.

A view from downstream of the dam wall, its abutments, long spillway, stepped face and water release channel is included as **Figure 1** of this report.

The base of the dam is at approximately RL 30m while the spillway is 37 metres above the stilling basin (refer to details in **Attachment 9**). As has become the practice with large dams constructed from roller compacted concrete, the dam has a stepped face to absorb energy as the dam overflows, apparently to minimise the dimensions of the stilling basin and consequently reduce capital costs (**Reference 12**).

It is considered that the integration of a stepped face into the dam increases the risk of lungfish injury and mortality significantly more than that which might have been expected from a dam with a smooth face and increases the need for the current capability of the downstream fishway to be significantly extended, as discussed later in this report. This issue was considered in the 2004 review of the design, operation and management of the Burnett Dam Fishway (**Reference 13**).

There are indications (**Reference 13**) that, at the design stage, the proposed height of the Paradise Dam was at the higher end of previous practice with regard to the use of stepped face dams as alternatives to dams with smooth spillways.

Views of the stepped face of the spillway and stilling basin are provided as **Figures 2(a) & 2(b)** of this report.

3.1.2 Dam Design Parameters

The dam has a design capacity of 300,000 ML and would be expected to supply water downstream for irrigation and other uses suitable for an allocation of 130,000 ML/yr.

The release of waters from the dam is carried out in accordance with the *Resource Operations Plan* and, as such, the releases depend upon the time varying demand for water from principally irrigators and upon the availability of water in the dam storage.

The manner in which flows are released from the dam is described in Section 3.2 below.

3.1.3 Details of the Upstream Reaches

Details of the dam catchment, influent streams and catchment hydrology are summarised in **Attachment 10** of this report.

Potentially, the dam can inundate some 3000 ha of essentially riverine habitat extending some 45 km upstream, including habitat which is considered important to the life cycle of the Queensland Lungfish (**Reference 14**).

Views of the current level of inundation caused by the dam are included with this report as **Figures 3 & 4**.

From information provided within **Reference 14** and as indicated in the views of the right and left hand banks of the storage, the northern bank of the dam upstream of the dam probably provides better habitat for lungfish than the southern bank.

Such considerations suggest that the fishways should have been located on the northern side of the dam rather than adjacent to the release intake structure near the southern bank.

3.1.4 Details of the Downstream Reaches

The reaches downstream of the dam are typically comprised of long pools, riffles and bars until the impounded areas upstream of the Ned Churchward Weir is reached and where the aquatic habitat become lacustrine rather than riverine.

The nearest stream gauging station downstream is at Figtree, some 12 km downstream of the dam wall.

Irrigation and environmental flow releases are via a long,, concrete-lined channel, approximately 10 metres in width along the southern channel of the former channel at the dam site. (**Figure** 1).

As such, it does not provide any natural habitat for lungfish travelling upstream to the upstream fishway nor downstream from the downstream fishway to above the dam.

Water overflowing from the stilling basin at the base of the dam spillway, is discharged virtually as an overland flow into the former river valley but on the northern side of the irrigation and environmental flow release channel.

3.2 Water Resource Management Provided via the Paradise Dam

The fundamental aim of the dam is to store water for controlled release downstream to supplement the availability of the water downstream for irrigation purposes from downstream weirs. Further details of the manner in which waters of the dam are required to be released are obtainable from **Reference 2** and from the operating manuals held in the dam Control Room to which the author has not had access to date.

Access to details of the irrigation water release strategy would assist the author of this report in addressing the detailed hydraulic assessment of such releases on the effectiveness of the attraction flows used in association with both the upstream and downstream fishways.

It is indicated that water drawn in from the intake tower may be discharged as environmental flows, irrigation releases or fishway flows.

Irrigation flow releases of up to 1550 ML/day can be made through dispersion chambers into the release channel downstream of the dam wall, while environmental flow releases of up to 10,400 ML/day can be separately released into the channel as indicated in **Figure 16(b)**.

Attraction flows into the upstream fishway and flows released from the downstream fish lock also discharge into the above release channel in the locations indicated in **Figure 16(b)**. It is thought that the combined fishway flow rate could reach 14 ML/day.

This issue is discussed later in this report.

Information has been received from Burnett Water regarding their irrigation releases since the dam has been in operation but has yet to be analysed for comparison with the 1550 ML/day apparent maximum release rate nor comparison with fishway operation and fishway release rates.

It is understood that there have been no significant environmental flow releases made since the dam was commissioned.

Both **Reference 1** and **Reference 2** detail the manner and the extent to which environmental flows are proposed to be released downstream into the flow release channel.

Because, as indicated above, it is expected that environmental flows released through the dam wall are likely to be larger than the irrigation flows, these flows are likely to have more impact upon the effectiveness of fishway entrance attraction flows than irrigation flows.

More information is required upon the operational rules regarding the release environmental flows through the dam before this matter can be addressed in hydraulic terms.

However, consideration of the results of the IQQM modelling of the extent of the flows as a composite of environmental flow releases and spillway overflows against spillway flow data (**Attachment 14**) and the environmental flow requirements detailed in the *Resource Operations Plan* and the *Flow Strategy for Lungfish* suggests that the most significant environmental flows are those which occur during spillway overflow events and therefore, to some extent, by dam level management.

The relevance of this to managing the extent to which the downstream fishway might be managed to reduce the risk of lungfish mortalities during spill events is discussed later in this report.

3.3 Potential Hydrological Impacts of Dam Wall on Flows Downstream of the Dam Crest

3.3.1 Impact of Dam on Levels and Incidence of Major River Flows

The following information has been extracted from IQQM files made available for analysis by MWA Environmental.

Figure 5 compares the percentage exceedance curves derived by IQQM modelling for the pre-dam and post-dam scenarios. It may be seen that, when averaged over the period 1890 – 1997, there would be very little reduction in the occurrence of daily flow rates passing the dam site in the range of flows greater than 100 ML/day.

This is due to the relatively frequent flooding events which might yield more than 100,000 ML and cause the dam waters to overflow the spillway for a considerable period of time.

Figure 6 has been provided to give an indication of the frequency and peak flows of a range of flood events covering the period of simulation

The daily flow sequences for each scenario for the period of flow simulation are compared on a compressed scale in **Figure 6** and this identifies that the dam makes only relatively minor reductions to the frequency of flood flows downstream.

Thus the dam is unlikely to change the incidence of major flood events downstream of the dam, except that it will reduce the flood peak flows and the volumes of water released in a flood event.

To this extent, the dam impacts upon the natural flood pulses downstream, particularly those at the lower end of the scale which occur more frequently and would be expected to stimulate fish migrations. These limitations are discussed below.

3.3.2 Impact of Dam on Environmental Flows

The *Resource Operations Plan*, at first glance, appears to adequately provide for the maintenance of flood pulses downstream of the dam. However the *ROP* applies only down to a 1.5 yr annual recurrence interval flood event which might be considered from **Figure 5** and Table 6 of the *ROP* as being approximately 38,000 ML/day and, as shown on **Figure 5** to apply to only a quite small percentage of the time over a 107 year simulation period.

In terms of percentage compliance with the *ROP* it might be seen that having a 10,000+ ML/day environmental flow release capacity (plus 1550 ML/day of irrigation flows), frequent spillway overflows, as identified later in this report, could readily make up the difference and satisfy this statutory constraint which has not been derived from considerations of lungfish biology.

Figure 7 provides a better example of the extent to which the frequency of occurrence of environmental flows relevant to lungfish biology might be reduced by the dam. It shows that the dam has already reduced the frequency and flows of flood events having peaks of < 2000 ML/day, i.e. flows which likely to signal to migratory fish that a flood pulse has commenced.

As there is already a 12,000 ML/day capacity built into the dam's environmental flow and irrigation flow release capacity, it is questionable why the environmental flow release from the dam has not already been used to replicate minor flood pulses whenever the upstream migration of lungfish might have needed to be stimulated.

It is however quite likely that the environmental flow release mechanism or the irrigation release mechanism could be used to provide the 2 ML/day minimum daily flow as required by the *Resource Operational Plan* at all times if the total of the fishway releases is incapable of providing this flow.

The other constraint on environmental flows is that of the 50% daily exceedance tables (Table 2 of Schedule 5). However these are only in the range 101 ML/day to 1108 ML/day and from 101 ML/day to only 244 ML/day during the potential upstream migration period of August to November each year.

Figure 8, which compares the downstream flows at the dam site for flows of less than 500 ML/day is a further demonstration of the impact of the dam resulting from attenuating environmental flows likely to be of ecological rather than geomorphological significance.

3.3.3 Impact of Dam on Low Flows Downstream of the Dam

A significant impact upon the downstream flow regime, which might be seen to be beneficial, is that the resultant flows from irrigation releases generally increase the low flow rates in the river downstream of the dam during dry periods when the irrigation demand is greatest.

This is evident from **Figure 9** which compares predicted flows in the range 0 – 100 ML/day and indicates that, with the anticipated level of demand for water, the downstream flow could be maintained in excess of 20 ML/day for more than 98% of the simulation period.

3.3.4 Impact of Dam upon Duration and Frequency of Downstream Flows and Periods of No or Little Flow

The potential for these flow variables to impact upon the life cycle of the lungfish population has been identified in **Reference 14**.

A time-series analysis of hydrological data produced by IQQM modelling has been subject to a “spells analysis” by Mr. Steve Burgess and a copy of his report on this issue is included for reference as **Attachment 11** of this report.

Figure 1 of **Attachment 11** identifies the years and months when ...”the predicted releases from the dam would be less than 14 ML/day during when the fish ways would not be expected to be operated”.

Figure 2 of **Attachment 11** identifies those seasons and periods during which “cease-to-flow” events would occur and “during which connectivity between pools in the vicinity of the dam wall site would be broken.

It is considered that the conclusions reached in **Attachment 15** provide information additional to that which is presented in the preceding sections of this report and would be useful when considering the future operation of the fishways at Paradise Dam in response to the results and analysis of lungfish monitoring data.

3.4 Potential Physical Impacts of Dam Wall upon Waters Upstream of Dam Wall

3.4.1 Inundation of Upstream Reaches

Figure 10 shows the percentage of time during the 107 year simulation period when the water level at the dam exceeds various levels, ranging virtually from the base of the dam at approximately RL 44 m to the spillway overflow levels of approximately RL 69 m.

It shows that inundation of the river’s pre-dam reaches and floodplains would occur for most of the time with the water level exceeding RL 60 m for 85% of the simulation period.

Figure 11 shows a time history of dam levels and indicates the relatively long amount of time that the water level would exceed RL 60 m and that this would only be broken infrequently and for relatively short duration during dry periods.

It also shows that the water level in the dam would be close to spillway level or overflowing for quite long periods, causing the inundated area becoming lacustrine rather than riverine in nature with attendant ecological impacts.

3.4.2 Potential to Decrease Depths & Inhibit Downstream Fish Movements

Also indicated on **Figure 10** is the lower limit of operation of the downstream fish lift at RL 62.5 m, as well as the level to which the entrance into the downstream fishway would need to be lowered for that fishway to give 95% availability to the downstream movement of lungfish, i.e. as considered to be roughly equivalent to that which existed prior to the construction of the dam.

Significantly, with respect to the operation of the currently constructed downstream fishway, the level would be lower than the RL 62.5 m entrance to the downstream fishway for 22% of the time over the 107 yr span of the IQQM modelling.

Figure 12 is a representative selection of the modelled dam water level history for the period 1976 to 1995. It shows how the water level would have been lower than RL 62.5 m for periods of one to almost three years on three occasions during that 20 year simulation.

It also shows how the potential impact upon the duration of such low flows at the entrance to the downstream fishway could be reduced if the entrance to that fishway was lowered to RL 50 m and reach approximate fish passage equivalence in this regard to the pre-existing river channel.

Figure 1 of **Attachment 11** shows the result of a "spells analysis" of the IQQM data, indicating the frequency and duration of those periods of the simulation during which the predicted dam water level would be less than the downstream fishway entrance level.

3.4.3 Potential for reduced water quality upstream of dam wall

A major change associated with transforming a riverine environment to a lacustrine environment arises out of the reduced mixing with depth that occurs in the latter case and leading to the formation of a thermocline.

Waters above the thermocline are generally warmer and less dense than the deeper waters below the thermocline. Also, because the deeper waters are less able to access the oxygen in the air above the lake but are adjacent to sources of de-oxygenation, the dissolved oxygen levels in the lower level can become lower than that necessary for the survival of many fish species.

It is common in lakes that a lake "turnover" occurs during late autumn when the surface waters cool faster than the waters below and become denser, requiring only a small amount of wind stress to cause the lake water to turn over and bring the de-oxygenated water to the surface.

In a filling dam, recently drowned organic matter increases the rate of de-oxygenation and the potential impact when the water level is sufficient for a thermocline to develop. It is possible that a reported fish kill upstream of Paradise Dam in April 2006 may have been the result of such an incident.

Having regard to the time-history of simulated dam water levels from 1976 to 1995 as shown in **Figure 12**, it is considered that there may have been several periods when the dam water level fell below RL 60 m that could have been conducive to significant de-oxygenation and lake turnover adversely impacting upon the water quality of the dam.

3.4.4 Potential to Increase Depth of Water to Levels at which Spillway Overflows Occur

Reference to **Figures 10, 11 & 12** highlights the frequency and duration of those periods when the water level in the dam may sufficient to cause overflows. The crest level of the spillway is RL 67.9 m AHD. The IQQM model shows that it exceeds this level some 20% of the time – mainly during late summer but often during other months.

This issue has been expanded upon in the "spells analyses" included as **Attachment 11**. Figure 1 of the analysis displays the "spells during which the predicted water level in the dam is above the spillway level of RL 67.6 m, thus presenting a risk of lungfish being carried over the spillway.

4.0 PROVISIONS MADE FOR FISH TRANSFER AT PARADISE DAM

4.1 General Description of the Fish Transfer Facility

There are two mechanisms which are operated independently, the downstream fish lock and the upstream fish lift.

Each has been made integral into the dam wall construction.

It is understood that the devices have been designed to allow for fish, particularly Lungfish, to move upstream for spawning via the "fish lift' and then downstream via the "fish lock".

The nature of the devices is such that they are only be used intermittently, rather than continuously and it appears that it may not be feasible to make them work automatically and unattended. There is a potential that continuous but batchwise operation of the devices would be advantageous on a 24/7 basis during the seasons in which they would be required to be most effective.

It is understood that the devices were designed by the Queensland Department of Primary Industries. Relevant reports and other documentation describing the upstream and downstream fishways and how to operate are summarised in **Attachment 12**.

4.2 Upstream Fish Lift

A lift style of fishway is used to provide passage for upstream migrating fish at Paradise Dam – reportedly the first of its type in Australia.

The fish lift, as described and shown in an extract from the DPI&F 2008 upstream fishway monitoring report (**Reference 8**), is included as **Attachment 13.**

The fish lift operates through three phases, viz:

- the attraction phase - in which a flow of dam water is released into an approach channel below the dam and fish enter the hopper;
- the lifting phase - in which the hopper is lifted up the downstream face of the dam, transferred across the crest of the dam and lowered into the water below;
- the exiting phase – during which the bottom of the hopper is opened and the hopper is lifted out of the dam.

Photographs of the fishlift hopper relevant to this assessment are included as **Figures 13(a) & (b)** of this report. Photographs relevant to the hydraulic assessment of the entrance slot and hopper attraction flows are included as **Figures 14(a) & (b).**

The timing, frequency and duration of upstream fishlift operation has yet to be confirmed and is expected to be varied in accordance with the results of further lungfish passage monitoring.

There are other variables which may be adjusted in response to the results of monitoring – principally the velocities and patterns of attraction flows into the entrance channel and hopper.

The river flow constraints to the upstream fish lift appear to be that the river flows and water levels downstream of the dam would need to be conducive to fish species wishing to move upstream into the irrigation release channel and thence into the entrance channel.

It is evident that the downstream flows and velocities need to be maintained sufficient to allow the fish to swim upstream but not so high that the velocities would significantly inhibit swimming against the flow in riffle sections and the above channels.

There is also a need for continuity of water in the channels connecting the low flow pools during those periods when lungfish are likely to move upstream and into the upstream fishlift.

The potential for the developed river flow regime to limit the successful use of the upstream fish lift is discussed earlier in this report.

However, by reference to the reports on monitoring of the operation of the fishway (**References 8 – 11**), it would appear that the optimum pattern of attraction flows into the device is one of the critical non-hydrological issues controlling its effectiveness – particularly with assisting in the migration upstream of lungfish.

4.3 Downstream Fish Lock

The fish lock, as described and shown in an extract from the DPI&F 2008 downstream fishway monitoring report (**Reference 9**) is included as **Attachment 14**.

The downstream fish lock also operates through three phases, viz:

- the attraction phase – in which the entrance gate is opened at a specific water level in the dam and an attraction flow is permitted through the lock by opening either the exit gate or a valve on the flushing line;
- the draining phase - during which the water in the entrance chamber is lowered through a 1.2m standpipe and then a 0.75m pipe leading to the exit gate at a 1% slope;
- the exiting phase –during which the exit gate is opened quickly to drain the sloped pipe into the exit chute and then into the stilling basin.

Photographs showing the entrance to the downstream fish lock are included as **Figures 15(a) & (b)** while those showing the details of the lock's discharge into the dam's flow release channel are included as **Figures 16 (a) & (b).**

The hydrological constraints to the successful operation of the downstream fishlift appear to be:

- dam water level **-** as the slide gate into the entrance chamber only operates for dam water levels between EL 62.5m and EL 67.9m, as discussed in Section 6.1 of this report;
- inflows into the dam of sufficient size and duration to induce fish to move downstream from the upper reaches; as discussed in Section 6.2 of this report;
- water levels and flows in the shallow reaches downstream of the dam to ensure that fish transferred downstream can reach suitable habitat, as discussed in Section 6.3 of this report;
- minimizing the risk of entrapping fish in flows over the dam spillway by providing sufficient attraction flows into the lock entrance chamber, as discussed in Section 6.4 of this report.
- Availability of access to the entrance to the fish lock such that lungfish can escape downstream from de-oxygenated water conditions following lake turnover events.

There is also a need to ensure that the flow regimes within the various components of the downstream fish lock are not such as to risk injury or mortalities to the larger fish, particularly lungfish, as discussed later in this report.

4.4 Flume from Spillway to Downstream Fish Lock

4.4.1 Need to Transfer Fish from Upstream of the Spillway to the Downstream Fish Lock

This is a fish transfer device which has not been able to be tested to date because the dam has not reached the zone in which it might operate.

Photographs which indicate the potential for death or injury to lungfish being carried over the spillway, hitting some or all of its 50 steps and hitting the base and edge of the stilling basin may be gauged by reference to the photographs included as **Figures 17(a) & (b)** of this report.

4.4.2 Design of the Flume from the Spillway to the Downstream Fishway

The requirements of this flume were previously described in the 2004 document, *Burnett River Dam – Design, Operation & Management of the Burnett Dam Fishway* (**Reference 13**).

With regard to the maximum operating range of the downstream fishway (fish lock) it states in Section 2.1:

> *The upper limit of the fishlock is at EL 67.9 or 0.3 above FSL. At that stage about 100 m^3/s will discharge over the ungated spillway crest rendering the attraction flow to the fishlock ineffective.*

Then, in Section 2.3, it states:

> *For downstream fish movement, the head differential between the reservoir and the water level in the fishlock provides a current to attract fish into the fish lock. The skewed alignment of the fine screens of the adjacent irrigation intake also aids in leading fish towards the fishlock entrance.*

In Section 2.4, with regard to maximising fish attraction into the fishlock

> *....at a time when the reservoir is near spilling point, a lead in channel is provided between the right-hand side of the spillway and the back of the fishlock.*
>
> *Prior to the onset of spillway operation or, whilst the surcharge over the spillway crest is still low enough to prevent fish from going over the spillway, fish are encouraged by the attraction flow into the lead-in channel to enter the channel, from which they cannot return and must pass through the fishlock.*

Photographs showing the location of the lead-in channel flume with respect to the spillway crest and the inlet to the fishlock are included as **Figures 15 (a) & 15 (b)**.

At the time of writing this report there was no information available to the writer of the detailed dimensions of the flume nor the attraction flow that it was intended to produce.

5.0 ASSESSMENT OF PERFORMANCE OF UPSTREAM FISHLIFT

5.1 Constraints Caused by Conditions Downstream of Dam

5.1.1 Constraint on Use Due to Very Low Flows Downstream

Lungfish will be constrained from moving upstream to spawn if the flow in the river downstream of the upstream fish lock is too low for hydraulic connectivity between the pools in the river and the stilling basin which forms the entrance into the fish lock, as required by Sections 7(f) and 11(2) of the ROP 2003.

The environmental flow objectives of *WRP 2000* require that, for the simulation period, the percentage of days in which the daily flow is less than 2 ML/day should be between 2% and 20%.

A review of the results of the IQQM modelling shows that the dam could be operated to provide such flows generally as irrigation release flows.

The review also shows that the storage of water in the dam could be managed to fully satisfy the 2 ML/day minimum environmental flow objective and that low flows downstream should not be a real constraint to operation of the upstream fish lift.

However, the Operations Manual for the dam should be revised to include a procedure that would ensure minimum release flows suitable for lungfish movement upstream is maintained at all times and that the minimum flow release strategy be developed by the fisheries management experts.

5.1.2 Constraint on Use Due to Excessive Stream Flows Downstream

To maximise the effectiveness of the upstream fish lift, it is apparent that the scheduling of environmental flow releases during periods when lungfish are likely to migrate upstream should have regard to the difficulty that a lungfish might experience in moving upstream against the current in critical stream cross sections to spawn.

The long, smooth-surfaced release channel is potentially critical in this regard.

The environmental flow regime set by the *Resource Operations Plan* does not recognise this issue. It is recommended that the fisheries management experts review this aspect of the *ROP* and the *Lungfish Strategy* and modify this part of the environmental flow strategy accordingly for inclusion in the Operations manual.

5.1.3 Constraint Due to Dam Overflowing

It might also be pointed out that it would be pointless to operate the upstream fish lift if the dam was overflowing or the downstream fishway was being operated during the incipient flow period.

The IQQM simulation has predicted that dam overflows or incipient overflow conditions would occur when the dam water level is equal to or higher than RL 67.6 m. Reference to **Figure 10** shows that this is likely to be a frequent occurrence.

As a consequence, it is recommended that the seasonality of such overflow or incipient overflow conditions be further reviewed using a “spells analysis”, as has been reported upon in **Attachment 11** or similar and that the need to improve the overall effectiveness of the downstream fishway and the flume from the spillway to the downstream fishway be re-assessed accordingly.

While this scenario is significant in itself, it is considered that, at the time of overflow, the flows downstream might be excessive for the upstream migration of lungfish and this constraint should also be included in an overall review of the lungfish fish transfer provisions and management of its various aspects.

5.2 Ability to provide appropriate attraction flows at and within entrance of fish lift

Reference to the fishway monitoring reports indicates that the success rate of the upstream fish lift has yet to reach a satisfactory level and that there are concerns that the attraction flow rates and patterns at and within the entrance to the upstream fish way need to be examined more-closely.

From an engineering perspective, there appear to be mechanisms to vary this to achieve the results sought by the fisheries scientists and that the geometry and flows in this area could be modified accordingly.

5.3 Ability to provide appropriate attraction flows at and within the hopper

Similar comments may be made about varying the attraction flow rates and levels at the fish lift hopper but it would appear that most of the feasible options have been tested and have only achieved a 50% success rate.

From an engineering perspective, the options available to change the geometry and flow patterns are heavily constrained by the current form of construction and offers little hope that future structural or hydraulic modifications can significantly increase the success rate at this important section of the upstream fish lift.

5.4 Ability to operate over full range of dam water levels

As noted above the hydraulics of the upstream fishway are essentially controlled by the irrigation and environmental flow releases from the dam into the channel and riverine sections downstream of the entrance to the upstream fishway.

To the extent that such flows may be varied by managing the amount of water held in storage, the operation of the upstream fishway is not significantly affected by low water levels in the dam but would be limited by high water levels in the dam when environmental flow releases would be necessary to delay and reduce spillway overflows, e.g. above RL 67.6 m.

5.5 Limitations on system availability

In view of the apparently low success rate to date of attracting lungfish into the fish lift hopper and the need to operate during the night when lung fish are more likely to move, it is important that the fish lift be capable of operating automatically.

It is also important that a program of scheduled maintenance of all parts of this relatively complex system be instituted such that there is a high degree of system availability when the upstream migration need is greatest.

6.0 ASSESSMENT OF PERFORMANCE OF DOWNSTREAM FISHWAY

6.1 Adequacy to operate over whole range of water levels

6.1.1 Constraint Imposed by Lower Limit of Entrance to Fishway

The downstream fish transfer device consists of a lock system into which fish can enter when the dam water level exceeds EL 62.5 m.

The IQQM data concerning dam water levels over the simulation period 1890 – 1997 is displayed as a time history as **Figure 7**. From this it may be seen that the dam water level is expected to be lower than EL 62.5 m on numerous occasions, averaging approximately once each three years and frequently for more than one year and often for more than two years (**Figure 12**).

The seasonality of such occurrences would be expected to be relevant to the effectiveness of the fish lock to provide for the downstream migration of lungfish.

A statistical analysis of the percentage of days during each month when the dam water level is predicted to be lower than EL 62.5 m is shown in the following table to assist in such considerations.

Table 5: Percentage of Days Dam Water Level Insufficient

Period	**Percentage**
Jan	25
Feb	22
Mar	21
Apr	21
May	19
Jun	11
Jul	17
Aug	19
Sep	21
Oct	23
Nov	24
Dec	15
All	19.9

This is a constraint which became quite obvious during the long period that it took the dam to fill post-construction to a level of RL 62.5 m, the level required to provide sufficient attraction flow and draft at the entrance into the entrance chamber of the downstream fishway.

In summary, the hydrological analyses described earlier in this report demonstrate three matters of significance with regard to the re-occurrence of such adverse conditions over the life of the dam or the lungfish population, viz:

- the dam water level will be lower than that required for the successful operation of the downstream fishway for approximately 20% of the time;
- it is forecast that there will be periods of between one and three years duration when the downstream fishway will be inoperable due to low dam water levels; and
- this constraint has the potential to occur during the downstream migration following spawning for up to 25% of those periods;

- it would prevent the ability of lungfish to move downstream and avoid exposure to low oxygen levels in the dam waters following a lake turnover.

A review of the reports which discuss the low entrance level constraint and those engineering options which have been advanced to rectify the situation and an inspection of the facility, it is evident that there will be substantial costs incurred in rectifying this significant limitation on the downstream movement of lungfish.

It is important therefore that any decision to not carry out such rectification should first carefully evaluate the above impacts on the lungfish population of not making such a provision.

Having regard to the modelled pre-dam water flow statistics and the post-dam water level statistics, it is considered that the lower limit of entry to the downstream fishway should be at RL 50 m, which would allow the downstream fishway to be available for approximately 95% of the time and so provide equivalent fish passage opportunities to that which prevailed prior to construction of the dam.

6.1.2 Constraint imposed by Upper Level Limit of Fishway

The principal entrance slot to the downstream fishway is such that it does not extend above RL 67.6 m.. Above this level to the spillway crest level of RL 67.9 m, entry to the entrance chamber is via the flume from the spillway.

Thus there is no direct upper water level constraint to the two entrances to the downstream fishway but there is an indirect limit in that excessive levels reduce the potential to provide effective attraction flows into the entrance chamber.

6.2 Ability to provide adequate attraction flows into entrance chamber

Unlike the entrance to the upstream fish way, the velocity and patterns of attraction flows into the principal entrance to the downstream fishway are limited by dam water levels, with flow controls being subject to manipulation of the head loss between the dam waters outside and the water level maintained within the entrance chamber.

There is no information available to demonstrate how effective the operating procedures may be in attracting fish into the downstream fishway.

The location of the entrance slot is such that it may not be possible to replicate the attraction flow velocities patterns that can be achieved and measured at the entrance to the upstream fishway, adding to the difficulty that might be experienced in testing modifications to increase the sphere of influence of the attraction flows.

While it is claimed that locating the entrance to the downstream fish lock adjacent to the “skewed face” of the intake chamber has the potential to attract fish to the fish lock, the flow velocity patterns of high environmental flows into the intake chamber are considered to be likely to mask the attraction flows into the entrance chamber.

The issue of modifying attraction flows into the downstream fish lock is one that the fisheries experts should be considering with some urgency – particularly when the dam levels have risen to such an extent that the dam could reach spillway level next summer.

It is suggested that a floating barrier could be positioned to increase the effectiveness of the attraction flows that can be created into the entrance chamber of the fish lock.

6.3 Potential to convey fish downstream without injury

There is little data available to make an engineering assessment of the risk of injury or mortality to lungfish due to velocity changes in the fishway nor to water pressure changes arising out of the water level changes during passage through the lock.

These are matters which will require urgent consideration if injuries or mortalities are observed during the monitoring process.

6.4 Potential downstream constraints to operation

As the downstream fishway discharges into the irrigation and environmental flow release channel, there is a need to ensure, firstly, that there is sufficient water in the release channel to convey the released fish to the riverine sections downstream and, secondly, that those riverine sections have sufficient flows to enable the released fish to disperse downstream.

These are constraints which should be capable of being satisfied if they are recognised in the fishway operating manual and the operators are trained accordingly.

6.5 Limitations on system availability

As with the upstream fishway, the apparently limited effectiveness of individual operations of the fishway to attract fish into the fishway and the need to operate the fishway at night, requires that the fishway be capable of being operated automatically and being maintained in a condition that can be relied upon during critical periods – particularly when there are indications that a lake turnover might occur or during an incipient spillway overflow occasion and while the overflow is occurring.

It is considered that the risks of mortalities associated with such incidents are such that maintaining the downstream fishway system such that it can be relieved upon to operate automatically during these scenarios is critical to the overall effectiveness of the fishway.

7.0 ASSESSMENT OF PERFORMANCE OF FLUME TO CONVEY LUNGFISH FROM UPSTREAM OF SPILLWAY TO DOWNSTREAM FISHWAY

7.1 General Comment

As explained in Section 4.4 of this report, this flume is an essential component of the system required to provide safe transfer for lungfish downstream when there is a potential for them to be drawn over the spillway and be killed or injured as they drop down the stepped face of the spillway into an inadequately-sized stilling basin.

7.2 Ability to provide adequate attraction flows into entrance chamber

The flume is simply an adjunct to the downstream fishway system, which not only requires the downstream fishway to be operated reliably and safely but that the attraction flows generated by the downstream fishway are sufficient to provide an attraction flow pattern that would be effective over a quite small area near one edge of the more than 300 metre wide spillway during the incipient spillway overflow period and during an actual spill event.

With regard to the capacity of the downstream fishway system to provide adequate flows at the entrance to the flume, it would appear that the dimensions of the valved entry from the flume into the entrance chamber are such that these are the limiting factor and that there is little capability to improve on this while there is only one flume of similarly limited dimensions.

With regard to the location and dimensions of the entry to the flume to create an effective attraction flow pattern into the flume, there is no information available to the author at this stage to suggest that satisfactory attraction flows can be provided prior to or during a spill.

However, as quoted in Section 4.4.2 of this report from **Reference 13**, there are known limitations, viz:

> *The upper limit of the fish lock is at EL 67.9 or 0.3 above FSL. At that stage about 100 m^3/s will discharge over the ungated spillway crest rendering the attraction flow to the fishlock ineffective.*

7.3 Limitations imposed by cycle time of downstream fishway

In view of the lower rate of flow into the fish lock via the flume, it is likely that longer cycle times would be required during this critical phase than during normal operation of the downstream fishway.

This reduces the capacity of the fish lock to transfer lungfish downstream during critical periods.

7.4 Impact of Ineffectiveness of Flume Before & During Dam Overflow Events

The importance of the flume is outlined in Section 6.2.3 of Burnett Water's September 2008 *Fishway Management Plan* (**Reference 15**) which deals with the subject of "minimising fish injury and mortality on the spillway" as follows:

A key element in the operation of the dam and fishways is to ensure fish injury and mortality are minimised. When practical, the best method of achieving this is to avoid small flows over the dam wall by releasing water through either the environmental or irrigation outlet works as the dam starts to fill. Prevention of small flows over the dam wall will aid in the prevention of the fish spilling over the wall and possibly being injured or killed as they fall over the concrete spillway steps and/or hitting the bottom of the spillway with force.

It is also noted that:

The process for achieving this requirement is included in the standard operating procedures provided in Appendix B.

Appendix B then simply states:

When practical to do so, preference is to be given to discharging through the environmental conduit as opposed to spilling over the spillway. When it becomes apparent that a spill cannot be avoided, the environmental gates are to be closed and the operation transferred to a spill event as quickly as practical.

This is an apparent reference to avoiding the existence of "non-skimming" flows down the stepped face of the dam during periods of lower spillway overflows, by increasing the spillway flow rate by the amount of the environmental flow release.

This action appears to be in the expectation that this would increase the probability that the flow down the face will become a "skimming" flow and reduce the extent to which the spillway flow will impinge upon each of the steps down the face of the spillway into the stilling basin below.

This proposal seems to be quite incongruous with the design of the spillway, when the real purpose of the stepped spillway is to interrupt the smooth flow down the spillway and so reduce the dimensions of the stilling basin.

The attendant risks to fish injury and mortality might be seen to be as follows:

- Fish striking the edge or base of each step down the face of the spillway during a non-skimming flow event.
- Fish being dropped at high velocity (estimated to be 18 metres/sec) into a stilling basin of inadequate dimensions during a skimming flow event.
- Fish striking the edge or the base of the steps during a so-called skimming flow event and then being unable to recover sufficiently to safely exit the highly turbulent stilling basin.
- Stranding of fish on the steps of the spillway following an overflow.

The comments made on the design of the dam spillway suggest that the potential for death or injury to fish carried over the spillway appears to be greater when the overflow is "non-skimming" rather than "skimming".

In this case "skimming" refers to the overflow principally skimming the steps of the spillway face as shown in **Figure 18(a),** whereas "non-skimming" refers to flows which substantially impact upon each step down the face of the spillway as shown in **Figure 18(b)**.

These figures have been extracted from **Reference 12** in which the so-called "non-skimming" flows are called "nappe flows" and a distinction might be made between stepped spillways and stepped channels.

As noted above, as the real purpose of the stepped face relies on it being more “non-skimming” than “skimming”. Thus the advice to close the environmental release gate when an overflow becomes imminent and so increase the potential for the flow down the spillway to become “skimming”, appears unlikely to be utilised in practice by the dam operators because of the damage that might be caused to the under-sized stilling basin and to the channel and other works immediately downstream of the spillway.

7.5 Comment Upon Current Attitude of Burnett Water to the Use of the Flume

In Section 2.5.6 of **Reference 13**, it is concluded

> *There is relatively little cost involved in modifying the proposed operational measures to minimise the risk of injury to fish. It essentially extends to having operating rules in place which ensure controlled releases through the outlet works at the onset of a flood wave entering the reservoir.*
>
> *The additional cost of physical modifications to the spillway design, on the other hand, would be substantial. The Alliance is of the opinion that there is currently insufficient data available to justify any deviation from the spillway design which was submitted to QFS at Stage 2 and refined during Stage 3 of the project.*
>
> *While design options have been examined in detail, for example the insertion of a control gate in a section of spillway, there is sufficient doubt about the effectiveness of such measures when so many variables are at play.*
>
> *It is considered prudent and reasonable to observe the Burnett Dam spillway in action and to analyse the results of the USBR research and Tallowa Dam operations before deciding on the need for and details of any further design modifications.*
>
> *If monitoring and the analysis of various results show that a design response is necessary, the process to retrofit a design solution such as a crest gate is marginally more expensive than incorporating a design change at this stage.*
>
> *The Alliance is committed to a rigorous monitoring program and wishes to consult further with QFS to develop performance criteria and triggers that would instigate further discussion on the effect of spillway passage on fish.*

It is considered that the above conclusions do not adequately address the requirements of the *EPBC Act* approval in that they do not provide at all for the safe passage downstream of lungfish.

It is considered that there is now sufficient evidence to review the need for the provision of a positive barrier to the movement of lungfish over the spillway and that the function of this barrier should be to direct lungfish on a downstream migration to a point where they would be exposed into the attraction flows at the entrance to the downstream fishway

8.0 REVIEW OF PERFORMANCE OF OVERALL LUNGFISH TRANSFER ARRANGEMENTS

8.1 General Comments

Having regard to the length of time since completion of construction of the dam that it has taken to fully test the effectiveness of the upstream fishlift, to wet commission the downstream fishlock and to be able to test the flume from the spillway to the downstream fish lock, it is considered that this report would not be complete if it did not conduct a review of the concept design, the objectives that the as-constructed works were expected to satisfy and how its operational performance was expected to be monitored and managed to achieve those objectives.

The following comments have been made in that context but without expansion of the comments made previously in this report.

8.2 Concept Design, Objectives and Performance Expected of Fishways

Reference is made to comments on the conceptual design of the proposed fishways in an untitled 27 September 2002 report by Sunwater listed in the documents discovered to date as BUR.002.001.0980 (**Reference 16**).

Section 1.1 of **Reference 16** outlines the objectives of the fishways as follows:

- ...*the fishway should provide upstream and downstream passage, when releases allowed, for the whole fish community;*
- *...the adjacent outlet works and spillway should complement the fishway operation;*
- *The fishway should be capable of operating under an acceptable range of headwater and tailwater conditions.*

It is relevant that the development of the concept design at this stage has turned out to be inappropriate in that:

- no specific provisions were made for the safe transfer of lungfish;
- the locations of the fishways were compromised by the need for proximity to the outlet works and spillway, even though the design at the time provided for a stepped face spillway (Figure 2.1 of **Reference 16**);
- the lower limit of operation of the downstream fishlock had previously been set at EL 62.5 m;
- it was noted in Section 8.2 of **Reference 16** with respect to fish protection considerations in the “downstream spillway passage” that ....*the spillway as proposed departs from conventional practice with the inclusion of steps on the downstream face to reduce construction costs.....*and that this introduced the risk of death or injury during spillway overflows;
- in Section 8.5 of **Reference 16** the potential for large releases up to 12,000 ML/day are proposed when fish would be migrating upstream and that, as these flows could physically block fish from finding the fishway entrance, a modified release strategy is required; and

- that there is a need to revisit some of the proposed water management arrangements, that an inappropriate amount of releases may have been allocated to fishway operation and that there is a detrimental effect of the large environmental releases on fish migration. The IQQM model should be amended accordingly.

These comments are then repeated to some extent in **Reference 13** as detailed in Section 4.4 of this report to the Court.

It is surprising then that the design concept has not materially changed as a result and that Burnett Water is not prepared to offer to make significant changes to the as-constructed fishway system, even though short-comings in the system's required capacity to comply with the *EPBC Act* approval Condition 3 have been readily identified.

8.3 Need for the Design of the Fish Transfer System to be Re-assessed

It is apparent that there has been a succession of design options considered during workshops held to assess options to the original concept and that these deliberations and management decisions have resulted in the finally constructed fish transfer system being substantially the same as that originally proposed in 2002.

It still retains an upstream fish lift and a downstream fishway, both located as originally proposed in relative proximity to the outlet channel, the intake works and the spillway - with attendant constraints on the performance of the fish transfer devices and non-recognition of the risks of mortalities occasioned by fish passage over the stepped spillway.

The development and operation of a comprehensive fish monitoring system by the DPI&F now offers the opportunity to undertake a basic risk assessment of the effectiveness of the fish transfer devices on the maintenance of a viable lungfish population in the Burnett River and to use the monitoring data to validate a model of lungfish population dynamics, to providing data for a quantitative risk assessment of the overall system and its various components.

It is considered that a BIDE model or similar might be used to account for population size being the result of three dynamic rate functions associated with the generic life cycles of lungfish viz. birth rate, growth rate and death rate, as well as those factors directly introduced by the dam wall of increased mortalities and changes to the net immigration and emigration rates imposed by the effectiveness or otherwise of the three fishway devices.

The results of lungfish monitoring should be evaluated to provide representative rate coefficients and other parameters to quantify these dynamic relationships and facilitate quantitative assessment of the extent to which each factor related to the fishway devices might be adjusted to protect the sustainability of the Burnett River's lungfish population.

The cost effectiveness of such modifications and opportunities to make such modifications can then be examined for priority of implementation.

9.0 CONCLUSIONS

9.1 Apparent Inability of As-constructed Fishway Devices to Provide for Safe Transfer of Lungfish Past Paradise Dam

A review of the results of lungfish monitoring since the dam has been completed against the recorded dam water levels, stream inflows and waters released from the dam has shown that very few lungfish have been lifted upstream of the dam.

Identifiable problems with maintaining appropriate attraction flows into the entrances to the upstream fish lift and the downstream fish lock indicate that the performance of each of these devices is unlikely to be significantly improved in the future.

Similar concerns have been identified about the effectiveness of the as-constructed flume to convey lungfish from the edge of the spillway to the entrance chamber of the downstream fish lock.

This reduces the effectiveness of the flume to prevent injuries and mortalities for those lungfish which would otherwise be drawn over the hard edges of the spillway steps and dropped into an inadequately-sized stilling basin, as well as being subjected to gas bubble trauma.

9.2 Implications of the Current Hydrological Constraints to the Effective Operation of the Fish Transfer System

The *Burnett River Dam – Flow Strategy for Lungfish*, by not reacting to the 2002 recommendations to vary the irrigation and flow release rules of the *Water Resource Plan (Burnett Basin) 2000* and the *Resource Operations Plan (Burnett Basin) 2003* has introduced the risk that planned releases of up to 12,000 ML/day during those months when lungfish might be expected to migrate upstream would physically block fish from finding the upstream fishway entrance.

Re-use, in the *Burnett River Dam – Flow Strategy for Lungfish* of the environmental performance indicators for the Figtree gauging station, as specified in the *Water Resources Plan (Burnett Basin) 2000*, being based upon stream geomorphology rather than lungfish biology, indicates that the designers of the fish transfer devices were not prepared to make realistic concessions to the protection of the lungfish.

A June 2000 report to the Department of Natural Resources (**Reference 7**) detailed how proposed environmental flow measures should be assessed. It referred to "medium and high flow indicators" as well as to "low flow indicators". Significantly, it is noted in the report (p.10) that:

> *The impact ratings used in the development of the environmental flow performance measures do not take into account any special conservation values of particular river or stream reaches. In the case of reaches which have high conservation values, it may be appropriate to set higher environmental flow limits than the basin-wide limits.*

It is surprising that "medium to high flow objectives" are the only key indicators referred to in the *Burnett River – Flow Strategy for Lungfish.*

Because the flow objectives were calculated over a 107 year simulation of rainfall and runoff using an IQQM model of the whole river basin, the *Resources Operations Plan* does not provide a basis for the results of annual natural ecosystems monitoring and river flow monitoring to be compared against the structure of the lungfish population.

The IQQM modelling should have been used to develop the *Strategy* into a form in which appropriate design rules for the fishways would have been provided and rules for the operation of the fishways. The results of the monitoring could then have been compared against the operational history of the fishways, such that the future operation of the fishways would achieve the expectations of the approval conditions.

The *Burnett River Dam – Flow Strategy for Lungfish* has avoided review of those of the dam's operating rules which do not provide for sufficient attraction flows to be produced when the demand for irrigation water is less than the required flows to attract lungfish towards the entrances to the upstream and downstream fishways.

The IQQM model should be re-calibrated to better predict low flows less than 500 ML/day past the dam and the re-calibrated model should then be modified to accept the flow release strategies recommended in 2002 in **Reference 16**.

9.3 Hydrological Constraints to the Effectiveness of the Upstream Fish Lift

The river flows and water levels downstream of the dam need to be conducive to fish species wishing to move upstream into the irrigation and environmental flow release channel and thence into the entrance channel.

The downstream flows and velocities need to be maintained sufficient to allow the fish to swim upstream but not so high that the velocities would significantly inhibit swimming against the flow in riffle sections and the release channel. The potential for large environmental flows provided for in the design of the dam to result in such a situation should be re-assessed and the *Operations Manual* for the dam modified accordingly.

There is also a need for continuity of water in the channels connecting the low flow pools during those periods when lungfish are likely to move upstream and into the upstream fishlift. The minimum flows required for this purpose need to be reviewed and the *Operations Manual* reviewed accordingly.

The optimum pattern of attraction flows into the upstream fish way entrance and lift hopper appear to be critical issues controlling its effectiveness – particularly with assisting in the migration upstream of lungfish. These attraction flows, while only indirectly affected by the hydrology of the dam, are nevertheless significantly modified by the extent to which environmental and irrigation flows are released from the dam into the entrance channel.

Because environmental flows released through the dam wall are likely to be larger than the irrigation flows, these flows are likely to have more impact upon the effectiveness of fishway entrance attraction flows than current irrigation flow rates and the dam *Operations Manual* should be reviewed accordingly.

9.4 Hydrological Constraints to the Effectiveness of the Downstream Fish Lock

These have been identified in Section 4.3 as being:

- dam water level - as the slide gate into the entrance chamber only operates for dam water levels above EL 62.5m;
- inflows into the dam of sufficient size and duration to induce fish to move downstream from the upper reaches;

- water levels and flows in the shallow reaches downstream of the dam to ensure that fish transferred downstream can reach suitable habitat;

- minimizing the risk of entrapping fish in flows over the dam spillway by providing sufficient attraction flows into the lock entrance chamber;

- availability of access to the entrance to the fish lock such that lungfish can escape downstream from de-oxygenated water conditions following lake turnover events.

Section 6.1.1 lists the three matters of significance introduced by the elevation of the lower level limit to the fish lock entrance as being:

- the dam water level will be lower than that required for the successful operation of the downstream fishway for approximately 20% of the time;

- it is forecast that there will be periods of between one and three years duration when the downstream fishway will be inoperable due to low dam water levels;

- this constraint has the potential to occur during the downstream migration following spawning for up to 25% of those periods;

- it would prevent the ability of lungfish to move downstream and avoid exposure to low oxygen levels in the dam waters following a lake turnover.

From a review of the reports which discuss the low entrance level constraint and those engineering options which have been advanced to rectify the situation and an inspection of the facility, it is evident that there will be substantial costs incurred in rectifying this significant limitation on the downstream movement of lungfish.

Having regard to the modelled pre-dam water flow statistics and the post-dam water level statistics, it is considered that the lower limit of entry to the downstream fishway should be at RL 50 m, which would allow the downstream fishway to be available for approximately 95% of the time and so provide equivalent fish passage opportunities to that which prevailed prior to construction of the dam.

Section 6.2 refers to the problem of producing adequate attraction flows into the entrance chamber and particularly:

> .....*the flow velocity patterns of high environmental flows into the intake chamber are considered to be likely to mask the attraction flows into the entrance chamber.*
>
> *The issue of modifying attraction flows into the downstream fish lock is one that the fisheries experts should be considering with some urgency – particularly when the dam levels have risen to such an extent that the dam could reach spillway level next summer.*
>
> *It is suggested that a floating barrier could be positioned to increase the effectiveness of the attraction flows that can be created into the entrance chamber of the fish lock.*

9.5 Hydrological Constraints to the Effectiveness of the Flume from the Spillway

A review of the IQQM modelling has shown a relatively high probability that lungfish may be drawn towards the spillway rather than towards the downstream fishway and that significant mortality may occur as a result of the 37 metre high drop into the stilling basin and flow dissipation devices below.

However, consideration of the results of the IQQM modelling of the extent of the flows as a composite of environmental flow releases and spillway overflows against spillway flow data (**Attachment 14**) and the environmental flow requirements detailed in the *Resource Operations Plan* and the *Flow Strategy for Lungfish*, suggests that the most significant environmental flows are those which occur during spillway overflow events and therefore, to some extent, may modified by dam level management.

9.6 Operational Constraints to the Effectiveness of the Fishway Devices

In view of the apparently low effectiveness of each cycle of fishway operation, both upstream and downstream and the need for each fishway to operate during the night, there is a need for the fish lift and the fish lock to function in automatic mode and to be maintained such that they can be relied upon to function continuously during periods when the maximum level of fish transfer effectiveness is demanded.

9.7 Potential to Adequately Improve the Effectiveness of the Lungfish Transfer System

From information provided within **Reference 14** and, as indicated in the views of the dam, the left bank probably provides better habitat for lungfish than the southern bank upstream of the dam wall.

Such considerations suggest that the fishways should have been located on the northern side of the dam rather than adjacent to the release intake structure near the southern bank.

Thus, if augmentation of the downstream fishway is indicated, then an additional downstream fishway and flume to the spillway should be constructed on the northern side of the spillway.

9.8 Need to Review the Overall Performance of the System and Identify Priorities for Major Upgrades

The as-constructed fish transfer system, despite earlier advice to the contrary, still retains an upstream fish lift and a downstream fishway both located in relative proximity to the outlet channel, the intake works and the spillway - with attendant constraints on the performance of the fish transfer devices and non-recognition of the risks of mortalities occasioned by fish passage over the stepped spillway.

There exists a risk that the fishways in their current form will not be able to comply with Condition 3 of the *EPBC Act* approval for the reasons outlined above.

To address this risk within a time-frame that would ensure that the lungfish population will not be permanently affected, there should be an immediate review of the concept design, the objectives that the as-constructed works were expected to satisfy and how its operational performance is expected to be monitored and managed to achieve those objectives.

Such a review should include a structured risk assessment of the effectiveness of the fish transfer devices on the maintenance of a viable lungfish population in the

Burnett River, using the available lungfish monitoring data to validate a model of lungfish population dynamics.

This model should be used to account for population size being the result of three dynamic rate functions associated with the generic life cycles of lungfish viz. birth rate, growth rate and death rate, as well as the other factors being directly introduced by the dam wall and the effectiveness or otherwise of the fish transfer devices, i.e. the factors of increased mortalities, as well as net immigration and emigration rates.

The results of lungfish monitoring should then be evaluated to provide rate coefficients and other parameters to quantify these dynamic relationships and so assess the extent to which each factor should be adjusted to protect the sustainability of the Burnett River's lungfish population.

The cost effectiveness of such modifications and opportunities to make such modifications should then be examined for priority of implementation.

9.9 Need to Review WRP, ROP, Lungfish Strategy & Dam Operations Manual

It is apparent that the water level and flow data produced by the IQQM modelling may not have been appropriately considered in the design of the fishways for Lungfish. As the IQQM model is fundamental to the *WRP, ROP* and *Lungfish Strategy,* these documents need to be reviewed and considered after the above re-assessment of the current and future effectiveness of the fish transfer devices at Paradise Dam.

In view of the impacts of environmental and irrigation flow releases upon the effectiveness of the upstream fish lift and the downstream fish lock, it is important that the *Operations Manual* for the Paradise Dam be reviewed as previously described in this report.

The *Operations Manual* should be modified to take account of the demonstrated need to review the incipient spillway flow strategy and to include for the deployment of a floating barrier to increase attraction to the downstream fishway and to prevent lungfish from becoming trapped into the spillway flows.

10.0 REFERENCES

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