Northern Territory Government

Department of Infrastructure, Planning and Environment

Environmental Water Requirements of the Daly River

Revision of Recommendations of Erskine *et al.* (2003)

based on Daly Region Water Allocation Workshop held in Darwin on 5 May 2004

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REVISION OF RECOMMENDATIONS OF ERSKINE *et al.* (2003) BASED ON DALY REGION WATER ALLOCATION WORKSHOP, DARWIN, 5 MAY 2004

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The purpose of this report is to present background information on Daly River hydrology and the recommendations of Erskine *et al.* (2003) as well as the outcomes of the Daly Region Water Allocation Workshop held at the Department of Business, Industry and Resource Development in Darwin on 5 May 2004. The purposes of the Workshop were to revisit the Erskine *et al.* (2003) recommended environmental water requirements and to propose changes to the original recommendations based on additional data, information and discussions.

Daly River Hydrology

The recommendations of Erskine *et al.* (2003) apply to the Daly River between Dorisvale Crossing and Mt Nancar. The currently operating gauging stations in this reach include Dorisvale (GS8140067), Beeboom Crossing (GS8140042) and Mt Nancar (GS8140040). A discontinued station was located at Gourley (GS 8140041) and a number of velocity-area gaugings to measure discharge have been undertaken at Oolloo Crossing. A brief introduction to hydrography and hydrology is provided below to answer previous questions from the Community Reference Group, to help understand the data collected at the river gauging stations and to provide background for the potential implementation of the following environmental water requirements. This information should be read in conjunction with the report by Peter Whitehead on the accuracy of ratings and the streamflows generated from the rating curves.

River gauging stations record stage or river height continuously over time by using a sensor such as a pressure transducer (records pressure that is calibrated to height), optical shaft encoder (float used to directly measure river height) or differential pressure or gas bubble gauge (records pressure – calibrated to height - where gas is emitted under constant pressure at a gauge from a gas bottle). Staff gauges are also installed at river gauging stations to manually check river heights during site visits. Dataloggers are programmed to interrogate the sensor at set times (every minute or 5 minutes) and to record and store the average stage over a longer time period (6 minutes, 10 minutes or 15 minutes). Longer time periods are used on large rivers such as the Daly River because river stage does not change as rapidly as on smaller rivers. The river height or stage is the height of the water surface recorded by reference to an arbitrary datum (gauge zero) which is used to set the staff gauge. Malfunction or damage of equipment and flat batteries often result in loss of record. This can be caused by leaks in pressure tubes, gas bottles running empty, optical shaft encoders becoming stuck, equipment being flooded and the like. A stage hydrograph is a continuous trace of water surface elevation over time and the stage hydrograph for the complete period of record at the Beeboom Crossing station is shown in Figure 1.

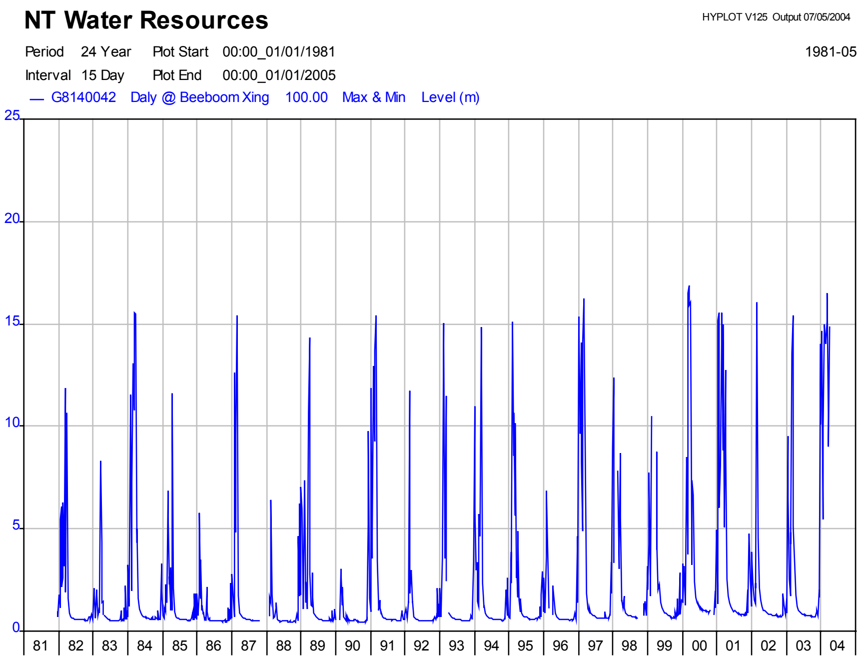

Figure 1. Stage hydrograph for the Daly River at Beeboom Crossing from 1981 to 2004. Note the strong signature of the annual wet season, the persistent flows during the dry season and short gaps in the record due to equipment malfunction (*Source*: Peter Jolly, NT Department of Infrastructure, Planning and Environment).

Stage is converted to discharge via a rating curve which is either a plot of stage versus measured discharge by velocity-area gaugings or, less commonly, stage versus calculated discharge by a theoretical equation derived for specific flow conditions at an accurately constructed weir or flume. All gauging stations on the Daly River have rating curves constructed from a series of velocity-area gaugings. Velocity is usually measured with a current meter or similar device at a number of verticals on a river cross section. Cross sectional area is measured with a tape and graduated staff, wading rod or lead weight. The discharge for each segment is calculated by either the mean or mid-section method and summed to determine the total discharge for the section. The latest rating curve at Mt Nancar (19 August 2000 to present) is shown in Figure 2 and was constructed from a series of velocity-area gaugings for a wide range of discharges. Chappell and Bardsley (1985) noted that there were no loops (different discharge for the same stage depending on whether stage is rising or falling) for the Mt Nancar rating when they did their analyses of the record and Figure 2 indicates that this is still the case. Rating curves often change over time because of changes to the channel cross section by erosion and deposition, localized changes to the gauge control (this can be a road crossing, a gravel riffle, a bedrock bar or a concrete weir) by road works or floods, or by changes in flow resistance due to growth or death of riparian and aquatic vegetation. It is difficult to gauge overbank floods when there is a lot of water on the floodplain and so the accuracy of the top end of the rating curve can be less than for within-channel flows. The accuracy of low discharges on large rivers can also be problematical because of the inaccuracy/lack of sensitivity of a flat river bed for determining the upstream stage height. Road works, tufa dams, organic matter and large wood accumulation can all change the low flow rating. Discharge hydrographs result from the conversion of the stage hydrograph via the rating curve. A discharge hydrograph is a graph of discharge over time (similar to Figure 1). It consists of irregular saw-toothed shaped fluctuations superimposed on a gently undulating trend during the wet season and a gradually declining flow through the dry season. Peter Whitehead's report discussed the likely errors associated with rating curves and the conversion of stage to discharge via rating curves. There are additional errors in determining discharge associated with velocity-area gaugings.

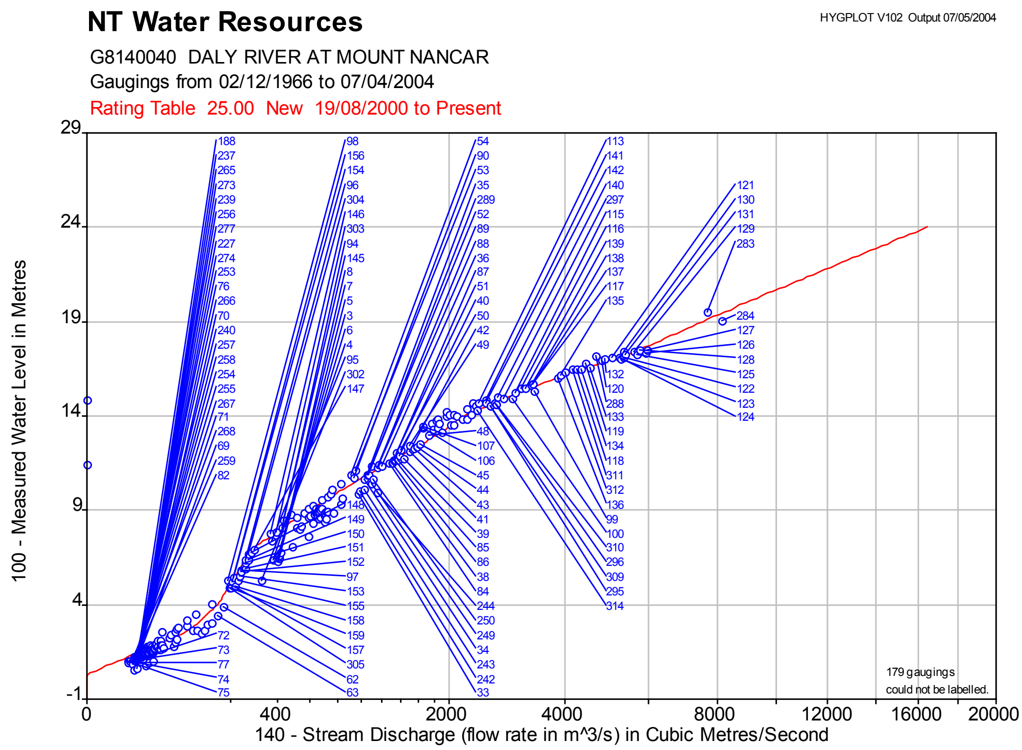

Figure 2. The latest rating curve for Daly River at Mt Nancar. The numbers refer to a specific velocity-area gauging. Note that there is some variation about the adopted curve and that there are objective statistical tests to determine when new data do not conform to the earlier curve (*Source*: Peter Jolly, NT Department of Infrastructure, Planning and Environment).

Flood hydrographs are parts of the discharge hydrograph where surface runoff dominates. On the Daly River, rain storms during the wet season cause surface runoff. Flood hydrographs are characterised by a *rising limb* (relatively rapid increase in discharge or stage), a *flood peak* (maximum discharge or stage) and a *recession* (exponential decrease in discharge or stage after the flood peak). Depending on the temporal distribution of rainfall, there can be two or three flood peaks before the recession. In-stream discharge between flood hydrographs is called *base flow discharge*, which is function of groundwater discharge via springs or directly to the river bed. It is this base flow discharge which maintains streamflow right through the dry season on the Daly River. Jolly (2001; 2002) analysed the streamflow records for the Daly River catchment and constructed an approximate water balance. The mean annual runoff for the Daly River at Mt Nancar was 148 mm, of which 135 mm was surface runoff and 13 mm was regional groundwater discharge. The unit of runoff of millimetres refers to the rainfall depth equivalent over the entire upstream catchment and is converted to megalitres (ML) by multiplying by the catchment area in km^2. Chappell and Bardsley (1985) found that sustained base flow of about 7 to 20 cumecs (m^3s^{-1}) or 605 to 1728 megalitres per day (MLd^{-1}) persisted right through the dry season at Mt Nancar. To convert cumecs (m^3s^{-1}) to megalitres per day (MLd^{-1}), multiply by 86.4. Clearly this means that 1 cumec equals 86.4 megalitres per day (MLd^{-1}).

Daly Region Water Allocation Workshop

This workshop was held in the seminar room of the Department of Business, Industry and Resource Development in Darwin on 5 May 2004 with the aim of revisiting the recommendations of Erskine *et al.* (2003) in light of additional information and knowledge. Those in attendance were:

- Mike Burgess (Chair),
- David Ritchie,
- Ian Smith,
- Peter Jolly,
- Mona Liddy,
- Naomi Rea,
- Peter Whitehead,
- Bruce Sawyer,
- Michael Storrs,
- Sue Jackson,
- Robbie Bright,
- Judy Faulks,
- Gary Higgins,
- John Etty,
- Dan Halloran,
- Peter Robertson,
- Simon Townsend,
- Stuart Gold and
- Wayne Erskine.

Following Mike Burgess' introductory comments, Wayne Erskine presented a summary of most of the main points of the five National River Health Environmental Flow Initiative studies on the Daly River. The purpose of this presentation was to outline the scope of work completed and the basis of some of the recommendations. Ian Smith then outlined the water allocation planning process in the Northern Territory and how he hoped that the Erskine *et al.* (2003) recommendations could be recast to better reflect environmental water requirements for the Daly River. Then the Erskine *et al.* (2003) recommendations were discussed in much detail for the rest of the day in terms of wet season, dry season, groundwater and water quality environmental water requirements. The linkage between the recommendations and the relevant studies was also discussed and it was emphasized that some recommendations were based on information from other parts of tropical Australia, such as the Alligator Rivers Region. It is fair to conclude that there was much scrutiny of each recommendation with a frank discussion of what each meant and how each should be implemented. There was much difference of opinion as to the reliability of some recommendations. Little progress was made in reaching consensus as to the environmental water requirements of the Daly River. Nevertheless, the discussion was helpful in raising many significant issues that the local community wanted addressed. Naomi Rea suggested a formal process for water assessment and allocation in the Northern Territory should be used and presented a possible model.

The Community Reference Group members requested that the outcome of the Workshop should be that the environmental water requirements of the Daly River needed to be recast in terms of:

1. a concise explanation of the underlying science.
2. the confidence in, or accuracy of, the specified discharges.
3. an appropriate regulatory response to the recommendations.
4. what they mean for discharges or flows in the Daly River.

Following subsequent discussions between Ian Smith, Peter Jolly and Wayne Erskine, the recommendations have been regrouped and reworded in a more logical framework and to provide the above information for the Community Reference Group for these revised recommendations.

Revised Environmental Water Requirements for the Daly River (between Dorisvale and Mt Nancar)

Following the scrutiny of the Erskine *et al.* (2003) environmental water requirements at the Daly Region Water Allocation Workshop and the previous questions raised by the Community Reference Group, it was felt that the recommendations needed to be recast in a clearer, more logical framework with greater explanation of the source, basis and likely implementation of the proposed conditions.

1. Floods and Wet Season Environmental Water Requirements

Combination of Environmental Issues 2 and 3 from recommendations of Erskine et al. *(2003)*

The rising limb and peak of floods should be protected because they cue important biotic responses and because they serve important geoecological functions, such as channel maintenance, reworking of sand bars for pig-nosed turtle nesting sites and lateral connection of floodplains.

Recommended Environmental Water Requirements

1.1 The rising limb and peak of significant <u>within-channel floods</u> should be maintained.
1.2 A flood is defined as a flood hydrograph with a peak stage at least 6 m higher than usual dry season river stage. As usual dry season river stage is about 1 m at most gauging stations on the Daly River, a flood on the Daly River is defined as a flood hydrograph with a peak stage greater than a gauge height of 7 m at any gauging station. This height was selected because it is high enough to generate sufficient shear stress to entrain sediment and because such floods are high enough to be objectively identified so as to enable the broadcasting of notices by local radio that a designated flood (within-channel or floodplain flood) is occurring and that all pumping must cease until notified otherwise.
1.3 Flood hydrographs with a peak stage lower than 7 m at a gauging station on the Daly River are not classed as within-channel floods for the purposes of environmental water requirements.
1.4 A flood peak stage of 7 m at any gauging station on the Daly River triggers this environmental water requirement and applies to the section of river centred on the gauging station. It is suggested that the Dorisvale gauge data be applied to the section of Daly River between the Flora River junction and Oolloo crossing, the Beeboom gauge data be applied to the section of Daly River between Oolloo and Beeboom crossings and the Mt Nancar gauge data to the section of Daly River between Beeboom crossing and Wooliana.
1.5 The rising limb, peak and recession to 1 m below the peak of <u>floodplain floods</u> should be maintained.
1.6 A floodplain flood is defined as an event with a peak stage higher than 19 m at Dorisvale, 13 m at Beeboom Crossing and 14 m at Mt Nancar. These flood stages were determined from surveyed cross sections at each gauging station.
1.7 A within-channel flood may develop into a floodplain flood and a floodplain flood will change to a within-channel flood on the recession.
1.8 The first flush event of each wet season, irrespective of size, should be investigated to determine whether it should also be protected from water extraction.

Scientific Basis

1.1 The rising limb and peak of within channel floods are important for:

- Stimulating and maintaining within-channel passage of fish and other aquatic fauna.
- Disturbing aquatic and riparian vegetation.
- Transporting suspended sediment and bedload.
- Depositing sand sheets used as nesting sites by the pig-nosed turtle.
- Diluting solute concentrations.
- Generating turbulence to mix pools.
- Removing mud veneers (fine-grained sediment laminae) and stripping periphyton from bed sediments.
- Stripping epiphytes from macrophytes.
- Scouring pools, filling riffles and maintaining aquatic habitats or channel units. Large events have a more significant role in channel maintenance on bedrock-confined rivers than on alluvial rivers.
- Reworking channel bar sediments

1.5 The rising limb, flood peak and recession to 1 m below the peak of floodplain floods are important for:

- Most of the above functions plus
- Fish passage onto and off the floodplain that cannot occur during lower within-channel floods.
- Stimulating the annual growth cycle of floodplain and billabong plants.
- Filling floodplain billabongs and wetlands.
- Recharging soil water stores.
- Recharging floodplain groundwater.
- Depositing sediment on the floodplain.
- Transporting solutes and organic matter onto and off the floodplain.
- Supplying freshwater, sediments and nutrients to the estuary and offshore zone.

1.7 The first flush event of each wet season may be important for supplying dissolved organic carbon and particulate organic matter to the river which is subsequently processed by phytoplankton and macroinvertebrates. However, fish kills have also been reported during such events due to organic matter breakdown by bacteria and resultant consumption of dissolved oxygen. Therefore, it is essential to determine the geoecological significance of the first flush event.

The National River Health Environmental Flow Initiative studies concentrated on dry season conditions and hence did not investigate floods and their geoecological significance. Therefore, the above recommendations are based on published research from northern Australia and elsewhere. The research on the role of large floods in forming channel morphology and bars on the Katherine River demonstrates the geomorphological significance of large events (Baker and Pickup, 1987).

Other Community Reference Group Concerns

All flood flows are important so the environmental impacts of losing 20 % of recessional flood flows are largely unknown. Sediment transport is duration dependent so any reduction in streamflow persistence will change sediment fluxes and patterns of erosion and deposition. Hence the confidence in this recommendation is low.

To determine that this environmental water requirement is preserved, it is essential that all pumps are metered and that all licence conditions are audited.

The recessional flood flows will decline to base flow levels quicker as a result of this condition.

2. Minimum Streamflows and Dry Season Environmental Water Requirements

Combination of Environmental Issues 5 and 7 from recommendations of Erskine et al. *(2003)*

Minimum streamflows should be maintained to protect *Vallisneria nana*, *Spirogyra*, pig-nosed turtles and other aquatic flora and fauna, and to ensure that the water requirements of riparian vegetation can be supplied at times of extreme water stress.

Recommended Environmental Water Requirements

2.1. The following minimum streamflows should be adopted at the relevant locations:

- *Dorisvale Crossing – 6.2cumecs (m^3s^{-1}) or 536 megalitres per day (MLd^{-1})*
- *Oolloo Crossing – 12 cumecs (m^3s^{-1}) or 1037 megalitres per day (MLd^{-1})*
- *Mt Nancar – 12 cumecs (m^3s^{-1}) or 1037 megalitres per day (MLd^{-1})*

2.2. At discharges greater than the above thresholds but less than those specified in recommendations 1.2 and 1.6, at least 80 % of the streamflow should be protected for the maintenance of streamflow, water quality, flow hydraulics, aquatic habitats, flora and fauna.

2.3. At discharges less than the above thresholds, at least 92 % of the streamflow at these locations must be protected for the maintenance of critical aquatic habitats and their associated flora and fauna.

Scientific Basis

A minimum discharge of 2 cumecs (m^3s^{-1}) or 173 megalitres per day (MLd^{-1}) is required for use by riparian vegetation and for protection of aquatic flora and fauna. It was determined as follows:

- the water demand of riparian vegetation between Dorisvale and Mt Nancar during extreme water stress when the soil moisture store was completely depleted and groundwater/river water was the only source was calculated by using a stand water use of 5 millimetres per day (mmd^{-1}) for the riparian zone area. O'Grady *et al.* (2002) found that stand water use by riparian vegetation can exceed 4.8 millimetres per day (mmd^{-1}) and so a maximum value of 5 millimetres per day (mmd^{-1}) was adopted. This water requirement was then assumed to be sourced solely from streamflow as base flow discharge which riparian tree roots can access.
- Cease-to-flow conditions on the Daly River would have catastrophic consequences for the pig-nosed turtle, *Vallisneria nana*, *Spirogyra,* fish and other aquatic species. Therefore, the Daly River must have additional discharge to that required by riparian vegetation to maintain some refuge aquatic habitat. Georges *et al.* (2002) classified cease to flow conditions as 'catastrophic' for pig-nosed turtle and flowing water is also required by *Vallisneria nana* and *Spirogyra*. Catastrophic conditions for pig-nosed turtles refer to river fragmentation with greatly restricted home range and turtle passage; restricted access to nesting banks; restricted access to feeding grounds; and changed thermal regime which alters sex ratios (Georges *et al.*, 2002). As a result, there is limited to no recruitment during catastrophic conditions. Therefore, not only must the Daly River never cease-to-flow but low streamflows must be high enough to generate sufficient turbulence for the optimum growth of at least *Vallisneria nana* and *Spirogyra*.

Minimum streamflows of less than 6.2 cumecs (m^{3}s^{-1}) or 536 megalitres per day (MLd^{-1}) at the Dorisvale gauge were classified as 'bust' conditions for the pig-nosed turtle by Georges *et al.* (2002) because of some restriction on home range and turtle passage. Such conditions are to be expected but their magnitude and persistence should not be greatly changed so as to ensure the viability of the pig-nosed turtles. Rea *et al.* (2002) cited streamflows of 10-12 cumecs (m^{3}s^{-1}) or 864-1037 megalitres per day (MLd^{-1}) at Oolloo Crossing as the threshold below which there is a sudden decrease in habitat availability for *V. nana*. Townsend *et al.* (2002) found that at streamflows of less than 12.5 cumecs (m^{3}s^{-1}) or 1080 megalitres per day (MLd^{-1}) downstream of Oolloo Crossing the rate of *Spirogyra* biomass loss with reduced streamflow was three times greater than at higher discharges. This is a measure of lost primary production.

Other Community Reference Group Concerns

The determination of the specified minimum streamflows was based on a number of studies which examined a range of requirements for a number of species. The combination of biological, ecological, hydrological, water quality, habitat, limnological and hydraulic investigations ensures that a reliable minimum streamflow has been identified at a number of sites. Hence the confidence in this recommendation is high.

To determine that this environmental water requirement is preserved, it is essential that all pumps are metered and that all licence conditions are audited. Furthermore, there is a need to ensure that double extraction (from groundwater and streamflow) does not occur and that the total extraction of the groundwater and surface water resource maintains these minimum streamflows. Double extraction refers to the possibility of water extraction direct from groundwater followed by water extraction of groundwater discharge to the Daly River which occurs as dry season base flow discharge. This means that groundwater can be extracted sequentially, which should not be the case.

The specified base flows should retain the perennial streamflow character of the Daly River which is essential for the maintenance of the current aquatic biota and geoecological processes.

3. Maintenance of Groundwater Discharge to the Daly River and Dry Season Environmental Water Requirements

Combination of Environmental Issues 4 and 7 from recommendations of Erskine et al. *(2003)*

Groundwater levels and spring inflows to the Daly River during the dry season should be maintained to ensure that current base flows persist.

Recommended Environmental Water Requirements

3.1. Spring inflows are the source of base flows in the Daly River during the dry season and must be maintained at existing discharge rates which vary with wet season rainfall and aquifer recharge.

Scientific Basis

A series of velocity-area gaugings on 3 June and 3 September 2001 by Georges *et al.* (2002) was used to construct a mass balance of streamflow. It was clearly established that 46-63 % of the net inflow to the Daly River between Dorisvale and Oolloo crossings occurred from springs in the 9 km near the Stray Creek development area. This is the Oolloo Dolostone aquifer. Then O'Grady *et al.* (2002a; 2002b) used stable isotope composition to confirm that groundwater discharging from this aquifer was the source of river base flows. Daly River base flows had essentially the same deuterium signature as groundwater (~-44‰ v ~-45‰, respectively). Jolly (2001; 2002) found that annual recharge of aquifers in the Daly Basin varied from 0 mm in dry years to 300 mm in wet years with an average of 90 mm. Dry season streamflows (base flow discharge) are groundwater discharge and cannot be managed separately from groundwater.

Other Community Reference Group Concerns

The source of dry season base flows in the Daly River between Dorisvale Crossing and Mt Nancar is unequivocally groundwater discharge via a series of springs. Hence the confidence in this recommendation is high.

To determine that this environmental water requirement is preserved, it is essential that all pumps are metered and that all licence conditions are audited. Furthermore, there is a need to ensure that double extraction (from groundwater and then streamflow) does not occur and that the total extraction of the groundwater and surface water resource maintains these minimum streamflows. The 3 km buffer distance has been removed to ensure that all groundwater extraction does not change the location and discharge of spring inflows to the Daly River. This should be demonstrated by field measurements and/or modelling before licences are approved.

The protected groundwater levels and spring discharges should retain the perennial character of the Daly River.

4. Water Quality Environmental Water Requirements

Combination of Environmental Issues 1 and 8 from recommendations of Erskine et al. *(2003)*

Existing groundwater and surface water quality in the Daly Basin should be maintained to protect aquatic ecosystem structure and function.

Recommended Environmental Water Requirements

4.1. The ANZECC and ARMCANZ (2000) water quality guidelines should be applied to the Daly River so that seasonal trigger values based on existing conditions are set to maintain current water quality. Management responses to exceedance of specific trigger values also need to be determined.

Scientific Basis

Townsend *et al.* (2002) established that river water physico-chemical properties of the Daly River differ greatly between seasons because of differences in water sources (surface runoff in the wet season but groundwater during the dry season). Groundwater discharge from the Oolloo aquifer has very low nutrient concentrations, high electrical conductivity, pH and bicarbonate concentrations (Townsend *et al.*, 2002) and is responsible for low primary productivity during the dry season (Rea *et al.*, 2002.

Other Community Reference Group Concerns

The low turbidity and high water transparency of base flows on the Daly River during the dry season are controlled by the quality of groundwater discharge. Furthermore, the low primary productivity is determined by the low nutrient concentrations (Rea *et al.*, 2002). Hence the confidence in this recommendation is high.

To determine that this environmental water requirement is preserved, it is essential that groundwater quality is maintained and that a monitoring program of groundwater and surface water quality is implemented.

Integrated management of groundwater and surface water quantity and quality is required.

5. Additional Issues

The Northern Land Council (NLC) requested that the record of the Workshop reflect the concerns raised by Michael Storrs of NLC and Sue Jackson of CSIRO highlighting the need for inclusion of Aboriginal knowledge and values in setting environmental water requirements. Although the workshop was predominantly focused on environmental flows research, the point made was that Aboriginal people have a strong interest in protecting both environmental and cultural values. A distinction between these two value sets is not made by Aboriginal people themselves and hence it is vital that they are afforded the opportunity to contribute their ecological knowledge to environmental flows research and policy, and to participate in designing a methodology for protecting their cultural values, perhaps through the allocation of a separate 'cultural flow'.

Cultural use is a recognized beneficial use of water under the *Water Act (1992)* of the Northern Territory. While cultural water requirements can be accommodated under the legislation, a scientifically rigorous and robust method to do this and an effective method of consultation with Aboriginal people to access their knowledge have not been developed. Furthermore, the combined environmental and cultural beneficial uses of water for Aboriginal people may have to be combined.

6. Additional Recommendations

Erskine *et al.* (2003) also recommended that:

- Integrated natural resource management is introduced for the Daly River catchment.
- Natural estuarine biophysical processes and aquatic habitats are maintained.
- Groundwater-dependent ecosystems are identified and protected.
- Significant groundwater-recharge areas are identified and protected.
- High quality streamflow data are collected at all gauging stations.
- A benchmarking and monitoring program is designed and implemented.
- An adaptive ecosystem management approach is implemented along with the environmental water requirements.
- A robust, formal process for the allocation of water is developed for the Northern Territory.

Jackson (2004) made nine recommendations on Aboriginal perspectives on land-use and water management for the Daly River Region, some of which relate to environmental water requirements. While these recommendations do not explicitly refer to the National River Health Environmental Flow Initiative studies that formed the basis of the recommendations of Erskine *et al.* (2003), Aboriginal perspectives and knowledge were not canvassed by these studies. This is clearly a shortcoming that should be redressed by adopting the relevant recommendations of Jackson (2004).

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