THE NORTHERN TERRITORY DEPARTMENT OF REGIONAL DEVELOPMENT, PRIMARY INDUSTRY, FISHERIES AND RESOURCES

THE ENVIRONMENTAL IMPACT OF PLANT INDUSTRIES ON INLAND WATER IN THE NORTHERN TERRITORY

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EXECUTIVE SUMMARY

There are three aims for this document:

- To scope the size of the water resource available to plant industries (cropping, forestry and horticulture) in the Northern Territory (NT).
- To review the impact of plant industries in the NT on inland water (all waters above the high tide level), with particular emphasis on hydrology, water quality and the effect of saline water on soils.
- To determine gaps in knowledge and to establish research needs to enable informed, evidence-based, government policy and effective industry practice.

Rainfall, in the NT, decreases with increasing latitude. Most rain falls in the summer months (the wet season), with intensity being a special threat to soil. Evaporation is high in the NT, meaning rain-fed agriculture is only possible in the Top End for two to three months on the year.

Rainfall accumulates in streams, rivers, billabongs, soaks, swamps, waterholes and lagoons, which is known collectively as surface water. Surface water drains to the sea in the Top End and to deserts in the arid south. Most rivers in the NT are ephemeral, with a few perennial rivers in the north that flow through the dry season fed by groundwater discharge.

Irrigation demand is mainly in the dry season, when surface water is at its lowest. Dry season supply of surface water depends on the amount of rain in the immediately preceding wet season.

A percentage of rainfall soaks through the surface of the NT into porous geology, and is stored there as ground water. These geology-groundwater systems are called aquifers. The NT is fortunate to have a number of useful aquifers that support irrigated plant industries from the Top End to the Arid Zone.

Surface and groundwater resources have many and often conflicting demands placed upon them by a variety of sources such as plant industries, human settlements, indigenous values, recreation (especially fishing), tourism and the environment. Water allocation planning, through the National Water Initiative, has been embraced in the NT, and several plans are being developed. Because of this, and the lack of water in the dry season (Top End) or all the time (Central Australia) when irrigation is needed, agricultural activities are clearly constrained by lack of water in the NT.

Plant industries have effects on surface hydrology, which changes the way water interacts with soil, subsequently changing erosion risk. Plant industries also affect the way water is partitioned between runoff, groundwater recharge and evaporation. More research is needed to quantify the effects.

Man-made surface water storage in the NT is rare. Public dams have been constructed for domestic and industrial water supply but there are no publicly-owned dams for irrigation and few privately owned dams. Because of lack of suitable sites, evaporation and possible negative environmental impacts, future surface water storage in the NT in dams or weirs is unlikely.

Hydrogeology is the science that deals with the distribution and movement of ground water in the soil and rocks of the Earth’s crust. Extraction of ground water for irrigation has effects on hydrogeology. The major current concern is that irrigation extraction will compromise groundwater recharge of dependent ecosystems. More research is needed to determine safe levels of utilisation.

Plant industries may also affect water quality by delivering pollutants such as pesticides, mineral nutrients or suspended sediment to natural water systems. More work is needed to determine how these pollutants reach water bodies and what practices are necessary to minimise this occurring.

Some ground water in the NT is naturally saline; therefore there is some risk that its use for irrigation may cause dryland salinity. After an assessment of the risks, it appears that the greatest concern is use of ground water in Central Australia. Further work is necessary in this area to ensure this risk is minimised.

The current impact of plant industries on water resources in the NT is relatively small. However, the environment is fragile and development needs to proceed in an informed and cautious manner.

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1. INTRODUCTION

There are three aims for this document:

- To scope the size of the water resource available to plant industries (cropping, forestry and horticulture) in the NT.
- To review the impact of plant industries in the NT on inland water, with particular emphasis on hydrology, water quality and the effect of saline water on soils.
- To determine gaps in knowledge and to establish research needs to enable informed, evidence-based, government policy and effective industry practice.

This review is limited to presenting information on the current impact of plant industry activities on inland waters. The review recognises, but does not embrace, emerging new pressures on inland water resources, such as pressures arising from the impact of climate change on future water resources and their availability, or pressures arising from increased irrigation in future.

2. INLAND WATER RESOURCES

Inland (non-marine) waters in the NT refers to both permanent and ephemeral water-based ecosystems and includes the NT's diverse riparian areas and wetland types and its groundwater systems. 'Inland' in this context refers to all waters occurring above the high tide level, thus including many coastal wetlands in the Top End and waterholes, permanent and intermittent rock holes, springs and soakages in the arid centre, as well as the more typical wetlands and rivers elsewhere (Landcare Council of the Northern Territory, 2005). Inland water has been separated from marine water because of its relevance to agricultural use. The water between inland and marine waters – estuarine water - is also considered in this review as it has been proposed for agricultural use in the NT.

This section will focus on the extent of the existing water resource in the NT available for agriculture, beginning with rainfall and the possibility of rain-fed farming, then followed by secondary water sources arising from the movement and accumulation of rain water, either on the surface of the land or stored in some way under the surface.

2.1 RAINFALL AND EVAPORATION

The annual distribution of rainfall and evaporation in representative centres in the NT is summarised in Figures 1 to 7, in order, from low to high latitudes. Data was taken from www.bom.gov.au, in June 2008. Katherine evaporation data is from CSIRO Research Station records 1974-1981, cited in (Williams et al. 1985), as there is no regular Bureau of Meteorology recording in this location.

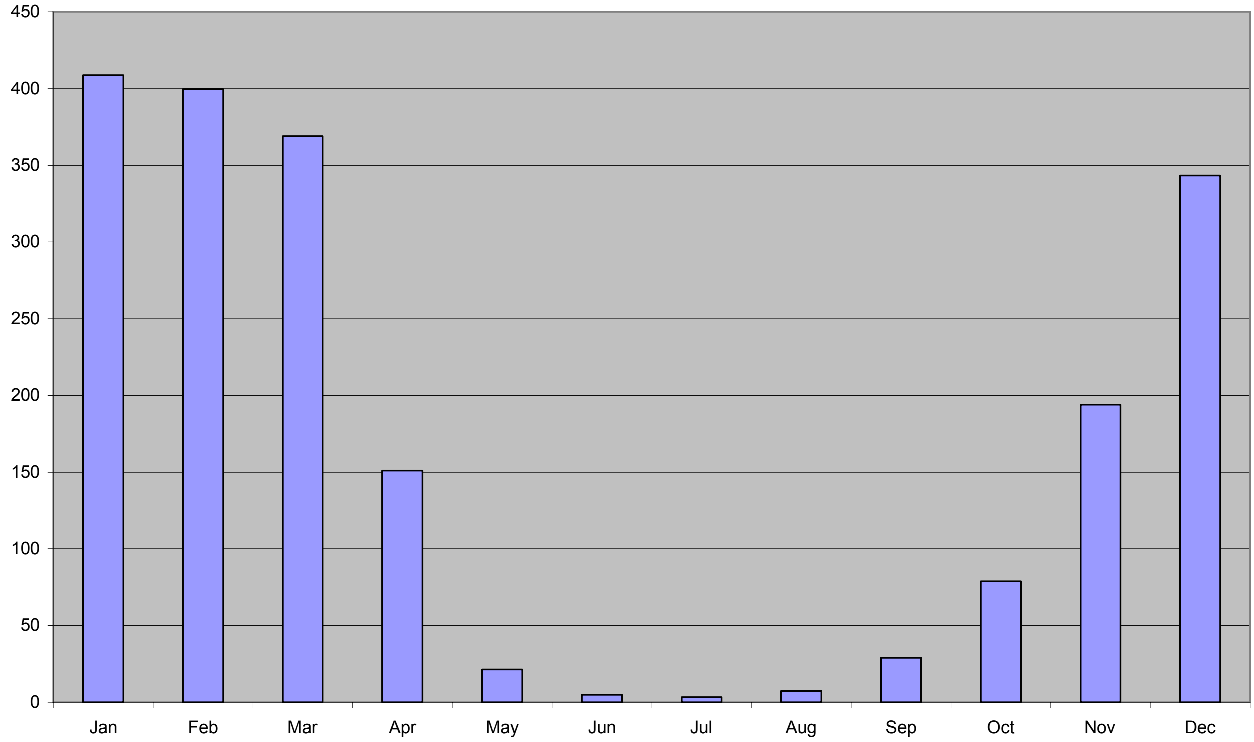

Figure 1. Mean rainfall data (mm), 1979-2008 for Pirlangimpi (Tiwi Islands) – latitude 11.40 ^{o} S

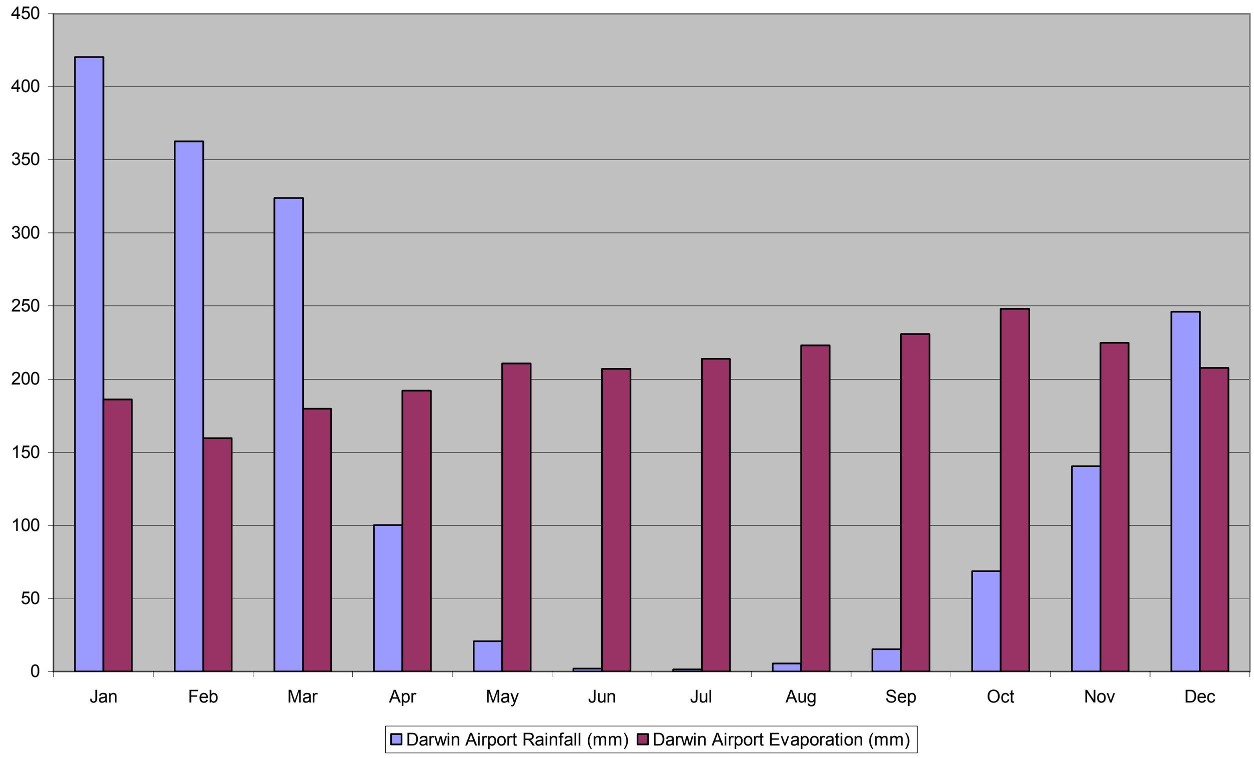

Figure 2. Mean rainfall and evaporation data (mm), 1941-2008 for Darwin Airport – Latitude 12.42^{o} S

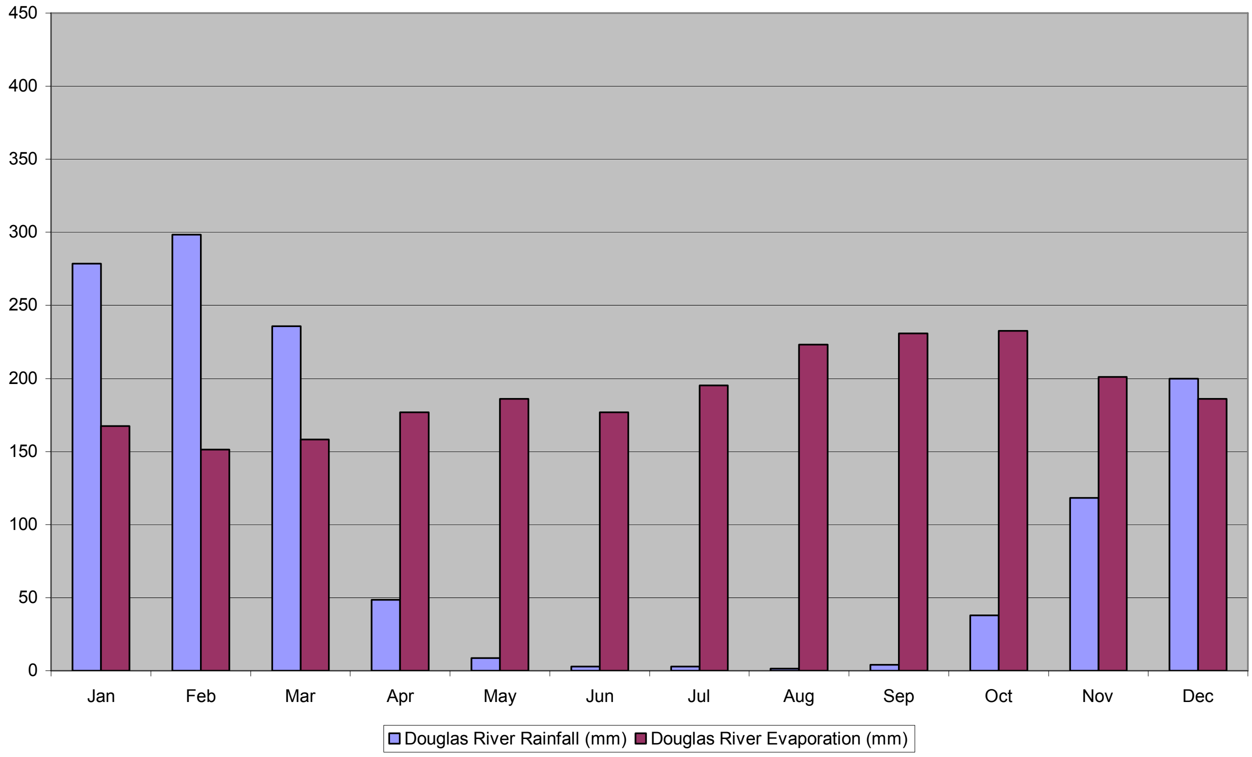

Figure 3. Mean rainfall and evaporation data (mm) 1968-2008 for Douglas River: 13.83^{o} S

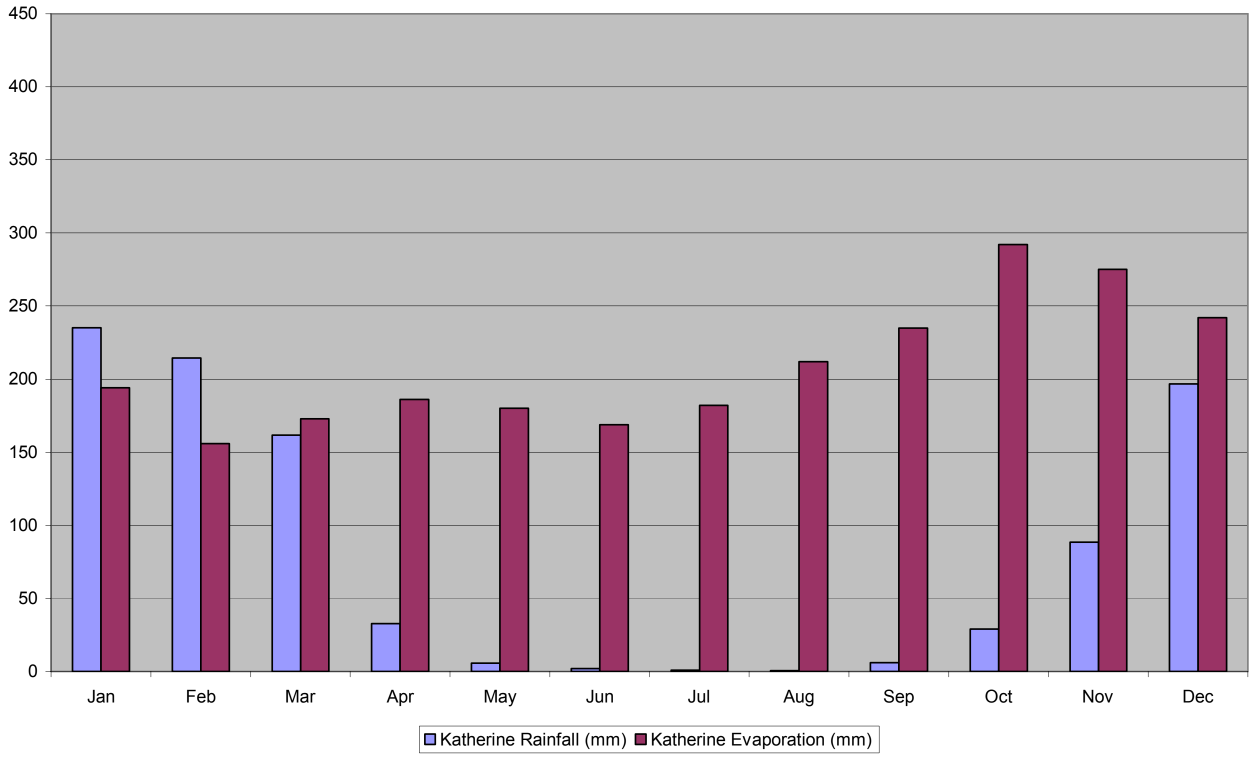

Figure 4. Mean rainfall and evaporation data (mm), 1942-2008 for Katherine Aviation Museum: 14.46^{o} S

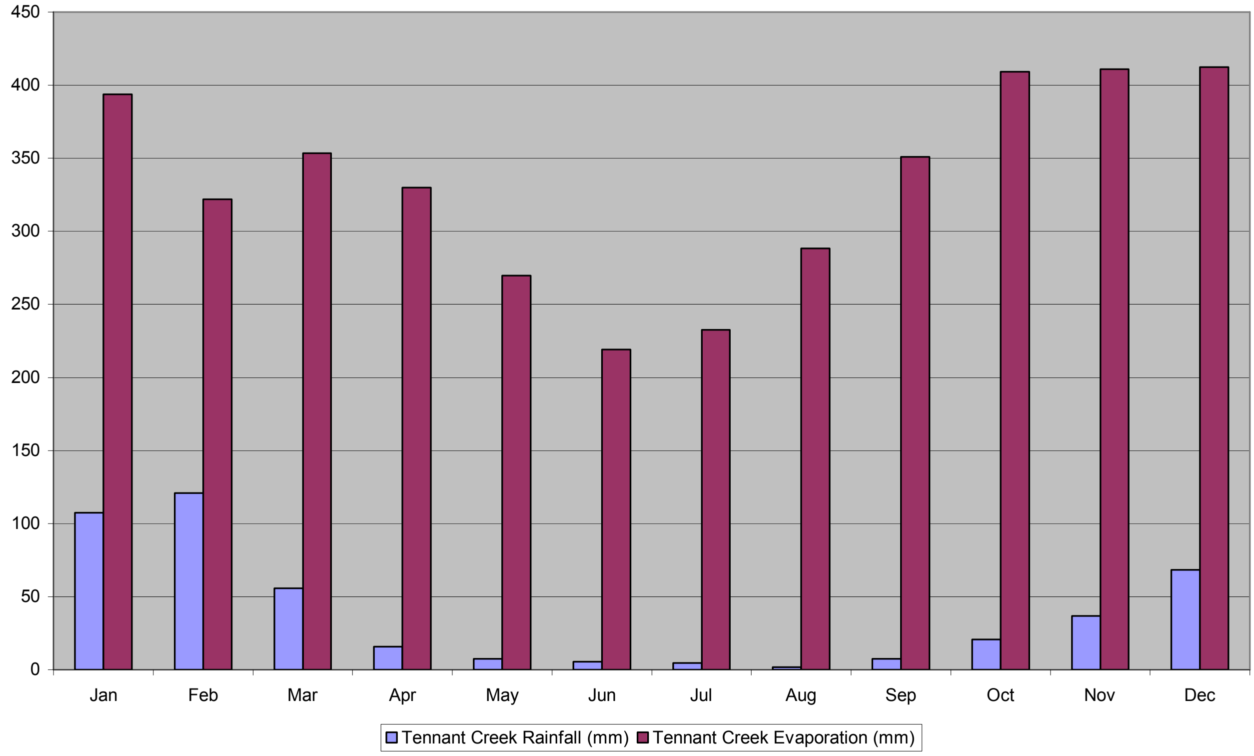

Figure 5. Mean rainfall and evaporation data (mm), 1969-2008 for Tennant Creek Airport: 19.64 ^{o} S

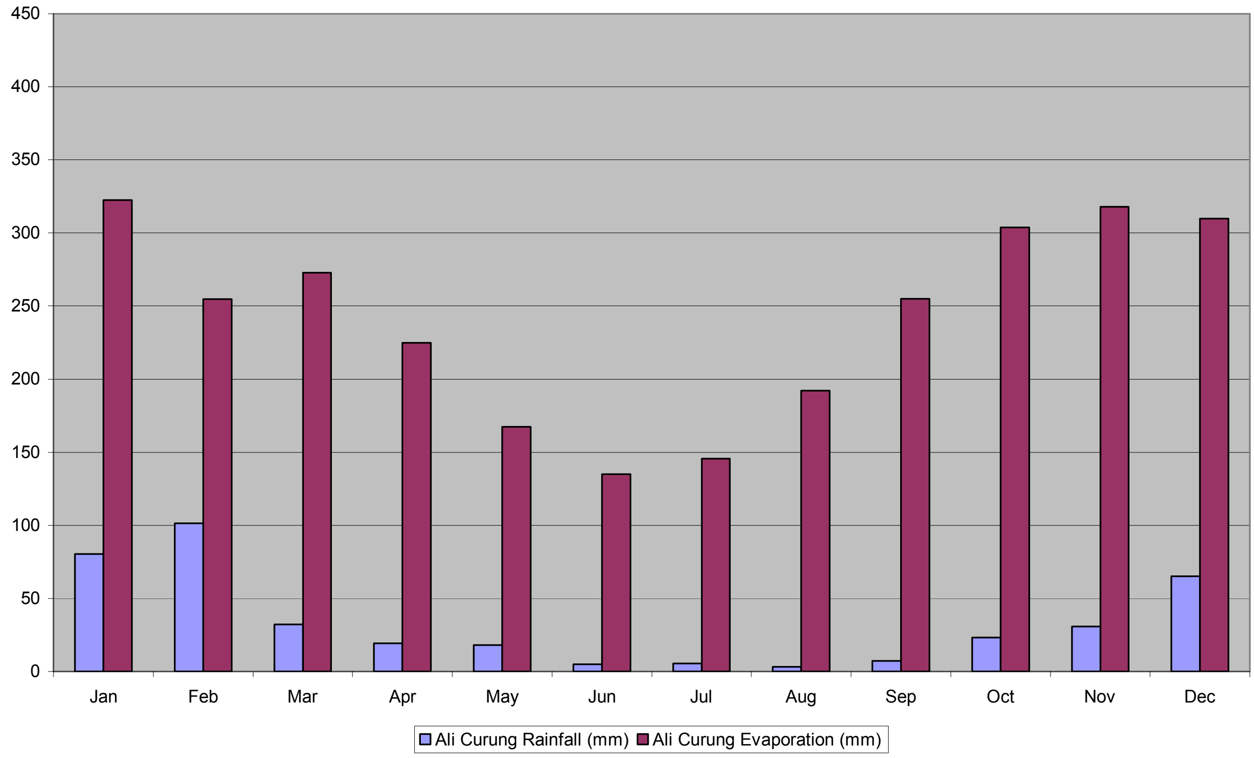

Figure 6. Mean rainfall and evaporation data (mm), 1967-2008 for Ali Curung: 21 ^{o} S

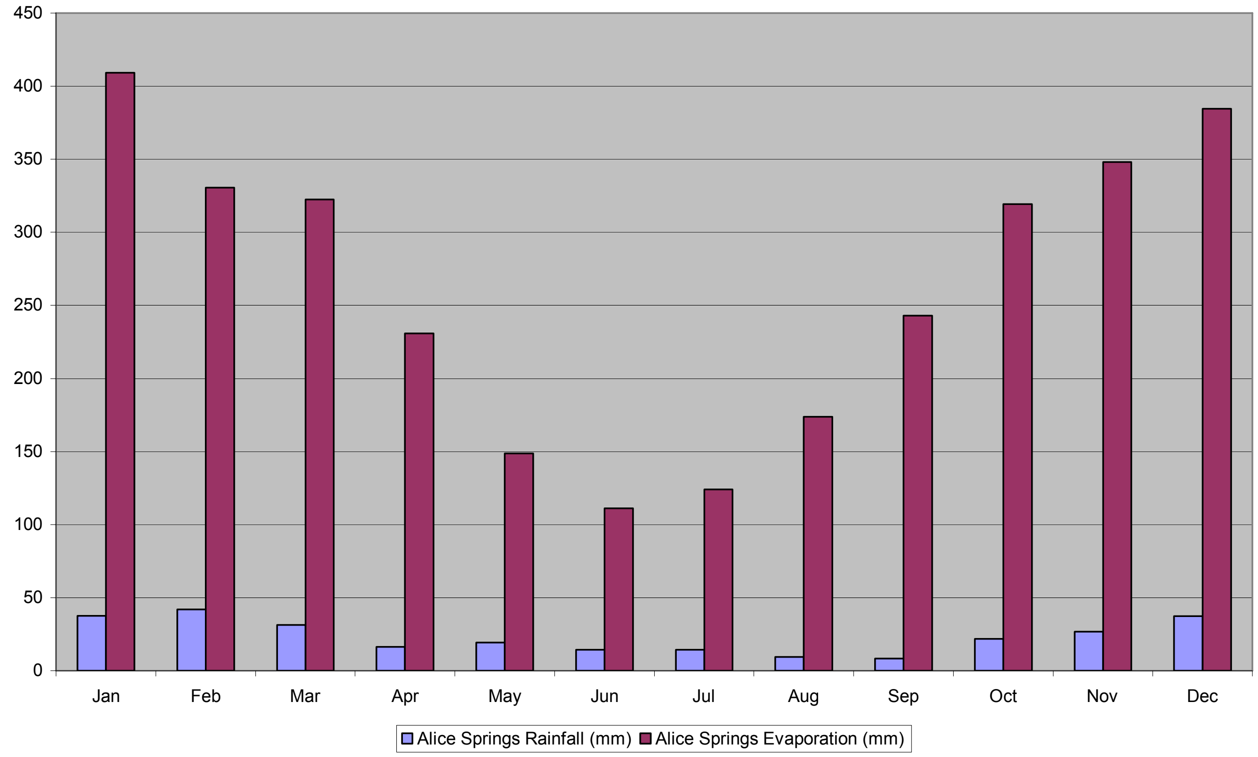

Figure 7. Mean rainfall and evaporation data (mm), 1940-2008 for Alice Springs airport: 14.46^{o} S

It can be seen from this data that mean annual rainfall decreases with increasing latitude. Figure 8 further demonstrates the strong relationship between latitude and mean annual rainfall for representative stations within 100 km of the Stuart Highway (except for Pirlangimpi) as it transects the NT from north to south. A curve fitted to these points gives the relationship as:

Mean annual rainfall = 2599300 x latitude S $^{-2.7846}$, with an R^2 value of 0.9960.

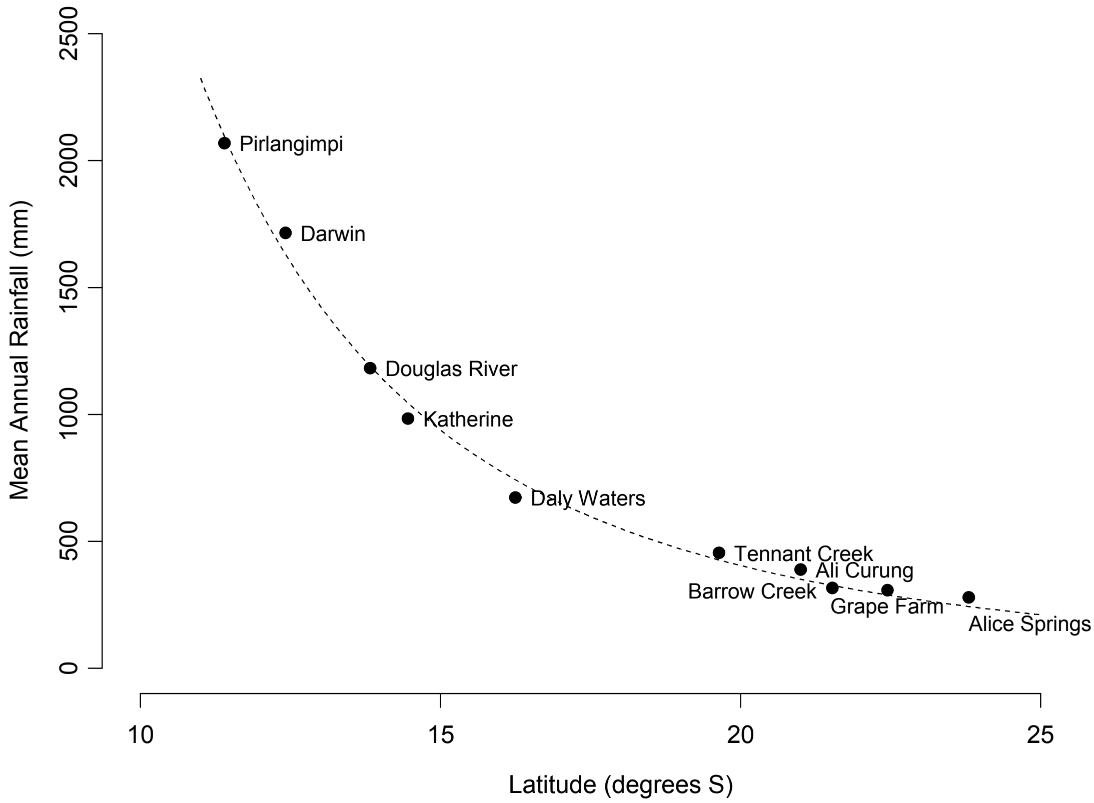

Figure 8. The relationship between latitude and mean annual rainfall for selected stations in the NT

Rainfall is mainly in the summer months for all stations; it is more pronounced in the north (distinct wet and dry seasons) than in the south (more even rainfall distribution) (see Figures 1 to 7).

The monsoon influences rainfall in the Top End, with a pattern of continuous or showery rain for one to two weeks at a time during the wet season, characterised by low pressure troughs along the northern coast, and returning approximately every 40 days, according to the Madden Julian Oscillation. Cyclones can sometimes be associated with these troughs of low pressure. As cyclones pass over the coast and move inland, they usually transform into depressions that move inland bearing heavy rain, sometimes as far as the southern arid zones. Thunderstorms also bring spatially patchy rain during the summer months. These storms are usually brief and intense, and dominate Top End rainfall during the early wet season from October to December. Central Australia can also receive rains from northern extensions of the westward moving weather patterns that dominate southern Australia (Department of Mines and Energy, Water Resources Division, 1986).

Evaporation figures show that Darwin and Douglas River, as representatives of the north coast, have four months when rainfall is greater than evaporation (Figures 2 and 3). Katherine has two months where this is the case, while none of the other representative weather stations south of Katherine have any month, on average, when rainfall exceeds evaporation.

Other important measures of precipitation that relate to agricultural development are variability and intensity. The annual variability of the region is low by Australian standards, but is higher than areas of similar climate in other continents. Annual variability is at a minimum in the north and increases moving south. Monthly variability of rainfall is high across the region, but also follows a trend of increasing variability moving from north to south (Williams et al. 1985). Intra month variability can also be a problem, with dry periods of several days up to several weeks occurring in the middle of the wet season (O'Gara 1998).

Intensity of rainfall in the NT, especially in the Top End, is high. For example, rainfall in excess of 150 mm in 24 hours has a return period of less than 10 years at Katherine; whilst for Oenpelli daily falls over 100 mm occur once every two years and over 150 mm once every ten years (Williams et al. 1985). The potential problems with this type of intensity are the level of runoff and erosion of unprotected soils (Dilshad et al. 1996).

Therefore, the Top End has potential for rain-fed agriculture for two or three months of the year, when rainfall exceeds evaporation and the probability of adequate falls is high, although dry periods of several weeks may limit yields in some years. Rain-fed farming practices do, however, have to be adaptable to high intensity storms, with practices such as minimum tillage, mulch retention, cover cropping and strategically-placed soil conservation banks to limit soil erosion. In areas south of Katherine, such as the Sturt Plateau, unreliable rainfall patterns increase the risks for annual grain cropping. However, there is good potential in this area for improved pastures, dry-land hay and opportunity cropping with short season niche-crops using conservation farming techniques. However, irrigated agriculture, based on natural or artificially stored rainfall, has a higher probability of success in these areas.

2.2 Surface water resources (fresh and estuarine)

Of all the rain that falls in the humid zone of the Top End, approximately 26% runs off as surface or shallow sub surface flow (Cook et al. 1998), while hardly any rainfall runs off in the arid zone of the south. This runoff concentrates in streams, rivers, billabongs, soaks, swamps, waterholes and lagoons. For the purposes of this paper, these waters are defined as surface water. The NT can be divided into two areas with regard to surface water: catchments that drain to the coast to the north, and catchments in the south that contain rivers and streams that never reach the sea but drain to vast central deserts (Department of Mines and Energy, Water Resources Division 1986). The north is the only area of the NT with perennial rivers. Most rivers in the NT, however, are ephemeral. The period of high flow for these rivers is the three-month wet season and the short period which follows the wet season when the landscape drains the last rains. The dry season flows are much lower and are almost entirely from groundwater discharge, except in the unusual case of dry season rains. In Central Australia, where rainfall is extremely variable, rivers and streams only flow after rare heavy rains.

The total mean flow to the coastline from the 31 major catchments in the Top End is 59 500 000 ML/year, while in sharp contrast, the total mean flow from the nine major catchments in the Arid Centre is 4 400 000 ML/year (Landcare Council of the Northern Territory 2005).

The NT landscape is divided into river basins, which are major catchment areas, the total land area from which surface runoff drains to the river. The river basins for the NT are shown in Figure 9. The name of the river draining the catchment area is normally used for the river basin. A basin may contain several other tributary rivers and streams that drain into the main basin river. Basins are then grouped into Drainage Divisions. In the NT there are four major divisions. The Timor Sea Division drains into the Timor Sea, the Gulf of Carpentaria Division drains into the Gulf of Carpentaria, the Western Plateau drains into inland deserts and the Lake Eyre Division drains into the direction of Lake Eyre (Department of Mines and Energy, Water Resources Division 1986).

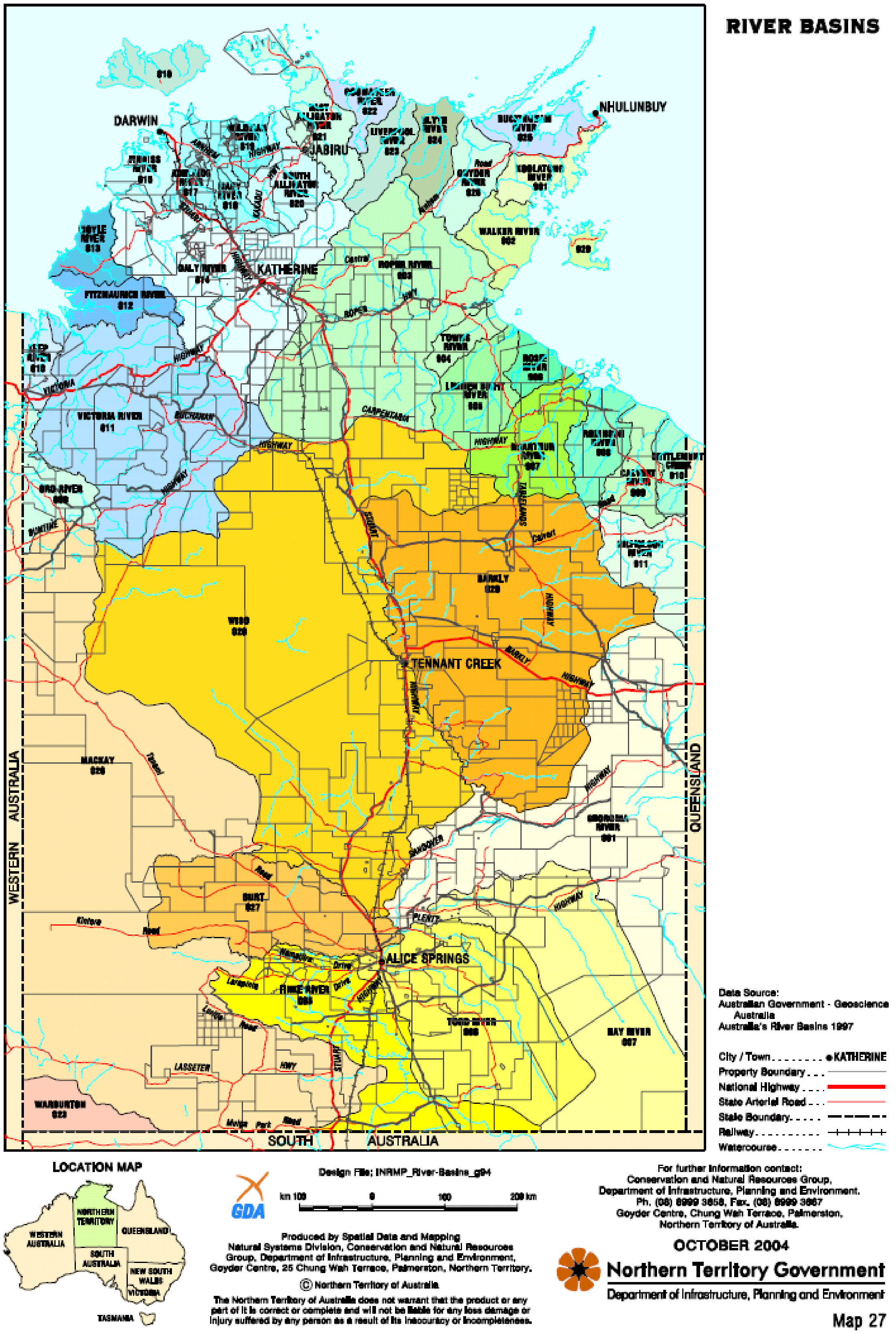

Figure 9. River basins in the NT

Table 1 shows the catchment area, average estimated total flow and irrigation water licensed volumes for the basins most affected by agricultural development (Australian Government 2007). These figures are based on the best currently available information.

Table 1. Catchment size and estimates of flow for basins most affected by agricultural development in the NT

Basin	**Area in NT (km^2)**	**Average estimated annual total flow (ML)**	**Allocation to irrigation (ML)**
Timor Division			
Keep	5900	510 000	50,000
Victoria	77 230	4 540 000	731
Daly	52 940	6 740 000 (ranging between 1 – 17 million ML (Jolly 2001))	445 300
Finniss	9320	3 120 000	48 188
Adelaide	7430	1 880 000	1106 (+ 8000 ML pending)
Mary	8060	2 180000	525
Wildman	4820	815 000	300 (Twin sisters lagoon)
Gulf of Carpentaria Division			
Roper	79 130	5 540 000	25

Even though the above figures show total discharge, these rivers flow mostly in the wet season when there is less need for irrigation. Dry season flows are more important to take into account when estimating size of irrigation resource. These flows mostly discharge from groundwater resources. Therefore, except in the cases of irrigation from lagoons sustained by perched water tables, the interdependence between aquifer supply and river-base flow is such that for most purposes both resources are considered part of the same system (Lancaster 2008, pers. comm.). Table 2, from Jolly (2001) shows instantaneous flows for various waterways in the Daly Basin at the end of the dry season, after preceding below average, average and above average wet seasons (in terms of precipitation). These numbers are indicative of groundwater discharge into these systems, and the potential for surface-water irrigation from the river. It is interesting to note the often large differences in flows given the amount of rainfall in the preceding wet season. Indeed, rainfall data for the wet season is being used to predict water availability for irrigation in the dry season from both surface and ground water for the new Tindal water allocation plan at Katherine (Department of Natural Resources, Environment, the Arts and Sport 2008).

Table 2. Gauged flows at various locations in Katherine/Daly Basin October/November 1970, 1982 and 2000

River or creek	Gauging station	Flow Oct 1970 (below average wet season) m^3/sec	Flow Oct 1982 (average wet season) m^3/sec	Flow Oct 2000 (above average wet season) m^3/sec
Seventeen Mile Creek	G8140159	0.2	0.4	0.5
Katherine River – Low level crossing	G8140001	0.9	1.9	2.9
Katherine River – Galloping Jacks	G8140301	1.0*	2.3	3.4
Flora River	G8140044	3.4*	3.4*	3.7
Daly River – Dorisvale crossing	G8140067	2.8	5.1	8.5
Daly River near Stray Creek		5.2	9.9	15.2
Daly River – Oolloo crossing		5.9	13	20.8
Douglas River	G8140063	0.3	0.7	1.2
Daly River – Nancar	G8140040	8.5	19.4	24*

Note: * indicates estimated value

Further work has been done by Paiva (1994) on water availability for irrigation downstream from the confluence of the Edith and Fergusson Rivers. Even though reliable flows for February and March were quite high, dry season flows were considered to be able to support less than 100 ha of irrigated cropping.

Therefore even though surface water is quite abundant during the wet season in the NT, it is scarce at the times of the year when needed for irrigation, that is, the dry season.

2.3 GROUNDWATER RESOURCES

The proportion of rainfall which soaks through the surface to drain into underlying geology is called ground water. Ground water inhabits spaces or pores in geological systems. Different rock types have different porosity, which is divided into primary porosity of intact rocks and secondary porosity from cracks, holes and cavities in the rock often caused by weathering. The NT landscape has been shaped by rock-forming processes that extend over large areas to form geological units. Geological basins and blocks are the two types of units. Basins have been formed from sediment from ancient seas and lakes and therefore consist mainly of sedimentary rock types, while blocks are primary rock formations formed under heat or deformation. The highest level of groundwater body nomenclature is closely aligned with these geological units and is called a groundwater province. The provinces and their associated geological units are shown in Figure 10.

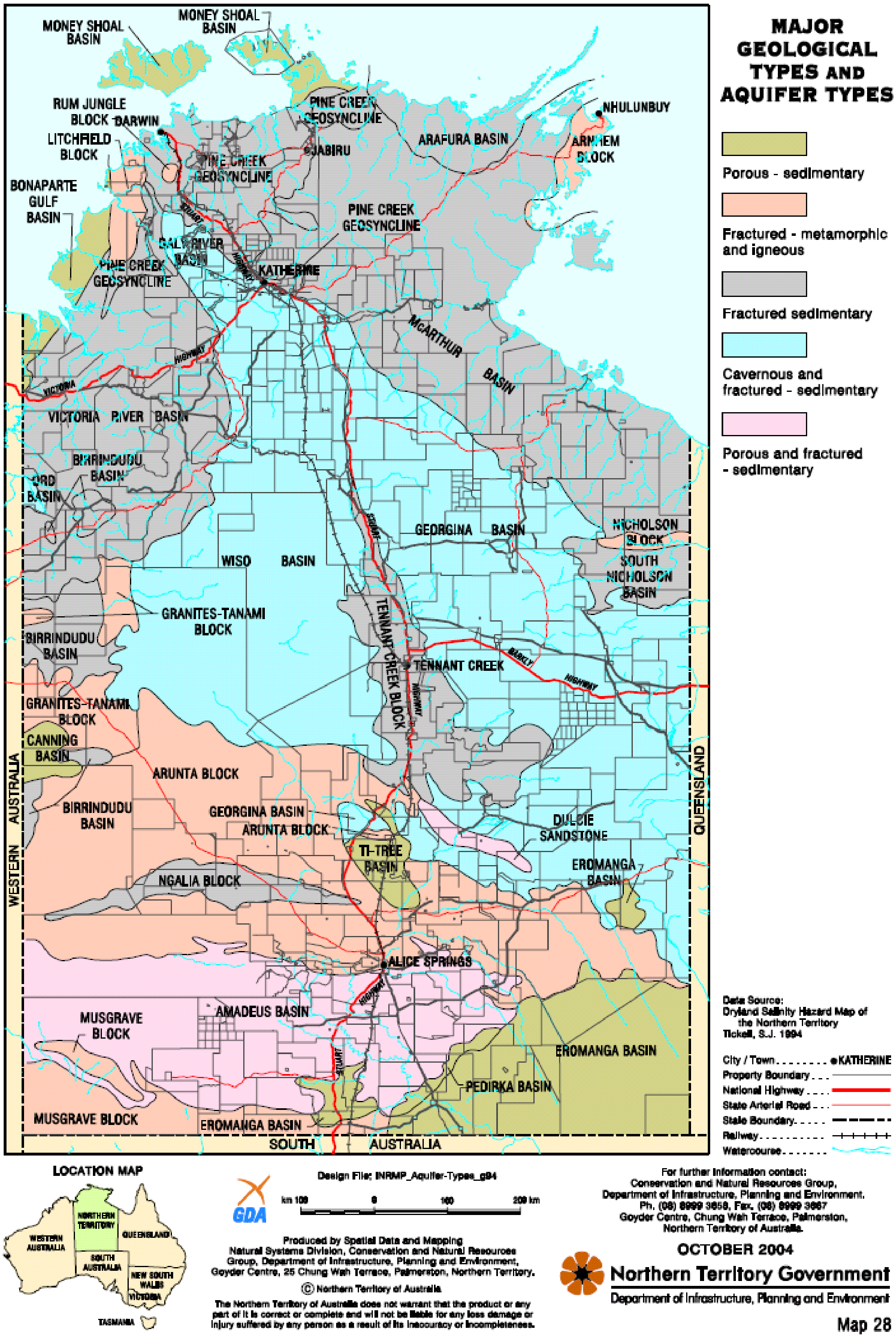

Figure 10. Ground water provinces in the NT

It is estimated that rainfall recharges the seven major groundwater provinces in the Top End by an average of 11 500 000 ML/year, while the nine major groundwater provinces of the arid centre receive only 1 265 000 ML/year on average, with high variability between years (Landcare Council of the Northern Territory 2005). Recharge rates vary depending on the transmissivity of soils and geology overlying provinces and the amount and timing of rainfall. As an example, the proportion of rainfall recharged has been estimated at 13% for a tropical woodland ecosystem at Howard River Catchment (Cook et al*.* 1998).

Geological units that bear water are called aquifers. In the NT, there are aquifers of importance for irrigation and other uses. Unlimited extraction of these waters is not current NT Government policy. Rather, allocations are based on a majority percentage of annual recharge allocated to groundwater-dependent ecosystems and cultural flows, and the rest is shared amongst different consumptive uses. The NT Department of Natural Resources, Environment, the Arts and Sport conducts assessment activities to improve the knowledge of groundwater resources. This includes determining the extent of ground water, hydrogeological and water quality characteristics, surface/groundwater connectivity, groundwater-dependent ecosystems, response of aquifers to stress and the availability or sustainability of the resource. The quantity of current extraction levels is shown in Table 3.

Table 3. Aquifers used for agricultural and horticultural irrigation in the NT

Groundwater Province, Irrigation area and aquifer	**Typical yield (L/sec)**	**Salinity (Total Dissolved Solids mg/L)**	**Depth to successful bores**	**Notes**
Pine Creek Groundwater Province				
Howard Springs/Humpty Doo irrigation area Koolpinyah Dolomite	5-50 L/sec	<1000	50 – 100 m	(Verma et al. 2004b)
Lambells Lagoon irrigation area Koolpinyah Dolomite	5-50 L/sec	145 – 400 (Jolly, Yin Foo 1988)	25-50	(Verma et al. 2004b)
Fogg Dam irrigation area Koolpinyah Dolomite	> 5 L/sec	<1000 (over 1000 in few areas)	25-50 m	(Verma et al. 2004b)
Marrakai irrigation area Koolpinyah Dolomite (mainly although there are a number of formations in the area such as Wildman siltstone, Mount Bonnie Formation and Gerrowie Tuff Formation)	0.5 – 20 L/sec	<1000	25-50 m	(Verma et al. 2004b)
Lake Bennett irrigation area Koolpin Formation (mainly although there are a number of formations in the area such as Wildman siltstone and Gerrowie Tuff Formation)	0.5 – 5 L/sec	<1000	25-50 m	(Verma et al. 2004b)
Berry Springs and Noonamah irrigation area Fractured and weathered dolomite	5-25 L/sec	200	20 m +	Major aquifer in dolomite layer of South Alligator Group. Others include Koolpin formation, South Alligator Group, Whites Formation, Crater Formation of Mt Partridge, amongst others (Verma, 1994)
Acacia irrigation area Whites formation Wildman Siltstone Coomalie Dolomite	3-20 L/sec <0.5 L/sec >5 L/sec (25 L/sec max)	<300	5-80 m 24-50 m	From (Tickell, 2000, Haig, 2003)
Batchelor irrigation area Beeston Formation and Coomalie Dolomite	> 10 L/sec, up to 50 L/sec	300		(Jolly, 1981)
Wildman River area Koolpinyah Dolomite	>5 L/sec	<1000	25-50 m	(Verma et al. 2004a)
Daly Basin Groundwater Province				
Douglas Daly irrigation region Oolloo Aquifer	Up to 50 L/sec	200-500	30-80 m	(Tickell, 2007)
Katherine irrigation region Oolloo Aquifer	Up to 50 L/sec	200-500 (mostly, but up to 1500 in some areas)	30-80 m	(Tickell, 2007)
Tindall Aquifer	Up to 60 L/sec	200-500	50-400 m	(Tickell, 2007)
Jinduckin Aquifer	Up to 20 L/sec, more commonly 0-5 L/sec	200-500	30-300 m	(Tickell, 2007)
Mataranka irrigation area Tindal Limestone	Up to 75 L/sec	25-1240	50-400 m	(Tickell, 2007, Qureshi, 1983, Jolly et al. 2004)
Ti-Tree Basin				
Ti-tree irrigation area Western and Central Zones in argillaceous tertiary sediments	> 5 L/sec	<1500	5-120 m	(Department of Infrastructure, Planning and Environment, 2002, Edworthy, 1967)
Amadeus Groundwater Province				
Alice Springs irrigation area Inner farm basin in alluvium	1-5 L/sec	800-1,500	6-40 m	(Water Management Branch, 2007)
Outer farm basin in alluvium	1-5 L/sec	700 – 2,000	12-60 m	(Water Management Branch, 2007)
Meereenie Aquifer system	25-50 L/sec	400-6,000	90-155 m	(Water Management Branch, 2007)

2.4 ALLOCATION AND AVAILABILITY FOR PLANT INDUSTRIES

The surface and groundwater resources of the NT have many, and often conflicting, demands placed upon them from a variety of sources such as plant industries, human settlements, indigenous values, recreation (especially fishing), tourism and the environment. Reform of how water is allocated in Australia, first agreed upon by the Council of Australian Governments in 1993, has been embraced in the NT through the National Water Initiative. Two water allocation plans have been declared for Alice Springs and Ti Tree, and others in the Top End of the NT are at an advanced stage of development, including drafts for the Tindal limestone aquifer at Katherine. Environmental protection of surface and groundwater ecosystems is seen as a high priority by the current Government, as evidenced in these water allocation plans, where a high percentage of groundwater recharge and surface water-flow have been allocated to the maintenance of dependent ecosystems, leaving a percentage for irrigated crop production. Even so, because of the dynamics of water in the landscape, and the lack of availability of water in the dry season (Top End) or all the time (Central Australia) when irrigation is needed, agricultural activities are clearly constrained by lack of water in the NT.

Nevertheless, agricultural activities have minor extraction impacts on inland waters in the NT at the present time compared with other areas of southern Australia. Irrigation is not a major driver that consumes water in the NT, with no publicly-owned major irrigation schemes and only small, fragmented, irrigation projects present based on limited surface and ground water. Based on currently available information, there is scope for further development of these resources in some areas to assure future availability of food and fibre for Australian and export markets.

The following Sections review published information on the effects of plant industries on the water resource and associated ecosystems. Discussion will focus on how plant industry practices affect the quantity of water and its distribution in the environment, as well as the quality of water. Finally, the effects of using water of naturally poor quality (saline) on soils will be discussed.

3. PLANT INDUSTRY EFFECTS ON HYDROLOGY

3.1 INTRODUCTION

Hydrology (from Greek: Yδωρ, hudōr, "water"; and λόγος, logos, "study") is the study of the movement, distribution, and quality of water throughout the earth and thus addresses both the hydrologic cycle and water resources (Wikipedia 2008). This Section reviews the current state of NT information on how agricultural practices may alter the natural movement and distribution of water in the landscape.

The first part will cover the effects on surface hydrology, that is, the movement of water at the soil surface, and its relationship to soil erosion. It will be followed by a discussion on the possible effects of surface water storage on the environment. Finally, the effects of irrigation extraction on ground water will be discussed.

3.2 SURFACE HYDROLOGY

Surface hydrology is the study of the relationships between water and the Earth's surface. Agricultural land use can have a large bearing on how water moves and interacts with the Earth's surface. Erskine et al. (2003), for example, have identified risks that could arise from the conversion of land use from native woodland to agricultural use in the Daly region. These risks include altered soil and catchment hydrology, increased runoff, accelerated soil erosion and sediment delivery to rivers, reduced groundwater recharge and base flow discharge, and increased incidence of fish kills. Further studies are needed to determine the likelihood of these risks occurring, although limited work has been already done. For example, Dilshad and Jonauskas (1992) reported the effects of tillage (under a maize/soybean rotation), grazing, native woodland and soil conservation bank spacing on surface runoff at Douglas Daly Research Farm, South of Darwin.

Results showed that in each season, conventional tillage (disc plough) produced the greatest volume and depth of runoff and the highest number of runoff events. At the other extreme, woodland produced the least number of runoff events and between 80 and 150 times lower runoff depth than the conventional treatments; and, on average, converted less than 1% of the rainfall to runoff compared to up to 25% for conventional tillage. Comparison of conventional practice versus no-till showed significantly lower runoff depth with no-till; grazing effects were between those for woodland and no-till. Soil conservation bank spacing had no effect on runoff depth.

Dilshad et al. (1994) followed up this work on pastoral lands to show that attached pasture cover on the soil surface was an important factor to influence runoff, especially when attached cover (measured in plan view using a quadrat method) fell below 50%, where runoff dramatically increased. This effect is due to ground cover slowing movement of water across the surface of the land, allowing more time for infiltration. This effect was confounded by:

- antecedent soil moisture, where an already saturated soil tended to produce more runoff (which was largely affected by land use);
- rainfall intensity and duration (more intense and longer events lead to more runoff); and
- influences of varying ratios of attached cover to non-attached vegetation (litter).

Haig and Townsend (2003) found similar increases in runoff for urban areas, compared with rural land uses due to the increased area of impervious surfaces and greater hydraulic efficiency of the urban drainage system. The runoff co-efficient (percentage of runoff compared with total precipitation) for the urbanised catchment of Karama was 78%, more than double the rural catchment of Howard River (33%). Although this is not directly relevant to agricultural systems, it was recommended that the impact of various rural land-uses on runoff volumes, particularly in the rural area around Darwin, was unknown and required further investigation.

These studies show how temporary or permanent conversion of land use that removes attached vegetation, such as land clearing, pasture or forestry establishment, can dramatically increase surface runoff, although extrapolation of these effects to catchment levels is often tenuous. Indeed Turner and Lambert (2004), in a review of hydrology publications relevant to South Eastern Australian forestry, found that if less than 20% of a catchment was disturbed, changes in stream flow were difficult to detect. However, there is no data to support this rule in tropical Australia. This review also found that removal of trees in native forests produced an increase in stream flow, which decreased when forests grew, because of higher water use, higher biomass production, greater rooting depth and greater canopy interception with forest age, but increased again when forests were thinned. More studies are needed to determine actual water balance relative to native forest, and at a larger catchment scale.

3.3 SURFACE WATER STORAGE

There is little water stored in dams in the NT, except in the Darwin region where Manton Dam and Darwin River Dam have been constructed for public water supply. Very few dams exist in the arid regions of the NT with less than 0.01% of total runoff being stored in this way (Townsend 2001). There are no large publicly-owned irrigation dams and there are few on-farm, as the flat landscape, lack of suitable soils and high evaporation rates make their use unattractive (Water Resources Branch 1976). Lagoons, formed in old river channels, for example Twin Sisters Lagoon and Finniss River Lagoon, are, however, used for irrigation in the coastal regions of the Top End.

In-stream dams are also unattractive ecologically because of:

- prevention of the movement of migratory fish species;
- prevention of the first floods of the wet season, which have a role in flushing aquatic habitats and allowing aquatic species to recolonise estuarine floodplains;
- cooling of water in deep dams, which may upset breeding patterns in some species;
- patterns of erosion and deposition are altered;
- dams prevent normal detrius moving down the river (Price et al. 2001).

In addition, flow regulation through the construction of weirs and levee banks (Arthington and Pusey 2003) has changed the hydrology of rivers in other Australian states in three temporal scales: the flood pulse (days to weeks), flow history (weeks to years) and the long-term statistical pattern of flows, or flow regime (decades or longer) (Arthington and Pusey 2003). Many initiatives of the National Water Reform are now attempting to reverse these changes.

In the NT weirs have not been recommended because of their impact on low season flows in the Adelaide River (Natural Resources Division 1999) and for horticulture downstream of Katherine Township because of the effects on the environment and downstream users, probability of mosquito build-up, damage to cultural sites and possible negative effects on aquifer recharge (Paiva 1995).

In spite of many possible negative effects of surface water storage, there are many sites that have been considered for development. These include dams for irrigation in the Douglas Daly region (Conservation Commission of the Northern Territory 1981), for rice growing at Tortilla Flats (Huq 1984), and for cropping and irrigation supply in the Adelaide River area such as Warrai Dam (large enough for 10 000 ha of cropping) and Marrakai Dam (large enough for 60 000 ha of cropping) (Natural Resources Division 1999). Ring tanks have also been suggested for off-stream storage down-stream from Katherine Township, but excessive evaporation mean losses are high (Paiva 1995).

Because of all of the possible negative environmental impacts, it is unlikely that large surface water storage projects for irrigation purposes will proceed in the near future in the NT.

3.4 HYDROGEOLOGY

Hydrogeology is the area of geology that deals with the distribution and movement of ground water in the soil and rocks of the Earth's crust, commonly in aquifers. The main influence of plant industries on hydrogeology is the extraction of ground water for irrigation. This lowers water tables, which can only be replenished with seepage of incident precipitation, recharge from waterways or sideways seepage from adjacent aquifers. An example of agricultural effects on hydrogeology is groundwater level depression at the end of the irrigation (dry) season in the Darwin rural area, which has been increasing over the last 20 years due to increased rural water use, which includes irrigation. At present, this is recharged by seepage by the end of each wet season (Haig and Townsend 2003). There is a risk that overuse of aquifers for irrigation, even though they may be deep and hold substantial reserves, will harm ecosystems that rely on groundwater discharge over the dry season, such as creeks, rivers, springs, swamps and wetlands. This is especially important in the NT where landscape relief is low; therefore excessive drawdown could quickly reduce or stop surface flows. Extraction some distance away from major waterways may be a solution to provide a predictable water supply for irrigators without impeding groundwater flow to dependent ecosystems, although more research is needed determine safe buffer sizes (CRC for Freshwater Ecology, Canberra 2004).

3.5 KNOWLEDGE GAPS IN HYDROLOGY

The following areas should be prioritised for further investigation:

1. Measurement of plant industry effects on water balance, hydrogeology, and surface hydrology.

2. The effect of land use on runoff, soil erosion and sediment delivery to rivers.

3. The effect of land use on groundwater recharge and how this affects groundwater connected systems.

4. Water balance changes when native forest or pasture is converted to plantation forestry.

5. Determination of safe buffer zones for extraction of water near waterways.

Bristow and Camkin (2008) partly pick up these research needs in their paper prepared for the Northern Australia Irrigation Futures (NAIF) group, where they propose Research Area 3: “Understanding the ability of Northern groundwater systems to serve as water storages for irrigation” This proposed research area focuses on improving understanding of water availability and environmentally sustainable yields in the highly event-driven climate of north Australia, with the intention of indicating where ground water (and aquifers) can be realistically used to support irrigation development in the north and informing policy makers of the consequences of development in specific regions.

4. PLANT INDUSTRY EFFECTS ON WATER QUALITY

4.1 INTRODUCTION

There are a number of plant industry activities that threaten inland water quality. The use of pesticides (herbicides, fungicides, insecticides and other chemicals) to protect crops and fertiliser to help them grow, pose risks to water based ecosystems as well as water users. Exposed soil, as mentioned in the previous Section on hydrology, can also increase the level of runoff after rainfall, with a proportional increase in the risk of erosion of soil and subsequent increase in waterway turbidity. Evidence of the occurrence of these processes in the NT is discussed below.

4.2 PESTICIDES

Jolly and Yin Foo (1988) have commented on potential contamination pathways in the Lambell’s Lagoon area. Bacterial contamination of shallow aquifers in Cretaceous sediments has occurred through ingress of contaminated surface water in poorly-constructed bores. This may also be possible with pesticides. Contamination of the deeper aquifers (such as those in Koolpinyah Dolomite) by surface spill or contamination would be unlikely because the movement of chemicals through the overlying sediments would be slow and that the majority of any contaminant would be dispersed by horizontal groundwater movement through the laterite. The only possible contamination source likely for these deeper aquifers therefore would be directly through poorly constructed bores (Jolly and Yin Foo 1988) . Therefore, protection of bore holes from pesticide contamination in the NT would be a priority for on-farm risk management.

Limited work has been completed to measure pesticide levels in NT ground and surface waters, and of this work, little is published. As a surrogate, Best (1973) found a range of organochlorine residues in aquatic species (fish, crocodile, buffalo) in the early 1970s. These types of pesticides are no longer used and, not surprisingly, there have not been any recent reports of bio-accumulation of these pesticides in wildlife.

More recently, Waugh and Padovan (2004) reviewed pesticide monitoring in water in the Darwin region, which included ten studies in 20 years and found negligible reports of pesticide contamination, except for urban surface waters where residual termiticides that were no longer registered or used, were sometimes found.

Eastick et al. (2007) investigated common cotton pesticide levels in a soil profile to 2 m, after several seasons' cropping with cotton at Katherine. Surface-applied pesticides found at depth could be an indicator of movement with water through the profile, which could possibly mean potential movement to ground water. It was found that virtually no pesticide remained in soils after several years, although pendimethalin was found at 1.4 m depth on one occasion, with no other positive samples above or below. This would cast some doubt on this particular sample. This work is continuing, with further laboratory analysis due soon of stored samples (C. Martin pers. comm.).

From available information, there does not appear to be a problem with pesticide contamination in ground water at present. However, intensive use of pesticides in the NT in horticultural enterprises over large areas is a relatively recent phenomenon and percolation times to utilised aquifers may be several years. Monitoring of pesticide in soil profile and ground water will therefore be expedient.

4.3 Mineral nutrients

Essential mineral nutrients are those needed by higher plants to carry out normal growth and reproduction. These nutrients are nitrogen, phosphorus, potassium (these three are known as macro-nutrients because they are used in much higher quantities by plants than the other essential elements), sulphur, calcium, magnesium, iron, copper, zinc, molybdenum, boron, manganese, chlorine, silicon and cobalt. Water systems usually have some or all of these elements at low levels, but pollution with excessive quantities of any, especially the macronutrients (nitrogen, phosphorus and potassium) can make water toxic for humans or animals. Plants, especially algae, many of which produce toxic secondary compounds, may also form unnaturally large populations in waterways after plant nutrient contamination, especially of nitrogen and phosphorus, negatively altering these ecosystems.

Sources of plant nutrient pollution may be manufactured fertiliser, animal (including human) manure, biological waste, nitrogen leaching from introduced nitrogen fixing species (legumes), or dissolution of nutrients from naturally-occurring rocks or soils. Therefore, it is possible that plant industry activities may contribute to plant nutrient pollution in water.

NT water systems, both ground and surface waters, have generally been determined to be low in essential plant macronutrients (nitrogen, phosphorus and potassium), reflecting the nutrient status of the surrounding countryside. Webster et al. (2005) stated that the Daly River, for example, had low nutrients, high turbidity, low pH and low conductivity in the wet and extremely low nutrients, high conductivity and high light transparency in the dry. Schult et al. (2007) confirmed that water in the Daly was generally low in nitrogen and phosphorus, with negligible, if any, point sources of pollution.

Schult and Metcalfe (2006), in contrast, found elevated nitrate levels in the lower reaches of the Douglas River, compared with elsewhere in the Douglas and Daly Rivers, perhaps reflecting high nitrate levels in the Tindal aquifer, which supplies water to the Douglas during the dry season. This is inconclusive, however, as some bores had elevated nitrate and others not. The Katherine River below the town also had high nitrate levels; the Tindal aquifer also supplies this river in the dry (Schult et al. 2007).

Possible reasons were pollution from septic tanks, animal faeces (bats), fertiliser seepage or seepage from leguminous plants. However, no conclusions were made as to the source.

Fortunately, high nitrate levels do not have any impact on phytoplankton levels in the Douglas River because phosphorus levels were too low and limiting to encourage growth (Schult and Metcalfe. 2006).

In other NT water systems, nutrient enrichment during first runoff rains in the wet season has been measured, stimulating algal growth (Schult et al. 2007). Schult (2004) investigated this phenomenon for three rural and one urban catchment focussing on changes in nitrogen and phosphorus content of their surface waters over time. The catchments were Bees Creek, Elizabeth River, Berry Creek (all rural) and Winnellie Drain (urban). Nitrogen and phosphorus levels were high in the early wet season in Bees Creek and Elizabeth River but later declined. Berry Creek and Winnellie Drain showed no patterns linking nitrogen levels with the wet season. Sampling, however, commenced after the first rains had fallen. Organic nitrogen was high in the rural catchments. In contrast, inorganic nitrogen was high in the urban catchment. The exact source of nutrients in these creeks is unknown and needs to be determined, although it is speculated that high concentrations at the start of the wet originate from a build-up of material in the catchment (e.g. leaf litter, ash, dead animals, rubbish, industrial waste, fertiliser etc) that are washed into creeks with the first rains (Julia Schult pers. comm.). Similar results were found in the billabongs of the Mary River, where maximum levels of phosphorus and nitrogen were found during first flows of the wet season, which decreased to low levels as the wet progressed (Powell and Townsend 1997).

Suspended sediment from erosion may be the source of possible nitrogen and phosphorus contaminants of inland water systems. This is because phosphorus in many tropical soils is tightly bound to organic and non-organic elements and phosphorus tends to be highest at the surface, decreasing with depth. Any phosphorus added to the surface tends to remain there, unless the soils are very sandy with little sorption capacity. Nitrogen also tends to be concentrated in surface soils (Jones et al. 1985). Some limited work has been done on nutrient losses associated with suspended sediment in runoff, where techniques were being developed to study nitrogen, phosphorus and potassium movement in surface runoff from Tippera loamy red earths, but this work was discontinued (Dilshad et al. 1996).

Groundwater contamination from fertiliser nutrient passage from surface to subsoils and beyond with deep drainage is also possible (Eastick et al. 2007; Macqueen 1985). Eastick et al. (2007) monitored deep drainage in soil profiles at the Katherine Research Station and found deep drainage could be avoided with a closely-monitored irrigation schedule. In the wet season, however, where heavy precipitation rates are common and, with unseasonal dry season rains, there is a possibility for deep drainage reaching ground water, although no nutrients were measured in this study. Day (1977) showed nitrogen movement through the soil profile of a sorghum crop during the wet season, with losses of nitrogen at depth. Indeed, the fertiliser nitrogen recovery of crops in north west Australia has been measured as poor. Table 4 adapted from (Jones et al. 1985), shows the apparent recovery of nitrogen (calculated as nitrogen yield in plant tops of fertilised treatments minus that of untreated controls, expressed as a percentage of the fertiliser nitrogen applied), compared with the rate of nitrogen applied (kg/ha), in different locations. It can be seen that in some cases, nitrogen recovery from fertiliser was as low as 5%, and never higher than 74%. The loss of nitrogen may be through several pathways, such as:

- leaching, especially on lighter soils;
- de-nitrification on waterlogged soils, especially during the wet season;
- volatilisation of ammonium fertilisers or urea from the soil surface depending on urease activity, temperature, rate of evaporation, pH, buffering capacity and fertiliser placement (Jones et al. 1985).

Table 4. Apparent recoveries of nitrogen by various crops grown under dry land conditions or under irrigation at various locations in north west Australia

Crop	Apparent recovery of N by crops (%)	N rate applied (kg N/ha)	Location and soil
Sorghum	12-30	50	Katherine, Tippera loamy red earth
“	17-74	50	Katherine, Tippera loamy red earth
“	13	112	Tipperary Station, Emu loamy red earth
“	20	112	Katherine, Tindal loamy red earth
Rice	5-50	150	Coastal plains NT, cracking clay
“	16-48	90-240	Cunanurra clay, Ord
“	19-35	50-500	Cunanurra clay, Ord
Safflower	14-28	40-160	Cunanurra clay, Ord
Wheat	23-45	40-160	Cunanurra clay, Ord
Linseed	11-29	40-160	Cunanurra clay, Ord
Sorghum	30-72	80-340	Cunanurra clay, Ord
Cotton	11-61	112-900	Cunanurra clay, Ord

Day (1977) found, however, that leaching was probably the major cause of nitrogen loss, with heavy rains quickly taking nitrate nitrogen out of the root zone of grain sorghum. Nitrification of ammonium to nitrate also occurred within six weeks, meaning that the use of this fertiliser, which has positively-charged cations that sorb to negatively-charged soil particles, only slightly delayed the loss of nitrogen. There may be some trapping of nitrate in subsoils (Wetselaar 1962) which could be used later by deep rooted crops such as millet, but the fate of this nitrogen needs further investigation.

4.4 KNOWLEDGE GAPS IN WATER QUALITY

The following areas should be prioritised for further investigation:

1. Fine scale monitoring of pesticide and plant nutrient contamination in water bodies of high risk.

2. Movement pathways of contemporary pesticides and plant nutrients including downward movement through soil to ground water and movement with surface water through suspended soil and in solution.

3. The causes of any currently identified water pollution that could possibly have been caused by plant industries.

These knowledge gaps have already been recognised by a number of organisations.

The Natural Resource Management Board in the NT has a management action relating to possible pollutants of water quality, under management action 5-11: “Identify catchments and groundwater aquifers at risk from salinity, nutrients, toxins or sediment pollution and recommend appropriate action”.

The NT Cattlemen's Association (2006) also, through a research and consultative process, identified a priority project to further understand the possible movement of herbicide and nutrients into the river and ground water in the Douglas-Daly region. Finally NAIF, (Bristow and Camkin 2008) also pick up on these themes in NAIF Research Area 1: "Understanding the geochemistry of ground water and fate of solutes in tropical irrigation". Clearly, there is stakeholder support for more work in these areas.

5. THE EFFECT OF SALINE WATER ON LAND

5.1 INTRODUCTION

Salinity is a measure of dissolved salts in water. For soil, it is the measure of dissolved salts in a sample of soil that has been mixed with water. Salt is defined as any inorganic compound formed as the result of a reaction between an acid and a base, but the most abundant and important compound that affects water and soil is sodium chloride. Salinity is measured as a concentration of total dissolved solids, expressed as milligrams per litre (mg/L) or parts per million (ppm). It is a measure of the sum of all the dissolved ions (both cations and anions) in a water sample. Drinking water and irrigation water are preferred to have total dissolved solids less that 1000 mg/L, while some tolerant irrigated crops can stand up to 1500 mg/L. There is little economic use for water with above 1500 mg/L, other than for stock use. Table 5 shows typical total dissolved solids levels in natural waters (Tickell 1994).

Table 5. Typical salinities of natural waters

Water type		Total dissolved solids (mg/L)
Rain water	Less than	10
River water	Less than	100
Ground water	Less than	10 000
Sea water	Approximately	35 000

Electrical conductivity is also used as a guide for the level of salt in a solution, as conductivity rises with the concentration of salt. Conductivity is usually measured in micro Siemens/cm. One micro Seimens/cm is approximately equivalent to total dissolved solids of 0.5 mg/L, but this depends on what salts the solution is composed of. Strictly speaking, conductivity and total dissolved solids are non-convertible measures of salinity.

Water salinity is generally harmful to most non-marine species that do not have specific physiological adaptations to high salt levels. This is particularly true with most flowering plants, which find water uptake difficult from saline sources due to weak, or even negative, osmotic gradient between soil and sap solution. The specific concentration of ions such as sodium and chloride, but also carbonate, bicarbonate, potassium, nitrate and boron, can also be toxic at high levels, which is often the case with saline water sources (Tickell 1994).

5.2 DRY-LAND SALINITY

Land degradation through increase in concentration of salt in the soil is called dryland salinity. It is caused by the clearing of native woodland for crops and pastures, thus reducing evapo-transpiration causing water tables to rise, bringing dissolved salt from subsoils into topsoil, or through irrigation with saline water. Dryland salinity is also referred to as salinity, secondary salinity, soil salinity or salinity seepage. Dryland salinity currently affects large areas of southern states of Australia, particularly Western Australia.

It can be argued that dry-land salinity from vegetation clearance will not become a major problem in the NT. This is because in higher rainfall areas of the NT, where deep-rooted vegetation is abundant, salt storages in the ground are low, so that even if conditions were such as to cause water tables to rise, they would contain little salt. In arid areas where there is salt in the sub soil, deep-rooted vegetation is absent and therefore any change in land use would have little change in evapo-transpiration. Therefore, it is unlikely that salt would be brought to the surface (Tickell 1994).

Since most of the water used for irrigation in the NT is ground water; its salinity needs to be considered to assess the risk of salinisation due to its use. Groundwater quality parameters generally follow a distinct trend from the north to the south of the NT of increasing total dissolved solids, sodium, calcium, magnesium, chloride, sulphate, alkalinity and hardness (Tickell 1994). This is because most aquifers of Central Australia are poorly-drained, perennial streams are non existent and recharge is limited by low rainfall and topography. The resulting sluggish movement of water through the aquifers means a long period for salt dissolution and therefore ground water is generally saline in the arid zone, with some exceptions. In contrast, most ground water in the Top End has been found to be of low salinity. For example, TDS for ground water in the Acacia region is less than 500 mg/L (Tickell, 2000); ground water in the Finniss – Dundee – Cox Peninsula has total dissolved solids ~ 100 mg/L (Knapton et al. 2004) and in Batchelor total dissolved solids from ground water bores ranged from 96-310 mg/L (Jolly 1981).

In the Ti-Tree region of Central Australia, irrigation ground water varies in salinity. In the Ti-Tree groundwater province, there is approximately 1800 km² of land overlying ground water with total dissolved solids at less than 1000 mg/L, which is ideal for drinking or irrigation use; 4300 km² overlying ground water with total dissolved solids from 1000 to1500 mg/L, which can be used on tolerant crops; and 2500 km² overlying ground water with total dissolved solids higher than 1500 mg/L, which is not recommended for cropping and would be a significant risk for salt build-up in soil (Department of Infrastructure, Planning and Environment, 2002). Nagarajah and Nesbitt (2002) have commented that even though groundwater salinity is often elevated in this area, it was not seen as a problem if correct irrigation techniques were used, as measured salt was not building up in soils or grapevines after up to 20 years of grapevine culture. This was partly attributed to the low clay content in the region's soils, promoting good leaching of salt during rainfall events. Salt resistant rootstocks were also mentioned to be of importance as a secondary insurance against possible salt build-up. Even so, monitoring will be especially important in Central Australia to warn against possible salt build-up in the top soil.

Surface waters in the Top End, where the NT's only perennial rivers are located and most likely to be used for irrigation, generally have low levels of salinity. The specific conductance of water in the Finniss River, for example, is less than 125 µS/cm, approximately 30 km inland from the mouth. Specific conductivity lowers even further in the river after the entrance of the tributary, Florence Creek (Knapton et al. 2004).

Use of estuarine waters for irrigation carries a greater risk. Work was done in the 1950s on the possibility of using Adelaide River water, near the estuary, for early irrigation of rice because of proximity to favourable soils (Planning Section, Water Use Branch 1959). It was found that the salinity in the estuarine section of the river fell markedly even with small flows, therefore could be used after early rains. Depth of sampling was not found to be significant i.e. the fresh water mixed with the salty and did not layer on top, as does occur in some other rivers. Use of estuarine rivers would only be recommended after pre-irrigation sampling in these situations, only after adequate consultation with other estuarine water users and consideration of environmental water requirements.

Two areas of the Top End have been intensively studied for the risk of dryland salinity developing from irrigation: Keep River Plains and the Douglas–Daly / Katherine region. About 5000 ha of the 10 600 ha proposed for development in the Keep River Plains (part of the Ord Irrigation Scheme) has saline soil and ground water 1 m or more under the surface. A study was completed by the Department of Natural Resources, Environment and the Arts to determine if irrigation would lead to rapid salinisation of these plains (Tickell et al. 2007). It was found that the salt in the soils was concentrated salt from the transpiration of rainfall, not from nearby estuaries. There were no layers showing abrupt decreases in hydraulic conductivity, such as hard pans, so the formation of perched water tables was unlikely. Also, efficient lateral groundwater flow to Keep River and Sandy Creek would slow any water table rise to the order of decades, and as long as adequate monitoring took place, it would be unlikely that irrigation would cause a salinity problem (Tickell et al. 2007).

In the Katherine/Douglas-Daly region, probably the most important agricultural region in the NT, it is unlikely that irrigation-induced salinity will occur because of the highly transmissive carbonate aquifers and the very strong connectivity of the ground water and incised drainage lines, which serve to ensure a steep hydraulic gradient to drive lateral groundwater flow. This would not preclude site-specific hydrogeological assessments to ensure good management of deep drainage water and prevention of salinity (Petheram et al. 2008).

5.3 Knowledge Gaps in Salinity

The following areas should be prioritised for further investigation:

1. Monitoring of water and soil salinity in all areas, particularly in Central Australia.

2. Determining sustainable irrigation practices for ground water affected by salt in Central Australia.

These priorities have been supported by NAIF, which has a proposed Research Area 3: “Solute (salt) and water table management in irrigated areas of Northern Australia”. The NT Natural Resource Management Board has also listed priorities for work with salinity. It has set a Resource Condition Target (4-1) that by 2015, there will be no increase from 2005 extent of land area affected by dryland and irrigation salinity. It has also set the following Management Action Targets and relevant management actions (see Box 1 below):

Box 1: Management Action Targets and Management Actions relating to salinity from the Integrated NRM Plan for the Northern Territory (Landcare Council of the Northern Territory 2005).

Management Action Target (MAT) 4-1 By 2008, areas at risk of salinisation are identified and monitored to avoid irrigation salinity.

Management actions relevant to this target

Management Action (MA) 4-2 Identify at-risk salinity areas, management requirements and associated development limitations, within regional development planning processes.

MA4-3 Develop and implement a soil and groundwater monitoring program in horticultural and agricultural areas to detect potential occurrence of irrigation salinity.

MAT4-2 By 2010, mechanisms are in place to prevent salinity from occurring in risk areas.

Management actions relevant to this target

MA4-4 Prioritise and support works to prevent salinisation.

MA4-5 Raise industry and community awareness of the environmental, social and economic implications of dry-land and irrigation salinity and disseminate information for prevention.

MAT5-1 By 2008 targeted research and monitoring programs are in place to provide priority information for social, economic, environmental and cultural planning for inland water environments and resources

Management actions relevant to this target

MA5-11: "Identify catchments and groundwater aquifers at risk from salinity, nutrients, toxins or sediment pollution and recommend appropriate action".

The Ti-Tree Water Resource Management Strategy 2002, (Department of Infrastructure, Planning and Environment 2002), also has actions relating to salinity (Table 6). These also should be actioned for management of salinity in the NT.

Table 6. Actions relation to salinity from the Ti-Tree Water Resource Management Strategy 2002

Publish continuing series of fact/information sheets for Ti-Tree water control district and conduct advisory/extension consultation programs to include irrigation guidelines (amongst others).	Continuing
Institute water level, salinity and pumping monitoring by all licence holders in the Ti-Tree water control district.	2002; continuing
Define new water resource development potential in all areas where groundwater salinity is less than 1000 mg/L.	2004
Preliminary assessment of new development potential in all areas where groundwater salinity is greater than 1000 mg/L.	2005

6. CONCLUSIONS

This paper has reviewed the extent of the water resource in the NT, its current plant industry use, the effects of plant industry on hydrology, the possible water pollution from pesticides and plant nutrients and the effect of saline water on soils.

In general, the impact of plant industry on inland water is now quite small, which reflects the state of development in the NT. But this review also highlights the scarcity of water and the fragility of the ecosystems that rely on water and how this should be protected, and water used sustainably into the future. There is much scope for development in an informed manner that takes into account the issues raised in this paper, in particular, knowledge gaps, so that food and fibre production can be ensured for the future.

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