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Hydrological Assessment for a Proposed Golf Course Development, Yulara, NT.

Prepared for Voyages Indigenous Tourism Australia Pty Ltd

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Executive Summary

As part of a referral under the *Environment Protection and Biodiversity Conservation Act 1999*, a hydrological assessment of potential impacts to the environment including impacts from increased water demand has been carried out for a proposed golf course development at Ayers Rock Resort (ARR), Yulara. The proposed ARR golf club comprises an area of 492 ha within dune fields occupying Lot 252 on land parcel, LT094/017A.

A principal concern for all users of aquifers in Uluru-Kata Tjuta National Park and Yulara is the need to operate in compliance with the principle of ecologically sustainable development in order to maintain a safe and sustainable supply of water from the aquifers. This includes ensuring support of dependent physiological and ecological systems.

Summary

- **Site hydrology alteration** – the site environs have already been subject to man-made alteration that has modified the natural drainage vectors; thus any additional intervention as a result of the proposed development, if carefully planned, will not influence the wider natural drainage.

- **Surface water** – occasional large volumes of stormwater are generated by rainfall over the catchment. This stormwater can be managed by maintaining the existing land surface with minimal surface disturbance (minimal compaction to soils and minimal landscaping). The major drainage grade to the north and north-east should be maintained by sympathetic planning of the fairways. Consideration should be given to harvesting this stormwater by means of ponds / water holes that can act as flood detention storages, a supply source providing freshwater make-up blend for irrigation, and as course features or ‘hazards’. Adaptive management of such ponds will be required otherwise they pose a danger of becoming salt ‘sinks’ (by evaporative concentration) during prolonged drought. In this regard such detention ponds should be considered as potential water sources for aquifer recharge.

- **Groundwater** – whilst the sustainable yield of the Dune Plains Aquifer (the major water supply source for Yulara) is poorly defined, estimates of its throughflow and its storage volume are considered conservative. The estimated total water demand (current user and anticipated development) is only some 1.2 % of the volume of groundwater in the DPA, and whilst some mining of groundwater will occur locally, such mining is considered sustainable because of intermittent natural recharge events to the aquifer. The perched water-table underlying the adjacent tree-lot presents an opportunity for resource use for the proposed development, either by direct supply of lower salinity (than the native groundwater) treated effluent from the Yulara wastewater treatment plant or via a managed aquifer recharge scheme.

- **Soil salinisation** – the use of the native groundwater from the DPA for irrigation is problematic in terms of soil salinisation and may impact the natural ecosystem. Instead, it is recommended that a blend of treated wastewater and groundwater be used (approximately 67%/33%, respectively); ideally supplemented by detained stormwater and /or potable (desalinated) water, to achieve an irrigation application quality of less than 1000 mg/L total dissolved salts (TDS) at all times. A TDS concentration threshold of less than 1000 mg/L should not be detrimental to the wider environment. This coupled with careful landscape and drainage design (possibly incorporating agricultural drains to assist drainage of low-lying areas), should combat soil salt build-up.

Catchment description and condition

Within Lot 252 centripetal drainage is evident resulting from a reticulate (star-shaped) dune formation that dominates its central northern sector.

The catchment encompassing Lot 252 drains an area of 294 km^2 made up of inter-dunal drainages, flood-outs and minor ephemeral creeks emanating from the southern edge of The Sedimentaries.

The flood-outs of the sand plains to the west of Lot 252 capture and concentrate nutrients and are biologically productive. Here mulga (*Acacia aneura*) groves form in "run-on" zones where sheet-water flow infiltrates from adjacent run-off areas. They may function as important refugia for flora and fauna including rare and endangered fauna.

The catchment to the south of the proposed development can be considered to be unmodified apart from the major sealed road (to Kata Tjuta) that bisects it, whilst the northern part of the catchment has been greatly modified by the development of Yulara. Stormwater 'cut-off' drains of the road network impede natural run-off and have dislocated the run-on zones.

Red earths, sandy loams and red earth sands formed on gently sloping sand plains (Kandosols) make up 70 % of Lot 252 in the west, whilst shallow, red siliceous sand and red earth sands; constituting sand dunes (Tenesols) occupy the eastern third.

In the neighbouring tree-lot north of Lot 252, the substrate is described as a permeable surficial silty fine sand (about 2.8 m thick) overlying a much less permeable 'very sandy clay' (dominant silt fraction) about 3 m thick, underlain by a more permeable clayey sandstone (upper strata of the Dune Plains Aquifer).

Hydrology

Mean monthly open pan evaporation exceeds rainfall in all months of the year; and on an annual basis by more than four-fold.

Occasional major rainfall events can yield enormous volumes of runoff (for a 3.5 mm/hour intensity rainfall event, consistent with maximum daily rainfalls, the catchment could produce of the order of 300ML/hr), and are important, hydrologically and ecologically, in recharging aquifers and for sustaining ecosystems. Any disruptions to overland flow can result in adverse effects to the soils and vegetation.

There are no known water holes in the study area.

Hydrogeology, aquifer sustainable yield and groundwater dependent ecosystems

Lot 252 overlies the Dune Plains Aquifer (DPA). Accessions to the water-table may occur via runoff recharge from sand hills / dunes and The Sedimentaries. In the northern extremity of Lot 252 the groundwater system is modified by flood irrigation of treated effluent to an abandoned tree-lot adjacent to Yulara's wastewater treatment plant (WWTP). Here a perched water-table aquifer has formed a local groundwater mound within the DPA. Vertical infiltration of this treated effluent appears to be relatively rapid.

There is a huge storage of marginally potable to brackish groundwater that is large in proportion to throughflow, recharge and usage. The sustainable yield of the DPA is not known; coarse, conservative estimates of its throughflow are 200 ML/year and its storage volume, 90,000 ML.

Despite nearly thirty years of withdrawal of groundwater from the DPA through pumping to meet water demand at Yulara there has been little impact with respect to derogating this water resource. Only localised 'cones of pumping drawdown' from the impacts of pumping have developed.

Current abstraction of groundwater of about 737 ML/year is in excess of the estimated throughflow of the DPA but is only some 0.8 % of available aquifer storage.

Despite 'pulse' rainfall-recharge events, surface water is disconnected from the water-table as the depth to the water-table precludes direct evaporation except, in the artificially induced groundwater mound beneath the tree-lot, and deep-rooted trees (e.g. Desert Oak) that are not prevalent in the study area. There has been a hypothesis that fauna, notably the Mulgara, are dependent on the water-table but this is believed to be a facet of moisture availability in the run-on areas.

Soil and groundwater salinity

In the tree-lot adjacent to Lot 252 previous study has indicated possible salt accumulation at the root zone (to 2 - 3 m depth) with decreased salinities deeper in the soil profile suggesting good infiltration via preferred vertical flow-paths. The study indicated the potential for remobilisation of salts stored within the soil profile particularly in the western portion of the tree-lot. The salinity of the perched water-table aquifer was about 1,400 - 2,200 mg/L TDS.

Native groundwater of the DPA is brackish (~2,000 - 2,400 mg/L TDS).

Current water users

Power and Water (PWC) is the operator of the Yulara water supply. The DPA supplies water to Yulara / Ayers Rock Resort from two wellfields, the 'New (or Northern) Wellfield' and the 'Old (Southern) Wellfield'. Apart from PWC there are no known competing water users exploiting the DPA.

Total water production for year, 2011 was 737.39 ML including 290.05 ML of treated (desalinated) potable water and 317.55 ML of non-potable water (not desalinated).

The salinity of the blend of raw water extracted from the two wellfields is about 1,500 mg/L TDS. The raw water is hard and high in nitrate. The potable water has an average salinity of about 210 mg/L TDS; the non-potable water has an average salinity of about 1,400 mg/L TDS.

Lot 252 lies outside the pumping capture zones of both of PWC's wellfields serving Yulara. Hence, the proposed development will not impact drinking water sources.

Water demand and sources

The anticipated water demand for the proposed golf course is 344.07 ML/year. Irrigation demand is seasonal ranging from a minimum daily average demand of 0.39 ML (13.5 L/s over an 8 hours irrigation period) in July to a maximum daily average demand of 1.61 ML (55.8 L/s over 8 hours) in January.

In order to satisfy the maximum monthly demand a bore capacity of 18.6 L/s instantaneous would be required. Given a typical bore pumping cycle of 12 hours pumping and 12 hours non-pumping would require three (3) new bores pumping approximately 12.5 L/s each. As peak irrigation rates over an

8 hours cycle exceed the instantaneous flow capacity of these proposed bores, balancing storage tanks would be needed.

The estimated water demand of 344.07 ML/year combined with the current take of 737.39 ML/year for Yulara would amount to approximately 1,081.5 ML/year. This volume is only some 1.2 % of the volume of groundwater in the DPA.

The use of the native groundwater (at its best, 1,500 mg/L TDS) from the DPA for irrigation is problematic in terms of soil salinisation.

The use of recycled treated wastewater from the Yulara WWTP might be considered. 231 ML/year is currently being disposed at the tree-lot with a quality of approximately 980 mg/L TDS and a SAR of 4.7 ('Class 3' for salinity of irrigation water - this salinity is considered high for soils with impeded or poor drainage, but given good infiltration rates and with careful management, should be suitable). This would provide on an annual basis 67 % of the estimated irrigation demand. Pre-treatment would be required to Class A standard unless a strict regime of non-contact irrigation was implemented.

To meet annual demand a blend of recycled treated wastewater and groundwater will be required (230 ML wastewater plus 114 ML groundwater). An option to reduce salinity is to negotiate the delivery of a quantity of potable water from PWC, but irrigation application may be perceived as inappropriate use of 'high value' water.

PWC's desalination plant's evaporation basin is too far down groundwater gradient to have any impact on Lot 252.

Water diverting activities

Water diverting activities will depend on the source of water for the proposed development.

Should groundwater be used then the infrastructure footprint should be minimal (say, three bore head-works and power control sheds in fenced compounds) with associated pipe to / or within Lot 252 to connect with the irrigation system.

Should treated wastewater be the source water then a delivery pipeline from the adjacent WWTP's holding basins together with a transfer pump would be needed. Should treatment to Class A be required then a treatment plant; this would probably be situated at the intake end; i.e. within PWC's WWTP land if agreed with PWC.

Should a combined recycled / groundwater blend be considered then the infrastructure would be a combination of the above.

Unless direct supply to the irrigation system is envisaged then a holding tank would be needed of about 1,500 kL capacity to allow for approximately 24 hours storage.

Major development risks

The main impacts to be avoided by the proposed development concern stormwater control, preservation of native mulga groves and avoidance of soil salinisation. Groundwater related impacts would chiefly consist of localised increases of pumping drawdown from increased water extraction.

Overall, the maintenance of the mulga groves on the sand plain country is critical to the maintenance of associated flora and fauna including endangered species. The major threat to these systems is disruption to surface water runoff sheet-flow.

The planting and maintenance of turf inevitably will alter the surface water drainage regime. Lot 252 is surrounded by roads and immediately to the north is situated the Yulara WWTP. These features already create a disruption to natural flow patterns; hence the area of disruption will be minimised to within the area bounded by this existing infrastructure.

Within the undeveloped Lot 252 it is probable that surface water pools in inter-dunal areas during rainfall events. These sites may be less susceptible to alteration of the drainage pattern than the mulga groves and, as such, there should be limited impact from the proposed golf course footprint.

Impacts to the water-table of the DPA will arise from pumping groundwater for irrigation. Whilst the sustainable yield of the DPA has not been determined, regional impacts to the water table via the additional demand would result in a further decline in the water-table of about 1 metre, with a local cone of pumping drawdown around each irrigation bore of about 5 m or more.

In detail the major development risks are considered to be;

- altering pre-existing drainage conditions that facilitate impacts (e.g. erosion) beyond the boundaries of Lot 252, especially to the sand plain country to the west;
- the potential for soil erosion by changed runoff dynamics, and possibly through inappropriate vehicle and plant use particularly during the construction phase;
- impedance to aquifer recharge by reworking, import and the compaction of soils during golf course construction;
- long-term, insidious soil salinisation from the uncontrolled disposal of treated effluent to the abandoned tree-lot from the Yulara WWTP that may be encroaching the northern part of the proposed development, possibly exacerbated by irrigation application of water of the same or worse salinity;
- a possible requirement to irrigate with desalinated (potable quality) water to prevent salt accretion in the soil that may be prohibitively expensive and considered an inappropriate use of ‘high value’ water;
- providing adequate irrigation water especially during the summer (in addition to the current high per capita demand for potable water for Yulara);
- damage to infrastructure foundations (e.g. proposed club-house) from soil salinisation (if located adjacent to the Yulara WWTP as indicated on ILC Map No. 1864);
- other localised risks such as invasion by pests (e.g. rabbits, exotic weeds) if not controlled and possible impacts of by-products of control methods;
- short-term water quality impacts from construction might include;
    - increase in suspended solids (sediment) of runoff associated with earthworks and landscaping;
    - nutrients associated with any construction camp ablution facilities;

- long-term water quality impacts from irrigation might include;
  - increase in soil salinity and sodicity dependent on the quality of application water;
  - build-up of soil salinity due to increased evaporation from irrigation returns;
  - possible groundwater mounding should excessive irrigation be practised;
  - use of herbicides applied to turf;
  - use of fertilisers applied to turf;
  - nutrients from ablution facilities associated with the club-house and related facilities

Mitigation strategies to minimise potential impacts

The following mitigating strategies are invoked to combat the perceived risks;

- contouring of any land development sympathetic with pre-existing drainage conditions so as to minimise changes in natural surface water drainage including maintaining the natural drainage grade to the north and north-east to prevent centripetal drainage that could initiate soil salt build-up;
- consider the use of agricultural drains to assist drainage of low-lying areas of the landscaping of the proposed golf course;
- the soils should not be compacted during construction and landscaping activities;
- it is important that the soils in this area of localised internal drainage exhibit good infiltration properties as the application of irrigation water could lead to a build-up of salts depending on the water quality of the applied water. Therefore on-site soil investigations should be undertaken to ascertain the infiltration capacity of the soils at Lot 252;
- stormwater flooding alleviation works will need to be considered for the proposed golf course that may impact the natural environment;
- although the local perched water aquifer underlying the tree-lot locally influences the groundwater system particularly in the northern part of Lot 252, it presents an opportunity for resource use for the proposed development, either by direct supply of lower salinity (than the native groundwater) treated effluent from Yulara WWTP or via a managed aquifer recharge scheme;
- tacit recognition that the additional groundwater extraction required for the proposed development may, inevitably, require the aquifer to be mined due to the rare, but significant recharge events experienced in this semi-arid environment;
- a salinity and irrigation management plan needs to be developed to appropriately manage and minimise soil salinisation.

Contents

Figures & Tables

1 Introduction

1.1 Background and Study Location

Australian Groundwater Technologies Pty. Ltd. (AGT) was commissioned by Voyages Indigenous Tourism Australia Pty Ltd to conduct a hydrological assessment of potential impacts to the environment including impacts from increased water demand for a proposed golf course development at Ayers Rock Resort (ARR), Yulara.

Yulara is located approximately 4 km due north of the northern boundary of the Uluṟu-Kata Tjuṯa National Park (UKTNP) (Figure 1). It exists as a service centre mostly for tourists visiting the World Heritage Site of UKTNP.

Yulara was declared in 1984 as a 10,400 ha reservation and approved for the development of a tourist facility and an associated airport.

A consequence of this World Heritage listing is that any development occurring within and in the vicinity of the UKTNP may trigger the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). As part of the feasibility and investigation studies a Referral under the EPBC Act is required including an assessment of the impact of the proposed development on surface water and groundwater.

The proposed ARR golf club comprises an area of 492 ha occupying Lot 252 on land parcel, LT094/017A. It is bounded to the east by the Lasseter Highway/Uluru Road, to the south by the UKTNP, and to the north by the Yulara wastewater treatment plant (Yulara WWTP), and an associated abandoned wood-lot. Both the ARR and the UKTNP are surrounded by Aboriginal freehold land held by the Petermann and Katiti Land Trusts.

The anticipated water demand for the proposed golf course is nearly 345 ML/year.

Reference is made in this report to the study region, study area and Lot 252, respectively. Generally, the study region refers to the UKTNP and wider region (as depicted by Figure 1), whereas the study area refers to the area that includes the estimated local catchment area to the proposed land development at Lot 252 (as depicted in Figure 1, Figure 9 and related figures that show this local catchment boundary). The proposed land development area (viz. the 'study site') is herein referred to as 'Lot 252'.

It is understood that the Northern Territory Government is considering establishing a Water Control District covering the UKTNP and adjacent Katiti Land Trust lands. Further details are not known of what the implications could be to any water taking activities.

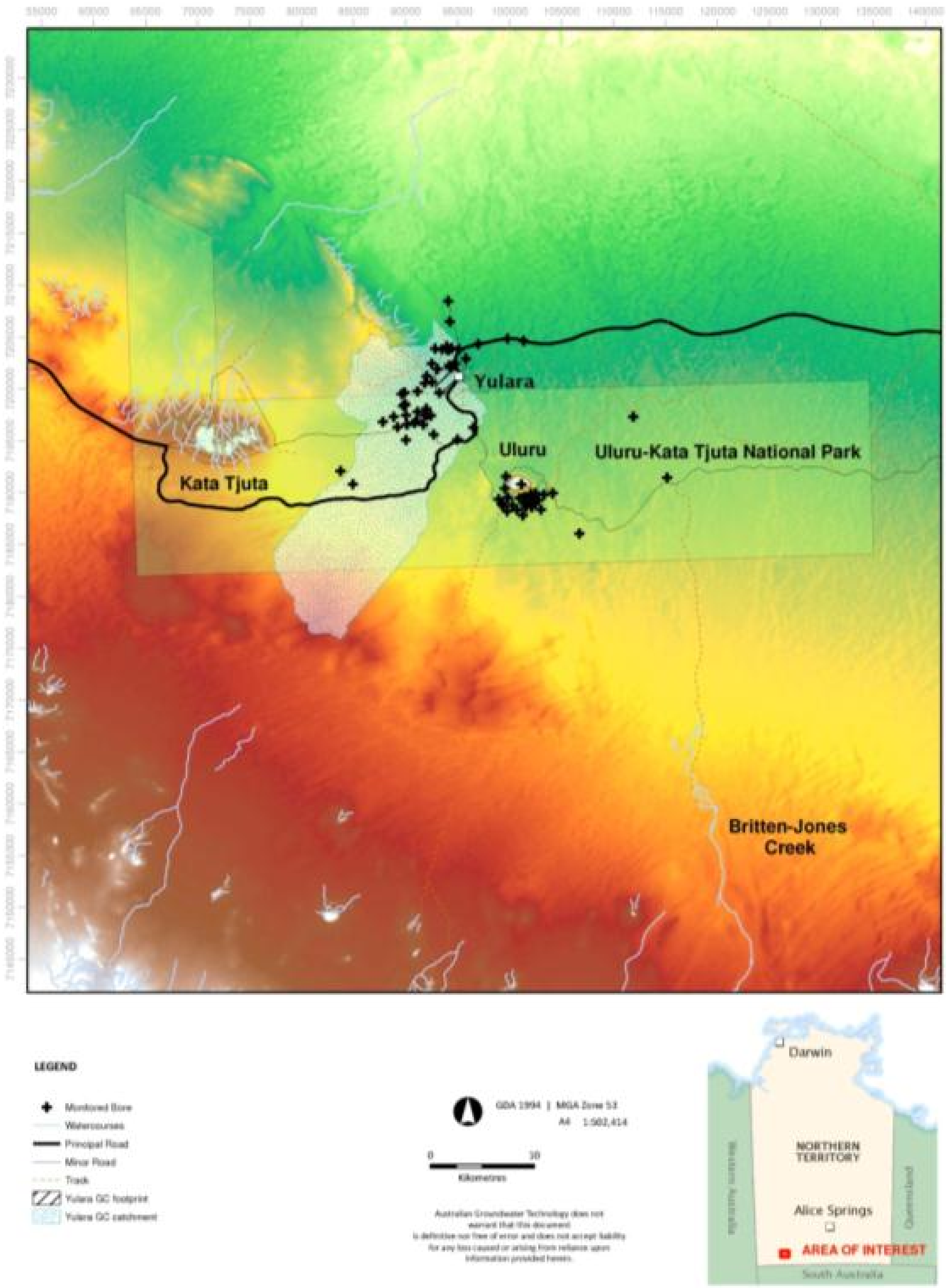

Figure 1 Location map of Yulara and proposed golf course catchment 'footprint' in relation to the Uluru-Kata Tjuta National Park

1.2 Scope of work

In order to satisfy the Referral, the following tasks are addressed in terms of their potential for deleterious impacts to the natural environment resulting from the proposed development;

- confirm and appraise the water source(s) and demand that is being considered for use (construction water for dust suppression and site stabilisation, to establish the fairways and greens, and for their ongoing irrigation). A number of source options may be available including;
    - recycled treated wastewater;
    - brackish groundwater;
    - blended recycled water / groundwater / desalinated water;
- understand the water (and salt) balance taking into account the construction and grassing schedules combined with monthly weather data;
- understand the proposed operational philosophy including type and rates of irrigation application to assess the impacts to the receiving environment including the soils, groundwater and natural drainages (cf localised soil salinisation / sodicity and salinisation / contamination of the aquifer from application of brackish groundwater and/or recycled water);
- determine any treatment requirements of that water source(s) to maintain the selected turf and implication of any treatment by-products (e.g. from the reverse osmosis of brackish groundwater, and/or treatment of recycled wastewater from Class B to Class A) to the receiving environment;
- examine the potential for impacts to the micro-environment within the local and wider area to the soil structure and landform stability, and native biota;
- assess other impacts to the environment from irrigation related infrastructure.

2 Hydrology and Hydrogeology

2.1 Rainfall

The Bureau of Meteorology measures daily rainfall and evaporation at Meteorological Station #015635, Yulara Airport (Table 1)[1].

Table 1: Summary of Rainfall and Evaporation Gauges, Yulara Airport

Station Name	Station Number	Parameter	Location (Lat/Long)	Elevation (mAHD)	Period of Record
Yulara Aero	015635	Daily Rainfall	25° 11' 23"S 130° 58' 25"E	492	Jun 1983 - present
Yulara Aero	015635	Daily Evaporation	25° 11' 23"S 130° 58' 25"E	492	Jun 1983 - Jul 1988

Figure 2 graphs mean monthly rainfall and evaporation data and Figure 3 graphs daily rainfall for Yulara Airport. These measurements commenced in 1983 and are ongoing but at times have been discontinuous; note the period on Figure 3, 1989 to 1994 inclusive is not nil rainfall but incomplete record.

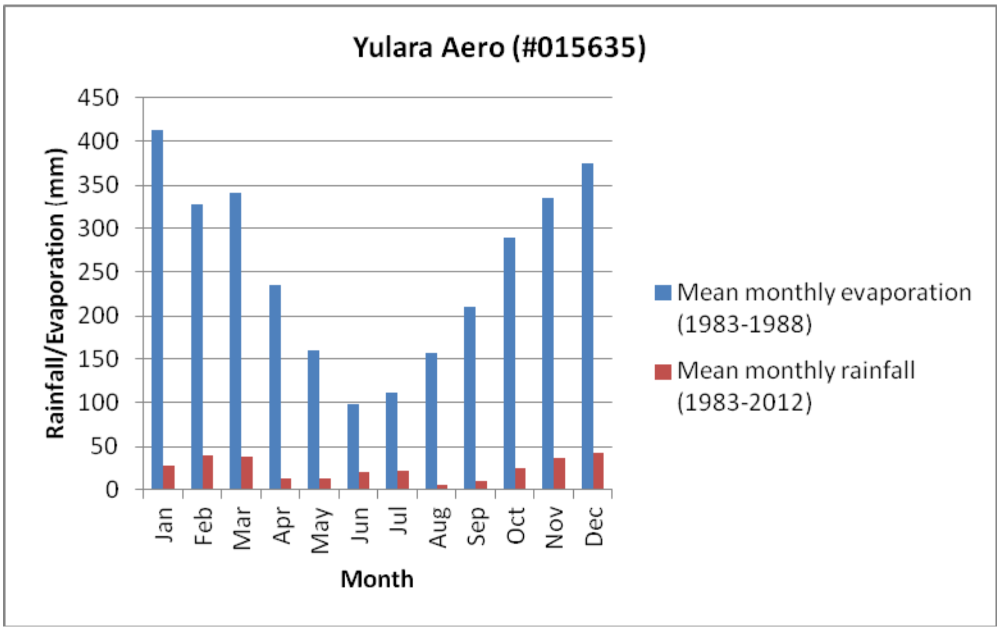

Figure 2: Mean monthly rainfall and pan evaporation, Yulara Aero (#015635)

[1] The duration of record at the nearby UKTNP Ranger Station (#015660) is too short for use in statistical analysis and has been disregarded.

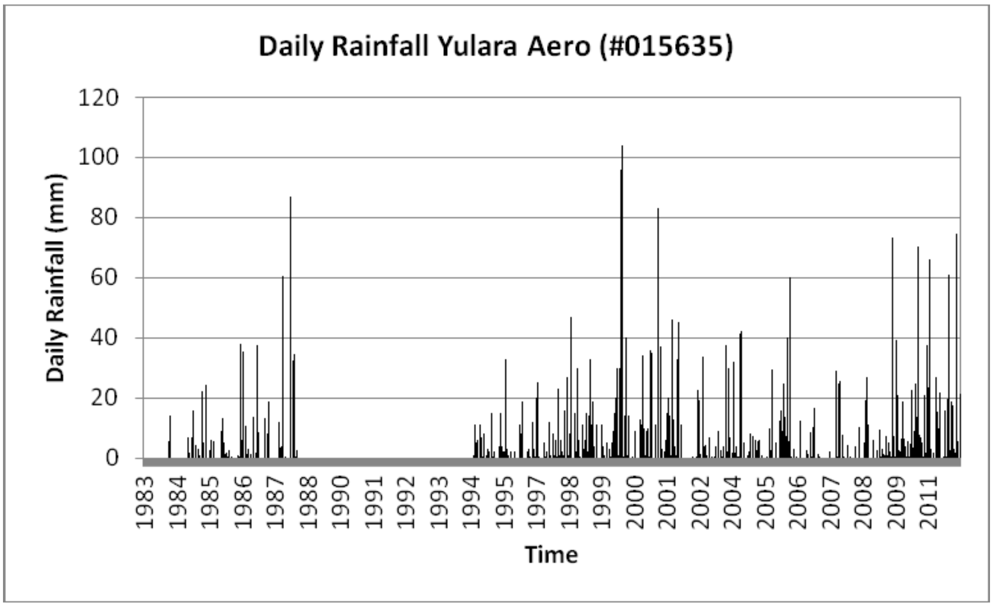

Figure 3: Daily Rainfall recorded at Yulara Aero (#015635)

Mean monthly open pan evaporation exceeds rainfall in all months of the year; and on an annual basis by more than four-fold, so that rainfall is evaporated and is transpired by vegetation or moistens the soil profile only. Weather systems resulting from the occasional southward migration of the Inter-Tropical Convergence Zone may bring substantial rainfall to Central Australia. Standing water can then pond for many days, or even weeks, and may allow deep infiltration and groundwater recharge.

Several floods have occurred in living memory in the UKTNP after heavy, prolonged and, at times, intense falls of rain.

Notable rainfall events recorded at Yulara / Uluru since records began are:

- January – May 1974: 516 mm recorded (Uluru - UKTNP Ranger Station);
- February – March 1982: 413 mm recorded (Uluru);
- December 1988: 199 mm (Uluru); (no record Yulara);
- March 1989: 419 mm (Uluru); (no record Yulara);
- 10th to 24th February 2000: 225 mm (Uluru); 349 mm (Yulara);
- November 2000: 130 mm (Uluru); 104 mm (Yulara);
- March 2001: 202 mm (Yulara);
- June 2001: 134 mm (Uluru); 147 mm (Yulara);
- December 2001: 244 mm (Uluru); 220 mm (Yulara);
- February 2002: 154 mm (Uluru); 135 mm (Yulara);
- October 2010 116.2 mm (Yulara);
- March 2011 133.2 mm (Yulara);
- November 2011 102.6 mm (Yulara).

Rainfall in the years, 1974, 1989, and period 2000 to 2002 was exceptional.

A ranked probability of daily rainfall exceedances for Yulara Aero (#015365) is plotted as Figure 4.

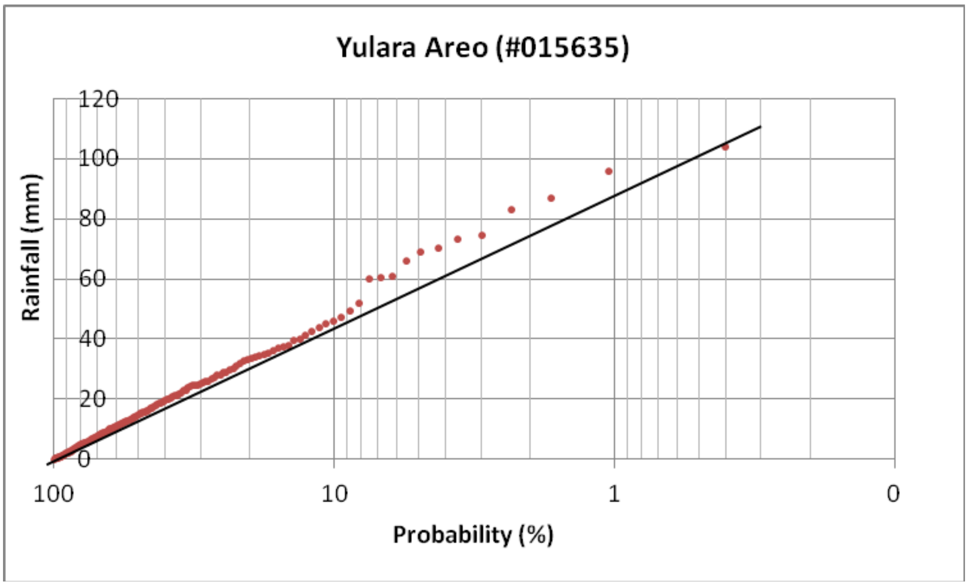

Figure 4: Ranked probability of rainfall Yulara Aero (#015365)

Return periods for the five recorded largest daily rainfall values at Yulara Airport are:

- 248 years 104 mm/day on 20th February 2000;
- 96 years 96 mm/day on 10th February 2000;
- 59 years 87 mm on 31st March 1988;
- 43 years 83 mm on 12th June 2001;
- 34 years 75 mm on 1st March 2012.

The first two return periods are from the same weather system that impacted the region in 2000 with nearly 350 mm of rain recorded over two weeks.

Simplistically, the ‘near 100 year event’ of 96 mm of rain could have generated about 11,000 ML of runoff over the local catchment area taking into account catchment losses (see Section 2.2.2 for further discussion).

It should be borne in mind that this analysis is for only 24 years of rainfall data and so is conservative. Given climate change predictions of more infrequent, more intense rainfall in Central Australia, future rainfall exceedances may well surpass the figures given above[2].

[2] Rainfall total is not predicted to vary much from the present, but may result from more intense rainfall events. With increased evaporation, the overall result is likely to be a net loss of surface water (Hyder, 2008 reported in Director of National Parks, 2010).

2.2 Surface Water

2.2.1 Catchment Definition

On a national scale, Yulara is located within the Mackay Drainage Basin of the Western Plateau Drainage Division http://www.bom.gov.au/hydro/wr/basins/basin-hi_grid.jpg.

At a regional scale, ill-defined catchments flanking the Petermann Ranges to the south-west slope imperceptibly in a north-easterly direction towards Lake Amadeus.

Surface water is largely restricted to seasonal pools fed by short, shallow watercourses from Uluru (and Kata Tjuta). Defined water courses do not exist in the dune formations dominating the UKTNP, although swales are moister and ponding occasionally occurs. The sole defined watercourse is ephemeral; namely Britten-Jones Creek (see Figure 1), and is situated well to the south-east of the study area.

Using the digital elevation model (DEM) (Geofabric v 2.0, BoM 2011), Figure 1 defines a local catchment area of area 294 km^2 for Lot 252. This catchment grades initially in a north-easterly direction, then sweeps around the rocky outcrops of The Sedimentaries, past Yulara township to trend in a northerly direction towards Yulara Airport and ultimately towards Lake Amadeus. Drainage within this sub-catchment is composed of inter-dunal drainages, minor ephemeral creeks and flood-outs consisting of several ephemeral watercourses, including many minor watercourses emanating locally from the southern edge of The Sedimentaries.

2.2.2 Local Catchment Yield

Given the absence of perennial streams there are no surface water gauging stations in the area. Consequently it is difficult to assess stream flow; hence catchment yield.

The assessment of rainfall (Section 2.1) indicated that while rainfall is low for most years it does occur and often as intense storms, and occasionally as long duration events. By estimating parameters and applying the Rational Method the catchment yield can be determined.

The Rational Method expresses a relationship between rainfall intensity and catchment area as independent variables and the peak flood discharge resulting from the rainfall as the dependent variable (Mainroads Western Australia, 2002):

$$Q = CIA$$

where:

Q = Peak discharge;
C = Rainfall-runoff coefficient;
I = rainfall intensity; and,
A = drainage area.

The drainage catchment that Lot 252 is located within has an area of 294.28 km^2

The Intensity-Frequency-Duration design rainfall chart for Yulara is shown in Figure 5 (Bureau of Meteorology, no date).

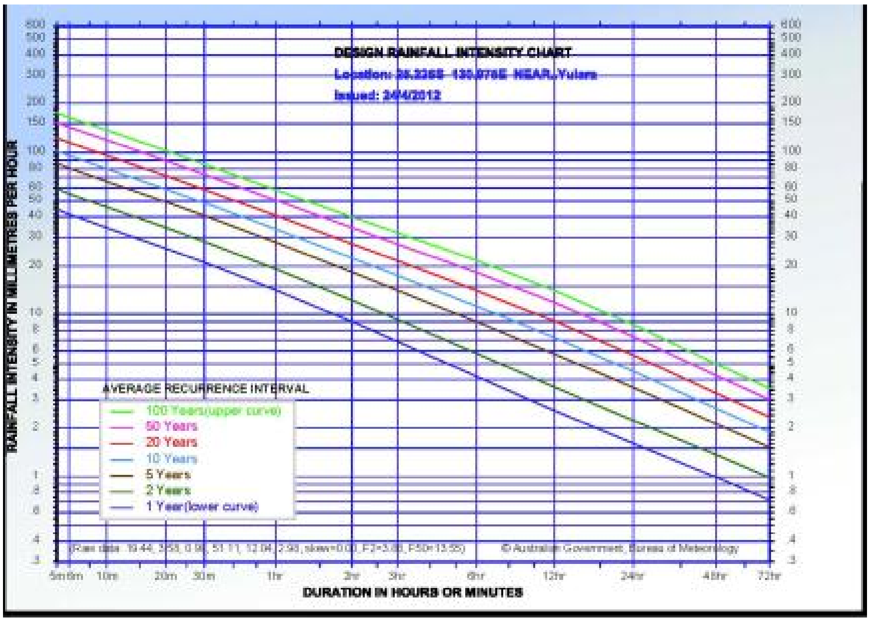

Figure 5: Design Rainfall Intensity Chart for Yulara (Bureau of Meteorology, no date)

For a 1 in 5 year storm[3] with a duration of 24 hours the rainfall intensity is 3.5 mm/hr.

From published tables the runoff coefficient, *C* for a 1 in 5 year flood is:

- undeveloped desert = 0.3-0.4; or,
- bare ground = 0.2-0.3[4].

Rational Method

Table 3.2
C Coefficients for Use with the Rational Method

Land Use	Return Period 2-10 Year	25 Year	50 Year	100 Year
Streets and Roads				
Paved Roads	0.75 – 0.85	0.83 – 0.94	0.90 – 0.95	0.94 – 0.95
Gravel Roadways & Shoulders	0.60 – 0.70	0.66 – 0.77	0.72 – 0.84	0.75 – 0.88
Industrial Areas				
Heavy	0.70 – 0.80	0.77 – 0.88	0.84 – 0.95	0.88 – 0.95
Light	0.60 – 0.70	0.66 – 0.77	0.72 – 0.84	0.75 – 0.88
Business Areas				
Downtown	0.75 – 0.85	0.83 – 0.94	0.90 – 0.95	0.94 – 0.95
Neighborhood	0.55 – 0.65	0.61 – 0.72	0.66 – 0.78	0.69 – 0.81
Residential Areas				
Lawns – Flat	0.10 – 0.25	0.11 – 0.28	0.12 – 0.30	0.13 – 0.31
– Steep	0.25 – 0.40	0.28 – 0.44	0.30 – 0.48	0.31 – 0.50
Suburban	0.30 – 0.40	0.33 – 0.44	0.36 – 0.48	0.38 – 0.50
Single Family	0.45 – 0.55	0.50 – 0.61	0.54 – 0.66	0.56 – 0.69
Multi-Unit	0.50 – 0.60	0.55 – 0.66	0.60 – 0.72	0.63 – 0.75
Apartments	0.60 – 0.70	0.66 – 0.77	0.72 – 0.84	0.75 – 0.88
Parks/Cemetaries	0.10 – 0.25	0.11 – 0.28	0.12 – 0.30	0.13 – 0.31
Playgrounds	0.40 – 0.50	0.44 – 0.55	0.48 – 0.60	0.50 – 0.63
Agricultural Areas	0.10 – 0.20	0.11 – 0.22	0.12 – 0.24	0.13 – 0.25
Bare Ground	0.20 – 0.30	0.22 – 0.33	0.24 – 0.36	0.25 – 0.38
Undeveloped Desert	0.30 – 0.40	0.33 – 0.44	0.36 – 0.48	0.38 – 0.50
Mountain Terrain (Slopes > 10%)	0.60 – 0.80	0.66 – 0.88	0.72 – 0.95	0.75 – 0.95

Note: Values of C for 25, 50 and 100 Year were derived using frequency adjustment factors of 1.10, 1.20, and 1.25, respectively, with an upper limit of 0.95 for C for the 2-10 Year values.

June 1, 1992 3-5

[3] Typical open 'estate' stormwater drainage design return period for northern Australia.
[4] Note that the selection of a suitable rainfall-runoff coefficient for the catchment is a significant factor affecting the estimate of the runoff volume.

$$Q = 0.4 \times 0.0035 \times 294282358 = 411{,}995 \text{ m}^3/\text{hr} = 412 \text{ ML/hr}$$

$$Q = 0.3 \times 0.0035 \times 294282358 = 308{,}996 \text{ m}^3/\text{hr} = 309 \text{ ML/hr}$$

$$Q = 0.2 \times 0.0035 \times 294282358 = 205{,}998 \text{ m}^3/\text{hr} = 206 \text{ ML/hr}$$

Therefore, estimates project that for a given high intensity rainfall event (3.5 mm/hour which is consistent with maximum daily rainfalls reported in Section 2.1), the local catchment could produce enormous volumes of water.

This simple analysis indicates that stormwater flooding alleviation works will need to be considered for the proposed golf course that may impact the natural environment. This is discussed in Section 4.

2.2.3 Drainage Morphology and Surface Water Quality

The major rainfall events are important, hydrologically and ecologically, in recharging aquifers and for sustaining ecosystems. Any disruptions to overland flow can result in adverse effects to the soils and vegetation. An example of this is given in Appendix A (Figure A.1) where vegetation appears to atrophy across a road cut-off drain.

Flood-outs are common in Central Australia, where water is lost slowly (by evapo-transpiration and percolation) and sediment is deposited over long reaches in semi-flat or undulating country. Flow energy dissipates along the channel by ‘overbank floods’, triggered by in-channel vegetation and/or by in-channel sedimentation. Such channels on plains tend to be shallow, with low levees, so overbank flooding occurs easily. When water is lost, it is the inability of the river to transport sediment, and choking of the system with deposited material, that can force branching of the channels and produce distributaries. The distal reaches often terminate as a ‘flood-out’.

In the sand plains around Yulara flood-outs occur on a relatively small scale; nevertheless they are significant in terms of nutrient capture and concentration. They are representative of the erosion cells described by Pickup (Pickup, 1985; Bourke & Pickup, 1999, as reported in AGT (2003); these so-called "STF" units are characterised by scour zones (S) dominated by erosion of sediment; transport zones (T) dominated by sediment bypass or temporary storage, and fill or sink zones (F) of relatively permanent sediment deposition. Figure 6 and Figure 7 show the development of flood-outs in section and plan, respectively.

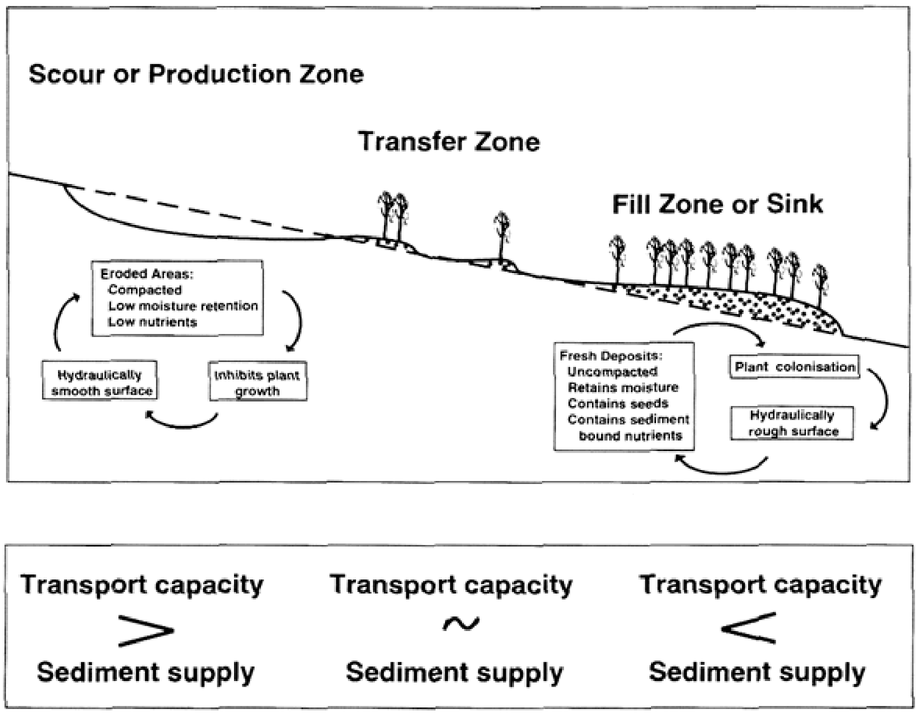

Figure 6: Floodout development - Conceptual model (after Pickup (1985))

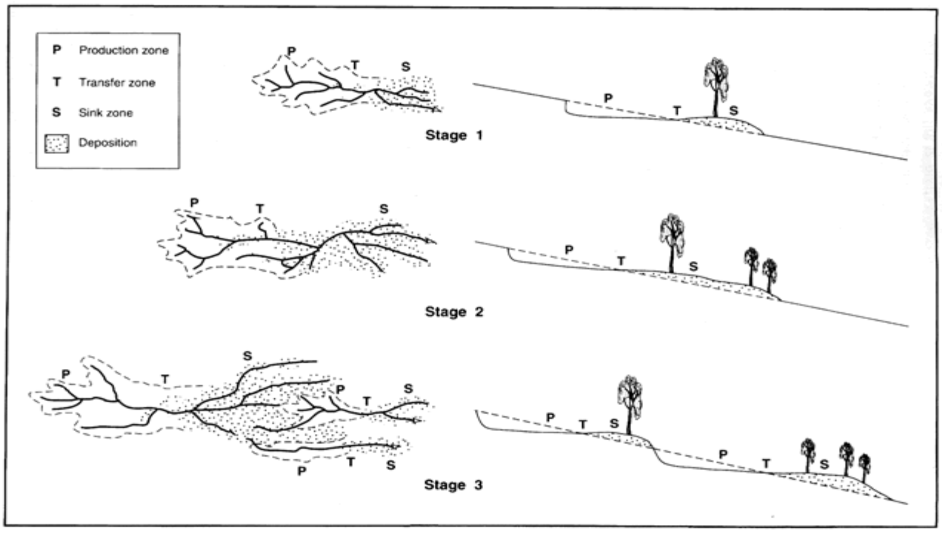

Figure 7: Development of a typical flood-out (after Bourke & Pickup (1999))

AGT (2003) reported on research in UKTNP that highlighted the significant interaction between landform, surface water runoff and groundwater recharge to the distribution and health of vegetation and native fauna[5].

The dominant vegetation is bands of mulga (*Acacia aneura*) groves perpendicular to the topographical slope. These mulga groves forms in "run-on" areas (represented by

[5] Several rare and endangered fauna are nominally associated with these run-on mulga groves, including the Mulgara *Dasycercus cristicauda*, Great Desert Skink *Egernia kintorei* and Hairy-Footed Dunnart *Sminthopsis hirtipes* (Reid & Hobbs 1996).

F zone in Figure 6 and Figure 7), which receive increased levels of moisture via sheet water flow from adjacent run-off areas and have faster infiltration rates compared to the run-off areas. These groves retard and trap transported nutrients, resulting in greater plant growth and productivity. They may function as important refugia for flora and fauna including rare and endangered fauna. Consequently, their maintenance is critical. An insight to this is given in the remotely sensed images in Appendix A (east of Yulara airport in Figure A1 and, in detail, far southern (bottom) part of Figure A.2 where run-on areas adjacent to dunes are observed).

There is no substantive evidence that links the formation of mulga bands and their ongoing existence and productivity to aquifers as the water-table is too deep[6]. The major threat to these systems is disruption to sheet flows caused by infrastructure and changes in the level and types of anthropomorphic activities in the area. These activities may lead to increased erosion in some areas, or decreased or diverted flows in others. Burrowing animals are not affected by the depth, or composition, of groundwater in this area. The depth of burrows is well above the depth of the water table. The main threat to flora and fauna in the region is changes to biophysical processes at the surface. Hence changes to surface water flows plus inappropriate remedial action remain the key threats to the biota of the region.

2.2.4 Local Natural Drainage

Figure 8 provides a visual interpretation of local drainage lines within and in the vicinity of Lot 252. A centripetal drainage is evident resulting from a reticulate (star-shaped[7]) dune formation that dominates the central northern sector of Lot 252. It is important that the soils in this area of localised internal drainage exhibit good infiltration properties as the application of irrigation water could lead to a build-up of salts depending on the water quality of the applied water.

Several shallow auger holes should be opened and the soils logged. The auger holes should be subject to falling head infiltration tests to assess the soil's drainage properties.

Should the development proceed, the soils should not be compacted during construction and landscaping activities.

[6] However, in areas near The Sedimentaries water may pond at much shallower depths, of the order of 6 m. In these areas there may be vegetation systems and individual plant species such as Desert Oak *Casuarina decasneana* and Ironwood *Acacia strophyliana* that may be linked to groundwater supplies near the surface.

[7] Possibly formed by the coalescence of at least two lunette dunes.

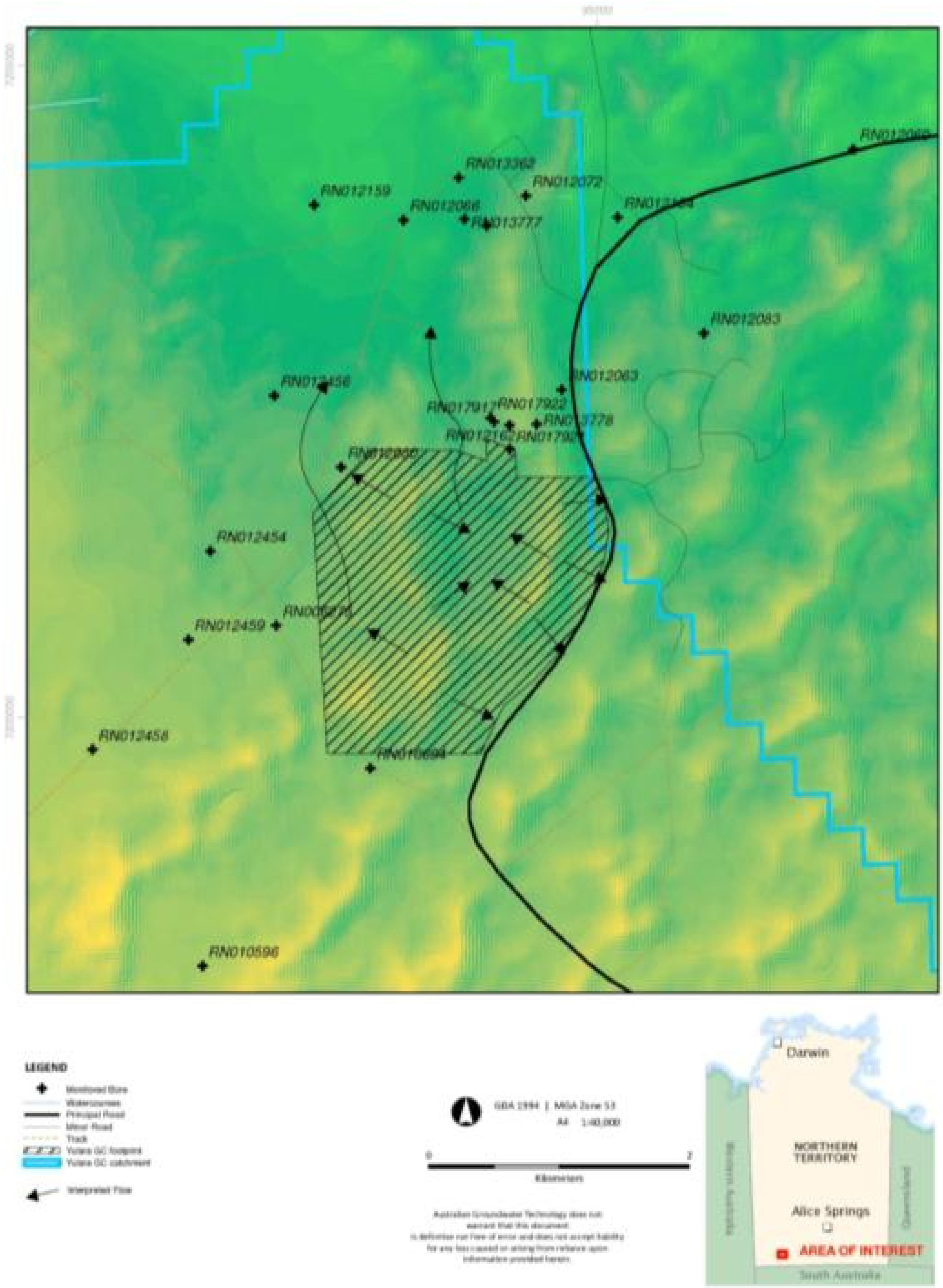

Figure 8 Lot 252 Local Drainage Vectors (from DEM derived from BoM Geofabric)

2.3 Geology

It is important to appreciate the recent (Cainozoic Period) geological history of UKTNP as it controls the hydrogeology including the presence and distribution of the aquifers.

Figure 9 and Figure 10 present a geological map and timescale, respectively of the UKTNP region.

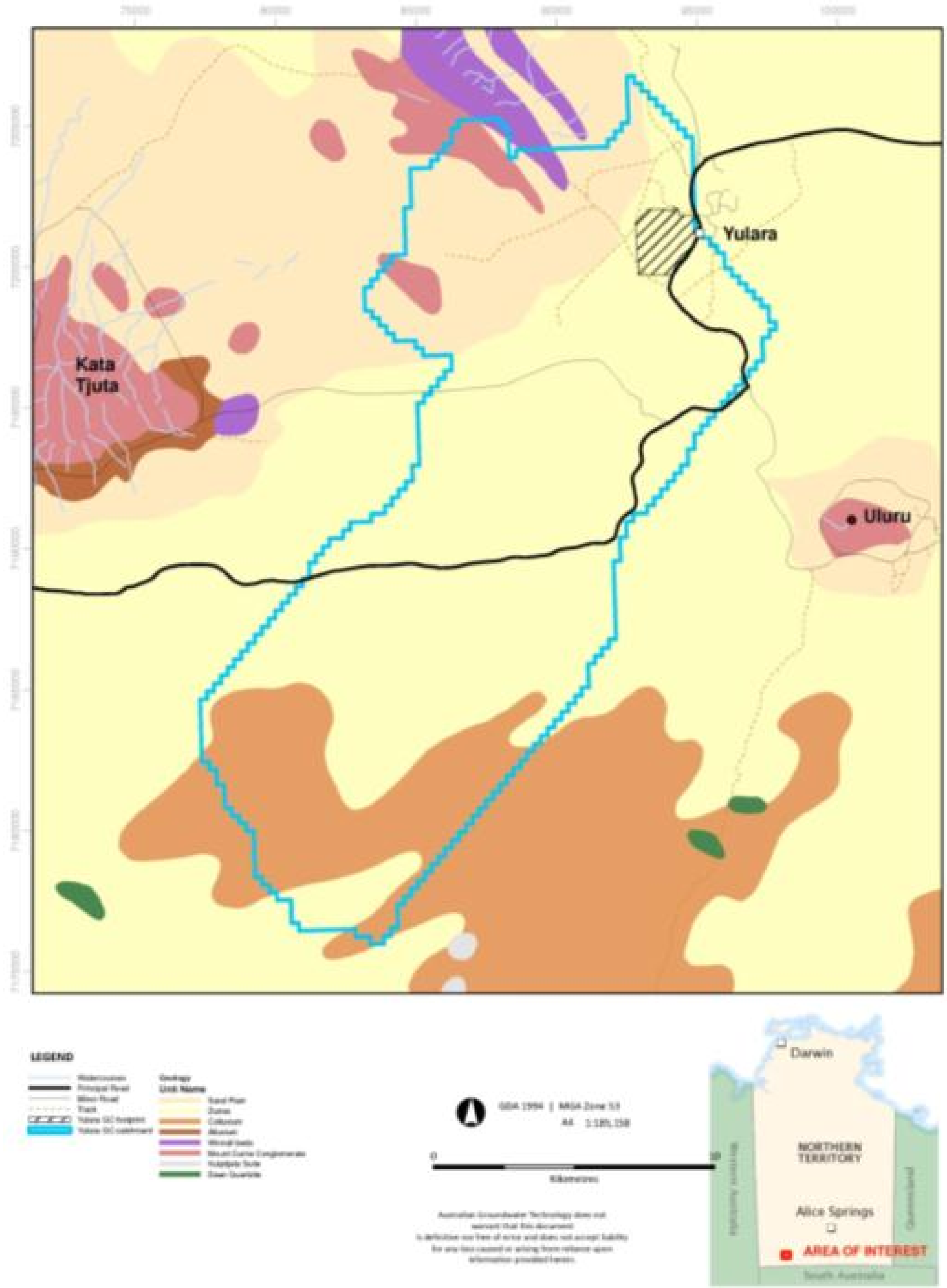

Figure 9 Uluru – Kata Tjuta Regional Geology

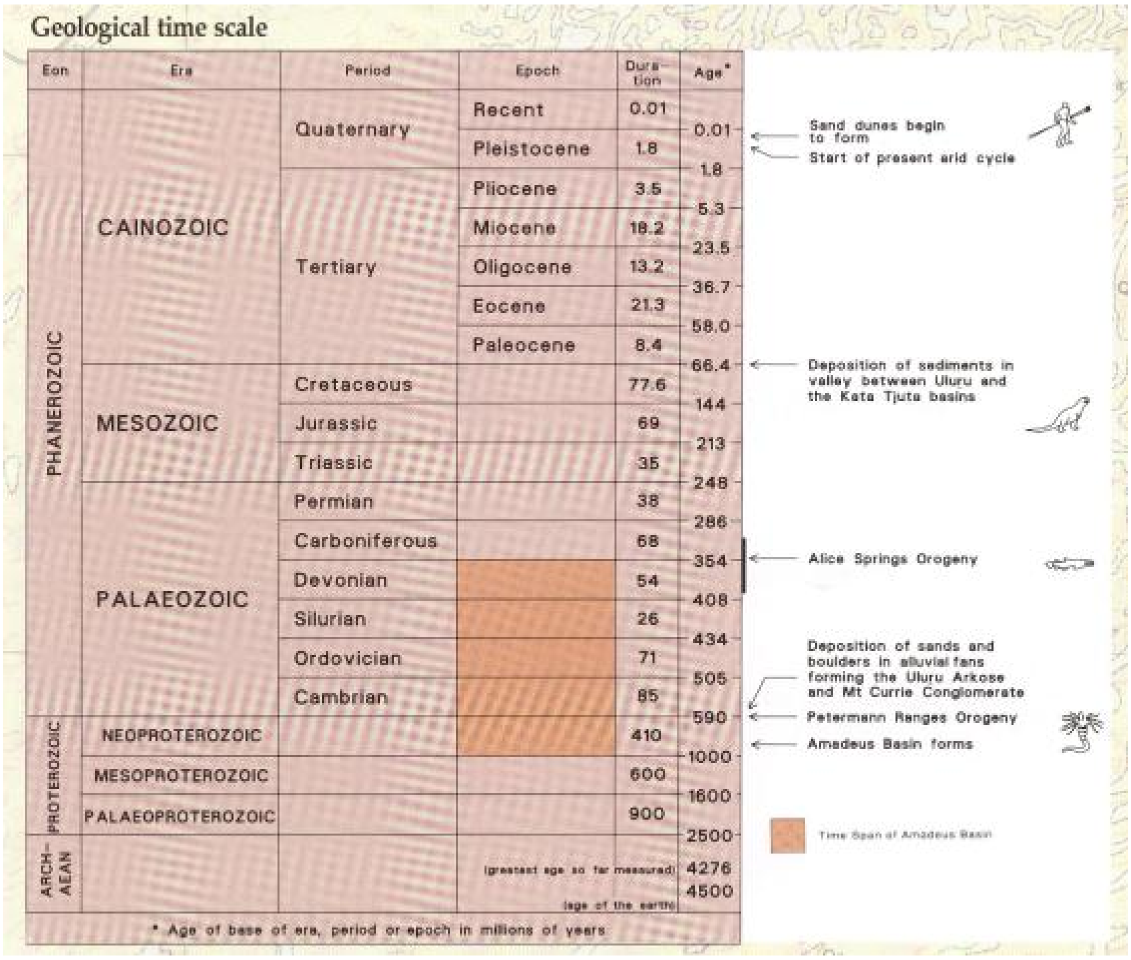

Figure 10 Geological Time Scale with reference to the Geology of UKTNP (reproduced from Sweet and Crick, 1992)

During the Palaeocene Epoch a broad shallow valley had been eroded into the land between Uluṟu and Kata Tjuṯa and drained east towards the present-day Finke River[8]. Thin layers of lignite resulted from peat deposited in swamps that formed part of this ancient river system (refer Figure 11).

In the Oligocene Epoch, the northern basement high was breached and a meandering river flowed north to northeast between peaks (Figure 12). In the Pliocene Epoch, basement highs were covered in alluvial sediments (with the exception of Uluṟu and Kata Tjuṯa) and a broad, braided stream flowed towards Lake Amadeus (Figure 13). Perennial creek flow in these drainage channels stopped before the mid-Miocene. Relict palaeodrainages[9] were preserved because of the tectonic stability of the region and the change of climate from humid to arid, which decelerated erosion and sedimentation.

[8] A recent geomorphological study has challenged the previous model of evolution (Patrick, 2010) with a hypothesis of a mega-flood and subsequent lacustrine environment supported by abundant rainfall in the early to middle Cainozoic responsible for the ultimate shape of the monoliths of Uluru and Kata Tjuta.
[9] Study of carbonaceous material near the bottom of the palaeochannel within the DPA indicates a Late Cretaceous - Late Palaeocene age (c 55 – 100 mya). At least three depositional phases are represented in palaeovalley sediments, spanning the Late Cretaceous to Late Eocene (MacPhail, 1997).

During the Pleistocene Epoch the climate became more arid, and aeolian deposits dominated sedimentation that continues to the present day, interrupted by cyclic wetter episodes. These deposits form gently sloping plains with occasional calcrete outcrops and irregular, reticulate or parallel dunes with stable flanks and enclosed swales containing alluvium, calcrete and gypsite.

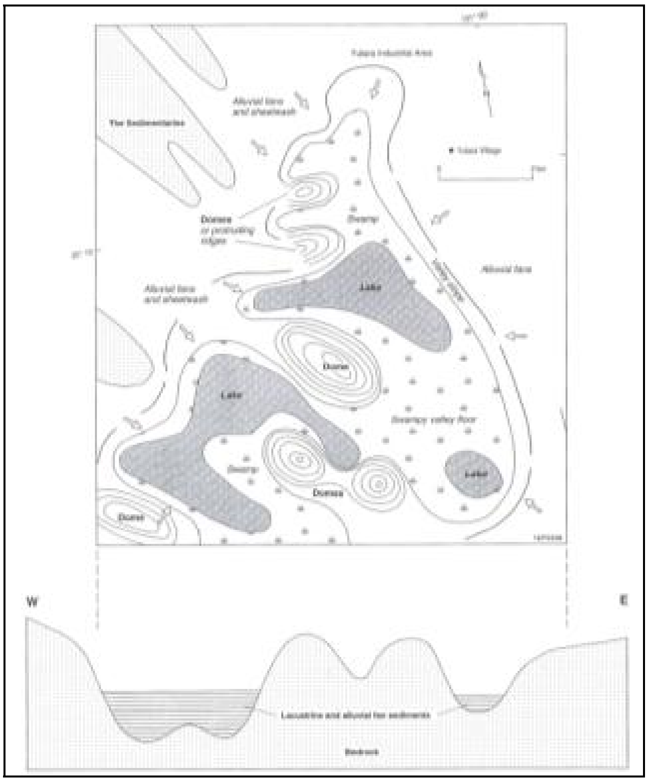

Figure 11 Schematic Diagram and Section of Palaeovalley between Uluru and the Sedimentaries; Early Tertiary time period (reproduced from English (1998))

Australian Groundwater Technologies AGT

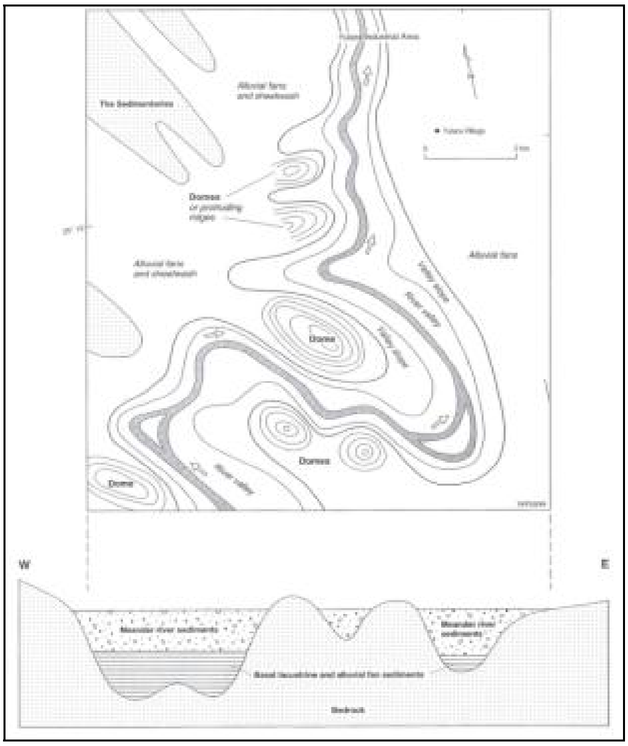

Figure 12 Schematic Diagram and Section of Palaeovalley between Uluru and the Sedimentaries; Mid-Tertiary time period (reproduced from English (1998))

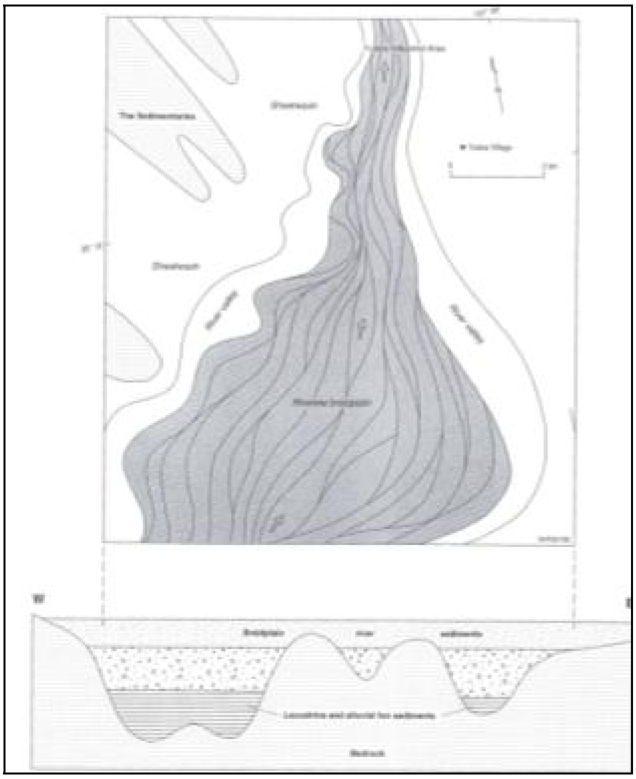

Figure 13 Schematic Diagram and Section of Palaeovalley between Uluru and the Sedimentaries; Late Tertiary time period (reproduced from English (1998))

The geology of the study area is influenced by two north-east striking faults between Kata Tjuṯa and Uluṟu (the Olga Thrust, a low angle fault and the Dune Plains Fault). Essentially, these two structures bound the north-east striking palaeovalley that constitutes the Dune Plains Aquifer; refer Section 2.6.2).

2.4 Geomorphology

2.4.1 Landforms

UKTNP comprises extensive sand plains, dunes and alluvial desert of lacustrine, alluvial and aeolian origin, punctuated by the Uluru monolith and Kata Tjuta. Following the development of aridity these deposits have come to be dominated by alluvial flood-outs, sheet-wash and aeolian processes (Figure 13).

The dunes (up to 30,000 years old) are stable, up to 30 m high, with mobile crests, vegetated flanks and swales with water-formed rills and gullies. With the sand plains they occupy the bulk of the UKTNP.

Lot 252 lies within the landform designated as 'Desert Dunefields'. At its closest point the Sandstone Ranges (viz. The Sedimentaries) comes within 1.2 km of the north-west boundary of Lot 252 (Figure 14).

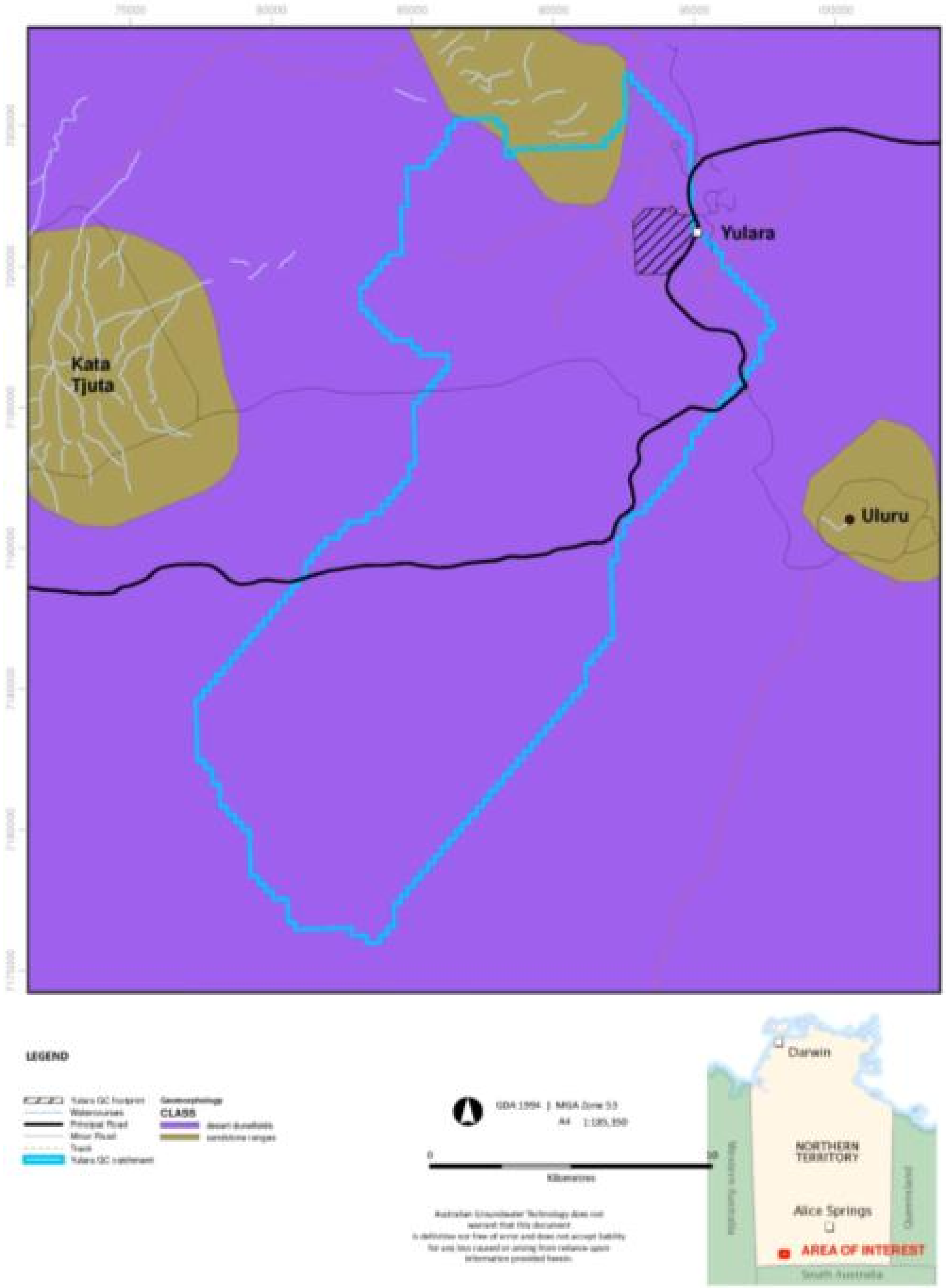

Figure 14 Uluru – Kata Tjuta Regional Geomorphology

Figure 15 indicates that Yulara township and Lot 252 appears to lay within an area of colluvial substrate as opposed to true alluvial sheet-wash and dune-field country.

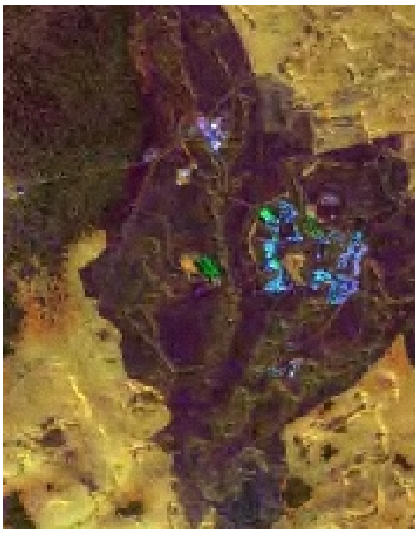

Figure 15 Ayers Rock Resort False colour image (TM bands 7 4 1[10] displayed as red, green, and blue) (generated from ERDAS image, www.erdas.com

2.4.2 Soil and land Units

The Yulara region displays three soil types (NRETAS, 2004).

- Tenesols – shallow, red siliceous sand and red earth sands; (makes up sand dunes in deserts).
- Kandosols – medium textured red earths, sandy loams and red earth sands, browny-red in colour (formed on gently sloping sand plains); and,
- Rudosols – shallow soils with little soil development. Very coarse siliceous sand; quite gravelly and rocky; (derived from weathered Mount Currie conglomerate).

Rudosols are developed over and directly adjacent to Uluru. Kandosols form a 'halo' surrounding Uluru (as isolated pockets on scree slopes and alluvial fans). Tenesols occur throughout the dune-fields.

Between Yulara and The Sedimentaries all three soil types occur successively with Rudosols developed over the rocky outcrops of The Sedimentaries, Kandosols developed adjacent to The Sedimentaries and Tenesols developed beneath Yulara and to the east.

Kandosols make up 70 % of Lot 252 in the west, whilst Tenesols occupy the eastern third (Figure 16).

[10] Band 4 highlights vegetation (green). Band 7 (red to orange) is sensitive to variations in moisture content; especially detects this in hydrous minerals (e.g. clays).

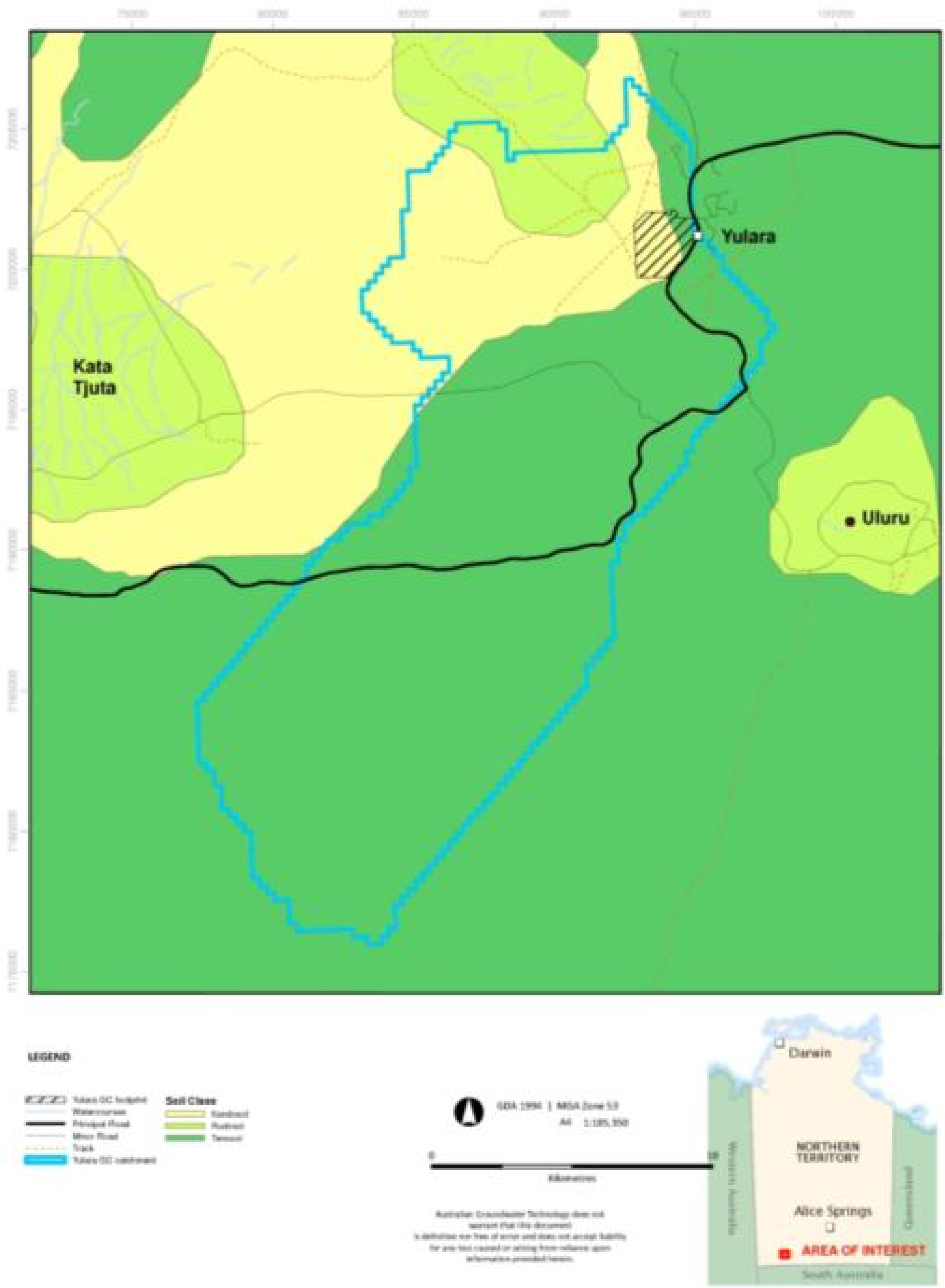

Figure 16 Uluru – Kata Tjuta Regional Soil Classes

There are no land units mapped for this area, however, NT government land use zoning indicates that the majority of the area surrounding UKTNP is designated for traditional indigenous use with the area surrounding Yulara (including Lot 252) designated for commercial services.

2.5 Local Geology and Hydrogeology

Site investigations for a proposed Soil Aquifer Treatment (SAT) scheme (using the controlled infiltration and recovery of treated wastewater for open space irrigation at Yulara) carried out at the tree-lot (AGT, 2006) provides valuable information with regards to the groundwater conditions at the adjacent Lot 252. Appendix B reproduces the site investigation plan and other visual information extracted from AGT (2006) that complements the following description.

AGT (2006) concluded that a SAT scheme situated at the tree-lot using treated wastewater of recharge capacity, 200 ML/year to the shallow aquifer was feasible and should operate without adverse environmental outcomes. However, there was some concern with respect to the maintenance of the salinity of the recovered water consistent with irrigation guideline values.

This issue has relevance to the current study as discussed in Section 3.2. Salient points derived from AGT (2006) are summarised below;

- Fieldwork consisted of;
    - water sampling from three existing monitoring bores close to the Yulara WWTP and tree-lot to investigate any localised contamination of groundwater from effluent within the saturated aquifer zone;
    - pits excavated in the tree-lot and adjacent to the unlined retention pond to sample and map soil horizons; and for preliminary infiltration tests;
    - drilling and soil sampling to complete boreholes as multilevel (nested) piezometers;
    - selected soil cores underwent petrophysical (hydraulic) and hydrochemical analyses comprising particle size distribution, porosity and permeability, and mineralogical analysis.

- Geology;
    - generally uniform horizontal lithologies with a surficial fine sand overlying a sandy clay about 3 m thick, underlain by a clayey sandstone;
    - there is a dominant silt fraction within the so-called 'very sandy clay' generally located at a depth interval of 2.8 to 5.5 m below ground level (bgl);
    - the 'clayey sandstone' is a red-brown, extremely weathered, ferruginous, very slightly arkosic, and siliceous, poorly sorted sandstone;
    - no bands of calcrete and/or silcrete were encountered (previously reported at Yulara; that may have made infiltration and 'effluent polishing' problematic either in terms of acting as a barrier or a preferred pathway);

- Hydrogeology;
    - the surficial, silty fine sand is permeable, whilst the sandy clay is much less permeable and forms an 'aquitard' upon which a perched

      water-table has developed beneath part of the tree-lot. The clayey sandstone is more permeable[11] than the sandy clay, and is deemed to constitute upper strata of the Dune Plains Aquifer (DPA);

- a perched watertable aquifer has formed a local groundwater mound within the DPA. It has developed at approximately 2 - 5 m bgl in the clayey sandstone aquifer over an estimated sub-surface semi-radial area of roughly 0.4 - 0.6 ha as a result of the application of about 3,200 ML of treated effluent over some 16 years (not accounting for the previous period of spray irrigation)[12];
- the up-gradient limit of the mound (i.e. southern boundary of the tree-lot, bordering Lot 252) was not defined and there was still some uncertainties as to the overall distribution of the perched water table and the groundwater mound;
- effluent infiltrates readily into the upper sandy soils and although this accumulates as a limited zone of perched water on the sandy clay "aquitard", the latter is sufficiently permeable to allow infiltration into the underlying DPA;
- the steep gradients in the main aquifer signify low permeabilities, and the elevated head from mounding (5 - 6 m or more) combine to give vertical movement of effluent;
- the hydraulic head imposed by the infiltrated effluent has displaced natural groundwater for a considerable vertical distance below the tree-lot. Thus the "bubble" of infiltrated effluent extends into and possibly to the base of the DPA at this location;
- beyond the tree-lot, the groundwater mound decays from 11 m to 22 m bgl northwards (in sympathy with regional groundwater throughflow, i.e. towards the Electric production bores) and lies at 15 m bgl east of the tree-lot. Ignoring the perched water table, the minimum SWL of the groundwater mound under the tree-lot is 6.5 m bgl.
- three lithological layers were categorised[13] with hydraulic conductivity, K values of 1 m/d for the surficial silty sands, 0.002 m/d for the sandy clay[14] and 0.5 m/d for the clayey sandstone aquifer.
- vertical infiltration of the treated effluent was relatively rapid (c.f. the historical "trouble-free" uncontrolled flood irrigation of the tree-lot);
- field testing of the silty sand indicated relatively high infiltration rates averaging nearly 8 m/d at 0.5 m depth and 7 m/d at 1.0 m soil depth;

- Water Quality;
  - there is little data on effluent water quality other than salinity (see table 4, AGT, 2006). The fluctuating, at times, higher salinities in effluent seems to derive mostly from use of raw, brackish groundwater for toilet flushing, etc. at ARR; or stem from the time when the potable treatment plant was electro-dialysis (EDR), and the

[11] With good porosity except where chemically altered (oxidised) with a high silt fraction; then the porosity was poor. Good permeability is questionable due to the cement matrix, non-connection of pores & chemical alteration of bedding planes. Whilst this sandstone is likely to accept water it may not readily give up water. Nevertheless, there are horizons that may freely yield water.

[12] to mid-2005.

[13] to form a conceptual model as the basis for groundwater numerical modelling.

[14] the measured K value for the sandy clay was an order of magnitude more than the value used in the modelling.

effluent would have been more saline than present, hence the reuse train was also more saline[15].

- o salinities within groundwater in the perched aquifer, and in the mounded aquifer are somewhat higher than the range found for raw effluent. Outside the tree-lot, salinities are higher, and farther out salinities are even greater as follows;
  - effluent irrigation had a surface salinity of 830-920 mg/L TDS (1,580-1,660 uS/cm EC)
  - salinity of the mounded watertable aquifer was 1,400 - 2,200 mg/L TDS (2,500 - 3,900 uS/cm EC) exclusive of two data 'outliers' of 860 mg/L (EC 1,570 uS/cm) and 3,300 mg/L (EC 5,860 uS/cm)
  - the lowest TDS value indicated freshening by the infiltrate (at Piezometer B; see Appendix B)
  - the greatest value (at Piezometer E; see Appendix B) appears to be a runoff 'sink' where it is postulated that a localised concentration of soil salt on the surface was flushed into the soil profile by some 70 mm of rainfall experienced during the first half of the drilling program. This site also has the shallowest depth to the perched watertable (about 1.1 m bgl);
- o the investigations confirmed that continued application of treated effluent formed a perched aquifer of lower salinity water than the ambient salinity of the regional aquifer (2,400 mg/L at the Electric Bores).
- o Re. Appendix B ("Fig 5" of AGT, 2006), there is a soil conductivity trend of about 1,500 uS/cm ECe that occurs below the tree root zone at 2.5 - 3 m upon application of 1,500 us/cm EC effluent. There is some indication of salt accumulation at the root zone (to 2 - 3 m depth); possibly due to transpiration. Lower salinities deeper in the profile suggest that there is preferred pathway flow from the furrows to the perched water table and possibly to deeper in the profile, with salinity 'spikes occurring within the shallower silty sand soils.
- o salinity peaks within the surficial silty sand progressively deepen in a westerly veering northerly 'transect'. Salinities progressively decrease along the same 'transect'. This may have represented an actively infiltrating 'wetting front'. The profile closest to the then current furrow irrigation suggests rapid infiltration that retains the signature of the effluent's salinity into the top of the clayey sandstone.
- o the underlying sandy clay allows contaminant adsorption and removal prior to infiltration to the underlying clayey sandstone (DPA);
- o infiltrated effluent is dispersed within more saline, native groundwater within 200 m down gradient of the northern boundary of the tree-lot.
- o the assessment of the soils through which the infiltrate moves indicate potential for remobilisation of salts stored within the soil profile particularly in the western portion of the tree-lot;
- o native groundwater is brackish (~2,000 - 2,400 mg/L TDS) and is considered problematic for irrigation in this environment.

[15] 1996 records show the ARR's camp ground irrigation was consistently around the 1900 uS/cm EC or 1200 mg/L TDS (D. Pidsley, Pers. Comm., as reported in AGT, 2006).

2.6 Groundwater

2.6.1 Aquifers of the UKTNP region

Two geographically separate aquifer systems have been developed for water supplies; the one of interest to this study is the ‘Dune Plains Aquifer’ (DPA).

On a regional scale, there is a hydraulically connected, two layered aquifer system; Cainozoic sedimentary aquifers overlie fractured bedrock aquifers of the Amadeus Basin. Groundwater throughflow is from south-west to north-east at a rate of about 1 m per year within palaeovalleys through the UKTNP region to a groundwater discharge zone at Lake Amadeus. The age of the groundwater in these Cainozoic aquifers ranges from new to 100,000 years old.

Where the aquifers are exploited, the weathered / fractured bedrock essentially is used as a collector system draining the Cainozoic aquifer that provides storage. Where sufficient permeability exists, public water supply bores have been constructed at shallow depths (generally less than 70 m) within the sediments (e.g. the 'Gas Bores' located in the ‘Old Wellfield’ at Yulara). In contrast, the 'Electric Bores' located in the ‘New Wellfield’ at Yulara have been constructed in bedrock at relatively shallow depths of less than 70 m (fractured Proterozoic rocks; the Pinyinna Beds).

The deep aquifer experiences reducing conditions and de-nitrification occurs whereas high nitrate concentrations, of biogenic origin, are associated with the surficial Cainozoic aquifers (Barnes et al., 1994).

2.6.2 The Dune Plains Aquifer

The DPA, which constitutes the water supply source for Yulara and ARR, is poorly understood in terms of its areal extent, volume and depth of Cainozoic sediments to bedrock[16]. This complicates estimation of the sustainable yield. Its aquifer storage volume is estimated to be about 90,000 ML (AGT, 2003).

Where investigated, the DPA is an arcuate, north-east trending palaeovalley, 20 km long that passes east of The Sedimentaries and beneath Yulara.

The southern boundary of the DPA has been taken as the zone of higher TDS in the south of the palaeovalley. Groundwater potential for water supply development is possibly limited by this up-gradient higher salinity groundwater. Ostensibly, the down-gradient (northerly) aquifer limit is related to the limits of known aquifer distribution from drilling investigations. There are potentially useable groundwater resources in the northerly extension of the palaeochannel (north and east of Yulara) which have yet to be investigated.

Table 2 summarises the stratigraphy and aquifer properties of the DPA.

[16] English (1998) placed the Cainozoic / bedrock contact some 50 m higher than Read (1977) in some bores, so there may be only 30 m of Cainozoic sediments and not 100 m as previously thought.

Table 2: Uluru –hydro-stratigraphy (after Read, 1999; file note reported in AGT, 2003))

Ground level to a depth of between 10 and 90 metres – Cainozoic (Cz) clay, sand and silt; some silcrete.	Where saturated the volume of water that can be extracted from the sands and silts has been estimated to be between 5 and 10 % of the volume the sands and silts occupy. Some permeable sands occasionally occur towards the bottom of the sequence.
Below the Cainozoic strata occurs between 10 and 50 m of extremely weathered rock of Proterozoic age (Pinyinna[17] beds) - has the appearance of white clay, silt or sand when drilled with a rotary drilling rig.	The volume of water that can be extracted from the extremely weathered Proterozoic rocks has been estimated to be between 1 and 3 % of the volume the sands and silts occupy. Low permeability.
Moderately weathered Proterozoic aged strata (Pinyinna beds) ('bedrock') comprised of interbedded shale, dolomite, chert and sandstone occurs beneath the extremely weathered rock.	The volume of water that can be extracted from these rocks has been estimated to be less than 0.5 % of the volume the rocks occupy. The permeability is high when the rocks are dolomite, chert or sandstone and low when shale is intersected. Most production bores are in this sequence

Figure 17 is a plan view of the DPA showing locations of registered water bores (investigation and monitoring bores; including abandoned bores) drilled within the Yulara Lease and northern Uluru area that have been used to delineate the extent of the DPA.

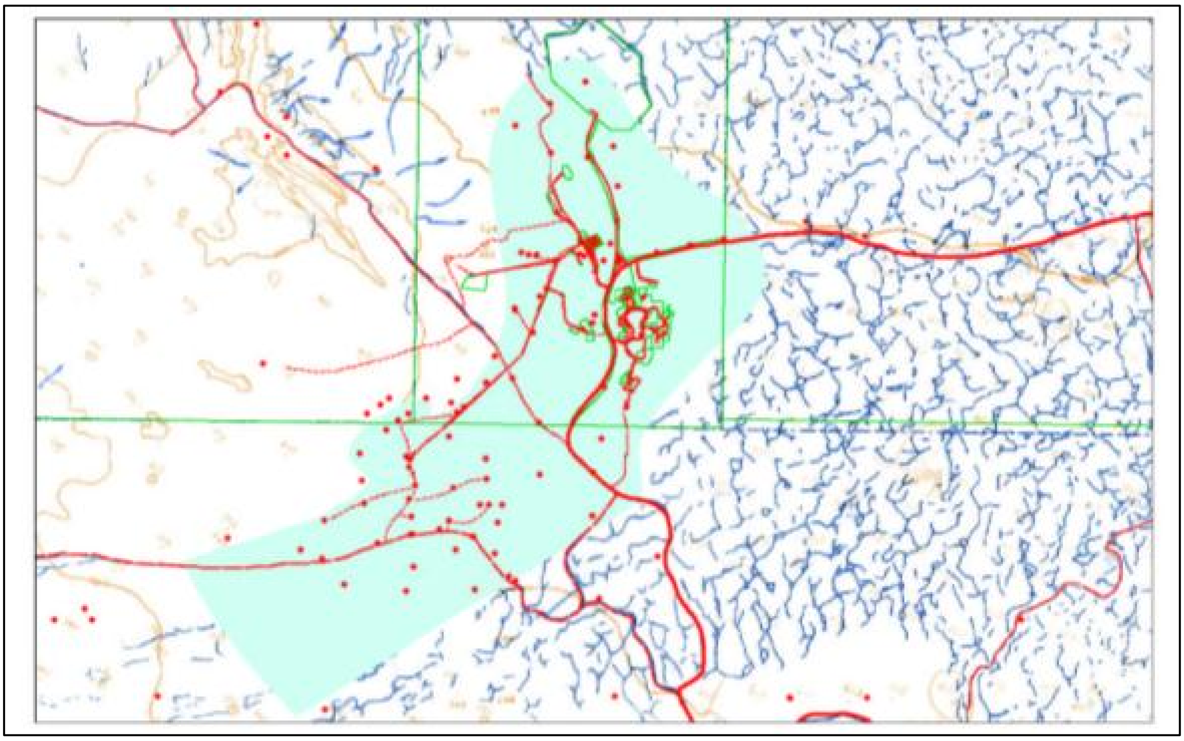

Figure 17 Bore location Map superimposed on 'the commonly accepted' Limits of the Dune Plain Aquifer (light green shading) (reproduced from AGT, 2003)

17 referred to in this report in a hydrogeological context as 'weathered / fractured bedrock' or 'bedrock'.

Figure 18 shows a simplified distribution of groundwater salinity as total dissolved solids (TDS) within the DPA. No systematic distinction can be made between water quality in the Cainozoic sediments and that in the underlying bedrock. North of Yulara, TDS is about 1500 mg/L, elsewhere it is in the range, 1500 - 5000 mg/L TDS. A tongue of poorer quality regional groundwater, purportedly enters the palaeovalley from south-west to north-east under the regional hydraulic gradient, and is diluted in the Dune Plains area by fresh (and lower nitrate) recharge waters emanating from The Sedimentaries.

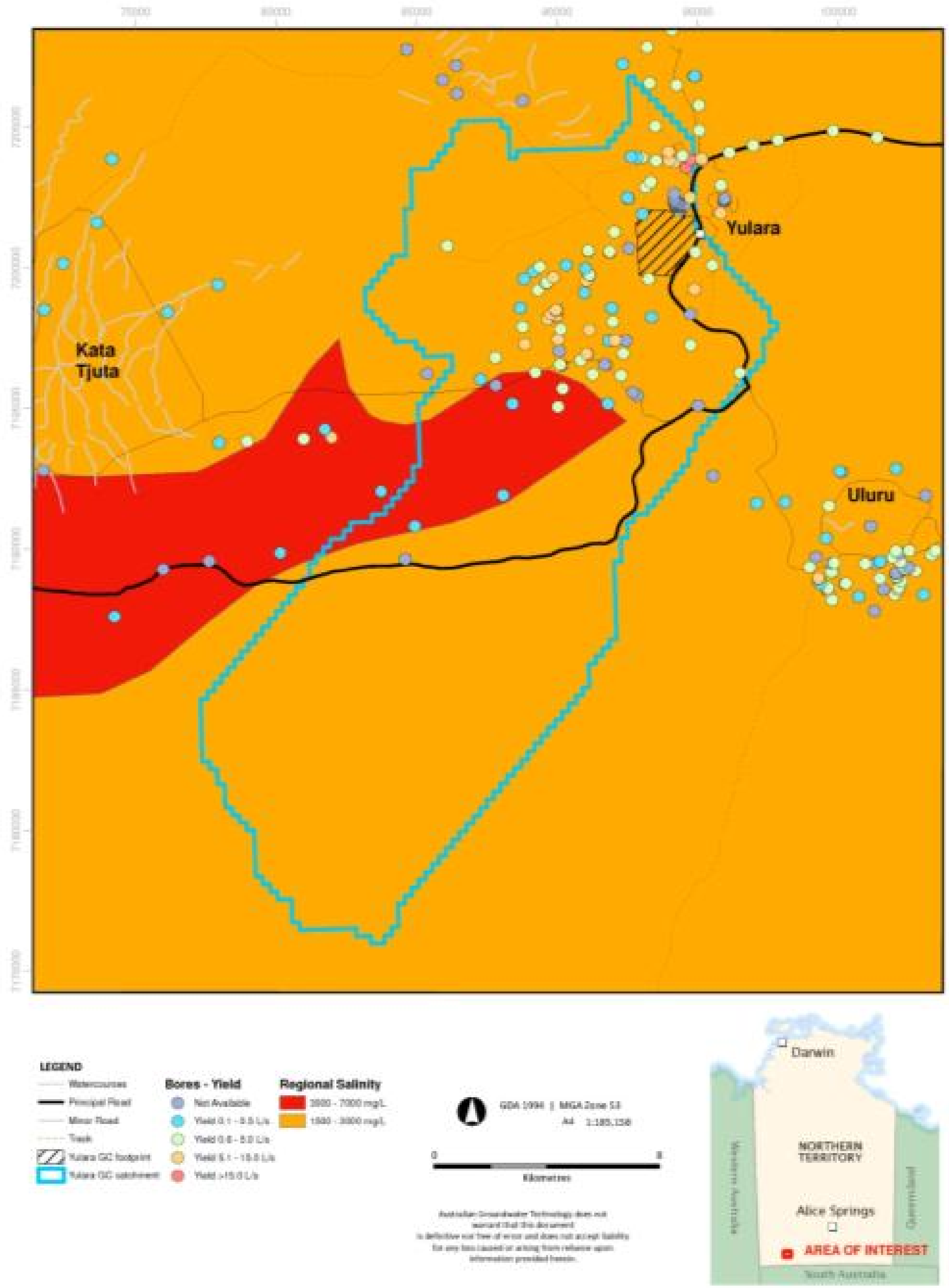

Figure 18 Groundwater Salinity Distribution Map for DPA

Better quality water is abstracted from the Old Wellfield where TDS averages about 1500 mg/L, with a low of 1,340 mg/L and a high of 2,210 mg/L. TDS of the New Wellfield is higher and ranges from 1,950 mg/L to 3,250 mg/L (year, 2002 data).

As depths to SWL increase, TDS content may increase. Also, when SWLs decline, due to long periods of limited or no recharge, groundwater quality appears to deteriorate. Perched fresh water tables may develop where local sub-surface deposits of impermeable calcrete occur; e.g. near the ‘New Wellfield’ (English, 1998). Over time, the chemistry of the calcrete aquifers may directly contribute to higher TDS in the main aquifers.

Native groundwater of the DPA underlies Lot 252 and is derived from regional throughflow from the south, possibly, augmented by local runoff recharge from sand hills / dunes and The Sedimentaries. In the northern extremity of Lot 252 this groundwater system is probably modified by uncontrolled flood irrigation of treated effluent (see Section 2.5). Although this local influence to the groundwater system has potential environmental implications it may also present an opportunity for resource use for the proposed development as discussed in Section 3.1.

2.6.3 Groundwater Levels and the Water Table

Groundwater levels (SWLs) are currently monitored quarterly in selected monitoring bores (MBs) in the DPA[18]. Some records extend back to 1968; although the majority of monitoring started in the mid-1970's to early 1980's.

Data from investigation bores indicates that there is generally little difference in SWL in the Cainozoic sediments compared with the bedrock aquifer.

Generally, SWLs range from about 40 m bgl between Uluṟu and Kata Tjuṯa to 12 m bgl north of Yulara, consistent with the regional groundwater flow towards the Lake Amadeus discharge zone. The water table in the ‘Old Wellfield’ is about 32 m bgl[19]; the water table in the ‘New Wellfield’ is between 17 and 21 m bgl.

Localised decline in SWL has been induced by pumping particularly in the vicinity (greater than 200 m) of the Old Wellfield where SWLs have declined about 3 m since groundwater abstraction commenced in 1984.

SWLs in the vicinity of the New Wellfield indicate a recovery in SWLs probably due to a combination of successful demand conservation measures, redistribution of pumping to abstract more groundwater from the Old Wellfield and natural recharge possibly enhanced by uncontrolled discharge of treated wastewater to the wood-lot. The water-table in the northern part of the aquifer, beyond the capture zone of the New Wellfield, has risen generally by 2.5 m since groundwater monitoring records commenced in 1979.

Figure 19, Figure 20 and Figure 21 illustrate groundwater hydrographs of selected monitoring bores for their entire duration of record (until in most cases, October 2011, plotted against monthly rainfall).

[18] Note that the density and frequency of bores monitored has greatly decreased in the past few years. At one time 35 MBs were measured with a subset of 20 MBs measured on a monthly basis up until the late 1990’s.

[19] Ignoring localised interference from neighbouring pumping of production bores.

From these hydrographs the following observations of relevance to potential impacts to Lot 252 are;

- Figure 19 – a sudden and marked head response post-1998 in RN 12162 adjacent to the Yulara WWTP – believed to coincide with the production of more effluent[20]. Subdued head rises in 1991 and post-1997 in RN 12063 located less than 1 km to the north of the WWTP – may be attributed to start of flood irrigation[21] and increased effluent production, respectively. Similarly Figure 20, a slight head rise response in 1991 attributed to the same cause inducing recharge locally to the DPA;
- Figure 20 – SWLs generally 2 m to 3 m higher than at the commencement of monitoring in the early 1980's in those MBs greater than 200 m from the New Wellfield and which reacted strongly to the 1989 rainfall recharge event and a subdued head rise to the 2000 flood in RNs 12066, 12159 and 12164[22]. Similarly Figure 21, in RNs 6275 and 12454 situated between the wellfields (up to 2 km from any pumping bore), SWLs are generally 3 m higher.

[20] There is also likely to be a component of natural recharge from the 2000 flood.
[21] previously irrigated by a dripper system.
[22] RN 13777 being within 250 m of the influence of production pumping shows drawdown interference.

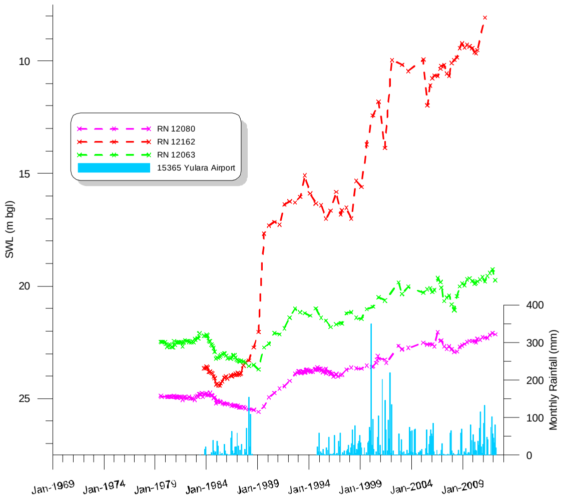

Figure 19 Groundwater Hydrographs – Yulara Wood-lot

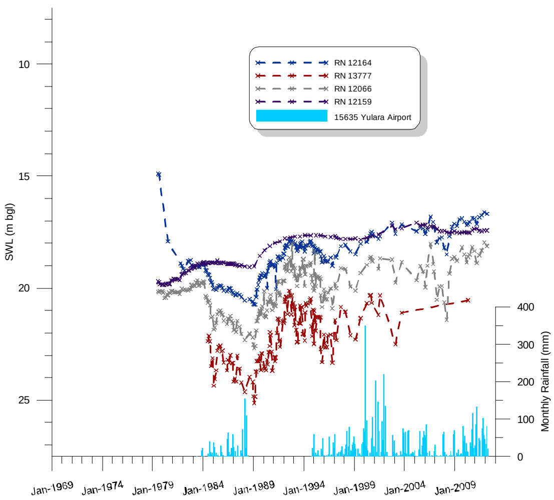

Figure 20 Groundwater Hydrographs – Yulara New Wellfield

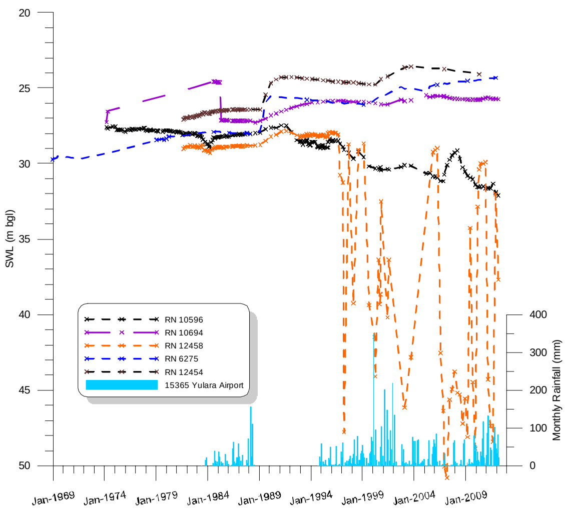

Figure 21 Groundwater Hydrographs – Yulara Old Wellfield

2.6.4 Recharge to the DPA

Groundwater hydrographs and stable isotope chemistry (Jacobson, Creswell et al (1989) indicate that the aquifer is actively recharged.

Sheet-flow runs off from Uluṟu and The Sedimentaries and recharges the western DPA especially where it accumulates and infiltrates in "run-on zones" (English, (1998) (described in Section 2.2.3).

Barnes et al (1994) examined recharge at Yulara and concluded that only extreme rainfall events of greater than 130 mm/month are capable of providing sufficient recharge to the Cainozoic aquifers. Such events recharged the DPA in 1973-4, 1982, 1988-9 and 2000. After each recharge event there has been prolonged recessions of the water table. Hydrographs / rainfall relationships empirically suggest that rainfall events would need to be in excess of 180 mm in any given month to induce significant aquifer recharge, although this would depend on a number of variables including rainfall intensity/duration/area, antecedent soil moisture conditions, etc (AGT, 2003).

The Old Wellfield area does not appear to respond as well to recharge events as the New Wellfield probably as a result of the latter's proximity to concentrated runoff recharge from The Sedimentaries.

2.6.5 Surface water – groundwater connectivity

As far as the author is aware no scientific study has been done on surface water – groundwater connectivity at Yulara and the UKTNP. It is apparent from data presented above and AGT (2003) that surface water does actively recharge the DPA on an infrequent 'pulse basis', however surface water is disconnected from the water-table in the sense of the depth to the water-table that precludes direct evaporation except, in the artificially induced groundwater mound beneath the tree-lot. There is no doubt that deep-rooted trees, such as the Desert Oak can tap the water-table and thus act as groundwater pumps via transpiration. There has also been a hypothesis (reported in AGT, 2003) that certain fauna notably the Mulgara are dependent on the water-table but this is believed to be a facet of the run-on areas (moisture availability), rather than the water-table *per se*[23].

2.6.6 Aquifer Throughflow, Aquifer Storage, Sustainable Yield and Water Balance

The yield that can be maintained from an aquifer is dependent on groundwater storage and recharge. When groundwater storage is not large compared with recharge and usage, and other source options are uneconomical (or non-existent), then usage should be limited to the recharge rate. If storage is extremely large in proportion to recharge and usage, the water resource may be mined. Careful water conservation measures need enforcing so that mining does not cause irrevocable derogation of the resource.

A principal concern for all users of aquifers in UKTNP and Yulara is the need to operate in compliance with the principle of ecologically sustainable development in

[23] all available evidence would suggest that plants like *Acacia aneura* and *Triodia basedowii* (plants considered important for rare and endangered wildlife like the Mulgara) are not securing their water from the aquifer (Director of National Parks, 2010).

order to maintain a safe and sustainable supply of water from the aquifers. This includes ensuring support of dependent physiological and ecological systems.

The throughflow in the DPA cannot be estimated due to uncertainty regarding throughflow contribution from weathered bedrock / bedrock, the complex nature of flow patterns (braided sand horizons with enhanced permeability; regional flow along the palaeovalley and west to east cross aquifer flow from The Sedimentaries runoff-recharge) (AGT, 2003).

The northern extent of the DPA has not yet been defined, therefore its groundwater storage volume, hence sustainable yield cannot be reliably estimated.

Despite nearly thirty years of withdrawal of groundwater from the DPA through pumping to meet water demand at Yulara there has been little impact with respect to derogating this water resource. Only localised 'cones of drawdown' from the impacts of pumping have developed.

Over the period of operation of the DPA wellfields:

- SWLs in the vicinity of the Old Wellfield have only declined about 1 m to 3 m depending on proximity to public water supply bores;
- ground water levels in the vicinity of the New Wellfield have slightly risen; and,
- SWLs in the northern part of the aquifer, beyond the capture zone of the New Wellfield, have risen generally by 2.5 - 3 m. (This rise may be due, not only to natural recharge, but also to irrigation returns from the 'flood irrigation' practised at the woodlot).

AGT, 2002 estimated an order of magnitude aquifer storage volume as 90,000 ML assuming an aquifer area of 60 km2, a saturated depth of 30 m and a specific yield of 0.05). Using a quoted figure of throughflow of 200 ML/yr (DIPE, File 58.3P3), the storage is 450 times the annual throughflow. Thus there is a huge storage of marginally potable to brackish groundwater that is large in proportion to throughflow, recharge and usage. Wellfield management may, inevitably, require the resource to be mined due to the rare, but significant recharge events experienced in this semi-arid environment.

Current abstraction of groundwater of about 737 ML/year is in excess of the estimated throughflow of the DPA (200 ML/yr but this estimate is considered low) but is only some 0.8 % of available storage based on conservative estimates of aquifer storage. This level of extraction from the DPA is thus deemed to be sustainable for the next decade, or so.

A simple water balance for Yulara (DPA) is presented as Figure 22. The main uncertainty in completing the water balance is a scientific study and assessment of groundwater recharge to the DPA, and a definitive study and calculation of groundwater throughflow. Much scientific work needs to be done on the hydrology of the UKTNP including evapo-transpiration, the role of surface water – groundwater connectivity, etc. All these aspects are beyond the terms of reference of this commission; (recommendations for such studies are given in AGT, 2003).

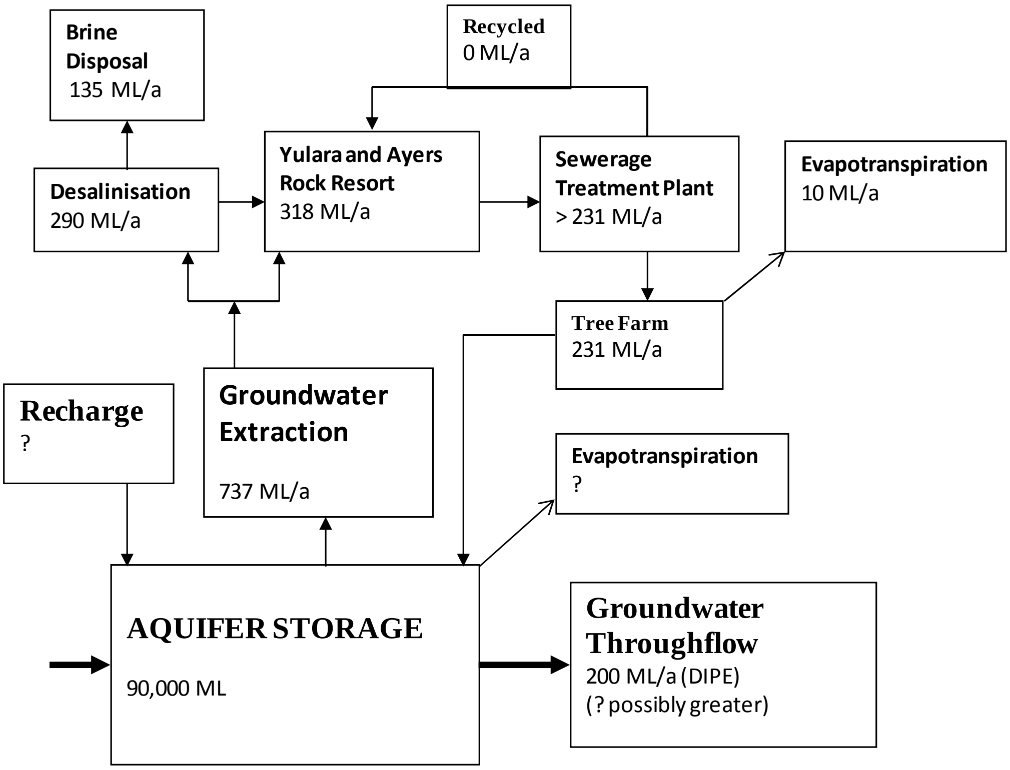

Figure 22 Water Balance for Yulara and the Dune Plains Aquifer (DPA) at year, 2011 (adapted and updated from AGT, 2003)

2.7 Catchment Condition and Competing Water Users

Basically, the local catchment to the south of the proposed development (Figure 1) can be considered to be unmodified apart from the major sealed road (to Kata Tjuta) that bisects it. The open-channel stormwater drains (‘cut-offs’) impede run-off and have dislocated the run-on zones.

The northern part of the catchment appears to have been greatly modified by the development of Yulara township including legacy issues such as excavation and compaction of utilities’ trenches, construction scrapes, numerous old vehicle tracks, large plant and vehicle turning circles, etc. The imagery presented in Appendix A gives some idea of the degree of alteration of the natural landscape. The main impact to the hydrology is again from cut-off drains associated with roads, soil compaction and notably locally, immediately north of the proposed development the Yulara WWTP and associated tree-lot.

Currently, there are no known competing water users exploiting the DPA. PWC alone is licensed to take water from the DPA. Mutitjulu community, and the Parks department’s ranger station and associated facilities obtain their water supplies from the Southern Aquifer, which is considered to be a separate aquifer system to that of the DPA (see AGT, 2003 for further discussion).

3 Impact Assessment

3.1 Golf Course Water Requirements

3.1.1 Construction phase

Details are not known regarding construction water requirements. Initially water will be needed for dust suppression as part of ground works to layout the course, and some construction water will be needed to build the club-house and related infrastructure. Most water will probably be required for the establishment of turf.

3.1.2 Operational phase

The water requirements for the proposed golf course at Yulara was estimated by Hydro Pumping & Controls Pty Ltd (5th March 2012 and David Hanby, pers. comm.).

These estimates reviewed the rainfall and evaporation data for Yulara Aero (#015635) and applied them against the proposed average areas for greens, tees and fairways combined with relevant crop factors for potential turf types. Table 3 presents the annual irrigation water requirements for the proposed golf course. Irrigation demand is seasonal ranging from a minimum daily average demand of 0.39 ML (4.5 L/s instantaneous or 13.5 L/s over an 8 hours irrigation period) in July to a maximum daily average demand of 1.61 ML (18.6 L/s instantaneous or 55.8 L/s over 8 hours) in January.

Table 3: Irrigation water requirements (reproduced from Hydro Pumping & Controls Pty Ltd (5th March 2012)

Month	Total (ML)	Running Total (ML)	Daily Average (ML)
January	49.81	49.81	1.61
February	36.01	85.82	1.29
March	33.58	119.4	1.08
April	23.55	142.95	0.78
May	17.05	160.00	0.55
June	11.89	171.89	0.40
July	12.23	184.12	0.39
August	18.84	202.96	0.61
September	24.27	227.22	0.78
October	36.54	263.77	1.18
November	37.02	300.78	1.19
December	43.28	344.07	1.40
Annual Total	**344.07**	**344.07**	**0.63**

The estimated annual volume required to satisfy irrigation demand is 344.07 ML/yr (10.9 L/s instantaneous).

In order to satisfy the maximum monthly demand a bore capacity of 18.6 L/s instantaneous would be required. Given a typical bore pumping cycle of 12 hours pumping and 12 hours non-pumping, then a bore capacity of 37.2 L/s would be required. From experience completing bores in the DPA, this rate of water production would require three (3) new bores pumping at a combined total rate of approximately 12.5 L/s each, producing about 5 m of drawdown at each well. Interference effects would compound this and would depend on the spacing between the bores (including the PWC production bores in the Northern wellfield). Peak irrigation rates over an 8 hours cycle exceed the instantaneous flow capacity of the proposed wellfield thus balancing storage tanks may be needed.

The water demand of 344.07 ML/year combined with the current take of 737.39 ML/year for Yulara would amount to approximately 1,081.5 ML/year. This volume is only some 1.2 % of the volume of groundwater in the DPA.

3.2 Potential Water Sources for the proposed development

Hydro Pumping & Controls Pty Ltd (5th March 2012) identified potential issues that would impact the design of the irrigation system for the proposed gold course. In so doing they recommended two options for water supply with proposed methods for mitigating any operational or environmental impacts. Of interest to this commission are;

- use of recycled water – mitigate by;
    - “treatment to a standard suitable for controlled application on golf course”;
    - use blended recycled water / ground water.
- use of high salinity ground water – mitigate by;
    - use of suitable turf types
    - treatment of water if required
    - use blended recycled water / ground water.
- High evaporation for open water storage re. “water wastage” – mitigate by;
    - ...direct pumping from aquifer to irrigation system;
    - ...use of tanks for balance storage

The use of the native groundwater (conservatively, 1,500 mg/L TDS) from the DPA is problematic in terms of soil salinization. For example the application of the required 1.61 ML/day for irrigation in January (i.e. the highest irrigation period) would result in some 2.4 tonnes of salt being introduced to the site; equivalent to some 563 mg (milligrammes) of salt being acceded per square metre of soil surface. Assuming the sub-soil is similar to that described at the neighbouring tree-lot by AGT (2006) (see Appendix B), infiltration should not be impeded. However, should there be areas of calcrete[24] in the substrate then saline ‘hot-spots’ may build up because of poorer infiltration capacities through such soils.

[24] caliche type soils

In this regard, the use of recycled treated wastewater (Class C equivalent; Ammonia =< 10 mg/L; BOD5 <48 mg/L; E.coli =< 1440 cfu/100 mL reported by PWC, 2006) from the Yulara WWTP might be considered. Some 231 ML/year is currently being disposed at the tree-lot with a quality of approximately 1,550 uS/cm (980 mg/L TDS) and a SAR of 4.7. This would provide on an annual basis some 67 % of the estimated irrigation demand. However, pre-treatment would be required to Class A standard (public access) unless a strict regime of non-contact irrigation was implemented (such as night-watering). Further, the salinity ('Class 3' for salinity of irrigation water) is still considered high especially for soils with impeded or poor drainage. Therefore on-site soil investigations should be undertaken to ascertain the infiltration capacity of the soils at Lot 252.

It is likely that to meet annual demand then a blend of recycled treated wastewater and groundwater will be required (230 ML wastewater plus 114 ML groundwater). An option to reduce salinity is to negotiate the delivery of a quantity of potable water from PWC but this will undoubtedly have cost implications and may be perceived as inappropriate use of high value water supply.

3.3 Current Water Use

3.3.1 Current Water Use, Brine and Wastewater (Treated Effluent) Disposal

Power and Water is the operator of the Yulara water supply. The DPA supplies water to Yulara / Ayers Rock Resort from two wellfields, the 'New (or Northern) Wellfield' (comprising two electric-powered bores, registered RNs 13363 and 13365) and the 'Old (Southern) Wellfield' (comprising four gas-powered bores, RNs 13626, 16360, 18298 and 18299).

It appears that PWC is licensed to take up to 19,200 ML per year (1,600 ML per month) from the DPA.

Total water production from the two wellfields for the past three years is;

2009: 835.78 ML;
2010: 802.22 ML;
2011: 737.39 ML.

The salinity of the blend of raw water extracted from the two wellfields is about 1,500 mg/L TDS. The raw water is hard and high in nitrate.

AGT (2003) predicted the production of water for Yulara to increase from an estimated 700 ML/year in years, 2001/2002 to 800 - 820 ML/yr by 2010, depending on the level of water conservation measures invoked. The production figures slightly exceed this estimate for financial years 2009 and 2010, but a marked reduction (some – 10 %) in production occurred in 2011 that is on track to be replicated in 2012.

For year, 2011 the breakdown of water supplied was 290.05 ML of treated (desalinated) potable water and 317.55 ML of non-potable water (not desalinated) supplied to ARR. The potable water had an average salinity of 377 uS/cm EC (about

210 mg/L TDS) (maximum of 448 uS/cm and minimum, 356 uS/cm EC). The non-potable water had an average salinity of 2,500 uS/cm EC (about 1,400 mg/L TDS).

Figure 23 summarises the monthly production of raw water from the two wellfields for the past four years to date, and that supplied to ARR by water type (desalinated water and non-desalinated water) for the past two years to date.

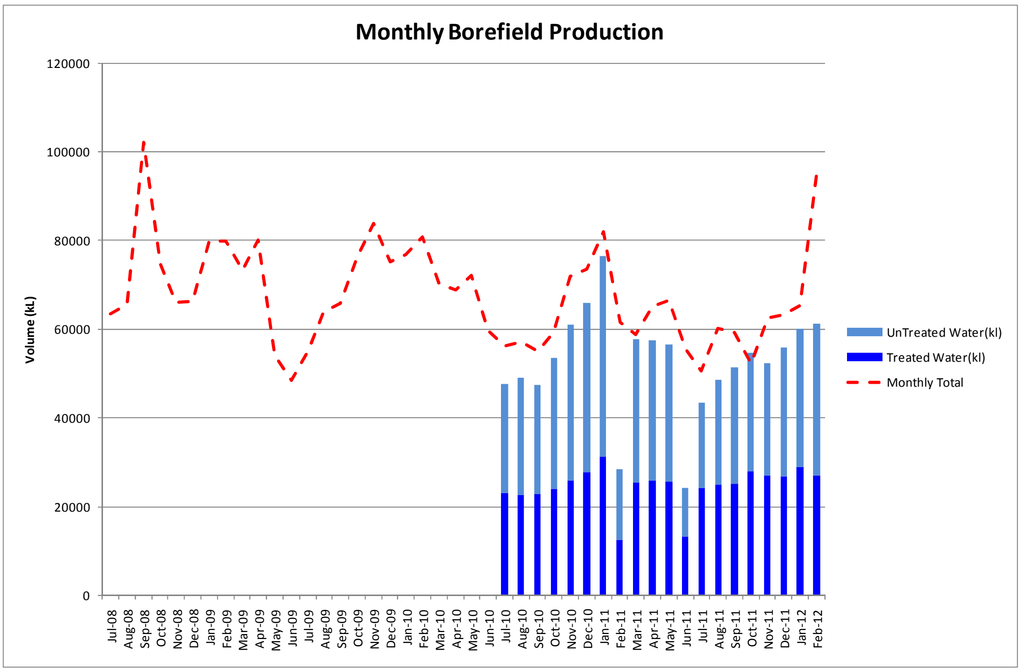

Figure 23 Yulara Wellfields – water production and supplied by water type to ARR (kilolitres, kL) (data courtesy of PWC)

The volume of concentrate (reject brine) produced by PWC's reverse osmosis desalination plant at Yulara and disposed to the evaporation basin[25] for the past two years (1/5/2010 – 30/5/2012) was 281,566 kL (T. Rammers, PWC, pers. comm.). This gives a yearly disposal volume of approximately 135.15 ML per year, equivalent to 11,262.6 kL per month. The average salinity of this reject brine is 30,000 uS/cm EC. The evaporation basin is too far down groundwater gradient to have any impact on Lot 252.

For year, 2011 some 231.19 ML of treated wastewater from the WWTP was disposed to trenches in the tree-lot via pumping from PWC's holding ponds. The monthly volumes disposed to the tree-lot for the past two years to date are given as Figure 24.

The average salinity of this treated wastewater is 1,550 uS/cm EC.

A proportion of the treated wastewater used to be supplied to ARR for public open space irrigation but this ceased in February 2003 ((T. Rammers, PWC, pers. comm.) apparently because of health concerns (D. George, PWC, pers. comm.), presumably over possible contact risk posed by this equivalent Class C treated effluent. The volume that was formerly supplied to ARR was about 90 ML/yr. (about 30 % of the total effluent produced at that time).

[25] located in an inter-dunal area between the township and Yulara airport.

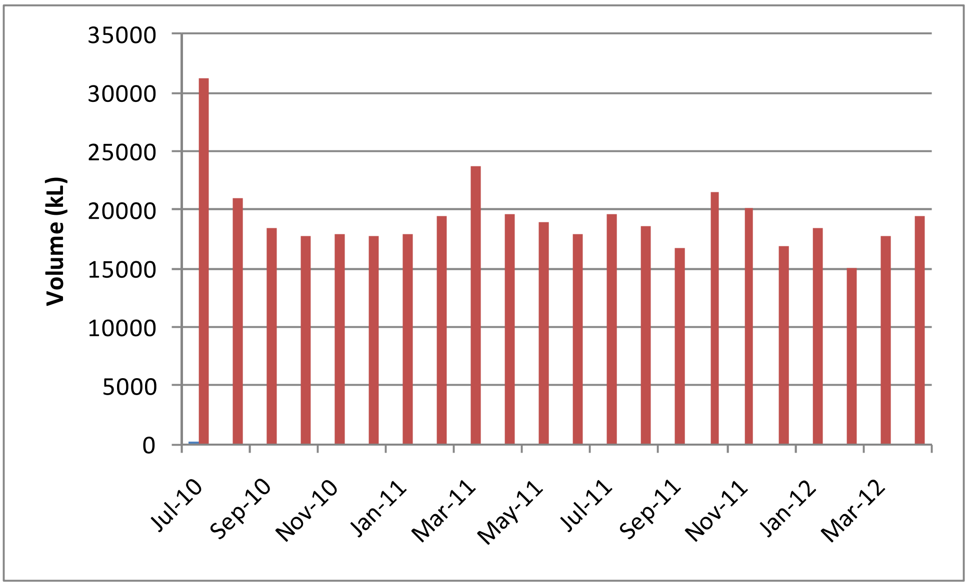

Figure 24 Yulara Wastewater Treatment Plant – wastewater (treated effluent) disposed to the tree-lot (kilolitres, kL) (data courtesy of PWC)

3.4 Potential Impacts

Developing a golf course in an arid environment such as the Yulara area will undoubtedly impact the natural environment.

As previously discussed, there are no surface water bodies or major drainage features within the study area.

Overall, the maintenance of the bands of more productive mulga vegetation in this landscape is critical to the maintenance of associated flora and fauna including endangered species. These are 'hot spots' that are sensitive to changes in surface biophysical processes. The major threat to these systems is disruption to sheet flows caused by infrastructure and changes in the level and types of anthropomorphic activities in the area. These activities may lead to increased erosion in some areas, or decreased or diverted flows in others. The changes to surface water flows plus inappropriate remedial action remain the key threats to the biota of the region.

Impacts to the water-table of the DPA are likely to arise from pumping groundwater for irrigation. Whilst the sustainable yield of the DPA has not been determined hydrogeological assessment and modelling indicated that wellfield development of an additional 15 L/s (480 ML/yr) capacity should be possible (Coffey, 1999). Regional impacts to the water table via abstracting from three additional bores (as discussed in Section 3.1.2) would result in a further decline in the water-table of about 1 metre.

The proposed development will not impact drinking water sources. The Old Wellfield although up-gradient of groundwater throughflow is situated some 2 km from the south-western corner of Lot 252 and the New Wellfield is situated some 2 km (down-gradient) from the northern boundary of Lot 252. As such Lot 252 lies outside the pumping capture zones of both wellfields.

3.4.1 Water Quality

There is very little baseline data available for comparisons of impacts on water quality.

Short-term impacts from construction might include;

- increase in suspended solids (sediment) of runoff associated with earthworks and landscaping;
- nutrients associated with any construction camp ablution facilities;

Long-term impacts from irrigation might include;

- increase in soil salinity and sodicity dependent on the quality of application water;
- build-up of soil salinity due to increased evaporation from irrigation returns;
- possible groundwater mounding should excessive irrigation be practised;
- use of herbicides applied to turf;
- use of fertilisers applied to turf;
- nutrients from ablution facilities associated with the club-house and related facilities

3.4.2 Surface Water

The planting and maintenance of turf inevitably will alter the surface water drainage regime. Surface water runoff is via sheet-flow; as such the interruption of this sheet-flow will likely impact run-on areas. Lot 252 is surrounded by roads and immediately to the north of the proposed site is situated the Yulara WWTP. These features already create a disruption to natural flow patterns; hence the area of disruption will be minimised to within the area bounded by roads.

Under the current local drainage regime pertaining at Lot 252, it is probable that surface water will pool in inter-dunal areas during rainfall events. These sites may be less susceptible to alteration of the drainage pattern than mulga-bands and as such there should be limited impact from the golf course footprint. It will be important to landscape the area in sympathy with the current local drainage vectors (Figure 8). It will be particularly important to maintain the natural drainage grade to the north and north-east to prevent centripetal drainage that could initiate soil salt build-up.

There are no known water-holes in the study area.

3.4.3 Groundwater Dependent Ecosystems

The fluctuations in depth to water in the DPA do not coincide with shifts in the type of vegetation suggesting the understory vegetation at least is incapable of reaching the water table and taking advantage of it. If there was a connection between the existence of mulga groves and access to ground water then one might expect the fluctuations in depth to groundwater to show similar distributional patterns to the bands of mulga groves. Hence, surface flows (and not access to groundwater) are thought to be far more important for the maintenance of the key plant communities associated with run-on areas.

In areas near The Sedimentaries water may pond at much shallower depths, of the order of six metres. In these areas there may be vegetation systems and individual plant species such as Desert Oak *Casuarina decasneana* and Ironwood *Acacia strophyliana* that may be linked to groundwater supplies near the surface (J. Reid pers. comm. reported in AGT, 2003).

3.4.4 Water Diverting Activities

Water diverting activities will depend on the source of water (determined mainly by water quality in terms of salinity) that is considered to be the most suitable. Should groundwater be used then the footprint should be minimal (say, three bore head-works and power control sheds in fenced compounds) with associated pipe to / or within Lot 252) to connect with the irrigation system.

Should treated wastewater be the source water then a delivery pipeline from the adjacent WWTP's holding basins together with a transfer pump would be needed. Should treatment to Class A be required then a treatment plant (micro-filtration and ultra-violet equipment would be needed; this would probably be situated at the intake end; i.e. within PWC's WWTP land if agreed with PWC.

Should a combined recycled / groundwater blend be considered then the infrastructure would be a combination of both the above.

Unless direct supply to the irrigation is envisaged then a holding tank would be needed of about 1,500 kL capacity to allow for approximately 24 hours storage.

4 Risk Assessment

The main impacts to be addressed concern the preservation of any native mulga groves from construction activities and the development of a salinity and irrigation management plan to minimise soil salinisation, and stormwater control.

Groundwater related impacts are more sentinel and are restricted to increased cones of pumping drawdown from further take of groundwater from the DPA. As a result of water-taking activities for the proposed irrigation, wellfield management may, inevitably, require the resource of the DPA to be mined due to the rare, but significant recharge events experienced in this semi-arid environment. This derogation may be mitigated by diverting the treated effluent from the Yulara WWTP currently being applied to the abandoned tree-lot to serve as a part source for irrigation with the balance of the demand coming from the DPA or from potable water (or a mix).

The major development risks are considered to be;

- long-term, insidious soil salinisation from the uncontrolled disposal of treated effluent to the abandoned tree-lot from the Yulara WWTP that may be encroaching the northern part of the proposed development, possibly exacerbated by irrigation application of water of the same or worse salinity;
- a possible requirement to irrigate with desalinated (potable quality) water to prevent salt accretion in the soil;
- providing adequate irrigation water especially during the summer (in addition to the current high per capita demand for potable water for Yulara);
- contouring of any land development sympathetic with pre-existing drainage conditions so as to minimise changes in natural surface water drainage;
- disturbance (possible impedance) to aquifer recharge by reworking, import and the compaction of soils during golf course construction;
- the potential for soil erosion by changed runoff dynamics, and possibly through inappropriate vehicle and plant use, and rabbits, if not controlled;
- invasion by exotic weeds, if not controlled; and,
- damage to infrastructure foundations (e.g. proposed club-house) from soil salinisation (if located adjacent to the Yulara WWTP as indicated on ILC Map No. 1864).

Table 4 presents a risk matrix of potential impacts to the hydrology emanating from the proposed Yulara golf course development.

Table 4: Risk assessment on impacts to the hydrology of the proposed golf course development at Yulara

Risk category	Perceived Risk		Comments
	Likelihood	Consequence	
Groundwater			
Environmental impact during construction and commissioning	Low	High	Only construction companies with a good history should be contracted. The engaged contractors will need to demonstrate their ability to conform to best practise standards and to have an environmental policy in place.
Falling groundwater levels impact on existing users	Low	Moderate	Monitoring of groundwater levels and the extent of pumping cones of depression.
Falling groundwater levels impact upon springs/waterholes	Low	High	No springs or waterholes identified in the near vicinity
Water extraction impacts – water-table decline may impact on sustainability of aquifer	Moderate	High	Volumes withdrawn will be monitored to ensure this does not occur
Increased irrigation intensity	Low	Moderate	Rising groundwater levels (mound) beneath irrigated area.
Quality decline (salinity)	Moderate	Moderate	Salinity monitoring required
Unmanaged leakage, leaky bores, loss of water above ground within scheme	Low	Low	Bore construction materials and method is based on best available practice
Flooding	Low	High	Severe flooding may inundate infrastructure
Tectonic movement, earthquakes, fault movement	Low	Moderate	Mild tremors are common in the Petermann Ranges
Aquifer and groundwater dependent ecosystems	Low	Low	No direct surface water - groundwater interaction. Stygofauna communities unknown
Energy and greenhouse gas considerations	High	Low	Some local increase in pumping and treatment costs are expected
Surface Water			
Water diverting activities – disruption of sheet-flow	High	High	Disruption to sheet-flow is almost certain but the site is contained within an area already subject to 'dislocated' drainage

Pathogens	Low	High	Water quality applied sourced from filtered groundwater & /or treated effluent (assumes Class A treatment)
Inorganic chemicals	Low	Low	
Soil salinity and sodicity	Moderate	High	Salt accretion in the soil profile
Nutrients	Moderate	Moderate	Fertilisers
Organic chemicals	Moderate	Moderate	Pesticides
Turbidity and particulates	Low	Low	Runoff resulting in erosion and turbidity
Radio-nuclides	Low	Low	No radio-nuclides likely to be in the vicinity

5 Conclusions and Recommendations

5.1 Conclusions

5.1.1 Summary conclusions and related recommendations

- **Site hydrology alteration** – the site environs have already been subject to man-made alteration that has modified the natural drainage vectors; thus any additional intervention as a result of the proposed development, if carefully planned, will not influence the wider natural drainage.

- **Surface water** – occasional large volumes of stormwater are generated by rainfall over the catchment. This stormwater can be managed by maintaining the existing land surface with minimal surface disturbance (minimal compaction to soils and minimal landscaping). The major drainage grade to the north and north-east should be maintained by sympathetic planning of the fairways. Consideration should be given to harvesting this stormwater by means of ponds / water holes that can act as flood detention storages, a supply source providing freshwater make-up blend for irrigation, and as course features or 'hazards'. Adaptive management of such ponds will be required otherwise they pose a danger of becoming salt 'sinks' (by evaporative concentration) during prolonged drought. In this regard such detention ponds should be considered as potential water sources for aquifer recharge.

- **Groundwater** – whilst the sustainable yield of the Dune Plains Aquifer (the major water supply source for Yulara) is poorly defined, estimates of its throughflow and its storage volume are considered conservative. The estimated total water demand (current user and anticipated development) is only some 1.2 % of the volume of groundwater in the DPA, and whilst some mining of groundwater will occur locally, such mining is considered sustainable because of intermittent natural recharge events to the aquifer. The perched water-table underlying the adjacent tree-lot presents an opportunity for resource use for the proposed development, either by direct supply of lower salinity (than the native groundwater) treated effluent from the Yulara wastewater treatment plant or via a managed aquifer recharge scheme.

- **Soil salinisation** – the use of the native groundwater from the DPA for irrigation is problematic in terms of soil salinisation and may impact the natural ecosystem. Instead, it is recommended that a blend of treated wastewater and groundwater be used (approximately 67%/33%, respectively); ideally supplemented by detained stormwater and /or potable (desalinated) water, to achieve an irrigation application quality of less than 1000 mg/L total dissolved salts (TDS) at all times. A TDS concentration threshold of less than 1000 mg/L should not be detrimental to the wider environment. This coupled with careful landscape and drainage design (possibly incorporating agricultural drains to assist drainage of low-lying areas), should combat soil salt build-up.

5.1.2 Detailed / wider conclusions

Lot 252 lies within dune fields and to its west there are sand plains. Its catchment area drains an area of 294 km^2 that grades in a north-easterly to north direction past Yulara township towards the Lake Amadeus discharge zone. Its drainage is composed of inter-dunal drainages, minor flood-outs and ephemeral creeks. Within Lot 252 a centripetal drainage is evident resulting from a reticulate (star-shaped) dune formation that dominates its central northern sector.

The flood-outs of the sand plains are biologically productive. Mulga groves form in “run-on” areas which receive increased levels of moisture via sheet-water flow from adjacent run-off areas. They may function as important refugia for flora and fauna including rare and endangered fauna. Consequently, their maintenance is critical. The major threat to these systems is disruption to sheet flows caused by infrastructure and associated construction activities. These activities may lead to increased erosion in some areas, or decreased or diverted flows in others.

The catchment to the south of the proposed development can be considered to be unmodified apart from the major sealed road (to Kata Tjuta) that bisects it, whilst the northern part of the catchment has been greatly modified by the development of Yulara. The open-channel stormwater drains of the road network impede natural run-off and have dislocated the run-on zones.

The planting and maintenance of turf inevitably will alter the surface water drainage regime. Surface water runoff is via sheet-flow; as such the interruption of this sheet-flow will likely impact run-on areas. Lot 252 is surrounded by roads and immediately to the north of the proposed site is situated the Yulara WWTP. These features already create a disruption to natural flow patterns; hence the area of disruption will be minimised to within the area bounded by roads.

Under the current local drainage regime pertaining at Lot 252, it is probable that surface water will pool in inter-dunal areas during rainfall events. These sites may be less susceptible to alteration of the drainage pattern than the mulga groves and, as such, there should be limited impact from the golf course footprint.

Red earths, sandy loams and red earth sands formed on gently sloping sand plains (Kandosols) make up 70 % of Lot 252 in the west, whilst shallow, red siliceous sand and red earth sands; making up the sand dune country (Tenesols) occupy the eastern third. In the neighbouring tree-lot north of Lot 252, the substrate is described as a surficial fine sand (about 2.8 m thick) overlying a silty sandy clay about 3 m thick, underlain by a clayey sandstone. At the tree-lot there is some indication of salt accumulation at the root zone (to 2 - 3 m depth); possibly due to transpiration. Lower salinities deeper in the profile suggest that there is preferred pathway flow from the ground to the perched water table and possibly to deeper in the profile, with salinity ‘spikes occurring within the shallower silty sand soils. The assessment of the soils through which the infiltrate moves indicate potential for remobilisation of salts stored within the soil profile particularly in the western portion of the tree-lot.

Mean monthly open pan evaporation exceeds rainfall in all months of the year; and on an annual basis by more than four-fold.

Major rainfall events are important, hydrologically and ecologically, in recharging aquifers and for sustaining ecosystems. For a 1 in 5 year storm of duration 24 hours, the rainfall intensity at Yulara is estimated to be 3.5 mm/hour (consistent with maximum daily rainfalls) that could result in the local catchment yielding enormous volumes of runoff (between about 200 ML/hr and 400 ML/hr).

There are no known water-holes in the study area.

Lot 252 overlies the Dune Plains Aquifer (DPA) with regional groundwater throughflow to the north. There is a huge storage of marginally potable to brackish groundwater that is large in proportion to throughflow, recharge and usage. The sustainable yield of the DPA is not known; coarse estimates of its throughflow are 200 ML/year and its storage volume, 90,000 ML.

Accessions to the water-table may occur via runoff recharge from sand hills / dunes and The Sedimentaries. The rainfall threshold for recharging the DPA is estimated to be 130 - 180 mm/month.

Despite spasmodic groundwater recharge, surface water is disconnected from the water-table in that the depth to the water-table precludes direct evaporation except in the artificially induced groundwater mound beneath the tree-lot and by deep-rooted trees (e.g. Desert Oak). A hypothesis that certain fauna notably the Mulgara are dependent on the water-table is questionable; this is believed to be a facet of the run-on areas (moisture availability), rather than the water-table *per se*.

In the northern extremity of Lot 252 the groundwater system is probably modified by uncontrolled flood irrigation of treated effluent at a tree-lot adjacent to Yulara's wastewater treatment plant. Here a perched watertable aquifer has formed a local groundwater mound within the DPA. It has developed at approximately 2 - 5 m bgl over an estimated sub-surface semi-radial area of roughly 0.4 - 0.6 ha. Its southern (up-gradient) limit (under Lot 252) is unknown. The effluent infiltrates readily into the upper sandy soils and although this accumulates as a limited zone of perched water on the sandy clay "aquitard", the latter is sufficiently permeable to allow infiltration into the underlying DPA. Field testing of the silty sand indicated relatively high infiltration rates averaging nearly 8 m/d at 0.5 m depth and 7 m/d at 1.0 m soil depth

There are potentially useable groundwater resources in the northerly extension of the palaeochannel (north and east of Yulara) which have yet to be investigated.

Despite nearly thirty years of withdrawal of groundwater from the DPA through pumping to meet water demand at Yulara there has been little impact with respect to derogating this water resource. Only localised ‘cones of drawdown’ from the impacts of pumping have developed. The water-table in the northern part of the aquifer, beyond the capture zone of PWC’s northern wellfield, has risen generally by 2.5 m.

Current abstraction of groundwater of about 737 ML/year is in excess of the estimated throughflow of the DPA, but is only some 0.8 % of available aquifer storage.

Wellfield management may, inevitably, require the resource to be mined due to the rare, but significant recharge events experienced in this semi-arid environment.

Power and Water is the operator of the Yulara water supply and is the sole water user exploiting the DPA. The DPA supplies water to Yulara / Ayers Rock Resort from two wellfields, the ‘New (or Northern) Wellfield’ and the ‘Old (Southern) Wellfield’. It appears that PWC is licensed to take up to 19,200 ML per year (1,600 ML per month) from the DPA. Total water production for year, 2011 was 737.39 ML including 290.05 ML of treated (desalinated) potable water and 317.55 ML of non-potable water (not desalinated) supplied to ARR.

The salinity of the blend of raw water extracted from the two wellfields is about 1,500 mg/L TDS. The raw water is hard and high in nitrate. The potable water had an average salinity of about 210 mg/L TDS; the non-potable water had an average salinity of about 1,400 mg/L TDS.

The anticipated water demand for the proposed golf course is 344.07 ML/year. Irrigation demand is seasonal ranging from a minimum daily average demand of 0.39 ML (13.5 L/s over an 8 hours irrigation period) in July to a maximum daily average demand of 1.61 ML (55.8 L/s over 8 hours) in January.

In order to satisfy the maximum monthly demand a bore capacity of 18.6 L/s instantaneous would be required. Given a typical bore pumping cycle of 12 hours pumping and 12 hours non-pumping would require three (3) new bores pumping approximately 12.5 L/s each, producing about 5 m of drawdown at each well. Interference effects would compound this and would depend on the spacing between the bores (including the PWC production bores in the Northern wellfield).

As peak irrigation rates over an 8 hours cycle exceed the instantaneous flow capacity of the proposed wellfield thus balancing storage tanks would be needed.

The water demand of 344.07 ML/year combined with the current take of 737.39 ML/year for Yulara would amount to approximately 1,081.5 ML/year. This volume is only some 1.2 % of the volume of groundwater in the DPA.

Impacts to the water-table of the DPA will arise from pumping groundwater for irrigation. Whilst the sustainable yield of the DPA has not been determined, hydrogeological assessment and modelling indicated that wellfield development of an additional 15 L/s (480 ML/yr) capacity should be possible (Coffey, 1999). Regional impacts to the water table via abstracting from three additional bores would result in a further decline in the water-table of about 1 metre.

The use of the native groundwater (conservatively, 1,500 mg/L TDS and up to ~2,000 - 2,400 mg/L TDS) from the DPA for irrigation is problematic in terms of soil salinisation.

The use of recycled treated wastewater (Class C equivalent) from the Yulara WWTP might be considered. Some 231 ML/year is currently being disposed at the tree-lot with a quality of approximately 980 mg/L TDS and a SAR of 4.7. This would provide on an annual basis some 67 % of the estimated irrigation demand. Pre-treatment would be required to Class A standard unless a strict regime of non-contact irrigation was implemented (such as night-watering). Further, the salinity ('Class 3' for salinity of irrigation water) is still considered high especially for soils with impeded or poor drainage.

It is likely that to meet annual demand then a blend of recycled treated wastewater and groundwater will be required (230 ML wastewater plus 114 ML groundwater). An option to reduce salinity is to negotiate the delivery of a quantity of potable water from PWC but this will undoubtedly have cost implications and may be perceived as inappropriate use of high value water supply.

The evaporation basin associated with PWC's desalination plant is too far down groundwater gradient to have any impact on Lot 252.

The proposed development will not impact drinking water sources as Lot 252 lies outside the pumping capture zones of PWC's wellfields.

Short-term water quality impacts from construction might include;

- increase in suspended solids (sediment) of runoff associated with earthworks and landscaping;
- nutrients associated with any construction camp ablution facilities;

Long-term water quality impacts from irrigation might include;

- increase in soil salinity and sodicity dependent on the quality of application water;
- build-up of soil salinity due to increased evaporation from irrigation returns;
- possible groundwater mounding should excessive irrigation be practised;
- use of herbicides applied to turf;
- use of fertilisers applied to turf;
- nutrients from ablution facilities associated with the club-house and related facilities

Water diverting activities will depend on the source of water, determined mainly by salinity suitable for irrigation application in this semi-arid environment. Should groundwater be used then the footprint should be minimal (say, three bore head-works and power control sheds in fenced compounds) with associated pipe to / or within Lot 252 to connect with the irrigation system.

Should treated wastewater be the source water then a delivery pipeline from the adjacent WWTP's holding basins together with a transfer pump would be needed.

Should treatment to Class A be required then a treatment plant (micro-filtration and ultra-violet) would be needed; this would probably be situated at the intake end; i.e. within PWC's WWTP land if agreed with PWC.

Should a combined recycled / groundwater blend be considered then the infrastructure would be a combination of both the above.

Unless direct supply to the irrigation is envisaged then a holding tank(s) would be needed of about 1,500 kL capacity to allow for approximately 24 hours storage.

5.2 Detailed recommendations

It is important that the soils in this area of localised internal drainage at Lot 252 exhibit good infiltration properties as the application of irrigation water could lead to a build-up of salts depending on the water quality of the applied water. Therefore on-site soil investigations should be undertaken to ascertain the infiltration capacity of the soils at Lot 252. Several shallow auger holes should be opened and the soils logged. The auger holes should be subject to falling head infiltration tests to assess the soil's drainage properties.

Should the development proceed, the soils should not be compacted during construction and landscaping activities.

It will be important to landscape the area in sympathy with the current local drainage vectors. It will be particularly important to maintain the natural drainage grade to the north and north-east to prevent centripetal drainage that could initiate soil salt build-up.

Stormwater flooding alleviation works will need to be considered for the proposed golf course that may impact the natural environment.

A salinity and irrigation management plan needs to be developed to appropriately manage and minimise soil salinisation. Such a plan would examine the quality of the source water, irrigation philosophy including application rates and scheduling, the need for agricultural drains in low-lying parts of the course, etc.

Treated effluent discharged from the Yulara WWTP currently applied in an uncontrolled fashion to the tree-lot should be considered as a water source to satisfy part of the estimated irrigation demand. The remaining volume to satisfy demand could come from native groundwater by developing a wellfield of three bores in the northern DPA and/or importing potable water from PWC. Further studies of the harvesting works, treatment requirements, and associated costs of developing these resources, needs to be undertaken.

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Appendix A True colour images indicating existing environmental impacts in the vicinity of Yulara

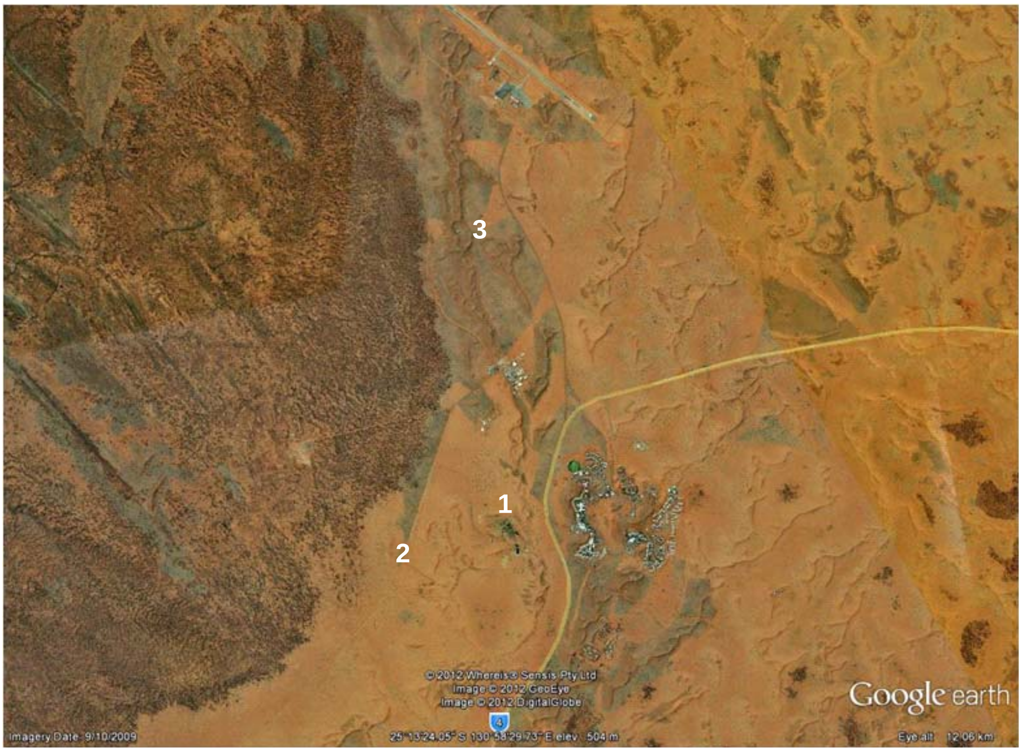


Figure A 25: Overview of area between Yulara and The Sedimentaries

1. Wastewater treatment plant
2. Change of vegetation across road boundary
3. RO process concentrate (reject brine) disposal basin

Figure A26: Yulara Wastewater Treatment Plant

a) Represents a patch of white on the image. This area appears to be associated with a change in vegetation. Possible kerosene grass or new Spinifex colonisation associated with ground disturbance or water release.

b) The wastewater treatment plant shows clear infiltration channels and vigorous vegetation growth. There are some white patches that may be associated with saline areas.

c) To the northwest there appears to be an area of salt affected land but this area can be seen to be disturbed and may represent a previous building site or similar.

Appendix B Infiltration studies at Yulara Woodlot (excerpts from AGT, 2006)

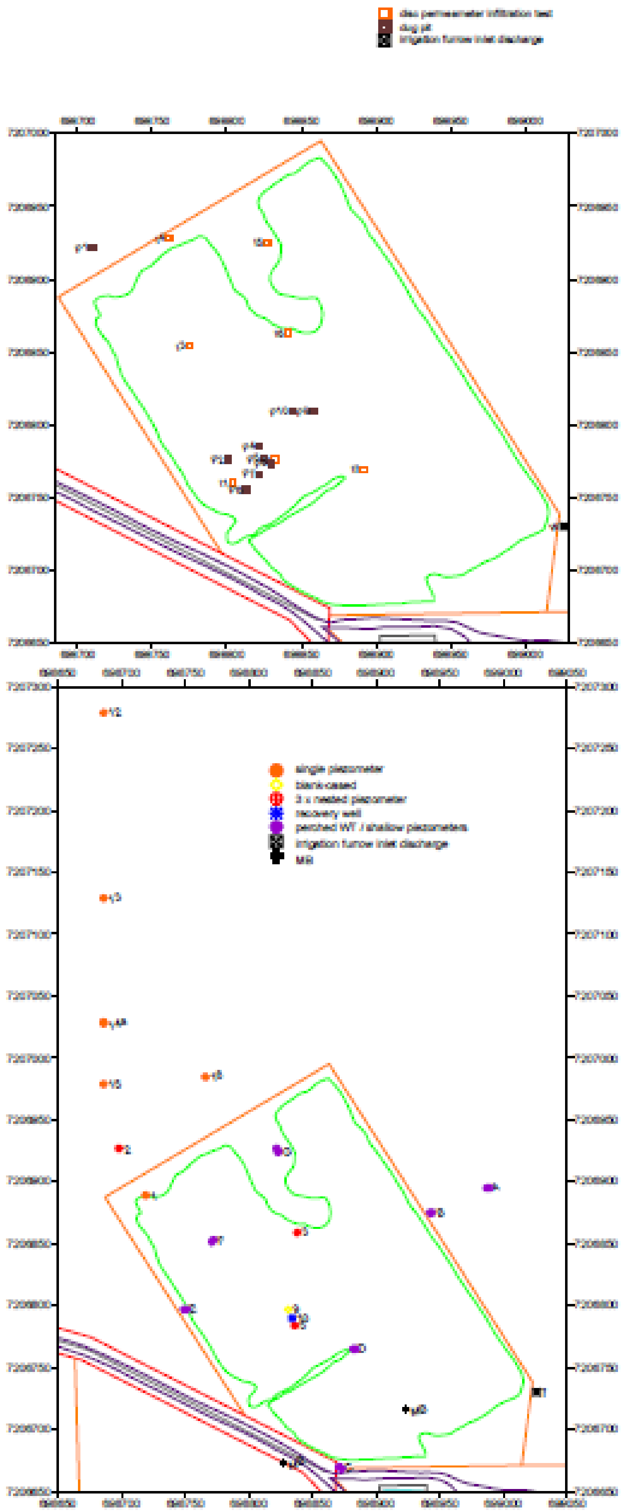


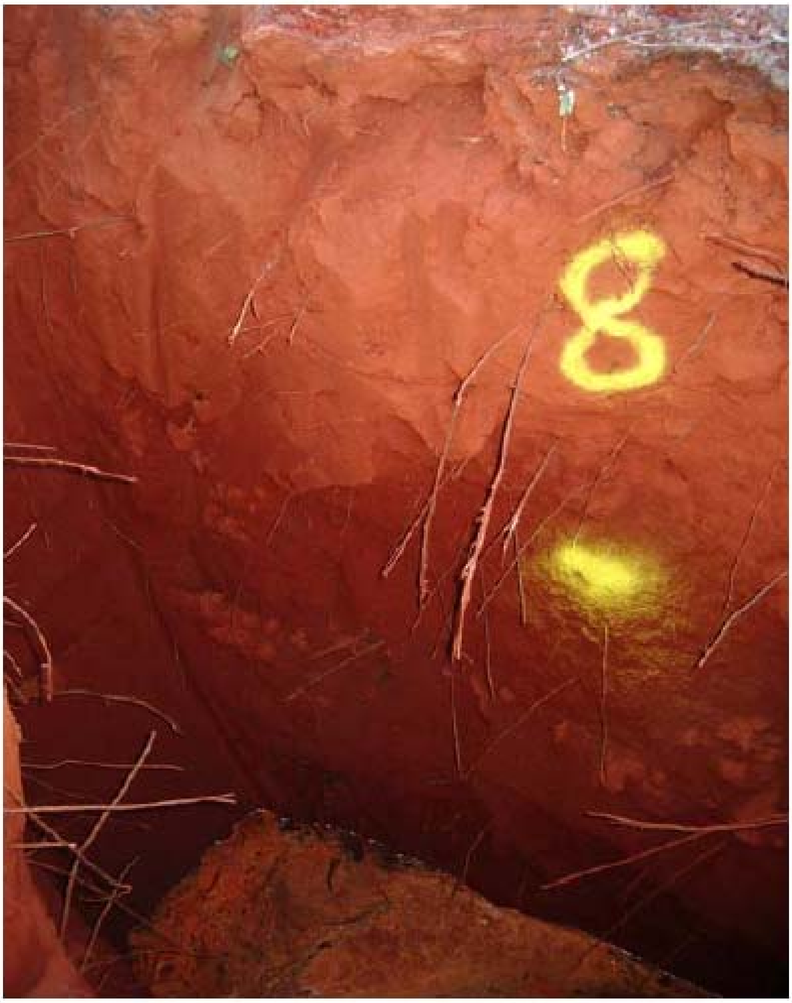
Figure 2 Feasibility Investigation Infrastructure installed June-July 2005

Hole No. C

Depth interval (m bgl)	Dominant soil/rock fraction	Description
0.0 – 3.2	SAND	Red (10R, 4/8) v. fine-medium; occasional coarse, silty, quartz; subangular-rounded. Grains are clean & opaque-red & clay coated. Most clay is as thin coatings in minor pits on grain surface
3.2 – 5.5	SANDSTONE	Firm tan (5YR 4/6) v. fine-coarse, sub rounded-angular. High interstitial clay matrix & 10% lithic & v. well rounded ironstone to 2 mm
5.5 – 7.0	SAND	As above with tan, sandy claystone
7.0 – 8.5	CLAYSTONE	Firm, tan (5YR 4/6) sandy CLAYSTONE with 25% very well rounded ironstone to 5 mm
8.5 – 10.0	SANDSTONE	Firm, tan, v. fine-fine; occasional coarse, sub rounded-angular. High interstitial clay matrix. Minor pale green claystone

Pit No. 8

0 – 0.2	SAND		V. fine-medium; occasional coarse silty quartz. Sub-angular-rounded grains are clean & frosted to red & clay-coated.	Dry. Most clay is as thin coatings in minor pits on grain surface. Minor heavy black mineral & shrub and grass roots
0.2 – 0.8	SAND	10R, 4/8 Red		Dry. As above, slightly more competent.
0.8 – 2.1	SAND		Silty.	As above with slightly increased clay and moisture content.
2.1 – 2.5	SAND		V. fine-medium; occasional coarse silty & clayey with 10% well rounded ironstone clasts to 4 mm.	Moderate amounts of tree roots to 2.5 m.
2.5 – 2.7	CLAY	10YR 8/1 white. 10YR 7/8 yellow	V. sandy. Quartz grains are v. fine-coarse, opaque to brown, sub-angular-sub-rounded.	Firm.



Pit No. 8

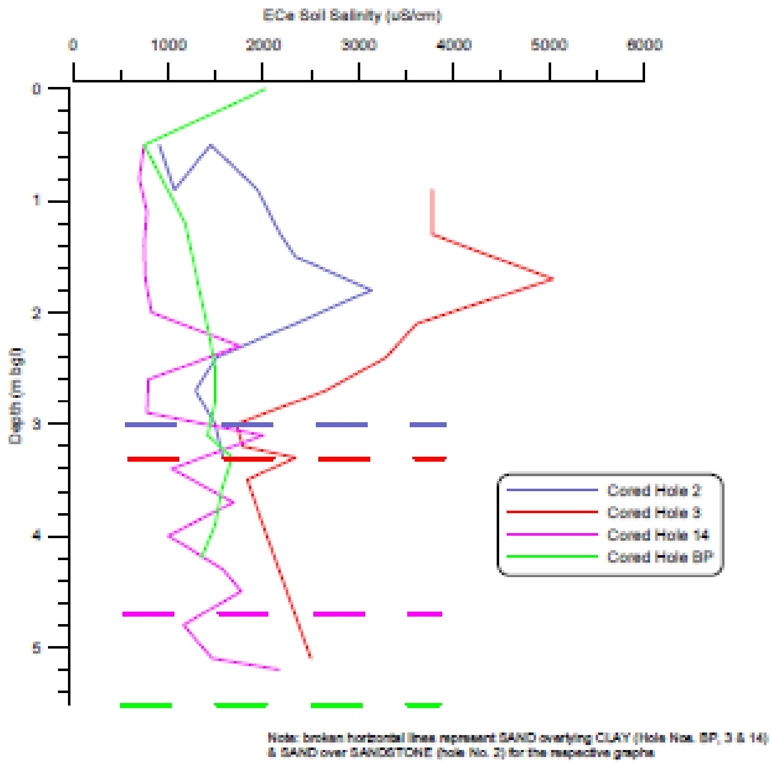


Figure 5 Soil Salinity Profiles

Table 8 Calculated Infiltration Rates from CSIRO Disc Permeameter Tests

Infiltration Test Site	Easting	Northing	I Rate (m/day) @ 0.5 m bgl	I Rate (m/day) @ 1.0 m bgl
1	698804	7206760	7.2	6.4
2	698832	7206776	5.8	6.6
3	698775	7206854	11.5	9.6
4	698761	7206928	3.8	NR > 0.5 (saturated)
5	698827	7206925	7.2	6.2
6	698841	7206863	9.4	7.6
7	698892	7206769	9.4	7.5
		Average	7.8 (excl. Sites 3 & 4)	6.9 (excl. site 3)

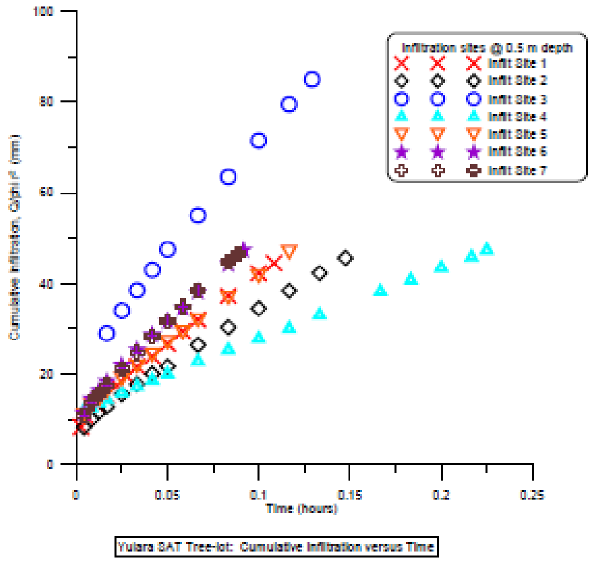


Figure 8 Infiltration Graphs for Infiltration Sites (using CSIRO Disc Permeameter) at Soil Depth of 0.5 m bgl

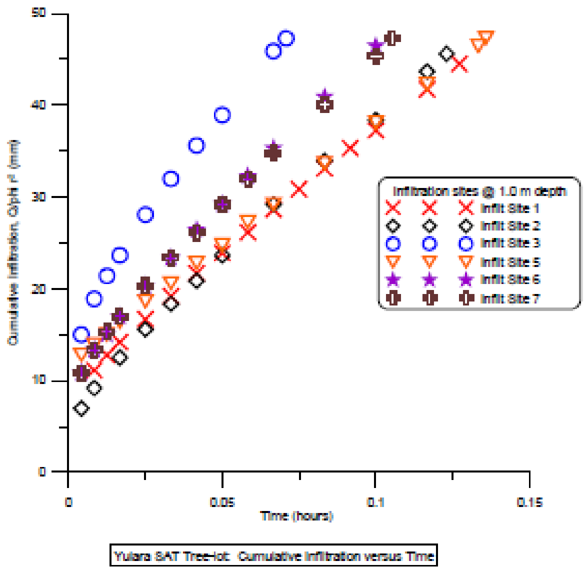


Figure 9 Infiltration Graphs for Infiltration Sites (using CSIRO Disc Permeameter) at Soil Depth of 1.0 m bgl