Government of **Western Australia**
Department of **Water**

Looking after all our water needs

Groundwater resource review

Dampier Peninsula

Hydrogeological record series

Report no. HG57
March 2012

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Summary

This report is the first review of the groundwater resources of the Dampier Peninsula in the Kimberley region of north-west Western Australia. It provides a summary of available data and an assessment of the current status of the resources. The report is intended to guide and support future allocation planning for the region, support licensing decision making in the interim and highlight knowledge gaps. The report also provides information to guide external stakeholders on the nature of available groundwater resources in the region.

A revised interpretation of the geology and hydrogeology of the Dampier Peninsula was carried out to guide assessment of current performance of the aquifers in the peninsula. Performance was assessed by analysing groundwater level and quality monitoring information. In preparing the revised interpretation, large gaps were found in temporal and spatial data in geological and hydrogeological information across the peninsula.

The unconfined regional Broome Sandstone aquifer, commonly referred to as the Broome aquifer, is the largest shallow aquifer across most of the peninsula. It varies in thickness from 34 m to 383 m thick, with the depth to groundwater varying from less than 10 m around the coast to over 100 m in the centre of the peninsula. Saturated thickness is greatest in the west, up to 300 m, and gradually thins to an unsaturated zone across the centre of the peninsula. Groundwater in this aquifer is generally fresh.

In the eastern part of the peninsula, the largest shallow aquifer is the Wallal Sandstone aquifer, commonly called the Wallal aquifer. This is generally unconfined, sub-crops near the surface, with water levels ranging from 2 m above ground level (where confined) to 25 m below ground level. The Wallal aquifer also occurs in the western part of the peninsula where it is overlain and confined by the Jarlemai Siltstone. The Jarlemai Siltstone is thickest in the south of the peninsula, and thins markedly in the north-west and east, ranging from 23 m to 259 m thick. The top of the Wallal aquifer is up to 400 m below ground surface on the western side of the peninsula, with artesian heads up to 39 m above ground level. Groundwater in the Wallal aquifer is fresh to saline.

Minor groundwater use from the Liveringa aquifer takes place in the eastern part of the peninsula.

The groundwater resources of the Dampier Peninsula are generally showing no signs of adverse effects due to current use, with the exception of some subareas of the Broome groundwater area, to the south-west of the peninsula. Changes in water quality in this area indicate that limits of sustainable abstraction have been reached.

This review suggests there are significant quantities of groundwater available across the Dampier Peninsula, in the Broome as well as underlying aquifers and that there is currently very little use made of this resource. Factors which need to be managed for the sustainable use of groundwater include the following:

- intrusion and upconing of the saline groundwater near coastal regions

- effects on groundwater-dependent ecosystems (GDEs)
- the ability of the aquifer to yield the high quantities of water required for large scale horticulture at single abstraction points (potential yields of production bores)
- uncertainty in the distribution of aquifer parameters.

Future planning and development of the resource would benefit from investigations to determine the limits of the resource.

Although there appears to be a significant quantity of groundwater available within the Broome and underlying aquifers across the Dampier Peninsula, quality is variable (and may constrain some uses). Table 4 summarises these possible limitations, and provides a quick reference guide to some of the characteristics of shallowest groundwater in the region (generally the Broome aquifer). Groundwater is available in the Wallal aquifer across the peninsula, but assessment of the opportunities and risks is limited by the few investigations of this deep resource. Although it is near the surface in the east, the aquifer is > 470 m below ground level across most of the peninsula. Data indicates that the water is moderately saline (1900 to 4700 mg/L TDS) and can contain high iron concentrations (up to 24 mg/L).

1 Introduction

The Department of Water is responsible for managing Western Australia's water resources through investigation, planning, regulation and management. We do this by:

- investigating and assessing water resources
- providing security of water use for the environment and communities
- developing policies for water service provision
- licensing water abstraction (through the assessment of licence applications and setting of licence conditions)
- drinking water source protection
- planning for drainage, floodplains and water allocation
- protection and management of waterways
- implementing water reform.

In areas that are proclaimed under the *Rights in Water and Irrigation Act 1914* where water use is low (and pressure on the resource is low), the department manages water use through the water licensing process. Through this process detailed operating strategies, including investigation and monitoring, can be developed for large water licences in otherwise low use water resources. When an area has high water use by multiple users or when there is increased pressure on the resource, detailed allocation plans are developed.

The Dampier Peninsula subregion (Figure 1) is currently managed through the licensing process, and does not have an allocation plan. There is an allocation plan for the Broome groundwater area which is located in the south-west corner of the Dampier Peninsula. However, due to changes in state priorities, consideration of the subregion as a whole has become important. Prior to the development of allocation plans, and to ensure licence conditions are appropriate, a review and hydrogeological assessment of the groundwater resources of the peninsula are required.

This study provides that review and assessment.

1.1 Aims

The overall aim was to provide a summary of available data and an assessment of the current status of groundwater resources. The assessment is intended to guide and support future allocation planning for the region, support licensing decision making in the interim and highlight knowledge gaps. This report also provides information to guide external stakeholders on the nature of available groundwater resources in the region.

Although there are large temporal and spatial gaps in geological and hydrogeological information across the peninsula, the report has been able to comment on:

- geological interpretation – paying particular attention to:
    - Variations in thickness of the shallowest regional aquifer (Broome Sandstone)
    - Depth to deeper underlying aquifers (particularly the Wallal Sandstone)
    - Connectivity between the shallowest and deeper aquifers indicated by variations in thickness of the confining layer between the two shallowest aquifers
- hydrogeological interpretation – with emphasis on the following issues:
    - Depth to watertable and saturated thickness of the Broome aquifer
    - Location of the saltwater interface
    - Presence of perched aquifers and ecosystems that might depend on regional groundwater levels
- current performance of the aquifers – by:
    - reviewing water level data, physiochemical parameters and collective parameters to identify any trends
    - assessing and comparing results from any available water source studies
- the gaps in our knowledge that are limiting management of the groundwater resources.

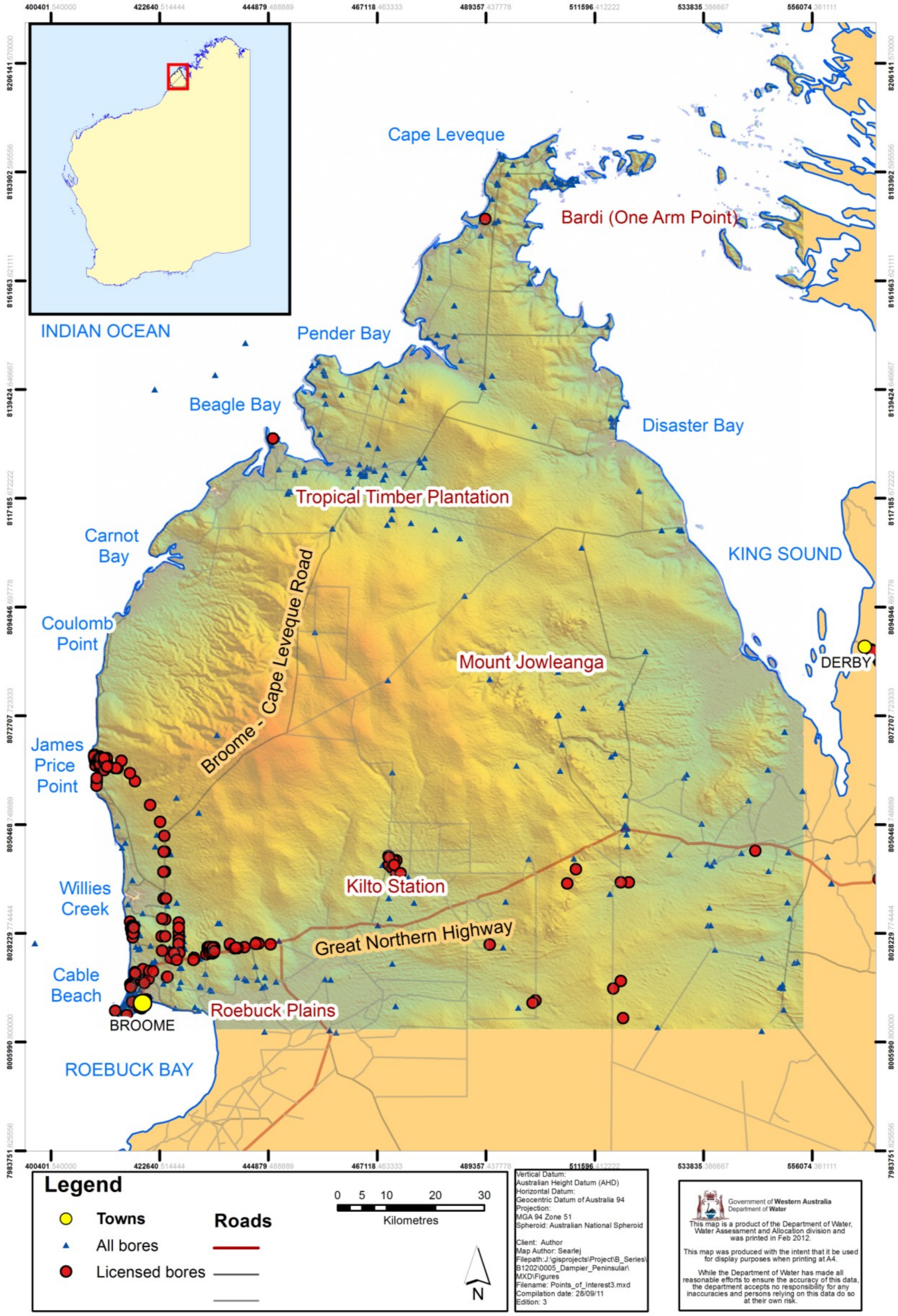


Figure 1 Location map

1.2 Method of analysis

1.2.1 Data management

The data acquisition and compilation phase of the project was extensive, as the Department of Water has only broad level information for much of the Dampier Peninsula. Data from private licence holders was obtained from accession reports provided to the department or directly from consultants, and then captured in electronic format.

The level of information available for each bore varied considerably. Appendix A contains a map and catalogue of all bores used in this review, showing whether information on lithology, stratigraphy and water levels was available. Most bores were not surveyed; therefore elevations were derived from a topographic map. This was derived from a digital elevation image, which was obtained from the Department of Mines and Petroleum. This method was used to convert water level measurements, construction information and formation depths from metres below surface or metres below top of casing to m AHD. Conversion to AHD allowed comparison of water levels and formations from a common elevation datum. Comparisons of 10 randomly selected derived elevations to surveyed points indicate that the accuracy of this method is between 10 cm and 10 m (Figure 2).

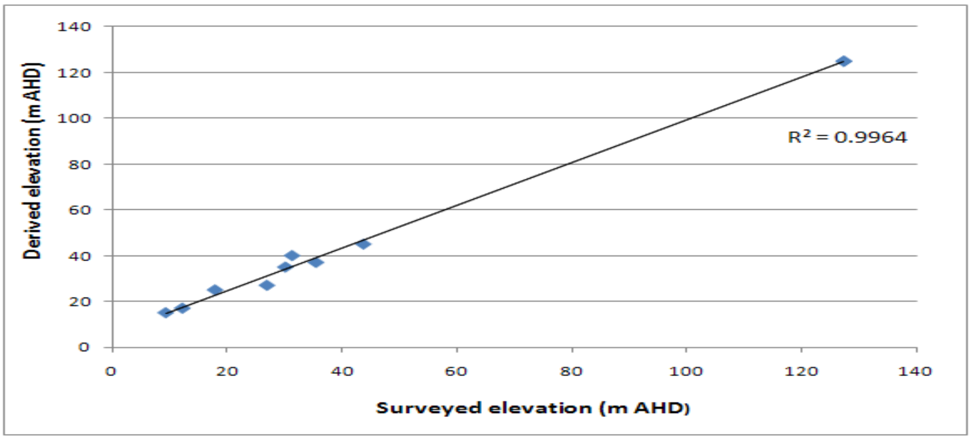


Figure 2 Comparison of surveyed and derived elevations.

1.2.2 Geology

Across the Dampier Peninsula, there were 122 bores with lithological logs and 105 bore logs where formations were identified (e.g. Broome Sandstone, Alexander Formation). Unfortunately, only 89 of the bores with lithological logs also had formation information. The vast majority of bores only penetrate the Broome aquifer, and of those only a few reach the base of the formation hosting the aquifer. Bore logs were plotted in ArcGIS. However, the spatial resolution did not allow for development of meaningful regional contour maps of geological surfaces. Extrapolation of strata across tens of kilometres was commonly required.

1.2.3 Groundwater levels

There are 3410 water level measurements for 265 bores across the peninsula. Of the 265 bores, 175 bores (66%) have only one water level record, and 31 bores (11%) have between 2 and 10 water level measurements. The remaining 59 bores (22%) have ongoing water level records, and are all restricted to the Broome groundwater area, the Tropical Timber Plantations Pty Ltd property and Kilto Station.

Dates were missing for many of the water level records, making evaluation of trends and groundwater flow paths difficult.

Often bores which had water level measurements did not have lithological or stratigraphic information, and also lacked construction information. This meant that, particularly in the east, an estimate of which aquifer the bores were screened in was made by assessing surface geology and logs of nearby bores.

1.2.4 Groundwater quality

When available, groundwater chemistry was compared to the Department of Environment and Conservation (DEC) guidelines in *Assessment levels for soil, sediment and water* (DEC 2010). These assessment levels were obtained from various Australian and international guidance documents, including ANZECC & ARMCANZ (2000) and NHMRC & NRMMC (2004). The Department of Environment and Conservation (DEC 2010) report chemical assessment levels for various water uses, including drinking water, freshwater, short- and long-term irrigation, and domestic non-potable groundwater. Although sampling and analysis methodologies are not consistent across the Dampier Peninsula, the available water quality data allows for a comparison of some chemical parameters against the Department of Environment and Conservation assessment levels.

Salinity was classified according to the Australian Government (NHMRC & NRMMC 2004). Salinity types are listed below in Table 1.

Table 1 Salinity categories

Salinity type	**Range mg/L TDS**
Fresh	< 500
Marginal	501–1000
Brackish	1001–2000
Moderately saline	2001–5000
Saline	5001–10 000
Highly saline	10 001–35 000
Hypersaline	> 35 000

When possible, ion balance calculations were carried out on all water quality samples. Where these calculations established a satisfactory ion balance (±6%) the chemistry was plotted on a Piper diagram. The Piper diagrams enabled a general classification of the groundwater type to be made.

2 Context and regional hydrogeology

2.1 Location

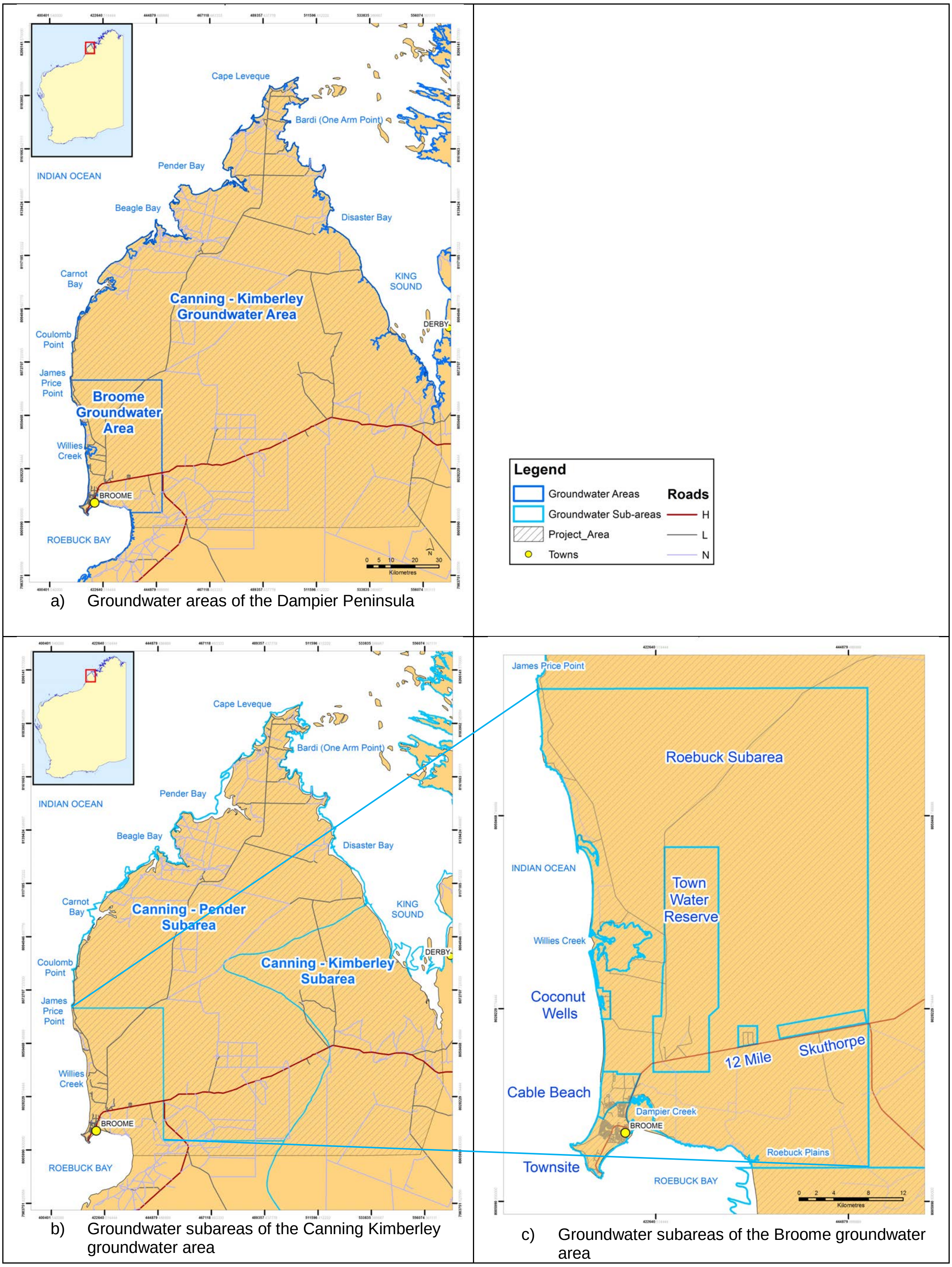
Dampier Peninsula is located in the south-west Kimberly region, over 2250 km north of Perth. For the purposes of this study, the peninsula is defined as the area north of a line from Broome in the south-west corner to Derby (Figure 1). The Indian Ocean borders the west and north of the peninsula, and King Sound is off the eastern coast.

For groundwater licensing and allocation purposes, the Dampier Peninsula subregion comprises two groundwater areas, the Canning–Kimberley and the Broome (Figure 3). These areas are divided into groundwater subareas as shown in Table 3.

Table 2 Groundwater areas and subareas of the Dampier Peninsula

Region or subregion	Groundwater area	Groundwater subarea
Dampier Peninsula subregion	Canning–Kimberley	Canning–Pender
		Canning–Kimberley
	Broome	Townsite
		Town water reserve
		Roebuck
		Cable Beach
		Skuthorpe
		12 Mile
		Coconut Well

The whole of the Broome groundwater area is within the Dampier Peninsula subregion but only a portion of the Canning–Kimberley groundwater area is within the subregion.



a) Groundwater areas of the Dampier Peninsula

b) Groundwater subareas of the Canning Kimberley groundwater area

c) Groundwater subareas of the Broome groundwater area

Figure 3 Groundwater allocation divisions.

2.2 Climate

Dampier Peninsula is characterised by hot, wet summers and warm, dry winters. Climatic conditions vary across the peninsula. Using a modified Koeppen classification system, the Bureau of Meteorology classifies the north-western portion of the Dampier Peninsula as 'tropical' and the rest as 'grassland' (BOM 2011). The northern part of the peninsula is wetter, receiving between 650 and 1200 mm of rainfall a year, while the southern portion ranges between 350 and 650 mm. Most of the rain falls in the distinct wet season, between December and March. Figure 4 and Figure 5 show the north–south rainfall gradient across the peninsula. Average rainfall for Broome in the south is 604 mm per year, but if the wet season fails, rainfall can be very low (e.g. 132 mm for 1992). Average annual rainfall for the northern most station, Cape Leveque, is 780 mm. The southern portion of the peninsula is hotter in summer and cooler in winter than the north (Figure 5). The recent climate (1996–2010) has been wetter than the historical climate (1930–2010).

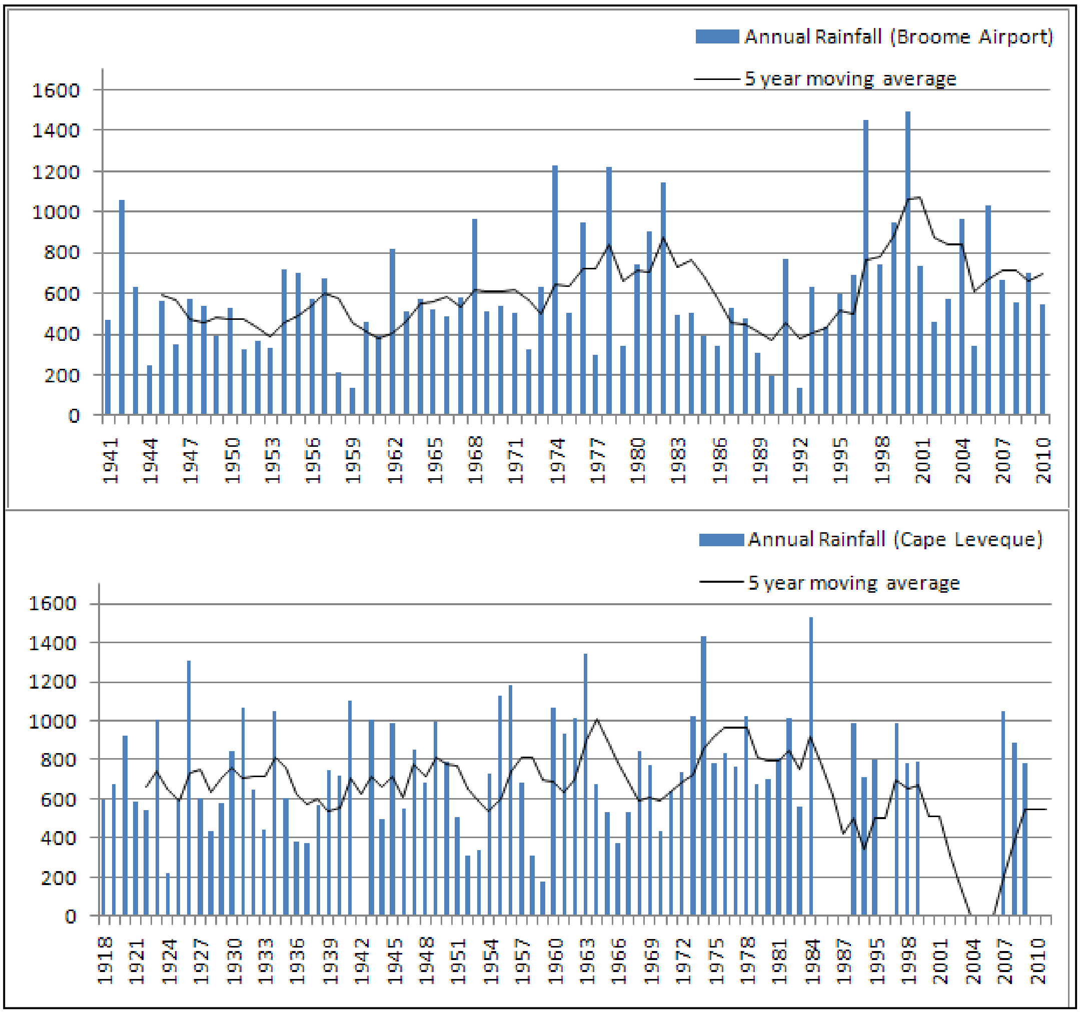


Figure 4 Annual rainfall

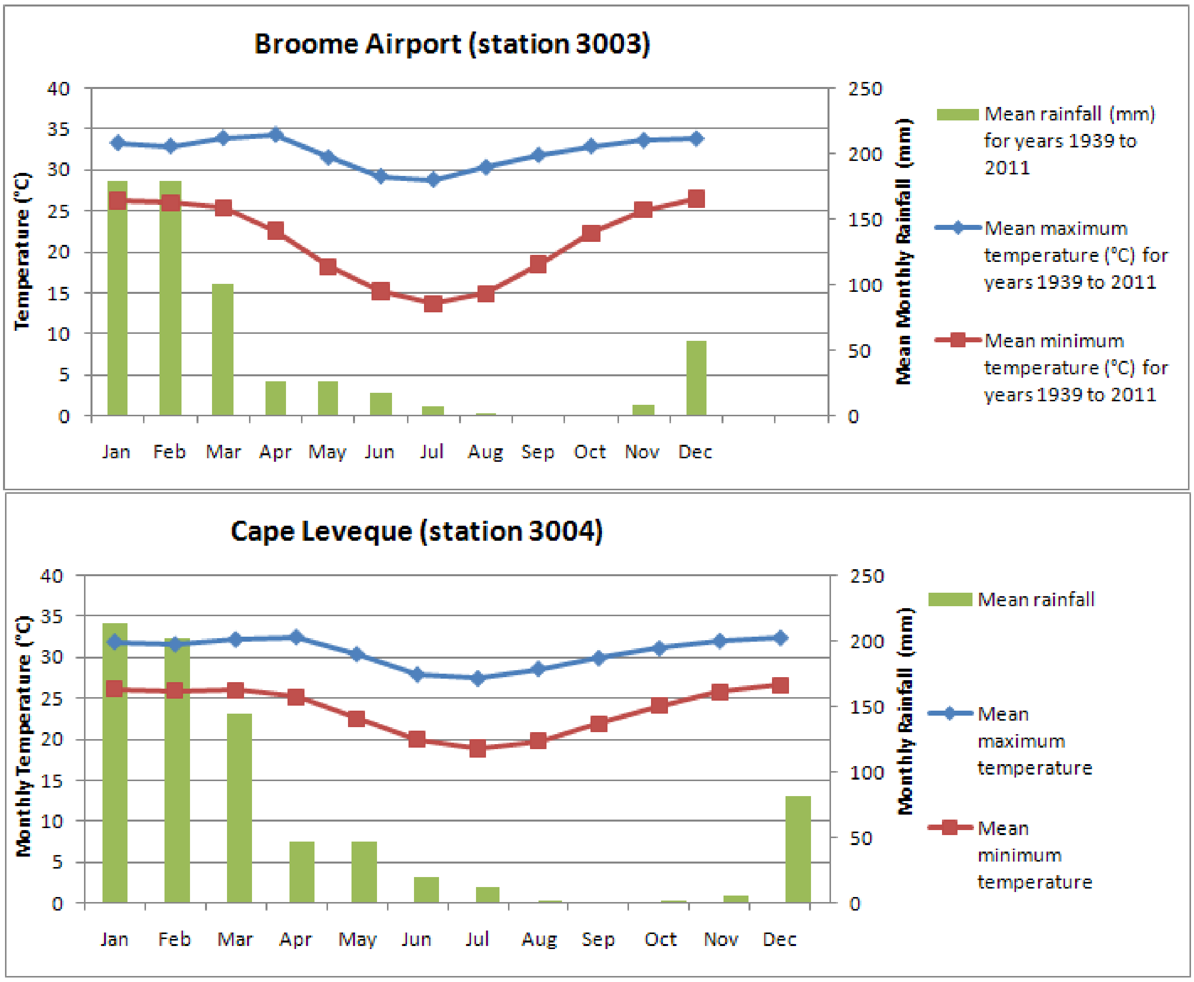


Figure 5 Monthly Climate statistics

2.2.1 Climate change

CSIRO undertook climate modelling as part of the Northern Australia Sustainable Yields Project. Three different climate scenarios were established: high, medium and low global warming scenarios (CSIRO 2009a). Each of the three scenarios was run for 15 different global climate models. The 45 resulting ranges of future climates were ranked. The 'median future climate' represents the mid-range conditions. The 'wet extreme future climate' represents the wet end of the range and the 'dry extreme future climate' represents the dry end of the range (CSIRO 2009b).

Using these climate models, CSIRO predict that future climate (around 2030) will be similar to the historical climate across the Dampier Peninsula (CSIRO 2009b). The near future is expected to be warmer, with rainfall events being more intense. Potential evapotranspiration is expected to increase, but runoff and groundwater recharge are expected to be similar to the historical past (CSIRO 2009a).

2.3 Geomorphology

The Dampier Peninsula is about 175 km long (north to south) and 130 km wide (east to west). It is gently domed, rising to approximately 245 m AHD just west of the centre of the peninsula (Figure 6). Around the coastline are narrow sandy beaches, aeolian dunes, platforms of lithified sediments and extensive mudflats. The Ramsar listed Roebuck Bay on the south-west coast is a tidal mudflat, extending 30 km inland east of Roebuck bay. Across the southern portion of the peninsula, there are west trending dunes, which are extensions of the Great Sandy Desert (Gibson 1983a). On the west coast between James Price Point and Coulomb Point, coastal cliffs are up to 20 m high, and the land becomes more rugged between Coulomb Point and Carnot Bay (Gibson 1983a). Along the western coastline numerous wetlands have formed at seepage faces, including some lake basins (Mathews et al. 2011). Gently undulating sand plains cover the north and east of the peninsula, with some rugged incised creeks and rocky outcrops in the north near Cygnet Bay (Gibson 1983b and Towner 1981). A thin veneer of red silty sandy soil covers much of the Dampier Peninsula, and is commonly known as Pindan sands.

Drainage is poorly developed over much of the peninsula. Sheet flooding is the main drainage pattern, with much of the water infiltrating to groundwater. There are numerous ephemeral creeks, and runoff is usually only generated after heavy summer rainfall. The main water courses on the peninsula are the Fraser River and Deep Creek. Fraser River begins in the centre of the peninsula and flow east to discharge into King Sound. Deep Creek is in the south-western corner of the peninsula, and flows south-west to discharge south-east of Broome. Groundwater-dependent surface waters, including mound springs, are known to exist. However, their locations, connectivity to groundwater systems and values have not been comprehensively investigated.

2.3.2 Groundwater-dependent ecosystems

The wetlands and groundwater-dependent ecosystems across the Dampier Peninsula have great cultural value to Indigenous groups such as the Jabirr Jabirr, Yawuru, Nyul Nyul and Ngumabal of the west coast. These systems also have ecological significance; however studies which identify them and demonstrate the degree of dependence on groundwater are limited. A broad scale, peninsula wide wetland mapping project was conducted using Landsat satellite imagery, by Charles Darwin University (Boggs 2011). Wetlands were classified using a geomorphic approach defined by Semeniuk and Semeniuk (1995), based on hydroperiod and landform type. Figure 6 and Figure 7 display the results of this study, classifying wetlands as permanent, seasonal or intermittent. No ground truthing has yet been carried out on this dataset to determine if vegetation is dependent on regional groundwater or on shallower forms of groundwater.

There have been two more detailed studies on potential groundwater-dependent ecosystems on the Dampier Peninsula. Ecologica (2004) carried out investigations of wetlands and groundwater-dependent ecosystems along Bobbys Creek in the north-west of the peninsula, near the Tropical Timber Plantations property and Beagle Bay.

This study identified three different types of ecosystems in the area; wetland, terrestrial and Pindan. It concluded that wetland and terrestrial ecosystems were likely to be groundwater dependent, and that the Pindan communities were probably not.

Mathews et al. (2011) investigated freshwater seepages along the western coastline of the Dampier Peninsula. Their work outlined the geological and stratigraphic framework, and the types of wetlands and environments produced. They showed that a variety of coastal wetlands are developed, depending on the mechanism by which fresh water is delivered to the coast, and the stratigraphic environment into which discharge takes place. The wetland environments defined are outlined below:

- linear zones of seepage along the edge of the red sand dunes, known as vine thickets
- basin wetlands developed along the interface of coastal dunes and red sand dunes
- variously barred rivulets.

The identification of ecosystems that are dependent on regional groundwater across the peninsula could be assisted by combining the wetland map with the two more detailed studies (Ecologica (2004) and Mathews et al. (2011)), and detailed depth to groundwater information. Figure 7 shows the wetland layer with existing water level information. The water levels shown are maximum depths to groundwater, in metres below ground level or metres below top of casing. This preliminary compilation shows that there is some correspondence between potential groundwater-dependent ecosystems and depth to shallow groundwater, but this is not consistent.

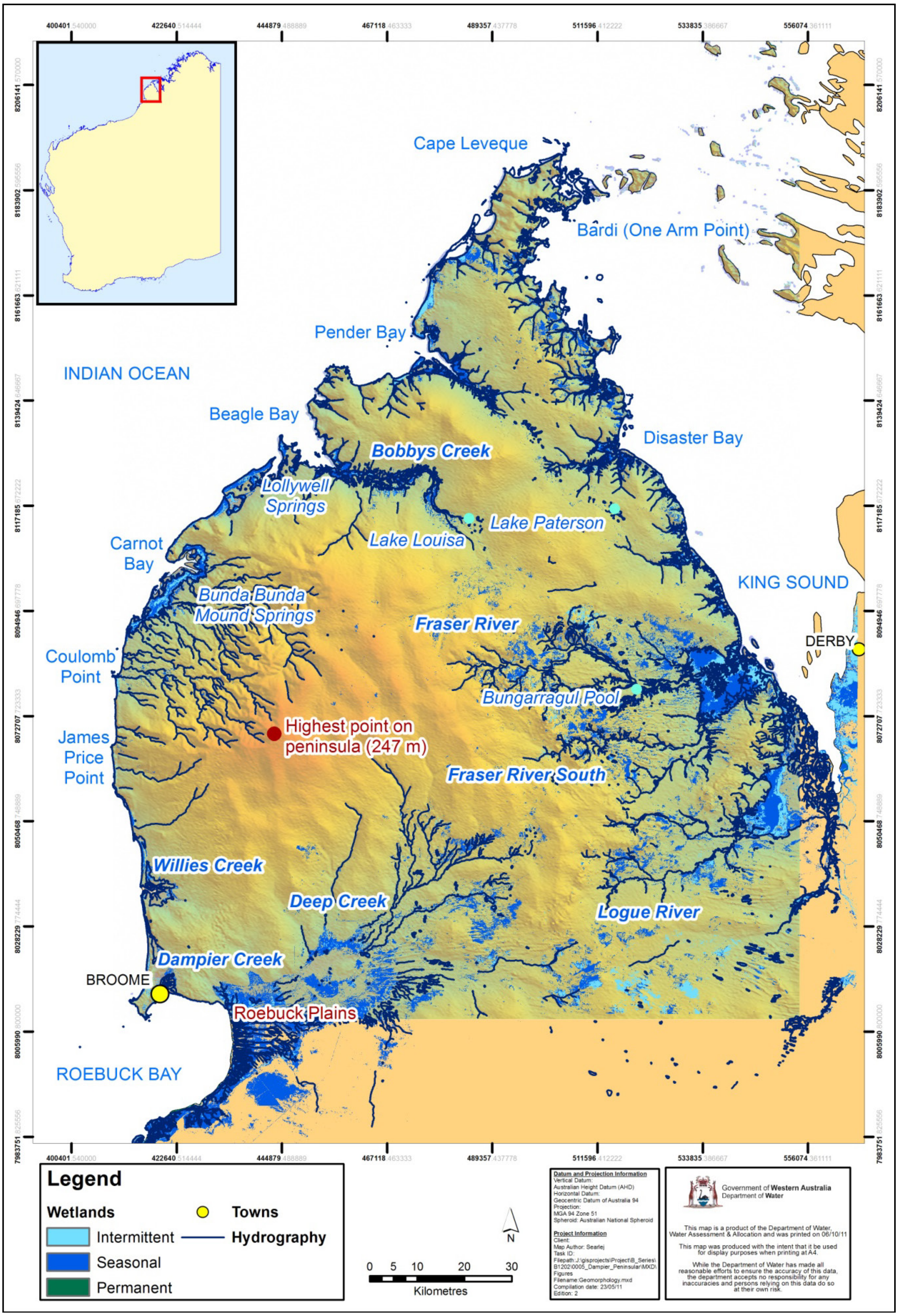


Figure 6 Regional drainage and geomorphology

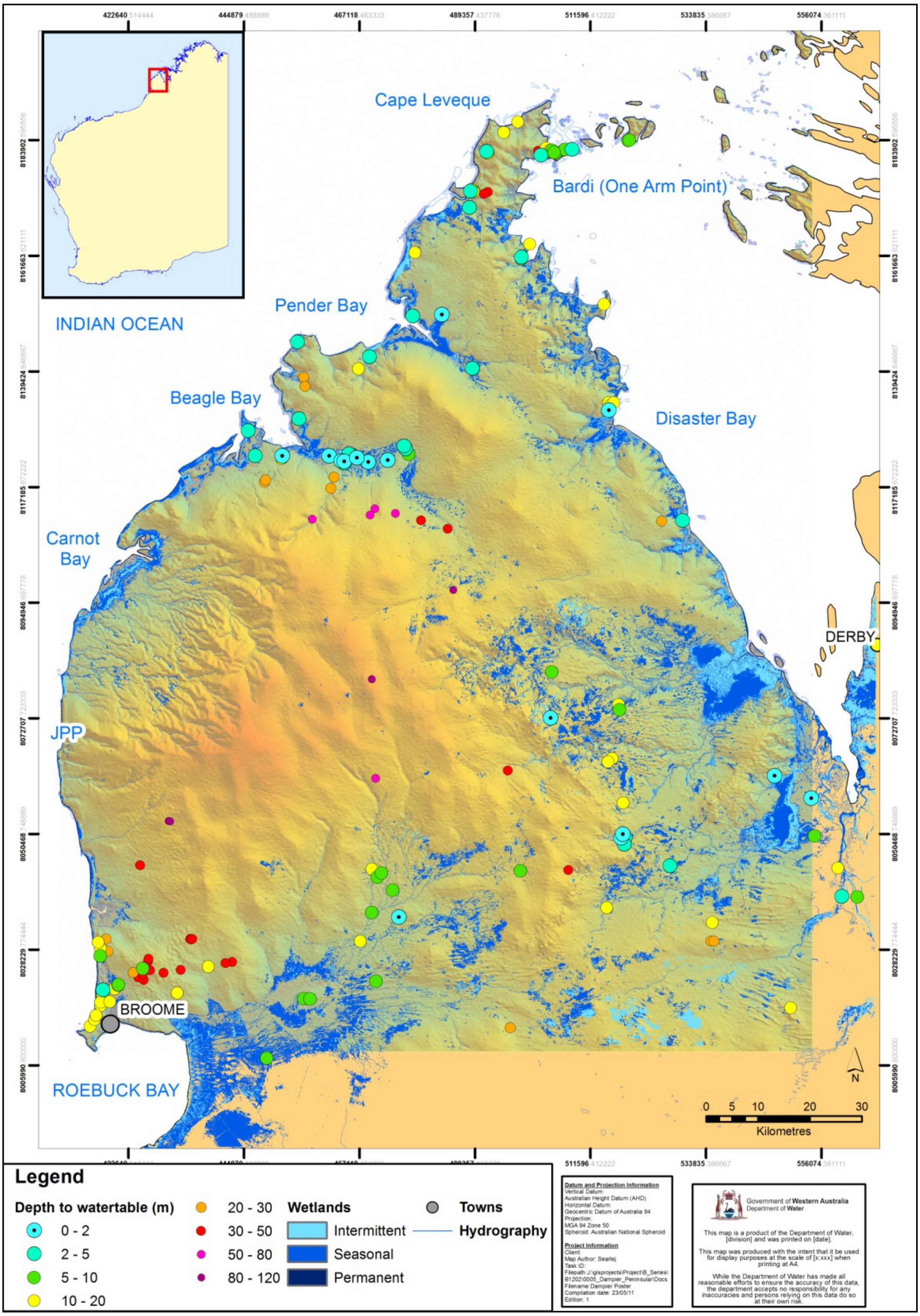


Figure 7 Wetlands and depth to watertable

2.4 Geology

The Dampier Peninsula is part of the Canning Basin, Australia's second largest groundwater province after the Great Artesian Basin. The Canning Basin developed as an intracratonic sag between the Pilbara and Kimberly basins, covering an area of over 530 000 km^2 (DMP 2011), with sediments up to 15 km thick (GA 2011). The succession ranges from Ordovician to Cretaceous, but is mainly Palaeozoic in age. The main basin elements trend north-west, including the two major troughs, which are separated by a mid-basin arch and marginal shelves (DMP 2011).

The Dampier Peninsula is part of the Fitzroy Trough in the north of the Canning Basin (insert in Figure 8). The Fitzroy Trough is bounded by the Beagle Bay Fault in the north and the Fenton Fault in the south, both of which are near-vertical normal faults (Yeates et al 1983). The trough is flanked by Lennard Shelf in the north and Jurgurra Terrace in the south (Gibson 1983a and 1983b). The Lennard Shelf is an area of shallow basement (~2000 m) with gently dipping strata (Gibson 1983b) whereas the Jurgurra Terrace is of intermediate basement depth (maximum of ~3000 m on the Dampier Peninsula (Gibson 1983b)).There are many east trending en echelon folds in the Triassic and older rocks of the Fitzroy Trough (Yeates et al 1983), the major fold being the Baskerville Anticline, in the centre of the Dampier Peninsula. These folds strike east–west and plunge to the west. Strata on the southern limb dip gently to the south-west and strata of the northern limb dip north-west. It is also likely that the shallower sediments of the Dampier Peninsula are faulted; however this is yet to be investigated.

The lithology of the Dampier Peninsula is described in the explanatory notes for three of the Geological Survey of Western Australia's 1: 250 000 map sheets; Broome, Pender and Derby (Gibson 1983a, Gibson 1983b and Towner 1981 respectively). The stratigraphy of the Dampier Peninsula is summarised in Table 3 below.

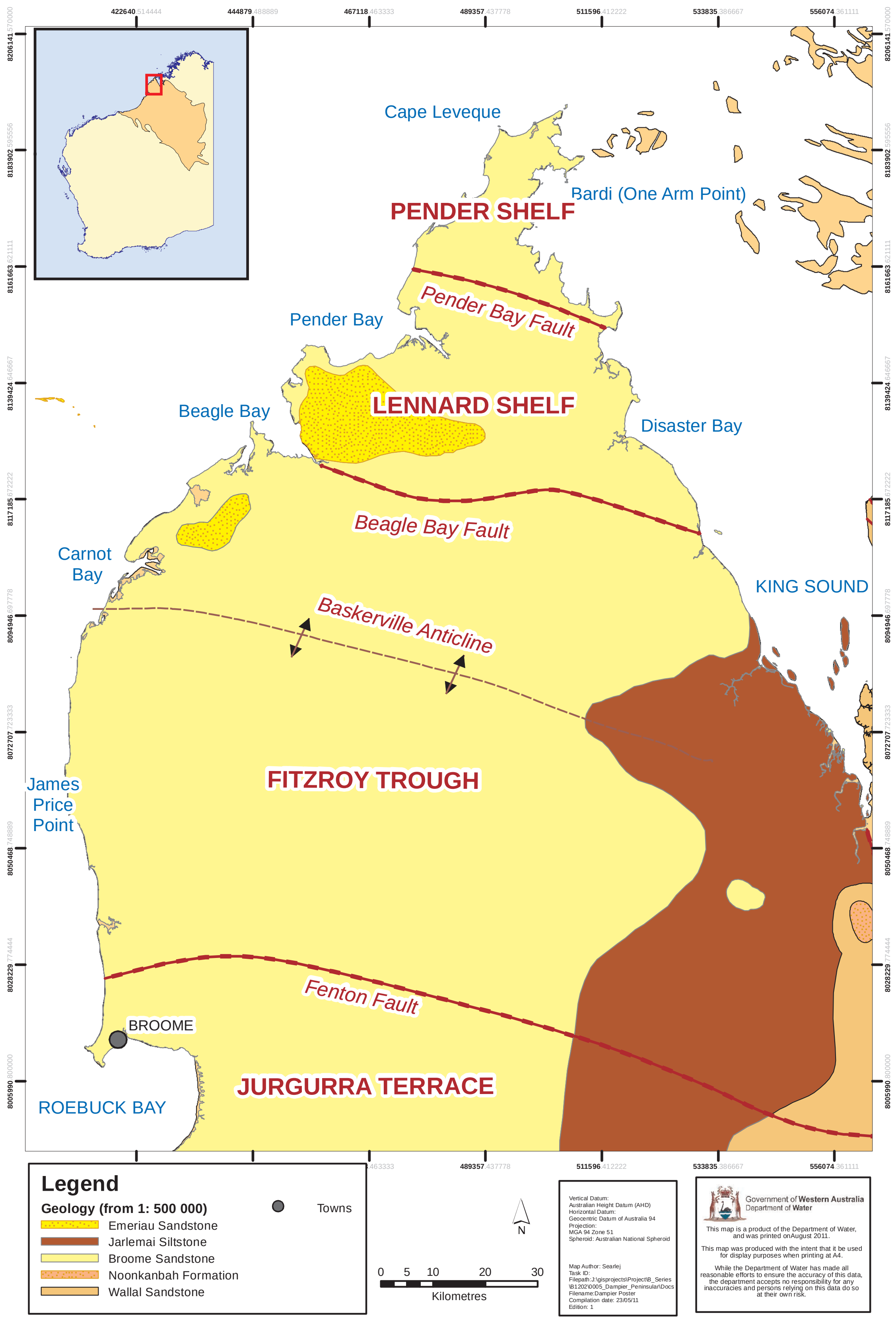


Figure 8 Geology (1:500 000 scale) with major tectonic features

Table 3 Summary stratigraphy for the Dampier Peninsula

Age	**Stratigraphy**	**Maximum or estimated thickness (m)**	**Lithology**	**Groundwater potential (as assessed on Dampier Peninsula)**
Quaternary	Qa, Qb, Qs, Qz, Qcs, Qci, Qcd	20	Sand, silt, clay, minor gravel, black organic clay.	Minor perched aquifer, fresh
	Bossut Formation	20	Fine to coarse calcareous and quartzose sandstone; calcilulite, oolite; cross-bedded in part.	Minor aquifer
Tertiary to Quaternary	Czl	2	Pisolitic and massive laterite.	None
Early Cretaceous	Emeriau Sandstone	30	Fine to coarse poorly sorted sandstone; minor conglomerate; cross-bedded; commonly ferruginous in outcrop.	None
	Melligo Sandstone	40	Fine to medium, well sorted, thin-bedded to laminated sandstone; pebbly in places; contains heavy minerals; partly silicified.	None
	Broome Sandstone	280	Fine to very coarse sandstone; some mudstone; minor conglomerate; ripple-marked, cross-bedded; bioturbated in part.	Major aquifer, mostly unconfined, fresh to saline
	Jowlaenga Formation	40	Fine to medium sandstone, well-sorted, with mudstone interbeds; bioturbated; large- and small-scale bedding; lenses of intraformational conglomerate.	Possibly part of Broome Sandstone aquifer
Late Jurassic to Early Cretaceous	Jarlemai Siltstone	259	Siltstone, claystone, sandstone; glauconitic, ferruginous (phosphatic?) in part.	Aquiclude, minor aquifer in parts

Age	Stratigraphy	Maximum or estimated thickness (m)	Lithology	Groundwater potential (as assessed on Dampier Peninsula)
Late Jurassic	Alexander Formation	50	Interbedded fine to coarse sandstone and mudstone; pyritic, glauconitic in part.	Minor aquifer, could be part of Wallal Sandstone aquifer. Artesian on eastern peninsula.
Early (?) to late Jurassic	Wallal Sandstone	364	Sandstone; minor siltstone, conglomerate, lignite.	Major aquifer, fresh to saline, artesian on the western portion of the Dampier Peninsula
Early to middle Triassic	Erskine Sandstone	240	Very fine to fine sandstone; laminated to thin-bedded, cross-bedded, ripple-marked, with minor clay-pellet conglomerate; laminated mudstone in upper parts	Major aquifer
Early Triassic	Blina Shale	78	Mudstone, sandy in places	Aquiclude
Early to late Permian	Liveringa Group	207	Sandstone, mudstone, minor conglomerate, limestone, coal.	Minor aquifer
Early Permian	Noonkanbah Formation	287	Calcareous mudstone, fine sandstone, limestone.	Minor aquifer
	Poole Sandstone	49	Very fine to fine sandstone; mudstone; minor limestone at base.	Major aquifer
Late Carboniferous to Early Permian	Grant Group	826	Fine to coarse sandstone; mudstone in middle part; minor conglomerate.	Major aquifer
Early Carboniferous	Anderson Formation	2551	Fine to coarse sandstone, siltstone, shale; minor limestone, dolomite, anhydrite.	Minor aquifer
Middle Devonian to Early Carboniferous (?)	DC	1163	Dolomite, limestone, shale, siltstone, fine sandstone.	Minor aquifer?

Age	Stratigraphy	Maximum or estimated thickness (m)	Lithology	Groundwater potential (as assessed on Dampier Peninsula)
Early Ordovician	O	800	Shale, limestone, dolomite, siltstone, fine sandstone.	Minor aquifer?
Precambrian	p€	Unknown	Igneous, metamorphic, and sedimentary rocks.	None

2.5 Hydrogeology

2.5.1 Groundwater occurrence

There are many potential groundwater resources in the strata of the Dampier Peninsula; however most have not been thoroughly investigated. Groundwater on the peninsula is likely to occur in five major and eight minor aquifers. From shallowest to deepest, the aquifers of the Dampier Peninsula subregion occur in the following geological formations:

- Surficial sediments (minor aquifer)
- Bossut Formation (minor aquifer)
- Broome Sandstone (major aquifer)
- Jowlaenga Formation (minor aquifer)
- Jarlemai Siltstone (major aquiclude, minor aquifer)
- Alexander Formation (minor aquifer)
- Wallal Sandstone (major aquifer)
- Erskine Sandstone (major aquifer)
- Liveringa Group (minor aquifer)
- Noonkanbah Formation (minor aquifer)
- Poole Sandstone (major aquifer)
- Grant Group (major aquifer)
- Anderson Formation (minor aquifer).

Many of the geological formations are hydraulically connected, and form major aquifers (discussed below). Current groundwater use is concentrated in the Broome aquifer, with minor use from the Surficial, Wallal and the Liveringa aquifers. Based on actual and potential future use in the Broome groundwater area and Canning–Pender subarea, the Department of Water has only set allocation limits for the Broome and Wallal aquifers. The Surficial aquifer is possibly in direct hydraulic continuity with the underlying Broome aquifer, and for licensing purposes they are considered a single resource. The Grant aquifer has an allocation limit in the Canning–Kimberley subarea, but there is no licensed use on the Dampier Peninsula.

2.5.2 Surficial aquifer

The Surficial aquifer is shallow, discontinuous and unconfined across the Dampier Peninsula. This aquifer is represented by coastal dues on the west coast, alluvial deposits on the Fitzroy river floodplain (in the east), and aeolian sands in the central west.

The coastal dune sands occur in the west and south-west of the Dampier Peninsula. These are made up of sand, silt, clay and minor gravel, and are up to 12 m thick. The dunes are recharged directly from rainfall (~ 30% rainfall recharge (WAWA 1994)), and discharge into the underlying Broome aquifer and the Indian Ocean.

The sands and gravels which make up the alluvial sediments of the Fitzroy River floodplain are around 30 m thick. This resource has been studied in depth in recent reports including Harrington et al (2011).

The aeolian sands cover an area of about km^2, and although thickness is unknown, it is suggested that they are possibly around 10 m thick (Laws 1991). These are commonly yellow-beige occurring as a sand sheet deposit. These sands are thought to form a major perched aquifer which feed the springs and streams draining west through Point Coulomb Nature Reserve (Laws 1991). Recharge has been estimated using chloride concentrations in rainfall and groundwater, to be 6.5% of rainfall (Laws 1991).

The relationship between the watertable in the Surficial aquifer and the underlying Broome aquifer is not well established, but perching is believed to occur in some places (Laws 1991). Downward flow into the Broome aquifer is also likely.

There is no water quality information in the department's Water Information Network (WIN) database for this aquifer, but Laws (1991) summarises the groundwater quality as: very low TDS (70–120 mg/L); of sodium chloride type; containing significant quantities of silica (28–31 mg/L); and slightly acidic (pH 6.7).

2.5.3 Broome aquifer

Geology

The Broome aquifer can be hosted in the following stratigraphic formations:

- Emeriau Sandstone formation
- Melligo Sandstone formation
- Broome Sandstone formation
- Jowlaenga Formation.

On the Dampier Peninsula the Melligo Sandstone formation has not been identified, and the Emeriau Sandstone formation is only present in the north-west (Figure 8). The Broome Sandstone and Jowlaenga Formations are present over the west and central parts of the Dampier Peninsula, except where they have eroded away towards the east and over the nose of the Baskerville Anticline (Figure 8 and Figure 9). Figure 9 shows schematic sections across the Dampier Peninsula, using ground surface derived from digital elevation model imagery. These sections show the gentle folding and thinning of the Broome aquifer over the Baskerville anticline in the centre of the peninsula.

The Broome Sandstone and Jowlaenga Formation are very similar lithologically, and can be difficult to differentiate. The formations consist of fine- to coarse-grained quartz sandstone with minor gravel and conglomerate beds. The formations also contain minor siltstone and claystone. The sandstone is variably consolidated and individual beds are discontinuous over large areas (consistent with alluvial deposition). Colours, hardness and grain sizes vary considerably. Iron staining is common, and laterite and pisolite are rare. Minor to trace coal is found in the lower half of the formation (Jowlaenga Formation). Trace mica, pyrite, lignite, carbonaceous material and glauconite are present in both the sandstone and siltstone layers.

Laws (1991 and 1984) and WAWA (1994) report continuity of some lithologies within the Broome Sandstone formation in the south-west of the peninsula (Broome groundwater area). They described an upper clayey zone which is consolidated and competent, and in down-hole geophysical measurements typically exhibits lower resistivity and higher gamma counts. Underlying this is a zone of mostly unconsolidated sand and gravel characterised by high resistivity and low gamma counts (GCS, 2008).

Regionally the formations which comprise this aquifer are folded over the east–west striking Baskerville Anticline, which dip gently to the west. These formations are thickest in the limbs of the fold, in the north and south of the peninsula (383 m at Moogana 1) and thin to the centre of the peninsula over the nose of the anticline (Figure 9). Detailed structural information is not available, but faulting and compartmentalising of the aquifer has been noted elsewhere in the Canning Basin (Koomberi 2011, pers. comm.), and is possible on the Dampier Peninsula.

Hydraulic parameters

Bore yields vary depending on depth, construction and local aquifer conditions. The coarser sands and conglomerates are higher yielding and fresher than the finer grained layers in between. Bores drilled and screened in the coarser sands can yield up to 3000 m^3/d. However, long-term pumping from the Broome town water supply bore field is generally less than 1500 m^3/d per bore. Reported hydraulic conductivities range from 2 m/d to 42 m/d, but are generally around 15 m/d. Transmissivity has a range of 120 to 7200 m^2/d.

Water levels

Depth to the watertable across the peninsula at specific bores is given in Figure 7. Across the peninsula depth to watertable is inferred to have the following range:

- generally 0–20 m around the coastline at the remote communities
- ~ 30 to 60 m in the central north (near the Tropical Timber Plantations property)
- over 100 m in the centre of the peninsula
- between 1 and 10 m in the central southern area (from Kilto Station southwards)
- 0–15 m in the east.

Saturated thickness varies from around 300 m in the northwest (Curringa 1), to ~ 275 m in the Broome area, and thins to unsaturated over the nose of the anticline. To the east the saturated thickness is only around 34 m in the Broome aquifer.

Water levels in the Broome aquifer closely correspond with monthly rainfall (Figure 10). There are no observable increasing or decreasing trends in groundwater levels, with the watertable at many places fluctuating in response to seasonal rainfall.

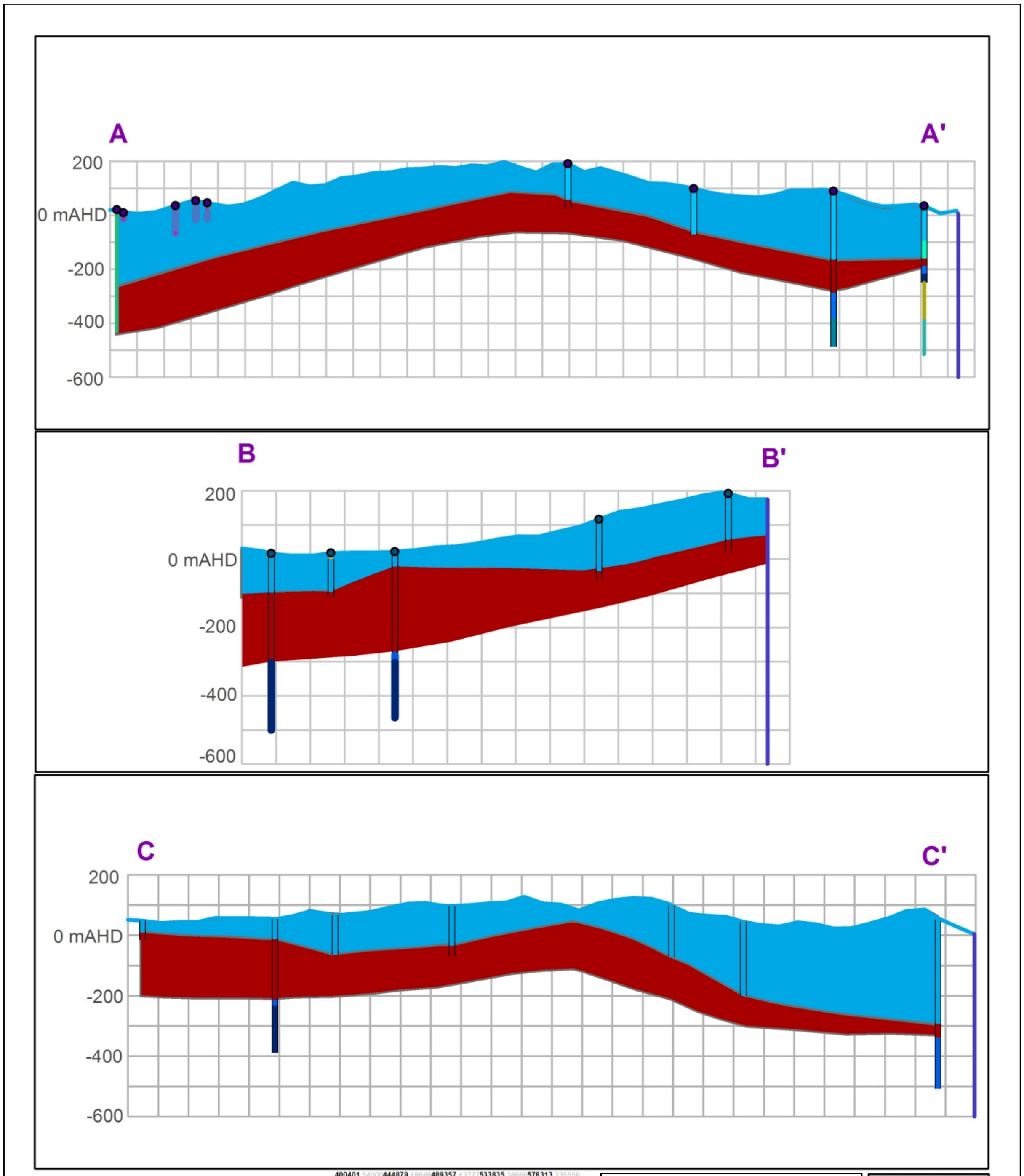


Figure 9 Schematic hydrogeological sections

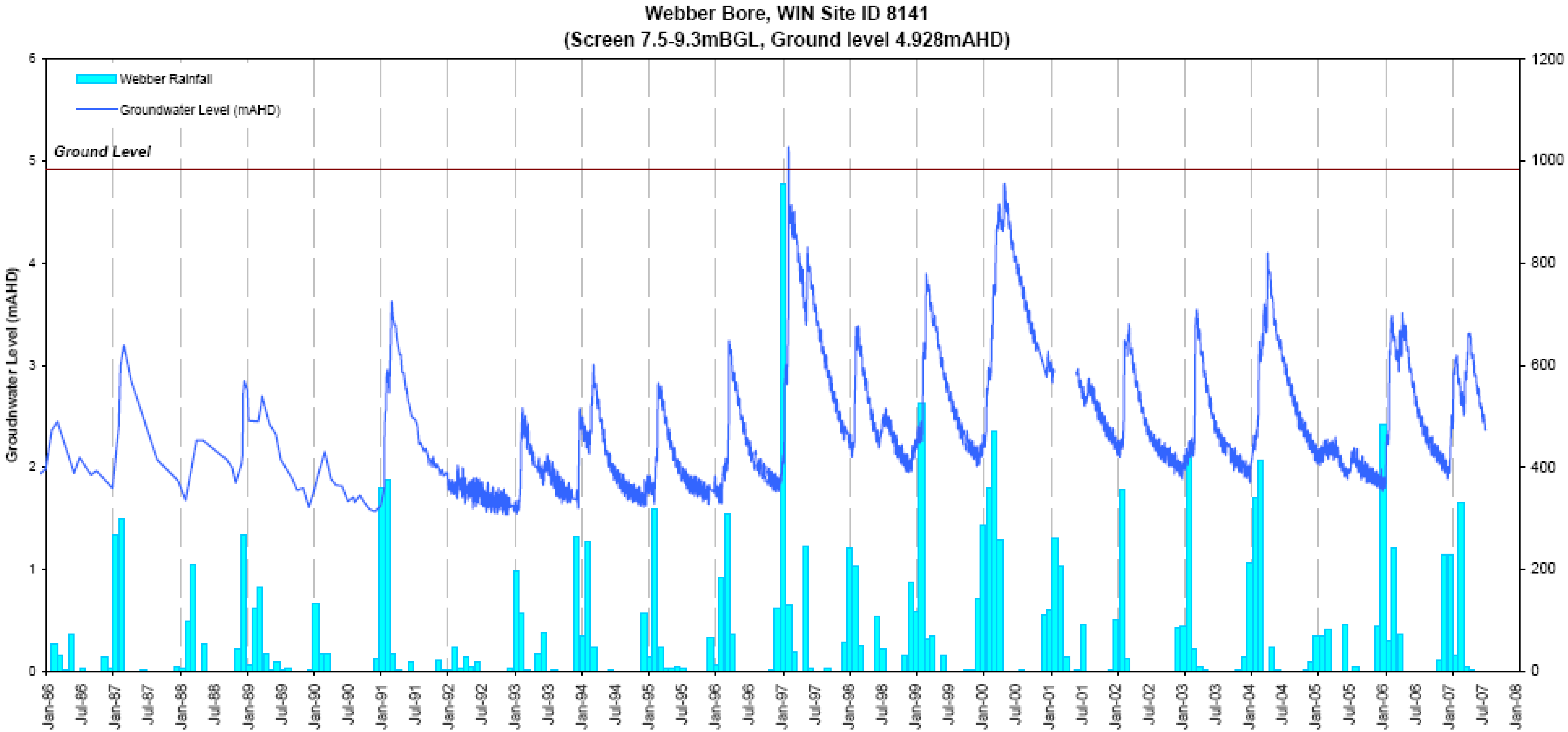


Figure 10 Relationship between rainfall and groundwater level (from GCS, 2008).

Groundwater flow

Groundwater in this aquifer flows radially from the centre of the peninsula towards the coast. Although this aquifer is generally unconfined and in direct contact with the Surficial aquifer the clay and siltstone layers can impede groundwater flow and lead to potentiometric heads being locally above the formation. The Jarlemai Siltstone underlies the Broome aquifer, and acts as an aquiclude between it and the Alexander Formation below. Groundwater contours for the Broome aquifer can only be broadly mapped on the peninsula due to gaps in the spatial and temporal monitoring of water levels (Figure 11). There is commonly > 15 km between bores with water level information, and decades between sampling events. There is insufficient data to contour groundwater levels for the Wallal aquifer on the east side of the peninsula. Conceptual groundwater contours (Figure 11) are presented based on the inference from the available data. It is concluded that:

- groundwater flows south and west from the Baskerville Anticline
- north of the Baskerville Anticline groundwater appears to flow north to north-east and north-west.

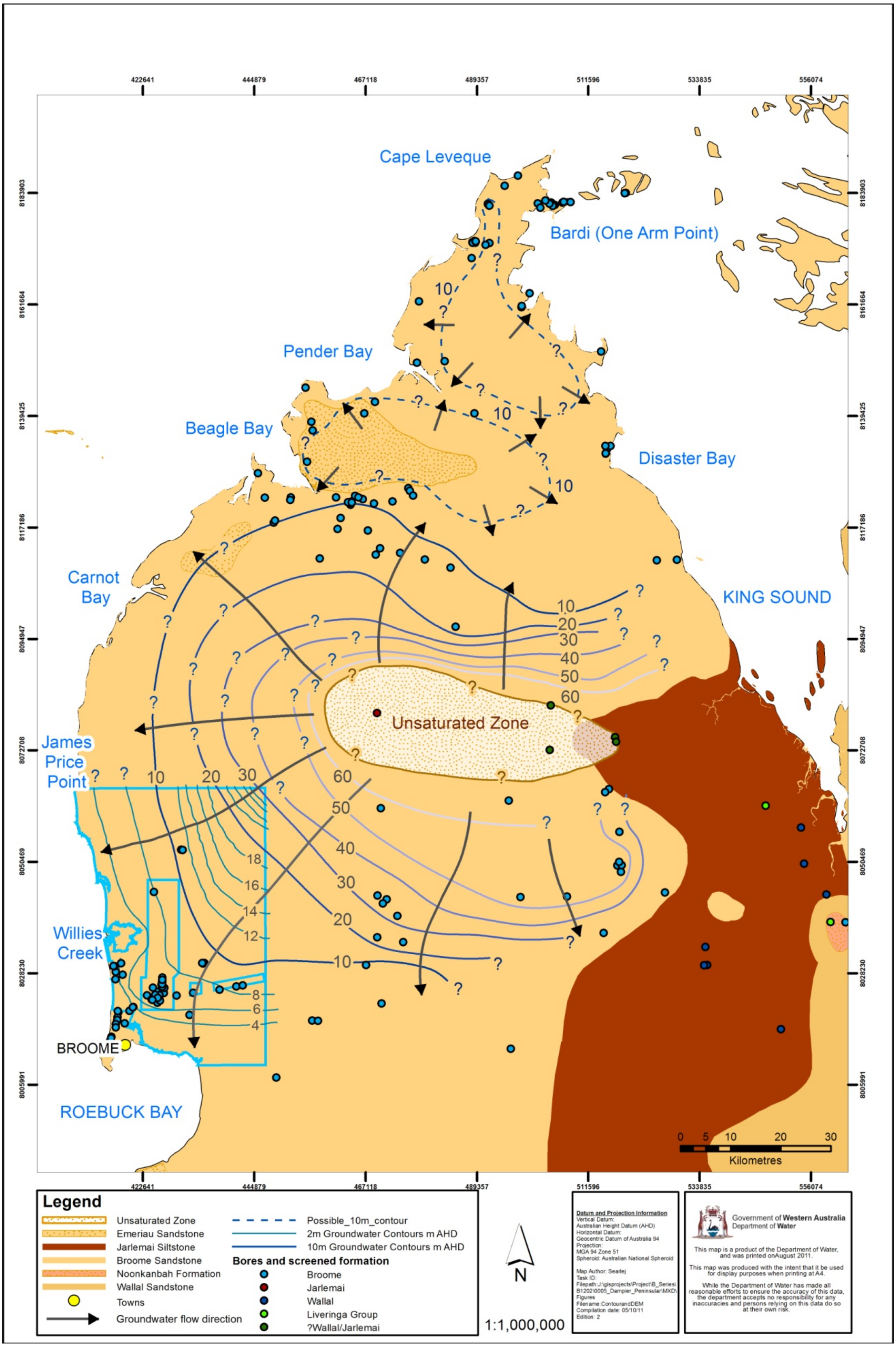


Figure 11 Regional groundwater contours (using maximum water levels)

Recharge and discharge to groundwater

Recharge to the Broome aquifer is predominately via direct rainfall infiltration, or leakage from the overlying surficial sediments. Minor upward leakage from the Wallal formation through the underlying Jarlemai Siltstone is also thought to take place, but has not been verified. If the aquifer is faulted as it is in other areas of the Canning Basin, recharge from the deeper aquifers would be expected. Rainfall recharge in the Broome groundwater area has been estimated at 5% using chloride ratios and flow net analysis (Laws 1991) and calculated as 11% in the Canning–Pender subarea (Rockwater 2004). The difference in recharge estimates could result from the rainfall gradient from the south of the peninsula to the north (Rockwater 2004), differences in calculation methods, or vegetation and surface lithology. Similar analysis over the coastal dunes (Surficial aquifer) has shown recharge to be about 30% of rainfall (WAWA 1994). The relationship between the Surficial and Broome aquifers has not been well defined, but recharge to the Broome aquifer from the overlying Surficial aquifer is highly likely.

Although drainage is poorly developed over most of the peninsula, and groundwater interaction with drainage features and wetlands is unknown, recharge and discharge from surface features such as Fraser River, Bobbys Creek and Deep Creek could contribute to the overall water balance.

Groundwater discharge from the Broome aquifer is to the Indian Ocean on the west, and to King Sound on the east.

Water quality

Water from the Broome aquifer is sodium chloride type, with occasional high bicarbonate and sulfate concentrations. Magnesium and sulfate appear to be associated with saltwater intrusion and the aquifer generally has high silica content.

Generally groundwater in the Broome aquifer is fresh inland, becoming marginal to saline at the coast (Figure 12). In the south-west of the peninsula, saltwater intrusion (from the sea) has led to an increase in salinity along the coast and at depths further inland (~ 10 km), most likely brought about by groundwater abstraction. Although it was not possible to determine the location of the saltwater interface, in the north of the peninsula ~ 8 km inland, Rockwater (2004) calculated it could be 300 to 400 m below the watertable. Salinities from the Broome town water supply borefield suggest either upconing or intrusion is starting to affect water quality at depths of around 100 m below ground level up to 10 km inland (Appendix B). The Water Corporation has reduced its use of these bores and redesigned the borefield to minimise the risk of saltwater intrusion or upconing.

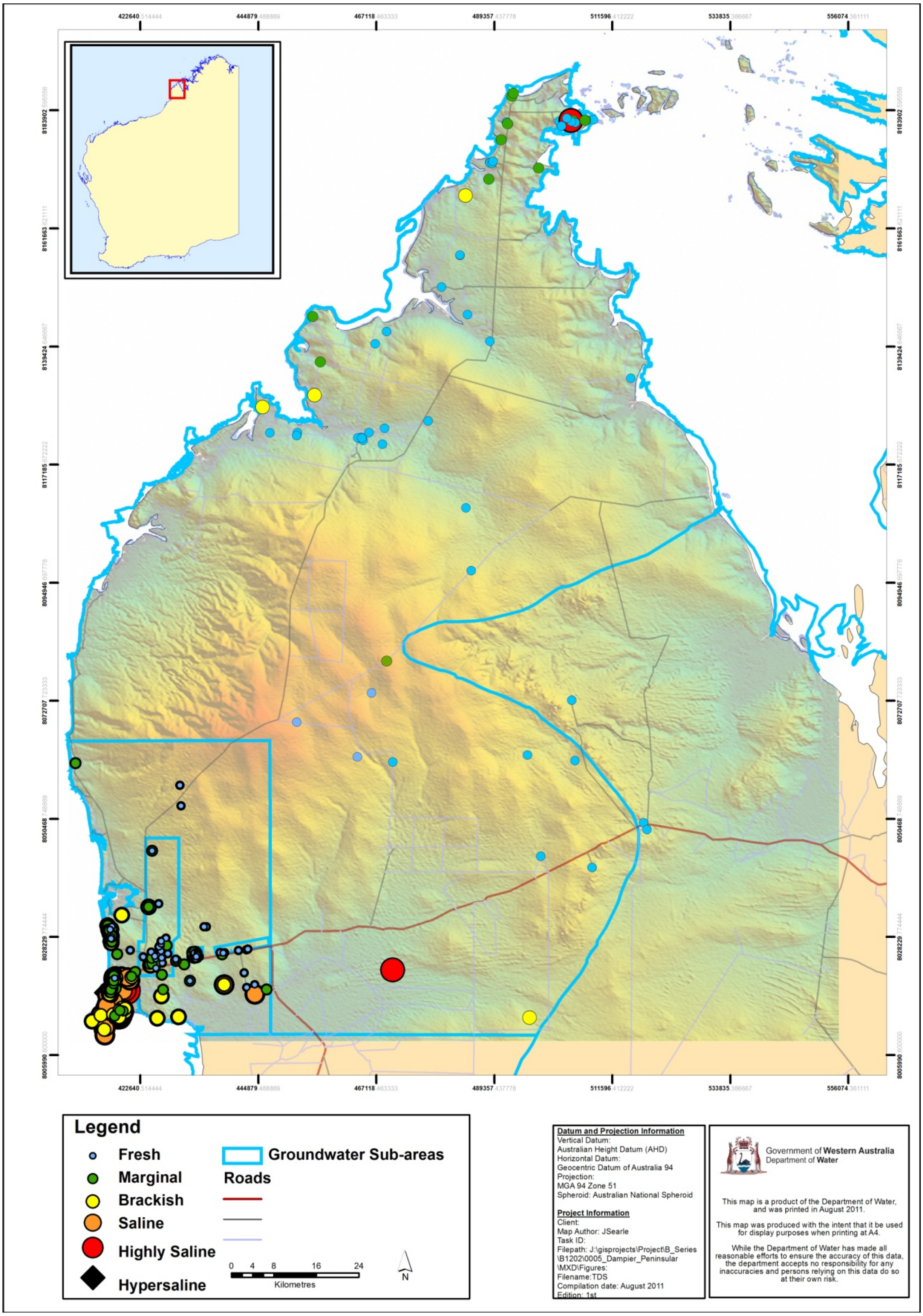


Figure 12 Salinity distribution in the Broome aquifer

2.5.4 Wallal aquifer

Geology

The Department of Water considers the Wallal Sandstone Formation and the Alexander Formation to form a single aquifer called the Wallal aquifer. This conclusion is based on the formations being in hydraulic continuity and containing essentially similar lithology. Laws (1991) and Smith (1992) have described the lithology of the formations, which is summarised here. The Alexander Formation is a light grey sandstone interbedded with minor blue-grey siltstones. The sandstone is a weakly cemented, moderately sorted, fine- to very fine-grained, quartz sand. The Wallal Sandstone Formation is similar, but it is coarser grained (fine- to coarse-grained) and poorly consolidated. Siltstone interbeds are grey to light brown, with minor coal seams towards the base of the unit. Across most of the peninsula the Jarlemai Siltstone overlies and confines groundwater in the Alexander Formation. This in turn overlies and is connected with the Wallal Sandstone Formation. In the far south-east of the peninsula the Wallal aquifer is unconfined, occurring at or near the surface, where the overlying strata have eroded away.

This review has shown the combined thickness of the Wallal Sandstone and Alexander Formation is up to 230 m (Crab Creek 1, in the south). The formations thin to 62 m in the north-east of the peninsula (Purrate 1), and 54 m in the south-east (DHM 8A). One bore intersected a combined thickness of 580 m of Wallal Sandstone and Alexander formation (YULLEROO No. 1); however this thickness is not seen in any other bores. The top of the Wallal aquifer is up to 412 m below surface in the north-west of the peninsula, and as shallow as 3 m in the east (DHM 8A (Deep)), reflecting the west plunging, east–west striking anticlines.

Hydraulic parameters

There is only limited pump test data available to describe the hydraulic properties of the Wallal aquifer. Hydraulic parameters for the Wallal aquifer were calculated from step-rate and constant-rate flow tests for the bore ACP No. 1 in the Cable Beach subarea (Rockwater 1987). Transmissivity in the Wallal Sandstone was reported to be 2200 m^2/d and the hydraulic conductivity was 44 m/d. The aquifer had an artesian flow rate of 1200 m^3/d, with a static water level of 38.84 m above ground level (51.72 m AHD). Within the Alexander Formation, bore Keelindi 1 (also at Cable Beach) reported a transmissivity of 10 m^2/d, artesian flow of 570 m^3/d and a shut-in head of 35.9 m above ground level (22 m AHD) (Rockwater, 1985).

Groundwater flow, recharge and discharge

Based on limited information, groundwater is believed to flow west and north-east from the centre of the peninsula (Laws 1991). Most recharge is believed to take place in the southern extent of the aquifer (south of the Dampier Peninsula) in the Canning Basin, with groundwater flowing north to the Fitzroy River and King Sound (Smith 1992). Recharge through rainfall infiltration and leakage from the Surficial formations is likely in the east of the peninsula where the Jarlemai Siltstone is absent. Based on the work of Harrington et al, (2011) discharge from the aquifer on the east of the peninsula is to the Fitzroy River and pools along the river where the Jarlemai Siltstone aquiclude is thin or absent, and into King Sound. The Wallal aquifer is very deep to the west of the Dampier Peninsula, extending under the Indian Ocean.

Water levels

In the eastern half of the peninsula water levels range from 2 m above ground to 25 m below ground (8 m AHD and 30 m AHD respectively). In the west, where the aquifer is much deeper and artesian, water levels were measured as 36–39 m above ground level (> 50 m AHD). There is insufficient data to determine seasonal or longer term trends, as only three bores had more than one water level record, all lacking dates.

Water quality

Groundwater in the Wallal aquifer has a neutral pH (6.3–7.8) and is dominated by sodium and chloride ions, often with significant sulfate (commonly over 500 mg/L SO_4). High sulfate concentrations are associated with saline water. Commonly groundwater from the Wallal aquifer has high concentrations of calcium and magnesium (up to 175 and 214 mg/L respectively). In the west groundwater is brackish to moderately saline (1900–4700 mg/L TDS), while in the east it is fresh to saline (120–7550 mg/L TDS) (Figure 13). Salinity in the aquifer on the east could result from natural seawater intrusion from King Sound.

Total silica concentrations were higher in the Alexander Formation than in the Wallal Sandstone (18 mg/L and 9.5 mg/L respectively); however the total iron concentrations were higher in the Wallal Sandstone than the Alexander Formation (13.4 mg/L and 3.65 mg/L). Dissolved iron concentrations were up to 24 mg/L in samples from bore Logue (NEW) (207) the east. There is no evidence of increased salinity over the life of the bore at Cable Beach screened in the Alexander Formation (> 20 years). The bore in the Wallal Sandstone at this point is no longer in use and hence has not been sampled since 1988.

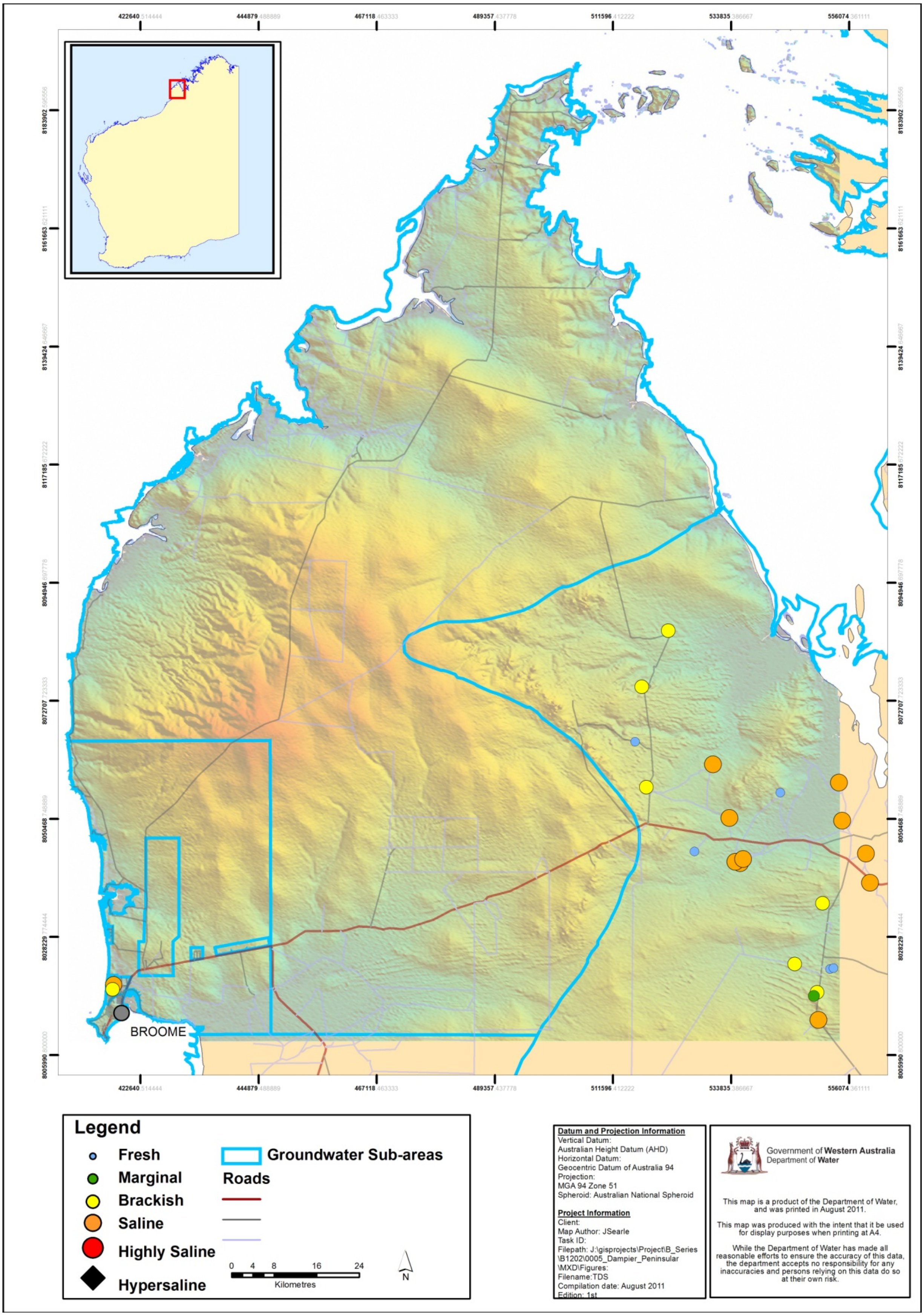


Figure 13 Salinity distribution in the Wallal aquifer

2.5.5 Liveringa aquifer

Groundwater is being used in the east of the Dampier Peninsula, where the aquifer is closer to the surface. The following information refers only to the part of the Canning–Kimberley groundwater subarea that falls within the Dampier Peninsula.

Geology

On the Dampier Peninsula, the Liveringa Group underlies the Wallal Sandstone, Alexander Formation or the Blina Shale, and overlies the Noonkanbah Formation. The unit comprises thickly interbedded sand and clay layers. The sand beds are 6–30 m thick, made up of light- to dark-grey, medium- to very coarse- grained, moderately to poorly sorted quartz sand, with trace garnet and dark fines. The clay layers are 2 to 48 m thick with thin white sandstone layers. The clay is dark grey to black, with trace mica. On the east of the peninsula where the groundwater is being used, the formation top is 21–57 m below ground surface, and the unit is 125 m thick. Elsewhere on the peninsula the top of the Liveringa aquifer is 565–919 m below ground level, and 18–232 m thick.

Hydraulic parameters

The two bores with recorded water levels (one record each) have potentiometric heads ranging from 0–4.84 m below ground level (10 to 15 m AHD). Water supply ranges from 110–116 m^3/d.

Groundwater flow, recharge and discharge

Groundwater flow, recharge and discharge cannot be determined from the available data. Previous work has indicated that recharge occurs to the east and north-east of King Sound, and that discharge could be taking place at the Fitzroy River and by upward leakage to the overlying Wallal Aquifer (Smith 1991). Based on a lack of a significant confining layer, and similar water levels, it is assumed that the Liveringa and the Wallal aquifers are hydraulically connected on the east of the peninsula.

Water quality

There are three water quality samples from three different bores, which indicate water quality is very similar to the Wallal aquifer. These samples indicate the groundwater in the Liveringa Group is moderately saline (2130–3600 mg/L TDS), neutral (pH between 7.3 and 7.9) and dominated by sodium and chloride ions. As with water from both the Broome aquifer and the Wallal aquifer, concentrations of iron exceed many assessment levels (drinking water 0.3 mg/L, domestic non-potable water 3 mg/L, and both long- and short-term irrigation water 10 and 0.2 mg/L). Drinking water assessment levels are breached by chloride concentrations (250 mg/L), sulfate concentrations (500 mg/L), and hardness as $CaCO_3$ (200 mg/L) (DEC 2010).

2.6 Monitoring

The current monitoring regime has recently been updated. The new monitoring program includes 26 sites. Measurements of static water level, total bore depth, conductivity and temperature are to be collected twice a year. Monitoring will take place at the end of the dry season, and if bores are accessible, at the end of the wet season. Of the 26 sites, 24 are in the Broome groundwater area, with the remaining 2 located near the centre of the peninsula.

Eight regional Department of Water monitoring bores were installed in the 1980s through the centre of the peninsula. After an initial round of water level and quality sampling, these bores were never monitored and the coordinates were entered incorrectly into the WIN database. The coordinates have now been corrected.

Licensee monitoring requirements are decided during the licensing process based on potential risks to the water resource, the environment and other users. Where licensees are required to monitor and sample groundwater bores, this is enforced through licence conditions (and sometimes an operating strategy) which set out a monitoring program and a reporting schedule. This data is supplied to the department, but is not captured the WIN database.

As part of this review, a desktop bore audit was conducted of department and non-department bores right across the peninsula. The audit highlighted bores which were likely to be suitable for monitoring. Two field trips were undertaken to locate these bores and collect water level measurements. Of the more than 50 bores on the target list (including the regional monitoring bores), only 8 were able to be located and sampled. Attempts to locate these bores were by helicopter and four-wheel-drive vehicle.

3 Main findings

3.1 Groundwater resources

Groundwater resources of the Dampier Peninsula are generally showing no signs of adverse effects due to the current use, with the exception of some subareas of the Broome groundwater area. Changes in water quality in this area indicate that limits to abstraction have been reached.

Additions of existing bores to the current monitoring program are recommended to enable improved assessment of the status of groundwater resources, at a level appropriate with current management pressures.

This review suggests there are significant quantities of groundwater available across the Dampier Peninsula, in the Broome as well as underlying aquifers and that there is currently very little use of this resource. Factors which constrain any proposed use of water resources include the following:

- intrusion and upconing of the saltwater interface
- effects on groundwater-dependent ecosystems
- the ability of the aquifer to yield the high quantities of water required for large scale horticulture at single abstraction points (potential yields of production bores)
- uncertainty in the distribution of aquifer parameters.

Table 4 below summarises these possible limitations, and provides a quick reference guide to some of the characteristics of shallowest groundwater in the region (generally the Broome aquifer). Groundwater is available in the Wallal aquifer across the peninsula, but assessment of the opportunities and risks is limited by the few investigations of this deep resource. The aquifer is > 470 m below ground level with data indicating that the water is moderately saline (1900-4700 mg/L TDS) and can contain high iron (up to 24 mg/L).

Table 4 Summary of risks, opportunities and guiding characteristics for groundwater development on the Dampier Peninsula

Groundwater area	Groundwater subarea	Risks and opportunities	Depth to watertable	Min. saturated thickness (shallowest aquifer)	Salinity range mg/L TDS
Canning–Kimberley	Canning–Pender	Large quantities of available fresh water in the Broome aquifer, depending on GDEs and saltwater interface	2–120 m	Broome: 30–300 m	Broome: generally < 500
	Canning–Kimberley	On the eastern side of the peninsula, there is limited water in the Broome aquifer but water available in the Wallal and Liveringa aquifers (shallower in this area). Limited data indicates groundwater is fresh to saline, with high iron and sulfate.	0–15 m	Broome: < 34 m Wallal: Unknown Liveringa: Unknown	Broome: 125–1718 Wallal: 120–7550 Liveringa: 2130–3600
Broome	Townsite	Salinity risk in the Broome aquifer is high. New private bores continue to be discouraged.	1–13 m	Broome: 280 m	Broome: 415–6626
	Town water reserve	Water is available but limited by salinity in the southern part.	20–40 m	Broome: 190 m	Broome: 230–700
	Roebuck	Large quantities of fresh water are available in the Broome aquifer, depending on GDEs and saltwater interface. Salinity is a significant risk in the south and south-east.	4.5–> 116 m	Broome: north-east: 84 m south-west: 273 m	Broome: 75–10 900
	Cable Beach	Salinity risk in the Broome aquifer is high. New private bores will be discouraged.	2–16 m	Broome: 273 m	Broome: 421–4272 Wallal: 1900–4700
	Skuthorpe	Water is available depending on the position of the saltwater interface.	13–37 m	Broome: 130 m	Broome: 140–400
	12 Mile	Limited water is available depending on the position of the saltwater interface.	15–25 m	Broome: 119 m	Broome: 347–689
	Coconut Wells	Salinity risk is in the Broome aquifer is moderate. Limited water is available depending on the position of the saltwater interface.	5–25 m	Broome: 270 m	Broome: 431–1660

3.2 Knowledge gaps

3.2.1 Surface water-groundwater interactions

In order to facilitate future planning and development, new investigations are required to determine limits of the resource within the constraints identified above. Knowledge gaps are identified below to guide development of immediate and future investigations (including 'Royalties for Region' projects).

Groundwater-dependent ecosystems must first be identified before the effects of abstraction on them can be assessed and managed. There have been two groundwater-dependent ecosystems studies on the Dampier Peninsula: work carried out by Ecologia for Tropical Timber Plantations Pty Ltd, which focuses on the groundwater-dependent ecosystems around Bobbys Creek near Beagle Bay; and the work of Mathews et al. (2011), which focuses on wetland complexes at seepage faces along the south-west coastline. Outside these studies, potential groundwater-dependent ecosystems have only been broadly identified using remote sensed data (Boggs 2011). Both investigations indicate that there are ecosystems with a dependency on some component of stored subsurface water within the landscape (soil water, perched groundwater or regional groundwater). The nature of the dependency on regional groundwater for the identified potential groundwater-dependent ecosystems remains to be determined.

The interactions between groundwater in the Broome aquifer, the shallow watertable and wetlands or potential groundwater-dependent ecosystems are unknown. Although the Broome aquifer is considered to be a regionally unconfined aquifer, it has been suggested that in places a Surficial aquifer is perched above it, supporting groundwater-dependent ecosystems (Laws 1991). However, clear evidence of perched groundwater systems is not available. Similarly, in the eastern part of the peninsula, interaction between the Wallal aquifer and potential groundwater-dependent ecosystems is unknown.

The extent to which ecosystems are dependent on the regional watertable as opposed to local perched systems or significant soil water needs to be determined.

3.2.2 Salt water interface

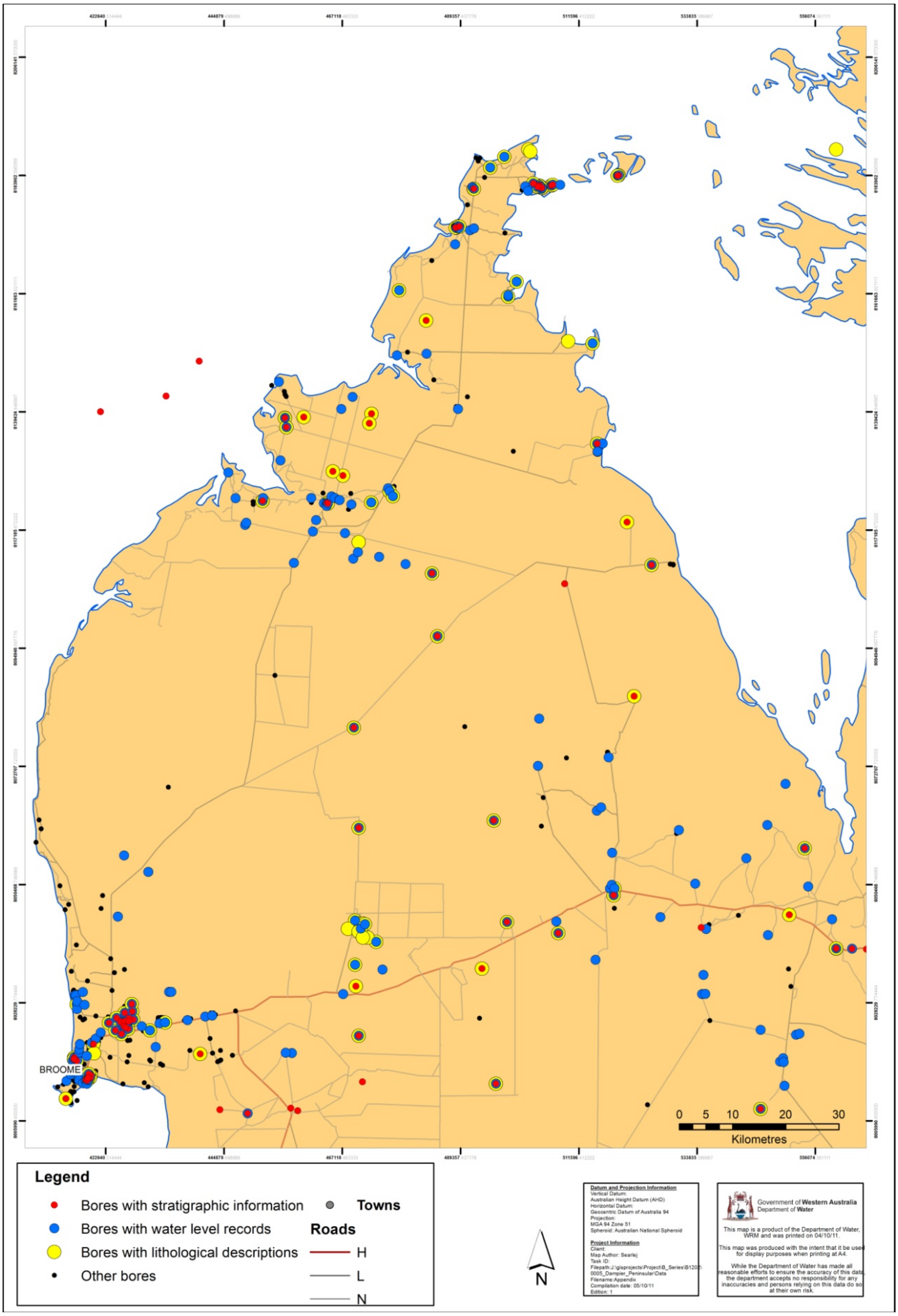
Increasing saline water intrusion is one of the factors limiting groundwater development on the Dampier Peninsula, particularly in coastal areas. Locating and monitoring the saline wedge is vital for assessing the performance of the groundwater system in response to use. The saline wedge would generally lie at the base of the Broome aquifer underlying fresh water around the whole coastline, but at present it is only of concern for use in the Broome groundwater area. Measurements of EC in monitoring bores and from licensees have been inadequate to delineate its location, as most bores are only screened in the upper part of the Broome aquifer and generally are not gamma logged.

3.2.3 Groundwater occurrence and aquifer properties

The uneven spatial distribution of bores has made it necessary to infer characteristics for large areas of the peninsula. The largest of these areas is from the centre of the peninsula, westward to the coast. In this zone there is over 60 km between bores, leaving an area of over 3600 km^2 with no measured data. There are often decades between water level measurements, and commonly there is only one measurement on record for each bore. With the current spatial and temporal distribution of hydrogeological information, flow directions and saturated thicknesses can only be broadly defined. Pump test information is restricted to only a few areas of the peninsula: Aboriginal communities around the coastline; the Tropical Timber Plantations property in the north-west; Kilto station in the central south; and a few monitoring bores in the Broome groundwater area. Demonstrating that the resource can support large scale horticultural development would reduce some of the uncertainties regarding development in the region. Knowledge gaps in flow direction and saturated thicknesses could also be addressed by infill drilling and synoptic water sampling.

Appendices

Appendix A — Bores used in groundwater resource review



Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
1026	Barlee 1	469682.5	8031330	y	y	n
1027	Cow Bore 1	470897.2	8013335	n	y	n
1028	Curringa 1	472611.3	8139065	y	y	n
1029	East Crab Creek 1	458736.9	8007896	n	y	n
1030	Freney 1	444073.3	8008087	n	y	n
1031	Jum Jum 1	508925.2	8107054	y	y	n
1032	Kambara 1	440189.2	8148944	n	y	n
1033	Minjin 1	433975.5	8142382	n	y	n
1034	Moogana 1	467218.7	8127426	y	y	n
1035	Padilpa 1	520671.4	8118662	y	y	n
1036	Pearl 1	397127.3	8026170	n	y	n
1037	Perindi 1	421631.3	8139438	n	y	n
1049	M1	469498.5	8035385	y	n	y
1050	M2	469514	8043697	y	n	y
1051	M3	473494.3	8039668	y	n	y
1052	P1	470198.9	8043121	y	n	n
1053	P10	471886.2	8040488	y	n	n
1054	P2	470486.9	8043121	y	n	n
1055	P3	471033.1	8043122	y	n	n
1056	P4	471369.1	8042984	y	n	y
1057	P5	468189.1	8042155	y	n	n
1058	P6	470589.1	8042159	y	n	y
1059	P7	470203.7	8114892	y	n	n
1060	P8	470169.3	8041589	y	n	n
1061	P9	471001.5	8040494	y	n	n
1062	Bygnum/Mudnum	499900	8163900	y	n	y
1063	Djoodood	477800	8162300	y	n	y
1064	Goolarrgoon	494917	8185374	y	n	y
1065	Gudumul	514200	8152300	y	n	y
1066	Gunbarnum	502100	8188800	y	n	n
1068	Malambo	509600	8152700	y	n	n
1069	Murphy Creek	497600	8187400	y	n	y
1070	Nywhan	502500	8188400	y	n	n
1071	Rumbul Bay	498300	8161100	y	n	y
1095	TTM13	476000	8124485	y	n	y
1096	TTM14	476635	8123535	y	n	y
1101	TTM17	472555	8122355	y	n	y
1105	Crab Creek 1	457421	8008378	n	y	n
1106	Pender 1	415137	8010161	y	y	n
1107	Fraser River No. S-1 Struct	415137	8010161	n	y	n
1108	Fraser River 1	488516	8174068	y	y	y
5000	ACP No.1	416480	8017500	n	n	n
5001	Keelindi No.1	416430	8017550	n	n	n
80100001	BORE A	496000	8013000	y	y	y
80100002	BORE B	498100	8043400	y	y	y
80100003	BORE C	495600	8062500	y	y	y
80100004	BORE D	485000	8097200	y	y	y

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80100005	BORE E	484000	8109000	y	y	y
80100006	BORE G	469300	8080000	y	y	y
80100007	BORE H	470196.9	8061136	y	y	y
80100008	BORE I	470200	8022000	y	y	y
80110005	NO 22 (3)	444336	7988031	n	y	n
80110031	BARN HILL (22)	399181	7969227	n	y	n
80110034	BORE	433787	8024511	y	n	y
80110036	BULLOCK PADDOCK BORE	440388	8018587	y	y	n
80110040	BORE	430937	8023011	y	n	y
80110042	BORE	417137	8027901	y	n	y
80110043	BROOME TOWNSITE BORI	419653	8014048	y	y	n
80110044	BROOME T-S BORE NO. 2	419853	8014522	y	y	n
80110045	BROOME T-S BORE NO 3	419670	8014089	y	y	n
80110046	BROOME T-S BORE NO 4	418904	8013670	y	y	y
80110047	CABLE BEACH	417493	8014706	n	n	y
80110048	UNITING CHURCH	419134	8013634	y	y	y
80110049	BORE	420308	8020410	y	y	n
80110050	BORE	419436	8014809	y	y	y
80110055	CRAB CREEK NO 1 (I)	449302	8007381	n	y	y
80110059	NEAR CEMETARY (29)	488465	8174087	y	y	y
80110060	(30)	488477	8174081	n	n	y
80110062	THOMAS (41)	488317	8170933	n	n	y
80110064	LOMBADINA 47	488516	8174068	n	n	y
80110065	LOMBADINA BORE 1 (NO.	488891	8174351	y	n	y
80110066	LOMBADINA BORE 2 (NO.	488891	8174351	y	n	y
80110069	(60)	498316	8161352	n	n	y
80110070	BRONGLO (38)	482941	8150345	n	n	y
80110073	PENDER NO 1-1	482888	8156613	y	y	n
80110078	(7)	466913	8139930	n	n	y
80110079	WEEDONG (89)	469025	8142216	n	n	y
80110080	TAPPERS INLET 1-1	456330	8138279	y	y	y
80110081	TAPPERS INLET 1-2	456324	8138273	y	y	y
80110082	MIDLAGOON? (9)	455173	8145047	n	n	y
80110083	TAPPER INLET NO 1(10)	456604	8136520	y	y	y
80110084	(11)	456604	8136527	n	n	y
80110085	BEAGLE BAY 1-82 NO 1 NE	465716	8123195	n	n	y
80110088	NOW KNOWN AS PWD NC	464261	8122288	n	n	y
80110089	NOW KNOWN AS PWD NC	464261	8122281	y	y	y
80110091	(5)	463626	8122213	n	n	y
80110094	BOOLAMAN (6)	447043	8123135	n	n	y
80110095	HENRYS (13)	452229	8123181	n	n	y
80110096	NYUL NYUL 1-93	452118	8122653	y	y	y
80110097	NYUL NYUL 2-93	452131	8122653	y	y	y
80110099	GNAMAGUN (43)	491605	8181689	n	n	y
80110102	NGAMAKOON 1-93	491842	8181379	y	y	y
80110103	NGAMAKOON 2-93	491861	8181379	y	y	y
80110105	MT CLARKSON (NEW) (20:	530424	8060707	n	n	y

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80110106	BAKERS (YEEDA) BORE (18	517852	8056433	n	n	y
80110107	SALT (178)	515774	8064974	n	n	y
80110108	CLAYPAN BORE (179)	514978	8064330	n	n	y
80110110	DANIEL'S (187)	521995	8085901	y	y	n
80110112	FRAZER RIVER NO. 1 (186)	517205	8074393	n	n	y
80110113	HOMESTEAD (177)	503918	8072777	n	n	y
80110114	Puratte 1	525298	8110606	y	y	y
80110115	PURRATE (17)	525298	8110613	n	n	y
80110117	BARDI VILLAGE 7-74	503808	8181950	y	y	y
80110118	NO 1 1-86 (50)	504215	8181986	y	y	y
80110119	(53)	504221	8181986	n	n	y
80110120	(58)	501527	8181838	n	n	y
80110121	BROOME T-S BORE NO 5	419293	8014029	y	y	n
80110126	BORE	426072	8055924	n	n	y
80110130	GOVT WELL NO 1	421658	8022594	n	n	y
80110131	NOBLES WELL	417577	8013639	n	n	y
80110133	BARGAJOC	445665	8127994	n	n	y
80110136	YULLEROO NO 1	493387	8034661	y	y	n
80110138	A PW6	472202	8137237	y	y	n
80110139	PWD NO 4 YARP	459857	8138408	y	y	n
80110140	B PWD 5	465329	8128214	y	y	n
80110141	YALLOT	455468	8130263	n	n	y
80110147	BARDI VILLAGE 1-74	503802	8181963	y	y	n
80110148	OBS NO 1	504215	8181986	n	n	y
80110149	(57)	502057	8180965	n	n	y
80110150	(49)	508074	8182109	n	n	y
80111001	BROOME RD	420425	8018714	y	n	n
80119001	PROD 3	427191	8024975	y	y	y
80119002	OBS 5	423209	8024449	y	y	y
80119003	OBS 4	427611	8026581	y	y	y
80119004	OBS 3	427820	8025042	y	y	y
80119005	OBS 2	425945	8024719	y	y	y
80119006	OBS 1	425589	8022344	y	y	y
80119007	PROD 4	426179	8026337	y	y	y
80119008	PROD 2	426817	8023286	y	y	y
80119009	PROD 1	425398	8024576	y	y	y
80119010	PROD 5	426575	8024710	y	y	y
80119011	OBS 6	427510	8027986	y	y	y
80119012	PROD 1-73	426984	8025292	y	y	y
80119013	PROD 2-73	426288	8024747	y	y	y
80119014	PROD 3-73	425990	8023841	y	y	y
80119015	PROD 4-73	424444	8023011	y	y	y
80119016	PROD 5-73	424679	8025335	y	y	y
80119017	PROD 6-73	426944	8024725	y	y	y
80119018	PROD 7-73	426311	8023538	y	y	y
80119031	2-74	504637	8181561	y	y	y
80119032	3-74	504637	8181561	y	y	y

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80119033	4-74	504637	8181561	y	y	y
80119034	5-74	506517	8182011	y	y	y
80119035	6-74	506457	8182011	y	y	y
80119036	1-84	504627	8181581	y	y	y
80119037	2-84	506697	8182141	y	y	y
80119039	1-86	504537	8181361	n	n	y
80119040	1-93	503887	8181779	y	y	y
80119041	2-93	503039	8182414	y	y	y
80119042	1-90	504139	8081656	n	n	y
80119043	1-96	504363	8181779	y	n	y
80119051	MAIN BORE	488707	8174121	n	n	y
80119052	GARDEN BORE	488527	8173981	n	n	y
80119053	1-83	489117	8174261	y	y	y
80119054	2-83	489127	8174271	y	y	y
80119071	1-83	464387	8122161	y	y	y
80119072	NO 2	464387	8122161	n	n	y
80119101	8-85(O)	416822	8029640	n	n	y
80119102	9-85(O)	417237	8028481	n	n	y
80119103	10-85(O)	417208	8027014	n	n	y
80119104	11-85(O)	418650	8027830	n	n	y
80119105	12-85(O)	416828	8029644	n	n	y
80119106	13-85(O)	418308	8030221	n	n	y
80119107	1-85(O)	417030	8029603	n	n	y
80119108	5-87(O)	416828	8029644	n	n	y
80119121	2-85 OBS	417750	8020419	n	n	y
80119122	3-85 OBS	417753	8020413	n	n	y
80119123	4-85 OBS	417613	8019459	n	n	y
80119124	5-85 OBS	417591	8018882	n	n	y
80119125	6-85 OBS	417261	8018085	n	n	y
80119126	7-85 OBS	417265	8017415	n	n	y
80119127	17-85 OBS	419048	8018219	n	n	y
80119128	16-85 OBS	419980	8020708	n	n	y
80119129	14-85(W14-85) OBS	420749	8021475	n	n	y
80119130	15-85(W15-85) OBS	420687	8021411	n	n	y
80119153	LOT 371 WELD ST	419402	8013789	n	n	y
80119154	LOT 100 HAMMERSLEY	419721	8014419	n	n	y
80119155	LOT 1332 FREDERICK ST	419386	8014576	n	n	y
80119157	SHIRE LOT 835 DORA ST.	418365	8013053	n	n	y
80119158	SHIRE LOT 232 GUY ST.	418904	8013542	n	n	y
80119208	WILDLIFE PARK LOT 1852	417180	8017301	y	y	y
80119209	LOT 985 MILLINGTON RD	416687	8017887	y	y	y
80119212	36477 CABLE BEACH RD	416434	8017337	n	n	y
80119216	LOT 983 MILLINGTON RD	416657	8017612	y	y	y
80119400	HCL 1	431999	8019893	n	n	y
80119401	HCL 1A	431998	8019890	n	n	y
80119402	HCL 2	429399	8023754	n	n	y
80119403	HCL 2A	429399	8023754	n	n	y

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80119404	HCL 3	434940	8030256	n	n	y
80119405	HCL 3A	434543	8030245	n	n	y
80119406	HCL 3B	434549	8030249	n	n	y
80119407	HCL 4	441350	8025608	n	n	y
80119408	HCL 4A	441350	8025608	n	n	y
80119409	3-90 12 MILE HORT	437985	8024944	n	n	y
80119410	4-90 12 MILE HORT	442624	8025801	n	n	y
80119411	12 MILE 5-90	432728	8024331	n	n	y
80119412	HCL 5	424892	8044421	n	n	y
80119413	HCL 6	430615	8052833	n	n	y
80119414	HCL 6A	430616	8052833	n	n	y
80119415	HCL 5A	424892	8044421	n	n	y
80119561	CBD1A VCL GUBINGE	416403	8015546	n	n	y
80119562	CBD1B VCL GUBINGE	416403	8015546	n	n	y
80119563	CBD2A VCL GUBINGE	416101	8014735	n	n	y
80119564	CBD3A VCL GUBINGE	416330	8015250	n	n	y
80119565	CBD4A VCL GANTHUME P	415267	8013481	n	n	y
80119701	TOWN BEACH ROBINSON	419078	8012968	n	n	y
80119710	LOT 138 HAMMERSLEY ST	419556	8014117	n	n	y
80120080	1-93	515057	8133429	y	y	y
80120140	1-93	519097	8183909	y	y	y
80120141	2-93	518897	8183861	y	y	y
80200016	YAKKAMUNGA NEW HOM	550110	8017034	n	n	y
80210001	LOVELL'S POCKET WATER	547489	7952934	n	y	n
80210002	AIR STRIP BORE-EDNAS (2	545763	8008242	y	y	y
80210007	PRIOR BORE YEEDA NO 2(	543077	8055378	n	n	y
80210008	DEEGANS NO. 3 (191)	547039	8061647	n	n	y
80210010	DEEGANS NO. 1 (COW PA	547165	8040949	n	n	y
80210011	MRD LOGUE NO. 1	551183	8044758	y	y	n
80210012	LOGUE (OLD) (208)	534606	8042376	n	y	n
80210013	ORANGE FLAT (205)	526935	8044320	n	n	y
80210014	EGANS (198)	533485	8050610	n	n	y
80210016	LOGUE MILL (209)	535530	8042090	n	n	y
80210019	DOLLYS (NEW)	534760	8029827	n	n	y
80210020	DOLLY'S (OLD) (31)	535364	8029857	n	n	y
80210021	FIELDER'S (195)	535025	8033440	n	n	y
80210022	MANGUEL CREEK WELL 30	553079	8022364	n	n	y
80210023	RODNEYS (20)	550264	8012570	n	n	y
80210024	OLD HOMESTEAD (9)	552447	8022189	n	n	y
80210025	NEW STATION HOUSE (21	550004	8017773	n	n	y
80210026	NEW STATION STOCK (22)	549435	8017127	n	n	y
80210027	HOWARDS (23)	545786	8023108	n	n	y
80210028	DINGO HOLE (204)	514712	8036277	n	n	y
80210029	NILLI BUBBACA WELL (203	517455	8049707	n	n	y
80210030	COLOURSTONE BORE (183	518295	8049765	y	n	y
80210031	NILLI BUBBACA (202)	517795	8050408	n	n	y
80210032	NILLI BUBBACA NO. 1-88	518131	8048445	y	y	y

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80210033	2-88 NILLI BUBBACA	518131	8048445	y	y	y
80210034	NILL BUBBACA QUARRY	507750	8041313	y	y	y
80210036	BULLEURA (OLD)	550456	8069392	n	n	y
80210044	HORSE PADDOCK BORE (1	595665	8006163	n	y	n
80210045	BLOODWOOD BORE (142)	604607	8000699	n	y	n
80210064	TAYLOR WOODROW	585474	8053714	n	y	n
80210067	BORE NO. 3	605703	8011832	n	y	n
80210068	NO 4 BORE	592686	8011809	n	y	n
80210069	NO 5 BORE	588481	8015287	n	y	n
80210086	NORTON'S (190)	554105	8057296	y	y	y
80210087	YEEDA ARTESIAN NO. 1 (W	575223	8047710	n	y	n
80210089	DHM 5A	567765	8039074	n	y	n
80210090	1-85 WILLARE BRIDGE RO/	569581	8040308	n	y	n
80210091	C8	566651	8038950	n	y	n
80210092	C6	566651	8038950	n	y	n
80210093	C4	566651	8038950	n	y	n
80210094	C1	566651	8038950	n	y	n
80210095	KENT BORE (189)	554726	8050086	n	n	y
80210096	DHM 6A	565701	8038289	n	y	n
80210097	DHM 7A	562989	8038371	n	y	y
80210098	DHM 8A (DEEP)	559995	8038413	y	y	y
80210099	DHM 8B (SHALLOW)	559989	8038413	y	y	y
80210100	DHM 8C (DEEP)	560015	8038426	y	y	n
80210102	RGI 3D (DEEP)	584399	8080794	n	y	n
80210103	RGI 3S (SHALLOW)	584392	8080788	n	y	n
80210105	OUTPOST (225)	580972	8083982	n	y	n
80210106	POLO PADDOCK MILL (226	581742	8081295	n	y	n
80210107	HORSE PADDOCK (227)	581325	8081905	n	y	n
80210109	POLO PADDOCK MONOPL	582291	8081885	n	y	n
80210111	MAYALL'S ARTESIAN DERB	570869	8081649	n	y	n
80210113	DCA; GSWA NO 1	571217	8082032	n	y	n
80210114	DCA; GSWA NO 2	571219	8081980	n	y	n
80210126	1-74	570819	8084478	n	y	n
80210128	MEATWORKS NO 1	570636	8083737	n	y	n
80210129	MEATWORKS NO 2	570676	8083534	n	y	n
80210130	MEATWORKS NO 3 (19)	570710	8083537	n	y	n
80210133	BORE	569119	8085198	n	y	n
80210134	BORE	572706	8082135	n	y	n
80210135	BALKERS	572322	8082139	n	y	n
80210136	BORE	569470	8085798	n	y	n
80210137	BORE	568880	8085798	n	y	n
80210138	BORE	572618	8082059	n	y	n
80210140	GAFF NOUSE	572868	8082197	n	y	n
80210141	MRD WODEHOUSE ST	568864	8085719	n	y	n
80210143	NICHOLSON SQ	568139	8086165	n	y	n
80210144	LYTTON PK BORE	568824	8085966	n	y	n
80210145	BORE	568660	8085865	n	y	n

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80210146	BORE	567689	8084873	n	y	n
80210148	BORE	569816	8085104	n	y	n
80210149	BORE	568717	8085874	n	y	n
80210150	BORE	571850	8082364	n	y	n
80210152	BORE	572466	8082856	n	y	n
80210153	SPRY'S WATERHOLE	572538	8082755	n	y	n
80210154	BORE	572278	8083114	n	y	n
80210155	SHALE BORE	573236	8082637	n	y	n
80210156	BORE	572085	8082756	n	y	n
80210157	BORE	572194	8082730	n	y	n
80210159	ROYAL FLYING DOCTOR	567427	8086224	n	y	n
80210160	MOWANJUM MISSION NO	572125	8079859	n	y	n
80210173	168	572814	8082139	n	y	n
80210179	175	572180	8082493	n	y	n
80210181	257	572162	8082879	n	y	n
80210185	262	572161	8083139	n	y	n
80210186	HOSPITAL BORE	567329	8086501	n	y	n
80210188	BORE	569355	8086184	n	y	n
80210192	269	572465	8083062	n	y	n
80210202	SUNNYSIDE BORE DEEP	573360	8079956	n	y	n
80210203	1-78 PRODUCTION	568572	8085710	n	y	n
80210204	2-78 PRODUCTION	568788	8085578	n	y	n
80210205	3-78	568783	8085129	n	y	n
80210206	4-78	568897	8085131	n	y	n
80210207	1-86	569194	8085334	n	y	n
80210208	2-88 (SITE PM 2D)	570066	8085540	n	y	n
80210209	3-88 (SITE PM3D)	567595	8084246	n	y	n
80210210	1-88	569887	8084243	n	y	n
80210211	1-89	569858	8084254	n	y	n
80210215	2-89 (SITE PM ID)	566387	8086785	n	y	n
80210218	MOWANJUM MISSION NO	572594	8077888	n	y	n
80210227	(238)	578855	8072716	n	y	n
80210228	RGI 2D (DEEP)	578816	8072698	n	y	n
80210230	RGI 15D (DEEP)	577486	8097391	n	y	n
80210231	RGI 15 S (SHALLOW)	577486	8097391	n	y	n
80210241	LANGS BORE (115)	606010	8005340	n	y	n
80210614	2-68 WHIPBILLABONG	573763	7942925	n	y	n
80210620	IRRIGATION BORE	594475	8008540	n	y	n
80210621	NO. 12 BORE	592744	8008303	n	y	n
80210632	NO. 1 BORE	600691	8023769	n	y	n
80210633	PWD FIELD NO 13	600268	8029095	n	y	n
80210634	NO. 2 BORE	592834	8024138	n	y	n
80210635	NO 10 BORE	589627	8024361	n	y	n
80210637	NO 7 BORE	599159	8013436	n	y	n
80210638	KEAVIE'S BORE	599301	8017336	n	y	n
80210639	PILLAWADDA BORE	600108	8011204	n	y	n
80210641	NO 6 BORE	592695	8020924	n	y	n

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80210642	NO 8 BORE	588196	8022436	n	y	n
80210650	BORE	578275	8051971	n	y	n
80210652	S10	566651	8038950	n	y	n
80210653	S8	566651	8038950	n	y	n
80210654	S6	566651	8038950	n	y	n
80210655	S4	566651	8038950	n	y	n
80210656	S2	566651	8038950	n	y	n
80210657	S1	566651	8038950	n	y	n
80210658	COCKATOO (188)	559212	8043909	n	n	y
80210687	BORE	567993	8086205	n	y	n
80210689	1-71 (1ST) DERBY	568477	8085499	n	y	n
80210690	MYALLS REPLACEMENT	570869	8081649	n	y	n
80219011	TEST 1	568251	8085922	n	y	n
80219012	TEST 2	568259	8085965	n	y	n
80219013	TEST 3	568311	8085904	n	y	n
80219014	1-71	568477	8085499	n	y	n
80219015	2-71	568409	8085502	n	y	n
80219016	3-71	568336	8085501	n	y	n
80219017	1	568097	8085994	n	y	n
80219018	2	568230	8086059	n	y	n
80219019	3	568238	8085979	n	y	n
80219020	4	568190	8085994	n	y	n
80219021	5	568228	8085910	n	y	n
80219022	6	568061	8085920	n	y	n
80219023	7	568344	8085888	n	y	n
80219024	8	568343	8086014	n	y	n
80219025	9	568461	8086015	n	y	n
80219026	10	568496	8085832	n	y	n
80219027	1-65	568971	8085316	n	y	n
80219028	2-65	569399	8084873	n	y	n
80219029	3-65	569242	8085527	n	y	n
80219030	1-69	568374	8085816	n	y	n
80219031	1-76	568850	8085293	n	y	n
80219032	2-76	569198	8085309	n	y	n
80219033	3-76	569239	8085209	n	y	n
80219034	4-76	569295	8085113	n	y	n
80219035	5-76	569341	8085005	n	y	n
80219040	1-82	568345	8085888	n	y	n
80219541	1-93	607141	8007812	n	y	n
80310011	EURYNGA NO 3	601948	8097248	n	y	n
80310013	BOLGERS	593104	8093290	n	y	n
80310015	MEDA ARTESIAN NO. 1	600195	8086562	n	y	n
80310017	HOMESTEAD BORE NO 2	605766	8079716	n	y	n
80310018	NO 4 BORE (MEDA)	606097	8086360	n	y	n
80310023	RGI 4D (DEEP)	587871	8085621	n	y	n
80310026	RGI 6D (DEEP)	595949	8074367	n	y	n
80310027	RGI 6S (SHALLOW)	595949	8074367	n	y	n

Unique_ID (AWRC or project code)	Name	Easting	Northing	Lithology	Stratigraphy	Water levels
80310028	RGI 5D (DEEP)	592100	8067543	n	y	n
80310029	RGI 5S (SHALLOW)	592100	8067543	n	y	n
80310109	MEDA NO 2 (LANGORA)	605369	8091715	n	y	n
80310110	BREEZER BORE	596582	8091958	n	y	n
80310111	GSI BORE AT BREEZER	596470	8092640	n	y	n
	PURRATE NO. 1 (16)	525298	8110606	n	n	y

Appendix B – Water Corporation Production bores (salts)

Some of these are total dissolved salts (mg/L) and some are electrical conductivity (mS/m)

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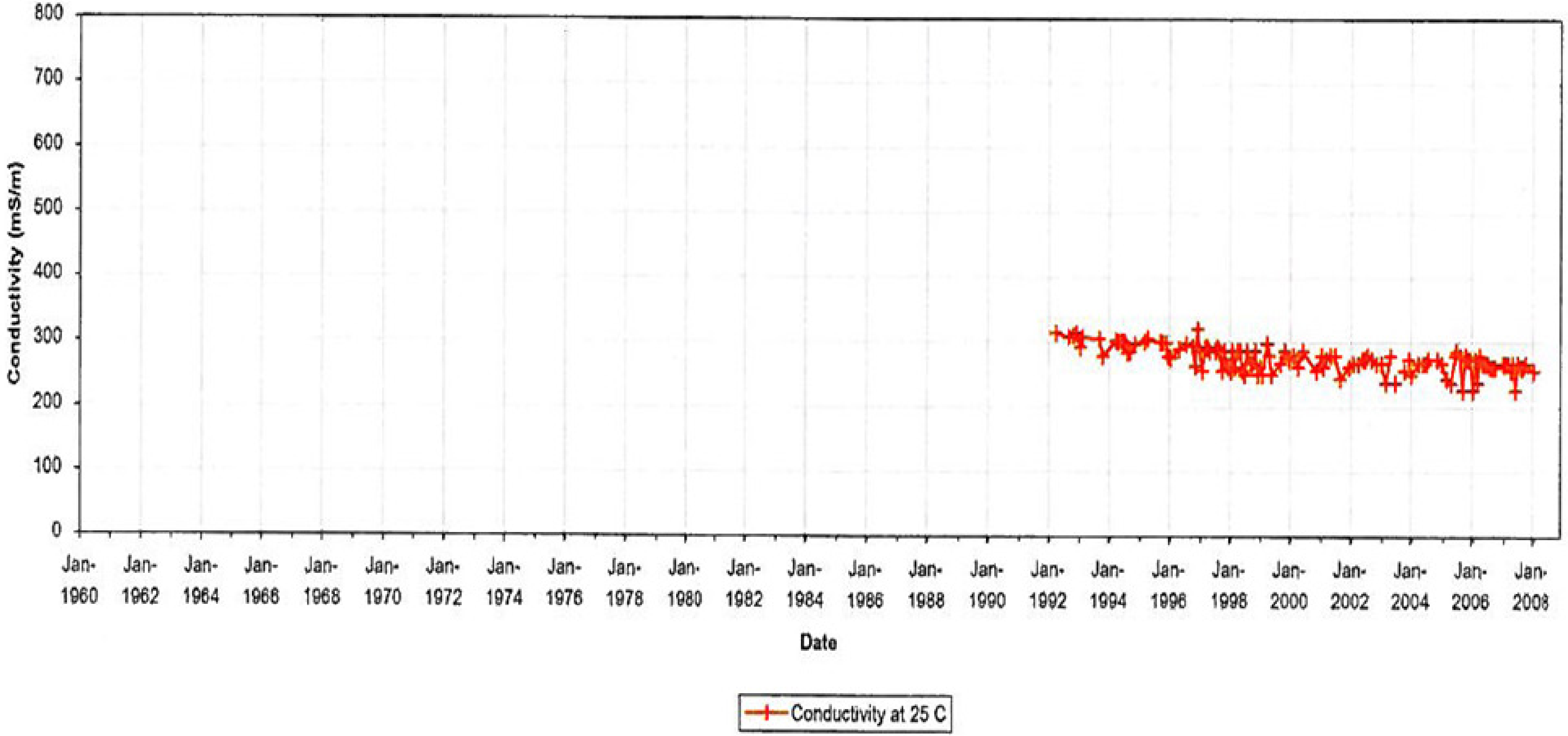

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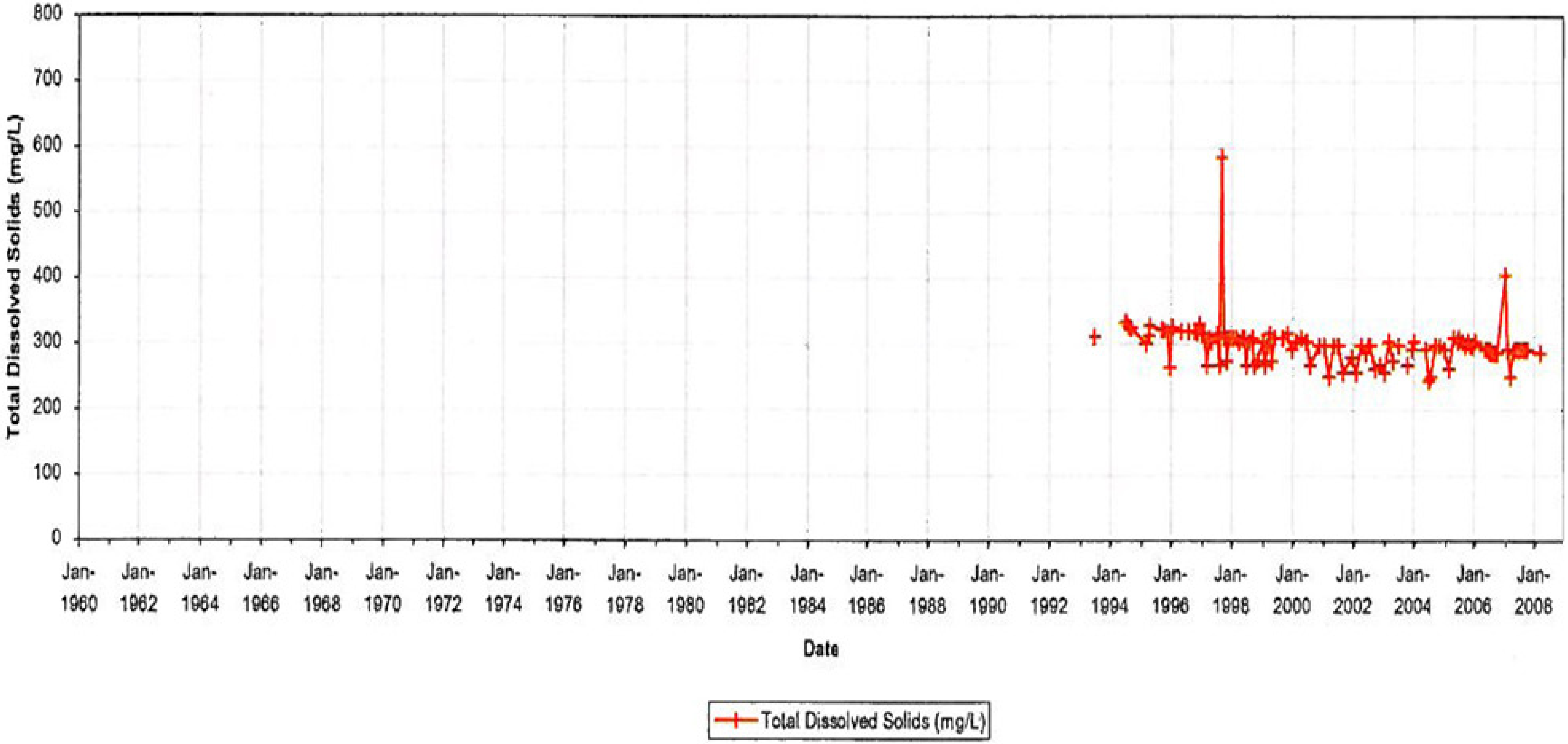

Total Dissolved Solids (mg/L)
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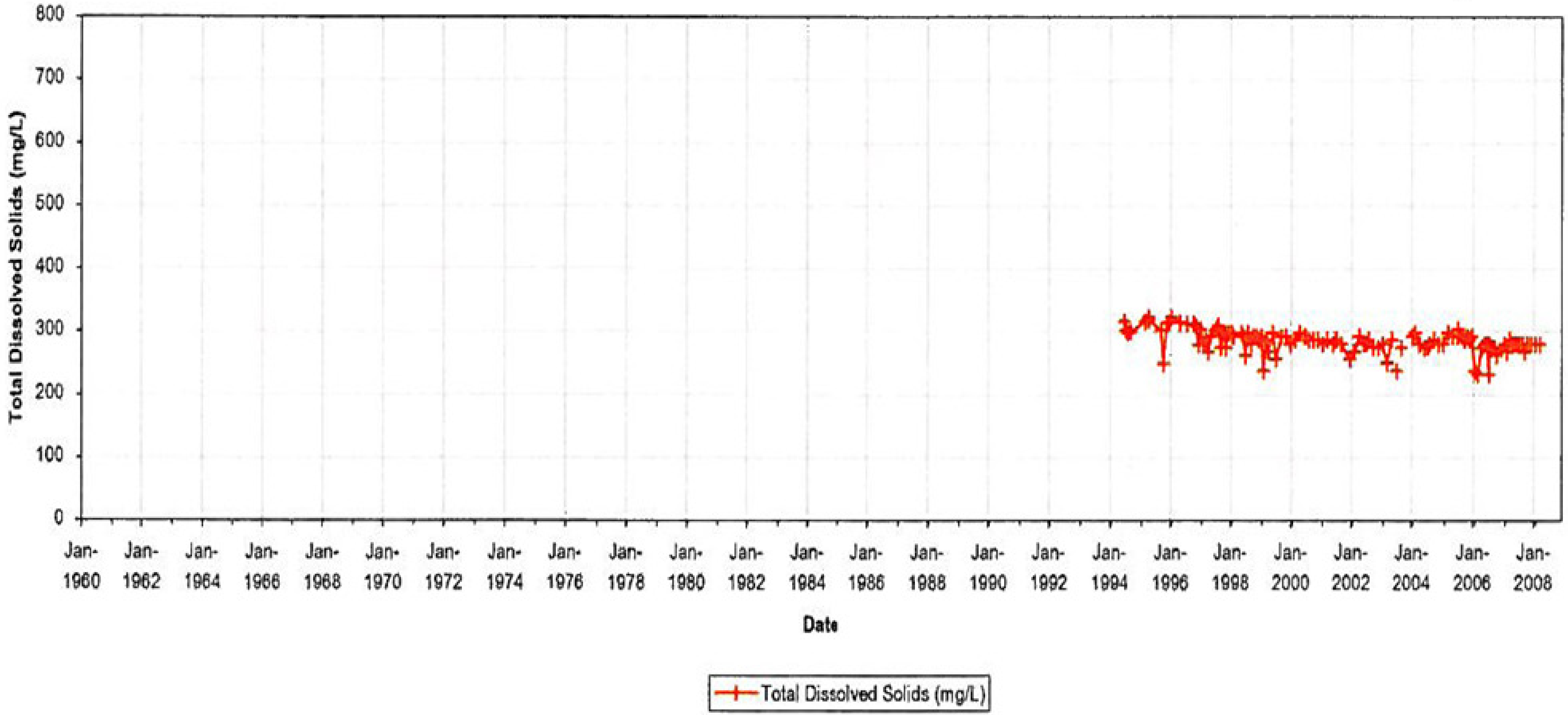

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Total Dissolved Solids (mg/L)

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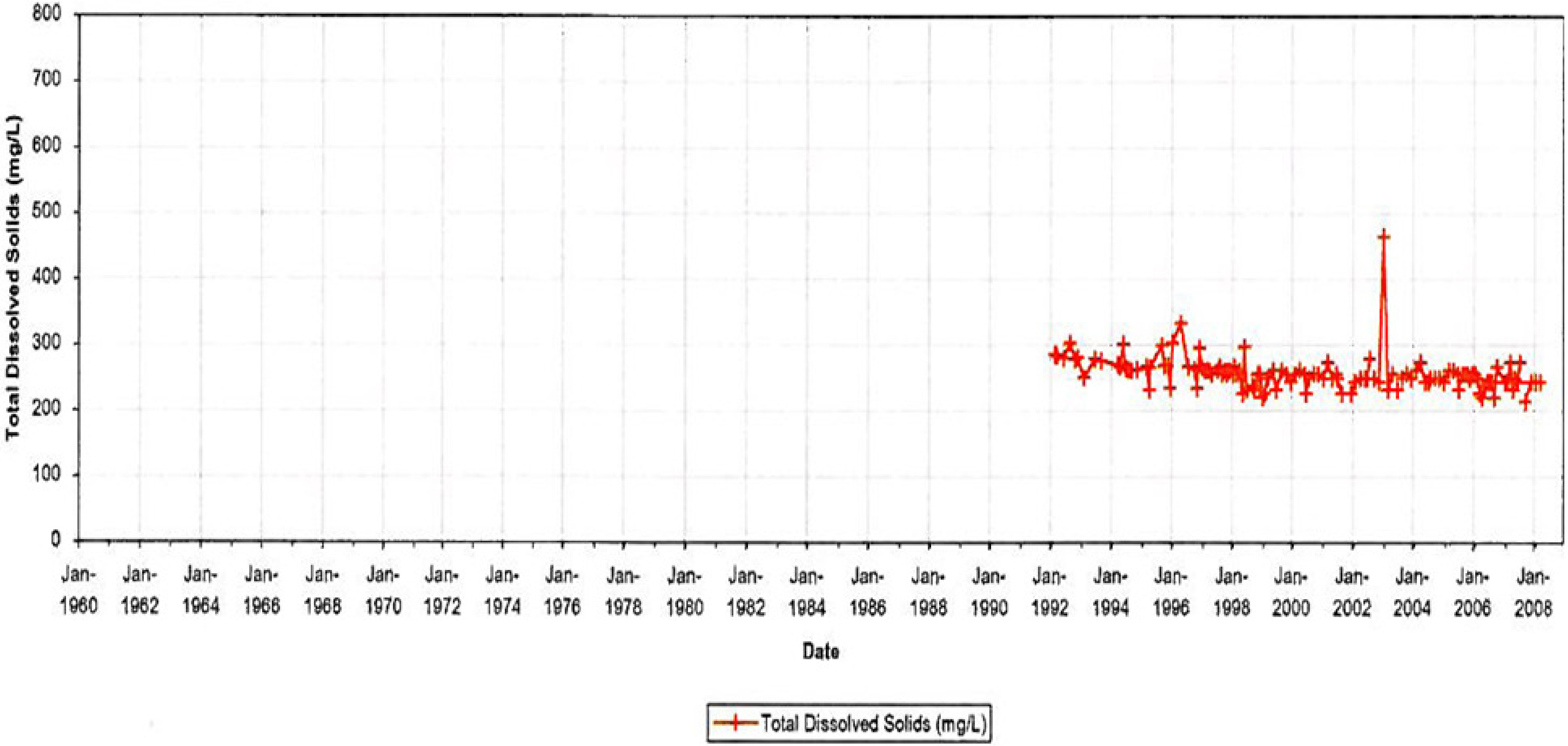
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Total Dissolved Solids (mg/L)

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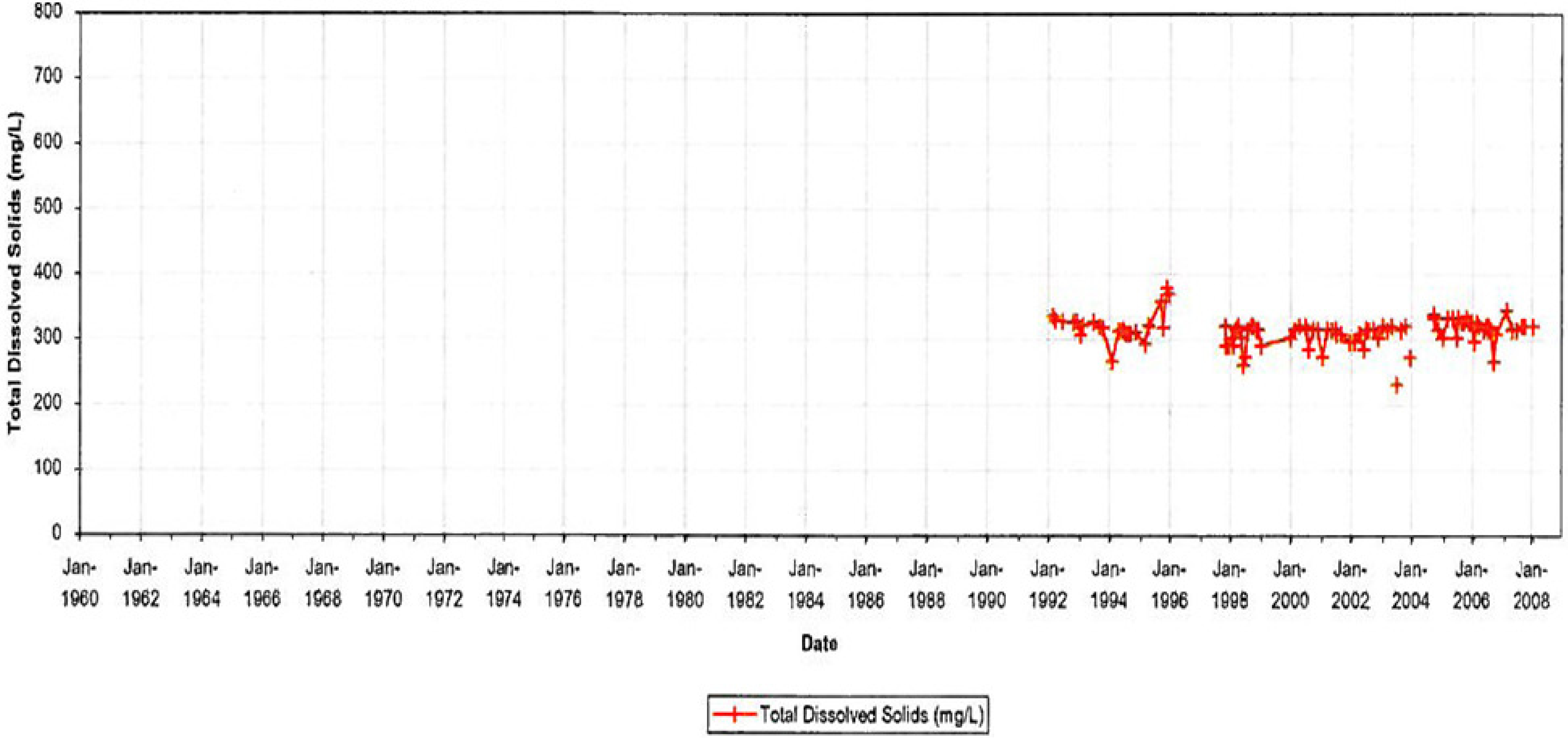
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Date
Total Dissolved Solids (mg/L)

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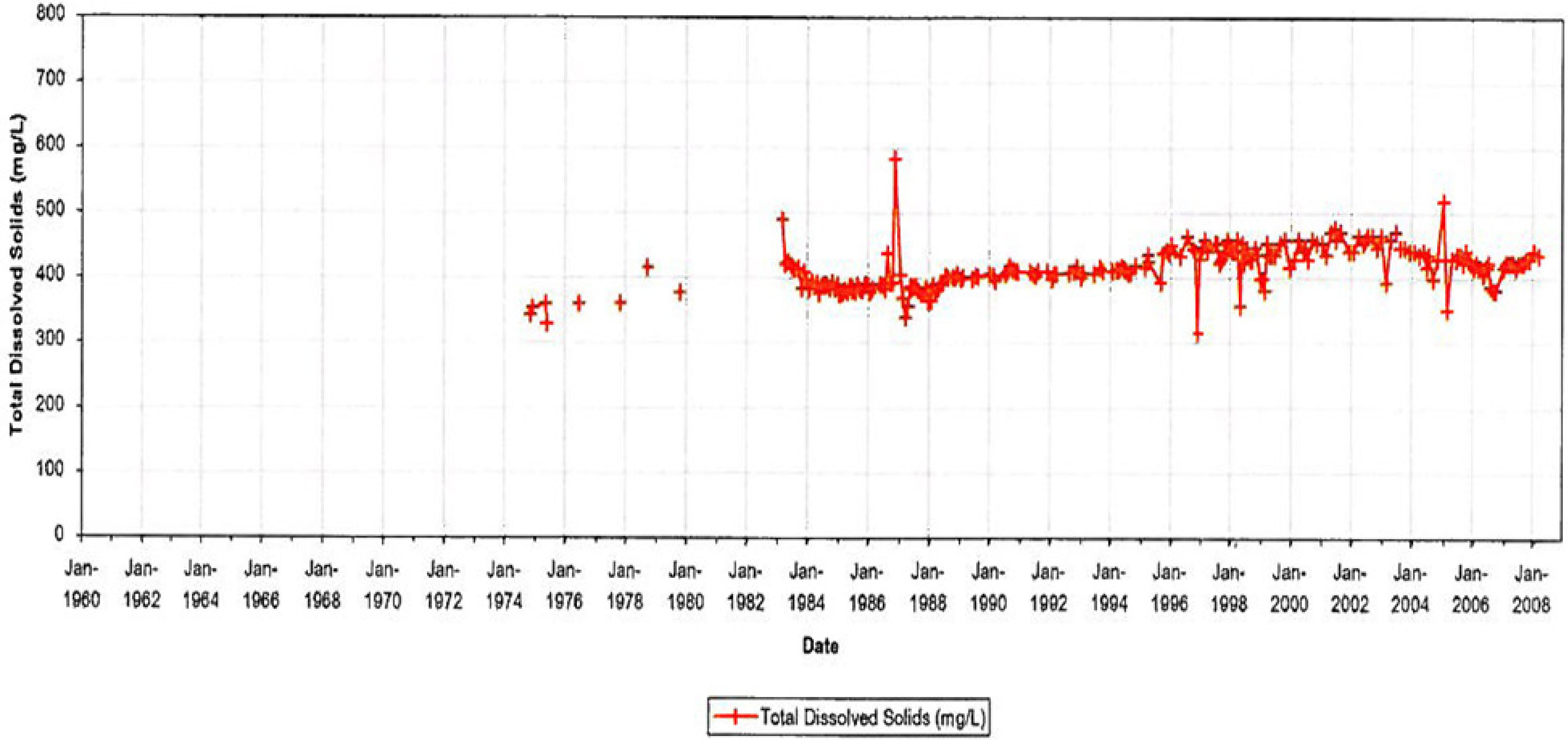

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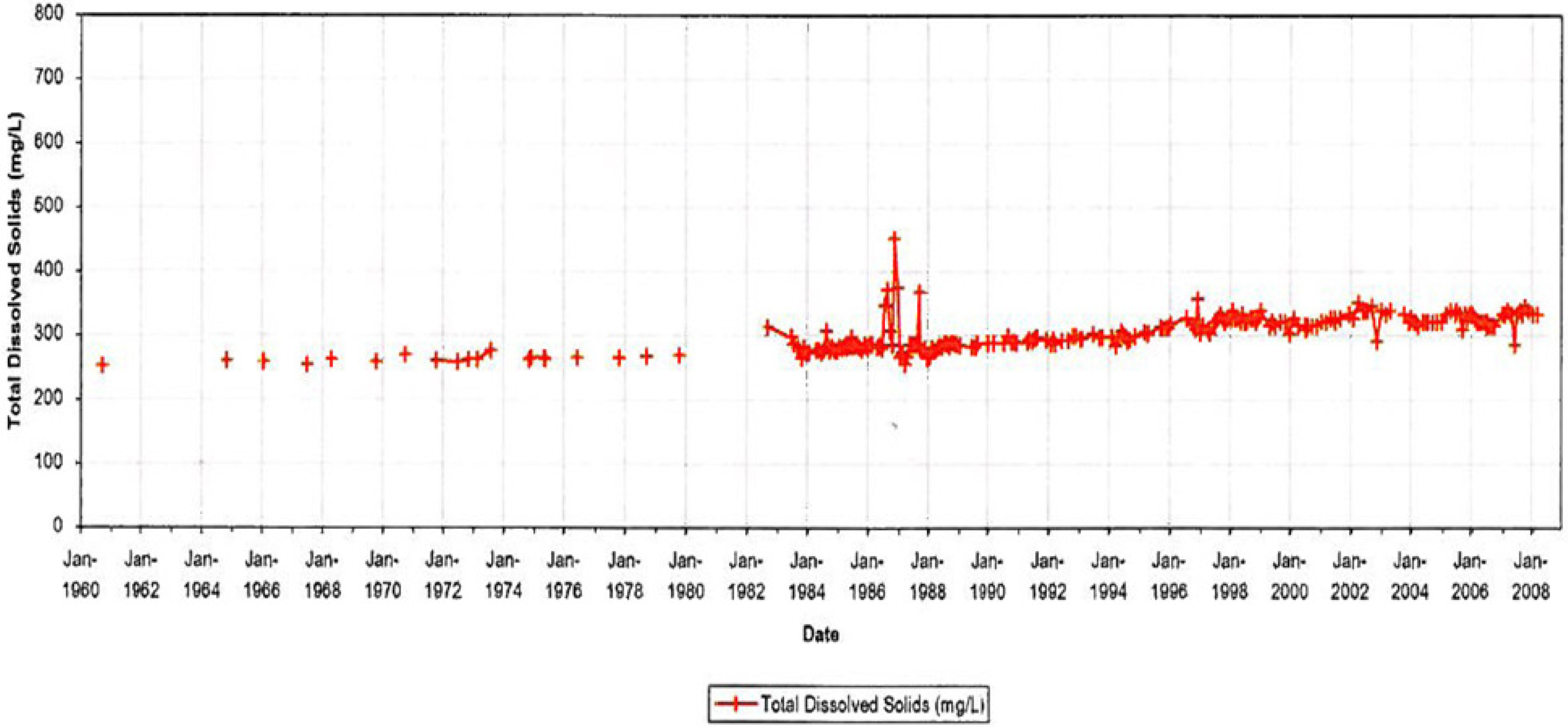
Total Dissolved Solids (mg/L)

1/81



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Total Dissolved Solids (mg/L)

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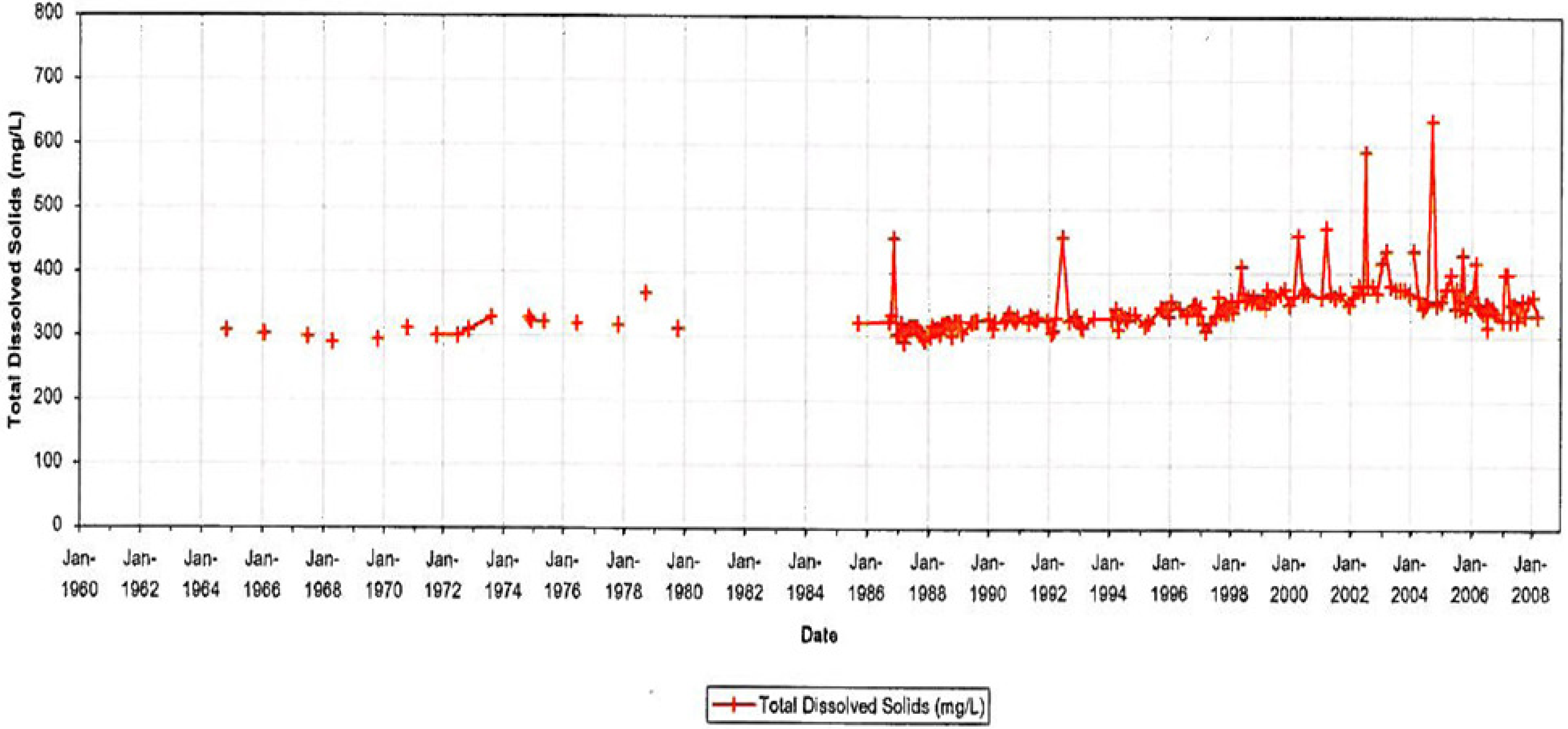
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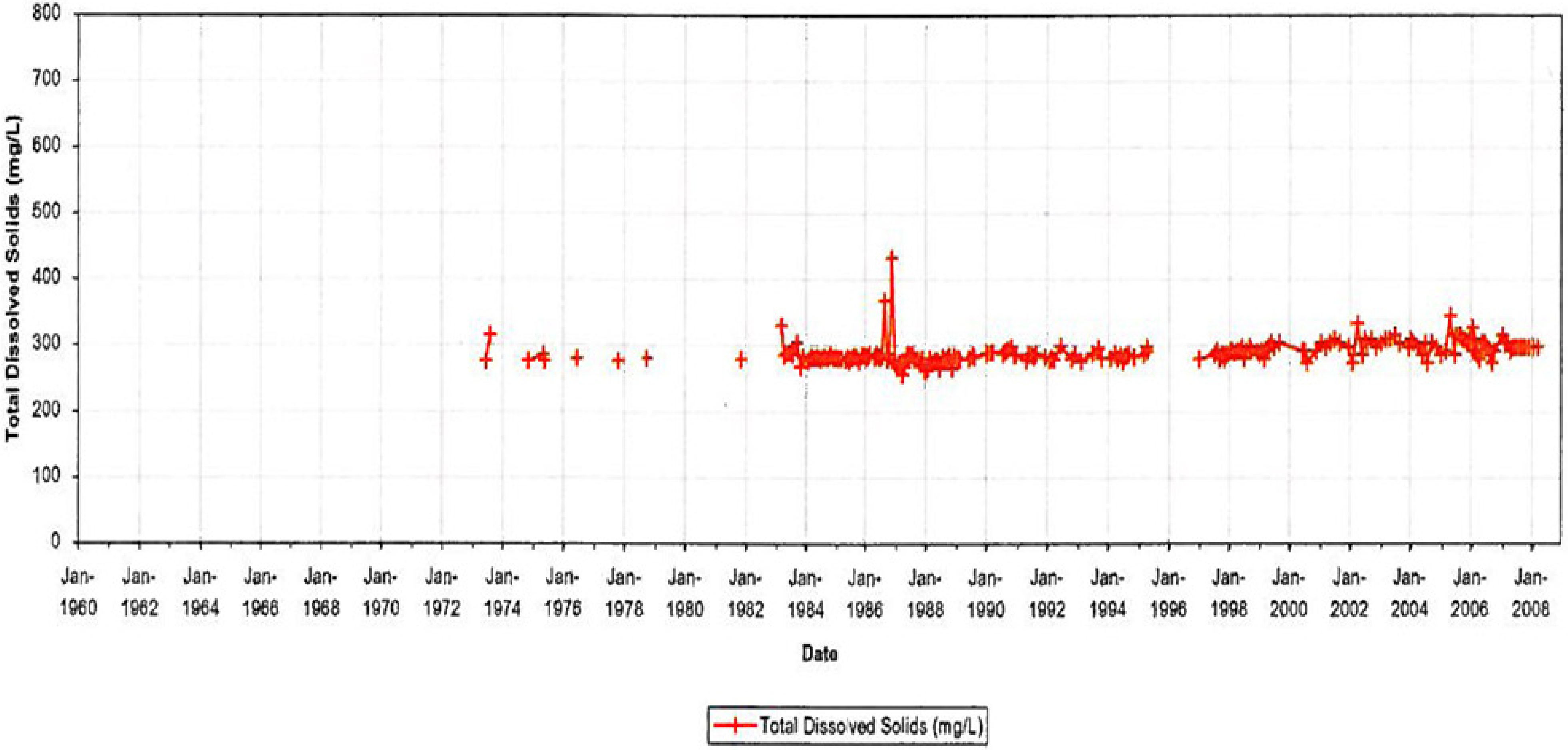
Total Dissolved Solids (mg/L)

1/73 1/95



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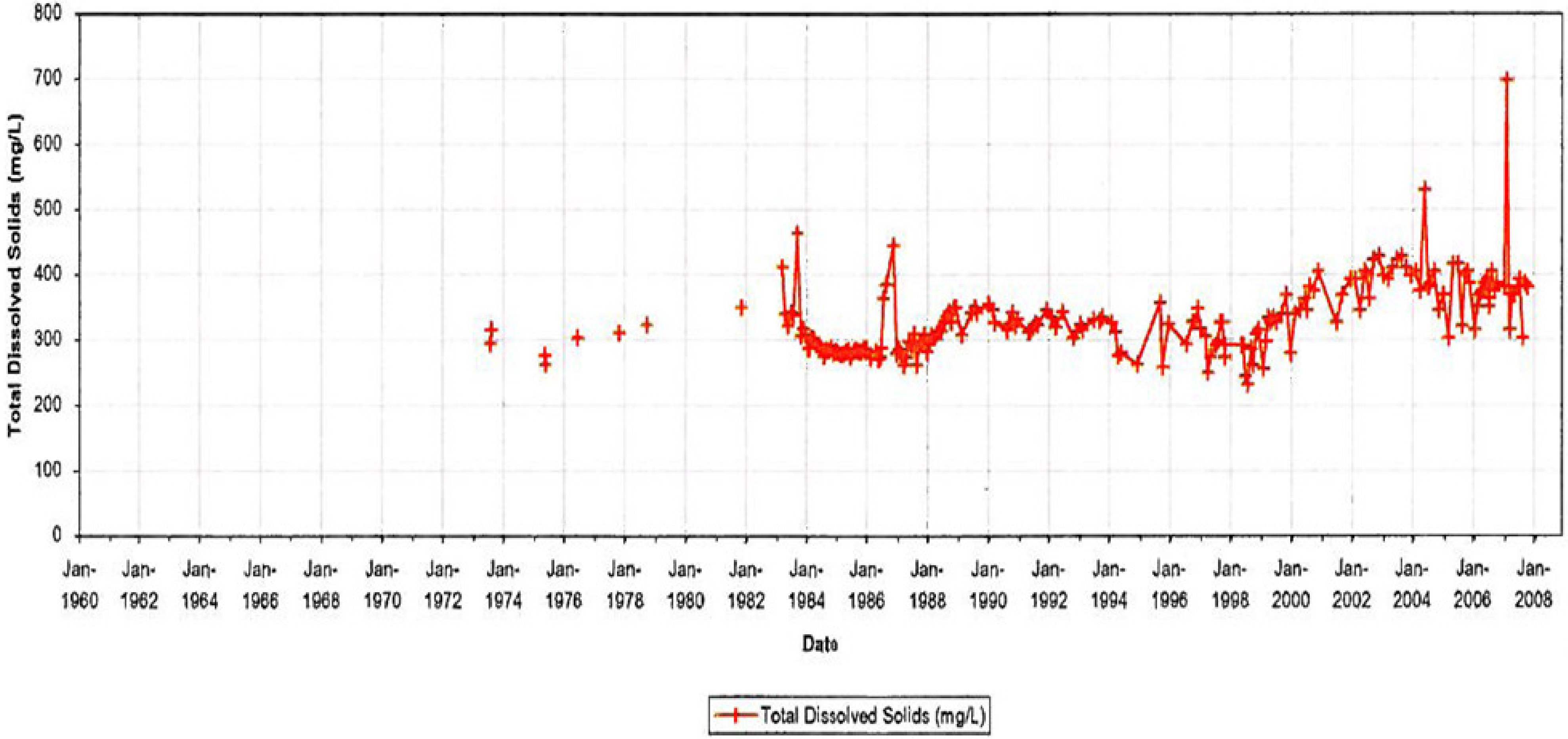
Date
Total Dissolved Solids (mg/L)

2/73 3/94



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Total Dissolved Solids (mg/L)

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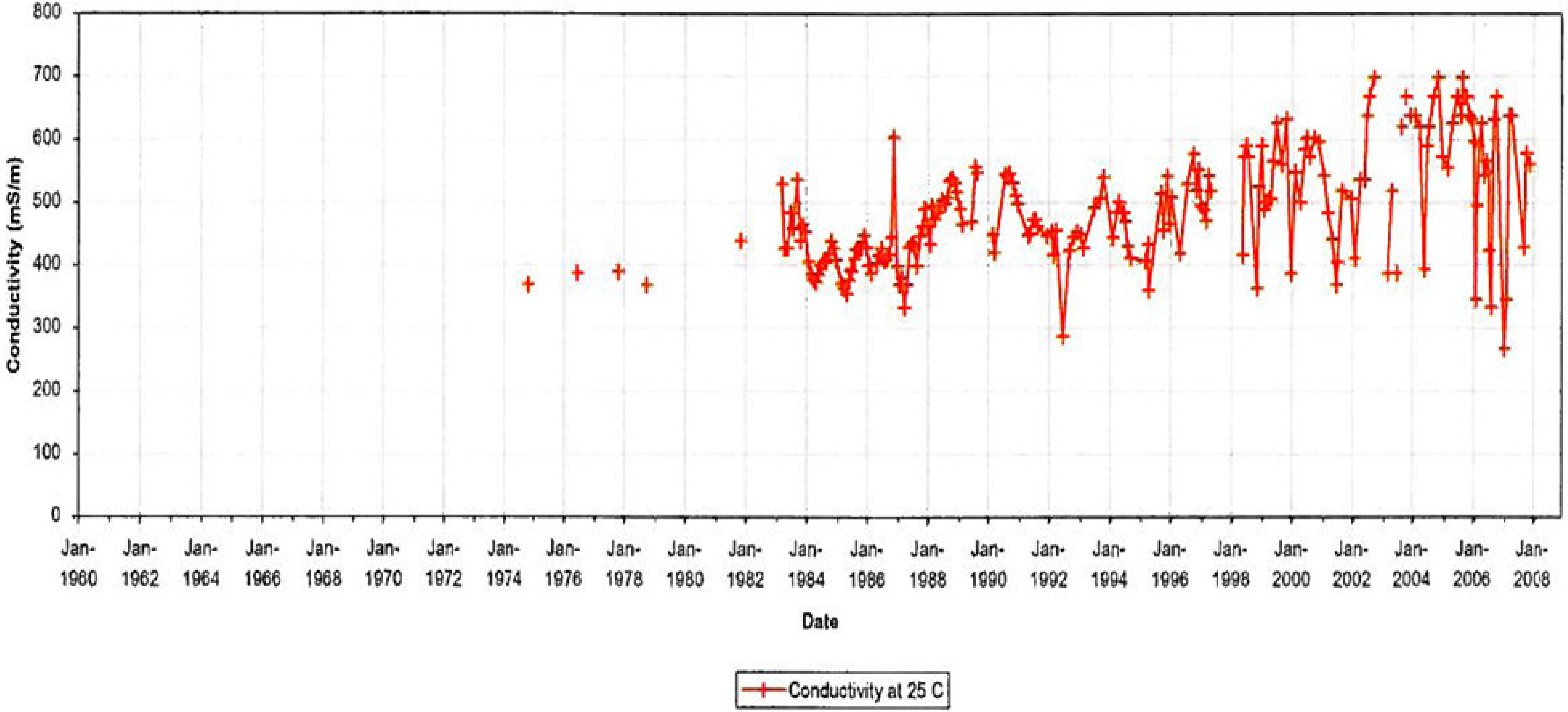

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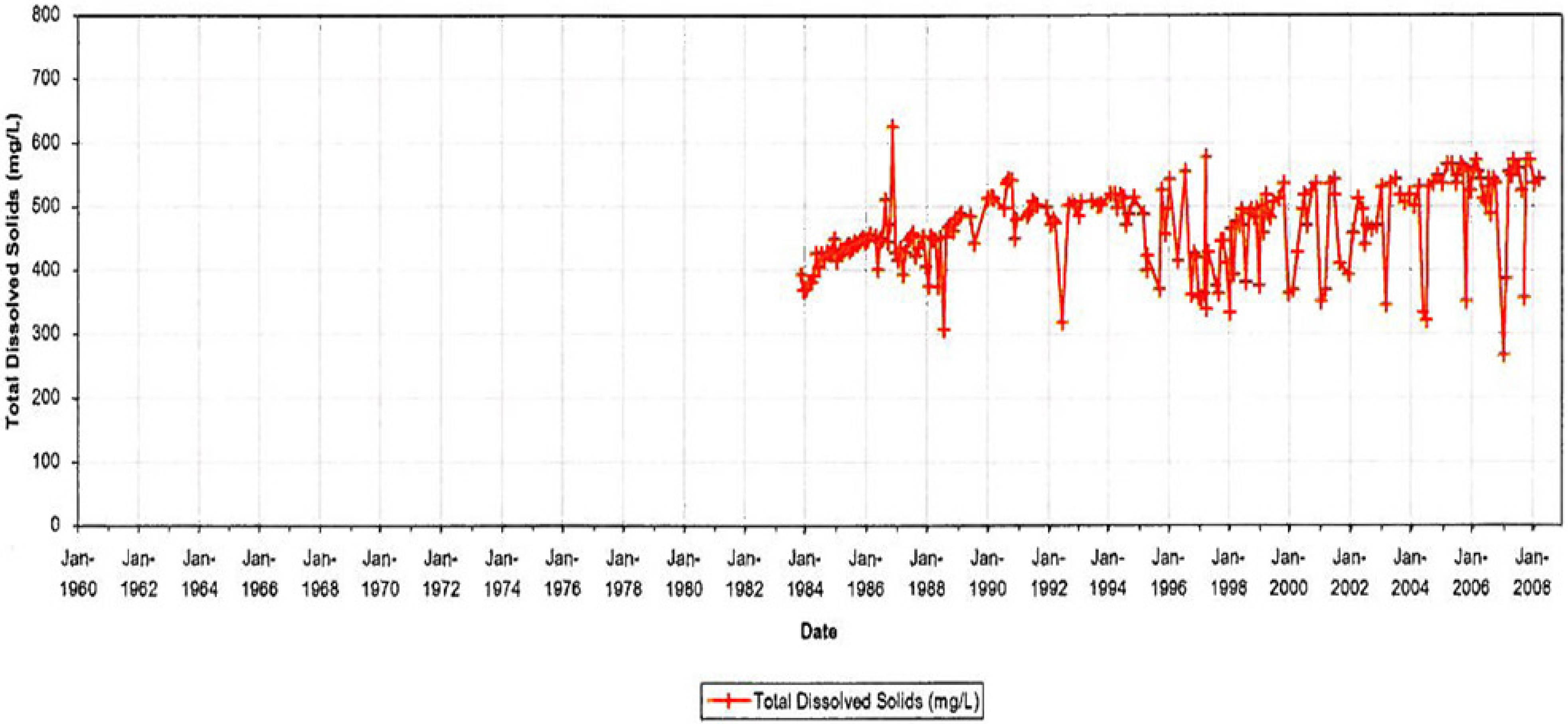
4/73 2/96



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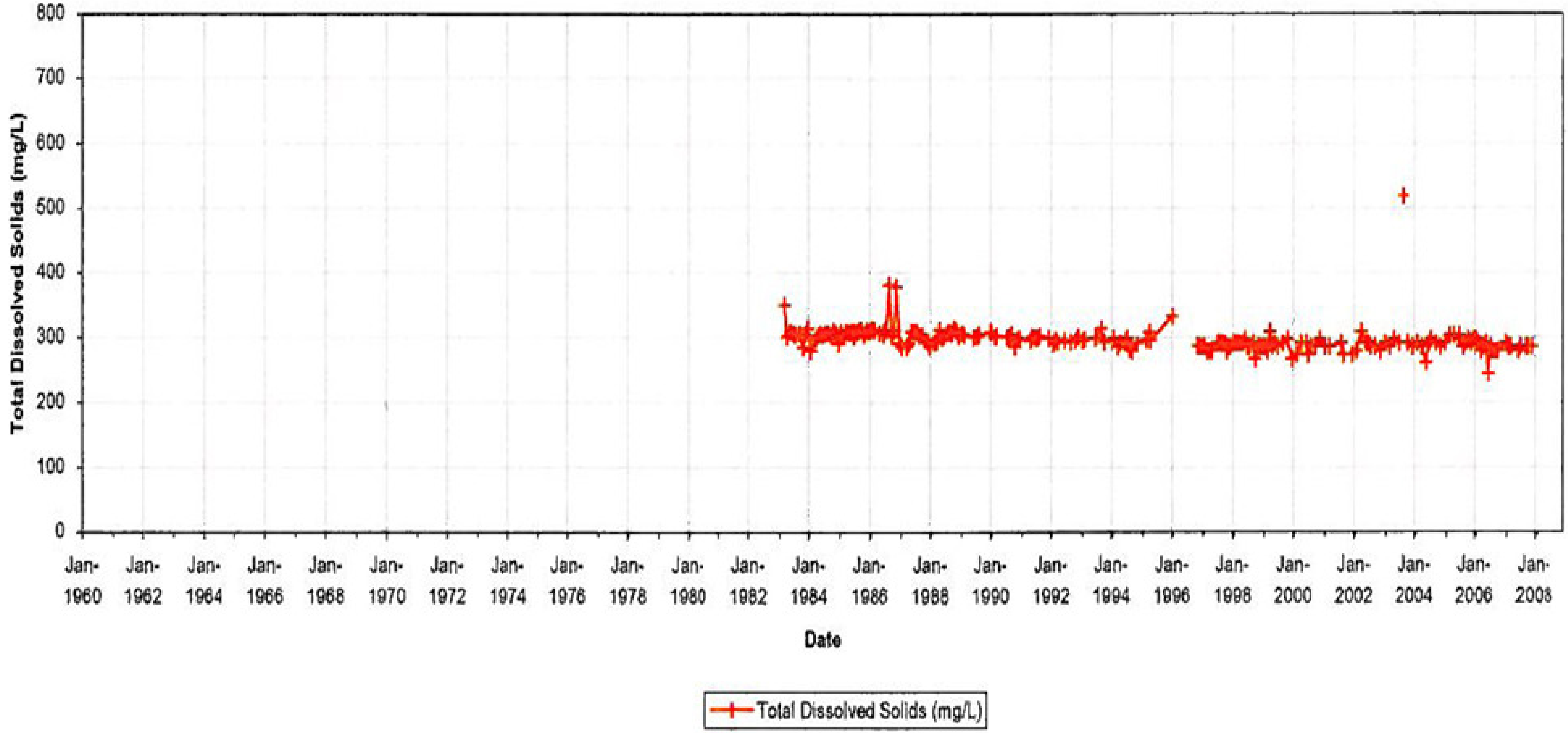
Total Dissolved Solids (mg/L)

5/73 2/95



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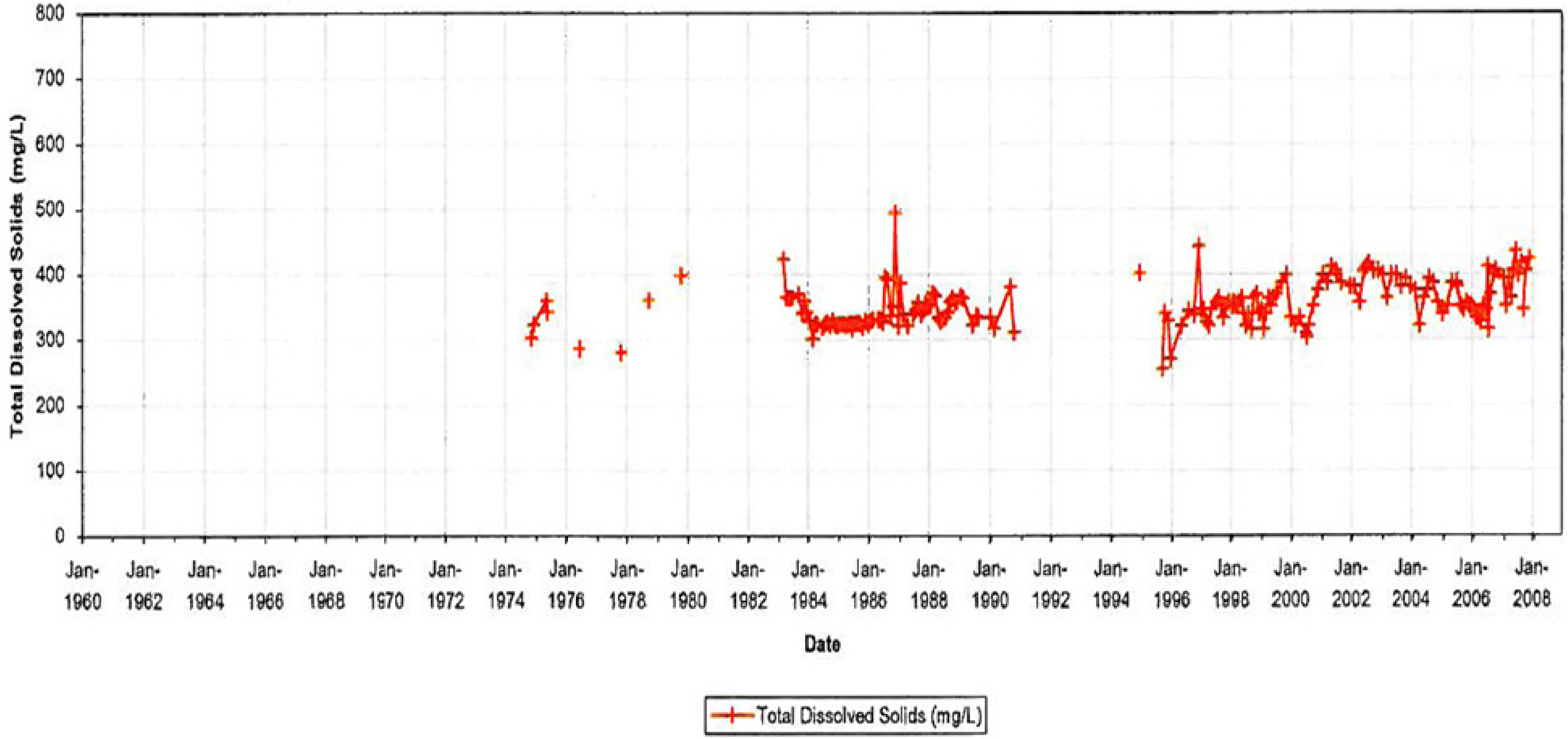
Total Dissolved Solids (mg/L)

6/73 2/94



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Total Dissolved Solids (mg/L)

Shortened forms

AHD	Australian height datum
ANZECC	Australia and New Zealand Environment and Conservation Council
ArcGIS	A software suite for working with maps and geographical information
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
BOM	Bureau of Meteorology
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEC	Department of Environment and Conservation
DMP	Department of Mines and Petroleum
EC	Electrical conductivity
GDE	Groundwater-dependent ecosystem
NHMRC	National Health and Medical Research Council
NRMMC	Natural Resource Management Ministerial Council
TDS	Total dissolved salts
WAWA	West Australian Water Authority
WIN	Water Information Network

Glossary

Abstraction	The permanent or temporary withdrawal of water from any source of supply, so that it is no longer part of the resources of the locality.
Allocation limit	Annual volume of water set aside for use from a water resource.
Anticline	A geological fold with strata sloping downward on both sides from a common crest.
Aquifer	A geological formation or group of formations able to receive, store and/or transmit large amounts of water.
Bioturbated	The displacement and mixing of sediment by organisms, often destroying its structure. Common examples are feeding burrows in the sea floor.
Bore	A narrow, normally vertical hole drilled into a geological formation to monitor or withdraw groundwater from an aquifer (see also Well).
Borefield	A network of bores, pipes, pumps, and hoses. These usually feed a water system used by mining, crop watering, property maintenance, and municipality utilities departments.
Confining layer	Sedimentary bed of very low hydraulic conductivity.
Conformably	Sediments deposited in a continuous sequence without a break.
Contaminants	A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful effects to humans or the environment.
Correlation	Indicates the strength and direction of the linear relationship between two variables.

Decline	The difference between the elevation of the initial watertable and its position after a decrease in recharge (i.e. rainfall).
Drawdown	The difference between the elevation of the initial piezometric surface and its position after pumping or gravitational drainage.
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirement	The water regime needed to maintain the ecological values (including assets, functions and processes) of water-dependent ecosystems at a low level of risk).
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact, e.g. lake, to include all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Evapotranspiration	The combined loss of water by evaporation and transpiration. Includes water evaporated from the soil surface and water transpired by plants.
Ferruginous	Pertaining to iron or containing it. Red or rust coloured from the presence of ferric oxide.
Formation	A group of rocks or sediments that have certain characteristics in common, were deposited about the same geological period, and that constitute a were deposited about the same geological period, and that constitute a convenient unit for description.
Glauconitic	Containing glauconite, a green (hydrous potassium iron silicate) mineral, closely related to mica minerals.
Gradient	The rate of change of total head per unit distance of flow at a given point and in a given direction.
Groundwater	Water that occupies the pores within the rock or soil profile.

Groundwater level	An imaginary surface representing the total head of groundwater. Defined by piezometer readings.
Groundwater mound	A mound shaped formation of the watertable resulting from rainwater trickling down into the open space between particles in an elevated area of deep sand or other porous material. Groundwater will move slowly away from the central area to discharge into wetlands, rivers and oceans.
Groundwater recharge	The rate at which infiltration water reaches the watertable.
Groundwater-dependent ecosystem	An ecosystem that depends on groundwater for its existence and health.
Hydraulic gradient	The rate of change of total head per unit distance of flow at a given point and in a given direction.
Interbedded	Geology occurring between beds, occurring between strata of a different origin or character.
Intracratonic	Located within a continental region.
Intraformational	Formed within the boundaries of a geological formation.
Laminated	Fine sedimentary layering.
Lithified	Having undergone the process where unconsolidated sediments are converted to solid rock.
pH	The negative logarithm of the concentration of hydrogen ions.
Phosphatic	Containing phosphate, commonly phosphatic nodules.
Pisolitic	Containing pisoliths, which is an accretionary formation in a sedimentary rock, similar in size and shape to a pea. Pisoliths are commonly composed of calcium carbonate.

Recharge	Water that infiltrates into the soil to replenish an aquifer.
Salinity	A measure of the concentration of total dissolved solids in water.
Silicified	Has undergone the processes of silicification, which is the introduction of or replacement by silica.
Strata	A bed or layer of sedimentary rock having approximately the same composition throughout.
Surficial	Pertaining to the surface. Surficial sediments occur at the earth's surface and are unconsolidated. The Surficial aquifer is the topmost, shallow aquifer, comprising surficial sediments.
Transmissivity	The rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient.
Transpiration	The loss of water vapour from a plant, mainly through the leaves.
Unconfined aquifer	A permeable bed only partially filled with water and overlying a relatively impermeable layer. Its upper boundary is formed by a free watertable or phreatic level under atmospheric pressure.
Upconing	Process by which saline water underlying fresh water in an aquifer rises up into the freshwater zone as a result of pumping water from the freshwater zone.
Watertable	The surface of a body of unconfined groundwater at which the pressure is equal to that of the atmosphere.
Well	An opening in the ground made or used to obtain access to underground water, oil or gas. This includes soaks, wells, bores and excavations.

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