Lungfish Passage through Fishways and the Impacts of Restricted Passage at Paradise Dam for Australian Lungfish (*Neoceratodus forsteri*) in the Burnett River

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Report prepared for the Federal Court of Australia at Brisbane in proceedings *Wide Bay Burnett Conservation Council Inc v Burnett Water Pty Ltd* (No. QUD 319/08)

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1. Introduction

1.1 Purpose of Report

The Wide Bay Burnett Conservation Council Inc (WBBCC) is undertaking litigation in the Federal Court of Australia in relation to an alleged failure by Burnett Water Pty Ltd to construct and operate a fishway that is suitable for Australian or Queensland lungfish (*Neoceratodus forsteri*) on the Paradise Dam. This obligation is imposed by a condition of approval for the dam (below) under the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act).

Condition 3 of the EPBC Act approval for Paradise Dam states:

> *Burnett Water Pty Ltd must install a fish transfer device on the Burnett River Dam suitable for the lungfish. The fishway will commence when the dam becomes operational.*

WBBCC seeks a declaration from the Court on the legal meaning of the condition and an injunction to compel Burnett Water Pty Ltd to comply with the condition.

I have been asked by the solicitor acting on behalf of the Wide Bay Burnett Conservation Council (WBBCC) to prepare an expert report to the Federal Court on *"Lungfish passage through fishways and the significance of restricted passage at Paradise Dam for lungfish in the Burnett River"*.

My letters of instructions (Appendix 1) set out a series of factual questions that I am asked to address in conjunction with a hydrology report from Mr Max Winders. They cover issues associated with:

- the biology, ecology and conservation status of the Australian Lungfish;
- the effectiveness of the Paradise Dam upstream and downstream fishway design and operation for facilitating lungfish passage; and
- the context and intensity of impacts to the lungfish population in the Burnett River associated with restricted passage at the Paradise Dam.

1.2 Expertise

I am an aquatic ecologist and fish biologist with extensive research and field experience in tropical and sub-tropical freshwater fish and river ecosystems in northern NSW, Queensland, Papua New Guinea and the Philippines including regional scale assessments of fish passage barriers. Since graduating as a Bachelor of Science from James Cook University in 1986 I have worked predominantly in freshwater fisheries and habitat research in Queensland.

Prior to being asked to prepare a report for these court proceedings I had not conducted research specifically into the lungfish or on the Burnett River. However, I have worked on freshwater fish and aquatic ecosystem management issues in most other south east Qld river basins inhabited by the Lungfish. I also have direct personal experience of the lower Burnett River as my parents are riparian landholders who have lived on the Burnett River for 14 years and I have considerable knowledge of lungfish and the aquatic habitats of the Burnett River from observations I have made during visits to their property.

1.3 Duty to the Court

I have been provided with a copy of the Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia (Version 6, 5 May 2008).

I understand that my primary duty is to assist the Court in these proceedings and that I do not act for WBBCC. I have endeavoured to meet my duty to the Court to the best of my ability.

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

2. Methodology

In preparing this report I have used standard scientific procedures and methods, including a site inspection and literature review. I have also drawn on my extensive background in field research into Queensland freshwater fish and my personal knowledge of the Burnett River.

I conducted a site visit to the Paradise Dam on Friday 19 December 2008 and observed the upstream fishway in operation. At that time the downstream fishway was not operating as the water levels were too low.

The literature on lungfish in the Burnett River is quite extensive. Major publications in this field include Brookes (1995), Johnson (2001), Frentiu, Ovenden & Street (2001), Brooks and Kind (2002), Simpson, Kind and Brooks (2002), Stuart & Berghuis (2002), Berghuis & Broadfoot (2004), Kind, Brooks & Piltz (2005), Kemp (2008), Arthington (2008), DPIF (2007, 2008), Kind & Brooks (2008) and Kind, Wohlsen & Brooks (2009).

I have been provided with over 4,000 documents disclosed by Burnett Water Pty Ltd up to January 2009. I also requested and received more recent fishway monitoring reports up to March 2009, and fishway operational log data up to April 2009. I have referred to many of those documents in forming by opinions, particular in relation to the fishway design and reports on lungfish monitoring and fishway operation.

3. Background

In this part I address the relevant features of Paradise Dam and the fish transfer devices based on the descriptions in the Amended Statement of Claim and the Defence to the Amended Statement of Claim filed in the proceedings that have been provided to me. Having viewed the structure and devices myself I believe that these descriptions are accurate summaries. I will address the features of the fishways in more detail later in this report.

3.1 Paradise Dam

The Paradise Dam is a major dam with a storage capacity of 300,000 megalitres constructed on the lower Burnett River approximately 80 km southwest of Bundaberg in Queensland. It was constructed during 2003 to 2005. The full supply level of the Paradise Dam is 67.60 m Australian Height Datum (AHD) or Elevation (EL) above sea level and it consists of a concrete dam wall up approximately 37 m high and spanning approximately 600 m across the Burnett River. The dam discharges water generally via a main water outlet and when water levels exceed the maximum storage capacity via a stepped spillway. The following maps and pictures show the location of the dam and its major relevant features.

Figure 1 - Location Map of Paradise Dam (circled) within Burnett River Basin
(from Queensland Department of Environment and Resource Management 2009)

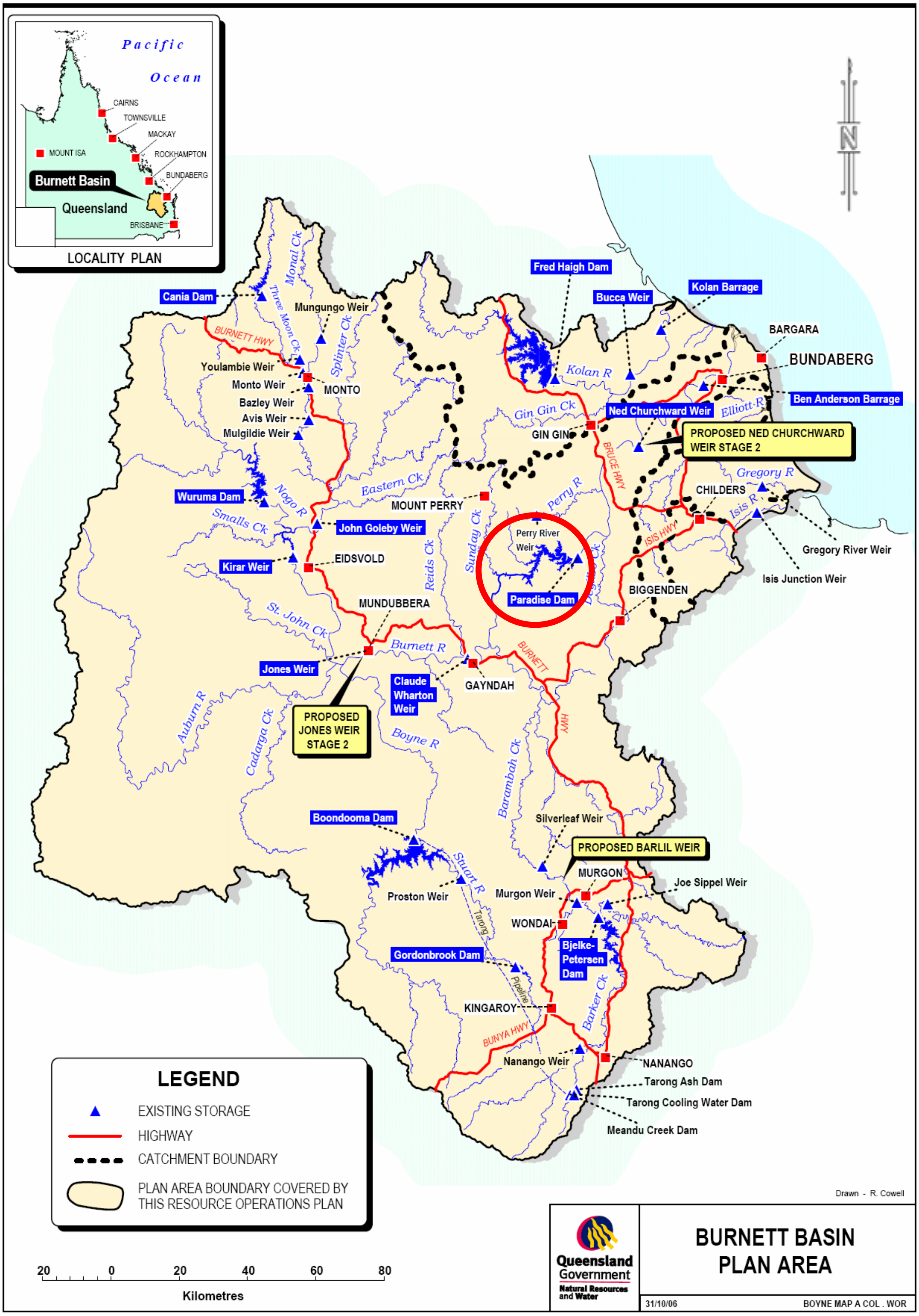


Figure 2 - Location of Dam, outlet works and fishway in relation to Pre-development River channel (orthophoto from Burnett Water Pty Ltd, 2003)

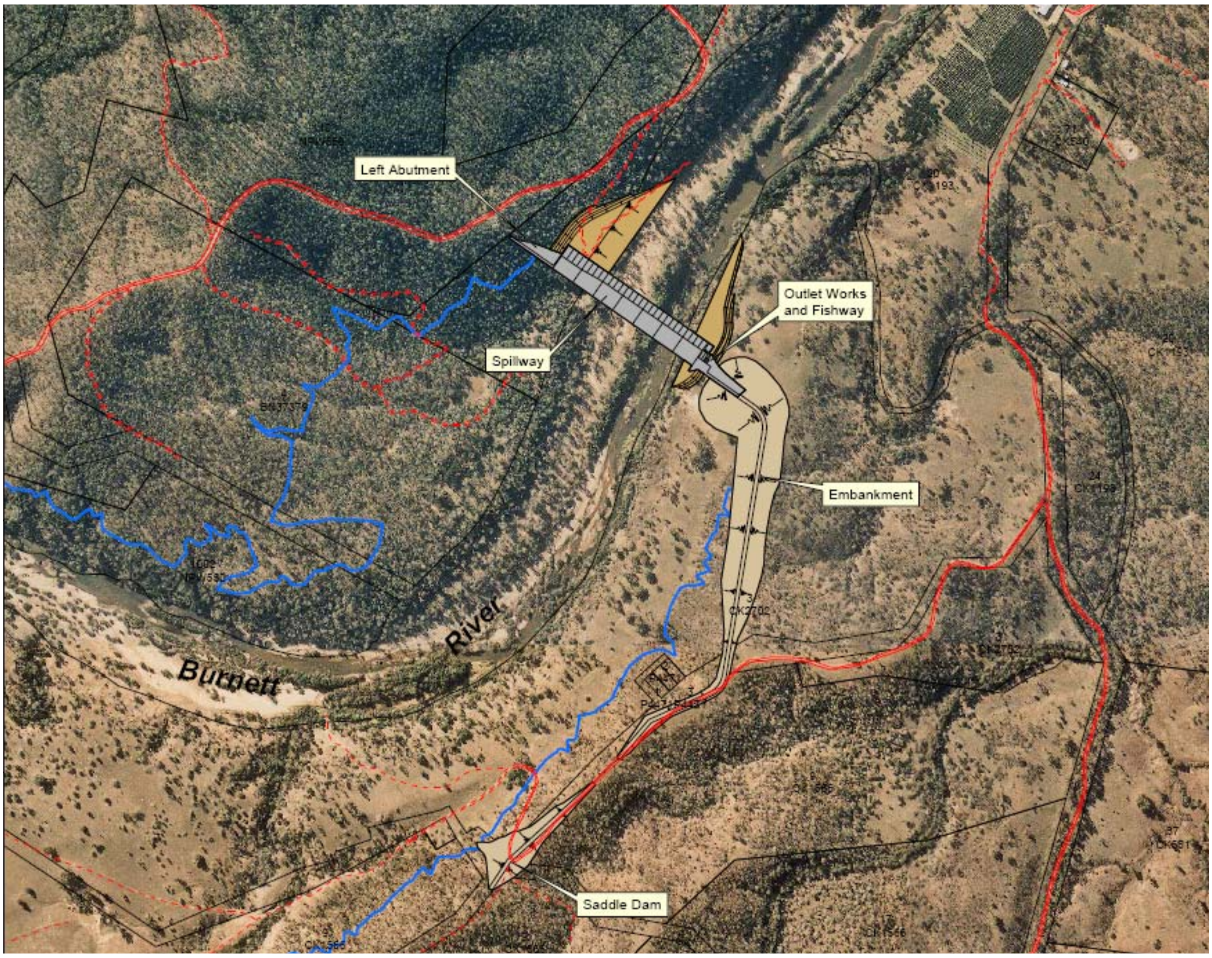


Figure 3 - Paradise Dam wall viewed from upstream (J Tait, December 2008)

Figure 4 - Paradise Dam wall viewed from downstream (A Mackay, August 2006)

Figure 5 - Paradise Dam with close view of Stepped Spillway (J Tait, Dec 2008)

The fish transfer device installed on the dam consists of a downstream fishway and a separate upstream fishway.

3.2 Downstream Fishway

In summary, the downstream fishway consists of an inlet chamber on the upstream side of the dam wall in the dam reservoir and a pipe to the downstream side of the dam. Fish, including lungfish, are intended to be attracted into the inlet chamber of the downstream fishway by flowing water. A lock or vertical gate approximately 0.5 m wide at the front entrance of the inlet chamber of the downstream fishway is designed to be periodically closed and the chamber drained to cause the fish to be transported into a pipe and released into a pool on the downstream side of the dam wall connected to the downstream river.

The entrance of the downstream fishway is installed between EL62.0 m and EL 67.9 m and the downstream fishway cannot operate at water levels in the dam reservoir outside this range. The minimum water level in the dam reservoir at which the downstream fishway can operate, EL62.0 m, is equivalent to 57% of the capacity of the dam. At times when the dam is full and the stepped spillway is overtopping, lungfish may enter the downstream fishway via a passage or "flume" installed from the side of the stepped spillway to the inlet chamber of the downstream fishway (see Figure 7).

Figure 6 - Close-up of dam outlet works showing downstream fishway entrance (circled) above water (R Currie, 11 May 2008)

Figure 7 - Passage or "flume" installed from the side of the stepped spillway crest to join to the downstream fishway (J Tait, December 2008)

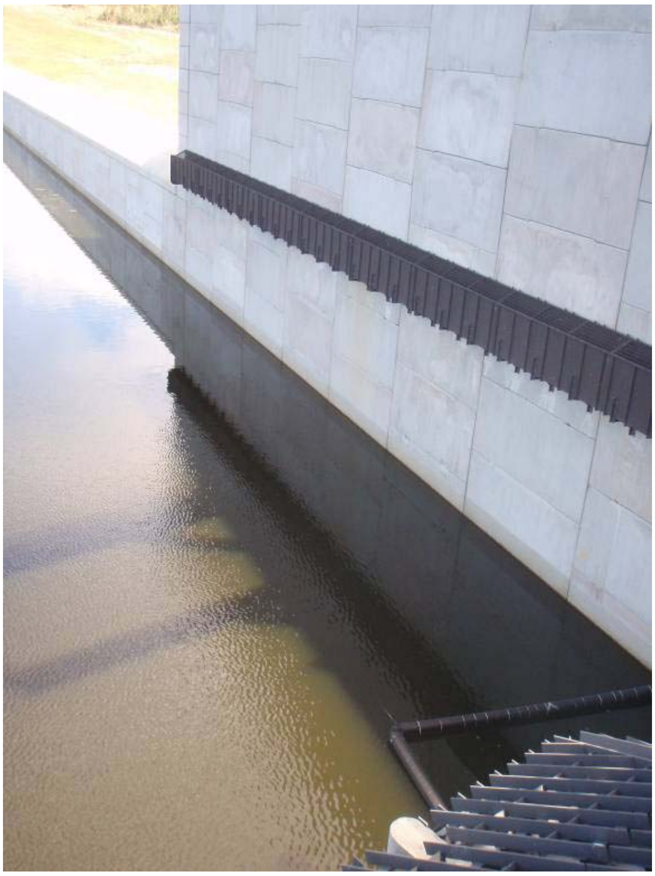


Figure 8 - Passage or "flume" joining to the inlet chamber of the downstream fishway (J Tait, December 2008)

Figure 9 - Cross sectional View of Downstream Fishway Inlet to Outlet Pipe through Dam

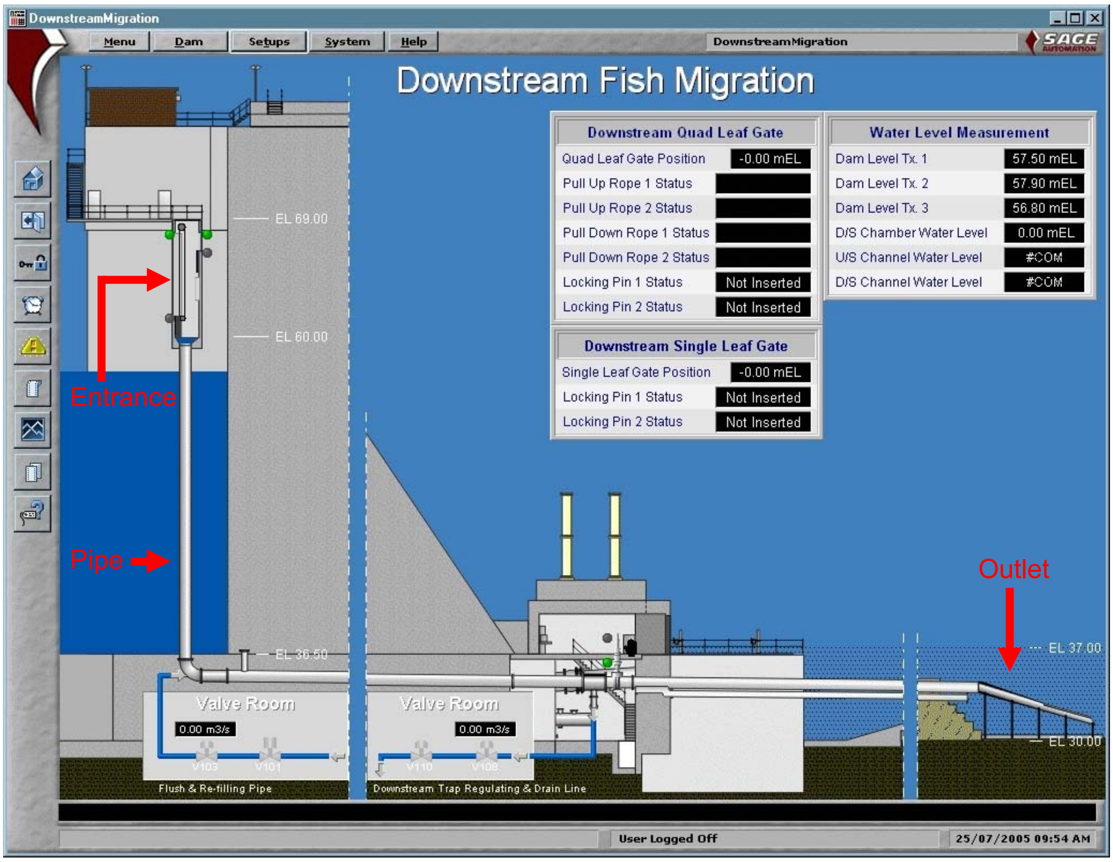


Figure 10 - Paradise Dam stepped spillway viewed from downstream showing shallow receiving basin (Arkin Mackay, August 2006).

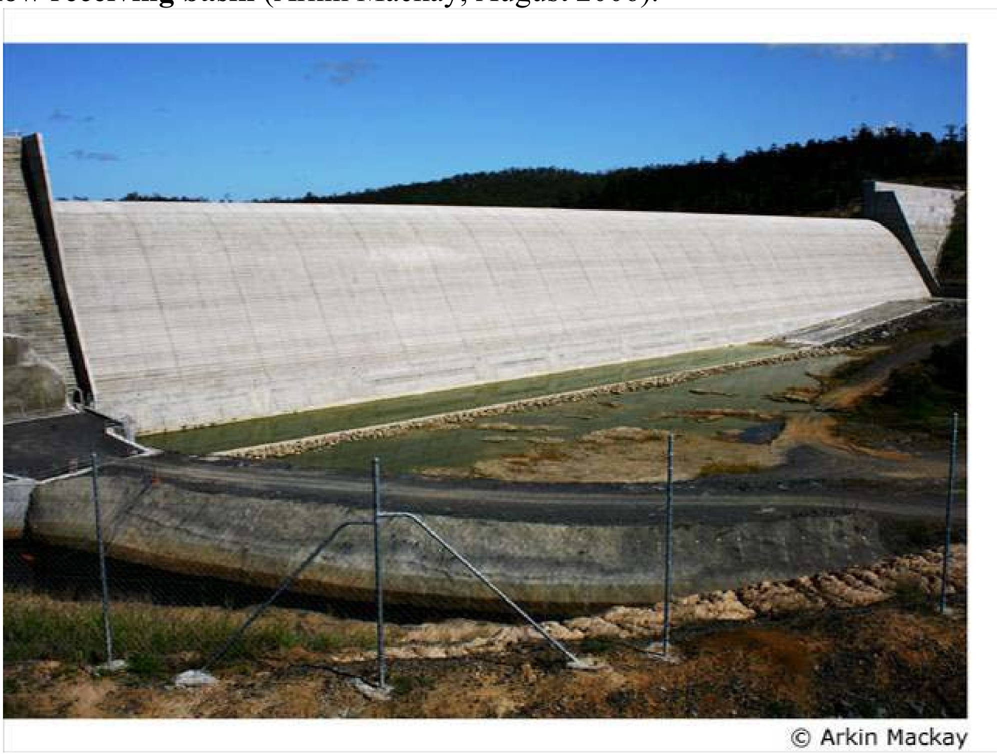
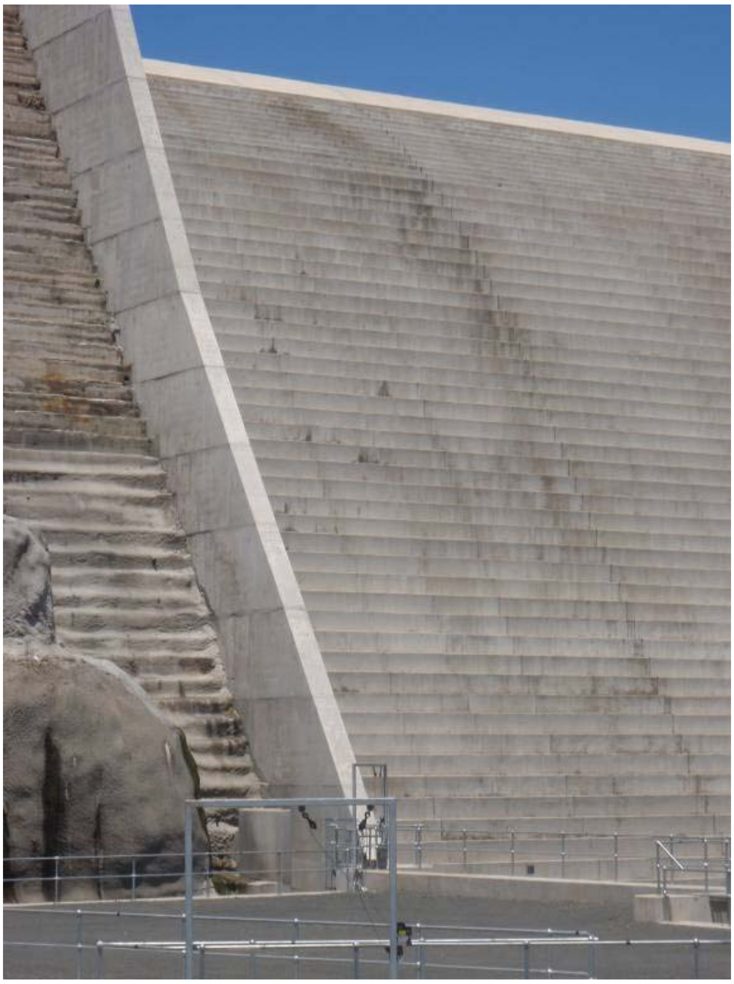


Figure 11 - Paradise Dam stepped spillway viewed from downstream showing steep stepped spillway (J Tait, December 2008).



3.3 Upstream Fishway

The upstream fishway consists of a large caged container (known as a "hopper") into which fish, including lungfish, are intended to be attracted by flowing water at the downstream base of the dam. When operating, the caged container is periodically lifted over the dam wall to enable any fish, including lungfish, in the container to be released on the upstream side of the dam. To reach the caged container lungfish must swim through either of two passages, one from the main water release channel beneath the dam wall ("hopper approach channel") or a second, from the side of the dam spillway ("spillway approach channel").

The following diagram and pictures of the upstream fishway were obtained from DPIF (2008) and the Sunwater Ltd website.[1]

[1] http://www.sunwater.com.au/burnettwater_environmental_fish_passage.htm.

Figure 12 - Paradise Dam outlet release channel and upstream fishway approaches (DPIF 2008)

Figure 13 - Entrance conditions to the upstream fishway channel (looking upstream) (DPIF 2008)

Figure 14 - Entrance to the trapping area and hopper (looking upstream from within the hopper approach channel) (DPIF 2008)

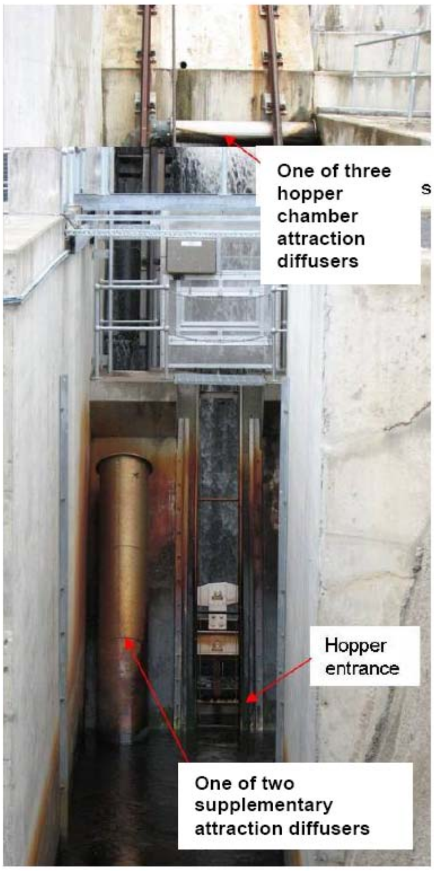
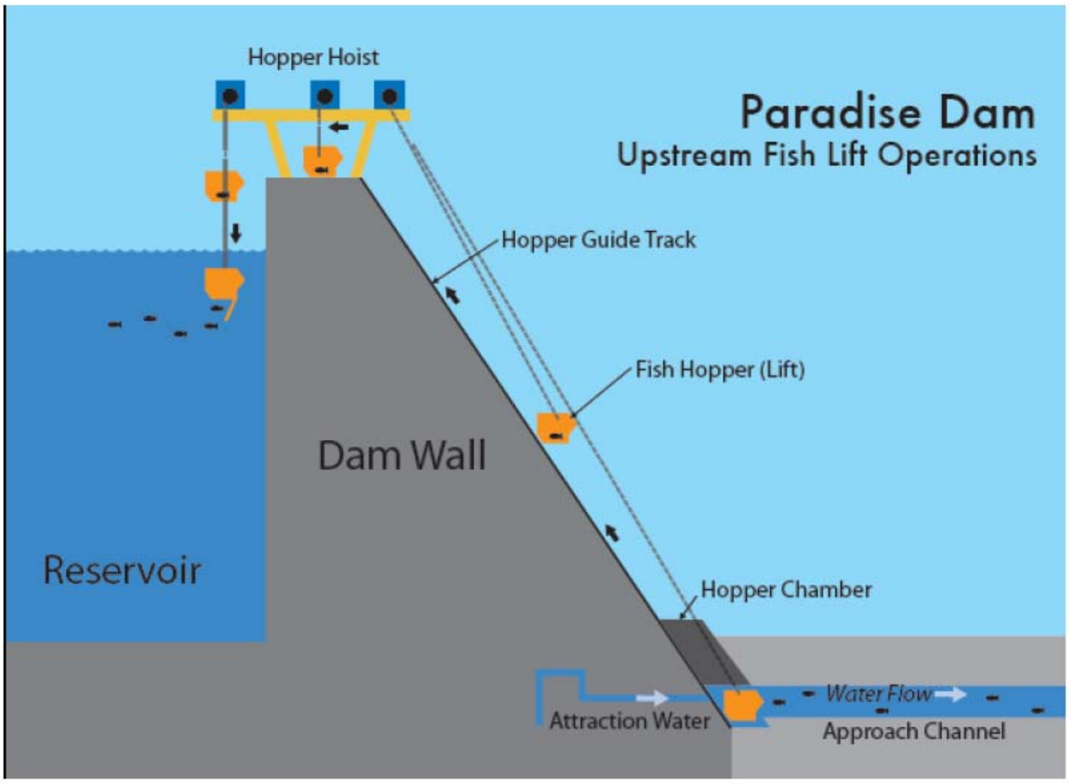


Figure 15 - Schematic of the upstream fishlift at the Paradise Dam (SunWater)



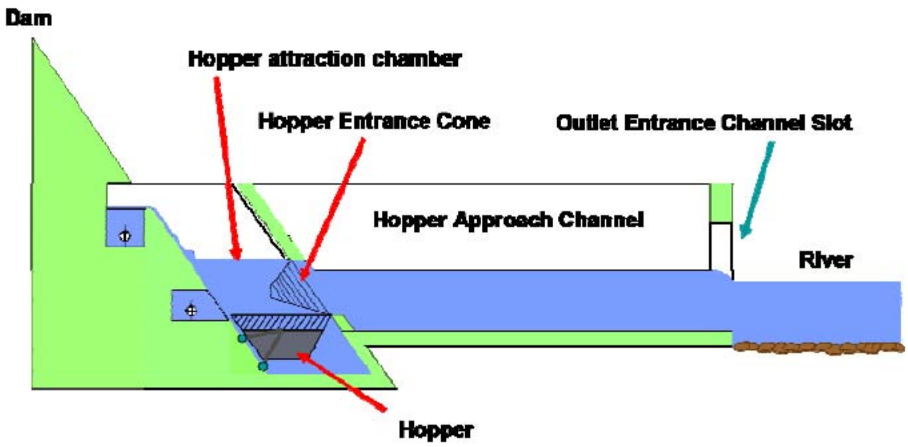


Figure 16 - Paradise Dam upstream fishway showing hopper ascending the downstream face of the dam wall (SunWater, ca 2006)

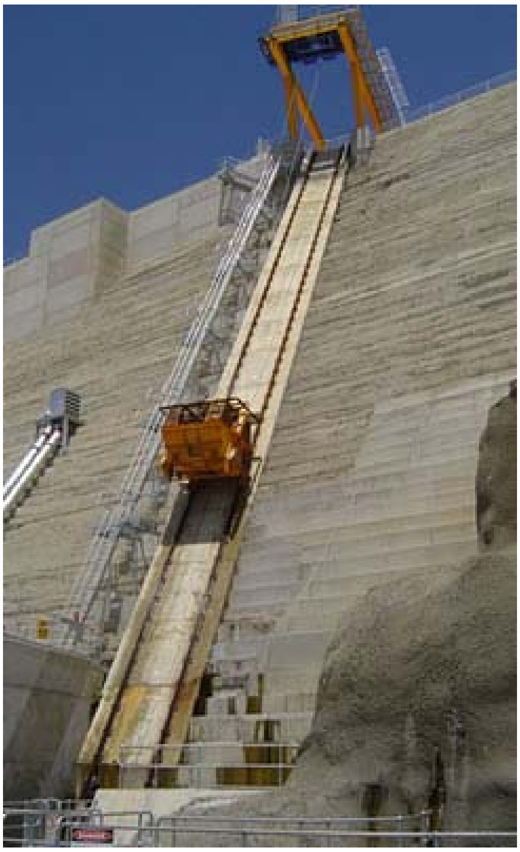


Figure 17 - Paradise Dam upstream fishway hopper traveling over the dam wall (SunWater, ca 2006)

Figure 18 - Paradise Dam Upstream Fishlift Fish hopper descending the upstream face of the dam wall (SunWater, ca 2006)

4. Lungfish Biology, Ecology and Conservation Status

This section summarises the biology, ecology and conservation status of lungfish as preliminary matters to assessing the effectiveness of the fish transfer device on the Paradise Dam. It draws on the published literature on the species, including the Draft Recovery Plan for Australian Lungfish (**Appendix 3**), prepared by Queensland Government Scientists (Kind et al. 2009), which represents one of the most current summaries of Lungfish biology, ecology and conservation status.

4.1 Distribution, population, life history, habitat requirements, migratory behaviour and requirements

4.1.1 Species Description

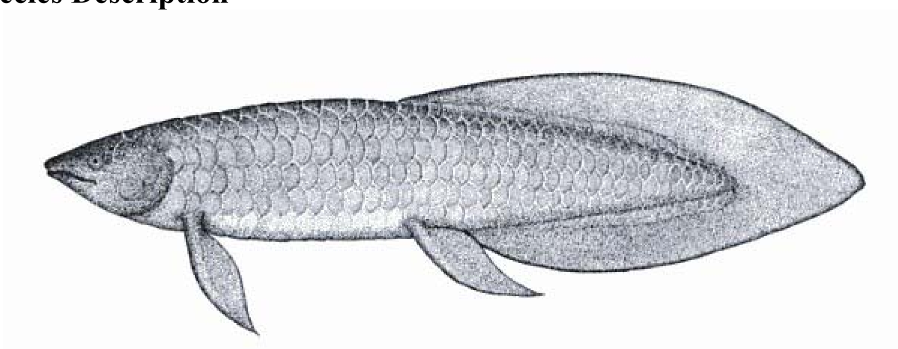


Figure 19 - The Australian Lungfish *Neoceratodus forsteri* (Krefft 1870). Drawing by Brad Pusey from Pusey *et al.* (2004)

Adult Australian lungfish are amongst the largest of Australia's freshwater fish exceeded only by the Barramundi, Murray Cod, and Freshwater Sawfish (Brooks and Kind 2002). Early scientific workers reported maximum sizes to 1.7m and 40kg though current evidence suggests that individuals of these proportions are extremely rare (Kind et al. 2009). A sample of almost 3000 lungfish collected by Brooks, and Kind (2002) included individuals ranging in length from 345-1420 mm, with a mean total length of 906 mm.

Australian lungfish have heavy elongate bodies covered in overlapping layers of large bony overlapping scales. As the name suggests, lungfish have the ability to supplement their respiration using a modified swim bladder (lung) to inhale air at times of poor water quality or increased activity. As with other fish lungfish primarily use gills to breathe. The lungfish is a lobe-finned fish with an internal skeleton composed mostly of cartilage and teeth in the form of crushing plates. The head is conical and dorsally flattened to produce a broad dorsal surface. The snout and head exhibit clusters of sensory pits used to detect weak electric fields emitted by potential prey items. The eyes and mouth are small relative to the overall body size. The pectoral and pelvic fins are lobed when compared to almost all other bony fish which have ray fins and are frequently described as 'flippers' or' paddles': The dorsal fin emerges roughly half way along the length of the adult body and joins the caudal and anal fins to form a flattened eel-like tail that tapers to a point. There are no fin spines or other sharp surfaces on the body or gill covers. Lungfish vary in colour from dull brown to olive green dorsally, whilst the ventral surface varies from cream to a vivid orange colour. Most lungfish have random black blotches on their back and sides towards the tail (DPIF 2008, Kind et al. 2009).

Figure 20 - Photograph of adult lungfish (Joss 2008)

Figure 21 - Photograph of lungfish (Hydrobiology 2007)

Juvenile Australian lungfish appear similar to adults, with some clear differences including a more pronounced and slightly rounded head, clustered darker spots on the body giving a mottled appearance, more prominent sensory pores on the head and snout and have a dorsal fin that arises further forward close to the back of the head (Kind et al. 2009).

4.1.2 Distribution and Populations

Lungfish distribution is restricted to the relatively developed and modified river systems of south east Queensland (Pusey et al. 2004; Arthington 2008). No census of the total number of Lungfish existing in Australia has been compiled. It has been estimated that less than 10,000 lungfish remain in south east Queensland (Catalyst 2006). Lungfish abundance is most commonly described by relative measures of catch per unit effort (CPU), most recently by reference to catches obtained by electro-fisher based surveys (Brooks and Kind 2002, 2008; Kind 2002; Hydrobiology 2007).

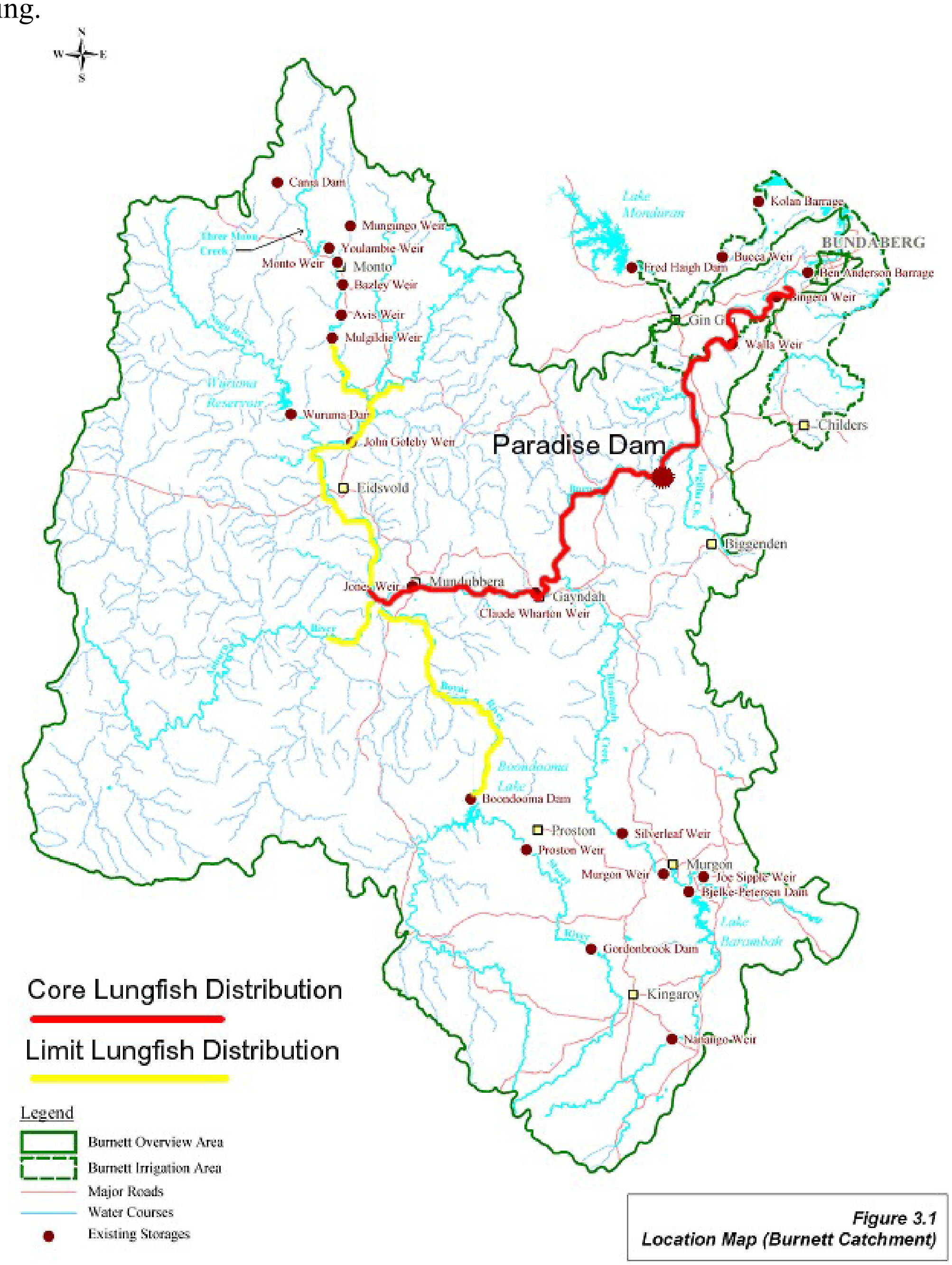
Lungfish populations are distributed across two river basins (Burnett and Mary) where the species are assumed to have been endemic at the time of European settlement and at least four more (Brisbane, Pine, Logan and Coomera River Basins) where they have been translocated (Kemp 1995, Kind, Kind et al. 2009). Translocation efforts in several other basins including the Condamine and Stradbroke Island have apparently been unsuccessful (Johnson 2001, Pusey et al. 2004). There has been some debate as to whether the Brisbane and Pine River populations are actually translocated given the small number of founders that were supposedly used to establish the species at these sites (Kemp 1986, 2008). Genetic evidence is inconclusive and has been interpreted both as being consistent with a translocation hypothesis (Frentiu et al. 2001, Pusey et al. 2004) and as indicative of a naturally differentiated population (Lissone 2002 cited in Kemp 2008).

Fossil records indicate that the Lungfish has existed unchanged as a species at least since the early Cretaceous period, 100 million years before present (Simpson, Kind & Brooks 2004) and that its range extended across much of Australia including to the centre of the continent prior to the Pleistocene, 1.6 M years before present (Kemp 1991, 2008; Arthington 2008). Since the Pleistocene its range has contracted to South East Queensland most likely due to an increasingly arid Australian climate and increased competition with more successful ray finned fishes (Joss 2004; Kemp 2008).

The largest Lungfish populations occur in the largest river basins i.e. the Burnett, Mary and Brisbane. Some 2888 lungfish were sampled during a 3 year (1997-2000) study of lungfish populations within the Burnett River (Brooks & Kind 2002) and 1387 lungfish have more recently been sampled during 2006-2007 sampling conducted at six sites in the vicinity of Paradise Dam as part of the Burnett Dam Baseline Lungfish Monitoring (Brooks & Kind 2008). Catch per Unit Effort data suggest that lungfish abundance in the riverine sections of the Brisbane and North Pine Rivers is at least equivalent to that recorded for endemic populations in the Mary and Burnett River systems (Hydrobiology 2007).

In the most recent summary of lungfish distribution Kind et al. (2009) report that surveys conducted by the DPI&F and other records indicate that-lungfish are widely distributed throughout the Mary River and its tributaries. In the main Mary River channel, lungfish occur from the tidal barrage upstream to the township of Conondale. However, little is known about the relative abundance of Lungfish between these two points. Lungfish are also common in tributary creek systems including the Tinana/Coondoo Creek system, Obi Obi Creek, Six Mile Creek, Yabba and Little Yabba Creek, and Wide Bay Creek (Simpson 1994; Kind 2002). A small number of individuals have been observed in Borumba Dam and some other minor tributary streams (DPI&F unpublished data cited in Kind et al. 2009).

Figure 22 - Lungfish distribution within the Burnett River Basin (Brooks & Kind 2002). Both the Limits of Distribution and the core distribution are shown as determined by sampling.



In the Burnett River Catchment Lungfish are largely restricted to areas of permanent water and by barriers to movement and do not occur in more ephemeral tributary basins such as the Perry or Nogo Rivers (Brooks & Kind 2002). Kind et al. (2009) report lungfish occur from the tidal barrage at AMTD 25.9 km upstream to at least AMTD 335 km and Three Moon Creek near Monto (Brooks & Kind 2002). An isolated population also occurs in Splitter Creek which joins the Burnett River below the tidal barrage (Pers. Obs.) They are also present in the Auburn River to Auburn River Gorge, Barambah Creek to the Barambah Gorge and in the Boyne River to the wall of Boondooma Dam (Brooks & Kind 2002). Despite anecdotal evidence that Lungfish inhabited the Boyne River above Boondooma Dam prior to its construction recent fisheries surveys have failed to find any evidence that they still inhabit this area (Alex Hamlyn, DPIF unpublished data cited in Brooks & Kind 2002). Fisheries surveys in Cania Dam have yielded lungfish that were apparently translocated from drying waterholes in the upper Burnett (Alex Hamlyn, DPIF unpublished data). In the main river channel, the majority of lungfish occur downstream from the township of Ceratodus. Brooks and Kind (2002) reported that Catch per Unit Effort (CPUE) data suggest the core Lungfish population in the Burnett occurs from the tidal barrage to approximately AMTD 275 km (see Figure 19).

The densest populations of lungfish in the Brisbane River occur between Wivenhoe Dam and the Mt Crosby Pumping Station and have been subject to long-term ecological studies (Kemp 1984, 1986, 1993). CPUE data from the lower and upper Brisbane River indicate Lungfish abundances at least equivalent to those observed in riverine reaches of the Burnett River (Hydrobiology 2007). Upstream of Wivenhoe Dam, lungfish inhabit Lake Wivenhoe, Lake Somerset the Brisbane River and the Stanley River. Kind et al. (2009) report that the distribution and abundance of lungfish in these areas is poorly understood. In a regional population comparison Hydrobiology (2007) obtained the lowest CPUE values for Lungfish in the reservoirs of the Brisbane and North Pine Rivers and noted reservoir samples were skewed toward large specimens indicating a relative low abundance of young fish at reservoir sites. Lungfish populations have also been established in artificial impoundments on tributary streams within the lower Brisbane catchment including Lake Manchester, Cressbrook Dam, the Gold Creek Reservoir, and the Enoggera Reservoir on Enoggera Creek. While the Enoggera Reservoir population was once described as thriving (Thompson 1978), later surveys were dominated by old age specimens (Pusey et al. 2004), and the population is now belied to be extinct (Kemp 2008). No specimens were onbtained during recent surveys at the site Hydrobiology (2007). Kemp (1995, 2008) attributes this to the loss of spawning habitat and juvenile refuges within the reservoir initiated by spaying based control of water hyacinth in 1974.

4.1.3 Life History

Lungfish complete their entire life cycle in freshwater (Kind et al. 2009); they are intolerant of high salinity (Brooks & Kind 2002). They are a long lived species which reach a maximum age in excess of 50 years in the wild (Brooks & Kind 2002) and 80 to 100 years in captivity (Joss 2004). Other than some variable indications for juvenile growth rates in captivity, lungfish exhibit slow growth rates across the bulk of their life span. Mark recapture data from Burnett River studies indicate growth rates a slow as 5 mm per year with sexual maturity calculated to occur at 15 years and 767 mm for males and 20 years and 834 mm for females (Brooks & Kind 2002). Johnson (2001) believed these age estimates may be exaggerated and recommended more work on this aspect of reproductive biology.

Australian lungfish are a predominantly nocturnal species (Kemp 1986; Kind 2002). Juveniles follow a similar daily rhythm, to adults, leaving daytime refuges in the late afternoon to forage during the night (Kind 2002). In flowing riverine habitats adult Lungfish usually exhibit largely localised movement around a distinct home range typically 1- 1.5 km in length moving around one or two pools to forage at night and returning each day to certain habitat feature such as a submerged log, rock or patch of macrophytes in one particular pool where they rest during the day. Movement patterns during the breeding season and in impounded river sections are more variable and are discussed further below.

Adult lungfish are benthic omnivores eating both plant and animal matter including worms, tadpoles, fish, crustaceans, insects, bivalve mollusks, snails, aquatic plants including macrophytes and filamentous algae and terrestrial plant material including moss and fallen flowers and fruits from Eucalypt and other native trees (Pusey et al. 2004).

The annual spawning season for Lungfish occurs predominantly through late winter to late spring (August – November) though may begin as early as July and end as late as January (Kind et al. 2009). Spawning activity occurs in shallow glides and along river margins in close proximity to aquatic plant beds or partially submerged riparian vegetation.

Lungfish have a complex courtship behaviour involving three phases:

a. a searching phase seeking suitable spawning sites;

b. a ‘follow the leader’ phase in which up to five males follow and nudge the cloaca of females; and

c. actual spawning where fish dive together through aquatic vegetation with the male following the female and shedding milt over eggs. In this stage fish may lie on their sides and become entwined, shaking their tails to facilitate the flow of spawning products (Pusey et al. 2004).

Lungfish have a large ovary and the potential to lay many eggs but produce hundreds of eggs at most in the wild (Kemp 1984). The species does not make a nest and there is no guarding or parental care once eggs are laid. The species does not necessarily spawn every year and spawning appears to follow a cyclical pattern with years of good spawning seasons followed by several years of poor spawning (Kemp 2008). The occurrence of good spawning years is linked to good precedent conditions some of which may need to be sequential over a couple of years e.g. suitable water levels, flood and baseflow conditions to benefit aquatic plant communities preferred as spawning areas (Kemp 2008; Brooks and Kind 2002).

Eggs are usually deposited singly, occasionally in pairs. Newly laid eggs are enclosed in a jelly envelope (10 mm total diameter) and remain sticky for a short while until they becomes attached to submerged vegetation and/or silt and aquatic organisms have covered it. Eggs are negatively buoyant and may fall to the substrate if not attached to aquatic vegetation, such eggs considered unlikely to survive to hatching due to the difficulty of adequate gaseous exchange (Pusey et al. 2004). Hatching occurs after 23-30 days. Upon hatching the young fish is close to 10mm long. During their first week hatchling lungfish are defenceless and lie on their sides hiding in aquatic vegetation and only moves when stimulated, but from time to time swim spontaneously (Kemp 1984; 1986). These larval lungfish do not feed until their yolk sack is fully absorbed at 3 – 6 weeks at which time a spiral valve has developed in their intestine and they start feeding on bottom dwelling small invertebrates (Pusey et al. 2004; Simpson et al. 2002). They gradually develop into the adult form over the following four of five months with recorded length of captive specimens at this age ranging from 26-44 mm. (Pusey et al. 2004). Juvenile lungfish <300 mm are rarely encountered in the wild and their growth rates are poorly understood. Laboratory based studies (Kemp 1981) indicate extremely slow growth rates of post larval fish reaching 60 mm after eight months and up to 12 cm after two years (Allen 1989). Growth curves of wild Lungfish on the Burnett River show they reach around 400 mm at five years of age (Brooks & Kind 2002). In contrast commercial hatchery operations utilising 'greenwater' conditions report growth rates of up to 300 mm in 12 months and 450 – 550 mm in 24 months (Kind et al. 2009).

On the basis of available evidence it seems likely that juveniles remain in the natal habitat of dense aquatic vegetation for long periods and this may be related to the vulnerability of juveniles as well as larvae and eggs to predators including shrimps, aquatic insects (e.g. beetles and dragonflies), fish and birds (Pusey et al. 2004; Kind et al. 2009). In contrast adult lungfish are considered relatively immune from predation (Kemp 2008).

Recruitment rates of juvenile lungfish to the adult population appear to be inherently low and only successful in a small minority of years (Brooks & Kind 2002; Pusey et al. 2004; Kemp 2008). This is attributed to the cyclical and infrequent occurrence of suitable spawning and larval feeding conditions and the high susceptibility of larvae to variable water levels, flood events and possibly predation. In the Brisbane River Kemp stated that successful breeding seems to have occurred at intervals of around 20 years since before 1900. In the Burnett River, Brooks & Kind (2002) found that Lungfish recruitment has been poor since 1996 with subsequent surveys to 2008 still indicating a population dominated by adults and exhibiting very limited recent recruitment of sub adults (Kind & Brooks 2008). Johnson (2001) suggests that for a long lived species with naturally low mortality rates, successful spawning and juvenile recruitment is not essential every year and may occur only irregularly possibly in medium, to long-term cycles even in natural systems. The length of these cycles could easily mask deleterious impacts on recruitment for many years while the longevity of adults means that large individuals could remain common for decades and give no indication of incipient population decline in the longer term (Pusey et al. 2004).

4.1.4 Habitat Requirements

Most of the habitat requirements of Lungfish have been alluded to in the discussion of life history above. Lungfish can be found in non ephemeral tributary streams, river channel and impounded river sections of river basins they inhibit (Kind et al. 2009). Lungfish breeding grounds, nursery areas and adult foraging areas share similar habitat features particularly the presence of submerged aquatic plants (Kind 2002).

Adult lungfish congregate in patches of complex underwater habitat, most often in submerged macrophyte beds or underneath partially submerged riparian vegetation (Kemp 1995; Kind 2002). Woody debris, undercut banks, and rocks provide alternative shelter sites in heavily populated reaches (Brooks & Kind 2002; Kind 2002). Juvenile lungfish also exhibit an affinity for complex instream habitat. Records of juveniles collected in the field have typically been taken from dense vegetation cover in shallow water, less than 300 mm deep (e.g. Brooks & Kind 2002).

Lungfish breeding predominantly occurs in shallow river margins where eggs are laid amongst dense beds of submerged macrophytes. The presence of flow is not a prerequisite for suitable spawning sites (Brooks 1995), though many of the macrophytes preferred by Lungfish are flow associated species (Brooks & Kind 2002). Suitable breeding habitat is often widespread after low, stable winter flows have provided opportunities for aquatic plant communities to flourish. Brooks (1995) suggest the specific suite of macrophyte species available for spawning and nursery areas may not be as important as the microhabitat they provide for eggs and juvenile fish in terms of depth, water quality and the complex variety of algae, protozoa, worms, small mollusks and crustacea they contain (Kemp 1993).

Lungfish breeding habitat is highly susceptible to flow and depth changes and current evidence from the Burnett River suggests that breeding rarely occurs in the deep steep sided pools created by dams and weirs (Brooks & Kind 2002; Kind & Brooks 2008). Lungfish eggs and juveniles are also vulnerable to desiccation due to variable water levels experienced within impounded water bodies and regulated flow reaches and, poor water quality particularly low dissolved oxygen experienced at depths of more than 300 mm or under eutrophic conditions created by high nutrient levels or aquatic weed infestations (Brooks & Kind 2002; Kemp 2008). Consequently the construction of water storage infrastructure has resulted in the loss of breeding habitat and evidence suggests that habitat within impoundments, including Paradise Dam, is not suitable for successful lungfish breeding (Kind & Brooks 2008; Kind et al 2009).

4.1.5 Migratory Behaviour & Requirements

In tagging studies conducted in both the Burnett and Mary Rivers, the majority of recaptured lungfish are commonly located in close proximity to release sites, leading to the species generally being considered a sedentary fish that exhibits strong site fidelity within a restricted area with home ranges rarely exceeding beyond a single pool or occasionally, two adjacent pools (Brooks & Kind 2002; Pusey et al. 2004). While movements between capture sites rarely exceeded 2 km, a small percentage of riverine populations do exhibit longer range movements of more than 5 km. In contrast, impounded reach populations, had mean linear ranges more than 28 km with some individuals ranging up to 47.9 km (Brooks & Kind 2002).

In the last decade and a half studies employing radio tracking (telemetry) methods and the use of Passive Integrated Transponder (PIT) tags (Brooks & Kind 2002; Berghuis & Broadfoot 2004a & b; DPIF 2007, 2008), have provided information that challenges the notion of lungfish being a solely sedentary species. While most individuals are still found to have strong home range site fidelity and the species as a whole cannot be considered migratory in terms of seasonally or demographically definable long range migration patterns, movements are clearly a biologically important part of the Lungfish life cycle (Simpson et al. 2002). Movement is important in providing access to spatially and temporally patchy resources within seasonally variable riverine habitats for breeding and feeding purposes, overwintering, recruitment and dispersal and for escaping localised adverse conditions (Brooks & Kind 2002; Simpson et al. 2002).

These studies have identified that a sub set of most Lungfish populations are inclined to undertake longer range movements and that this behaviour is accentuated within populations living with modified riverine conditions particularly those generated by impoundment associated loss of spawning habitat. In considering why certain lungfish migrate considerable distances upstream and downstream and others do not, Berghuis & Broadfoot (2004) note similar individualistic migratory behaviour has been documented in other fish species and is considered to assist in maintaining genetic homogeneity within populations.

Lungfish in impounded waters are described as highly mobile (Kind et al 2009). In the case of the highly modified Burnet River in which 55% of the known core distribution of Lungfish within the main river channel has been subject to impoundment by barrages, weirs and dams (DEWHA 2009), adult fish are observed to undertake regular longitudinal seasonal upstream migrations to locate suitable spawning areas (Brooks & Kind 2002; Berghuis & Broadfoot 2004a; Kind et al 2009). Lungfish PIT tag detections at the entrance channel to upstream fishways indicate that even fish from non impounded Burnett River reaches also undertake significant upstream movements beyond normal home ranges. Greater than 23% of lungfish detected at the Paradise Dam upstream fishway had moved more than 5 km upstream from riverine tag sites and 5% had moved more than 50 km from below Ned Churchward Weir (DPIF 2008).

An interesting finding from fishway monitoring programs has been the recording of juvenile lungfish actively moving upstream (Berghuis & Broadfoot 2004a; DPIF 2007, 2008), most presumably in order to disperse away from nursery areas in search of suitable feeding and overwintering habitats (Brooks & Kind 2002; Berghuis & Broadfoot 2004a).

Essentially movement study findings indicate that Lungfish move as much as they need to. If feeding and breeding resources are available locally they can live a relatively sedentary existence and be successful, however where such resources are not available within a home reach they will undertake active movement to locate them. "*There is no such thing as a free lunch in ecology*" (Commoner 1971). The fact that a significant proportion of the Burnett River Lungfish population now undertake seasonally regular long distance movement in association with the spawning season is indicative that migration to find suitable spawning habitat is now a prerequisite for population success in the highly impounded and modified Burnett River system. Consequently Berghuis & Broadfoot (2004) assert that the maintenance of free passage beyond man made barriers should be considered an important aspect of maintaining viable lungfish populations.

More specific detail concerning Lungfish movement patterns and behaviour is provided in the next section.

4.2 Movement and migration of lungfish

In considering issues associated with the design of fish passage through the Paradise Dam the importance of integrating fishway operation and design elements for determining successful fish passage outcomes is recognised, and assumed. Fishways are designed within the context of a known or planned operational environment and, as such, it is my opinion that fishway operation is an inherent component of fishway 'design'.

There are at least five non-exclusive areas for consideration in terms of identifying lungfish behaviour relevant to the design of fish passage through the Paradise Dam.

4.2.1 Physical capacity of lungfish to move

The physical capacity of lungfish to move is relevant in terms of designing the physical size and hydrological entrance conditions of fishways.

There have been no specific studies conducted on the swimming capacity of lungfish. Lungfish are a large fish reaching 1.5 m in length and have a large girth. They are reputed to be a sluggish and inactive fish but are capable of rapid escape movements using its strong tail (Kemp 1986, 1990). Brooks (1995) observed lungfish attempting to move upstream and over the Walla gauging weir through particularly fast less than 2 ms^{-1} flowing water. These lungfish were also observed breathing at the surface in a backwater below the weir on a regular basis possibly as a response to an increased physiological requirement for oxygen. During large flood flows lungfish have been observed to avoid main channel current velocities and turbulence by sheltering amongst inundated bank side vegetation and other current refuges (Kind 2002). Only 4% of adult lungfish (maximum size 930 mm) sampled from a vertical slot fishway on the lower Burnet River successfully negotiated to the top of the fishway which had 15 cm slots, a water depth of 1m, slope of 6.3%, flow velocity of 1.4 ms^{-1} and within pool turbulence of 33Wm^{-3} (Stuart & Berghuis 2002). These authors noted that larger slots and lower turbulence levels were required to accommodate adult lungfish. Lungfish movements are usually slow and sinuous using the tail with or without the use of fins (Kemp1986). Despite their large size lungfish are capable of traversing very shallow riffle zones (12 cm deep) into other pools to find feeding and spawning habitat (Kind 2002).

4.2.2 Lungfish habitats

The habitat types lungfish naturally move through or to is relevant in considering what physical habitat conditions may need to be replicated within fishway designs to make them attractive to lungfish.

Lungfish predominantly occur in complex underwater habitats (discussed above) that include macrophytes, submerged riparian vegetation, snags, rocks and undercuts used as sites for feeding and sheltering. In the Burnett catchment Lungfish do not distribute into ephemeral tributary systems or past natural rock gorge or waterfall barriers, but they do negotiate pass riffle reaches where there is sufficient flow and depth. Lungfish apparently have a high level of awareness of their physical surroundings as evidenced by their strong home range and shelter site fidelity (Brooks & Kind 2002). Limited observation of immature lungfish movement indicate that while they did exhibit linear ranges of up to 2100 m, they remained close to cover at all times and that observed upstream movement like adults, coincided with a period of increased flow (Brooks & Kind 2002).

4.2.3 Life history stage, season, flow and other cues and motivations for lungfish movement

Life history stage, season, flow and other cues and motivations for lungfish movement are relevant to identifying the size range of lungfish that need to be accommodated by fishways. They are also relevant to identifying the most important operating periods for fishways and the broader regime of regulated flows and other environmental conditions that need to be addressed by river managers to ensure riverine lungfish populations are able, and inclined to, undertake movement through fishways and intervening river reaches.

As discussed in the life history section (above, see 4.1.3) early year class juvenile lungfish predominantly remain in their natal habitat of dense shallow macrophytes and undertake only limited (~200 m) nocturnal movements from their daytime retreats for feeding and remain close to cover (Kind 2002). The majority of lungfish observed to undertake reach scale longitudinal movements within the Burnett River including those detected at the Ned Churchward fishlock entrance are sexually mature adults (80% greater than 850 mm) of both sexes, indicating that reproductive needs (i.e. suitable spawning habitat) is the most likely motivator for such movements (Berghuis & Broadfoot 2004). However, the smaller percentage of immature lungfish recorded undertaking such movements indicate that lungfish are not migrating upstream solely to find spawning habitat.

Movements of tagged Burnett River lungfish during the spawning season are observed to follow a cyclical pattern (Simpson *et al.* 2002). During the late autumn and winter Lungfish move upstream particularly out of impounded waters, to locate suitable spawning habitat in shallow pools and glides. Such sites include riverine sections upstream of impoundments and side tributary streams and involve movements greater than 30 km and up to 50 km (Brooks & Kind 2002). The association of Lungfish upstream movement with flow events was first observed by Brooks (1995). PIT tag and telementry studies have now demonstrated the timing of upstream movements to be associated with minor flow events that provide increased connectivity between pools (Brooks & Kind 2002; Berghuis & Broadfoot 2004). Following the spawning period (late spring to summer) return movements occur on a staggered basis, with individuals again using minor river flow events to assist their downstream passage (Brooks & Kind 2002; Berghuis & Broadfoot 2004; DPIF 2008; Kind et al 2009).

4.2.4 Pre-dam lungfish movement

Establishing the pre-dam capacity of lungfish for movement through the dam reach for breeding, feeding, recruitment and dispersal provides a prudent baseline against which the design (& operational) requirements of fishways may be identified. Maintaining original levels of population connectivity and genetic mixing is necessary for the species due to its low genetic diversity and high extinction risk (Arthington 2008).

Unfortunately there have been no specific studies of lungfish movement through the dam site reach pre-dam. Movement of lungfish individuals through this reach, pre or post-dam, was not included as a study focus of the Paradise Dam Baseline Lungfish Monitoring Program being conducted for Burnett Water Pty Ltd (Kind et al. 2005; Kind & Brooks 2008). Recaptures of fish tagged by earlier studies (e.g. Brooks & Kind 2002; Berghuis & Broadfoot 2005) in the vicinity of Paradise Dam were reported by Kind et al. (2005) indicating that lungfish have moved through or to the dam reach pre-dam completion but this data has not been published. Post dam movement of lungfish through the dam reach is being monitored along with all other fish species as part of the Paradise Dam upstream and downstream fishway monitoring programs (DPIF 2006, 2007, 2008, 2009). These monitoring programs have detected that a very small number of non representative sized lungfish have moved through the upstream fishway and that adult lungfish have moved downstream to the dam wall in an unsuccessful attempt to pass downstream, the implication of which are examined more fully in latter sections of this report concerning the effectiveness of Paradise Dam fishway design and operation.

In the absence of temporally quantified data, the ability of lungfish to move through the dam reach pre-dam can only be surmised by reference to the flow conditions and hydrological connectivity of the aquatic habitats available at the site pre-dam and by knowledge of lungfish movement capacity and behaviour within the Burnett River. The riverine habitat of the Burnett River in the dam reach pre-dam is illustrated in the following satellite image and photographs.

Figure 23 - Satellite image of dam wall during construction on 6 May 2003 showing location of pre-dam photographs (Figures 24-27) relative to dam wall
(GoogleEarth, 2009)

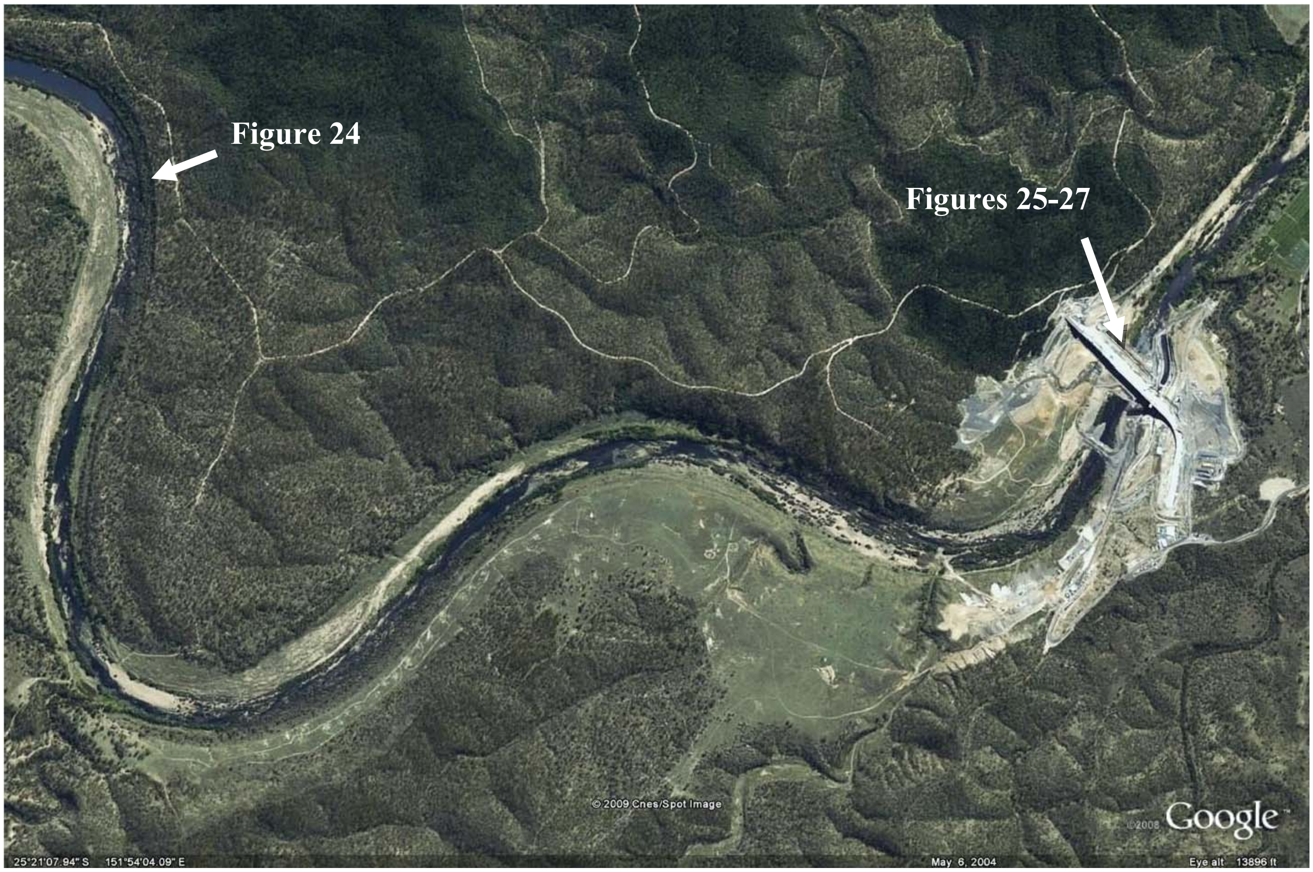


Figure 24 - Burnett River in 2003 looking downstream 5 km upstream of dam wall in reach flooded by dam reservoir (Carl Moller, May 2003)

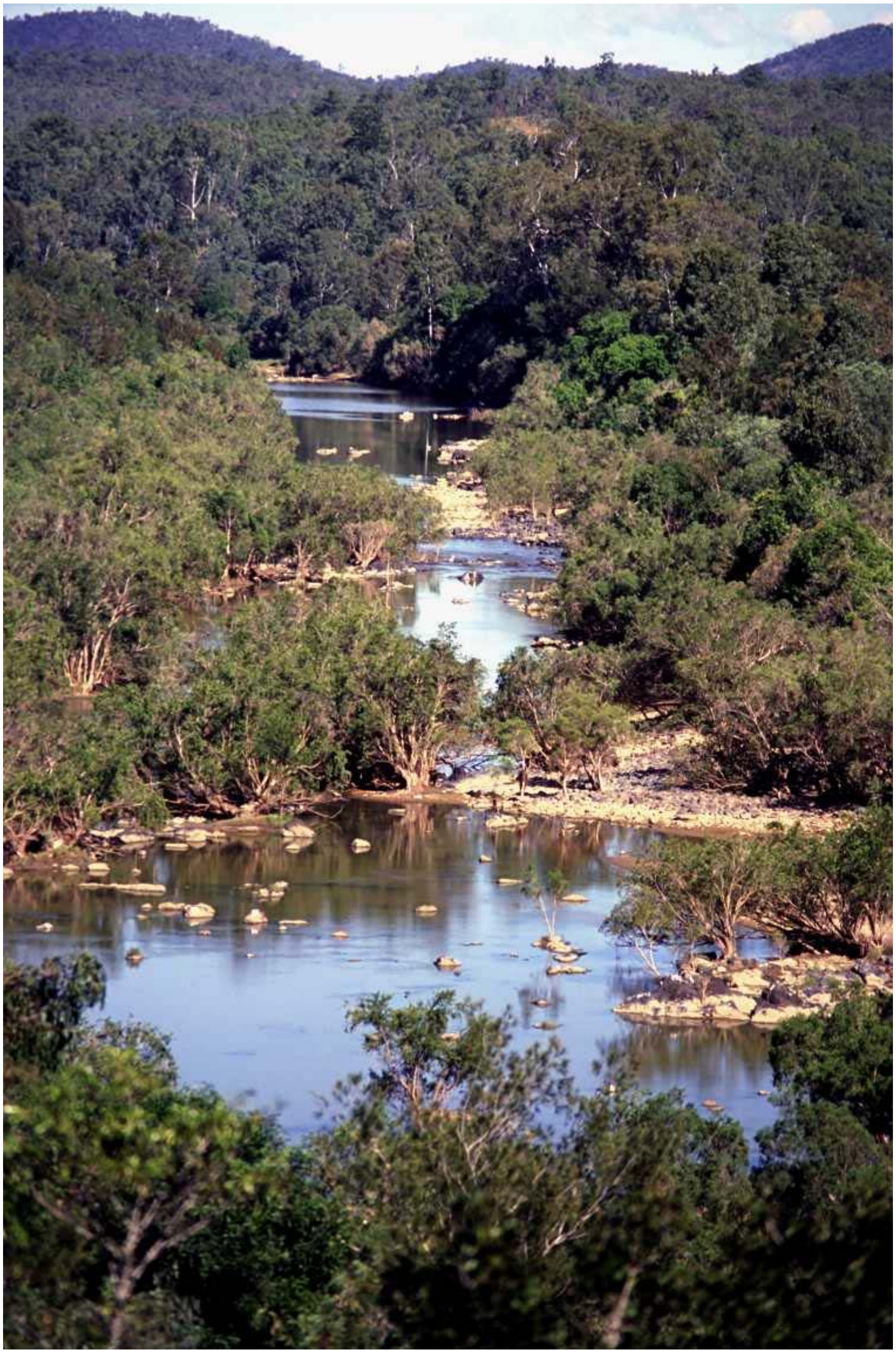


Figure 25 - Paradise Dam site in 2003 looking downstream from dam site

Figure 26 - Paradise Dam site in 2003 looking upstream from dam site

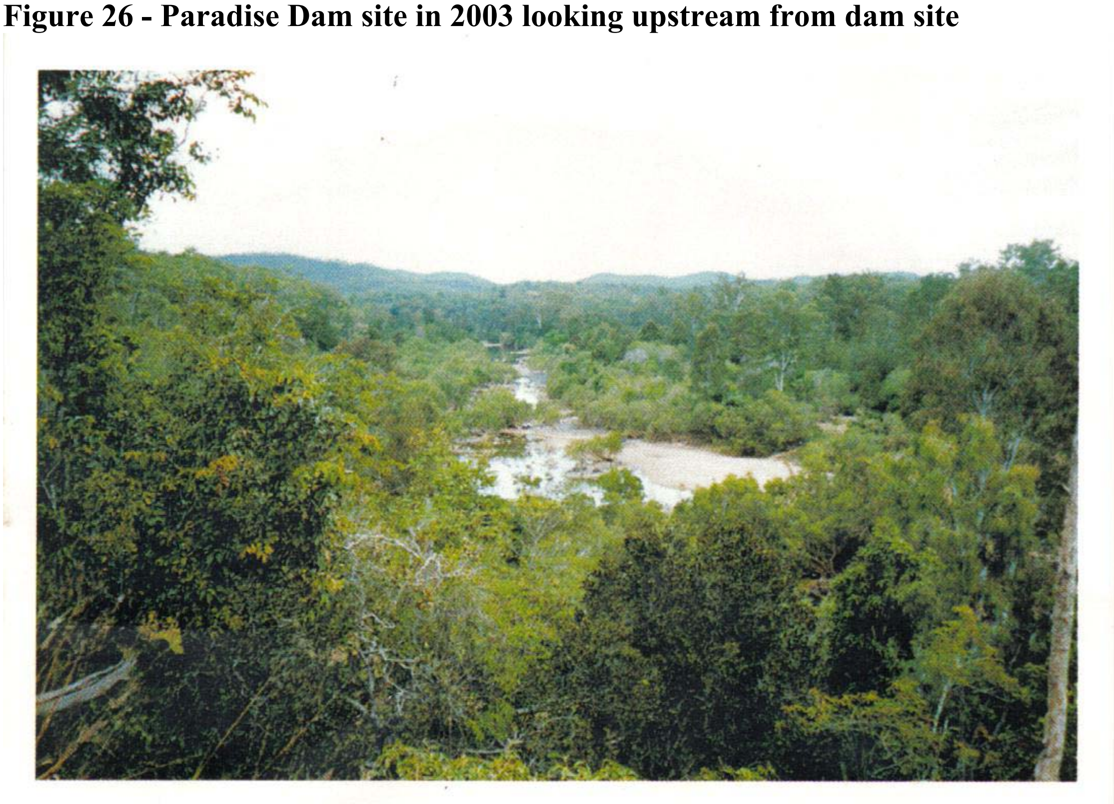


Figure 27 - Paradise Dam site in 2003 looking across river in vicinity of dam site.

The behaviour of lungfish moving within the Burnett River has been discussed in a preceding section, above at 4.2.3, . The demonstrated capacity of lungfish to move through very shallow (~12 cm) water including over riffles particularly when seeking access to spawning habitat (Brooks & Kind 2002), has been interpreted here as a capacity for movement within and between river reaches when ever there is hydrological connectivity i.e. flow or inundated river bed of sufficient depth linking reaches. It is acknowledged that this estimated capacity for movement would overstate the actual frequency of lungfish movements which has been found to be primarily associated with minor flow events (Brooks & Kind 2002; Berghuis & Broadfoot 2004; DPIF 2008),

Descriptions of the pre dam Burnett River environment including channel cross sections are provided in the Burnett River Dam Baseline Aquatic Surveys (Richardson et al 2003). These descriptions were compiled in April 2003 following changes in water levels associated with prolonged drought conditions and, following subsequent major floods in February 2003 (Richardson et al 2003). Two site descriptions from within the Paradise dam reach, taken from Richardson *et al* (2003), are provided below:

> ***Site 3* - Within the impoundment zone for the proposed Burnett River Dam, adjacent Goodnight Scrub National Park Easting - 387380 Northing - 7194810**
> *Dominated by glide habitats of moderate flow over sand substrate. A wide (approx. 100 m) sandy stretch of exposed river bank, with sparse vegetation cover and a*

veneer of mud. A riffle zone of shallow, turbulent, fast flowing waters over pebbles and cobbles, with sparse macrophytic cover, lay downstream from the transect.

<u>Site 4</u> - Within the impoundment zone for the proposed Burnett River Dam, east of Mingo Crossing Easting - 377099 Northing – 7190374
Comprised of a variety of habitats including;
- *Pools- wide, open, slow flowing, and deep;*
- *Glides- moderate flow over sand substrate*
- *Riffle zones- shallow, turbulent, fast flowing waters over pebbles or cobbles. and*
- *Backwaters- areas of low flow.*

Additional information regarding the hydrological connectivity of river reaches in the vicinity of Paradise Dam can be ascertained from modelled and measured flow data for the Paradise Dam reach (see **Appendix 6**), and aerial photo interpretation. Modelled flows based on historical rainfall data for the Burnett River basin (see **Appendix 6**) indicate that zero flow periods (cessation of flow) that would result in breaks to the hydrological connectivity of aquatic habitats in the Paradise Dam reach pre-dam occur for approximately 3.95% of the 107.5 year simulation period. Conversely, simulated hydrological connectivity in the Paradise Dam reach pre-dam occurs for 96.05% of the time of the 107.5 year historical rainfall record. Importantly, in the 107.5 year pre-dam flow simulation period there are no zero flow periods that extend through an entire lungfish spawning migration period (see **Appendix 6**).

While it may be argued that hydrological connectivity through some pre-Paradise Dam riverine reach may have been maintained with water depths less than the 12 cm required to enable lungfish access, this is not supported by pre-dam river channel profiles compiled for the Paradise Dam site (Richardson et al 2003). It should also be acknowledged that flow gauging station data used to calibrate simulated flow models are known to be inaccurate at measuring low flows resulting in recorded low flow volumes being less than present and modelled low flow and zero flow periods being overstated (Bewster 2008). Consequently it is proposed that the interpretation of periods of hydrological connectivity as equivalent to the period of capacity for lungfish movement through the Paradise Dam reach is conservative and valid.

The most recent readily available aerial photo and satellite imagery for the Burnett River reach downstream of the Paradise Dam sites includes for November 1996, June 2002, May 2004 (pre-dam construction) and July 2007 (post-dam construction) (see Figures 28 - 31). A close examination of these images indicates that hydrological connectivity occurs throughout the Paradise Dam reach of the Burnett River in all but the post dam images. Figures 32 & 33, taken in 2007, highlight the loss of connectivity following construction of the dam.

Figure 28 – Aerial photograph of Burnett River reach downstream of Paradise Dam site 13 November 1996 (Department of Natural Resources, 1996)

Figure 29 - Aerial photograph of Burnett River reach downstream of Paradise Dam 30 June 2002 (Department of Natural Resources, 2002)

Figure 30 - Satellite image of Burnett River reach downstream of Paradise Dam 6 May 2004 (GoogleEarth, 2009)

Figure 31 - Aerial photograph of Burnett River reach downstream of Paradise Dam in 10 July 2007 (Department of Natural Resources and Mines 2007)

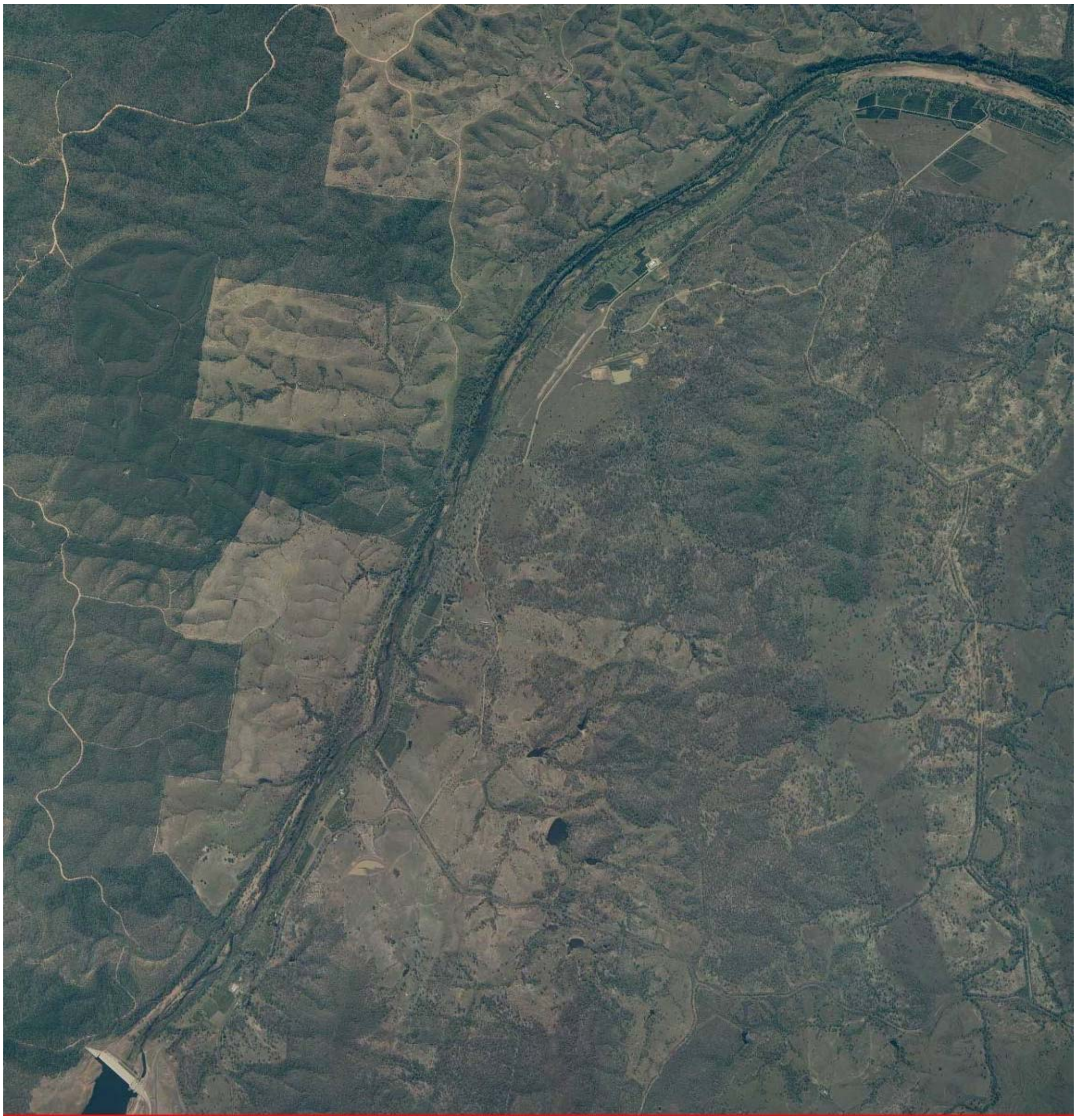
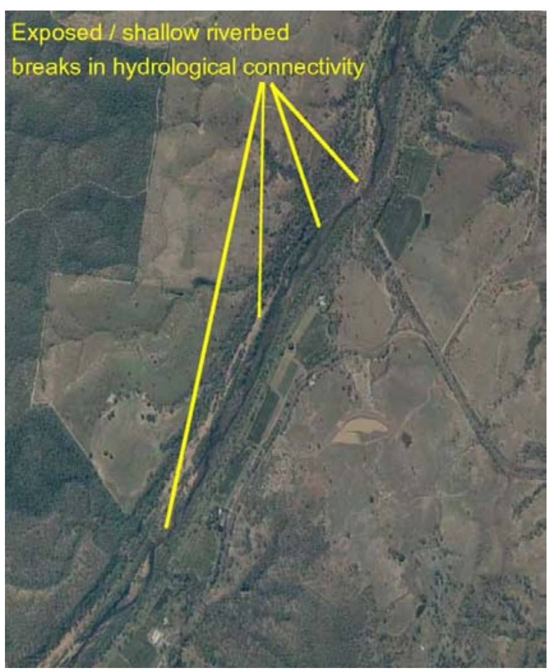


Figure 32 - Enlarged view Burnett River reach pre- dam downstream of Paradise Dam site 30th June 2002. 2002 experienced the second lowest rainfall total in the last decade (for Gayndah Post Office) of 558.9 mm. Rainfall totals for the 3 months preceding this aerial photo were 133.1 mm.

Figure 33 - Enlarged view Burnett River reach post-dam downstream of Paradise Dam site 10th July 2007. 2007 experienced the 4th highest rainfall total in the last decade (for Gayndah Post Office) of 667.9 mm. Rainfall totals for the 3 months preceding this aerial photo were 169.4 mm.



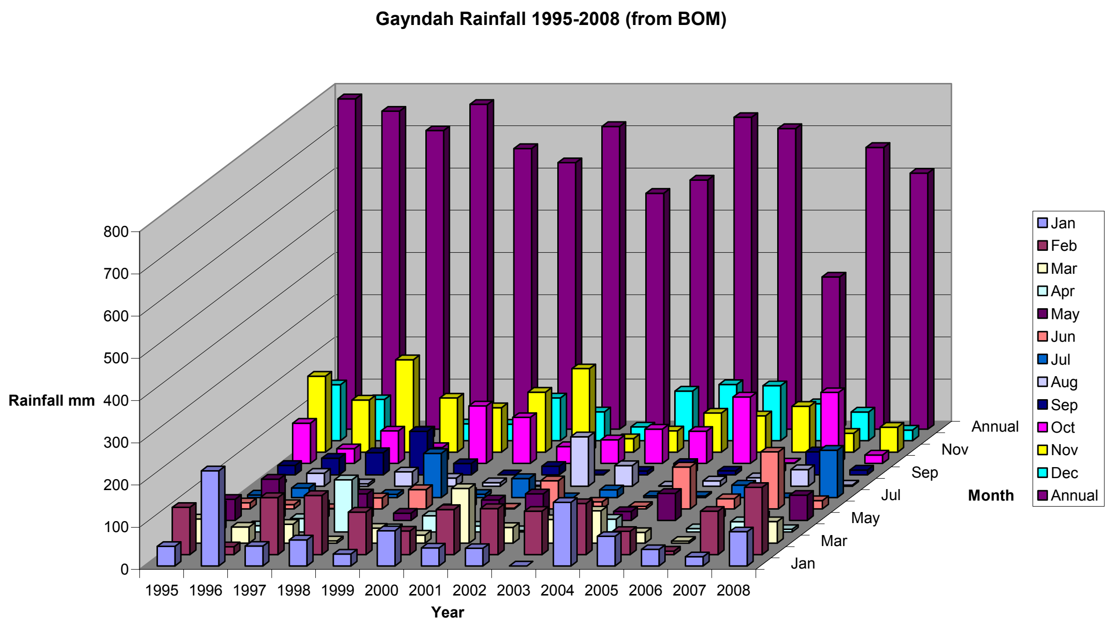
Obviously the date of the aerial photographs and the precedent rainfall / flow conditions need to be considered in interpreting the observed extent of hydrological connectivity through the dam reach. Rainfall data for the closest rainfall station upstream of the dam (Gayndah Post Office) is presented in Table 1 and Figure 34 (below). While the November 1996, May 2004 and July 2007 images (figures 23, 25 & 26) were all taken in years with relatively high rainfall totals compared to decadal averages, the June 2002 image was taken in a year which had the 2nd lowest rainfall total in the last decade. Despite this, the 2002 aerial photo (Figure 32) indicates hydrological connectivity throughout the reach and importantly in June a period recognised to coincide with pre-spawning upstream movement in lungfish (discussed above).

In contrast, the post-dam aerial photo taken in July 2007 a year with the 4th highest rainfall total of the last decade and with rainfall in the 3 months preceding the photo greater than that preceding the 2002 image, hydrological connectivity downstream of the partially filled dam is broken by exposed and shallow river bed (Figure 33).

Table 1 - Gayndah Post Office Rainfall Data 1995 – 2008
(Australian Bureau of Meteorology http://www.bom.gov.au/)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1995	46.5	111.8	57.5	61.6	49.8	14.6	6.4	4.9	22.4	95.2	179.9	132.4	783
1996	225.4	18.3	38.4	14.4	97.5	10.8	22.9	30.5	39.5	35.1	123.2	97.5	753.5
1997	47	135.2	44.8	31.4	36.7	1.2	34.2	5.8	52.7	77.1	218.6	22.8	707.5
1998	61.7	140	5.3	123.3	62.9	26.4	7.6	33.9	103	38	128	39.8	769.9
1999	28.2	100.6	35.6	7.2	17.1	46	104.8	19.1	26.6	136.2	105	38.9	665.3
2000	83.5	55.9	19.1	38.1	27.8	39	8	8.3	0.2	109	141.7	101.1	631.7
2001	42.6	106.9	129.8	13.6	48.6	2.3	45.4	2	20.2	40.1	197.5	68.3	717.3
2002	41.7	108.9	37.3	3	63	67.1	0	117.2	0.8	55.7	31.7	32.5	558.9
2003	0	102.7	56	56.4	34.3	16.6	18.2	49.1	8.7	81.1	50.2	117.3	590.6
2004	150.9	121.1	76.6	30	20.9	6.1	4.3	0.6	26.9	76.1	92.5	133	739
2005	70.2	55	25.3		63.8	99.6	3.6	12.8	9.1	157.4	85.6	130.3	712.7
2006	39.1	8.5	4.8	7.5	12.8	24.6	29.6	20.1	16.5	1.4	108.4	87.5	360.8
2007	21.7	102.7		23.9	10.4	135.1	0.1	39.4	54.3	168	44.5	67.8	667.9
2008	81.1	159.1	51.2	5.8	59.7	19.7	112.4	2.5	11.4	19.9	58.9	25.1	606.8

Figure 34 - Gayndah Post Office Monthly and Annual Rainfall 1995 – 2008



The causes and implications of post-dam loss of hydrological connectivity in the riverine reaches below the Paradise Dam are examined more fully in latter sections of this report concerning the effectiveness of Paradise Dam fishway design and operation. **The key point to be communicated in this section is that the pre-dam, riverine habitat, depth, hydrological connectivity and flow characteristics of the Paradise Dam site reach of the Burnett River predominantly (~90% of time) provided conditions in which lungfish had the capacity for undertaking movement upstream or downstream of the dam wall site to contiguous river reaches.**

4.2.5 Lungfish behaviour at fishways

Lungfish behaviour had been studied at a number of fishways and fish passage barriers prior to the construction of the Paradise Dam (Stuart & Berghuis 2002; Brooks & Kind 2002; Berghuis & Broadfoot 2004). Identifying the behavioural responses of lungfish to the design and operational conditions provided by existing fishways and barriers and addressing identified constraints is prerequisite to the successful design and operation of new fishway installations intended to serve the needs of lungfish.

A number of interactions of lungfish with fishways and fish passage barriers were reported above at 4.2.1.

A year long study of PIT tagged lungfish behaviour was conducted at the Ned Churchward Weir fish lock by Berghuis & Broadfoot (2004). Ned Churchward Weir (formerly Walla Weir) is a 15.0 m high, concrete gravity structure with a total storage capacity of 29,500 ML at full supply level and fitted with fishlock fishway that is configured to alternatively provide both upstream and downstream fish passage. Ned Churchward Weir provides water primarily for surface water irrigation within the Bundaberg Irrigation Area. Construction of the weir was completed and subsequently filled in November 1998. The weir was constructed on a rock-bar that spans the width of the river in a reach that was recognised to be one of the most important lungfish spawning areas in the lower Burnett River system (Brooks and Kind 2002).

In the study of PIT tagged lungfish at the Ned Churchward Weir Berghuis & Broadfoot (2004) recorded a total of 41 individuals at the downstream entrance to the fish lock of which only 7 (17%) successfully passed upstream through the fish lock. 12 lungfish successfully used the fish lock in a 1999 – 2000 study. Berghuis & Broadfoot (2004) considered the current design and operation of the fish lock "less than optimal" for lungfish passage.

Most detected lungfish swam in and out of the downstream fish lock channel several times over a number of hours before moving through the fish lock or moving away entirely. The size range of fish that successfully used the fish lock was 1170 – 385 mm and not significantly different to the size range of the tagged population. 85% of lungfish detections at the fish lock upstream entrance occurred between March to May 2003 a period that coincided with low-level flood events and sustained outlet works release flows. No detection occurred from 17th June to 13th November 2003, a period with no major flow releases, but did occur in this period in the 2000 study when minor flood flows occurred during this period. Attraction flows coincided with 95.7% of all initial lungfish detections at the fish lock upstream entrance. Of the lungfish detected at the fish lock upstream entrance 2 came from 25 and 36 km upstream of the weir, 22 from immediately downstream of the weir and 17 from sites up to 9 km downstream.

The majority of fish detected approaching the Ned Churchward Weir fish lock entrance including those tracked by Brooks & Kind (2002) to have travelled long distances upstream to reach that point, moved back downstream after only spending a short time at the weir, a result Berghuis & Broadfoot (2004) noted had implications for the future design of mechanical fishways. Simpson et al. (2002) presumed lungfish confronted with this situation would then spawn in the most suitable habitat available but Joss (2004) notes that it is not uncommon for lungfish to relinquish spawning and to reabsorb eggs and sperm if conditions are unsuitable.

Not all recaptured lungfish that had migrated up to the Ned Churchward Weir were detected at the fish lock entrance suggesting to Berghuis & Broadfoot (2004) that the entrance and approach conditions in the fish lock are not effective at attracting lungfish for more than one possible contributory factor including:

a. The restriction of fish to a small percentage of the river channel, in contrast to the broad expanse of channel naturally available to most Australian fish under elevated flood flow conditions;

b. Possible avoidance behavioural aspects of lungfish to unnatural discontinuous attractant flows and small channel conditions;

c. The relatively small flows emanating from the fish lock entrance in comparison to other flows below the weir.

Given that the majority of lungfish detections at the weir occurred during low level spillway flows and high level outlet release flows the capacity of fishway attractant flows to compete with these larger flows is critical to their success. It is salient to note that the fish lock was designed to operate on a release volume of 86.4 Ml/day though is operated by SunWater with a release volume of approximately 12 Ml/day (Berghuis & Broadfoot 2004). In comparison to the volume of water released by the outlet works and over the weir spillway during river flow events the volume of water released via the fish lock is likely to be insignificant in terms of competing as an attractant flow (Berghuis & Broadfoot 2004).

During downstream movements the majority of lungfish passages pass the Ned Churchward Weir occurred over the spillway during high flows, though some Lungfish also passed over the spillway during low flows (Berghuis & Broadfoot 2004). Following the February 2003 floods Berghuis & Broadfoot (2004) found a substantial number of dead fish below the 15 m high Ned Churchward Weir. Based on observed spillway overflow mortality of lungfish at the Lake Samsonvale dam wall on the North Pine River, Johnson (2001) suggested that many lungfish are likely to be killed or injured passing over the dam and weir walls in the Burnett River during severe floods and that a very large flood could potentially kill hundreds of individuals. Berghuis & Broadfoot (2004) recommended that regardless of improvements to fishway design, passage over spillway walls is likely to be the major mode of passage for downstream migrating fish and therefore future design of weirs should include the provision of safe passage of fish over the spillway.

Other recommendation of Berghuis & Broadfoot (2004) in relation to improving the efficacy of the Ned Churchward Weir fish lock for passing lungfish included:

a. Provision of continuous attraction flow at both the upstream and the downstream fish lock channels with minimal variation in flow intensity between cycle phases;

b. Vary the operation of the fish lock to suit the full range of conditions such as incrementally increasing fishway attraction flows during outlet release and spillway flows;

c. Reduce the duration of low level spillway flows by increasing the volume of outlet works releases which also provide a more competitive attraction flow to the fishway entrance.

d. Attract fish away from the spillway by releasing through the outlet works when flows over the spillway are within the capacity of the outlet works;

e. Devise mechanical means to retain lungfish once they have entered the fish lock channels, without compromising the ability to provide for downstream passage;

f. Investigate mechanical means to encourage lungfish to exit as quickly as possible once the lock chamber is full;

g. Design entrances that assist lungfish to move away from spillway and outlet flows and into the fishway;

h. Investigate the benefits of faster fishway cycling during peak migration periods such as during flood flows; and

i. Address issues of predation of small fish within the fish lock.

The adoption or otherwise of these types of recommendations is reviewed in latter sections of this report concerning the effectiveness of Paradise Dam fishway design and operation.

4.3 Evolutionary and Ecological Significance of the Lungfish

Neoceratodus forsteri is the most primitive surviving member of the ancient and once speciose air-breathing Dipnoi (lungfishes) that flourished in the Devonian (413- 365 m.y.b. p), a linage now represented by *N. forsteri*, one South American species and four African species (Arthington 2008). It is frequently labeled a 'living fossil' because since evolving from its Devonian ancestors the species has existed unchanged at least since the early Cretaceous period, 100 million years before present (Joss 2004; Simpson et al. 2004).

Lungfish are remarkable as examples of an evolutionary line that possess pre-adaptive features which supported the transition of vertebrate animals from aquatic to terrestrial environments. They provide an invaluable source of information about the transition of vertebrate animals from water to land 350 million years ago, including even our own ancestry and the only opportunity to study the development and physiology of the aquatic predecessor of all land vertebrates (Joss 2004). Joss (Pers. Comm. 2009) explains:

> *Lungfish, amphibians, reptiles, birds and mammals, including humans, all belong to the sarcopterygian clade. Here, Neoceratodus is of particular significance since this is the living lungfish species most ancestral to all tetrapod (land vertebrate) species. Studies of this lungfish developmental biology can shed light on the evolutionary processes that led to the vertebrate transition on to land. Because of this, it is also being studied more and more for its potential to shed light on several genetic-based diseases of man, eg. Cystic fibrosus.*

Fossil evidence indicates that the range of lungfish once extended across much of Australia including to the centre of the continent prior to the Pleistocene (1.6 m.y.b.p.) (Kemp 1991, 2008; Arthington 2008), and that in the Miocene (15 m.y.b.p) there were an additional 8 species of lungfishes living in Australian lakes and rivers in central, eastern and northern Australia (Pusey et al. 2004). Since the Pleistocene the range of *N. forsteri* has contracted to south east Queensland most likely due to an increasingly arid Australian climate and increased competition with more successful ray finned fishes (Joss, 2004; Kemp 2008).

4.4 EPBC Act listing of lungfish

The following extract from the Nationally Threatened Species and Ecological Communities Information Sheet - Australian lungfish *Neoceratodus forsteri* (DEWHA 2003; **Appendix 5**) summarises why the species' survival is considered threatened.

> *"Evidence suggests that in recent years only small numbers of young lungfish are growing-up into adult fish. In addition, changes to the quality and extent of breeding habitat appear to be reducing the likelihood of successful spawning.*
>
> *Two of the key problems affecting the lungfish are the flooding of suitable spawning sites and physical barriers that block the movement of adult lungfish to the remaining breeding sites.*
>
> *While the waters of dams and weirs provide feeding habitat for the species, they rarely provide the shallow water and dense cover of water plants like ribbon weed which the lungfish need for successful spawning. In addition, dams and weirs do not provide suitable nursery habitat for the species as the young also require a cover of water plants.*
>
> *Because of the long life span of the lungfish (with some research suggesting that the fish may live up to 100 years) the lack of breeding success may not become evident in the adult population for many years.*
>
> *It is estimated that there has been a 26 per cent loss or reduction in the amount of breeding and nursery habitat for the Australian Lungfish (the main channels of the Burnett and Mary Rivers). As a result, the adult breeding population is likely to undergo a substantial decline within the next three generations.*
>
> *In addition, exotic and translocated native fishes, such as the exotic Tilapia (Oreochromis mossambica) are believed to prey on lungfish eggs and young and compete with adults for breeding habitat."*

The lungfish was listed as vulnerable to extinction under the EPBC Act of the basis of eligibility under two of the five criterion used for species listing, specifically (1) their decline in numbers, and (2) their geographic distribution. The full description of the species' eligibility under these criteria, as provided to the Commonwealth Government Minister for the Environment and Heritage by the Threatened Species Scientific Committee (TSSC) in 2003, is included in **Appendix 4**.

4.5 Importance of connectivity for lungfish

The preceding discussion on lungfish biology and ecology has identified that lungfish have evolved to exploit seasonally variable riverine environments in which the resources they require for feeding, breeding and general survival (e.g. good water quality) are patchily distributed in space and time. To be able to successfully exploit such environments lungfish require connectivity between riverine reaches to move when suitable resources are not locally available. The observed movement patterns of both sub adult and adult lungfish have led researchers that have studied lungfish movement in the Burnett River to conclude that movement between river reaches is a biologically important part of the lungfish life cycle (Brooks & Kind 2002; Simpson et al. 2002; Berghuis & Broadfoot 2004; Kind et al. 2009).

4.5.1 Spawning

In the Burnett River lungfish are particularly being compelled to undertake spawning associated migrations due to the impoundment of 55% of the main river channel within the known core distribution lungfish by barrages, weirs and dams (DEWHA 2009) and, the associated degradation of suitable spawning habitat (Brooks and Kind 2002, 2008; Kind et al 2009). Lungfish in such impounded water are described as 'highly mobile' (Kind et al 2009) and numbers of adult fish are observed to undertake regular longitudinal seasonal upstream migrations to locate suitable spawning areas and then to undertake return movements (Brooks & Kind 2002; Berghuis & Broadfoot 2004). Detected movements of lungfish upstream to the Paradise Dam fishway entrance and downstream to the Paradise Dam wall, including some originating from distances more than 5 km away, indicate that lungfish are seeking to move past the Paradise Dam (DPIF 2008). The significance of these movement detections is examined further in latter sections of this report concerning the effectiveness of Paradise Dam fishway design and operation.

4.5.2 Mortality when spillway overflows

Prior to the construction of Paradise Dam lungfish were known to be subject to spillway overflow mortality at a number of existing dams and weirs both within the Burnett and other river basins. Early in the design phase DPIF set as a approval requirement "*that the spillway design and operation of the dam shall; be such as to minimise the adverse impact on the state of health of fish moving downstream*" (DPIF 2003). DPIF have continued to express concerns regarding the high impact risks posed by the 37 m high and stepped spillway that has been constructed at Paradise Dam to the present time (Fishway Workshop. 25 August 2008). Even, prior to the construction of Paradise Dam Johnson (2001), suggested that many lungfish are likely to be killed or injured passing dam and weir walls in the Burnett River during severe floods and that a very large flood could potentially kill hundreds of individuals. Berghuis & Broadfoot (2004) recommended that regardless of improvements to fishway design, passage over spillway walls is likely to be the major mode of passage for downstream migrating fish and therefore future design of spillways should include provisions for the safe passage of fish. Given that spillway design features recommended by the Burnett Dam Alliance's own fishway experts to accommodate the safe downstream passage of fish (Mallen –Cooper 2004), have not been included in the design of the Paradise Dam spillway, the importance of providing effective downstream passage of fish past Paradise Dam via an effective fishway has been elevated by the need to minimise the opportunities for Lungfish spillway overflow mortality.

4.5.3 Maintenance of Genetic Variability and Viability

Genetic studies by Frentiu et al. (2001) demonstrate that lungfish, including Burnett River populations, are not genetically diverse, a feature shared with other endangered species and often associated with population declines (Arthington 2008). They exhibit low allelic diversity at allozyme and mitochondrial DNA loci, possibly including loci linked to fitness and resistance to disease (Arthington 2008). This has been interpreted as evidence of past severe population 'bottlenecks' in which the entire lungfish population have been reduced to a small size possibly due to episodic or prolonged drought in ancient or recent times (Kemp 1991). Frentiu et al. (2001) suggests that post bottleneck recovery of lungfish populations was most likely slow given the long generation time of the species (Brooks & Kind 2002) and the high predator vulnerability of juveniles (Bancroft 1928). This low genetic variation is identified as a cause for concern as it may lead to inbreeding depression, population decline, reduced evolutionary potential and high extinction risk (Arthington 2008). Given the escalating levels of anthropogenic disturbance of lungfish habitat, Brooks & Kind (2002) noted their potentially vulnerability to novel or introduced diseases and other perturbations. These authors recommended that in order to achieve the goal of preserving the limited amount of genetic variation still evident in lungfish populations, management actions should aim to maintain high adult survival, limit the loss of suitable spawning habitat and provide for suitable Lungfish passage throughout the Burnett River system.

In summary, lungfish are a species listed as vulnerable to extinction under the EPBC Act. They are recognised to have low levels of genetic diversity and infrequent and low levels of population recruitment and survive by a life history strategy that depends on longevity to counter low annual recruitment success. While lungfish will spawn annually, environmental conditions for successful spawning and recruitment of Lungfish young are recognised to not occur every year. Effective fish passage upstream and downstream of the Paradise Dam is therefore required to support the viability of the lungfish population by providing regular access to habitat and feeding including spawning grounds, to maximise opportunities for recruitment success including the dispersal of juveniles, to prevent spillway overflow associated mortality of adults and to allow for population genetic mixing to maximise the genetic vigour and evolutionary potential of the species.

4.6 Lungfish Impacts if no fishway installed

Impacts to the Burnett River lungfish population that would be expected from the construction of the Paradise Dam without a fish transfer device include the realisation of risks associated with a loss of connectivity identified in above, at 4.5, and, also habitat impacts associated with hydrological changes due to the impoundment of the Paradise Dam reach and regulation of downstream flows.

4.6.1 Reduced lungfish habitat

In addition to the creation of a fish passage barrier, a range of other impacts to lungfish and their habitat are associated with dam construction. The most well documented in the loss of suitable spawning and nursery habitat within impounded reaches upstream of the dam wall following the inundation of shallow pool, riffle, and glide sequences and their associated marginal macrophyte (aquatic plant) communities. Brooks & Kind (2002) note that there is good evidence that the creation of lacustrine (lake) habitat by the construction of weirs and dams leads to a net loss of suitable lungfish spawning habitat in the Burnet River system. Subject to channel depth, impacts to lungfish spawning and nursery habitats are caused by loss of flow, deep inundation and/or highly variable water levels that make it difficult for macrophytes to establish and /or for eggs and larvae to survive. Monitoring results within the impounded reach of Paradise Dam (Kind & Brooks 2008) provide evidence that these types of impacts to habitat and lungfish spawning success are now occurring within the filling impoundment.

In the draft recovery plan for lungfish, flow regulation is recognised as a key threat (Kind et al. 2009). The recovery plan states that the construction and operation of water storage infrastructure has altered the volume, frequency, duration and timing (seasonality) of riverine flows. Altered flow can significantly impact growth and condition of macrophyte beds downstream of barriers. There is evidence that flow regulation has led to increased fluctuations in water level, reduced volumes of water in river channels and therefore reduced habitat for fish, stranding of adult lungfish, exposure of breeding habitat including eggs and inundation of habitat leading to reduced habitat availability and changes in lungfish movement patterns. Present water allocation practices in the Burnett River have occasionally resulted in the stranding of lungfish in drying pools (Kind et al. 2009).

The changed habitat conditions apparent in aerial photos of the reach downstream of the Paradise Dam post-dam construction were discussed above, see Figures 28 – 33 at 4.2.4. Further insight to the flow regime and connectivity impacts associated with Paradise Dam is provided by an analysis of simulated flow regimes pre-dam and post-dam based on 107 years of rainfall data (see **Appendix 6**). This analysis found that the longest period of no hydrological connectivity i.e. zero flow, downstream of the dam pre-dam was 150 days, while post-dam it was 793 days. This same analysis also found that there were no occasions in the pre-dam scenario where connectivity was lost for an entire lungfish spawning movement period, but there were 9 years in the post-dam scenario where connectivity was lost for an entire lungfish spawning movement period and 13 years where it was lost for most of the spawning movement period. These losses in hydrological connectivity would serve to accentuate the physical barrier impacts to connectivity caused by a dam lacking effective fish transfer devices.

4.6.2 Reduced connectivity

Dams, particularly tall ones such as Paradise Dam, are fish passage barriers. This would be accentuated by the absence of any fish transfer device with the only prospect of lungfish movement past the dam being downstream via spillway overflows and possibly via irrigation or environmental releases. The impacts of reduced population and habitat connectivity on lungfish are explored further below.

4.6.3 Reduced spawning success & overcrowding

Suitable spawning habitat for lungfish is becoming an increasingly limited resource within the Burnett River basin as a consequence of river impoundment and flow regulation (discussed above). Lungfish in many reaches of the Burnett River must now undertake longitudinal movements within the river system to access suitable spawning areas. If the Paradise Dam had no fishway, lungfish would be unable to access suitable spawning areas that are distributed or periodically occur, on the other side of the dam wall to the reach occupy. This would be likely to result in reduced breeding success for the Burnet River lungfish population as a whole. Another consequence of reduced lungfish access to suitable habitat areas is the congregation of fish at residual suitable and accessible habitats or in the vicinity of fish passage barriers. Kind et al. (2005) observed that the condition of lungfish within an aggregation accumulated at the base of the Claude Wharton Weir which lacked an effective fish passageway was significantly poorer than the general population. During 2004 spawning season surveys conducted by Kind et al. (2005) it was also noted that the only three sites where there was no evidence of lungfish spawning were downstream of the Claude Wharton and Jones Weirs neither of which have effective fish passage devices suggesting that density dependent effects affecting fish condition downstream of these fish passage barriers may have been impacting on their ability to successfully spawn. Brooks & Kind (2002) also identified crowding on residual accessible suitable spawning habitat as likely to lead to less successful spawning and increased cannibalistic predation of eggs and young.

4.6.4 Reduced recruitment of juveniles

Lungfish populations are acknowledged to be vulnerable on account of their long generation time and naturally low and punctuated levels of recruitment (Frentiu et al. 2001, Pusey et al. 2004). Therefore any additional anthropogenic sources of impact to recruitment levels pose significant risks to the viability of lungfish populations. The preceding discussion has identified impacts to lungfish recruitment success that are associated with hydrological impacts generated by the Paradise Dam and impacts that would be accentuated by a lack of fish passage device at the dam including:

a. Reduced extent of suitable spawning habitat (impoundment and flow regulation impact);

b. Reduced access to suitable spawning habitat (fish passage barrier and flow regulation impact);

c. Reduced survivability of eggs and young in nursery habitat (impoundment and flow regulation impact);

d. Crowding impacts on adult condition and subsequent spawning success (fish passage barrier impact);

e. Crowding impacts including cannibalistic predation on eggs and young (fish passage barrier and impoundment based loss of spawning habitat impact); and

f. Reduced adult population due to spillway overflow mortality (fish passage barrier impact).

Another likely impact to recruitment success that has become apparent by the documentation of juvenile lungfish movement within the river system (Berghuis & Broadfoot 2004; DPIF 2008) is reduced upstream and downstream dispersal of juvenile lungfish from natal habitats.

4.6.5 Increased adult lungfish mortality

The potential for the high stepped spillway of the Paradise Dam wall to cause adult lungfish mortality during a spillway overflow event has been well recognised including by experts and agencies providing advice to the Burnett Dam Alliance and Burnett Water Pty Ltd (Mallen - Cooper 2004; Berghuis 2008) and has been discussed previously at 4.5.2). Recent monitoring of PIT tagged lungfish in the Paradise Dam impoundment reach (DPIF 2008) has confirmed that downstream movements are significant within the Burnett River lungfish population. PIT detections indicated that downstream movement and detections at the dam wall peaked with dam inflow events during January to March 2008 and again during a smaller inflow events in June and particularly during the pre-spawning period July - August reconfirming previously identified 'home return' and 'spawning ground seeking' movement patterns for the species in the Burnett River. The large numbers of lungfish that remained at the dam wall site after the February 2008 inflow event particularly suggested they were actively trying to move downstream (DPIF 2008).

In the absence of an effective downstream fish transfer device the only opportunity for downstream lungfish movement would be via the spillway. This will result in increased mortality of adult lungfish within the Burnett River population and significant risks to the population's viability on the basis that longevity and low adult mortality are prerequisites for the species survival strategy.

4.6.6 Reduced genetic variability and viability

The importance of maintaining genetic variability and viability in the lungfish population was discussed above at 4.5.3. In the absence of effective fish transfer devices at the Paradise Dam the lungfish populations above and below the dam would, essentially, be isolated other than for an unknown percentage of fish from the upstream population that survived spillway overflow events, and were successful in joining the breeding population of the downstream population. If the number of downstream lungfish movements achieved somewhere in the order of 10 migrants per generation, genetic differentiation is likely to be avoided given the demonstrated capacity of limited levels of population mixing to maintain the genetic variability of endangered species (Vucetich & Waite 2000).

However, even if downstream movement of lungfish was in the order of 10 migrants per generation, there would be no gene flow from the downstream population to the upstream population. There is evidence of the impact of fish passage barriers on the genetic variability of upstream fish populations from both Australian and overseas studies. Above the Nymboida Weir in the Clarence River Basin NSW, levels of population admixture, heterozygosity and allelic richness in the endangered Eastern Freshwater Cod *Maccullochella ikei* have been found to be reduced (Cathy Nock pers. comm. Centre for Conservation Genetics Southern Cross University, June 2009). In the United States, Hänfling & Weetman (2006) found that weirs reduced upstream migration of the locally endangered Bullhead *Cottus gobio* and that allelic richness and effective population size were lower at sites above weirs compared to those below.

It is therefore highly likely that without an effective fish transfer device at Paradise Dam the upstream lungfish populations (and possible the downstream population) would be exposed to the risks of inbreeding depression, reduced genetic variability and diminished adaptive potential.

4.7 Other threats to lungfish in the Burnett River

The Burnett River Basin is one of the most developed river catchments in Queensland (DEWHA 2009). In the draft recovery plan for lungfish (Kind et al.2009, reproducted at **Appendix 3**), more current threats to lungfish are identified for the Burnett River population than for any other (see Table 2 below). Many of these threats have already been discussed in relation to the risks posed to the lungfish population by the Paradise Dam and are only revisited here to demonstrate that they occur more widely within the Burnett River Basin. Other threats that have not been discussed in relation to the Paradise Dam are covered in more detail below.

Table 2 - Current Threats to Lungfish Populations (Adapted from Kind et al. 2009)

Location	Current threats and other potentially threatening activities
Burnett River	- Barriers to passage (fish passage provided on some barriers) - marine stranding - boat strike - regulated flow - altered flow - water extraction - loss of breeding habitat - fish stocking - land clearing and grazing pressure
Mary River	- Barriers to passage (fish passage provided on some barriers) - Boat strike - regulated flow - water extraction - expanded water 'infrastructure proposals, fish stocking - land clearing and grazing pressure
Brisbane River	- Barriers to passage - marine stranding - regulated flow - noxious fish

	- fish stocking - land clearing and grazing pressure
North Pine River	- Barriers to passage - marine stranding - noxious fish - fish stocking

4.7.1 Threats from water infrastructure and flow regulation

The Burnett River Basin contains 26 water storages (see Figure 1, above at 3.1) including seven on the main channel of the Burnet River. Collectively these storages impound 55% of the main river channel within the core distribution of lungfish within the Burnett River. Impacts to lungfish associated with this water infrastructure and the associated regulation of river flows includes loss of suitable spawning and nursery habitat, spill way overflow mortality (and marine stranding in the case of lungfish that pass over the tidal interface barrage), barriers to movement, population fragmentation, reduced gene pool exchange and lowered recruitment success.

4.7.2 Loss of spawning and nursery habitat

Lungfish preferred spawning and nursery habitat is characterised by submerged aquatic plant communities associated with the shallow (less than 500 mm) margins of riverine riffle, run, glide and pool sequences. Inundation of these riverine habitats by impoundments and weirs and/or unnatural variations in water levels and flow regimes due to flow regulation impact the quality and quantity of these marginal aquatic plant communities and their functional viability as spawning and nursery areas. Of the 45% of the main river channel within the core distribution of lungfish that isn't affected by impounding, only a smaller percentage contains riverine riffle, run, glide and pool sequences suitable as lungfish spawning and nursery habitat and only reaches occurring upstream of Paradise Dam is not substantially impacted by flow regulation. In summary good spawning and nursery habitat is an increasingly rare resource within the Burnett River and this threat is predicted to contribute to a substantial decline in the adult lungfish breeding population over the next three generations (TSSC 2003, reproduced in **Appendix 4**).

4.7.3 Low Genetic Diversity

The lungfish population has been found to have low genetic diversity and available data indicates that this applies across the Burnett River population (Frentiu et al. 2001). Low genetic diversity is of itself considered a threat to the survival of a species as genetic diversity is linked to species survival fitness including resistance to disease (Arthington 2008). As discussed in preceding sections the risks associated with low genetic diversity are accentuated where there is population fragmentation and high levels of anthropogenic disturbance of ecosystems as observed in the Burnett River Basin.

4.7.4 Translocated and Exotic Fish Predators

The vulnerability of lungfish eggs, larvae and juveniles to a range of predators has long been recognised (Bancroft 1928; Pusey et al. 2004). One theory regarding the limited natural distribution of lungfish to the Burnett and Mary River basins is the relative lack of large predatory fish that naturally occurred within the freshwater reaches of these systems (Joss 2004). In the last two decades fish stocking for recreational fishery development has occurred in all major dams and weirs within the Burnett River and is now often conducted annually (Kind et al. 2009). Stocked fish predominantly include predatory Australian native species that did not naturally occur within the Burnett River basin e.g. Yellow Belly *Macquaria ambigua* and Australian Bass *Macquaria novemaculeata*. Stocking of species that are native to the Burnett Basin but which historically occurred in low densities or predominantly in lower reaches only e.g. Barramundi *Lates calcarifer*, also occurs. Fisheries monitoring data (DPIF 2008) now indicates predatory native species are widespread and common within the Burnett River basin and there is also good evidence that both Yellow Belly *Macquaria ambigua* and Australian Bass *Macquaria novemaculeata* have established breeding populations there (Stuart & Berghuis 2002; A. Berghuis DPIF pers. comm.).

Threats to lungfish posed by these stocking activities include not only the risk of increased predation pressure caused by translocated fish and unnaturally high predator recruitment levels, but also the risks of introducing foreign organisms and diseases (Kind et al. 2009).

In addition to these native translocated species, a noxious exotic species Tilapia *Oreochromis mossambicus* has also been established within the Boondooma Dam in the Burnett River Basin and threatens to distribute more widely including through the range of the Australian lungfish (Pusey et al. 2004). This species dwells in marginal macrophyte habitats and is a know predator of fish eggs and larvae (DEWHA 2009).

Collectively the threat posed to lungfish populations by fish stocking activities, stocked, translocated native and exotic fish populations within the Burnett River system must be considered high.

4.7.5 Aquatic Weeds

There are a host of invasive aquatic weed species established within the Burnett River system. In the last decade three species, Water hyacinth *Eichhornia crassipes*, Salvinia *Salvinia molesta* and Olive Hymenachne *Hymenachne amplexicaulis* have been responsible for major infestations that have threatened the ecological integrity of the lower reaches of the river system and threaten to spread more widely to upper catchment reaches, particularly water storages (BMRG 2005). Both water hyacinth and salvinia are floating weeds that often occur together to form dense floating mats that can cover an entire river channel. At the height of recent infestations in the lower Burnett some estimates suggested greater than 500 ha of water hyacinth cover in the lower Burnett and Kolan River systems (ABC Rural Report 22 February 2006). Hymenachne is an emergent aquatic grass species that dominates the shallow margins of river channels. Collectively these three species shade and out compete native aquatic plant communities and contribute large organic matter loads that collapse dissolved oxygen levels within the water column. This often results in fish kills and the formation of anoxic reach fish passage barriers (Tait & Perna 2001; Perna & Burrows 2004). While the ability of lungfish to breathe air could provide them with greater survival capacity than most fish species confronted with such weed infestations, the water quality and habitat loss impacts on spawning and nursery resources, egg and larval survivability and food organisms would be major.

The main areas of aquatic weed infestation in the lower Burnett River system has included the last 10 km of flowing reach remaining between the Ned Churchward Weir and the Ben Andersen Barrage (see Figures 35-36). Personal observations indicate that these aquatic weeds have become more prolific in the last decade with the reduction of river flushes that has accompanied the completion of the Ned Churchward Weir in 1998 and Paradise Dam in 2005.

Figure 35 - Burnett River dominated by native aquatic plants at the downstream margin of flowing habitat remaining below Ned Churchward Weir December 2006 (Photo J. Tait on Property of G. Tait)

Figure 36 - Same site downstream of Ned Churchward Weir at height of a Water Hyacinth Infestation July 2007 (Photo J. Tait on Property of G. Tait).

This reach was identified by Brooks and King (2002) as the last spawning and nursery area for the lungfish population of the lower Burnett River. Impacts to water quality and habitat as a consequence of these aquatic weeds include those associated with implemented chemical spray based control programs as well as the weed infestations themselves. During 2007 lungfish spawning surveys in this reach the mortality of lungfish eggs was found to be higher than preceding years (Kind & Brooks 2008). This was attributed to the recent spraying of pest aquatic weeds that had resulted in decaying vegetation on the river bed which in combination with reduced flows and exotic macrophyte cover and algae had resulted in an anoxic substrate layer not conducive to the survival of lungfish eggs (Kind & Brooks 2008). Aquatic weeds represent a major threat to residual suitable lungfish spawning and nursery habitats not impounded by water infrastructure. The observed aquatic weed infestations and associated impacts in the lower Burnett high light the severity of threat particularly facing the lower Burnett River lungfish population.

4.7.6 Recreational and illegal fishing

Although lungfish are protected as a 'no-take' species under the *Queensland Fisheries Act 1994*, lungfish are caught by recreational anglers targeting other fish (Kemp 1995; Kind 2002). Of 52 radio-tagged fish studied by Kind (2002) in the Burnett and Mary Rivers 7% (4) may have been caught by anglers. The aerial of one transmitter had apparently been cut by a tool, but the fish was released and continued to live in the river. One transmitter that had been implanted in a fish was recovered away from the water, and two were recovered next to campgrounds. Johnson (2001) noted that lungfish are often caught accidentally by anglers in the North Pine River.

Historically, recreational freshwater fishing opportunities were limited within the Burnett River due to the relative low number of large predatory fish species that occur there and most freshwater fishing was targeted at two species of freshwater mullet *Myxus petardi* and *Mugil cephalus* and less frequently freshwater catfish *Arius graeffei* and *Tandanus tandanus*. While the recreational mullet fishery has largely collapsed due to impacts of fish passage barriers on mullet migrations, stocking of translocated native fish has been responsible for the development of major recreational fisheries within water storages through out the Burnett River basin (discussed above). Methods used by these recreational fisheries patrticularly live baiting using shrimps or worms pose very high risk of lungfish capture. Associated mortality risks to lungfish due to poor handling or illegal take have not been assessed but may be high given the experience of Kind (2002) with tagged individuals.

One of the primary traditional methods of freshwater mullet capture by riparian landholders on the Burnett River is gill nets and this practice remains common despite it illegality (Pers. Obs.). With improvements in fishway functionality providing some recovery of freshwater mullet populations (Stuart & Berghuis 2002) and stocking providing an increased abundance of other desirable species (e.g. Barramundi, Bass and Yellowbelly) there is a very real prospect that illegal gill netting will increase with concomitant impacts to adult lungfish.

4.7.7 Poor Water Quality

The principal water quality impacts identified to be threatening lungfish are associated with releases of deoxygenated and cooler water from dams which are reported to have impacted on spawning habitat within the Burnett River (Kind et al. 2009). Given the extent of aquatic weed infestation in the lower river system, deoxygenated water associated with the anoxic conditions existing below aquatic weed infestations (Perna and Burrows 2004) is also a significant source of water quality impact particularly on lungfish eggs and larvae. Less direct though potentially more significant is the pervasive impact of elevated sediment and nutrient loads within the Burnett River basin as a consequence of land use impacts and catchment exports. Data compiled by the National Land and Water Resources Audit (2002) indicated contemporary sediment supply to the Burnett River system is 96 times pre-European levels, phosphorus loads 6.3 times pre-European levels and nitrogen loads 3 times pre-European levels. These levels of change in sediment and nutrient load are likely to have as yet unquantified influences on the invertebrate communities that constitute the food sources for juvenile and adult lungfish and pose ambient water quality risks particularly in a regulated flow regime that has reduces the natural flushing capacity of the system.

4.7.8 Decline in riparian vegetation and stream bank condition

Lungfish prefer complex in-stream habitats associated with terrestrial riparian vegetation and marginal aquatic plant communities (Brooks & Kind 2002; Pusey et al. 2004). In the

Burnett River basin these habitats are threatened by declines in riparian vegetation and stream bank condition. Principle sources of these declines in condition include historical riparian vegetation clearing, riparian zone weeds, uncontrolled stock access and soil erosion. While it is not possible to accurately quantify the level of threat to lungfish posed by riparian and bank condition degradation basins-wide studies indicate that the overall condition of the Burnett River basin riparian and channel environs is highly modified in keeping with its highly developed status. Data compiled by the National Land and Water Resources Audit (2002) indicated that 19% of the almost 100 fold increased (on pre-European levels) sediment load in the Burnett River basin was derived from bank erosion sources. In a Queensland Department of Natural Resources 'State of the Rivers (SOR)' assessment of the Burnett Basin, Van Manen (1999) reported that cattle grazing was evident at 86% or reach environs survey sites, bank slumping was documented at 21% of survey sites and riparian vegetation across the catchment was generally in poor condition due to the impact of weeds. Overall 28% of the streams surveyed within the basin were in good condition, 40% in moderate condition and 26% in poor condition. No section of stream length was rated as being in overall very good condition (Van Manen 1999). The primary message that emerges from these data is that in addition to fish passage barriers and the host of other 'in-stream' threats that have been identified to be confronting lungfish populations, riparian vegetation and stream bank condition within the Burnett Basin is far from natural and represents another source of threat to the survival of the species.

4.8 Threats to lungfish populations outside the Burnett River

Table 2, above at 4.7, identifies current threats to all lungfish populations including those that occur outside of the Burnett River Basin. To better understand the threats faced by populations of lungfish outside of the Burnett River the draft recovery plan (Kind et al. 2009) under preparation for the species is one of the most current analyses of lungfish population threats and recovery action options. The draft recovery plan is reproduced in Appendix 3.

5. Effectiveness of Paradise Dam Upstream Fishway Design and Operation for Lungfish

This section examines the design and operational effectiveness of the Paradise Dam upstream fishway for lungfish passage.

5.1 Upstream fish passage before the dam

The nature of the Paradise Dam reach of the Burnett River pre-dam was described in the preceding section of this report that considered the behavior of lungfish populations in this reach pre-dam. Essentially it included pools of variable depth with interconnected flow channels, riffles, runs and glides and marginal macrophytes and riparian vegetation. The swimming capacity and behavior of lungfish is described at 4.2.3 and 4.2.4, including the demonstrated capacity of adults to move through shallow pools (~12 cm) and riffles to reach spawning and feeding resources. Only later stage juveniles are known to move from their natal habitat of marginal aquatic plant beds, generally keeping close to edge habitats and structure. Both later stage juveniles and adults are found to undertake active longitudinal movements within the Burnett River system, adults particularly from impounded reaches often moving long distances to seek suitable spawning habitat or to return to home sites. Movement of adult lungfish is often timed to coincide with minor river flushes but is also stimulated by larger flow events and elevated temperatures (DPIF 2008).

As previously identified there have been no specific studies or published data on lungfish movement through the dam site reach pre-dam, and a temporally quantified assessment of lungfish movements within the reach pre-dam is not possible. However, based on the previously described habitat characteristics of the reach pre-dam including depth profiles and the known swimming capacity and behavior of lungfish the case has been made that periods of hydrological connectivity within this reach would have provided the capacity for lungfish movement through it.

Zero flow spells analysis based on a simulated flow model using 107.5 years of measured rainfall data (**at Appendix 6**) indicated that flow ceased in the Paradise Dam reach for 3.95% of the simulation period, i.e. hydrological connectivity was maintained within the reach on average for 96% of the time with the longest single no flow event being 150 days. Importantly in the 107.5 year pre-dam flow simulation period there are no zero flow periods that extend through an entire lungfish spawning migration period.

It is acknowledged that this estimated capacity for lungfish movement would overstate the actual frequency of lungfish movements which has been found to be primarily associated with minor flow events (Brooks & Kind 2002; Berghuis & Broadfoot 2004; DPIF 2008). However it does highlight the relatively unrestricted opportunities for lungfish movement that existed in the Paradise Dam reach pre-dam. It would also suggest that the numerous PIT tagged lungfish detected to have moved greater than home range distances upstream or downstream to the dam wall but not beyond it (DPIF 2008), would have passed through the reach in the pre-development scenario.

5.2 Restriction on upstream fish passage

The passage opportunities available to lungfish through the upstream fishway since the Paradise Dam became operational in late 2005 are governed by a combination of factors that include both fishway design functionality and operational practice which collectively interact to determine lungfish passage outcomes. Issues associated with design are discussed further below.

Operational aspects that may affect fishway effectiveness and lungfish movement opportunities also have multiple components (DPIF 2008; Burnett Water 2008) including:

a. The period of time the fishway was operated or malfunctioned,

b. Elected operational practices when the fishway is operating including attraction flow throughput volumes, hopper trapping times, cycle time, use of supplementary diffuser attraction flows, and

c. Hydrological conditions created within the irrigation release channel (adjoining the fishway entrance) and downstream riverine reaches by dam releases.

The fishway effectiveness issues associated with the latter two points are discussed further below in consideration of the operational aspects of the fishway. The time that the fish way has been operational and/or operated to provide opportunity for lungfish movement since commissioning is considered here.

Although the fishway was completed late in 2005, delays in the delivery of monitoring equipment, interruptions to the dam's operation, access issues relating to the construction of the mini hydro scheme and system failures or shut downs have all contributed to the unreliability of the fishway operation (DPIF 2007). On the 14th August 2006 the Burnett Dam Alliance issued a cessation of fishway operation below EL 40.09m (44,819ML) directive due to concerns that the hopper and/or dam infrastructure could be damaged. As a result the fishway did not operate from mid August 2006 to October 2007 (DPIF 2008). I note that this statement from DPIF is in contrast to the graph presented in Figure 37, below, although it does largely concur with upstream fishway operation logs disclosed by Burnett Water Pty Ltd, as illustrated in Figure 38.

Figure 37 - Operation of the Upstream Fishway and Sampling Times at Paradise Dam (from DPIF 2008)

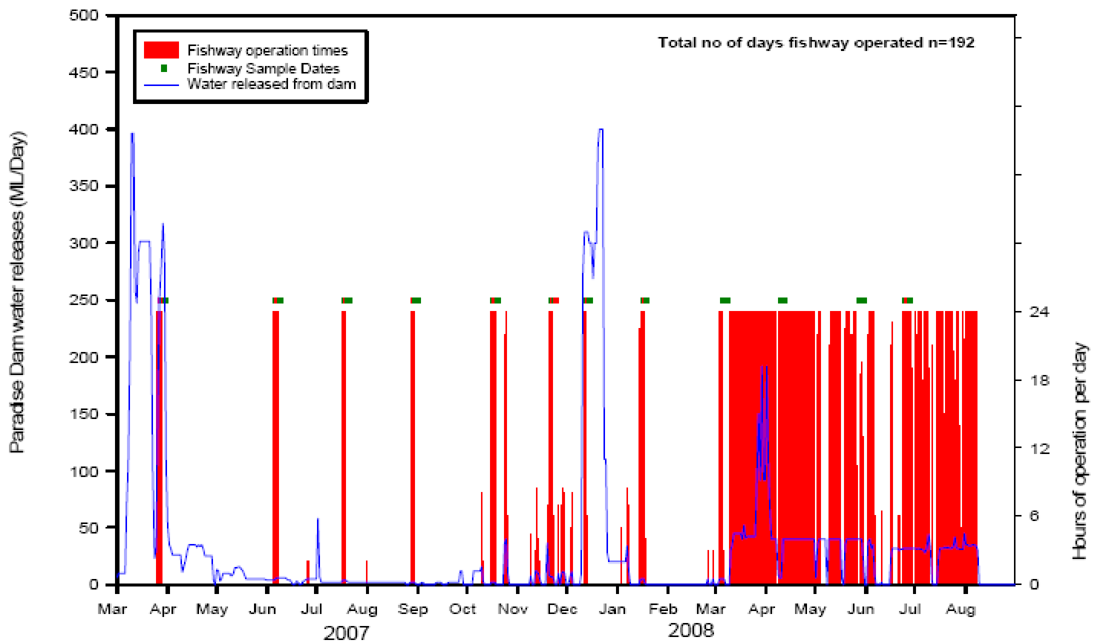
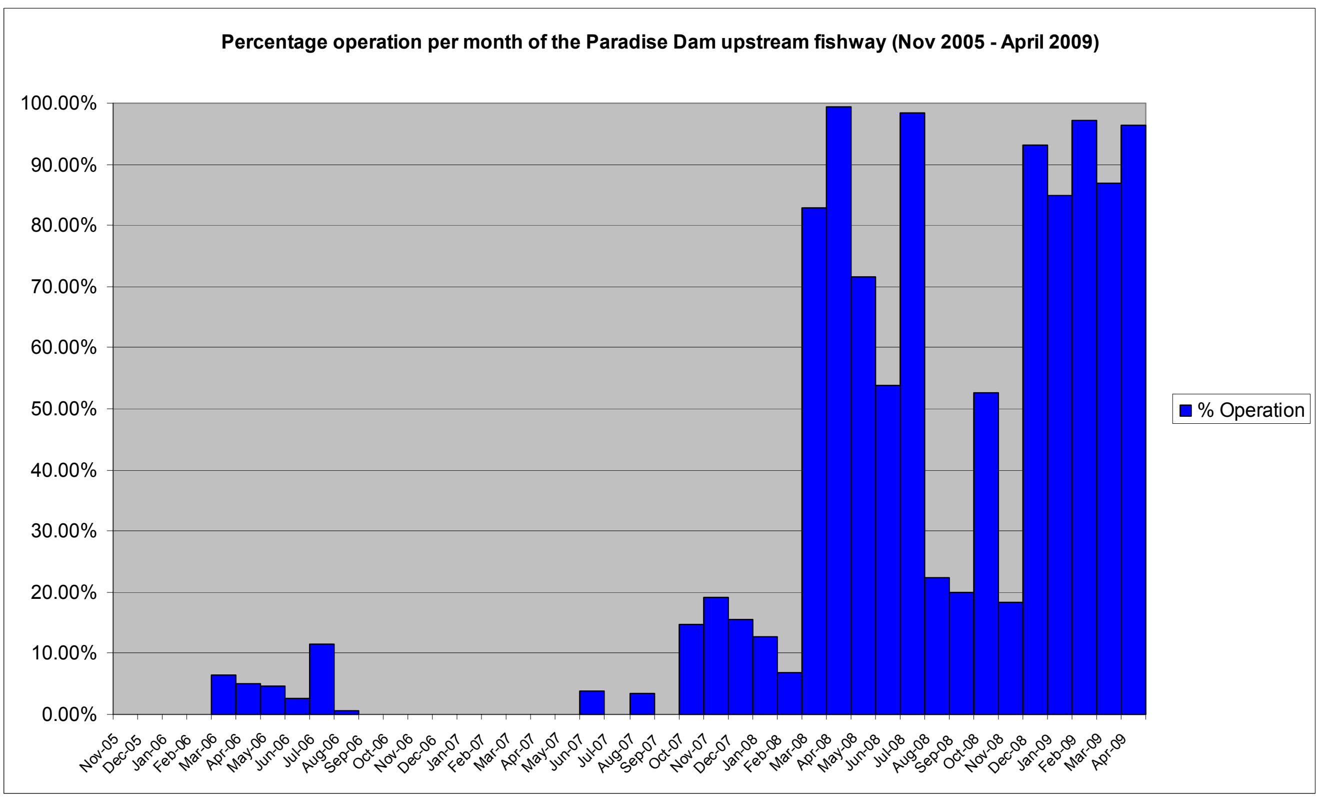


Figure 38 – Percentage operation per month of upstream fishway based on operating logs disclosed by Burnett Water Pty Ltd (data in Appendix 7)



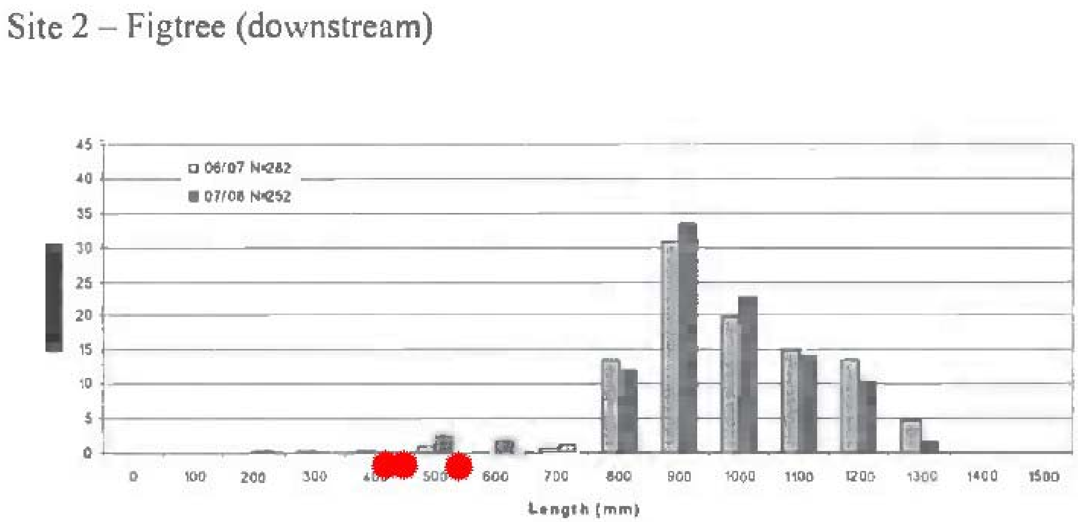
The key point in terms of lungfish movement opportunity is that passage through the dam reach has been severely curtailed by the lack of fishway operation. For Figure 37 covering the period March 07 – August 08, the reported operation period of 192 days is equivalent to approximately 35% of the available days in that period, and the plot indicates that for many of these days operation were not conducted for the full 24 hour period.

Based on the disclosed fishway operating logs from November 2005 to April 2009 the fishway has operated for approximately 25% of the hours available, though most of this operational time has been in the last year and there has been next to no operation for an entire year and two breeding seasons. The most prevalent entry in the operation logs in regard to a lack of fishway operation is "*system off due to no releases* (irrigation) *required downstream*'. The aspect of operational constraint is discussed further below.

If, for comparison, purposes the fishway is afforded the capacity to move the full complement of lungfish upstream migrants that approached the fishway on any give day or hour and lungfish upstream movement is treated as consistent across days and hours (two conditions that not met), the lack of upstream fishway operation at the Paradise Dam would impose as a minimum constraint on the upstream movement opportunity for lungfish between a 65 – 75% over the November 2005 – April 2009 period. If the fishway operational times coincide with peak movement periods for lungfish this estimated movement opportunity constraint may be lower, if the operational periods don't coincide with peak movement periods (which has been in case in some years) and if there are additional constraints on lungfish movement opportunity imposed by other aspects of the fishway operation and/or its design (of which the case is made) this constraint will be greater.

Documented use of the fishway by a notable proportion of the available migrant lungfish population would be the ultimate endorsement of its effectiveness. From the DPIF fishway monitoring data that has been made available, i.e. that compiled from the inception of monitoring activities following the commissioning of the fishway in March 2006 to March 2009, it would appear that a total of 3 lungfish have been recorded to have entered the upstream fishway hopper, one of which was captured during twelve replicate samples from the hopper during trapping surveys and two PIT tagged fish which appear to have successfully used it to pass to the upstream side of the dam (DPIF 2007, 2008). The size of PIT tagged fish was not reported by DPIF but based on the finding that *'only small numbers of juvenile lungfish have been captured in the entrance of the fish way and the hopper'* (QDPI 2008) and '*Large sized Lungfish and long finned eels are yet to be adequately represented in the fishway to date'* (QDPI 2008) and that no adult lungfish have been reported by DPIF to have successfully used the upstream fishway, it would appear that most, if not all of these fish, are juveniles. DPIF (2007) length data provided for three lungfish captured in the fishway entrance channel trap (2) and from the hopper (1) are presented in figure 33. DPIF (2008) report another two juvenile lungfish making a total of four in monitoring program data reported to date but do not provide length data. This suggests that there are particular constraints operating to restrict the movement of large sized adult lungfish at the upstream fish way.

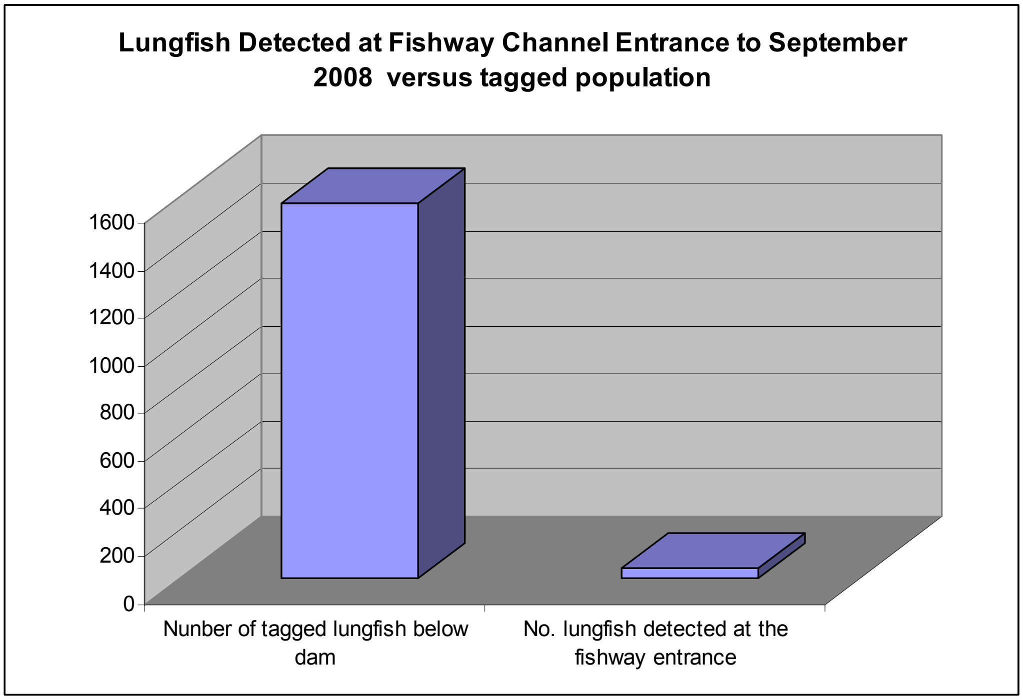
Figure 39 - Unrepresentative lengths of 3 lungfish (red dots) captured in upstream fishway entrance channel (425 & 450 mm) and in hopper (531 mm) trapping samples compared to size frequency distribution for lungfish population in Figtree Reach below Paradise Dam (Plot from Kind & Brooks 2008; lungfish length data from DPIF 2007)



It needs to be noted that fishway trap based sampling has only been conducted on twelve occasions (see Figure 37) and that the PIT tag detectors have only operated from March 2006– January 2007, and again from July 2007 – August 2008 with non operating periods during November – December 2007; first half of March 2008; and November – December 2008 (DPIF 2007, 2008). PIT tagged fish detection data for the upstream fishway since August 2008 has not been made available. Therefore there has been approximately 9.5 months of PIT reader inoperability and 7 months of as yet unreported data for the 39 months since the upstream fish way was commissioned. Therefore it is possible that unmonitored and/or unreported lungfish movement through the upstream fishway is greater than the number of lungfish that have been monitored to enter or pass through the upstream fishway hopper. However, given the small number of lungfish detected to have successfully used the upstream fishway during the extensive PIT monitoring period and the single fish captured in twelve replicate samples at the hopper, there is ample evidence to believe that the number may not be large.

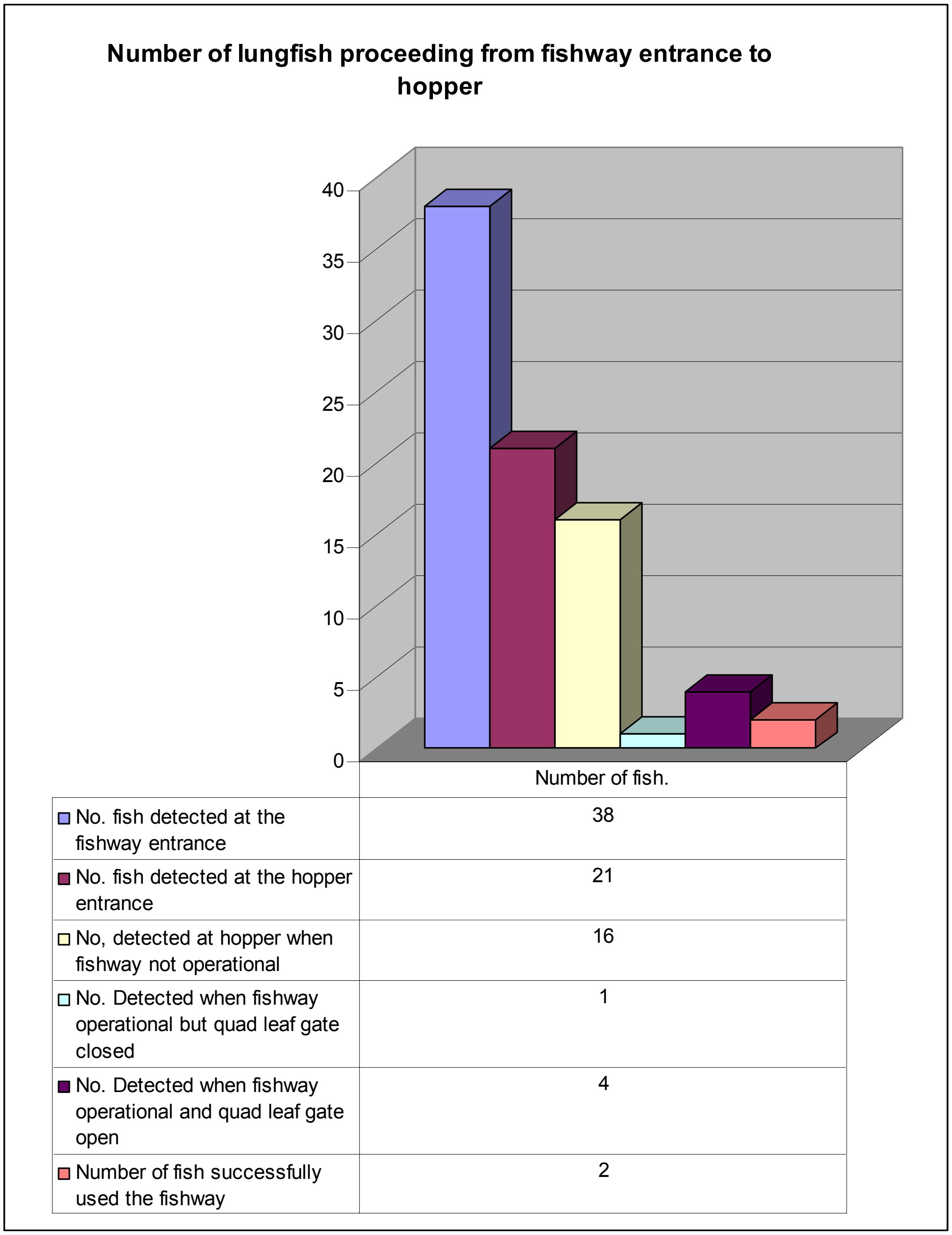
Based on the single juvenile lungfish obtained in the 24 hour hopper trap sample DPIF (2008) have provided a migration rate for the species in terms of a range of 0-1 per 24 hours through the upstream fishway. However, a mean value for movement probability from the 12 replicate 24 hour hopper samples would suggest a migration rate of 0.08 lungfish / 24 hours. Applied to the full operational period of 7923 hours for the upstream fish way since 2005 obtained from the fishway operation logs, the total number of lungfish estimated to have moved upstream during the period would be in the order of 634 fish, an optimistic estimate clearly not supported by PIT tag monitoring of the large and significant proportion (1576 individuals) of the lungfish population now PIT tagged downstream of the dam since monitoring activities commenced (DPIF 2008) see Figure 40.

Figure 40 - Number of PIT tagged lungfish detected at fishway entrance versus tagged population (data from DPIF 2008)



What has also been shown by monitoring detections of PIT tagged lungfish in the channel entrance to the upstream fishway is that many do not proceed to the hopper entrance and the majority of those that have proceeded to the hopper entrance have done so when the fishway is not operational and of those that that have had the opportunity to enter the hopper, half have avoided doing so (DPIF 2008). Of the total 38 lungfish reported to have been detected at the fishway channel entrance, 2 (0.05%) successfully entered the hopper and used it to pass upstream see Figure 41.

Figure 41 - Lungfish detected at the Paradise Dam upstream fishway PIT tag readers and the operational status of the upstream fishway during detections (from DPIF 2008)



Information concerning the original tagging locations of lungfish detected at the upstream fishway entrance indicate that many had travelled greater than home range distances upstream. This suggests their movements were part of a purposeful upstream migration. This implies that in the absence of a fish passage barrier many of these fish would have continued moving further upstream. Of the 38 lungfish detected 76% had travelled only 0-5 km from their original tag sites, but 23% had travelled from 5 – 20 km downstream and 2 fish had travelled greater than 50 km upstream from tagging locations below Ned Churchward Weir (DPIF 2008). This certainly challenges any residual notion of the Burnett

River lungfish population being a sedentary species and is probably indicative of the decreased local reach availability of habitat resources for many lungfish inhabiting the greater than 50% of reach length below Paradise Dam that is now impacted by water resource infrastructure impoundment effects (DEHWA 2009. Pers. Obs.).

Further evidence that suggests that the general lungfish population is not readily attracted to the upstream fishway channel entrance in terms of offering migration prospects or suitable habitat cues is provided by riverine fyke netting and electro fishing surveys conducted in the riverine reach immediately downstream of the fishway concurrently with the trapping surveys conducted in the fishway entrance channel and hopper. Twelve riverine fyke netting samples linked to the hopper sampling period produced 12 lungfish and an estimated 0-3 fish per day migration rate while the linked hopper sampling produced a single fish (8% fyke catch) and a 0-1 fish per day migration rate. Twelve riverine fyke netting samples linked to the fishway entrance trap sampling period produced 21 lungfish and an estimated 0-5 fish per day migration rate while the linked fishway entrance trap sampling produced 4 fish (19% fyke catch) and a 0-2 fish per day migration rate (DPIF 2007, 2008).

Electro fisher surveying of the irrigation release channel produced two lungfish while the fishway entrance channel produced 1 lungfish (DPIF 2008). These results reinforce findings from the fishway entrance monitoring that suggest lower numbers of lungfish are encountered the further up the constructed channel entrance features sampling is conducted. Fishway design and operational features that may be contributing to these results are discussed below.

5.3 Safety of lungfish moving upstream

The primary issues that have been identified in relation to the safety of lungfish moving through the upstream fishway concerns predation and upstream release location in relation to its close proximity to the dam outlet intakes and spillway during spillway overflow events.

Predation risks would only apply to juveniles as adult lungfish are essentially free of predation risks as discussed in the earlier section of the report. There is potentially a greater though small predation risk that would have applied to adult lungfish moving through shallow sections of the pre-dam reach from terrestrial / aerial predators such as dogs /dingoes, eagles given their exposure to such predators when negotiating very shallow river margins or riffles (Pers. Obs.).

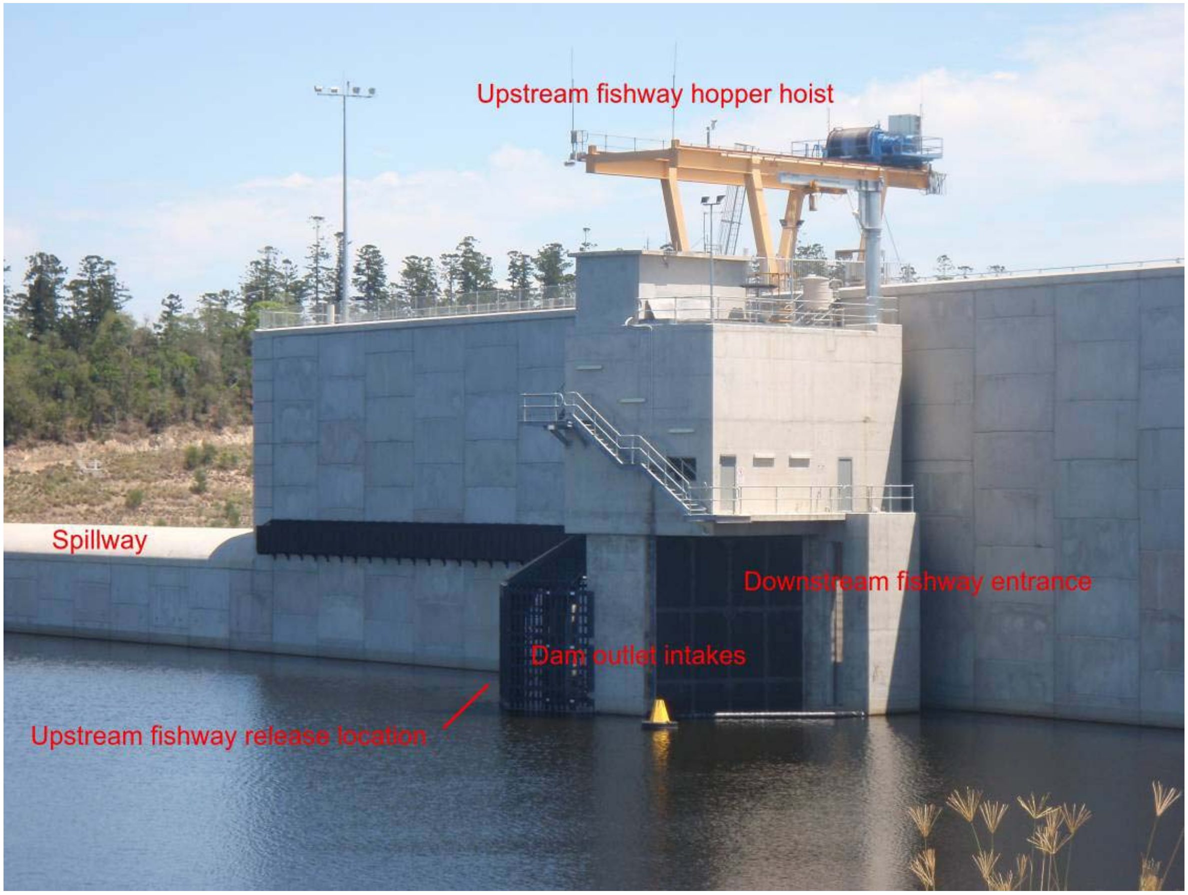
While narrow (~50cm) upstream fishway channel and hopper entrance and constrained hopper size features may present discomfort to large adult specimens (and is potentially partially responsible for the low numbers observed) they are not considered to present significant safety risks to robust adult fish other than some potential for crowding and scuffing / abrasion due to the confined space the hopper presents for large fish great than 1m.

Low dissolved oxygen levels in the hopper when transporting large numbers of fish during summer have been identified by DPIF (2008) as an issue warranting further investigation though this is also likely to be not as significant to lungfish given their respiratory capacities.

In the pre-dam riverine reach sub adult lungfish undertaking dispersal movements would have had access to shallow complex edge structure (aquatic plants, rocks, snags) which they move through to limit predator exposure. During passage through the upstream fishway juveniles are exposed to predation in the irrigation release channel which has deep, steep sided cement walls generally lacking complex habitat and cover other than sparse patches of established aquatic plants. High predator exposure would also be associated with the fishway entrance channel and within the hopper which lack any form of cover and is often co-occupied by large predators e.g. often fork tailed catfish and possibly barramundi, bass, yellow belly, all of which pose a predation risk to sub adult lungfish. The other major area of predation risk is the upstream release site which is located adjacent the outlet building and the dam wall in deep water away from cover. Given the demonstrated behavior of large downstream migratory species such as barramundi and Australian Bass to accumulate at the dam wall (DPIF 2008), the predation risks to juvenile lungfish at the hopper upstream release site would have to be considered high. Predation risks within the upstream fishway are currently the focus of a Fish way Monitoring Program investigation (DPIF 2008).

The upstream hopper release site is located in close proximity to the spillway, dam release intakes, and the downstream fishway entrance (see Figure 43, below). During high volume flow releases and during the operation of the downstream fishway there is a very high prospect that released fish will be entrained in release flows and or attracted to the downstream fishway entrance. In the case of juvenile lungfish, grids and screening covering the outlet works are unlikely to prevent them entering outlet flow pathways which would be traumatic and likely to cause death or injury. High flow events including spill way overflow events are a recognised stimulus for upstream lungfish movement (Berghuis & Broadfoot 2004; DPIF 2008) and therefore represent a period where there needs to be effective functioning of the upstream fishway. As yet there has been limited operation of the upstream fish way in conjunction with high flow events and none in conjunction with a spill way overflow event. When a spillway overflow event does occur the proximity of the hopper release site to the spillway presents a real risk of released fish being attracted to the spillway overflow with a high probability of injury or mortality given the stepped spillway design and the lack of a deep plunge pool.

Figure 43 - Proximity of upstream fishway hopper release site to dam spillway, outlet intakes and downstream fishway entrance (J. Tait, December 2008)



5.4 Fish passage constraints: operational practices or design constraints?

Given the limited duration of operation of the upstream fishway and limited operational spectrum of dam release flows since the Paradise Dam has become operational it is difficult to fully identify upstream fishway design constraints as it has not yet operated across the full operational range of dam tailwater and headwater heights or in conjunction with a full spectrum of dam flow release regimes. The need to test the fishway within this broader operational environment has been consistently expressed by the DPIF Fishway Monitoring Team (DPIF 2007, 2008).

The upstream fishway has been lauded as ‘State of the art’ (Meredith 2008) and ‘cutting edge’ (Worley Parsons 2008) for a high dam wall and given the input of fishway expertise during its design and construction phase (Taylor 2006), does appear to represent a well considered if not previously untested, design within the constraints of budget and conventional fishway wisdom for its time. While some aspects of the original fishway design principles were modified and potentially compromised during construction (document BUR.014.002.0510, BDA Design Management Plan Version 2) i.e. relocation of the fishway entrance in relation to the irrigation release channel and spillway, the resulting upstream fishway still appears to have the design capacity to function to some capacity in the upstream passage of lungfish if provided with appropriate operational conditions. This statement is qualified by the observation that there are still a host of design constraints associated with the upstream fishway most of which have been identified during the commissioning phase and operational monitoring conducted by the DPIF fishways Monitoring Team (DPIF 2006, 2007, 2008, 2009). Further monitoring of the upstream fishway across a broader operational regime will reveal if these design limitations are rectifiable or insurmountable. These design issues are identified below in terms of opportunities to improve the design of the existing upstream fishway.

It is the absence of full operational testing of the upstream fishway I can only express an opinion as to the relative contribution of operational and design issues affecting the upstream passage opportunity for lungfish. In my opinion operational aspects associated with the upstream fishway have the lion's share (~66%) of impact in terms of observed limited effectiveness for facilitating the upstream passage of lungfish. The two primary operational issues to date have been the limited duration of fishway operation and the flow release regime that has occurred in conjunction with fishway operation. These two issues are discussed below under operational improvement options.

5.5 Measures that would improve the design of the upstream fishway

The following have been identified as opportunities for improving the design of the upstream fishway:

a. Design to operate over greater range of tail water heights i.e. during spillway overflow and extremely low flows (entrance cone partially exposed under low tail water levels);

b. Establish shallow margins with available cover on irrigation release channel and fish way entrance;

c. Establish flow baffles within irrigation release channel that reduce flow velocities during large flow releases;

d. Devise features to retain fish in fishway entrance channel during cycle;

e. Develop a broader fishway and hopper entrance less restrictive to large size adult lungfish;

f. Facilitate a hopper release location further removed from spill way;

g. Address the limited habitat attractiveness and size constraints of 'hole in the wall' for adult lungfish. The strong site fidelity of lungfish is indicative of the awareness they have of their physical surroundings. Constricted entrances through cement and steel structures appear (on the basis of detected movements) not to be attractive to large adult lungfish.

h. Address the range of competing flows (irrigation channel, supplementary diffuser, spillway, downstream fishway outlet) that have the capacity to mask the entrance to the fishway channel and hopper;

i. Improve the mechanical / moving parts components subject to failure and periods of inoperability;

j. Devise mechanisms to limit the exposure of juvenile lungfish to predation within the hopper and at the release site.

5.6 Measures that would improve the operation of the upstream fishway

5.6.1 Operate fishway continuously

The design of fishways for year round operation was one of the ‘general fishway design principles’ nominated for the Paradise Dam by consulting experts early in the design phase (disclosed document No. BUR.014.002.0510). This has not been the operational experience with the Paradise Dam upstream fishway to date. The pre-dam reach conditions at the site of the Paradise Dam provided nearly consistent hydrological connectivity (~96% of time see Appendix 6) in terms of meeting the passage needs of lungfish.

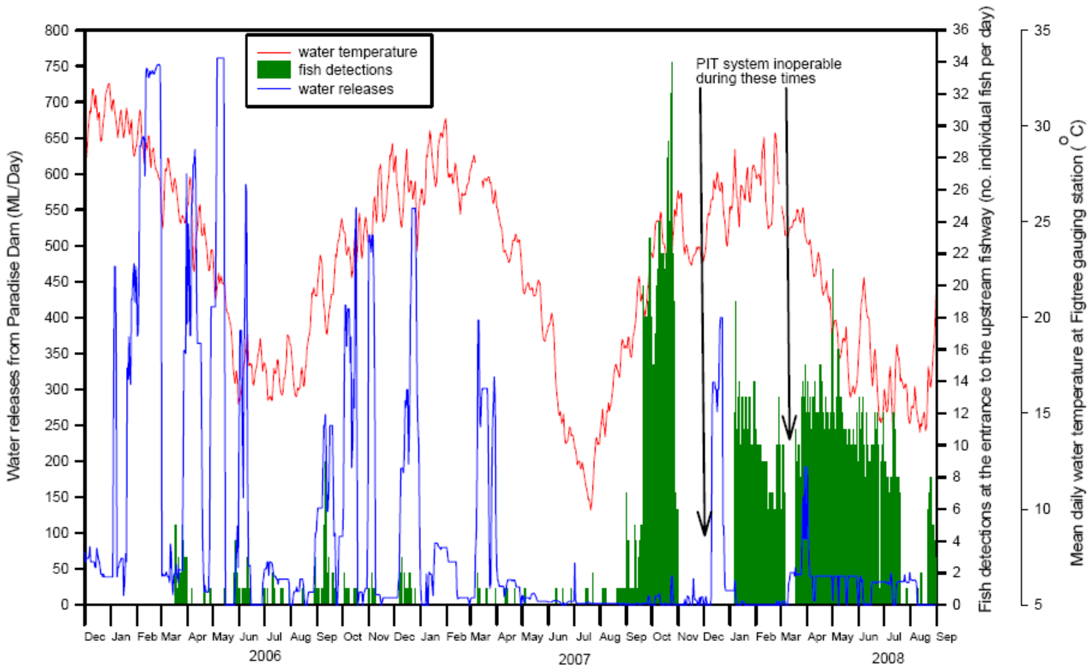
To date it would appear that the overall low flow volume and intermittent and cyclical nature of water releases discharged via the irrigation supply weir and the fishway entrance channel have not been sufficiently analogous to natural riverine ecosystem flow/discharge behavior to clearly define the upstream orientation and /or to stimulate lungfish to prospect upstream.

Continuous operation of the upstream fishway is the most readily implemented operational change that can be pursued to improve the movement opportunity for lungfish through the upstream fishway.

5.6.2 Operate fishway in conjunction with larger releases

The upstream fishway has been designed for effective operation under flows ranging from 69 ML/day to 394 ML/day (SunWater 2005). For the majority of fishway operational periods to date, flows have been a vestige of this designed optimum (see Figure 44) and generally below 50 ML/day even in recent more regular operating periods. Operating the fishway with dedicated flow releases from the dam beyond that required for downstream irrigation system demands were not part of early operational protocols proposed for the fishway (SunWater 2005). On the basis of fishway operational logs, dedicated releases of the volume required for optimum fishway performance would still appear to be infrequent or non-existent.

Figure 44 - Flow release from Paradise Dam with the daily number of PIT tagged fish detections and water temperature



Fish detections at the upstream fishway are clearly linked to flow releases with detections peaking with flow releases of 265 ML / day. For lungfish to want to move upstream they need to be convinced that there is an exploitable riverine environment upstream. The increase in zero flow spells that have been experienced downstream of Paradise Dam since its construction (**Appendix 6**) are beyond the natural regime and represent greater than 18% of the downstream flow record. Beyond the physical constraints this would impose on fish movement, this regime would provide lungfish environmental cues that the river system is less than perennial and potentially risky to move through. To achieve more effective flow volumes for fishway operation and fish movement dedicated releases need to be allocated for this purpose. These releases should be targeted to coincide with the seasonal upstream spawning and return movement patterns that have been recognised for lungfish and also to mimic seasonal river flushes recorded as inflows to the Paradise Dam.

5.6.3 Develop inflow – outflow operating rules

Studies of lungfish movement have indicated that they are stimulated to move by natural river rises that provide opportunities to negotiate riffles and shallow reaches during upstream movement to spawning areas or to undertake energy efficient return movements to home sites. One of the hydrological consequences of the Paradise Dam has been the absorption of inflow pulses that historically would have been transmitted throughout the lower river system providing cues for fish behavior and other ecological processes. The development and implementation of inflow – outflow operational procedures that allow for dedicated dam releases and upstream fish way operation in response to natural inflow events would serve to better promote lungfish movement through the upstream fishway and the broader river system

5.7 Alternative upstream fishway design

Within the constraints of conventional budget allocations, the migratory fish community behavior of the Burnett River and fishway design wisdom, there are few alternative designs for the upstream fishway that might be considered for a dam wall as high as that of the Paradise Dam.

Rather than an alternative design, options that would improve the likelihood of lungfish passage would be to:

a. Use the existing fishway design but reconfigure its relationship to the irrigation release channel and spillway to minimise the potential for competing flow impacts on attracting fish into the fish way;

b. Address all of the design constraints identified above; and

c. Replicate the structure on the other side of the dam spillway in the natural river channel.

In considering future fishway designs for lungfish it is important that the existing engineering paradigm of fishways being an ‘add on’ to the principal design consideration which is the water storage be challenged. This is reflected in traditional budget allocations to fishways representing several percent at most of the capital cost of dam construction. A more balanced appreciation of the fact that fishways are intended to compensate for the interruption to the riverine ecosystem that a dam represents, would see an equivalent capital cost allocation made to the cause of maintaining riverine connectivity through an impoundment wall as is dedicated to the cause of interrupting it. Low gradient ‘constructed’ river channel bypasses represent one of the most natural forms of fishways in terms of the passage environment presented to aquatic organisms and are increasingly being utilised for low level passage barriers. In terms of engineering feasibility they are entirely possible but on high wall structures the cost is considered exorbitant. With a greater commitment to Ecologically Sustainable Development (ESD) matched by a more significant allocation of dam capital costs to fishways such feature could be integrally designed into reservoirs of the future.

5.8 Summary of Effectiveness of Upstream Fishway

The effectiveness of the Paradise Dam upstream fishway for lungfish passage must be assessed by reference to both design functionality and operational practice which collectively interact to determine lungfish passage outcomes. The evidence gathered for the preparation of this report indicates that since the Paradise Dam became operational in late 2005 lungfish passage through the upstream fishway has been very restricted and that both the operation and design of the fishway have contributed to it being less than suitable for facilitating lungfish passage. This conclusion is based on:

a. The very small number of lungfish of an unrepresentative size class (juveniles only) that have been monitored to have successfully used the upstream fishway since the dam became operational. Lungfish use of the fishway is the ultimate endorsement of its suitability, the observed lack of significant use is the most salient evidence of the contrary.

b. The small percentage of time that the upstream fishway has actually operated since the dam became operational. The limited duration of operation of the fishway would undermine the effectiveness of even a fully functional fishway design in terms of meeting lungfish passage needs.

c. The numerous design and operational limitations of the upstream fishway that have been identified by the DPIF and private contractors engaged by Burnett Water Pty Ltd during the fishway's design, commissioning and operational monitoring. An external expert can seldom provide the intimate critique of a new system's limitations to the same extent as those most closely involved in its development can. The cumulative total of limitations identified by fishway experts most closely associated with the design, commissioning and operation of the upstream fishway is substantial.

6. Effectiveness of Paradise Dam Downstream Fishway Design and Operation for Lungfish

This section examines the design and operational effectiveness of the Paradise Dam downstream fishway for lungfish passage.

6.1 Downstream fish passage opportunities pre-dam

As discussed for the preceding section the pre-dam condition of this reach of the Burnett River was one that offered relatively unrestricted movement opportunities for lungfish.

6.2 Restrictions on downstream fish passage

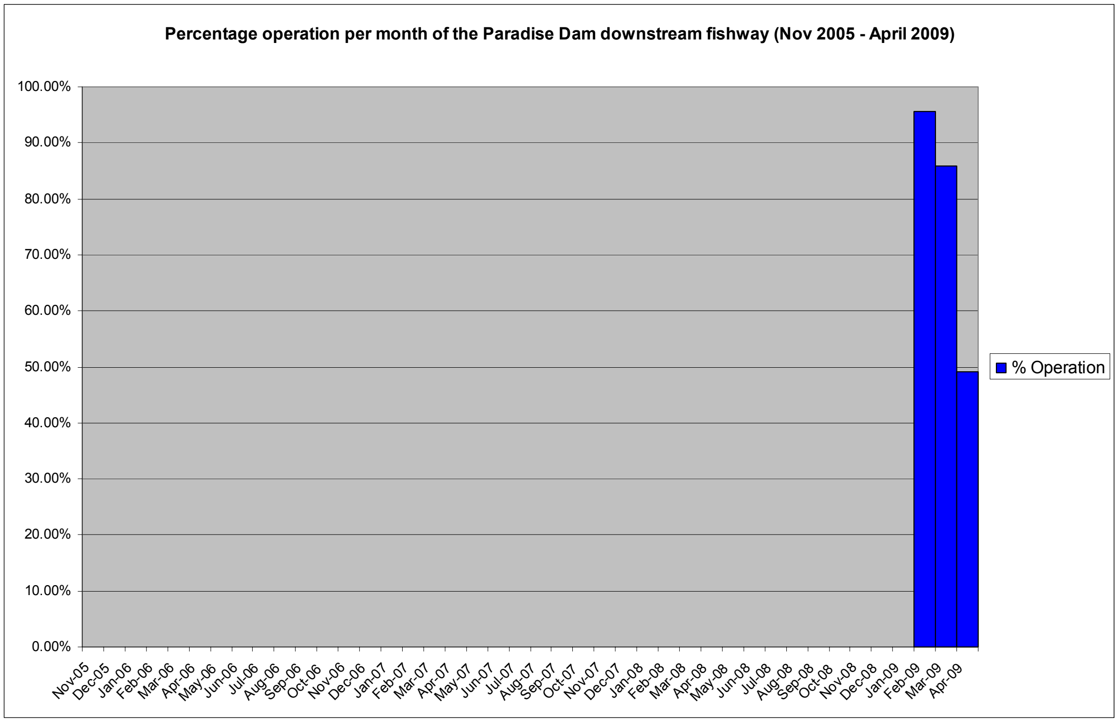
The passage opportunities available to lungfish through the downstream fishway since the Paradise Dam became operation are best depicted by Figure 45 below. Downstream passage opportunities for lungfish are primarily dependent on access to the fishway entrance. As discussed in the introduction to the report the entrance to the downstream fishway has an operational range between 62.0 and 67.9 m EL i.e. access to the downstream fishway is initiated when the dam reaches 57% of its storage volume. The operational level for the downstream fishway was only achieved for the first time in 2009 since 2005 i.e. three years of non operation (2006, 2007, and 2008).

Flow simulation modeling for the Burnett River basin (Appendix 6) indicates that the occurrence of storage volumes below the operation level required for the downstream fishway are likely to occur for durations that will severely restrict lungfish movement downstream from the Paradise Dam. In the 107.5 year flow simulation based on recorded rainfall within the Burnett River basin there were 9 years in which low storage volume would prevent access to the downstream fishway for an entire spawning period and 13 years in which access was prevented for the majority of the spawning season.

This contrasts poorly with the natural hydrological conditions and connectivity opportunities of the pre-dam reach. In the predevelopment scenario small river rises associated with rainfall events through the spawning season would result in punctuated opportunities for downstream movement of lungfish even during most drought years. Under post dam conditions such rises are absorbed within the impoundment and do not translate into it reaching the storage levels required for the downstream fishway to operate..

Since wet commissioning of the downstream fishway in February 2009, it has been shown to provide passage for a number of small fish species only and information available to date (DPIF 2009) indicates that no lungfish have used the downstream fishway.

Figure 45 - Percentage operation per month of the downstream fishway November 2005 – April 2009 based on Burnett Water log reports (see data in Appendix 7)



6.3 Evidence of lungfish aggregating above the downstream fishway

Monitoring of PIT tagged lungfish in the Paradise Dam impoundment reach (DPIF 2008) during 2008 confirmed that downstream movements are significant within the lungfish population. Tag detections indicated that downstream movement and detections at the dam wall peaked with dam inflow events during January to March 2008 and again during a smaller inflow events in June and particularly during the pre-spawning period July - August reconfirming previously identified ‘home return’ and ‘spawning ground seeking’ movement periods for the species in the Burnett River. The large numbers of lungfish that remained at the dam wall site after the February 2008 inflow event particularly suggested they were actively trying to move downstream (DPIF 2008).

Given the accumulation of lungfish at the upstream side of the dam wall during the 2008 summer inflow event to Paradise dam it would be expected that an equivalent accumulation occurred during the 2009 summer inflow event but PIT tag detection data for this period has not been reported by DPIF (2009). In terms of the operational effectiveness of the downstream fishway it is telling that no lungfish presumably accumulated at the dam wall, were recorded in the sampling undertaken at the downstream fishway by DPIF (2009).

6.4 Threats to lungfish using the downstream fishway

While a number of risks to the safety of fish passing through the downstream fishway have previously been identified i.e. abrasion and disorientation due to pipe diameter restrictions, pipe surface condition and transport/discharge velocities (Sunwater 2005, DPIF 2009), the principal threat to the safety of lungfish is associated with its ineffective design resulting in lungfish choosing to use spillway overflow events as the principal means of downstream movement (discussed earlier in report). Given the life history strategy of lungfish and threats to lungfish recruitment success described earlier, any significant increase in the mortality of adults will possibly result in the species entering an ‘extinction vortex’ due to low levels of recruitment being unable to effectively replace adults that have long generation times. Formulation of a traditional population model (Haldane 1953), for lungfish should be undertaken as part of the lungfish monitoring program to examine the level of risk presented by spillway overflow mortality.

Prior to the construction of Paradise Dam, Johnson (2001) suggested that many lungfish are likely to be killed or injured passing over dam and weir walls in the Burnett River during severe floods and that a very large flood could potentially kill hundreds of individuals. Berghuis & Broadfoot (2004) recommended that regardless of improvements to fishway design, passage over spillway walls is likely to be the major mode of passage for downstream migrating fish and therefore future design of weirs should include the provision of safe passage of fish over the spillway. The simulated flows analysis (Appendix 6) indicates that spillway overflows could potentially be a frequent, almost annual, event within some decadal sequences. If mortalities of hundreds of lungfish were associated with such events, the lungfish population above the Paradise Dam and potentially in the Burnett River is likely to be unsustainable. A population model as suggested for the Burnett River lungfish population would be able to elucidate such concerns.

6.5 Fish passage constraints: operational practices or design constraints

The downstream fishway has not operated for a sufficient period of time for operational limitations to be fully assessed, though the observed lack of lungfish in monitoring of fish using the fishway to date (DPIF 2009) is noted.

6.6 Measures to improve the design of the downstream fishway

The two principle requirements for addressing the design limitations of the downstream fishway are to:

a. Address the spillway design limitations in order to reduce its potential for spillway overflow mortality; and

b. Increase the operational range of the inlet to the downstream fishway to operate at lower storage levels

6.7 Measures to improve operation of downstream fishway

The highest priority for improving the downstream passage of lungfish is to address the mortality risks associated with the stepped spillway. In effect, the dam spillway is an integral component of the downstream path way available to fish and needs to be designed, managed and operated as thus. Evidence of the linkages between the spillway and downstream fishway in terms of the passage options available to lungfish are demonstrated by an existing downstream fishway design feature i.e the spillway crest flume channel that runs from the southern side of the spillway crest to the downstream fishway entrance (Figures 8 and 9). This feature of the downstream fishway is at yet untested but would appear to have a limited capacity to provide a competitive attraction flow relative to the broad spillway crest (pers. Obs).

As recommended by Berghuis & Broadfoot (2004) regardless of improvements to fishway design, passage over spillway walls is likely to be the major mode of passage for downstream migrating fish and therefore future design of dams and weirs should include the provision of safe passage of fish over the spillway.

Documents obtained through the discovery process identify that this concern was related to the Burnett Dam Alliance by fishway experts early in the design stage of the Paradise Dam. Structural means to minimise the spillway overflow impacts on fish including lungfish were recommended to the Burnett Dam Alliance including a spillway gate and plunge pool. These recommendations have never been implemented. It is telling that the 37 m high steep stepped spillway of the Paradise Dam has been colloquially referred to as a 'fish shredder' by fish biologist familiar with is design and impact potential (Pers. Comm).

6.8 Alternative fishway design

The best alternative design would be some form of low gradient spillway bypass as has been proposed for turtle migration out of the proposed Traveston Dam on the Mary River but configured to emulate a natural stream channel (Wildman et al. 2005) and to operate for fish and preferably with a range of off take outlet levels that initiate operation before the spillway overflow height is reached. The secondary spillway located on the southern bank of the Paradise dam is nominated as having a potentially suitable foundation and gradient to provide the basis for such a structure.

7. Impacts on Lungfish

This section examines the context and intensity of the impacts to the lungfish population caused by restricted passage associated with design and operational limitations of the Paradise Dam fishways.

7.1 Context of Impacts

The context of the impacts to lungfish posed by restricted passage associated with the design and operation limitations of the Paradise Dam fishways were fully discussed above, where the importance of connectivity to the Burnett River lungfish populations was discussed, the implication of restrictive fish passage at Paradise Dam and other threats faced by the lungfish population other than the Paradise Dam (Sections 4.5, 4.6 & 4.7).

7.2 Intensity of impacts

The EPBC approval in respect of lungfish passage granted for the operation of Paradise Dam (EPBC 2001-422) is effective to January 2052. Therefore the impact potential of restricted passage for lungfish at the Paradise Dam needs to be considered within the context of what has been observed to occur to date and also with regard to the potential associated with impacts extending for at least the full duration of the EPBC approval period.

Impacts on lungfish from restricted fish passage upstream and downstream of the Paradise Dam associated with the design and operational limitations of the fishways are:

a. Lack of ecologically significant upstream movement (past Paradise Dam) of lungfish population ~3years + and continued restricted movement

b. Absence of lungfish downstream movement ~3years + and continued restricted movement

c. Increased mortality rates for adult lungfish due to compulsion for downstream movement via spill way overflows

d. Increased genetic isolation of lungfish populations above and below Paradise Dam and reduced genetic vigor/viability of lungfish in the Burnett Basin.

e. Reduction in population recruitment levels due to reduced access to spawning grounds, reduced spawning success (access, crowding and predation effects) and reduced juvenile dispersal.

It is my professional judgment that the most intense impact will be caused by the impact of increased adult mortality and reduced population recruitment levels. These impacts combined have the potential to undermine the viability of the lungfish population within the

Burnett River and the development of a population model to examine the potential implications of these impacts is recommended as a priority.

Demonstrated low levels of lungfish upstream movement and the potential for some survival of spillway overflow migrants may be sufficient to avoid serious genetic consequences.

7.3 Consequence of impacts for the conservation of the lungfish species

It is my professional judgment that the consequences of impacts to the conservation of the lungfish are likely to include:

a. Increase in the cumulative impact load experienced by the Burnett River lungfish population;

b. Subject to extent of adult spillway overflow mortality and recruitment level reductions, the reduced viability and potential extinction of the Burnett River lungfish population (one of only two endemic river basin populations) in the longer term;

c. Reduced security overall for the species; and

d. Poor precedent established in terms of protective management provisions for a listed vulnerable species.

8. Conclusion

Lungfish are a species listed as vulnerable to extinction under the EPBC Act. They are recognised to have low levels of genetic diversity and infrequent and low levels of population recruitment and survive by a life history strategy that depends on longevity to counter low annual recruitment success. The Burnett River lungfish population is under serious threat due to a host of environmental impacts associated with the modified river system in addition to those posed by the Paradise Dam. Effective fish passage upstream and downstream of the Paradise Dam is essential for maintaining the viability of the lungfish population in the Burnett River in terms of providing access to habitat and feeding resources required to maximise population recruitment success, to prevent spillway overflow associated mortality of adults and to allow for population genetic mixing to maximise the genetic vigour and evolutionary potential of the species.

The ineffective design and operation of the existing fishways on the Paradise Dam is collectively contributing to a lack of sufficient and safe passage opportunities for lungfish upstream and downstream of the Paradise Dam. If not rectified this passage restriction has the potential of tipping the Burnett River lungfish population toward extinction within several generations.

Declaration

I have made all the enquiries I consider desirable and appropriate and no matters of significance I regard as relevant have, to my knowledge, been withheld from the Court. The factual matters stated 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 paramount duty is to assist the Court and believe I have complied with this duty to the best of my ability.

Jim Tait (BSc) Senior Environmental Scientist

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Appendix 1 – Summary of Qualifications and Experience

Aquatic Ecology and Natural Resource Management

Jim Tait is an aquatic ecologist with over twenty years experience in tropical and sub-tropical river systems spanning from northern NSW Australia to Papua New Guinea and the Philippines. Jim's primary professional interests include freshwater fish, riparian ecosystems and wetlands. Since graduating from Townsville's James Cook University, much of Jim's work has involved regional natural resource assessments and management planning in relation to water resources and infrastructure development. This has included participation as a consultant Technical Advisory Panel member in the development of Water Resource Plans for five Queensland basins including the Barron, Calliope, Proserpine – O'Connell, Baffle and Southern Gulf. As a member of the Queensland Fisheries Management Authority's Management Advisory Committees for both Tropical Finfish and Freshwater, Jim contributed to the development of both the Qld Gulf of Carpentaria Inshore Finfish and Freshwater Fishery Discussion Papers (QFMA 1996). As a consultant wetland ecologist Jim played a pivotal role in the delivery of the Commonwealth Government's Great Barrier Reef Coastal Wetland Protection Program (2005-2007) in both the development of a wetland prioritisation Decision Support System and in the delivery of a multimillion dollar on ground works program. Jim is also an experienced conservation biologist who has undertaken assessments of biodiversity values and management needs at local to national scales. His interest in broader NRM issues has seen him lead the development of community based NRM strategies within the Burdekin Dry Tropics Region of north Queensland. Jim's client base as a consultant has spanned three levels of government, mining, energy and primary industry sectors, research, international aid and community based organisations.

Jim is a Member of the Australian Society for Fish Biology, a Member of the Australian and New Guinea Fishes Association and a Life Member of the Australian Society for Limnology.

JIM TAIT – CURRICULUM VITAE

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Address: 56 McPhails Road Huonbrook NSW 2482 **ABN** 99607411256

CAREER SUMARY:

- 2002 – Current (2009) **Senior Environmental Scientist & Principal** Econcern Consulting – Huonbrook NSW – Example project work: Qld Dept NR&W assessment of flow dependent assets for Gulf, Mitchell, Calliope, Proserpine /O'Connell and Baffle Basin Water Resource Plans, Values assessment Gregory Wild River, Habitat and River Process Studies for Bremer & Stanley Rivers, DEWHA Canberra - Great Barrier Reef Coastal Wetland Protection Program delivery of on-ground works and development prioritisation DSS, State-wide fish passage funding proposal developed for NSW Fisheries, QWI – Baseline ecological studies for proposed Traveston Dam, Rio Tinto –

Development Ely Dam Monitoring Program and South of Emberly IAS, Consortium for Integrated Management - R & D Issues paper for Sustainable Vegetation Mgt in Qld, Land and Water Australia - A national river conservation assessment framework, WWF Australia Biodiversity Conservation – Priorities for a Living Continent and Southern Gulf Wetlands Management Practices and Needs, Maroochy Shire - Biodiversity Strategy, Burdekin Dry Tropics NRM Board - Regional Overview for NRM Strategy and Regional Prioritisation of Fish Passage Barriers, NSWF - Prioritisation of habitat rehabilitation for Eastern Cod in the Richmond River Basin.

- 2002 - 2003 **Development Manager** Wetland Care Australia – Ballina NSW
- 2000-2002 **Technical Manager Ecology** National Land and Water Resource Audit – Canberra, ACT – Australia-wide assessments ($6M) for Ecosystem Health and Biodiversity Themes.
- 1998-99 **Research Officer / Project Consultant** Australian Centre for Tropical Freshwater Research - Townsville, Queensland – Project responsibilities included Senior Conservation Officer EPA, floodplain management, water resource infrastructure assessment (WIPDIP), freshwater fish surveys, remnant vegetation assessment, regional natural resource strategy .development.
- 1993-97 **Environmental Consultant** Private – Townsville, Qld – Regional natural resource assessment and biodiversity conservation planning, fish habitat, wetland and floodplain management and environmental impact assessment for range of clients including State & Local Government**,** industry, engineering, legal, ICM and Landcare organisations.
- 1990-93 **Special Projects Biologist** Ok Tedi Mining Ltd - Papua New Guinea – Freshwater fisheries monitoring program development and reporting.
- 1989 **Campaign Officer** North Queensland Conservation Council – Environmental conservation.
- 1988 **Consultant Fish Biologist** Dames and Moore Pty Ltd - Cape York – Fish survey / IAS.

KEY SKILLS

- Aquatic and terrestrial ecology
- Biodiversity survey / evaluation.
- Environmental impact assessment
- Catchment / regional planning
- Project scoping and management
- Team management and coordination
- Stakeholder consultation
- Multi media and oral communication
- Report preparation, review and publication

KEY ACHIEVEMENTS

- Successful environmental consultancy
- Government, industry and community adoption of report recommendations
- Regional NRM strategies
- Obtaining funding >$1M for environmental research & management programs
- International /national publications
- Managing Australia-wide assessments in water quality, ecosystem health and biodiversity ($6M/5yrs)

QUALIFICATIONS:

1986 Bachelor of Science (Zoology & Geography) James Cook University, Townsville.

SELECTED PUBLICATIONS:

Carter, J., Tait, J.T.P., Kapitzke, R. and Corfield, J. (2007). **Final Report Burdekin Dry Tropics NRM Region Fish Passage Study.** 17 November 2007. Prepared for Burdekin Dry Tropics NRM.

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Tait, J. (1996). (i) **Natural Resources Discussion Paper, (**ii) **Appendix 1 – Wetlands of Regional Significance in the Townsville – Thuringowa Sub-region,** prepared for the Natural Resources Working Group for the Townsville - Thuringowa Area Strategy Plan.

Tait, J. (1994), **'Lowland Habitat Mapping and Management Recommendations, Tully - Murray Catchments'** An ICM Initiative of the Queensland Department of Primary Industries. Cardwell Shire Catchment Coordinating Committee

REFEREES:

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Appendix 2 – Letters of Instructions

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25 November 2008

Jim Tait
Senior Environmental Scientist
Econcern Environmental Consultancy
56 McPhails Rd
Wanganui NSW 2482
Email: econcern@bigpond.com

Dear Mr Tait,

Wide Bay Burnett Conservation Council Inc v Burnett Water Pty Ltd – Federal Court of Australia proceedings No. QUD 319 / 08

We act for the Wide Bay Burnett Conservation Council (WBBCC) in litigation in the Federal Court of Australia in relation to an alleged failure by Burnett Water Pty Ltd to construct and operate a fishway that is suitable for Australian or Queensland lungfish (*Neoceratodus forsteri*) on the Paradise Dam. This obligation is imposed by a condition of approval for the dam under the *Environment Protection and Biodiversity Conservation Act* 1999 (Cth) (EPBC Act). WBBCC seeks a declaration from the Court on the legal meaning of the condition and an injunction to compel Burnett Water Pty Ltd to comply with the condition.

You are requested to provide an expert report to the Federal Court on "Lungfish passage through fishways and the significance of restricted passage on Paradise Dam for lungfish in the Burnett River". Additional reports are being sought from other experts, including reports on the baseline and altered hydrology of the Burnett River and a background report from Professor Jean Joss on the biology, ecology and conservation status of lungfish.

The timetable for the litigation has not been finalised but we anticipate it will ultimately result in a 5 day hearing in the Federal Court in Brisbane in March or April 2009. A directions hearing on 5 December 2008 will decide the steps to be taken in preparing for the hearing, including dates for the exchange of expert reports. We ask that you appear at the hearing to present your report to the Court and for cross-examination.

Duty to the Court

We note as a preliminary matter that your paramount duty in preparing your report is to assist the Court and you are not an advocate for WBBCC.[2] We stress that WBBCC asks you to prepare a truly independent report that is clear and well-written and rigorously based on the best science to assist the Court to determine the issues in dispute in these proceedings.

Material included for your consideration

The following material has been included with this letter of instructions:

- Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia (Version 6, 5 May 2008).[3]
- The referral of the Paradise Dam by Burnett Water Pty Ltd under the EPBC Act in 2001.
- Relevant extracts from the Paradise Dam Environmental Impact Study (EIS) in 2001.[4]
- Photographs of the upstream and the downstream fishway in 2006 and 2008.
- The Application and Statement of Claim in the Federal Court proceedings.
- Request for Further & Better Particulars filed by Burnett Water Pty Ltd on 12 November 2008.
- Further and Better Particulars filed by WBBCC on 19 November 2008.

We anticipate obtaining further documents from Burnett Water Pty Ltd regarding the operation of the upstream and downstream fishways and ongoing monitoring of the lungfish population on the Burnett River during the course of the litigation and we will provide those documents to you when they become available.

Brief history of the Paradise Dam

The Paradise Dam is a major dam with a storage capacity of 300,000 megalitres constructed on the lower Burnett River approximately 80 km southwest of Bundaberg in Queensland. The dam's name comes from its location near the site of an old mining town of Paradise but at one stage it was called the "Burnett River Dam".

Burnett Water Pty Ltd referred the Paradise Dam under the EPBC Act on 30 August 2001 and it was approved by the Federal Environment Minister under section 133 of the Act on 25 January 2002. Only two conditions were originally attached to the approval. These two conditions required the preparation of plans to mitigate impacts to a listed threatened species (the Black-breasted Quail) and listed migratory species.

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[2] See Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia (Version 6, 5 May 2008), available at http://www.fedcourt.gov.au/how/prac_direction.html.
[3] Available at http://www.fedcourt.gov.au/how/prac_direction.html.
[4] The full EIS is available at http://www.sunwater.com.au/burnettwater_docs.htm#B_EIS.

The Burnett River is one of only two known endemic populations of the lungfish, which was listed as vulnerable to extinction under the EPBC Act on 6 August 2003. As a result of this listing, on 8 August 2003 the conditions of the approval for the dam were varied to attach further conditions requiring the installation of a fish transfer device, ongoing monitoring and other measures to conserve lungfish. These conditions provided as follows:

> 3. Burnett Water Pty Ltd must install a fish transfer device on the Burnett River Dam suitable for the 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 Basis) 2000* and the *Resource Operation Plan (Burnett Basin) 2003* and the Burnett River Dam Flow Strategy for Lungfish dated 22 May 2003.
>
> 5. Prior to commencing operation of the Burnett River Dam, Burnett Water Pty Ltd must provide to the Minister a report detailing the results of baseline monitoring of the lungfish population in the vicinity of the Burnett River Dam wall.
>
> 6. Burnett Water Pty Ltd must undertake annual aquatic ecosystem monitoring at about AMDT 119 km, AMTD 201 km and at least two sites between these points and provide to the Minister five biennial summary reports. This 10-year monitoring program will include the measurement of the condition of lungfish and lungfish habitat / macrophytes. Monitoring will commence when the dam becomes operational.
>
> 7. Burnett Water Pty Ltd must conduct a review of the impacts of Burnett River Dam on the lungfish at the conclusion of the 10 year monitoring program in consultation with the Commonwealth Environment portfolio, to determine whether future monitoring is required.
>
> 8. Burnett Water Pty Ltd must make lungfish information and data from research and monitoring activities freely available for inclusion in State and Commonwealth lungfish recovery programs or programs relating to water quality in the Burnett River.
>
> 9. If aquatic ecosystem monitoring required under paragraph 4 or the review required under paragraph 5 indicates ongoing lungfish population decline at about AMTD 199 km that cannot be attributed to natural periodic fluctuations, then Burnett Water Pty Ltd will initiate appropriate recovery actions. The recovery actions cannot be inconsistent with an adopted Commonwealth Lungfish Recovery Plan.

Construction of the Paradise Dam was completed in 2005.[5] It has a usable storage of 286,610 ML (approximately 95% of total storage capacity) and a dead storage (beneath which water cannot effectively be used) of 13,390 ML (approximately 5% of total storage capacity). Controlled discharges of water are made from the dam by sluice gates. When the water level in the dam exceeds its maximum storage, water is released from the dam via a spillway.

In an attempt to comply with condition 3 of the EPBC Act approval, Burnett Water Pty Ltd has constructed an upstream fishway and a downstream fishway. Although located in close proximity to each other, these are two separate structures with very different designs:[6]

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[5] See http://www.sunwater.com.au/burnettwater_paradisedam.htm.
[6] Pictures and diagrams of the upstream fishway and the downstream fishway are available at http://www.sunwater.com.au/burnettwater_environmental_fish_passage.htm

(a) The upstream fishway (also known as the “upstream fishlift”) consists of a 7,500 litre caged container (known as a “hopper”) into which fish are intended to be attracted by flowing water at the downstream base of the dam. The caged container is designed to be periodically lifted over the dam wall and for any fish in the container to be released on the upstream side of the dam.

(b) The downstream fishway (also known as the “downstream fishlock”) consists of an inlet chamber on the upstream side of the dam wall in the dam reservoir and a pipe to the downstream side of the dam. Fish are intended to be attracted into the inlet chamber by flowing water. A lock or vertical gate at the entrance of the inlet chamber is designed to be periodically closed and the chamber drained to cause the fish to be transported into a pipe and released into a pool on the downstream side of the dam wall connected to the downstream river.

We anticipate obtaining detailed information from Burnett Water Pty Ltd concerning the design and actual operation of the upstream fishway and the downstream fishway and we will provide that information to you when it is available to us.

Instructions regarding the legal context of the appeal

As a preliminary matter, please note that you are not permitted to express an opinion on any question of law in your report and that your report should confine itself to the relevant issues of fact within your area of expertise. However, you need to understand the legal context of the appeal to understand the relevant questions of fact that the Federal Court requires your assistance on. The legal questions are quite complex and it may be of assistance to the Court in understanding your report if you set out your instructions in an introductory section to explain how you understand the relevant concepts involved in the questions of fact addressed in the body of your report.

You are instructed that the question the Federal Court must consider in the appeal is whether the design and operation of the fishway on the Paradise Dam contravenes condition 3 of the EPBC Act approval for the Paradise Dam. An offence will occur against sections 142 and 142B of the EPBC Act if the condition is contravened without any actual impact on the lungfish being proven on the balance of probabilities. An offence will occur against section 142A of the EPBC Act if the condition is contravened recklessly by Burnett Water Pty Ltd and results in a significant impact[7] on the lungfish being proven on the balance of probabilities.

Condition 3 of the EPBC Act approval for Paradise Dam states:

> Burnett Water Pty Ltd must install a fish transfer device on the Burnett River Dam suitable for the lungfish. The fishway will commence when the dam becomes operational.

[7] For the purposes of the EPBC Act, a significant impact has been defined by the Federal Court as “an impact that is important, notable or of consequence having regard to its context or intensity”: *Booth v Bosworth* (2001) 114 FCR 39; [2001] FCA 1453 at 64 [99] (Branson J). Cf. *Minister for the Environment and Heritage v Greentree (No 2)* (2004) 138 FCR 198; [2004] FCA 741 at [191]-[201] (Sackville J).

Whether the upstream fishway and the downstream fishway meet the standard of being "suitable for lungfish" is an issue that is ultimately for the Court to determine. As it involves questions of the legal interpretation of the condition it is not something that you can give an opinion upon directly. We cannot ask you to simply state whether in your opinion the upstream fishway and the downstream fishway are suitable for lungfish and comply with condition 3 because that inherently involves a decision about the legal meaning of the condition. Your report and other expert reports can, however, assist the Court in resolving this ultimate issue by explaining the likelihood of lungfish passing through the upstream and the downstream fishway and any likely impacts on the lungfish population due to restricted passage.

Alleged contraventions of Condition 3

WBBCC has set out nine particulars of the conduct it alleges contravenes Condition 3 of the EPBC Act approval at paragraph 6 of the Statement of Claim provided to you. These are that Burnett Water Pty Ltd has installed and operated, is operating, and intends to continue to operate the upstream fishway and downstream fishway in a manner whereby:

(a) The entrances to the upstream fishway and the downstream fishway are not likely to be found by lungfish attempting to move or migrate upstream or downstream of the dam wall.

(b) The entrances to the upstream fishway and downstream fishway are too small for fully grown lungfish to enter.

(c) The caged container in the upstream fishway is too small for fully grown lungfish.

(d) The upstream fishway and downstream fishway do not operate continuously.

(e) The downstream fishway is not suitable for lungfish to move or migrate downstream of the dam when water levels in the dam are beneath EL 62.0 m (57% of the full storage capacity of the dam) because the inlet to the downstream fishway is constructed above this height.

(f) Lungfish are likely to be injured by the speed at which they are transported through the downstream fishway and the small dimensions of the pipes and downstream release pool.

(g) Lungfish, particularly juveniles, are susceptible to predation while moving through the upstream fishway and the downstream fishway.

(h) Lungfish exiting the upstream fishway or the downstream fishway are susceptible to predation at the release point.

(i) Due to the matters raised in paragraphs 6(a)-(h), the upstream fishway and the downstream fishway are not likely (more than 50% probable) to allow any normal sized lungfish to move upstream or downstream of the dam without injury irrespective of the water level in the dam.

WBBCC has also set out particulars of why it alleges the conduct of Burnett Water Pty Ltd has, will have or is likely to have a significant impact on lungfish at paragraph 8(b) of the Statement of Claim, namely by:

(i) Stopping, hindering, or reducing upstream and downstream movement or migration of lungfish in the Burnett River for feeding or reproduction.

(ii) Causing a greater number of lungfish to move downstream in flood events over the dam spillway and, thereby, increasing mortality in the lungfish population due to death or injury of lungfish on the spillway.

(iii) Unless restrained by the Court the impacts in paragraphs 8 (b) (i) and (ii) will continue during the operation of the dam for the indefinite future.

Burnett Water Pty Ltd requested further details of these particulars in a series of questions filed on 12 November 2008 and WBBCC filed a reply to those questions on 19 November 2008. The further and better particulars provided by WBBCC have been provided to you and provide further guidance on the case alleged by WBBCC.

These particulars are not intended to constrain or improperly influence your consideration of this case. The purpose of stating them in the Statement of Claim and the Further and Better Particulars is to allow Burnett Water Pty Ltd to know the case it is required to address in the proceedings and to narrow the scope of the issues in dispute and the evidence that is relevant to resolve these issues. If you disagree with these particulars or believe that further specific factual issues should be raised please inform us. It is possible for WBBCC to amend its Statement of Claim and its particulars to change the nature of the case but this should be done as soon as possible to avoid delays and unnecessary costs for both parties.

Factual questions that expert evidence is required for

The following questions are the factual issues that we consider expert evidence may assist the Court in determining the ultimate question of whether Burnett Water Pty Ltd has complied with Condition 3 of the approval for Paradise Dam:

<u>Lungfish biology, ecology and conservation status</u>

1. Explain the biology, ecology and conservation status of the lungfish species, including:

   (a) The species' known distribution, populations, life history, habitat requirements, migratory behaviour and requirements (i.e. does it need to migrate and, if so, to what extent).

   (b) The known behaviour of the lungfish relevant to the design of fish passage through the Paradise Dam.

   (c) What demographic variables affect the natural movement or migration of lungfish, including age, sex and size?

(d) Does movement or migration of lungfish vary with seasons, river flow or other naturally variable factors?

(e) The evolutionary and ecological significance of the lungfish.

(f) Why the lungfish has been listed as vulnerable to extinction under the EPBC Act.

(g) The importance (if any) of connectivity in the lungfish population in the Burnett River and, in particular, whether there is any need for effective fish passage upstream or downstream on the Paradise Dam to provide breeding and feeding opportunities and to maintain the genetic variability and viability of the lungfish population.

(h) What impacts would be expected on the lungfish population in the Burnett River from the construction of the Paradise Dam without a fish transfer device, such as changes in habitat and changes in the genetic variability and viability of the lungfish population?

(i) Other than the Paradise Dam, what threats and impacts are faced by the lungfish population in the Burnett River?

(j) What other threats and impacts are faced by the lungfish species outside the population in the Burnett River?

<u>Hydrology</u>

2. Explain the hydrology of the Burnett River at the location of the upstream fishway and the downstream fishway prior to, and following, the construction of the Paradise Dam, including:

(a) What was the water flow regime, particularly periods of zero flow, at the site of the upstream fishway and the downstream fishway prior to the construction of the dam?

(b) Review and evaluate in terms of best or sound scientific practice the hydrological modelling carried out by the respondent, Burnett Water Pty Ltd, prior to the construction of the dam particularly the modelling of:

(i) likely water levels in the dam;

(ii) water releases from the dam for downstream uses, including environmental flows;

(iii) water releases from the dam for the operation of the upstream fishway and the downstream fishway;

(iv) rainfall and periods of drought in the Burnett Basin; and

(v) use of water by upstream water-users diverting water from the dam.

(c) To what extent can it be expected that water levels in the dam in the future will obtain and remain above 62m AHD (57% of the dam capacity), thereby allowing the downstream fishway as currently constructed to operate?

Upstream fishway

3. What is the likelihood that lungfish[8] will pass through the upstream fishway safely, in particular:

    (a) What is the likelihood that the upstream fishway design will allow safe lungfish passage in comparison to unrestricted passage?

    (b) What is the likelihood that the upstream fishway will allow safe lungfish passage as actually operated by Burnett Water Pty Ltd in comparison to unrestricted passage?

    (c) What other measures would improve upstream fish passage, including both an entirely different designed fishway and changes to the existing fishway and its operation, and to what extent would those measures improve the likelihood of safe lungfish passage upstream in comparison to unrestricted passage?[9]

Downstream fishway

4. What is the likelihood that lungfish[10] will pass through the downstream fishway safely, in particular:

    (a) What is the likelihood that the downstream fishway design will allow safe lungfish passage in comparison to unrestricted passage?

    (b) What is the likelihood that the downstream fishway will allow safe lungfish passage as actually operated by Burnett Water Pty Ltd in comparison to unrestricted passage?

    (c) What other measures would improve the downstream fish passage, including both an entirely different designed fishway and changes to the existing fishway and its operation, and to what extent would those measures improve the likelihood of safe lungfish passage downstream in comparison to unrestricted passage?[11]

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[8] Please consider all age and size classes and both male and female lungfish.
[9] Do not assume that cost is a constraint but include estimates of the cost of different measures where possible.
[10] Please consider all age and size classes and both male and female lungfish.
[11] Do not assume that cost is a constraint but include estimates of the cost of different measures where possible.

Significance of impacts

5. What are the impacts for the lungfish population in the Burnett River and the species generally of any restrictions in the movement of lungfish caused by the design and operation of the upstream fishway and the downstream fishway, in particular changes in the genetic variability and viability of the lungfish population?

6. Having regard to the context and intensity of the impacts, are they important, notable or of consequence for the conservation of the lungfish species?

We ask that you address questions 3-6 in your report. The answers to these questions should, as much as possible, be based on actual evidence (e.g. data of the lungfish actually using the fishways to move past the dam in either direction).

Both the design and the operation of the fishways are relevant

We note as further background that Condition 3 requires both the design and operation of the fishway to be considered and we ask you to consider both of these matters. The design of the fishway affects the likelihood that it will allow lungfish to find and pass through it safely. The operation of the fishway affects the amount of time available and, therefore, when it is possible for lungfish to pass through it (including consideration of seasonal variation in lungfish movement).

The combined effect of the design and operation of the upstream fishway and the downstream fishway on the likelihood that lungfish will pass upstream or downstream for the dam wall may be represented graphically. The following graph considers three fictitious/hypothetical examples as follows (note that due to the different design and operation of the upstream and downstream fishways, separate consideration is required for each):

- **Hypothetical example 1**: The blue square ( ) shows the area of graph for probability of 2.5% that lungfish will move or migrate through the fishway in comparison to a natural river or unobstructed passage through the dam. This supposes that there is a 10% probability that the design of the fishway will allow lungfish to find & pass safely through it & the fishway operates for 25% of the total time (1 in every 4 days).

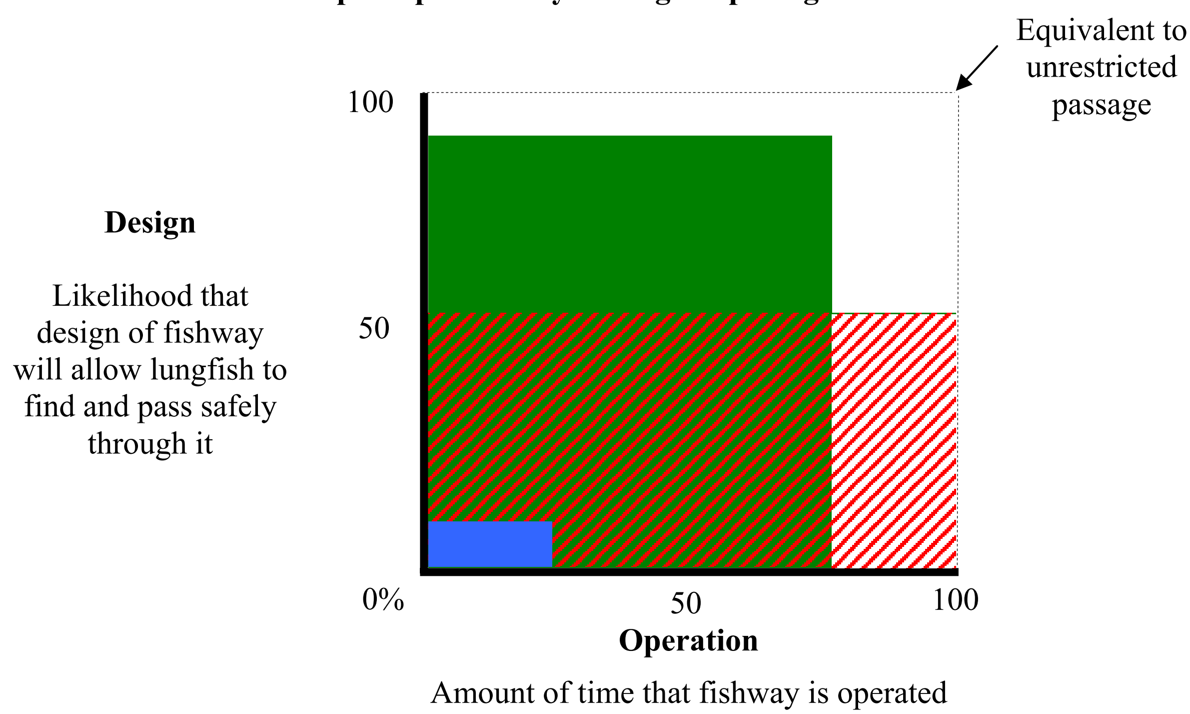
- **Hypothetical example 2**: The red hatched square ( ) shows the area of graph for probability of 50% that lungfish will move or migrate through the fishway in comparison to a natural river or unobstructed passage through the dam. This supposes that there is a 50% probability that the design of the fishway will allow lungfish to find & pass safely through it & the fishway operates continuously (i.e. 100% of the total time).

- **Hypothetical example 3**: The green square ( ) shows the area of graph for probability of 67.5% that lungfish will move or migrate through the fishway in comparison to a natural river or unobstructed passage through the dam. This supposes that there is a

90% probability that the design of the fishway will allow lungfish to find & pass safely through it & the fishway operates for 75% of the total time (3 in every 4 days).

Note that these hypothetical examples are not based on actual data or knowledge and are intended merely to illustrate the point that it is the combined effect of the design and operation of the fishways that give the actual likelihood that lungfish will be able to pass through the fishways.

Graph of probability of lungfish passage



Required information

The Federal Court's *Guidelines for Expert Witnesses in Proceedings in the Federal Court of Australia* specifies the information your report is required to contain. This includes:

- Your qualifications;

- A statement of the questions or issues that you are asked to address;

- The factual premises upon which your report proceeds;

- The documents and other materials that you have been instructed to consider;

- All assumptions of fact that you make should be clearly and fully stated;

- If your opinion is not fully researched because you consider that insufficient data is available, or for any other reason, this must be stated with an indication that the opinion is no more than a provisional one;

- Where you believe that any statement in your report may be incomplete or inaccurate without some qualification, that qualification must be stated in the report;

- You should make it clear when a particular question or issue falls outside your expertise;

- References to any literature or other material relied upon by you to prepare the report;

- If your report refers to photographs, plans, calculations, analyses, measurements, survey reports or other extrinsic materials that are not included in the report, these must be provided to the opposite party at the same time as the exchange of expert reports;

- For any inspection, examination or experiment conducted or relied on in preparing your report, a description of what was done, who conducted it, their qualifications, and the result;

- If there is a range of opinion on the matters dealt with in your report, a summary of the range of opinion, and the reasons why you adopted a particular opinion; and

- A summary of the conclusions you reached.

Declaration

At the conclusion of your report, you must include the following declaration (assuming, of course, the declaration is correct to your knowledge):

> I have made all the enquiries I consider desirable and appropriate and no matters of significance I regard as relevant have, to my knowledge, been withheld from the Court. The factual matters stated 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 paramount duty is to assist the Court and believe I have complied with this duty to the best of my ability.

Formatting of report

Please format your report as follows:

- Address your report to the Court;

- Sign and date your report;

- Include a summary of your qualifications and experience as an appendix to your report;

- Use 12 point type and at least 2cm page margins;

- Print your report single sided and supply 5 bound copies of it, or supply a PDF version of your report for printing and binding;

- Number each paragraph of your report;[12]

- Number all pages, including attachments and annexes, continuously from the first page to the last page (excluding any cover page to your report);

- Annex this letter of instructions to your report.

Draft of report

We request that you provide us with a draft of your report for review before finalising it, the dates of which will depend on the timetable determined by the Court on 5 December 2008. The purpose of this is not to influence the substantive conclusions or recommendations you make but to ensure that the report is clear and addresses the required questions and issues adequately.

Conclusion

Thankyou for your assistance and diligence in preparing your report in the manner set out in this letter. Please contact us if you have any further questions.

Yours faithfully

Jo-Ann Bragg.

Jo Bragg
Principal Solicitor
Environmental Defenders Office (Qld) Inc

[12] This greatly assists references and discussion of your report in the Courtroom.

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15 June 2009

Mr. Jim Tait
Senior Environmental Scientist
Econcern Environmental Consultancy
56 McPhails Rd
Wanganui NSW 2482
Email: econcern@bigpond.com

Dear Mr Tait,

Wide Bay Burnett Conservation Council Inc v Burnett Water Pty Ltd – Federal Court of Australia proceedings No. QUD 319 / 08

We refer to your letter of instructions dated 25 November 2008.

Additional Material for your Consideration

Since our initial letter of instruction we have supplied you with additional documentation sourced from Burnett Water through the discovery process and other documentation that either you requested or we thought was potentially relevant. We have emailed you the following pleadings which we list here for a convenient record:

1. Amended Statement of Claim filed 14 April 2009

2. Defence filed 1 June 2009

3. Reply filed 15 June 2009

Factual Questions that Expert Evidence is Required for

In our original letter of instructions, we requested that you address factual matters 3-6 in your report. Since then, rather than having a separate report from Professor Jean Joss, it appeared most efficient if you could also address factual matter 1 (Lungfish Biology, Ecology and Conservation Status). We, therefore, request that you address those questions in your report with the exception of the evolutionary significance of the lungfish, which is not in dispute in the proceedings. We also request that you address factual matters 5 & 6 under a fresh label of “Harm to Lungfish” or “Impacts to Lungfish” instead of

“Significance of Impacts” while there is no change to the questions posed for your consideration.

Instructions Regarding the Legal Context of Appeal

As included in the original letter of instructions, the experts’ role is to assist on factual matters. However it is useful for you to be updated on the legal context of the case. The Amended Statement of Claim now **omits** reference to any offence against section 142A of the EPBC Act, which concerns if the condition is contravened recklessly by Burnett Water Pty Ltd and results in a significant impact on the lungfish being proven. While that offence is omitted, we still need your report to cover all the factual matters previously addressed.

Dates

We have previously advised you of key dates in this matter and list them for your convenience as follows:

- Report due to be filed 19 June 2009;
- Burnett Water’s Expert Reports due to be filed by 24 July 2009
- Experts to confer to identify or clarify any issues and to resolve or narrow any points of difference by 14 August 2009

No date has been specified by the Court for a joint expert report to be filed but we will liaise with the solicitor representing Burnett Water Pty Ltd to agree on a suitable date. We anticipate that this will be by 14 August or shortly thereafter.

Please advise us of dates between Monday 27 July and Friday 14 August when you can meet in Brisbane with any opposing expert witness or witnesses. We anticipate that a full day will be required for the meeting. The timing of the meeting should allow sufficient time to prepare a joint report by 14 August or shortly thereafter.

Please contact us if you have any further questions.

Yours faithfully

Jo-Ann Bragg.

Environmental Defenders Office (Qld) Inc.
Jo-Anne Bragg
Principal Solicitor

Appendix 3

Draft Recovery Plan for the Australian lungfish *Neoceratodus forsteri*

(38 pages)

Recovery Plan for the Australian lungfish
Neoceratodus forsteri ~~2007-2012~~

Queensland Government
Environmental Protection Agency

Australian Government

Recovery Plan for the Australian lungfish *Neoceratodus forsteri* ~~2007-2012~~

Prepared by: Peter Kind, Anita Wohlsen and Steve Brooks for the Australian lungfish recovery team

Title Page: Australian lungfish (Gunther Schmida)

Copies may be obtained from the:
Executive Director
~~Conservation Services~~Sustainable Communities
~~Queensland Parks and Wildlife Service~~Environmental Protection Agency
PO Box 15155
City East Qld 4002

Disclaimer:
The Australian Government, in partnership with the Environmental Protection Agency ~~/ Queensland Parks and Wildlife Service~~ facilitates the publication of recovery plans to detail the actions needed for conservation of threatened native wildlife.

The attainment of objectives and the provision of funds may be subject to budgetary and other constraints affecting the parties involved, and may also be constrained by the need to address other conservation priorities. Approved recovery actions may be subject to modification due to changes in knowledge and changes in conservation status.

Publication Reference
Kind, P., Wohlsen, A. and Brooks, S. 2008~~7~~. Recovery Plan for the Australian lungfish *Neoceratodus forsteri* 2007-2012. Report to Department of Environment and Water, Canberra. ~~Queensland Parks and Wildlife Service~~Environmental Protection Agency, Brisbane.

Contents

Executive Summary

Species
This plan specifically addresses the Australian lungfish *Neoceratodus forsteri*.

Conservation status
This species is listed as 'Vulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The Australian lungfish is also listed as a 'no take' species in Queensland under the *Fisheries Act 1994*.

International o~~O~~bligations
Australian lungfish are protected from international trade under Appendix II of the Convention on International Trade in Endangered Species (CITES).

Habitat and distribution s~~S~~ummary
Australian lungfish occur in freshwater reaches of coastal river systems within a highly restricted distribution in south east Queensland. Well documented populations exist within sections of the Burnett, Mary, North Pine and Brisbane Catchments and Enoggera Creek as well as a small number of other standing water bodies.

Threats summary
1. Instream barriers
2. Regulated flows
3. Habitat degradation/reduced water quality
4. Introduced species
5. Fishing and boating activities

~~Overall~~ Recovery objective
Maintain viable lungfish populations throughout the species' range in the face of increasing threats.

Summary of ~~high priority recovery~~ actions
- Identify and document priority lungfish breeding grounds and key refugia
- Catalogue artificial barriers within the distribution of *N. forsteri* and develop potential mitigation measures.
- Prepare fishway management plans for new fishways
- Develop measures to minimise lungfish stranding events
- Expand efforts to prevent the spread of noxious pests
- Review fish stocking activities within the distribution of *N. forsteri*
- Implement long-term lungfish monitoring programs
- Investigate options to increase spawning rates in and near impoundments
- Encourage and promote participation by community groups, Traditional Owners and local councils in lungfish conservation and management

Evaluation and review
Progress towards meeting the ~~plan~~ recovery objectives will be evaluated at an annual meeting of the lungfish recovery team. An independent evaluation of progress should be undertaken by an external reviewer prior to the year 2012.

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1. General iInformation

Conservation status

The Australian lungfish *Neoceratodus forsteri* (Krefft 1870) is listed as 'V~~v~~ulnerable' under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). The lungfish is also listed as a 'no take' species in Queensland under the *Fisheries Act 1994*.

International oObligations

Australian lungfish are protected from international trade under Appendix II of the Convention on International Trade in Endangered Species (CITES).

Affected iInterests

Australian lungfish occupy a highly restricted distribution coinciding with major population centres and some of Queensland's most regulated waterways. Consequently, water allocation is a major issue within the distribution of *N. forsteri*. Water resource planning in Queensland is administered by the Department of Natural Resources, and Water (DNR&W) under the *Water Act 2000*. Plans for sustainable management of water supply are detailed in Water Resource Plans (WRP) published as subordinate legislation under the *Water Act 2000*. Rules for the use and management of water are encompassed in Resource Operating Plans (ROP).

Services such as water infrastructure management and bulk water supply are provided largely by SunWater, a Queensland government owned corporation. Within the Brisbane River catchment, major water storages including Wivenhoe, Somerset and North Pine Dams are managed by SEQWater, a public company jointly owned by the Queensland Government, Brisbane City Council and various Local Councils. Further details of water resource planning in Queensland are provided in Appendix II.

Water storages in the Brisbane, North Pine, and Mary and Burnett catchments have been heavily stocked with native fish since the mid 1980's under a scheme administered by The Department of Primary Industries and Fisheries (DPI&F). Recreational fishing is now recognised as a major recreational activity in all three catchments within the distribution of *N. forsteri*. The Department of Primary Industries and Fisheries (DPI&F) manages the harvest of lungfish under the provisions of the *Fisheries Act 1994*.

Parties potentially affected by the implementation of this plan are listed in Table 1. These groups have management responsibilities or interests that may be affected by the recovery actions in this plan.

Table 1. Affected iInterests

Organisation	Type
National	
Department of Environment, ~~and~~ Water, Heritage and the Arts ~~Resources~~	Australian government
Queensland	
Department of Primary Industries and Fisheries	State Government
Department of Natural Resources and Water	State Government
Environmental Protection Agency	State Government
Queensland Treasury	State Government
Department of State Development and Innovation	State Government

Department of Premier and Cabinet	State Government
Department of Infrastructure	State Government
Department of Local Government, Planning, Sport and Recreation	State Government
SunWater	Water authority
SEQWater	Water authority
Biggenden Shire Council, Bundaberg City Council, Burnett Shire Council, Cooloola Shire Council, Eidsvold Shire Council, Gayndah Shire Council, Hervey Bay City Council, Isis Shire Council, Kilkivan Shire Council, Kingaroy Shire Council, Kolan Shire Council, Maryborough City Council, Miriam Vale Shire Council, Monto Shire Council, Mundubbera Shire Council, Murgon Shire Council, Nanango Shire Council, Perry Shire Council, Tiaro Shire Council, Wondai Shire Council, Woocoo Shire Council	Wide Bay/Burnett Local Government
Brisbane City Council, Caboolture Shire Council, Esk Shire Council, Ipswich City Council, Kilcoy Shire Council, Laidley Shire Council, Pine Rivers Shire Council, Redland Shire Council	South east Local Government [11]
SEQ Water	Local Government
Burnett Mary Regional Group	NRM Regional body
Mary River Catchment Coordinating Committee	Regional authority
SEQ Catchments	NRM Regional body
Traditional Owners	
Conservation groups e.g. Queensland Conservation Council Wide Bay Burnett Conservation Council	Community group
Freshwater Fish and Stocking Association of Queensland	Community group
Burnett Catchment Care Association	Community group
Private landholders	
Aquaculture Association Queensland	
Australia New Guinea Fishes Association	Community group
Canegrowers	
Waterski clubs	
Aquarium trade / lungfish breeders	

Consultation with indigenous people

Traditional Owners have expressed strong interest in the ongoing conservation of lungfish, citing the benefits to other species and general river health as positive outcomes that will be associated with the implementation of this plan. The Burnett/Mary Regional Group (BMRG) has facilitated the development of a Traditional Owner Working Group (TOWG), one role of which is to develop protocols for indigenous engagement in regional natural resource management issues. The TOWG have ~~discussed the lungfish recovery plan at a forum in November 2006 and~~ indicated their interest in ongoing proactive participation in the implementation of the plan. The group has formed two sub-committees, one for the Burnett and one for the Mary, who will review the plan and identify opportunities for indigenous groups to participate in lungfish conservation programs. Eve Mumewa Doreen Fesl, Elder of the Gubbi Gubbi people has stated publicly that lungfish have sacred (totemic) value. The Gubbi Gubbi did not kill or eat lungfish, but sought to ensure that it was protected from harm.

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Where possible, involvement of Traditional Owners should be encouraged in the implementation of all the recovery actions. Any management proposal with potential to affect indigenous interests (e.g. restrictions on fishing activities, declaration of protected areas) will require specific consultation via these sub-committees and other interested indigenous groups.

Benefits to other species

In the Mary River catchment, Australian lungfish coexist with two other threatened aquatic species, the Mary River cod *Maccullochella peelii mariensis* and the Mary River ~~Tortoise~~ turtle *Elusor macrurus*. Both these species are listed as 'Endangered' under the EPBC Act. The Mary River ~~Tortoise~~ turtle is also listed as 'Endangered' under the Queensland *Nature Conservation Act 1992* and Mary River cod ~~are~~ is a protected species under the *Fisheries Act 1994*.

In the Burnett River, the distribution of lungfish coincides with the recently described ~~S~~southern ~~S~~snapping t~~T~~urtle *Elseya albagula*. This species is considered to be threatened and has high conservation value as assessed under the EPA 'Back on Track Species Prioritisation Framework'.

The successful implementation of recovery actions in this plan including in-stream and riparian habitat rehabilitation, improved fish passage, improved management of water storages, provision of suitable flow regimes, maintenance of water quality, prevention of further disruptions to hydrology and management of introduced species will benefit all of these species as well as other native aquatic species.

Social and economic impacts

Lungfish are not targeted by the recreational or commercial fishing sectors. A small number of captive bred lungfish are sold legally to the aquarium trade. Recreational fishing is widespread within the distribution of lungfish and lungfish inhabit several stocked weirs and dams. Stocked impoundment fisheries provide significant social and economic benefits to regional communities within the distribution of *N. forsteri*. Restricting or preventing fish stocking within this distribution would potentially reduce the extent of these benefits. Likewise, the introduction of closed seasons or protected waters would limit access for recreational anglers and incur social and economic costs. Any amendment to fisheries legislation requires socio-economic as well as ecological impacts to be taken into consideration and will be subject to public consultation. Water skiing is also a popular recreational pastime in the lower Burnett and Mary River systems. Restricting boating activity to reduce the incidence of boat strike on lungfish would incur some social cost and would also be subject to public consultation.

Legislative provisions in the *Fisheries Act 1994* require that fish passage is provided on all new barriers to fish movement in Queensland. This legislation relates to the movement of all fish species, including lungfish. Design, construction, maintenance and ongoing monitoring costs associated with the provision of fishways increases the costs of new projects. These costs are not a direct result of the implementation of this plan.

Some specific actions such as limiting stock access in important lungfish breeding area may have short-term economic costs however this must be balanced with the long-term goal of achieving sustainable lungfish populations. Actions related to rehabilitation of riverine habitat and improved flow regimes should be undertaken in the context of responsible resource management and not specifically linked to the implementation of this plan.

2. Biological i~~I~~nformation

Species d~~D~~escription
Frequently labelled a 'living fossil', the Australian lungfish *Neoceratodus forsteri* is the only surviving lungfish species in Australia and one of only six worldwide. The species has attracted significant attention from the worldwide scientific community for more than a century. While many aspects of lungfish anatomy and physiology are now well documented, crucial parameters such as population size and structure, recruitment rates and mortality levels remain poorly understood.

Adult Australian lungfish can attain considerable size, with early authors reporting maximum dimensions in the order of 1.7m and 40kg (e.g. Krefft 1870, Spencer 1892, Longman 1928). Current evidence suggests that individuals of these proportions are extremely rare. A sample of almost 3000 lungfish collected by Brooks and Kind (2002) included individuals ranging in length from 345-1420mm, with a mean total length of 906mm.

Australian lungfish are characterised by a robust elongate body covered in overlapping layers of large, thick scales. The head is somewhat conical but flattened to produce a broad dorsal surface. The snout and head exhibit clusters of sensory pits or 'ampullary organs' used to detect weak electric fields emitted by potential prey items (Watt et. al. 1999). The eyes and mouth are small relative to the overall body size. The pectoral and pelvic fins are frequently described as 'flippers' or 'paddles' reflecting their roughly diamond shape. The dorsal fin emerges roughly half way along the length of the body and joins the caudal and anal fins to outline the broad flattened tail. There are no fin spines or other sharp surfaces on the body or gill covers. The upper body surface varies from light shades of olive-green to brown or almost black, with a series of smaller dark marks scattered in random patterns. In contrast, the underbelly is brightly coloured in various shades of orange, yellow, pink or white.

Juvenile Australian lungfish appear similar to adults, with some clear differences. Juveniles exhibit a more pronounced and slightly rounded head (Kemp 1986). Darker spots on the body are frequently clustered giving a mottled appearance and the sensory pores are more prominent on the head and snout. As noted by Kemp (1986), the dorsal fin arises further forward, close to the back of the head.

Life h~~H~~istory and e~~E~~cology
Australian lungfish complete their life cycle entirely in freshwater. The annual spawning season can commence as early as July and continue until ~~at least~~ January (Kemp 1986, Brooks 1995, Joss and Joss 1995). However, the majority of spawning occurs between August and November. Early authors noted that spawning activity occurs in shallow glides and along river margins in close proximity to macrophyte beds or partially submerged riparian vegetation (e.g. Caldwell 1885, Illidge 1893, Semon 1899). Kemp (1984) collected viable eggs from submerged macrophytes and tree roots in the Brisbane River and from root masses of the noxious weed water hyacinth in Enoggera Reservoir. Following a series of similar collections, Kemp (1993) noted that lungfish spawning is largely restricted to submerged plants that occur in shallow water, have dense growth forms and contain food items such as algae, protozoa, small molluscs and crustaceans. Subsequent studies (Brooks 1995,

Brooks and Kind 2002) have demonstrated that lungfish spawning occurs in a diverse range of aquatic, semi-aquatic and submerged terrestrial plant species. There is a strong positive correlation between macrophyte density and the intensity of lungfish spawning. Water flow is not mandatory in spawning areas but influences the depth at which eggs are deposited (Kemp 1993, Brooks 1995, Brooks and Kind 2002). The unifying features of lungfish spawning sites are that they provide protection from predators, suitable dissolved oxygen levels for developing embryos and abundant food supplies for recently hatched lungfish (Kemp 1984, Brooks 1995, Brooks and Kind 2002).

During courtship individuals separate into pairs or small groups (Grigg 1965b, Brooks 1995). There are no visible external features that reliably distinguish the sex of adult Australian lungfish. A collection of 586 gonad samples examined by Brooks and Kind (2002) returned an overall sex ratio close to 50:50. However, more than 80% of individuals > 1200mm were female. Males appear to mature at an earlier age than females. The average length of mature males collected by Brooks and Kind (2002) was 767 mm compared to 834 mm for females. Growth curves based on mark/recapture data predict that lungfish of these lengths would be 15 and 20 years old respectively. In keeping with its slow growth, *N. forsteri* is likely to be a long-lived species and may regularly reach 50+ years in the wild (Brooks and Kind 2002). No parental care is evident after the eggs have been deposited. The negatively buoyant eggs have an outer membrane that remains sticky for a short period allowing the eggs to adhere to the spawning substrate (Kemp 1986).

Fertilised lungfish eggs are hemispherical, green or brown in colour and 2-3 mm in diameter (Kemp 1982). Kemp (1994) reported that a proportion of eggs are infertile or suffer mortal physical damage. In most cases where the egg or embryo is damaged, bacterial or fungal infection follows. The rate of infection varies between locations and can exceed 30% (Kemp 1994, Brooks and Kind 2002). Because the eggs are laid in shallow water, even small fluctuations in water level can expose the eggs or inundate them to unsatisfactory levels. Kemp (1981) also demonstrated that extreme temperatures (<10^0C or >30^0C) can be lethal to cleaving eggs. The extent of predation on early lungfish life history stages is poorly understood. However, a range of potential predators including fish, birds, invertebrates and even other lungfish are believed to prey on lungfish eggs, larvae and juveniles. Recently hatched lungfish are essentially defenceless and avoid predation only by lying motionless on their side in dense cover. The hatchlings do not begin feeding for a period of 2-3 weeks during which they rely on remaining yolk supplies for nutrition.

Juvenile Australian lungfish are rarely encountered in the wild. Late stage eggs and hatchlings can be easily collected from the spawning habitat using push nets or active searches amongst the macrophytes (Kemp 1984,1986,1993, Brooks 1995). After this point, lungfish rarely appear in fisheries surveys until they are approximately 300mm in length (Brooks and Kind 2002). On the basis of available evidence it seems likely that juveniles remain in the natal habitat for long periods. Records collated by Kemp (1986) provide evidence of sporadic peaks in recruitment.

Because so few specimens have been collected from the wild, growth rates of juvenile lungfish are poorly understood. Laboratory studies such as Kemp (1981) reflect extremely slow growth in keeping with small enclosures and individual feeding. At the other extreme, commercial hatchery operators have reported that fish reared in 'green water' conditions can attain lengths of 300 mm in 12 months and 450-550 mm in 24 months (Gordon Hides pers comm.). Notwithstanding some uncertainty in relation to juvenile growth rates, *N. forsteri* is a slow-growing species across the bulk of its life span. Mark/recapture data from the Burnett River indicates that growth may as slow as 5 mm/yr after individuals reach sexual maturity (Brooks and Kind 2002). There is also good evidence of resource mediated variability in growth patterns across the range of *N. forsteri*. (DPI&F unpublished survey data).

Australian lungfish are a predominantly nocturnal species (Dean 1906, Longman 1928, Grigg 1965a, Kemp 1986, Kind 2002). Juveniles follow a similar daily rhythm, to adults, leaving daytime refuges in the late afternoon to forage during the night (Kind 2002). In flowing river sections, Australian lungfish exhibit largely localised movements around a distinct home range typically 1-1.5 km in length (Kind 2002). The home range is typically centred on a small number of regular refuges, where individuals shelter during the day. Movements outside of the home range are rare and only observed in a small proportion of the population. In contrast, lungfish in impounded waters can be highly mobile. During late autumn and winter lungfish tagged by Brooks and Kind (2002) moved out of instream impoundments on the Burnett River to seek out suitable spawning habitat in shallow pools and glides. This included sections upstream of the impoundments and in tributary streams, up to 35km from the impoundment. Following the spawning period, return movements occurred on a staggered basis with individuals often utilising small flow events to assist their downstream passage (Brooks and Kind 2002). Berghuis and Broadfoot (2004) reported that lungfish downstream of Ned Churchward Weir also made upstream movements during minor flow events, taking advantage of increased connectivity to move between pools.

The diet of *N. forsteri* changes over time reflecting a progression from larval to adult dentition (Kemp 1986). Recently hatched lungfish possess isolated conical tooth cusps, which are used to catch and hold tiny crustaceans and worms, occasionally supplemented by filamentous algae (Kemp 1977, 1995). Adults are opportunistic omnivores with individuals foraging amongst macrophytes, along the banks and on the river bed. Large quantities of plant material and silt are ingested during feeding, much of which passes through the digestive system in a relatively intact state. Food items such as small molluscs, crustaceans and worms are gleaned from the plant material and broken down by the crushing action of the mouthparts (Kemp 1986). There are also reports of lungfish ingesting the fruits and seed pods of terrestrial plants such as *Eucalyptus sp*, *Ficus sp* and prickly pears (Whitley 1927, Spencer 1892, G Green pers comm.).

Distribution

At the time of European settlement *N. forsteri* is assumed to have inhabited only the Mary and Burnett Rivers (De Vis 1885, Illidge 1893). In response to fears for their extinction, O'Connor (1897) translocated 78 adult lungfish from the Mary River at Miva to various waterways further south. These included the North Pine River, a lagoon near the Albert River, a Dam on the upper Brisbane River, Enoggera Reservoir, the Condamine River, the Coomera River and the Brisbane Botanic Gardens (O'Connor 1897). A small number of lungfish were also translocated into Blue Lake and Eighteen Mile Swamp on North Stradbroke Island (Thompson 1975, Kemp 1990).

Kemp (1995) listed the known distribution of Australian lungfish as the Burnett, Mary, North Pine, Brisbane, Logan, Albert and Coomera Catchments, as well as Enoggera and Gold Creek Reservoirs, Lake Manchester and possibly the Condamine River. The introduction of lungfish to Stradbroke Island appears to have failed and no lungfish remain in the Brisbane Botanic Gardens. Johnson (2001) questioned the inclusion of the Condamine River and Coomera Rivers, Lake Manchester and Gold Creek Reservoir stating that no recent museum records exist for these waterways. However, a small number of lungfish recently collected in the Coomera River and

Lake Manchester confirms their presence in these waterbodies (DPI&F unpublished data). Kemp (1986) argued that the Brisbane and North Pine populations are unlikely to have expanded from such a small number of translocated fish, and therefore probably form part of the historical distribution. A genetic study published by Frentiu et. al. (2001) was unable to resolve this ongoing debate.

In the Burnett River Catchment, lungfish occur from the tidal barrage at AMTD 25.9 km upstream to at least Three Moon Creek near Monto (Brooks and Kind 2002). Lungfish are present in the Boyne River to the wall of Boondooma Dam, the Auburn River to Auburn River Gorge and Barambah Creek to the Barambah Gorge (Brooks and Kind 2002). Fisheries surveys in Cania Dam have yielded lungfish that were apparently translocated from drying waterholes in the upper Burnett (Alex Hamlyn, DPI&F unpublished data). In the main river channel, the majority of lungfish occur downstream from the township of Ceratodus. Brooks and Kind (2002) reported that Catch Per Unit Effort (CPUE) was highest in river reaches 50-100km from the river mouth.

Surveys conducted by the DPI&F and other records indicate that lungfish are widely distributed throughout the Mary River and its tributaries. In the main river channel, lungfish occur from the tidal barrage upstream to the township of Conondale. Little is known about the relative abundance of *N. forsteri* between these two points. Lungfish are also common in the Tinana/Coondoo Creekk system, Obi Obi Creek, Six Mile Creek, Yabba and Little Yabba Creek, and Wide Bay Creek (Simpson 1994, Kind 2002). A small number of individuals have been observed in Borumba Dam and some other minor tributary streams (DPI&F unpublished data).

Lungfish populations in the Brisbane River between Wivenhoe Dam and the Mt Crosby Pumping Station have been subject to long-term ecological studies (e.g. Kemp 1984, 1986, 1993). Upstream of Wivenhoe Dam, lungfish inhabit Lake Wivenhoe, Lake Somerset the Brisbane River and the Stanley River. The distribution and abundance of lungfish in these areas is poorly understood.

Habitat critical to the survival of the species
Australian lungfish complete their life cycle entirely in freshwater and occur widely throughout the catchments within their distribution. Within each catchment lungfish can be found in tributary streams, the river channel, and impounded river sections. Lungfish breeding grounds, nursery areas and adult foraging areas share similar habitat features and frequently coincide or overlap. All three are unified by the presence of submerged aquatic plants (macrophytes) (Kind 2002).

Lungfish breeding predominantly occurs in shallow river margins where eggs are laid between August and December [12]amongst dense beds of submerged macrophytes. Suitable breeding habitat is often widespread during this period after low, stable winter flows have provided opportunities for aquatic plant communities to flourish. Lungfish breeding habitat is highly susceptible to flow changes and current evidence from the Burnett River suggests that breeding rarely in occurs in the deep, steep-sided pools created by dams and weirs (Brooks and Kind 2002).

Juvenile lungfish exhibit an affinity for complex instream habitat. Records of juveniles collected in the field have typically been taken from dense cover in water < 300 mm deep (e.g. Brooks and Kind 2002). Adult lungfish also congregate in patches of complex underwater habitat, most often in submerged macrophyte beds or underneath partially submerged riparian vegetation (Kemp 1995, Kind 2002). Woody debris, undercut banks, and rocks provide alternative shelter sites in heavily populated reaches (Brooks and Kind 2002, Kind 2002).

Important ~~p~~Populations

At the time of European settlement *N. forsteri* is assumed to have inhabited only the Mary and Burnett River systems (De Vis 1885, Illidge 1893). However, debate over the origin of established populations in the Brisbane and North Pine Rivers remains unresolved. Therefore, no particular river system should automatically assume elevated importance over the others. Genetic studies have thus far been unable to clearly separate specific management units identified by different genetic strains.

Barriers to lungfish movement have effectively fragmented lungfish populations within the individual catchments. Some of these populations appear to be at higher risk than others.

Grey's Waterhole, a deep permanent pool on the Burnett River (Adopted Middle Thread Distance 182.8km) has been identified as a special feature with high conservation value (Clayton et. al. 2006). Research conducted by Brooks and Kind (2002) and subsequent DPI&F monitoring indicates that the waterhole supports a resident population of very large lungfish that are likely to represent an important breeding group.

3. Threats

Identification of threats

Instream barriers [13]
Man-made barriers to lungfish movement such as dams, weirs and culverts are common throughout the distribution of *N. forsteri*. Only a small proportion of these barriers are fitted with fishways capable of passing lungfish. Australian lungfish have highly specialised spawning requirements characterised by shallow water and submerged aquatic vegetation. Barriers to fish movement prevent individuals from accessing suitable spawning habitat and restrict the potential for gene flow within catchments. Waterway infrastructure such as dams and weirs may also be causing physical damage to lungfish as they are known to move over impoundment walls during flow events (Kind 2002, Brooks and Kind 2002, Stuart and Berghuis 2002). The extent of damage to these individuals is unknown. Tidal barrages that divide fresh and saline water also lead to stranding of lungfish in estuarine waters and other isolated river sections. Marine stranding is a common occurrence in the Burnett River (Brooks and Kind 2002, Stuart and Berghuis 2002), Mary River (Berghuis 2001), Enoggera Creek (Kemp 1986) and the North Pine River (DPI&F unpublished data). Lungfish are intolerant of elevated salinity and rarely survive in this situation. There is also evidence that lungfish accumulating at the base of barriers to fish passage remain there for long periods, leading to a decline in condition (DPI&F unpublished data).

Regulated flows **(level of threat)**
Natural flow regimes within the distribution of Australian lungfish have been significantly altered by water regulation. Numerous dams and weirs have been built, particularly within the Burnett, Mary and Brisbane catchments. The construction and operation of water storage infrastructure, has altered the volume, frequency, duration and timing (seasonality) of riverine flows. Permanently flooded and fluctuating water levels make it difficult for macrophytes to establish within impounded areas. Altered flow can also significantly impact on growth and condition of macrophyte beds downstream of barriers. There is evidence [14]that flow regulation has led to increased fluctuations in water level, reduced volumes of water in river channels and therefore reduced habitat for fish, stranding of adult lungfish, exposure of breeding habitat including eggs and inundation of habitat leading to reduced habitat availability and changes in lungfish movement patterns. Present water allocations in the Burnett River have occasionally resulted in the stranding of lungfish in drying pools. It is not known whether any lungfish are physically extracted from the river or injured by pumps, however, this is known to occur in other catchments such as the Murray-Darling Basin where significant losses of native fish have been documented.

Habitat degradation/reduced water quality
Juvenile and adult lungfish rely on complex underwater habitat, predominately macrophyte beds, woody debris and undercut banks for foraging and shelter (Kemp 1986, Kind 2002, Brooks and Kind 2002). Degradation of this habitat can occur via numerous causes including livestock trampling, de-snagging, erosion, increased sedimentation and land clearing. Livestock watering is widespread throughout the distribution of lungfish. Livestock drinking in the shallows have been observed trampling lungfish eggs and breeding habitat (DPI&F unpublished notes). Reduced habitat availability is likely to expose juvenile lungfish to increased predation.

Lungfish also have highly specialised breeding requirements incorporating shallow waters with dense macrophyte cover. The construction of water storage infrastructure has resulted in the loss of breeding habitat and evidence suggests that habitat within impoundments is sub-optimal for lungfish breeding (Brooks and Kind 2002). Loss of breeding habitat has the potential to impact on recruitment levels and the capacity for lungfish to increase in numbers.

Brooks and Kind (2002) suggested that loss of spawning habitat and infrequent spawning in impounded waters may lead to overcrowding in the remaining breeding grounds. Overcrowding may lead to a number of negative impacts on lungfish including increased stress, damage to eggs, increased predation on eggs and juveniles, and increased competition between hatched juveniles.

A reduction in water quality parameters such as dissolved oxygen, temperature, pH, salinity and waterborne toxins can negatively impact on lungfish growth and egg development. Increased salinity is an issue for many inland river catchments and the Burnett and Mary Rivers have been identified in the National Action Plan for Salinity and Water Quality as one of the 21 areas most affected by salinity and water quality problems in Australia. Increased salinity could have major effects on lungfish due to their intolerance for saline conditions. The sub-lethal impacts of salinity and effects of salinity on early stages of lungfish life-history are poorly understood. ~~and increasing river salinity could therefore be devastating for lungfish populations.~~

Increased sedimentation and turbidity due to erosion and runoff can affect river productivity and thereby reduce macrophyte growth that is important breeding habitat for lungfish. Increased suspended particles can lead to smothering of eggs and substrates essential for spawning, refuge and feeding. Observational data suggests that no eggs are found on macrophytes that are covered in fine sediment (Brooks pers comm.).

Introduced species

Native fish have been stocked widely throughout the distribution of *N. forsteri* to enhance recreational fishing opportunities (Hollaway and Hamlyn 2001). In most areas, stocking occurs annually. The main stocked species include Australian bass, golden perch, saratoga, silver perch and barramundi. The impacts of stocked fish on lungfish are poorly understood. Many stocked species are highly predatory and may prey on juvenile lungfish or eggs. However, there is no conclusive evidence to demonstrate the extent of this threat.

Introduced species also increase the threat of competition for food and habitat or disturbance to spawning habitat and spread of disease and parasites. The noxious pest fish *Oreochromis mossambicus* (a species of tilapia) occurs widely in the Brisbane River Catchment. The species has also established in Boondooma Dam within the Burnett River Catchment. Tilapias are highly invasive species that disturb macrophyte beds when making their nests, which could reduce the availability of suitable lungfish breeding habitat. The noxious European carp *Cyprinus carpio* is also widespread in parts of Queensland, but has not yet established any populations within the distribution of *N. forsteri.* [15]

Noxious aquatic weeds such as water hyacinth and salvinia are already widespread within the distribution of *N. forsteri*. These floating weeds cover the water surface, leading to reduced temperature and oxygen levels in the water below, inhibiting the growth of submerged plants used for spawning by lungfish. Limited weed removal programs are currently in place.

Fishing and boating activities

Lungfish are listed as a 'no take' species under the *Fisheries Act 1994*. Despite this status, fishing competition data and other reports confirm that incidental capture of lungfish occurs in the recreational fishery. Interviews with local residents indicate that some lungfish are still taken illegally for human consumption or for use as pet food. Discarded lungfish carcasses have been found on river banks at popular angling sites (Kind 2002, DPI&F unpublished data). No data are currently available on the post-release survival rate of lungfish taken by recreational anglers. The extent of illegal take has not been quantified. The use of funnel/opera house traps and 'shrimp rakes' is also widespread within the distribution of *N. forsteri*. Both these bait collection methods disturb aquatic plants necessary for lungfish breeding.

Lungfish deaths from boat strike have been observed in the lower reaches of the Burnett and Mary Rivers (DPI&F unpublished data). This artificially increases adult mortality rates. The extent of mortality from this occurrence is poorly understood.

Areas and populations under threat
Areas most under threat are those that are likely to be impacted by the development of new water infrastructure where the loss of breeding habitat through flooding, noxious weed infestations or inappropriate downstream flow regime may result. Areas where habitat is impacted by physical damage through livestock trampling are also at threat.

All lungfish populations are subject to pressure from one or more threatening processes described previously. Table 2 below summarises the known threats and potentially threatening activities applicable to lungfish in the major catchments within their distribution.

Table 2. Current threats to lungfish populations

Location	Current threats and other potentially threatening activities
Burnett River	Barriers to passage (fish passage provided on some barriers), marine stranding, boat strike, regulated flow, altered flow, water extraction, loss of breeding habitat, fish stocking, land clearing and grazing pressure.
Mary River	Barriers to passage (fish passage provided on some barriers), boat strike, regulated flow, water extraction, expanded water infrastructure proposals, fish stocking, land clearing and grazing pressure
Brisbane River	Barriers to passage, marine stranding, regulated flow, noxious fish, fish stocking, land clearing and grazing pressure
North Pine River	Barriers to passage, marine stranding, noxious fish, fish stocking

Marine stranding is a common occurrence in the lower Burnett River following flow events (DPI&F, SunWater unpublished data). There is also little suitable lungfish breeding habitat between the Ben Anderson Barrage (AMTD 25.9 km) and Ned Churchward Weir (Brooks and Kind 2002). Lungfish apparently struck by boats have also been observed within this section (DPI&F unpublished data). On this basis, the lungfish population between AMTD 74.5 km – 25.9km has been suggested as a population under threat.

Individual barriers to lungfish passage may also be impacting lungfish populations at a local scale. Recent surveys by DPI&F have revealed that lungfish immediately downstream of Claude Wharton Weir were in poor condition relative to other samples collected along the river. Plans are now in place to provide for fish movement at this barrier, but similar examples exist elsewhere, notably in the North Pine River below North Pine Dam.

4. Recovery oObjectives

Overall oObjective
Maintain lungfish populations throughout the range of the species in the face of increasing threats.

Specific objectives
1. Reduce the impacts of artificial barriers.
2. Manage waterways to optimise breeding and recruitment opportunities
3. Limit habitat degradation and maintain or enhance water quality
4. Reduce the impacts of introduced species
5. Manage the impacts of water-based recreational activities
6. Pursue key knowledge gaps to improve lungfish management
7. Facilitate high levels of community participation and support in the implementation of the Recovery Plan

Evaluation of recovery plan
Individual agencies should regularly review progress towards recovery actions relevant to their jurisdictions. Progress towards meeting the plan objectives will be undertaken at an annual meeting of the lungfish recovery team. An independent evaluation of progress should be undertaken prior to the year 2012. This review should consider;
- evaluation of implementation – what has been done towards implementing actions
- evaluation of plan performance – is implementation of the plan achieving the objectives

5. Performance criteria and recovery actions

Objective 1. Reduce the impacts of artificial barriers.

Performance criteria 1.1. Natural lungfish movements are not compromised by new barriers or existing fishways.

Action 1.1.1. Ensure that new waterway barrier works comply with fish passage requirements contained in the *Fisheries Act 1994*.

The *Fisheries Act 1994* requires that a person must not construct or raise waterway barrier works without making adequate provision for fish movement across the barrier. In the case of permanent or long-term temporary barriers where fish passage is not adequately provided by other means, one or more fishways may be necessary. The proponent must demonstrate that the proposed fishway design will adequately provide for fish movement. Approval conditions may be applicable to
- The design or construction of a fishway
- Monitoring or operation of a fishway

***Potential contributors**:* DPI&F, Co-ordinator General, QWI, local councils, water infrastructure operators, regional NRM groups and catchment bodies

Action 1.1.2. Complete existing fishway monitoring programs.

Fishway monitoring programs have commenced or have been completed on fishways at Ben Anderson Barrage, Ned Churchwood Weir,- Paradise Dam and Claude Wharton and Kirar Weirs in the Burnett River Catchment and the Mary and Tinana Barrages in the Mary Catchment. Recommendations from these assessments related to lungfish passage should be implemented and incorporated into new and existing fishways where feasible.

***Potential contributors**:* DPI&F, Co-ordinator General, QWI, local councils, water infrastructure operators, regional NRM groups and catchment bodies.

Performance criteria 1.2. Existing barriers are described and assessed. Potential mitigation measures are documented.

Action 1.2.1. Document artificial barriers to lungfish movement and develop potential mitigation measures.

A large number of man-made barriers to fish passage are located within the distribution of *N. forsteri*. Only a small proportion of these barriers incorporate a working fishway. It is recommended that a report be compiled documenting the location and details of these barriers. The report should describe the likely impacts of each barrier and potential mitigation measures that may be applied.

Potential contributors: NRM regional bodies, consultants, water infrastructure operators, DPI&F, Co-ordinator General, NGO's, regional NRM groups and catchment bodies.

Performance criteria 1.3. The extent of injuries and mortality associated with lungfish movement over barriers and stranding events are reduced.

Action 1.3.1. Develop measures to minimise lungfish stranding events.

Lungfish are known to move over weir and dam walls and become stranded in estuarine waters and other isolated water bodies (for details refer to description of threats). Stranding can also occur as a result of water drawdown. A policy, decision-making tree and response protocols should be developed describing options for minimising the occurrence of these events, reducing injuries and mortality associated with stranding and relocating stranded lungfish. This action should incorporate development of suitable fish passage for lungfish at the Burnett River and Mary River tidal barrages.

***Potential contributors**:* DPI&F, SunWater, other water infrastructure operators, DNR&W

Action 1.3.2[16]**.** Determine injury/mortality rates associated with stranding events and movements over weir and dam walls.

Lungfish are known to move downstream over weir and dam walls. The extent of these movements and injuries resulting from them are yet to be determined. A project assessing the extent of injuries suffered by fish moving over the wall has commenced at Paradise Dam. The results of the initial study will determine the need for expansion of this research area. No studies are in place to determine the rate of marine stranding events.

Potential contributors: DPI&F, SunWater, other water infrastructure operators, universities, consultants.

Performance criteria 1.4. The operation of fishways is optimised through operation according to management plans.

Action 1.4.1. Produce detailed fishway management plans.

Individual fishway management plans should be produced detailing maintenance and operation requirements necessary to maximise the passage of lungfish. These need to include scheduled shutdown and maintenance periods. Conditions of approval for new structures should include the formulation of an appropriate fishway management plan.

Objective 2. Manage waterways to optimise breeding and recruitment opportunities

Performance criteria 2.1. Future water resource planning processes incorporate lungfish management plans.

Action 2.1.1. Ensure that water resource planning processes recognis~~z~~e appropriate management plans for lungfish and fishway operations.

A technical working group should be established to:

- Ensure that water releases maintain lungfish breeding habitat downstream of impoundments.
- Ensure adequate flows downstream of impoundments to prevent sediment build up on suitable breeding habitat

Potential contributors: DNR&W, DPI&F, SunWater, other water infrastructure operators, Co-ordinator General

Objective 3. Limit habitat degradation and maintain or enhance water quality.

Performance criteria 3.1. Key lungfish habitat identified protected and restoration commenced.

Action 3.1.1. Identify priority lungfish breeding sites and key refugia for protection, restoration and management.

The distribution of high quality lungfish habitat and potential breeding sites is well documented in some sections of the Burnett and Brisbane Catchments, but poorly understood elsewhere. Priority lungfish habitat should be described from current knowledge and assessment criteria developed to identify priority habitat areas for protection, restoration and management.

Potential contributors: DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.

Action 3.1.2. Identify and implement strategies to conserve key lungfish habitat.

On the basis of habitat areas identified in 3.1.1, relevant authorities, landholders and the community should be consulted to identify potential habitat protection options and management measures for implementation. These may include fish habitat areas, closed areas etc.

Potential contributors: DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.

Performance criteria 3.32. Damage caused by livestock in key lungfish habitat reduced.

Action 3.23.1. Minimise impacts of stock in shallow river margins.

Stock access is widespread throughout the distribution of *N. forsteri*, in both impounded and riverine areas. Options for reducing stock access should be explored in consultation with the community and landholders. These discussions should target priority breeding sites identified in 3.1.1 and concentrate on reducing stock access during the annual lungfish spawning season.

Potential contributors: DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.

Performance criteria 3.34. Impact of poor water quality on lungfish is minimised.

Action 3.34.1. Maintain water quality in water storages and during releases.

Water storages should be managed to ensure that the quality of water released does not impact on either lungfish or key habitat. Water drawn from the lower levels of impoundments is often low in oxygen, substantially cooler and in new impoundments or those that have recently filled may be acidic with high levels of hydrogen sulphide. Poor water quality during releases is known to impact on fish and habitat downstream of many impoundments throughout the world and has impacted on spawning habitat within the Burnett River.

Potential contributors: DPI&F, SunWater, QWI, other water infrastructure operators, DNR&W, Co-ordinator General

Objective 4. Reduce the impacts of introduced species.

Performance Criteria 4.1. The extent of aquatic water weed infestations are decreased in key lungfish habitats.

Action 4.1.1. Expand existing aquatic weed removal programs.

Aquatic weed infestations are widespread throughout the distribution of *N. forsteri*. Existing programs should be maintained including ongoing control programs and expanded where possible. Programs should target key habitat identified in 3.1.1.

Potential contributors: DNR&W, DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.

Performance Criteria 4.2. Public awareness of the impacts of releasing pest species particularly within the distribution of *N. forsteri* is increased.

Action 4.2.1. Develop education programs to stop the further spread of pest animals and plants within the distribution of *N. forsteri.*

A number of community education programs already exist in relation to pest species management in Queensland. These education programs should be expanded into target areas throughout the distribution of lungfish.

Potential contributors: DPI&F, DNR&W, Education Queensland, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.

Performance Criteria 4.3. Translocation of non-endemic fauna within the distribution of *N. forsteri* does not occur via water transfer.

Action 4.3.1. Control or screen water releases to prevent the translocation of non-endemic and pest species between and within catchments where feasible.

Ensure that all future pipelines and irrigation supplies are screened where feasible to reduce the risk of translocating non-endemic flora and fauna.

Potential contributors: NR&W, SunWater, other water storage operators, DPI&F, *NRM regional bodies.*

Performance Criteria 4.4. The impacts of fish stocking programs on lungfish populations are understood and managed.

Action 4.4.1. Review fish stocking activities within the distribution of Australian lungfish.

All major dams and weirs within the Brisbane, North Pine, Mary and Burnett Catchments are stocked annually with native fish to improve recreational fishing opportunities. The impacts of fish release outside of their natural ranges are currently being reviewed by DEWHA following a nomination to list this action as a threatening process under the EPBC Act. A review of fish stocking activities coinciding with the occurrence of Australian lungfish should be conducted in consultation with key stakeholders and the community.

Potential contributors: DPI&F, FFSAQ, fish stocking groups, AAQ, hatchery operators, universities, consultants, Traditional Owners

Action 4.4.2. Develop protocols to minimise the risks of future fish stocking on lungfish populations.

There is evidence that poor quality control in fish stocking activities can lead to the introduction of foreign organisms and/or diseases into new water bodies. Protocols for fish stocking will be developed on the basis of the review described in 4.4.1 in cooperation with FFSAQ, fish stocking groups and the aquaculture industry.

Potential contributors: DPI&F, FFSAQ, fish stocking groups, AAQ, hatchery operators, NRM regional bodies, Traditional Owners.

Performance Criteria 4.5. Effective legislative control reduces the incidence of accidental and illegal release of non-endemic and pest species.

Action 4.5.1. Identify additional regulatory controls to reduce the spread of non-endemic and pest species.

Further options for legislative controls to reduce the further spread and/or introduction of non-endemic and pest species should be reviewed.

Potential contributors: DPI&F, SunWater, QWI, other water infrastructure operators, DNR&W.

Objective 5. Manage the impacts of fishing and boating

Performance criteria 5.1. The impacts of recreational fishing and bait collection are understood and managed.

Action 5.1.1 Maintain the 'no take' status of lungfish under the *Fisheries Act 1994*.

Australian lungfish are listed under the *Fisheries Act 1994* a 'no take species' throughout Queensland. The Lungfish Recovery Team recommended that this status be maintained throughout the duration of the Recovery Plan. The *Fisheries Act 1994* has provisions to prevent harvest of lungfish and is supported by an established enforcement body, the Queensland Boating and Fisheries Patrol.

Potential contributors: DPI&F

Action 5.1.2. Investigate the social and economic implications of additional fisheries management measures.

Possession or 'bag' limits are only one of several management tools available to manage fish stocks. Management arrangements pertaining to Australian lungfish will be examined during a review of the *Fisheries (Freshwater) Management Plan 1999* to be completed during 2007. An example of other measures for consideration would be to close important breeding areas as identified in 3.1.1 to recreational fishing during the lungfish breeding season. Any proposed changes resulting from the review will be subject to public consultation.

Potential contributors: DPI&F, FFSAQ, fish stocking groups, recreational fishing bodies, Traditional Owners, the community (via public consultation)

Action 5.1.3. Estimate the extent of lungfish mortality from recreational angling.

The recreational catch of Australian lungfish and the associated injury / mortality rate should be estimated. Tagging lungfish released during recreational fishing competitions could provide a mechanism to assess the post-capture survival rate from data gathered by fisheries independent lungfish monitoring programs. The impact of habitat damage through bait collection in spawning areas should also be quantified.

Potential contributors: DPI&F, universities, other research providers, fish stocking groups, recreational fishing bodies, Traditional Owners

Performance criteria 5.4. The impacts of recreational skiing and boating are understood and managed.

Action 5.4.1. Determine the extent of mortality associated with recreational boating.

The injury /mortality rate associated with boat strikes is presently unknown. These impacts could be estimated by distributing questionnaires or undertaking boat ramp surveys of recreational boat users within the distribution of lungfish.

***Potential contributors**:* DPI&F, universities, other research providers, fish stocking groups, recreational fishing, skiing and boating bodies, Traditional Owners

Objective 6. Pursue key knowledge gaps to improve lungfish management

Performance criteria 6.1. Key aspects of lungfish biology are understood and incorporated into lungfish management strategies.

Action 6.1.1. Develop methods for ageing lungfish.

No reliable method exists to accurately age lungfish. A program of testing traditional and novel ageing methods should be commenced with a view to documenting the age-structure of existing lungfish populations.

***Potential contributors**:* DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers.

Action 6.1.2. Implement long-term lungfish monitoring programs.

With the exception of a 10 year monitoring program in the Burnett Catchment, no ongoing programs are in place to document and monitor the structure of lungfish populations. Ongoing monitoring programs should be implemented to document lungfish population dynamics and breeding behaviour in the Mary, Brisbane and North Pine Catchments, including Enoggera Reservoir. Results of this program should be used to develop a predictive population model for Australian lungfish (see Action 6.1.3).

***Potential contributors**:* DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers.

Action 6.1.3. Model lungfish population responses to alternate management arrangements.

Recruitment processes in Australian lungfish are poorly understood. Studies should commence to estimate the minimum area of breeding habitat required to maintain positive recruitment levels. These studies should also examine the effects of overcrowding on lungfish breeding success.

***Potential contributors**:* DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers.

Action 6.1.4. Determine the impacts of poor water quality on lungfish recruitment.

Little is known about the effects of poor water quality on the development of lungfish eggs. Laboratory studies should commence to test the tolerance of lungfish eggs and juveniles to factors such as elevated salinity, reduced oxygen concentration and pH.

***Potential contributors**:* DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers.

Action 6.1.5. Determine habitat requirements, survival and dispersal patterns of juvenile lungfish.

Knowledge of all aspects of juvenile lungfish ecology has long been identified as a major shortfall in understanding the recruitment process. In particular the effects of fluctuating water levels on habitat use, mortality and movements of juvenile lungfish will require long-term targeted research.

***Potential contributors**:* DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers.

Performance criteria 6.2. Opportunities for lungfish recruitment within impounded waters are improved.

Action 6.2.1. Commence development and testing of methods to maximise potential for lungfish spawning in or near impoundments.

There is good evidence that impoundments provide sub-optimal habitat for lungfish spawning and recruitment. Methods for improving lungfish spawning potential within and near impoundments should be initiated.

***Potential contributors**:* DNR&W, DPI&F, SunWater, other water infrastructure operators, Co-ordinator General, universites, consultants, other research providers, NRM Regional Bodies, MRCCC, Traditional Owners

Performance criteria 6.3. Key aspects of macrophyte are understood and incorporated into management strategies.

Action 6.3.1. Investigate ecology of aquatic macrophytes required for successful lungfish recruitment.

Research should be initiated to improve current understanding of the ecology of macrophytes, in particular environmental factors contributing to the establishment of suitable lungfish spawning habitat.

***Potential contributors**:* DPI&F, SunWater, other water infrastructure operators, DNR&W, Universities, Private consultants, Interstate Fisheries agencies, other research providers, NRM Regional Bodies, MRCCC.

Action 6.3.2. Investigate causes of aquatic weed proliferation.

The proliferation of aquatic weeds is known to have a large impact on both lungfish and their habitat. Environmental conditions that facilitate proliferation should be investigated.

***Potential contributors**:* DPI&F, SunWater, other water infrastructure operators, DNR&W, Universities, Private consultants, Interstate Fisheries agencies, other research providers, NRM Regional Bodies, MRCCC.

Objective 7. Facilitate high levels of community participation in the implementation of the Recovery Plan

Performance criteria 7.1. Increased levels of community understanding of lungfish conservation and involvement in implementing the lungfish recovery plan.

Action 7.1.1. Encourage and promote community groups and local councils to participate in programs promoting lungfish conservation and management.

Many community groups, NGO's and NRM Regional Bodies are already taking a proactive role in promoting lungfish conservation and management. The current scope of these activities should be reviewed to facilitate a coordinated approach and identify further opportunities in this area.

Local communities will be encouraged to participate in recovery actions including habitat restoration, monitoring and education programs. Issues to be specifically promoted would include but not be limited to;

- safe handling and release of lungfish caught by recreational anglers.
- the importance of aquatic macrophytes in shallow water for lungfish breeding
- safe bait collection practices
- risks of boating to lungfish
- best practices for stock watering to avoid damage to riverine habitat
- best practices for landholders for safe use and disposal of chemicals
- control of noxious aquatic weeds
- the importance of in-stream and riparian vegetation
- water quality monitoring and improvement
- riparian vegetation restoration

***Potential contributors**:* NRM regional bodies, MRCCC, Traditional owners, local councils, conservation groups, other NGO's, -DNR&W, DPI&F, other local authorities.

Action 7.1.2. Develop protocols for ongoing liaison with the Burnett-Mary Traditional Owner Working Group and other indigenous groups to establish proactive ongoing roles for Traditional Owners in lungfish conservation and management.

Traditional Owners have indicated strong interest in future management and preservation of Australian lungfish through the Burnett-Mary Traditional Owner Working Group (TOWG). Implementation of this plan will require ongoing consultation with the TOWG and other indigenous communities and people to facilitate their participation in recovery actions on country.

***Potential contributors**:* NRM regional bodies, MRCCC, Traditional owners, local councils, conservation groups, other NGO's, DNR&W, DPI&F, other local authorities.

Action 7.1.3 Educate landholders on measures to mitigate dryland salinity.

The Burnett and Mary Rivers have been identified in the National Action Plan for Salinity and Water Quality as one of the 21 areas most affected by salinity and water quality problems in Australia. Community education programs will be developed to highlight the benefits of planting trees, preventing run-off etc in reducing salinity.

Potential contributors: DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities.

6. Management Practices

Current management arrangements protect lungfish from recreational and commercial harvest and restrict international trade in lungfish. There are also legislative requirements in place for suitable fish passage to be provided on all new barriers to lungfish movement. The proposed actions in the current plan will build on these measures, largely by reducing unnatural mortality events and maximising access to and availability of suitable lungfish breeding habitat. The plan also identifies significant knowledge gaps, which are currently limiting the capacity for effective management of the species.

Development activities that would have a significant impact on Australian lungfish populations are those that could:

- iIncrease the natural mortality rate of adult lungfish,
- lead to a decline in the extent and/or quality of lungfish breeding habitat
- subject juvenile lungfish to increased predation and other environmental stresses.

Examples of management practices and development activities with the potential for detrimental impacts on lungfish populations include:

- Building new barriers to lungfish movement without a fishway or with ineffective fishway design
- Flow management regimes resulting in a decline in the extent and/or quality of lungfish breeding habitat
- Storage management practices that lead to a decline in water quality
- Release of poor quality water from water storages
- Water extraction methods that lead to the loss of lungfish eggs and larvae from the river
- Removal or degradation of riparian and/or instream vegetation
- Removal of instream structure such as woody debris, rocks etc
- Land management resulting in increased catchment salinity levels
- Introduction of non-endemic plant and animal species (including translocations of native species)
- Chemical runoff from agriculture leading to changes in water quality

Management practices required for conservation of lungfish include:

- Improved flow regimes/flow management leading to maintenance of suitable lungfish breeding habitat
- Advances in fishway design and operation that lead to improved upstream and downstream fish passage
- Protection of riparian and instream vegetation
- Habitat restoration programs
- Research programs addressing key knowledge gaps
- Enforcement of strong recreational angling regulations

- Education and communication campaigns
- Consideration of closed waters/protected areas
- Control programs for non-endemic aquatic plants and animals

Table 3. Summary of Actions

Objective	Performance Criteria	Actions	Potential Contributors	Priority
1. Reduce the impacts of artificial barriers.	1.1 Natural lungfish movements are not compromised by new barriers or existing fishways	1.1.1 Ensure that new waterway barrier works comply with fish passage requirements contained in the *Fisheries Act 1994*.	DPI&F, Co-ordinator General, QWI, local councils, water infrastructure operators, regional NRM groups and catchment bodies	
		1.1.2 Complete existing fishway monitoring programs	DPI&F, Co-ordinator General, QWI, local councils, water infrastructure operators, regional NRM groups and catchment bodies	
	1.2 Existing barriers are described and assessed. Potential mitigation measures are documented.	1.2.1 Document artificial barriers to lungfish movement and develop potential mitigation measures.	NRM regional bodies, consultants, water infrastructure operators, DPI&F, Co-ordinator General, NGO's, regional NRM groups and catchment bodies	
	1.3 The extent of injuries associated with movements over barriers and lungfish stranding events are reduced	1.3.1 Develop measures to minimise lungfish stranding events.	DPI&F, SunWater, other water infrastructure operators, DNR&W	
		1.3.2 Determine injury/mortality rates associated with stranding events and movements over weir and dam walls.	DPI&F, SunWater, other water infrastructure operators, universities, consultants	
	1.4 The operation of fishways is optimised through operation according to management plans	1.4.1 Produce fishway management plans	DPI&F, SunWater, other water infrastructure operators	
2. Manage	2.1 Future water	2.1.1 Ensure that water resource	DNR&W, DPI&F, SunWater, other water	

waterways to optimise breeding and recruitment opportunities	resource planning processes incorporate lungfish management plans	planning processes recognisze appropriate management plans for lungfish and fishway operation.	infrastructure operators, Co-ordinator General	
3. Limit habitat degradation and maintain or enhance water quality	3.1 Key lungfish habitat identified protected and restoration commenced.	3.1.1 Identify priority lungfish breeding sites and key refugia for protection, restoration and management.	DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities	
		3.1.2 Identify and implement strategies to conserve key lungfish habitat.	DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities	
	3.2 Stock damage to key lungfish habitat is reduced	3.2.1 Minimise impacts of stock in shallow river margins	DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities	
	3.3 Impact of poor water quality on lungfish is minimised	3.3.1 Maintain water quality during releases	DPI&F, SunWater, QWI, other water infrastructure operators, DNR&W, Co-ordinator General	
4. Reduce the impacts of introduced species	4.1 Aquatic water weed infestations are decreased in key lungfish habitats	4.1.1 Expand existing aquatic weed removal programs	DNR&W, DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities	
	4.2 Public awareness of the impacts of releasing pest species particularly within the distribution of *N. forsteri* is increased	4.2.1 Develop education programs to stop the further spread of pest animals and plants within the distribution of *N. forsteri*	DPI&F, DNR&W, Education Queensland, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities	
	4.3 Translocation of non-endemic fauna within the distribution of *N. forsteri* does not occur via water transfer	4.3.1 Control or screen water releases to prevent the translocation of non-endemic and pest species between and within catchments where feasible	NR&W, SunWater, other water storage operators, DPI&F, NRM regional bodies	

	4.4 The impacts of fish stocking programs on lungfish populations are understood and managed	4.4.1 Review fish stocking activities within the distribution of Australian lungfish	DPI&F, FFSAQ, fish stocking groups, AAQ, hatchery operators, universities, consultants, Traditional Owners	
		4.4.2 Develop protocols to minimise the risks of fish stocking on lungfish populations	DPI&F, FFSAQ, fish stocking groups, AAQ, hatchery operators, NRM regional bodies, Traditional Owners	
	4.5 Effective legislative control reduces the incidence of accidental and illegal release of pest species	4.5.1 Identify regulatory controls to reduce the spread of aquatic pests	DPI&F, SunWater, QWI, other water infrastructure operators, DNR&W	
5. Manage the impacts of water-based recreational activities	5.1 The impacts of recreational fishing and bait collection are understood and managed	5.1.1 Maintain the 'no take' status of lungfish under the *Fisheries Act 1994*.	DPI&F	
		5.1.2 Investigate the social and economic implications of additional fisheries management measures	DPI&F, FFSAQ, fish stocking groups, recreational fishing bodies, Traditional Owners, the community (via public consultation)	
		5.1.3 Estimate the extent of lungfish mortality associated with recreational angling	DPI&F, universities, other research providers, fish stocking groups, recreational fishing bodies, Traditional Owners	
	5.2 The impacts of recreational skiing and boating are understood and managed.	5.2.1 Determine the extent of mortality associated with recreational boating	DPI&F, universities, other research providers, fish stocking groups, recreational fishing, skiing and boating bodies, Traditional Owners	
6. Pursue key knowledge gaps to improve lungfish	6.1 Key aspects of lungfish biology are understood and incorporated into lungfish management	6.1.1 Develop methods for ageing lungfish	DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers	
		6.1.2 Implement long-term lungfish monitoring programs	DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other	

management	strategies		research providers	
		6.1.3. Model lungfish population responses to alternate management arrangements	DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers	
		6.1.4 Determine the impacts of poor water quality on lungfish recruitment	DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers	
		6.1.5 Determine habitat requirements, survival and dispersal patterns of juvenile lungfish	DPI&F, Universities, Private consultants, Interstate Fisheries agencies, other research providers	
	6.2 Opportunities for Lungfish recruitment within impounded waters are improved	6.2.1 Commence development and testing of methods to maximise potential for lungfish spawning in or near impoundments	DNR&W, DPI&F, SunWater, other water infrastructure operators, Co-ordinator General, universites, consultants, other research providers, NRM Regional Bodies, MRCCC, Traditional Owners	
	6.3 Key aspects of macrophyte are understood and incorporated into management strategies	6.3.1 Investigate ecology of aquatic macrophytes required for successful lungfish recruitment	DPI&F, SunWater, other water infrastructure operators, DNR&W, Universities, Private consultants, Interstate Fisheries agencies, other research providers, NRM Regional Bodies, MRCCC	
		6.3.2 Investigate causes of aquatic weed proliferation	DPI&F, SunWater, other water infrastructure operators, DNR&W, Universities, Private consultants, Interstate Fisheries agencies, other research providers, NRM Regional Bodies, MRCCC	
7. Facilitate high levels of community participation <u>in the</u>	7.1 Increased levels of community <u>understanding of lungfish conservation and involvement in</u>	7.1.1 Encourage and promote community groups and local councils to participate in programs promoting lungfish conservation and management.	NRM regional bodies, MRCCC, Traditional owners, local councils, conservation groups, other NGO's, DNR&W, DPI&F, other local authorities	
		7.1.2 Develop protocols for ongoing	NRM regional bodies, MRCCC,	

implementation of ~~and support in the implementation of~~ the Recovery Plan	implementing the ~~involvement in implementing the~~ lungfish recovery plan	liaison with the Burnett-Mary Traditional Owner Working Group and other indigenous groups to establish proactive ongoing roles for Traditional Owners in lungfish conservation and management	Traditional owners, local councils, conservation groups, other NGO's, DNR&W, DPI&F, other local authorities	
		7.1.3 Educate landholders on measures to mitigate dryland salinity	DPI&F, NRM regional bodies, MRCCC, Traditional owners, local councils, other local authorities	

7. Costs of Recovery

Table 4. Estimated costs of recovery ($000/yr)

Action	Description	Comment	Yr 1	Yr 2	Yr 3	Yr 4	Yr 5	Total
1.1.1	Ensure new water infrastructure proposals comply with fish passage requirements of the *Fisheries Act 1994*	Action currently delivered by DPI&F. No additional costs required.						
1.1.2	Complete existing fishway monitoring programs on the Burnett River	Funded and in progress. Due for completion in 2010						
1.2.1	Document artificial barriers to lungfish movement and develop potential mitigation measures	Funded for Burnett/Mary catchments by BMRG Aquatic Biopass Project			75	50		
1.3.1	Develop measures to minimise lungfish stranding events, including installation of lungfish passage at tidal barrages		15	220	50	220	50	
1.3.2	Determine injury rates associated with marine stranding and movements over dam walls	Preliminary study in progress. Funded under Burnett Program of Actions (II)						
1.4.1	Produce fishway management plans for new fishways							
2.1.1	Ensure that WRP processes recognise management plans for fishways and lungfish							
3.1.1	Identify priority lungfish breeding sites and key refugia in the Brisbane, Mary and Burnett Catchments		80	80	80			
3.1.2	Develop and implement strategies to conserve key lungfish habitat		25	30	30			
3.2.1	Minimise impacts of stock in shallow river margins							
3.3.1	Maintain water quality in water storages and during releasesd ~~from water storages~~							
4.1.1	Expand existing aquatic weed removal programs		250	250	200	200	175	
4.2.1	Develop education programs to minimise the spread of noxious and non-endemic species within the distribution of *N. forsteri*		85	85	65	65	65	
4.3.1	Screen water releases where feasible to prevent the spread of noxious and non-endemic species							
4.4.1	Review fish stocking activities within the distribution of *N. forsteri*		15	10				
4.4.2	Develop ~~measures~~ protocols to minimise the risks of			15				

	~~future~~associated with fish stocking ~~within the distribution of~~ ~~*N. forsteri*~~ on lungfish populations							
4.5.1	Identify ~~additional~~ regulatory controls to ~~stop~~ reduce the spread of non-endemic and pest species~~aquatic pests~~			10				
5.1.1	Maintain the 'no take' status of lungfish under the *Fisheries Act 1994*							
5.1.2	Investigate the ~~Assess~~ social and economic implications of additional fisheries management measures			5				
5.1.3	Estimate the extent of lungfish mortality associated with recreational angling		15	10	10			
5.2.1	Determine the extent of mortality associated with recreational boating			10	10	5		
6.1.1	Develop methods for ageing lungfish		100	100	100	100	100	
6.1.2	Implement long-term lungfish monitoring programs		200	200	200	200	200	1000
6.1.3	Model lungfish population responses to alternate management arrangements		100	50	50			
6.1.4	Determine the impacts of poor water quality on lungfish recruitment		100	100	100			
6.1.5	Determine habitat requirements, survival and dispersal patterns of juvenile lungfish		100	100	100	100		
6.2.1	Commence development and testing of methods to maximise potential for lungfish spawning in or near impoundments		175	150	150	100	100	
6.3.1	Investigate ecology of aquatic macrophytes required for successful lungfish recruitment		100	100	75			
6.3.2	Investigate the causes of aquatic weed proliferation		100	100	75			
7.1.1	Encourage and promote community groups and local councils to participate in programs promoting lungfish conservation and management		125	100	100	100	100	
7.1.2	Develop protocols for ongoing liaison with the Burnett-Mary Traditional Owner Working Group and other indigenous groups to establish proactive ongoing roles for Traditional Owners in lungfish conservation and management		75	75	50	50	50	
7.1.3	Educate landholders on measures to mitigate dryland salinity		75	75	50	50	50	

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Appendix 4 – Ministerial Advice Preceding listing of Australian Lungfish *Neoceradodus forssteri* as Vulnerable under the EPBC Act 6th August 2003

A copy of the criteria used to list the Australian Lungfish under the EPBC Act as well as the listing advice can also be obtained from the Department of the Environment and Heritage's website at *http://www.ea.gov.au/biodiversity/threatened/nominations/index.html*.

Neoceratodus forsteri (Queensland Lungfish, Australian Lungfish)

Advice to the Minister for the Environment and Heritage from the Threatened Species Scientific Committee (TSSC) on Amendments to the list of Threatened Species under the Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

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1. Scientific name, common name (where appropriate), major taxon group

Neoceratodus forsteri (Queensland Lungfish, Australian Lungfish).

2. National Context

The Australian Lungfish is restricted to the river systems of south-eastern Queensland.

The Australian Lungfish occurs naturally in the Burnett, Mary, and possibly Brisbane and North Pine, Rivers. In 1897, 78 adult fish were translocated from the Mary River, at Miva, to various waterways further south: in the North Pine (8), Condamine (21) and Coomera (16) Rivers; in a lagoon near the Albert River (5); in a dam near Cressbrook on the upper Brisbane River (8); in the Enoggera Reservoir (18); and in the Brisbane Botanic Gardens (2). Translocations were undertaken because the natural historians of the time could not locate juvenile Australian Lungfish, and the general consensus was that the Australian Lungfish were becoming extinct within their natural distribution. There have not been any recent surveys to ascertain whether the introductions into the Coomera and Condamine Rivers were successful. Recent sampling at several sites on the Albert River did not record this species.

The species is not listed under the EPBC Act. It was listed as 'non-threatened' in the Action Plan for Freshwater Fishes (1993). A nomination in 1997, under the *Endangered Species Protection Act 1992*, to have the species listed as endangered was unsuccessful. The nomination was assessed by the Endangered Species Scientific Subcommittee as not meeting the relevant criteria as "its numbers have not been reduced to such a critical level, and its habitats so drastically reduced, that it is in immediate danger of extinction."

In Queensland, it is not listed as threatened under the Queensland *Nature Conservation Act 1992*. The taking of Australian Lungfish has been prohibited since they were declared a protected species under the Queensland *Fish and Oyster Act 1914*. It is currently protected from fishing, and collection requires a permit, in Queensland under the *Fisheries Act 1994*.

3. How judged by TSSC in relation to the EPBC Act criteria.

TSSC judges the species to be eligible for listing as vulnerable under the EPBC Act. The justification against the criteria is as follows:

Criterion 1 - Decline in numbers

The core natural distribution of the Australian Lungfish is the main river channels of the Burnett and Mary Rivers. Data indicates that 26% of this core distribution is presently impounded by weirs and dams, with a further 13% likely to be impounded if proposed water infrastructure developments for the Burnett River catchment go ahead. There are also water infrastructure developments planned for the Mary River. (The figures do not consider distribution of impoundments within the tributaries of the Burnett and Mary Rivers, where habitat is marginal for the Australian Lungfish, nor the translocated populations).

Currently, there is debate as to whether the Australian Lungfish in the Brisbane and North Pine Rivers are natural or translocated populations. At another translocated site, the Enoggera Reservoir, with the removal of plants which are required for successful breeding, the Australian Lungfish are likely to be no longer breeding. The conservation value of the successfully translocated populations of the Australian Lungfish is not clear: in areas where it occurs naturally, the species has an inherently low genetic variation, and, as only limited numbers of individuals from one natural site were used to found the translocated populations, the translocated populations are likely to have particularly limited genetic variation. Therefore, only the natural populations are likely to possess the full evolutionary potential of the species.

Australian Lungfish are slow-growing, with age of first breeding estimated to be 15 years for males and 20 years for females. Adults have a high survival rate and are long-lived, with a claim that they possibly live to 60-100 years of age. Large adults have been found to be relatively common in various localities at the present time, and may continue to be so for many years. There is no data on decline in adult numbers, and it is suspected that recruitment into the adult population is inherently low. Juveniles are harder to observe and locate than adults, and little is known of their ecology.

Current research shows that there is little evidence of juveniles or young fish recruiting into the Burnett River populations, particularly in impoundments: Data on population structure has been collected by the Queensland Department of Primary Industries over the last 6 years in the Burnett River. By 2000-2001, 2770 Australian Lungfish had been sampled, and the length-frequency analysis shows levels of recruitment to the adult population for at least the last five years that are lower than had been previously experienced. There is also an earlier distinct break in recruitment in the adult population based on length analysis, indicating a long period in the recent past where few fish were successfully recruited into the adult population. It is not clear if the current period of low recruitment is part of natural cycle or the result of past threats beginning to impact on the adult population. Some experts are expressing concern that an unsustainably low, or total absence of, recruitment of juveniles to the adult population could easily be overlooked for many years with disastrous consequences for long-term survival of the species.

Studies have shown that there has been a marked decline in the quality and extent of breeding habitat of the Australian Lungfish because of impoundments. While impoundments provide feeding habitat for the species, conditions suitable for successful spawning rarely occur within them, as the species has highly specific requirements for spawning. Generally, spawning habitat is characterised by relatively shallow water and dense macrophyte (aquatic plants) coverage. Impoundments tend to be steep-sided with deep water and fluctuating water-levels, conditions that are not suitable for the dense growth of macrophytes. In addition, impoundments do not provide suitable nursery habitat for the species as the young also require a cover of macrophytes.

There are also claims that the Australian Lungfish is potentially threatened by exotic and translocated native fishes (in particular the exotic Tilapia *Oreochromis mossambica*) that have been introduced to the river systems, and that are likely to be predating on eggs and young and competing with adults for breeding habitat. These introduced fishes may also contribute to future declines in the number of breeding adults.

In summary, there have been losses or reduction in quality of the breeding and nursery habitat of the Australian Lungfish of 26% within its core habitat, the main channels of the Burnett and Mary Rivers. At a result of this, it has been suggested that the adult breeding population may undergo a substantial decline over the next three generations. In addition to this, the breeding and nursery habitat will continue to be threatened by further water infrastructure development in these highly populated areas. The impact of introduced fishes into the river systems is not known, but it is suspected that it will result in a further population reduction. On the basis of the losses and threats, there is sufficient evidence to suspect that the adult breeding population will undergo a substantial decline over the next three generations.

Therefore, the species is **eligible** for listing as **vulnerable** under this criterion.

Criterion 2 - Geographic distribution

The Australian Lungfish is restricted to south-eastern Queensland, with its natural distribution being the Mary, Burnett and, possibly, Brisbane and North Pine Rivers. It was translocated to a number of sites in the late 1800s.

There have not been any recent surveys to ascertain whether the introductions into the Coomera and Condamine Rivers were successful. Recent sampling at several sites on the Albert River did not record this species Although the Australian Lungfish has been recorded as breeding at Enoggera Reservoir in the past, recent records suggest that the species is no longer breeding at this location.

One viewpoint is that the current natural distribution of the Australian Lungfish is the Mary and Burnett River systems with translocated populations surviving in the Brisbane and North Pine Rivers and Enoggera Reservoir. The corresponding area of occupancy is estimated at less than 2000 km^2. The exact number of locations where it occurs within this distribution is uncertain, but it is less than ten. It can be considered to occur at five locations, where each river system represents a location; or at nine locations, three being on the Burnett River, where each river system represents a location but, where barriers to movement exist, each section of the system is considered to be a location. It has been suggested that the very low genetic variation of the three translocated locations may be of little conservation value to the future of this species (see comments in Criterion 1). At Enoggera Reservoir, with the removal of plants which are required for successful breeding, the Australian Lungfish are likely to be no longer breeding.

A continued decline in quality and extent of spawning and nursery habitat is likely as further water infrastructure development occurs in this highly populated area of Queensland. In the past, there has been a marked decline in the area of suitable breeding habitat available to the species. Within the stronghold of its natural distribution, the main channels of the Burnett and Mary Rivers, the data indicates that, as a result of impoundments, there has been a loss or reduction in the quality of spawning and nursery habitat of 26%, with a further 13%, and likely more, to be lost if proposed water impoundments go ahead.

Therefore, the species is **eligible** for listing as **vulnerable** under this criterion.

Criterion 3 - Population size and decline in numbers or distribution

The total population number of Australian Lungfish is unknown at this time though is likely to be more than 10 000 mature individuals. There is no data on decline in adult numbers,

Therefore, the species is **not eligible** for listing under this criterion.

Criterion 4 - Population size

The total population number of the Australian Lungfish is unknown at this time, though it is larger than 1,000 mature individuals.

Therefore, the species **not eligible** for listing under this criterion.

Criterion 5 - Probability of extinction in the wild

Quantitative data for the Australian Lungfish is not available against this criterion.

Therefore, the species is **not eligible** for listing under this criterion.

4. Conclusion

The natural distribution of the Australian Lungfish appears to be restricted to the Burnett, Mary, and possibly Brisbane and North Pine, River systems of south-eastern Queensland. The Australian Lungfish was translocated to a number of sites in the late 1800s.

There have not been any recent surveys to ascertain whether the introductions into the Coomera and Condamine Rivers were successful. Recent sampling at several sites on the Albert River did not record this species. The species is present at the Brisbane and North Pine Rivers and at the Enoggera Reservoir. Although the Australian Lungfish has been recorded as breeding at Enoggera Reservoir in the past, recent records suggest that the species is no longer breeding at this location.

The conservation value of translocated populations is uncertain, both as self-replacing populations and on the basis of limited genetic diversity. Currently, it occurs at less than ten locations with an estimated area of occupancy of less than 2000 km^2.

The river systems where the Australian Lungfish occurs are subject to much disturbance, particularly by the construction of dams and weirs. Impoundments presently inundate about 26% of the river systems that are considered to be its core natural distribution, with a further 13%, and possibly more, under threat from the proposed construction. Data indicates that this represents a substantial loss of suitable breeding and nursery habitat. The species is also potentially threatened by introduced fishes. As Australian Lungfish are slow-growing and long-lived, fluctuations in the adult population are expected to occur slowly. As a result of past changes to its core habitat, it is suspected that the recruitment to the adult breeding population has been, and is still, unsustainably low, and that the species is likely to undergo a substantial population reduction over the next three generations.

Although there is some uncertainty in data pertaining to the Australian Lungfish, it is rarely possible to have access to data on native species that is complete. It is, however, common practice to use both anecdotal and historical data to assist in the determination of long-term population trends. Limitations are acknowledged, and the data has been used cautiously.

The species is eligible for listing as vulnerable under criteria 1 and 2.

5. Recommendation

TSSC recommends that the list referred to in section 178 of the EPBC Act be amended by **including** in the list in the **vulnerable** category:

***Neoceratodus forsteri* (Australian Lungfish, Queensland Lungfish)**

Appendix 5 –Nationally Threatened Species and Ecological Communities Information Sheet - Australian Lungfish (*Neoceratodus forsteri*) - Department of the Environment and Heritage, August 2003

http://www.environment.gov.au/biodiversity/threatened/publications/pubs/lungfish.pdf

(2 pages)






AUSTRALIAN LUNGFISH (*Neoceratodus forsteri*)

The Australian Lungfish has been listed as a vulnerable species under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (the EPBC Act).

What is the Australian Lungfish?

The Australian Lungfish is a long, heavy bodied freshwater fish with five pairs of gills and fins which resemble flippers. They are called lungfish from their ability to breath air via a 'lung'. Adult lungfish can grow to more than 1.5 metres and weight up to 40 kilograms.

The Australian Lungfish is the sole Australian survivor of a family of fishes that have been around since the dinosaurs. Fossil remains of this species have been found in New South Wales dating from more than 100 million years ago.

Where does the Australian Lungfish live?

The Australian Lungfish is restricted to south-eastern Queensland, with its natural distribution being the Mary, Burnett and possibly Brisbane and North Pine Rivers. Lungfish have also been introduced to other rivers and dams including the Condamine and Coomera Rivers and the Enoggera Reservoir.

Why is the Australian Lungfish threatened?

Evidence suggests that in recent years only small numbers of young lungfish are growing-up into adult fish. In addition, changes to the quality and extent of breeding habitat appear to be reducing the likelihood of successful spawning.

Two of the key problems affecting the lungfish are the flooding of suitable spawning sites and physical barriers that block the movement of adult lungfish to the remaining breeding sites.

While the waters of dams and weirs provide feeding habitat for the species, they rarely provide the shallow water and dense cover of water plants like ribbonweed which the lungfish need for successful spawning. In addition, dams and weirs do not provide suitable nursery habitat for the species as the young also require a cover of water plants.

Because of the long life span of the lungfish (with some research suggesting that the fish may live up to 100 years) the lack of breeding success may not become evident in the adult population for many years.

It is estimated that there has been a 26 per cent loss or reduction in the amount of breeding and nursery habitat for the Australian Lungfish (the main channels of the Burnett and Mary Rivers). As a result, the adult breeding population is likely to undergo a substantial decline within the next three generations.

In addition, exotic and translocated native fishes, such as the exotic Tilapia (*Oreochromis mossambica*) are believed to prey on lungfish eggs and young and compete with adults for breeding habitat.

How is the Australian Lungfish protected?

In addition to the listing of the Australian Lungfish as a nationally threatened species under the EPBC Act, the species is protected from fishing under the Queensland *Fisheries Act 1994*. Under the Queensland Act, a permit is required to collect this species for eligible purposes such as educational display, aquaculture and research.

The Australian Lungfish is also listed on Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) and strict conditions apply to its export under the EPBC Act.

Environment **P**rotection and **B**iodiversity **C**onservation Act

Nationally threatened species and ecological communities

What are the implications of listing the Australian Lungfish as a nationally threatened species under the EPBC Act?

Listing of the Australian Lungfish as a nationally threatened species under the EPBC Act means that any action that is likely to have a significant impact on the species will need to be referred to the Commonwealth Environment Minister for a decision as to whether assessment and approval is required.

It is an offence for any person to undertake an action that is likely to have a significant impact on a matter of national environmental significance without approval.

Guidelines have been produced to assist people to identify whether their activity is likely to have a significant impact on a nationally listed species. These guidelines "EPBC Act Administrative Guidelines on Significance July 2000" can be obtained from the Environment Australia website or by contacting Environment Australia.

Examples of activities that are likely to trigger a significant impact referral under the EPBC Act include:

- activities that flood, degrade or involve significant disturbance to Lungfish spawning or nursery habitat areas;
- activities that disrupt the breeding cycle of important populations of Lungfish; and
- activities that restrict access of adult Lungfish to suitable spawning sites.

How does this decision affect current activities?

Actions do not require approval under Part 9 of the EPBC Act if:

- the action required specific authorisations such as a permit or approval under a Commonwealth, State or Territory law; and
- immediately before 16 July 2000, all necessary environmental authorisations were obtained; and
- the action did or does not require specific authorisations; and
- the action is a lawful continuation of a use of land, sea or seabed; and
- the action was occurring immediately before 16 July 2000; and
- the use has not been enlarged, expanded or intensified.

Please note that an EPBC Act approval does not remove the need to obtain the necessary State or Territory government authorisations or other Commonwealth authorisations, including permits under the EPBC Act, for an activity.

Where can I get further information?

Administrative Guidelines regarding what constitutes a 'significant impact', referral forms and a guide for submitting a referral can be obtained from the Environment Australia website at **http://www.ea.gov.au/epbc** or by contacting Environment Australia's Community Information Unit on **1800 803 772**.

A copy of the criteria used to list the Australian Lungfish under the EPBC Act as well as the listing advice can also be obtained from the Environment Australia website at **http://www.ea.gov.au/biodiversity/threatened/nominations/index.html**.

Further information on the Australian Lungfish may also be obtained from the following organisations/websites:

- The Queensland Department of Primary Industries;
- The Queensland Fisheries Service;
- The Australian Museum; and
- The Queensland Museum.

Photography credits

Front (top to bottom):
Rudie Kuiter | Auscape |
Gordon Hides | Kathie Atkinson |
Rudie Kuiter | Auscape

Reverse (top to bottom):
Rudie Kuiter | Kathie Atkinson |
Gordon Hides | Auscape |
Rudie Kuiter

Appendix 6 –Flows Analysis Paradise Dam Reach

Spells analysis of the predicted long-term potential for operation of the fishway devices at Paradise Dam **S. Burgess. 13/06/2009**

A 'spells' analysis is a standard technique used in ecological studies of time-series based hydrological data. The technique used here is described in the standard text: **Stream Hydrology: An Introduction for Ecologists, 2nd Edition,** by Gordon et al., 2004. The analyses presented here were produced using the AQUAPAK software package described in that text, used under license to Sinclair Knight Mertz, the firm which produced the Environmental Impact Statement for the Paradise Dam.

The data used for the analysis is the IQQM (integrated Quantity and Quality Model) simulated data set used to formulate the operational rules for the Paradise Dam as described in the Resource Operations Plan for the Burnett Basin, June 2008. These data were obtained under license from the Queensland Department of Natural Resources and Water (now DERM). The operational levels and required flows for the fishway devices are as published in the June 2008 Resource Operations Plan for the Burnett Basin. Because there are no long term directly measured streamflow data for the Paradise damsite, these simulated data are the best available long-term data for that location, and are the data upon which the current licensed design and operation of the dam and its fishways are based.

These data represent simulated daily water levels and flows as if the weather sequence was the same as that experienced from 1890 to 1997, for a hypothetical 'no-development' scenario (the 'natural' state) and the infrastructure and water use scenario (including Paradise dam) as currently planned for in the Resource Operations Plan.

Paradise Dam IQQM simulation._ Risks to fishway operation.

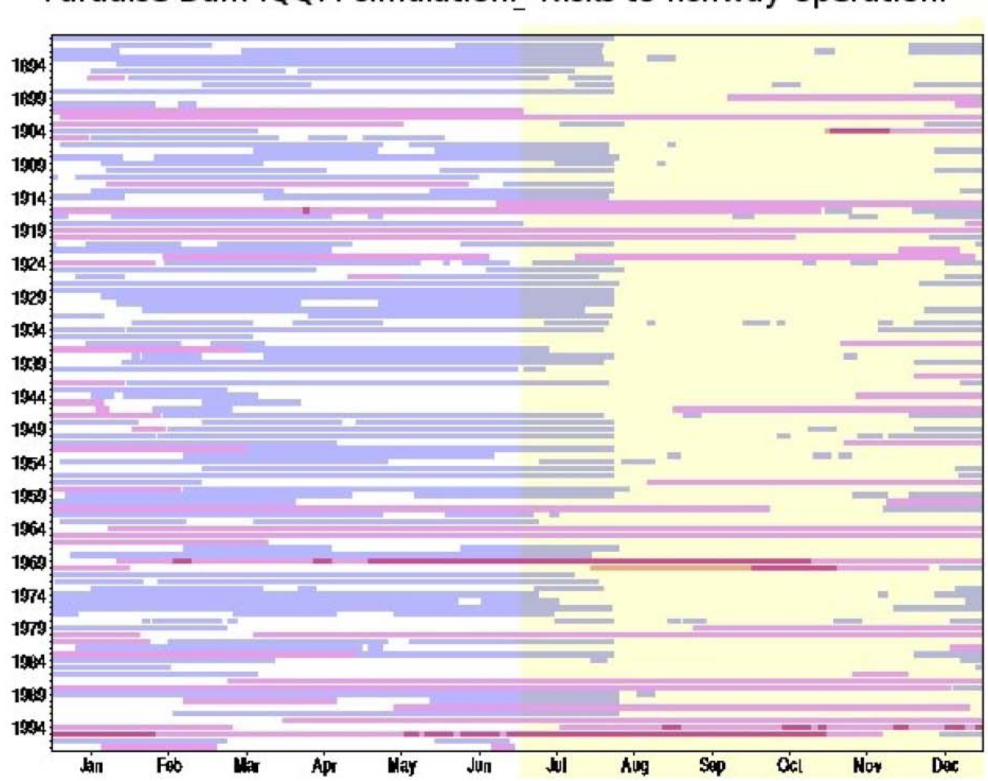

Figure 1. Spells during which the IQQM data from the Burnett Basin Water Resource Plan predict aspects of the operational range of the fishways at Paradise Dam

- Pale blue areas represent spells during which the predicted water level in the dam is above the spillway level of 67.6 m AHD, thus presenting a risk of lungfish being carried over the spillway.
- Pink areas represent spells during which the predicted water level in the dam is less than 62m AHD, thus preventing entry to the downstream fishlock.
- Brown areas represent spells when predicted releases from the dam are less than 14mL/day – during which the fishways are not expected to be operated.
- Red areas represent spells during which the two preceding conditions occur concurrently.
- Pale yellow area represents times during which lungfish would normally be moving to or from spawning sites on the Burnett River. (Brookes and Kind, 2002)

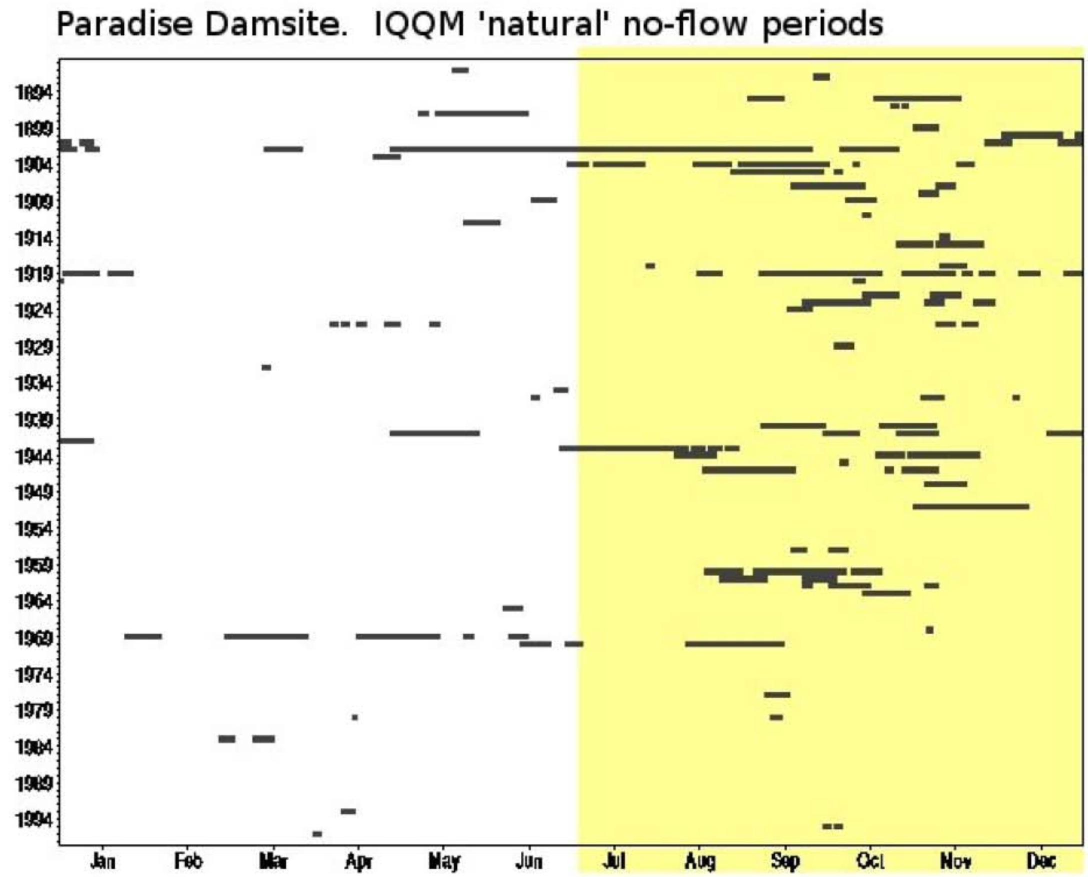

Figure 2. Spells during which the IQQM data from the Burnett Basin Water Resource Plan predicts cease-to-flow at the Paradise Dam site for the pre-development ('natural flows') scenario.

- Black areas represent cease-to-flow events, during which connectivity between pools in the the vicinity of the dam wall site would be broken.
- Yellow area represents the times during which lungfish would normally be moving to or from spawning sites on the Burnett River. (Brookes and Kind, 2002)

Notes on the comparison between the 'developed' and 'natural' scenario

- There are no occasions in the 'natural' scenario where connectivity is lost for a complete spawning movement period (July to December), and only two where connectivity is not maintained for most of the spawning movement period.
- There are 9 years in the 'developed' scenario where downstream connectivity is lost for a complete spawning movement period, and 13 years where connectivity is lost for most of the spawning movement period.
- The longest spell of no downstream connectivity in the 'natural' scenario is 150 days, while the longest continuous spell of no downstream connectivity in the 'developed' scenario is 793 days.
- The most obvious feature of the analysis is that there are very significant periods of time during which lungfish are at risk of overtopping the spillway structure in the developed scenario, a risk which does not occur at all in the 'natural' scenario.
- These analyses only investigate the stated operational range of the fishway devices. They do not investigate any risks posed to lungfish by the operation of fishway devices, nor do they relate to the efficacy of the devices while they are within their stated operational range.

A spells analysis of the water levels and daily releases reported from the Paradise Dam **S. Burgess. 14/06/2009**

A 'spells' analysis (as described previously) was conducted on the daily data published by SunWater for the water height and volumes of water released from Paradise Dam. These two parameters govern the operational rules for the Paradise Dam fishway as described in the Resource Operations Licence for the Bundaberg Water Supply Scheme. These rules are related in turn to the conditions currently required for the upstream and downstream fish transfer devices to operate successfully.

In addition to examining the water levels and water release rates needed for the fishway to operate, this analysis also investigated periods of time during which no water at all was released from the dam. This information relates to connectivity in the river reaches downstream of the dam as well as connectivity at the dam site itself.

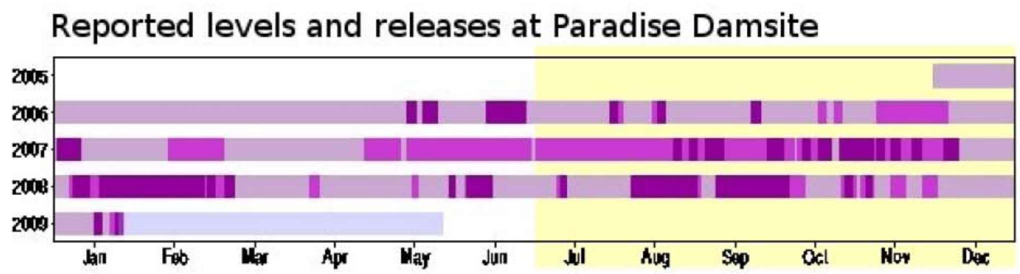

Figure 1. Spells analysis of water level and daily flow release data reported for Paradise Dam on SunwaterOnline

Conditions met for operation of upstream and downstream fishway (water level between 62 and 67.6 m AHD, daily water release above 14 Ml.)

Water level below 62 m AHD – operation of downstream fishlock not possible, operation of 'fishway' not required by operations licence.

Water level below 62 m AHD and daily release less than 14 Ml. (Water release required for 'fishway' operation)

Water level below 62 m AHD and a 'zero' water release reported.

Period of time when lungfish movement to and from spawning sites normally occurs in the Burnett River (Brookes and Kind 2002)

Notes/observations:

- Data analyzed are those reported by Sunwater Online for the operation of Paradise Dam from 1/12/2005 (the start of the record for reported water level and release data) until 28/05/2009. This represents the longest data record available for both water level and daily releases at the time of analysis
- Water levels were below the elevation of the entrance to the downstream fishway for 90.35% of the record analyzed. This included for the entire duration of 3 consecutive spawning movement seasons in 2006, 2007 and 2008.
- There are 46 spells of no daily water release from the dam in the 3.5 year data record analyzed, collectively representing 18.37% of the record. The longest of these spells was 37 days. Some no-flow spells were interrupted by a single daily record of flow which broke what would have been a longer spell into two shorter spells. This frequency of no flow events equates to a frequency of about 1319 events per century
- The long-term IQQM simulations used in the Burnett Basin water resource plan to represent the 'natural' or pre-development state of the river at this location predict 169 no-flow spells (157 events per century), collectively accounting for 3.95% of the total 107.5 year simulation period. However these predictions encompass one extreme continuous no-flow event of 150 days duration, and three others longer than 37 days duration. Therefore, although the reported proportion of time for which no water was released and the frequency of these no-flow events has been significantly greater than the long term average for the 'natural' state of flow, the duration of the individual no-flow events recorded are within the range predicted for the 'natural' state of flow.
- To properly investigate how the periods of time during which no water releases were made from the dam compare to the estimated 'natural' no-flow regime for the river at that location, more detailed analysis is required. Such an analysis needs to consider the climatic conditions prevailing during the dam's operation in context with the long-term climate record.

A spells analysis comparing no-flow events reported from the Mt Lawless stream gauging station with periods of no water release from Paradise Dam

S. Burgess. 15/06/2009

A 'spells' analysis (as described previously) was conducted on the daily data published by SunWater for periods of time during which no releases were made from Paradise Dam. These periods were compared with the pattern of no-flow events recorded by the Department of Natural Resources and Water for the same period of time at the Mt Lawless stream gauging station. The Mt. Lawless station is the closest currently active station upstream of the impounded area of the Paradise Dam, in a free-flowing (non-impounded) section of the Burnett River.

Comparison of recorded 'no-flow' conditions at the Mt Lawless stream gauging station with the 'no-release' conditions at Paradise Dam

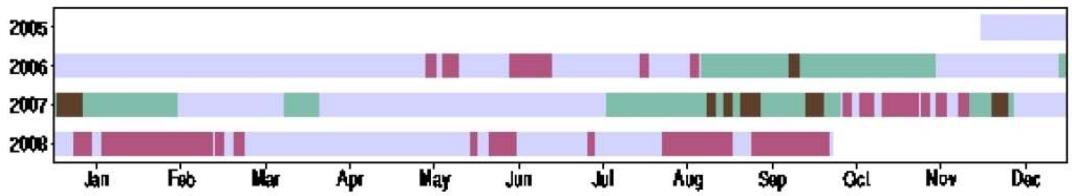

Figure 1. Spells analysis comparing periods of no-release from Paradise Dam as reported on SunwaterOnline with recorded no-flow events at the Mt Lawless gauging station.

- Common data record for both Mt Lawless and Paradise Dam
- No water released from Paradise Dam
- Zero flow recorded at Mt Lawless gauge.
- Zero flow at Mt Lawless and zero release from Paradise Dam

Notes/observations:

- The Mt. Lawless gauging station is approximately 52 km upstream from the Paradise Dam wall and in the natural state would generally experience lower flows than the reaches of the river further downstream.
- Licenced, validated data from the Mt Lawless station were sourced from the Department of Natural Resources and Water on 19/11/2008 and are used subject to the standard departmental disclaimer that applies to the use of such data.
- Analysis of the entire data record available shows that the period of time presented in this graph represents the most extreme period of no-flow events recorded at the Mt Lawless station since it commenced operation in 1975.
- The pattern and duration of no-release events from Paradise Dam during 2008 is very different to the no-flow pattern at the Mt Lawless gauge. In that year there were no cease-to-flow events at all recorded at Mt Lawless, yet there were very significant spells during which there was no water released at all from Paradise Dam.

Appendix 7 – Calculation of percentage operation per month of upstream and downstream fishways

The following data was obtained by staff of the Environmental Defenders Office from documents disclosed by Burnett Water Pty Ltd.

Percentage of operation per month of upstream fishway (Nov 2005 – April 2009)

Month	Hrs in Month	Hrs of Op	% Operation	Principal Source Document
Nov-05	720	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Dec-05	744	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Jan-06	744	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Feb-06	672	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Mar-06	744	48	**6.5 %**	BUR.008.004.2416 & BUR.009.003.0102
Apr-06	720	36	**5.0 %**	BUR.008.004.2416 & BUR.009.003.0102
May-06	744	34	**4.6 %**	BUR.008.004.2416 & BUR.009.003.0102
Jun-06	720	19	**2.6 %**	BUR.008.004.2416 & BUR.009.003.0102
Jul-06	744	86	**11.6 %**	BUR.008.004.2416 & BUR.009.003.0102
Aug-06	744	4	**0.5 %**	BUR.008.004.2416 & BUR.009.003.0102
Sep-06	720	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Oct-06	744	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Nov-06	720	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Dec-06	744	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Jan-07	744	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Feb-07	672	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102
Mar-07	744	0	**0.0 %**	BUR.008.004.2416 & BUR.009.003.0102

Apr-07	720	0	**0.0 %**	BUR.008.004.0199 & BUR.009.003.0102
May-07	744	0	**0.0 %**	BUR.008.004.0199 & BUR.009.003.0102
Jun-07	720	28	**3.9 %**	BUR.008.004.0199
Jul-07	744	0	**0.0 %**	BUR.008.004.0199
Aug-07	744	26	**3.5 %**	BUR.008.004.0199
Sep-07	720	0	**0.0 %**	BUR.008.004.0199
Oct-07	744	110	**14.8 %**	BUR.008.004.0199
Nov-07	720	137.5	**19.1 %**	BUR.008.004.0199
Dec-07	744	115	**15.5 %**	BUR.008.004.0199
Jan-08	744	95	**12.8 %**	BUR.008.004.0199
Feb-08	696	48	**6.9 %**	BUR.015.001.0285
Mar-08	744	616.5	**82.9 %**	BUR.015.001.0285
Apr-08	720	715.5	**99.4 %**	BUR.015.001.0285
May-08	744	532	**71.5 %**	BUR.015.001.0285
Jun-08	720	387.5	**53.8 %**	BUR.015.001.0285
Jul-08	744	732	**98.4 %**	BUR.015.001.0285
Aug-08	744	166	**22.3 %**	BUR.015.001.0285
Sep-08	720	144	**20.0 %**	BUR.015.001.0278
Oct-08	744	392.08	**52.7 %**	BUR.008.004.0956
Nov-08	720	132	**18.3 %**	BUR.008.004.0955
Dec-08	744	693	**93.4 %**	BUR.015.001.0281
Jan-09	744	632	**85.0 %**	Allens letter 26 May 2009
Feb-09	672	652.5	**97.1 %**	Allens letter 26 May 2009
Mar-09	744	647.2	**87.0 %**	Allens letter 26 May 2009
Apr-09	720	694.4	**96.4 %**	Allens letter 26 May 2009

Percentage of operation per month of downstream fishway (Nov 2005 – April 2009)

Month	**Hrs in Month**	**Hrs of Op**	**% Operation**	**Principal Source Document**
Nov-05	720	0	**0.0 %**	Water level < EL 62m
Dec-05	744	0	**0.0 %**	Water level < EL 62m
Jan-06	744	0	**0.0 %**	Water level < EL 62m
Feb-06	672	0	**0.0 %**	Water level < EL 62m
Mar-06	744	0	**0.0 %**	Water level < EL 62m
Apr-06	720	0	**0.0 %**	Water level < EL 62m
May-06	744	0	**0.0 %**	Water level < EL 62m
Jun-06	720	0	**0.0 %**	Water level < EL 62m
Jul-06	744	0	**0.0 %**	Water level < EL 62m
Aug-06	744	0	**0.0 %**	Water level < EL 62m
Sep-06	720	0	**0.0 %**	Water level < EL 62m
Oct-06	744	0	**0.0 %**	Water level < EL 62m

Nov-06	720	0	**0.0 %**	Water level < EL 62m
Dec-06	744	0	**0.0 %**	Water level < EL 62m
Jan-07	744	0	**0.0 %**	Water level < EL 62m
Feb-07	672	0	**0.0 %**	Water level < EL 62m
Mar-07	744	0	**0.0 %**	Water level < EL 62m
Apr-07	720	0	**0.0 %**	Water level < EL 62m
May-07	744	0	**0.0 %**	Water level < EL 62m
Jun-07	720	0	**0.0 %**	Water level < EL 62m
Jul-07	744	0	**0.0 %**	Water level < EL 62m
Aug-07	744	0	**0.0 %**	Water level < EL 62m
Sep-07	720	0	**0.0 %**	Water level < EL 62m
Oct-07	744	0	**0.0 %**	Water level < EL 62m
Nov-07	720	0	**0.0 %**	Water level < EL 62m
Dec-07	744	0	**0.0 %**	Water level < EL 62m
Jan-08	744	0	**0.0 %**	Water level < EL 62m
Feb-08	696	0	**0.0 %**	Water level < EL 62m
Mar-08	744	0	**0.0 %**	Water level < EL 62m
Apr-08	720	0	**0.0 %**	Water level < EL 62m
May-08	744	0	**0.0 %**	Water level < EL 62m
Jun-08	720	0	**0.0 %**	Water level < EL 62m
Jul-08	744	0	**0.0 %**	Water level < EL 62m
Aug-08	744	0	**0.0 %**	Water level < EL 62m
Sep-08	720	0	**0.0 %**	Water level < EL 62m
Oct-08	744	0	**0.0 %**	Water level < EL 62m
Nov-08	720	0	**0.0 %**	Water level < EL 62m
Dec-08	744	0	**0.0 %**	Water level < EL 62m
Jan-09	744	0	**0.0 %**	Allens letter 26 May 2009
Feb-09	672	669.33	**95.6 %**	Allens letter 26 May 2009
Mar-09	744	668.5	**85.9 %**	Allens letter 26 May 2009
Apr-09	720	353.15	**49.1 %**	Allens letter 26 May 2009