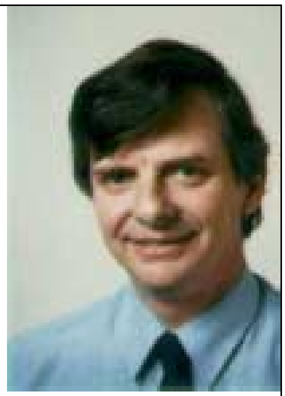
Wildlife Friendly Design of Road Structures

Brendon Hyde Technical Adviser, Australia. Brendon has 36 years experience designing bridges and heavy industrial structures, engaged with government authorities and consulting firms both in Australia and 9 overseas countries - from Asia to Africa. He has authored several technical guidelines for the Roads and Traffic Authority, NSW		***Gordon Chirgwin*** Manager, Bridge Policies, Standards and Records, Roads and Traffic Authority, NSW Australia Gordon has 31 years experience in roads and bridges, and for the last 10 years has been managing technical policy in the bridge and structural fields.	

1 INTRODUCTION

Many road projects cross watercourses and wildlife corridors that are important for the survival of native wildlife. Insensitive construction of the road structures that cross such watercourses and wildlife corridors can sever both fish and fauna passage. Such practices can cause potentially serious consequences for the local fish and fauna populations (Figure 1).

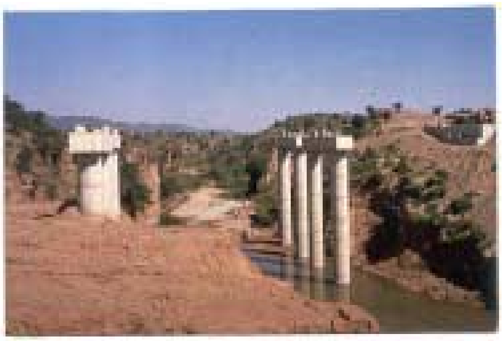


Fig 1: Fish unfriendly design. Piers located in midstream, abutments located too close to top of bank – eliminating riparian vegetation and causing pollution. Construction method pollutes river and destroys riparian vegetation.

Where road structures are not ‘fauna friendly’, terrestrial, arboreal and aquatic fauna or flightless birds will attempt to cross over the roadway. Thus a considerable variety of our unique native wildlife, especially kangaroos, wombats, koalas, platypuses and cassowaries, are killed annually on Australian roads. In addition to these wildlife mortalities, road user fatalities occur annually when motorists loose control of their vehicles after hitting or swerving to avoid wildlife obstructing the carriageway.

Current road projects provide for passage of identified local wildlife, accommodating issues raised during the Environmental Impact Assessment for the project. However, as Bennett (3) points out, good design and construction cannot substitute for poor environmental planning.

This paper adopts the definition of ‘fish’ in the NSW Fisheries Management Act 1994. Thus ‘aquatic fauna’ refers only to air breathing water dwelling animals, including amphibians.

2 KEY ISSUES TO ENSURE FISH PASSAGE

Impacts on aquatic habitat and survival of local fish species may be caused both during and after construction of waterway structures. During construction works, riparian and sub-tidal fish habitat may be lost due to physical disturbance of foreshore, banks or the stream bed by shading, accelerated erosion or sedimentation. After construction completion, impacts may include a long-term barrier to fish movement, changes to habitat and water pollution.

The majority of Australian native freshwater fish species have adapted to a mobile life style due to the dry and seasonal nature of water flow in this country. Therefore, it is important to ensure that wherever possible bridges, culverts and causeway crossings are designed to allow passage for both adult and juvenile fish during both high and low flow conditions so that options for upstream as well as downstream movement are maximised [NSW Fisheries (8,9)].

While typical adult Australian native fish might generate a thrust up to 4g to swim 3m/sec 'burst speed' over several metres between rest areas, they cannot continuously swim more than 1m/sec 'sustained speed' for 12 to 14 metres before being fatigued. However, most native fish can swim at 0.2 to 0.3m/sec 'cruising speed' indefinitely [NSW Fisheries (8,9)].

Most Australian native fish (except sea mullet) are unable to 'jump' over obstructions or small waterfalls in order to move upstream [Mallen-Cooper (6)]. Fish can negotiate rapids by avoiding aerated (less buoyant) turbulence and swimming at 'burst speed' up the continuous sheets of laminar water flow - but must then rest in eddies between these bursts. Where rest areas are absent the resulting fatigue may prevent fish passage [NSW Fisheries (8,9)].

Research in 1985 at Manly Hydraulics Laboratory [Mallen-Cooper (7)] illustrated the differences in swimming ability between adult and juvenile fish. The study found that for a 95% success criterion for four species of juvenile native fish to negotiate an experimental vertical slot fishway the maximum water velocity needed to be less than 1m/sec.

In typical waterway openings, due to drag effects, water velocities are highest at the free water surface towards the opening centre and lowest against the wetted perimeter of the opening. Hence, it is thought that fish generally seek out the regions of lower velocity flow near the base and sides of culverts, or the stream bed beneath bridges, to gain the easiest passage through the opening [NSW Fisheries (8,9)].

Consequently barriers to fish passage (especially for fish movement upstream) can be created by waterway passages with the following characteristics:

- the maximum water velocity created in the waterway passage is too high in relation to the burst speed capacity of fish;
- water velocity is lower but the waterway passage is too long in relation to the capacity of fish to maintain either burst or sustained speed;
- waterway passages requiring either burst or sustained speed capacity of fish have insufficient eddies created for rest areas;
- waterway passages requiring only cruising speed of fish have constant laminar flow extending through the passage without small local disturbances;
- water turbulence and aeration created is too great or is too extensive without alternative adjacent regions of laminar flow;
- water depths created in the waterway passage are too shallow;
- the profile of the waterway opening is too narrow or confined;
- the waterway passage is physically blocked by obstacles or a waterfall.

Although NSW Fisheries (8,9) believe that darkness may inhibit fish passage, the threshold of light required for fish passage has not been established for any fish species.

For fish passage, the following key issues must be addressed in a waterway structure design:

- ensure that under normal flow conditions:
  - water velocities are within swim abilities of local fish;
  - there is sufficient permanent depth of water in the waterway passage;
  - Super Critical flow conditions and jumps through the waterway are avoided;
- ensure or provide:
  - sufficient rest areas in the waterway to assist fish passage;
  - suitable material on the invert of waterway openings;
  - suitable material on the disturbed stream bed of the adjacent watercourse;
  - where excavation is required, design and documentation address prevention of pollution from excavated material, sediment run-off, dewatering, and cleaning up;
  - where high sulfate soils exist, the design and documentation allow for treatment of the soils and soil water, and
- minimise:
  - upstream hydraulic controls that increase water velocity and reduce flow depth;
  - abrupt changes in the velocity profile over the various waterway flow depths ;
  - water pollution;
  - changes to aquatic plant cover in the stream bed;
  - changes to riparian plant cover on the stream banks.

3 ISSUES TO ENSURE FAUNA PASSAGE

3.1 Terrestrial Fauna

Reptiles or amphibians and small marsupials may utilise pipes and very narrow confined openings as well as any type of opening of any dimension. In larger openings, very small animals such as antechinus, rats and lizards typically travel on internal structures, such as logs or ledges, placed through the underpasses. Smaller animals also tend to travel along the floor adjacent to the walls of the opening [QDMR (10)].

While medium sized marsupials such as wallabies or larger species such as kangaroos naturally are restricted by the size of the opening, smaller sized openings can be most useful for small species such as Long-nosed bandicoots, Mountain Pygmy possums or echidnas.

Large species (such as Eastern Grey Kangaroos) require much wider and higher areas for daily movement. Typically the provision of 3m x 3m box culverts is considered a sufficient opening for the passage of all macropods. Factors that are considered to deter larger terrestrial fauna from using underpass structures include flooding, boggy ground, presence of stumps blocking the entrance or long, narrow (and therefore dark) passages [QDMR (10)].

The exception is fully grown wombats who will willingly enter pipes 0.6m diameter (or even less) to cross beneath carriageways - as this diameter is ideal for them to brace their backs against the pipe surface in defence against an attacking predator [Giles J (pers. com. 2001)]. Wombats like to burrow into steep banks where the soil is friable. It is therefore suggested that the embankments adjacent to such pipes be stabilized with vegetation.

With all terrestrial fauna, security from predators is important. Therefore, it is necessary to provide a clear line of sight to light and vegetation at both ends of the crossing [QDMR (10)].

For smaller species, provision of protective cover and structures such as ledges or horizontal logs that are designed to restrict access by larger predators will aid their security.

While the shaded interiors of road crossing structures cannot be easily vegetated, higher numbers of fauna species are always recorded using those structures with revegetated approaches and entrances and those structures with entrances contiguous with native bushland. Road crossing structures with dry natural flooring (either dirt or sediment) also encourage increased fauna usage [QDMR (10)]. All terrestrial fauna require exclusion fencing for guidance through the crossing structure and to prevent access to the carriageway.

3.2 Arboreal Fauna

Exclusively tree-dwelling marsupial species such as gliders have not been observed using underpasses. Semi tree-dwelling species such as possums (including Eastern Pygmy, Common Brushtail and Mountain Brushtail species) as well as koalas have occasionally been recorded using underpasses [AMBS (2)]. Travel of arboreal fauna along bare ground in an underpass increases their vulnerability to introduced predators such as dogs, foxes and cats. Therefore underpasses now include elevated frameworks of logs to facilitate fauna passage.

Fauna overpasses in road projects are considered relevant where many tree-dwelling species are common [QDMR(10)]. To allow successful movement of arboreal fauna, easy passage between upper canopy layers both over and adjacent to the overpass is desirable [QDMR(10)].

Before justifying the installation of a land bridge type overpass for arboreal fauna, some observations should be considered: both Greater and Sugar gliders can easily cross roads to feeding areas by downward glides from 50-100m; all possum species can travel extensively over the ground and along fallen logs while koalas frequently cross large tracts of open unvegetated land [QDMR (10)]. Alternative canopy link structures trialed in NSW have been used regularly by Common Ringtail possums [Coughlan J (pers. com. 2001)].

3.3 Flightless Birds and Bats

Issues outlined for larger terrestrial fauna species equally apply as issues to encourage passage of larger flightless birds such as cassowaries in northern tropical rainforests or feasibly emus [QDMR (10)]. No known provisions have ever been made in road structures to accommodate nesting birds. Frequently provisions have been made to limit their access.

Bats are insectivorous flying mammals and are the fauna species likely to seek alternative roosts beneath bridge decks when their natural habitat in caves and sheltered cliff overhangs have been disturbed. The larger flying foxes (often called fruit bats) are fruit and flower eaters and dwell typically in riparian trees or those located near watercourses. While their natural arboreal habitat needs to be preserved no provisions in road structures are made to accommodate any flying foxes.

Bats have the largest surface area ratio to body mass of any mammal. This results in their significant body heat loss, which requires bats to develop special techniques to maintain body temperatures. To conserve energy, bats can regularly go in and out of torpor during a days cycle but generally seek warmer situations to regenerate energy. Bats seek out roosting locations where warm air is trapped and where light intensity and air movement is reduced [Keeley and Tuttle (5)].

Bats establish both day and night roosts. Day roosts are a protection from predators and buffer against the weather while night roosts are a meeting place to digest food and socialise. Typical day roosts are in hidden crevices or corners between the girders or deck expansion gaps of bridges or in the central ceiling portion of long sheltered culverts as all these areas are shielded from view as well as rain and wind. Bats typically seek out night roosting areas beneath portions of bridge decks with the greatest daytime sun exposure - as bridge decks can act as daytime heat sinks [Keeley and Tuttle (5)].

3.4 Aquatic Fauna

Generally many of the considerations outlined in the discussion of 'fish friendly' design of road structures will equally apply to 'fauna friendly' design for water dwelling species such as platypus and water rats, as well as for water dragons and frogs [Rankin T (pers. com. (2001)].

Riparian and aquatic vegetation with deep pools and boulders provide shelter for aquatic fauna from predators, sunlight and heat – similarly as for fish. Different substrates such as snags, silt, sand, pebbles and rocks are essential habitat [Rankin T (pers. com. (2001)].

The diet of a platypus, for example, is similar to that of a fish. The voids between rocks and gravel provide shelter for the aquatic invertebrates upon which platypus feed. Therefore it is important that local aquatic invertebrates are not killed by water pollution and sedimentation or by disturbing the substrates and natural stream bed materials. Platypus need stable banks to burrow into, therefore maintaining the presence of plenty of riparian tree roots (such as from Casuarina trees) in the vicinity of the waterway crossing structure is essential.

Most species of aquatic fauna are nocturnal feeders so that long dark crossings are not a problem - so long as the waterway openings are large [Rankin T (pers.com. (2001)].

Generally aquatic fauna cannot achieve the same 'burst' swimming speeds as fish – although a platypus was once observed negotiating a culvert with 2.4 m/sec flows [Tanner (12)]. However, provided there is plenty of riparian vegetation cover and natural ground surrounding the crossing site, aquatic fauna - unlike fish - can often negotiate minor obstacles in the waterway by moving around them along the stream banks.

During peak high flood flow conditions aquatic fauna will take refuge. During stable lower flow conditions, constricted waterway openings, or those waterways blocked by large piers and silt traps, or those forming weirs and waterfalls, may produce excessive local stream velocities preventing passage by aquatic fauna. Even in some ideal situations platypus have been observed to prefer dry land passage adjacent to the stream [Tanner (12)].

4 DESIGN GUIDELINES

4.1 Choosing Fish Friendly Structural Form

To assist bridge designers with a way of proposing the most preferred waterway structure at the watercourse crossing, a classification scheme rating the importance of the watercourse for fish habitat should be developed - similar to that prepared by NSW Fisheries (8,9).

For optimum fish passage and to minimise impact on the fish habitat, single span bridges (Figure 2) and single span buried arches, encompassing the whole waterway to high flood level, are preferred over either precast arches or inverted U sections founded on cast-in-situ concrete bases, or a single or series of cast-in-situ box culverts. For less important habitat, culverts formed with concrete bases but designed for fish passage, are an acceptable structural form for crossings. For minor habitat, causeways designed to allow upstream fish passage, are an acceptable structural form for crossings. Pipe causeways, pipes, minimum energy loss waterway structures and energy dissipaters should only be used in areas of insignificant fish habitat. For more detailed guidance see Hyde and Chirgwin (4) and NSW Fisheries (8,9).

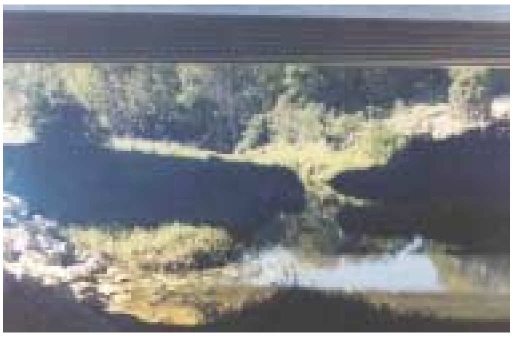


Fig. 2: Fish friendly bridge design for a shorter bridge. A single span avoids works in the streambed. The set backs of the abutments preserve the riparian vegetation on the stream banks and also permit the passage of fauna.

Fig. 3: Fish friendly design of scour protection using individual cobbles and small boulders, with riparian vegetation planted along the streambed and stream banks to simulate the natural habitat.

Fig. 4: Good control on water pollution - temporary rock platform for pier constructed in watercourse.

To avoid excessive afflux, turbulence and scour during flood flow, the size of the waterway structure opening should be chosen so that the structure's Opening Ratio for the Serviceability Flood profile of the natural watercourse is at least greater than 0.7 [Hyde and Chirgwin (4)].

The relocation or training of the stream bed is generally not preferred. For bridge and buried arch substructures it is preferable to use foundation designs that retain the existing soils in place, such as driven piles, rather than those that require excavation. Excavation should particularly be avoided in areas that may contain acid sulfate or contaminated soils. Scour protection must be designed so that the fish can navigate the watercourse channel in normal to low flow conditions and contain refuge areas in periods of high flow (Figure 3).

Where fish passage is required, the waterway should not be totally dark entirely across any section of the passage. ‘Fish friendly’ construction constraints should also be specified (Figure 4). ‘Fauna friendly’ passage may often be incorporated within ‘fish friendly’ road structures at waterway crossings. Proper design of these dual function structures can both reduce costs and result in improved fauna performance. For further 'fish friendly' guidelines and references refer to Hyde and Chirgwin (4), NSWFisheries (8,9) and Witheridge (14).

4.2 Fish Friendly Design Details

4.2.1 Bridges

Where multiple spans are required, only the minimum number of bridge piers should be positioned within the main channel of the permanent waterway. Spans lengths over the permanent waterway channel should be chosen to be as large as possible (Figures 5&6). Designers should avoid positioning bridge piers on river banks to minimise damage to the banks and their riparian vegetation. Submerged components of bridge piers should be circular or streamlined in section to minimise turbulence and subsequent scour of the river bed.

Fig. 5: Fish friendly bridge design for a longer bridge. Streamlined pier columns and pile caps placed clear of the permanent river banks - which retain natural snags. Abutments placed behind the high flood banks. Long spans minimise stream bed disturbance.

Fig. 6: Fish friendly bridge design. Circular section pier columns placed clear of the permanent stream and stream banks to minimise bed disturbance and loss of aquatic and riparian vegetation. Spill through abutment batters placed clear of permanent stream banks minimise loss of riparian vegetation and maximise the opening ratio during floods.

Spill through abutments are preferred with the toes of gently sloping 1 to 2 embankment batters positioned well behind the banks of the permanent watercourse - to avoid scouring of the banks during flood flow and to avoid disturbing the essential riparian vegetation (Figure 6). The choice of walled abutments and vertical training walls is undesirable as these structural types cause turbulence and reflect wave energy [Simonds (11)].

Scuppers traditionally placed within bridge decks are a source of rainwater runoff and pollution into watercourses. Where pollution control of waters from the bridge deck is critical, alternative deck drainage should be provided.

4.2.2 Culverts

To ensure successful upstream fish passage during low flow conditions, fish need a continuous water passage through a culvert with a minimum water depth of 0.2m to 0.3m over a minimum width of 1.0m and a recommended maximum invert gradient of 1:100 [NSWFisheries (8,9)]. To encourage unhindered fish passage Mallen-Cooper (6) recommends to limit flow velocities to between 0.2-0.3m/sec.and water turbulent energy to 30 watts/cu.m.

Culvert designs that retain the natural watercourse width, gradient and cross sectional area are preferred. There should be no vertical drops within or at either end of the culvert. Gravel, cobbles and small rocks could be placed inside existing culverts to cover the base slab in order to provide riffles and familiar fish habitat (Figures 7&8). Metal or concrete baffles can also be installed on the base or side walls of culverts to create eddies in flow (Figure 8). Rock inclusions and baffles and sculpting must be designed to avoid excessive turbulence that could act as a barrier to fish passage. Good design procedures are outlined in Witheridge (14).

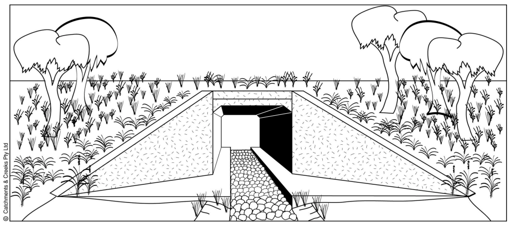


Fig. 7: Single box culvert with a recessed low flow channel base covered with cobbles and rocks. Side benching provides fauna passage.

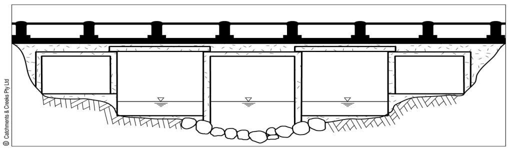


Fig. 9: Series of box culvert cells with invert levels varied to follow the streambed contour. High cells are for fauna passage. Lowest cell for fish passage has base covered with cobbles and rocks.

Fig. 8: Fish friendly culvert design. Bases of multiple cell culverts set below stream bed with rocks placed on stream bed and base of culverts and side baffles attached to walls of culverts.

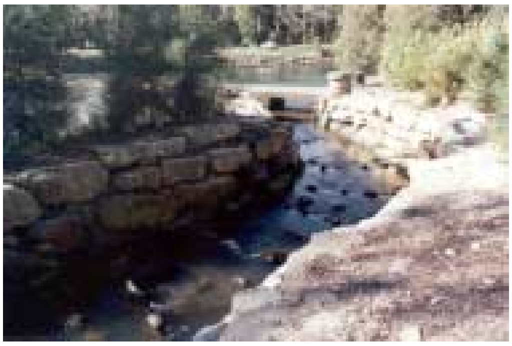


Fig. 10: Rock ramp fishway in a tidal zone, installed at a culvert with a "waterfall" effect: the fishway was designed for a maximum flow velocity of 1 m/sec.

Designers using multiple culverts, placed side by side in a series, should either depress one cell or vary the culvert invert levels to follow the streambed contour (Figures 9) so that, during low flow conditions, fish passage is possible through the lowest culvert.

Where culverts cannot be designed with fish friendly invert gradients or the 'waterfall effect' is unavoidable, fishways (fishladders) could be incorporated into adjacent lengthened spillway chutes. Rock Ramp fishways are preferred aesthetically. They should be hydraulically designed so that the flow below the constriction at each fishway step remains generally stable and the velocity of the laminar flow through the constriction does not exceed the 'burst speed' ability of the local fish species (Figure 10). Mallen-Cooper (6) suggests 50-100mm steps to limit flow velocities to 1m/sec. and water turbulent energy to 100 watts/cu.m.

4.3 Choosing Fauna Friendly Structural Form

Usually the most appropriate locations for fauna underpass structures are creek lines. Creek lines provide both corridors of riparian forest for the dispersal and movement of fauna and refuges in times of fire and drought [Bennett (3), QDMR (10)]. The disturbed area within the easement for construction works should be kept as narrow as possible. This disturbed area surrounding the base of bridge abutment batters and adjacent road embankments should be replanted with flora species native to the surrounding habitats.

Opening widths of the underpass structures should be sufficient to encourage the identified wildlife corridors to be as wide as possible. The height of an opening determines the degree of shading or even darkness extending through the opening, the ability of vegetation to generate just past the entrances and the view of habitat beyond the far side exit of the opening.

The opening size and structural form can influence which animals will use the passage. The necessary opening width and height of a useful passage therefore varies greatly among the anticipated user wildlife species. It is generally considered desirable that opening dimensions should be large enough to encourage natural movement of a large variety of animal species.

Studies have revealed that a greater number of terrestrial fauna species utilise bridge underpasses in comparison with culverts or reinforced concrete pipes [QDMR (10)]. Large ground-dwelling mammals, especially Macropods, generally prefer bridge underpasses which provide more open and better illuminated spaces and as well, natural base materials.

The ideal crossing structures to encourage aquatic fauna passage are, as for fish passage, bridges or buried arches as these structures maintain the natural stream bed and embankments.

A typical location for a land bridge type fauna overpass is at a road cutting severing a well forested ridge. Forested ridges provide habitation for different fauna species than at nearby creek lines [Bennett (3)]. For high cuts, the land bridge should be located at the ends of the cutting to align with the ridge contours. While land bridges are well utilised by all fauna species their main advantage is to mitigate impacts on arboreal marsupials [QDMR (10)].

Land bridge type fauna overpasses are much more costly to provide than fauna underpasses because they support a significant depth of earth fill over a much wider passageway. Observations on local arboreal fauna should be considered before justifying the adoption of expensive land bridges. Canopy link overpasses are much less expensive.

Location of the crossing structure based on knowledge of popular fauna travel routes may be far more important in determining fauna utilisation of the crossing rather than other factors such as providing generous opening dimensions or vegetation [Bennett (3), QDMR (10)].

4.4 Fauna Friendly Design Details

4.4.1 Fauna Underpasses - Bridges and Culverts

Underpasses formed by bridges and buried arches (Figures 2, 6&11), which typically provide openings wider than 6m, are the ideal solution to mitigate the passage of the greatest variety of species - especially where the length of the passage exceeds 20m. Bridge abutments and toes of spill-through batters should be set back from the banks of the watercourse by at least 3m to allow a land passage for both terrestrial and occasional aquatic fauna (Figure 6).

Minimum vertical clearances beneath the bridge superstructure or arch crown will be to accommodate the fauna species targeted. A minimum vertical clearance of 3m to preferably 5m is generally considered necessary to encourage the passage of a variety of small to large fauna species. However very large dedicated structures are not considered to be cost effective.

Underpasses formed by 3mx3m box culverts are generally considered to accommodate a wide variety of fauna species - including all sizes of macropods and flightless birds. As dry passage is preferable for all species of terrestrial fauna, a dry culvert floor, preferably covered in ‘natural’ materials, is required. Where multiple culverts are placed side by side in a series, one outer cell may be raised (Figure 9) so that, during low flow conditions dry fauna passage is possible. For single cell culverts side benching can be incorporated to enable fauna passage (Figure 7). Side benching dimensions can be chosen to provide maintenance access for a small excavator. Good examples are illustrated in Witheridge (14).

Fig. 11: Large buried arch type fauna underpass. In this case the span exceeds 20 m, which is more than double the required dimension.

Fig.12: Fauna underpass with natural base cover and an elevated lizard run for reptiles and small terrestrial fauna.

Fig. 13: Fauna underpass with elevated log framework placed near culvert sides for arboreal fauna. Note that sloping logs should not be used at the ends.

Fig. 14: Typical fauna underpass with refuge pole at entrance. Clear sight through culvert encourages use.

‘Lizard Runs’ can be attached along the walls of culverts or bridge abutments (Figure 12). Log frames comprising only vertical and horizontal members can be placed through the passageway near the opening sides - the opening centre being avoided. Note foxes can climb inclined logs. The horizontal logs should be placed as high above the base of the opening as practical, allowing say 0.6m ceiling clearance for fauna passage. Typically the vertical logs are secured to the invert of the concrete base slab and soffit of the culvert ceilings by attachment brackets or cast into concrete footings beneath bridge and arch spans (Figures 13). Overlapping rocks and boulders should also be placed inside larger openings for protection.

Underpasses with smaller sized openings (say 0.9m x 1.2m wide) may be used to target small species such as bandicoots. Pipes 0.6m diameter may be used to target wombats.

Vertical refuge poles several metres high may also be placed outside opening entrances (Figure 14). Typically poles are 3m high and at least 200mm diameter and cast into concrete footings. Refuge poles may be effective both at the entrances as well as within the passageway in areas where introduced predators are likely to attack native fauna such as koalas. It is important to locate such poles at least 3 m away from koala exclusion fencing.

To encourage passage of aquatic fauna, there should ideally remain a continuous link of water through the opening, in contrast to the provisions for terrestrial fauna. Unlike the situation for fish, a minimum continuous water depth is not essential. However the retention of continuous riparian vegetation coverage and natural substrates along the passage base is important. There should be plenty of flow disturbances, such as boulders and rocks, placed in the waterway of the culvert, bridge or arch crossings. Even under stable low flow conditions, platypus have been observed avoiding passage through culverts where the water flows over smooth concrete bases [Tanner (12)]. At large waterway openings removal of debris, such as tree trunks, should be restricted to the minimum necessary for the operation of the waterway.

For frogs, there should be plenty of protective upstands and riparian vegetation over both the waterway and adjacent land passage sections [Rankin T (pers.com. (2001)]. Unless otherwise shown by the EIA, the passage should have damp surfaces available adjacent to the waterway.

4.4.2 Fauna Overpasses – Land Bridges and Canopy Links

Fauna overpasses formed by land bridges typically provide a much wider passageway than fauna underpasses because they must provide an extension of the natural vegetation, including a continuation or link between the upper canopy in the wildlife corridor. This requires a passageway wide enough (40-50m) to plant several adjacent trees. Rock and log protective cover should be provided together with artificial refuges such as log frames and refuge poles.

Land bridges may be formed either by buried arch structures which can support several metres of earth fill - sufficient to grow shrubs and smaller trees, or may be formed by especially constructed overbridges utilising side planter structures sufficiently deep to grow just shrubs. Ideally, land bridge structures need to be constructed so that terrestrial fauna cannot see the traffic passing on the road beneath and have natural material floor bases with protective vegetation matching the surrounding habitat [USDT (13)].

Canopy links that facilitate the movement of arboreal fauna over a road may include vertical poles and elevated canopy bridges comprising suspended ropeways and steel cables or suspended ‘fauna funnels’ (typically 300mm diameter perforated aluminium tubes suspended over the carriageway from climbable stay poles and cables (Figures 15&16).

4.4.3 Bat Roosts

Some road crossing structures have been retrofitted with various geometric designs of timber bat roosts - usually installed beneath bridge decks or culvert ceilings. The central ceiling areas of long sheltered culverts or the soffit of concrete bridge decks between composite girders is the best location to encourage the roosting of small bats because warm air is trapped there while light intensity and air movement is reduced [Keeley and Tuttle (5)]. Bat roosts have also been fixed in NSW bridges against the sides of the central area of the abutment or against the front face or of the pier headstocks [Williams R (pers.com. 2001)].

Bat droppings are a health hazard. Where provisions are made for bat roosting, such roosts must be well clear of areas requiring maintenance access.

4.4.4 *Exclusion Fencing*

Properly designed exclusion fencing will direct terrestrial and arboreal fauna through the crossing structure and prevent access to the carriageway without trapping fauna at the entrances to the road crossing structures. Fencing must be splayed outwards from the entrances. Some fence designs include breaks to allow trapped fauna to escape off the carriageway. Both 'smooth top' and 'floppy top' type fences have been successfully used as koala barriers. To be effective, koala fences must be constantly maintained and tree branches cleared within 3m of the fence (Figures 17 & 18). Macropods require high 1.8m fences.

Experiments placing artificial fox urine alongside road corridors is showing some promise in deterring fauna from crossing roadways - and is a much cheaper solution than barrier fencing.

Fig. 15: Suspended fauna funnel – suitable for possums.

Fig. 16: Close up of perforated tube of fauna funnel showing entrance baffle.

Fig. 17: Fauna fencing (smooth top type).

Fig. 18: Placement of fauna fencing (floppy top type) at a fauna underpass entrance.

5 CONCLUSION

The authors have presented the key issues affecting 'wildlife friendly' design of road structures - particularly for Australian conditions. They have elucidated economic and practical design concepts to address those issues and conclude that it is reasonable to provide for wildlife passage in the design and construction of road projects. However they emphasize that 'wildlife friendly' design of road structures cannot substitute for poor road planning.

6 DISCLAIMER

Any opinions expressed in this paper are those of the authors and may not represent the policies and practices of the RTA.

7 REFERENCES

[1] AMBS: *"Fauna Usage of Three Underpasses Beneath the F3 Freeway Between Sydney and Newcastle".* Study for Roads and Traffic Authority NSW by Australian Museum Business Services, Sydney – 1997 and discussions.

[2] AMBS: *"Fauna Underpass Monitoring: Herons Creek - Taree - Brunswick Heads - Bulahdelah to Coolongolook ".* Study for Roads and Traffic Authority NSW by Australian Museum Business Services, Sydney - Mar 2001 and discussions.

[3] BENNETT A F: *"Linkages In The Landscape: The Role Of Corridors And Connectivity In Wildlife Conservation".* IUCN Publ , Cambridge UK – 1999.

[4] HYDE B AND CHIRGWIN G: "Fish Friendly Design of Road Structures". *IABSE 2002 Symposium 'Towards a Better Built Environment'*: International Association for Bridge and Structural Engineering, Melbourne – Sep 2002.

[5] KEELEY B and TUTTLE M: *"Bats in American Bridges".* Bat Conservation International Inc, Resource Publ No 4 - 1999

[6] MALLEN-COOPER M: "How High Can Fish Jump". *New Scientist* Apr1994, pp32-37.

[7] MALLEN-COOPER M: "Swimming Ability of Juvenile Australian Bass and Juvenile Barramundi in an Experimental Vertical Slot Fishway". *Australian Journal of Marine and Freshwater Research* V43 - 1992, pp823-834.

[8] NSW FISHERIES: *"Policy and Guidelines for Bridges, Roads, Causeways, Culverts and Similar Structures 1999"* (Fairfull S. and Carter S). NSW Fisheries, Sydney – 1999

[9] NSW FISHERIES: *"Why Do Fish Need to Cross the Road: National Guidelines on Fish Passage Requirements for Waterway Crossings"* (Fairfull S and Witheridge G), NSW Fisheries, Sydney - Aug 2002 and discussions.

[10] QDMR: *"Fauna Sensitive Road Design: Vol 1: Past and Existing Practices".* Queensland Department of Main Roads, Technology and Environment Division - 2000

[11] SIMONDS JO: *"Earthscape: A Manual of Environmental Planning".* McGraw Hill - 1978, pp82 and 296.

[12] TANNER Z (comp.): *"Culvert Avoidance by Platypus and Subsequent Road Deaths: Workshop Aims and Outcomes".* Tasmanian Environment Centre, Hobart - 2003.

[13] USDT: *"Critter Crossings: Linking Habitats and Reducing Roadkill".* United States Department of Transport, Federal Highway Administration - 2001.

[14] WITHERIDGE G: *"Fish Passage Requirements for Waterway Crossings - Engineering Guidelines".* Catchments and Creeks P/L, Brisbane - Dec 2002.