DEPARTMENT OF INFRASTRUCTURE PLANNING AND ENVIRONMENT
NATURAL RESOURCES DIVISION

Stream Baseflows in the Daly Basin

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Cover Photo: Crystal Falls on the Douglas River (G8145386).

Summary

The Daly River is one of the few Northern Territories rivers that maintain significant flow throughout the Dry season. This survey took a snapshot of flows in mid-September at various sites in the catchment. The majority of the 34 cumecs measured at Mount Nancar is sourced from groundwater discharge from fractured and karstic aquifers within the Daly Basin. Discharge occurs at various sections along the Daly River and its tributaries where the streams cut into aquifers. The two main aquifers in the basin, the Tindall Limestone and the Oolloo Dolostone were discharging 15.8 and 17.8 cumecs respectively. The largest individual groundwater inflow is 7.7 cumecs, which discharges into the Daly River immediately upstream from Stray Creek.

Introduction

Aim

Dry season stream gaugings were carried out in the Daly River catchment in order to determine the locations and quantities of groundwater inflow (and or loss) to the river system. The main areas of interest were those stretches of the rivers that cross the Tindall and Oolloo aquifers of the Daly Basin.

Previous Work

Detailed water quality surveys of the Daly, Douglas, Flora and Katherine Rivers were carried out during the Dry seasons of 1982 and 1983 (unnamed 1983, 1985 and 1988). Although flows were not gauged, a range of water quality parameters was measured at many sites. More recently White (2001) and Tickell (2002) did dry season surveys of the Katherine and Daly Rivers. Some flows were measured and the locations of springs were recorded. Springs on the Flora River were described by Karp (1997) and those on the Katherine River at Katherine were documented by Karp (2002). Jolly et al (2000) used rainfall and streamflow records to develop a relationship to predict Dry season flows in the absence of low-flow gaugings. A broad scale water balance of the Daly River catchment including groundwater contribution to streamflow was made by Jolly (2002).

Study Area

The area investigated covers the Daly Basin, a geological unit that extends from Mataranka in the southeast to Tipperary Station in the northwest.

Methodology

A series of twenty-two stream gaugings were done at strategic sites in the Daly River catchment (Figure 4). Depending on river conditions they were either done from a boat or by wading, using a flow current meter and tape measure. Each gauging consists of selecting a suitable site with the most uniform depth and flow conditions possible. The cross section is divided into a series of segments. Within each segment the area is determined and a series of water velocity measurements taken, at suitable depths to define the average velocity for that segment. The total area and average velocity for the entire cross section is then calculated, and from that the flow determined using the following formulae.

$$\text{Flow} = \text{Area} \times \text{Velocity}.$$

The accuracy of this method is considered to be approximately +/-5% where flow conditions at the site are optimal.

Electrical conductivity, temperature and pH of the river water were measured at each location and most sites were photographed (Plates 1 to 12). Stream flow and water quality data are listed in Table 1. Two parties comprising Simon Cruickshank and Errol Kerle and Gary Willis and Steven Tickell did the work between Tuesday the 10th and Friday the 13th of September 2002. All data were included in an ArcView GIS project, from which down-river distances between stations were calculated.

Site	Name	Zone	Easting	Northing	Date/ time	Flow(cumecs, m^3/s)	EC(uS/cm)	pH	Temp(^0C)
G8145683	King R.west of Fishers Ridge	53	244989	8394196	10/09/02	0.52	28	6.2	27.7
G8140086	King R. d/s Stuart Hwy.	53	240255	8381465	10/09/02	0.38	28	6.73	29.1
G8145045	Dry R. @ Wongalla Lagoon	53	220701	8351219	11/09/02	Dry			
G8145027	King R., Kowai Lagoon	53	206424	8357092	11/09/02	0.17	40	6.7	27.1
G8145128	King R. @ Daly junction	52	820957	8373298	11/09/02	0.07	360	7.84	29.8
G8140029	Katherine R. @ Blue Metal Crossing	53	208390	8403596	13/09/02	1.3	26	7.2	27.9
G8140301	Katherine R. @ Galloping Jacks	53	190726	8389732	13/09/02	4.0	537	8.1	29.6
G8140303	Katherine R. 70m d/s of King R.	52	820825	8373311	11/09/02	4.0	497	8	30.5
G8145113	Daly R. @ Florina Station	52	787754	8402609	13/09/02	8.8	550	8.33	28.7
G8140067	Dorisvale Crossing Daly R.	52	777730	8410561	10/09/02	9.8	514	6.93	29.4
G8140393	Daly R. @ Black Bull Yard	52	758350	8430200	11/09/02	19.7	610	6.75	31.4
G8140042	Daly R., BeeBoom Crossing (old crossing)	52	723783	8466464	12/09/02	28.4	524	8.21	30.4
G8140040	Daly R. @ Mount Nancar	52	686853	8470831	13/09/02	34.0	570	8.51	29.6
G8140048	Edith R. @ Stuart Hwy.	53	179883	8430124	10/09/02	0.08	17	6.63	28.9
G8140157	Ferguson R.u/s Bondi Ck.	52	810198	8419008	10/09/02	0.52			
G8145200	Flora R., 2km u/s Mathison Ck.	52	771259	8362645	12/09/02	0.16	498	8.7	31.1
G8145021	Flora R. @ Kathleen Falls	52	779330	8366862	12/09/02	3.6	818	7.66	30.7
G8145686	Stray Ck.adjacent to se corner NT Por 6069	52	768181	8445860	11/09/02	0.47	603	7.46	27.3
G8145192	Stray Ck, 20m u/s Daly R.	52	760516	8429769	11/09/02	0.57	507	6.97	29.8
	Douglas River, right hand channel @ 50m U/S of Hot Springs outlet						30	5.77	29.5
	Douglas River, left hand channel @ 50m U/S of Hot Springs outlet						97		
G8145683	Douglas Hot Springs, outlet channel	52	764042	8476840	11/09/02	0.07	50	5.33	43.9
G8145643	Douglas River @ 200m D/S of Hot Springs outlet	52	763588	8476785	10/09/02	0.51	53	5.77	32.9
G8140322	Douglas R. @ Research Farm	52	739247	8470817	12/09/02	2.5	492	8.15	29
G8145386	Douglas R. u/s Crystal Falls	52	732163	8468831	12/09/02	3.1	523	8.17	29.1

Table 1 Summary of field measurements

Observations

Stream Flows

The individual flows are plotted on a map showing the river system and the extent of the two major aquifers of the Daly Basin, the Tindall Limestone and the Oolloo Dolostone (Figure 1). Only minor flows originate from areas outside of the basin. The largest of these is in the Katherine River at Blue Metal Crossing with a flow of 1.25 cumecs. Smaller flows totalling just over 2 cumecs also enter the northeastern side of the basin in the King, Ferguson / Cullen and Douglas Rivers.

In the case of the Douglas River, the 0.51 cumecs recorded near the Douglas Hot Spring is likely to originate largely from outside the basin because the water has a low electrical conductivity typical of a non-carbonate rock source. The 1982 baseflow survey of that river (unnamed 1988) confirms that this is the case. The Hot Spring itself has a relatively small flow at 0.074 cumecs. Its water also has low conductivity. This together with its relatively high temperature (45^0C) suggests a source aquifer beneath the Daly Basin connected to the surface by a fault.

The Cullen River, a tributary of the Ferguson had no flow at the Stuart Highway at the time of the survey, so it is assumed to also have no flow where it enters the basin. The upstream section of Stray Creek was not inspected but springs are known to occur where it cuts the Tindall Limestone on Jindare Station. The creek is assumed to have either no flow or only very minor flow upstream of the basin. On the southwestern side of the basin only two main streams flow into it, the Flora River and Bradshaw Creek. The latter is known to be dry upstream of the Oolloo Dolostone.

Once the rivers cross into the basin and pass over either the Tindall Limestone or the Oolloo Dolostone they generally gain water from groundwater inflow. Gain to the rivers is much greater than loss because at Mount Nancar the station immediately downstream of the basin, the flow was 34 cumecs compared to a total flow of just over 2 cumecs in the streams that enter the basin.

Water Quality

Electrical conductivity is an indication of the total dissolved solids in the water. The measurements made are plotted on Figure 2. An obvious feature is that waters upstream of the basin have values less than 50 µS/cm. While those within and downstream of the basin are of the order of 500 to 600 µS/cm. The former reflect non-carbonate source aquifers such as granite or sandstone while the latter are typical of waters originating from carbonate aquifers such as limestone or dolomite. Electrical conductivity along with pH and temperature are listed in Table 1.

Discussion

Karp (1997), White (2001), Karp (2002) and Tickell (2002) have previously documented the locations of most of the major springs in the Daly Basin. Using this knowledge together with the current stream gaugings and the underlying geology, it is possible to determine groundwater inflows (and or losses) along individual stretches of the rivers.

Other factors that can influence streamflow include losses due to evapotranspiration and pumping. Jolly (pers.com.) estimated an evapotranspiration loss of between 3 and 5 litres/second per kilometre of river. A figure of 4 litres/second/km (.004 cumecs/km) was used here. The stretch of the King River between stations G8140086 and G8145027 provided a test for this value because the underlying geology suggests that losses or gains to groundwater should be minimal. Over a distance of 60 km the rivers flow decreased by 0.22 cumecs, which equates to 4 litres/second/km. No account was taken here of pumping from the rivers. Some extraction for irrigation and stock and domestic purposes is however known to occur in the Katherine River between Katherine the King River junction, and on the Fergusson River downstream of the Stuart Highway.

Springs are normally visible along the stretches of rivers where groundwater discharge has been measured. The flows estimated from the springs are however only a minor proportion of the total discharge as measured by stream gauging. An example include the Katherine River at Katherine where the discharge of the three main springs totalled less than 0.5 cumecs in September 2001 (Karp 2002). This compares to the total groundwater discharge to the river in that area of some 2.8 cumecs. Similar situations are observed in the Flora River (Karp 1996) and the Daly River (Tickell 2002). The additional discharge is presumably occurring from springs beneath the waterlevel and via diffuse riverbed seepage.

Figure 3 summarises the gains and losses to the rivers adjusted for evapotranspiration losses. A total of 33.6 cumecs was discharging from the Daly Basin aquifers. Of this the Tindall Limestone contributes 15.8 cumecs and the Oolloo Dolostone contributes 17.8 cumecs.

Tindall Limestone

In the case of the Tindall, the main inflows occur where the Daly, Flora, Katherine and Douglas Rivers cut the aquifer. The lower sections of Middle and Hays Creeks both tributaries of the Douglas River also receive groundwater discharge.

Minor inflows from the Tindall aquifer also occur in the Ferguson River and Stray Creek. An exception to the trend of groundwater discharging to the rivers is the King River, which loses a small quantity of water to the Tindall Limestone via the overlying Cretaceous sand.

The 5.8 cumecs estimated to be entering the Daly downstream of the Douglas River appears to be too large considering the area of outcropping Tindall Limestone adjacent to the river. The quality of the gaugings above and below this section of limestone were however considered to be good. Given a 5% accuracy the actual groundwater inflow could be as low as 2.4 cumecs. A one day field trip was made in early October 2002 with the aim of locating springs along that stretch of the river. It was only possible to inspect the upstream third of the section and just a few minor springs were located (Roger Farrow, pers. comm.). It would be useful to complete this traverse at some time in the future and also to repeat dry season gaugings at the two sites G8140040 and G8140042, to confirm the magnitude of the discharge.

Oolloo Dolostone

The Daly River runs along the axis of the basin and is the main avenue for groundwater discharge from the Oolloo Dolostone. The bulk of the discharge, 7.7 cumecs occurs along a seven kilometre stretch of the river immediately upstream from the junction with Stray Creek (Tickell 2002). Downstream from Stray Creek as far as the Douglas River a further 6 cumecs discharges into the Daly River. Lesser discharges from the Oolloo Dolostone also occur in the Daly upstream from Dorisvale Crossing, in the Katherine River downstream of the King River, in Stray Creek and the lower reaches of the Douglas River. Both the King and Katherine Rivers lose a small amount of water to the Oolloo Dolostone in those sections furthermost upstream also via the overlying Cretaceous sand.

Water Balance, a snapshot

A water balance of surface water entering and leaving the Daly Basin at the time of the survey has the following components:

(a) Stream flow leaving the basin via the Daly River at Mount Nancar (G8140040)……34.0 cumecs.

(b) Stream flow entering the basin in the Douglas, Ferguson, Katherine and King Rivers…2.3 cumecs.
(c) Evapotranspiration losses……2.6 cumecs.
(d) Riverbed seepage losses to groundwater in the King and Katherine Rivers…0.2 cumecs.
(e) Groundwater discharge into streams…..33.6 cumecs.

The groundwater discharge component listed above is the sum of values calculated between successive gauging stations. This can be compared to an overall value, calculated using the following water balance equation:

$$e = a - b + c + d$$
$$e = 34.0 - 2.3 + 2.6 + .2$$

Groundwater discharge to streams = 34.5 cumecs.

The two values for groundwater discharge calculated by the different methods are therefore in agreement, as the accuracy of the gaugings is considered to be 5%.

***Salt balance*, a snapshot**

A simple salt balance for dissolved solids (salts) entering and leaving the Daly Basin at the time of the survey was derived from the stream flow and electrical conductivity measurements. The two parameters were multiplied to obtain a weight of dissolved material passing each site per unit time. Electrical conductivities were converted to milligrams per litre by multiplying by a factor of 0.6 and the other appropriate conversions were applied to result in units of tonnes/day. The salt load Mount Nanacar is about 1000 tonnes/day and it is largely derrived from the Daly Basin because the loads entering the upstream side of the basin are negligable by comparison. Salt loads calculated for individual sections of the streams are plotted on Figure 5. Summing these individual loads indicates that 360 tonnes/day is sourced from the Tindall Limestone and 450 tonnes/day is from the Oolloo Dolostone. The value of 233 tonnes/day sourced from the Tindall Limestone in the Daly River downstream of the Douglas River stands out as anomalously high in comparison to the other sections of that aquifer. If a lower groundwater inflow of 2.4 cumecs (see above) is used for that section, then the salt load for that section reduces to 77 tonnes/day and the total basin load reduces to 850 tonnes/day.

The material dissolved in the river water largely consists of magnesium, calcium and bicarbonate ions. These represent the dissolution products of the dolomite and limestone aquifers of the Daly Basin. An analysis of Daly River water at Mount Nancar, sampled on the 27/8/1981 is shown in Table2. The flow was about 20 cumecs at that time.

Table 2 Water chemistry, G8140040, 27/8/1981

	mg/L	meq/L
Conductivity lab	540 (uS/cm)	
TDS (mg/L)	310	
pH lab	7.7	
Alkalinity	278	
Hardness total	283	
Calcium	46	2.3
Magnesium	46	3.8
Sodium	11	0.5
Potassium	3	0.1
Bicarbonate	339	5.6
Sulphate	23	0.5
Chloride	16	0.5
Fluoride	0.2	0.01
Iron - total	0.1	

References

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Unnamed, 1988. Baseflow water quality surveys in rivers in the Northern Territory, Volume 7, Douglas, Flora and Reynolds Rivers. Report No. WRD88002, Water Resources Division, Northern Territory Department of Mines and Energy.

White, E., 2001. A late dry season survey of the Katherine and Daly Rivers. WRD 24/2001, Natural Resources Division, Northern Territory Department of Lands, Planning and Environment.

Figure 1. Stream flows, September 2002

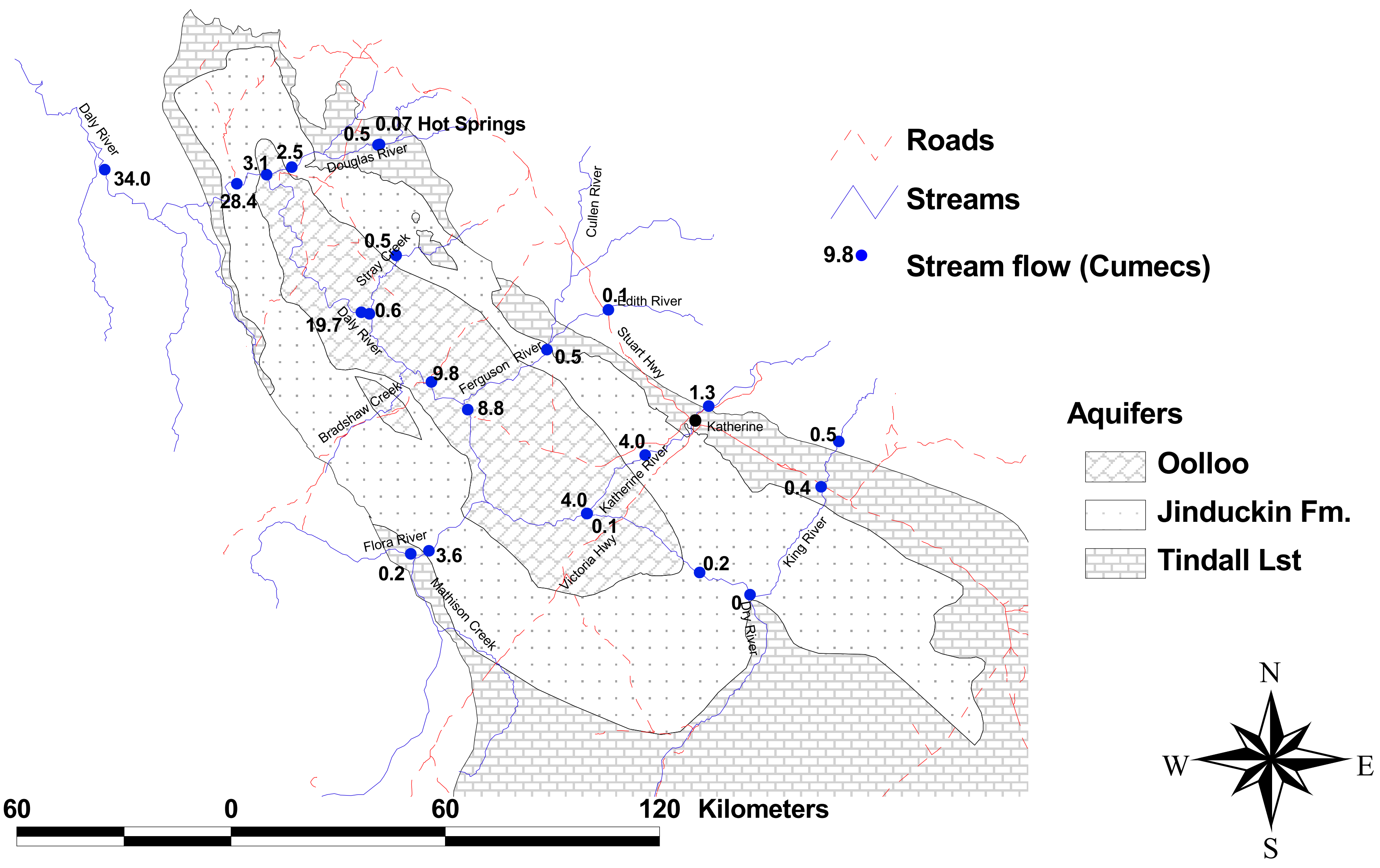

Figure 2 Electrical conductivities, September 2002

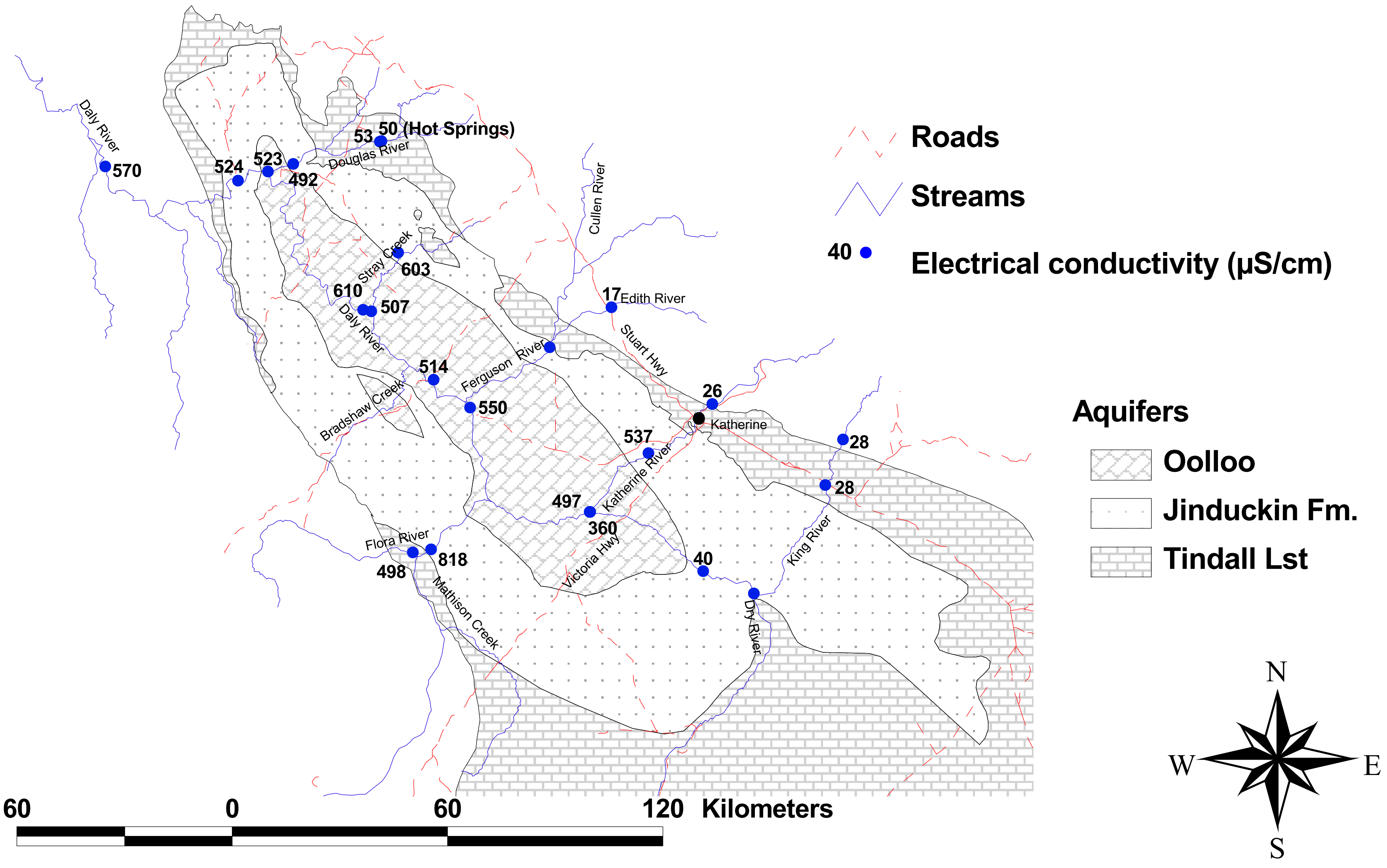

Figure 3. Zones of gain or loss to the rivers, September 2002

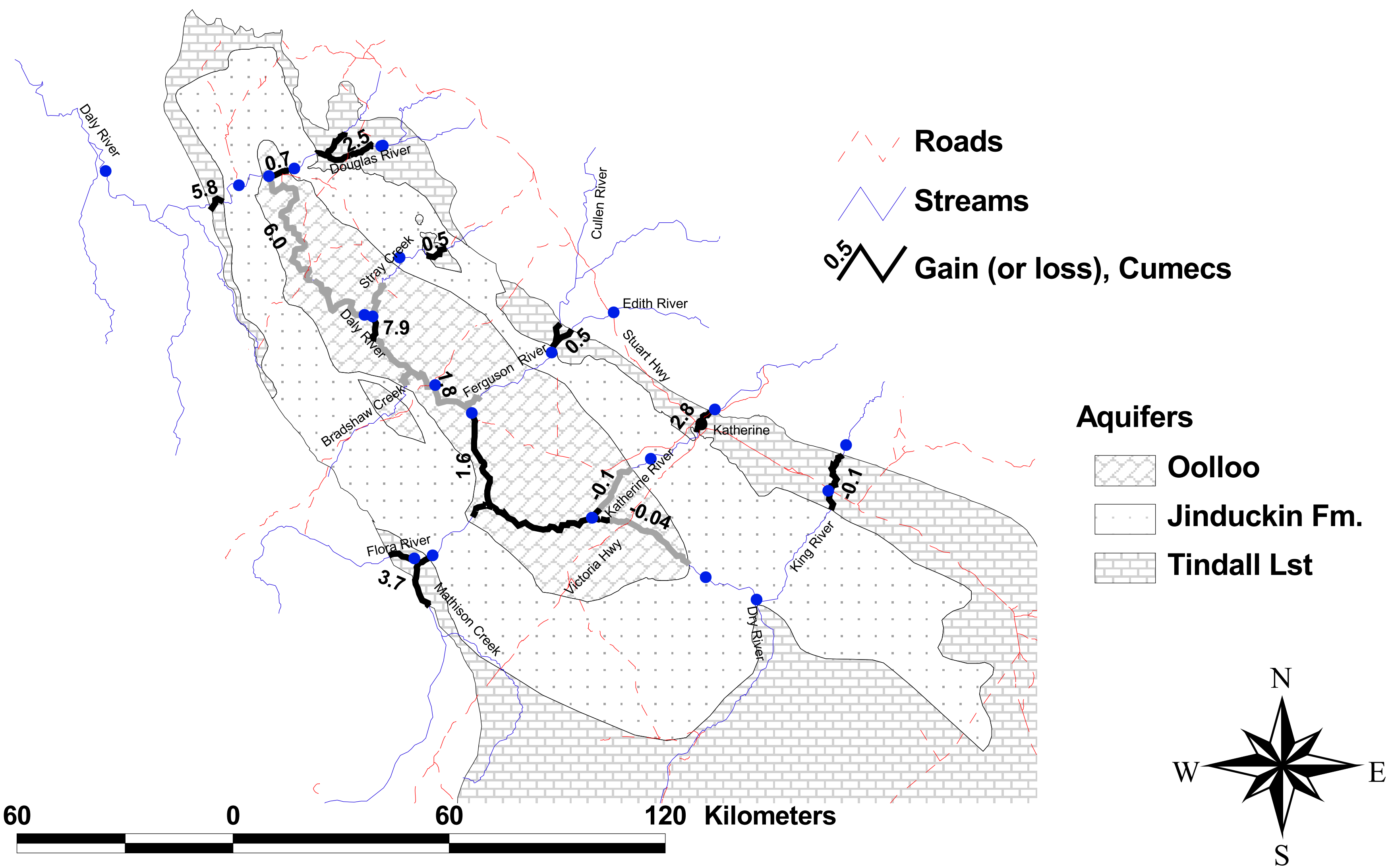

Figure 4 Site Locations

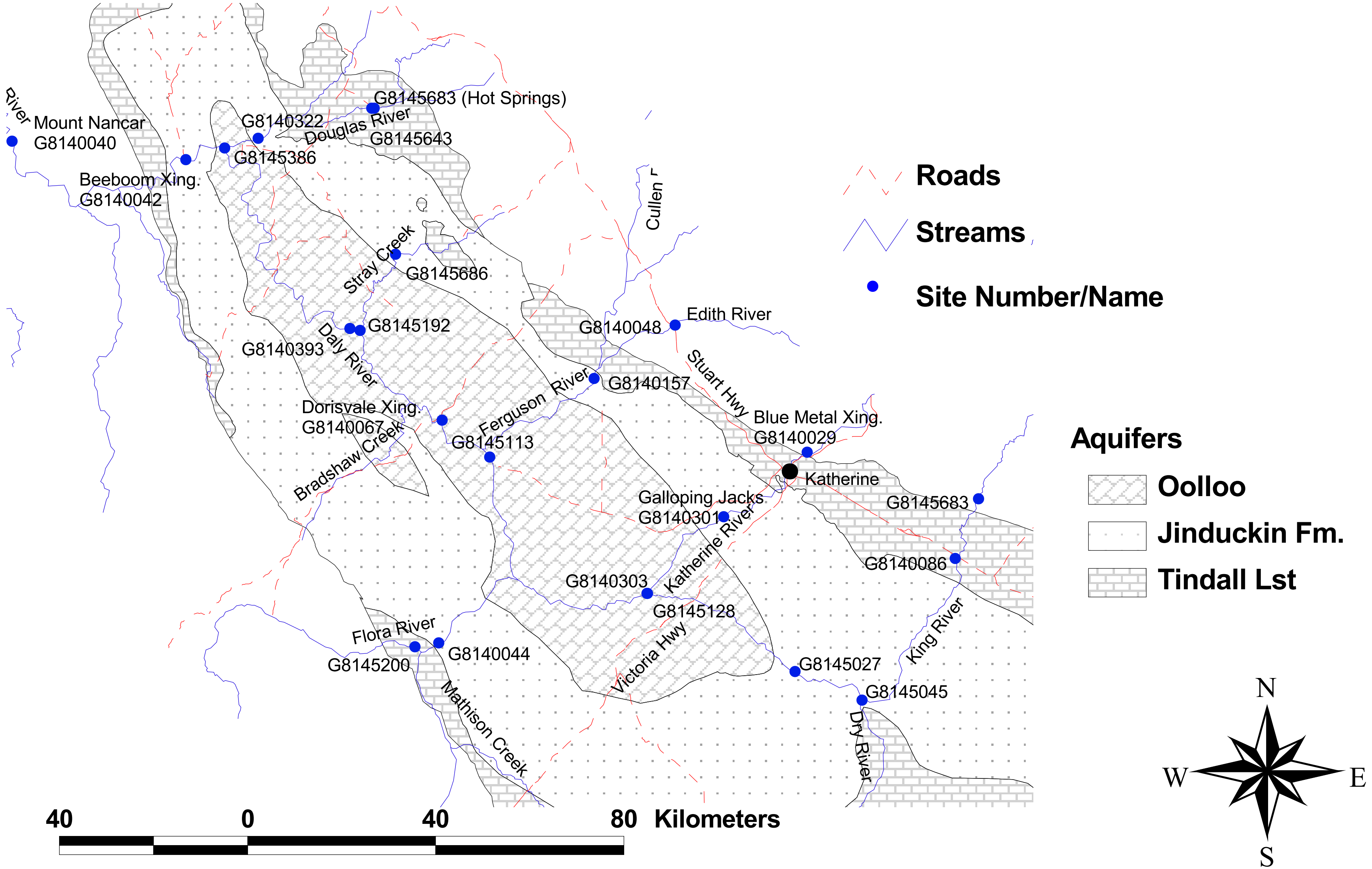

Figure 5 Salt Loads

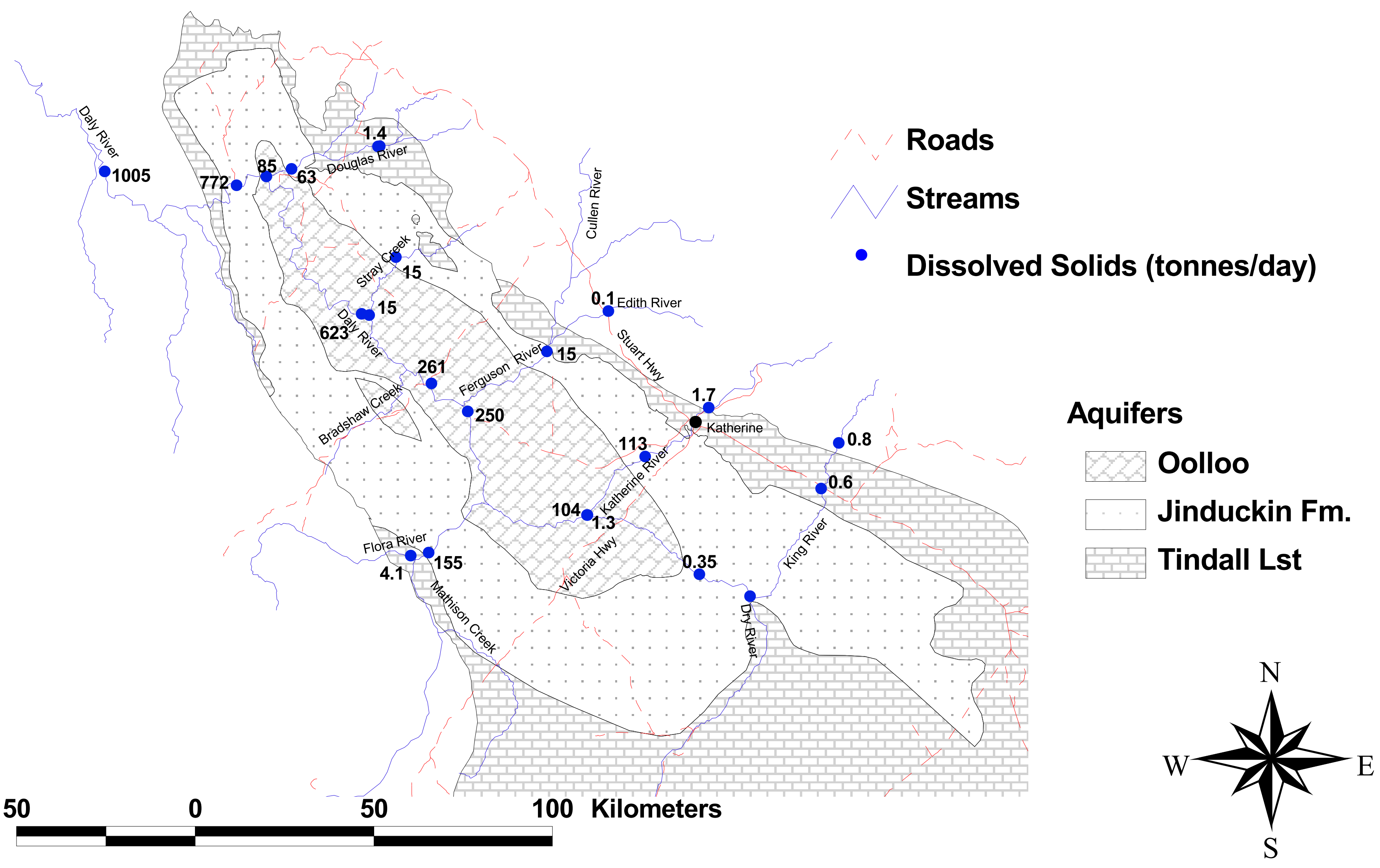

Plate1 Katherine River at Blue Metal Crossing, G8140029

Plate 2 Katherine River at Galloping Jacks, G8140301

Plate 3 Katherine River, 70 metres downstream of the King River G8140303.

Plate 4 Daly River at Florina Station, G8145113

Plate 5 Stray Creek / Daly River junction, G8145192

Plate 6 Daly River at Beeboom Crossing

Plate 7 Daly River at Beeboom recorder site, G8140042

Plate 8 Daly River at Mount Nancar, G8140040

Plate 9 King River upstream of the Stuart Hwy, G8145683

Plate 10 Flora River at Kathleen Falls, G8140044

Plate 11 Douglas Hot Springs, main outlet channel, G8145683

Plate 12 Douglas River at the Research Station, G8140322