Mataranka Background Report 2024-2034

NORTHERN TERRITORY GOVERNMENT

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Acknowledgement of Country

The Department of Lands Planning and Environment respectfully and proudly acknowledges the Northern Territory's Aboriginal people and their rich culture, and pays respect to the Elders past and present.

We acknowledge Wubalawun, Yangman, Mangarrayi and Jawoyn peoples as the Traditional Owners and custodians of the lands and waters of the Mataranka water allocation plan area, and Aboriginal peoples connected to the waterways of the lower Roper River.

We recognise the intrinsic connection of Traditional Owners to Country and value their ongoing contribution to managing the lands and waters. We support the need for genuine and lasting partnerships with Traditional Owners to better understand cultural connections, and we will work to establish lasting partnerships to manage water together, now and into the future.

Contents

List of tables

List of figures

1. Overview

About the water allocation process

Water allocation is the process of determining how much water must stay in the environment to protect ecological functions and environmental requirements and how much is available for drinking and regional economic priorities. Water allocation in the Northern Territory is undertaken at a regional level within defined areas known as water control districts, which are declared by the Minister for Water Resources (Minister) by *Gazette* notice.

About the Mataranka plan area

The Mataranka plan is within the Daly Roper Beetaloo water control district (the district), an area of 330,000 km^2 (Schedule C). The district includes a number of river basins and aquifers. Separate water allocation plans have been declared or are in development for different parts of the district.

The Mataranka plan applies to an area of approximately 9,282 km^2 extending about 190 km from north to south, and up to 70 km east to west shown in Schedule C (the plan area). The plan area includes the towns of Mataranka and Larrimah and the community of Jilkminggan. Pastoral leases cover about 40 per cent of the plan area, with approximately 36 per cent of the plan area recognised as Aboriginal land.

About this document

This document is one of three core documents prepared as part of the water allocation process for the plan area. This document references other documents and guidelines that may relate to the plan area, but which do not form part of the core documents. The three core documents are:

Mataranka Water Allocation Plan 2024–2034 (the plan). The plan is declared by the Minister under section 22B(1) of the *Water Act 1992* (Act)[1]. The plan describes the estimated sustainable yield for the water resources of the plan area over three water management zones (Schedule D). The estimated sustainable yield is the volume of water that can be taken sustainably from the water resources to which this plan applies. The plan allocates that water amongst declared beneficial uses and provides for trading of water. The plan takes effect from the date in the *Gazette* by the Minister and will remain in force for a period of ten years.

Mataranka Background Report 2024–2034 (this document, the report) provides details on the information and processes that informed the plan, including available data and research on the surface water and groundwater resources of the plan area. It also describes the key environmental values of the plan area and their dependency on water resources, and the social and developmental context of the region, including existing water use and projections of future water demand. The report collates the information and knowledge regarding the plan area at the time of its preparation.

Mataranka Implementation Actions 2024-2034 (the implementation actions) details how the requirements in section 34 of the Act, with respect to the water resources of the plan area, are fulfilled. It defines a continuous program for the assessment of water resources in the plan area, including the investigation, collection and analysis of data concerning the occurrence, volume, flow, characteristics, quality and use of water resources. That program is described within the document as a series of implementation actions which includes a body of research, monitoring and analytical work.

The Controller of Water Resources must consider any water allocation plan applying to the area in question when making a decision referred to in section 90(1) of the Act. The Mataranka Water Allocation Plan 2024-2034, background report and implementation actions and other factors may be taken into account, where relevant to the decision.

[1] https://legislation.nt.gov.au/Legislation/WATER-ACT-1992

2. Summary

Overview

This section provides an overview of the development of the water allocation plan and the planning processes used in the plan area and district.

The plan is comprised of three water management zones: North Mataranka, South Mataranka and Larrimah, across an area of approximately 9,282 km^2 extending about 190 km from north to south, and up to 70 km east to west. These areas are aligned to different hydrogeological characteristics of the aquifer, climatic conditions and environmental and ecological values.

Separation of a plan into different management zones is a logical and nationally accepted approach to managing a resource where hydrological, hydrogeological, ecological characteristics and behaviour vary across the resource or where there is highly variable usage. Applying management zones allows location specific management arrangements to be applied to meet the objectives of the plan.

The Tindall Limestone Aquifer in North Mataranka and South Mataranka water management zones are characterised as Top End systems. These systems are seasonal. Where groundwater and surface water are connected, water availability is based on flows. The Larrimah zone behaves like, and is characterised as, an Arid Zone system where recharge to water resources is episodic. This approach is consistent with the Classification of the Top End and Arid Zone for Northern Territory water resources (Short and Bond, 2021).

The purpose of this document is to reference and summarise the foundational information and knowledge that informed the development of the Mataranka Water Allocation Plan 2024–2034 and the Mataranka Implementation Actions 2024–2034.

The dictionary in Schedule A defines particular words used in this report. Acronyms are provided in Schedule B. Unless otherwise stated, terms defined in the Act have the same meaning when used in this report.

2.1. Planning processes

Information on the department's approach to water allocation planning is available on the department's website[2].

As part of the department's commitment to the National Water Initiative the department is continuously improving water management in the Territory. The structure of the Territory's water planning documents clearly present the statutory requirements, supported by applicable information relevant to respective water control districts and plan areas. The new structure is being applied to new plans under development and progressively applied to existing plans as they are reviewed and replaced over the coming years.

2.1.1. Daly Roper Beetaloo water control district

Under section 22 of the Act, the Daly Roper Beetaloo water control district was declared on 19 October 2022. A map of the district and plan area is provided in Schedule C.

This report is about the area subject to the Mataranka Water Allocation Plan 2024–2034, which is contained within the district. Other water allocation plans apply to other parts of the district.

[2] https://nt.gov.au/environment/water

2.1.2. Water management zones

The Tindall Limestone Aquifer (TLA) is one of a number of aquifers within the regionally extensive groundwater system called the Cambrian Limestone Aquifer. While these aquifers are interconnected each has distinct hydrogeological characteristics, which means that water flow through the aquifers is not uniform. Hydrogeological characteristics within an aquifer may also vary, which is the case in the TLA within the plan area.

There are three water management zones recognised within the plan area: North Mataranka, South Mataranka, and Larrimah. Each of these zones are hydrogeologically distinct environments. The three zones are shown in Schedule D. The TLA in North Mataranka and South Mataranka water management zones are characterised as Top End systems with distinct seasonal recharge and discharge. Groundwater flow in North Mataranka flows south, draining to the Roper River, while groundwater flow in South Mataranka flows north and east, also toward the Roper River. The Larrimah zone behaves like, and is characterised as, an Arid Zone system where recharge to water resources is episodic and groundwater flow rates are slower. This approach is consistent with the classification of the Top End and Arid Zone for Northern Territory water resources (Short and Bond, 2021).

The delineation of these zones is informed by principles to:

- maintain natural groundwater flow direction and rate through the aquifer
- maintain water quality and natural mixing of groundwater from each zone, recognising that this is a significant determinate of water quality in the Roper River
- reflect (existing and forecast) land use intensity and essential infrastructure needs, for example location of bores for drinking water
- reflect the aquifer properties and water quality across the plan area, and distinguish zones where changes in aquifer conditions may impact beneficial uses within or adjacent to that zone
- distribute extraction and mitigate localised drawdown
- deliver environmental flows to iconic features and groundwater dependent ecosystems.

The western and eastern boundaries of the plan area correspond to the edges of the Daly geological basin, which hosts the TLA. The northern boundary near the King River represents a groundwater divide in the Tindall Limestone formation, where groundwater flows north towards the Katherine River and south towards the Roper River. The southern boundary is adjacent to the Georgina geological basin.

2.2. Population and land uses

The land within the plan area has an established pastoral industry, and the region draws a significant number of tourists each year for fishing, camping, and recreation. Groundwater from the high yielding TLA is used for agricultural and pastoral purposes, as well as public water supply, industrial, and domestic consumption. The aquifer also contributes significantly to the dry season flows of the Roper River, and groundwater discharge from the aquifer feeds the famous springs of Elsey National Park, contains prominent surface water features including springs, creeks and the Roper and Waterhouse rivers. These are valued by the Mataranka community and visitors to the region for their social, cultural, environmental and economic significance.

The plan area includes several small towns and settlements, the largest of which is Mataranka, which has a population of 384 people (2021, ABS census) and sees a major rise in visitors during the tourism season. The plan area includes the Aboriginal community of Jilkminggan, population 254, as well as the township of Larrimah and other minor settlements.

The plan area contains land held by the Wubalawun, Yangman, Mangarrayi, and Beswick Aboriginal Land Trusts. It is acknowledged that Aboriginal people have a spiritual connection to the springs, soaks, billabongs, streams, creeks, and rivers that are related to the aquifer. Culturally significant sites include Bitter Springs (Gorran), Rainbow Spring (Najig), Roper River, Elsey Creek and Red Lily Lagoon (Ngarrmirngan).

Aboriginal land covers approximately 36 per cent of the plan area and supports a variety of land uses including residential areas, pastoralism, mining, tourism and conservation.

Pastoralism covers most of the plan area at an estimated 40 per cent and is reliant on access to the aquifer via stock bores. Irrigated agriculture and light industry operators also rely on groundwater for production, with tourism operators, councils and schools needing water to maintain greenspaces including camping grounds, sporting ovals and rest stops, Schedule E.

3. Water resources

Overview

This section outlines the foundational information and knowledge about the water resources in the plan area. The scientific understanding of the water resources is underpinned by water monitoring, assessments and modelling.

The groundwater resource managed through the plan is the regionally extensive and multilayered Tindall Limestone formation and overlying Cretaceous sediments, which are collectively known as the Tindall Limestone Aquifer (TLA).

The extensive understanding of the TLA and flows to the Roper River is informed by:

- a network of groundwater and surface water monitoring, groundwater investigations, and resource assessments undertaken over many decades
- a comprehensive integrated surface water – groundwater model, which is used to inform the water plan and licence decisions or conditions, i.e. announced allocations – the Northern Territory's approach to adaptive water management
- the Strategic Regional Environmental and Baseline Assessment
- CSIRO Roper River Water Resource Assessment (Taylor et al., 2023).

It is also a region where some water dependant development has occurred, primarily for agriculture, tourism and for public water supply, further informing the understanding of the resource and its response to water extraction.

Groundwater discharge to the Roper River occurs at Bitter and Rainbow springs but also through the bed and banks of the river and tributaries that intercept the TLA. Studies (including Taylor et al., 2023) have shown that the dominant groundwater flow that feeds these springs comes primarily from local groundwaters that flow from the south west for Bitter Springs and from the north for Rainbow Springs.

Long term monitoring and assessment studies show end of dry season flow rates in recent years are at least 2-3 times greater than dry periods in the 1960's despite the commencement of groundwater extraction from 2014 onwards. Dry season flows in the Roper River are maintained by groundwater flows in the dry season and groundwater levels have continued to increase despite extraction, confirming that:

- water extraction to date has had a negligible impact on groundwater levels or on dry season flows to the Roper River
- groundwater levels and dry season flows of the Roper River are more directly affected by variations in climate over the long term
- the impact of extraction is dependent on where extraction occurs as well as the volume of extraction.

The North Mataranka and South Mataranka water management zones are particularly important as they provide:

- approximately 95 per cent of the recharge to the TLA due to the thickness (>30 m) of cretaceous cover towards the south of these zones
- dry season flows to the Roper River.

In contrast, extraction in the Larrimah water management zone has minimal impact on flows in the Roper River given the distance and gradients; groundwater travel times from Larrimah to the Roper River are exceedingly slow.

3.1. Topography

The majority of the plan area lies within the Roper River Basin, with a small portion in the northwest overlying the Daly River Basin. The Roper River is a large, perennial flowing river with a catchment area of approximately 82,000 km^2 that drains into the Gulf of Carpentaria.

The plan area is relatively flat throughout its extent with terrain generally sloping towards the Roper River and its tributaries, and no discernible high points in the landscape. In the Larrimah zone the maximum elevation is approximately 200 m Australian Height Datum (AHD), gently decreasing to 150 m AHD to the east, along the Strangways River floodplain, and to the west along Birdum Creek.

In South Mataranka the landscape continues to drain towards Elsey Creek in the north and the Roper River to the north east. Elevation is about 100 m A HD where the Roper River crosses the eastern boundary of the plan area, approximately 12 km downstream of Elsey Homestead.

The maximum elevation of 200 m AHD in the North Mataranka zone is along the northern boundary of the plan area with the landscape draining southeast towards the Waterhouse and Roper Rivers. The town of Mataranka has an elevation of 145 m AHD.

3.2. Climate and rainfall

The plan area lies within the wet dry tropics of northern Australia and spans both the tropical savannah and hot semi arid grassland based on the Köppen climate classifications (Köppen, 1884), see Schedule F. Rainfall occurs predominantly between November and March when the monsoon trough is drawn southward from the equator; from May to October very little rainfall occurs, as per Figure 1.

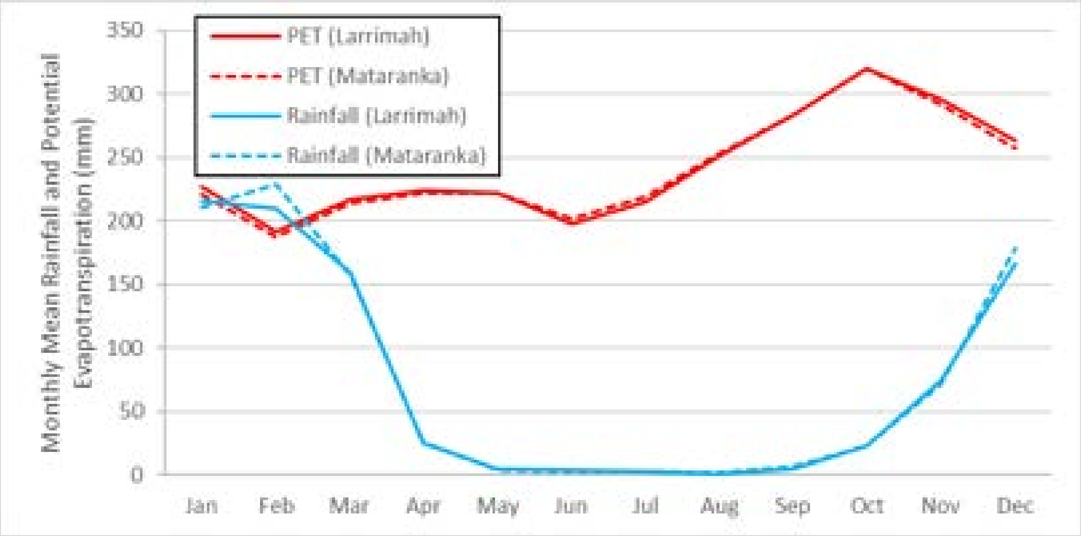


Figure 1. Mataranka and Larrimah average monthly rainfall and potential evapotranspiration

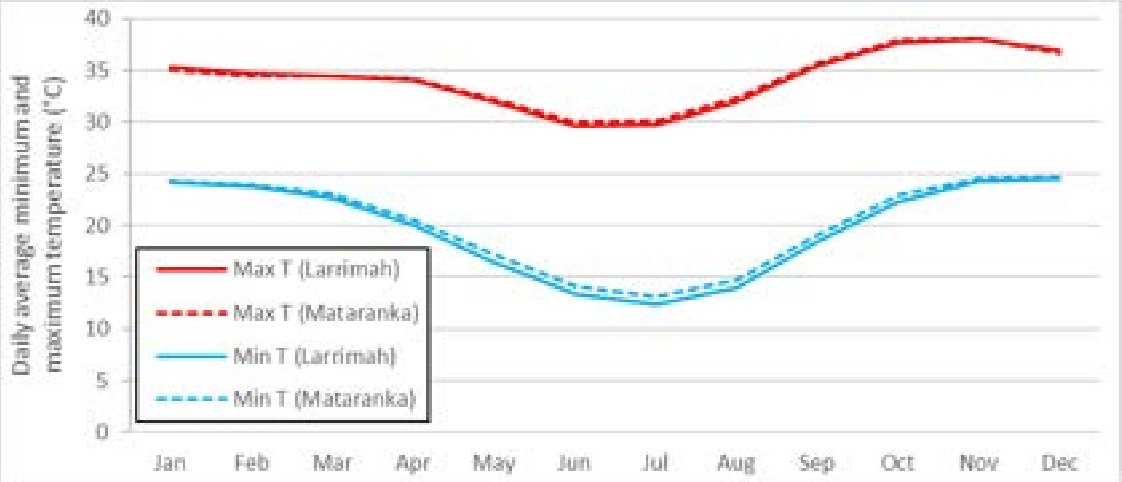


Figure 2. Mataranka and Larrimah average monthly temperature

Potential evapotranspiration is approximately 2000 mm per year and generally exceeds rainfall. Average monthly potential evapotranspiration for the area is higher in the south and varies throughout the year ranging from approximately 320 mm in October to 200 mm in July.

The area is hot year round, with average daily maximum temperatures reaching up to 38°C in the wet season. Average daily minimum temperatures rarely fall below 12°C in the dry season and 23°C in the wet season. July is typically the coldest month of the year as per Figure 2.

3.2.1. Rainfall variability

While rainfall in the plan area has low variability from one year to the next, relative to other parts of southern and northern Australia, there is still considerable variation from one year to another (Watson et al., 2023). The highest annual rainfall at Mataranka, 1779 mm, occurred in the 2010-11 wet season, which was six times higher than the lowest annual rainfall, 297 mm in 1951-52, and more than twice the average annual rainfall value, approximately 820 mm.

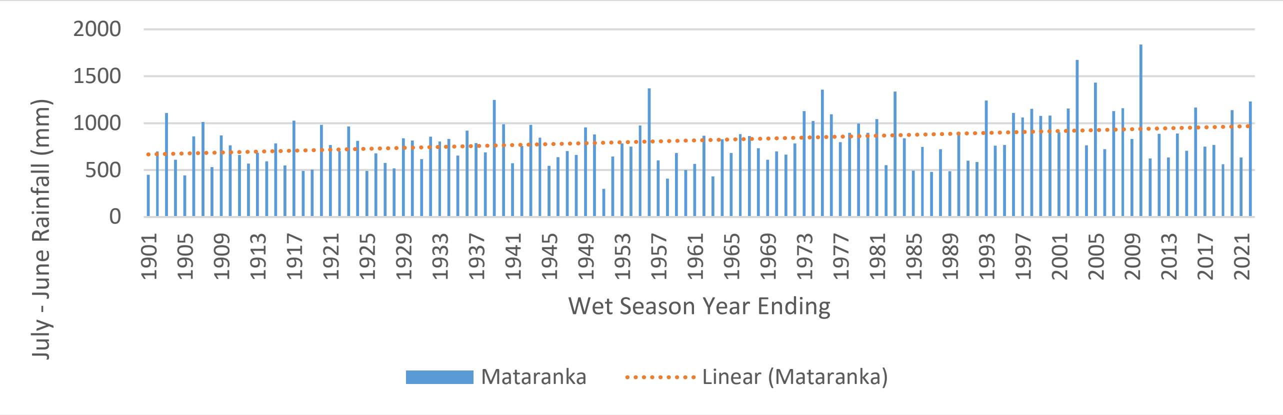


Figure 3. Mataranka rainfall

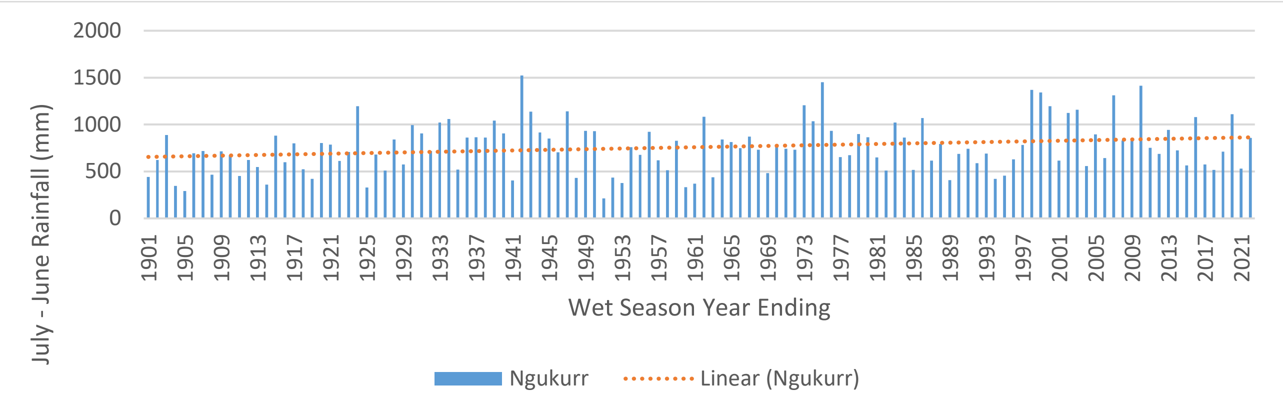


Figure 4. Ngukurr rainfall

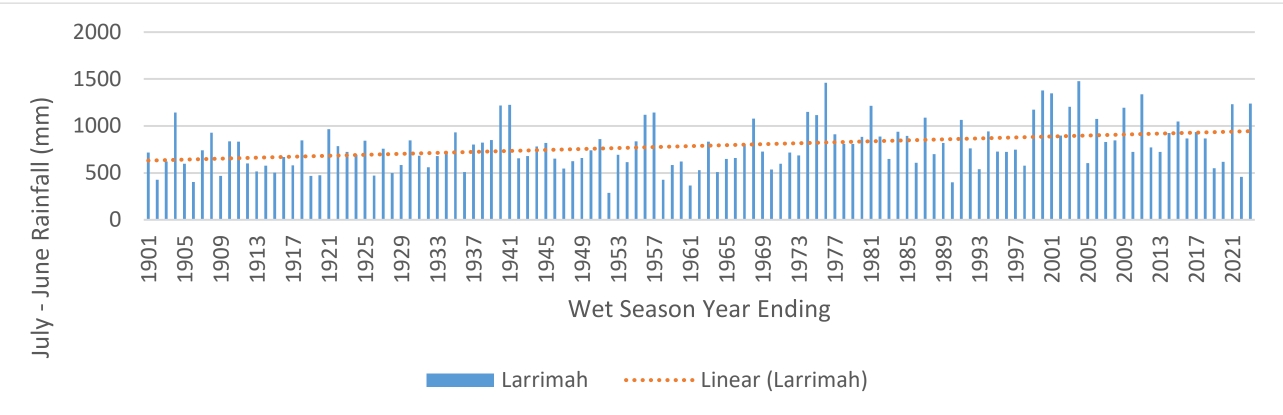


Figure 5. Larrimah rainfall

Rainfall records demonstrate an overall trend of gradually increasing rainfall observed within the plan area since 1900. Figure 3, Figure 4 and Figure 5 show total annual rainfall from 1900-2021 for Mataranka, Ngukurr and Larrimah as extracted from the scientific information for land owners database (Jeffrey et al., 2001). The climate period trend can be observed from the cumulative deviation from average annual rainfall. The cumulative deviation shows an increasing trend in rainfall in the plan area since approximately 1970, Figure 6.

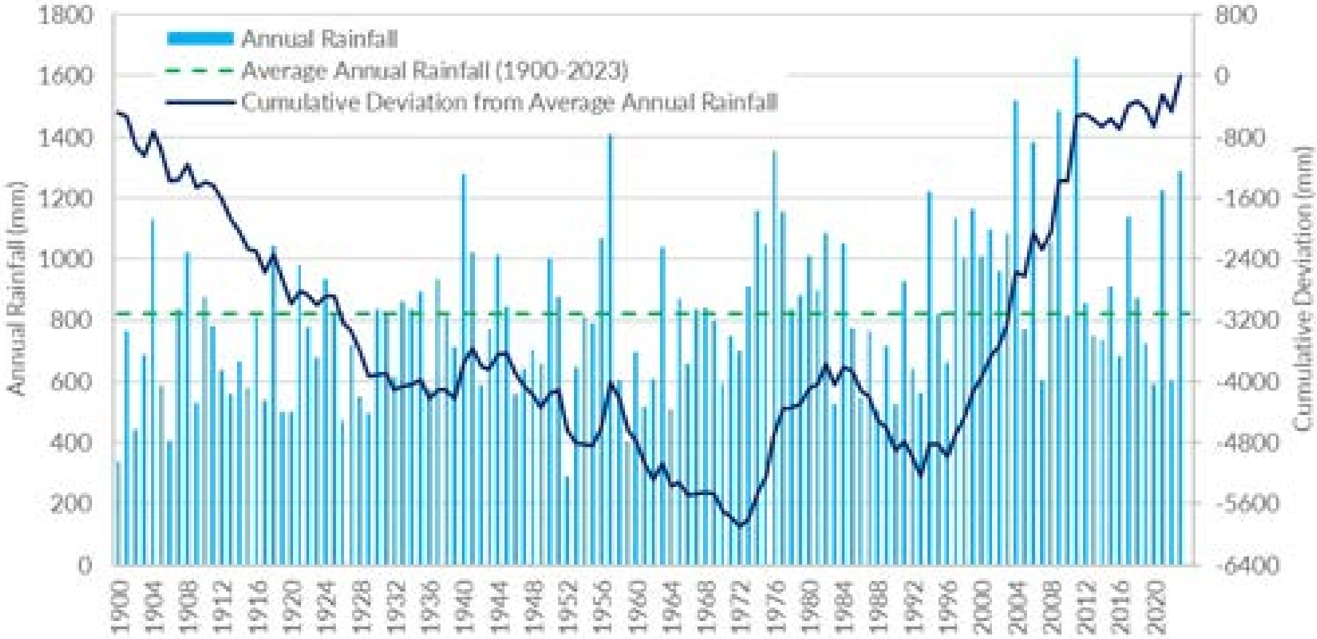


Figure 6. Mataranka annual rainfall and cumulative deviation from average

However, to assess these trends relative to the previous period, cumulative deviation from the long term average trend is a useful measure, Figure 7. This shows periods of increasing or decreasing residual trend over the 120 year period and while the current trend, compared to the previous period, has been decreasing the average annual rainfall is well above the long term average.

Figure 7. Mataranka cumulative deviation from the long-term average trend (taken from Waugh, 2023)

Predicting future climate and the potential impacts on water resources around Australia is difficult. There have been several scientific studies undertaken by CSIRO during the Northern Australia sustainable yields project (Crosbie et al., 2009) and more recently through the Roper River Water Resource Assessment (RoWRA) (Watson et al., 2023) addressing this topic. The latest study focused on the Roper River (Watson et al., 2023) analysed projections from 32 global climate models. Results for predicted future rainfall were variable and possibly little change (within 5 per cent) however most models indicated a potential evaporation increase of approximately 5 to 10 per cent (Watson, 2023).

Table 1. Mataranka rainfall periods based on the cumulative deviation from the long term average (Waugh, 2023)

Rainfall period	Average annual rainfall (mm) 1 July–30 June	Rainfall description
1945-1973	719	Drier period
1974-1985	997	Wetter period
1986-1996	709	Drier period
1997-2011	1139	Wetter period
2012-current	796	Drier period

3.3. Key water resource investigations

3.3.1. Strategic Regional Environmental and Baseline Assessment

The Strategic Regional Environmental and Baseline Assessment (SREBA) included various studies within the Mataranka plan area.

The water quality and quantity baseline summary report (ELA, 2022) provides an update to other significant baseline characterisations of the water resources of the region already produced as part of the Commonwealth Government's geological and bioregional assessment and gas industry social and environmental research alliance programs, and water resource assessments by the Northern Territory Government, Department of Lands. Planning and Environment.

Collectively these studies provide a strong understanding of:

- regional hydrology conceptualisation
- the hydraulic characteristics of each aquifer, including the identification of key geologic features that may control groundwater movement and connectivity
- mapping of aquifer depths and properties, and potentiometric surfaces
- identification of key recharge and discharge areas, and characterisation of mechanisms
- quantification of recharge, discharge and groundwater flow
- presentation of water quality data and how it may relate to water movement, such as resource extent
- identification of the location and source for springs and potential groundwater dependent ecosystems.

Recommendations for further studies by ELA (2022) have been included in the implementation actions for this plan.

3.3.2. Roper River water resource assessment

In 2023 CSIRO completed an investigation of the opportunities and risks of water resource development in the catchment of the Roper River in the Northern Territory. The RoWRA provides a comprehensive and integrated evaluation of the feasibility, economic viability and sustainability of water and agricultural development in the Roper River catchment. Reports completed as part of the assessment include a summary report, catchment report and a series of technical reports.

This independent assessment was conducted during development of the plan and published after the publication of the draft plan. Content from the technical reports that provides additional surface water, groundwater and ecology information relevant to the plan area have been added and referenced in this final documentation.

3.4. Surface water resources

Information in this section is primarily sourced from content within the technical report synthesising the surface water resources of the Roper River Basin (Waugh, 2023). While the water related to the plan is groundwater, groundwater flow into the Roper River is recognised as a key process for maintaining the hydrologic, environmental and cultural values of both the plan area and the downstream environments of the lower Roper River.

The plan area is primarily contained within the Roper River Basin, with approximately 900 km^2 of the North Mataranka zone contained within the Katherine River (Daly) catchment, see Schedule H.

The Roper River Basin covers an area of approximately 82,000 km^2 which drains to the Gulf of Carpentaria. The plan area is located near the headwaters of the Roper River Basin, at the confluence of the Waterhouse River and Roper Creek, also known as Little Roper River, to the south-east of Mataranka. Other tributaries to the Roper River intersecting the plan area include Elsey Creek and Strangways River. Major tributaries to the Roper River downstream of the plan area include Flying Fox Creek and the Wilton River to the north, and the Hodgson River to the south.

For much of its length, the Roper River and its tributaries are characterised as a series of linked pools. Several of these pools exceed 15 km in length, are over 60 m wide and can be over 8 m deep in places. Connection to downstream pools during low flows may be via a pool riffle or pool step sequence whereby one pool overflows directly into the next pool. While the Roper River predominately conveys low flows via a primary channel, this channel is punctuated in parts by numerous braided channel segments, up to 30 km in length, between the primary channel segments. Braided channel segments are characterised by multiple, shallow flow paths which are highly dynamic, changing regularly after flooding events, and support a large expanse of riparian vegetation and ecological communities. Substantial losses to evapotranspiration are thought to occur through these braided channel segments relative to the deep primary channel segments, however this is yet to be quantified.

The Roper River is characterised by high interannual flow variability. The bulk of total surface water flows are driven by runoff from rainfall across the basin, particularly during the northern wet season from November to April each year. Major rainfall events resulting from monsoonal activity and degrading tropical cyclones can lead to significant flows along the tributaries and main Roper River channel during the wet season. On average, over 97 per cent of the total flow volume entering the Roper River estuary occurs during the wet season.

Figure 8 shows a typical annual hydrograph for the Roper River at Mataranka Homestead. It demonstrates high flows driven by rainfall events during the wet season, receding to baseflows in June to July. Baseflows gradually decline as the dry season progresses due to decreasing groundwater flow, increasing evapotranspiration and extraction.

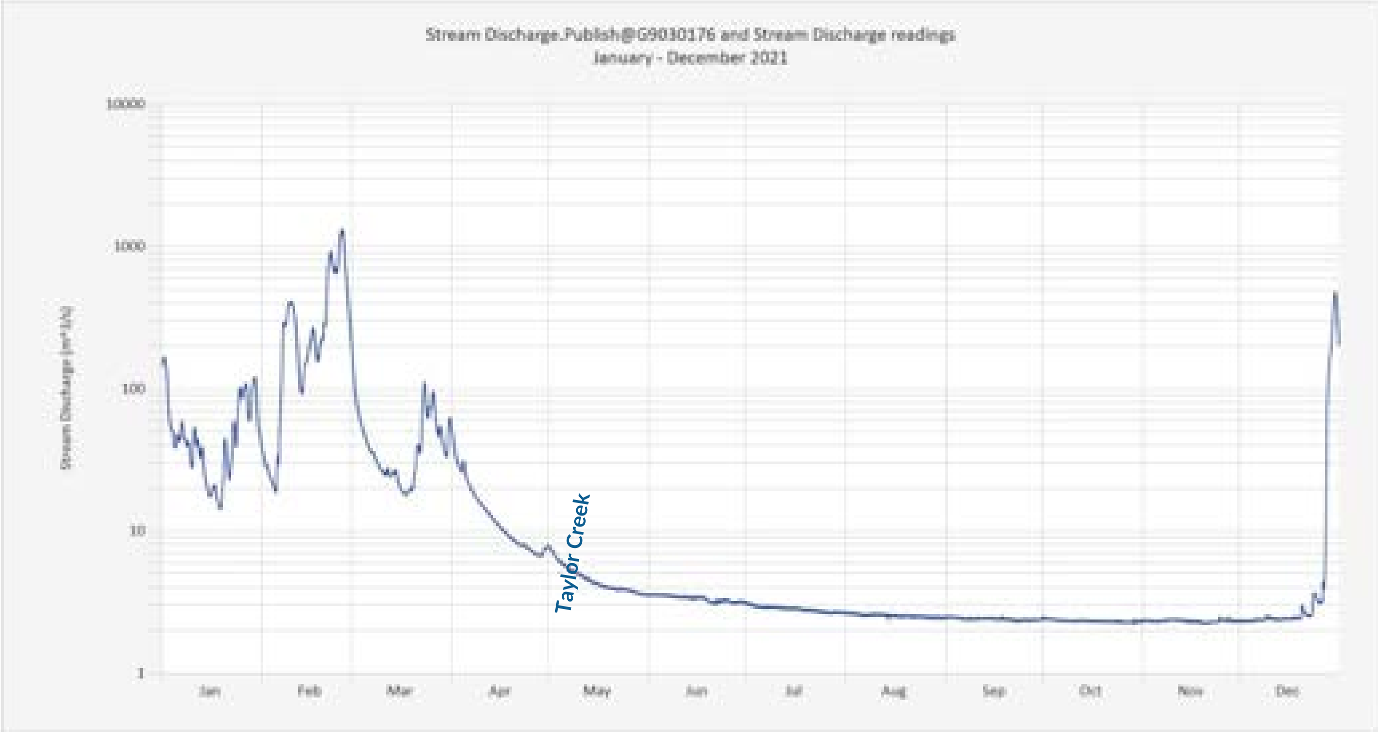


Figure 8. Annual hydrograph on Roper River at Mataranka Homestead (G9030176)

Flows in Top End waterways can be categorised into four distinct hydrological groupings based on the nature of climatic conditions and environmental responses that have adapted to those conditions. These include:

- dry season flows: flows sourced entirely from storage (baseflows) and not directly contributed to by rainfall or overland flows
- dry–wet transitional flows: transitional flows sourced mostly from baseflow but with contributions from early intermittent rainfall and storm runoff. These flows include first flush events and are key ecological triggers for some species
- wet season flows: flows sourced mainly by rainfall and runoff within the basin, with baseflows making little or no contribution, and high flows are contributing to the replenishment of storage
- wet–dry transitional flows: recessional flows where streamflow is dominated by wet season rainfall, runoff and short term storage, such as soil storage; transition to baseflow dominated dry season flows.

3.4.1. Dry season flows

Long term flow records illustrate an overarching trend of increasing end of dry season flow at monitoring locations in the Roper River Basin since the 1950's. Figure and Figure 10 show annual minimum flow for monitoring sites at Mataranka Homestead (G9030176) and Elsey Homestead (G9030013). Figure 9 shows modelled data until late 2014 when the Elsey Homestead gauging station became operational.

While minimum annual flows exiting the plan area were less than 80 ML per day in the 1960's and early 1970's, baseflow has increased significantly in recent decades, measuring as high as 680 ML per day in late September 2011, Figure 11. Documented evidence shows that prior to the commencement of monitoring at Elsey Homestead in 1953, flow in the Roper River was considered intermittent at that location. A flow measurement of just 51 ML per day was recorded in 1953 (Waugh, 2023).

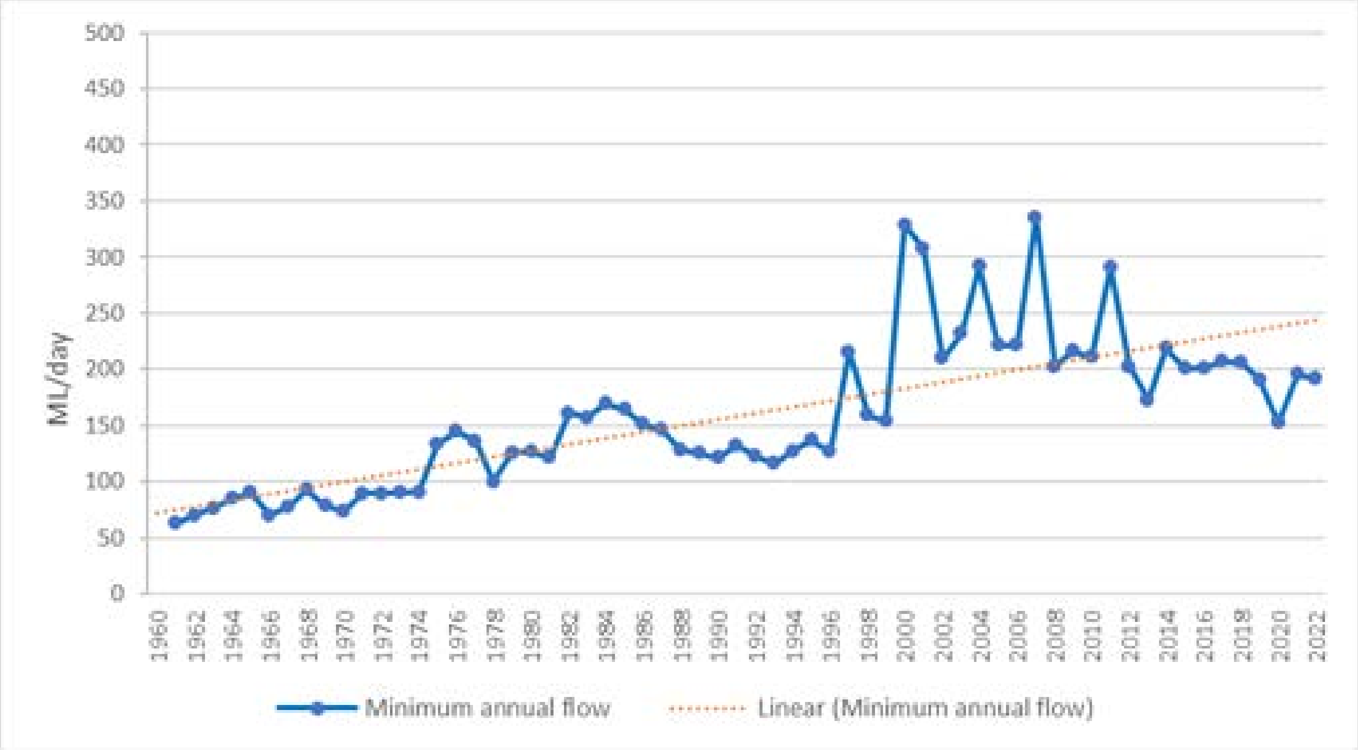


Figure 9. Minimum annual flow on Roper River at Mataranka Homestead (G9030176)

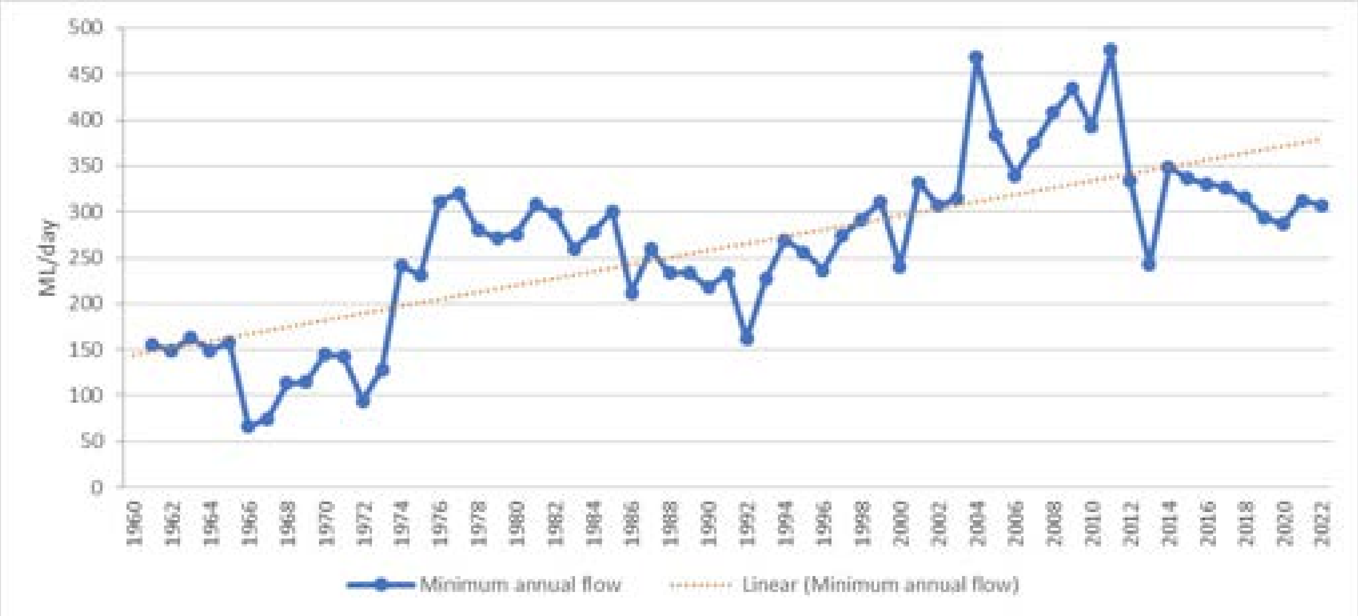


Figure 10. Minimum annual flow on Roper River at Elsey Homestead (G9030013)

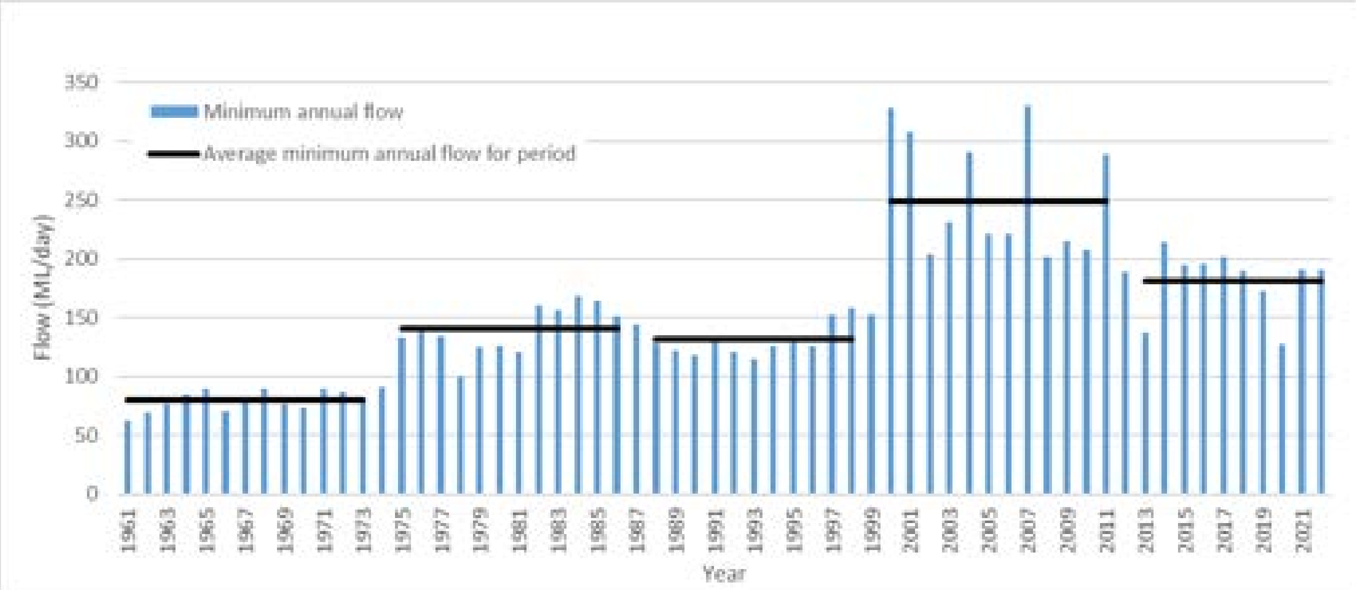


Figure 11. Minimum annual flow on Roper River at Elsey Homestead (G9030013) including average flow for periods (Waugh, 2023)

Periods of lower and higher flows have a strong correlation with periods of low and high rainfall at Mataranka presented in Figure 6. It is clear that climatic variability is the determining factor for groundwater flows. The relationship between climate variability and flows at Elsey Homestead is presented in Figure 12 where a dry climatic condition is associated with flows below 180 ML per day, average climatic conditions result in flows between 180 and 275 ML per day and wet climatic conditions result in flows greater than 275 ML per day.

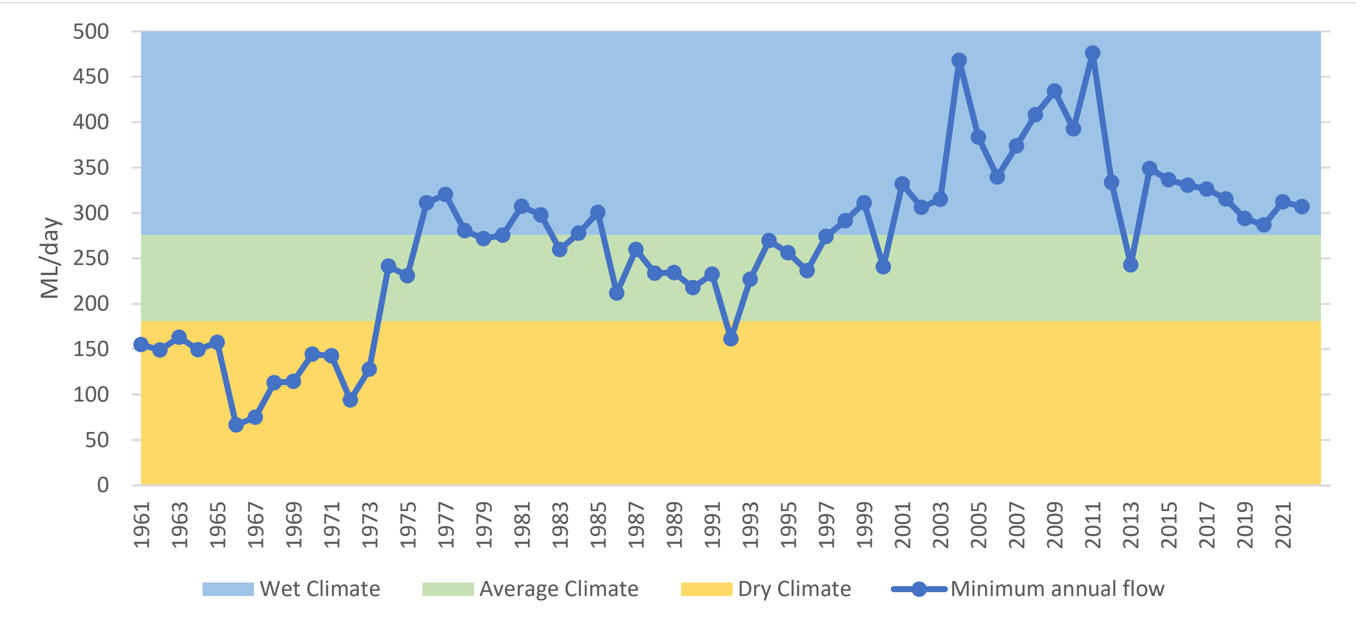


Figure 12. Climate periods and flow on Roper River at Elsey Homestead (G9030013)

The flow range for each climatic condition (dry, average and wet) corresponds with the pattern of decadal flow trends from 1960–2020.

Elsey Homestead is a significant monitoring location as it is the most downstream flow monitoring site and is at the point of lowest elevation within the plan area. Flows measured and modelled at this location incorporate nearly all groundwater flows from the TLA into the Roper River. Elsey Homestead also has the longest period of record from 1953 to present.

The department has conducted a number of simultaneous flow measurement exercises to better understand the relative contribution of springs and bed and bank discharge to the Roper River, Schedule I, provides an overview of changes in flow within the river as measured during the late dry season in 2022.

Published results (Waugh, 2023), reproduced in Schedule I, demonstrates that there is no flow from the upper Roper Creek or Waterhouse River after the wet season runoff, as their channels are at a higher elevation to the TLA and do not yet incise the aquifer. Only the downstream sections of Roper Creek and Waterhouse River incise the TLA, near to where they combine to form the Roper River.

Approximately one third of flow measured on Roper Creek at the Mataranka Homestead crossing (G9035085) is derived from water discharged from the TLA through point sources such as Bitter Springs, while the remaining two thirds is from diffuse discharges through the creek bed and banks. Point discharge flows from Rainbow Springs (G9035092) contribute up to two thirds of total flow in the lower Waterhouse River, with the remainder coming from diffuse discharges through the bed and banks.

Flow rates increase moving downstream from Mataranka with several other relatively minor point source contributions from Figtree Spring, Salt Creek and Elsey Creek and more significant discharge through bed and banks, to a location of maximum flow at Red Lily Lagoon (G9030024) which forms the boundary where the river no longer intersects the TLA and the plan boundary. From that point onwards flow to the Roper River at Red Rock (G9030250), near Ngukurr 170 km downstream diminishes with losses of approximately 60 per cent to seepage and evaporation and no further contribution from groundwater discharge.

These flow measurements highlight the highly localised nature of groundwater flow concentrated within an area defined as the Roper Discharge Zone.

While continuous records for Red Rock commenced in 1966, flow records and anecdotal evidence from residents and traditional custodians of the Roper Bar region indicate that between 1952 and 1967, the Roper River stopped flowing in its lower reaches in every year (Zaar, 2009). Modelled outputs indicate cease to flow conditions occurred in 42 of 67 years between 1900 and 1967 (Knapton, 2009a-c). In summary:

- end of dry season flows are highly variable with a strong dependency on climate
- since licensed extraction commenced in 2014, extraction has had no significant impact on end of dry season flows.

3.4.2. Surface water quality

Declared surface water quality objectives for the Daly Roper Beetaloo Water Control District[3] are as described in Volume 1, Chapters 3 to 5 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). Chapter 3 relates to the biological assessment of aquatic ecosystems including physical and chemical stressors and guidelines for toxicants and sediment quality. Chapter 4 considers water quality for primary industries including irrigation use, drinking water for livestock and aquaculture activities, while Chapter 5 relates to recreational water quality and aesthetics.

Water quality data within the plan area has been collected on an opportunistic basis from 2008 until a dedicated groundwater and surface water quality sampling and field measurements program was conducted between 2014 and 2018 to establish a baseline dataset. Details of sampling locations and timing are provided in Table 2.

At each location, field measurements were undertaken for dissolved oxygen, electrical conductivity, turbidity, pH and temperature. Water samples were collected for subsequent analyses at accredited laboratories[4].

[3] https://nt.gov.au/environment/water/management-security/water-control-districts/daly-roper-beetaloo
[4] National Association of Testing Authorities: https://nata.com.au/

Laboratory analysis of water chemistry includes the following suite of analysis:

- general water quality parameters: pH (lab), electrical conductivity, alkalinity, total dissolved solids, Si, hardness
- major ions (HCO_3, Cl, SO_4) and (Ca, Mg, Na, K)
- filtered and total nutrients suites
- chlorophyll and
- 59 metals.

Additional surface water sampling has been undertaken at various other times and monitoring locations for ad hoc requirements, including targeted analysis for nutrients, BTEX and Total Organic Carbon.

Table 2. Baseline surface water quality sampling locations

Bore number	Sampling events	Laboratory analysis*	Note
G9035092	2014, 2015, 2016, 2017, 2018	GP, TM, FN, TN	Roper River, Rainbow Springs
G9035157	2014, 2015, 2016, 2017, 2018	GP, TM, FN, TN	Roper River, Fig Tree Spring
G9035212	2014, 2015, 2016, 2017, 2018	GP, TM, FN, TN	Bitter Springs, swimming access

GP refers to General Parameters, TM refers to Total Metals, FN refers to Filtered Nutrients, TN refers to Total Nutrients *Laboratory Analysis differs for some years sampled

Schult and Novak (2017) explored longitudinal, downstream, and temporal variations in water quality between the early to late dry season and interannually, as well as the relationship of water quality to flow over one wet season. Studies undertaken by Schult (2018), in collaboration with Mangarrayi Rangers, assessed the temporal changes in water quality at Elsey Station over one dry season.

Schult and Novak used the ionic composition of dry season samples to determine the different groundwater origins. Their report concludes that waters of Rainbow Springs and the lower Waterhouse River are sourced from the TLA and contain higher proportions of calcium and bicarbonate ions compared to samples from Fig Tree Springs, which is dominated by water from the Georgina Basin with a higher sodium, chloride and sulphate content. Samples from other sites on the Little Roper and Roper River, Elsey Creek and the Waterhouse River plot in an almost straight line between these two extremes, indicating that they are a mix of the two water types.

They established that longitudinal variability in the dry season water quality of the Roper River and its tributaries is determined by the origin of the groundwater flow and by biological and chemical processes in the river. Because of their different groundwater sources, the headwater streams of the Roper River have more variable water quality than the Roper River itself, which is a mix of water types and therefore more uniform downstream of the groundwater inflows.

High conductivity and alkaline pH are typical of the limestone dominated waters of the Daly and Georgina geological formations that are high in calcium, magnesium and bicarbonate.

Soluble nutrient inputs, in particular nitrate, are sourced from groundwater in the headwaters of the Roper River in the Mataranka area and are not replenished downstream of the groundwater inputs, presumably leading to a change from phosphorus limitation of algal growth in the headwaters to nitrogen limitation in the Roper River downstream.

The changes in water quality over the dry season are mainly driven by a reduction in flow, increased groundwater dominance, and biological processes. Increased groundwater dominance due to a gradual reduction in residual storage from the wet season and evapotranspiration, lead to an increase in conductivity and pH towards the end of the dry. The natural reduction in flow from the nutrient rich springs contributes to a large reduction in nutrient load over the dry season.

Groundwater nitrogen may support significant plant biomass in the Roper River system. Seasonal changes in productivity inferred from the diel range of dissolved oxygen differs between upstream and downstream sites. Productivity is affected by a range of factors including flow, light and nutrient availability. Aquatic vegetation, in particular filamentous green algae, has been observed to grow in extensive carpets in the upper reaches of the river in the early dry season, while in the lower reaches aquatic vegetation, notably macroalgae, is established later. The high nutrient availability in the upper reaches may mean that algae are able to establish quickly as soon as flow and light conditions become favourable after the wet. In the lower reaches, the reduced nutrient and light availability could be delaying the growth of aquatic vegetation.

While baseflow water quality is determined by the groundwater inputs, wet season water quality is predominantly dependent on flow. Storm flows are characterised by the dominance of low conductivity rain water and higher turbidity due to overland runoff with high sediment loads.

More recently, the Beetaloo Sub-basin water quality and quantity baseline summary report (ELA, 2022), undertaken as part of the SREBA, assessed groundwater and surface water quality using data from an extensive dataset. In addition to archived data, samples were collected from watercourses and waterholes within the Roper River and its catchments including Western and Elsey creeks and Strangways River. The vast majority of available data was collected during the dry season.

Most surface water in the region is calcium-magnesium-bicarbonate ($Ca\text{-}Mg\text{-}HCO_3$) dominated, with some sodium bicarbonate ($Na\text{-}HCO_3$) and sodium chloride (Na-Cl) dominated sites. Most dry season surface waters in the Roper River near Mataranka have salinities of 500 to 1000 mg/L with slightly alkaline pH (7.1 to 8.4), due to their limestone/dolostone groundwater source. In contrast, sites in areas with no groundwater discharge, Western Creek and Dry River, have much lower salinity (<100 mg/L) and are slightly acidic (pH 6.2-6.9).

The Roper River is typically very clear during the dry season, with median dry season turbidity across most sites. Similarly, total suspended solids concentrations are very low during the dry season but more variable during the wet, depending on the seasonal onset and timing of wet season runoff events. During the dry season, the majority of suspended solids consist of organic material, reflecting the lack of sediment runoff during this time.

Dry season nutrient concentrations are generally low and comparable to those in other streams in the region (e.g. DEPWS, 2019). Nitrate concentrations are elevated at some TLA springs compared to other surface waters in the region, but remain well below the drinking water guideline value of 11 mg/L. Regional environmental guideline values are not available for the area, however, there is no evidence that elevated nitrate is having a detrimental effect on the aquatic ecosystem. Elevated nitrate concentrations also occur elsewhere in the region where the TLA discharges to the surface, for instance in the Katherine and Douglas River regions. The cause of these elevated concentrations is unknown but is thought to be at least in part related to human activities (Schult and Metcalfe 2006, Schult 2016).

3.5. Groundwater resources

3.5.1. Hydrogeological setting

Approximately 10 per cent of the plan area lies within the Daly Basin, which is the northern most of a series of Cambrian aged limestone basins collectively occupying approximately 160,000 km^2 in the Northern Territory. The Daly Basin comprises four distinct stratigraphic layers, including the basal Tindall Limestone, Jinduckin Formation, Oolloo Dolostone and the Florina Formation, from oldest to youngest, respectively.

The two oldest stratigraphic layers, namely the Tindall Limestone and Jinduckin Formation, exist within the plan area while the younger layers are located further north, to the west of Katherine. The Tindall Limestone is classified as a regional aquifer, extending into the neighbouring Georgina Wiso and Katherine plan areas.

The TLA is the primary aquifer in the plan area. Water subject to the plan is limited to the TLA and the cretaceous layer that sits over the TLA contained within the plan boundary. Underlying the TLA is a thick layer of basalt interspersed with sandstone and siltstone towards the north corner of the plan area. Figure 13 provides a conceptual diagram of the various layers.

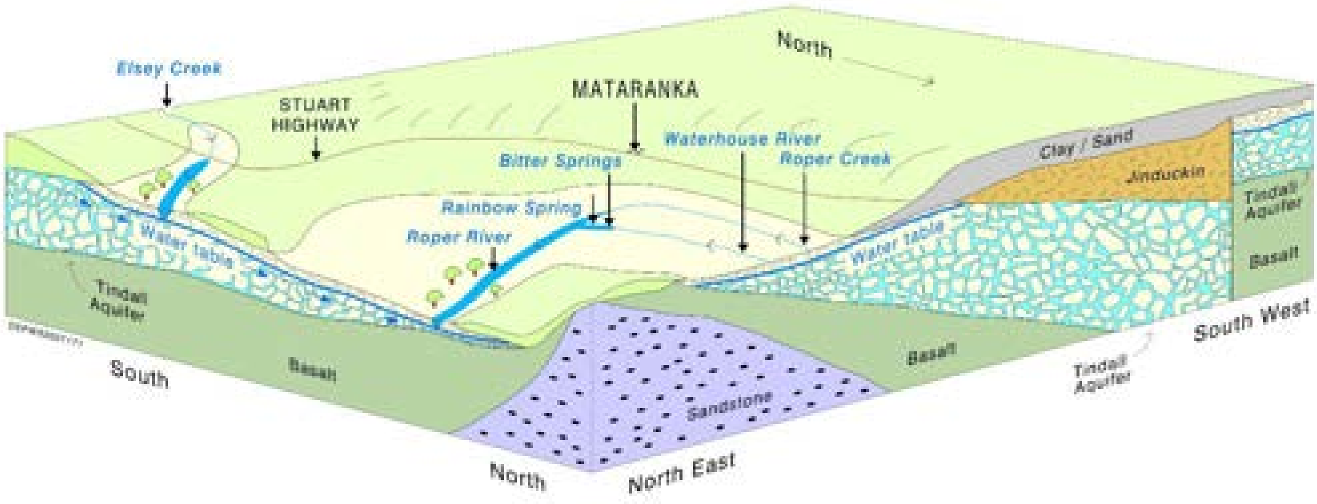


Figure 13. Conceptual diagram of groundwater resources in plan area

The TLA is a significant water resource for the Katherine and Mataranka regions and is considered a suitable and reliable source of groundwater for agricultural and pastoral development. The TLA forms an extensive fractured and cavernous rock aquifer, formed through the dissolution and weathering of limestone by natural acidic rainwater and surface water percolating into the formation over an extensive period. The weathering process contributed to the formation of a karstic aquifer system, comprising interconnected cavities and fractures that allow for groundwater movement within the rock (Tickell, 2005). Aquifer hydraulic properties are highly variable due to the karstic nature of the TLA and are largely influenced by the presence of caverns or cavities in the rock formation. Water quality is generally fresh to brackish and slightly alkaline to neutral.

The TLA is highly influenced by the presence or absence of overlying less permeable formations, such as the Jinduckin Formation, which can affect patterns of groundwater flow, hydraulic characteristics and water quality (Tickell, 2005). The TLA within the plan area varies in thickness from approximately 50 m in the south where it borders the Georgina Wiso plan boundary to 150 m further north where it outcrops and is incised by the Roper River. Other than where outcropping occurs, the TLA is overlaid by a layer of relatively low yielding Cretaceous clay and sandstone. The TLA is largely unconfined within the plan area, with the exception of the north-western portion of the North Mataranka zone, where the Jinduckin Formation occurs, see Schedule J.

The Jinduckin Formation is a minor local scale aquifer which is also widely distributed throughout the Daly Basin. The formation is conformable, of similar age, or locally disconformable, parallel but of different age due to erosion and a period of nondeposition, on the TLA Limestone and comprises primarily dolomitic siltstone with inter-beds of dolostone and sandstone. The formation exists in the northwest portion of the plan area, where it likely acts as a confining unit to the underlying TLA. Where saturated, the Jinduckin Formation represents a local aquifer system and is generally sufficient for stock and domestic purposes. Groundwater within the formation can be high in sulphates, which creates a corrosive environment for the galvanised steel typically used in the construction of water bores. Bore yields are typically less than 5 L/s (Tickell, 2018).

Water within the Jinduckin Formation is not subject to the plan due to its low yield, generally poor water quality, lack of current licensed water use, and lack of data to assess recharge and discharge from the resource. Further investigations may allow the Jinduckin Formation to be included in future revisions of the plan.

3.5.2. Groundwater recharge

Studies by the CSIRO (Taylor et al., 2023) state that recharge to the Cambrian Limestone Aquifer (CLA) in the Roper catchment, which includes the entire plan area, occurs across almost the entire spatial extent of the aquifer in the catchment where it is unconfined but most prominent around the margins. However, recharge processes and rates, are highly spatially and temporally variable. Higher rates of recharge occur as localised recharge following intense wet season rainfall at aquifer margins, as reflected in places across the northern and eastern parts of the aquifer by a calcium carbonate ($Ca–HCO_3$) ionic composition of groundwater, a depleted isotopic composition in groundwater and higher concentrations of tritium (^3H) in groundwater.

Localised recharge occurs via: (i) direct infiltration of rainfall and streamflow via sinkholes in and near the northern aquifer outcrop, or (ii) where surperficial features including sinkholes, ephemeral streams or waterholes are incised through thinner, i.e. 30 m thick, of the overlying Cretaceous strata around aquifer margins, northern and eastern margin of the aquifer in the Roper catchment. It is important to note, however, that despite the northern aquifer outcrop being an area of highly localised recharge, the outcrop is predominantly a net regional groundwater discharge zone exhibiting a shallow watertable, i.e. <5 m below ground level. While high rates of localised recharge can occur in this zone, recharge fluxes are constrained by the lack of available aquifer storage, i.e. the aquifer completely fills prior to groundwater flowing laterally when adjacent stream levels decline and via evapotranspiration from phreatophytes.

Localised recharge to the aquifer outcrop is also important for providing the source of discharge to maintain spring flows at Fig Tree Spring and contributing additional baseflow, i.e. in addition to regional groundwater flow and discharge, from lateral outflow to the eastern parts of the upper Roper River downstream of the spring. Evidence for this includes: (i) changes in dry season baseflows, (ii) a more enriched isotopic composition, and (iii) higher concentrations of tritium in surface water compared to springs and reaches of the upper Roper River and its tributaries upstream to the west of Fig Tree.

Broader recharge to the CLA occurs as diffuse vertical leakage the overlying Cretaceous strata, though recharge rates are highly spatially variable and are often much lower through thicker parts, i.e. >30 m thick, of the overlying strata. Evidence of this leakage is reflected by: (i) a sodium bicarbonate composition in groundwater, (ii) a more enriched stable isotopic composition in groundwater, and (iii) measurable but lower concentrations of tritium, i.e. 30 m, veneer of overlying Cretaceous strata.

Recharge rates estimated by both upscaled chloride mass balance and tritium concentrations in groundwater indicate a range in contemporary recharge rates, i.e. over several recent decades, for the CLA from 3 to 70 mm per year. These rates are consistent with a range of previous estimates provided from historical investigations across the same parts of the CLA by Bruwer and Tickell (2015), Crosbie and Rachakonda (2021), Jolly et al. (2004) and Knapton (2009a-c, 2020). In addition, numerical modelling of mean annual recharge highlights the temporal variability in recharge across the aquifer.

Estimates of mean annual recharge fluxes within the Roper catchment ranged from 1 to 2,177 GL per year with a mean and median of 243 and 119 GL per year, respectively. Numerical modelling of mean annual recharge has also highlighted the sensitivity of the CLA's water balance to climate variability. Despite sinkholes being a direct conduit for localised recharge, they are also mapped in places at the surface across thick, i.e. >30 m, Cretaceous strata overlying large areas of the central parts of the aquifer away from the northern and eastern margins. In these areas, low but measurable concentrations of tritium, i.e. 1,000 mg/L, and with a sodium bicarbonate ionic composition occur in the CLA. This highlights that not all sinkholes are permeable and connected to the underlying CLA particularly where Cretaceous strata is thick, i.e. >30 m.

Sinkhole features have long been thought to act as discrete recharge features across the Cambrian Basin, e.g. Evans et al. 2020; Yin Foo and Matthews 2001; Karp 2002; Karp 2005. This is because they can act as a focal point for surface runoff and, once filled with surface water, recharge is much more likely to occur.

In the areas where the CLA (carbonate-dominant) outcrops or is near the surface, sinkholes are formed through traditional karstic mechanisms, dissolution of the rock due to continuous infiltration of slightly acidic rainwater.

By contrast, in areas where there is thick Cretaceous cover, sinkholes can still be abundant but are unlikely to have formed due to dissolution of the underlying carbonate rock because of its depth. Such features are termed pseudokarst, parakarst or laterite karst, (e.g. Twidale 1987; Alkemade 1991; Grimes and Spate 2008) and are related to physical erosion of sediments and the soil profile than to carbonate rock dissolution.

Within the plan area diffuse and particularly localised discrete recharge are considered to dominate, with the highest recharge rates occurring in South Mataranka where the TLA outcrops at the surface and where there is an absence of overlying Cretaceous sediments. In Larrimah recharge is less prevalent as the overlying Cretaceous is thicker, while recharge in the North Mataranka is constrained where the Jinduckin Formation overlies the TLA, see Schedule K.

Estimates of recharge for the region are available from four main derived datasets by methods that are relatively independent.

1. Bureau of Meteorology's Australia-wide landscape water model (AWRA-L; Frost et al., 2018)
2. CSIRO's Australia-wide recharge model (Crosbie *et al.* 2009; Crosbie et al., 2013)
3. Chloride mass balance methods (Crosbie and Rachakonda, 2021)
4. Daly Roper (DR2 2020) model (Knapton, 2020).

The first three methods are useful for determining recharge zones over the plan area, that is to predict where relatively high or low recharge rates occur spatially, and provide potential estimates of recharge. However, they suffer from significant uncertainty relating to the assumptions on which they depend, for example broad scale landscape mapping and climate fluxes, and assumptions relating to chloride dynamics and recharge mechanisms, which may or may not be specifically applicable to the TLA resource. They also typically only consider unsaturated zone processes rather than observations of actual aquifer storage change observed in groundwater levels and flow rates.

The Daly Roper model (DR2), which uses data and information collected through the SREBA, is considered to be the most accurate in regard to the quantitative estimates of recharge across the Mataranka plan area. This is because the model is constructed specifically for the region and is supported by the most current conceptualisation of the entire connected water resource, as well as being calibrated to observed groundwater levels and river flows. The model is less powerful for predicting recharge locations and requires a prior understanding of the differences in recharge areas to be built into it (Knapton, 2020); however, these areas are refined based on how well the model performs at replicating groundwater pressures and flow rates.

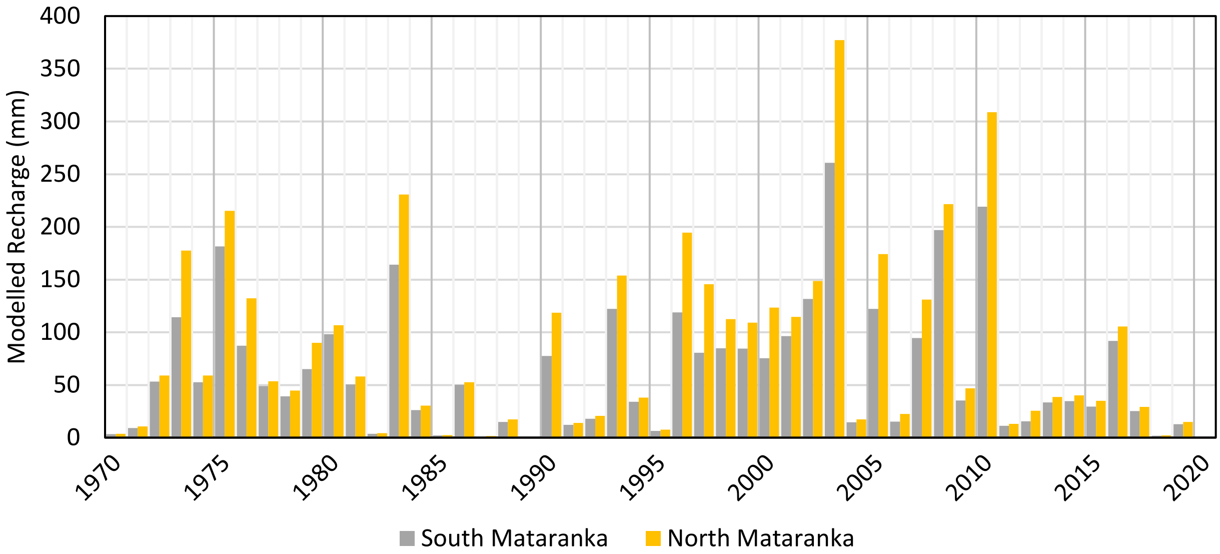


Figure 14. North Mataranka and South Mataranka zone modelled recharge

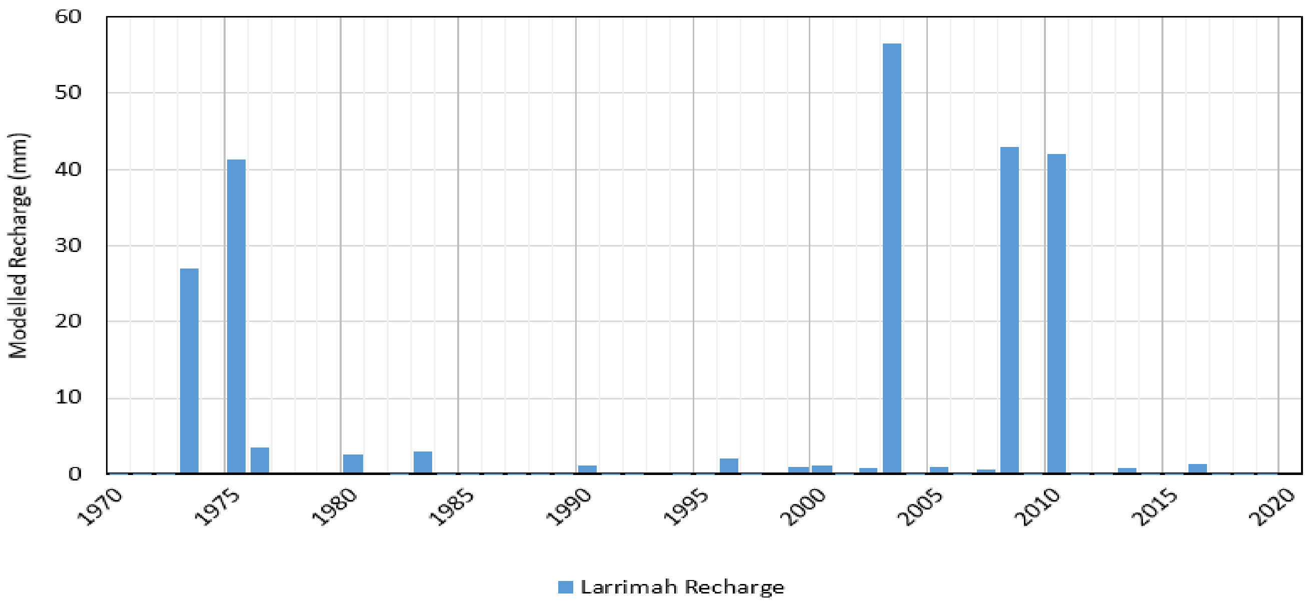


Figure 15. Larrimah zone modelled recharge

Of the four methods, DR2 provides the most conservative estimate of recharge which has been adopted for the plan. Recharge values are provided for each management zone in section 3.6.2 of this document, modelled annual recharge is presented for North Mataranka and South Mataranka in Figure 14 and Larrimah in Figure 15.

While the annual recharge trend in North Mataranka and South Mataranka are similar, recharge in North Mataranka is consistently higher reflecting the higher rainfall in the north and hydrogeological conditions.

3.5.3. Groundwater storage

The TLA has a substantial groundwater storage feature. Groundwater storage changes in response to recharge, discharge and throughflow, with groundwater level data providing an overview of seasonal and long term variability. As recharge and discharge vary both spatially and over time, analyses of groundwater level data from multiple bores is required to gain an understanding of groundwater storage variability. Figure 16 shows the relationship between rainfall, which results in recharge, and modelled end of dry season groundwater levels. While there is a time lag between rainfall and groundwater level peaks and troughs, the plot shows generally higher groundwater levels associated with increasing rainfall trend, and lower groundwater levels associated with decreasing rainfall trends.

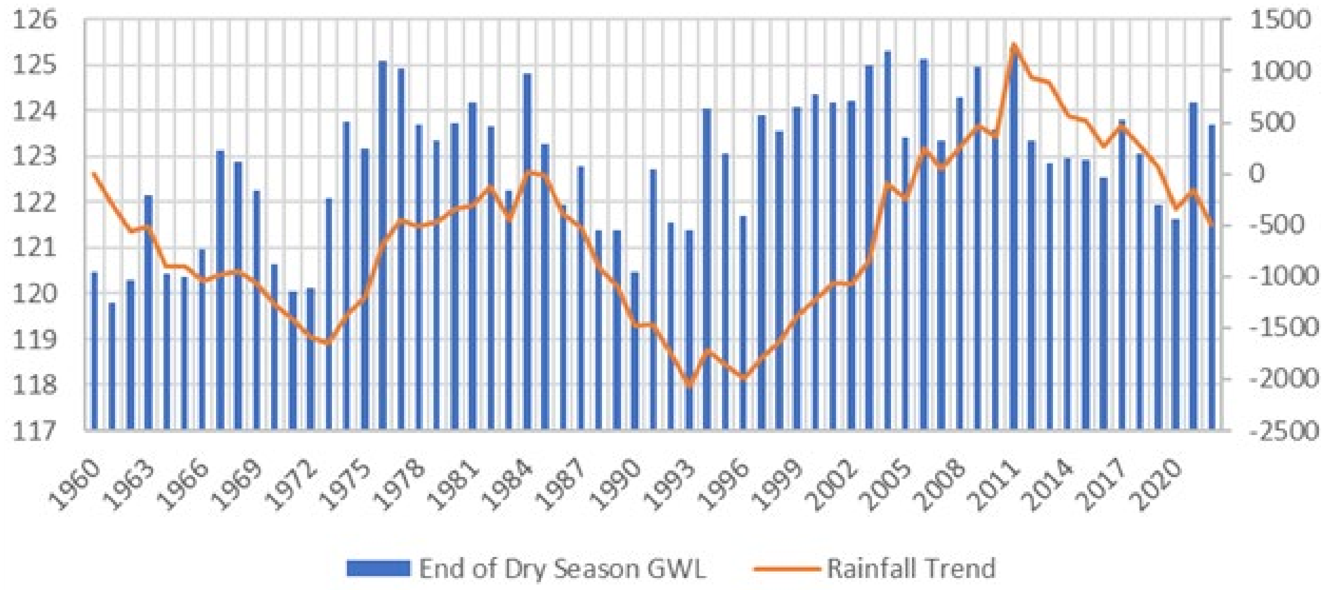


Figure 16. Mataranka relationship between groundwater level and rainfall

While little groundwater level data is available in the Mataranka area prior to 2000 (Zaar, 2009), modelled groundwater levels allow us to develop longer term groundwater level records. Figure 17, Figure 18 and Figure 19 present modelled groundwater levels for a monitoring bore in North Mataranka, South Mataranka and Larrimah.

From 1960 to 2022 groundwater storage is estimated to have increased by 4 m, 5 m and 8 m respectively, demonstrating that the aquifer has generally been in a filling phase. While reduced rainfall since 2011 has resulted in a reduction in storage, 2022 end of dry season groundwater levels remain 3 to 4 m higher in the Mataranka region and 6 m higher in the Larrimah region relative to the 1960's and early 1970's. These long term variations closely align with rainfall patterns identified in section 3.2 of this document.

In North Mataranka and South Mataranka, the groundwater surface fluctuates significantly each year between the wet and dry season as a result of consistent recharge, and it is not unusual to see differences of 6 m to 8 m between peak wet season level and end of dry season levels. The groundwater trace in Figure 17 and Figure 18 are typical of Top End fill and spill systems where rainfall is relatively consistent year on year and groundwater recharge occurs in a corresponding manner.

The groundwater trace in Figure 19 has a very different profile with no discernible seasonal variation, only a longer term trend with steps during periods of high rainfall and significant recharge. This profile is typical of Arid Zone systems and demonstrates why North Mataranka and South Mataranka are managed as Top End systems while a longer term groundwater management approach for Larrimah is more appropriate.

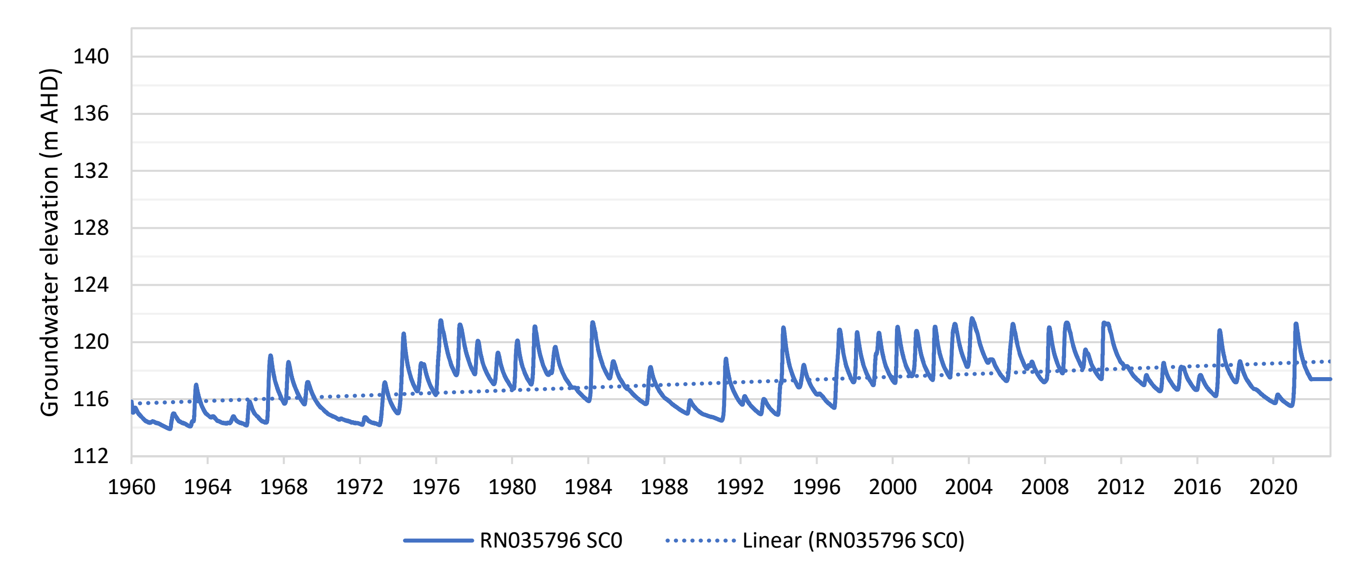


Figure 17. North Mataranka modelled groundwater levels for bore RN035796

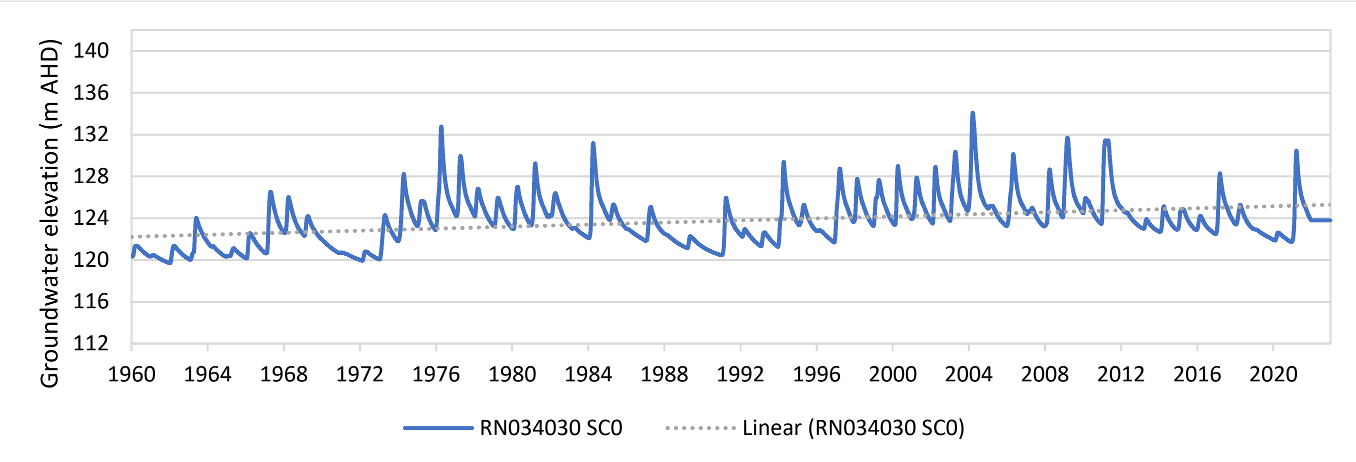


Figure 18. South Mataranka modelled groundwater levels for bore RN034030

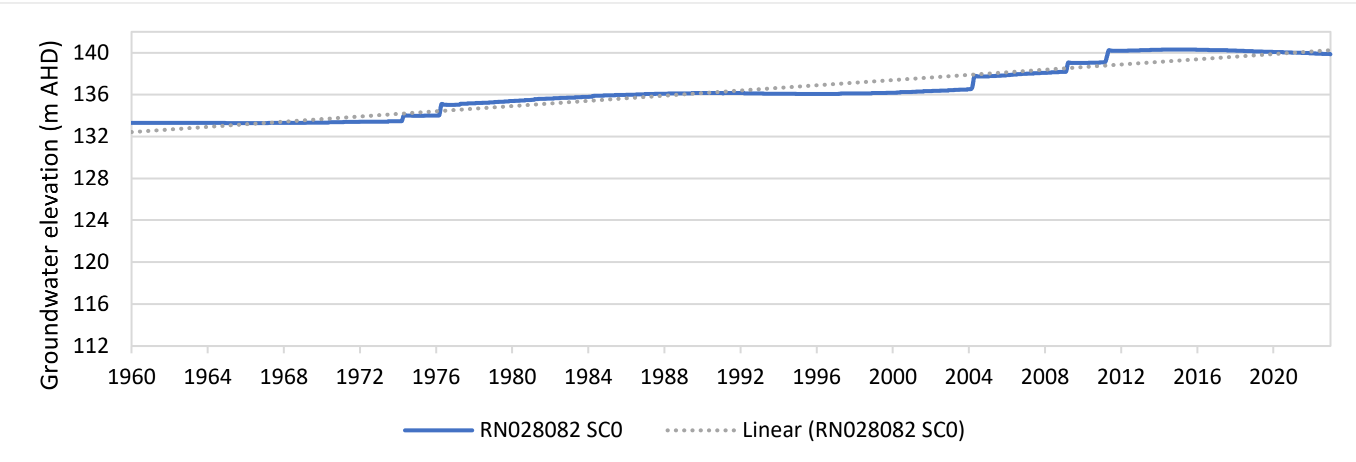


Figure 19. Larrimah modelled groundwater levels for bore RN028082

3.5.4. Groundwater discharge

Natural groundwater discharge from the TLA to the surface is thought to occur through three main mechanisms (ELA, 2022): diffusely through riverbeds where the water table is intercepted, discrete springs where geological features allow for discharge from artesian portions of the aquifer, and diffuse or discrete areas of evapotranspiration where vegetation uses groundwater or water tables are shallow. All three mechanisms occur within the plan area, although diffuse discharge along riverbeds and evapotranspiration cause the greatest overall discharge fluxes.

Long term monitoring and assessment studies show end of dry season flow rates are currently approximately double that of dry periods in the 1960's and 70's despite the commencement of groundwater extraction from 2012 onwards (Waugh, 2023). Dry season flows in the Roper River are maintained by groundwater discharge in the dry season and groundwater levels have continued to increase despite extraction.

The TLA water table is intercepted by the ground surface and riverbed, resulting in groundwater flow to the Roper River at Mataranka. Groundwater flow occurs along the bed of the river and tributaries, for example Elsey Creek, as well as through discrete springs, for example Bitter Springs, Rainbow Spring and Fig Tree Spring. Groundwater levels rise to above the natural ground surface in Elsey National Park where the underlying basement rock sub crops at shallow depth, resulting in shallow diffuse discharge, wetlands, and, in some areas, water logging (Yin Foo and Dilshad 2021). These shallow water table locations are common across the Roper River and are anticipated to cause significant evapotranspiration flux.

Recent CSIRO environmental tracer investigations as part of the Geological and Bioregional Assessment (GBA) program and the Gas Industry Social and Environmental Research Alliance (GISERA) program (Deslandes et al., 2019; Lamontagne et al., 2021) have validated that groundwater flow at the Roper River discharge area is predominantly derived from the TLA.

Another key finding of the CSIRO environmental tracer work was that multiple lines of evidence, for example relatively 'young' discharge water and decreasing apparent groundwater ages along the flowpath, suggest that groundwater discharge at the Roper River is likely to be sourced from groundwater that originated relatively close to the river. This is confirmed by groundwater modelling which shows that groundwater recharge within around 100 km of the Roper River is sufficient to support the majority of the observed discharge fluxes. As a result, groundwater originating from deeper formations or places further south, such as the Georgina Basin, account for a very small part of overall discharge at the Roper River.

End of dry season flow information is provided in section 3.4.1 of this document. The location of flow areas is presented in Schedule L.

3.5.5. Springs

Karstic springs and seepages that discharge groundwater to the Roper River and its tributaries are a unique feature of the plan area. All known permanent springs associated with the Mataranka TLA are located within the Roper Discharge Zone, see Schedule L. The springs are very important to local Aboriginal culture and the largest, Bitter Springs and Rainbow Spring, are iconic Northern Territory tourist attractions.

Recent studies (Taylor et al., 2023) by CSIRO state that slightly brackish salinities, depleted isotopic composition and low tritium concentrations in water sampled at Roper Creek and Bitter Springs suggest their source of discharge is primarily from eastward flowing groundwater in the CLA originating from a groundwater flow divide near the western margin of the Roper catchment approximately 50 km west of Mataranka. The slightly fresher salinities and depleted isotopic composition reflected in water sampled from Rainbow Spring and the Waterhouse River are more consistent with flow in the CLA originating from the northern aquifer margin in the Daly Basin flowing south to the Roper River (Bruwer and Tickell, 2015).

More enriched isotopic compositions and the highest salinity waters sampled in Fig Tree Spring and Salt Creek suggest their sources of discharge are more reflective of much shorter localised flow within the aquifer outcrop. The isotopic compositions of water sampled in Elsey Creek and the Roper River downstream of its junction with Elsey Creek suggest their source of flow originated from regional groundwater flow from the south in the Georgina Basin flowing north to the north-eastern parts of the upper Roper River. These groundwater flow paths are presented in Schedule M.

Discrete springs and seepages can be vulnerable to the localised effects of groundwater extraction, particularly during dry periods. This risk increases where cavernous groundwater flow paths in the karstic limestone may be intersected by a water extraction bore.

At Warloch Ponds to the south of Mataranka multiple spring vents flow groundwater to the Elsey Creek, sustaining extensive pools such as Longreach Waterhole throughout the dry season. Fig Tree Spring to the east of Mataranka flow horizontally from the side of a tufa cliff to the Roper River below. The thickness of the tufa layer, more than 10 m, is an indication that the area has been a regional groundwater flow zone for millennia (Lamontagne et al., 2021).

Spring flows are difficult to accurately measure. The total flow from within the discharge zone is more accurately reflected in dry season flows at the Roper River at Elsey Homestead, see section 3.4.1 of this document. The department has conducted 215 flow measurements at this location and Mataranka Homestead (G9030176) since 1953 the bulk of which have been undertaken during low flow dry season months, providing a valuable and accurate flow record.

End of dry season flow measurements have also been conducted at Bitter Springs (G9035212), Rainbow Spring (G9035092) and Fig Tree Spring (G9035157) since 2006, with average flow rates of 71 ML per day, 33 ML per day and 34 ML per day respectively while the average dry season flow for Elsey Homestead (G9030013) for the same period was 368 ML per day.

The relationship between spring flows and total discharge measured at Elsey Homestead is presented in Figure 20. Spring flows are more uniform than total discharge measured at Elsey Homestead however the combined spring flow only represents approximately one third of total discharge, the remainder derived from bed and bank seepage where the river and tributaries intercept the TLA.

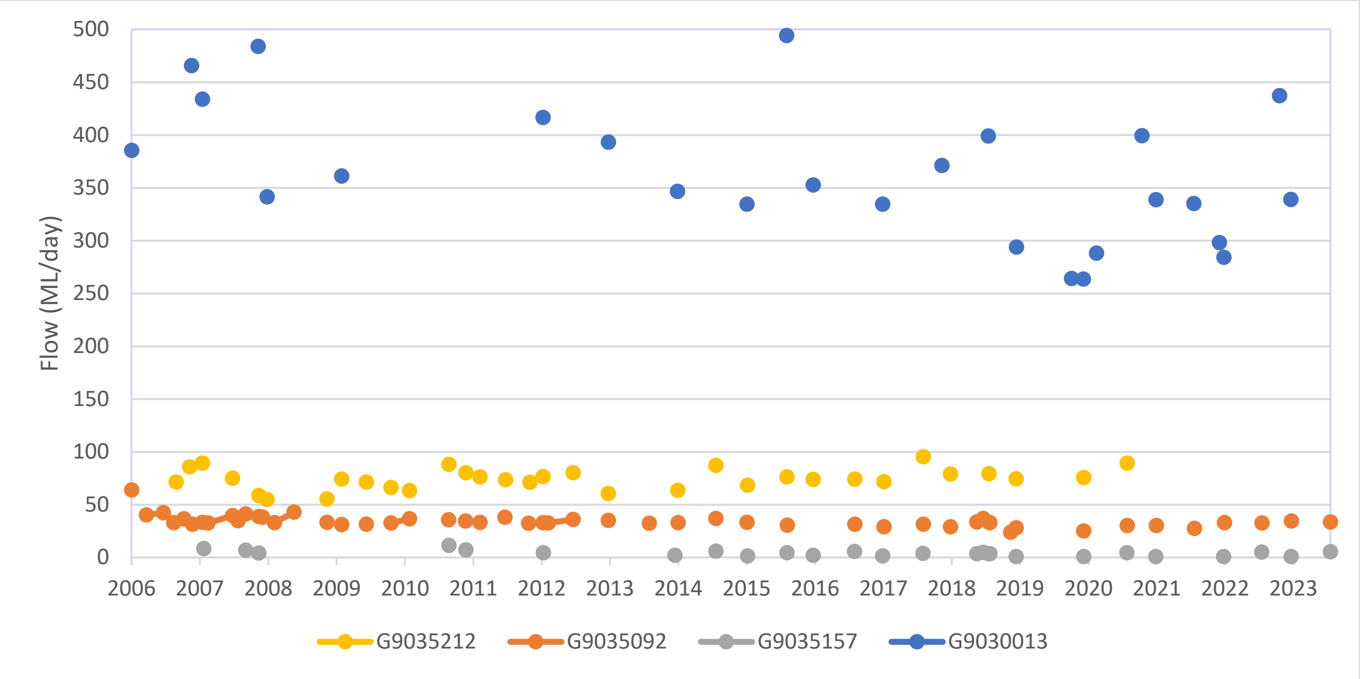


Figure 20. End of dry season flow between Bitter Springs (G9035212), Rainbow Springs (G9035092), Fig Tree Spring (G9030013) and the Roper River at Elsey Homestead (G9030013)

3.5.6. Groundwater evapotranspiration

Evapotranspiration represents another major natural flux of water from the TLA. However, the relatively deep groundwater levels across most of the plan area mean that much of the evapotranspiration across the region likely represents fluxes derived from recent rainfall, rather than being from the regional groundwater system. Groundwater derived evapotranspiration is limited to areas to the north where the water table is shallow enough for use by terrestrial vegetation, typically less than 15 m below ground level, or for direct evaporation where groundwater is typically less than 1 m, or from open water.

Within the plan area evapotranspiration occurs due to terrestrial vegetation water use, as well as direct evaporation from shallow water tables and open surface water bodies. As part of the SREBA, DEPWS commissioned investigators at Charles Darwin University (Gautam et al., 2022) to undertake a desktop assessment of actual evapotranspiration fluxes from the TLA discharge areas based on estimates produced by CSIRO's remote sensing derived CMRSET (CSIRO MODIS Reflectance based Scaling EvapoTranspiration) algorithm (McVicar et al., 2022).

Gautam et al. (2022) found that actual evapotranspiration at the Roper River discharge area was strongly seasonal and directly correlated with wet season rainfall. This indicates that the majority of the annual actual evapotranspiration flux is derived from recent rainfall rather than from the TLA. However, during the middle and end of the dry season, there were still appreciable levels of actual evapotranspiration when compared to nearby areas where actual evapotranspiration from groundwater sources is unlikely, because of different vegetation types and deeper groundwater levels. The areas of elevated actual evapotranspiration provide insight into where vegetation is using groundwater and where there may be direct evapotranspiration from waterlogged ground. This mapping indicates that actual evapotranspiration is a greater component of discharge in the areas around Mataranka, where there are large regions of vegetated land and swampy wetland areas associated with shallow groundwater.

The CMRSET estimated total actual evapotranspiration for the groundwater discharge areas of the Roper River to be 43,300 ML per year for the period 2000-2022. This correlates with evapotranspiration values in the natural water account provided by the department's DR2 model, see section 3.6.1 of this document.

3.5.7. Groundwater quality

Declared groundwater quality objectives for the district are as described in Volume 1, Chapters 3 to 6 of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (2000). Chapter 3 relates to the biological assessment of aquatic ecosystems including physical and chemical stressors and guidelines for toxicants and sediment quality. Chapter 4 considers water quality for primary industries including irrigation use, drinking water for livestock and aqua cultural activities while Chapter 5 relates to recreational water quality and aesthetics. Chapter 6 is dedicated to drinking water guidelines.

Water quality data within the plan area was collected on an opportunistic bases from 2008 until a dedicated groundwater and surface water quality sampling and field measurements program was conducted between 2014 and 2018 to establish a baseline dataset. Details of sample program locations and timing are provided in Table 3. At each location field measurements were undertaken for dissolved oxygen, electrical conductivity, turbidity, pH and temperature. Water samples were collected for subsequent analyses at an accredited[5] laboratory.

[5] National Association of Testing Authorities: https://nata.com.au/

Table 3. Baseline groundwater quality sampling locations

Bore number	Sampling events	Laboratory analysis*	Note
RN008299	2015, 2016, 2018	GP, TM	Mataranka Township
RN035790	2014, 2015, 2016, 2018	GP, TM, FN, TN	Mataranka – Elsey Station
RN035796	2014, 2015, 2016, 2018	GP, TM, FN, TN	Mataranka Homestead Airstrip
RN035927	2014, 2015, 2016, 2018	GP, TM, FN, TN	Elsey National Park

GP refers to General Parameters, TM refers to Total Metals, FN refers to Filtered Nutrients, TN refers to Total Nutrients *Laboratory Analysis differs for some years sampled

Laboratory analysis of water chemistry includes the following suite of analysis:

- general water quality parameters: pH (lab), electrical conductivity, alkalinity, total dissolved solids, Si, hardness
- major ions (HCO_3, Cl, SO_4) and (Ca, Mg, Na, K)
- filtered and total nutrients suites
- chlorophyll and
- 59 metals.

A number of reports relate to water quality within the plan area. Bruwer and Tickell (2015) found that all groundwater tested was suitable for human consumption albeit with high hardness. Water quality for the North Mataranka zone exhibited low total dissolved solids and sulphate while bores located south of Mataranka and from Mataranka Springs had unusually high sulphate, sodium and chloride suggesting the groundwater is coming from a different geological source.

The total dissolved solids is relatively high for irrigation purposes and it should not be used on soils with restricted drainage. Salt tolerance of the plants to be irrigated must be considered. Groundwater with similar chemical composition has been used at Mataranka for irrigation of mangoes and melons with no adverse effects to the crops or the soils reported (Bruwer and Tickell, 2015).

Electrical conductivity directly reflects the amount of dissolved salts contained in water. All groundwater contains dissolved salts derived from the rocks which it passes through and from rainwater. Bruwer and Tickell noted that there is an increase in electrical conductivity from east to west and from the north at the King River to Mataranka. The bores closer to the eastern margin are closer to the recharge area where the Tindall Limestone is exposed. As the freshly recharged water infiltrates and moves through the geology there is an increase in salinity towards the east and north that corresponds with the groundwater flow direction. Recharge potentially occurs in the north at the King River and moves south towards the Roper River.

Groundwater quality data was assessed from a range of sources including bore completion reports, Northern Territory Government water resource assessments, Power and Water Corporation, recent Commonwealth Government programs (GBA, GISERA and EFTF), petroleum industry monitoring as well as data collected during the SREBA.

Further analyses have also been presented in the SREBA Environmental health studies report (Meyer 2023). The Environmental Health Studies assessment of water quality in the Beetaloo Sub-basin region focused primarily on the human health implications of the existing water quality in the area, and the potential for anthropogenic features such as petrol stations and airstrips to be legacy sources of pollutants.

See Schedule N for the location of water quality sampling points. Assessment of the key water quality parameters relevant to the plan area found that:

- groundwater salinity varies within the plan area with the TLA in North Mataranka hosting the freshest water. Salinity generally increases to the south and areas of elevated salinity are observed between Daly Waters and Larrimah, see Schedule O
- levels of sulphates in the TLA are lowest in North Mataranka. By comparison, sulphate levels in the Jinduckin Formation are relatively high. Higher concentration in Larrimah are likely to be influenced by groundwater throughflow from the Georgina Basin which is known to contain gypsum, see Schedule P
- pH generally ranges from lower neutral to slightly acidic
- dissolved oxygen concentrations are typically <2.5 mg/L across the plan area, but there are elevated concentrations around areas that are inferred to be recharge areas, such as west of Larrimah and towards the outer margins of the TLA. Variable dissolved oxygen concentrations are common where large karst voids/cavities are present which allow groundwater to interact more readily with air
- metal concentrations are generally low and remain below the health and aesthetic guidelines
- dissolved methane and ethane concentrations are very low in groundwater across the plan area and are typically below standard limits of reporting, e.g. less than 10 µg/L. However, dissolved methane concentrations of 10-500 µg/L are not uncommon to the south in the Beetaloo Sub-basin region and were observed on several occasions during the GISERA, industry and SREBA monitoring programs.

The SREBA groundwater quality dataset is extensive and continues to grow as new data is provided by ongoing DEPWS and Power and Water Corporation monitoring programs, as well as petroleum exploration companies that are active in the broader region. Water quality data is stored in the department's water database and is available by request.

Drinking water supplies at serviced townships and Aboriginal communities of Mataranka, Larrimah and Jilkminggan are sourced from groundwater. Routine groundwater quality monitoring is conducted by Power and Water Corporation and details of water quality results are provided in an annual drinking water quality report accessible via Power and Water Corporation publications[6].

3.5.8. Groundwater flow

The pattern of dominant regional groundwater flow has been derived from the watertable elevation map, see Schedule M. The map shows the height above sea level of the water table in the TLA. Groundwater moves under the action of gravity from higher to lower elevations, so the direction of flow is at right angles to the contours. The arrows shown on the map indicate a generalised flow pattern.

The regional flow direction is from the south for Larrimah and from the north and west for the North Mataranka. Flow direction in the South Mataranka is from the south and west. These flows discharge to the Roper River. Widely spaced watertable contours indicate a very low water table gradient, which implies groundwater flow is slow. Conversely, closely spaced contours indicate a larger gradient and therefore faster groundwater flow. The hydraulic properties and therefore scale of groundwater flow vary significantly across the extent of the aquifer. They are influenced by both topographic and geological structures and highs as well as the degree of interconnectivity between karstic features, i.e. sinkholes, caves, caverns and springs, across large areas (Taylor et al., 2023). Small localised flow paths occur in the northern aquifer outcrop of the Daly Basin. These include flow from the northern aquifer margin south toward the Roper River and flow from localised lateral outflow from the aquifer outcrop north toward the river.

[6] https://www.powerwater.com.au/about/what-we-do/water-supply/drinking-water-quality/past-drinking-water-quality-reports

Semiquantitative estimates of mean residence times for groundwater flow derived using tritium and carbon-14 (^{14}C) concentrations in groundwater vary significantly across the aquifer. These range from several years for localised flow paths of less than 5 km in and near the aquifer outcrop to many hundreds of years for regional flow paths greater than 150 km from the southern basins. There is a high degree of uncertainty in the mean residence time due to carbonate dissolution in the aquifer, but these estimates agree with the ranges in timescales for flow based on numerical modelling (ELA, 2022; Knapton et al., 2023).

3.6. Groundwater modelling

A model is a tool designed to simplify reality to assist with predicting future behaviour. Computer models of natural systems are used to help humans better understand their environments, and can be used to find sustainable ways of living in them.

A water model uses physics and maths to represent the flow of water and its underground storage by simulating the system in 3 dimensions. They provide a useful tool for managing systems, particular in water where systems are complex.

3.6.1. Model development

The plan area is covered by the Daly Roper integrated surface water – groundwater model version DR2 (Knapton, 2020). The DR2 model covers 196,000 km^2 extending across the southern Daly Basin to the southern Georgina Basin and west into the northern Wiso Basin with development of the model commencing in 2004 and uses all available data.

The model incorporates a pre 1970 phase using it as a warmup period for the model and includes input datasets such as climate and all available hydrographic data; noting that rainfall records commenced in 1900 and groundwater and surface water datasets, for the most part, started in the 1960's.

Using data from this period, a steady state ('long term average') calibration for the model was achieved with a goodness of fit of <7 per cent scaled root mean square (SRMS) error, a measure for evaluating quality of predictions.

The model recharge input is based on daily weather observations which for evaporation can vary significantly on a daily basis during the wet season depending on the amount of cloud cover and rainfall. However, daily evaporation monitoring is unreliable for the period prior to 1970. There is also limited temporal hydrographic data prior to 1970 with which to validate the model. Given the model is particularly sensitive to changes in evaporation and the impact that it has on recharge, using datasets post 1970 increases the model's ability to history match with the transient simulation post 1970 improving the goodness of fit SRMS error to <5 per cent.

The geological model is based on 2,364 bores that provide lithological data to inform the hydrostratigraphy and 110 bores provide the hydraulic data. The integrated surface water – groundwater model is history matched to 221 bores with groundwater level data spanning 30 years and river flows from eight gauging sites, six in the Daly River and two in the Roper River, spanning 60 years.

This scientific information underpins the department's knowledge of the resource, which is incorporated in the integrated model for the area, consistent with best practice as outlined in the Australian groundwater modelling guideline (Barnett et al. 2012). The model development has been independently peer reviewed on several occasions and found to be a Class 2 model with elements of Class 3 (Class 3 being the highest Class). An independent review of the DR2 model in 2020 found that the model design and execution has been conducted to a high professional standard and is a leading example of best practice for a Class 2-3 coupled surface and groundwater model (Middlemis, 2020).

Water resource assessment is an iterative process and future investigations and data will be incorporated into the next version of the water model, including surface LiDAR along key river reaches, which is important to adequately represent surface groundwater interaction processes. The plan is proposed to be reviewed within five years, providing an opportunity to incorporate knowledge gained in the intervening period.

The model is a useful tool in water management in terms of simulating the water system and providing indicative predictions. An example of modelled flow prediction for the Roper River at Elsey Homestead is provided in Figure 21 for the 2021 dry season which are modelling outputs from DR2. The blue line represents modelled natural flow assuming zero extraction, the orange line represents modelled flow based on full extraction. The area between the blue and orange line represents the total volume of water allocated under full entitlements.

This demonstrates that DR2's predictions can reliably predict the end of dry season flow and that current water extraction is having minimal impact on flows at Elsey Homestead.

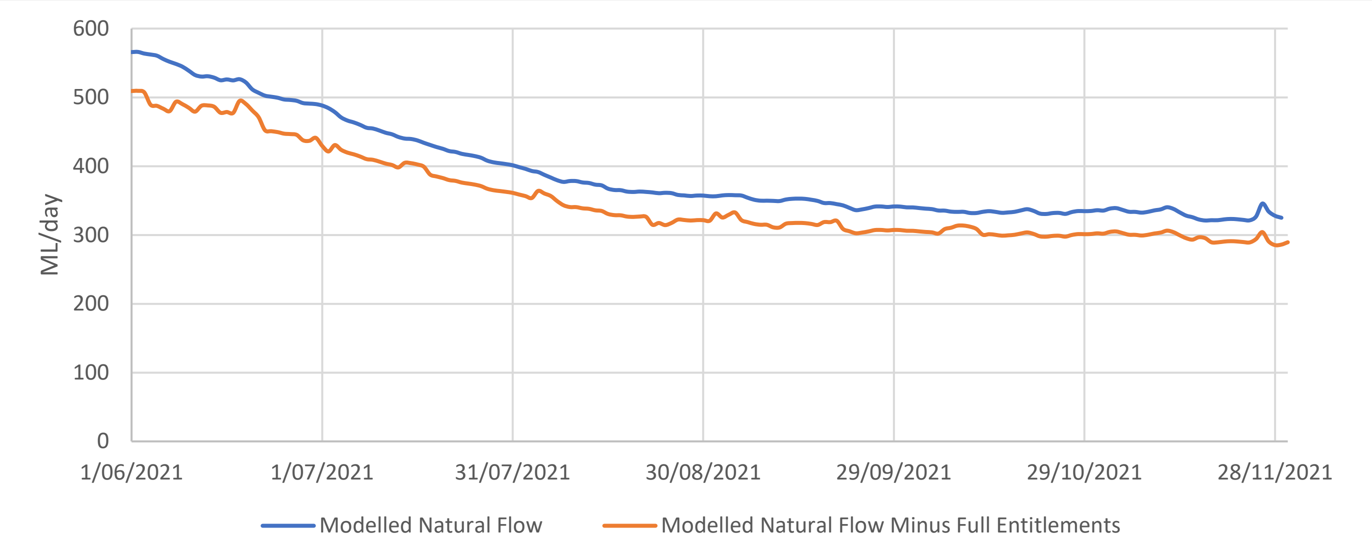


Figure 21. Modelled natural flow versus full entitlement on Roper River at Elsey Homestead (G9030013)

3.6.2. Natural water balance

The natural water balance is an important concept in water resource management. It describes the inflows and outflows of water in a given area, and the resulting change in water storage over time. The natural water balance can be expressed using a simple flux equation:

Inflow = outflow +/- change in storage

The water balance is used to assess water availability in a given area and to plan the sustainable use of water resources. The natural water balance for the plan area has been produced using the DR2 model.

The components of the natural water balance for the TLA within the plan area and each of the management zones are shown in Figure 22. Inflow parameters are recharge and throughflow in; outflow parameters are discharge, evapotranspiration and throughflow out.

The flux equation is a general expression of the water balance. Fluxes vary in space and time so the equation may not provide an exact balance at all times and all locations within the model domain. The value of the individual flux components is likely to contain errors due to spatial lumping, parameter estimation and calculation assumptions (Knapton, 2020). In addition, the flux components have been averaged from daily values to long term averages.

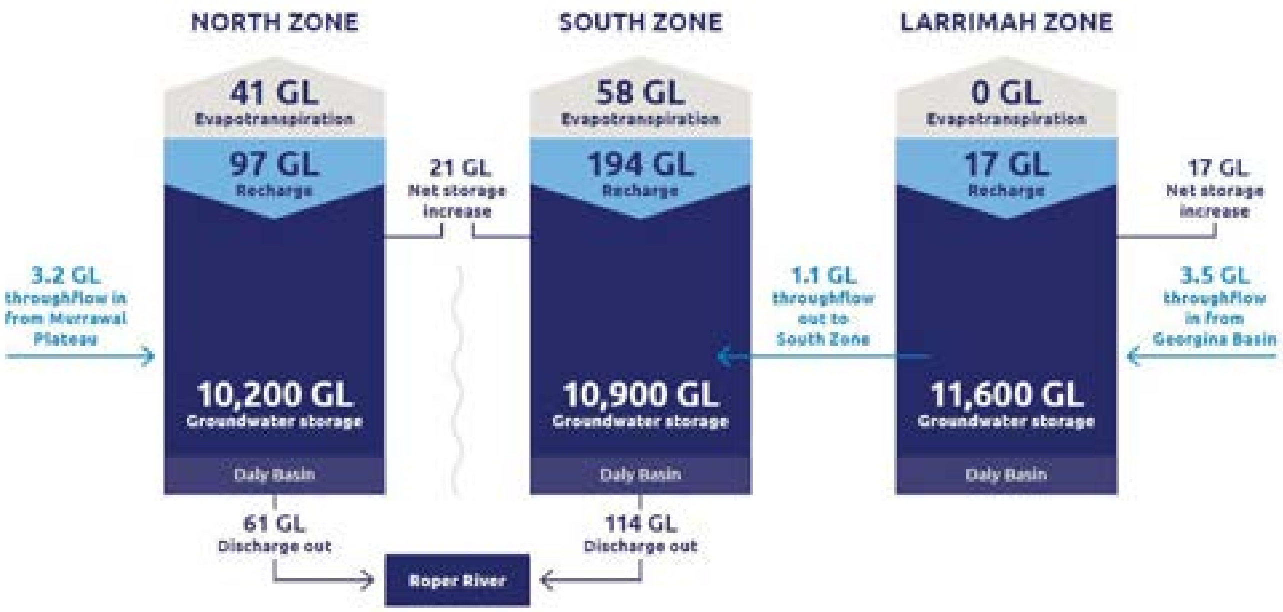


Figure 22. Natural water balance for the Mataranka water management zones

Storage volume is determined from saturated thickness as at the 1 November 2021 when storage is considered to be at its lowest for the year. All other components of the water balance are annualised averages for the period 1970 to 2022 using the DR2 numerical model (Knapton, 2020).

Storage relates to the saturated thickness of the TLA within the plan area, and includes all lithological layers occurring above the underlying basalt basement. The lithological layers include the TLA and minor local aquifers within the overlying Cretaceous sediments.

Groundwater throughflow is presented as inflow from the Georgina Basin into the Larrimah water management zone, and inflow from the Larrimah water management zone into the South Mataranka water management zone. Throughflow from the Cretaceous Sandstone of the Murrawal Plateau also occurs along the eastern boundary of the North Mataranka water management zone.

When the water table is at or above the ground surface, evaporation loss occurs at a maximum rate of 2 mm per day. An approximation of the evapotranspiration rate is made on the basis of research undertaken by Kelley et al (2002) for melaleuca swamp and wet monsoon forests, where plant water usage rates ranged from 508 mm to 568 mm per year, respectively. The maximum extinction depth in the groundwater model is assumed to be 15 m below ground level, which is equivalent to maximum rooting depth. Where the water table is deeper than the extinction depth, no further evapotranspiration can take place.

Discharge out of the North Mataranka and South Mataranka water management zones represents the flow of groundwater from the TLA into the Roper River and Elsey Creek. The flow volumes include discharge from Bitter and Rainbow Springs, Fig Tree Spring and other in channel springs.

Storage change is the net increase/decrease of water within the aquifer. The flux boundary between North Mataranka and South Mataranka is variable. Groundwater may cross this boundary in different directions and at different locations depending upon the instantaneous relative difference in groundwater levels. Therefore, the storage change is presented as a combined value for North Mataranka and South Mataranka water management zones. Storage change across the plan area is increasing annually for the modelled time period. This corresponds to the increasing trend in rainfall, Figure 3, Figure 4 and Figure 5, increases in groundwater storage levels, Figure 17, Figure 18 and Figure 19, and a corresponding increase in discharge Figure 10.

4. Environmental water

Overview

This section outlines the natural ecosystems related to the water resources managed through the plan.

The first priority of the plan is to ensure the majority of water in the plan area is retained for ecological and environmental functions and cultural water requirements.

Knowledge of environmental water values and requirements within the plan area and the region have been significantly improved with the completion of the SREBA. The key ecological values of the plan area are the springs, pools and wetlands within Elsey National Park, Elsey Creek and the Roper Discharge Zone, collectively as an area of outstanding environmental value.

Within the Roper Discharge Zone, the depth to groundwater is shallow, supporting vegetation and surface water features of outstanding ecological and cultural significance. Groundwater levels are maintained through localised recharge and are influenced by extraction and water uses in this area. This indicates that the closer water extraction is to the discharge zone, the more significant the impact on Roper River dry season flows.

Near Larrimah, there are limited environmental values dependant on water. This is consistent with the groundwater resources in the plan area move much more slowly, are deeper than 30 m below ground, have limited connectivity with terrestrial ecosystems (vegetation) and do not discharge to the surface.

The plan considers the water needed to maintain natural ecosystems over time. In the plan area natural ecosystems have evolved to access their water requirements from rainfall, surface water flows and groundwater. These ecosystems are adapted to variable water availability from these three sources.

While the plan area is relatively small, the environmental water characteristics and requirements vary significantly, with areas of rich biodiversity associated with both surface and groundwater resources. During the dry season the creeks, rivers and springs rely on discharges from groundwater to maintain flows. Flows are driven by climatic conditions, which can vary from very dry to very wet.

It is widely recognised that groundwater in the region not only supports wildlife, habitats and ecosystem processes, but also the delivery of ecosystem services, such as food for subsistence harvesting and tourism value, that are essential to the welfare of people and communities in this region.

Knowledge of environmental values in the region has been significantly improved with the completion of the SREBA. This significant body of work systematically assessed the extent and condition of terrestrial vegetation, riparian vegetation and wetlands, and the distribution of important fauna habitat and local threatened fauna species, including waterbirds, throughout the Beetaloo region and most of the Mataranka plan area.

The TLA flows an average of 175,000 ML per year to the Roper River via springs, creek beds and bank seepages in this area, sustaining permanent streamflows in the upper reaches of the Roper River. These flows support significant aquatic species richness, a unique assemblage of fish and other aquatic species, and a nationally recognised site of conservation significance, Mataranka Thermal Pools. Sustaining the overall conservation values of this area through appropriate management of groundwater quality and groundwater flows, is a critical consideration of the plan and its associated implementation actions.

Some of these key ecological assets include:

- springs, pools and wetlands of Elsey National Park including Bitter Springs, Rainbow Spring and Salt Creek
- springs, pools and wetlands along Elsey Creek, including Warloch Ponds and Longreach Waterhole
- aquatic ecosystems of the upper Roper River and its tributaries, including the main channel, off stream wetlands and riffle habitats

- riparian vegetation of the Roper River and its tributaries, most notably the extensive forests of shallow rooted cabbage palm, *Livistona mariae subsp. rigida*
- melaleuca forests in riparian areas, drainage depressions and floodplains
- Red Lily Lagoon located downstream of the plan area, which is supported by TLA groundwater baseflows.

4.1. Roper discharge zone

The Beetaloo SREBA Terrestrial Ecosystems Report (Young et al., 2022) identified that features of high ecological value within the plan area mostly depend on permanent or seasonal access to groundwater. Ecological values in arid areas were limited, however, a significant concentration of ecological values occurs in the Roper Discharge Zone which is reporting in SREBA as an area of outstanding environmental value, see Schedule Q.

The values of the discharge zone identified by the SREBA are:

- estimated annual discharge of 63,2000–252,000 ML from the Roper flowpath of the CLA through creek beds, springs and shallow diffuse discharge — which sustains permanent water flow in the upper Roper River
- the highest aquatic biodiversity value in the Beetaloo study area, including high species richness of fish and of all aquatic taxa, the highest number of unique aquatic species and the presence of threatened species, including a significant population of the Gulf Snapping Turtle, and distinct genetic lineages of some aquatic taxa
- most of the groundwater dependent vegetation communities in the Beetaloo study area and particularly those dependent on shallow groundwater including *Melaleuca forests*, *springs*, *river channels*, and *Monsoon forest and thicket*
- a breeding locality for the threatened Red Goshawk
- high social and economic value associated with the Mataranka Thermal Pools.

The SREBA recommended additional measures to protect the discharge zone from any onshore petroleum development by declaring the entire area, with a buffer, as a reserve block under the *Petroleum Act 1984*, or declared as a protected environmental area under section 36 of the *Environment Protection Act 2019*.

4.2. Groundwater dependent ecosystems

The Northern Territory Government uses the definition of groundwater dependent ecosystems (GDEs) in Schedule A.

In general, GDEs in Australia are diverse. Eamus et al. (2006) classified GDEs into three major categories:

1. Terrestrial GDEs that rely on the presence of groundwater within the rooting depth, especially during drought.
2. Subterranean GDEs such as caves, aquifers and the hyporheic zones of rivers, areas where stygofauna may exist.
3. Aquatic GDEs such as springs, baseflow, rivers, streams and wetlands that rely on an influx of groundwater to maintain water levels and functionality.

These include ecosystems that depend on permanent or seasonal access to groundwater.

Depth to groundwater is a key influence on the type of GDE which is likely to be present in each water management zone. Based on GDE mapping and the location of spring discharges, it is unlikely that aquatic GDEs and terrestrial GDEs associated with the TLA are present in the Larrimah water management zone.

4.2.1. Terrestrial ecosystems – groundwater dependent vegetation

The potential distribution of terrestrial GDEs across the plan area has been modelled and field validated using the methodology developed by Brim Box et al. (2022). The probability map at Schedule R depicts the potential distribution of terrestrial GDEs within a model probability threshold of 75 per cent correlated with a depth to TLA groundwater of less than 20 m.

The probability threshold of 75 per cent provides the greatest level of accuracy for distinguishing GDE sites from non GDE sites, out of a total sample of 89 field validation sites, when compared with higher and lower probability settings which are more likely to misclassify sites.

The mapping shows a high concentration of groundwater dependent vegetation in areas of shallow groundwater up to 10 m below ground, a lesser concentration in areas up to 15 m, and occasional occurrence where the water table approaches 20 m below ground. Where the water table is deeper than 20 m below ground, such as throughout most of the Larrimah water management zone, the few GDEs mapped are sustained by shallower perched aquifers which are not associated with the TLA. Depth to groundwater is mapped in Schedule S and Schedule T. The contours are derived from the DR2 model and should be considered as indicative.

A summary of proportional GDE extent for each water management zone is provided in Table 4.

Table 4. Area of potential terrestrial GDEs

Water management zone	Potential GDE extent (km^2)	Total land area (km^2)	Percentage
North Mataranka	415	2,692	15
South Mataranka	376	2,821	13
Larrimah	26	3,768	0.7
Total plan area	**818**	**9,282**	**9**

GDE mapping has been further validated by GDE vegetation surveys undertaken as part of the SREBA studies which mapped melaleuca forests associated with springs and river channels, *Corymbia bella* woodland on alluvial plains and riparian woodland on ephemeral streams (Young et al, 2022), see Schedule R.

4.2.2. Subterranean groundwater dependent ecosystems

The karstic geology of the TLA provides a widely connected and highly transmissive habitat space for stygofauna, which is replenished regularly by recharge from the surface through sinkholes and other surface karst features. Karstic limestone is widely recognised as an important habitat for subterranean fauna in Australia and globally.

Recent aquatic ecosystem surveys undertaken as part of the SREBA (DEPWS, 2022b) have significantly improved knowledge of stygofauna assemblages in the region. Of the 38 species level taxa now recorded for the broader SREBA study area, 34 of these occur in the TLA within the plan area. This abundance of stygofauna is consistent with the geological and hydrological characteristics of the TLA which create suitable habitat space for stygal communities. Annual aquifer recharge may also be important for maintaining suitable groundwater quality and the supply of nutrients and organic material to these subterranean ecosystems.

The SREBA (DEPWS, 2022b) indicates that maintaining recharge regimes, groundwater quality and avoiding desaturation of stygofauna habitat are important considerations for minimising impacts on the stygofauna community.

4.3. Aquatic ecosystems

The perennial streamflows of the upper Roper River, which are sustained by groundwater discharges from the TLA, support a diversity of aquatic ecosystems within and downstream of the plan area. As water levels recede during the dry season, these perennial flows support aquatic habitats within the main channel of the Roper River and Elsey Creek, and prolong connectivity between pools in the main channels and with surrounding billabongs, wetlands and floodplains. Recent studies confirm the importance of these groundwater flows to the persistence of baseflows in the upper Roper River (Lamontagne et al., 2021).

Fish surveys coordinated by Charles Darwin University in 2020 and 2021 confirmed the findings of earlier surveys that fish species are widespread across northern Australian river systems, including the Roper River, with a corresponding low level of species endemism (Davis et al., 2023). This is likely to be a consequence of consistently high aquatic connectivity across catchments, including in the upper Roper River where this connectivity is supported by critical groundwater flows that sustain perennial river flows and the persistence of seasonal waterbodies, such as Warloch Ponds and Salt Creek. High species diversity in the upper Roper River relative to more arid parts of the basin which lack groundwater inputs, emphasises the importance of groundwater to the fish fauna of this area (Davis et al., 2023).

The perennial groundwater fed waterways within the plan area and connected downstream channels and wetlands provide critical habitat for freshwater sawfish, *Pristis pristis*. The species is listed as critically endangered on the International Union for Conservation of Nature's Red List of threatened species and a threatened species and migratory species under both the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) and the *Territory Parks and Wildlife Conservation Act 1976*.

Other groundwater dependent listed threatened aquatic fauna associated with the plan area include Mertens' Water Monitor *Varanus mertensi*, Mitchell's Water Monitor *Varanus mitchelli* and the Gulf Snapping Turtle *Elseya lavarackorum* (DEPWS, 2022b).

In 2022, the department undertook an analysis of ecological and hydrological datasets to assess the dependency of ecological assets and ecosystems on the water resources of the plan area. It focussed on three key species of significant ecological, cultural, recreational and economic value: cabbage palm, freshwater sawfish and barramundi, to describe in broad terms, how dry season groundwater level and flow can influence lifecycle factors, habitat condition and the seasonal threats such as fire and extreme heat affecting these species.

The study recognised that the Mataranka region and Roper River are subject to natural seasonal and decadal climate variations, which can often result in unfavourable conditions for the study species, for example poor recruitment and habitat loss, and that the water requirements of these species and habitats are unlikely to be met during these periods. The study developed a range of baseflow conditions and groundwater levels associated with the Elsey Homestead gauging station (G9030013) and monitoring bore RN034230 near Bitter Springs that correlate to a classification of good to poor years for the three study species.

By looking specifically at ecohydrological relationships, the study provides guidance on some key aspects of groundwater and discharge condition that are likely to influence health and survival outcomes for these species, to inform the setting of limits of acceptable change in the plan.

4.3.1. Cabbage palm

Cabbage palm *Livistona mariae subsp. rigida* (Becc.) Todd, occurs along the Roper River and its tributaries, in areas of shallow groundwater or where groundwater is accessed via seepage from the river or creek banks. A closely related subspecies, the red cabbage palm *Livistona mariae* F.Muell. subsp. *mariae*, requires permanent access to groundwater and is sensitive to changes in groundwater levels (Nano, 2008). Similarly, the cabbage palm is considered to be an obligate groundwater species that is very shallow rooted, less than 2 m, and requires permanent access to groundwater.

Analysis of the groundwater requirements of cabbage palms suggests that protective measures are needed to mitigate the potential amplification of water stress as a result of groundwater extraction. Protective measures should aim to:

1. Avoid prolonging or extending dry season conditions for cabbage palm forests beyond what would be expected under modelled natural climate conditions.
2. Maintain groundwater levels within a maximum depth below ground for palm forests inside the plan area recognising that these limits can be exceeded during natural climate extremes irrespective of groundwater extraction levels.

4.3.2. Freshwater sawfish

Freshwater sawfish *Pristis pristis*, the largest freshwater fish in Australia, is found in the main channel and tributaries of the Roper River, as well as throughout its network of connected backwaters and billabongs, for example Red Lily Lagoon.

Freshwater sawfish are born at the mouth of rivers and in estuaries and migrate upstream into freshwater as pups (Thorburn et al., 2004). Sawfish migrate between the Gulf of Carpentaria and the upper Roper River in the plan area. Recent studies of freshwater sawfish in the Roper River indicate that pups may spend up to seven years in freshwater (E. Playanyi-Lloyd pers. comm.). During this time they rely not only on wet season flood pulses, but also dry season baseflows which maintain deeper and more complex habitats and prevent anoxic conditions. High water temperatures, poor water quality and/or a lack of prey in shallow pools results in undesirable habitat compression in the latter part of the dry season when sawfish are especially prone to loss of body condition and starvation (Lear et al., 2021). SREBA aquatic ecosystems studies indicate that barriers to migratory pathways, created by reduced water levels as a result of groundwater extraction, pose a potential threat to the persistence of populations of freshwater sawfish in the Roper River (DEPWS, 2022a).

The department's preliminary ecohydrological assessment of environmental water requirements utilised sawfish recruitment data (Plaganyi et al., 2002) and flow data for Elsey Homestead to identify a relationship between annual patterns of streamflow in the plan area and recruitment outcomes for the sawfish. The study identified a discernible difference in dry season flow recession rates associated with good and poor recruitment year outcomes for sawfish, where minimum baseflow in poor years is reached several months earlier in the dry season than in good years. The study also highlighted substantial interannual variability in the ecohydrological relationship for sawfish over the data period, 52 years, describing a general pattern of two good to three poor years (2:3) for sawfish recruitment.

4.3.3. Barramundi

Barramundi *Lates calcarifer*, are arguably the most widely known fish in the Top End. The species is highly regarded for its cultural importance and popularity as a sports and table fish. In the Roper River Basin, the species is of primary importance for subsistence hunting by Aboriginal people.

Like the freshwater sawfish, barramundi can move between the upper and estuarine parts of the river at different stages in their life cycle and may spend multiple years upstream as juveniles. Recent studies (e.g. Crook et al., 2017) showed that barramundi could remain in upstream freshwater habitat for up to 11 years. Their ability to migrate up and down the river system is facilitated by the availability of suitable habitat in the upper catchment, and sufficient water depth over rocky riffles and barriers downstream, for example the Roper Bar. Studies of barramundi habitat preferences from the Daly River suggest that juvenile fish strongly prefer the deepest areas of the river channel in both the early and late dry season, with evidence that a reduction in river flow can result in a loss of optimal habitat for this species (Brim Box, 2015). A similar habitat preference is likely to be true for barramundi in the Roper system.

Modelled barramundi recruitment data from Crook et al. (2022) and flow data for Elsey Homestead were assessed to identify a relationship between seasonal streamflows in the plan area and overall recruitment outcomes for barramundi. The analysis identifies a general pattern of one good to one poor year (1:1) for recruitment over the data period.

4.3.4. Gulf snapping turtle

SREBA aquatic ecosystem studies detected greater numbers of this species in areas of the Roper River with high conductivity, low total nitrogen and chlorophyll, high water clarity, and dense meadows of submerged macrophytes, aquatic plants. DEPWS (2022b) identifies that reduction in Roper River dry season flows (baseflow) and increases in the nitrate concentration of groundwater from agricultural development are two key potential threats to the species.

5. Cultural water

Overview

This section outlines the current understanding of the water needs of key cultural sites related to the water resources managed through the plan.

The first priority of the plan is to ensure the majority of water in the plan area is retained for ecological and environmental functions and cultural water requirements.

The Wubalawun, Yangman, Mangarrayi and Jawoyn people have a deep spiritual connection with the region's many springs, soaks, billabongs, creeks, rivers and landscapes. Similarly, Aboriginal people along the Roper River downstream from the plan area, have cultural values associated with groundwater from the plan area. These values relate to the social, cultural, and recreational activities that are crucial to the health, wellbeing and livelihoods of those in the Mataranka Roper River region. The economic value of tourism drawn to the region by the iconic springs and the Roper River is also important.

Better reflection and understanding of Aboriginal cultural water knowledge and associated requirements in the plan area and will continue through the implementation actions. As this information is considered, the water resources related to key cultural values can be appropriately managed through the plan.

5.1. Cultural values

5.1.1. Aboriginal cultural values

Wubalawun, Yangman, Mangarrayi and Jawoyn people and other Aboriginal people along the Roper River downstream from the plan area, have deep spiritual connection with the region's many springs, soaks, billabongs, creeks, rivers and landscapes.

Aboriginal people from the region have substantial biocultural knowledge of plants, animals, climate, stream flows and ecosystem processes, and have important responsibilities as custodians of land and water to care for these areas according to customary law. This includes sacred sites that are registered or recorded under the *Northern Territory Aboriginal Sacred Sites Act 1989*, as well as other spiritual and heritage sites in the plan area. The cultural integrity of these sites may be reliant on groundwater from the TLA.

The Elsey Creek system and Roper River are particularly significant because they contain high densities of recognised sacred sites, such as trees, soaks, springs, and waterholes, in conjunction with a relatively shallow water table and permanent groundwater flow from the TLA. A similar cluster of registered sacred sites near the Larrimah township are likewise associated with permanent water, however, considering the depth to the regional water table in this area, these sites are most likely tied to shallow localised perched aquifers.

The stories of creation by ancestral beings, known commonly as Dreamings, are rich with meaning for local Aboriginal people and are often associated with permanent water places. Degradation of a significant water place, such as the drying up of a groundwater fed spring, would constitute a direct impact on the ancestral beings that created them, and represent a social cost for the people connected with that Dreaming (Barber and Jackson, 2011).

Spring sites Gorran (Bitter Springs) and Najig (Rainbow Spring) are both linked to the Whirlwind Dreaming which describes the whirlwind pushing a yam stick into the ground to create the gushing spring water. The Mangarrayi people believe Garlyag (Warloch Ponds) and Longreach Waterhole on the Elsey Creek to be sites that never dry out, due to the complex of springs that sustain the area.

Providing water for the country is of ongoing importance to Aboriginal people. The Mangarrayi people of the Elsey area have maintained strong cultural practices, such as hunting and fishing, which are of critical importance to contemporary life in the region (Barber and Jackson, 2011).

Over the past five years, the department has engaged in various ways with Aboriginal people across the plan area and the wider Roper River region, to better appreciate how the water resource supports places and practices of importance to Aboriginal people, and the management measures required to protect cultural values from any unacceptable impacts of groundwater extraction. The information shared with department staff is provided below as a high level summary of Aboriginal cultural water values, expressed as elements of traditional and contemporary daily life that rely heavily on a healthy water system. The summary reflects the way the information was spoken about and shared during consultation sessions but is not intended to be complete or exhaustive:

- sacred water places are not drying out
- water flowing over Roper Bar all year, very important for Ngukurr Community
- water for drinking at communities and outstations
- fish and river animals can move up and down the river
- water for healing and ceremony is available when needed
- food plants can be collected in the usual places
- river water stays good for drinking
- enough water for floodplain animals
- turtles are nesting and eggs can be collected
- enough fish for catching at the usual places
- river, creeks and springs are flowing at good levels
- families can camp and swim at the usual places
- hunting is good near river, creeks and on floodplains
- trees on banks have water
- water is not too hot, smells good, is clear and clean, with not too much algae
- flows sustain key species to support a viable subsistence economy
- recognition that traditional weir building on the Roper at Red Lily and Moroak, diverting flow to wetlands was important for maintaining subsistence food supplies during dry periods of low flow.

In the context of environmental water requirements, water availability is not just about supporting the presence of animals and plants, but the presence of key species in sufficient numbers to make subsistence hunting viable (Barber and Jackson, 2011). Mangarrayi people rely on the swamps and lagoons immediately downstream of the plan area for hunting, fishing, food gathering and ceremony. As water managers, the Mangarrayi historically built weirs across the Roper out of logs and palms to raise or lower water levels in the swamps to maintain favourable conditions for wildlife and subsistence hunting. While this traditional practice ceased in the 1950's following court prosecution by downstream pastoralists who objected to the diversion of baseflows, traditional knowledge of river hydrology is enduring and today aligns well with contemporary western science understanding of hydrological connectivity and wetland productivity in the upper Roper.

While Aboriginal water values and biocultural knowledge have been reasonably well documented for the broader Roper region, much less is known about the specific water requirements (quality and quantity) of cultural values and assets. While the process of developing the plan has had some input from local Aboriginal people via the Mataranka Tindall Water Advisory Committee and other consultation forums, ongoing participation of Aboriginal people will be a key focus for implementation of the plan.

5.1.2. Other cultural values

Groundwater sustains a variety of social, cultural, and recreational activities that are crucial to the health, wellbeing and livelihoods of individuals and communities in the Mataranka Roper River region and throughout the Territory. The following cultural water values have been compiled through interaction with the Mataranka Tindall Water Advisory Committee and numerous stakeholder groups:

- cultural heritage and identity associated with healthy springs, river systems and surrounding wetlands
- recreational fishing, boating and camping
- lifestyle benefits of access to the natural environment and water related activities, including opportunities for self sufficiency
- ability to swim in thermal springs
- social benefits of taking troubled youth out to fish and camp
- water to support community events, sporting venues and parks
- access to reliable, clean water for drinking and economic development that keeps people and families in the region to support social cohesion.

Residents and visitors alike use the Roper River and its tributaries for camping, fishing, swimming, boating, and hunting. The waterways, springs, and waterholes provide a sense of connection to place and opportunities to enhance wellbeing. Recreational fishers rely on connectivity along the Roper River and neighbouring floodplains and wetlands to sustain boating access, as well as healthy populations of critical aquatic species such as barramundi, sooty grunter, and cherabin.

Tourism and fishing activities contribute significantly to the regional economy, while many community based events and sporting activities rely heavily on the availability of groundwater to maintain sporting fields and to create cooler, shaded picnic areas.

6. Water use

Overview

This section outlines the key considerations to determine the amount of water that may be taken from the water resources managed under the plan. This includes an overview of the policy and processes to establish the estimated sustainable yield (ESY) and Aboriginal water reserve allocations. Information is also presented on existing water use and water licence entitlements in the plan area.

The first priority of the plan is to ensure the majority of water in the plan area is retained to ensure ecological and environmental functions and requirements of the resource. It defines the water available for allocation and for stock and domestic take by establishing the take of water that is sustainable (known as the estimated sustainable yield).

The ESY of 62,474 ML per year is informed by a scientific understanding of the water resources, underpinned by water monitoring, assessments and modelling. The plan area is comprised of three water management zones: North Mataranka, South Mataranka and Larrimah. These areas are aligned to different hydrogeological characteristics of the aquifer, climatic conditions and environmental and ecological values and as such different management rules apply:

- the ESY of 2,744 ML per year in North Mataranka and 24,492 ML per year in South Mataranka operate in conjunction with rules to maintain minimum flow thresholds within the Roper River that align to climate and limits extraction and trade in the protection area
- the ESY for Larrimah of 35,238 ML per year allows further development where the groundwater storage volume is increasing and ecosystems are not dominated by this groundwater since it is too deep for vegetation and moves slowly and long distances to the river system therefore having negligible impact from extraction.

Together the ESY and the management rules preserve approximately 88 per cent of the dry season flows to the Roper River.

Within the ESY, 4,574 ML per year has been allocated for the Aboriginal water reserve and Aboriginal economic development, which could increase to a maximum of 11,171 ML per year with the recovery of unused water.

In 2024, licensed water use is low and water licence entitlements are primarily for agriculture activities.

The Act provides that a water allocation plan is to ensure that water is allocated within the ESY to beneficial uses. The ESY determines the proportion of water from a water resource within the district that can be sustainably allocated to beneficial uses. This includes an allocation to the environment, and to an Aboriginal water reserve for Aboriginal economic development.

There are defined criteria to assess whether water resources behave like Top End or Arid Zone to ensure the approach to the management and monitoring is consistent for the sustainability of the water resources (Short and Bond, 2021).

The TLA in North Mataranka and South Mataranka are characterised as Top End systems. Where groundwater and surface water are interconnected, water availability is based on flow. Larrimah behaves like, and is characterised as, an Arid Zone system where recharge to water resources is episodic and aquifers must be relied upon to sustain life and water availability is based on storage.

6.1. Water entitlements and use

Understanding existing water entitlements and how much water is reported as used is important when determining allocations to beneficial uses within the ESY. Water entitlements can be categorised by those that require a licence and those that do not require a licence.

6.1.1. Unlicensed entitlements

Rural stock and domestic water use does not require licensing.

Section 11 of the Act provides that, the owner or occupier of land on or immediately adjacent to which there is a waterway may take water from that waterway for:

a) the use of the owner or occupier or the owner's or occupier's family and employees, for domestic purposes on the land or

b) drinking water for grazing stock on the land or

c) irrigating a garden, not exceeding 0.5 hectares, which is part of the land and used solely in connection with a dwelling.

Similarly, section 14 of the Act provides that the owner or occupier of land may take groundwater from beneath the land for the same purposes as those in section 11.

Rural domestic use includes the water used by outstations from a source other than a public water supply and domestic use on pastoral properties.

Estimates of rural stock and domestic groundwater use is provided in Table 5.

Table 5. Rural stock and domestic water use estimates (ML per year) for each water management zone

Estimated water use (ML per year)	North Mataranka	South Mataranka	Larrimah	Downstream*	Total
Domestic	25	15	30	25	95
Stock	109	123	170	235	637
Total	**133**	**138**	**200**	**260**	**732**

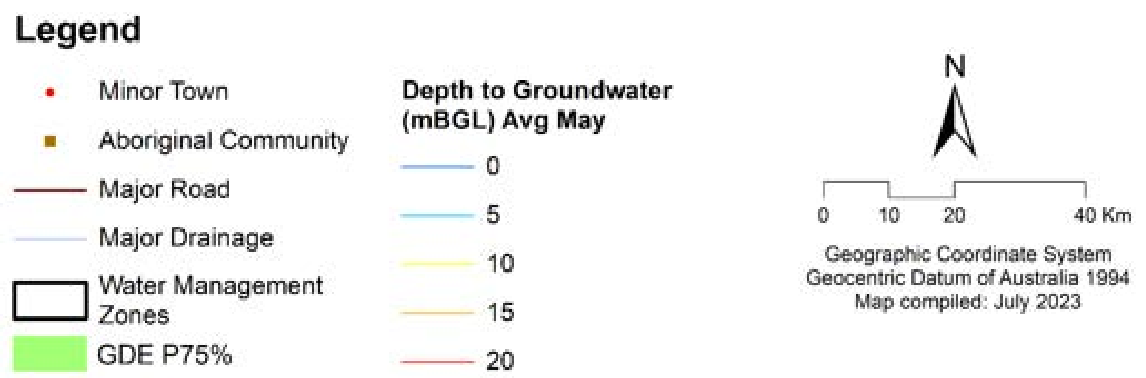
* Surface water take downstream of the plan area is included to ensure the ESY accounts for take from baseflow discharge from the plan area

Estimates for stock water use are based on the methodology provided by Meat and Livestock Australia's best practice guidelines[7] that determine water consumption based on animal carrying capacity per unit of land.

6.1.2. Licensed entitlements

Sections 45 and 60 of the Act provides that the Controller may grant to a person a water extraction licence to take groundwater from a bore or to take surface water. The licence permits a maximum annual water entitlement to be taken for a nominated beneficial use or uses. Existing water licence entitlements to each beneficial use are summarised in Table 6 and mapped spatially in Schedule T. Wet season depth to groundwater

[7] Meat and Livestock Australia's Cattle and land management best practices guide: https://industry.nt.gov.au/__data/assets/pdf_file/0010/227827/kbp_apr09_web_96dpi.pdf



Schedule U. Licensed groundwater use

Table 6. Total water licensed entitlements for the plan area (ML per year)

Beneficial uses (ML per year)	North Mataranka	South Mataranka	Larrimah	Downstream*	Total
Public water supply	75**	200**	20	80	375
Agriculture	1,650	21,496	7,998	0	31,144
Industry	150	184	0	32	366
Cultural	0	0	0	0	0
Mining activity	0	0	450	1,649	2,099
Petroleum activity	0	0	0	0	0
Total	**1,875**	**21,880**	**8,468**	**1,761**	**33,984**

* Surface water take downstream of the plan area is included to ensure the ESY accounts for take from baseflow discharge from the plan area

**Existing licence TLAM09 has bores in each management zone; for planning purposes the volume is shared 50:50 between North Mataranka and South Mataranka water management zones

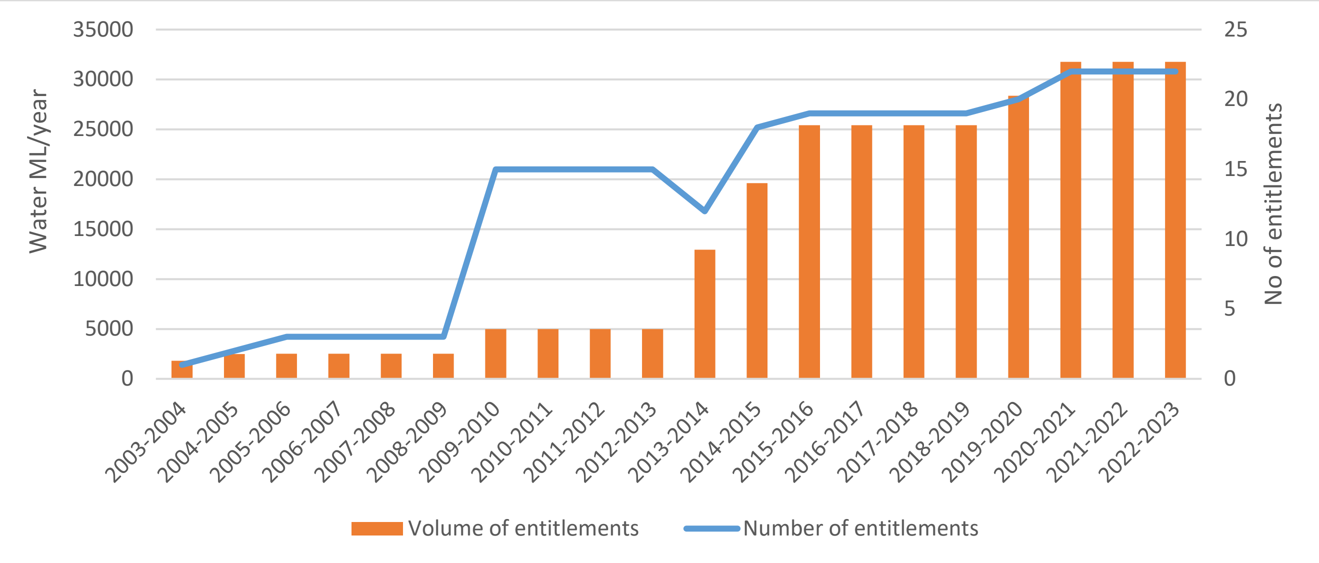


Figure 23. Mataranka plan area licensed water entitlements

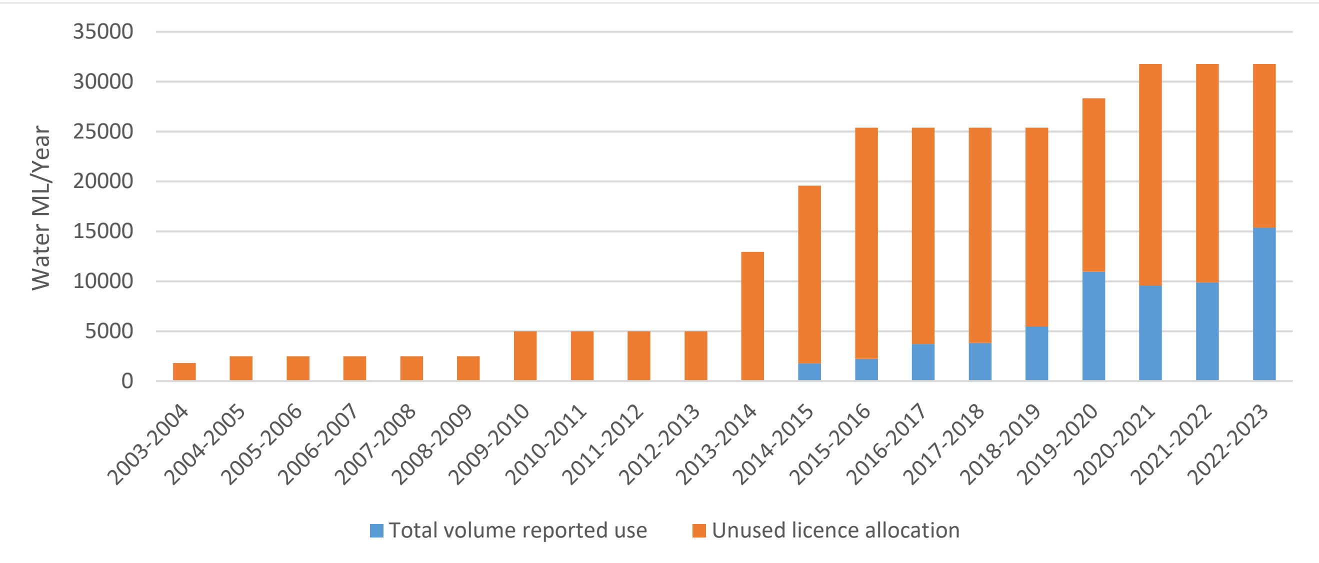


Figure 24. Mataranka plan area reported water use of water licence entitlements

Water extraction licences within the plan area were first granted in the 1990's. Figure 23 provides a profile of licensed entitlements from 2003 to July 2023.

Under the terms of a water extraction licence, water use is to be measured and reported monthly. Figure 24 shows licensed water use within the plan area relative to entitlements. Total water use is less than 50 per cent. This means that there is opportunity for new development to occur based on trade of existing entitlements.

6.1.3. Public water supply

Public water supply is water delivered through community water supply systems.

In the Northern Territory the Chief Health Officer provides directions related to safe drinking water and has a key role in the protection of public health.

The *Public and Environmental Health Act 2011*, *Water Supply and Sewerage Services Act 2000*, and *Power and Water Corporation Act 2002* provides the regulatory framework for service delivery of public drinking water in urban centres and by agreement with the Northern Territory Government for remote centres.

In the plan area public water supply is provided to the communities of Mataranka, Jilkminggan and Larrimah. A water licence is issued to Power and Water Corporation for each of these communities based on existing average demand and forecasted 30 year bulk demand estimates. The existing water licence entitlements for each community includes a significant buffer for expansion of the community or emergency provision. A summary of licensed public water supply is provided in Table 7.

Table 7. Existing licensed entitlements for public water supply (ML per year)

Groundwater (ML per year)	Iorth Mataranka	South Mataranka		Larrimah	ownstream	Total
		Mataranka	Jilkminggan			
Forecast 30 year bulk demand	-	153	260	12	0	
Licensed entitlement** (2023)	75	75	125	20	0	375
Licensed entitlement relative to forecast 30 year bulk demand (%)	-	98	48	167	00	
Total	75	200		20	0	375

**source water for public water supply for Mataranka is taken from North Mataranka and South Mataranka water management zones; for planning purposes the volume is shared 50:50 between North and South water management zones.

Details of water quality results are provided by Power and Water Corporation in an annual drinking water quality report accessible via the Power and Water Corporation website[8].

6.1.4. Agriculture water use

The main use of water in the plan area is for agricultural purposes, with 70 per cent of all entitlements held by 10 licensees in South Mataranka, 25 per cent held by three licensees in Larrimah, and the remaining 5 per cent held by one licensee in North Mataranka.

[8] https://www.powerwater.com.au/about/what-we-do/water-supply/drinking-water-quality/past-drinking-water-quality-reports

6.1.5. Industry, cultural, mining and petroleum water use

There are five water licences for the beneficial use of industry, one in North Mataranka and four in South Mataranka and one licence for mining in Larrimah. There are no licences issued for cultural or petroleum activities within the plan area, however, there is surface water taken downstream of the plan, predominantly for the beneficial use of mining.

6.2. Future water use

Future demand for water within the life of the plan is expected to come from the agricultural and mining industries.

Stock and domestic use may increase in South Mataranka where nearly 83 per cent of land is Aboriginal land and only half of that is grazed.

Industry development is likely to be required to support workforce development and expansion associated with petroleum activities in the Beetaloo Sub-basin. Larrimah and Mataranka are identified as potential service centres for a future work force of up to 300 people. There is likely to be an associated increase in demand for public water supply if that occurred.

Soil and land capability studies have been conducted in North Mataranka and Larrimah where 265 ha of Aboriginal land northwest of Mataranka and a further 24,180 ha near Larrimah have been identified as suited to a range of irrigated agricultural cropping options. Copies of reports, maps and spatial data are available via the department's development opportunities website.[9]

According to STRIKE[10], the Northern Territory Government web mapping application for geoscientific data and minerals and energy tenure information, as of June 2023 mineral exploration licences have been granted across the entire Larrimah with the exception of freehold land held by the Wubalawun Aboriginal Land Trust. A small proportion of pastoral and Crown lease land on the western edge of the South Mataranka and North Mataranka is also subject to mineral exploration licences. Mining titles totalling 145 ha have been granted for portions of land east of Jilkminggan and north of Mataranka, Schedule V. Petroleum titles

The Beetaloo Sub-basin has been identified for potential gas production. Only a very small proportion of the basin intercepts the plan boundary, primarily in Larrimah. Petroleum exploration permits have been granted across the Larrimah with the exception of freehold land held by the Wubalawun Aboriginal Land Trust, and across the southern half of the South Mataranka. No petroleum exploration permits have been granted in North Mataranka and there are no petroleum wells within the plan area.

6.3. Estimated sustainable yield

The ESY is the amount of water that can be extracted from the water resource to support declared beneficial uses that is sustainable.

The process for determining the ESY follows department practices that began with revisiting existing knowledge of the water resource, identifying the environmental values associated with water, including cultural values where they have been described, considering natural variability and water requirements of these values, and finally, determining how much water can be taken from a water resource for beneficial uses.

The first priority of the plan is to ensure the majority of water in the plan area is retained to meet environmental and cultural water requirements. This approach ensures the Territory is able to be precautionary as it develops water resources to support the growth of its communities and economy in regional and remote areas.

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[9] https://depws.nt.gov.au/land-resource-management/development-opportunities
[10] http://strike.nt.gov.au/wss.html

After considering water requirements for environment and culture, the ESY is established and water is allocated to beneficial uses such as public water supply, agriculture, industry, mining and petroleum activities and the Aboriginal water reserve.

6.3.1. Surface water

There is no licensed surface water take within the plan area and the plan does not apply to surface water. The baseflow discharge to the Roper River within the plan area is a negligible proportion of total flow, which is mostly driven by wet season runoff.

However, the plan recognises existing licensed entitlements and unlicensed use downstream of the plan area that utilise baseflow from the Roper River, and allocates that use to the ESY for North Mataranka and South Mataranka in proportion to the respective contribution of each zone to groundwater discharge. According to the natural water account, one third of all discharge originates in North Mataranka and two thirds in South Mataranka.

6.3.2. Groundwater

The natural water account, Figure 22, derived from long term historical data, indicates that the total groundwater storage volume of 32,700,000 ML is relatively evenly distributed between the three management zones.

The TLA in North Mataranka and South Mataranka are characterised as Top End systems. These systems are seasonal. Where groundwater and surface water are interconnected, water availability is based on flow. Larrimah behaves like, and is characterised as, an Arid Zone system where recharge to water resources is episodic. This approach is consistent the Classification of the Top End and Arid Zone for Northern Territory water resources. Water Resources Division Technical Report 55/2020.

In North Mataranka and South Mataranka, rainfall during the annual wet season groundwater recharges, then discharges to the river, fill and spill. Within the natural climate variability, maintaining minimum flow protects the ecological water requirements for surface water and groundwater at the same time.

Further south in Larrimah where recharge to water resources is episodic, aquifers must be relied upon to sustain life. It is necessary to use aquifer storage to balance infrequent recharge with a continuous demand for water. Relying on available stored water is a more cautious approach than relying on recharge, as it protects against uncertainties associated with climate variability.

The ESY of the water resource is informed by the following principles:

- maintaining stored volumes of water in the TLA and discharge to the Roper River to ensure minimal impact on environmental and cultural values
- maintaining existing and future rural stock and domestic needs, and ensuring availability of public water supplies
- maintaining a reliable supply of water to existing licence holders
- supporting sustainable development of the region.

The direct application of the Framework to discharge rates in North Mataranka and South Mataranka and total storage in Larrimah provides a maximum potential ESY of 127,800 ML per year[11], without considering any changes in the water balance that will occur over time. In recognition of the highly significant ecological and cultural assets within the plan area, this Framework approach was discounted early in the planning process.

[11] Comprising 20 per cent of discharge in North Mataranka and South Mataranka (35,000 ML per year) plus 80 per cent of storage over 100 years or 0.8 per cent of storage per year in Larrimah (261,600 ML per year)

After considering environmental and cultural water requirements and the scientific analyses that indicates climate variability has the greatest impact on groundwater storage and flows in the Roper River, determination of the ESY is guided by existing entitlements, future water demand, water to support regional and Aboriginal economic development and modelling results.

In setting the ESY for the plan area, the following matters are relevant.

North Mataranka and South Mataranka water management zones:

- Contain extensive GDEs and features of significant ecological significance; the Roper Discharge Zone, being recommended by the SREBA as an area of outstanding environmental value.
- Areas of ecological and cultural value in the Roper River downstream of the plan area are dependent on intermittent or year round groundwater supply.
- Monitoring of groundwater levels and river flow in the region since the 1960's indicate that groundwater storage and discharge to the Roper River is increasing. The plan area is experiencing relatively wet climatic conditions, but much drier conditions have been experienced in the past.
- In 2024 groundwater levels are several metres higher than they were in the 1960's, and groundwater discharge is routinely three to four times more than it was during the extremely dry periods when sections of the Roper River ceased to flow.
- Studies show that groundwater storage levels and flow rates in the Roper River, which are essential to safeguard and preserve important ecological resources, are determined by naturally occurring climatic variability.
- Potential locations of terrestrial GDEs in the plan area have been mapped using satellite imagery and statistical analysis, validated by field surveys. Understanding the distribution of these systems is key to assessing potential impacts of future groundwater use and development because these impacts are spatially variable.

Larrimah water management zone:

- Depth to groundwater is greater than 30 m. SREBA reports there are limited ecological values dependent on the TLA largely due to the depth to groundwater being too great for groundwater dependent vegetation to access.
- Groundwater levels have been steadily increasing with levels in 2024 up to 6.7 m higher than in the 1960's.
- There are no significant ecological considerations associated with water extraction from the TLA as there are no springs or groundwater discharges to surface water. Stygofauna have been found extensively throughout the plan area they are highly unlikely to be impacted by the levels of extraction proposed.
- The natural environmental conditions in the plan area have historically experienced large variation in wet and dry periods.
- Modelling the results of licensed water use and entitlements over a 50 year period shows that extraction has minor impact on groundwater outflow and storage when compared to natural conditions.

6.3.3. Modelling extraction scenarios

Modelling is a useful tool to assess the potential and relative impact for a range of management decisions. Modelling results show how the system responds to extraction and, when assessed against limits of acceptable change, inform options for the determination of an ESY.

In developing the plan a number of groundwater extraction scenarios were modelled to assess the relative impact of extraction on groundwater levels across the plan area, including the groundwater discharge zone and discharge to the Roper River within the plan area.

A suite of water extraction scenarios (SC1–SC4) for volumes ranging from 35,000 ML per year to 97,000 ML per year were formulated to test a suite of potential ESY's against natural conditions (SC0), as presented in Table 8.

Table 8. Extraction scenarios

Scenario	Scenario description	Extraction volumes (ML per year)				
		Groundwater			Surface water	Total
		North Mataranka	South Mataranka	Larrimah	Downstream of plan area	
SC0	Natural conditions, no extraction	0	0	0	0	0
SC1	All existing entitlements (licensed use, stock and domestic)	2,097	22,095	8,256	1,940	34,388
SC2.1	All existing entitlements plus estimated AWR	2,673	31,438	9,173	1,940	45,224
SC2.2	All existing entitlements plus 1 GL per year in South Mataranka	2,097	23,154	8,256	1,940	35,447
SC2.3	All existing entitlements plus 4 GL per year in South Mataranka	2,097	26,303	8,256	1,940	38,596
SC3.1	All existing entitlements plus 35 GL per year in Larrimah	2,097	22,095	35,238	1,940	61,370
SC3.2	All existing entitlements plus 70 GL per year in Larrimah	2,097	22,095	70,238	1,940	96,370
SC4	All existing entitlements plus 1 GL per year in South Mataranka and 35 GL per year in Larrimah	2,097	23,154	35,238	1,940	62,429

Each of the scenarios have been assessed against the following metrics:

1. Modelled end of dry season flow on the Roper River at Elsey Station (G9030013).
2. Assurance of supply in the North Mataranka and South Mataranka zones.
3. Potential impacts to spring flow at Bitter Springs and Rainbow Spring.
4. Potential impact on throughflow from Larrimah to South Mataranka.
5. Modelled change in storage in the Larrimah.

Modelling results are provided in Table 9. Resultant values should be considered indicative, providing a relative impact of each scenario and the sensitivity of each metric. All scenarios were run for the period 1970 to 2020. Additional results for metric 1 and 2 have been provided for 1988 to 1990 which represent three consecutive years of below average rainfall.

Table 9. Scenario modelling outcomes

Metric	Scenario							
	SC0	SC1	SC2.1	SC2.2	SC2.3	SC3.1	SC3.2	SC4
Metric 1: Flows at Elsey Homestead (G9030013)								
Average reduction in flows (%) 1970-2020	N/A	9	16	10	11	12	15	12
Average reduction in flows (%) 1988-1990	N/A	14	23	15	16	17	21	18
Metric 2: Assurance of supply in North/South Mataranka WMZs[1]								
Assurance of supply (%) 1970-2020	N/A	100	75	100	100	100	85	100
Assurance of supply (%) 1988-1990	N/A	100	0	100	100	100	65	100
Metric 3: Potential impacts to spring flow at Bitter Springs and Rainbow Spring								
Bitter Springs average annual reduction in groundwater elevation (%)	N/A	0.5	0.5	0.5	0.5	0.6	0.6	0.6
Rainbow Spring average annual reduction in groundwater elevation (%)	N/A	0.4	0.5	0.4	0.4	0.5	0.5	0.5
Metric 4: Groundwater levels at boundary nodes								
Difference in groundwater level between 1970 and 2020 (m) - Node 1	N/A	4.2	N/A	N/A	N/A	2.7	0.4	2.6
Difference in groundwater level between 1970 and 2020 (m) - Node 2	N/A	5.1	N/A	N/A	N/A	2.7	-0.8	2.6
Difference in groundwater level between 1970 and 2020 (m) - Node 3	N/A	6.0	N/A	N/A	N/A	2.3	-3.0	2.2
Metric 5: Modelled change in groundwater storage in the Larrimah WMZ[1,2]								
Storage change (%) relative to SC0 (natural conditions)	N/A	N/A	N/A	N/A	N/A	-7	-15	-7
Storage change (mm/year) relative to SC0 (natural conditions)	N/A	N/A	N/A	N/A	N/A	-4.6	-9.5	-4.6
Number of years	0	0	0	0		N/A	N/A	0

Note: [1]Rounded to nearest whole number

[2]Change in storage is calculated at the end of the modelled time period (2020)

N/A (not applicable) – indicates metric is not applicable to the stated scenario

Scenario 1: (SC1) consists of existing full entitlements (as at 2022-2023) for licensed use and unlicensed use, rural stock and domestic. SC1 shows an average reduction in flow of 9 per cent over the 50 year period, assurance of supply is 100 per cent, groundwater levels in the vicinity of Bitter Springs and Rainbow Springs are reduced by an average of 0.6 and 0.5 m. For context the modelled natural variation in groundwater level at these sites is approximately 10 m and 8 m respectively. Groundwater levels across the Larrimah South Mataranka boundary increase 4 m to 6 m over the 50 year period. Depth to groundwater never exceeded 20 m.

Scenario 2: (SC2.1, SC2.2 and SC2.3) combine SC1 and three different extraction volumes for a range of Aboriginal water reserve allocations in North Mataranka and South Mataranka. Of these scenarios, SC2.2 shows the lowest average reduction in flow at 10 per cent, assurance of supply is 100 per cent, groundwater levels in the vicinity of Bitter Springs and Rainbow Springs are reduced by an average of 0.6 and 0.5 m. Depth to groundwater never exceeded 20 m.

Scenario 3: (SC3.1 and SC3.2) combine SC1 and two different extraction volumes for Larrimah. Larrimah extraction volumes are equivalent to 30 per cent (SC3.1) and 60 per cent (SC3.2) of storage calculated over 100 years. SC3.1 shows an average reduction in flow of 12 per cent, 100 per cent assurance, groundwater levels in the vicinity of Bitter Springs and Rainbow Springs are reduced by an average of 0.7 and 0.5 m. Groundwater levels across the boundary increase 2.3 m to 2.7 m and storage is reduced by 7 per cent over 100 years equivalent to 4.6 mm per year. SC3.2: shows an average reduction in flow of 15 per cent, 85 per cent assurance, and groundwater levels are reduced by an average of 0.8 and 0.6 m and groundwater levels across the boundary increase 0.4 m at Node 1, but reduce by to 3 m at Node 3. Storage is reduced by 15 per cent over 100 year's equivalent to 9.5 mm per year.

Scenario 4: is a combination of the scenarios which result in lowest impact volumes for North and South Zones (SC2.2) and Larrimah Zone (SC3.1). This scenario shows a net reduction in flow of 12 per cent and 18 per cent during a three successive year dry period from 1988 to 1990. A distribution histogram of modelled flow reduction during dry season months is provided in Figure 25.

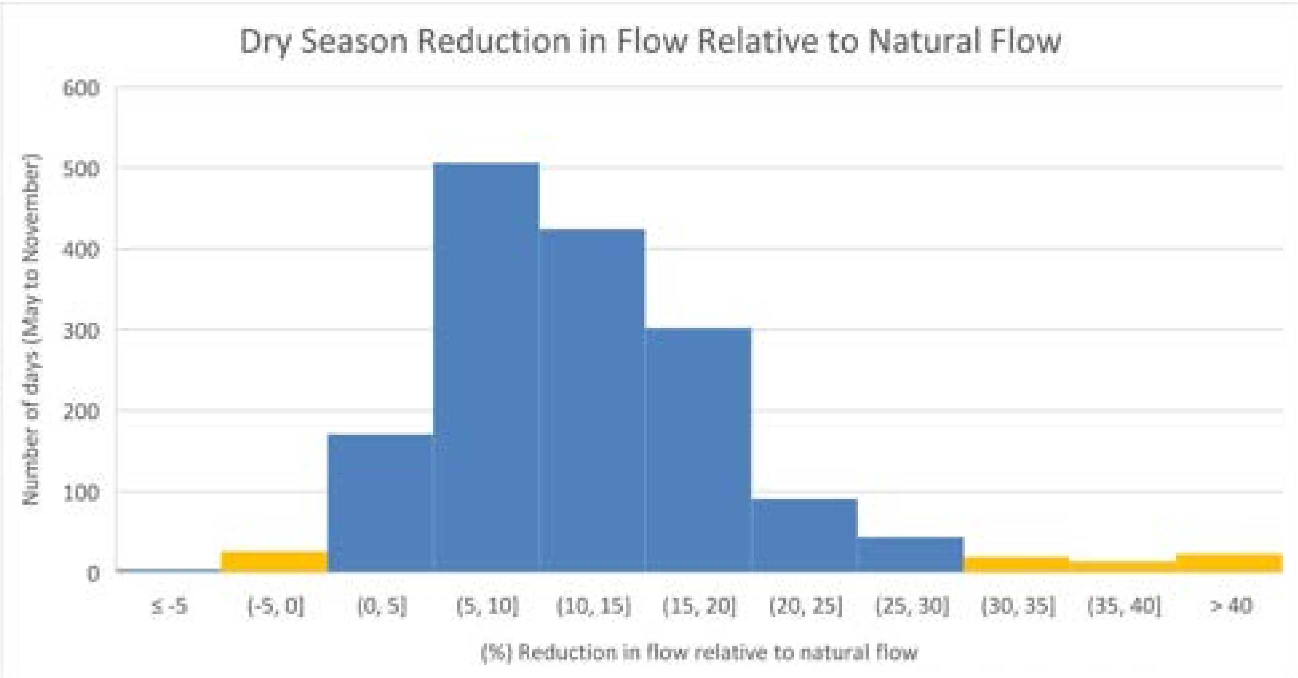


Figure 25. Dry season flow reduction at Elsey Homestead for scenario SC4

The most frequent reduction in flow at Elsey Homestead is between 5 and 15 per cent. The bars in orange are considered to represent 'noisy data' in the modelling dataset and not reflective of true flow reduction. Recognising limitations in modelling, this data is indicative and regarded as worst case scenario based on the following assumptions:

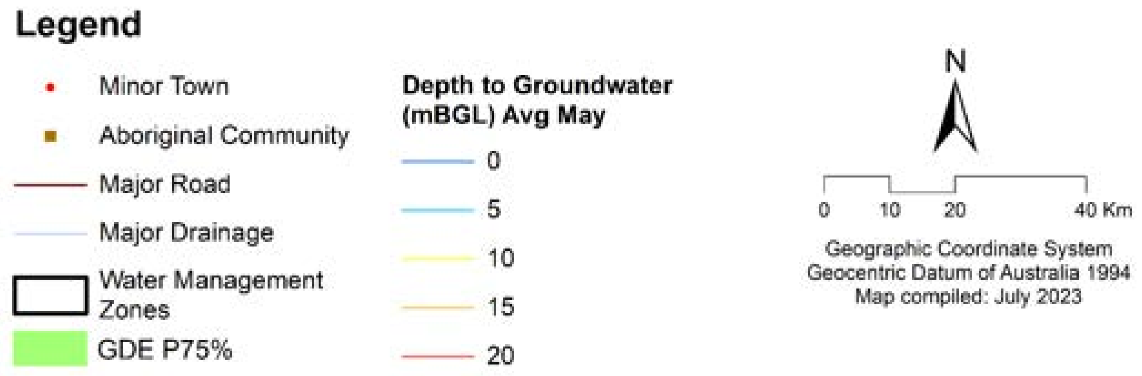
a) from the first day of the modelling period (1970), 100 per cent use of all licensed entitlements are used every day
b) no rainfall occurs during May to November in any year
c) the Aboriginal water reserve is fully utilised for the full modelling period
d) model outcomes do not take into account the impact of applying announced allocations
e) model outcomes do not take into account provisioning the Aboriginal water reserve from existing entitlements which will move extraction away from the groundwater discharge zone.

Application of the plan's management arrangements will mitigate the impact on flows for the Roper River at Elsey Homestead.

Scenario 4 also provides 100 per cent assurance of supply, groundwater levels at the springs are reduced by an average of 0.7 and 0.6 m. Groundwater levels across the Larrimah South Mataranka boundary increases between 2.2 m to 2.6 m and storage in Larrimah is reduced by 7 per cent over 100 years, equivalent to 4.6 mm per year. The plan sets the estimated sustainable yield at 62,429 ML per year, equivalent to Scenario 4. Schedule W. Impact of extraction shows a cross section of the likely impact of extraction on groundwater flow direction across the plan area from the southern plan boundary to the Roper River.

CSIROs RoWRA also undertook scenario modelling for potential developments, i.e. hypothetical water extractions, under projected climate scenarios. These scenarios show relative flow reductions in the Roper River over 50 years and 436 years for different water extractions and climate projections. See Taylor et al. (2023) for further details however scenarios using current development extractions, nominally 32,000 ML per year, are projected to reduce flow to the Roper River by 9 per cent in 2070 (50 years) with 0 per cent increase after 436 years using CSIROs 50 year climate sequencing methodology. An additional extraction volume of 70,000 ML per year, i.e. 102,000 ML per year total for the area equating to 38,000 ML per year for Larrimah, for hypothetical developments increases the reduction in discharge to the river by a further 1 per cent in 2070. These simulations highlight that climate variability is more significant than that of current groundwater extraction of the potential impact on water resources in the Roper catchment (Taylor et al., 2023).

Figure 26, Figure 27 and Figure 28 show various monitoring locations across the three different management zones, Schedule T. Wet season depth to groundwater



Schedule U. Licensed groundwater useThese bores are representative of the regional groundwater system response to rainfall and usage since extensive groundwater monitoring began in the mid 2000's. It is important to note that while the first water extraction licences were issued in 2013, usage didn't start until 2014 with significant extractions, > 10 GL per year, commencing in 2019.

According to the data, groundwater level trends increase (in what limited data is available) before 2011 then decrease. This correlates well with rainfall data and river flow data shown in section 3.4.1 of this document, where periods of very high flow in the Roper River occurred from 2000 to 2011. In 2018-2019 and 2019-2020 the Top End experienced two consecutive poor wet seasons, this is also reflected in groundwater level trends over this period. The following wet season in 2020-2021 was good and groundwater levels (despite water extractions) increased accordingly and continue to do so.

This measured data is further evidence that climate variability is more significant than the current groundwater extraction impact on water resources. However the department will continue to monitor the water resource and apply adaptive management measures, see section 6.4.3 of this document, on an annual basis for the plan area.

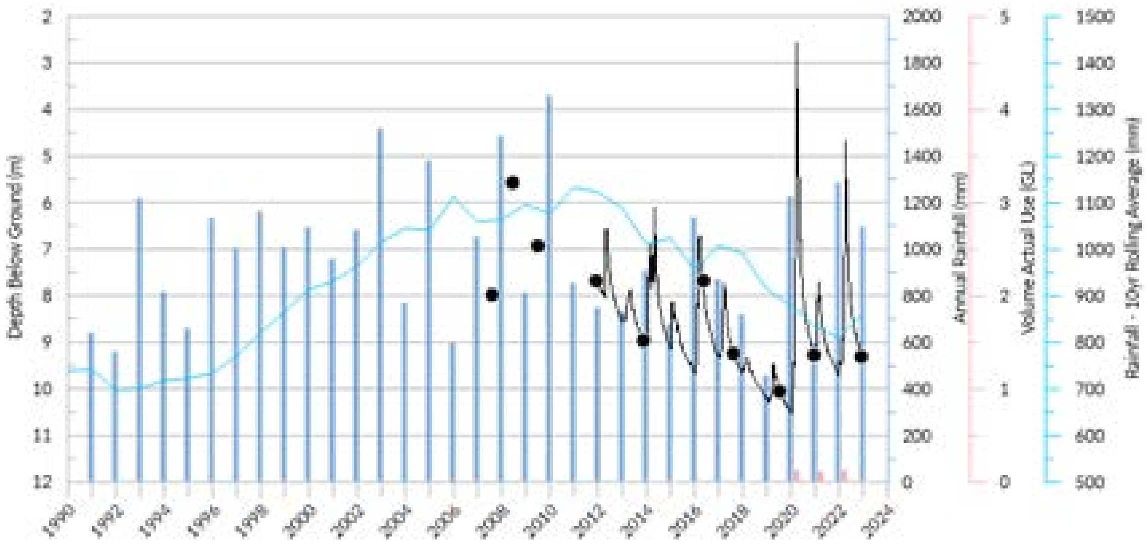


Figure 26. Groundwater level data at bore RN035793, Mataranka rainfall data and use in North Mataranka

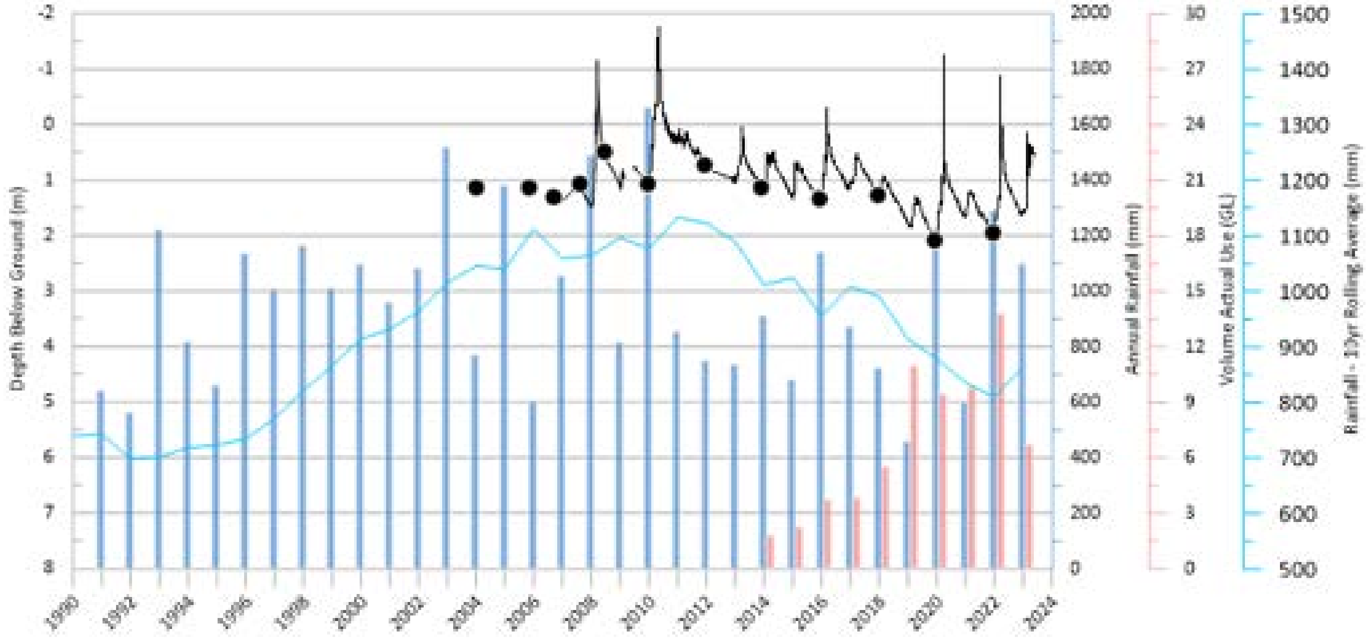


Figure 27. Groundwater level data at bore RN034038, Mataranka rainfall data and use in South Mataranka

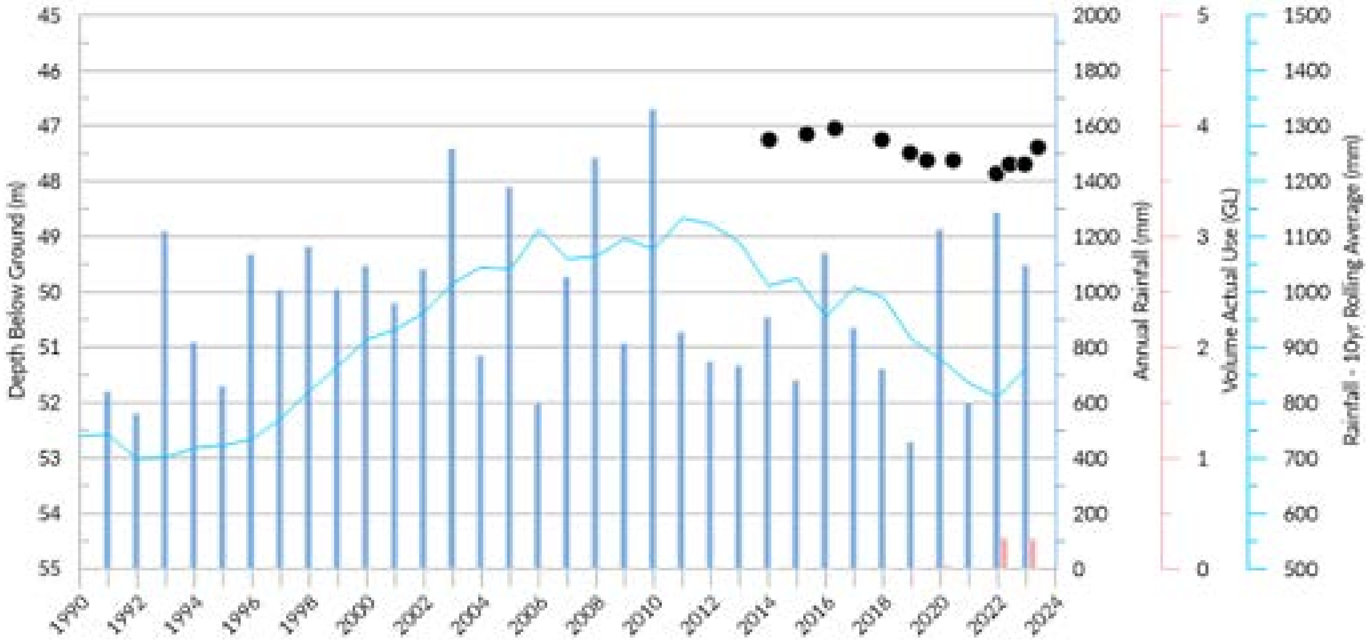


Figure 28. Groundwater level data at bore RN038811, Mataranka rainfall data and use in Larrimah

Figure 29 shows two bores located near irrigation precincts. Again despite use, maxing out at almost 14 GL per year in 2022, groundwater levels are rising after the two consecutive poor wet seasons in 2018-2019 and 2019-2020.

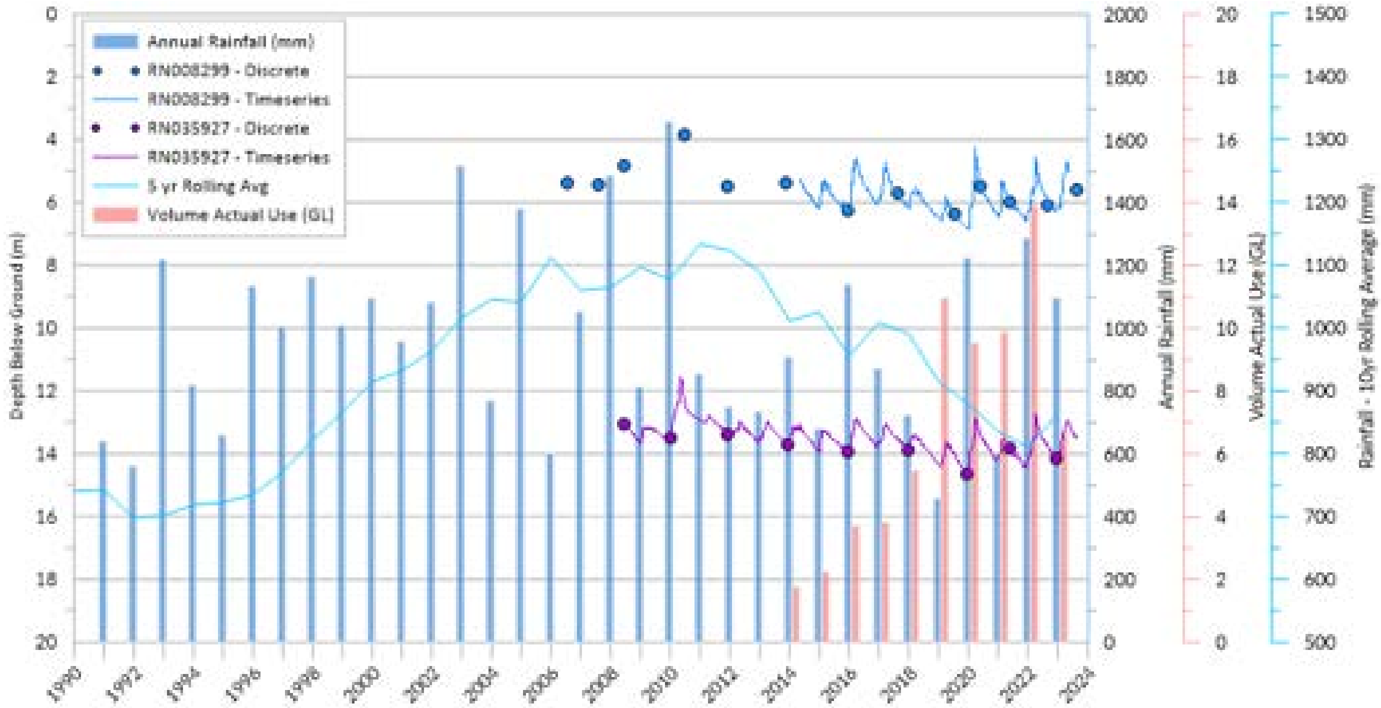


Figure 29. Groundwater level at bores RN008299 and RN03527, Mataranka rainfall and use in all zones

6.4. Protection of environmental and cultural values

A key outcome of this plan is that environmental values are appropriately accounted for in water planning and licensing. The following sections identify how this will be achieved.

6.4.1. Monitoring and assessment

The department conducts an ongoing monitoring and assessment program focussed on groundwater levels, groundwater flow and water quality in areas of possible extraction impact. The implementation actions include details of the monitoring program which is frequently evaluated to ensure that data is fit for purpose and knowledge gaps are addressed. The monitoring program focuses on sites related to the limits of change, the water quality baseline and expanding knowledge of flow relationships between Elsey Homestead and Roper Bar to account for evapotranspiration losses.

Water licence conditions require licence holders to meter and report water take which allows the department to assess how the system is responding to extraction. Significant licences may contain additional monitoring requirements as part of a risk management process.

Bore drilling logs provide valuable detail of lithology, aquifer parameters, depth to groundwater and water quality data. Additional drilling and monitoring is being conducted in collaboration with CSIRO to refine knowledge of groundwater flow paths and outcomes from the Roper River water resource assessment that will inform the review of the plan.

Recently collected LiDAR (light detecting and ranging) data for the plan area will significantly improve accuracy of digital elevation models, depth to groundwater datasets and the next iteration of the model (version DR3).

6.4.2. Protections under other environmental legislation

There are a number of statutory provisions provided by other legislation that are relevant to the protection of environmental and cultural values within the plan. These include:

6.4.2.1. Petroleum Act 1994

- Section 9: the Minister may not grant an exploration permit or licence under that Act in a reserved block. Reserved blocks exist within each of the management zones, see Schedule X. The SREBA Regional Report (DEPWS, 2022a) proposes extending the boundary of an existing reserved block to capture the full extent of the Roper Discharge Zone.
- Section 111(1): construction of a petroleum well, wellhead, pipeline or petroleum processing facility on land within 2 km of land being used as a habitable building is prohibited.
- Section 112: construction of a well or well pad, within 1 km of a designated bore, which includes a bore used for rural stock and domestic beneficial use, is prohibited.
- Section 57AAC(1): an application for a petroleum interest on Aboriginal land may only be granted if the applicant has obtained a permit, consent or agreement required under the *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth).
- SREBA recommended amendments to the Onshore Petroleum Activities Code of Practice[12] to exclude some activities associated with onshore gas development in the vicinity of high value areas, and where there is a shallow depth to groundwater within unconfined parts of the aquifer.

6.4.2.2. Environment Protection Act 2019

SREBA recommended the creation of a protected environmental area to incorporate the Roper discharge zone.

Sections 35 and 36 of the *Environment Protection Act* 2019 allows for the Minister to declare an area as a protected environmental area. A declaration may specify various matters, including that certain actions in the area are prohibited.

There are currently 28 bores associated with 14 groundwater extraction licences within or near the Roper discharge zone, see Schedule Q. Of the 14 licences, four have significant entitlements, over 500 ML per year. The process to declare a protected environmental area has been included in the implementation actions.

6.4.3. Announced allocations

Announced allocations are part of the Northern Territory's adaptive water resource management toolkit[13]. This regulatory mechanism is used to ensure environmental thresholds, suck as specific river flow targets, will be met, before provisioning water for extraction.

The use of announced allocations is appropriate in a climate driven system especially in the context of the life of a plan. It does not prevent the determination of longer term strategies as knowledge improves over time.

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[12] https://depws.nt.gov.au/onshore-gas/onshore-gas-in-the-northern-territory/code-of-practice-onshore-petroleum-activities-in-the-nt

[13] https://nt.gov.au/environment/water/management-security/water-allocation/announced-water-allocations#:~:text=Every%20year%20on%20May%201,annual%20announced%20allocations%20or%20AAAs

Minimum flow thresholds of 180 ML per day and 275 ML per day, see section 3.4.1 of this document, are applied in the plan for the North Mataranka and South Mataranka. For example, in 2021 the minimum annual flow reflected a wet climatic condition, Figure 30.

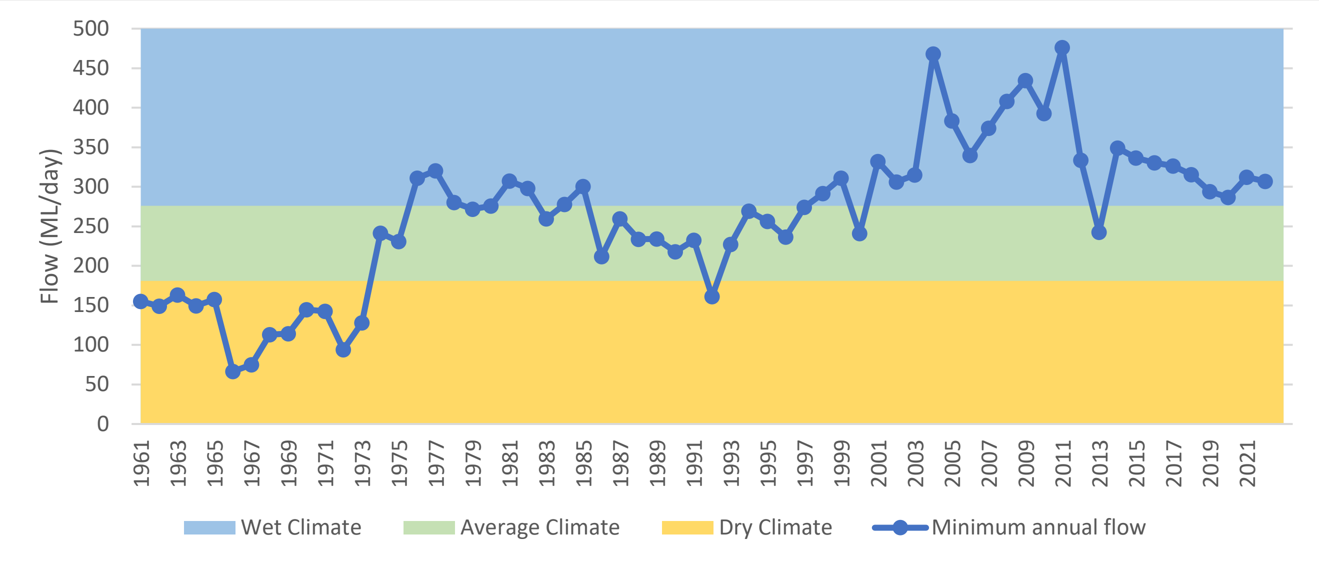


Figure 30. Flow thresholds and minimum annual flow on Roper River at Elsey Homestead (G9030013) 1961-2021

Modelling is conducted early in the calendar year to provide predicted daily flow for each day up to the beginning of the wet season, 1 November each year. The model output provides for two scenarios, one assumes no extraction, representing natural conditions, the other assumes water extraction based on full entitlements. Figure 31 shows the modelled predictions against the climatic categories for 2021.

Modelling is conducted early in the calendar year to provide predicted daily flow for each day up to the beginning of the wet season, 1 November each year. The model output provides for two scenarios, one assumes no extraction, representing natural conditions, the other assumes water extraction based on full entitlements.

Figure 31 shows the modelled predictions and against the climatic categories for 2021.

In this example modelled natural flow at 1 November is predicted to exhibit a wet climatic condition, i.e. flows above 275 ML per day. Modelled flow under full entitlements on 1 November is predicted to be an average climatic condition, i.e. between 275 and 180 ML per day. Therefore the limit of change threshold would be exceeded and the Controller of Water Resources would consider making an announced allocation. Other factors that would influence the Controller of Water Resources decision would be the likelihood of rain between March and May, and the percentage of use relative to entitlement in the preceding years. The volume of reduction is determined by modelling a number of scenario iterations until the limit of change criteria is upheld and the reduction applied uniformly across each water licence in North Mataranka and South Mataranka water management zones.

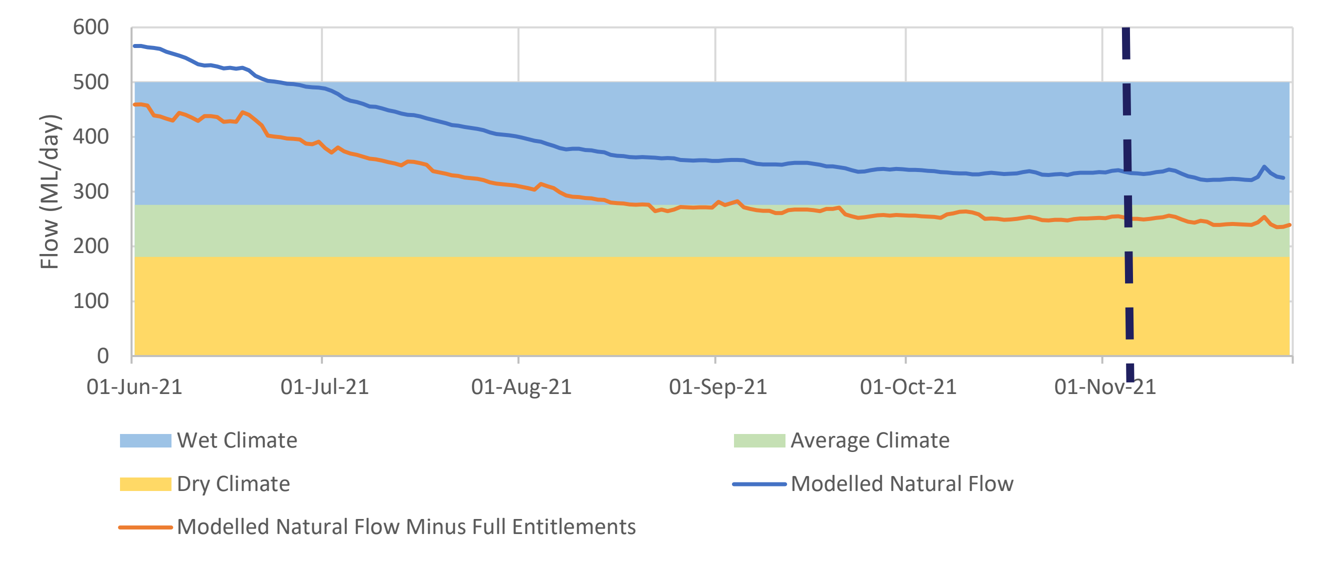


Figure 31. Modelled flow predictions and climatic bands on Roper River at Elsey Homestead (G9030013)

6.5. Aboriginal water reserve

In 2017 the Northern Territory Government approved the Strategic Aboriginal Water Reserve (AWR) Policy Framework[14] to provide Aboriginal people with increased opportunity to access water resources for their economic benefit. The policy seeks to address the disadvantage faced by Aboriginal people in relation to economic opportunities and development.

Water in an Aboriginal water reserve is held for the economic benefit of eligible Aboriginal people in perpetuity. Aboriginal people benefit from the reserve by applying for a water licence for their own use, or by agreement with a third party who applies for a water licence from a reserve. Separate to the reserve, Aboriginal enterprises may also apply for water from the general consumptive pool, water available for all other beneficial uses after allocations are made to the Aboriginal water reserve.

The Act requires water to be allocated to an Aboriginal water reserve under a water allocation plan if any of the land in the water control district to which the water allocation plan relates is eligible land (section 22B(7)). Section 22C(1) provides that a water allocation plan may designate eligible land as land in respect of which an Aboriginal water reserve applies if (a) the land is of more than 1 ha; and (b) there are water resources on, under or adjacent to the land.

Section 22C(2) requires that, before declaring a plan which designates land as above, the Minister must consult with the relevant Aboriginal land council in relation to the land.

A detailed report on the eligible land for the Mataranka reserve developed in consultation with the Northern Land Council details the methodology for to determining the eligible land. An indication of the percentage of water that should be allocated to the Aboriginal water reserve and each management zone is presented in Table 10.

Table 10. Aboriginal water reserve (percentage %)

Groundwater, ML per year	North Mataranka %	South Mataranka %	Larrimah %
Aboriginal water reserve	19.50	30.00	10.26

[14] https://nt.gov.au/environment/water/management-security/water-allocation/aboriginal-water-reserves

The volume of water allocated to the Aboriginal water reserve at the time of plan declaration depends on the percentage of eligible land in each management zone, the volume of water allocated to other beneficial uses and how much water was granted under licences before the Aboriginal water reserve commenced.

Where the Aboriginal water reserve is not fully provisioned implementation actions will prioritise the department's strategy to recover unused water in accordance with Northern Territory Government's Recovery of Unused Licensed Water Entitlements Policy[15].

Current licence entitlements mean that the Aboriginal water reserve is not fully provisioned at the time of the plan's declaration. Table 11 identifies current water availability in the Aboriginal Water Reserve, and the future volume at full allocation.

Table 11: Aboriginal water reserve volume

Groundwater ML per year	North Mataranka	South Mataranka	Larrimah	Total
Available - Aboriginal water reserve for Aboriginal economic development	47	935	3,592	11,171
Maximum - Aboriginal water reserve for Aboriginal economic development	458	7,121	3,592	11,171

In the 2022-2023 water accounting year, actual water use in North Mataranka and South Mataranka was around 65 per cent of licence volumes, indicating an opportunity to recover unused water in these zones.

[15] https://nt.gov.au/environment/water/management-security/water-policies-and-guidelines

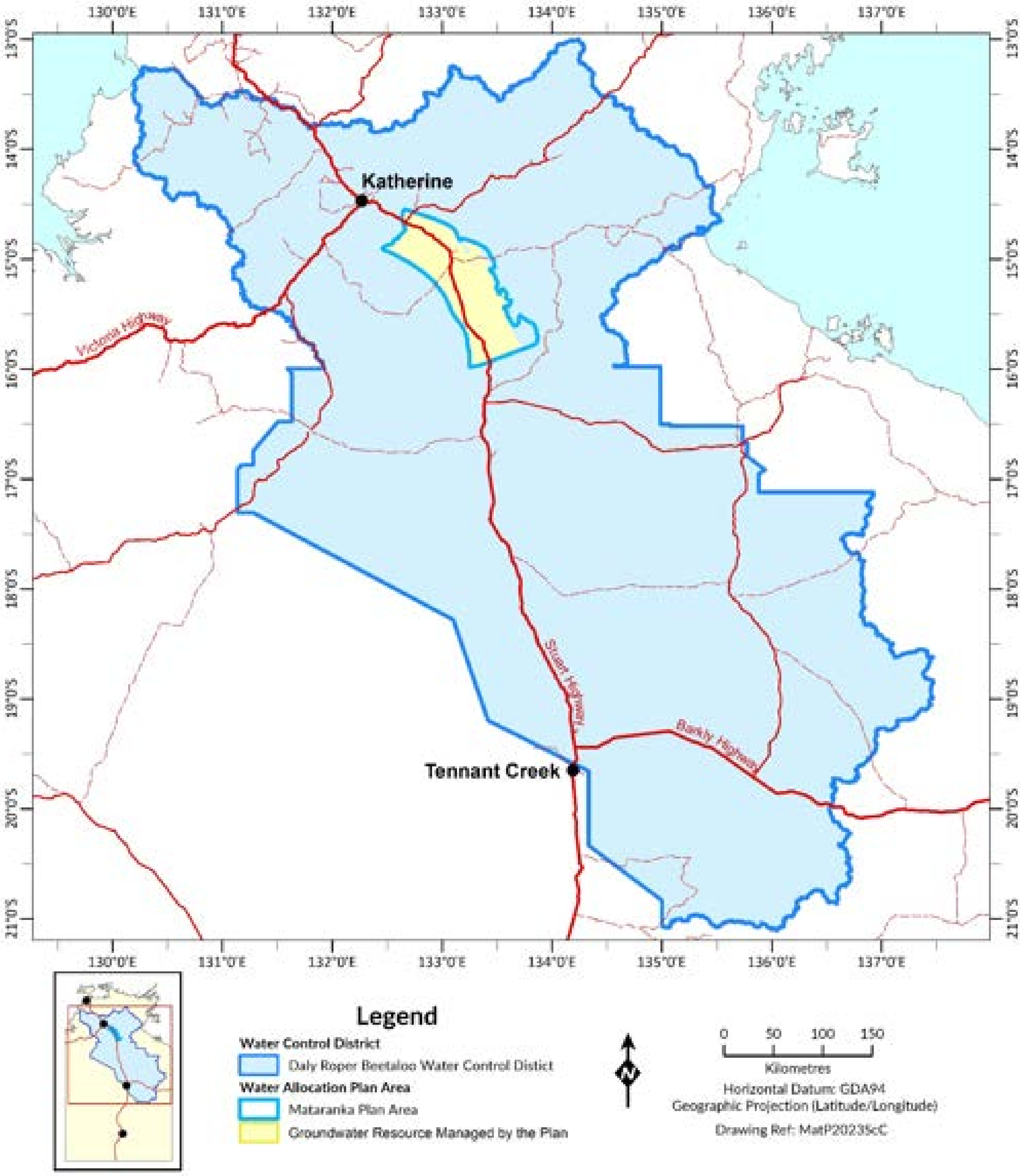
Schedule A. Dictionary

Term	Definition or reference
Aboriginal water reserve	see *Water Act 1992*, section 4(1)
Act	the *Water Act 1992*
available consumptive pool	the volume in the consumptive pool after subtracting allocations to the environment under section 22B(6) and the beneficial uses of rural stock and domestic and public water supply
beneficial uses	the beneficial uses for the Daly Roper Beetaloo water control district declared by *Gazette* no. G41, 19 October 2022
Cambrian Limestone Aquifer	collective term for an extensive groundwater system covering 570,000 km^2 straddling the NT and QLD border. The CLA comprises the geological basins of the Daly, Georgina and Wiso. The aquifer consists primarily of limestone
Controller	the Controller of Water Resources appointed under the *Water Act 1992*, section 18
department	the department with the responsibility for administering the *Water Act 1992*, according to the Northern Territory of Australia Administrative Arrangements Order
eligible Aboriginal people	see *Water Act 1992*, section 4(1)
eligible land	see *Water Act 1992*, section 4B
estimated sustainable yield	the amount of water that can be allocated from the water resource to support declared beneficial uses that is sustainable, Section 6.3 of this document refers
groundwater	see *Water Act 1992*, section 4(1)
groundwater dependent ecosystem	an ecosystem that requires access to groundwater to meet all or some of their water requirements
Tindall Limestone Aquifer	a regional limestone aquifer that extends from north of Katherine to south east of Tennant Creek. Locally referred to as the Katherine and Mataranka Tindall limestone aquifers in the Daly Basin, Gum Ridge formation in the Georgina Basin and Montjinni limestone in the Wiso Basin
water control district	the Daly Roper Beetaloo water control district, declared by *Gazette* no. G41, 19 October 2022 under section 22 of the *Water Act 1992*
water licence / water extraction licence	see *Water Act 1992*, section 4(1)
water management zone	areas of land within the plan area separated for management purposes as depicted in Schedule D of this document
waterway	see *Water Act 1992*, section 4(1)

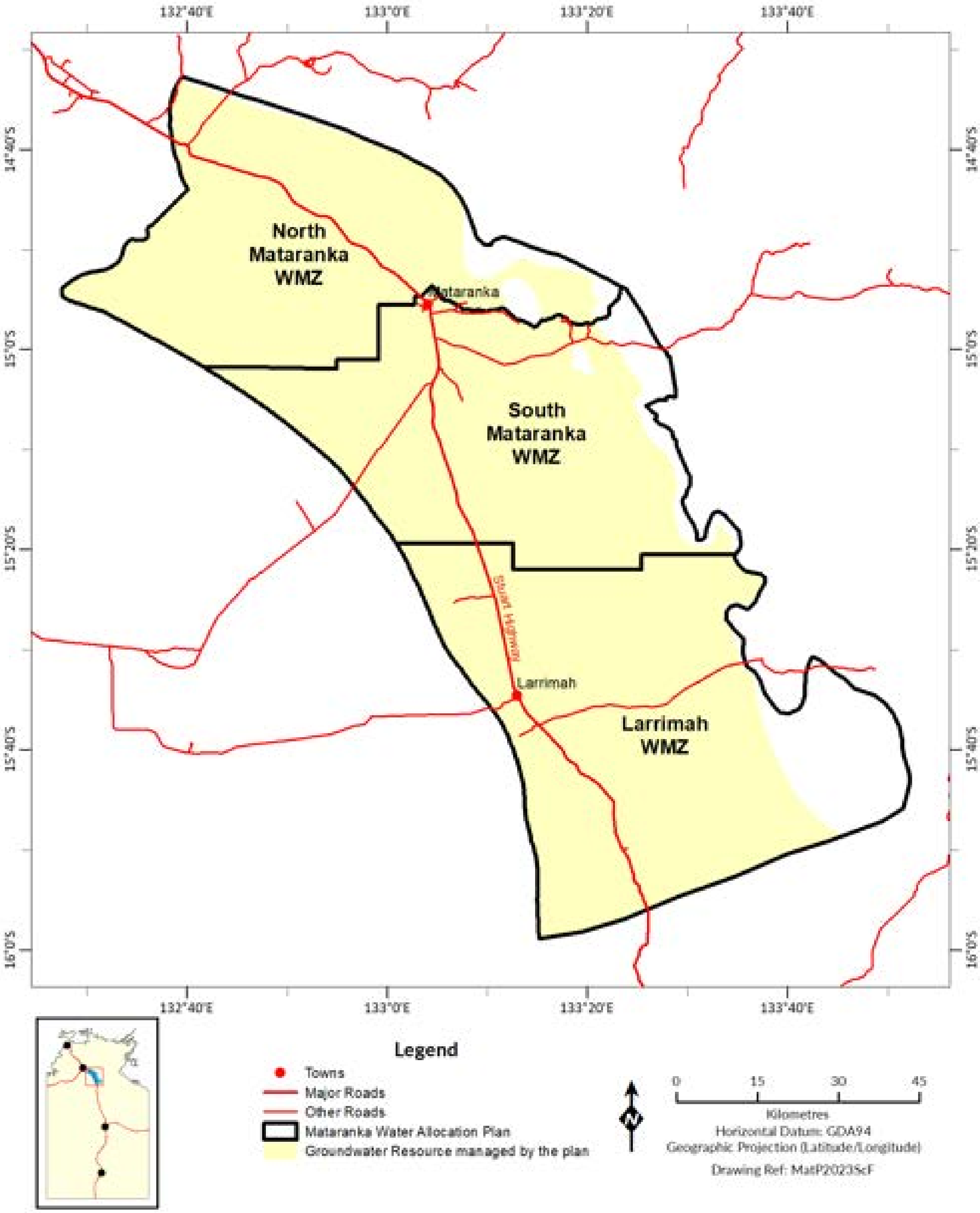
Schedule B. Acronyms

Acronyms	Full form
Act	*Water Act 1992*
AHD	Australian height datum
CLA	Cambrian Limestone Aquifer
CSIRO	Commonwealth Scientific and Industrial Research Organisation
Cth	Commonwealth
DLPE	Department of Lands, Planning and Environment
district	Daly Roper Beetaloo water control district
ESY	estimated sustainable yield
GBA	Geological and Bioregional Assessment
GISERA	Gas Industry Social and Environmental Research Alliance
GL	gigalitre
GDE	groundwater dependent ecosystem
km	kilometre
ML	megalitre
Minister	Minister for Water Resources
plan	Mataranka Water Allocation Plan 2024–2034
SREBA	Strategical Regional Environment and Baseline Assessment
TLA	Tindall Limestone Aquifer
WMZ	water management zone

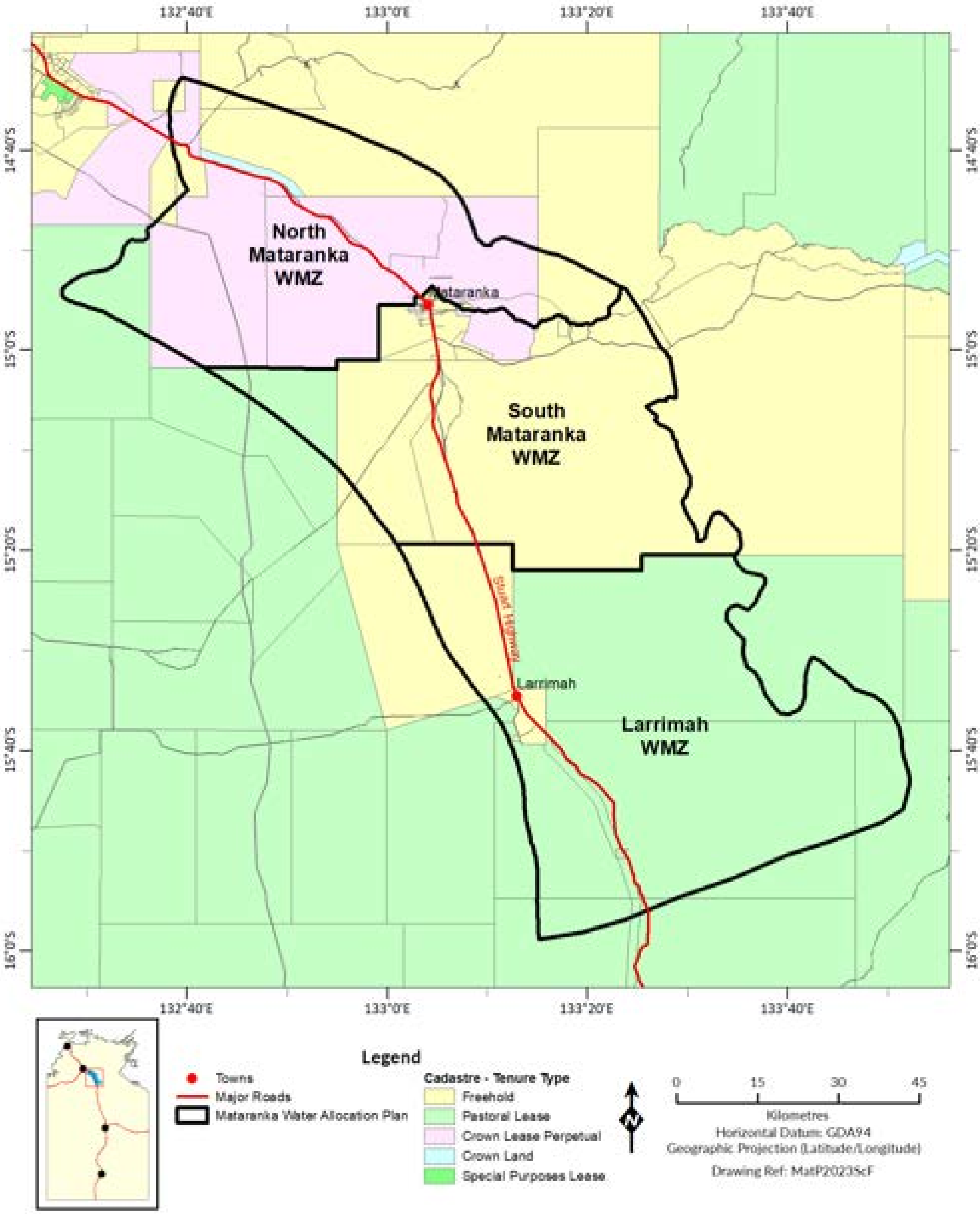
Schedule C. Daly Roper Beetaloo water control district and Mataranka plan area



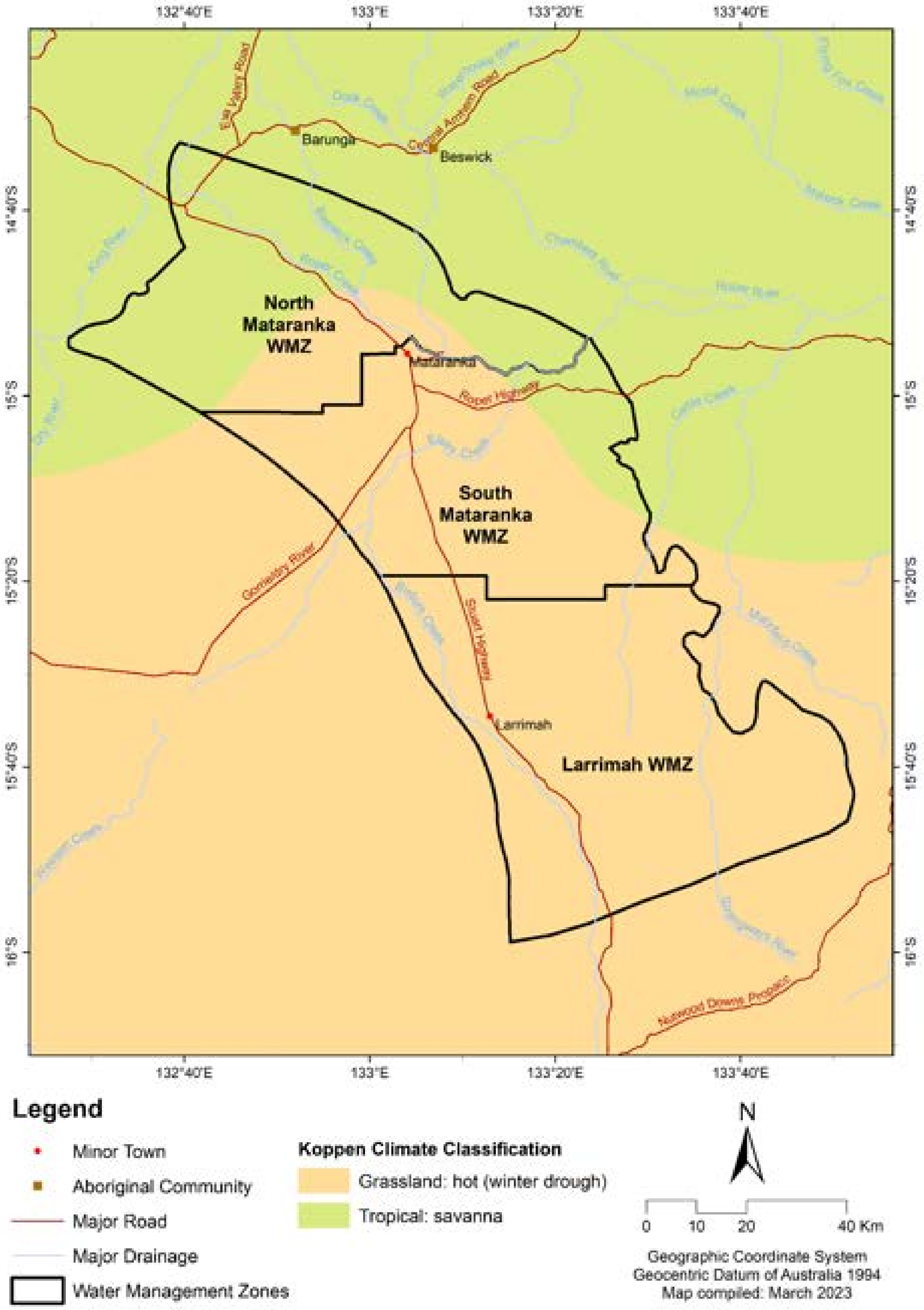
Schedule D. Mataranka water management zones



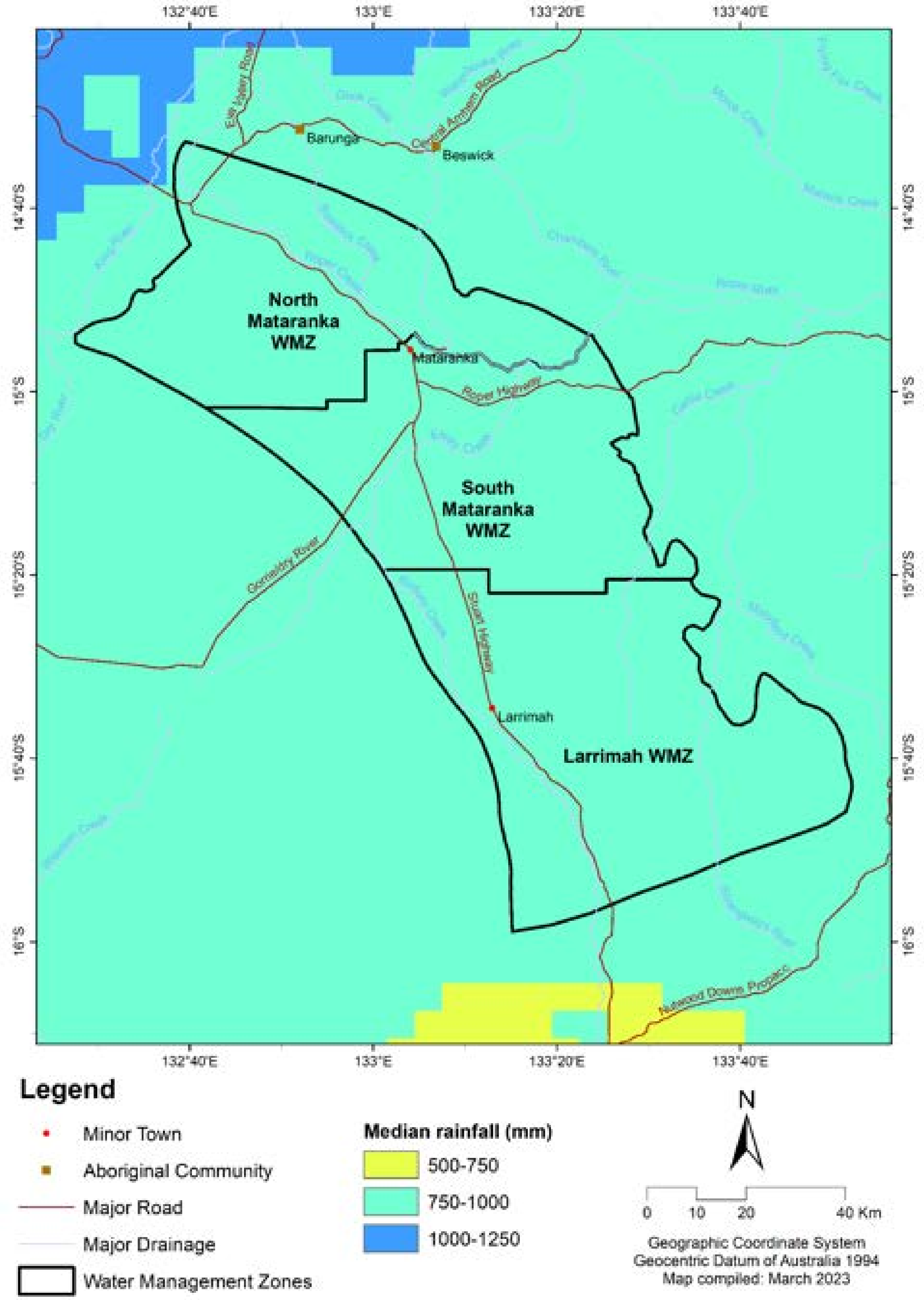
Schedule E. Tenure of plan area



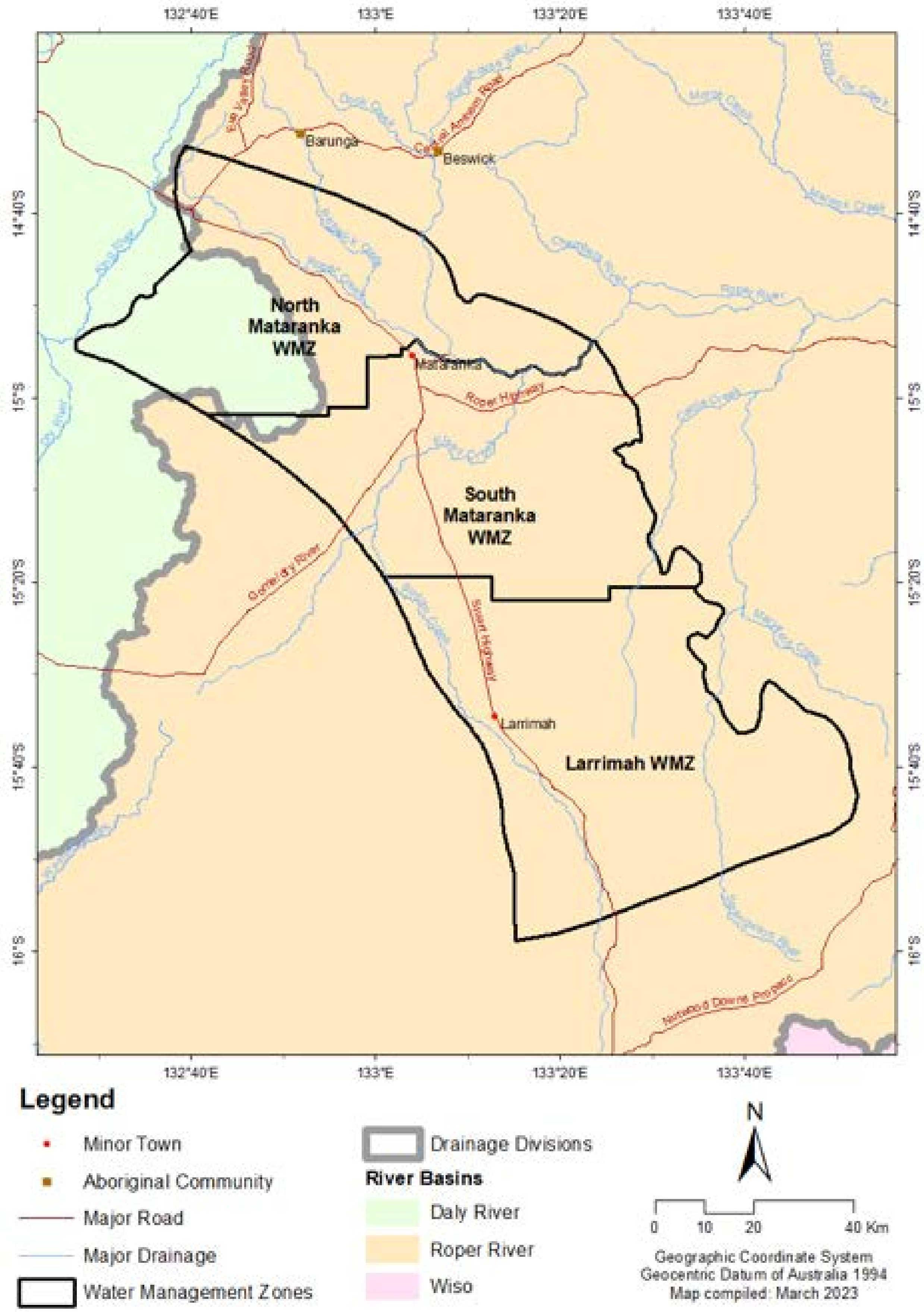
Schedule F. Climate of plan area



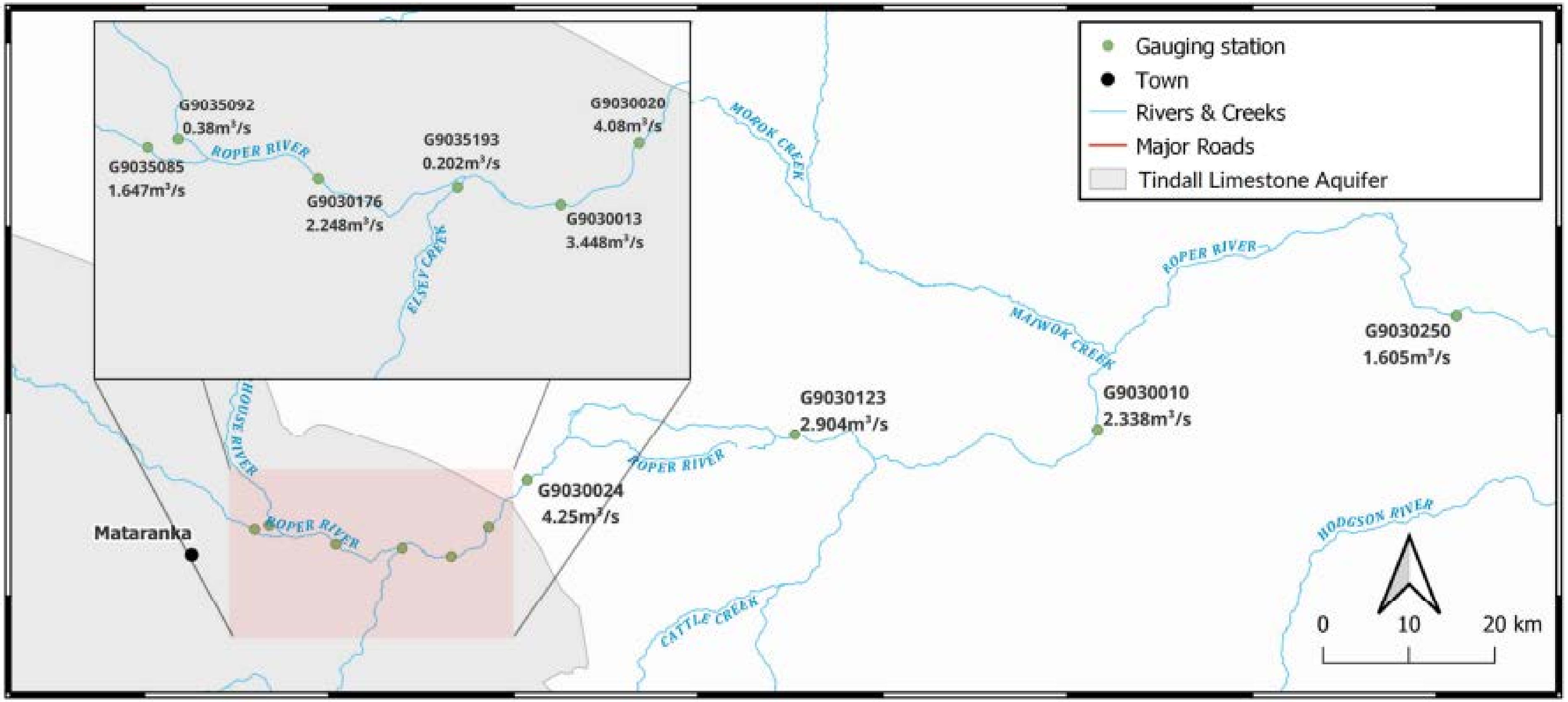
Schedule G. Rainfall of plan area



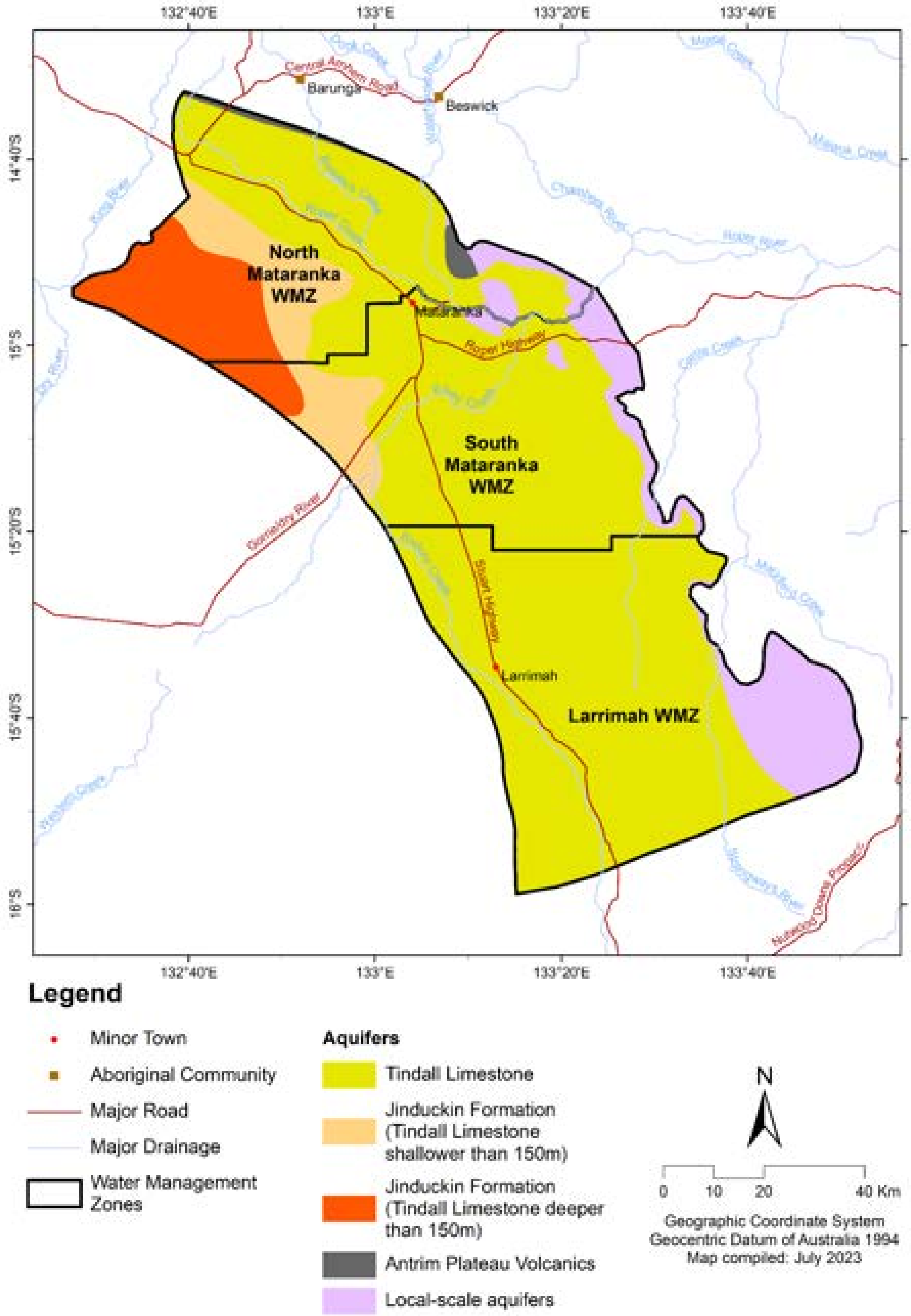
Schedule H. Surface water drainage divisions of plan area



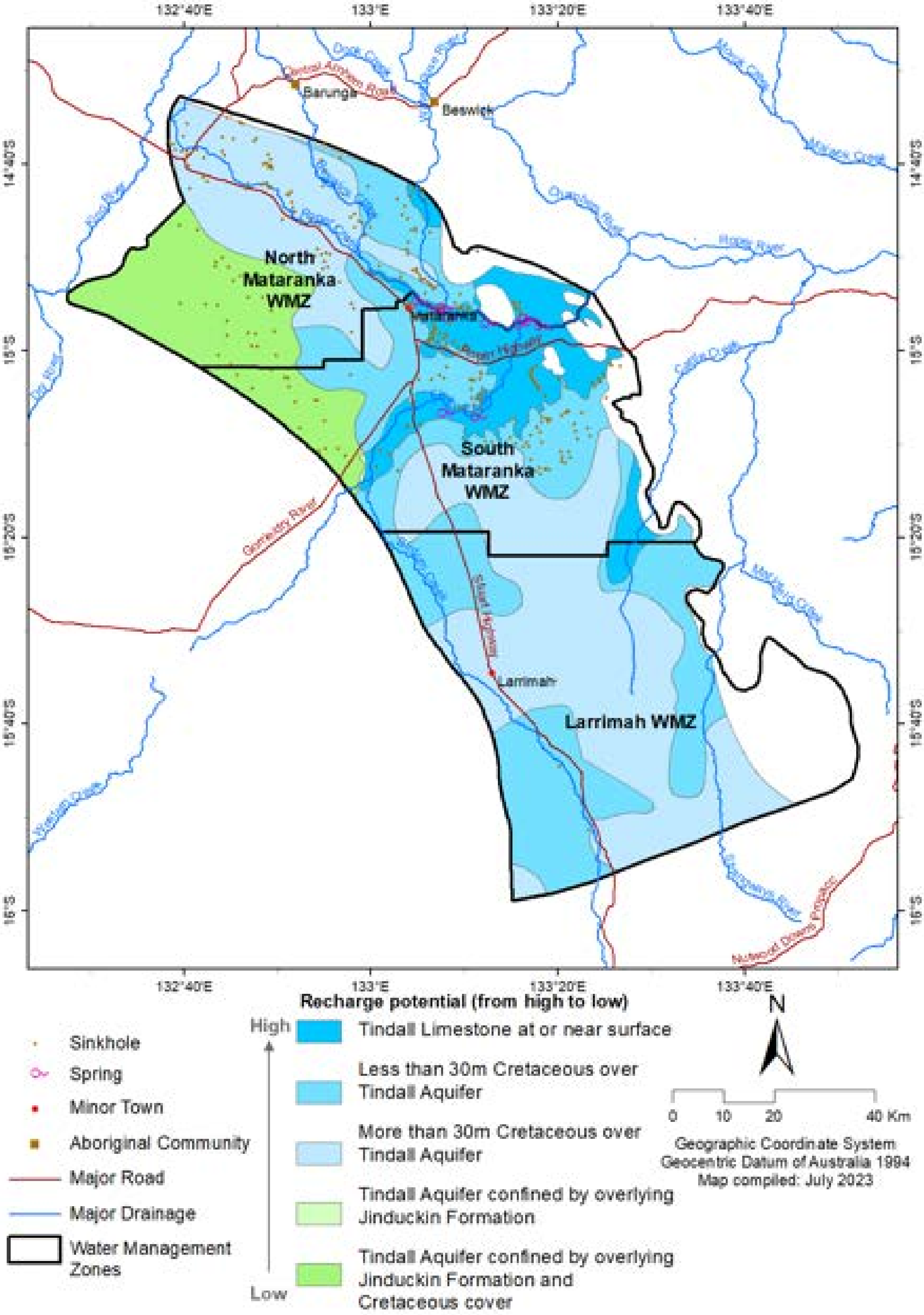
Schedule I. Roper River flow profile for end of dry 2022



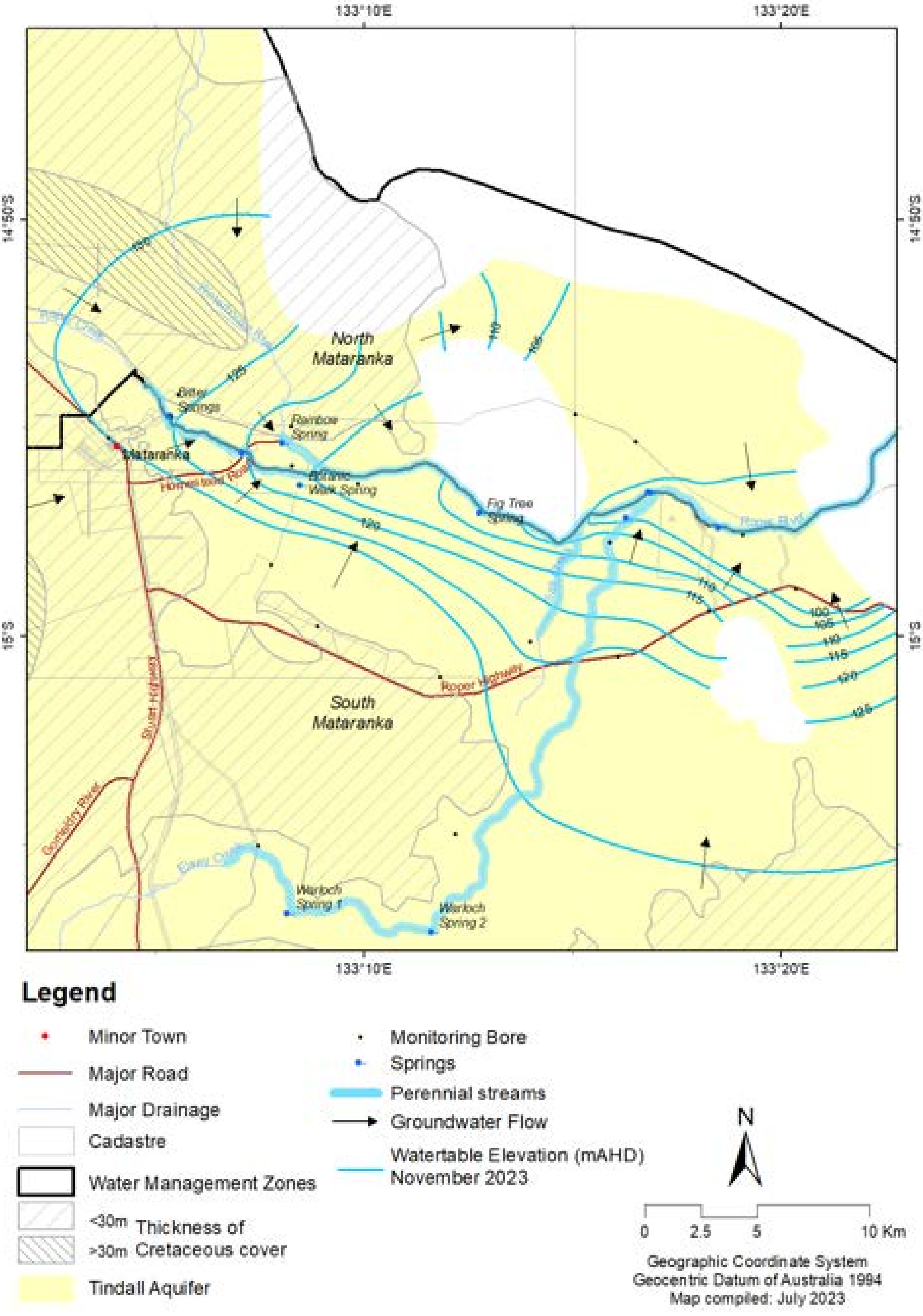
Schedule J. Hydrogeological provinces of plan area



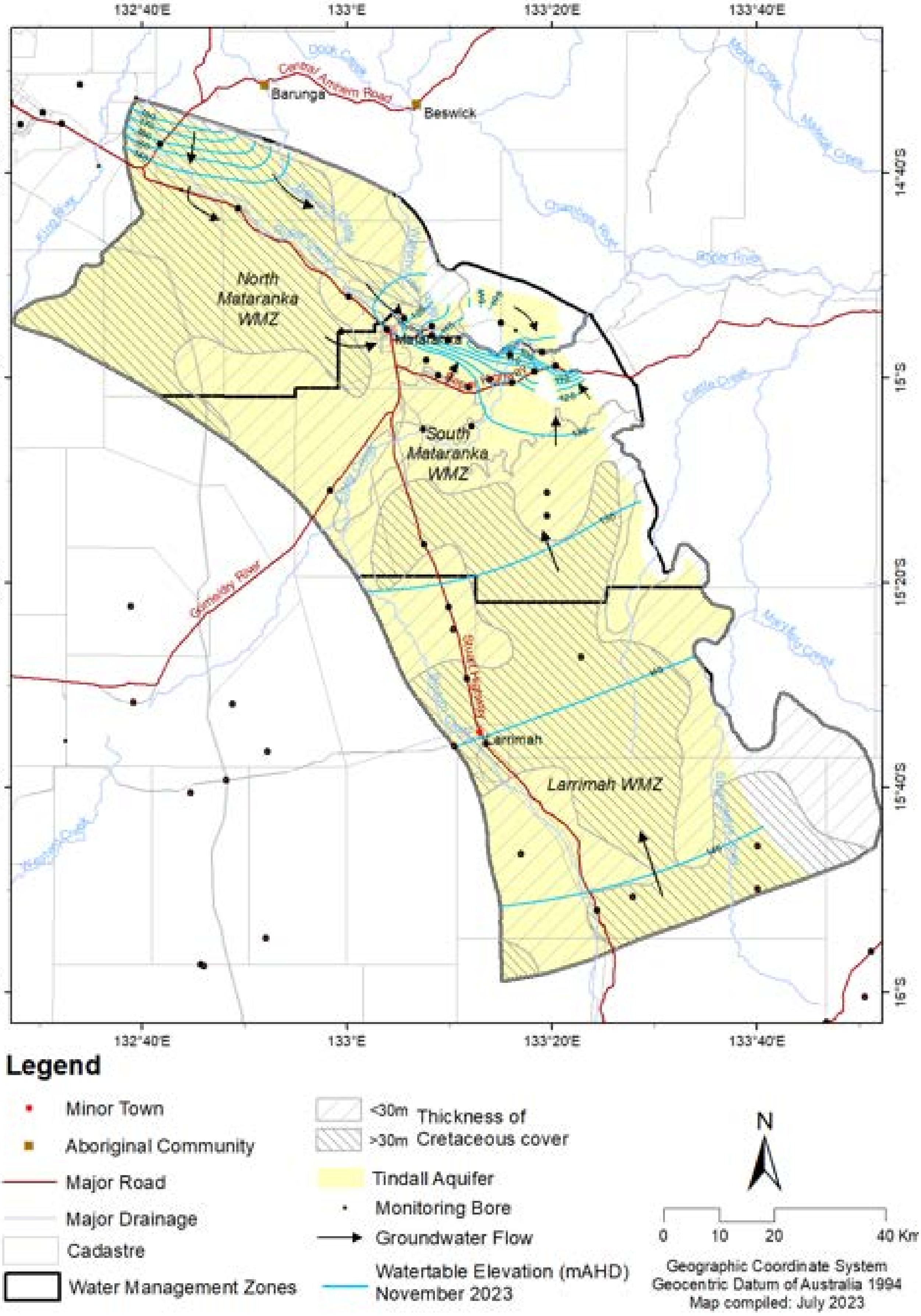
Schedule K. Aquifer recharge potential



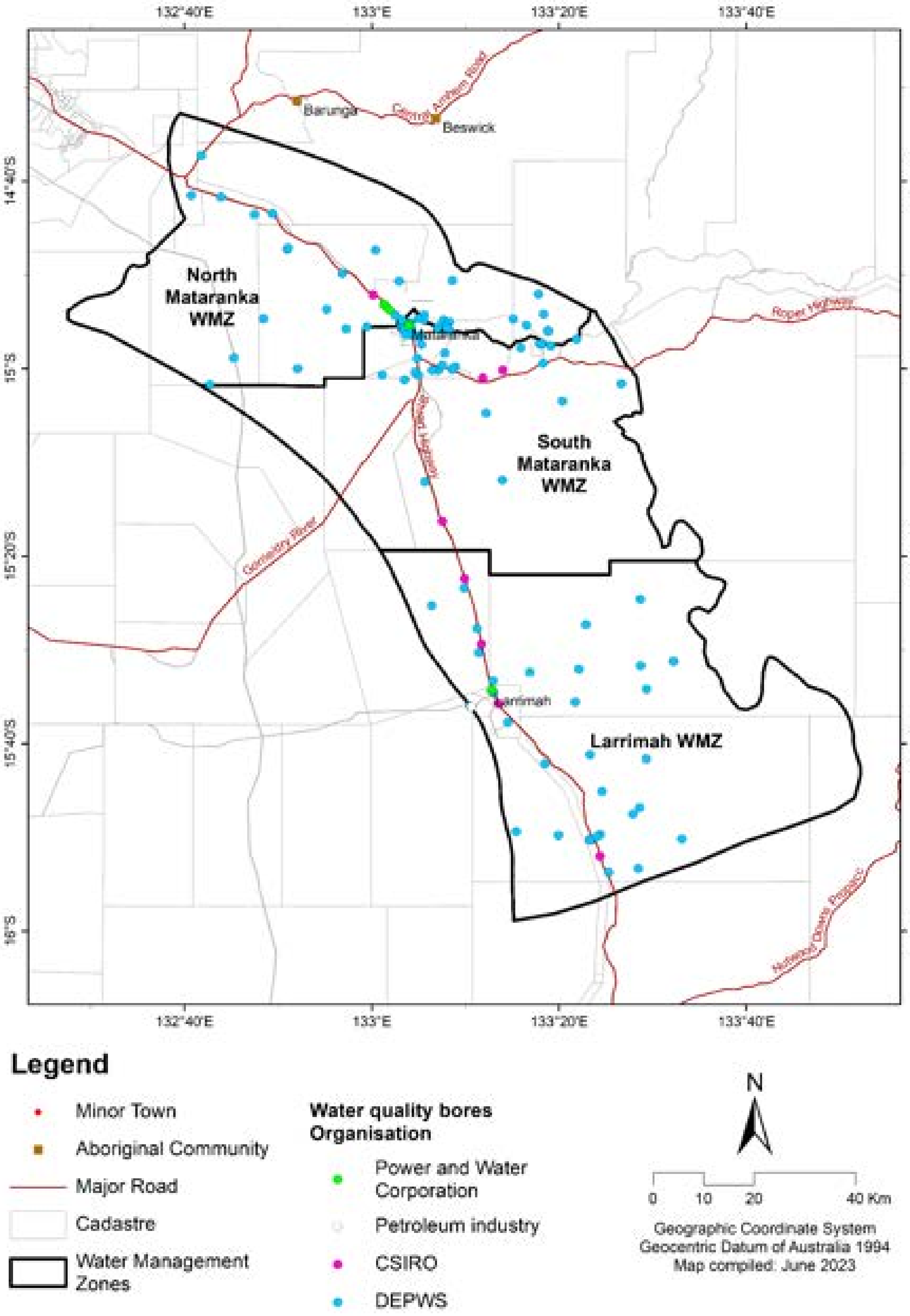
Schedule L. Springs and groundwater flow to streams



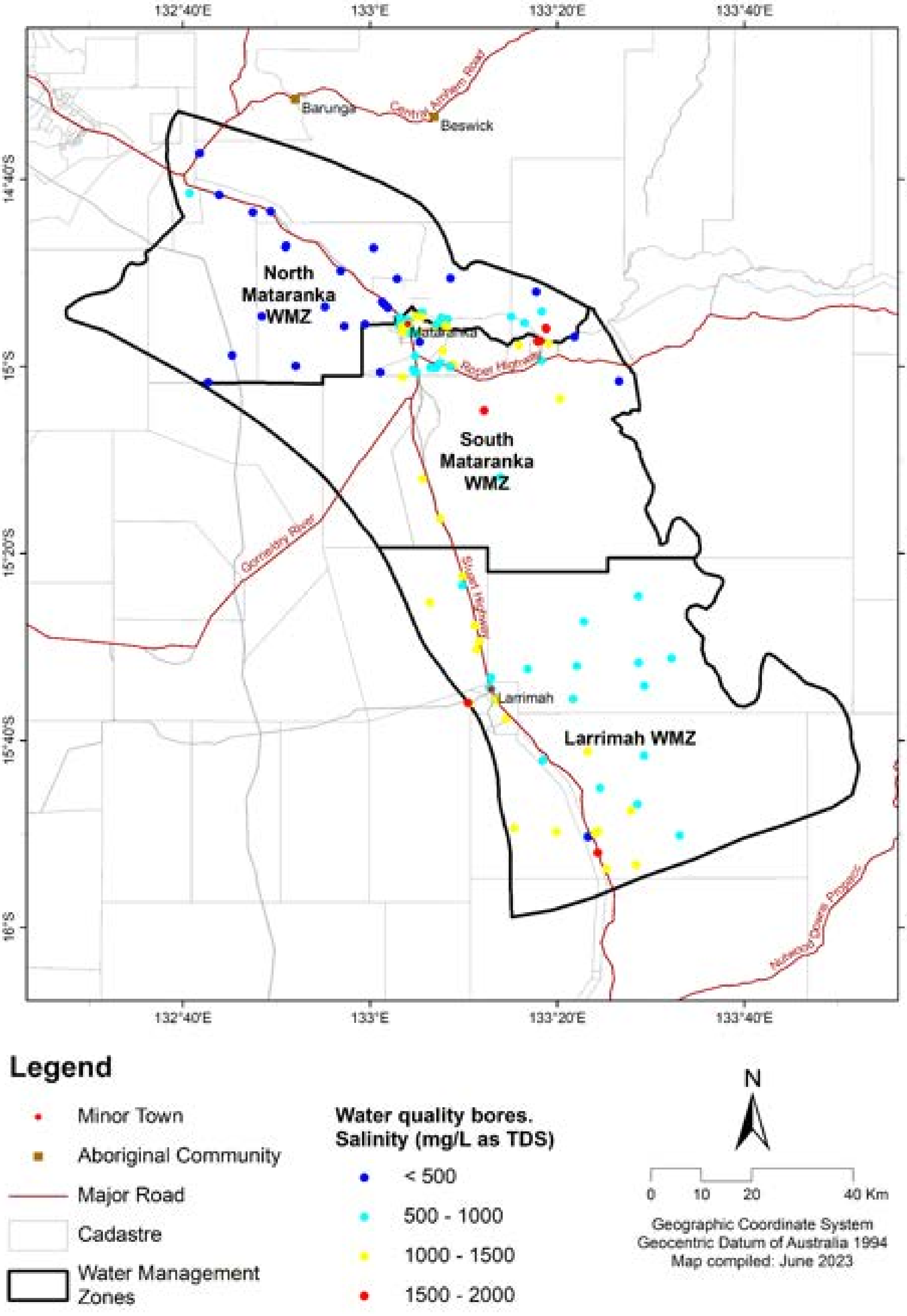
Schedule M. Groundwater elevation and flow direction



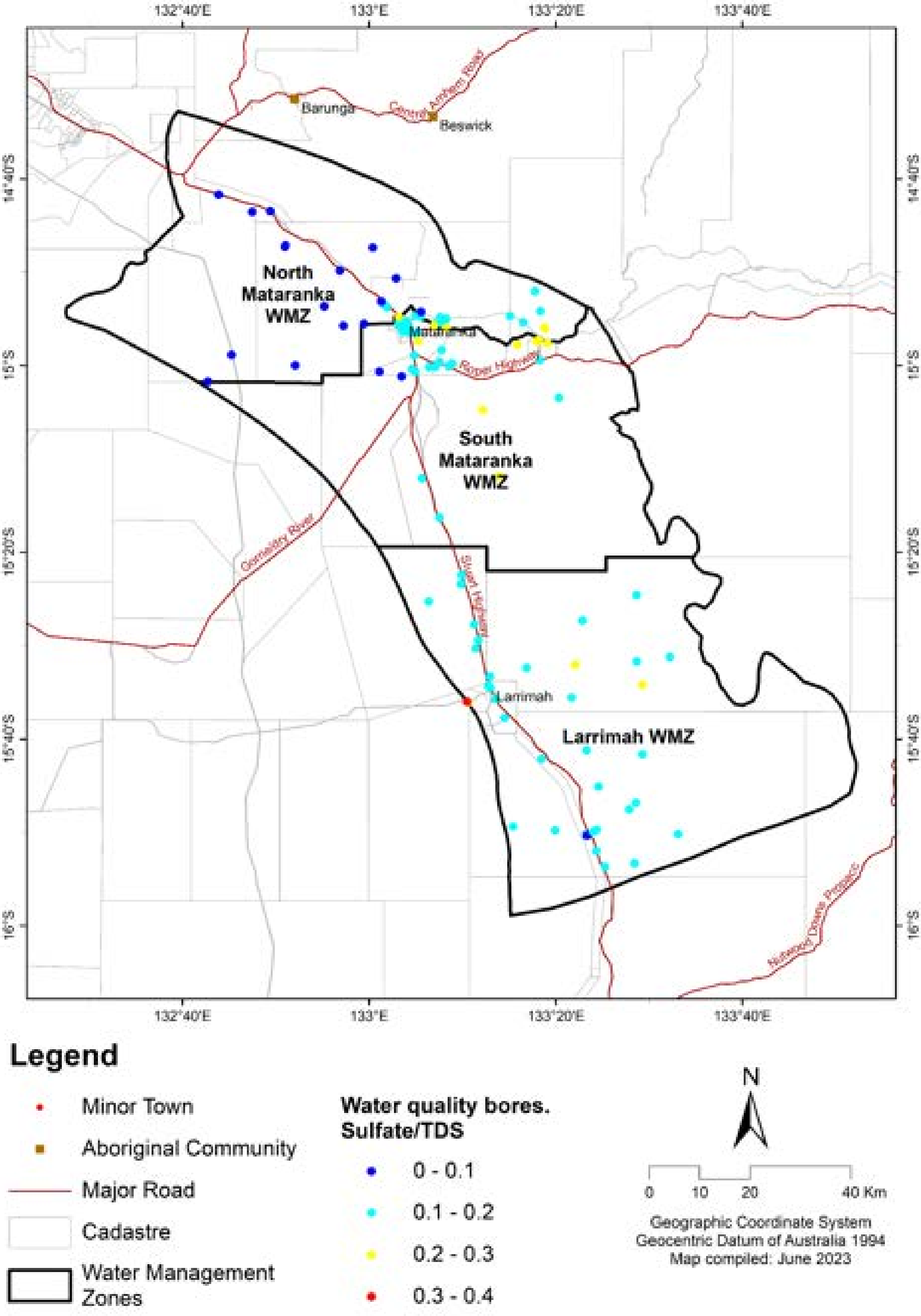
Schedule N. Water quality data locations



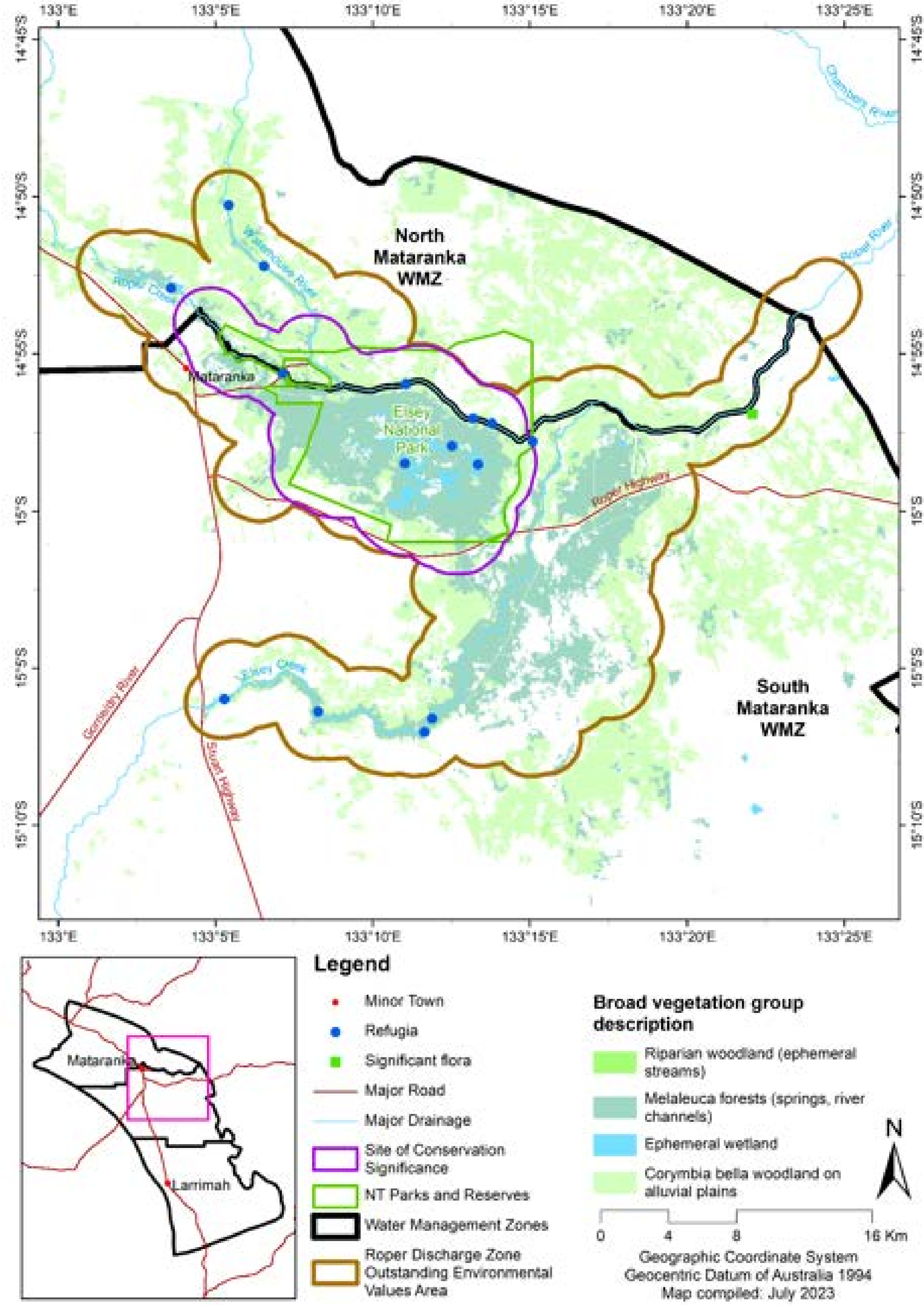
Schedule O. Groundwater salinity levels



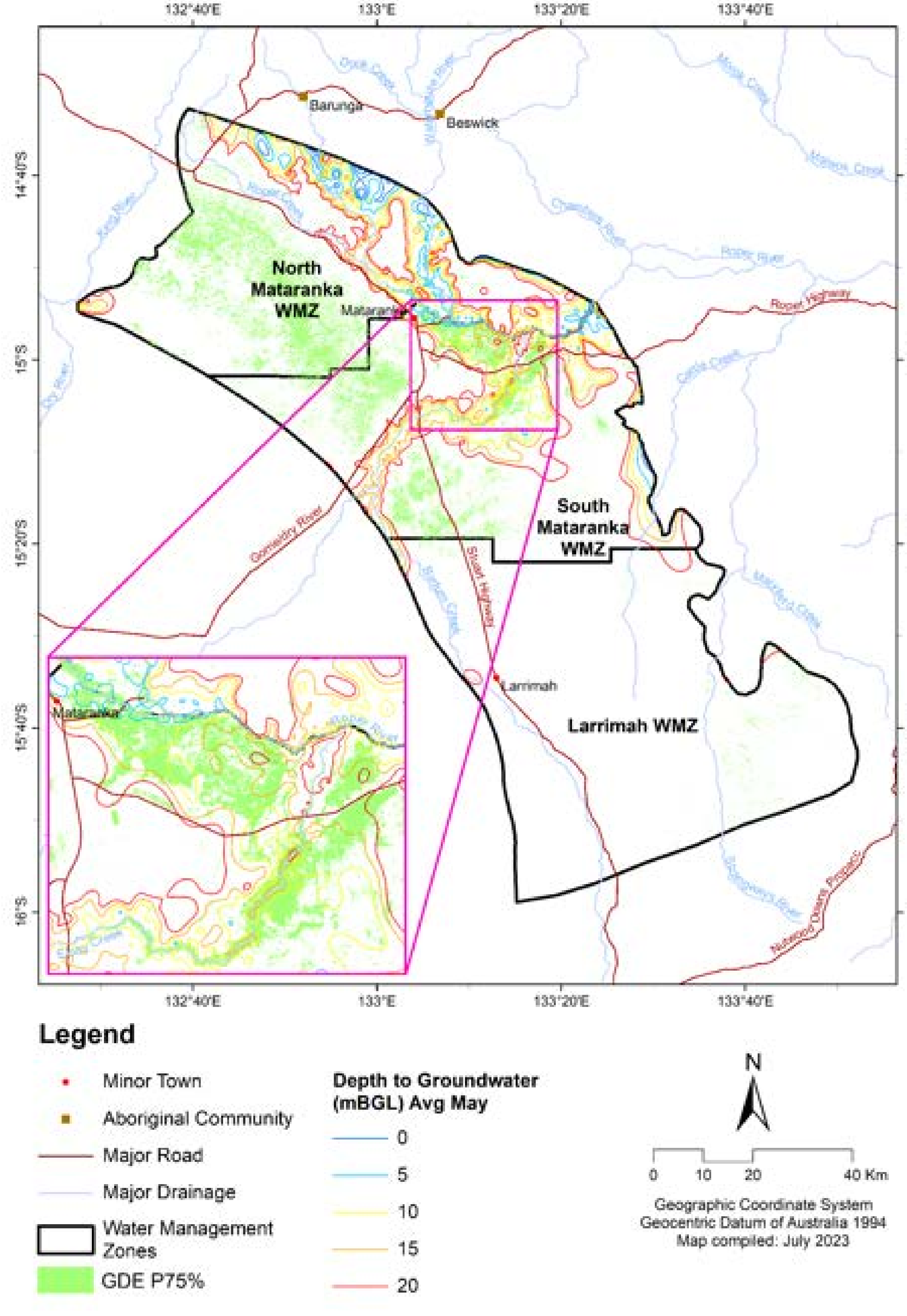
Schedule P. Groundwater sulphate levels



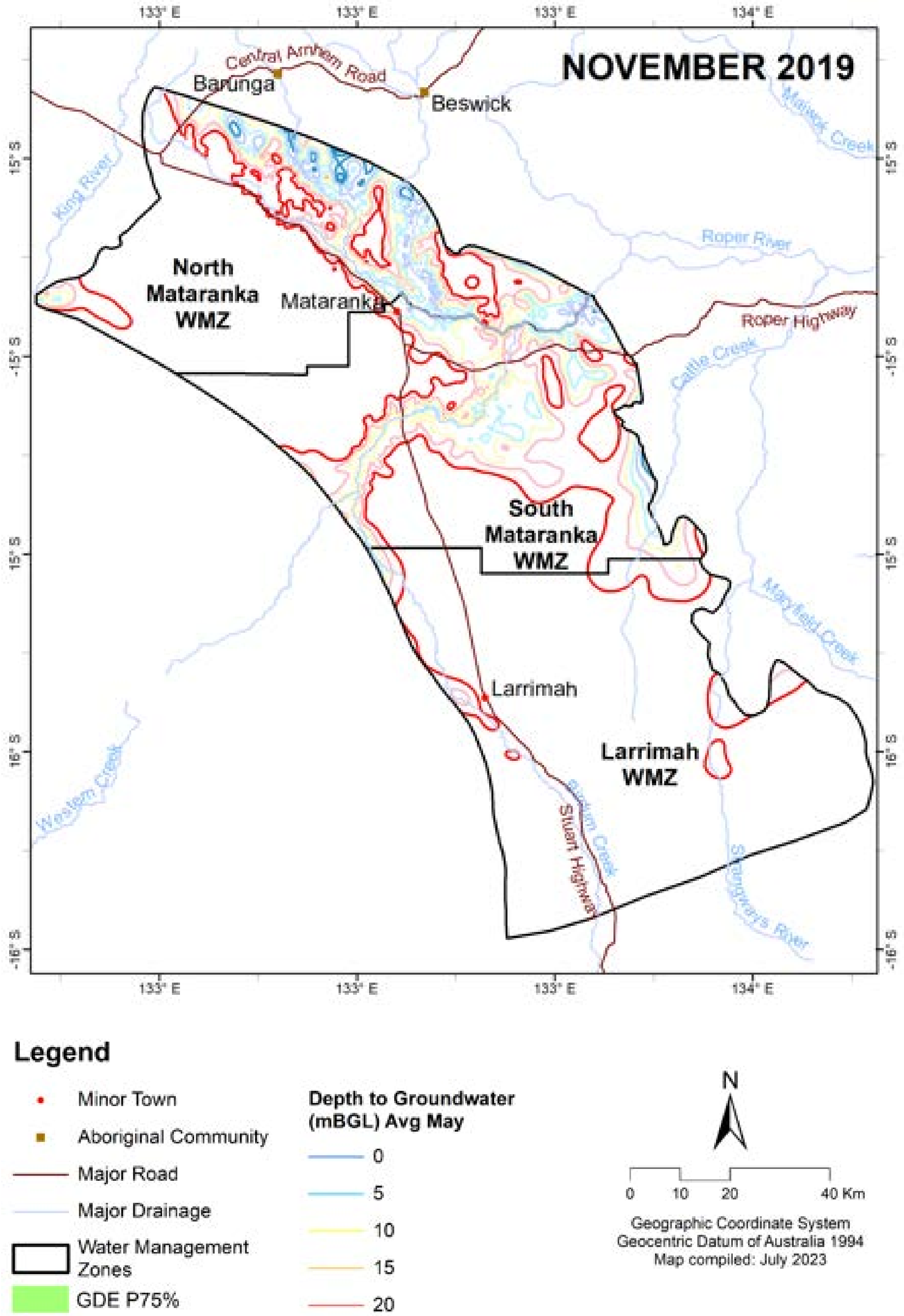
Schedule Q. Roper discharge zone



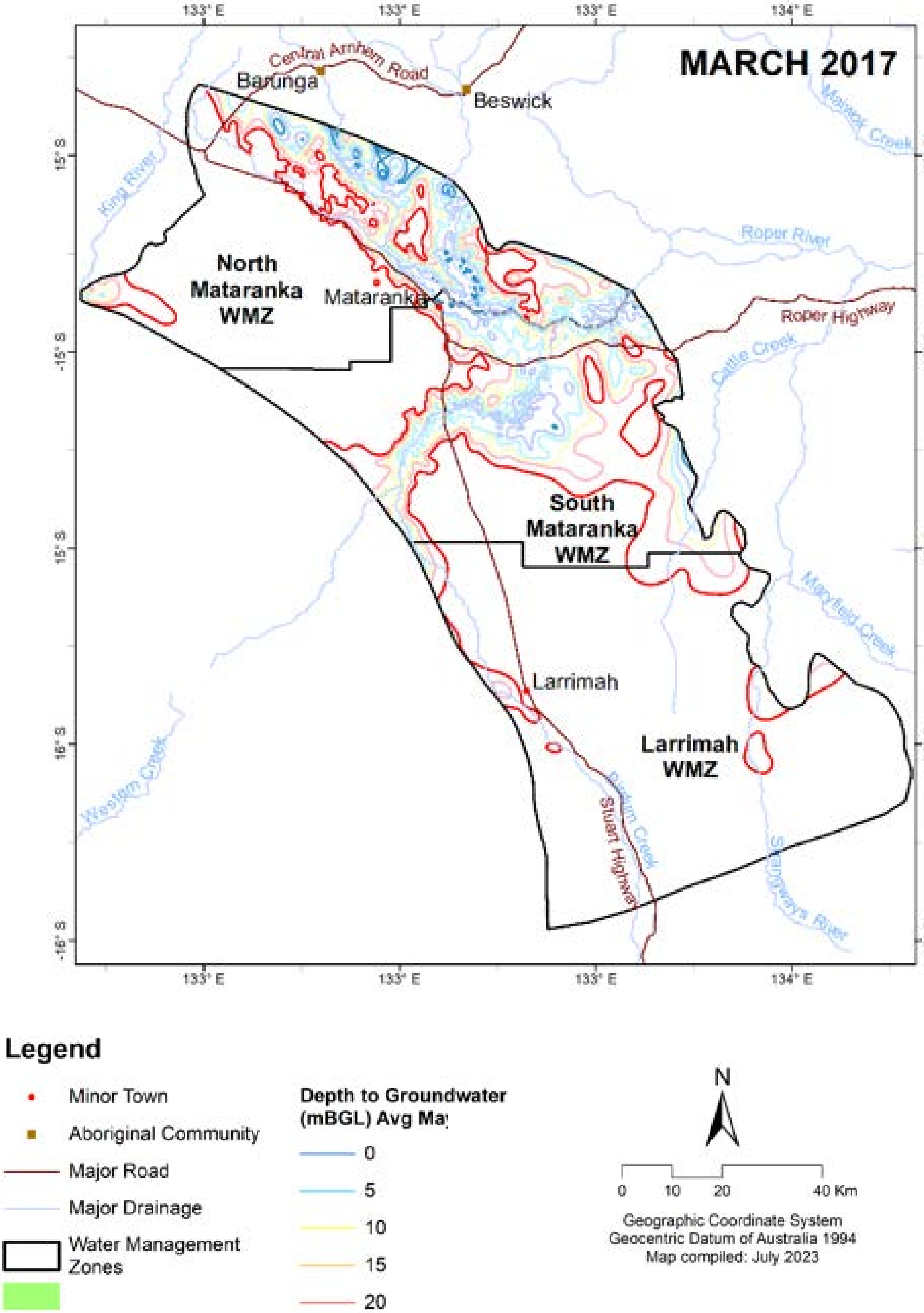
Schedule R. Terrestrial groundwater dependent ecosystems probability map



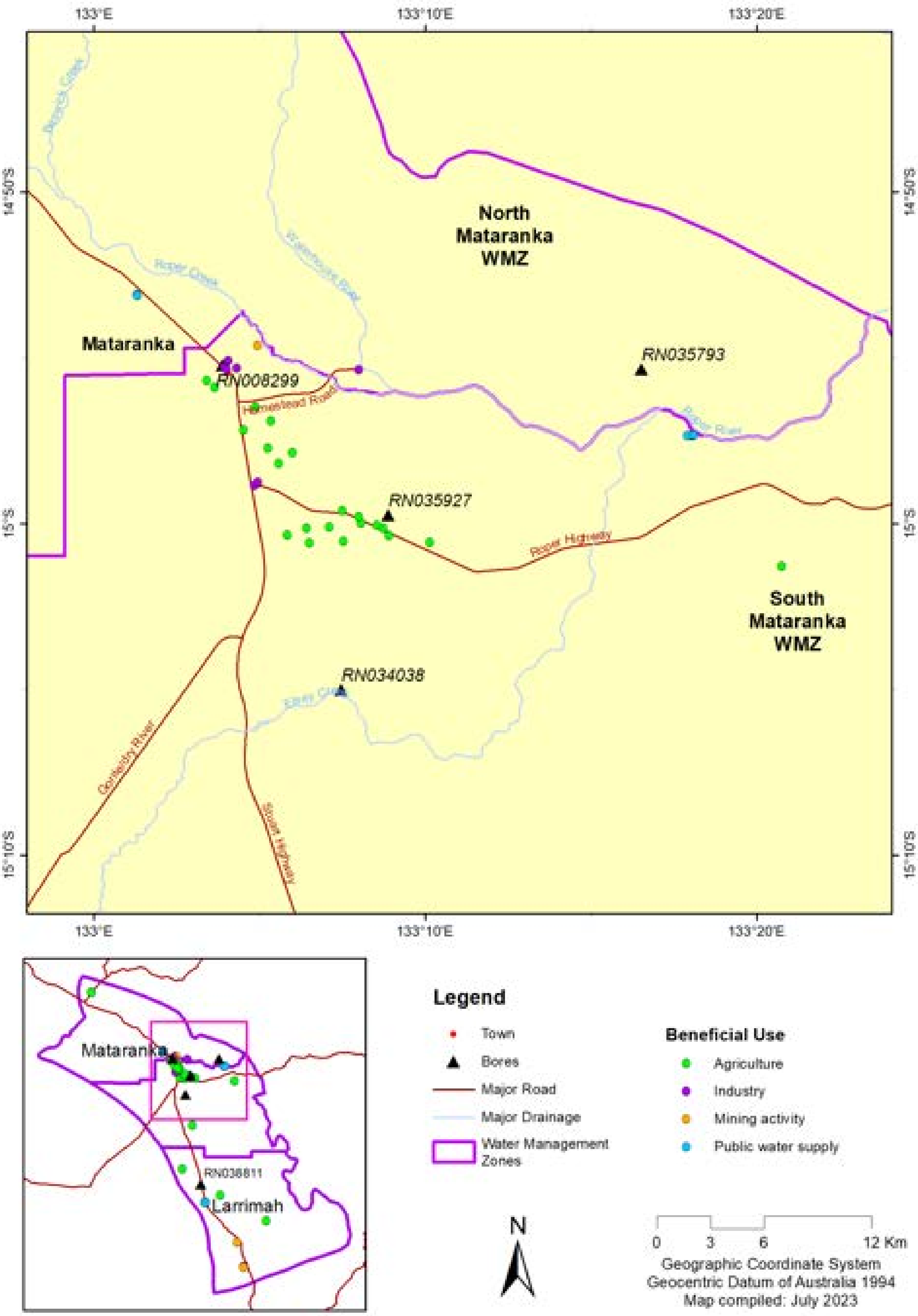
Schedule S. Dry season depth to groundwater



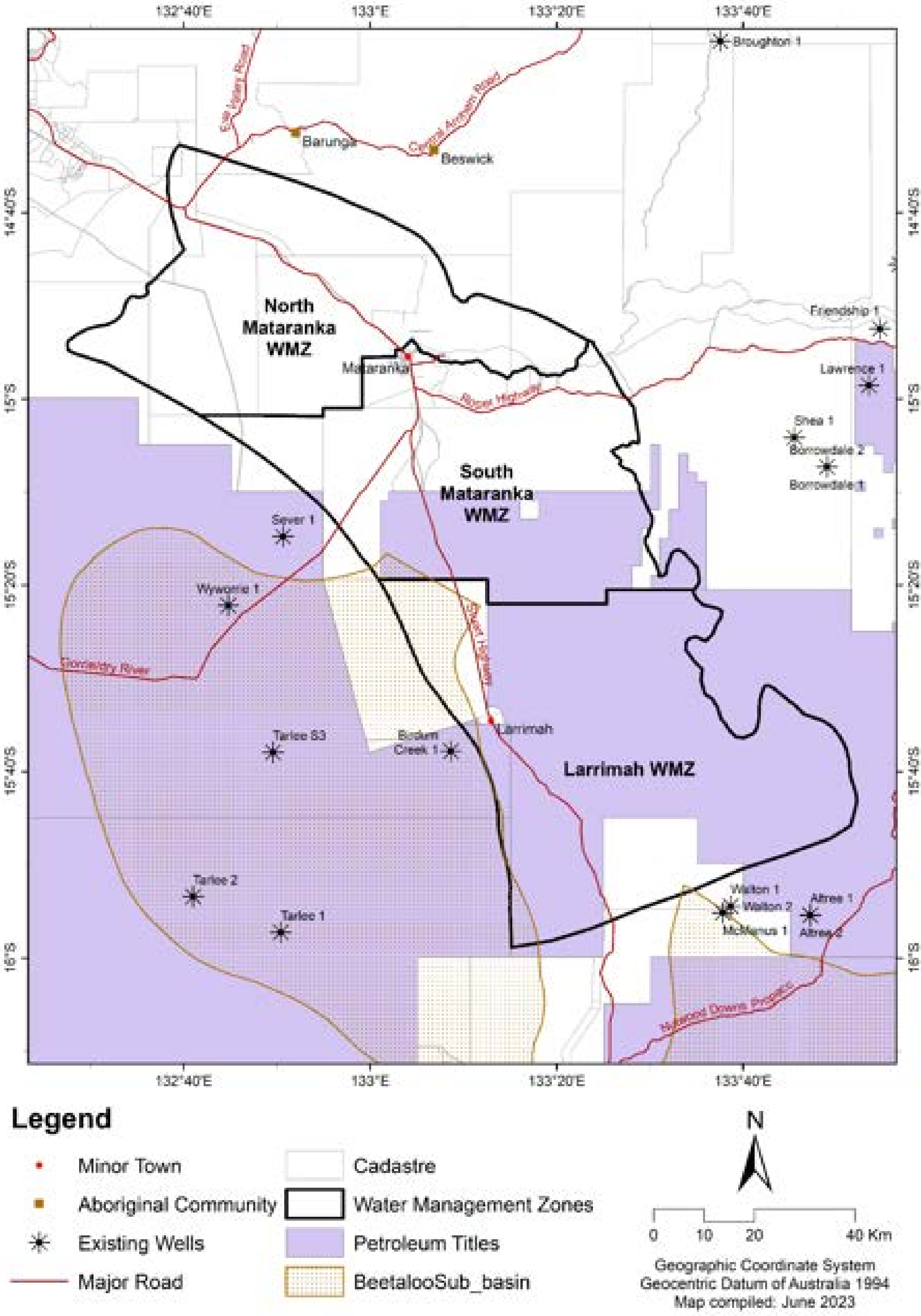
Schedule T. Wet season depth to groundwater



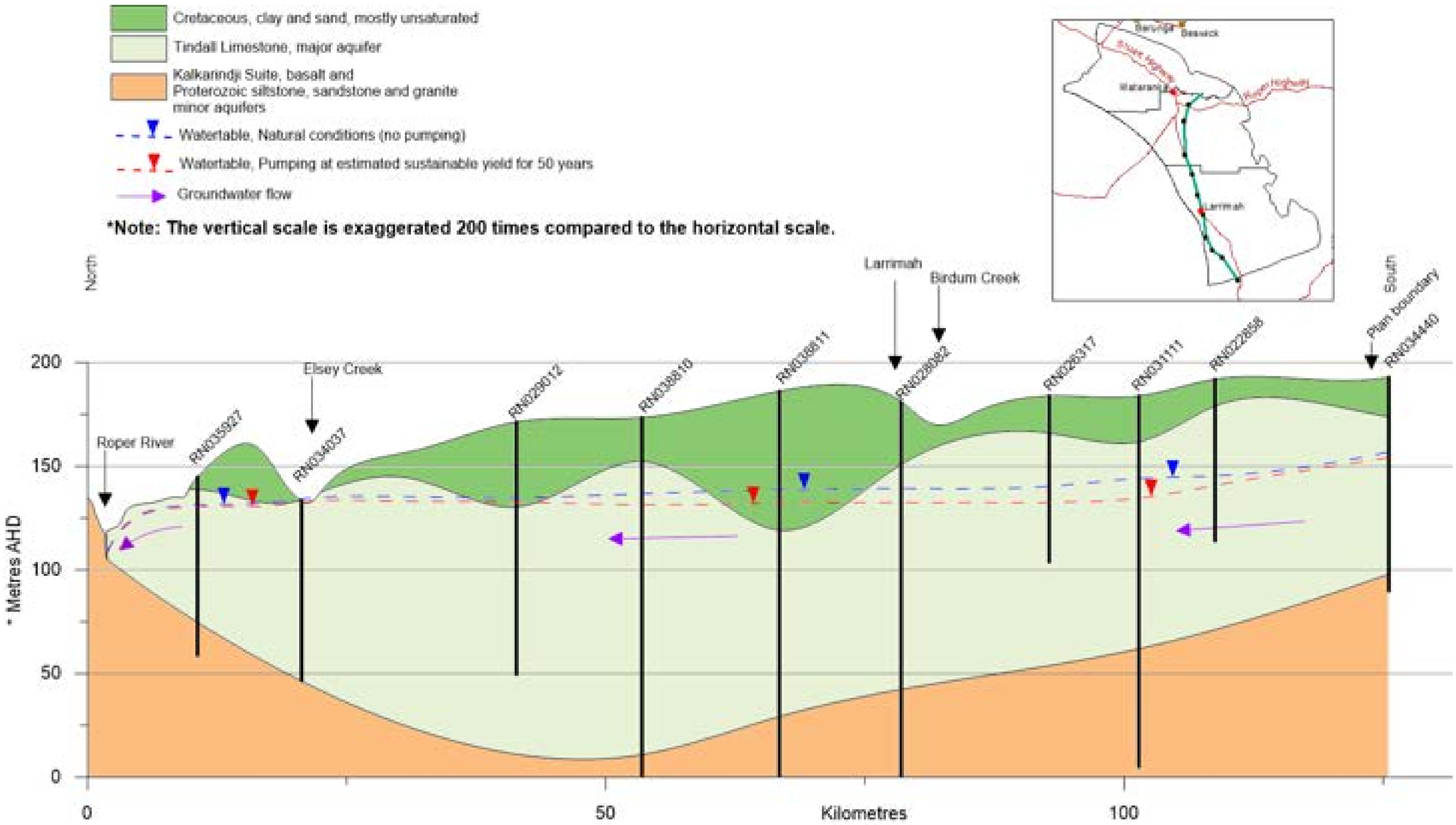
Schedule U. Licensed groundwater use



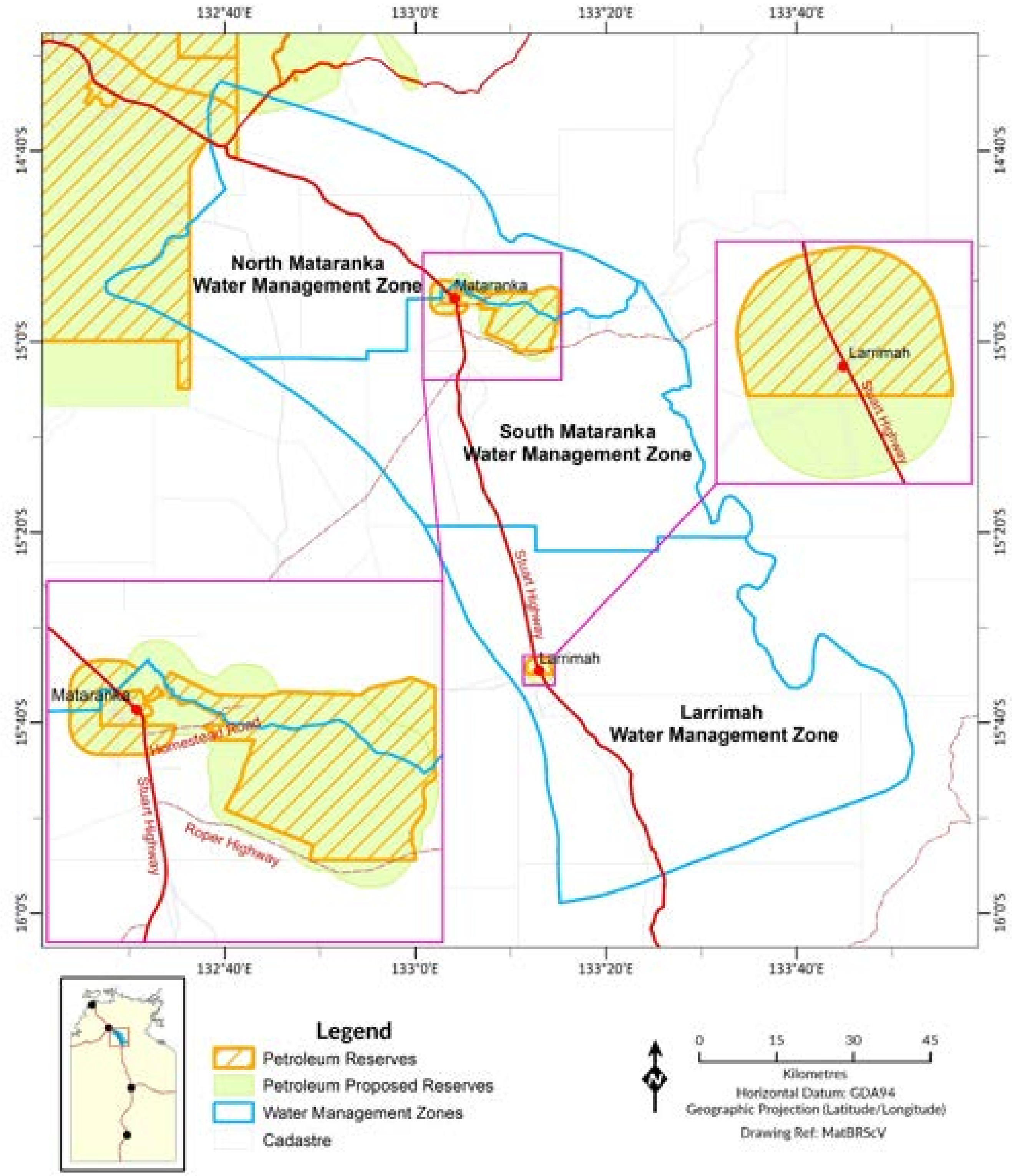
Schedule V. Petroleum titles



Schedule W. Impact of extraction



Schedule X. Reserved blocks



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