Groundwater resources of the East Kimberley – Tanami Minerals Province

Prepared by

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Department of Water

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DISCLAIMER: This report has been compiled in response to requests from the public for the previously unpublished Department of Environment report HR231 from 2004. Interpretations contained in this report are based on data up until 2003.

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Contents

Figures

1 Introduction

The East Kimberley – Tanami study area is located in the Kimberley Region of northern Western Australia and is defined by the boundaries of the Halls Creek Shire. The study area is sparsely populated with the town of Halls Creek (population of about 1500) servicing isolated aboriginal communities and pastoral stations. The Great Northern Highway is the only major sealed road in the study area with most access via unsealed roads and tracks ranging from well-graded to being in poor condition.

The East Kimberley – Tanami is under-explored for minerals and petroleum due to largely to its remoteness, poor infrastructure, difficulties with land access and limited geological information (ACIL Tasman, 2003). There are currently few operating mines, although some areas are considered highly prospective for gold (the Tanami), lead-zinc (the Lennard Shelf area), base metals and platinum-group minerals (north of Halls Creek) and diamonds along the northern boundary. The Canning Basin occupies the southwestern portion of the study area and is considered prospective for petroleum. All future mining developments and activities will be dependent on the availability of groundwater resources.

This report provides an overview of groundwater occurrence, evaluates potential for groundwater development by various industries, and identifies any significant knowledge gaps that will require additional investigations. The study addresses Recommendation 12 in the East Kimberley – Tanami Regional Minerals Study (ACIL Tasman, 2003) that states ‘State Government to undertake a review of water resources in the East Kimberley – Tanami to ensure adequate supplies for mining operations and other uses, including domestic supplies, and to foster sustainable use’.

2 Previous Investigations

The earliest reports on groundwater are related to mine water supplies in the Kimberley Goldfields around Halls Creek (Woodward, 1891; Maitland, 1908). The Geological Survey of Western Australia (GSWA) compiled various groundwater reports that detail the hydrogeology on individual pastoral stations throughout the East Kimberley (Ellis, 1954; Berliat, 1954, 1956; Morgan, 1963; Allen, 1966a). A bore and well inventory with a brief description of the hydrogeology is provided in the explanatory notes for the 1:250 000 geological map sheets prepared by GSWA.

Allen (1966b) described the regional hydrogeology of the Kimberley Plateau located in the northwestern portion of the study area. Passmore (1967) subsequently detailed the availability of groundwater resources for the pastoral industry throughout the Eastern Kimberley. The hydrogeology of the Canning Basin has been summarised by Laws (1990).

Most other groundwater reports are unpublished and detail investigations carried out to locate water supplies for pastoral leases, road construction, and town water supplies operated by the Water Corporation. There are also numerous reports of proposed groundwater investigations for locating water supplies at aboriginal communities throughout the area. A substantial amount of drilling during petroleum exploration has also been carried out in the eastern Canning Basin.

3 Physical environment

3.1 Climate

The climate is largely tropical monsoon comprising two distinct seasons ('the dry' and 'the wet'). The wet season occurs from December to April is characterised by heavy rainfall and high humidity. The average annual rainfall ranges from 600mm/yr in the north to less than 300mm/yr in southern areas. More than 90 per cent of annual rainfall occurs during this period related to intense tropical activity. In contrast, the dry season sees lower humidity with warm, sunny days and cool to mild, clear nights. The climate becomes less defined to the south of Halls Creek, where desert conditions are more prevalent.

3.2 Physiography

The East Kimberley – Tanami has some of the most varied and interesting topography in Western Australia with these variations closely related to geological diversity. The Kimberley Plateau is a broad, uplifted, dissected peneplain that is developed across the flat-lying rocks of the Kimberley Basin. The igneous and metamorphic rocks of the two mobile zones flanking the plateau, known as the Halls Creek Province, comprise a wide belt of rugged topography with rapid changes in elevation related to the metamorphic rocks that form strike ridges. In contrast, the southern part of the area forming part of the Sturt Plateau and Canning Basin is of flat to low-lying relief with isolated ranges of steeply dipping sediments or limestone reefs. The Granite-Tanami Province is also of low relief with frequent sand dunes and low rounded hills related to granite outcrops.

The headwaters and a number of tributaries of the Fitzroy, Ord and Pentecost Rivers, which are major drainage features, lie within the area. All drainages are ephemeral flowing only during the wet season, and for the rest of the year exist as lines of water holes. The course of most rivers is closely related to geological structure, particular in the upper reaches.

3.3 Geology

The wide geological diversity within the Kimberley Region creates problems in presenting a concise but systematic description of the regional geology. The study area is dominated by the Halls Creek Orogen, the Canning Basin, part of the Granites–Tanami Complex, and parts of the Speewah, Kimberley, Ord, and Birrindudu Basins (Fig. 1). There are more detailed descriptions of the regional geology and mineralisation in the Kimberley region provided by Griffin and Grey (1990), Plumb (1990), Hassan (2000) and Tyler et al. (*in prep*).

The East Kimberley – Tanami area covers most of the Halls Creek Orogen. The orogen, or mobile zone, is a major tectonic belt that has been affected by metamorphism and

abundant plutonic intrusions. The main rock types are metamorphosed sedimentary, volcanic, granitoid and gabbroic rocks, including layered mafic-ultramafic intrusives. The Halls Creek Orogen represents a plate margin setting between the Kimberley Craton to the northwest, concealed beneath the Kimberley Basin, and a composite North Australian Craton to the southwest comprising the Granites–Tanami Complex.

There are a number of Palaeoproterozoic basins (Speewah and Kimberley Basin) that unconformably overlie parts of the Halls Creek Orogen, comprising metasedimentary rocks of sandstone, siltstone, shale and minor basic volcanics.

The Granites - Tanami Complex comprises metamorphosed sedimentary and mafic rocks of Archaean to Palaeoproterozoic age that host a number of recent gold discoveries. The complex is probably a continuation of the Halls Creek Orogen (Plumb, 1990) and can be correlated with the host rocks of the large gold deposits in the Tanami Region of the Northern Territory.

The Birrindudu Basin is positioned between the Halls Creek Orogen and the Granites - Tanami Complex. It consists of gently dipping Proterozoic sedimentary rocks that are predominantly sandstone with minor limestone, siltstone and shale.

The Ord Basin comprises mafic volcanic rock related to the Antrim Plateau Volcanics, a variety of sedimentary rocks including sandstone and limestones forming the Goose Hole Group, and sandstone and conglomerates of the Devonian Mahony Group.

The Canning Basin, a large multi-layered sedimentary basin, overlaps eastward onto the Birrindudu Basin and northward onto the Halls Creek Orogen. The basin comprises interbedded sandstone, shale and siltstone of Carboniferous-Permian to Triassic age. Devonian limestone on the Lennard Shelf is positioned along the western boundary of the study area.

A veneer of unconsolidated or partly consolidated sediments including sand, silt, calcrete and silcrete of Tertiary and Quaternary age cover large parts of the Birrindudu and Canning Basins in the south, and is locally developed in the vicinity of rivers and creeks in the remainder of the area.

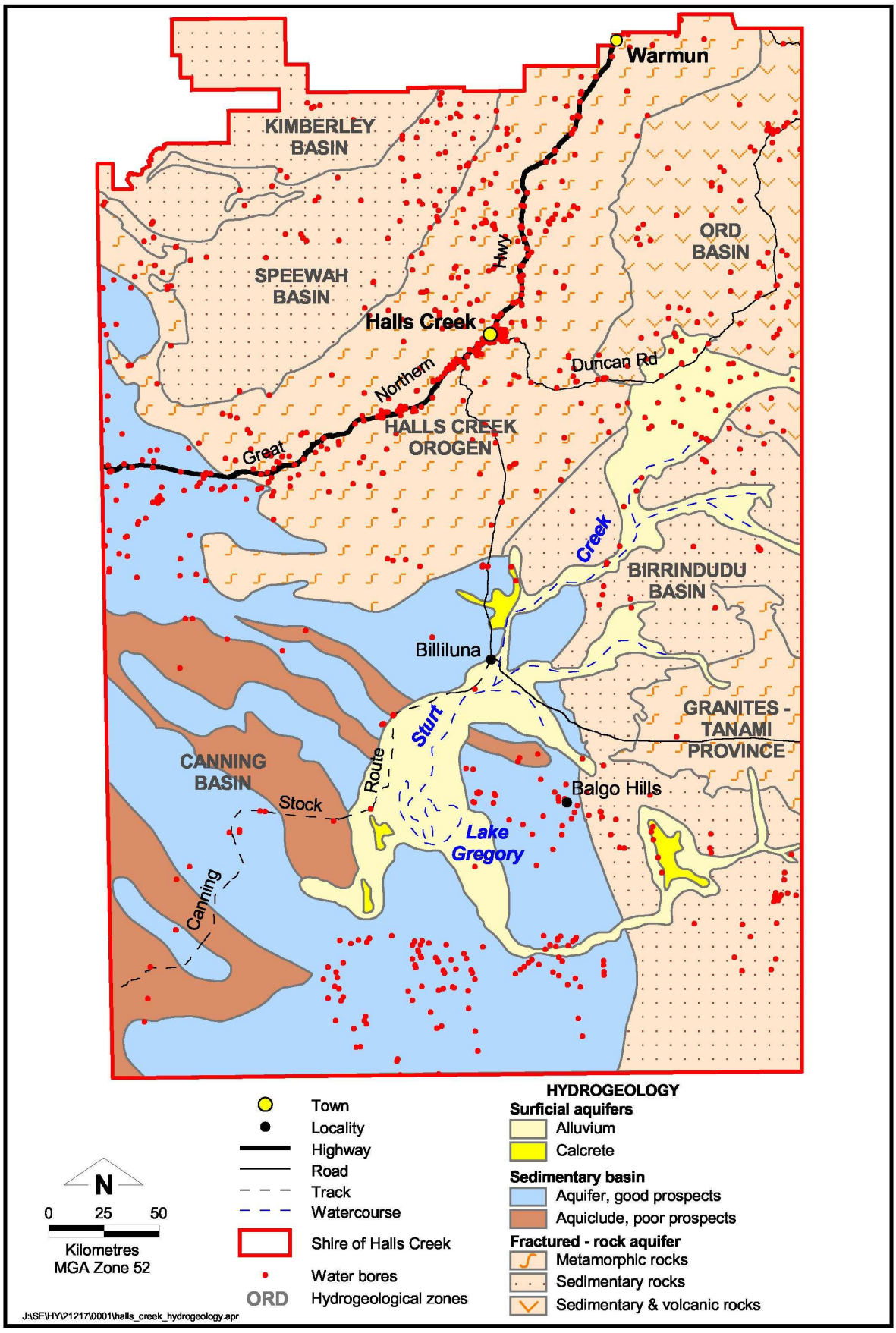

Figure 1. Regional hydrogeology of the East Kimberley – Tanami study area.

4 Hydrogeology

4.1 Source of data

In addition to the published sources of geological and groundwater information, a number of unpublished reports held by Department of Water related to aboriginal community, mine and town water supplies in the East Kimberley were consulted. Other sources of information included GSWA town water supply investigations, Water Corporation groundwater scheme reviews, and bore data stored in the Department of Water's information database (WIN).

4.2 Occurrence of groundwater

Groundwater occurs throughout the study area. It may occur within sparse fractures in the basement rocks; within fractures and secondary porosity produced by chemical alteration in the weathering profile; within karstic features developed in calcrete; and within primary porosity in alluvial and eolian deposits. The most significant aquifers are within sedimentary basins occurring as discrete formations of sandstone or limestone.

The groundwater flow systems throughout the area are maintained by rainfall recharge. Groundwater recharge is difficult to estimate as it constitutes a very small proportion of rainfall, most of which is either directly evaporated or utilised by the native vegetation, with a small component of runoff into rivers, claypans and lakes. Most recharge is likely to occur during heavy rainfall (ie; the wet season) when it is enhanced by recharge from surface runoff and local flooding. Groundwater discharge is dominated by evaporation.

Groundwater in the Canning Basin is essentially 'fossil water' that cannot be replenished in the time scale of human groundwater management. It is most likely that recharge into this aquifer system may only result from major flooding on a recurrence interval of decades or centuries. The current rate of recharge is therefore largely irrelevant, in terms of managing groundwater in the arid zone.

4.3 Main aquifers

The location of large groundwater supplies, irrespective of salinity, is dependent on the presence of suitable groundwater-yielding rock types and site-specific geological conditions, such as the presence of fractures or shear zones. The hydrogeology is described in the broad tectonic units of the East Kimberley – Tanami area is shown in Figure 1.

4.3.1 Alluvium

Alluvium comprising sand, silt and pebbles occurs within many of the drainage lines. The saturated thickness is highly variable, which affects its potential as a reliable long-term aquifer. In most cases, the alluvium is thin (less than 5m), although where thick

sections are encountered it may yield good supplies (up to 100kL/day) of low salinity groundwater. In the southern portion, there are large areas of alluvium related to Sturt Creek but there is little known about the groundwater conditions. Although, it is considered that the alluvium would be sufficiently thick to obtain a water supply but groundwater would be probably brackish to saline (greater than 3000mg/L).

4.3.2 Calcrete

Calcrete is a carbonate rock formed by the *in situ* replacement of valley-fill debris by magnesium and calcium carbonate precipitated from percolating carbonate-saturated groundwater (Mann and Horwitz, 1979). Bodies of calcrete occur within the Sturt Creek drainage line and extend over areas of 1 km^2 to over 100 km^2, such as east of Balgo Mission. In the study area, there are few bores into the calcrete and consequently there is little known about groundwater quality and supply. Calcrete is the main aquifer supplying the Tanami mining centre in the Northern Territory (Domahidy, 1990). In other parts of arid Western Australia, calcrete is a highly prospective aquifer with large bore yields in excess of 1000 kL/day; however, it often contains brackish groundwater due to its low position in the groundwater flow system.

4.3.3 Canning Basin

Groundwater may be readily obtained from sandstone aquifers in the Canning Basin. The Canning Basin dominates the southwestern portion of the study area. The most prospective aquifers in the study area include the Triassic Erskine Sandstone within the Gregory sub-basin, the Poole Sandstone and Grant Group of Permian age, and the Devonian Knobby Sandstone. Both the quantity and quality of groundwater can be variable ranging from potable to saline, and yielding less than 100kL/day to more than 2000kL/day. The sandstone aquifers have been utilised for oil exploration camps and aboriginal communities. Laws (1990) provided a regional description of the hydrogeology of the entire Canning Basin. Area of Blina Shale and Noonkanbah Formation are considered unprospective themselves, but are underlain by regional aquifers.

Erskine Sandstone

The Erskine Sandstone comprises sandstone and shales of Triassic age, and is restricted to the Gregory sub-basin. It is partly confined, and is recharged where it crops out or subcrops beneath Quaternary deposits. The formation is poorly utilised in the study area; however, it is considered a highly prospective aquifer for providing large supplies of low salinity groundwater. Elsewhere, it is the main aquifer that supplies Derby.

Poole Sandstone

The Poole Sandstone has been widely explored and developed for aboriginal water supplies, particularly at Balgo community. The locating of water supplies is site-specific and is dependent on intersecting thick sections of sandy material. The water quality is variable and stratified with potable groundwater (500-1000mg/L) present in sandy

sections and in the vicinity of recharge areas, whereas silt and clay beds typically contain brackish to saline groundwater (exceeding 2500mg/L). Appropriate bore construction (fine aperture screens and gravel pack) is important in these formations, as clogging problems due to siltation are common (R. Nixon, Global Groundwater, Pers. Comm., 2004).

Grant Group

The Grant Group comprises sandstone and shales of Permian age, and occupies the most northerly portion of the Canning Basin. The aquifer is under-utilised in the study area; however, it is considered to have potential for provide large supplies of groundwater. Elsewhere, the Grant Group is the main aquifer utilised for the Ellendale Diamond Operation that is located to the west of the study area.

Knobby Sandstone

The Devonian Knobby Sandstone crops out on the Billiluna Shelf and underlies part of the Gregory Sub-basin. In areas of outcrop, where unconfined, yields of greater than 200kL/day of potable water (less than 500 mg/L) have been obtained. Laws (1990) noted that the salinity increases rapidly with progressive increasing depth (greater than 15 000mg/L). The aquifer is under-utilised in the study area; however, it has potential for provide large supplies of groundwater.

4.3.4 Birrindudu Basin

Proterozoic sediments of the Birrindudu Basin, particularly beds of sandstone, may yield small supplies of variable quality water. Laws (1990) noted that bores positioned on fracture zones within the sandstones have an increased likelihood of encountering larger supplies of groundwater.

4.3.5 Ord Basin

The Antrim Plateau Volcanics and sediments of the Goose Hole Group constitute fractured-rock aquifers with groundwater present within highly localised fracture and joint structures. The more successful bores in these aquifers are often positioned near drainage lines, where associated with shallow depth to groundwater and bore yields of up to 500 kL/day. The Devonian Mahony Group comprises sandstone and conglomerates that may form a potential sedimentary aquifer; however, there have been few bores drilled to date as it occurs largely within the Purnululu National Park.

4.3.6 Speewah and Kimberley Basins

The Speewah and Kimberley Basins contain a variety of metasedimentary and volcanic rocks that may form localised fractured-rock aquifers, based on the limited groundwater information available. There is potential for moderate groundwater supplies from fracture and joint structures with bore yields of up to 200kL/day.

The Hart Dolerite forms massive sills within these metamorphosed sequences and has been more frequently drilled, as it weathers to produce overlying, fertile black soils.

Allen (1965) noted the dolerite is an important local aquifer that is sufficiently well jointed to yield supplies of up to 100kL/day from depths of about 6 to 10m below ground level. Groundwater salinity is variable ranging between 300 and 1500mg/L.

4.3.7 Granites – Tanami Complex

The Granites – Tanami Complex comprises metamorphosed sedimentary and mafic rocks that are lateritised, weathered and largely concealed beneath aeolian sand dunes. There is little data on the groundwater conditions in these rocks. It is considered that groundwater may be obtained from localised sections within the weathering profile, and open joints and fractures in the fresh bedrock. Bore yields from the weathering profile would be small, although larger supplies may be obtained from structural features.

4.3.8 Halls Creek Orogen

The metamorphosed sedimentary, volcanic, granitoid and gabbroic rocks of the Halls Creek Orogen have been variably faulted and fractured. These rocks are largely unweathered except for localised, thin weathering profiles developed on granite rocks to the southwest of Halls Creek; hence, groundwater occurrence is generally related to the presence of fracture systems. Allen (1965) noted that metasedimentary and granitoid rocks constitute better aquifers, compared to volcanic rocks that have fractures often full of clay.

The Halls Creek Orogen is considered a difficult terrain for locating large, reliable groundwater supplies due to the lack of weathering profile and infrequency of water-bearing structures. Allen (1965) stated that there were two abandoned sites for every successful, operating bore because of drilling difficulties or insufficient supply. The more successful bores are positioned within fracture systems, in particular where overlain by alluvial deposits and/or drainage lines. The town supply for Halls Creek is supplied from fractured-rock aquifers within the King Leopold Sandstone.

5 Groundwater development

5.1 Public water supplies

The water supply for Halls Creek and most aboriginal communities in the East Kimberley – Tanami area is sourced from groundwater resources. The Halls Creek borefield, operated by the Water Corporation, has an allocation of 700ML/yr with an annual abstraction of about 400ML/yr (Water Corporation, 1999). The borefield comprises 15 production bores that yield up to 300kL/day from localised joints and fractures within the King Leopold Sandstone. Parts of the aquifer are showing signs of depletion; however, it is proposed to install new, deeper production bores into the King Leopold Sandstone. Groundwater salinity across the borefield ranges from 500 to 750mg/L.

There has been widespread exploration and development of groundwater resources to meet the potable water requirements of aboriginal communities throughout the study area. Water supplies have proven difficult to locate in areas to the north of Halls Creek; however, localised fractured-rock aquifers of the Halls Creek Orogen have been utilised. Whereas in the southern areas, aboriginal communities obtain groundwater from a variety of aquifers ranging from shallow surficial deposits (alluvium and calcrete) through to deep sedimentary aquifers (particularly sandstone) within the Canning Basin.

5.2 Stock water supplies

The pastoral industry is reliant on surface water held in riverine pools to meet stock water requirements. In areas away from drainage features, bores and wells (about 200 in total) have been constructed to supplement surface water supplies. The relatively small number of bores and wells reflects the abundance of surface water, as well as the rugged topography that is considered poor pastoral country.

Most bores and wells used by the pastoral industry are less than 50m deep. The Hart Dolerite, Carson Volcanics and Antrim Plateau Volcanic are the most widely explored and utilised aquifers, which is mainly because these rock types are overlain by residual black soil plains that are ideally suited for holding stock. Many exploratory sites were abandoned due to drilling problems related to rock hardness or inadequate supplies. Unlike other parts of the State, groundwater salinity is not an issue for the pastoral industry in the Kimberley.

5.3 Mining water supplies

The Sally Malay nickel mine is the only mining operation with a current groundwater license. The annual groundwater allocation of 1.44GL/year is used for mineral processing, dust suppression and domestic purposes. In addition to groundwater

abstraction, surface water is abstracted during periods of river flooding and contributes to the total water requirements at Sally Malay. The production bores are positioned in fractured granitoids and gabbroic rocks of the Halls Creek Orogen (Tickalara Metamorphics and Sally Malay Intrusive), where aquifer potential is associated with structural and secondary weathering features. Bore yields are up to 250kL/day and groundwater salinity being about 500mg/L.

The majority of current and future mining projects in the study area occur within the Halls Creek Orogen, as such their water demands will be sourced from localised fractured-rock aquifers. The proposed projects in the Granites – Tanami Complex will probably utilise groundwater from either site-specific weathering profiles, water-bearing structural features or possibly from alluvium/calcrete. It is highly probably that considerable efforts will be required by mining companies to identify reliable, large groundwater supplies in these fractured-rock aquifers. In those mining operations near the Canning Basin, it may be more cost-effective to consider developing groundwater supplies from the sedimentary aquifers.

A substantial amount of drilling during petroleum exploration has been carried out in the eastern Canning Basin. Water supplies for exploration camps and drilling purposes are readily available, although the location of larger supplies can be site-specific.

6 Conclusions

The most reliable, low salinity groundwater resources occur within the Canning Basin, which dominates the southern portion of the East Kimberley – Tanami study area. The resource is essentially unutilised, except for providing potable water for a number of remote aboriginal communities. There is considerable scope for increasing groundwater abstraction from the Canning Basin.

There are generally adequate groundwater resources available for utilisation by the mining industry through the area. Sally Malay nickel mine is the only active groundwater user with a borefield abstracting from the fractured-rock aquifer. It is most likely that most future mining operations will utilise fractured-rock aquifers due to the large distances from the Canning Basin. Although, the identification of a reliable, large groundwater supply in fractured-rock aquifers may require considerable effort.

Surface water is the preferred source for stock watering; however, bores and wells have been developed in black soil plains. The town water supply at Halls Creek abstracts groundwater from the local fractured-rock aquifer. Aboriginal communities throughout the East Kimberley – Tanami utilise groundwater from fractured-rock aquifers in the north and the Canning Basin in the south to meet their potable water requirements. There are no major concerns with the adequate provision of potable water from groundwater sources for aboriginal community or town water supplies. Salinity is generally fresh, although saline groundwater is anticipated near Lake Gregory.

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