Regional groundwater chemistry zones:
South East Queensland region
Summary and results

Environmental Protection (Water and Wetland Biodiversity) Policy 2019

DRAFT FOR CONSULTATION – NOT GOVERNMENT POLICY

October 2023

Queensland Government

Prepared by: Environment and Heritage Policy and Programs, Healthy Waters and Wetlands, Department of Environment and Science

© State of Queensland, 2023

The Department of Environment and Science acknowledges Aboriginal peoples and Torres Strait Islander peoples as the Traditional Owners and custodians of the land. We recognise their connection to land, sea and community, and pay our respects to Elders past, present and emerging.

The department is committed to respecting, protecting and promoting human rights, and our obligations under the Human Rights Act 2019.

The Queensland Government supports and encourages the dissemination and exchange of its information. This work is licensed under a Creative Commons Attribution 4.0 International License.

Under this licence you are free, without having to seek our permission, to use this publication in accordance with the licence terms. You must keep intact the copyright notice and attribute the State of Queensland as the source of the publication.

For more information on this licence, visit https://creativecommons.org/licenses/by/4.0/

Disclaimer

This document has been prepared with care, based on the best available information at the time of publication. The department holds no responsibility for any errors or omissions within this document. Any decisions made by other parties based on this document are solely the responsibility of those parties. Information contained in this document is from numerous sources and, as such, does not necessarily represent government or departmental policy.

If you need to access this document in a language other than English, please call the Translating and Interpreting Service (TIS National) on 131 450 and ask them to telephone Library Services on +61 7 3170 5470.

This publication can be made available in an alternative format (e.g. large print or audiotape) on request for people with vision impairment; phone +61 7 3170 5470 or email <library@des.qld.gov.au>.

Citation

DES (2023). Regional groundwater chemistry zones: South East Queensland region Summary and results, DRAFT for consultation, DES Science Division and DES Environment and Heritage Policy and Programs Division, September, DRAFT for consultation

A draft of this publication was the subject of two peer reviews external to the Department, and revised following peer reviewer comments.

October 2023

Contents

List of Tables

List of Figures

Executive Summary

The Environmental Protection (Water and Wetland Biodiversity) Policy 2019 (EPP (Water)), subordinate legislation to the *Environmental Protection Act 1994* (Qld.) (EP Act), provides a framework for establishing environmental values, management goals, and water quality objectives (WQOs) for Queensland waters (surface and groundwater). Subject to Queensland Government approval, EVs, WQOs and management intent mapping will be included in Schedule 1 of the EPP (Water).

This report and accompanying mapping forms the technical basis for the development of groundwater EVs, WQOs, and management intent mapping in the South East Queensland region pursuant to the EPP (Water)[1].

In particular, the consultation report identifies draft groundwater types (aquifers and water chemistry zones), environmental values and water quality percentile ranges for groundwaters in the South East Queensland region.

The geographical scope of the project area of SEQ groundwaters includes those underlying the Noosa River, Maroochy River, Pine Rivers, Brisbane River, Stradbroke Island, Logan and Albert Rivers, and South Coast rivers basins.

Groundwaters extending under coastal and marine waters have not been included in the relevant mapping or analyses, as bore and water chemistry data are not available for groundwaters under coastal/marine waters. More detailed maps accompanying this report are available from the department's website.

At the completion of consultation and after consideration of all submissions, updated EVs, WQOs, and management intent mapping will be recommended for inclusion under Schedule 1 of the EPP (Water). If approved, they will inform statutory and non-statutory water quality management planning and decision-making processes.

Additionally under the EP Act, resource projects and resource activities place a key focus on the impact of the exercise of underground water rights on water quality and EVs, including the requirements under section 126 A (2) that an application must state:

> *'(d) the environmental values that will, or may, be affected by the exercise of underground water rights and the nature and extent of the impacts on the environmental values, and*
>
> *(e) any impacts on the quality of groundwater that will, or may, happen because of the exercise of underground water rights during or after the period in which resource activities are carried out;'*

The report identifies six major aquifer classes: 'Alluvium', 'Fractured rock', 'Cainozoic deposits overlying the Great Artesian Basin (GAB)', 'Lower Great Artesian Basin', 'Basal Great Artesian Basin', and 'Earlier basins partially underlying the Great Artesian Basin'. Each aquifer class is divided into multiple groundwater chemistry zones with reasonably consistent baseline water chemistry.

Chemistry zone boundaries are shown in mapping in this report, and in larger scale maps on the department's website, which also show draft EVs by each chemistry zone. A groundwater chemistry zone may contain more than one aquifer, as well as other geological formations (e.g., aquitards) from the same aquifer class, but the aquifers will generally be closely related. Chemistry zones may extend across (under) surface water basin boundaries.

A total of 23 alluvial zones are defined. There are 16 fractured rock zones covering mainly basalts, granites, and metamorphic fractured rocks (trap rock), 10 zones in Cainozoic deposits, 9 zones in the Lower GAB (excluding upper and mid GAB layers which do not extend into the project area), 16 Basal GAB zones, and four zones underlying the GAB.

Water quality percentiles are provided by chemistry zone in for different indicators (e.g., salinity expressed as electrical conductivity (EC), and major ions). For some groundwater chemistry zones found closer to stream channels (e.g., Alluvium 'near stream'), separate water quality percentile ranges have been provided, given the potential for recent interaction with surface waters can significantly vary the water chemistry.

The report is based on data collected mostly between the 1940s and the present, however there are 170 records collected before 1940, going back to 1919. This represents a comprehensive dataset, although there are spatial and temporal variations in coverage. Groundwater chemistry data was extracted from the Queensland Government Groundwater Database and comprises 11,951 samples.

[1] EVs are the qualities of water that make water suitable for supporting aquatic ecosystems and human uses and values (e.g. irrigation, stock watering, cultural and spiritual values). WQOs are long-term goals for water quality management that protect environmental values.

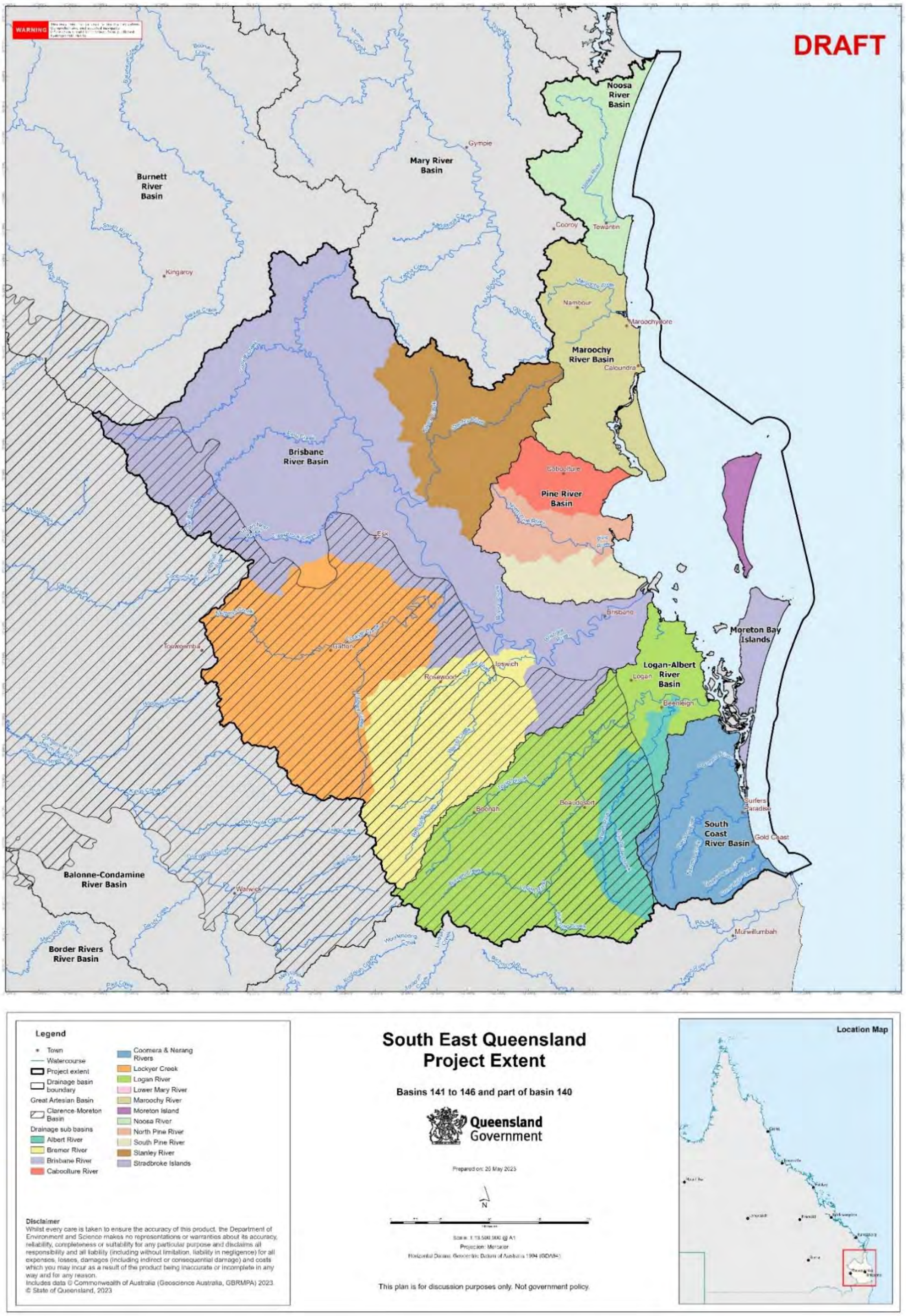


Figure 1: Project extent

1.1 The issue

Groundwater quality issues, including salinity and the composition of individual salts, can negatively impact agricultural production, the viability of infrastructure, the health of aquatic and terrestrial ecosystems, and the welfare of regional communities. Within Queensland, groundwater is a major and increasingly significant resource, particularly in rural areas, and supports a range of groundwater dependent ecosystems.

Comparatively homogeneous water chemistry zones have previously been defined for Queensland's surface waters, so that baseline ranges could be determined for surface water salinity and water quality parameters. However, the chemical zonation of groundwater is a more complex task, because the sources and flow paths are less clear, spatial variation is three dimensional, and the chemistry is influenced by many factors. Some natural factors include recharge composition, soils, geology, and rainfall. Other, more localised influences are related to human activities and the interaction between water bodies. The resulting high natural variability of groundwater chemistry may exceed guidelines or WQOs for environmental values (EVs) pertaining to surface water, even in the absence of human impacts. This project employed both statistical and conceptual methods to define zones of similar groundwater chemistry within the South East Queensland (SEQ) region (after Raymond & McNeil (2013, 2011)).

1.2 Project aim

The aim of this project is to define and characterise groundwater chemistry zones for the SEQ Region (

Figure **1**; above), and to calculate background ranges of water quality constituents within them, as an aid to establishing appropriate groundwater quality guidelines for the region (an input to water quality objectives (WQOs) – see below). The calculated ranges exclude outliers caused by either local contamination or small, uncharacteristic aquifers that are not part of the prevailing groundwater system.

The report presents the regional groundwater chemistry zones for South East Queensland, including adjoining coastal islands of Moreton Bay – North Stradbroke Island, South Stradbroke Island, Moreton Island, and Bribie Island. Groundwaters extending under coastal and marine waters have not been included in the relevant mapping or analyses, as bore and water chemistry data are not available for groundwaters under coastal/marine waters.

This study acknowledges that the groundwater chemistry zones and their baseline ranges represent current conditions with varying levels of accuracy, primarily because data is limited, particularly for the pre-European period; however, it is emphasised that these draft values are consistent with the precautionary principle (Cousins et al. 2016; Eberhard et al. 2009) in providing a filter to identify outlying sites and sudden or rapid change. Outlying sites may reflect human activity but may also be a result of naturally atypical geology or hydrology. In areas of high priority, groundwater models or other more intensive assessment methods can be applied at a later date. Given the identified data gaps in chemistry data, it is likely that more detailed monitoring and assessment would need to take place before groundwater models are constructed. This would allow the ranges to be refined, natural processes to be differentiated, and anomalies due to atypical local aquifers to be identified.

The project intends to inform water quality planning and decision-making processes.

1.3 Management intent for groundwaters

Several significant national policy updates have been released for groundwaters in recent years. These are summarised below.

1.3.1 NWQMS groundwater protection

The National Water Quality Management Strategy (NWQMS) is an Australian Government initiative in partnership with state and territory governments. It includes the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (AWQG) and other guidance materials (Australian Government 2013). Under the NWQMS and the EPP (Water), properly developed and approved local water quality guidelines have a higher precedence than state or national guidelines. Hence, local water quality guidelines form a technical basis for development of WQOs under the EPP (Water). This approach enables WQOs to be tailored to reflect regional aquifer conditions for the relevant indicators.

The development of percentiles as a basis for local WQOs for South East Queensland groundwaters is in line with this approach to provide the best protection for fresh water-dependent ecosystems.

The NWQMS includes national Guidelines for Groundwater Quality Protection in Australia to protect or enhance groundwater quality. Statements articulating a protective management intent for groundwater quality and derivation of local water quality benchmarks for protection (underlined) are provided below:

'Protection of groundwater quality is imperative to ensure the protection of healthy ecosystems and maintenance of environmental values as well as for future economic and population growth.'…(Australian Government 2013)

This publication forms the updated Guidelines for groundwater quality protection in Australia and focuses on the adoption of risk-based management to protect and enhance groundwater quality for the maintenance of specified environmental values. (Australian Government 2013)

'Practical applications of the guidelines include the assessment of groundwater, the identification of groundwater quality objectives and the development of specific groundwater protection mechanisms. The intention is that state and territory governments will take these guidelines into account when developing policies and legislation to protect the groundwater quality of each water resource, thus maintaining or enhancing the associated environmental value and preventing contamination within their respective jurisdictions' (Australian Government, 2013;1,2)

The Guidelines for Groundwater Quality Protection in Australia also provide advice on localising information where possible:

Even where guideline values are available, it may be more appropriate to determine guideline values that are specific to an individual groundwater system so that local conditions, groundwater quality and its variability, and community values can be explicitly recognised in the guideline values' (2013; 19).

The guidelines also provide further information on particular groundwater quality aspects:

'*In some circumstances, the natural groundwater quality will exceed some of the water quality guideline values for the agreed environmental value category. In this case, the groundwater quality should be maintained within the natural range of variability. This approach would require a detailed baseline assessment to establish natural groundwater quality and variability upon which the water quality objectives and guideline values can be based.' (2013; 20).*

The national application of the guidelines will enable management of groundwater quality of aquifers, as well as their connected surface water systems, across traditional management boundaries. Groundwater quality protection also applies to groundwater that extends under coastal waters.

Consideration of the unsaturated zone within groundwater quality management is also enabled by these guidelines and may be required where state or territory legislation includes the unsaturated zone in their definitions of groundwater or where consideration of the unsaturated zone could contribute to more effective management of groundwater quality'. (2013; 5-6)

'Within the context of these guidelines the 'aquatic ecosystem' category of environmental value refers to the groundwater quality that supports groundwater-dependent ecosystems (GDEs), such as groundwater discharge to rivers and wetlands, and to aquatic organisms that solely inhabit groundwater. Stygofauna are mostly invertebrates that inhabit pore spaces and voids within aquifers, occur in discrete communities and are likely to be sensitive to changes in groundwater quality (which may be poor quality and limited to a small number of environmental value categories). Where stygofauna communities have been identified, they should be accounted for in determining an appropriate environmental value and setting water quality objectives.' (2013; 20)

1.3.2 Great Artesian Basin (GAB) groundwater

The GAB underlies 22% of Australia. In recognition of the key role of GAB groundwaters as a source of water for human activities and aquatic ecosystem values, the Australian Government and jurisdictions have prepared an updated version of the Great Artesian Basin Strategic Management Plan (the GABSPM) (Australian, New South Wales, Queensland, South Australian and Northern Territory governments 2019). The GABSPM provides a framework to achieve economic, environmental, cultural, and social outcomes for the GAB and its users, including recommendations for risk-based water quantity and quality monitoring as part of groundwater resource condition assessments.

'*The Plan envisages that scientifically defensible limits relating to both quantity of water take and water quality will be established and adhered to. Specifically, measures are to be implemented so that features important to natural groundwater recharge are not unduly impacted*.' (p9)

The plan also includes a strategic outcome to:

'*set out scientifically defensible water quality limits' and extraction impact management measures that minimise impacts on the Basin resources, its users and dependent ecosystems'. (p 20)*

1.3.3 Australian and New Zealand water quality guidelines (ANZG) for groundwater

The ANZG policy on groundwater (ANZG 2018) links to the above policy frameworks and the earlier ANZECC (2000) guidelines, and reiterates the intent to protectively manage water quality.

'The ANZECC/ARMCANZ (2000) Water Quality Guidelines outlined linkages to groundwater, which remain applicable under the ANZG (2018) *Water Quality Guidelines. Groundwater is an essential water resource for many aquatic, riparian and terrestrial ecosystems. For substantial periods, groundwater can be the sole source of water to some rivers, streams and wetlands. Groundwater is also very important for primary and secondary industry as well as for domestic drinking water, particularly in low rainfall areas with significant underground aquifers. Generally, the Water Quality Guidelines should apply to the quality of both surface water and of groundwater, since the community values which they protect relate to above-ground uses (e.g. irrigation, drinking water, farm animal or fish production and maintenance of aquatic ecosystems). Hence, groundwater should be managed in such a way that when it comes to the surface, whether from natural seepages or from bores, it will not cause the established water quality objectives for these waters to be exceeded, nor compromise their designated community values.*

In addition to this, underground aquatic ecosystems and any novel fauna also need to be protected. Relatively little is still known of the lifecycles and environmental requirements of groundwater communities. Where potentially high conservation values are identified, the groundwater upon which the communities depend should be afforded the highest level of protection, at least until further knowledge is gained. Basing groundwater quality objectives on data from groundwater reference condition locations is recommended to achieve this protection.'

Accordingly, the intent is to maintain current water quality (where water quality is in natural condition). Where there is evidence of anthropogenic disturbance in groundwater quality, a long-term goal to improve water quality may be established and reflected by the adoption of WQOs for affected indicators.

Further details on groundwater planning and management are contained in the above resources.

1.4 Environmental Protection (Water and Wetland Biodiversity) Policy 2019

The quality of Queensland surface and groundwaters is protected under the Environmental Protection (Water and Wetland Biodiversity) Policy 2019 – the EPP (Water). The EPP (Water) achieves the object of the *Environmental Protection Act 1994*, to protect Queensland's waters while supporting ecologically sustainable development. It provides the structure for establishing environmental values (EVs), management goals, and water quality objectives (WQOs), including consulting with stakeholders, and considering the economic and social impacts of protecting EVs. At the completion of consultation and consideration of all submissions, EVs and WQOs are recommended for inclusion in Schedule 1 of the EPP (Water).

This report and related mapping seek to build on the national policy framework summarised above and inform Queensland water quality planning and decision making processes by providing regionally relevant information on groundwater EVs and water quality throughout the SEQ region. This information forms a technical basis for the development of groundwater EVs, WQOs, and mapping in the South East Queensland region pursuant to the EPP (Water). If the general water quality characteristics of the environment are known, the certainty attached to site specific testing is enhanced, decision making can employ more locally relevant information sources, and efforts can be focussed on addressing any identified gaps. Further details on EVs and WQOs are provided below.

EPP (Water) EVs and WQOs inform statutory and non-statutory water quality management planning and decision-making.

In particular, amendments to the *Environmental Protection Act 1994* in regard to resource projects and resource activities have placed a key focus on the impact of the exercise of underground water rights on groundwater quality and EVs:

'126A Requirements for site-specific applications—particular resource projects and resource activities

(1) This section applies to a site-specific application, involving the exercise of underground water rights, for—

(a) a resource project that includes a resource tenure that is a mineral development licence, mining lease or petroleum lease; or

(b) a resource activity for which the relevant tenure is a mineral development licence, mining lease or petroleum lease.

(2) The application must also state the following—

(a)-(c)…

(d) the environmental values that will, or may, be affected by the exercise of underground water rights and the

nature and extent of the impacts on the environmental values;

(e) any impacts on the quality of groundwater that will, or may, happen because of the exercise of underground water rights during or after the period in which resource activities are carried out;

(f) strategies for avoiding, mitigating or managing the predicted impacts on the environmental values stated for paragraph (d) or the impacts on the quality of groundwater mentioned in paragraph (e).'

Provisions of the *Environmental Protection Regulation 2019* provide additional specification re consideration of groundwater water quality for environmental management decisions under the EP Act. As an example:

S35 'The administering authority must, for making an environmental management decision relating to an environmentally relevant activity, other than a prescribed ERA—

(a) carry out an environmental objective assessment against the environmental objective and performance outcomes mentioned in schedule 8, part 3, divisions 1 and 2; and

(b) consider the environmental values declared under this regulation; and

(c) …and

(d) consider each of the following under any relevant environmental protection policies— (i) the management hierarchy; (ii) environmental values; (iii) quality objectives; (iv) the management intent;

In relation to s35(a), schedule 8 (part 3, division 1) of the EP Regulation includes the following objectives and outcomes specific to groundwater.

<u>Environmental Objective</u>: *The activity will be operated in a way that protects the environmental values of groundwater and any associated surface ecological systems.*

<u>*Performance Outcomes*</u>

1. Both of the following apply—

(a) there will be no direct or indirect release of contaminants to groundwater from the operation of the activity;

(b) there will be no actual or potential adverse effect on groundwater from the operation of the activity.

2. The activity will be managed to prevent or minimise adverse effects on groundwater or any associated surface ecological systems.

Note— Some activities involving direct releases to groundwater are prohibited under section 41 of this regulation.

1.4.1 Environmental values (EVs)

EVs are the qualities of water that make water suitable for supporting aquatic ecosystems and human uses and values (summarised in Appendix 2 – e.g. irrigation, stock watering, drinking water, recreation, cultural and spiritual values). Refer to the EPP (Water) for more details. The Guidelines for Groundwater Quality Protection in Australia note that:

'More than one environmental value category will often be applicable for a single groundwater system. Different parts of the groundwater system and connected surface water systems may also be assigned different environmental value categories due to natural variations in quality and value or variable land uses across the extent of the aquifer. This may result in the need to delineate zones of the groundwater system that encapsulate the different categories.' (2013; 19)

Details on sources used in identifying EVs are provided in section 3. Post consultation feedback and any further amendment, final EVs (and WQOs, outlined below) will be recommended for inclusion in the EPP (Water) amendment materials.

1.4.2 Water quality objectives (WQOs)

WQOs are long-term goals for water quality management that protect EVs. They are established for a range of water quality characteristics (e.g. nutrients, salinity, toxicants). For human use EVs, WQOs under the EPP (Water) are typically based on national water quality guidelines, including the following:

- stock watering, irrigation: the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZG 2018) and

- human uses (recreation, drinking water): National Health and Medical Research Council (NHMRC & NRMMC 2011 as amended) guidelines, including Guidelines for Managing Risks in Recreational Water and the Australian Drinking Water Guidelines.

Under the ANZG, a rolling program of updates is underway for numerous national guidelines, including stock watering and irrigation. Further information on the status of these and other ANZG guideline materials can be obtained by subscribing for updates to the ANZG.

WQOs tables for human use EVs are provided in EPP (Water) schedule 1 documents, based on the above and other sources. The following discussion is focussed on the identification of water quality within groundwaters which informs protection of groundwater ecosystems.

In relation to aquatic ecosystem water quality requirements, the Guidelines for Groundwater Quality Protection in Australia note that:

'In some circumstances, the natural groundwater quality will exceed some of the water quality guideline values for the agreed environmental value category. In this case, the groundwater quality should be maintained within the natural range of variability. This approach would require a detailed baseline assessment to establish natural groundwater quality and variability upon which the water quality objectives and guideline values can be based.' (2013; 20)

This report includes background water quality results (as a range of percentiles) from the updated analyses of data. Based on analysed data, Table 8 of this report provides broad commentary on the characteristics of chemistry zones and a general indication of their potential suitability for different human water uses, relative to guideline values. Note that to ascertain suitability of a specific water source (e.g. a bore) for a given use (e.g. irrigation) more detailed testing may be required, and the broad results in Table 8 are not intended to provide this level of detail.

For the aquatic ecosystem EV, this can include both aquatic communities that solely inhabit groundwater (including bacteria, e.g. iron-reducing bacteria, stygofauna, e.g. crustaceans, beetles, worms), and groundwater dependent ecosystems (GDEs). However, the Guidelines for groundwater quality protection in Australia note that '*no water quality guidelines are available for these (stygofauna) communities*' and that *'there are currently no water quality guidelines for groundwater-dependent ecosystems (GDEs) that rely on the subsurface presence of groundwater (vegetation*)' (2013; 35). This status is also reflected in the DES guideline Using monitoring data to assess groundwater quality and potential environmental impact, which notes: '*There are currently no water quality guidelines for the protection of stygofauna (subterranean fauna*)…' (2021; 47).

Further information on subterranean habitats and fauna is available from the WetlandInfo website, and from the Queensland Subterranean Aquatic Fauna Database, which provides a catalogue of subterranean aquatic fauna sampling undertaken in Queensland. These environments and their supported stygofauna include:

- lack of sunlight and corresponding stable temperature (minimal daily or seasonal change)
- low/limited nutrient supply from external sources (and no primary photosynthesis)
- generally stable water quality (within a given aquifer, but may vary spatially across different aquifers)
- reliance on a minimum pore space to enable habitation (where pore space varies by geology)
- high degree of endemism (adapted to local habitat conditions)
- low dispersal capabilities
- low reproduction rates
- high sensitivity to changes in water quality relative to natural conditions

Hose et al. (2015) note that:

'Stygofauna are generally adapted to stable environmental conditions, including water quality. Changes to water quality that are beyond the range of conditions normally experienced by stygofauna pose a threat to their survival.' (Hose et al. 2015; 40)

The Department's Monitoring and Sampling Manual reports that in Queensland, stygofauna have been described at depths of up to 60 m below ground, at electrical conductivities above 50,000 µS/cm and in both acidic and alkaline environments (DES 2018).

In relation to pH, Hose et al. (2015) note that:

'*Importantly, it is changes to pH away from the typical background level that are likely to be problematic for stygofauna, as they are for other freshwater invertebrates…. thus requiring understanding the local conditions in order to assess the risks associated with changed in water quality.'* (Hose et al. 2015; 42)

For salinity they note that:

> *'Field studies…suggest that the salinity tolerance of most stygofauna is limited to salinity level (measured by water electrical conductivity) less than 5000 µS/cm…. It might be expected then that changes to salinity of groundwater above 5000 µS/cm may by (sic) toxic to stygofauna. However, this threshold does not indicate the sensitivity of stygofauna to changes in salinity; those inhabiting and adapted to relatively fresh groundwater will be potentially sensitive to changes well below this level. It is likely that stygofauna are adapted to local conditions so that changes from background salinity could be deleterious.'* (Hose et al. 2015; 41)

Accordingly, for the aquatic ecosystem EV, this report establishes background water quality percentile values for pH, salinity, and other indicators by groundwater chemistry zone. For larger alluvial zones, this report identifies percentiles for groundwaters found closer to stream channels (Alluvium 'near stream') because of the potential for recent interaction with surface waters, which can significantly vary the water chemistry. The full suite of indicators and percentiles is shown in Appendix 3 (Table 9). These percentiles are intended to form a basis for derivation of aquatic ecosystem groundwater WQOs under the EPP (Water). The intent is to maintain current water quality (20th, 50^{th}, and 80th percentile ranges) where water quality is in natural condition. Where there is evidence of anthropogenic disturbance in groundwater quality, a long term goal to improve water quality may be reflected adopting an alternative (e.g. 40th percentile) value.

2 Project scope

2.1 Regional setting

The South East Queensland region is the most densely populated area of Queensland, home to over 3 million people (Healthy Land & Water 2021). The region covers considerable variations in climate, topography and land use.

Rainfall is characterised by a distinct summer wet season (December–February), and it's variability is probably dominated by ENSO (El Niño-Southern Oscillation), with the associated La Niña events increasing rainfall in the region, and conversely El Niño events reducing rainfall (Cai et al. 2009). Many of the gauged streams in the region have been classified as 'unpredictable intermittent' or 'unpredictable summer highly intermittent' (Kennard et al. 2010). The main tributary of the Bremer River may occasionally cease to flow, however, the main tributaries of the Albert, Brisbane, Logan, and Maroochy rivers have perennial flow (Queensland Government Bureau of Meterology 2023).

Hilly to mountainous headwaters are associated with the Great Dividing Range (GDR), particularly in the west around the Upper Brisbane, Upper Lockyer, and Upper Bremer sub basins. The Scenic Rim separates parts of South East Queensland from New South Wales in the south. Flat, fertile lands are a characteristic of the lower Lockyer Valley. The region is surrounded by the Mary, Burnett, and Condamine-Balonne River basins in Queensland, and the Clarence, Richmond, and Tweed River basins in New South Wales.

Land uses in the region include grazing, residential use (urban and rural), agriculture (dryland and irrigated), horticulture, cropping, plantations, mining, industrial, tourism, fisheries, and water storages (Healthy Land & Water 2021). Grazing is the predominant land use outside of the urban centres, occupying more than half of the region (Queensland Government Bureau of Meterology 2023). Conservation areas are also significant, and there are more than forty national parks in the region, including Bunya Mountains, D'Aguilar (North and South), Conondale, Girraween, Glasshouse Mountains, Lamington, Main Range, Mapleton, Springbrook, and Tamborine. Large areas of the sand islands in Moreton Bay are designated national parks, including Gheebulum Kunungai (Moreton Island) National Park, Bribie Island National Park, and Naree Budjong Djara National Park. The major towns of the region include Beaudesert, Brisbane, Caboolture, Esk, Gatton, Gold Coast, Ipswich, and Kilcoy.

The combined capacity of several drinking water supply dams make up the SEQ Water Grid storage: Wivenhoe, Somerset, North Pine, Hinze, Baroon Pocket, Leslie Harrison, Ewen Maddock, Cooloolabin, Sideling Creek, Lake Macdonald, Little Nerang, and Wappa. Other dams in the region include Atkinson, Bill Gunn, Borumba, Cedar Pocket, Clarendon, Enoggera, Gold Creek, Lake Manchester, Maroon, Moogerah, Nindooinbah, Poona, and Wyaralong. There are also several water supply schemes in the region: Baroon Pocket, Central Brisbane, Central Lockyer Valley, Cressbrook, Logan River, Lower Lockyer, Nerang, Pine Valley, Stanley, and Warrill Valley (Seqwater 2023). Groundwater in the area is used for many purposes, including domestic gardens, drinking supply, commercial crop irrigation, and commercial extraction. Tamborine Mountain, for example, is a rural area with no reticulated water supply or sewerage system, with residents relying on bores and rainwater for their water needs (Catania & Reading 2023). Commercial groundwater extraction for the bottled water industry operates in the region, including Springbrook.

2.2 Geology and groundwater

Although climate and local hydrology are important, the varied and complex geology of the South East Queensland region, as described in Day (1983), Kingham (1998) and Radke et al. (2012) has a major influence on groundwater quality (Figure 2). The groundwaters are defined by the geology of the GDR, the Clarence–Moreton sub basin of the GAB and its predecessors (Pre-GAB), and more recent units overlying them including Cainozoic sediments, Tertiary basalts, recent alluvium, estuarine and deltaic deposits, and dune fields on the coast and on the Barrier Islands which form the eastern border of Moreton Bay. Refer to the glossary for further definitions.

The geology of the South East Queensland region is shown on Figure 3, which is adapted from the Queensland geology map provided by the Department of Natural Resources and Mines (Qld) (2015). A colour scheme has been adopted which summarises the geology to highlight the aspects of most significance to water quality.

The oldest rocks in the region are part of the Tasman Fold Belt System, formed during the Palaeozoic Era, which lasted between 600 to 250 million years ago. The Tasman Fold Belt developed along the eastern side of Australia, which at the time was situated in cool temperate latitudes at the south-eastern tip of a supercontinent called Pangaea, into which almost all the Earth's land mass was becoming concentrated. Material was eroded from the continental mass to fill a deep, offshore trench to the east. This process was accompanied by copious volcanic activity. Subsequently, the marine sediments and volcanics that had accumulated in the trench were folded, metamorphosed and intruded by granite over several episodes during the long period that the fold belt was active, before being raised above sea level where their roots now form the GDR and are often referred to as 'Trap rocks' (Foster 2016; Richard et al. 1983). These Palaeozoic rocks are now exposed as a diagonal band from northwest to southeast, along the course of the Brisbane River, including the northern headwaters, and continuing through ranges of the Gold Coast hinterland. They also form the basement underlying other, more recent geological formations (Rast & Delany 1983).

Since 'Trap rocks' are hard and impervious, groundwaters associated with them are pooled in weathered joints and fractures. The yield is very limited, typically just sufficient for stock or domestic needs, and nearby bores may not be hydrologically connected. The waters are variable but tend to be moderately saline (500–1,500 µS/cm) and hard, with evenly proportioned cations except for a slight preponderance of sodium. In granitic terrains, as in the North-eastern and Western GDR, the groundwater tends to be fresher and more sodic.

By the middle of the Palaeozoic Era, the Tasman Fold Belt had stabilised west of the GDR, and joined with the old continent (craton) to form a basement block. The surface of the craton sagged unevenly, rising and falling over time to form successive generations of freshwater sedimentary basins over an evolving hydrological landscape.

The most significant of the early (Pre-GAB) basins is the Ipswich Basin. It formed about 250 million years ago, when stresses built up along the margin of the Pangaea land mass, close to what is now the eastern Australian coastline. The West Ipswich Fault formed as a consequence, with the basement sagging to the east of the fault, forming a depression that filled with freshwater sediments (including coal) by the early Mesozoic. The full extent of the Ipswich Basin is not clear because it has been largely overlain by younger sediments, and Chern (2004), Falkner (1986) and Pinder (2004) consider that it may be part of a much larger Triassic basin. It is separated from the Clarence-Moreton outcrops by the West Ipswich Fault system as discussed by Babaahmadi, Rosenbaum & Esterle (2015), and continues from Ipswich in the north, for an unknown distance to the south into NSW, with a smaller lobe extending northeast beneath Brisbane and Moreton Bay (Pinder 2004), and is found in scattered exposures over the central and eastern South East Queensland region (Chern 2004). It is considered to have Coal Seam Gas potential (Pinder 2004). The smaller Tarong Basin to the north also contains several economically important coal seams (Hutton 2009).

There is very little water quality information available from groundwaters extracted from the Pre-GAB deposits in the South East Queensland region, but an extensive study by Rebello et al. (2017) of untreated water from coal seam gas wells in the Surat Basin reported high levels for pH, sodium adsorption ratios (SAR), salinity (TDS) and alkalinity, which corresponded well with findings from other countries. The only samples available from the SEQ region show high but variable salinity levels dominated by Na and Cl. This corresponds well with the literature and is typical of fine grained sediments in Queensland.

At the beginning of the Jurassic period, around 205 million years ago, forces associated with the process of Gondwana breaking off from Pangaea caused the uplift and subsequent erosion of the surface of the Ipswich Basin. This period of erosion ended later in the Mesozoic, when the surface again began to sink into a new series of depressions to the east and south of the Ipswich Basin, which were filled by freshwater sediments overlying those of the earlier basin. These sediments, consisting of permeable quartzose sandstones alternating with relatively impermeable confining beds of mudstone and siltstone, formed the GAB aquifer system. The Queensland section of the GAB consists of two major sub basins, the Surat and Eromanga Basins, and the smaller Moreton Basin, which is separated from the Surat by the subsurface Kumbarilla Ridge which is situated between Dalby and Chinchilla to the west. The Clarence-Moreton Basin is the only part of the GAB which is present in the South East Queensland Area. It is divided into three sub-basins, the Cecil Plains sub-basin to the west of the SEQ, the Laidley sub basin, and the Logan sub basin to the south.

Sedimentation began in the Clarence-Moreton Basin during the Basal GAB phase with deposition of the freshwater quartzose sandstones of the Woogaroo Subgroup. This is the equivalent of the Precipice Sandstone in the Surat Basin. It was followed by the Lower GAB sediments of the Marburg Subgroup, which have been divided within the SEQ area into the Gatton Sandstone and the overlying Koukandowie Formation. The Koukandowie Formation has been further subdivided in the central and eastern parts of the basin around Lockyer Creek into the Ma Ma Creek Member and the more porous overlying Heifer Creek Sandstone Member. The sequence was finalised by the Walloon Coal Measures and is the major coal-bearing geological formation in the Clarence-Moreton Basin, although coal is also contained within the Koukandowie Formation, the Gatton Sandstone and the Raceview Formation which is a member of the Woogaroo Subgroup.

Around 110 million years ago, during the Cretaceous period, sea levels began to rise and the GAB was inundated by a shallow sea, completing the GAB sedimentary sequence with a silty, almost impermeable marine layer, the GAB Cap, as it withdrew towards the end of the Mesozoic (about 90 million years ago). Although the Clarence-Moreton sub basin was linked to the Surat by a narrow strait throughout the formation of the GAB, the southern part of Queensland was an island during the marine inundation, so that the Middle and Upper GAB Formations were not deposited in the Clarence-Moreton Basin. The seas eventually drained away, leaving the landscape more or less as it is today (Day, Cranfield & Schwarzböck 1974; Wells & O'Brien 1994; Jansson 2006; Rassam et al. 2014; Goscombe & Coxhead 1995).

The GAB aquifers typically yield sodium bicarbonate groundwaters of moderate salinity, with some corrosive tendencies, however those of the Clarence-Moreton sub basin appear to have a higher chloride content than those further west. Alluvial aquifers overlying the Clarence-Moreton Basin include the Lockyer Valley and Bremer River basins, as well as the mid and upper parts of the Logan-Albert river basins. Upwelling from the artesian aquifers has been shown to interact with surface waters in the Lockyer Valley, particularly around Helidon, and contribute significant recharge to the streams during periods of low flow and low groundwater levels (Cox & Wilson 2005).

The early Jurassic Landsborough Sandstone is the dominant sedimentary unit within the Nambour Basin, which is up to 30 km wide, and underlies much of the coastal plain between the northern suburbs of Brisbane to Coolum on the Sunshine Coast. It also extends offshore, forming the bedrock of the sand islands and outcropping to form promontories such as Alexandra Headland. The history of the Nambour Basin parallels that of the Clarence-Moreton Basin to which it is linked via a small area of Woogaroo sediments around Brisbane. Freshwater quartzose sandstones and conglomerates, and later finer grained material and minor coal, were being deposited on the eroded surface of the Ipswich Coal Measures around 200–175 million years ago.

The formation contains traces of plants such as fossil wood, spores, and pollen. The southern part of the basin overlies Palaeozoic basement and the Ipswich Basin, whilst to the north it grades into the Maryborough Basin. The thick almost-horizontal layers of sandstone were eroded, forming an extensive plateau, which was intruded 25 million years ago by the Glasshouse Mountains volcanoes, which are composed of rhyolite and trachyte which are lavas rich in silica. Erosion of the sandstone has exposed the remains of the volcanic plugs, while basalt flows and recent coastal sediments cover the sandstone in places. Any hydrocarbons (probably gas) would be sourced from the underlying Ipswich Basin; the Nambour Basin is regarded as being unlikely to contain commercial quantities of hydrocarbons (Goscombe & Coxhead 1995; McKellar 1993; McLoughlin 2015; Doig & Stanmore 2012). From this study, groundwater quality in the Nambour Basin appears typical of Wallum country, being very low in salinity, but high in sodium chloride, but it also contains significant calcium, and is also relatively high in nitrate.

After the retreat of the inland sea, approximately 120 million years ago Gondwana began to break up. And about 80 million years ago the New Zealand land mass separated from Australia through the opening of the Tasman Sea, creating the present eastern Australian coastline (Doig & Stanmore 2012; Veevers 2001; Willmott 2004; Day 1983). The surface inland from the coast was tilted upwards during the rifting process, creating the GDR around 70 to 32 million years ago, at the beginning of the Cenozoic (the Era that began at the end of the Mesozoic, about 65 million years ago, and continues to the present). The uplift of the GDR tilted the GAB to the southwest, creating artesian pressures in the aquifers.

At the time, the east coast of Australia was of a type that is characterised by mountain ranges flanking a narrow coastal area, where small basins are formed by local subsidence. Examples of these are the Petrie, Oxley and Amberley Basins, with swampy or lacustrine environments, which accumulated Tertiary sediments such as silts, clay, limestones, or oil shale with interbedded basalts. For instance, the Petrie Formation consists of sandstones with oil shales, brown coal and inter-bedded basalts. It rests with a slight unconformity upon the Ipswich coal measures with some plant fossils (Macphail et al. 2014; Cranflied, Schwarzbock & Day 1976). The groundwaters are moderately saline, with a composition typical of alluvium or fine grained sediment, possibly influenced by human activities. The Amberley Basin, around Warrill Creek, is infilled by freshwater limestones (Hodgkinson, McLoughlin & Cox 2007).

After the breakup of Gondwana, the Australian continent drifted northwards during the Cainozoic (the era that began at the end of the Mesozoic, about 65 million years ago, continuing through the Tertiary to the present). During this process, it is considered to have moved over one or more ‘hotspots’. This gave rise to widespread basaltic eruptions over the last 20 to 2 million years, blanketing the emerging GDR with extensive lava flows. This included the Tweed Volcanic Complex surrounding Mount Warning, and Main Range Volcanics to the northwest. Many of the original surface exposures of GAB aquifers and the Walloon Coal Measures have been covered by basalt, which limits current recharge. However, subsequent erosion has largely reduced the flows to dissected, basalt capped remnants or volcanic necks, although extensive areas remain in the south and west, for instance in the headwaters of Laidley and Tenthill Creeks in the Lockyer Valley. The largest remaining basaltic area is on the Lamington Plateau in the Gold Coast hinterland. This is composed of extensive flows that erupted from fissures in the west and the Tweed Volcano in the south (GABCC 2014; Doig & Stanmore 2012).

Basalt is classed as fractured rock aquifer, but in many areas has pervious zones which can provide useful water supplies, particularly for domestic use. The groundwater seeps through vertical joints, between flows, and the surfaces of flows which have been cracked by rapid cooling or contain porous vesicles formed by escaping gases, and is stored in fractured and weathered zones which may not be hydrologically connected to those nearby. Springs occur at the base of the flows, as they tend to be elevated above the surrounding terrain, and since recharge is purely from rainfall, they are vulnerable to droughts. The groundwaters are often of moderate salinity unusually high in magnesium compared to most groundwaters in Queensland, and suitable for most purposes (Singhal & Gupta 1999; Locsey 2004; McNeil, Cox & Preda 2005).

The path of the ‘hot spot’ which caused the basaltic eruptions also produced chains of non-basaltic volcanoes, including the Glasshouse Mountains and the Tweed Volcano (Willmott 2004), which have been eroded to plugs which do not generally have groundwater potential (Hodgkinson, McLoughlin & Cox 2007).

As Australia drifted northwards during the Cainozoic, the landscape of southern Queensland was subject to erosion, leading to the modern, relatively subdued, topography and intense chemical weathering due to the prevailing climate. An extensive lateritic weathering profile up to 20 m thick developed on older land surfaces. In this process, silica was leached from the surficial horizons, leaving clay with iron-stained bands. The dissolved silica was flushed lower in the soil profile as a gel, where it solidified into rocky layers and masses known as silcrete. Removal of overlying material by subsequent erosion exposes the silcrete, resulting in a hard, stony surface referred to as duricrust.

Cainozoic flood plains were subjected to this regime, as well as the Landsborough Sandstone, Tertiary freshwater sediments such as the Petrie Formation, and the older basalt flows associated with Mount Tamborine and the Main Range Volcanics in the north-western headwaters of the Brisbane River (Willmott 2004; Hodgkinson, McLoughlin & Cox 2007). This intensive weathering greatly reduced the permeability of unconsolidated deposits such as alluvium, and although Cainozoic alluvium may contain limited supplies of groundwater it is usually too saline and high in sodium chloride for most purposes, and may produce saline seepages into adjoining recent alluvium if it becomes stressed by over pumping (Croke et al. 2011; Jones 2006).

Erosion and deposition have continued into the Quaternary (the most recent period of the Cainozoic, spanning the last 2.58 million years to the present), with the accumulation of recent alluvium by streams incised into older floodplains, the growth of coastal dune fields, swamps, estuaries and deltaic deposits, and the development of Moreton Bay with its barrier islands (Hodgkinson, McLoughlin & Cox 2007).

Drainage patterns have changed substantially since the early formation of the GDR. Initially, the divide between coastward and inland draining catchments was further to the east. However, the higher coastal rainfall and steeper topography enabled the Lockyer Catchment to cut through the coastal range and erode into the headwaters of the drier Murray Darling Basin to the west. In addition, a drying climate over the last 12 million years has reduced stream discharge, leaving outer edges of the original floodplain that are no longer active as weathered Cainozoic alluvium, particularly in the Lockyer.

The most extensive floodplains within the SEQ are in the Lockyer, Bremer and Logan-Albert catchments, usually yielding good quality groundwaters which may be relatively hard in terms of usage guidelines, but generally suitable for all purposes. The Lockyer Valley alluvium provides the most economically important aquifer system in South East Queensland. It is an important area of crop production, based on intensive groundwater irrigation with a trend of increasing salinity in many parts of the valley. Recharge to the groundwaters is highly variable in source and chemistry throughout the valley, being contributed by local runoff from the sandstone catchment, flood waters from basalt terrains in the surrounding ranges and upwelling from the underlying GAB aquifers during dry spells. In addition, the alluvial valleys of the southern tributaries have a restricted groundwater drainage at the downstream because of a hard rock barrier of Heifer Creek Sandstone, which has led to accumulation of salt through evapotranspiration. This has caused high salinity groundwaters in the lower reaches of southern tributaries with limited headwaters, such as Flagstone, Ma Ma, and Sandy Creeks. As a result, the groundwater is variable in chemistry, and variable up and down stream but suitable for all purposes except in the lower southern tributaries mentioned, where it may be too saline for irrigation (Cox & Wilson 2005; Wilson 2005).

The shorelines of Moreton Bay and the adjacent coastlines have been formed by dune building and longshore sand drift during the changes in sea level over the late Quaternary. Moreton Bay is a large, shallow expanse of water with a maximum depth of 30m and an area of 1500 km^2. It is narrower and deltaic in the south, with numerous small islands, and is enclosed by the four large barrier islands of Moreton, North and South Stradbroke and Bribie (Dennison & Abal 1999). The barrier islands, some of which exceed 275 m in height, have evolved through climate changes associated with phases in the Ice Ages over recent geological times. In the warmer interglacial periods, the whole of Moreton Bay was below water, and longshore currents were transporting large quantities of sand northwards where it became trapped and accumulated between rocky outcrops. During the cooler glacial advances, the sea levels in South East Queensland fell by up to 140 m below present AHD, exposing sand accumulations over a 40km wide extension of the continental shelf to the east of the present North Stradbroke Island. The arid climate and strong, south-easterly prevailing winds stripped the vegetation, allowing the sands to be blown into transgressive and parabolic dunes, moving towards the north west in stages, with the older dune profiles being modified during the wetter interglacial periods by leaching, erosion and revegetation They are highly sensitive to the climatic and sea level fluctuations which shaped them (Laycock 1975; Chen 2001; EHA 2005a, 2005b; Armstrong 2006; Gibbes et al. 2014).

The dunes themselves are composed of fine to medium grained quartz sand, with patchy interbedded layers of carbonaceous sandrock (coffee rock) and some ironstone bands. Concentrations of heavy minerals such as rutile, ilmenite and zircon were formed during the dune building process, being first separated from the lighter silica sands by wave action, then being further concentrated at the crests of high dunes, due to wind action. The coffee rock is formed where organic debris and peat accumulate in the moist, protected depressions that occur as swales between the dunes. These depressions are less permeable than the surrounding sandmass, and may support either persistent or ephemeral perched lakes and swamps well above the regional water table. Some of these features have been buried by progressive dunes in the past, and their existence within the deeper sand mass may locally retard or occlude recharge to the regional aquifer. In contrast to the perched lakes, dune lakes form where an eroded depression has intersected the regional water table. Blue Lake is an example of such a window lake (Laycock 1975; Chen 2001; EHA 2005a, 2005b). Its water level is controlled by the regional groundwater level, making it more stable than that of a perched lake (Bensink & Burton 1975; EPA 2006).

The hydrology and water balance in a sand island is shown in Figure 2. This diagram illustrates the mound of fresh groundwater that is maintained within the island sands as a result of the balance of water entering and leaving the aquifer. There is little surface drainage because of the porosity of the sands, and recharge to the aquifer is entirely from rainfall and is dependent on recent rainfall, evapotranspiration, and infiltration, while losses occur through both evapotranspiration and groundwater flow around the edges of the mound. Because of this, sand island aquifers are more vulnerable to drought than alluvial aquifers because the elevated water table declines due to unrestricted losses around the perimeter with the potential for salt water intrusion.

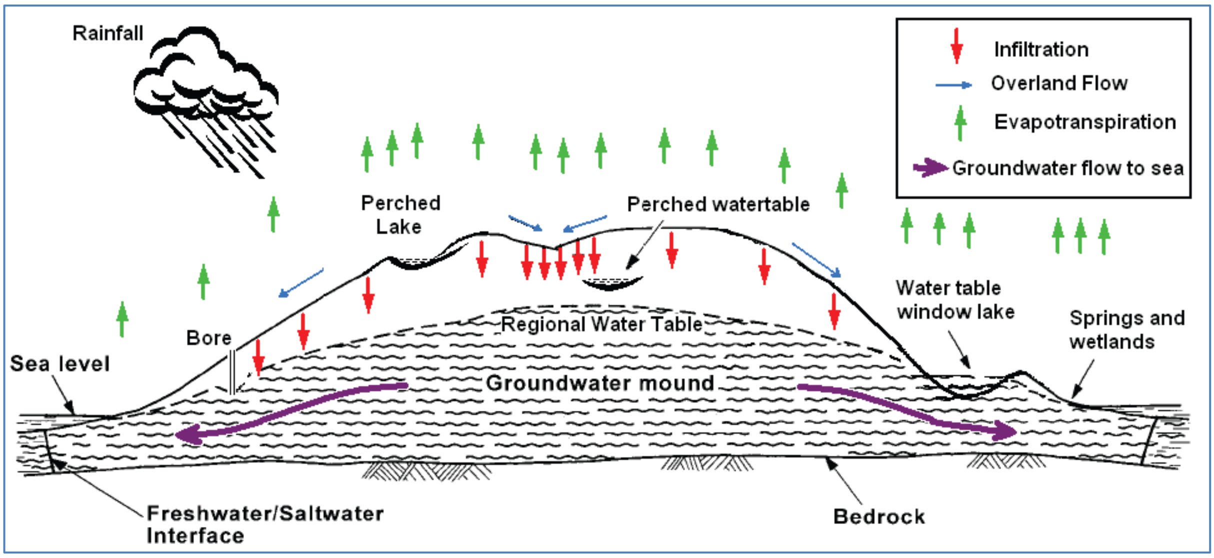


Figure 2: Generalised cross section of a sand island illustrating water balance (DNRW 2007).

The dunes and coastal sand masses are characterised by wallum country, typified by coastal heath, with stunted trees and shrubs with a flowering heath understorey. it is located on dune sands of very low fertility, with dystrophic lakes between the dunes, containing peaty brown acidic water (Thatcher & Westman 1975; Clifford & Specht 1979; Kikkawa 1975). Both ground and surface water are very fresh, with negligible nutrients, but corrosive due to the low pH and carbonate levels as well as very low salinity dominated by sodium chloride. The groundwater usually shows a high clarity, whereas some of the surface water tends to be highly coloured by tannin from the swampy soils. This water exceeds some (ANZECC & ARMCANZ 2013) drinking and domestic guidelines for corrosiveness and colour, and water quality problems could potentially occur through trace constituents being dissolved or kept in solution by the acidity. However, the flora, fauna and aquatic ecosystems are adapted to this type of water quality and would be threatened if it were substantially altered, or if pollutants disturb the naturally low nutrient levels in swamps and wetlands.

An important groundwater feature on the sand islands is Eighteen Mile Swamp, a unique, 26km long, swamp and wetland system on North Stradbroke Island. It is fed by the regional groundwater table and is therefore included in the zone ‘North Stradbroke and Moreton Islands’, rather than as an estuarine feature.

The final event in the formation of the barrier Islands occurred about 6,500 years ago, when a short period of slightly elevated sea level established a coastal platform around the island’s circumferences. Present day beaches form the margins of this platform and support the freshwater swamps at the edges of the main island aquifers (Laycock 1975; Chen 2001; EHA 2005a, 2005b).

Quaternary coastal or estuarine sediments are dominated by marine sand and impermeable clays, which are commonly pyritic and may contain potential acid sulphate soils (Santos & Eyre 2011). Localised subsidence and Quaternary erosion has produced the modern, relatively subdued, topography in the Moreton district (Willmott 2004; Hodgkinson, McLoughlin & Cox 2007; Bryan & Jones 1951).

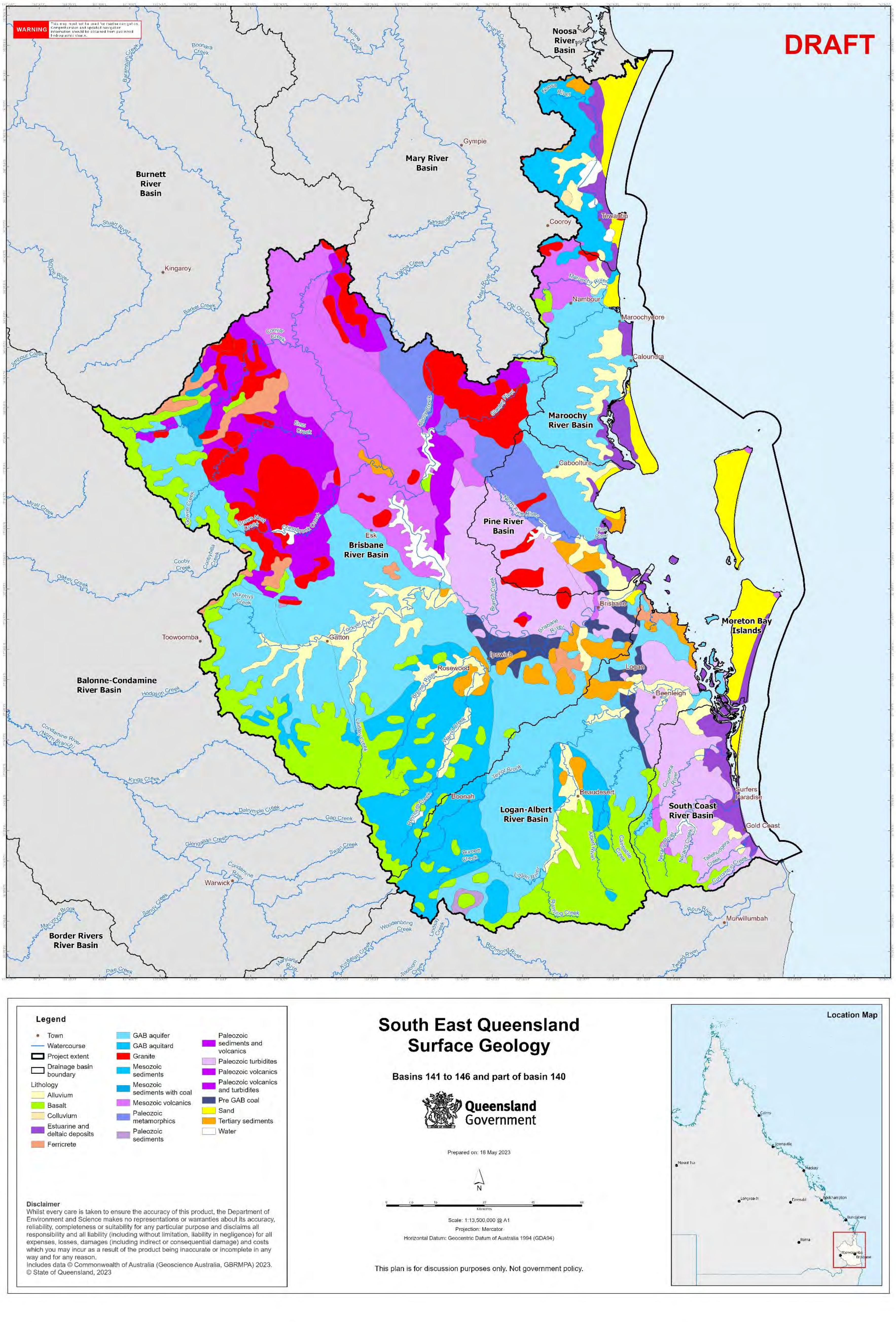


Figure 3: Surface geology of South East Queensland

2.3 Aquifer class, aquifer types and permeability

Groundwater has been defined by many sources (Kresic 2007; Marsily 1986; Manning 1997; NWS_NOAA 2017; Sen 2014). In summary it can be considered as any water that lies in the saturated zone below the water table, the point where all interconnected pores or voids within soils, rocks, and permeable sediments are saturated. It does not include soil moisture, or the capillary fringe peripheral to the water table, where porous material remains damp from upward seepage.

The term ‘aquifer’ does not have a precise definition, but it can be described as ‘a layer of rock or sediment that contains sufficient permeable material to store and transmit significant quantities of water to wells, springs and groundwater fed (gaining) streams.’ The hydraulic conductivity of a material is its capacity to transmit water (in m/day) at a hydraulic gradient of one (a 45-degree slope), so that the actual flow transmitted is the permeability multiplied by the existing hydraulic gradient and cross-sectional area (Ferris et al. 1962). This definition of an aquifer is partially subjective, as the term ‘significant quantities’ of water depends on the required use. For instance, a permeability of less than 1 m/day may be satisfactory for domestic purposes (Drever 2005), but not for irrigation.

Aquifers are classified as either confined, semi-confined, or unconfined, and then by the type of material or lithology that they are composed of. In an unconfined aquifer, the water table fluctuates freely with variations in recharge, groundwater flow and pumping rates, and the hydraulic gradient is calculated as the difference in water table elevation between two points. By contrast, a confined aquifer is overlain by an aquiclude or confining layer. An aquiclude or confining layer is a bed of rock or sediment which, although it may be porous and capable of storing water, can only transmit it at negligible rates. If a confined aquifer is penetrated by a bore, the water will rise to the potentiometric surface, which is an elevation related to the height of the recharge source and hydraulic gradient. This may be above the local water table or even the ground surface. A layer that retards but does not prevent the flow of water to or from an adjacent aquifer is referred to as an aquitard, and the adjacent aquifer is semi-confined, or leaky aquifer. Distinguishing between aquifers and aquitards is often particularly difficult within the GAB because of complex hydrology and structural disruptions such as faulting and fracturing.

To better represent the variability of geological formations in the GAB (GABCC 2014), Smerdon et al. (2012) expanded classifications into five intermediates: ‘aquifer’, ‘partial aquifer’, ‘leaky aquitard’, ‘tight aquitard’ and 'aquiclude'. Rocks such as unweathered granite which have no interconnected voids and are unable to store or transmit water are referred to as aquifuges.

Geoscience Australia (AGGA 2017) class aquifer lithology as unconsolidated or consolidated. Unconsolidated sediments are generally unconfined, and made up of soft loose, friable, surficial material, ranging from clay to sand to gravel. In Queensland unconsolidated aquifers mainly occur in alluvium, dune sands, colluvium, lake bed, or coastal and deltaic deposits. Of these, alluvium deposited in river channels or on floodplains provide the most productive aquifers in the State. For this assessment, the alluvium has been further subdivided at 30 m below surface into shallow and deeper categories, so that the groundwater chemistry zone percentiles can take account of the differing water quality processes that operate at depth.

Aquifers can be either fractured rocks, for example granite, limestone, basalt, and metamorphics, or sediments such as sandstone, siltstone and shale which are cemented but contain pore spaces. In fractured rock aquifers, the groundwater is stored in fissures, joints, bedding planes and cavities. Yield is extremely variable, and recharge is usually local and intermittent. The most important type of fractured rock aquifer in Queensland in terms of groundwater yield is porous basalt, with occasional supplies also found in granites, limestones, and trap rocks (metamorphics, volcanics and deep water marine sediments) usually associated with the GDR. Basalts were deposited over the landscape as lava flows interbedded with other volcanic materials and sediments. Water is stored in and flows through vertical joints, interflow deposits, and the tops and bottoms of flows which are jointed by rapid cooling, and contain porous vesicles formed by escaping gases (Singhal & Gupta 1999). Groundwater associated with Queensland basalts tend to be high in magnesium. They are also rich in the accessory mineral olivine. Drever (2005) showed that if a basalt contained even a small percentage of olivine, this could release sufficient magnesium to account for the relatively high proportion observed in basaltic groundwaters.

Another distinctive type of consolidated aquifer is formed by the dissolution of carbonate rocks such as limestone, dolomite, or marble. As explained by AGSA (2017), fractures and weathered zones may become considerably enlarged due to dissolution of the rock by carbon dioxide and soil acids in percolating waters, and the rock may become sufficiently porous to store and transmit large quantities of groundwater. The resulting landscape, known as karst, contains unusual surface and subsurface features including sinkholes and caves, springs and disappearing streams, as well as complex underground drainage systems. The water quality of karst aquifers tends to be very hard because of the dissolved calcium and magnesium bicarbonates, but such aquifers are rare in Queensland, and of limited extent.

Although less permeable than alluvium and fractured rock aquifers, consolidated sediments cover vast areas. They may retain significant intergranular porosity, depending on how well the grains are rounded and sorted, and the extent to which they are cemented together, particularly in coarse grained sandstones. Porosity is also enhanced in sediments with prominent layering, as water can seep between the surfaces, and the structure of the rock is also relatively soft and weak which makes it prone to fracturing (Kresic 2007). These aquifers are an important resource for Queensland, particularly the major confined sandstone aquifers of the GAB. There are also several smaller sedimentary basins of various ages which are not part of the GAB, as well as underlying terrestrial basins such as the Ipswich Basin, which predated the GAB and were uplifted and eroded before its formation. Some of these non-GAB sedimentary sequences contain locally important aquifers, or other resources such as coal and oil shale.

‘The extensive Cainozoic deposits which overlie the GAB are mostly unconsolidated, they also include Tertiary sediments such as the Petrie Formation as well as weathered alluvium. The Cainozoic alluvial flood plains overlying much of the GAB cover a greater area than their modern counterparts because they were deposited in wetter periods during the Cainozoic (Radke et al. 2012), and, because of stream piracy following uplift of the GDR, westward flowing lost their high rainfall headwaters to the steeper eastern catchments (GABCC 2014; Herbert 1980). These systems were then subjected to the intense weathering regimes that occurred over the period. As a result, the minerals which comprised the sands and gravels of the older alluvials became decayed, losing their structure and porosity. Soluble salts were liberated in the process, and were added to those accumulated through rainfall in an environment where evapotranspiration greatly exceeds precipitation. Because of these factors, yields are generally poor, and quality is saline to brackish (GABCC 2014; DPI 1994).

Hydraulic conductivity is a property of aquifer material that describes the rate at which water can move through fractures pore spaces. It depends on the permeability and degree of saturation of the material, and determines the travel time of the water between two points. It is measured in m/day. Some representative values of hydraulic conductivity from published sources are shown in Table 1, to illustrate typical rates of groundwater flow for a few, relevant, aquifer types. Although such hydrological parameters vary greatly, both vertically and spatially, within a large aquifer. The time needed for an area to recover from pumping stress depends on the hydrological properties of the aquifer as well as other factors including rainfall, aquifer interconnectivity, groundwater-surface water connectivity, and the level of drawdown.

Characteristics of general aquifer types and their water quality concerns are illustrated in Figure 4 (adapted from McNeil & Raymond (2011).

Table 1: Examples from the literature of hydraulic conductivities for aquifer types relevant to the South East Queensland region.

Aquifer type	Aquifer geology	Examples of hydraulic conductivity (m/day)	Reference
Unconsolidated	Queensland alluvium	0.01 – > 20	GWDB Pump Test Database, Bioregional Assessment Programme (2014)
Unconsolidated	Medium sand	0.081 – 45	Spring (2005), Domenico & Schwartz (1990)
Unconsolidated	Dune sand Bribie and Stradbroke Island	0.8 – 15	Spring (2005), Laycock (1975)
Unconsolidated	Marine clay	0.000000072 – 0.00018	Dafny & Silburn (2013)
Fractured rock	Permeable basalt	0.01 – 1.04	GWDB Pump Test Database, USQ (2011)
Cainozoic deposits	Weathered alluvium	0.0002 – 0.0025	GWDB Pump Test Database
Consolidated (GAB aquifer)	Hutton Sandstone	0.1 – 10	USQ (2011), OGIA (2019)
Consolidated (GAB aquifer)	Woogaroo Subgroup	0.008 – 23.857	Bioregional Assessment Programme (2014)
Consolidated (GAB partial aquifer)	Helidon Sandstone	0.008 – 21.5	GWDB Pump Test Database, Bioregional Assessment Programme (2014)
Consolidated (GAB partial aquifer)	Gatton Sandstone	1.1 – 4.92	Bioregional Assessment Programme (2014)
Consolidated (GAB aquitard)	Walloon Coal Measures	0.001 – 17.22	USQ (2011), Bioregional Assessment Programme (2014)
Consolidated (GAB aquitard)	Evergreen Formation	0.0005 – 0.001	USQ (2011)
Consolidated (GAB aquiclude)	Rolling Downs Group	< 0.00001 – 1.0	Jiang (2014), CSIRO (2014)

Table 2. Number of samples used to determine the groundwater chemistry zones.

Aquifer type	Number of samples
Alluvium and other recent deposits	4516
Fractured rock	3130
Cainozoic deposits	150
Lower GAB aquifers and aquitards	1908
Basal GAB Formations	2190
Earlier sedimentary basins underlying the GAB	57
Total	11,951

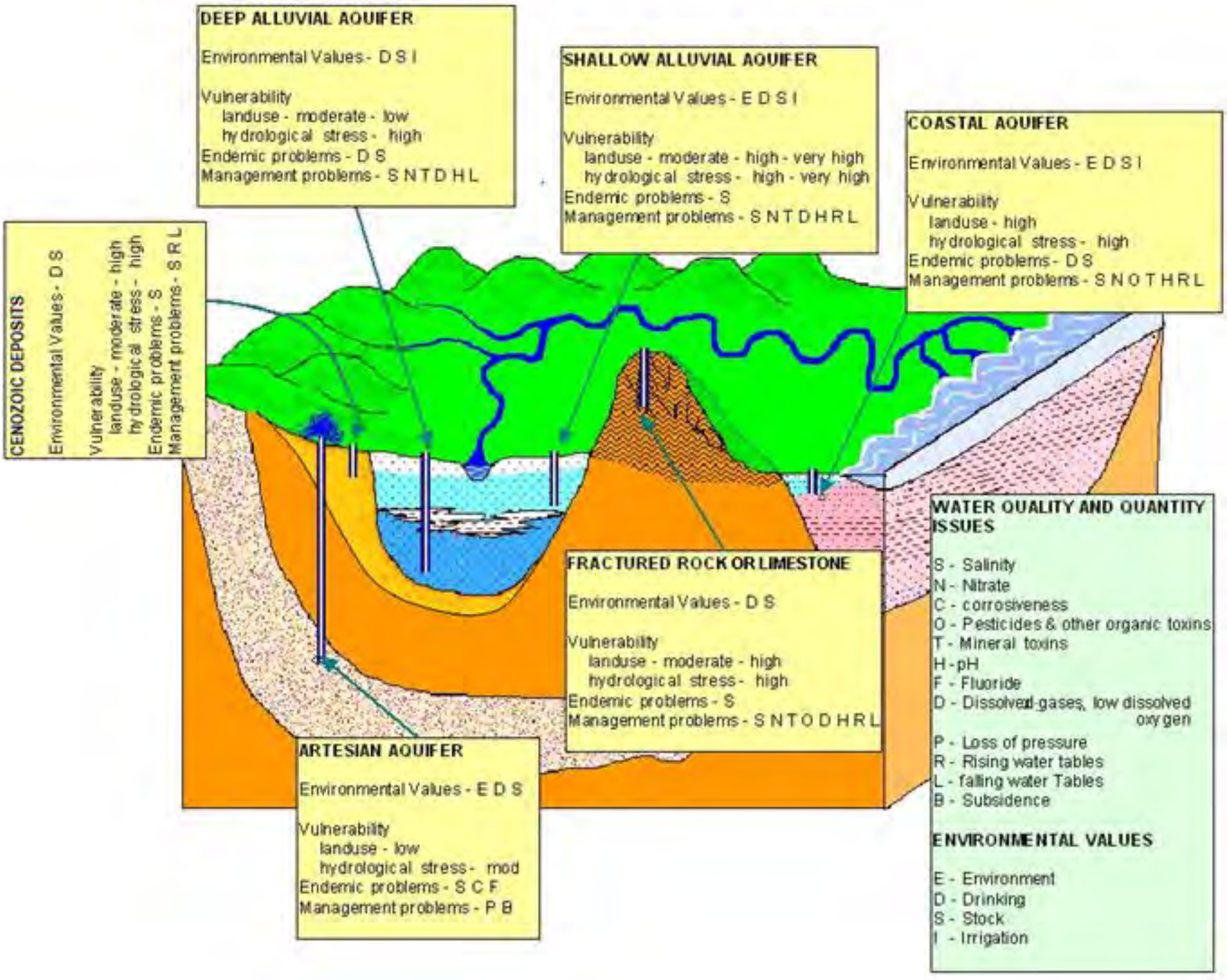


Figure 4: Aquifer types in South East Queensland, with water quality vulnerabilities and EVs, adapted from McNeil & Raymond (2011).

3 Methods

The statistical and conceptual methods used to assess groundwater quality and establish zones in the South East Queensland region is consistent with those used for the adjoining Queensland Murray Darling Basin (QMDB) (McNeil et al. 2015), and the zones spatially connect across these regions where appropriate. The data assessment was conducted using a suite of automated procedures designed to integrate with the Queensland Government's (DRDMW) groundwater and surface water databases.

3.1 Data

The main data source for the project was the Department of Regional Development, Manufacturing and Water Groundwater Database (GWDB), with some data from the Office of Groundwater Impact Assessment (OGIA). The current groundwater chemistry data of South East Queensland is extensive, but was unevenly collected in space and time, with most emphasis on highly productive coastal aquifers.

11,951 lab-analysed samples were used (Table 2), and nearly all samples were collected between the 1940s and the present, however there are 170 records collected before 1940, going back to 1919. This represents a comprehensive dataset, although there are spatial and temporal variations in coverage.

The distribution of complete water quality samples across the region is shown in Figure 5, indicating that sampling intensity has been uneven, and reflecting the fact that groundwater is not present in all areas.

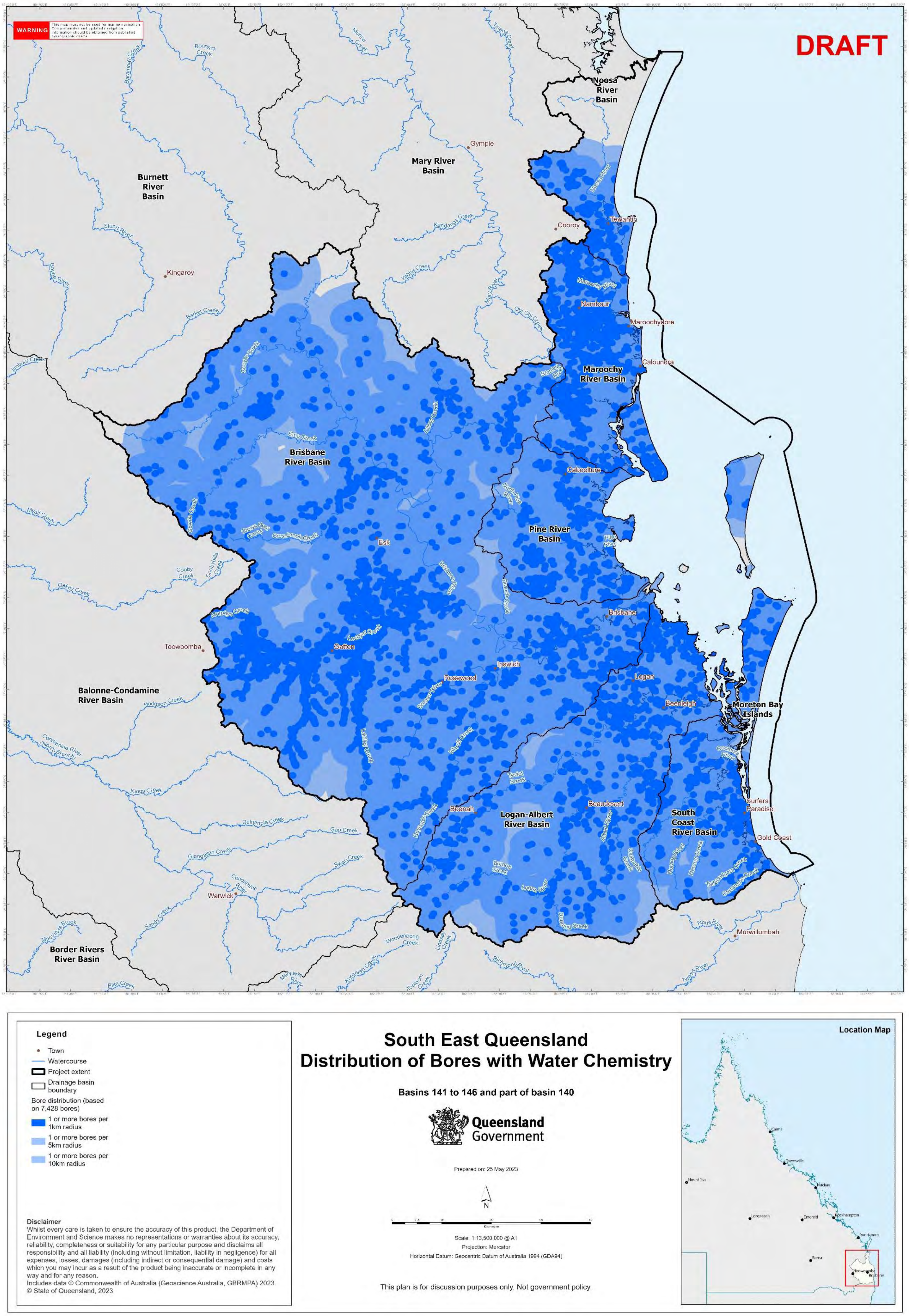


Figure 5: Distribution of bores with water chemistry data across South East Queensland

3.2 Procedure used to define water chemistry zones

Groundwater quality is extremely variable because of frequently prolonged water-rock interactions. Groundwater chemistry zones are therefore intended to differentiate reasonably homogeneous portions of aquifers, so that water chemistry ranges within them are narrow enough to differentiate them. The method used to define the zones is as follows:

3.2.1 Data adequacy and quality

There are several important aquifer systems as well as broad regions where groundwater is only found sporadically. Because of this, and the fact that most sampling has been largely opportunistic and therefore unsystematic, the distribution of data is not even throughout the SEQ. For this reason, the degree of subdivision and levels of uncertainty will vary across the region. However, the data were consistently analysed at the Queensland Health Scientific Services (QHSS) laboratories, a NATA registered facility with high levels of internal quality control and a documented history of changes in analytical procedures. Analyses are now transferred electronically to Queensland Government databases, but were historically typed in by hand, allowing the possibility of transcription errors, but the more significant of these will have been screened through the validation procedures outlined below.

3.2.2 Data validation

Validation tests to identify atypical outliers and errors in salinity and bulk chemistry were based on the chemical balance of the major ions, and by comparing independent salinity measures as described below:

Chemical balance test

The multivariate procedures to be used in this study require complete analysis with all major ions accounted for. Validation of the water chemistry data was therefore based on the chemical balance of the major cations (Na, K, Ca, Mg) and anions (HCO3 CO3, Cl, NO3, SO4), as well as a multivariate comparison of salinity measures. The applied balance test was the formula for the percent charge balance error (%CBE) recommended by Freeze and Cherry (1979) and Eaton et al. (1995), based on the major ions. The equation for the %CBE is:

The equation for the %CBE is:

$$\%CBE = \frac{100 * \left(\sum z * m_c - \sum z * m_a\right)}{\sum z * m_c + \sum z * m_a}$$

where z = the charge on an individual anion or cation (absolute value), mc= molality of a cation, and ma = molality of an anion (where molality in most natural waters can be regarded as the concentration of the ion in mg/L divided by 1000 times the atomic weight).

If chemical balance were exact, the %CBE would be zero, but this is never the case, particularly in surface water and generally if salinity is low. There are a number of reasons for this, including 'rounding off' approximations, non-analysed constituents such as organic acids and complexes, minor constituents such as iron and ammonia, and charged colloidal particles. Differing analytical procedures used for anions and cations by some laboratories (not QHSS) can also contribute to poor chemical balance (Fritz 1994; Murray and Wade 1996; Oliver, Thurman & Malcolm 1983 & G. Denaro pers. com.). Because of this, a %CBE of up to 5% was accepted if the TDI was at least 200 mg/L, in accordance with QHSS and recent studies such as Lambrakis (2006). Tolerance was increased to a %CBE of 10% for TDI 100 - 200mg/L, and 15% if the TDI was below 100mg/L.

Salinity measures test

Salinity represents the majority of dissolved constituents in natural water and can be measured in several independent or semi-independent ways which are not exactly comparable. These are:

- Total Dissolved Ions (TDI), which is the sum of the directly measured dissolved ions in solution, whether they are dissociated or not;
- Total Dissolved Solids (TDS), which is the concentration of dissolved substances in water, which includes organic matter and mineral such as silica, whether or not they are in ionic form (Helmer 1987). The TDS

can be approximated as the silica (SiO_2), plus half of the HCO_3^- (because HCO_3^- converts to divalent CO_3^{2-} on precipitation), plus the rest of the major ions.

- Electrical Conductivity (EC in µS/cm), which is the ability of a solution to conduct an electric current. It is not only dependent on the concentration of dissociated salts and dissolved gases (Pelkie et al. 1992), but also on colloidal suspensions. Consequently, conductivity is affected by temperature, pressure and rate of flow, but it is not affected by dissolved silica or undissociated salts such as H_2CO_3 which do not carry an electric charge.

TDS and TDI are recalculated during the validation process, and the TDI/EC ratio is also checked to ensure it is within normal ranges as presented in McNeil and Cox (2000).

All samples which passed the validation procedures were considered sufficiently accurate and complete to be used in the multivariate analysis to define groupings and interrelationships.

3.3 Statistical assessment

All available surface and groundwater water data were combined, and samples with similar chemistry were grouped through a two-stage clustering procedure, based on the major ions, which is described in McNeil et al. (2005). Surface water was included because it is affected by local geology, and the similarity with the groundwater indicates potential interaction. It must be kept in mind that clustering analysis is a sorting procedure to facilitate interpretation and the choice of method and set of clustering variables should reflect patterns in the data that are significant to the study. In this case, distinctive chemistry of local water bodies. The surface water was included in the clustering process so that comparable chemistry could be used as an indicator of possible surface water/groundwater interaction. After the initial clustering, some very large groups were re-clustered to provide more definition of the bulk chemistry.

The ground and surface water datasets were combined to define groupings and similarities. It is assumed that if the groundwater and surface water systems are not connected, the proportions of major ions in each would be substantially different, reflecting their disparate physical and chemical environments. Conversely, if the groundwater were reasonably similar in bulk chemistry to the nearby surface water, this would imply that the two had been in recent contact either through recharge or baseflow or both. There are a variety of multivariate techniques which are suited to differing types of data and assessment objectives. Those selected here have proved suitable for defining regional water types that would indicate the stream/aquifer/geology relationship using a large and unevenly sampled set of water chemistry data.

3.3.3 Cluster analysis

The water samples were subjected to a multi-stage cluster analysis which sorted them into ten separate water types categorised by their distribution of major ions. In this procedure, the combined groundwater and surface water dataset was sorted through a two-stage cluster analysis described in McNeil, Cox and Preda (2005). This method differentiates groups of predominant water chemistry, and avoids domination by the outliers which are common for analyses of water from complex sources. The variables used for clustering are the percentage equivalents of the major ions. These are readily available and reasonably reliable, and previous studies (for instance, McNeil 1983; McNeil & Poplawski 1993, McNeil, Cox & Preda 2005) prove that they form a very good basis for classifying Queensland groundwaters and surface waters. The type of clustering selected as being most suitable was K Means Divisive Clustering, based on Hartigan (1975) and Hartigan and Wong (1979). This procedure assigns samples to a specified number of clusters. No relationship 'tree' is produced, because the data is divided by allocating from above rather than joining from below. It works well on larger data sets.

Before clustering, the data were sorted by EC and split into groups of 100 samples, each representing a narrow salinity range. Each bunch was then clustered into five groups. These groups were replaced by simulated samples with ion percentages representing the means of the samples in the group. The new data set was then re-clustered into regional water types.

3.3.4 Principal component analyses

Because of the size of, and variability within, the chemistry dataset and its ubiquitous outliers, the water types identified by the cluster analysis were further confirmed by using principal component analysis (PCA). This multivariate procedure is frequently combined with cluster analysis in water quality assessments, for instance by van Tonder and Hodgson (1986). Cluster analysis groups cases on the basis of selected variables, whereas the function of PCA is to define the association between the variables (Wilkinson 1990). This can be represented as lines of best fit, plotted in terms of components derived from relationships detected within the data. The PCA technique used for this study was developed by Swain (1993), using inbuilt routines provided by the SYSTAT statistical and graphical package. It was designed to complement the multi-stage clustering procedure. The results of the PCA indicate that the water types are suitably representative.

PCA is dependent on the original data being normally distributed, and is therefore less robust than cluster analysis. However, it is useful for confirming the results by indicating whether the clusters are sufficiently tight, whether they substantially overlap, or whether they contain natural separations.

The resulting water types, when spatially mapped, formed consistent regional patterns and the basis of a zonal structure, however geological and climatic information provided as GIS layers provided conceptual guidance in defining boundaries where there were few if any data.

Five major chemical groups were identified, noting that many bores are mixtures:

1. Moderately saline with even cations: Characteristic of trap rocks and alluvium draining mixed catchments
2. Mg rich: Mostly associated with basalts (salinity categories are described in Appendix 1)
3. Low to moderate salinity, sodium chloride and bicarbonate with low magnesium: associated with GAB Sandstones
4. Highly saline sodium chloride: related to poor drainage, residual salt or seawater intrusion
5. Very fresh (<200 mS/cm) sodium and calcium chloride with low pH: Found mainly in wallum country and sand dunes

Each bore was assigned, with its aquifer class, to a colour representing its most consistent water group, and each group was plotted as a GIS layer.

3.3.5 Assigning aquifers

There are numerous aquifers of varying size and significance within the region, some overlying or inter fingering with others, a classification of major aquifer types was required, including division of large systems such as the GAB, to avoid difficulties in mapping overlapping units. Therefore, aquifer types occurring in Queensland have been subdivided into nine major classes for mapping purposes. Six of these classes occur in the South East Queensland region, each of which includes a few dominant aquifers as well as a number of minor geological formations accessed by some bores. The zone boundaries for each aquifer class were intended to be mapped around distributions of similar water chemistry and a consistent suite of aquifers. As an example, in the Lower GAB Zone, ‘2 Central Huttons’, most but not all of the bores access the Hutton Sandstone, but with some using the Durabilla member of the Walloons aquitard.

For this reason, all bores used in the study were required to be attributed to a specific aquifer, and the aquifers to a specific class for zoning and calculation of percentiles.

Many bores contributing water quality and water level information were already attributed to individual aquifers during the development of the Water Plan (Great Artesian Basin and Other Regional Aquifers) 2017, and the remainder were attributed using OGIA (2019), or surface geology if shallow and satisfactorily located.

An attribution table (Table 3) was constructed to classify the relevant aquifers into classes for mapping the South East Queensland region. There are three subartesian types representing alluvial and fractured rock systems, and the deposits overlying the GAB. Two classes were used to represent the GAB, which is a complex of layered and interconnected aquifers and aquitards, some of which are not present in South East Queensland. These were broadly grouped on the divisions used by Smerdon et al. (2012), but with the bottom sequence divided into ‘lower’ and ‘basal’ layers to reduce inhomogeneity. A class was also defined for the basins underlying the GAB, in this case the Ipswich basin. The classes relevant to the South East Queensland region are listed below. Two intermediate aquifer classes are also used, these being Mesozoic sediments that are not part of the GAB, and the Palaeozoic sedimentary basins, which probably also retain some porosity. In this instance, the Mesozoic non-GAB sediments were included with the basal GAB on Figure 17 because they were contemporaneous sandstone aquifers. The Palaeozoic sedimentary basins were included with fractured rock on Figure 14, because they were related to the formation of the GDR.

Table 3: Summary of aquifer classes in South East Queensland, to which bores were assigned on basis of their attributed water-bearing geological formation

Aquifer Class	Range	Aquifer types	Aquifer sub types	Examples
Aquifer Class 1: Unconsolidated Alluvium (on Figure 13)	Quaternary to recent alluvium and other recent deposits such as sand dunes and deltas	Alluvium		Lockyer Creek alluvium, Bremer River Alluvium, Floodplain deposits
		Estuarine delta and coastal deposits		Estuarine and deltaic deposits, coastal swamps and salt flats
		Sand		Sand dunes on North Stradbroke Island and Moreton Island
		Miscellaneous		Anthropological debris
		Open water (as recorded on the geological map, DNRM, 2015)		Wivenhoe Dam
Aquifer Class 2: Fractured rock (on Figure 14)	Hard (non-porous) rock aquifers with water contained in fractures, joints, or solution cavities in the case of limestones.	Basalt (Cainozoic)		Main Range Volcanics, Beechmont Basalt
		Granite (including all coarse grained plutonic rocks)		Granite, i.e. Samford Granodiorite
		Mesozoic to Cainozoic volcanic complexes with mainly non-basaltic lavas		Triassic South East Queensland Volcanics
		Trap Rock: Palaeozoic, usually deep water marine sediments and volcanics, mostly associated with formation of the Great Dividing Range (GDR)	Metamorphics	Bunya Phyllite, Neranleigh Fernvale Beds
			Deep water marine deposits, usually deformed	Marumba Beds, Esk Formation
			Volcanics, mostly andesitic	Bellthorpe Andesite, Hampton Road Rhyolite
	Serpentinite	Serpentinite minerals, very high in magnesium and low in silica, intruded into major fault zones in the Palaeozoic		Rocksberg Greenstone
Aquifer Class 11: Palaeozoic sedimentary basins which are normally assigned to	Includes basins containing relatively unaltered freshwater or shallow marine sediments, where deposition took place	Esk Trough. Included with Figure 14, Fractured rock	Paleozoic sediments	Esk Formation, Maronghi Beds, Cressbrook Creek Group, Toogoolawah Group

Aquifer Class	Range	Aquifer types	Aquifer sub types	Examples
another aquifer class depending on locality (Added to Fractured rock Figure 14)	between the Proterozoic and Triassic. They may or may not underlie the GAB or earlier basins.			
Aquifer Class 3: Cainozoic deposits including sediments overlying the GAB (on Figure 15)	Tertiary deposits, mostly weathered and unconsolidated or poorly consolidated, overlying older formations including the (GAB)	Weathered Cainozoic alluvium incised by streams		Bordering Lockyer Creek floodplain
		Colluvium		Colluvium, Cainozoic colluvium, Hillwash
		Duricrust, Ferricrete, Silcrete		Covering weathered basalt or Tertiary sediments
		Tertiary formations deposited within sedimentary basins		Darra Formation, Sunnybank Formation
		Tertiary sediments containing lignite, coal, oil shale and limestone		Petrie Formation
	Localised Cainozoic volcanic activity	Non basaltic lava plugs which followed flood basalts		Glasshouse Mountains, Volcanic plugs in the headwaters of the Bremer River
Aquifer Class 7: Lower GAB aquifers and aquitards (on Figure 16)	Series of Jurassic aquitards and confined aquifers underlying the Mid-Level Aquifers	Clarence – Moreton Sub-basin	Aquifer	Hutton Sandstone
			Part aquifer	Koukandowie Formation
			Aquitard	Durabilla Formation
Aquifer Class 8: Basal GAB formations (on Figure 17)	Lower Jurassic aquifers and aquitards subdivided from the Lower GAB for convenience as they tend to overlap	Clarence – Moreton Sub-basin	Aquifer	Woogaroo Subgroup
			Part aquifer	Gatton Sandstone, Raceview Formation
			Aquitard	Evergreen Formation
Aquifer Class 10: Mesozoic sediments which are not part of the GAB and are normally assigned to another map class depending on locality (Added to Basal GAB on Figure 17)	Includes reasonably undisturbed Late Palaeozoic to Mesozoic sediments that are not within the boundaries of the GAB.	Nambour Basin. This is included as part of Figure 17 Basal GAB Formations, with which it is contemporaneous	Aquifer	Landsborough Sandstone

Aquifer Class	Range	Aquifer types	Aquifer sub types	Examples
Aquifer Class 9: Earlier sedimentary basins underlying the GAB (on Figure 18)	Terrestrial, late Palaeozoic to Triassic basins that predate the GAB. They were uplifted and eroded before the GAB was formed and may wholly or partially underlie it. These basins may contain coal and hydrocarbons.	Ipswich and Tarong Basin coal measures	Coal measures	Tarong Beds, Blackstone Formation, Tivoli Formation, Brassall Subgroup, Kholo Subgroup

The groundwater sample data, having been assigned to individual aquifers, were further categorised into aquifer classes as described in Table 7.

3.4 Defining chemistry zone boundaries

3.4.1 Defining groundwater chemistry zones

Alignment across space and depth

Water types for each aquifer class were spatially mapped across the SEQ region using ArcGIS 10.1. Where suites of water types could be grouped, areas were traced around clusters of homogenous data for each depth class. The results from all depth classes were then merged to form interim groundwater chemistry zones.

Refinement by aligning with landscape and climate

The interim zones were visually assessed alongside other landscape and climate characteristics to identify areas where refinements could be made. As bores vary in density, with tight concentrations divided by sparsely populated peripheral areas, the refinement of zone boundaries has been driven by features likely to be associated with particular groundwater chemistry, primarily the dominant geology and further guided by elevation and surface water chemistry. Land use and historical rainfall were also investigated as additional information sources for guidance in zone delineation. Zone boundaries have been delineated and refined on a tentative basis, with a degree of uncertainty that increases as data becomes less abundant or overly complex.

Geology

Dominant rock unit information was drawn from the State government SIR-QRY database and categorised into groups based on hydrological and hydro-geochemical characteristics. Plotting of the groups indicated general alignment between sequences of water type and broad geological divisions.

Elevation

Contoured relief data for the region drawn from the Department's SIR-QRY database. Some broad alignments were observed between dominant groundwater types and land elevation.

Rainfall

Total annual and long term average rainfall data sets were obtained from the SILO Australian climate archive, which stores daily time step rainfall interpolations in 5km grids (for interpolation methods, see Jeffrey et al. 2001). The data was then processed for visualisation in ArcGIS 9.3.1.

Land use

Land use data were obtained from the Queensland Land Use Mapping Project (QLUMP) which uses the Australian Land Use and Management Classification (ALUMC) Version 7, May 2010. A general alignment is expected between groundwater chemistry and land use on the broad scale because they are both related to geology, soils, topography and climate. Local anomalies may indicate more direct or causal relationships in some areas and may be used to validate small areas of unusual chemistry.

Surface water and groundwater interaction

There is a stronger likelihood of surface water and groundwater systems having been in recent contact through recharge or base flow if their bulk chemistries are reasonably alike. Conversely, such systems can be considered physically unconnected where their proportions of major ions are dissimilar.

Groundwater Management Units (GMUs)

The groundwater resources of Australia were divided into two types of regions as defined by ANRA (2000). These GMUs include the most productive aquifers, as well as Unincorporated Units (UAs), which differentiate the intervening areas. A GMU is a hydraulically connected groundwater system that allows identified issues and intensity of use to be incorporated into management practices.

Regional EC tendencies

Areas with otherwise homogenous groundwater chemistry were subdivided where regions within them showed marked differences in overall EC, as reflected by bore log data.

Resulting chemistry zones delineated for the SEQ groundwater

Despite the unevenness in distribution and density of groundwater data in SEQ, and the complexity of the water chemistry, 83 discrete groundwater chemistry zones were able to be delineated on 6 map classes. These zones are shown in Figure 13 - Figure 18 and summarised in Table 7. More detailed descriptive information for each zone is provided in Table 8 in Appendix 1, with nomograms of chemical equivalence. Statistical summaries of salinity and major ions are presented in Table 9 in Appendix 3. The main chemical groups are: sodium, calcium, magnesium, bicarbonate, chlorine, sulphate, nitrate, silicon dioxide and fluorine.

Reliability

The confidence with which the zones could be defined and characterised was dependent on the abundance and chemical homogeneity or complexity of the data. However, all of the defined zones reflected sufficiently consistent chemistry to enable an indicative association with a particular water type when aligned with relevant geological, topographic, climatic and land use indicators. Zones defined with least confidence tend to be in areas with only small local groundwater supplies which tend to be highly variable in chemistry because of local environments and land use influences. Most areas with no data will have no substantive groundwater reserves.

The bores for each aquifer class, coloured in terms of predominant water group, were plotted spatially using ArcGIS Pro 3.03. The bores were also used to produce another layer, including surface and bore geology (as attributed in the GWDB), rainfall, climate, and topography. The major features of each aquifer class were used as a background layer, over which to construct the zones. The background features were catchment boundaries for the alluvial map, surface geology for the Cainozoic deposits, and areas mapped as fractured rock. Specific layers were obtained for widespread GAB formations and outlines of the Ipswich basin to define sub surface aquifers and basin boundaries for the GAB and underlying basins maps. For each aquifer class, zones were initially traced subjectively around clusters of similar water and aquifer groups, then the interim zones were visually assessed alongside other landscape and climate characteristics to identify areas where refinements could be made. As bores vary in density, with tight concentrations divided by sparsely populated peripheral areas, the refinement of zone boundaries was driven by features likely to be associated with particular groundwater chemistry, primarily the dominant geology, and, where data was scarce, elevation and surface water chemistry also guided boundary definition. Land use (DSITI 2017) and historical rainfall were also investigated as additional information sources for guidance in zone delineation.

3.5 Defining parameter ranges for chemistry zones

Current baseline water quality was then estimated for each zone, represented by percentiles of each parameter recorded in the GWDB. Appendix 1 provides detailed information for zones, with descriptions in Table 8, and water quality percentile ranges in Table 9. Some of the more extensive alluvial zones, as well as some overlying the GAB, show substantial water quality variation close to the stream. This is expected given the proximity to recharge in cases where the stream is a major recharge source. Therefore, the alluvial zones concerned are provided with percentiles for a 1.5 km buffered area around the major streams (“near stream”) as well as for the zone as a whole.

Data mining programmes were then applied to extract hydrological and aquifer statistics for each zone, and to compare the water quality to guidelines, calculate trends for groundwater level, EC and nitrate converted to NT for alluvial zones, as presented in section 3.7, and to identify general water quality hazards. These are presented on Table 8 in Appendix 1, with a major ion plot to define the character of the zone, and its reason for its inclusion as a separate identity. Current baseline water quality for each zone was then calculated as percentiles of available water quality parameters. Data mining procedures were then used to further define the zone water quality characteristics in terms of condition, as defined by Department of Environment and Resource Management (2009) guidelines, and trend (refer to section 3.7) using the methodology developed by McNeil & Raymond (2011).

This study acknowledges that the zones and their baseline ranges only represent current mid-range levels, chiefly because data is limited particularly for the pre-European period; however, it is emphasised that these interim values are in line with the precautionary principle in providing a filter to identify outlying sites and sudden or rapid change.

Zone borders are acknowledged as being approximate, because there is often a gradual or irregular merging of the groundwater between adjacent zones, because there is uncertainty in the boundaries between individual aquifers, and because data is often scarce around zone borders. Therefore, refinement of the borders would be expected with the support of ongoing data collection. It could also be enhanced for areas of sufficient priority, by the use of groundwater models, or other more intensive assessment techniques. Groundwater models enable an understanding of the local hydrology, and its interactions with water chemistry, for instance in North Stradbroke Island (Chen 2001). Assessment techniques, including multivariate analyses and trend analysis, also help to chemically define individual water bodies, as demonstrated for the Atherton Basalts, north of the region, by Locsey & Cox (2003), and changes in dominant source through time, as in the Callide by McNeil (2002). In summary, investment in monitoring and assessment would allow percentile ranges to be refined, natural processes to be differentiated and anomalies due to atypical local aquifers to be identified.

3.6 Defining EVs for each chemistry zone

Environmental values (EVs) were determined for each groundwater chemistry zone, as per the EVs in Appendix 2 and with consideration to the sources listed below. These are drafts for consultation and may be revised in response to comments. All groundwater chemistry zones by default included the aquatic ecosystem EV and the cultural, spiritual and ceremonial EV.

Human EVs were identified following consideration of a range of sources, including:

Relevant water legislation, water plans and supporting reporting (e.g. Logan, Gold Coast, Moreton, Great Artesian Basin and other regional aquifers [GABORA]) pertaining to water entitlements and water use – including as-of-right uses.

The Queensland Government's Water Entitlement Register Database (WERD), now replaced by WMS (Water Management System), and associated information - in consultation with Department of Regional Development, Manufacturing and Water (DRDMW).

Publicly available (e.g. web-accessible) information and reporting on known groundwater resource areas (e.g. Bribie Island, Stradbroke Island, Bremer, Lockyer Valley, Tamborine, Springbrook, Cooloola sandmass), including any applicable results of surveys or other stakeholder inputs

Human use EVs identified in previous EPP(Water) schedule 1 materials (note: these were identified at a generic level – not identified by aquifer)

Land use mapping (QLUMP), as described in section 3.4

SEQ regional plan ('*ShapingSEQ*')

A review of potential water suitability (this report – Appendix 1) was also undertaken to determine the broad water quality characteristics of groundwater resources relative to identified human uses. However, to ascertain suitability of a specific water source (e.g. a bore) for a given use (e.g. irrigation), more detailed testing may be required, and the broad results in Table 8 are not intended to provide this level of detail. Hence, particular water sources may not be suitable for all uses identified in the broader chemistry zone.

In relation to interpretation of water use data from the water management system (WMS), the types of water use recorded in the WMS vary to a degree from the broader categories of EVs used in the national and state water quality frameworks. As an example, there are multiple different categories of stock water use potentially applicable under the WMS (e.g. 'stock', 'stock intensive', 'feedlot'), all of which correspond to the single 'stock watering' EV. Accordingly, the following 'translation' of potential uses under the WMS has been applied to inform identification of EVs in this project region based on information in the WMS (note that not all uses occur in a given area). Revisions to the translation framework may in turn be made where local information on the water activities (for example Todd (2011), regarding water use in the Gold Coast hinterland) provided greater clarity on the applicable EVs to adopt.

Further consultation will be undertaken with DRDMW during the process of finalising EVs.

Table 4: EVs attribution from water use information

"Use" as listed in water management system	Proposed corresponding EV in accordance with EPP Water (subject to local review and revision)
Irrigation	Irrigation
School (where use is distinct from reticulated supply)	Irrigation (e.g. fields)
Education Facility (where use is distinct from reticulated supply)	Irrigation (e.g. fields)
Agriculture	Irrigation
Stock	Stock watering
Stock Intensive	Stock watering
Feed lot	Stock watering
Dairying	Stock watering
Commercial	Farm water supply/use (depending on activity and subject to local review)
Amenities	Farm water supply/use
Public Supply	Farm water supply/use
Industrial	Industrial
Mining	Industrial
Roadworks	Industrial
Aquaculture	Aquaculture
Domestic Supply	Drinking water supply
Town Water Supply	Drinking water supply
Urban	Drinking water supply
Group Domestic	Drinking water supply
Rural Water Supply	Drinking water supply
Test Purposes (required to test pump bore)	N/A
Water harvesting	N/A

Results are shown in the chemistry zone mapping under section 4.

3.7 Trends and vulnerability

A review of existing public information regarding the vulnerability of groundwaters in the region was undertaken. This review was complemented by a regional scale trend review of the selected indicators for this project.

The review informs decisions on the percentiles adopted in the Water Policy for the aquatic ecosystem EV: where there is no clear evidence of declining water quality linked to anthropogenic activity, the focus is on maintaining current water quality distribution (20^{th}-50^{th}-80^{th} percentiles of data), as per national guidance. Where there is evidence of declining trends linked to local conditions (rather than long term underlying natural trends), a focus may be to seek stabilisation of decline and/or an improvement in the water quality distribution for relevant indicators (e.g. 20^{th} – 40^{th} – 70^{th} percentiles). Note that water quality requirements to support human use EVs, such as stock watering and irrigation of crops, are typically based on separate state or national (e.g. ANZG, NHMRC) water quality guideline sources.

Scale of review varied according to sources used and included surface water catchments or basins, groundwater aquifers and, for chemistry zones, local water quality/level trend assessment, where information was available.

3.7.1 Existing reviews

The team firstly reviewed existing risk/vulnerability assessments which provided a starting source of information on locations where groundwater was likely to be impacted by human activities to a greater degree than other areas. It then considered existing land use (QLUMP) and proposed future development (eg future urban) identified in regional planning (including the Draft Shaping SEQ South East Queensland Regional Plan 2023 Update

Key reference sources reviewed for the vulnerability assessment included:

- Department of Natural Resources and Mines (2002) *Groundwater vulnerability mapping of Queensland, QNRM02262*

This series of maps was associated with a groundwaters vulnerability assessment of different regions across Queensland. Vulnerability assessment considered recharge, aquifer media, soil media, topography, impact of vadose zone, and hydraulic conductivity to determine vulnerability ratings. Note that the assessment reported that a high vulnerability result does not mean that a groundwater source was degraded: '*Groundwater vulnerability maps identify aquifers that are susceptible from various landuse practices. A groundwater vulnerability map is a graphic representation of how much physical resistance the land has against the possibility of a non-specific contaminant entering the groundwater from the surface. The maps were produced with regional data and should not be used at a paddock scale*.'

The groundwater vulnerability mapping product did not distinguish aquifer type (e.g. alluvial vs GAB). Highest vulnerability areas included Moreton Island, Stradbroke Island (high) followed by sections of upper Logan, Albert and Coomera catchments, a band between Esk-Gatton, and sections of the Bremer and Locker, and a Moreton Bay-fringing urban strip stretching south from Caboolture through Brisbane to the Redlands, with some extension into the Gold Coast (moderate-high).

- Department of Natural Resources, Mines and Energy (2018) *State-wide risk assessment of water resource pressure*. Documentation of catchment risk assessment approach used to inform prioritisation of measurement under the Rural Water Management Program, October.

A 2018 state wide review of water resource pressures was also referred to, with its 2022 summary. This document, (DNRME 2018) is available from the DRDMW strengthened water measurement website. The risk assessment for each catchment was based on water resource pressure across the state and overlays the current metering network against this information. There were five key indicators used for water resource pressure, namely:

- Percentage of water use relative to entitlements
- End of system (EOS) flow
- Level of demonstrated competition for existing, unallocated and new water
- Complexity of water management issues
- Compliance data.

The assessment considered both surface and groundwaters with the results provided being an overall assessment of both. Water resource pressure was ranked as (i) Low, (ii) Medium, (iii) High or (iv) Very High. The four categories of risk are based on an assessment of the water resource pressure risk rating of the catchment overall, noting that some localised higher risk hotspots may exist within a catchment.

The majority of high and very high risk rankings identified by the review were not within the SEQ project area. In fact, lowest risk areas identified included Moreton Island and Stradbroke Island.

- Department of Regional Development, Manufacturing and Water (2022*) Groundwater Monitoring Network Review Methodology Guideline February 2022*

A third document, (DRDMW 2022) and its accompanying recommendations covers the Groundwater monitoring network review methodology guide. This report is also referred to, and is available from the Queensland Government water monitoring information portal. It outlines the risk-based methodology for the review of the current departmental groundwater monitoring bore network across the state. It is focused on water level monitoring, and is in three main parts:

Part A involved prioritising groundwater units: four criteria were identified in the process of prioritising groundwater units:

- Resource risk – an assessment of the risk to the resource, based on criteria relating to resource development and use, groundwater system responses, demand for new water, long term storage behaviour, enquiry/complaints/ compliance issues and natural contamination risks to the resource as a potential consequence of development
- Water management – consideration of existing management
- Resource assessment – planning – data (groundwater level) requirements for assessment purposes
- specific management requirements – local issues impacting data requirements.

Part B involved a review of monitoring bores within groundwater units, and established seven criteria to rank the individual importance of each bore relative to other monitoring bores in the same groundwater unit (e.g. whether monitoring bore was representative of the aquifer; purposes the bore is monitored for; bore construction; whether located in an area where there is groundwater demand; the level of influence on the bore from pumping; access considerations; and distance from other monitoring bores in the same unit).

Part C involved recommendations to for each groundwater unit incorporating the priority ranking identified in Part A and the recommended sites to be monitored as determined at the end of Part B.

The results of this review therefore assist in identifying groundwater units that have lower evidence of resource risk, and correspondingly, units where high levels of risk based on water use and other pressures have been flagged.

A desktop assessment of land use, bore density and groundwater vulnerability was undertaken for each zone. The following GIS datasets were used to assess demand for groundwater in each zone: Queensland Land Use Mapping Program (residential areas and irrigated agricultural areas); South East Queensland Regional Plan major development and future growth areas, and the Department of Regional Development; Manufacturing and Water’s Groundwater entitlements database (active water licences and permits) and its bore distribution data.

The Groundwater Vulnerability Mapping of Queensland (DNRM 2002) was used to assess each zone’s groundwater vulnerability status. The multi-criteria assessment maps incorporate the following datasets: the groundwater recharge network; aquifer and soil media; topography; impact of vadose zone and conductivity.

This assessment provided a comparison of each zone’s demand for groundwater and it’s groundwater vulnerability. The results will inform the EPP(Water) schedule 1 materials.

3.7.2 Review of trends in groundwater

Following from the regional level appraisals above, further trend reporting was undertaken by chemistry zone.

Trends in groundwater levels and quality can be used to determine whether the aquifer is stable or subject to change due to natural or anthropogenic processes. It was decided to estimate trends in water levels over the twenty year period from 1992 to 2022, and to EC and TN over a 10 year period since 2012. Trends for the entire record were also calculated to provide a long term perspective. Selecting a suitable method for regional trend analysis in a complex groundwater system is problematic because of the irregularity of the records, the fact that the aquifers are not uniform or continuous, and bores within a small proximity may not be hydraulically connected. This means that traditional methods such as contouring for various time periods are not practical. It was therefore decided that an appropriate method of regional trend analysis would be a modification of the Zoned Trend Test developed by (McNeil 2002), which uses a Mann-Kendall Test (Box & Jenkins 1976). on the trimmed means of annual water levels in defined sections of the aquifer system within an area. The trimmed mean is used to prevent outliers (which may not represent the primary aquifer) from biasing the results. The median was not used because it is not considered sufficiently precise to represent small changes where data are limited. This method relies on the non-parametric Kendall-Mann Statistic, but uses normal distribution methods to trim outliers and isolate the main local aquifers.

To carry out the test, time series were prepared for each zone, using water level data collected since 1992, with the proviso that data from any one bore was limited to four water levels a year to avoid bias by certain bores which are very intensively sampled. Each zone was then tested for data sufficiency, with the record being considered adequate and representative for a valid trend result if data met the following criteria:

- At least 10 data points to represent each year, other than outliers.
- Data collected over at least a 7-year period with at least 5 individual years being sampled.
- At least 1 sample/yr for each 100 km^2 of zone area (1000 for artesian zones).
- If no data has been collected in the last 5 years, the trend is described as ‘historical’.

The means and standard deviations (SD) were calculated for each year of the required period within each zone. Samples were then rejected as atypical outliers if their value was more than two times the annual SD above or below the annual mean for the zone. The means and SDs were then recalculated, and the data trimmed again in the same fashion as the first trim. Zone years with less than five samples were also deleted as not being sufficiently representative. A final time series of annual means and SDs was constructed for each zone and analysed for trend using the non-parametric Kendall Tau test. The parametric Pearson trend analysis was also applied to the time series for confirmation, with a t-test method described in (McBean & Rovers 1998) used to estimate statistical significance.

The remaining data are considered highly representative of the major aquifer in their zone during the particular year of measurement, and the time series of these means and standard deviations (SD) were used to represent the zone/years in the trend estimate. Water level trends for each zone were then calculated using the rank Mann Kendall Test. The results of the trend tests were categorised subjectively, based on the criteria summarised in Table 5. As a visual check, the trend analysis results are also graphed below, with both linear and non-linear (loess) lines of best fit.

Table 5 Trend rating criteria

Trend result	Kendall Tau	Significance of Pearson correlation	Other factors
Probable rise	>0.01	95%	
Possible rise A	>0.01	90%	
Possible rise B	>0.01	95%	record <8 years long (<16 for 20 or more-year trend)
Probable fall	<-0.01	95%	
Possible fall A	<-0.01	90%	
Possible fall B	<-0.01	95%	record <8 years long (<16 for 20 or more-year trend)
Stable	-0.01 to 0.01	'non sig'	
Uncertain		At least 90%	Kendall and Pearson contradict
Unknown			Insufficient or non-representative data

The high degree of inherent variability in Australian weather patterns means that it can be difficult to interpret water related trends unless they are referenced to a control which can differentiate decadal scale natural climatic fluctuations from local factors such as atypical weather or landuse (Tisdell, Ward & Grudzinski 2002). Groundwater is susceptible to prevailing decadal climate trends, particularly in the case of shallow groundwaters. This is because the process of recharge necessitates a saturated pathway to the aquifer which can usually only be achieved in a period of reasonably sustained rainfall. This is particularly so in Queensland where the wettest period of the year is also the hottest and most susceptible to evapotranspiration. Moreover, there are continual losses from the groundwater system through capillary rise and subsequent evapotranspiration, as well as baseflow to streams and down-valley flow to distant parts of the aquifer. The effects of climate will be superimposed on anthropogenic impacts, either counteracting and temporarily obscuring them, or making them more extreme.

Authors such as Cavanagh et al. (1998) advise comparison with a site in undisturbed condition in a similar catchment. However, these are seldom available for Queensland studies. Because of this, a ‘virtual’ control site has been prepared from smoothed monthly water level readings throughout the state. A previous study (McNeil & Cox 2007) shows that decadal scale climatic trends are the best model for groundwater behaviour because of the slow and lagged response times. The climate control over the trend period is shown in Figure 8. It fell in response to drier conditions in the mid-1990s, with a major rise around 2000, followed by a long decline through the millennial drought. Stabilisation followed the 2010–2011 weather events and subsequent tropical cyclones, then a current rapid rise. The rainfall at Archerfield Airport is shown on Figure 7 for comparison.

Figure 6: Climate trend for monthly groundwater levels in Queensland (McNeil & Cox 2007)

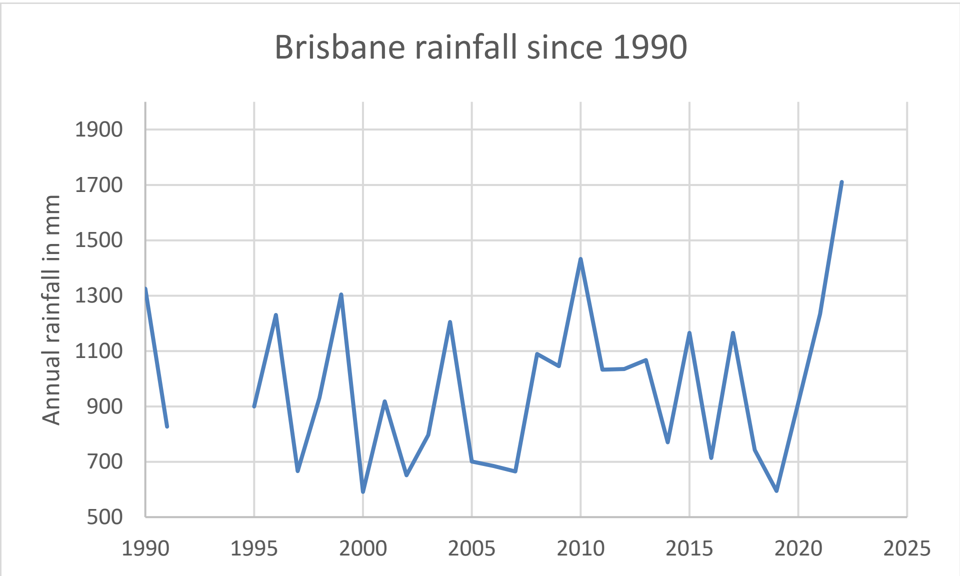


Figure 7: Annual rainfall in Brisbane at station 040211 at Archerfield Airport since 1990, covering the trend period. Records for 1992 to 1994 are incomplete.

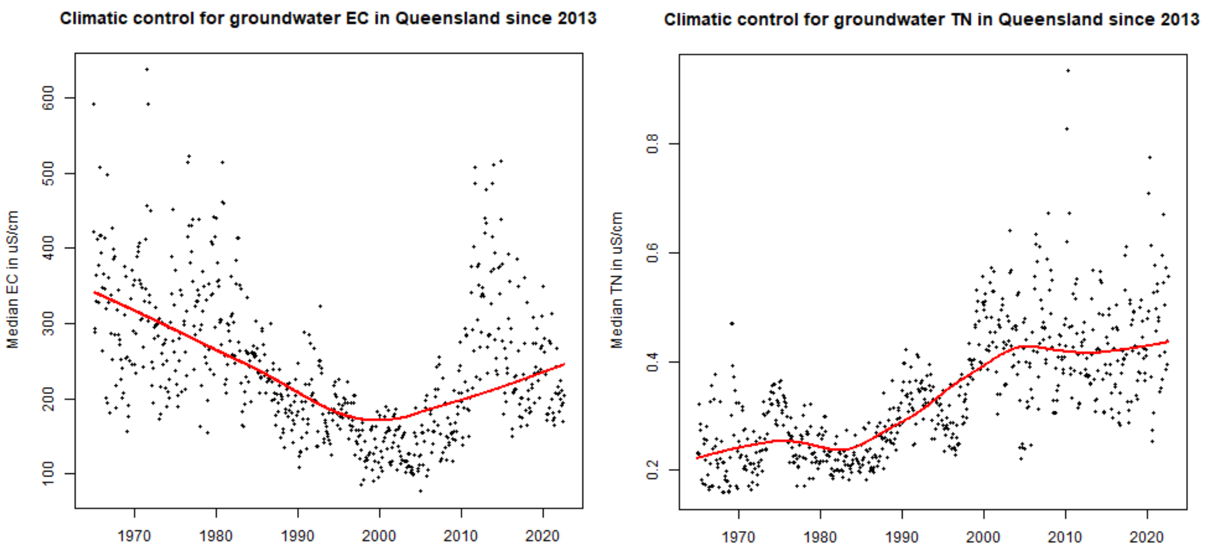


Figure 8: Water quality climate controls based on state-wide means as described in McNeil & Cox (2007)

The patterns in these time series are detectable in sites throughout the state and have also been shown to be related to climatic indicators (McNeil & Cox 2007). The climate control series was used to assess groundwater levels for climatic influence at individual sites using Spearman rank correlation (R2) with paired monthly values. Classification of climatic influence was then based on the strength of the correlation coefficient as follows:

R2	< 40%	Mainly local influences
R2	40% – 60%	Local and climatic influences
R2	60% – 70%	Influenced by climate
R2	< 70%	Consistent with climate

The term ‘Consistent with climate’ infers that the broad trends are consistent with those of climate with random noise superimposed, whereas ‘Mainly local influences’ implies that the overall trend bears little relationship with that of climate, although a climate signal may be superimposed on all or part of the record. In these cases, the trend may be related to human activity, but this cannot be substantiated based on the trend analysis alone.

The zone ‘5 Upper Lockyer Creek’ on Figure 13 is used here as an example to illustrate the trend analysis process. The series of mean annual water levels are shown on Figure 9, showing the pattern of change over the period, with smoothed and linear trends, and with an accompanying bar plot showing the number of data available for each year. The test result indicated a probable rise, due mainly to local influences, obtained from a moderate quality record. It is clear that a long-term falling trend was interrupted by the exceptional rainfalls around 2010 and 2011. This was followed by a decline that was arrested around 2020. Figure 10 shows the water level records of two bores in the zone with long term records to compare with the time series of means. Water levels in many of the SEQ zones approximate this complex pattern, with overall rises or falls depending on the phase of recovery.

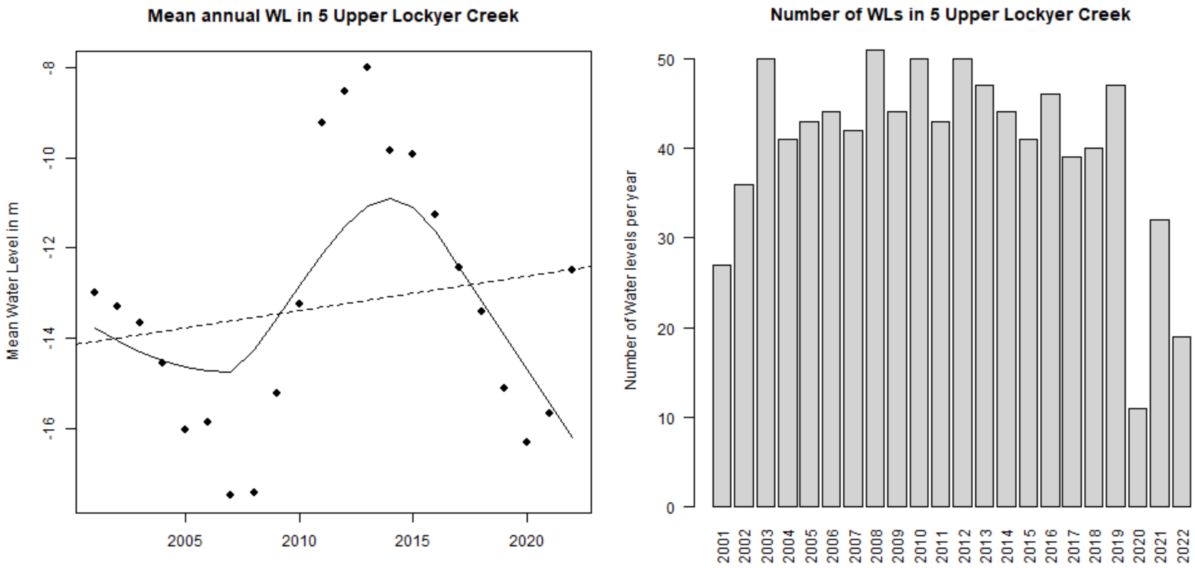


Figure 9: Average annual water levels in Upper Lockyer.

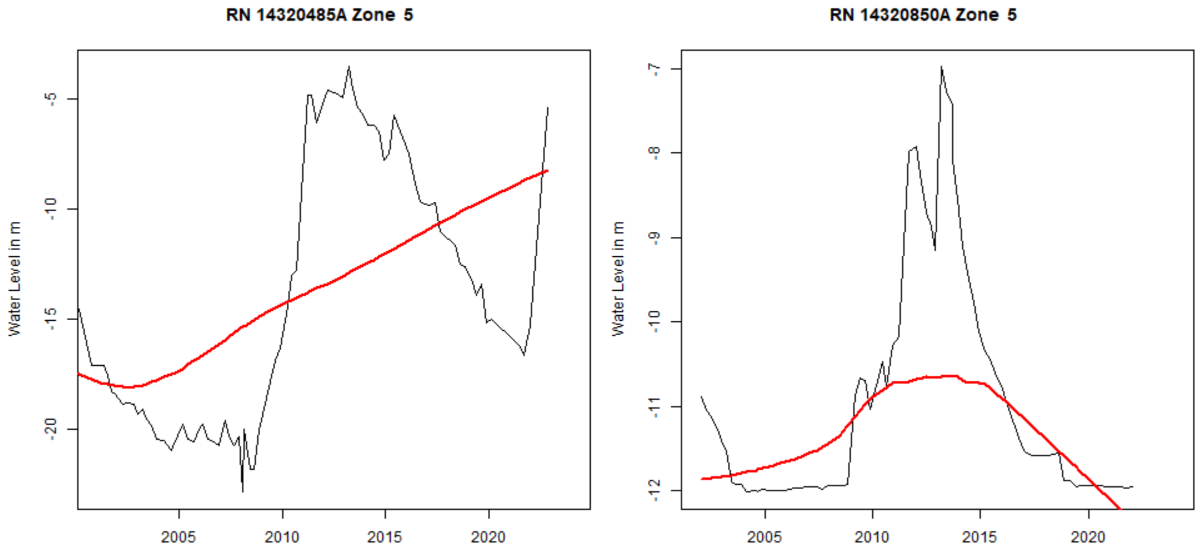


Figure 10: Bores with water level records from Zone 5 which cover the whole period.

Water quality trends for EC and TN are also indirectly related to rainfall, as discussed in McNeil & Cox (2007), and are calculated in a similar fashion to water levels. Those for EC and TN in Zone 5, ‘Upper Lockyer Creek’ are shown on Figure 8, which although based on limited data suggest a rise for EC and fall for TN. Figure 12 gives another example from Figure 13, Zone 14, ‘Logan Albert Basaltic Headwaters’. The results for this zone also show rising EC and falling TN.

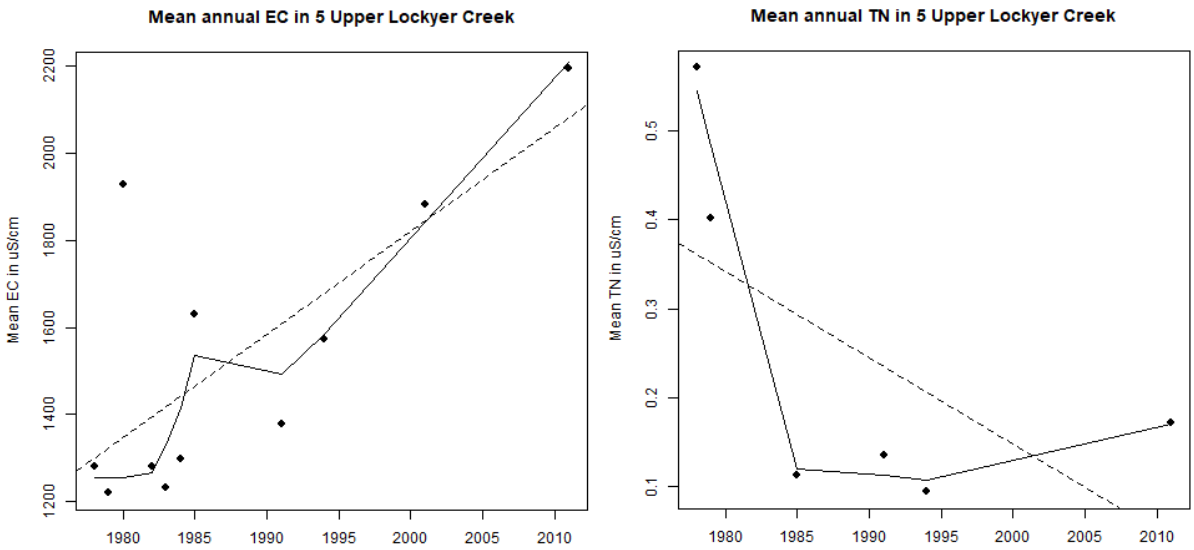


Figure 11: Example of long term water quality trends, EC and TN in Upper Lockyer Creek.

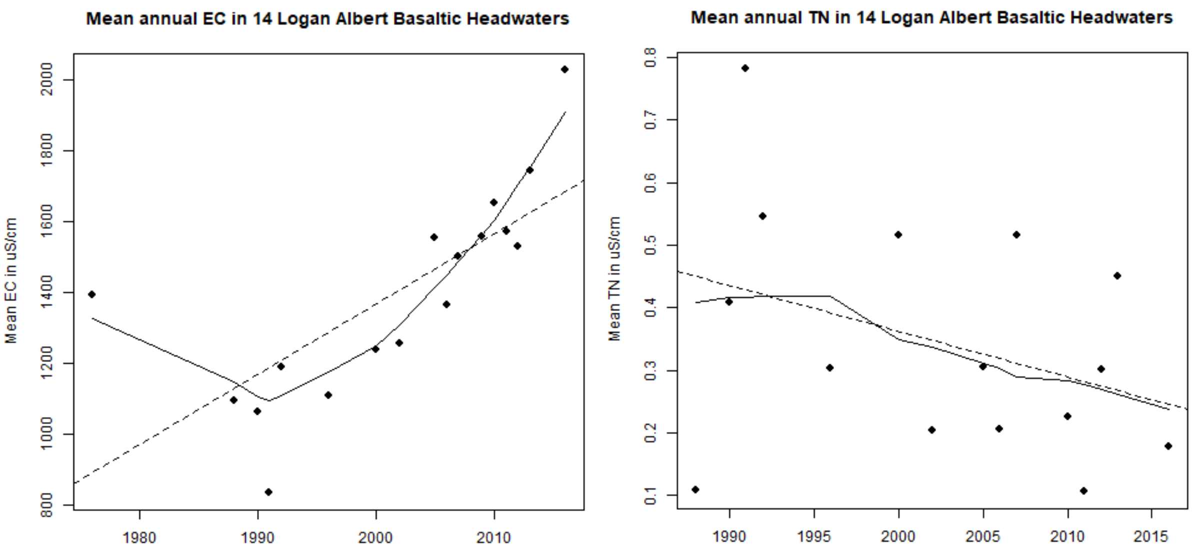


Figure 12: Example of long term water quality trends, EC and TN in Logan and Albert basaltic headwaters.

In presenting the results of a broadscale trend analysis it is acknowledged that, even if the data is adequate, and a trend result appears clear and significant, there are external sources of uncertainty that must be considered which are discussed in Zhang et al. (1999) and Stone & Kalisz (1991). These uncertainties are addressed to the extent practicable in the methodology with outputs to indicate any sampling bias. These include plots to indicate temporal sampling bias, as well as the degree of variability in the annual data used to derive the time series for trend estimation. If available, bores with long term records from the zone are valuable to confirm results. An estimate of data adequacy was also carried out, based on the density of bores compared to the area of the zone, and potential spatial bias was addressed by plotting the locations of bores used for each year of the trend series. A climate control series was also provided, with correlations to indicate whether the observed trend was consistent with climate fluctuation or dominated by local factors. Lastly, results for a zone were automatically disregarded where there was insufficient data to support them. These reliability checks were considered when interpreting the trend result. Residual uncertainty may exist where the result for a zone is dominated by one single locality, rather than being representative of the zone as a whole.

Very few zones have sufficient data to estimate water quality trends over the last ten years, but It is apparent that there is a broad consistency in long term water quality trends and twenty year water level trends in SEQ. However, they do not tend to follow the broadscale climatic controls. This suggests that local weather patterns or other influences have been the determining factors. A summary of results for ten year or long term trends for EC and TN, as well as twenty year or long term trends for shallow (< 30m) groundwater levels is listed in Table 6.

Table 6 Summary trend results

Map	Zone	Water levels (number)	Bores (number)	Area of zone (Km^2)	Water level 20 year trends	Water quality trends
1	1 North Coast Alluvium	524	17	245	Probably rose	No trends detected
	2 Glasshouses	651	40	189	Stable	No trends detected
	3 Northern Moreton Bay Alluvium	700	106	144	Probably fell	No trends detected
	4 Upper Brisbane	15600	313	118	Probably rose	EC stable over the long term, TN probably fell
	5 Upper Lockyer Creek	3008	87	39	Probably rose	EC rose over the long term, TN probably fell
	6 Central Lockyer Creek	23394	356	66	Fluctuating, but probably rose	EC rose over the long term, insufficient data for TN
	7 Lower Lockyer	51195	514	268	Fluctuating, but probably rose	EC rose over the long term, TN probably fell
	8 Southwest Lockyer Tributaries	5122	110	43	Fluctuating, but probably rose	EC rose over the long term, TN variable
	9 Lockyer Southern Basaltic Headwaters	3786	202	56	Probably rose	EC stable over long term, TN probably fell
	10 Warrill and Upper Bremer River	3786	202	56	Fluctuating, but probably rose	EC rose over the long term, no trend detected for TN
	11 Gatton Sandstones Saline Area	16198	260	248	Probably rose	Insufficient data
	12 Lower Bremer	73352	200	88	Insufficient data	Insufficient data
	13 Logan and Albert	18215	168	247	Fluctuating, but probably rose	EC rose over the long term, TN probably fell
	14 Logan Albert Basaltic Headwaters	42876	228	205	Probably rose	EC rose over the long term, TN probably fell
	15 Gold Coast Alluvials	18	14	95	Probably rose	No trends detected for EC, TN probably rose
	16 Southern Deltaic and Estuarine Deposits				Insufficient data	Insufficient data

Map	Zone	Water levels (number)	Bores (number)	Area of zone (Km^2)	Water level 20 year trends	Water quality trends
	17 Moreton Bay Estuarine and Deltaic Area	556	88	166	Fluctuating, but probably fell	No trends detected
	18 Pumicestone	4658	11	70	Insufficient data	The EC and TN record is poor and no trends could be determined.
	19 Northern Estuarine Deposits	1	1	379	Probably fell	No trends detected
	20 Southern Coastal Sands	3166	24	34	Insufficient data	No trends detected
	21 North Stradbroke and Moreton Islands	73328	240	403	Fluctuating, but probably fell	EC and TN fell over the long term. EC unstable over the last 10 years, while TN probably fell
	22 Northern Coastal Sands	78861	155	463	Probably rose	EC and TN fell over the long term. EC unstable and TN probably fell the last 10 years.
	23 Lower Brisbane River	1684	122	795	Fluctuating, but probably fell	EC and TN probably fell over the long term.
2	1 Upper Condamine Basalts (cont)	3913	699	893	Probably rose	EC probably rose and TN probably fell over the long term. No 10 year trends were detectable.
	2 Lower Condamine Basalts (cont) weathered	131	84	282	Probably rose	Insufficient data
	3 Lower Condamine Basalts (cont)	8782	396	578	Probably rose	EC and TN probably fell over the long term.
	4 Toowoomba Region Basalts (cont)	47353	3273	216	Probably fell	No trends could be determined.
	5 Toowoomba Region Basalts (cont) weathered	22	22	55	Insufficient data	EC and TN probably fell over the long term.
	6 Lamington Basalt	57	57	1071	Probably fell	EC and TN probably fell over the long term.
	7 Mount Tamborine	50	50	30	Probably fell	Insufficient data
	8 Sunnybank weathered basalt remnants	10	4	55	Insufficient data	Insufficient data
	9 Northern Basalts (cont)	1	1	47	Insufficient data	Insufficient data
	10 Northeast Mesozoic Volcanics			387	Probably rose	Insufficient data
	11 Eastern Trap Rocks	1316	595	5295	Probably rose	No trends could be determined.
	12 Western Great Dividing Range	120	90	1535	Probably fell	Insufficient data

Map	Zone	Water levels (number)	Bores (number)	Area of zone (Km^2)	Water level 20 year trends	Water quality trends
	13 Esk Trough Paleozoic sediments	315	109	654	Probably rose	EC fell over the long term, no trends detected for TN
	14 North eastern Great Dividing Range	46	46	718	Probably fell	Insufficient data
	15 Cressbrook Creek	2538	34	348	Probably rose	No trends could be determined.
	16 Northern Granite Outcrops			6		Insufficient data
3	1 Petrie Basin	383	89	389	Probably rose	No trends could be determined.
	2 Central Tertiary Sediments	10627	159	296	Probably rose	Insufficient data
	3 Sediments Overlying Coal Measures	42	42	82	Insufficient data	Insufficient data
	4 Amberley Basin	3	3	81	Insufficient data	Insufficient data
	5 Beaudesert Beds	4	4	195	Insufficient data	Insufficient data
	6 Duricrust Main Range	7	7	376	Insufficient data	Insufficient data
	7 Minor Northern Tertiary Deposits			46	Insufficient data	Insufficient data
	8 Northern Tertiary Remnants	1	1	85	Insufficient data	Insufficient data
	9 Sandy Creek Saline Weathered Alluvium	314	31	134	Stable	No trends could be determined.
	10 Minor Weathered Tertiary Deposits	1866	76	2890	Probably fell	No trends could be determined.
7	1 Southeastern Hutton Outcrop (cont)	8455	920	1596	Fluctuating, but probably fell	EC and TN fell over the long term.
	2 Central Huttons	9	9	321	Insufficient data	Insufficient data
	3 Laidly Creek Sandstones	2449	62	864	Probably rose	No trends could be determined.
	4 Southeastern Marburgs	216	50	2086	Probably rose	No trends could be determined.
	5 South East Walloons (cont)	8780	984	2238	Probably rose	EC rose over the long term, TN fell
	6 Logan Albert Walloons	145	29	1015	Probably fell	Insufficient data
	7 Locker Valley Sandstones	4585	94	515	Probably rose	EC rose over the long term, no trends detected for TN
	8 Locker Valley Southern Headwaters	11860	60	309	Fluctuating, but probably rose	EC stable over the long term, TN probably fell

Map	Zone	Water levels (number)	Bores (number)	Area of zone (Km^2)	Water level 20 year trends	Water quality trends
	9 Locker Sandstones Recharged Area	6710	119	133	Probably rose	EC rose over the long term, TN probably fell
8	1 Eastern Evergreen Outcrop (cont)	2823	35	392	Probably fell	No trends could be determined.
	2 Eastern Central Area (cont)	51985	94	793	Fluctuating, but probably fell	No trends could be determined
	3 Southeastern Evergreen (cont)	2271	152	2450	Probably rose	EC fell over the long term, no trends could be determined for TN
	4 Beuaraba Woogaroo	7487	436	738	Probably fell	No trends could be determined for EC, TN probably fell over the long term
	5 Gatton Sandstone Southwestern Headwaters	79	79	49	Insufficient data	No trends could be determined
	6 Gatton Sandstone Saline Area	51680	265	387	Fluctuating, but probably rose	EC rose over the long term, TN unstable
	7 Lower Lockyer Recharged Area	242865	178	516	Probably rose	EC rose over the long term, with instability over the last 10 years. No trends could be determined for TN
	8 Logan Albert Sandstones	264	51	3176	Insufficient data	Insufficient data
	9 Albert River Woogaroo	87	87	234	Insufficient data	No trends could be determined
	10 Clarence Morton Nambour Connection	180	112	938	Insufficient data	No trends could be determined
	11 Nambour Basin	258	258	1276	Probably fell	No trends could be determined
	12 Eudlo Creek Nambour Formation	3	3	178	Probably fell	Insufficient data
	13 Kin Kin Beds			195	Insufficient data	Insufficient data
	14 Noosa River Sandstone	1	1	884	Stable	No trend could be determined for EC, TN probably fell.
	15 Tarong Basin	57	6	224	Probably fell	Insufficient data
	16 Southern Moreton Bay and Barrier Islands	10	10	705	Although the record is poor, unknown NA	Insufficient data
9	1 Logan Coal Measures	274	26	166	Insufficient data	Insufficient data
	2 Brisbane Coal Bearing Beds	38	38	392	Probably rose	Insufficient data
	3 Ipswich Coal Deposits	492	21	120	Probably rose	Insufficient data

Map	Zone	Water levels (number)	Bores (number)	Area of zone (Km^2)	Water level 20 year trends	Water quality trends
	4 Kholo Sediments and Volcanics	7	7	112	Insufficient data	Insufficient data

4 Results

4.1 Groundwater chemistry zones for South East Queensland

Regional groundwater chemistry zones were established across six aquifer classes as listed in table 7 and mapped on figures 13 to 18. The ranges for major ions, pH, and electrical conductivity were calculated where sufficient data were available (Table 8).

Attribution of bores (for which there was lab-analysed water quality data) to aquifer classes is shown in Figure 21. From the review of landuse and water use sources, the accompanying plans also show the proposed EVs for each chemistry zone. Larger scale map plans showing EVs by chemistry zone are provided on the department's web page accompanying this report. Further discussion of the geographical chemistry variations across the region is provided by the main surface water basins and catchments in Section 5.

Table 7: Aquifer class descriptions for South East Queensland

Aquifer class	Description	Figure reference
Alluvium	Recent alluvium divided into 23 chemistry zones based on water quality and factors such as extent of alluvium, and sub-catchment characteristics. It includes chemistry zones of low salinity such as the North Coast Alluvium, Noosa, North Stradbroke and Moreton Islands, and Northern Coastal Sands, particularly in wallum country. There are also zones of moderate to high salinity, as well as brackish zones. Dominant ions include Na, Mg, HCO_3, Cl, and NO_3. (Most of the Cooloola sandmass is in the Northern Coastal Sand zone. The western portion is in the North Coast Alluvium zone.)	Figure 13
Fractured rock	Aquifers in hard rock with water stored in fractures or permeable sandstones other than those considered part of the GAB. Divided into 16 chemistry zones on the basis of rock type, location and water quality. Dominant ions include Ca, Mg, Na, Cl, HCO_3. Salinity is typically moderate to very high, with only two zones of low (Toowoomba Region Basalts (cont) weathered) or very low (Lamington Basalt) salinity.	Figure 14
Sediments overlying the GAB	Sediments overlying the GAB are divided into 10 chemistry zones, however, only 2 of the zones had sufficient data for calculating percentiles. The Petrie Basin is typical of fine grained sediment influenced by development, whereas both Sandy Creek Saline Weathered Alluvium and Minor Weathered Tertiary Deposits are typical of the Great Dividing Range overlain by basalt. Dominant ions include Ca, Mg, Na, Cl, and HCO_3, and salinity is moderate.	Figure 15
Lower GAB	The groundwater in the lower GAB has been divided into nine chemistry zones: Central Huttons, Laidley Creek Sandstones, Lockyer Valley Sandstones, Lockyer Valley Sandstones Headwaters, Lockyer Sandstones Recharged Area, Logan Albert Walloons, South East Walloons (cont), South Eastern Hutton Outcrop (cont), and South Eastern Marburgs. Dominant ions include Na, Ca, Cl, Mg, and HCO_3. Salinity ranges from moderate to very high, mostly typical of fine grained sediments, although the chemistry of the Laidley Creek Sandstones and the Lockyer Valley Southern Headwaters is typical of basalt.	Figure 16
Basal GAB	Sixteen chemistry zones have been defined, however 7 of the zones did not have sufficient data for calculating percentiles. Dominant ions include Na, Ca, Cl, Mg, and HCO_3. Salinity is highly variable and ranges from low to very high. The zone of very low salinity, the Nambour Basin, is typical of wallum country.	Figure 17
Earlier basins	This aquifer class has been divided up into the following four groundwater chemistry zones: Brisbane Coal Bearing Beds, Ipswich Coal Deposits, Kholo	Figure 18

partially underlying the GAB	Sediments and Volcanics, and Logan Coal Measures. However only the Logan Coal Measure zone has sufficient data for calculating percentiles. This zone has high salinity, but it can be variable. Dominant ions are Na and Cl, which is typical of fine grained sediment.	

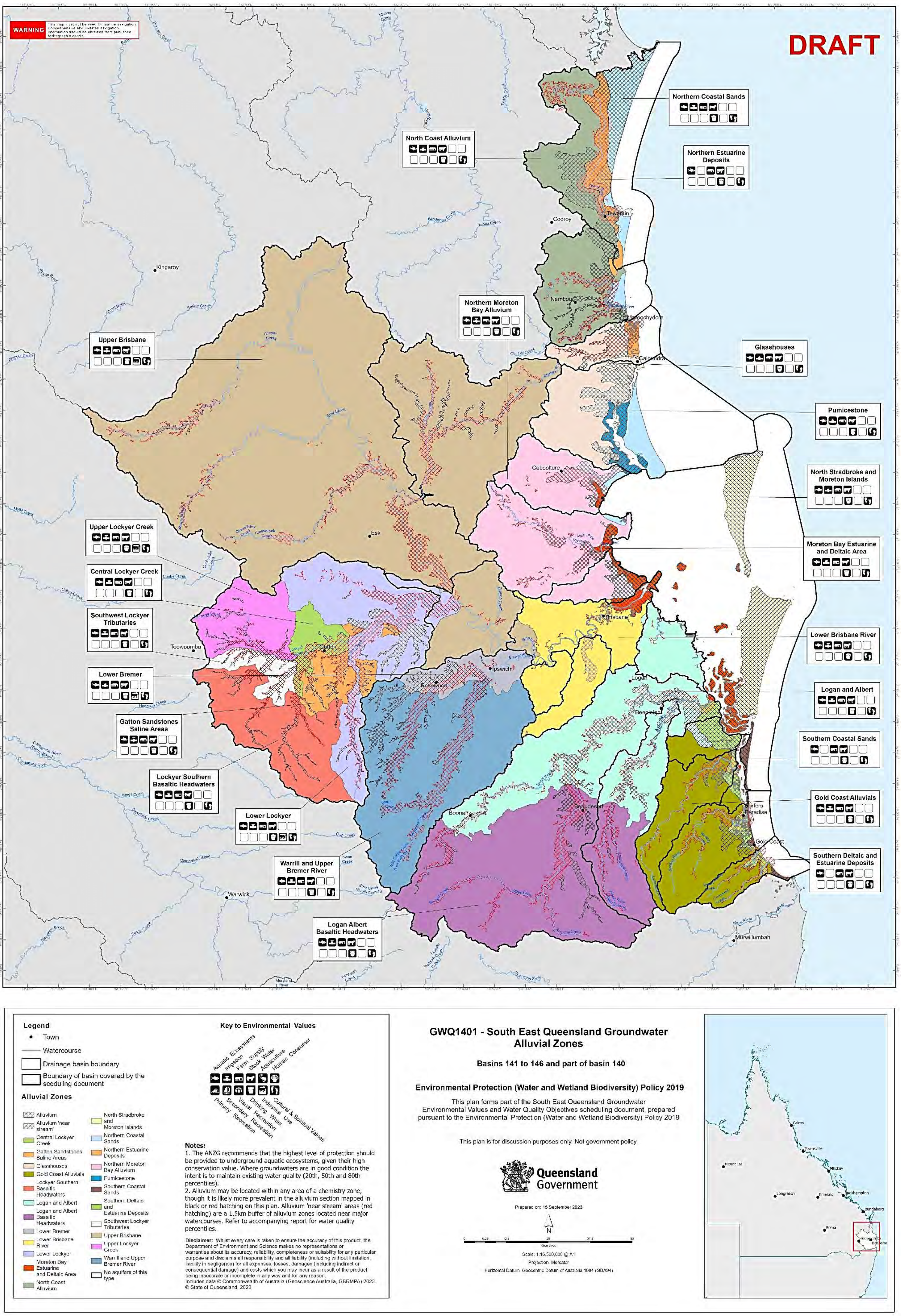


Figure 13: Alluvium zones – South East Queensland (Plan GWQ1401)

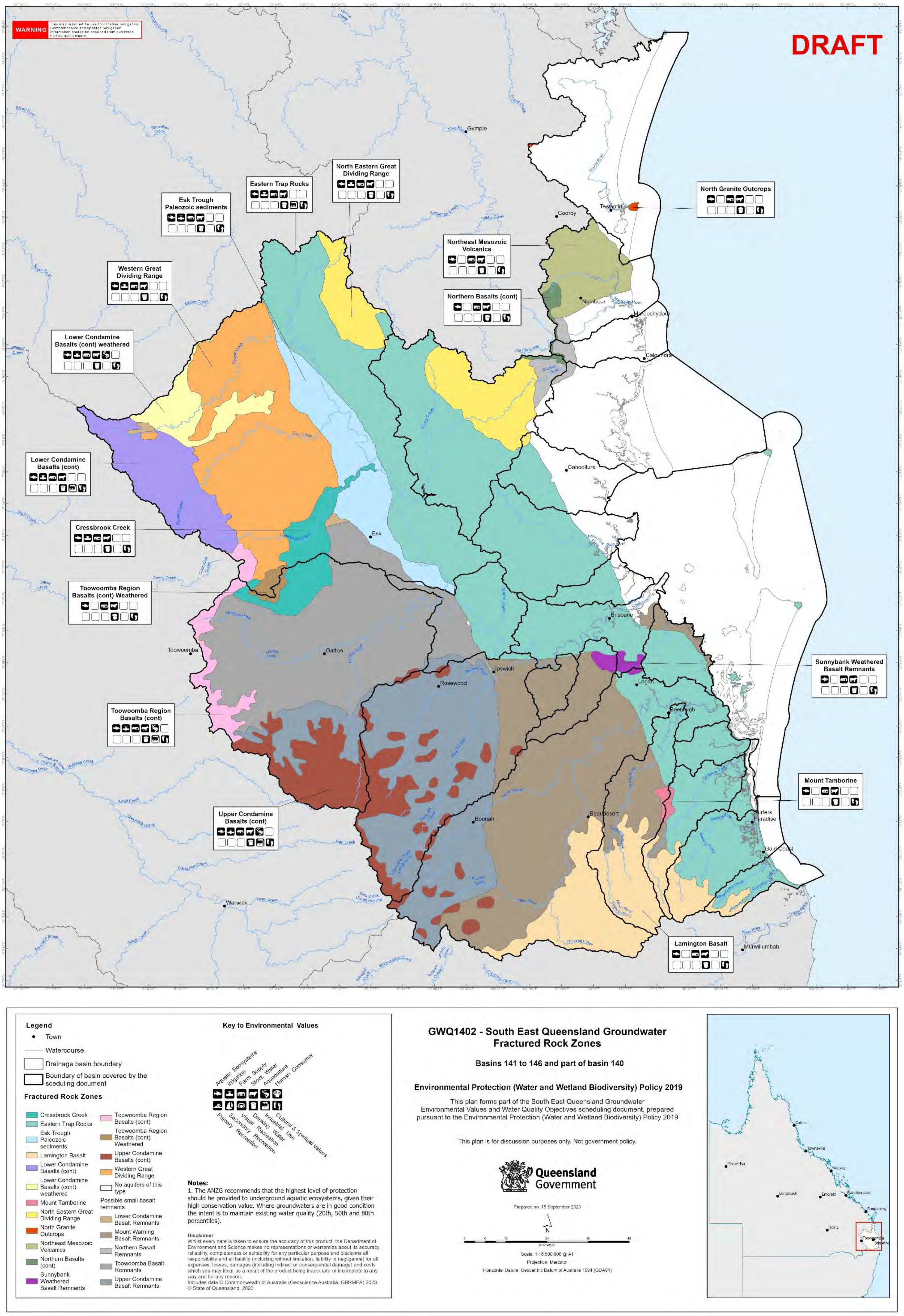


Figure 14: Fractured rock zones – South East Queensland (Plan GWQ1402)

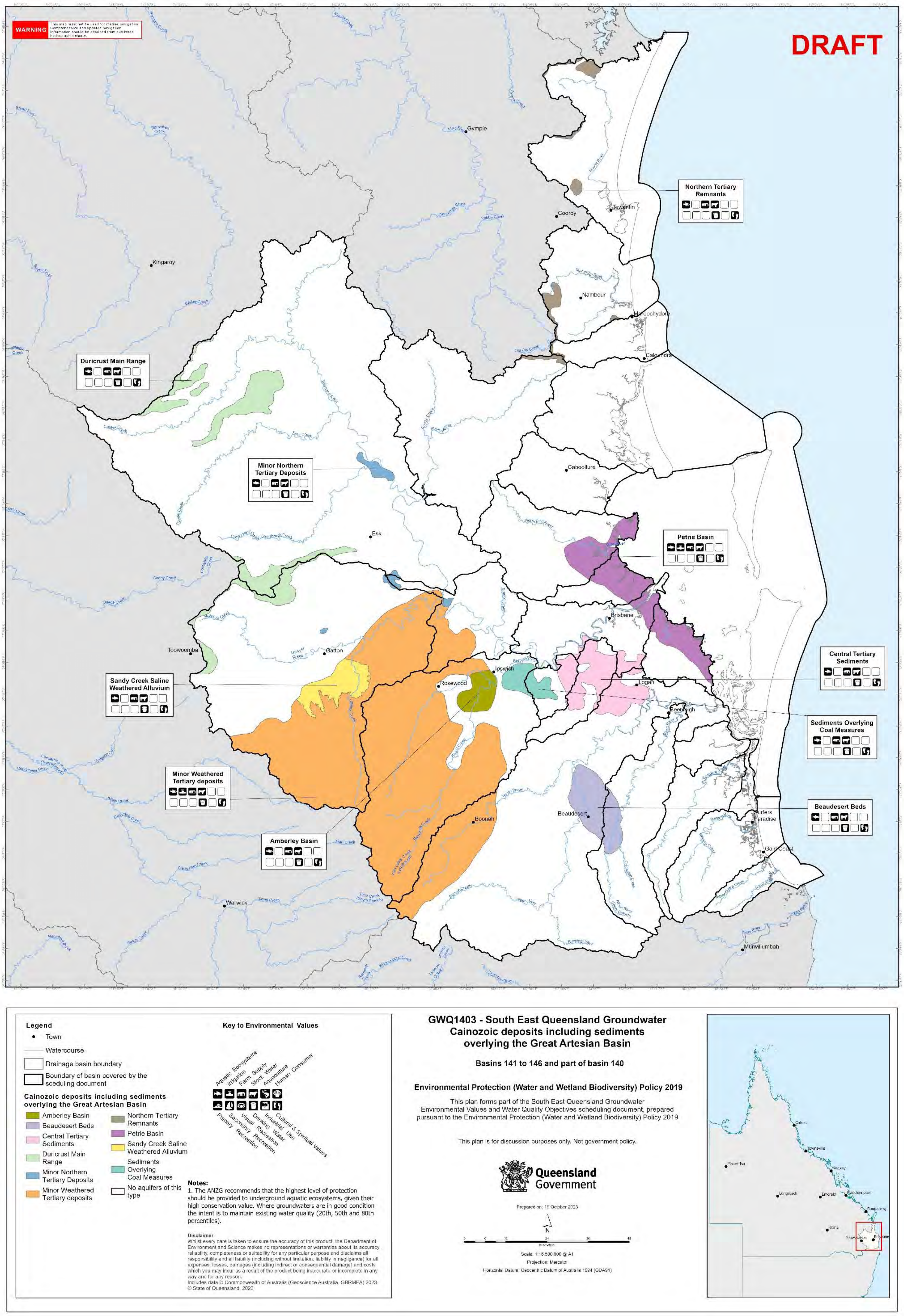


Figure 15: Cainozoic deposits including sediments overlying the Great Artesian Basin zones – South East Queensland (Plan GWQ1403)

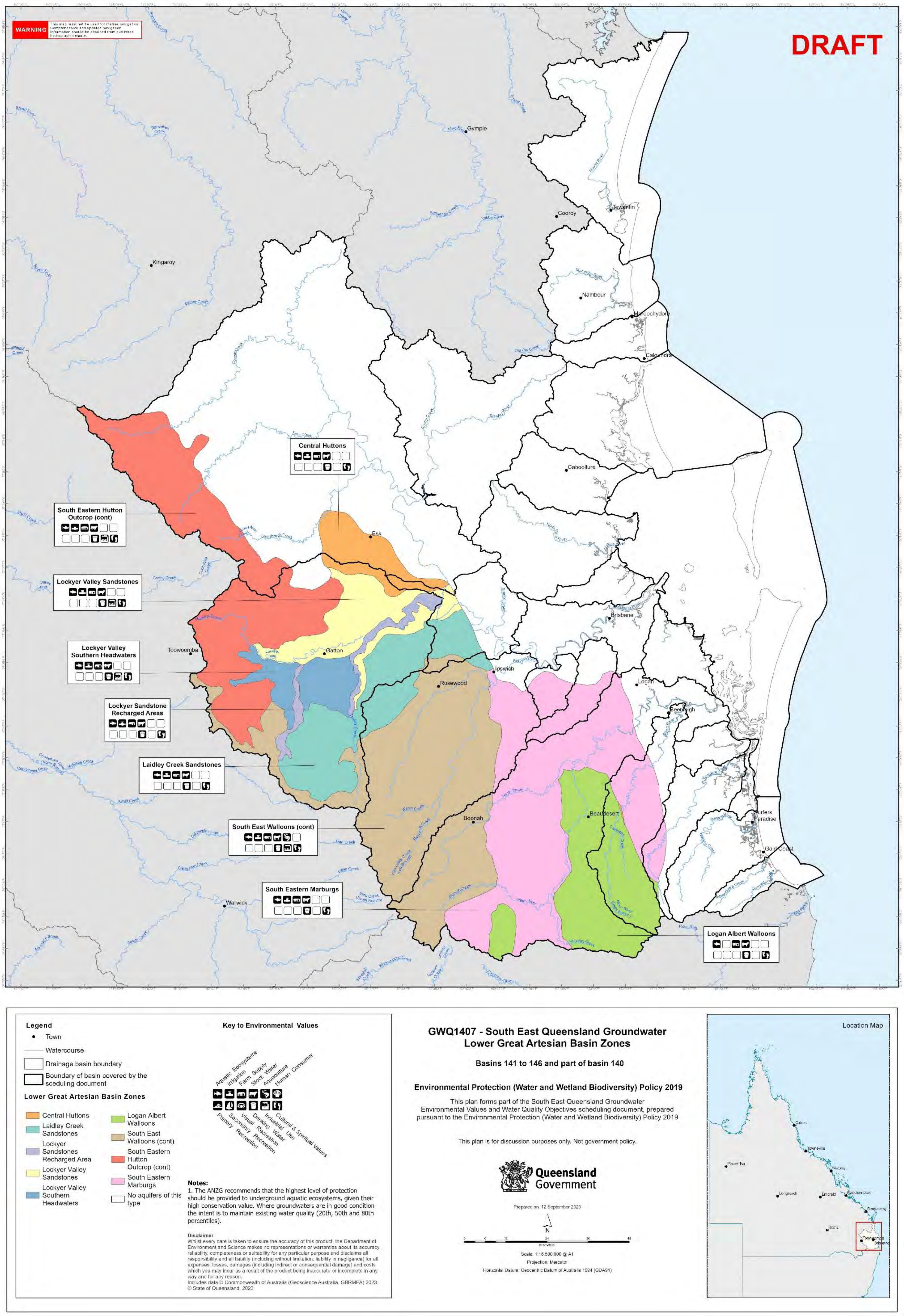


Figure 16: Lower Great Artesian Basin zones – South East Queensland (Plan GWQ1407)

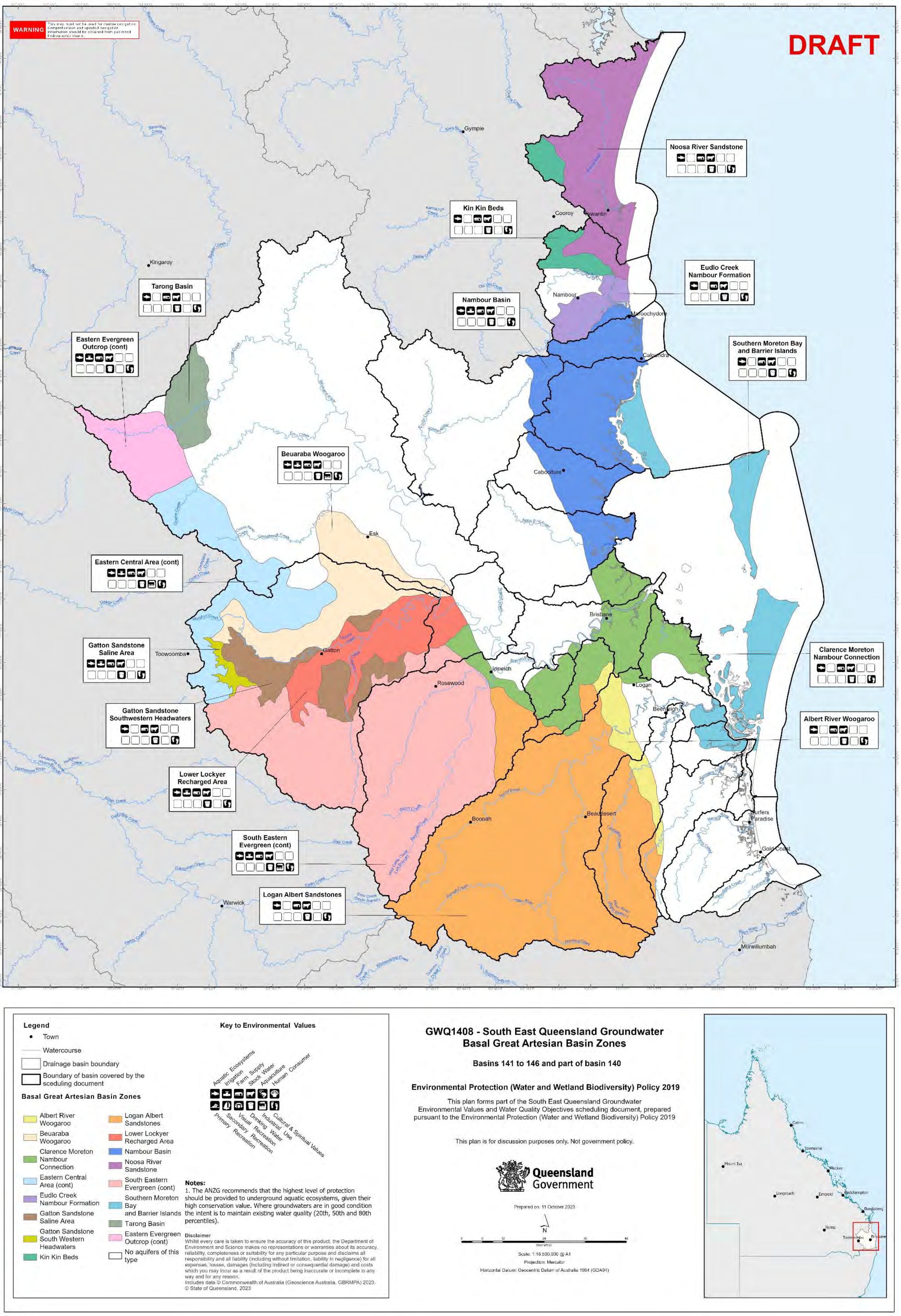


Figure 17: Basal Great Artesian Basin zones – South East Queensland (Plan GWQ1408)

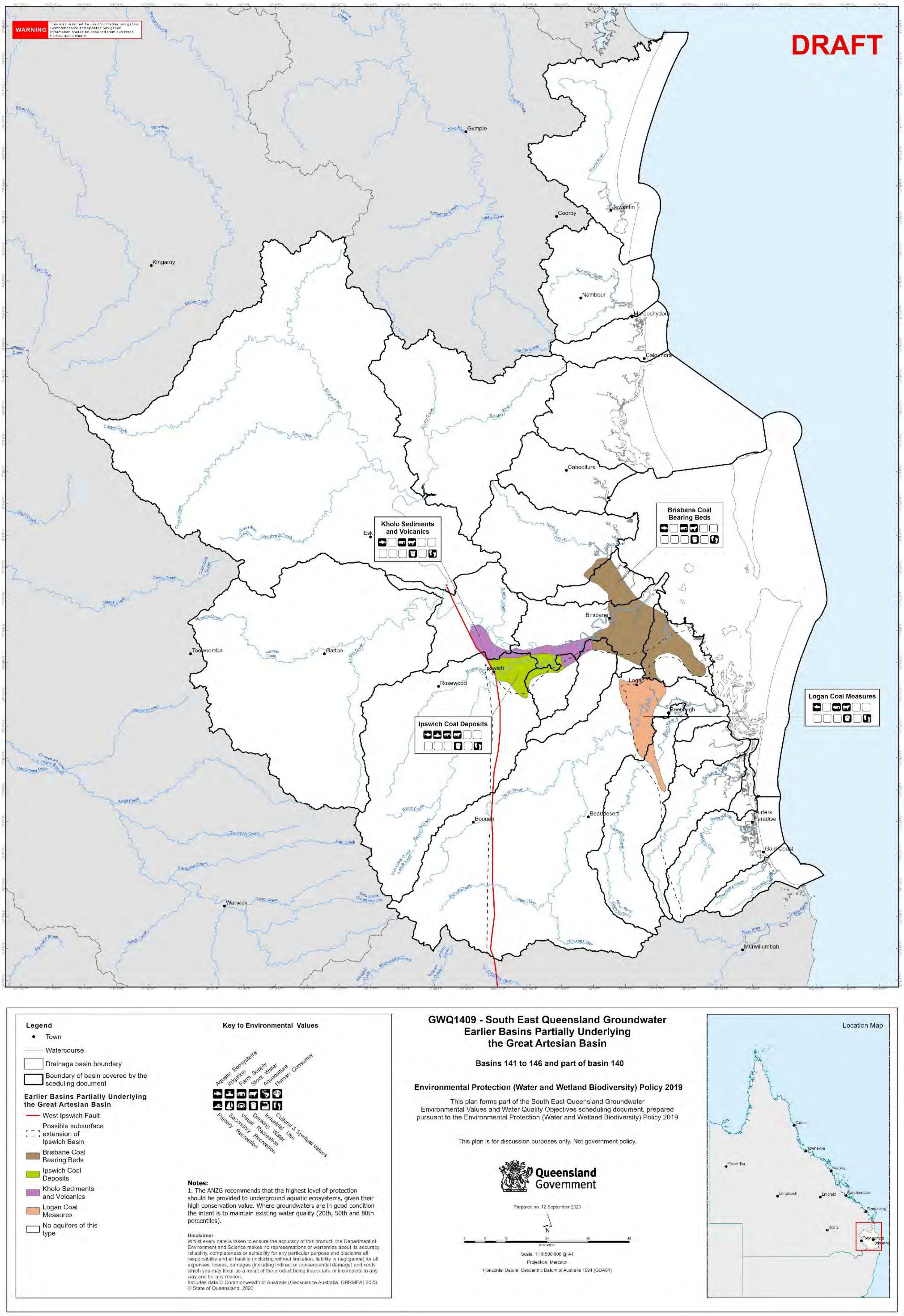


Figure 18: Earlier basins partially underlying the Great Artesian Basin zones – South East Queensland (Plan GWQ1409)

5 Discussion of regional groundwater chemistry variation across South East Queensland

5.1 Groundwater chemistry zones for South East Queensland

This document presents a broad summary of the groundwater chemistry in Southeast Queensland, based on a statistical assessment of data in the GWDB as well as other sources of information including the scientific literature. Through this process, the aquifers and groundwater chemistry in the region have been divided into reasonably homogeneous zones, and the 20th and 80th percentiles of a number of water quality parameters have been tabled. Data reliability for characterisation/comparisons was calculated on the basis of number of samples per km2, with ‘excellent’ being more than 1 per km2, to ‘poor’ with less than 0.05 per km2. Less than 20 samples are regarded as unreliable for characterisation/comparison.

Table 8 in Appendix 1 summarises these results. It is advised that to ascertain suitability of a specific water source (e.g. a bore) for a given use (e.g. irrigation) more detailed testing may be required, and the broad results in Table 8 are not intended to provide this level of detail.

The SEQ region is relatively small, but very complex from a groundwater perspective, with a variety of distinct aquifer systems, each with characteristic groundwater chemistry patterns and management issues. The most important of these from an economic and environmental point of view are:

- Alluvial floodplains of the Lockyer Valley, and to a lesser extent those of the Bremer and Logan-Albert Rivers,
- Sandstone aquifers of the Lower and Basal GAB with the contemporaneous Landsborough Sandstone
- Permeable basalts capping upland areas,
- Sand dunes of the barrier islands as well as onshore sand deposits.

There are also scattered local aquifer systems such as small stretches of alluvium, Tertiary or other sediments, and fractured rock, which may provide domestic and stock supplies for individual properties.

The salinity and chemical composition of the groundwater varies across the region, but is generally characteristic of the geology and aquifer type. The widespread water quality type is typical of alluvium recharged by drainage from GDR catchments where the bedrock may be partially overlain by basalts. It is moderately saline and hard, with evenly distributed cations, although magnesium tends to dominate in the immediate vicinity of the basalts. This water type is suitable for most purposes as long as the EC is not elevated, which may occur if concentrated by evapotranspiration. This causes the proportions of the highly soluble sodium and chloride to increase, moving the composition in the direction of seawater, as in some parts of the Lockyer Valley. For instance, they tend to be low to moderate in the alluvium of small catchments, and very low in coastal sand aquifers. However, they tend to be considerably higher in the alluvium of larger streams draining the drier western areas of the GDR due to a variety of factors as described in, for instance, Raiber et al. (2019), Tien et al. (2004) McMahon and Cox (1996) and Wilson (2005).

It is noted in this study that the chemistry of the GAB sandstones in the SEQ, which are all within the Clarence-Moreton Subbasin, is more saline and higher in chloride than the sodium bicarbonate groundwaters which are regarded in studies such as Herczeg et al. (1991) as typical of the GAB. This was corroborated in a previous study, (McNeil et al. 2015), which observed that GAB samples from east of the Kumbarilla Ridge, which separates the Clarence-Moreton from the Surat Subbasin to the west, tended to be more saline and chloride dominated than the rest of the GAB within the Queensland section of the Murray-Darling Basin. The present study suggests that the more saline, sodium chloride rich water type continues across the Ridge and is, in fact, characteristic of the GAB in the SEQ section of the Clarence-Moreton Subbasin. By contrast, the Landsborough Sandstones in the coastal Nambour Basin appear to be fresh with a tendency to be corrosive, and a sodium, calcium chloride composition, and relatively high levels of nitrate.

The most unique groundwaters in the SEQ are found in the sand dunes of the Wallum country on the coast and barrier islands. It is similar to the surface water of this region in being very fresh and acidic, dominated by sodium chloride, and with pH levels of less than 6. These sand aquifers are dependent on the coastal processes that formed them, and are particularly vulnerable to climate change. However, there are a number of other potential water quality types which cannot be assessed at present because of limited data. For instance, the estuarine and deltaic areas along the coast have been mapped as containing quite extensive areas of acid sulphate soils. This broadscale study did not detect widespread salt water intrusion in any coastal aquifer, and the alluvial zones shown on Fig 6 do not show many areas where heavy groundwater usage is known to occur near the coast. However, studies such as Surawski, et al. (2020) and Anorov, et al. (2008) have highlighted a potential risk, particularly in the face of increasing development, or if sea levels rise due to climate change.

Most of the groundwater in the SEQ was found to exceed local surface water environmental guidelines for salinity, and frequently also for TN, and the pH range may also not be within local environmental guidelines. EC may be sufficiently high to affect the taste of groundwater used for potable supplies, and EC and percentage of sodium (SAR >8) are frequently elevated for sensitive crops. However, the water is almost always acceptable for stock, despite rare concerns about salinity, nitrate and fluoride.

5.2 Regional groundwater variation

5.2.1 Northern coastal catchments

The northeast of the SEQ region is characterised by a series of small to medium sized catchments, with short streams that drain the coastal ranges, flowing eastwards to the Pacific Ocean or Northern Moreton Bay. Thee alluvial groundwaters are normally fresh, with a tendency for salinity to increase towards the south. The natural waters near the coast are typical of Wallum country, being characteristically fresh, acidic, and dominated by Sodium chloride. This chemistry is. The major non-alluvial aquifer system is the Nambour Basin, a geological unit composed of the Basal GAB Woogaroo and Landsborough Sandstones. It extends from north to south, crossing several of the catchments, as does the Tertiary Petrie Basin.

The northernmost catchment in the SEQ is the Noosa River (Basin 1400), which is moderate sized and elongated from east to west. It lies onshore from Fraser Island and has several dune fields on the southeast coastline including the Cooloola Sandmass. The southward flowing Noosa River occupies the southern half of the catchment, while small streams drain the north, often passing through minor stretches of alluvium and estuarine deposits near the coast. There are wetlands opposite Fraser Island. The terrain west of the coastal plain is hilly, with landuse being mainly scattered residential developments at the southern end of the catchment, and forestry with nature conservation elsewhere. The climate is moist, with a rainfall of 1000-1500 mm pa in the north and 1500-1800 mm in the wetter south. The surface water tends to be fresh, but acidic near the coast and typical of wallum country. It does not chemically resemble nearby groundwater, implying poor hydrological connectivity.

Groundwater use is low, with most bores accessing either alluvium underlain by the Landsborough Sandstone, or the various sedimentary formations. The alluvium averages 30 m in depth and belongs to alluvial Zone 1 ‘North Coast Alluvium’. Its chemistry is Sodium bicarbonate, with low but variable EC typical of a sandstone or granitic catchment. It is normally suitable for drinking, but only moderately suitable for general purposes because of corrosive tendencies due to low EC and hardness. It is suitable for stock and irrigation apart from sensitive crops because of the occasional high EC or sodium levels and is moderately compliant with surface water environmental guidelines. Water levels probably rose on average over the last 20 years, although records are poor, but water tables may be very shallow (under 5m) in places.

The sand masses belong to alluvial Zone 22 ‘Northern Coastal Sands’, with the low salinity, sodium chloride groundwaters typical of wallum country. As with other such waters, it is normally suitable for drinking but poor for general purposes because of corrosive tendencies due to low pH and hardness. It is suitable for stock and irrigation apart from crops that are sensitive to low pH, but incompatible with environmental guidelines because of elevated EC and usually TN, while pH is occasionally too low. The aquifers may be susceptible to contamination because of contact with seawater and shallow water levels in places.

The sediments belong to Pre-GAB Zone 14 ‘Noosa River Sandstone’, but little is known of their water quality. The Cooloola Sandmass is part of alluvial Zone 22 ‘Northern Coastal Sands’ which is also a low salinity sodium chloride water type, typical of wallum country. It is normally suitable for drinking, but poor for general purposes because of corrosive tendencies due to low pH and hardness. It is suitable for stock and irrigation except for crops that are sensitive to low pH levels, but incompatible with environmental guidelines because EC and usually TN are elevated and pH is occasionally too low. This aquifer may be susceptible to contamination because of contact with seawater, and because water levels are shallow in places.

The **Maroochy River c**atchment (Basin 1410) is also moderate in size, undulating in the south and hilly to rugged in the north, with a flat alluvial coastal plain. A number of streams drain the catchment, the main ones being the Maroochy River, Eudlo Creek, Mooloolah River, Bells Creek, Coochin Creek and Elimbah Creek. Alluvial bores have an average depth of 24 m. The annual rainfall is relatively high at 1600-1800 mm in the wetter north, and 1400 mm in the Southern third of the catchment. There is dense residential development in the north, becoming more scattered in the southern third of the catchment, where it is interspersed with forestry and nature conservation. At the southern end of the coastline is Pumicestone Passage, which separates Bribie Island from the mainland. It is a shallow barrier estuary, being about 1-5 km wide and mostly less than 2 m deep with a maximum depth of 7 m. It is flanked by intertidal mudflats and seagrass beds, and is fringed by mangrove along most of its length with a number of small streams draining into it from the mainland. (Malcolm E. Cox et al., 2000) (Lanyon et al., 2005) (Larsen, 2007).

Groundwater in the catchment is obtained mostly from the alluvium, the sand dunes, and the estuarine deposits around Pumicestone Passage. The surface water chemistry is very mixed, but mainly of a GDR or basaltic catchment, and is compatible with nearby groundwater in the south, implying a hydrological connection. The alluvium on Eudlo Creek belongs to alluvial Zone 1 ‘North Coast Alluvium’, the same zone as the Noosa alluvium. Zone 2 ‘Glasshouses’ In the more southern parts of the catchment is very fresh, and dominated by sodium chloride with nitrate which could be related to wallum country influenced by development. It is suitable for drinking but poor for general purposes because it is moderately corrosive due to low EC, hardness, and pH. It is suitable for stock and irrigation apart from crops sensitive to low pH levels but is incompatible with environmental guidelines because of elevated levels TN and low pH. No water quality trends could be determined, but water levels appear to have been stable over the past 20 years. The alluvium contains very shallow water levels (under 5m) in places. The sand dunes are included in Alluvial Zone 22 ‘Northern Coastal Sands’ described for the Noosa Catchment.

The chemistry of the estuarine Zone 18 ‘Pumicestone’, which covers both west and east shorelines of the Passage, is sodium chloride which is typical of coastal deposits. The salinity is usually moderate, but high ECs may occur. It is normally suitable for drinking but moderate for general purposes, with variable EC and is occasionally corrosive or incrusting. It is of poor quality for irrigation because of variable EC levels, which are occasionally unsuitable even for tolerant crops. In some cases, it is also unsuitable for crops that are sensitive to high sodium, low pH or fluoride. It is moderately suitable for stock, although EC is occasionally elevated, and it is incompatible with environmental guidelines because of elevated EC and TN and low pH. No trends could be determined because of lack of data, but the aquifer may be susceptible to contamination because of contact with seawater and very shallow water levels (under 5 m) in places and an average bore depth of only 8 m.

The third north coast catchment is **Caboolture River** (Basin 1420). It is relatively small and largely residential, particularly in the central area. The terrain inland of the alluvium and coastal plain is undulating, with ranges in the southwest. There are some wetlands and deltaic deposits near the coast, and dunes included in Alluvial Zone 22 ‘Northern Coastal Sands’ just to the north of Pumicestone Passage. The annual rainfall is moderately high at 1000-1500 mm, increasing in the catchment headwaters. The EC of the surface water is low to moderate with even cations, and is dominated by either chloride or bicarbonate depending on salinity. It resembles nearby groundwater at least at the upstream end of the alluvium, implying a likely connection.

There is minor groundwater use, with bores accessing the minor alluvial deposits, sand dunes, or the underlying Landsborough sandstones. Most of the bores are in alluvial Zone 3 ‘Northern Moreton Bay Alluvium’ Caboolture River. The water chemistry here is moderate saline sodium chloride, but EC can be variable. This is typical of coastal alluvium, and normally suitable for drinking although moderate for general purposes because of occasional corrosive tendencies due to low hardness. It is suitable for stock, and moderately suitable for irrigation, but poor for sensitive crops due to EC and sodium levels. It is poorly compatible with environmental guidelines because EC and at times TN tend to be elevated, while pH is occasionally too low. No water quality trends were determined, but water levels probably fell on average over the last 20 years. The alluvium contains very shallow and fluctuating water levels (under 5m) in places. The sand dunes are included in Alluvial Zone 22 ‘Northern Coastal Sands’ described for the Noosa Catchment.

The other important aquifer is the Landsborough Sandstone of the Basal GAB Zone 11 ‘Nambour Basin’. The water is normally suitable for drinking, but, like other waters in the catchment, poor for general purposes because of corrosive tendencies due to low EC, pH and hardness. It is suitable for stock and irrigation apart from crops that are sensitive to low pH, and it is incompatible with environmental guidelines because EC and TN are elevated, and pH is usually too low.

North Pine River catchment (Basin 1421) is also relatively small, although geologically complex. The North Pine River drains into Moreton Bay, with the very minor stretches of alluvial and Tertiary deposits overlying Landsborough Sandstone downstream of the confluence with the South Pine. The Tertiary Petrie Basin extends along the lower reaches of the North and South Pine, merging into estuarine deposits with wetlands which line the coast, and sand dunes on the north coast of the Redcliff Peninsula. The rest of the catchment consists mostly of trap rock. The terrain away from the streams is undulating to hilly in the mainly residential eastern third of the catchment, but the settlements become scattered towards the more rugged western area, and interspersed with rural activities and nature conservation, particularly around North Pine Dam. The annual rainfall of 1000-1500 mm is moderately high for the region and increases in the headwaters. The surface water is low to moderate in salinity, with evenly distributed cations, and dominated by chloride or bicarbonate depending on EC. It tends to resemble groundwater, at least at the upstream end of the alluvium, so that a hydrological connection there is highly likely.

There is minor use of groundwater, with about 30% of bores in the alluvium represented by alluvial Zone 3 ‘Northern Moreton Bay Alluvium’, described for the Caboolture Catchment. A further 20% of bores are in the Landsborough Sandstone with groundwater quality as described for Basal GAB Zone 11 ‘Nambour Basin’ also in the Caboolture Catchment. Minor use is made of the Tertiary Petrie Formation, Cainozoic Zone 1 ‘Petrie Basin’. This groundwater is normally suitable for drinking, and moderate for general purposes. It is suitable for stock and irrigation, apart from salt sensitive crops, but may be incompatible with environmental guidelines due to elevated TN. The remainder of the bores access coastal deposits, dunes, fractured rocks,

The **South Pine** River (Basin 1422) is a mainly residential subcatchment of the North Pine. The geology is mixed, with large areas of sediments and hard rock, particularly of a granitic nature. The terrain is undulating to hilly away from coastal plain, becoming steep in the west and central area. Landuse is mainly urban, and the annual rainfall is a moderately high 1000-1500 mm. The downstream alluvium of the South Pine merges with that of the North Pine at the northeastern subcatchment boundary. Alluvium overlies Basal GAB Landsborough Sandstone in the south, around coastal streams and near the confluence with the North Pine River. There are estuarine deposits near the coast, as well as some wetlands. A narrow band of Ipswich Coal Measures lies across the central part of the subcatchment, with the Tertiary Petrie Formation covering the downstream area.

Groundwater usage is minor, with about 40% of bores accessing the alluvium or the extensive estuarine and deltaic deposits. The alluvial bores are within Zone 3 ‘Northern Moreton Bay Alluvium’, described for the Caboolture Catchment. It contains very shallow and fluctuating water levels (under 5m) in places, although the average bore depth is 14m. Minor amounts of water are also extracted from the Petrie Formation (Cainozoic Zone 1 ‘Petrie Basin’), with the rest of the bores mostly in fractured rock. The surface water is low to moderate in salinity, with evenly distributed cations and dominated by chloride or bicarbonate depending on the EC. It tends to resemble nearby groundwater, although less saline, so a hydrological connection is possible.

5.2.2 Upper Brisbane River

The Upper headwaters of the Brisbane River consists of two subcatchments, the Upper Brisbane and the Stanley. There are no major groundwater resources in this area, which is mainly rugged uplands with relatively low density landuse. The groundwater is moderately saline, and chloride dominated, with evenly distributed cations which are typical of GDR catchments. It is normally suitable for most purposes, but with some incrustation tendency due to hardness. Wivenhoe and Somerset Dams, are situated in this region, which provide the main water supply for Brisbane as well as supplementing other communities in the SEQ.

The **Upper Brisbane River** (northwestern portion of Basin1430) comprises the northwestern headwaters of the Brisbane River, including Cooyar, Emu and Cressbrook Creeks in the west. It is the largest portion of the SEQ region, with 20% of the total area, but with limited groundwater resources and only about 350 bores. The terrain is hilly to rugged, apart from narrow strips of alluvium on Cooyar and Cressbrook Creeks. Landuse is mainly rural, with scattered residential areas interspersed with forestry and grazing, but some groundwater is used for irrigation on the Cressbrook Creek alluvium. There is national park on the ranges. The annual rainfall is relatively low, being only 700-900 mm over most of the area, rising to 1100 mm in the South.

The alluvium falls within Zone 4 ‘Upper Brisbane Alluvium’, which is moderately saline and Chloride dominated, with the evenly distributed cations typical of a GDR catchment. It is normally suitable for drinking, and moderate for general purposes, but with some incrustation tendency due to hardness. It is suitable for stock and irrigation apart from sensitive crops, where EC is occasionally elevated, however it is not compatible with environmental guidelines because of elevated EC and TN. The EC appears to have been stable over the long term, while TN has probably fallen, and water levels probably rose on average over the last 20 years.

A Basal GAB outcrop is located over the southwest corner of the subcatchment which underllies the alluvium and continues into the Lockyer Subcatchment. It comprises four Basal GAB zones; Zone 15 ‘Tarong Basin’ underlying the middle reaches of alluvium on Cooyar Creek, Zone 1 ‘Eastern Evergreen (cont)’ in the Cooyar Creek headwaters, Zone 2 ‘Eastern Central Area (cont)’ in the headwaters of Emu and Cressbrook Creeks, Zone 4 ‘Beauaraba Woogaroo’, downstream just west of the confluence with Lockyer Creek. Zone 4 ‘Beauaraba Woogaroo’ is the most significant of these in terms of groundwater yield. The main aquifer is the Woogaroo, with some Gatton and Precipice Sandstones. The chemistry is moderately saline sodium chloride, typical of fine grained sediments. It is normally suitable for drinking, but moderate for general purposes because of occasional corrosive tendencies due to low pH and hardness. It is suitable for stock and irrigation apart from sensitive crops because of occasionally elevated EC, but incompatible with environmental guidelines because EC and TN are elevated. Basalt remnants are scattered over the southwest, becoming heavily weathered towards the northern central area. The rest of the catchment is underlain by Triassic sediments, trap rocks and a few outcrops of Lower GAB formations. The surface water chemistry is typical of GDR or basaltic catchments and resembles groundwater near streams, implying possible hydrological connection.

Stanley River (Basin 1433) adjoins the Upper Brisbane subcatchment in the northeast of the Brisbane River headwaters. The landscape is also hilly, with ranges on the borders and narrow stretches of alluvium in the central area upstream of the confluence between the Stanley River and Kilcoy Creek above Somerset Dam. Most of the subcatchment is rural, centred on grazing with some forestry, although there are scattered residential developments in the east and national park around Somerset Dam. Narrow stretches of alluvium overlie the mostly granitic trap rock in the northeast and central part of the subcatchment, with some of the Basal GAB Nambour Basin in the east. The rainfall is 800-1800 mm pa, becoming drier towards the west.

Groundwater use is low, with about 36% of bores in alluvium and the rest in sediments or in fractured rocks which include scattered basalt remnants from the Main Range Volcanics. The alluvium is in 4 'Upper Brisbane Alluvium,' as in the Upper Brisbane subcatchment. Despite the relatively low rainfall, the surface water is characterised by very low salinity and is quite varied. The cations are usually roughly even, with the anions dominated by either chloride or chloride with bicarbonate, depending on EC which is compatible with GDR or basaltic chemistry.

5.2.3 Western Brisbane River subcatchments

The Lockyer and Bremer subcatchments on the western side of the Brisbane River are the most highly developed in terms of groundwater use, particularly for irrigation.

The northernmost of these, **Lockyer Creek Subcatchmen**t (Basin 1432) comprises a relatively large portion of the SEQ, with about 13% of the total area, but it has the most intensive groundwater use with 57% of the bores. The extensive alluvial deposits around Lockyer Creek and its tributaries, particularly those in the south, support a major groundwater irrigation area. The rest of the subcatchment is used for grazing, National Park, or scattered residential areas especially east of Laidley. Lockyer Creek flows eastwards over a broad central valley, surrounded by ranges and elongated to the south with several major tributaries. It joins the Brisbane River downstream of Wivenhoe Dam. Both lower and Basal GAB formations extend over virtually the entire Lockyer Valley, underlying the alluvium and the basalt flows that extend over the western and southern headwaters, including many of the watersheds between the southern tributaries. The annual rainfall is relatively low for the SEQ, being mainly around 800 mm but above 1000 mm on the ranges at the northern subcatchment boundary and southern headwaters.

The subcatchment has multiple aquifer systems in the GAB, as well as the alluvium and fractured basalts, some of which overlie or interact with each other. Subsequently, a large body of literature has been published concerning the hydrogeology and groundwater chemistry of this region because of its complexity and economic importance. The alluvium contains over 40% of the bores, however, 50% source the GAB formations for smaller yields, particularly from the Lower GAB Injune Creek and Basal GAB Evergreen aquitards. Some groundwater is also obtained from the Basal GAB Helidon, Gatton and Precipice Sandstones. Minor amounts of groundwater are also obtained from the basalts of the Main Range Volcanics.

There are six alluvial zones in the Lockyer Valley, all of which are at least moderately saline and incompatible with environmental guidelines because EC and TN are elevated. The freshest groundwaters are in the southern headwaters and the lower reaches of Lockyer Creek downstream of Laidley Creek. to the confluence with the Brisbane River. These zones have the benefit of recharge from the wetter southern ranges. Zone 9 'Lockyer Southern Basaltic Headwaters' has a moderately saline chloride chemistry with no dominant cations, which is typical of the GDR with overlying basalt. It is normally suitable for drinking, but poor for general purposes because of hardness with some incrustation. It is suitable for irrigation and stock, except for sensitive crops because EC is frequently elevated. Zone 7 'Lower Lockyer', which extends from Laidley to the Brisbane River, is also moderately saline but bicarbonate dominated, with magnesium exceeding sodium which is more typical of basalt. The suitability for EVs is the same as for Zone 9, and long term records indicates that EC appears to have risen while TN probably fell, and water levels probably rose on average over the last 20 years.

The upper and middle reaches of Lockyer Creek are fed by drier headwaters and are rated as saline, however, they are suitable for irrigation and stock, except for sensitive crops because EC is frequently elevated. Zone 5 'Upper Lockyer Creek' is chloride dominated with sodium exceeding magnesium which is typical of fine grained sediments with stagnant flow. It is normally suitable for drinking, but poor for general purposes because of hardness with some incrustation. EC appears to have risen in the long term, while TN probably fell, and water levels probably rose on average over the last 20 years. Zone 6 'Central Lockyer Creek' extends from the middle reaches of Tenthill Creek to Zone 7 'Lower Lockyer' is similar in chemistry to Zone 5 upstream, except that EC is a little higher and magnesium exceeds sodium, suggesting more basaltic influence. It is poor quality for drinking because of undesirably high EC, and for general purposes because of high EC and hardness, with some incrustation. EC appears to have risen over the long term, while water levels were fluctuating, and probably rose on average over the last 20 years.

Very saline alluvial groundwaters occur on some short tributaries or around poorly recharged edges of the floodplain. These waters are poor quality for drinking and general purposes because of very high EC and hardness with incrustation, but are suitable for stock. They are incompatible with environmental guidelines because EC and TN are usually elevated. Zone 8 'Southwest Lockyer Tributaries' covers Ma Ma and Flagstone Creeks is chloride dominated, with magnesium exceeding sodium as typical of concentrated basaltic waters. It is poor quality for irrigation because EC is generally unsuitable for sensitive crops and occasionally also for tolerant crops. EC appears to have risen over the long term, while TN has been unstable, while water levels were fluctuating, and probably rose on average over the last 20 years. Zone 11 'Gatton Sandstones Saline Area' is scattered around the edges of the alluvium of the Lockyer and the central to lower reaches of the main tributaries. The chemistry is similar to Zone 8, except that sodium exceeds magnesium which is typical of fine grained sediments with stagnant flow. It is poor quality for irrigation with EC being elevated for sensitive crops and only moderate for tolerant crops. EC appears to have risen over the long term, while TN probably fell and water levels probably rose on average over the last 20 years.

The Lower GAB continues through the watershed with the QMDB in this region and underlies most of the Lockyer Valley. There are several zones with varying aquifers and water quality. Lower GAB Zone 1 'Southeastern Hutton Outcrop (cont)' covers the northwestern headwaters in continuation from the QMDB. The main aquifer is the Hutton Sandstone with its equivalent the Koukandowie. The groundwater is saline, and chloride dominated, with sodium exceeding calcium typical of a poorly drained sandstone. It is usually suitable for drinking because the EC may be undesirably high, but poor for general purposes because of high EC and hardness, with a moderate tendency for incrustation. It is suitable for stock, and irrigation apart from crops sensitive to high EC and occasionally sodium but incompatible with environmental guidelines because EC, TN and occasionally pH are elevated. Zone 7 'Lockyer Valley Sandstones' underlies the Lockyer alluvium and Beauaraba Creek. The main aquifer is the Injune Creek Group, with some underlying Hutton or other Marburg aquifers. The salinity is usually high, but EC can be variable. The Sodium Chloride chemistry is typical of fine grained sediments and suitable for drinking, but aesthetically undesirable with some hardness and incrustation. It is suitable for stock and irrigation, apart from salt sensitive crops, but is incompatible with environmental guidelines because EC is elevated. The only other significant Lower GAB zone is the southernmost Zone 3 'Laidley Creek Sandstones'. Its main aquifer is the Hutton or equivalent Koukandowie. The chemistry is bicarbonate with no dominant cations, and moderately saline although EC can be variable. This is typical of the GDR, probably affected by overlying basalts It is suitable for drinking, but aesthetically undesirable with some hardness or scaling. It is also suitable for stock but poor quality for irrigation because the EC is elevated for sensitive crops and only moderate for tolerant crops. It may exceed environmental guidelines for EC.

Over most of the Lockyer, Lower GAB formations are underlain by the Basal GAB which tends to be more saline. Basal GAB Zone 2 'Eastern Central Area (cont)' continues over the watershed with the QMDB in the northwest of the subcatchment. The main aquifer is the Woogaroo Subgroup, with some Evergreen in the west. It is moderately saline, with sodium bicarbonate chemistry typical of GAB sandstones. The water is poor quality for drinking because fluoride levels may exceed health guidelines. It is poor for general purposes and irrigation due to high EC which is occasionally unsuitable even for salt tolerant crops while sodium or fluoride tend to be elevated for sensitive crops. It is moderately suitable for stock, but bores should be tested for elevated fluoride. It is moderately compliant with environmental guidelines, but TN and EC are elevated at times. Underlying the south of the subcatchment is the large Zone 3 'Southeastern Evergreen (cont)', which continues from the QMDB and extends beyond the Lockyer. The main aquifer in this zone is uncertain but assumed to be the Woogaroo Subgroup. The chemistry is a saline sodium chloride, typical of fine grained sediments with poor drainage. It is poor quality for drinking because of the very high EC, and moderate for general purposes, due to high EC and occasional incrustation tendencies. It is suitable for stock, but poor quality for irrigation because EC and sometimes sodium is elevated for sensitive crops and EC is occasionally too high for tolerant crops, however, it is compatible with default environmental guidelines. A band of Zone 4 'Beauraba Woogaroo extends from west to east just north of the Lockyer alluvium, and continues into the Upper Brisbane subcatchment, where it is described.

The pattern of Basal GAB zones within the central Lockyer Valley is affected by recharge and hydrological connections. Zone 6 'Gatton Sandstone Saline Area' underlies the Lockyer mainstream alluvium and the downstream reaches of the tributaries. The aquifers are mixed but mainly Evergreen and Gatton Sandstone. The water chemistry is saline, dominated by chloride with sodium exceeding magnesium. This is typical of poorly drained fine grained sediments. It is poor quality for drinking and general purposes due to high EC and hardness with some incrustation tendencies. It is suitable for stock and irrigation apart from salt and occasionally sodium sensitive crops. However, it is incompatible with environmental guidelines because EC and TN and occasionally pH are elevated. Zone 7 'Lower Lockyer Recharged Area' lies within the boundaries of Zone 6 below the Lockyer mainstream alluvium and the downstream reaches of its tributaries, but less saline, probably because of the potential for recharge from the streams. The main aquifers are the Evergreen and Gatton Sandstone, and the chemistry is saline but fresher than that of Zone 6. Magnesium exceeds sodium and bicarbonate exceeds chloride, indicating basaltic influence. The water is moderately suitable for drinking, but EC may be occasionally elevated. It is poor for general purposes due to hardness and some incrustation, but suitable for stock and irrigation apart from salt sensitive crops. It is incompatible with environmental guidelines because EC, TN and occasionally pH are elevated.

The only other significant groundwater source is fractured basalt flows covering watersheds, particularly the Main Range Volcanics. Fractured Zone 1 ‘Upper Condamine Basalts (cont)’ is the most widespread zone, distributed mainly around the headwaters and watersheds of the southern tributaries. It is moderately saline with variable EC, dominated by bicarbonate with magnesium exceeding sodium, considered typical of basalt. It is normally suitable for drinking and moderate for general purposes because of occasional corrosiveness or incrustation. It is suitable for stock and most irrigation apart from crops that are sensitive to pH, high EC or sodium, however it is incompatible with environmental guidelines because TN, usually EC, and occasionally pH are elevated. It may be susceptible to contamination from the surface as recharge infiltrates basalt aquifers relatively rapidly with little opportunity for soil filtration and biological interactions. The surface water is mostly of moderate salinity with even cations and dominated by chloride or bicarbonate depending on the EC. It reflects the basaltic headwaters and tends to resemble the groundwater chemistry in the southwest, where several weirs have been constructed to encourage recharge. However, groundwaters in the mid and lower reaches of the Lockyer are considerably more saline than the surface water.

The **Bremer River (Basin 1431)** is a relatively large subcatchment of the Brisbane River which is drained by the tributaries of Bremer River and Worrill Creek. Extensive alluvium overlies the GAB over most of the catchment, with the Lower GAB underlain by Basal GAB formations, and Pre-GAB coal measures in the downstream section. The terrain is hilly to rugged away from alluvium with ranges on the subcatchment borders. Irrigated cropping is established on the Bremer and Warrill alluvium, while the northern section, downstream of the confluence of Warrill Creek and the Bremer River, is dominated by residential development and mining. The landuse in the rest of the catchment is grazing or National Park. The annual rainfall is relatively low at 800-1000 mm in most of area, but more than 1000 mm on the southern headwaters.

The subcatchment is a high user of groundwater due to irrigation on the alluvial deposits of the Bremer River and Warrill Creek. The alluvium hosts just over half the bores with an average depth of 16 m. There are two alluvial zones, Zone 11 ‘Warrill and Upper Bremer River’, and 12 ‘Lower Bremer’ which covers the lower reaches of the Bremer to its confluence with the Warrill. Zone 11 ‘Warrill and Upper Bremer River’ is moderately saline bicarbonate water with no dominant cations. This would be typical of the GDR with overlying basalt. The water is normally suitable for drinking, but poor for general purposes due to hardness with possible incrustation. It is suitable for stock and irrigation apart from salt sensitive crops. It is incompatible with environmental guidelines because EC, TN and occasionally pH are elevated. EC appears to have risen over the long term although no trends could be determined for TN, while water levels were fluctuating, and probably rose on average over the last 20 years. Most of the remaining bores are low yielding and access GAB and Pre-GAB formations, particularly aquitards such as the Injune Creek and Walloon coal measures. There are also a few bores in basalts, or in Tertiary sediments such as the Silkstone and Redbank Plans Formations. The surface water is mostly moderate salinity chloride bicarbonate with no dominant cations, typical of basaltic catchments. It chemically resembles nearby alluvial groundwater implying likely interaction.

5.2.4 Lower Brisbane subcatchment

The **Lower Brisbane River** comprises the lower reaches of the Brisbane River catchment (Basin 1430) downstream of Wivenhoe Dam. The area is moderate in size, undulating to hilly away from the streams, rising to ranges northwest of the Brisbane River as well as on the southern and western borders of the catchment. Landuse is mainly urban and residential, particularly towards the coast, but with grazing in the west and southern areas, and some Irrigation near the junction with Lockyer Creek. The ranges in the northwest are National Park. The annual rainfall is moderate for the SEQ, being 1000-1200 mm in the east and being up to 1100 mm on the southern ranges, but decreasing to 900 mm in the west. The surface water chemistry is varied, but basaltic and GDR types predominate, probably with some groundwater compatibility where they associate.

There are a variety of groundwater types but no major aquifers, and groundwater usage is relatively low. About half of the bores are alluvial. The largest stretch of alluvium is upstream around Lowood, where the lower reaches of the Lockyer Creek alluvium extends onto the Brisbane River at its confluence. This is included in alluvial Zone 7 ‘Lower Lockyer Alluvium’ as described in the Lockyer discussion. There is also a small area of alluvium on Oxley Creek, a tributary within the tidal limit of the Brisbane River. This is within alluvial Zone 23 ‘Lower Brisbane’, which is moderately saline although EC can be variable particularly around tidal streams. The chemistry is sodium chloride, typical of coastal deposits. It is normally suitable for drinking, but poor for general purposes because of corrosive tendencies due to low pH and hardness. It is suitable for stock and usually for irrigation, apart from crops that are sensitive to low pH levels. It is incompatible with environmental guidelines because EC and TN are elevated. The estuarine deposits at the mouth of the Brisbane River are within alluvial Zone 17 ‘Moreton Bay Estuarine and Deltaic Area’, and there is a small sand mass just to the south of the Brisbane River estuary.

Both Lower GAB and Basal GAB formations are present in the area, with the Lower GAB being confined to the west. These are underlain by Pre-GAB coal measures. The main Lower GAB zones are Zone 3 ‘Laidley Creek Sandstones’ and Zone 7 ‘Locker Valley Sandstones’. They continue across the Brisbane River from the Lockyer basin where they are described. Zone 6 ‘South East Walloons (cont)’ continues into the western headwaters adjoining the Lockyer, and Zone 4 ‘Southeastern Marburgs’ forms the headwaters of Oxley Creek. The Basal GAB also continues across the confluence with the Lockyer, but the largest Zone in the Lower Brisbane is the Woogaroo in Zone 10 ‘Clarence Moreton Nambour Connection’ which occupies much of the area south of the Brisbane River and continues across the estuarine area in the east and into the watershed with the South Pine Catchment.

Outcrops of Tertiary sediments such as the Darra, Sunnybank and Corinda Formations are found across the central area of the catchment and may be locally important as aquifers, although low yielding. Other minor aquifers include the Neranleigh Fernvale Beds in the north of the catchment, and coal measures such as the Tingalpa Formation.

5.2.5 Logan Albert and Gold Coast

These are the catchments that drain the southern end of the SEQ, from below Moreton Bay to the NSW border.

The **Logan River (Basin 1450)** with its eastern tributary Teviot Brook is a large, elongated catchment in the south of the SEQ that drains into the deltaic area forming the southern end of Moreton Bay. It has two main tributaries, the Albert River in the east, and Teviot Brook in the west. The bed rock is trap rock and both Lower GAB and Basal GAB formations, with the middle reaches of the main streams running through alluvial floodplains, and with estuarine deposits at the mouth of the Logan. The rest of the catchment is hilly to mountainous, especially in the southern headwaters. There is dense residential development in the northern, downstream area, with scattered irrigation on the alluvial flats. Grazing is the primary landuse elsewhere, with National Park in the southern ranges. The annual rainfall is 900-1300 mm, being driest in the central area away from the coast. The surface water chemistry, at least upstream, is low salinity bicarbonate with no dominant cations typical of GDR, or moderate salinity chloride bicarbonate typical of basalt. It is reasonably similar to nearby groundwater except on Teviot Brook.

There are a variety of aquifers in the catchment, which is a relatively high user of groundwater because of the alluvial irrigation area. 40% of the bores are in alluvium with an average depth of 21 m. The upstream sections are part of alluvial Zone 14 ‘Logan and Albert Basaltic Headwaters’, which is moderately saline bicarbonate, with no dominant cations. This is typical of GDR with overlying basalt, and occasional elevated TN indicates possible influence of development. It is suitable for drinking, but aesthetically undesirable with occasional hardness or scaling. The groundwater is generally suitable for irrigation and stock, apart from sensitive crops. It may exceed environmental guidelines.

The more saline downstream alluvium is within Zone 13 ‘Logan and Albert. The chemistry is saline, with chloride and no dominant cations, typical of fine grained sediments, possibly affected by brackish recharge. It is poor quality for drinking because of undesirably high EC levels, and for general purposes due to high EC and hardness with some incrustation. It is suitable for stock but poor for irrigation because EC is occasionally unsuitable for tolerant crops, and generally unsuitable for sensitive crops. It is incompatible with environmental guidelines because EC and TN are usually elevated, and pH is occasionally too low. A moderate quality record indicates that EC appears to have risen over the long term while TN probably fell, and water levels probably rose on average over the last 20 years and very shallow water levels (under 5 m) occur in places.

Another 30% of the bores, with lower yields, access GAB and Pre-GAB formations. There are three Lower GAB Zones, 4 ‘Southeastern Marburgs’, 5 ‘Southeast Walloons (cont)’ and 6 ‘Logan Albert Walloons’, These mainly access the Woogaroo Subgroup and the Walloon and Ipswich Coal Measures. There is insufficient data to assess them, but most bores appear to be saline. There are several Basal GAB zones within the Logan catchment, with the largest being Zone 8 ‘Logan Albert Sandstones’ which underlies the upstream two thirds of the catchment. The main aquifers supplying these zones are the Gatton Sandstone and Woogaroo Subgroup. Most of the chemistry appears to be very saline sodium chloride, typical of poorly drained fine-grained sediments, but there is insufficient data to rate for EVs.

The Pre-GAB Zone 1 ‘Logan Coal Measures’ underlies the Logan River alluvium in the lower catchment, upstream of the confluence with the Albert River. The main aquifer is the Ipswich Coal Measures, with high but variable salinity and, like the Basal GAB, sodium chloride chemistry typical of fine grained sediment. Other significant aquifers are the Tertiary Petrie Formation and Oxley Group, fractured aquifers in basalt, or the Neranleigh Fernvale Beds.

Albert River 1451 The Albert River is the main tributary of the Logan River, with the confluence at Beenleigh, within the tidal limits. The annual rainfall is variable, 900-1600 m, being wettest in Southern headwaters. The alluvial floodplain supports an irrigation area which is sufficient to rate the subcatchment as a moderate user of groundwater. The terrain away from the floodplain is hilly to mountainous, especially in the southern headwaters. Landuse is mainly grazing, with scattered residential developments in the downstream third of the subcatchment and National Park in the southern headwater ranges.

The geology of the Albert is relatively complex, and contiguous with the Logan to the west. Over 50% of the bores are situated in the alluvium. The alluvial zones are equivalent to those of the Logan, with Zone 13 'Lower Logan and Albert' downstream, and 14 'Logan and Albert Basaltic Headwaters' upstream. A quarter of the bores are in the GAB zones, mostly the Woogaroo Subgroup and Walloon Coal Measures aquifers, that underlie most of the subcatchment and are continuous with those in the Logan, particularly Lower GAB Zones 6 'Logan and Albert Walloons' and 4 'Southeastern Marburgs', and Basal GAB Zones 8 'Logan Albert Sandstones' which underlies most of the alluvium, and 9 'Albert River Woogaroo' in the north. Basalt flows from Zone 6 'Lamington Basalt' that cover the headwaters in the southern third of the catchment also supply groundwater, while there are a few bores in Tertiary sediments, and in the Neranleigh-Fernvale Beds and Ipswich Coal Measures. The surface water chemistry is low salinity Na Ca Cl, typical of steep, wetter catchments facing the coast. It is usually dissimilar to nearby groundwater, but there is little data available.

Gold Coast Hinterland (Basin 1460). The South Coast is a moderate sized portion of the SEQ, representing short to moderate length streams draining the southeastern ranges and flowing to the ocean south of Moreton Bay, the main streams being the Coomera and Nerang Rivers as well as Tallebudgera and Currumbin Creeks. The coastal plain is continuous but narrows southwards, with small stretches of alluvium on the streams, which pass through estuarine or sandy deposits as they approach the sea. The rest of the catchment is undulating to rugged, especially in the south. There is dense to scattered residential development over most of the area, and some cropping at the northern end, with the remainder of the landuse being grazing or nature conservation, particularly in the southwest. There are coastal Wetlands around Coomera, opposite the deltaic area of southern Moreton Bay. The annual rainfall is very high for the SEQ, being 1200-2000 mm, and wettest in the Southern headwaters. The surface water is very fresh with variable chemistry. On the basis of very little data, there is no clear association with nearby groundwater.

This is an area of mixed aquifers, with relatively low groundwater use. The aquifer containing the most bores, with about 40%, is the Neranleigh-Fernvale Beds but these are in fractured rock and low yielding. The others are divided between the patchy alluvium, basalts in the southwestern headwaters, some estuarine deposits and sand dunes, and various other formations, including Fracture Zone 7 'Mount Tamborine' on mid-western headwaters. This zone covers the Beechmont Basalts, which are elevated in terms of local relief, and therefore vulnerable to groundwater losses due to seepage during dry spells. There is insufficient data to assess the chemistry or EV status of this aquifer, but it may be of local importance for domestic use. The groundwater chemistry of the very minor stretches of alluvium is represented by alluvial Zone 15 'Gold Coast Alluvials'. It is moderately saline, but EC can be variable. The chemistry is sodium chloride, typical of coastal deposits. It is poor quality for drinking because EC may be undesirably high, and poor for general purposes due to high EC and hardness with occasional incrustation. It is suitable for stock and moderately suitable for irrigation although EC and sodium are frequently elevated for sensitive crops. It is incompatible with environmental guidelines because EC and TN are elevated. No trend could be determined for EC, although TN probably rose in the long term and water levels probably rose on average over the last 20 years.

5.2.6 Sand Islands

Moreton Bay is a large, shallow expanse of water, enclosed on the east by the four large sand islands of Moreton, North Stradbroke, and South Stradbroke and Bribie. The dunes are composed of siliceous sands that were carried northward by longshore currents from the coast of New South Wales, and were then shaped by wind action during changes in sea level associated with glacial phases over recent geological times (Gibbes et al., 2014) (Davie et al., 1998). Most of the natural waters are Wallum type, being acidic with very low salinity.

Bribie Island (Yarun, Basin 1410) Bribie is the smallest and lowest of the sand islands, separated from the mainland by the shallow tidal estuary of Pumicestone Passage. It is flat lying, with a maximum elevation of 17 m and a significant proportion is less than 5 m above sea level. Sand deposits extend over the west of the Island, but estuarine conditions occur in the east bordering Pumicestone Passage. A few short streams drain the island, most of which is national park or forestry plantations, although the southern area is intensively residential. Annual rainfall is 1000-1500 mm. There is moderate use of groundwater, with about 190 bores. The sand deposits are represented by alluvial Zone 22 'North Coastal Sands' described for the Noosa Catchment. The estuarine deposits in alluvial Zone 18 'Pumicestone coastal deposits' line both sides of Pumicestone Passage. This aquifer has higher and much more variable salinity as described for the Maroochy Catchment on the mainland side. Surface water is very low in salinity and pH, typical of wallum country. However, it does not chemically resemble nearby groundwaters.

Moreton Island (Moorgumpin **Basin 1441)** is the furthest offshore of the sand islands, and the least disturbed, with most of it included in the Moreton Bay Ramsar Site and Moreton Island National Park. The landscape consisting of sand dunes, lakes and wetlands, apart from a small outcrop of Mesozoic sandstones and volcanics forming the headland at Cape Moreton on the northeastern tip of the island. It is underlain at depth by Basal GAB Zone 16 'Moreton Bay and Barrier Islands'. The highest point is Mount Tempest, which at 285 m AHD is reputedly the highest stabilised dune in the world. Moreton Island has a relatively moist climate for the SEQ with an annual rainfall of 1400-1700 mm which is greatest in the central part of the catchment. There are only a few small streams, but more than 70 perched and window lakes or swamps. The island is mainly national park, with very little groundwater usage. The few recorded bores in sand deposits or associated alluvium are part of Zone 21 'North Stradbroke and Moreton Islands', with very low salinity sodium chloride chemistry typical of wallum country. It is normally suitable for drinking, but poor for general purposes with corrosive tendencies due to low pH and hardness. It is suitable for stock and irrigation apart from crops that are sensitive to low pH levels. It is incompatible with environmental guidelines because TN and usually EC are elevated, and pH is occasionally too low. EC and TN appear to have fallen over the long term, with instability in EC and a probable fall in TN over the last 10 years. Water levels were fluctuating, and probably fell on average over the last 20 years. The aquifer may be susceptible to contamination because of contact with seawater and very shallow water levels in places. The low salinity acidic surface water is compatible with the groundwater, implying hydrological connection.

Stradbroke Islands (Minjerribah **Basin 1440)** North Stradbroke Island was separated from South Stradbroke Island in the mid-1890s as a result of coastal erosion. It is separated from the mainland in the south by a network of small deltaic islands. Landuse is mainly National Park with mining, and minor residential development around the north coast. The annual rainfall is 1400-1800 mm, being highest in the central part of the catchment. North Stradbroke is essentially a massive, vegetated dune system with a maximum elevation of 219 m, featuring perched and window lakes and wetlands as well as a few minor streams. The dune sands extend to a maximum depth of about 80m below AHD in places. The most significant stream is Freshwater Creek which drains Eighteen Mile Swamp, a 26 km long freshwater system composed of swamp and wetland lying parallel to the eastern coast. It is fed by groundwater seepage from the dunes, rather than by surface water (Everist, 1975). The escarpment on the inland edge is able to maintain a slope which is steeper than the angle of rest for dry, fine-grained sand, because it is bound by vegetation. (Laycock, 1975), (Chen, 2001) and (EHA, 2005a, 2005b) (Gibbes et al., 2014). A relatively high volume of groundwater is extracted from the dunes to support the sand mining industry and domestic consumption on the mainland. Infiltration from mining sites also redistributes groundwater within the aquifer. As with the other sand islands, the groundwater is part of Zone 21 'North Stradbroke and Moreton Islands' as described for Bribie Island. The surface is also typical of wallum country or coastal alluvium, and chemically resembles nearby groundwater with which it is hydrologically connected.

South Stradbroke Island (Currigee) is small, flat lying, and lies close to the mainland. It consists mainly of sand dunes, with little expression of surface water as rainfall infiltrates directly through the sand to recharge the groundwater. The maximum height of the water table is about 3 m above AHD at the centre of the island.

6 References

AGGA 2017, 'Groundwater', accessed May 4, 2017, from <http://www.ga.gov.au/scientific-topics/water/groundwater>.

Anorov, JM, Dale, PE, Powell, B & Greenway, M 2008, 'An Interdisciplinary Approach for Understanding and Managing a Sub-tropical Coastal Wetland Ecosystem: Native Dog Creek, Southeast Queensland, Australia', *Proceedings of the Royal Society of Queensland*, vol. 114, pp. 19–32.

ANRA

ANZECC & ARMCANZ 2013, *Australian Drinking Water Guidelines 6*, Canberra.

ANZG 2018, 'Application of the water quality guidelines to groundwater', accessed January 23, 2023, from <https://www.waterquality.gov.au/anz-guidelines/resources/guidance/groundwater>.

Armstrong, TJ 2006, 'Determination of Aquifer Properties and Heterogeneity in a larg Coastal Sand Mass: Bribie Island, Southeast Queensland',.

Australian, New South Wales, Queensland, South Australian and Northern Territory governments, . 2019, 'Great Artesian Basin Strategic Management Plan', *DCCEEW*, accessed May 18, 2023, from <https://www.dcceew.gov.au/water/policy/national/great-artesian-basin/strategic-management-plan>.

Australian Government 2013, *Guidelines for groundwater quality protection in Australia*, Canberra.

Babaahmadi, A, Rosenbaum, G & Esterle, J 2015, ‘Alternating episodes of extension and contraction during the Triassic: evidence from Mesozoic sedimentary basins in eastern Australia’, *Australian Journal of Earth Sciences*, vol. 62, no. 5, pp. 563–579.

Bensink, A & Burton, H 1975, ‘North Stradbroke Island: a place for freshwater invertebrates’, *Proceedings of the Royal Society of Queensland*, vol. 86, no. 7, pp. 29–45.

Bioregional Assessment Programme 2014, ‘Bioregional Assessment Derived Dataset CLM - Hydraulic conductivity NSW’, accessed September 28, 2017, from <http://data.bioregionalassessments.gov.au/dataset/cecfa372-52ca-49f8-b61c-6506279eafb5>.

Box, GEP & Jenkins, G 1976, *Time series analysis: forecasting and control.*, Holden-Day Inc., San Francisco, California.

Brindha, K & Elango, L 2015, ‘Cross comparison of five popular groundwater pollution vulnerability index approaches’, *Journal of Hydrology*, vol. 524, pp. 597–613.

Bryan, WH & Jones, 0. A. 1951, ‘Explanatory Notes to Accompany a Geological Map of the City of Brisbane’, *University of Queensland Papers*, vol. 3, no. 13, p. 6.

Cai, W, van Rensch, P, Cowan, T & Sullivan, A 2009, *Asymmetry in ENSO Teleconnection, Its Collapse and Impact on South East Queensland Summer Rainfall, Urban Water Security Research Alliance Technical Report No. 18.*, accessed from <http://www.urbanwateralliance.org.au/publications/UWSRA-tr18.pdf%5Cnpapers2://publication/uuid/A736025B-679C-4453-88DB-94068CB65654>.

Catania, ST & Reading, L 2023, ‘Hydrogeochemical evolution of the shallow and deep basaltic aquifers in Tamborine Mountain, Queensland (Australia)’, *Hydrogeology Journal*, no. 0123456789, accessed from <https://doi.org/10.1007/s10040-023-02617-6>.

Cavanagh, N, Nordin, RN, Pommen, LW & Swain, LG 1998, *Guidelines for designing and implementing a water quality monitoring program in British Columbia*,.

Chen, D 2001, *North Stradbroke Island Whole-of-Island Groundwater Management Model, Phase 3: Development of Computer Model and User Interface Draft for Comments*,.

Chern, PZKN 2004, ‘Patterns of coal sedimentation in the Ipswich Basin southeast Queensland’, *Thesis*, pp. 1–195.

Clifford, HT & Specht, RL 1979, *The Vegetation of North Stradbroke Island, Queensland*, University of Queensland Press, Brisbane, QLD, Australia.

Cousins, IT, Vestergren, R, Wang, Z, Scheringer, M & McLachlan, MS 2016, ‘The precautionary principle and chemicals management: The example of perfluoroalkyl acids in groundwater’, *Environment International*, no. 94, pp. 331–340.

Cox, ME & Wilson, AS 2005, ‘Use of geochemical and isotope plots to determine recharge to alluvial aquifers: Lockyer Valley, Queensland, Australia’, in *International Conference of Recharge, Berlin*, pp. 12–17.

Cranflied, LC, Schwarzbock, H & Day, RW 1976, *Geology of the Ipswich and Brisbane 1:250,000 sheet areas*,.

Croke, J, Jansen, JD, Amos, K & Pietsch, TJ 2011, ‘A 100 ka record of fluvial activity in the Fitzroy River Basin, tropical northeastern Australia’, *Quaternary Science Reviews*, vol. 30, no. 13–14, pp. 1681–1695, accessed from <http://dx.doi.org/10.1016/j.quascirev.2011.03.012>.

CSIRO 2014, *Aquifer connectivity within the Great Artesian Basin, and the Surat, Bowen and Galilee Basins, Background review*,.

Dafny, E & Silburn, DM 2013, *The hydrogeology of the Condamine River Alluvial Aquifer (Australia) - critical review*, University of Southern Queensland, Toowoomba, Australia.

Day, RW 1983, *Queensland Geology: A companion volume to the 1: 2,500,000 scale geological map*, Geological Survey of Queensland.

Day, RW, Cranfield, LC & Schwarzböck, H 1974, ‘Stratigraphy and structural setting of mesozoic basins in southeastern Queensland and northeastern New South Wales’, in *The Tasman Geosyncline: A Symposium*, pp. 319–363.

Decelles, P 2002, ‘The pH scale’, *Virtually Biology Course, Basic Chemistry Concepts, Johnson County Community College*, accessed July 14, 2013, from <http://staff.jccc.net/pde-cell/chemistry/phscale.html>.

Dennison, WC & Abal, EG 1999, *Moreton Bay Study: A Scientific Basis for the Healthy Waterways Campaign.*

Brisbane,.

Department of Environment and Resource Management 2009, *Queensland Water Quality Guidelines 2009*, The State of Queensland, Department of Environment and Resource Management.

DES 2018, *Monitoring and Sampling Manual: Environmental Protection (Water) Policy*, Department of Environment and Science, Queensland Government, Brisbane, accessed from <https://environment.des.qld.gov.au/water/monitoring/sampling-manual/pdf/monitoring-sampling-manual-2018.pdf>.

DNRM 2015, *Mines Qld geology, 2m surface layer*, Last accessed 2017.

DNRW 2007, *Logan Basin water resource plan: draft amendment to include southern Moreton Bay islands Information Report*, Queensland Government, Brisbane Australia.

Doig, A & Stanmore, P 2012, 'The Clarence-Moreton Basin in New South Wales ; geology, stratigraphy and coal seam gas characteristics', in *Eastern Australasian Basins Symposium IV*, Petroleum Exploration Society of Australia, Brisbane, QLD, 10–14 September, 2012.

Domenico, PA & Schwartz, FW 1990, *Physical and chemical hydrogeology*, John Wiley & Sons, New York.

DPI 1994, *Queensland Water Quality Atlas*,.

Drever, J 2005, 'Surface and Ground Water, Weathering, and Soils 1st Edition, Treatise on Geochemistry, 2nd Edition', , vol. Volume 5.

Eberhard, R, Robinson, CJ, Waterhouse, J, Parslow, J, Hart, B, Grayson, R & Taylor, B 2009, 'Adaptive management for water quality planning - From theory to practice', *Marine and Freshwater Research*, vol. 60, no. 11, pp. 1189–1195.

EHA 2005a, *Groundwater Review of South East Queensland on-Shore Sandmass Systems & Sand Islands Draft North Stradbroke Island Report 12 September 2005*,.

EHA 2005b, *Groundwater Review of South East Queensland on-Shore Sandmass Systems and Sand Islands: North Stradbroke Island Report Draft Additional Supplementary Groundwater Modelling Report 12 October 2005*,.

EPA 2006, *Wetland Management Profiles: Coastal Dune Lakes*,.

Falkner, AJ 1986, 'Sedimentology of the Blackstone Formation, Ipswich Coal Measures, Southeast Queensland',.

Ferris, JG, D.B.Knowles, R.H.Brown & R.W.Stallman 1962, *Theory of aquifer tests*, US Government Department of the Interior.

Foster, AD 2016, 'Australia: Tasman Orogenic Belt', *Reference Module in Earth Systems and Environmental Sciences*, p. 100p.

Freeze, RA, & JA Cherry, 1979, '*Groundwater*', Prentice-Hall, englewood Cliffs N.J

GABCC 2014, *Great Artesian Basin: Resource Study 2014*, Great Artesian Basin Co-ordinating Committee, Canberra.

Gibbes, B, Grinham, A, Neil, D, Olds, A, Maxwell, P, Connolly, R, Weber, T, Udy, N & Udy, J 2014, 'Moreton Bay and Its Estuaries: A Sub-tropical System Under Pressure from Rapid Population Growth', in *Estuaries of Australia in 2050 and beyond*, Springer, Dordrecht, pp. 203–222.

Goscombe, PW & Coxhead, BA 1995, 'Clarence-Moreton, Surat, Eromanga, Nambour and Mulgildie basins', in CR Ward, HJ Harrington, CW Mallett, & JW Beeston (eds), *Geology of Australian Coal Basins*, Geological Society of Australia, Coal Geology Group, Special Publication, pp. 489–511.

Healthy Land & Water 2021, *South East Queensland Natural Resource Management Plan (2009–2031) – 2021 Update*,.

Herbert, C 1980, 'A tectonic origin for southeast Australian streams', in *Abstract from Symposium on Cainozoic Evolution of Continental Southeastern Australia*, Bureau of Mineral Resources, Geology and Geophysics, Canberra.

Herczeg, AL, Torgersen, T, Chivas, AR & Habermehl, MA 1991, 'Geochemistry of ground waters from the Great Artesian Basin, Australia', *Journal of Hydrology*, vol. 126, no. 3–4, pp. 225–245.

Hodgkinson, JH, McLoughlin, S & Cox, ME 2007, 'Drainage patterns in southeast Queensland: The key to concealed geological structures?', *Australian Journal of Earth Sciences*, vol. 54, no. 8, pp. 1137–1150.

Hose, GC, Sreekanth, J, Barron, O & others 2015, ‘Stygofauna in Australian groundwater systems: Extent of knowledge’, *CSIRO*, no. July, p. 71, accessed from <https://pdfs.semanticscholar.org/a560/c500fa537b609c42c4ea33f2f2168ca731ba.pdf>.

Hutton, AC 2009, ‘Geological Setting of Australasian Coal Deposits’, *Australasian Coal Mining Practice*, vol. 3053, pp. 40–84.

Jansson, I-M 2006, ‘An Early Jurassic conifer-dominated assemblage of the Clarence-Moreton Basin , eastern Australia’, *Geology*, no. 203.

Jiang, Z 2014, ‘Analysis and modelling of the hydraulic conductivity in aquitards: Application to the Galilee Basin and the Great Artesian Basin, Australia’,.

Jones, MR 2006, ‘Cenozoic landscape evolution in central Queensland’, *Australian Journal of Earth Sciences*, vol. 53, no. 3, pp. 433–444.

Kennard, MJ, Pusey, BJ, Olden, JD, MacKay, SJ, Stein, JAL & Marsh, N 2010, ‘Classification of natural flow regime in Australia to support environmental flow management’, *Freshwater Biology*, vol. 55, no. 1, pp. 171–193, accessed from <https://doi.org/10.1111/j.1365-2427.2009.02307.x>.

Kikkawa, J 1975, ‘A place for land vertebrates’, *Proceedings of the Royal Society of Queensland*, vol. 86, pp. 15–19.

Kingham, RA 1998, *Geology of the Murray-Darling Basin: Simplified Lithostratigraphic Groupings*, Australian Geological Survey Organisation, Department of Primary Industries & Energy.

Kresic, N 2007, *Hydrogeology and Groundwater Modeling, Second Edition* 2nd edn, Taylor and Francis Group, LLC CRC Press, Boca Raton.

Laycock, JW 1975, ‘Hydrogeology of North Stradbroke Island’, in *Proceedings of North Stradbroke Island Symposium 1974: 86, 4*, Royal Society of Queensland, pp. 15–19.

Locsey, KL 2004, ‘Hydrogeochemistry and Hydrology of a Basalt Aquifer’,.

Locsey, KL & Cox, ME 2003, ‘Statistical and hydrochemical methods to compare basalt- and basement rock-hosted groundwaters: Atherton Tablelands, north-eastern Australia’, *Environmental Geology*, vol. 43, no. 6, pp. 698–713.

Machiwal, D, Jha, MK, Singh, VP & Mohan, C 2018, ‘Assessment and mapping of groundwater vulnerability to pollution: Current status and challenges’, *Earth-Science Reviews*, vol. 185, pp. 901–927.

Macphail, MK, Hill, RS, Carpenter, RJ & McKellar, JL 2014, *Cenozoic oil-shale deposits in southeastern-central Queensland: palynostratigraphic age determinations and correlations for the Biloela Formation (Biloela Basin) in GSQ Monto*,.

Manning, JC 1997, *Applied Principles of Hydrology. 3rd Edition* 3rd edn, Prentice Hall.

Marsily, G de. 1986, *Quantitative Hydrogeology*, Academic Press.

McBean, EA & Rovers, FA 1998, *Statistical Procedures for Analysis of Environmental Monitoring Data and Risk Assessment*, Prentice-Hall Publishing Co. Inc, Englewood Cliffs, New Jersey.

McKellar, JL 1993, ‘Stratigraphic relationships in the Nambour Basin, southeastern Queensland’, *Queensland Geology*, vol. 5, pp. 1–17.

McLoughlin, S 2015, ‘The Landsborough Sandstone: the Sunshine Coast’s Jurassic Park’, *Australian Age of Dinosaurs Journal*, vol. 12, pp. 78–82.

McMahon, GA & E.M. Cox 1996, ‘The relationship between groundwater chemical type and Jurassic sedimentary formations: The example of the Sandy creek catchment, Lockyer, Southeast Queensland’, in *Mesozoic ’96, Brisbane, Australia, Geological Society of Australia (Queensland Division)*, 23-26 September, 1996, Brisbane, pp. 374 – 382.

McNeil, VH 2002, ‘Assessment methodologies for very large, irregularly collected water quality data sets with special reference to the natural waters of Queensland’,.

McNeil, VH & Cox, ME 2007, ‘Defining the climatic signal in stream salinity trends using the Interdecadal Pacific Oscillation and its rate of change’, *Hydrology and Earth System Sciences*, vol. 11, no. 4.

McNeil, VH, Cox, ME & Preda, M 2005, ‘Assessment of chemical water types and their spatial variation using multi-stage cluster analysis, Queensland, Australia’, *Journal of Hydrology*, vol. 310, pp. 181–200, accessed from

<http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V6C-4FH5KG5-2&_user=613232&_coverDate=08%2F01%2F2005&_alid=521166702&_rdoc=1&_fmt=full&_orig=search&_cdi=5811&_sort=d&_docanchor=&view=c&_acct=C000032020&_version=1&_urlVersion=0&_userid=613232&md>.

McNeil, VH & Raymond, MAA 2011, *2011 State of the Environment: Inland Waters - Groundwater Technical Report*, The State of Queensland, Department of Environment and Resource Management, Brisbane.

McNeil, VH, Raymond, MAA, Bennett, L & McGregor, GB 2015, *Regional groundwater chemistry zones of the Queensland Murray-Darling Basin: Summary and results.*, State of Queensland, Department of Science Information Technology and Innovation, Australia, Queensland, Brisbane.

Moody, DW 1996, 'Water quality & waste management: sources and extent of groundwater contamination. North Carolina Cooperative Extension Service. Internet site: http://www.bae.ncsu.edu/bae/programs/extension/publicat/wqwm/ag441_4.html',.

Mull, R, Bugner, C, Härig, F, Pfingsten, W & Pielke, M 1991, 'Nitrate balances in aquifers', in *Nitrate Contamination: Exposure, Consequence, and Control*, Springer, Berlin Heidelberg, pp. 129–139.

NHMRC & NRMMC 2011 (as amended), *Australian Drinking Water Guidelines 6 National Water Quality Management Strategy*, National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

NWS_NOAA 2017, 'Glossary of Hydrologic Terms. National Oceanic and Atmospheric Administrations National Weather Service',.

OGIA 2019, *Groundwater Modelling Report – Surat Cumulative Management Area*, Brisbane.

Pinder, BJ 2004, 'Coal Seam Gas Prospectivity of the Ipswich and Clarence-Moreton Basin in Queensland', *PESA's Eastern Australasian Basins Symposium 2*, pp. 339–344.

Queensland Government Bureau of Meterology 2023, 'South East Queensland: Geographic information', accessed June 1, 2023, from <http://www.bom.gov.au/water/nwa/2018/seq/regiondescription/geographicinformation.shtml#land_use>.

Radke, BM, Kellett, JR, Ransley, TR & Bell, JG 2012, *Lexicon of the lithostratigraphic and hydrogeological units of the Great Artesian Basin and its Cenozoic cover*, A technical report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment.

Raiber, M, Lewis, S, Cendón, DI, Cui, T, Cox, ME, Gilfedder, M & Rassam, DW 2019, 'Significance of the connection between bedrock, alluvium and streams: A spatial and temporal hydrogeological and hydrogeochemical assessment from Queensland, Australia', *Journal of Hydrology*, vol. 569, no. August 2018, pp. 666–684, accessed from <https://doi.org/10.1016/j.jhydrol.2018.12.020>.

Rassam, D, Raiber, M, McJannet, D, Janardhanan, S, Murray, J, Gilfedder, M, Cui, T, Matveev, V, Doody, T, Hodgen, M & Ahmad, ME 2014, *Context statement for the Clarence-Moreton bioregion. Product 1.1 from the Clarence-Moreton Bioregional Assessment*, Australia.

Rast, N & Delany, MF 1983, 'Tasman Orogen, Australia, in Profile of Orogenic Belts',.

Raymond, M & McNeil, VH 2013, *Queensland Wet Tropics and Black and Ross catchments: Regional chemistry of the groundwater*, State of Queensland; Department of Science, Information Technology, Innovation and the Arts; Science Delivery, Queensland, Australia.

Raymond, MAA & McNeil, VH 2011, *Regional chemistry of the Fitzroy Basin groundwater*, DERM, Brisbane, accessed from <http://www.derm.qld.gov.au/environmental_management/water/environmental_values_environmental_protection_water_policy/pdf/fitzroy_regional_chemistry_290911.pdf>.

Rebello, C, Couperthwaite, S, Millar, G & Dawes, L 2017, 'Coal seam water quality and the impact upon management strategies', *Journal of Petroleum Science and Engineering*, vol. 150, pp. 323–333.

Richard, JM, Duff, BA, Korsh, JR, Heidecker, JE, Scheibner, E & Turner, JN 1983, 'Tasman Orogen, Australia', in N Rast & MF Delany (eds), *Profile of Orogenic Belts*, American Geophysical Union, Washington, D. C.

Santos, IR & Eyre, BB 2011, 'Radon tracing of groundwater discharge into an Australian estuary surrounded by coastal acid sulphate soils', *Journal of Hydrology*, vol. 396, pp. 246–257.

Sen, Z 2014, *Practical and Applied Hydrogeology*, Elsevier.

Seqwater 2023, 'Dams and weirs', accessed May 4, 2023, from <https://www.seqwater.com.au/dam-levels>.

Singhal, BBS & Gupta, RP 1999, *Applied hydrogeology of fractured rocks*, Kluwer Academic Publishers, Dordrecht, The Netherlands.

Smerdon, BD, Ransley, TR, Radke, BM & Kellett, JR 2012, *Water resource assessment for the Great Artesian Basin. A report to the Australian Government from the CSIRO Great Artesian Basin Water Resource Assessment*, CSIRO Water for a Healthy Country Flagship, Australia.

Spalding, RF & Exner, M. 1991, 'Nitrate contamination in the contiguous United States', in *Nitrate Contamination: Exposure, Consequence, and Control*, Springer, Berlin Heidelberg, pp. 13–48.

Spring, K 2005, 'Groundwater flow model for a large sand mass with heterogeneous media, Bribie Island, Southeast Queensland',.

Stone, EL & Kalisz, PJ 1991, 'On the maximum extent of tree roots', *Forest Ecology and Management*, vol. 46, no. 5, pp. 9–102.

Surawski, N., Tularam, A & Braddock, R 2020, 'Sustainability of groundwater extraction for the Pimpama coastal-plain, Queensland, Australia', in *MODSIM 2005-International Congress on Modelling and Simulation: Advances and Applications for Management and Decision Making*.

Thatcher, AC & Westman, WE 1975, 'Succession Following Mining on High Dunes of Coastal South East Queensland', in *Proceedings of the Ecological Society of Australia 9*, pp. 17–31.

Tien, AT, Jolly, PB, McNeil, VH, Preda, M & Cox, ME 2004, 'A comparison of salinity trends in the irrigated Lockyer Valley, Queensland, and the Upper Roper Catchment, Northern Territory', in *Proceedings of the 2nd Asian Regional Conference on Irrigation and Drainage*, pp. 17–26.

Tisdell, J, Ward, J & Grudzinski, T 2002, *The development of water reform in Australia*,.

Todd, A 2011, *Groundwater Investigation, Tamborine Mountain, South East Queensland*, Institute for Sustainable Resources, Queensland University of Technology technical report to South East Queensland Catchments Ltd.

USQ 2011, *Preliminary assessment of cumulative drawdown impacts in the Surat Basin associated with the coal seam gas industry: Investigation of parameters and features for a regional model of Surat Basin coal seam gas developments*, Toowoomba.

Veevers, JJ 2001, *Atlas of Billion-Year Earth History of Australia and Neighbours in Gondwanaland*, GEMOC Press, Sydney.

Vrba, J & Zaporozec, A 1994, *Guidebook on Mapping Groundwater Vulnerability*, Heise, Hannover.

Wells, AT & O'Brien, PE 1994, 'Lithostratigraphic framework of the Clarence-Moreton Basin', in AT Wells & PE O'Brien (eds), *Geology and Petroleum Potential of the Clarence-Moreton Basin, New South Wales and Queensland*, Australian Geological Survey Organisation, Bulletin 241, pp. 4–47.

Willmott, W 2004, *Rocks and landscapes of the national parks of Southern Queensland*, Brisbane.

Wilson, AS 2005, 'Hydrogeology, conceptual model and groundwater flow within alluvial aquifers of the Tenthill and Ma Ma catchments, Lockyer Valley, Queensland',.

Zhang, L, Dawes, WR, Slavich, PG, Meyer, WS, Thorburn, PJ, Smith, DJ & Walker, GR 1999, 'Growth and ground water uptake responses of lucerne to changes in groundwater levels and salinity: lysimeter, isotope and modelling studies', *Agricultural Water Management*, vol. 39, no. 2–3, pp. 265–282.

7 Appendix 1 Chemistry zone descriptions

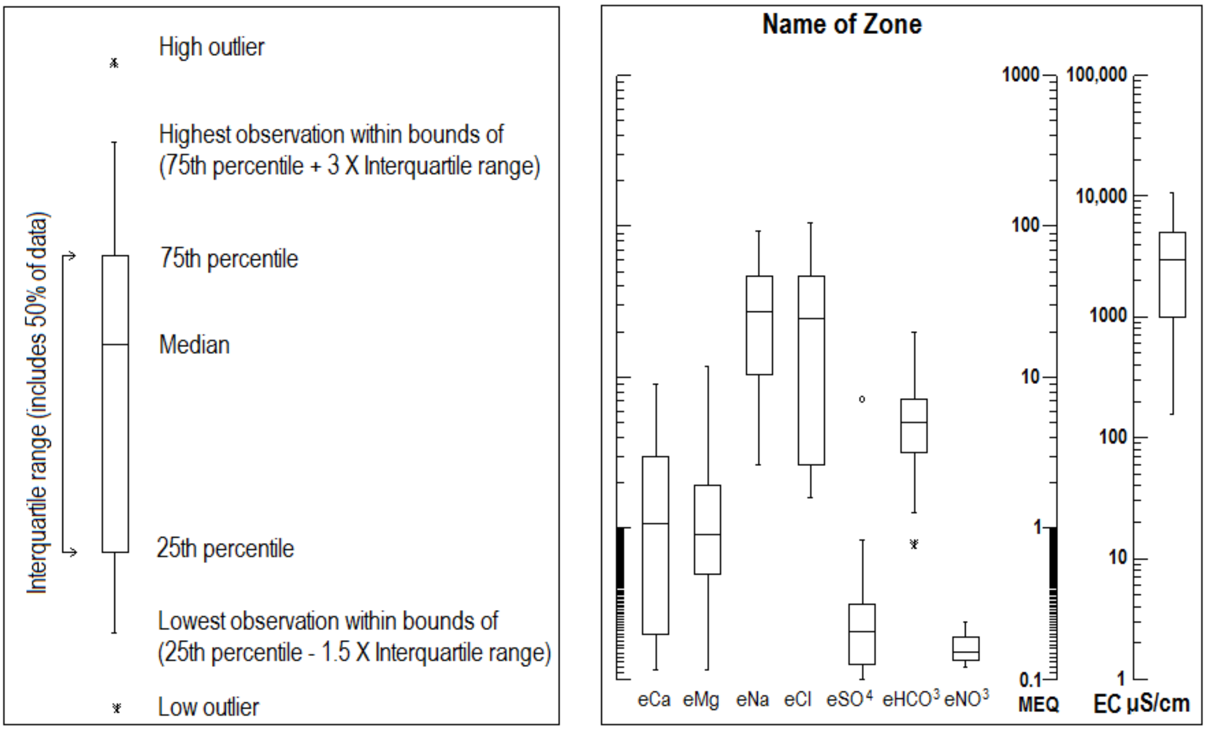
The information in Table 8 and Table 9 apply to the groundwater zones shown in Figures 13 to 18. A brief description of the zone characteristics are provided in Table 8, and percentile ranges of water quality parameters at each zone provided in Table 9. Note that to ascertain suitability of a specific water source (e.g. a bore) for a given use (e.g. irrigation) more detailed testing may be required, and the broad results in Table 8 are not intended to provide this level of detail.

The salinity categories in the tables are based on median EC in µS/cm:

EC <200	very low
EC <200–500	low
EC <500–1500	moderate
EC <1500–5000	high
EC >5000	very high

Salinity is classified variable if the range is more than twice the median.

The comments in Table 8 are more detailed for the alluvial zones, which cover the entire region and account for the most productive aquifers. Zone areas mentioned in the comments are compared only with zones of the same type, for instance, a 'smaller' alluvial zone may be of much greater area than a 'smaller' Lower GAB zone. The plots shown on Table 8 display the essential chemical character of the zone, and are explained in Figure 19. These patterns of salinity and major ion distribution reflect the processes affecting the water, and vulnerability to unmeasured water quality aspects such as contaminants, corrosiveness and dissolved metals.



The higher the box on the EC column on the right, the greater the overall salinity. The longer the box, the greater the variability.

Units of major ions are milliequivalents per litre (MEQ) which reflects their chemical strength, rather than by weight (mg/L)

Figure 19: Explanation of major ion plots shown on Table 8

Examples of major ion plots of groundwater types which are typical of Queensland are shown on Figure 20, although the groundwater in most zones is of an intermediate type.

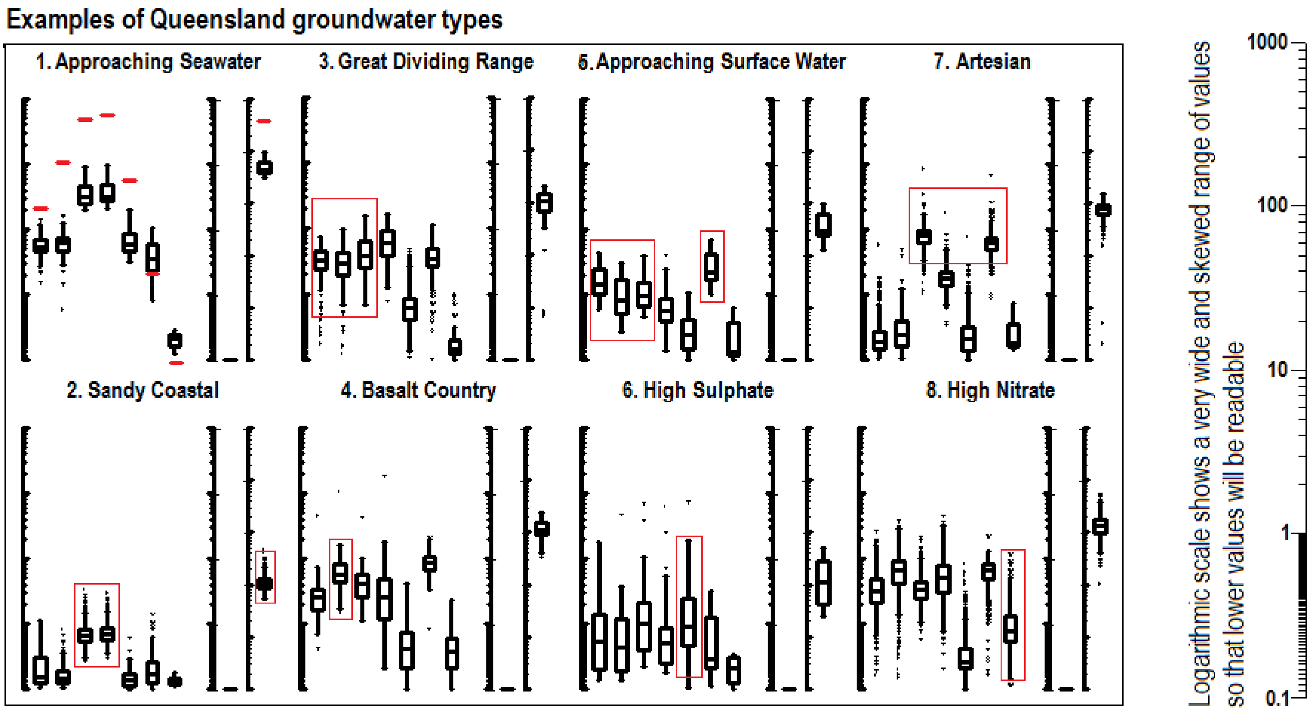


Figure 20: Examples of nomograms representing groundwater types found in Queensland

Most groundwaters in Queensland show tendencies towards one of these examples.

Approaching seawater–High salinity NaCl. The higher the salinity rises, the more the composition tends to be dominated by sodium chloride and resembles that of seawater, shown in red. This is because as groundwater from most sources increases in salinity, the more soluble cation sodium becomes more prominent, as does chloride among the anions and to a lesser extent sulphate. On the other hand, calcium bicarbonate may precipitate. This example is from the Rolling Downs Group, the main aquitard overlying the GAB.

Sandy coastal–Low salinity NaCl. These groundwaters are also high in sodium chloride, as indicated, but low to very low in salinity. Recharge is rapid, through porous, leached sands with very little mineral content, so that most of the salts are derived from marine spray droplets, either windblown or in rainfall. The very low salinity, alkalinity and hardness of such waters leads to unstable pH, with values below four not being uncommon. The groundwater in these areas resembles the surface water, which supports highly specialised ecosystems. The porous nature of the sand leaves these waters vulnerable to pollution from overlying development, and the acidity can make them corrosive to metals with which they come in contact. The example is from North Stradbroke Island.

Great Dividing Range–Broadly even cations, with Na slightly dominant, and the proportion of Cl with respect to HCO_3 rising with salinity. These groundwaters are typical of alluvial valleys draining the GDR. The salinity and hardness is moderate to high as a result of plentiful weathering minerals in the landscape and relatively slow groundwater movement through clayey lensoidal aquifers, and the pH is usually 7.5 to 8. This example is from the alluvium of Callide Creek.

Basalt country–Cations dominated by Mg**.** This groundwater type resembles the Great Dividing Range type, apart from the high proportion of magnesium, which is very rare in Queensland except in ground and surface waters in the immediate vicinity of basaltic terrain. Bores in basalt may be vulnerable to pollution from overlying development because of rapid recharge into often small, localised aquifers. The example shown is from the Main Range Volcanics around the Upper Condamine catchment.

Approaching typical surface water composition–Low to moderate salinity, high in HCO_3 with Ca, being the highest cation but none dominating overall. This type is very common in streams, particularly over the interiors of large, subhumid, inland catchments (rainfall 500–1000 mm/year) (McNeil et al. (2005)). Similar chemistry in groundwater suggests recent interaction with surface water. This example is from the Barratta Creek alluvium.

High sulphate–Low to moderate salinity, with anions dominated by SO_4**.** SO_4 concentrations in Queensland's natural waters are, on average, relatively low when compared to international data (McNeil et al. (2005)). SO_4, like Cl, is a conservative ion, and increases in prominence as salinity rises, but only 20 per cent of analyses with EC less than 5000 µS/cm in the GWDB have more than eight per cent, SO_4, and only 10 per cent have more than 12 per cent. The reason is probably the age and weathered character of much of the Queensland landscape, and the fact that most Tertiary volcanic activity was basaltic. High background levels of groundwater sulphate are only found where there is low relief and less than 500 mm rainfall, allowing gypsum to accumulate in the soil profile. The given example represents weathered alluvium and ferricrete from the south-eastern Gulf of Carpentaria around Einasleigh

Most common artesian groundwater–Moderately saline $NaHCO_3$. Ground waters from the eastern and central parts of the GAB are characterised by $NaHCO_3$ type waters, thought to be due to dissolution of carbonates in the aquifer, and cation exchange of Na for Ca and Mg (Herczeg et al. 1991). The example is from the Hooray Sandstone in the western QMDB.

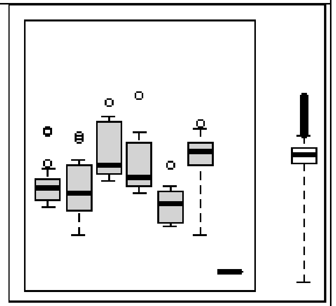
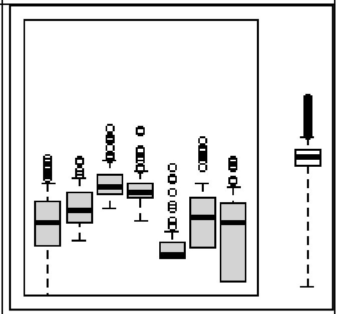
High nitrate–NO_3 greater than 1 mg/L. The common form of nitrogen analysed in groundwater is NO_3, because of the relatively anaerobic environment, and consequently its concentration is much less than other major ions. It is sourced from the surface, and reaches the groundwater when either the nitrogen supply is too great, or the leaching too rapid for the uptake capacity of plants. Although most occurrences of high NO_3 are anthropogenic in origin, natural sources such as native legumes, termite nests, birds inhabiting recharge waters, or some geological deposits can contribute. The highest concentrations of groundwater nitrate are generally closest to the water table, due to active denitrification processes deeper in the aquifer (Mull et al. 1991). The groundwater systems most vulnerable to nitrate contamination are sand and gravel or fractured rock (Spalding & Exner 1991). Moody (1996) considers that, at least in the US, NO_3-N concentrations greater than 3 mg/L (14 mg/L NO_3) in groundwater may be influenced by human activities. The median concentration in the GWDB is 1 mg/L (0.2 mg/L TN), with only 12 per cent exceeding 14 mg/L NO_3. Only 20 per cent of GWDB analyses have a NO_3 reading of over one per cent, and only 10 per cent have have more than three per cent NO_3. The example of high NO_3 waters shown is from the Toowoomba basalts. Another example of proportionately high NO_3 would be low salinity groundwaters from the Mulgrave River alluvium underlying the irrigation of sugar cane.

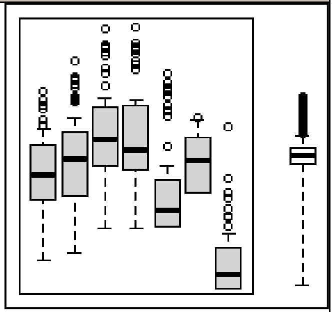
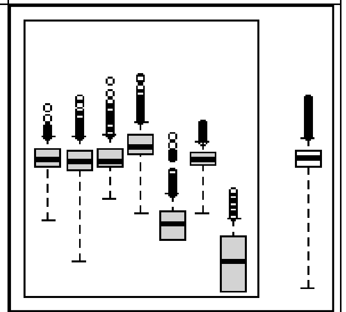
Data sufficiency

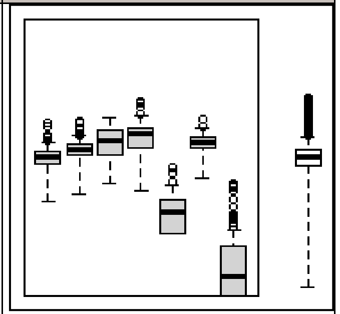
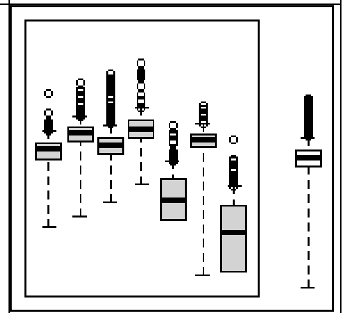
Data sufficiency in Table 8 is based on adequate samples per km^2. Note that for alluvial zones it is based on area of alluvium, rather than area of catchment.

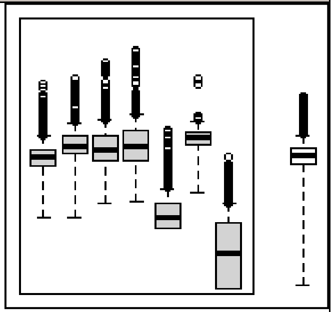
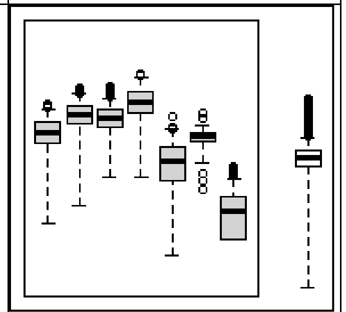
- ‘excellent’ >1 adequate samples per km^2
- ‘good’ 1–0.5 adequate samples per km^2
- ‘moderate’ 0.5–0.1 adequate samples per km^2
- ‘poor’ 0.1–0.05 adequate sample per km^2 or < 20 samplings overall
- ‘insufficient’ <0.05 adequate samples per Km^2 or < 8 samplings overall

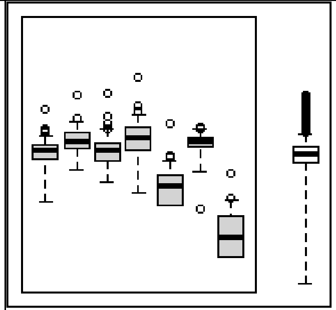
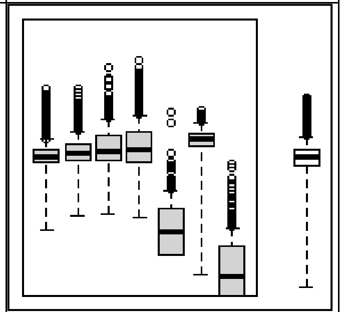
Table 8: Groundwater chemistry zone descriptions and characteristics

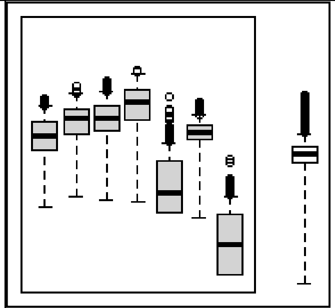
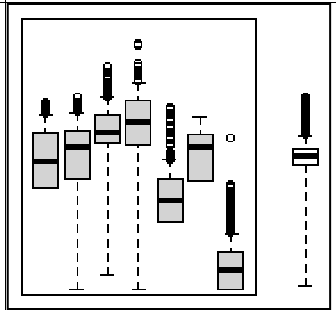
<table>
<tr><th rowspan="2">Aquifer class</th><th rowspan="2">Zone</th><th rowspan="2">* Data sufficiency</th><th colspan="2">Dominant Ions</th><th colspan="3">EC Percentiles (µS/cm)</th><th rowspan="2">Salinity description and major ion plots</th></tr>
<tr><th>Cations</th><th>Anions</th><th>20th</th><th>50th</th><th>80th</th></tr>
<tr><td rowspan="3">Alluvium Zone 1</td><td>1 - North Coast Alluvium</td><td>moderate</td><td>Na</td><td>HCO_3</td><td>255</td><td>455</td><td>1600</td><td>low EC variable</td></tr>
<tr><td>1 - North Coast Alluvium near stream</td><td>insufficient</td><td>Na</td><td>HCO_3</td><td>920</td><td>1600</td><td>1700</td><td>high</td></tr>
<tr><td colspan="7">Comments
The main aquifer is alluvium. Low salinity but EC can be variable: Na HCO_3 typical of a sandstone or granitic catchment.
The water is normally suitable for drinking, but only moderate for general purposes because of corrosive tendencies due to low EC and hardness. It is suitable for stock and irrigation although only moderate for sensitive crops because of occasional high EC or sodium levels. It is moderately compliant with surface water environmental guidelines. The EC record is poor and no long term or 10 year trends could be determined. Although the record is poor, water levels probably rose on average over the last 20 years. Water levels may be very shallow (under 5m) in places.</td><td></td></tr>
<tr><td rowspan="3">Alluvium Zone 2</td><td>2 - Glasshouses</td><td>moderate</td><td>Na</td><td>Cl NO_3</td><td>109</td><td>173</td><td>400</td><td>very low</td></tr>
<tr><td>2 - Glasshouses near stream</td><td>insufficient</td><td>Na</td><td>Cl NO_3</td><td>108</td><td>170</td><td>404</td><td>very low</td></tr>
<tr><td colspan="7">Comments
The main aquifer is alluvium. Very low salinity: Na Cl NO_3 typical of wallum country influenced by development.
The water is normally suitable for drinking, but poor for general purposes because it is moderately corrosive due to low EC, hardness, and pH. It is suitable for stock and moderately suitable for irrigation but poor for crops sensitive to low pH levels. It is incompatible with surface water environmental guidelines because levels of TN are usually elevated, and pH is usually too low. The long term EC and TN records are of moderate quality but no trends could be determined. There is a lack of recent data. Although the record is poor, water levels appear to have been stable over the past 20 years. The alluvium contains very shallow water levels (under 5m) in places.</td><td></td></tr>
<tr><td rowspan="2">Alluvium Zone 3</td><td>3 - Northern Moreton Bay Alluvium</td><td>moderate</td><td>Na</td><td>Cl</td><td>317</td><td>1100</td><td>6090</td><td>moderate EC variable</td></tr>
<tr><td>3 - Northern Moreton Bay Alluvium near stream</td><td>insufficient</td><td>Na Mg</td><td>HCO_3</td><td>872</td><td>1148</td><td>1674</td><td>moderate</td></tr>
</table>

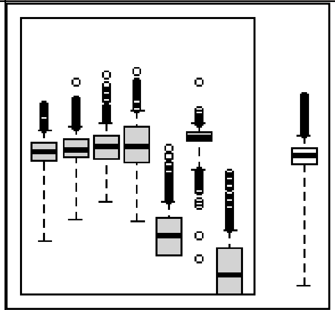
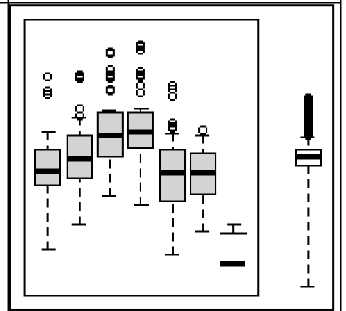
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is alluvium. Moderate salinity but EC can be variable: Na Cl typical of coastal alluvium. Near stream, it is moderately saline: Na > Mg, HCO3 typical of coastal alluvium. The water is normally suitable for drinking, but moderate for general purposes because of occasional corrosive tendencies due to low hardness. It is suitable for stock and moderately suitable for irrigation, but poor for crops sensitive high to EC and sodium levels. It is incompatible with surface water environmental guidelines because EC is usually elevated and TN at times also, while pH is occasionally too low. The long term EC and TN records are of moderate quality but no trends could be determined and there is a lack of recent data. Although the record is poor, water levels probably fell on average over the last 20 years. The alluvium contains very shallow and fluctuating water levels (under 5m) in places.							
Alluvium Zone 4	4 - Upper Brisbane	excellent	no dominant	Cl	626	957	1595	moderate
	4 - Upper Brisbane near stream	insufficient	no dominant	Cl	642	945	1496	moderate
	Comments The main aquifer is alluvium. Moderately saline: no dominant cations, Cl typical of GDR catchment. The water is normally suitable for drinking, and moderate for general purposes, with some incrustation tendency due to hardness. It is suitable for stock and irrigation, although only moderate for sensitive crops because EC is occasionally elevated. It is incompatible with surface water environmental guidelines because EC and TN are elevated. There is a lack of recent data, but based on a moderate quality record, EC appears to have been stable over the long term, while TN has probably fallen. A moderate quality record suggests that water levels probably rose on average over the last 20 years.							
Alluvium Zone 5	5 - Upper Lockyer Creek	excellent	Na Mg	Cl	982	1585	2150	high
	5 - Upper Lockyer Creek near stream	insufficient	Na Mg	Cl	968	1650	2240	high

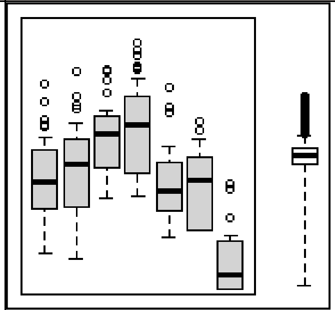
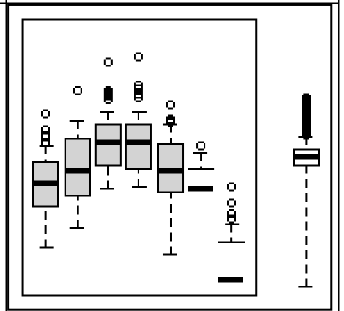
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is alluvium. Saline: Na > Mg, Cl typical of fine grained sediments with stagnant flow. The water is normally suitable for drinking, but poor for general purposes because of hardness with some incrustation. It is suitable for stock and irrigation although poor for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are elevated. A moderate quality long term record indicates that EC appears to have risen while TN probably fell, although no trends could be determined for the last 10 years. A moderate quality record suggests that water levels probably rose on average over the last 20 years.							
Alluvium Zone 6	6 - Central Lockyer Creek	excellent	Mg Na	Cl	1410	1990	3000	high
	6 - Central Lockyer Creek near stream	insufficient	Mg Na	Cl	1550	2080	3026	high
	Comments The main aquifer is alluvium. Saline: Mg > Na, Cl typical of basalt. The water is poor quality for drinking because of undesirably high EC. It is poor for general purposes because of high EC and hardness, with some incrustation. It is suitable for stock and irrigation, although poor for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are elevated. A moderate quality record indicates that EC appears to have risen over the long term, although no trend could be determined over the last 10 years. An adequate water level record indicates that water levels were fluctuating, and probably rose on average over the last 20 years.							
Alluvium Zone 7	7 - Lower Lockyer	excellent	Mg Na	HCO_3	820	1250	2084	moderate
	7 - Lower Lockyer near stream	insufficient	no dominant	HCO_3	820	1219	2020	moderate

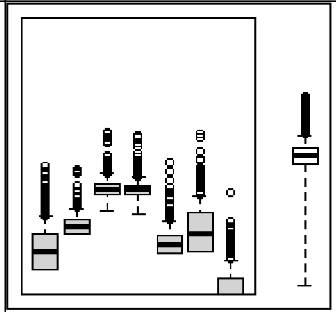
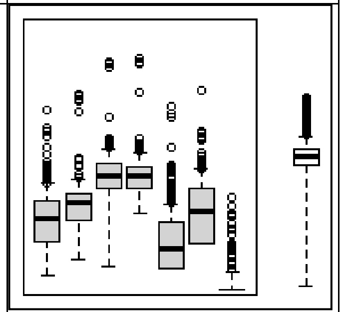
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is alluvium. Moderately saline: Mg > Na, HCO3 typical of basalt Near stream, it is moderately saline: no dominant cations, HCO3 typical of GDR with overlying basalt. The water is normally suitable for drinking, but poor for general purposes due to hardness with some incrustation. It is suitable for stock and irrigation although poor for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC, TN and occasionally pH are elevated. Although the records are poor, EC appears to have risen over the long term, while TN probably fell. A moderate quality record suggests that water levels were fluctuating, and probably rose on average over the last 20 years.							
Alluvium Zone 8	8 – South West Lockyer Tributaries	excellent	Mg Na	Cl	3314	5050	7918	very high
	8 – South West Lockyer Tributaries near stream	insufficient	Mg Na	Cl	3350	5050	7900	very high
	Comments The main aquifer is alluvium. Very Saline: Mg > Na, Cl typical of basalt. The water is poor quality for drinking and for general purposes because of very high EC and hardness with some incrustation. It is suitable for stock but poor quality for irrigation. EC is occasionally unsuitable for tolerant crops, and generally unsuitable for sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are elevated. A moderate quality record indicates that EC appears to have risen over the long term, while TN has been unstable. No trends could be determined over the last 10 years. A moderate quality record suggests that water levels were fluctuating, and probably rose on average over the last 20 years.							
Alluvium Zone 9	9 – Lockyer Southern Basaltic Headwaters	excellent	no dominant	Cl	770	1396	1900	moderate
	9 – Lockyer Southern Basaltic Headwaters near stream	insufficient	no dominant	Cl	1320	1700	2000	high

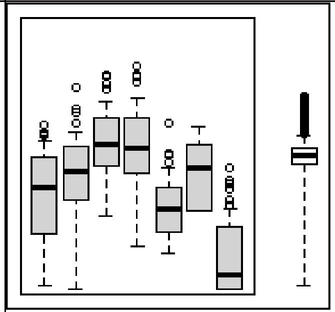
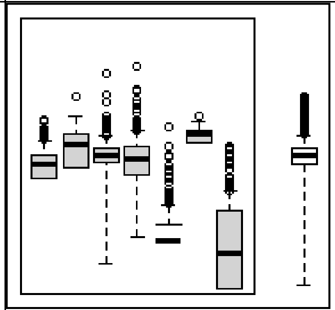
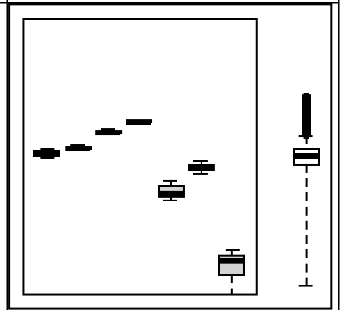
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is alluvium. Moderately saline: no dominant cations, Cl typical of GDR with overlying basalt Saline: no dominant cations, Cl typical of GDR with overlying basalt. The water is poor quality for drinking because of high EC, and for general purposes because of hardness with some incrustation. It is suitable for irrigation and stock, except for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are elevated. A moderate quality record indicates that EC probably rose over the long term, while no trends could be determined for TN or water levels.							
Alluvium Zone 10	10 – Warrill and Upper Bremer River	excellent	no dominant	HCO_3	780	1164	2076	moderate
	10 – Warrill and Upper Bremer River near stream	insufficient	no dominant	HCO_3	779	1096	2000	moderate
	Comments The main aquifer is alluvium. Moderately saline: no dominant cations, HCO_3 typical of GDR with overlying basalt. The water is normally suitable for drinking, but poor for general purposes due to hardness with possible incrustation. It is suitable for stock and irrigation although poor for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC, TN and occasionally pH are elevated. A moderate quality record indicates that EC appears to have risen over the long term although no trend could be determined over the last 10 years. No trends could be determined for TN. A moderate quality record suggests that water levels were fluctuating, and probably rose on average over the last 20 years.							
Alluvium Zone 11	11 – Gatton Sandstones Saline Area	excellent	Na Mg	Cl	2196	4275	7314	high
	11 – Gatton Sandstones Saline Area near stream	insufficient	Na Mg	Cl	2160	4075	7172	high

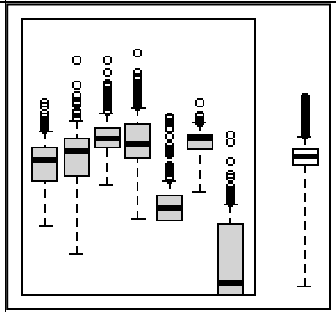
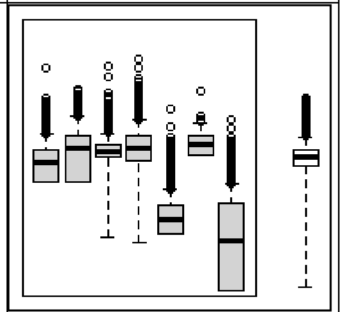
Aquifer class	**Zone**	*** Data sufficiency**	**Dominant Ions**		**EC Percentiles (µS/cm)**			**Salinity description and major ion plots**
			Cations	**Anions**	**20th**	**50th**	**80th**	
	Comments The main aquifer is alluvium. Saline: Na > Mg, Cl typical of fine grained sediments. The water is poor quality for drinking because of high EC levels. It is also poor for general purposes due to hardness with occasional incrustation. It is suitable for stock and irrigation although poor for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are usually elevated. Although the record is poor, EC appears to have risen over the long term, while TN probably fell. A moderate quality record suggests that water levels probably rose on average over the last 20 years.							
Alluvium Zone 12	12 – Lower Bremer	Insufficient data						
Alluvium Zone 13	13 – Logan and Albert	excellent	Na	Cl	869	2350	5200	high
	13 – Logan and Albert near stream	insufficient	no dominant	Cl	1800	3495	6733	high
	Comments The main aquifer is alluvium. Saline: typical of fine grained sediments. Saline: no dominant cations, Cl Great Dividing Range with overlying basalt. The water is poor quality for drinking because of high EC levels. It is also poor for general purposes due to high EC and hardness with some incrustation. It is suitable for stock but poor quality for irrigation. EC is occasionally unsuitable for tolerant crops, and generally unsuitable for sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are elevated. A moderate quality record indicates that EC appears to have risen over the long term, and TN probably fell. No trends could be determined over the last 10 years. An adequate record indicates that water levels were fluctuating, and probably rose on average over the last 20 years.							
Alluvium Zone 14	14 – Logan Albert Basaltic Headwaters	excellent	no dominant	HCO_3	809	1178	2220	moderate
	14 – Logan Albert Basaltic Headwaters near stream	insufficient	no dominant	HCO_3	842	1196	2314	moderate

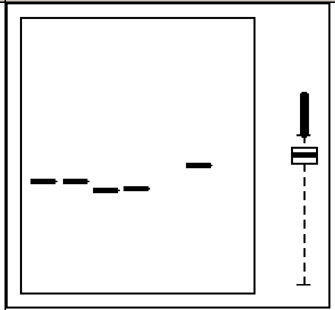
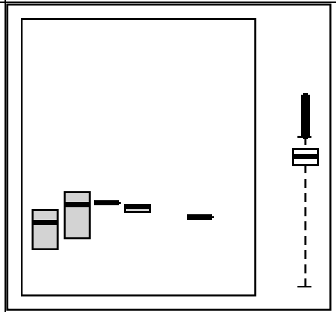
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is alluvium. Moderately saline: no dominant cations, HCO_3 GDR with overlying basalt Near stream, it is moderately saline: no dominant cations, HCO3 GDR with overlying basalt, influenced by development. The water is poor quality for drinking because of undesirably high EC levels. It is poor for general purposes due to high EC and hardness with some incrustation. It is suitable for stock but poor quality for irrigation. EC is occasionally unsuitable for tolerant crops, and generally unsuitable for sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are usually elevated, and pH is occasionally too low. A moderate quality long term record indicates that EC appears to have risen while TN probably fell, but no trends could be determined over the last 10 years. Although the record is poor, water levels probably rose on average over the last 20 years, and very shallow water levels occur (under 5 m) in places.							
Alluvium Zone 15	15 – Gold Coast Alluvials	moderate	Na	Cl	535	1500	7850	moderate EC variable
	15 – Gold Coast Alluvials near stream	insufficient	Na	Cl	1110	1500	3140	moderate
	Comments The main aquifer is alluvium. Moderate salinity but EC can be variable: Na Cl typical of coastal deposits. Moderately saline: Na Cl typical of coastal deposits, and possibly indicative of seawater intrusion. The water is poor quality for drinking because of very high EC. It is also poor for general purposes, due to high EC and hardness with occasional incrustation. It is suitable for stock and moderately suitable for irrigation although poor for sensitive crops because EC and sodium are frequently elevated. It is incompatible with surface water environmental guidelines because EC and TN are elevated. The record is poor and no long term trend could be determined for EC, although TN probably rose. A moderate quality record suggests that water levels probably rose on average over the last 20 years.							
Alluvium Zone 16	16 – Southern Deltaic and Estuarine Deposits	insufficient data	Na	Cl	573	12800	18260	
	The main aquifer is mud deposits. Salinity is high, but EC can be variable: Na Cl typical of coastal deposits.							
Alluvium Zone 17	17 – Moreton Bay Estuarine and Deltaic Area	moderate	Na	Cl	403	1675	11480	high EC variable
	17 – Moreton Bay Estuarine and Deltaic Area near stream	insufficient	Na	Cl	573	12800	18260	brackish

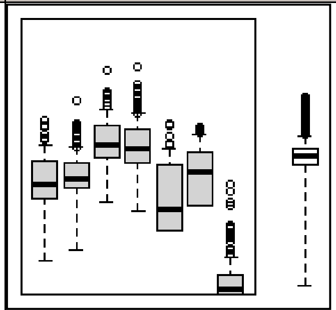
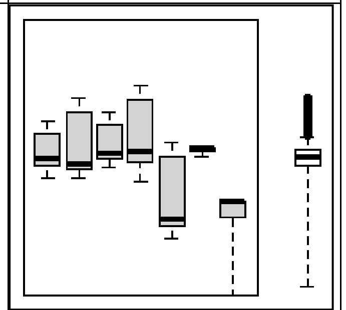
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is mud deposits. High salinity but EC can be variable: Na Cl typical of coastal deposits Near stream, the salinity is brackish: Na Cl typical of coastal deposits. The water is only moderate quality for drinking because EC may be undesirably high. It is also moderate for general purposes because of hardness with occasional incrustation. It is Generally suitable for stock, although EC is occasionally elevated, but poor quality for irrigation. EC is occasionally unsuitable for tolerant crops and generally unsuitable for sensitive crops. Sodium and fluoride may also be elevated for sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are usually elevated, and pH is usually too low. No EC or TN trends could be determined despite a moderate quality record. Although the record is poor, water levels were fluctuating, and probably fell on average over the last 20 years. There is little evidence of contamination, although the aquifer is in contact with seawater, and very shallow and fluctuating water levels (under 5 m) have been recorded in places.							
Alluvium Zone 18	18 – Pumicestone	good	Na	Cl	410	1100	2990	moderate EC variable
	18 – Pumicestone near stream	insufficient	Na	Cl	283	1100	1452	moderate
	Comments The main aquifer is mud deposits. Moderate salinity but EC can be variable: Na Cl typical of coastal deposits Near stream, it is moderately saline: Na Cl typical of coastal deposits. The water is normally suitable for drinking but moderate for general purposes, being variable in salinity and occasionally corrosive or incrusting. It is moderately suitable for stock, although EC is occasionally elevated, but poor quality for irrigation, with EC being occasionally unsuitable for tolerant crops and in some cases for crops that are sensitive to EC, sodium, or low pH levels. Fluoride may also exceed guidelines for sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are usually elevated, and pH is usually too low. The EC and TN record is poor, and no trends could be determined. Unable to determine water level trends because of lack of data. The aquifer may be susceptible to contamination because of contact with seawater and very shallow water levels (under 5 m) in places.							
Alluvium Zone 19	19 – Northern Estuarine Deposits	Insufficient data						
Alluvium Zone 20	20 – Southern Coastal Sands	Insufficient data						
Alluvium	21 – North Stradbroke and Moreton Islands	good	Na	Cl	87	112	148	very low

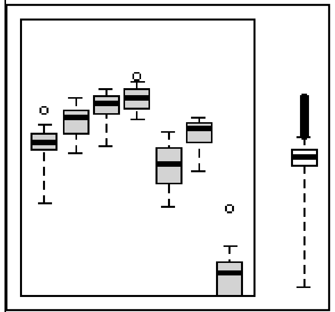
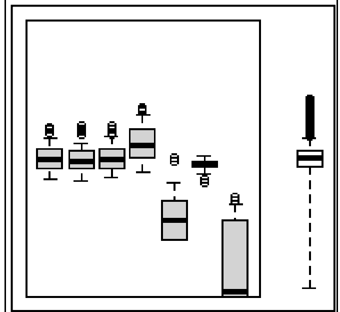
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
Zone 21	**Comments** The main aquifer is sand deposits. Very low salinity: Na Cl typical of wallum country. The water is normally suitable for drinking, but poor for general purposes because of corrosive tendencies due to low pH and hardness. It is suitable for stock and moderately suitable for irrigation but poor quality for crops that are sensitive to low pH levels. It is incompatible with surface water guidelines because TN and usually EC are elevated, and pH is occasionally too low. Although the record is poor, EC and TN appear to have fallen over the long term, with instability in EC and a probable fall in TN over the last 10 years. Although the record is poor, water levels were fluctuating, and probably fell on average over the last 20 years. The aquifer may be susceptible to contamination because of contact with seawater and very shallow water levels in places.							
Alluvium Zone 22	22 – Northern Coastal Sands	good	Na	Cl	132	258	426	low
	Comments The main aquifer is sand deposits. Low salinity: Na Cl typical of wallum country. The water is normally suitable for drinking, but poor for general purposes because of corrosive tendencies due to low pH and hardness. It is suitable for stock and moderately suitable for irrigation but poor quality for crops that are sensitive to low pH levels. It is incompatible with surface water environmental guidelines because EC and usually TN are elevated, and pH is occasionally too low. Although the record is poor, EC and TN appear to have fallen over the long term, with a probable fall in TN over the last 10 years. A moderate quality record suggests that water levels probably rose on average over the last 20 years. The aquifer may be susceptible to contamination because of contact with seawater and shallow water levels in places.							
Alluvium Zone 23	23 – Lower Brisbane River	poor	Na	Cl	254	890	2840	moderate EC variable
	23 – Lower Brisbane River near stream	insufficient	Na	Cl	698	1175	2360	moderate

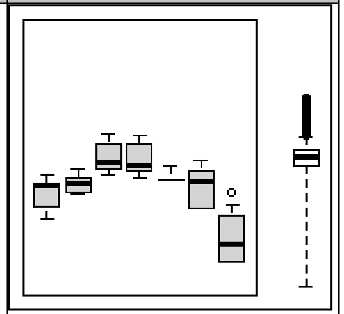
<table>
<tr><th rowspan="2">Aquifer class</th><th rowspan="2">Zone</th><th rowspan="2">* Data sufficiency</th><th colspan="2">Dominant Ions</th><th colspan="3">EC Percentiles (µS/cm)</th><th rowspan="2">Salinity description and major ion plots</th></tr>
<tr><th>Cations</th><th>Anions</th><th>20th</th><th>50th</th><th>80th</th></tr>
<tr><td></td><td colspan="7">Comments
The main aquifer is alluvium. Moderate salinity but EC can be variable: Na Cl typical of coastal deposits.
Near stream, it is moderately saline: Na Cl typical of coastal deposits.
The water is normally suitable for drinking, but poor for general purposes because of corrosive tendencies due to low pH and hardness. It is suitable for stock and moderately suitable for irrigation but poor quality for crops that are sensitive to low pH levels. It is incompatible with surface water environmental guidelines because EC and TN are elevated. Although the record is poor, EC and TN appear to have fallen over the long term, but no trend could be determined over the last 10 years. A moderate quality record suggests that water levels were fluctuating, and probably fell on average over the last 20 years. The aquifer may be susceptible to contamination because sand allows rapid penetration of surface contaminants. The aquifer may also be susceptible to contamination because of contact with seawater and very shallow water levels in places.</td><td></td></tr>
<tr><td rowspan="2">Fractured Rock 1</td><td>1 – Upper Condamine Basalts (cont)</td><td>moderate</td><td>Mg Na</td><td>HCO_3</td><td>688</td><td>1050</td><td>1500</td><td>moderate</td></tr>
<tr><td colspan="7">Comments
The main aquifer is Main Range Volcanics. Moderately saline: Mg > Na, HCO3 typical of basalt.
The water is normally suitable for drinking, and moderate for general purposes because of variable EC and occasional corrosiveness or incrustation. It is suitable for stock and moderately suitable for irrigation but may be poor quality for crops that are sensitive to pH, high EC or sodium. It is incompatible with surface water environmental guidelines because TN, usually EC, and occasionally pH are elevated. Basalt aquifers may be susceptible to contamination from the surface because water infiltrates quite rapidly with little soil interaction.</td><td></td></tr>
<tr><td rowspan="2">Fractured Rock 2</td><td>2 – Lower Condamine Basalts (cont) weathered</td><td>insufficient</td><td>Na Mg</td><td>Cl</td><td>2088</td><td>2100</td><td>2100</td><td>high</td></tr>
<tr><td colspan="7">Comments
The main aquifer is Main Range Volcanics. Saline: Na > Mg, Cl typical of GDR overlain by basalt.
Insufficient data to rate for EVs.
Basalt aquifers may be susceptible to contamination from the surface because water infiltrates quite rapidly with little soil interaction. The aquifer is also shallow and is therefore susceptible to stress from declining water levels.</td><td></td></tr>
</table>

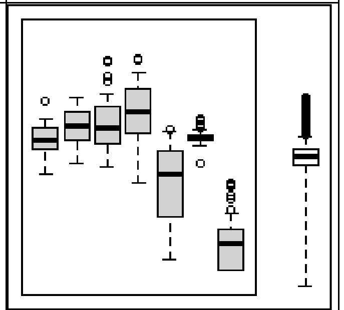
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
Fractured Rock 3	3 – Lower Condamine Basalts (cont)	moderate	Na Mg	HCO_3 Cl	810	1300	2600	moderate
	Comments The main aquifer is Main Range Volcanics. Moderately saline: Na > Mg, HCO_3 > Cl typical of GDR overlain by basalt. The water is normally suitable for drinking, but moderate for general purposes because of some hardness and incrustation. It is suitable for stock and moderately suitable for irrigation but may be poor for salt sensitive crops. It is Generally compatible with surface water environmental guidelines. Basalt aquifers may be susceptible to contamination from the surface because water infiltrates quite rapidly with little soil interaction.							
Fractured Rock 4	4 – Toowoomba Region Basalts (cont)	excellent	Mg Na	HCO_3 Cl	660	1178	1809	moderate
	Comments The main aquifer is Main Range Volcanics. Moderately saline: Mg > Na, HCO_3 > Cl typical of basalt. Moderately suitable for domestic and general uses. Good quality for drinking, acceptable aesthetically with some hardness or scaling. The groundwater is moderately suitable for irrigation, being poor for sensitive crops although suitable for tolerant crops. It is suitable for stock. The groundwater is compatible with surface water environmental guidelines. Basalt aquifers may be susceptible to contamination from the surface because water infiltrates quite rapidly with little soil interaction. .							
Fractured	5 – Toowoomba Region Basalts (cont) weathered	insufficient	Ca Mg	HCO3	255	255	255	low

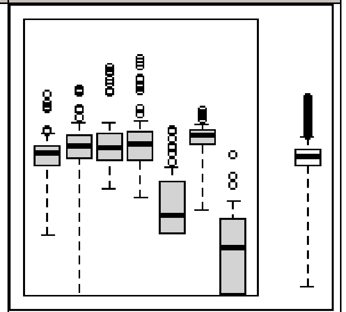
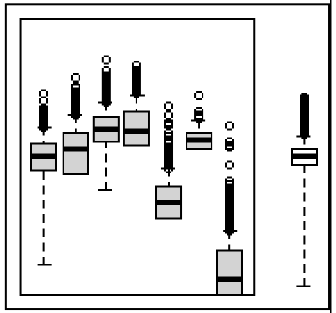
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
Rock 5	**Comments** The main aquifer is Main Range Volcanics. Low salinity: Ca > Mg, HCO_3 typical of rangelands. Insufficient data to rate for EVs. Basalt aquifers may be susceptible to contamination from the surface because water infiltrates quite rapidly with little soil interaction.							
Fractured Rock 6	6 – Lamington Basalt	insufficient	Na		55	57	59	very low
	Comments The main aquifer is Albert Basalts, Hobwee Archerfield and Beechmont Basalts. Very low salinity: Na, typical of GDR overlain by basalt. Insufficient data to rate for EVs. Basalt aquifers may be susceptible to contamination from the surface because water infiltrates quite rapidly with little soil interaction.							
Fractured Rock 7	7 – Mount Tamborine	insufficient data						
Fractured Rock 8	8 – Sunnybank weathered basalt remnants	insufficient data						
Fractured Rock 9	9 – Northern Basalts (cont)	insufficient data						
Fractured Rock 10	10 – North East Mesozoic Volcanics	insufficient data						
Fractured	11 - Eastern Trap Rocks	insufficient	Na	Cl	521	1000	1732	moderate

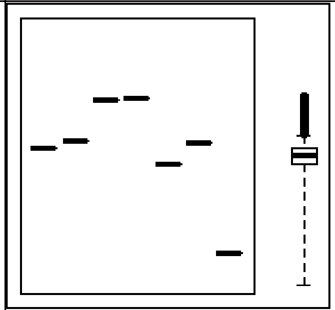
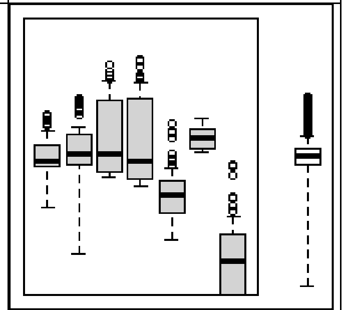
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
Rock 11	**Comments** The main aquifer is Paleo Sediments, Volcanics, and Metamorphics, and rare granite. Moderately saline: Na Cl typical of GDR. The water is normally suitable for drinking, and moderate for general purposes despite a tendency to be corrosive. It is suitable for stock and generally suitable for irrigation, although EC or sodium are occasionally elevated for sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are usually elevated. The aquifer may be vulnerable to contamination because it has very shallow water levels (under 5m) in places. It is also shallow (under 30m deep) and is therefore vulnerable to declining water levels.							
Fractured Rock 12	12 - Western Great Dividing Range	insufficient	no dominant	HCO_3 Cl	709	990	5256	moderate EC variable
	Comments The main aquifer is granite with Maronghi Beds, Sugarloaf Metamorphics, and Main Range Volcanics. Moderate salinity but EC can be variable: no dominant cations, HCO3 > Cl typical of GDR. Insufficient data to rate for EVs.							
Fractured	13 - Esk Trough Paleozoic sediments	insufficient	Na Mg	Cl	4050	6005	8100	very high

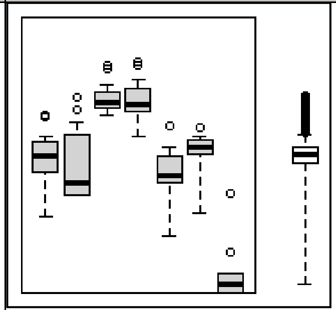
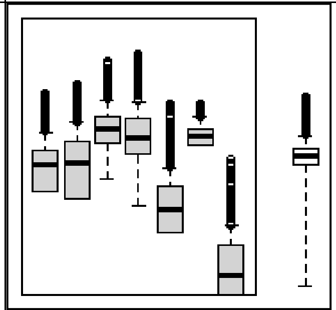
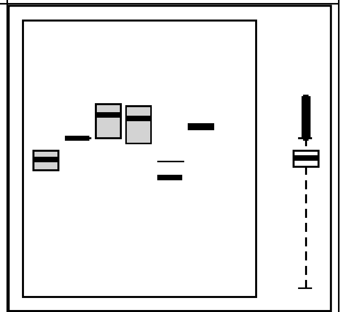
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
Rock 13	**Comments** The main aquifer is the Esk Formation Maronghi Beds. Very Saline: Na > Mg, Cl typical of poorly drained fine sediment. The water is normally suitable for drinking and moderate for general purposes. It is suitable for stock and moderately suitable for irrigation but poor for crops that are sensitive to low pH, high sodium, or high EC. It is incompatible with surface water environmental guidelines because EC is elevated.							
Fractured Rock 14	14 - North Eastern Great Dividing Range	insufficient data						
Fractured Rock 15	15 - Cressbrook Creek	moderate	no dominant	Cl	648	975	1800	moderate
	Comments The main aquifer is the Cressbrook Creek Group with Bjelke Petersen Beds. Moderately saline: no dominant cations, Cl typical of GDR. The water is normally suitable for drinking, and moderate for general purposes despite a tendency for incrustation. It is suitable for stock and irrigation although moderate for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC is elevated, and TN and pH also occasionally.							
Fractured Rock 16	16 - Northern Granite Outcrops	insufficient data						
Cainozoic deposits,	1 - Petrie Basin	insufficient	Na Ca	Cl	348	536	1134	moderate

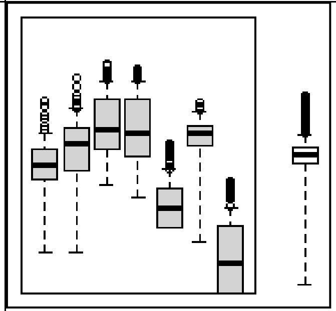
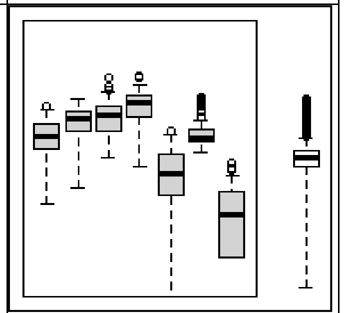
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
including sediments overlying the GAB 1	**Comments** The main aquifer is the Petrie Formation. Moderately saline: Na > Ca, Cl typical of fine grained sediment influenced by development. The water is normally suitable for drinking and moderate for general purposes. It is suitable for stock and irrigation although moderate for crops that are sensitive to high EC. It is incompatible with surface water environmental guidelines because TN may be elevated.							
Cainozoic deposits, including sediments overlying the GAB 2	2 - Central Tertiary Sediments	insufficient data						
Cainozoic deposits, including sediments overlying the GAB 3	3 - Sediments Overlying Coal Measures	insufficient data						
Cainozoic deposits, including sediments overlying the GAB 4	4 - Amberley Basin	insufficient data						
Cainozoic deposits, including sediments overlying the GAB 5	5 - Beaudesert Beds	insufficient data						
Deposits overlying	6 - Duricrust Main Range	insufficient data						

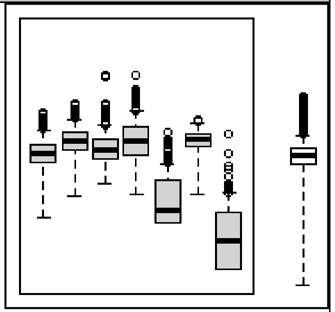
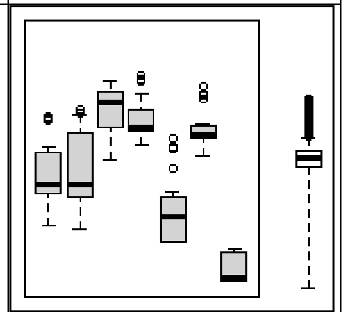
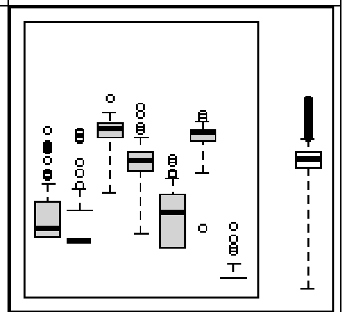
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
GAB 6								
Cainozoic deposits, including sediments overlying the GAB 7	7 - Minor Weathered Tertiary Deposits	insufficient data						
Cainozoic deposits, including sediments overlying the GAB 8	8 - Northern Tertiary Remnants	insufficient data						
Cainozoic deposits, including sediments overlying the GAB 9	9 - Sandy Creek Saline Weathered Alluvium	moderate	Na Mg	Cl	1580	3600	7824	High
	Comments The main aquifer is Weathered Alluvium. Saline: Na > Mg, Cl typical of GDR overlain by basalt. The water is unsuitable for drinking because of very high EC. It is poor for general purposes because of high EC and hardness, with tendency for incrustation. It is suitable for stock but poor quality for irrigation. EC and occasionally sodium are unsuitable for sensitive crops and occasionally for tolerant crops also. It is incompatible with surface water environmental guidelines because EC and TN and occasionally pH are elevated.							
Cainozoic deposits,	10 - Minor Weathered Tertiary Deposits	insufficient	no dominant	HCO_3	867	1450	2234	moderate

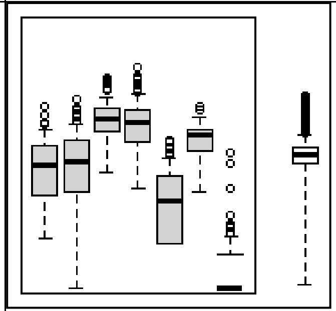
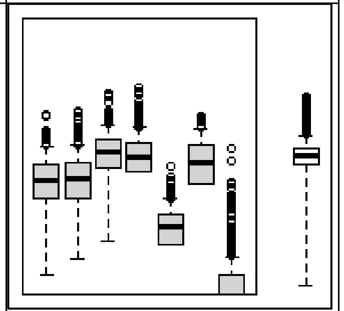
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
including sediments overlying the GAB 10	**Comments** The main aquifer is Weathered Cainozoic deposits bordering Alluvium or Basalt. Moderately saline: no dominant cations, HCO_3 typical of GDR overlain by basalt. The water is normally suitable for drinking but poor for general purposes, with high levels of hardness and a tendency for incrustation. It is suitable for stock and moderately suitable for irrigation apart from salt sensitive crops. It is incompatible with surface water environmental guidelines.							
Lower GAB 1	1 – South Eastern Hutton Outcrop (cont)	moderate	Na Ca	Cl	1100	1780	3806	high
	Comments The main aquifer is Hutton, with its equivalent as the Koukandowie or other Marburg formations. Saline: Na > Ca, Cl typical of poorly drained sandstone. The water is only moderate for drinking because EC may be high. It is poor for general purposes because of high EC and hardness. with a moderate tendency for incrustation. It is suitable for stock and moderately suitable for irrigation apart from crops sensitive to high EC and occasionally sodium. It is incompatible with surface water environmental guidelines because EC and TN and occasionally pH are elevated.							
Lower GAB	2 - Central Huttons	insufficient	Na	Cl	id	5009	id	very high

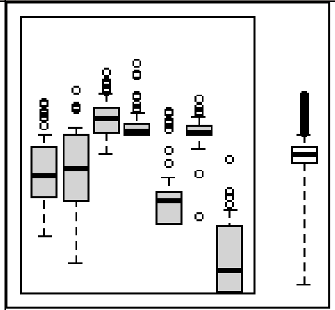
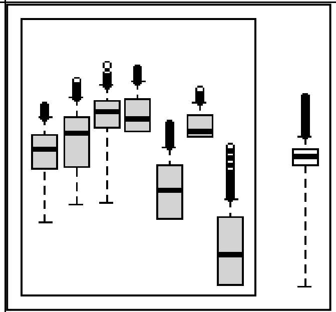
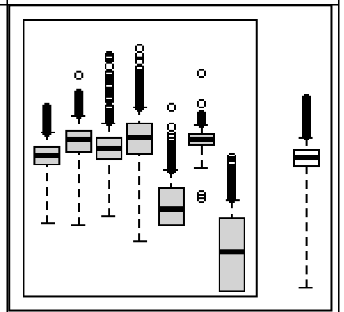
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
2	**Comments** The main aquifer is the Hutton or overlying Injune. Very Saline: Na Cl typical of fine grained sediment poorly drained. Insufficient data to rate for EVs.							
Lower GAB 3	3 - Laidley Creek Sandstones	poor	no dominant	HCO_3	551	1143	7884	moderate EC variable
	Comments The main aquifer is the Hutton or equivalent Koukandowie or other Marburg formations, some Injune. Moderate salinity but EC can be variable: no dominant cations, HCO3 typical of GDR overlain by basalt. The water is normally suitable for drinking, but poor for general purposes because of variable EC and high levels of hardness with moderate incrusting tendencies. It is suitable for stock but poor quality for irrigation. EC is elevated for sensitive crops and occasionally for tolerant crops also. It is incompatible with surface water environmental guidelines because EC and TN and occasionally pH are elevated.							
Lower GAB	4 – South Eastern Marburgs	insufficient	Na	Cl	3160	4100	9200	high

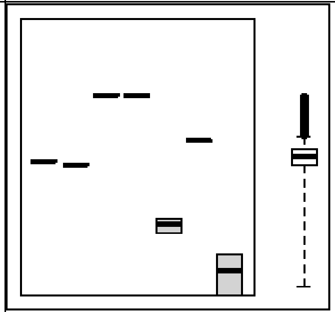
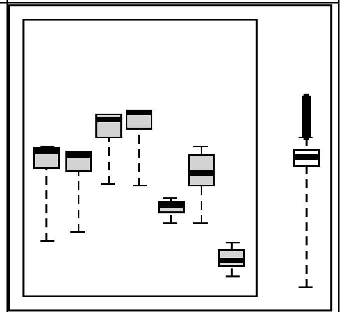
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
4	**Comments** The main aquifer is mainly the Marburg formation. Saline: Na Cl typical of fine grained sediments. Insufficient data to rate for EVs.							
Lower GAB 5	5 - South East Walloons (cont)	moderate	Na	HCO_3 Cl	930	1640	3300	high
	Comments The main aquifer is the Walloon, with associated Injune and occasional underlying Hutton. Saline: Na, HCO_3 > Cl typical of fine grained sediments. The water is poor to moderate quality for drinking because EC may be high. It is also poor for general purposes because of high levels of EC and hardness with occasional incrustation. It is suitable for stock and moderately suitable for irrigation, but EC and sodium may be elevated for sensitive crops. It is moderately compliant with surface water environmental guidelines but EC TN and occasionally pH may be elevated.							
Lower GAB 6	6 - Logan Albert Walloons	insufficient	Na	Cl	id	5070	id	very high
	Comments The main aquifer is the Walloon Coal Measures. Very Saline: Na Cl typical of fine grained sediments. Insufficient data to rate for EVs.							

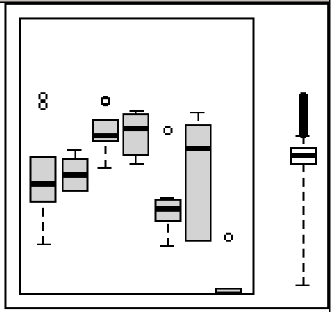
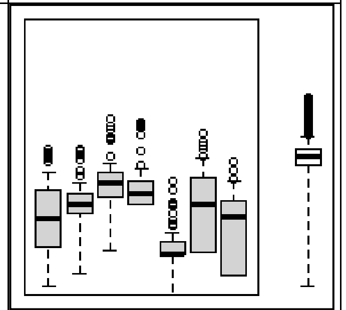
<table>
<tr><th rowspan="2">Aquifer class</th><th rowspan="2">Zone</th><th rowspan="2">* Data sufficiency</th><th colspan="2">Dominant Ions</th><th colspan="3">EC Percentiles (µS/cm)</th><th rowspan="2">Salinity description and major ion plots</th></tr>
<tr><th>Cations</th><th>Anions</th><th>20th</th><th>50th</th><th>80th</th></tr>
<tr><td rowspan="2">Lower GAB 7</td><td>7 - Locker Valley Sandstones</td><td>moderate</td><td>Na</td><td>Cl</td><td>642</td><td>1863</td><td>6120</td><td>high EC variable</td></tr>
<tr><td colspan="7">Comments
The main aquifer is Injune, with some underlying Hutton or other Marburg aquifers. High salinity but EC can be variable: Na Cl typical of fine grained sediments.
The water is moderately suitable for drinking, but EC may be undesirably high. Poor for general purposes because of variable EC and high levels of hardness with incrusting tendencies. It is suitable for stock and moderately suitable for irrigation, but EC and sodium may be elevated for sensitive crops. It is incompatible with surface water environmental guidelines because EC, TN and occasionally pH are elevated.
.</td><td></td></tr>
<tr><td rowspan="2">Lower GAB 8</td><td>8 - Lockyer Valley Southern Headwaters</td><td>moderate</td><td>Mg Na</td><td>Cl</td><td>3000</td><td>5010</td><td>6652</td><td>very high</td></tr>
<tr><td colspan="7">Comments
The main aquifer is the Injune, with other overlying Marburg aquifers. Very Saline: Mg > Na, Cl typical of basalt.
The water is poor quality for drinking because of very high EC, and nitrate levels which may exceed health guidelines. It is poor for general purposes because of high EC and hardness, with some incrustation. It is suitable for stock and moderately suitable for irrigation but EC and occasionally sodium are elevated for sensitive crops. It is moderately compatible with surface water environmental guidelines but pH is usually elevated.</td><td></td></tr>
<tr><td>Lower GAB 9</td><td>9 - Lockyer Sandstones Recharged Area</td><td>excellent</td><td>no dominant</td><td>HCO_3</td><td>943</td><td>1450</td><td>2256</td><td>moderate</td></tr>
</table>

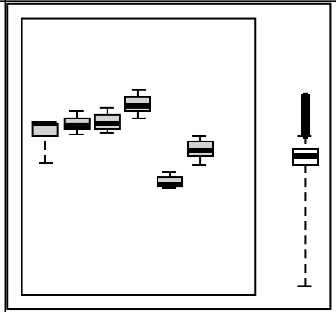
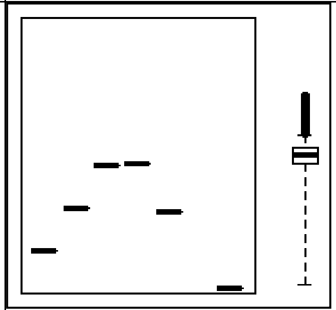
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is the Injune. Moderately saline: no dominant cations, HCO3 typical of GDR overlain by basalt. The water is normally suitable for drinking, but poor for general purposes because of high levels of hardness with some incrustation. It is suitable for stock and moderately suitable for irrigation, but EC is elevated for sensitive crops. It is incompatible with surface water environmental guidelines because EC, pH usually TN are elevated.							
Basal GAB 1	1 - Eastern Evergreen Outcrop (cont)	poor	Na	Cl	1400	2950	5524	high
	Comments The main aquifer is the Evergreen Formation. Saline: Na Cl typical of fine grained sediments. The water is poor quality for drinking because of undesirably high EC, and fluoride levels which may exceed health guidelines. It is moderate for general purposes, because of the high levels of EC and hardness with occasional incrustation. It is moderately suitable for stock, but bores should be tested for elevated fluoride. It is Poor quality for irrigation because EC is elevated for sensitive crops, and frequently for tolerant crops. Sodium or fluoride may also be elevated for sensitive crops. It is compatible with surface water environmental guidelines although pH is occasionally elevated.							
Basal GAB 2	2 - Eastern Central Area (cont)	poor	Na	HCO_3	946	1260	1742	moderate
	Comments The main aquifer is the Woogaroo, with some Evergreen in the west. Moderately saline: Na HCO3 typical of sandstone. The water is poor quality for drinking because fluoride levels may exceed health guidelines. It is poor for general purposes. It is moderately suitable for stock, but bores should be tested for elevated fluoride. It is poor quality for irrigation because EC is elevated for sensitive crops and occasionally for tolerant crops. Sodium or fluoride also tend to be elevated for sensitive crops. It is moderately compliant with surface water environmental guidelines, but TN and EC are elevated at times.							

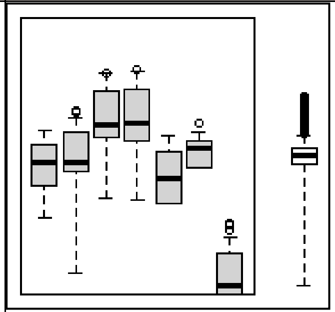
Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
Basal GAB 3	3 – South Eastern Evergreen (cont)	insufficient	Na	Cl	1047	2325	3788	high
	Comments The main aquifer is assumed to be the Woogaroo Subgroup. Saline: Na Cl typical of fine grained sediments. The water is poor quality for drinking because of undesirably high EC. It is only moderate for general purposes because of the high EC with occasional incrustation tendencies. It is suitable for stock but poor quality for irrigation. EC is elevated for sensitive crops, and occasionally for tolerant crops. Sodium also tends to be elevated for sensitive crops. It is compatible with surface water environmental guidelines.							
Basal GAB 4	4 – Beuaraba Woogaroo	good	Na	Cl	274	683	1250	moderate
	Comments The main aquifer is the Woogaroo with some Gatton and Precipice Sandstones. Moderately saline: Na Cl typical of fine grained sediments. The water is normally suitable for drinking, but only moderate for general purposes because of occasional corrosive tendencies due to the low pH and hardness. It is suitable for stock and irrigation although only moderate for salt sensitive crops because EC occasionally excessive. It is incompatible with surface water environmental guidelines because EC and TN are elevated.							
Basal GAB 5	5 – Gatton Sandstone South Western Headwaters	excellent	Na	Cl	1600	1850	2920	high

Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
	Comments The main aquifer is the Evergreen. Saline: Na Cl typical of fine grained sediments. The water is of poor quality for drinking because EC may be elevated. It is only moderate for general purposes because of hardness with some incrustation. It is suitable for stock but poor quality for irrigation because EC is generally unsuitable for sensitive crops and occasionally for tolerant crops. Sodium is also occasionally elevated for sensitive crops. It is incompatible with surface water environmental guidelines because EC and TN are elevated.							
Basal GAB 6	6 - Gatton Sandstone Saline Area	excellent	Na Mg	Cl	2196	3740	6258	high
	Comments The main aquifer is mixed but mainly Evergreen and Gatton. Saline: Na > Mg, Cl typical of fine grained sediments poorly drained. The water is poor quality for drinking because of high EC. It is poor for general purposes because of high EC and hardness with some incrustation tendency. It is suitable for stock and moderately suitable for irrigation, but EC is generally elevated for sensitive crops, with sodium occasionally being elevated also. It is incompatible with surface water environmental guidelines because EC, TN and occasionally pH are elevated.							
Basal GAB 7	7 - Lower Lockyer Recharged Area	excellent	Mg Na	HCO_3 Cl	980	1650	2600	high
	Comments The main aquifer is the Evergreen and Gatton. Saline: Mg > Na, HCO3 > Cl typical of basalt. The water is moderately suitable for drinking, but EC may occasionally be elevated. It is poor for general purposes because of hardness and some incrustation. It is suitable for stock and moderately suitable for irrigation, except occasionally for salt sensitive crops. It is incompatible with surface water environmental guidelines because EC, TN and occasionally pH are elevated.							

Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
Basal GAB 8	8 - Logan Albert Sandstones	insufficient	Na	Cl	6320	6350	6380	very high
	Comments The main aquifer is the Gatton with some Woogaroo. Very Saline: Na Cl typical of typical of fine grained sediments poorly drained. Insufficient data to rate for EVs. Insufficient data to rate suitability, but fluoride levels have been detected which may exceed health guidelines.							
Basal GAB 9	9 - Albert River Woogaroo	insufficient	Na	Cl	1498	2565	2918	high
	Comments The main aquifer is the Woogaroo Subgroup. Saline: Na Cl typical of fine grained sediments. Insufficient data to rate for EVs.							
Basal GAB	10 - Clarence Moreton Nambour Connection	insufficient	Na	Cl	762	1380	6160	moderate EC variable

Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
10	**Comments** The main aquifer is the Woogaroo but includes Aspley. Moderate salinity but EC can be variable: Na Cl typical of fine grained sediments influenced by development. Insufficient data to rate for EVs.							
Basal GAB 11	11 - Nambour Basin	insufficient	Na Ca	Cl NO_3	119	192	368	very low
	Comments The main aquifer is the Landsborough Sandstone. Very low salinity: Na > Ca, Cl NO3 typical of wallum country. The water is normally suitable for drinking, but poor for general purposes because of corrosive tendencies due to low EC, pH and hardness. It is suitable for stock and moderately suitable for irrigation but poor quality for crops which are sensitive to low pH. It is incompatible with surface water environmental guidelines because EC and TN are elevated, and pH is usually too low.							
Basal GAB 12	12 - Eudlo Creek Nambour Formation	Insufficient data						
Basal GAB 13	13 - Kin Kin Beds	Insufficient data						
Basal GAB 14	14 - Noosa River Sandstone	Insufficient data						
Basal GAB	15 - Tarong Basin	insufficient	Na Mg	Cl	id	id	id	unknown

Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
15	**Comments** The main aquifer is the Tarong Beds. Unknown salinity: Na > Mg, Cl typical of GDR overlain by basalts. Insufficient data to rate for EVs.							
Basal GAB 16	16 - Southern Moreton Bay and Barrier Islands	insufficient	Na	Cl	305	305	305	low
	Comments The main aquifer is probably the Landsborough Sandstone. Low salinity: Na Cl typical of wallum country. Insufficient data to rate for EVs.							
Basins	1 - Logan Coal Measures	moderate	Na	Cl	1104	2150	8940	high EC variable

Aquifer class	Zone	* Data sufficiency	Dominant Ions		EC Percentiles (µS/cm)			Salinity description and major ion plots
			Cations	Anions	20th	50th	80th	
underlying GAB 1	**Comments** The main aquifer is the Ipswich Coal Measures with some Tingalpa Formation. High salinity but EC can be variable: Na Cl typical of fine grained sediment. The water is poor for drinking because EC is variable and frequently undesirably high. It is moderate for general purposes, although EC may be high and variable, with occasional incrustation. It is suitable for stock but poor quality for irrigation because EC may be elevated for sensitive crops, and occasionally for tolerant crops also. May also be unsuitable for crops sensitive to elevated sodium, or low pH levels. It is incompatible with surface water environmental guidelines because pH is too low.							
Basins underlying GAB 2	2 - Brisbane Coal Bearing Beds	Insufficient data						
Basins underlying GAB 3	3 - Ipswich Coal Deposits	Insufficient data						
Basins underlying GAB 4	4 - Kholo Sediments and Volcanics	Insufficient data						

Notes to Table 8

1. Aquifer class and chemistry zone: refer to descriptions (including Table 7) and mapping in this report. In some locations (mainly within the alluvial aquifer class) a chemistry zone is identified by the entire zone and the ‘near stream’ (within 1.5km of stream channel) component of the zone, where near stream water quality characteristics may be different from overall zone. Overall zone includes near stream and other areas. Near stream zone is shown on large scale plans accompanying this report, available on the department’s website. Since it is known that alluvial boundaries are not precise at a local scale, any bores designated as alluvium within a catchment are subject to the criteria of the catchment alluvial zone, even if there is no presently-known alluvium in the catchment.

2. Data reliability for making comparisons with water suitability is based on adequate samples per km^2: ‘excellent’ >1; ‘good’ 1–0.5; ‘moderate’ 0.5–0.1; ‘poor’ 0.1–0.05 or < 20 samplings overall; and ‘insufficient’ <0.05 adequate samples per Km^2 or < 8 samplings overall. Sample numbers for each chemistry zone are provided in Table 2. Data sufficiency in Table 8 is based on adequate samples per km^2. Note that for alluvial zones it is based on area of alluvium, rather than area of catchment.

3. EC percentiles: refer to Table 9 for greater detail on EC and other indicator percentiles.

4. Comparison with guideline values. Note that to ascertain suitability of a specific water source (e.g. a bore) for a given use (e.g. irrigation) more detailed testing may be required, and the broad results in Table 8 are not intended to provide this level of detail. The following values have been used for comparison purposes in Table 8. Note that these are indicative/average values and variations in tolerances will occur within a given water use (e.g. according to stock or crop type) and according to particular groundwater source. Outliers may have lower suitability than other percentile values:

<u>Stock:</u>

- Total dissolved solids (TDS) is a measure of salinity which is roughly proportional to EC. TDS guideline values for stock are based on tolerances and effects on stock condition etc. They vary by type of stock, with sheep being the most resilient and poultry and dairy cattle being among the most vulnerable. Refer to ANZECC 2000 Table 4.3.1 for more details applicable to particular stock tolerances. The guideline value of <6,000mg/L which is used here to assess suitability, equates to approximately EC<10,000µs/cm (rounded), and is the level at which moderately tolerant stock such as horses and pigs may start to lose condition (Table 9.3.3 “Tolerances of livestock to total dissolved solids (salinity) in drinking water”, P 9.3–11, Volume 3, Primary industries, Chapter 9, ANZECC 2000).
- Nitrogen in groundwater is virtually all in the form of nitrate, because organic nitrogen is broken down or recycled by chemical and biological processes in the soils and unsaturated zone (Hem 1985, DeSimone & Howes 1998). Therefore, the nitrate/nitrite guideline given in ANZECC section 4.3.3.3 is a satisfactory representation of total nitrogen in groundwater. This is equivalent to TN <90mg/L.
- F <2mg/L – ANZECC 2000 Table 4.3.2, page 4.3–5
- Note that livestock water quality guidelines are currently under review as part of ANZG. Refer to the ANZG website for updates.

Hem, JD 1985, 'Study and Interpretation of the Chemical Characteristics of Natural Water'. USGS Water Supply Paper 2254, 3. US Govt. Printing Office, Washington, DC., 264 p.

DeSimone, LA & Howes, BL 1998, 'Nitrogen transport and transformations in a shallow aquifer receiving wastewater discharge: A mass balance approach'. Water Resources Research, vol. 34, no 2: 271-285.

<u>Irrigation:</u>

- Irrigation water quality requirements vary according to multiple factors, e.g. crop type and tolerances, root zone, soil characteristics and whether application is under short term or longer term conditions. Refer to ANZECC (2000) section 4.2.4 for further details (including Table 4.2.4 and 4.2.5). Values adopted for comparison are:
- EC short term < 7,000µS/cm; long term/sensitive crops < 1,000µS/cm. Sources: ANZECC 2000 Section 4.2.4.1 ‘Irrigation salinity and sodicity’, and Chapter 9 Sections 9.2.1 and 9.2.3, explain the complex relationship between salt tolerance, soil type, and the salinity of irrigation water, and the problems with picking general guidelines. These values were selected and adapted from Table 9.2.5, with 1,000µS/cm being mid-range for moderately sensitive crops such as most fruit, and 7,000µS/cm being towards the upper limit for very tolerant crops such as cotton.
- Sodium Adsorption Ratio (SAR) is related to the percentages of calcium and magnesium in the water. It affects soil structure and permeability, particularly over time, with the Impact depending on salinity, soil structure, and rainfall and crop type. The guidelines adopted from ANZECC (2000) Table 9.2.15, Table 9.2.6 and Figure 9.2.3, are <8 SAR, which may cause leaf damage to very sensitive crops or long term damage to the structure of clayey soils, and <46, above which soil structure is likely to be damaged over time, and moderately sensitive crops can suffer stunted growth. Refer to ANZECC (2000) Section 9.2.3 ‘Salinity and sodicity’ for more details.
- F <2 mg/L – which is the short-term trigger value for irrigation water given in ANZECC (2000) Section 9.2.5.11 ‘Fluoride’.
- Note that under the ANZG program irrigation water quality guidelines are currently under review. Refer to ANZG website for updates.

<u>Domestic use:</u>
Corrosiveness/fouling: The following have been applied as an indication of water quality corrosion and fouling potential relating to general farm/domestic use (impacts on wells, pumping, pipeline, storage tanks, etc.). Source: ANZECC (2000), section 4.2.10.

- pH: 5-8.5
- hardness ($CaCO_3$): 60-350mg/L
- LSI: >2 - The Langelier Saturation Index (LSI) is mainly a predictor of fouling. A value of 2 is scale forming but non corrosive, CAC (1965).
- Ryznar Index: <6. The Ryznar Stability Index (RSI) is based on a number of variables, and is similar to the LSI but tends to give more conservative results. Scaling becomes more likely as the level drops below 6. This measure is not considered a good indicator of corrosion, although this may occur due to other factors at levels above 6 (CAC 1965)
- LR: >10 - The Larson-Skold Index (LR) is based on the ratio between sulphate and chloride to bicarbonate and carbonate. Withers (2005) reports that waters are less likely to be corrosive if the LR is below 0.8, but increasingly likely as the LR exceeds 1.2.

<u>Drinking water:</u>
The health and aesthetic guidelines used were those given in NHMRC & NRMMC (2011, as amended), with the health criteria for which there was sufficient data being nitrate (50 mg/L as nitrate, equivalent to 10 mg/L as N), and fluoride (1.5mg/L). EC (aesthetic/taste) <1,700µS/cm. The relationship between EC and TDS varies. EC X 0.64 approximately generates TDS values of about 1,100mg/L (no specific health guideline established).

CAC 1965, 'Handbook of Air Conditioning System Design'. Carrier Air Conditioning Company, McGraw-Hill Books, New York.

NHMRC & NRMMC, 2011 (as amended), 'Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy', National Health and Medical Research Council, National Resource Management Ministerial Council, Commonwealth of Australia, Canberra.

Withers, A 2005, 'Options for recarbonation, remineralisation and disinfection for desalinisation plants'. Desalinisation, vol. 179, 11-24.

Surface water aquatic ecosystem comparisons:

An important aspect of groundwater chemistry is its impact if discharged into surface water. Groundwater quality has been compared with the surface water aquatic ecosystem guidelines from QWQG (2009, as amended). In the case of EC, these guidelines are those for the surface water Queensland Salinity Zones provided in Appendix G of QWQG (2009). Where a groundwater chemistry zone underlies more than one surface water salinity zone, the surface water zone that covers the majority of the area has been used. For other indicators (e.g. pH, TN), comparisons are in relation to QWQG surface water regional guidelines (e.g. pH 6.5–8, TN 500μg/L or 0.5 mg/L), unless otherwise indicated.

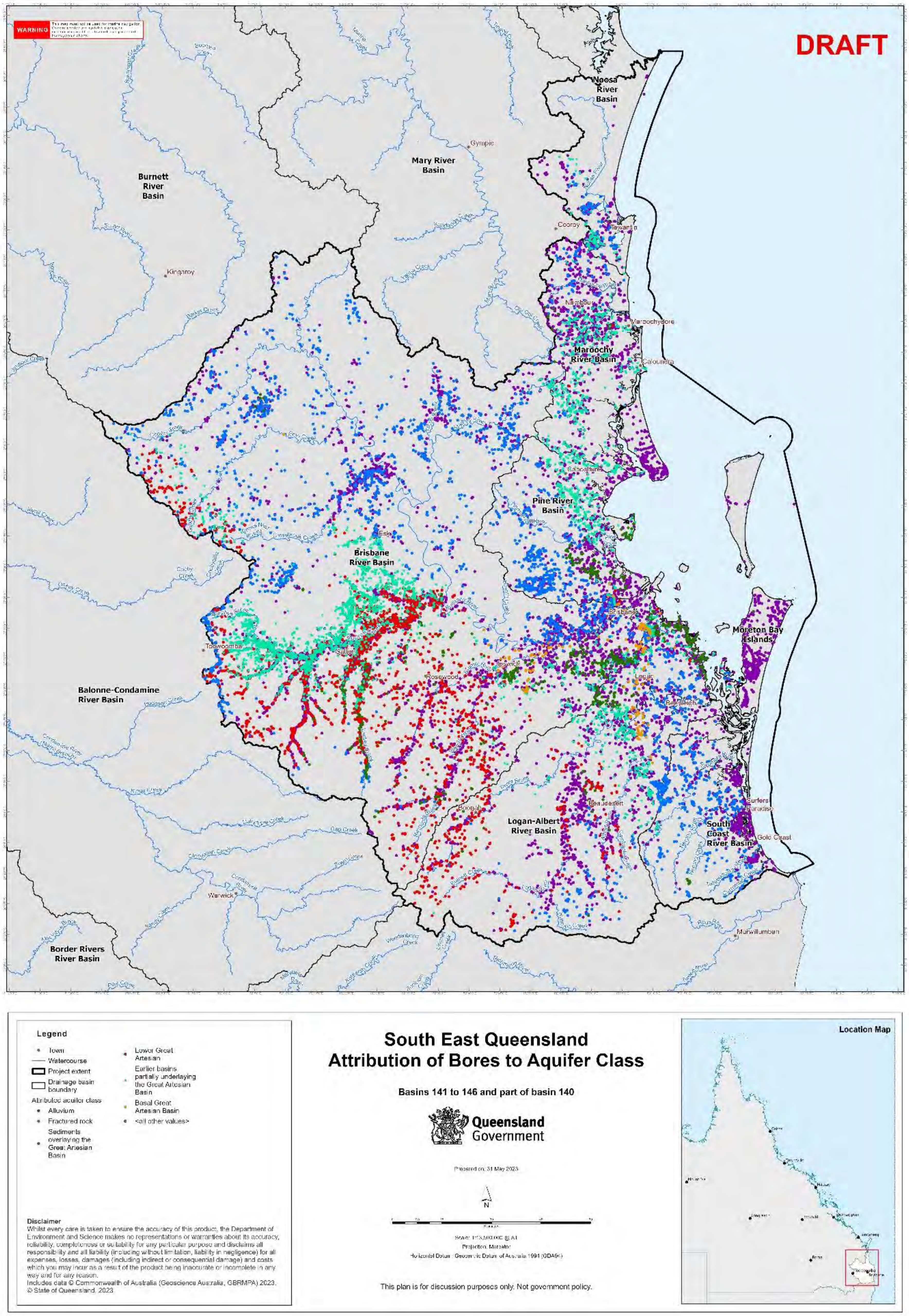


Figure 21: Bore attribution to aquifer class in South East Queensland

8 Appendix 2 Human use Environmental Values (EVs)

Human use EVs are shown in Figures 13 to 18, and detailed mapping is available from the department's website. Guidelines to support human use EVs are based on relevant national guidelines (updated where applicable by State sources). The Queensland Government's Water Entitlement Register Database (WERD) now replaced by WMS (Water Management System), was used with other sources to determine EVs. A description of each EV is summarised in the figure below.

Aquatic ecosystem
- The intrinsic value of aquatic ecosystems, habitat and wildlife in waterways, waterholes and riparian areas, for example, biodiversity, ecological interactions, plants, animals, key species (such as turtles, yellowbelly, cod and yabbies) and their habitat, food and drinking water.

Irrigation
- Suitability of water supply for irrigation, for example, irrigation of crops, pastures, parks, gardens and recreational areas.

Farm water supply/use
- Suitability of domestic farm water supply, other than drinking water. For example, water used for laundry and produce preparation.

Stock watering
- Suitability of water supply for production of healthy livestock.

Aquaculture
- Health of aquaculture species and humans consuming aquatic foods (such as fish and prawns) from commercial ventures.

Human consumers of aquatic foods
- Health of humans consuming aquatic foods, such as fish and prawns, from natural waterways.

Primary recreation
- Health of humans during recreation which involves direct contact and a high probability of water being swallowed, for example, swimming, diving and water-skiing..

Secondary recreation
- Health of humans during recreation which involves indirect contact and a low probability of water being swallowed, for example, wading, boating, rowing and fishing.

Visual recreation
- Amenity of waterways for recreation which does not involve contact with water. For example, walking and picnicking adjacent to a waterway.

Drinking water supply
- Suitability of raw drinking water supply. This assumes minimal treatment of water is required, for example, coarse screening and/or disinfection.

Industrial use
- Suitability of water supply for industrial use, for example, food, beverage, paper, petroleum and power industries, mining and minerals refining/processing. Industries usually treat water supplies to meet their needs.

Cultural, spiritual and ceremonial values
- Cultural, spiritual and ceremonial values of water means its aesthetic, historical, scientific, social or other significance, to the past, present or future generations.

Figure 22: Environmental values icons and definitions

9 Appendix 3 Water quality percentiles (basis for aquatic ecosystem WQOs)

Table 9: South East Queensland: Statistical summaries of water chemistry by groundwater chemistry zone

Refer to notes after the table

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
Alluvium and other recent deposits																												
1 - North Coast Alluvium	Sam.	26	26	26	26	25	25	26	26	26	26	12	12	2	2	26	26	26	26	1	23	8	1	0	0	25	2	1
	10th	27	32	7	2	2	2	88	25	26	22	id	id	id	id	205	30	7.4	72.0	id	0.10	id	id	id	id	1.12	id	id
	20th	32	37	8	4	3	3	122	49	26	24	id	id	id	id	255	32	7.5	100.0	id	0.14	id	id	id	id	1.43	id	id
	30th	36	45	8	12	4	6	146	61	31	26	id	id	id	id	333	44	7.6	120.0	id	0.20	id	id	id	id	1.66	id	id
	40th	40	58	12	16	7	12	186	64	35	29	id	id	id	id	410	46	7.6	153.0	id	0.20	id	id	id	id	1.97	id	id
	50th	48	61	15	18	7	16	240	67	40	30	**17**	**2**	id	id	455	83	7.7	196.0	id	0.20	**7.00**	id	id	id	2.10	id	id
	60th	61	68	18	19	10	22	268	70	52	33	id	id	id	id	540	118	7.7	220.0	id	0.25	id	id	id	id	2.82	id	id
	70th	267	77	20	20	19	25	323	71	167	35	id	id	id	id	1230	122	7.8	264.5	id	0.34	id	id	id	id	12.84	id	id
	80th	370	93	24	24	26	44	427	76	200	37	id	id	id	id	1600	148	7.9	350.0	id	0.40	id	id	id	id	13.83	id	id
	90th	415	96	40	25	32	46	648	77	328	55	id	id	id	id	1675	185	8.2	541.5	id	5.26	id	id	id	id	24.00	id	id
1 - North Coast Alluvium near stream	Sam.	11	11	11	11	10	10	11	11	11	11	9	9	2	2	11	11	11	11	1	11	3	1	0	0	10	2	1
	50th	**370**	**93**	**8**	**4**	**4**	**3**	**427**	**58**	**200**	**37**	**17**	**1**	id	id	**1600**	**32**	**7.6**	**350.0**	id	**0.40**	id	id	id	id	**14.56**	id	id
2 - Glasshouses	Sam.	91	91	91	91	91	91	91	91	91	91	90	90	91	91	91	91	91	89	91	91	90	90	3	3	91	91	0
	10th	12	36	1	2	1	9	2	1	14	21	1	1	0.50	0	100	9	4.6	1.0	6.0	0.00	0.00	0.000	id	id	0.90	0.109	id
	20th	13	50	1	4	2	12	3	4	17	27	1	1	0.50	0	109	13	5.1	2.0	8.0	0.00	0.00	0.010	id	id	1.11	0.109	id
	30th	15	55	2	6	2	15	4	5	20	39	2	1	1.60	2	122	18	5.3	3.4	9.0	0.00	0.00	0.020	id	id	1.25	0.348	id
	40th	16	58	3	9	3	16	10	11	22	42	2	2	4.70	3	151	22	5.7	8.2	10.0	0.00	0.01	0.020	id	id	1.51	1.022	id
	50th	18	64	3	10	4	18	13	16	24	49	2	3	10.50	12	173	26	5.9	11.0	11.0	0.04	0.02	0.020	id	id	1.79	2.283	id
	60th	22	70	5	14	5	22	19	22	28	55	2	4	15.00	22	201	33	6.1	16.8	14.0	0.10	0.02	0.040	id	id	2.04	3.261	id
	70th	28	73	7	19	6	26	27	30	34	63	3	4	23.50	33	254	44	6.3	22.0	16.0	0.10	0.02	0.056	id	id	2.44	5.109	id
	80th	40	77	11	29	10	30	38	42	41	69	4	6	33.10	44	400	69	6.5	33.8	20.0	0.10	0.02	0.124	id	id	2.83	7.196	id
	90th	67	83	26	35	13	38	174	63	65	84	6	7	52.00	53	472	112	7.1	146.4	37.0	0.15	0.04	0.283	id	id	3.83	11.304	id
2 - Glasshouses near stream	Sam.	71	71	71	71	71	71	71	71	71	71	70	70	71	71	71	71	71	70	71	71	70	70	3	3	71	71	0
	10th	12	36	1	2	2	9	2	1	13	21	0	1	0.10	0	96	9	4.6	1.0	7.0	0.00	0.00	0.000	id	id	0.90	0.022	id
	20th	13	47	1	4	2	11	3	4	17	27	1	1	0.50	1	108	13	5.1	2.0	8.0	0.00	0.00	0.010	id	id	1.10	0.109	id
	30th	15	54	2	6	2	15	4	5	19	35	2	1	2.10	2	120	20	5.3	3.0	9.0	0.00	0.00	0.020	id	id	1.20	0.457	id
	40th	16	57	3	8	3	17	7	8	21	42	2	2	6.40	7	151	24	5.6	5.6	10.0	0.00	0.00	0.020	id	id	1.39	1.391	id
	50th	17	60	4	9	4	22	13	14	24	47	2	2	13.60	18	170	27	5.8	10.5	11.0	0.00	0.01	0.020	id	id	1.70	2.957	id
	60th	20	69	5	14	5	24	19	18	26	51	2	4	20.40	24	201	35	6.1	16.4	12.0	0.10	0.02	0.040	id	id	1.99	4.435	id
	70th	28	71	7	19	6	28	25	28	30	59	3	4	24.60	38	254	52	6.3	20.6	14.0	0.10	0.02	0.056	id	id	2.28	5.348	id
	80th	40	76	11	30	10	31	38	43	40	67	4	6	38.90	49	404	69	6.5	32.4	19.0	0.10	0.02	0.140	id	id	2.71	8.457	id
	90th	67	79	26	36	13	44	195	72	65	80	5	7	66.80	57	472	112	7.1	160.1	34.0	0.15	0.04	0.316	id	id	3.41	14.522	id
3 - Northern Moreton Bay Alluvium	Sam.	57	57	58	58	57	57	57	57	57	57	55	55	53	53	57	58	57	55	51	57	28	27	0	0	56	53	1
	10th	29	37	2	2	3	9	8	0	38	21	4	1	0.00	0	238	16	5.8	9.4	10.0	0.04	0.00	0.010	id	id	1.68	0.000	id
	20th	42	48	7	3	5	14	28	1	52	39	6	2	0.31	0	317	42	6.4	26.4	12.0	0.10	0.01	0.010	id	id	2.48	0.067	id
	30th	55	56	10	7	9	16	50	6	68	44	8	2	0.50	0	496	87	6.7	61.6	17.0	0.10	0.01	0.018	id	id	3.27	0.109	id
	40th	119	65	23	9	17	17	118	16	79	58	9	3	0.50	0	914	122	6.8	106.0	25.0	0.10	0.01	0.020	id	id	4.15	0.109	id
	50th	160	71	27	11	35	19	161	24	149	70	13	5	1.00	0	1100	188	7.0	134.0	33.0	0.20	0.02	0.020	id	id	5.38	0.217	id
	60th	227	75	36	13	59	21	250	33	367	76	23	6	1.10	0	1492	326	7.4	227.0	40.0	0.30	0.02	0.030	id	id	7.20	0.239	id
	70th	441	78	56	15	101	23	377	44	772	82	42	8	2.70	0	3380	529	7.5	316.0	52.0	0.40	0.02	0.080	id	id	9.59	0.587	id
	80th	908	81	183	24	386	29	508	61	1404	87	81	10	5.68	1	6090	1802	7.6	429.8	66.0	0.48	0.05	0.118	id	id	16.29	1.235	id
	90th	7100	86	380	30	1044	43	770	79	11920	93	1350	13	14.00	7	35500	5243	7.9	641.0	86.0	0.70	0.06	0.606	id	id	40.37	3.043	id
3 - Northern Moreton Bay	Insufficient data																											

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
Alluvium near stream																												
4 - Upper Brisbane	Sam.	283	283	282	282	282	282	283	283	283	283	272	272	219	219	272	284	279	284	210	278	87	81	36	36	280	219	2
	10th	38	26	25	19	16	24	96	19	64	35	2	1	0.00	0	450	129	6.7	90.0	24.0	0.00	0.00	0.005	0.010	0.000	1.23	0.000	id
	20th	47	29	37	26	21	28	123	23	114	48	3	1	0.25	0	626	180	6.9	107.0	28.8	0.10	0.00	0.010	0.100	0.010	1.36	0.054	id
	30th	53	32	46	30	25	29	145	26	150	55	5	1	0.74	0	750	220	7.0	121.9	31.0	0.10	0.01	0.020	0.170	0.015	1.49	0.161	id
	40th	58	34	52	32	29	31	157	30	169	61	6	1	1.00	0	850	256	7.3	134.4	33.0	0.10	0.01	0.030	0.250	0.015	1.60	0.217	id
	50th	65	35	60	34	33	32	174	33	190	64	8	2	2.00	0	958	295	7.4	146.5	36.0	0.12	0.01	0.130	0.650	0.015	1.71	0.435	id
	60th	78	36	69	34	38	32	197	36	215	67	10	2	3.50	1	1080	337	7.6	167.6	39.0	0.17	0.01	0.260	1.200	0.015	1.91	0.761	id
	70th	96	38	89	36	46	33	220	41	279	71	13	2	4.86	1	1250	404	7.8	190.1	42.3	0.20	0.02	0.490	3.500	0.015	2.17	1.057	id
	80th	130	43	105	38	65	34	270	48	393	75	20	3	8.00	1	1595	543	8.0	242.4	47.0	0.20	0.03	0.960	12.000	0.015	2.85	1.739	id
	90th	228	50	160	41	112	38	465	63	743	80	28	5	12.20	2	2709	898	8.2	412.4	51.1	0.33	0.05	1.600	21.095	0.015	4.24	2.652	id
4 - Upper Brisbane near stream	Sam.	246	246	245	245	246	246	246	246	246	246	237	237	195	195	242	247	242	247	189	243	69	63	30	30	244	195	2
	10th	41	26	30	23	18	24	106	19	79	40	2	1	0.00	0	484	143	6.7	90.0	24.0	0.00	0.00	0.001	0.010	0.000	1.24	0.000	id
	20th	48	29	42	29	22	28	128	23	126	53	3	1	0.40	0	642	195	6.9	107.0	29.0	0.08	0.00	0.010	0.082	0.009	1.36	0.087	id
	30th	53	32	48	32	26	29	146	25	153	58	5	1	1.00	0	760	225	7.0	121.0	31.0	0.10	0.01	0.020	0.172	0.015	1.49	0.217	id
	40th	58	33	53	33	29	31	158	29	172	62	6	1	1.23	0	847	257	7.2	132.0	34.2	0.10	0.01	0.056	0.238	0.015	1.60	0.267	id
	50th	63	35	61	34	33	31	174	31	192	65	8	2	2.40	0	945	289	7.4	144.0	37.0	0.10	0.01	0.200	0.595	0.015	1.69	0.522	id
	60th	75	36	69	35	37	32	195	35	215	69	10	2	4.00	1	1048	326	7.5	161.6	40.0	0.15	0.01	0.308	1.052	0.015	1.88	0.870	id
	70th	92	37	85	37	44	33	216	38	276	72	12	2	5.56	1	1237	383	7.7	180.0	43.0	0.20	0.01	0.670	1.700	0.015	2.09	1.209	id
	80th	120	41	102	39	59	34	250	44	384	75	17	3	8.32	1	1497	473	7.9	212.4	47.0	0.20	0.02	1.066	9.040	0.015	2.62	1.809	id
	90th	215	48	160	41	99	36	326	53	725	80	25	5	13.00	2	2648	814	8.1	272.2	51.2	0.22	0.05	1.680	15.419	0.015	3.81	2.826	id
5 - Upper Lockyer Creek	Sam.	124	124	124	124	124	124	101	101	123	123	98	98	95	95	119	124	105	123	90	97	61	61	26	26	124	95	2
	10th	62	28	33	12	30	19	163	28	140	36	3	1	0.00	0	812	225	7.4	172.0	25.0	0.10	0.00	0.000	0.003	0.000	1.56	0.000	id
	20th	74	30	45	16	40	24	268	33	166	44	5	1	0.25	0	983	298	7.6	237.6	29.8	0.12	0.01	0.010	0.005	0.010	1.76	0.054	id
	30th	87	34	55	21	45	26	299	38	198	50	7	1	0.50	0	1150	320	7.7	254.6	32.0	0.17	0.01	0.010	0.005	0.010	1.97	0.109	id
	40th	119	39	60	23	51	29	330	41	258	52	10	1	0.50	0	1270	365	7.8	280.8	33.0	0.20	0.01	0.010	0.005	0.015	2.61	0.109	id
	50th	160	44	66	25	55	31	372	44	325	55	13	2	1.00	0	1585	395	7.9	311.0	36.5	0.20	0.01	0.010	0.005	0.015	3.18	0.217	id
	60th	180	47	72	26	60	33	422	47	366	60	16	2	1.84	0	1700	429	8.0	331.6	39.0	0.20	0.02	0.010	0.005	0.015	3.74	0.400	id
	70th	207	51	76	28	66	36	459	49	392	68	21	3	3.00	0	1912	456	8.0	371.4	41.0	0.23	0.03	0.050	0.010	0.015	4.27	0.652	id
	80th	269	57	87	29	73	38	502	55	445	76	28	3	5.92	1	2150	510	8.2	396.2	43.2	0.30	0.06	0.270	0.010	0.015	5.09	1.287	id
	90th	350	68	115	34	87	43	600	61	525	100	35	4	12.00	1	2350	625	8.3	498.8	46.0	0.35	0.08	0.440	0.020	0.020	7.75	2.609	id
5 - Upper Lockyer Creek near stream	Sam.	110	110	110	110	110	110	87	87	109	109	84	84	82	82	105	110	91	109	78	83	54	54	26	26	110	82	2
	10th	65	29	32	11	29	19	160	28	149	44	3	1	0.00	0	816	224	7.4	167.8	25.0	0.10	0.00	0.002	0.003	0.000	1.68	0.001	id
	20th	83	33	43	15	38	23	263	32	191	50	4	1	0.26	0	968	289	7.6	228.0	29.4	0.11	0.01	0.010	0.005	0.010	1.88	0.057	id
	30th	111	37	55	20	45	25	295	36	240	51	6	1	0.50	0	1250	314	7.7	249.4	32.1	0.15	0.01	0.010	0.005	0.010	2.34	0.109	id
	40th	152	43	60	23	49	28	314	40	293	54	9	1	0.50	0	1500	345	7.8	274.0	33.8	0.20	0.01	0.010	0.005	0.015	3.09	0.109	id
	50th	171	46	67	24	53	30	336	43	351	58	13	2	1.23	0	1650	386	7.9	301.0	37.5	0.20	0.01	0.010	0.005	0.015	3.53	0.266	id
	60th	193	49	74	26	57	31	388	45	384	63	17	2	2.08	0	1820	422	8.0	324.6	40.0	0.20	0.02	0.020	0.005	0.015	3.99	0.452	id
	70th	245	52	79	28	63	34	454	47	407	69	22	3	3.00	0	1958	456	8.0	360.6	41.9	0.21	0.03	0.085	0.010	0.015	4.42	0.652	id
	80th	297	59	90	30	74	36	538	49	459	89	32	3	5.72	0	2240	532	8.2	407.8	44.0	0.30	0.05	0.300	0.010	0.015	5.72	1.243	id
	90th	356	69	118	35	93	38	607	54	547	100	37	4	11.90	1	2350	642	8.3	501.0	46.3	0.40	0.08	0.503	0.020	0.020	8.23	2.587	id
6 - Central Lockyer Creek	Sam.	428	428	429	429	426	426	351	351	426	426	341	341	342	342	414	429	366	424	310	335	166	162	87	87	426	342	6
	10th	57	20	19	12	17	23	52	17	96	40	4	0	0.25	0	559	122	7.4	76.3	15.0	0.10	0.00	0.000	0.000	0.000	1.44	0.054	id
	20th	85	22	54	17	75	32	189	23	225	50	7	1	1.00	0	1411	482	7.6	260.0	25.0	0.10	0.01	0.005	0.005	0.000	1.60	0.217	id
	30th	96	24	70	20	93	40	345	28	311	53	11	1	2.00	0	1650	585	7.7	319.5	29.0	0.10	0.01	0.010	0.005	0.010	1.72	0.435	id
	40th	110	26	86	22	105	44	394	32	360	58	16	2	4.04	0	1850	664	7.8	359.2	33.0	0.10	0.01	0.010	0.005	0.015	1.91	0.878	id
	50th	128	29	95	24	120	46	449	36	410	63	23	3	7.25	1	1990	727	7.8	393.0	35.0	0.15	0.01	0.010	0.005	0.015	2.16	1.576	id
	60th	145	33	105	25	128	48	485	39	470	67	36	4	11.68	1	2200	806	7.9	422.6	37.0	0.20	0.02	0.010	0.010	0.015	2.45	2.539	id
	70th	172	39	115	27	141	49	530	43	540	73	53	5	17.00	1	2500	885	8.0	453.1	41.0	0.20	0.03	0.020	0.010	0.015	2.76	3.696	id
	80th	210	49	132	29	168	52	570	48	710	87	69	7	28.48	2	3000	987	8.1	502.0	44.2	0.20	0.05	0.038	0.018	0.015	3.19	6.191	id
	90th	347	60	154	31	207	55	660	58	889	100	99	8	48.90	4	3557	1220	8.2	567.7	50.0	0.24	0.17	0.219	0.024	0.025	5.07	10.630	id

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
6 - Central Lockyer Creek near stream	Sam.	392	392	393	393	390	390	318	318	390	390	310	310	310	310	378	393	332	388	280	305	150	146	85	85	390	310	6
	10th	75	20	42	12	59	26	84	18	185	41	5	0	0.25	0	1214	370	7.4	212.0	13.0	0.10	0.00	0.000	0.000	0.000	1.44	0.054	id
	20th	91	22	62	17	84	36	315	23	285	50	10	1	1.00	0	1550	537	7.6	295.4	26.0	0.10	0.01	0.005	0.005	0.000	1.60	0.217	id
	30th	101	24	80	19	99	42	375	28	340	54	13	1	2.00	0	1750	611	7.7	341.0	30.0	0.10	0.01	0.010	0.005	0.010	1.70	0.435	id
	40th	115	26	90	22	111	45	423	32	386	59	20	2	4.06	0	1900	697	7.8	370.0	33.0	0.11	0.01	0.010	0.005	0.015	1.91	0.883	id
	50th	133	28	98	24	122	47	461	36	430	63	28	3	7.25	1	2080	746	7.8	402.0	35.0	0.15	0.01	0.010	0.005	0.015	2.17	1.576	id
	60th	151	31	108	25	131	48	498	39	491	68	44	4	11.52	1	2272	831	7.9	431.8	37.0	0.20	0.01	0.010	0.010	0.015	2.48	2.504	id
	70th	177	36	117	27	148	50	539	43	569	74	57	6	17.12	1	2598	902	8.0	459.0	41.0	0.20	0.03	0.020	0.010	0.015	2.78	3.722	id
	80th	218	43	134	29	173	53	575	48	728	88	72	7	28.68	2	3026	1039	8.1	506.6	44.0	0.20	0.05	0.040	0.010	0.015	3.34	6.235	id
	90th	355	58	160	31	212	55	673	57	923	100	101	8	50.10	3	3600	1237	8.3	572.6	50.0	0.23	0.11	0.240	0.020	0.025	5.10	10.891	id
7 - Lower Lockyer	Sam.	706	706	706	706	704	704	638	638	706	706	620	620	588	588	694	706	638	705	542	610	425	417	221	219	704	588	6
	10th	42	22	28	10	28	25	227	24	51	20	3	0	0.00	0	633	207	7.4	210.8	26.0	0.09	0.00	0.000	0.000	0.000	1.08	0.000	id
	20th	55	25	37	14	38	31	296	38	78	24	5	1	0.50	0	820	266	7.6	256.0	30.0	0.10	0.01	0.005	0.005	0.010	1.28	0.109	id
	30th	66	27	43	18	46	36	343	47	104	29	7	1	0.50	0	979	311	7.8	306.6	34.0	0.10	0.01	0.010	0.005	0.015	1.48	0.109	id
	40th	78	30	51	21	53	38	399	54	140	34	9	1	1.00	0	1100	362	7.9	342.0	37.0	0.10	0.01	0.010	0.005	0.015	1.72	0.217	id
	50th	99	32	60	25	61	40	442	60	178	40	10	2	2.50	0	1250	415	8.0	380.0	39.0	0.14	0.01	0.010	0.005	0.015	2.01	0.543	id
	60th	125	37	69	27	76	41	489	65	215	46	12	2	4.00	0	1500	486	8.1	416.0	41.0	0.18	0.01	0.020	0.010	0.015	2.45	0.870	id
	70th	168	42	79	30	90	44	532	70	290	55	15	2	6.79	1	1700	554	8.1	455.8	44.0	0.20	0.02	0.020	0.010	0.015	3.17	1.476	id
	80th	210	51	97	33	106	46	610	74	420	69	21	3	12.50	2	2084	656	8.3	522.4	48.0	0.20	0.03	0.108	0.010	0.022	4.39	2.717	id
	90th	301	61	135	37	145	50	724	78	638	95	41	4	29.50	3	2827	862	8.4	607.4	52.0	0.30	0.06	0.350	0.030	0.025	6.07	6.413	id
7 - Lower Lockyer near stream	Sam.	679	679	679	679	677	677	611	611	679	679	593	593	562	562	667	679	611	678	516	583	401	394	205	203	677	562	6
	10th	42	22	28	10	28	25	231	26	51	19	3	0	0.00	0	636	207	7.4	213.4	26.0	0.09	0.00	0.000	0.000	0.000	1.07	0.000	id
	20th	54	24	37	14	38	32	296	39	77	24	5	1	0.50	0	820	266	7.6	256.0	30.0	0.10	0.01	0.005	0.005	0.010	1.27	0.109	id
	30th	66	27	43	18	46	36	340	48	100	28	7	1	0.50	0	965	309	7.8	305.1	34.0	0.10	0.01	0.010	0.005	0.015	1.46	0.109	id
	40th	76	29	51	22	53	38	395	54	135	33	8	1	1.00	0	1100	358	7.9	341.0	37.0	0.10	0.01	0.010	0.005	0.015	1.68	0.217	id
	50th	96	32	60	25	60	40	440	60	172	39	10	2	2.50	0	1219	409	8.0	379.0	39.0	0.13	0.01	0.010	0.005	0.015	1.94	0.543	id
	60th	120	36	69	28	75	41	485	66	214	46	12	2	3.90	0	1440	477	8.1	411.2	41.0	0.17	0.01	0.015	0.010	0.015	2.35	0.848	id
	70th	161	41	79	31	88	44	530	70	285	55	15	2	6.40	1	1660	549	8.2	451.0	44.0	0.20	0.02	0.020	0.010	0.015	3.08	1.391	id
	80th	200	50	95	33	105	46	600	74	405	68	20	3	11.90	2	2020	650	8.3	517.2	48.0	0.20	0.03	0.084	0.010	0.015	4.03	2.587	id
	90th	281	61	129	37	139	50	711	78	582	95	36	4	29.45	3	2700	837	8.4	601.0	52.0	0.25	0.06	0.327	0.026	0.025	5.87	6.402	id
8 - Southwest Lockyer Tributaries	Sam.	201	201	201	201	198	198	185	185	198	198	183	183	170	170	193	201	181	198	159	179	88	86	43	43	198	170	1
	10th	192	25	86	11	132	28	269	8	614	63	33	2	0.50	0	2522	750	7.2	239.7	22.8	0.10	0.00	0.000	0.005	0.000	2.61	0.109	id
	20th	248	26	115	15	167	35	385	9	822	68	48	3	2.76	0	3314	959	7.3	319.0	26.0	0.12	0.01	0.005	0.005	0.004	3.03	0.600	id
	30th	315	30	140	16	200	39	434	11	981	72	66	3	5.85	0	3718	1182	7.5	354.2	29.0	0.20	0.01	0.010	0.005	0.013	3.46	1.272	id
	40th	367	33	168	18	233	41	465	12	1190	75	100	4	10.30	0	4300	1398	7.5	379.8	32.0	0.20	0.01	0.010	0.009	0.015	4.04	2.239	id
	50th	435	36	202	19	277	43	524	15	1435	78	133	6	18.15	0	5050	1650	7.6	428.0	34.0	0.20	0.01	0.018	0.010	0.015	4.43	3.946	id
	60th	540	39	240	21	326	46	550	18	1752	81	165	7	23.00	1	5950	1934	7.7	452.6	35.8	0.23	0.02	0.020	0.010	0.015	5.19	5.000	id
	70th	600	42	273	23	368	49	589	21	2057	84	241	8	31.00	1	6500	2205	7.8	483.0	38.0	0.30	0.06	0.040	0.010	0.017	5.87	6.739	id
	80th	690	47	344	25	435	51	640	24	2506	87	283	9	43.20	1	7918	2650	7.9	524.8	42.0	0.34	0.14	0.170	0.023	0.030	6.91	9.391	id
	90th	885	53	442	27	555	57	700	31	3230	90	384	10	75.10	1	10088	3179	8.0	569.9	45.0	0.50	0.27	0.660	0.030	0.046	8.95	16.326	id
8 - Southwest Lockyer Tributaries near stream	Sam.	199	199	199	199	196	196	183	183	196	196	182	182	169	169	191	199	179	196	158	177	87	86	43	43	196	169	1
	10th	191	25	86	11	132	29	269	7	614	63	33	2	0.50	0	2500	745	7.2	235.5	22.7	0.10	0.00	0.000	0.005	0.000	2.60	0.109	id
	20th	247	26	117	15	165	35	385	9	840	68	48	3	2.92	0	3350	961	7.3	319.0	26.0	0.12	0.01	0.005	0.005	0.004	3.02	0.635	id
	30th	313	30	144	16	201	39	432	10	985	72	66	3	6.00	0	3730	1182	7.5	352.5	29.0	0.20	0.01	0.010	0.005	0.013	3.44	1.304	id
	40th	367	33	171	18	235	41	464	12	1190	75	100	4	10.60	0	4300	1419	7.5	379.0	32.0	0.20	0.01	0.010	0.009	0.015	4.00	2.304	id
	50th	435	36	210	20	280	43	519	15	1435	78	133	6	18.30	0	5050	1652	7.6	423.0	34.0	0.20	0.01	0.018	0.010	0.015	4.42	3.978	id
	60th	538	39	240	21	328	46	550	18	1750	82	165	7	23.00	1	5950	1942	7.7	452.0	36.0	0.22	0.02	0.020	0.010	0.015	5.18	5.000	id
	70th	600	42	274	23	369	49	587	21	2054	84	241	8	31.00	1	6500	2212	7.8	483.0	38.0	0.30	0.06	0.040	0.010	0.017	5.86	6.739	id
	80th	690	47	344	25	435	51	638	24	2485	87	284	9	43.40	1	7900	2662	7.9	520.0	42.0	0.32	0.14	0.170	0.023	0.030	6.83	9.435	id
	90th	872	53	443	27	559	57	692	31	3230	90	385	10	75.20	1	10110	3219	8.0	562.5	45.0	0.50	0.27	0.660	0.030	0.046	8.89	16.348	id
	Sam.	137	137	137	137	136	136	115	115	137	137	106	106	104	104	129	137	115	137	99	104	28	28	18	18	136	104	1
	10th	26	19	35	20	31	39	210	26	40	19	6	2	0.53	0	500	213	7.4	190.0	17.8	0.10	0.00	0.000	id	id	0.71	0.115	id

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
9 - Lockyer Southern Basaltic Headwaters	20th	44	21	46	22	47	42	239	33	88	28	12	3	1.24	0	770	320	7.6	227.2	23.6	0.10	0.01	0.002	id	id	1.05	0.270	id
	30th	64	23	56	26	58	43	279	36	154	43	18	3	2.49	0	1050	383	7.7	245.8	27.0	0.10	0.01	0.005	id	id	1.26	0.541	id
	40th	75	25	64	27	66	45	307	41	220	49	25	4	3.58	1	1234	434	7.8	270.0	28.0	0.10	0.01	0.005	id	id	1.50	0.778	id
	50th	86	27	75	28	72	46	338	44	245	52	37	5	4.80	1	1396	472	7.9	287.0	30.0	0.13	0.01	0.005	**0.005**	**0.015**	1.63	1.043	id
	60th	96	28	82	29	84	46	374	48	310	57	45	6	8.06	1	1590	557	8.0	310.6	31.8	0.20	0.01	0.006	id	id	1.84	1.752	id
	70th	109	31	92	31	98	47	393	58	352	62	52	8	10.10	1	1738	633	8.1	325.0	34.0	0.20	0.01	0.010	id	id	2.07	2.196	id
	80th	133	33	102	32	106	49	425	70	415	71	62	8	15.00	2	1900	691	8.2	350.0	36.4	0.20	0.03	0.020	id	id	2.29	3.261	id
	90th	165	37	117	33	121	51	510	80	490	100	75	9	23.00	2	2204	773	8.3	419.2	41.2	0.30	0.05	0.197	id	id	3.00	5.000	id
9 - Lockyer Southern Basaltic Headwaters near stream	Sam.	75	75	75	75	75	75	56	56	75	75	56	56	54	54	71	75	61	75	49	53	19	19	11	11	75	54	1
	10th	67	20	56	19	57	39	212	25	209	47	30	3	2.39	0	1180	410	7.4	224.0	14.2	0.10	id	id	id	id	1.23	0.520	id
	20th	76	23	70	22	68	42	276	30	230	50	35	4	3.00	0	1320	465	7.6	244.8	21.6	0.10	id	id	id	id	1.43	0.652	id
	30th	85	24	77	25	73	43	304	34	254	52	41	5	5.37	1	1448	497	7.7	261.4	29.0	0.10	id	id	id	id	1.55	1.167	id
	40th	90	27	81	26	83	44	334	36	286	56	46	6	9.06	1	1530	555	7.8	275.6	31.0	0.13	id	id	id	id	1.71	1.970	id
	50th	100	28	86	28	92	45	353	37	332	60	50	7	10.50	1	1700	610	7.8	291.0	33.0	0.19	**0.01**	**0.005**	**0.005**	**0.015**	1.82	2.283	id
	60th	111	29	95	29	100	46	386	40	369	62	58	8	13.00	1	1790	651	7.9	312.6	36.0	0.20	id	id	id	id	1.95	2.826	id
	70th	125	31	99	29	105	47	404	42	415	70	62	8	16.20	2	1900	691	8.0	329.6	38.0	0.20	id	id	id	id	2.18	3.522	id
	80th	144	33	105	31	116	49	464	44	446	99	67	9	21.40	2	2000	728	8.2	351.0	40.8	0.30	id	id	id	id	2.34	4.652	id
	90th	184	37	118	32	125	50	522	45	495	100	79	10	24.97	2	2220	781	8.3	422.2	43.2	0.30	id	id	id	id	3.07	5.428	id
10 - Warrill and Upper Bremer River	Sam.	358	358	358	358	358	358	358	358	358	358	353	353	260	260	349	358	358	358	266	350	221	221	163	163	358	260	1
	10th	47	24	30	12	24	21	123	14	60	21	0	0	0.00	0	653	207	7.1	150.6	8.5	0.10	0.00	0.000	0.005	0.000	1.22	0.000	id
	20th	57	27	46	18	32	25	243	36	80	24	2	0	0.10	0	780	264	7.3	233.4	22.0	0.10	0.00	0.005	0.005	0.010	1.40	0.022	id
	30th	68	29	55	23	35	28	321	45	97	29	3	0	0.25	0	883	297	7.5	280.2	26.5	0.12	0.00	0.010	0.010	0.015	1.58	0.054	id
	40th	83	32	61	26	40	30	383	51	129	35	4	1	0.50	0	989	320	7.6	333.0	34.0	0.15	0.00	0.020	0.018	0.015	1.96	0.109	id
	50th	99	37	66	30	46	32	427	58	165	40	5	1	0.95	0	1164	356	7.7	371.0	38.0	0.19	0.01	0.050	0.030	0.015	2.35	0.207	id
	60th	140	41	72	33	55	34	479	64	213	46	7	1	1.30	0	1330	391	7.9	410.0	40.0	0.20	0.01	0.130	0.072	0.015	2.84	0.283	id
	70th	183	47	84	35	63	36	527	69	326	52	12	1	2.30	0	1729	473	8.0	449.8	44.0	0.22	0.01	0.320	0.314	0.015	3.43	0.500	id
	80th	243	54	102	38	83	38	585	74	411	62	19	2	5.10	1	2076	605	8.1	490.0	48.0	0.25	0.01	0.690	0.840	0.015	4.92	1.109	id
	90th	460	64	174	40	141	42	694	78	979	83	30	5	12.57	1	3209	912	8.3	580.9	52.0	0.40	0.01	1.200	2.954	0.015	7.86	2.733	id
10 - Warrill and Upper Bremer River near stream	Sam.	285	285	285	285	285	285	285	285	285	285	282	282	215	215	276	285	285	285	221	277	192	192	140	140	285	215	0
	10th	46	24	28	13	24	20	91	13	60	20	0	0	0.00	0	650	199	7.1	138.6	7.0	0.09	0.00	0.001	0.005	0.000	1.21	0.000	id
	20th	56	26	46	20	31	25	210	33	78	23	2	0	0.10	0	779	255	7.4	218.4	20.0	0.10	0.00	0.005	0.005	0.010	1.40	0.022	id
	30th	67	28	55	26	34	28	303	44	97	28	3	0	0.25	0	859	291	7.5	274.2	25.0	0.11	0.00	0.010	0.005	0.015	1.54	0.054	id
	40th	80	31	62	28	37	30	350	52	120	34	4	1	0.46	0	963	311	7.6	316.8	33.0	0.13	0.00	0.020	0.010	0.015	1.76	0.100	id
	50th	92	36	67	31	42	33	409	60	150	39	5	1	0.90	0	1097	340	7.7	350.0	38.0	0.16	0.01	0.045	0.025	0.015	2.12	0.196	id
	60th	113	39	73	34	49	34	453	64	186	43	7	1	1.30	0	1250	371	7.9	392.4	40.0	0.20	0.01	0.120	0.050	0.015	2.60	0.283	id
	70th	152	44	86	36	61	35	512	70	292	53	11	1	2.26	0	1570	462	8.0	434.6	44.0	0.20	0.01	0.257	0.276	0.015	3.21	0.491	id
	80th	225	50	120	38	83	37	566	75	409	66	19	2	5.14	1	2000	608	8.1	480.4	48.0	0.25	0.01	0.546	0.864	0.015	3.95	1.117	id
	90th	457	64	205	40	144	41	672	78	1000	85	30	5	13.88	1	3223	1028	8.3	579.6	52.0	0.40	0.01	1.200	3.010	0.015	7.36	3.017	id
11 - Gatton Sandstones Saline Area	Insufficient data																											
12 - Lower Bremer	Sam.	438	438	438	438	437	437	385	385	438	438	385	385	350	350	434	438	400	437	331	382	248	244	150	147	437	350	10
	10th	120	22	45	8	48	22	275	8	257	43	5	0	0.00	0	1545	335	7.2	262.8	19.0	0.09	0.00	0.000	0.005	0.000	1.97	0.000	id
	20th	171	28	70	11	76	26	365	11	441	55	10	1	0.50	0	2196	530	7.4	312.2	27.0	0.10	0.00	0.000	0.005	0.010	2.61	0.109	id
	30th	255	33	90	14	110	28	400	13	625	65	13	1	1.20	0	2747	707	7.5	346.8	30.0	0.10	0.01	0.010	0.010	0.010	3.22	0.261	id
	40th	324	38	113	17	145	31	451	17	917	71	19	1	2.32	0	3550	934	7.6	384.8	33.0	0.12	0.01	0.010	0.010	0.015	4.06	0.504	id
	50th	380	43	152	20	192	35	500	22	1200	78	27	2	3.55	0	4275	1137	7.7	425.0	36.0	0.15	0.01	0.020	0.020	0.015	4.92	0.772	**0.000**
	60th	441	48	194	23	230	38	559	28	1481	81	45	2	5.82	0	5100	1444	7.8	468.6	39.0	0.20	0.01	0.030	0.020	0.015	5.91	1.265	id
	70th	540	55	245	26	280	42	635	35	1879	84	76	4	9.49	0	6046	1761	7.9	525.0	41.0	0.20	0.01	0.100	0.030	0.020	7.38	2.063	id
	80th	755	61	295	29	338	46	714	45	2242	88	157	5	17.56	1	7314	2162	8.0	594.4	44.0	0.23	0.02	0.254	0.042	0.030	9.49	3.817	id
	90th	1113	67	370	33	420	51	850	56	2573	100	290	9	32.82	1	8450	2642	8.2	696.0	49.0	0.30	0.07	1.100	0.284	0.040	12.73	7.135	id
	Sam.	372	372	372	372	371	371	362	362	377	377	372	372	330	330	373	372	371	347	338	358	317	306	128	128	371	330	2

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
13 - Logan and Albert	10th	46	27	3	3	6	9	5	1	54	45	3	0	0.00	0	374	39	5.3	11.0	13.0	0.05	0.00	0.000	0.005	0.000	2.08	0.000	id
	20th	97	34	8	5	10	13	24	5	136	53	6	1	0.29	0	869	84	6.2	50.6	20.0	0.10	0.00	0.010	0.005	0.010	2.55	0.063	id
	30th	146	47	22	7	19	15	88	11	248	60	10	1	0.50	0	1193	137	6.7	94.8	24.0	0.13	0.01	0.020	0.010	0.015	3.37	0.109	id
	40th	186	58	34	11	38	18	165	14	370	68	13	2	0.80	0	1699	253	7.1	187.8	29.0	0.20	0.01	0.120	0.020	0.015	4.01	0.174	id
	50th	217	67	53	16	62	21	283	17	550	75	22	2	1.20	0	2350	415	7.3	257.0	34.0	0.20	0.01	0.270	0.020	0.015	5.30	0.261	id
	60th	320	71	98	20	86	23	362	23	830	81	32	3	1.60	0	3106	614	7.5	311.6	36.0	0.25	0.02	0.450	0.030	0.025	7.02	0.348	id
	70th	423	75	151	26	110	28	451	31	1169	85	46	4	2.50	0	4100	792	7.7	389.0	39.9	0.30	0.03	0.905	0.050	0.025	9.25	0.543	id
	80th	614	81	205	33	151	32	533	43	1530	89	70	6	3.34	0	5200	1089	7.9	455.2	46.0	0.40	0.06	1.470	0.090	0.040	12.56	0.726	id
	90th	1011	84	363	39	197	35	660	52	2491	96	133	12	11.08	2	7783	1779	8.1	557.0	61.0	0.87	0.28	3.565	0.379	0.050	17.59	2.409	id
13 - Logan and Albert near stream	Sam.	188	188	188	188	187	187	181	181	187	187	185	185	164	164	182	188	181	176	175	178	160	161	77	77	187	164	1
	10th	123	21	30	6	31	15	24	3	241	47	5	0	0.00	0	1364	229	6.8	90.0	22.0	0.08	0.00	0.000	0.000	0.000	2.00	0.000	id
	20th	157	27	64	11	57	18	200	11	370	56	10	1	0.50	0	1800	429	7.1	223.0	26.8	0.10	0.00	0.005	0.005	0.002	2.31	0.109	id
	30th	186	31	104	17	80	22	313	14	517	65	14	1	0.50	0	2247	609	7.3	281.0	31.0	0.18	0.00	0.015	0.005	0.010	2.62	0.109	id
	40th	206	35	138	21	92	23	384	16	672	71	21	1	1.00	0	2820	717	7.5	333.0	34.0	0.20	0.01	0.050	0.010	0.015	3.57	0.217	id
	50th	298	45	170	28	110	28	460	20	970	78	28	2	1.30	0	3495	954	7.6	390.5	36.0	0.21	0.01	0.310	0.010	0.015	4.28	0.283	id
	60th	354	53	202	33	128	32	503	27	1174	82	32	2	2.50	0	4042	1052	7.7	431.0	36.0	0.25	0.01	0.740	0.020	0.015	5.54	0.543	id
	70th	445	64	252	36	166	34	560	34	1405	84	46	3	2.50	0	4703	1430	7.8	487.0	39.0	0.30	0.02	1.200	0.020	0.015	7.31	0.543	id
	80th	709	71	359	39	188	34	617	42	2053	87	63	3	3.00	0	6733	1760	8.0	521.0	42.0	0.32	0.05	2.300	0.030	0.015	12.13	0.652	id
	90th	1232	76	462	45	296	36	707	52	2640	95	100	5	5.00	0	8525	2324	8.1	609.5	58.8	0.50	0.08	3.800	0.078	0.030	17.11	1.087	id
14 - Logan Albert Basaltic Headwaters	Sam.	487	487	487	487	487	487	474	474	487	487	487	487	372	372	383	487	474	474	379	432	363	363	188	188	487	372	0
	10th	43	22	34	18	20	22	0	22	45	19	0	0	0.00	0	661	185	7.0	186.9	13.8	0.10	0.00	0.000	0.000	0.000	1.06	0.000	id
	20th	53	26	46	22	34	26	57	37	75	24	1	0	0.25	0	809	266	7.3	280.2	25.0	0.11	0.00	0.000	0.005	0.004	1.32	0.054	id
	30th	70	29	58	25	39	29	281	44	93	27	2	0	0.50	0	904	322	7.4	323.0	30.0	0.14	0.00	0.010	0.005	0.010	1.60	0.109	id
	40th	92	32	69	28	43	32	369	52	129	34	3	1	0.50	0	990	360	7.6	355.2	34.0	0.17	0.01	0.010	0.005	0.015	1.93	0.109	id
	50th	112	35	78	31	50	33	420	58	171	40	4	1	1.00	0	1178	396	7.7	378.5	39.0	0.20	0.01	0.015	0.005	0.015	2.27	0.217	id
	60th	136	39	89	34	58	35	455	65	228	47	6	1	1.50	0	1353	453	7.9	404.0	46.0	0.20	0.01	0.060	0.005	0.015	2.79	0.326	id
	70th	161	43	106	36	71	36	489	72	340	56	8	1	2.50	0	1764	530	8.0	439.0	50.0	0.24	0.01	0.224	0.010	0.015	3.21	0.543	id
	80th	194	47	131	38	84	38	540	76	468	64	10	2	4.30	1	2220	681	8.1	472.0	53.4	0.30	0.02	0.480	0.020	0.015	3.80	0.935	id
	90th	245	56	176	41	143	42	604	80	792	82	18	2	7.69	1	3155	1050	8.2	536.1	60.0	0.36	0.04	1.164	0.033	0.015	4.58	1.672	id
14 - Logan Albert Basaltic Headwaters near stream	Sam.	447	447	447	447	447	447	435	435	447	447	447	447	344	344	354	447	435	435	351	394	336	336	176	176	447	344	0
	10th	46	22	37	18	23	22	0	22	57	20	0	0	0.00	0	730	199	7.0	187.2	14.0	0.10	0.00	0.000	0.000	0.000	1.06	0.000	id
	20th	57	25	50	22	37	26	68	36	78	24	1	0	0.23	0	842	297	7.3	295.0	23.0	0.11	0.00	0.000	0.005	0.000	1.45	0.050	id
	30th	74	29	64	26	40	28	317	42	100	29	2	0	0.49	0	934	333	7.5	334.2	30.0	0.14	0.00	0.010	0.005	0.010	1.64	0.107	id
	40th	96	32	72	28	45	31	379	50	140	35	3	1	0.50	0	1050	370	7.6	363.2	35.0	0.16	0.01	0.010	0.005	0.015	1.95	0.109	id
	50th	116	35	80	31	51	33	430	57	181	42	4	1	1.00	0	1196	411	7.8	386.0	41.0	0.20	0.01	0.020	0.005	0.015	2.29	0.217	id
	60th	139	39	95	33	60	35	461	62	249	49	6	1	1.48	0	1399	468	7.9	411.0	47.0	0.20	0.01	0.090	0.010	0.015	2.84	0.322	id
	70th	163	43	110	36	74	37	496	70	360	57	8	1	2.50	0	1841	560	8.0	443.0	50.0	0.23	0.01	0.270	0.010	0.015	3.24	0.543	id
	80th	195	47	134	38	84	39	545	75	490	65	11	1	4.40	1	2314	691	8.1	474.2	54.0	0.29	0.02	0.490	0.020	0.015	3.85	0.957	id
	90th	245	56	183	41	149	42	609	79	794	82	18	2	7.77	1	3267	1064	8.2	541.6	61.0	0.37	0.04	1.255	0.040	0.015	4.57	1.689	id
15 - Gold Coast Alluvium	Sam.	41	41	41	41	41	41	40	40	41	41	40	40	4	4	41	41	41	41	37	38	25	19	3	3	41	4	1
	10th	32	50	7	4	5	12	17	2	59	56	4	3	id	id	305	39	6.4	14.0	12.0	0.20	0.10	id	id	id	2.13	id	id
	20th	55	59	14	5	12	13	28	4	98	68	17	5	id	id	535	73	6.9	23.0	13.2	0.24	0.10	id	id	id	2.33	id	id
	30th	142	64	24	9	20	15	76	6	224	71	34	6	id	id	940	158	7.3	63.0	15.0	0.40	0.10	id	id	id	4.89	id	id
	40th	179	65	27	10	33	18	99	11	323	73	62	8	id	id	1400	215	7.6	83.0	18.4	0.60	0.12	id	id	id	5.47	id	id
	50th	198	66	34	11	38	21	100	13	360	75	80	10	id	id	1500	217	7.9	83.0	21.0	0.80	0.30	**0.490**	id	id	6.12	id	id
	60th	300	67	49	12	42	22	130	14	483	78	95	12	id	id	2250	284	8.0	104.0	25.0	0.92	0.40	id	id	id	7.91	id	id
	70th	435	72	76	16	67	24	194	15	820	84	142	13	id	id	2950	506	8.2	164.0	35.8	1.00	0.40	id	id	id	8.55	id	id
	80th	1420	82	100	19	121	25	279	20	2110	86	417	13	id	id	7850	762	8.3	218.0	58.6	1.10	0.52	id	id	id	17.93	id	id
	90th	2860	83	170	28	250	26	379	25	4770	89	635	19	id	id	15000	1433	8.4	309.0	64.0	1.56	1.84	id	id	id	32.13	id	id
15 - Gold Coast Alluvium near stream	Sam.	21	21	21	21	21	21	21	21	21	21	20	20	1	1	21	21	21	21	18	19	15	12	2	2	21	1	1
	10th	37	41	24	9	15	18	75	1	80	47	id	id	id	id	505	157	6.9	64.0	id	id	id	id	id	id	2.26	id	id
	20th	142	54	24	10	25	19	98	6	224	68	id	id	id	id	1110	215	7.1	83.0	id	id	id	id	id	id	3.78	id	id

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
	30th	179	59	25	10	38	22	99	12	323	71	id	id	id	id	1400	217	7.3	83.0	id	id	id	id	id	id	5.30	id	id
	40th	185	65	27	11	38	24	100	13	330	73	id	id	id	id	1500	217	8.0	83.0	id	id	id	id	id	id	5.47	id	id
	50th	198	65	38	12	38	25	101	13	360	73	**81**	**12**	id	id	1500	241	8.1	84.0	**46.0**	**0.80**	**0.40**	**0.565**	id	id	5.56	id	id
	60th	300	65	51	15	42	25	152	14	413	75	id	id	id	id	2250	284	8.2	125.0	id	id	id	id	id	id	6.12	id	id
	70th	340	66	92	19	67	25	202	16	615	77	id	id	id	id	2540	506	8.3	171.0	id	id	id	id	id	id	7.38	id	id
	80th	468	67	135	27	103	25	265	20	878	82	id	id	id	id	3140	762	8.4	218.0	id	id	id	id	id	id	8.78	id	id
	90th	3850	67	1060	28	1400	28	354	36	13928	85	id	id	id	id	30000	8410	8.4	291.0	id	id	id	id	id	id	36.31	id	id
16 - Southern Deltaic and Estuarine Deposits near stream	Sam.	8	8	8	8	8	8	8	8	9	9	9	9	5	5	9	8	9	8	8	9	8	6	1	1	8	5	0
	50th	**1193**	**72**	**97**	**10**	**173**	**17**	**322**	**8**	**3600**	**75**	**88**	**5**	id	id	**12800**	**1018**	**7.6**	**268.5**	**19.0**	**0.70**	**0.10**	id	id	id	**14.83**	id	id
17 - Moreton Bay Estuarine and Deltaic Area	Sam.	30	30	30	30	30	30	27	27	32	32	31	31	20	20	32	30	32	24	30	32	29	21	1	1	30	20	0
	10th	19	32	2	2	3	11	0	0	28	41	5	1	0.25	0	167	27	3.2	2.9	11.0	0.10	0.04	0.010	id	id	1.44	id	id
	20th	36	47	5	3	4	12	4	0	45	51	8	1	0.50	0	403	37	3.8	8.4	13.0	0.10	0.07	0.070	id	id	1.68	id	id
	30th	45	55	7	5	8	16	11	2	62	66	15	2	0.50	0	567	81	5.1	17.4	15.0	0.10	0.10	0.100	id	id	2.23	id	id
	40th	99	62	12	8	14	18	28	3	200	71	20	5	0.56	0	888	144	5.6	51.0	16.6	0.20	0.18	0.300	id	id	2.75	id	id
	50th	185	65	20	13	26	19	66	7	465	77	32	7	0.95	0	1675	212	6.4	63.0	19.5	0.40	0.30	0.450	id	id	5.44	**0.207**	id
	60th	266	70	31	17	55	20	90	14	812	90	56	11	1.00	0	2650	265	6.8	114.0	21.4	0.66	1.04	0.800	id	id	8.39	id	id
	70th	366	78	70	20	67	23	152	22	1049	94	98	14	3.80	0	3270	329	7.2	137.1	26.3	0.77	2.06	1.700	id	id	9.32	id	id
	80th	696	81	118	25	165	26	235	32	3280	97	140	19	5.12	0	11480	960	7.7	217.6	31.0	1.00	3.26	4.600	id	id	13.09	id	id
	90th	2249	83	259	31	371	37	361	47	6062	98	1080	23	15.20	1	18460	2190	7.7	313.6	55.5	1.19	8.16	5.800	id	id	23.81	id	id
18 - Pumicestone	Sam.	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	36	39	39	39	39	13	13	39	39	0
	10th	28	43	3	3	5	11	0	0	55	40	10	5	0.00	0	252	32	3.6	0.0	8.0	0.08	0.01	0.010	id	id	1.63	0.000	id
	20th	38	49	5	5	6	12	0	0	60	51	20	8	0.00	0	410	42	4.0	1.0	9.6	0.10	0.02	0.020	id	id	2.04	0.000	id
	30th	59	59	10	6	8	13	8	2	84	57	39	10	0.10	0	560	77	4.5	12.0	11.0	0.11	0.07	0.020	id	id	3.00	0.022	id
	40th	110	65	14	8	14	17	26	3	130	69	61	12	0.50	0	947	111	5.5	27.0	12.0	0.20	0.15	0.030	id	id	3.76	0.109	id
	50th	143	69	20	9	21	19	49	5	220	71	84	16	0.80	0	1100	143	6.0	48.0	14.0	0.40	0.42	0.060	**0.080**	**0.030**	4.66	0.174	id
	60th	180	71	26	10	38	22	76	7	304	74	104	19	1.08	0	1410	197	6.2	78.0	15.8	0.46	0.97	0.138	id	id	6.58	0.235	id
	70th	254	74	44	12	65	24	109	16	405	79	209	21	3.30	0	1656	372	6.4	92.0	18.0	0.56	2.48	0.308	id	id	9.13	0.717	id
	80th	425	77	75	18	122	31	133	21	690	82	314	27	5.58	1	2990	650	6.6	111.0	31.4	0.68	5.00	0.452	id	id	12.77	1.213	id
	90th	1196	85	127	25	157	39	201	31	1975	89	671	53	10.58	1	7103	965	6.8	165.5	40.8	1.10	23.20	1.360	id	id	16.60	2.300	id
18 - Pumicestone near stream	Insufficient data																											
19 - Northern Estuarine Deposits	Insufficient data																											
20 - Southern Coastal Sands	Insufficient data																											
21 - North Stradbroke and Moreton Islands	Sam.	401	401	396	396	398	398	398	398	401	401	381	381	353	353	399	401	399	369	298	383	340	320	133	133	393	353	43
	10th	11	66	0	2	1	7	0	0	18	54	1	1	0.00	0	81	5	4.9	1.0	4.0	0.00	0.00	0.005	0.005	0.005	1.63	0.000	0.000
	20th	12	73	0	2	1	12	2	3	19	64	2	3	0.02	0	87	7	5.2	2.0	6.0	0.00	0.00	0.005	0.010	0.005	1.80	0.004	0.000
	30th	13	76	1	3	1	14	3	6	21	70	2	5	0.05	0	94	7	5.4	3.0	7.0	0.00	0.01	0.010	0.010	0.015	1.91	0.011	0.000
	40th	14	78	1	4	2	15	5	9	23	75	3	6	0.25	0	104	8	5.6	4.0	8.0	0.00	0.01	0.010	0.020	0.015	2.02	0.054	0.000
	50th	16	79	1	5	2	16	6	11	25	79	3	7	0.30	1	112	9	5.8	5.0	9.0	0.01	0.02	0.010	0.030	0.015	2.19	0.065	0.082
	60th	17	80	1	6	2	17	8	15	27	82	4	8	0.50	1	119	10	6.0	8.0	9.0	0.03	0.04	0.020	0.050	0.015	2.35	0.109	0.082
	70th	19	81	2	7	2	18	12	20	29	85	4	9	0.54	1	132	13	6.3	11.0	9.0	0.05	0.08	0.030	0.070	0.020	2.53	0.117	0.082
	80th	23	83	2	11	3	19	18	26	32	87	5	10	1.10	2	148	16	6.6	17.0	10.0	0.10	0.20	0.050	0.110	0.036	2.77	0.239	0.082
	90th	28	86	5	15	3	21	35	39	42	90	7	14	1.90	4	195	24	7.0	31.0	11.0	0.10	0.56	0.100	0.220	0.060	3.61	0.413	0.082
	Sam.	246	246	246	246	246	246	243	243	246	246	245	245	237	237	241	246	242	242	240	240	237	237	194	194	246	237	3

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
22 - Northern Coastal Sands	10th	11	49	1	3	1	11	0	0	20	40	0	0	0.00	0	97	8	4.5	1.0	7.0	0.00	0.01	0.005	0.010	0.000	1.21	0.000	id
	20th	15	54	1	4	2	14	3	5	24	46	1	1	0.00	0	132	13	4.9	2.0	8.0	0.00	0.03	0.010	0.020	0.010	1.56	0.000	id
	30th	20	64	2	5	3	15	5	7	31	57	1	1	0.00	0	164	18	5.1	4.3	9.0	0.00	0.13	0.015	0.030	0.010	1.82	0.000	id
	40th	23	70	3	7	4	17	9	10	38	73	2	2	0.25	0	206	25	5.3	8.0	10.0	0.01	0.25	0.020	0.050	0.015	2.04	0.054	id
	50th	30	74	4	8	5	18	16	14	47	79	3	3	0.25	0	258	34	5.5	14.0	10.0	0.03	0.38	0.030	0.070	0.015	2.37	0.054	id
	60th	40	76	5	10	6	19	30	18	60	83	3	6	0.25	0	320	39	5.8	24.0	12.0	0.03	0.82	0.050	0.090	0.020	2.96	0.054	id
	70th	45	78	8	16	7	21	40	26	69	85	6	8	0.30	0	347	46	6.2	33.0	12.0	0.05	1.62	0.080	0.130	0.040	3.34	0.065	id
	80th	55	80	11	19	8	23	66	42	86	88	12	12	0.50	1	426	60	6.4	55.0	14.0	0.09	2.72	0.120	0.160	0.060	3.81	0.109	id
	90th	79	82	20	28	11	29	110	54	123	93	30	20	1.30	1	680	96	6.7	92.0	20.0	0.10	5.80	0.284	0.230	0.120	4.93	0.283	id
23 - Lower Brisbane River	Sam.	50	50	48	48	50	50	47	47	50	50	43	43	37	37	50	50	50	44	38	43	37	33	2	2	48	37	0
	10th	26	44	1	2	2	10	4	2	33	33	3	2	0.00	0	169	14	4.7	5.0	9.7	0.10	0.00	0.010	id	id	2.03	0.000	id
	20th	35	58	2	3	5	11	8	4	46	44	4	2	0.42	0	254	23	5.5	15.2	11.8	0.10	0.01	0.010	id	id	3.07	0.091	id
	30th	51	68	2	4	7	13	21	8	62	58	7	2	0.50	0	349	36	6.5	29.3	19.0	0.10	0.01	0.010	id	id	3.72	0.109	id
	40th	76	71	7	7	10	16	58	13	85	67	9	3	0.50	0	536	54	6.8	82.2	21.6	0.20	0.02	0.028	id	id	4.35	0.109	id
	50th	108	75	16	8	20	18	115	15	163	77	14	3	1.00	0	891	118	7.1	110.0	27.0	0.20	0.03	0.040	id	id	5.11	0.217	id
	60th	154	77	35	10	28	21	197	19	235	82	22	3	1.64	0	1120	215	7.4	178.0	32.2	0.30	0.04	0.092	id	id	7.11	0.357	id
	70th	310	80	52	12	41	23	239	30	413	83	31	4	4.34	2	1915	286	7.6	243.4	35.8	0.50	0.06	0.258	id	id	8.92	0.943	id
	80th	451	81	80	15	70	26	435	41	762	88	57	6	18.24	9	2840	471	7.8	366.0	45.0	0.56	0.22	0.442	id	id	11.03	3.965	id
	90th	1468	87	168	18	180	34	518	62	3165	95	118	8	45.60	35	8700	1163	8.1	435.0	50.1	0.68	0.76	0.498	id	id	17.10	9.913	id
23 - Lower Brisbane River near stream	Sam.	8	8	8	8	8	8	8	8	8	8	7	7	7	7	8	8	8	8	8	8	8	8	0	0	8	7	0
	50th	**198**	**76**	**31**	**10**	**25**	**14**	**163**	**15**	**320**	**80**	id	id	id	id	**1175**	**203**	**7.0**	**134.5**	**32.5**	**0.15**	**0.03**	**0.195**	id	id	**7.89**	id	id
Fractured rock																												
1 - Upper Condamine Basalts (cont)	Sam.	385	385	384	384	384	384	384	384	385	385	333	333	279	279	380	385	364	385	211	358	162	149	21	21	383	279	36
	10th	42	16	7	5	3	4	197	44	33	12	0	0	0.00	0	477	29	7.4	162.8	17.0	0.10	0.00	0.000	0.000	0.000	0.85	0.000	0.000
	20th	50	18	18	9	16	18	293	56	45	16	0	0	0.00	0	688	123	7.6	241.6	24.0	0.10	0.00	0.000	0.010	0.000	0.99	0.000	0.000
	30th	57	21	27	13	39	30	399	62	57	19	2	0	0.50	0	800	259	7.8	330.0	29.0	0.10	0.01	0.000	0.010	0.000	1.15	0.109	0.000
	40th	68	24	37	17	54	41	450	68	76	23	2	0	0.72	0	901	348	7.9	380.6	33.0	0.15	0.01	0.000	0.010	0.010	1.37	0.157	0.000
	50th	76	27	46	19	65	47	513	71	96	26	3	1	2.50	0	1050	413	7.9	425.0	36.0	0.20	0.02	0.010	0.020	0.010	1.54	0.543	0.000
	60th	87	35	55	22	84	52	560	74	120	30	5	1	6.40	1	1186	495	8.0	462.4	38.0	0.20	0.02	0.010	0.020	0.010	1.99	1.391	0.000
	70th	99	46	62	25	98	57	600	78	151	34	6	1	12.00	2	1300	557	8.2	500.0	42.0	0.20	0.04	0.010	0.020	0.020	2.88	2.609	0.016
	80th	120	69	72	28	115	60	650	83	205	41	9	2	23.00	3	1500	639	8.3	535.2	45.0	0.30	0.10	0.010	0.050	0.030	5.20	5.000	0.082
	90th	157	88	86	31	139	68	706	87	293	50	16	3	36.28	5	1800	744	8.5	581.0	52.0	0.40	0.43	0.022	0.110	0.050	9.56	7.887	0.114
2 - Lower Condamine Basalts (cont) weathered	Insufficient data																											
3 - Lower Condamine Basalts (cont)	Sam.	256	256	256	256	255	255	255	255	255	255	252	252	166.00	166	251	255	251	256	134	248	116	113	11	11	254	166	24
	10th	79	29	13	6	5	6	211	18	61	21	3	1	0.00	0	710	56	7.4	192.5	19.0	0.10	0.00	0.000	id	id	1.76	0.000	0.000
	20th	100	36	17	9	9	9	265	28	95	28	7	1	0.00	0	810	90	7.6	226.0	31.6	0.20	0.00	0.000	id	id	2.26	0.000	0.000
	30th	120	41	28	12	25	17	301	36	121	35	11	1	0.50	0	950	214	7.7	257.0	41.0	0.25	0.01	0.000	id	id	3.08	0.109	0.000
	40th	138	46	42	15	38	23	354	43	155	39	13	2	0.50	0	1114	284	7.9	303.0	46.0	0.30	0.01	0.010	id	id	3.62	0.109	0.000
	50th	160	51	57	19	51	28	410	49	210	47	16	2	0.70	0	1300	390	8.0	360.0	51.0	0.32	0.01	0.010	**0.000**	**0.020**	4.01	0.152	0.000
	60th	185	56	71	21	67	32	464	57	289	54	19	3	1.90	0	1550	451	8.1	404.0	53.0	0.40	0.02	0.010	id	id	4.86	0.413	0.000
	70th	245	66	85	25	84	36	516	60	381	60	22	4	6.05	0	1950	551	8.2	434.0	56.1	0.50	0.03	0.010	id	id	6.36	1.315	0.000
	80th	300	78	115	28	110	41	553	66	634	68	35	5	17.50	1	2600	688	8.3	468.0	60.0	0.60	0.05	0.020	id	id	8.10	3.804	0.000
	90th	479	85	173	32	144	47	653	76	1084	77	74	7	33.00	4	3600	967	8.5	544.5	69.0	0.80	0.10	0.029	id	id	11.92	7.174	0.114
4 - Toowoomba Region Basalts (cont)	Sam.	2252	2252	2249	2249	2213	2213	2239	2239	2251	2251	2082	2082	1695	1695	2192	2230	2135	2241	1230	2081	895	862	162	162	2208	1695	146
	10th	55	18	6	5	2	2	117	24	60	25	0	0	0.00	0	510	26	7.2	100.0	16.0	0.05	0.00	0.000	0.005	0.000	1.11	0.000	0.000
	20th	67	21	16	10	7	8	179	32	85	31	4	1	0.25	0	660	83	7.5	150.0	20.0	0.10	0.00	0.000	0.005	0.010	1.31	0.054	0.000
	30th	78	25	28	14	18	20	244	39	113	36	6	1	0.52	0	810	160	7.7	206.0	25.0	0.10	0.01	0.000	0.005	0.015	1.53	0.113	0.000
	40th	88	29	41	19	38	32	300	45	144	41	8	1	1.66	0	990	279	7.8	251.0	31.0	0.10	0.01	0.010	0.005	0.015	1.81	0.361	0.000
	50th	97	34	52	21	59	40	356	50	180	46	10	2	4.70	1	1179	396	7.9	297.0	34.0	0.19	0.02	0.010	0.005	0.015	2.17	1.022	0.000
	60th	108	45	64	24	80	45	415	54	220	50	12	2	10.00	1	1350	501	8.0	347.0	37.4	0.20	0.02	0.010	0.010	0.015	2.81	2.174	0.000

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
	70th	122	60	80	26	97	50	470	59	269	56	16	3	19.00	2	1550	602	8.1	392.0	41.0	0.20	0.03	0.010	0.010	0.015	4.07	4.130	0.000
	80th	143	80	100	29	119	54	540	65	350	63	22	4	33.84	4	1809	717	8.2	450.0	46.0	0.30	0.05	0.020	0.025	0.015	6.80	7.357	0.000
	90th	179	92	128	34	156	59	632	72	530	73	40	6	62.00	7	2339	917	8.4	525.0	53.0	0.35	0.10	0.040	0.050	0.025	11.50	13.478	0.000
5 - Toowoomba Region Basalts (cont) weathered	Insufficient data																											
6 - Lamington Basalt	Insufficient data																											
7 - Mount Tamborine	Insufficient data																											
8 - Sunnybank weathered basalt remnants	Insufficient data																											
9 - Northern Basalts (cont)	Insufficient data																											
10 - Northeast Mesozoic Volcanics	Insufficient data																											
11 - Eastern Trap Rocks	Sam.	160	160	160	160	160	160	160	160	160	160	160	160	151	151	159	160	160	156	146	157	149	150	79	79	160	151	7
	10th	31	49	5	4	3	7	0	0	33	26	2	0	0.00	0	244	33	4.7	1.0	9.0	0.06	0.00	0.020	0.010	0.010	1.96	0.000	id
	20th	58	54	9	6	7	11	10	3	64	34	4	1	0.00	0	521	61	5.6	11.0	14.0	0.10	0.00	0.078	0.020	0.010	2.58	0.000	id
	30th	80	61	12	7	10	12	32	8	105	43	7	1	0.25	0	690	82	6.1	29.5	16.5	0.15	0.01	0.200	0.020	0.025	3.11	0.054	id
	40th	99	65	16	9	12	13	59	14	127	56	9	3	0.25	0	853	95	6.5	56.0	21.0	0.18	0.01	0.612	0.030	0.025	3.65	0.054	id
	50th	106	69	18	13	14	15	96	21	165	64	14	4	0.50	0	1000	113	6.7	88.5	28.0	0.20	0.01	1.150	0.040	0.025	4.33	0.109	id
	60th	152	73	25	17	16	18	157	28	233	71	23	7	0.50	0	1170	151	7.1	143.0	33.0	0.21	0.02	1.900	0.078	0.040	5.34	0.109	id
	70th	237	77	39	21	23	20	217	35	295	81	73	13	0.80	0	1386	223	7.5	183.0	41.5	0.29	0.02	2.730	0.100	0.050	8.22	0.174	id
	80th	327	79	64	25	34	23	265	41	474	88	113	25	1.40	0	1732	278	7.8	224.0	56.0	0.40	0.05	3.402	0.130	0.050	10.57	0.304	id
	90th	446	88	84	32	77	28	454	54	842	95	151	38	3.30	1	3210	506	8.0	376.0	66.0	0.68	0.41	4.529	0.190	0.070	15.56	0.717	id
12 - Western Great Dividing Range	Insufficient data																											
13 - Esk Trough Paleozoic sediments	Sam.	16	16	15	15	16	16	16	16	16	16	16	16	14	14	16	16	16	16	1	16	0	0	0	0	15	14	14
	50th	**849**	**55**	**126**	**9**	**226**	**32**	**727**	**19**	**1600**	**76**	**120**	**5**	**1.10**	**0**	**6005**	**1247**	**8.0**	**598.0**	id	**0.02**	id	id	id	id	**9.76**	**0.239**	**0.163**
14 - North eastern Great Dividing Range	Insufficient data																											
15 - Cressbrook Creek	Sam.	54	54	54	54	54	54	54	54	54	54	54	54	51	51	56	54	56	54	52	54	49	49	34	34	54	51	2
	10th	42	27	34	30	19	28	121	10	95	51	1	0	0.00	0	562	166	6.8	100.0	27.1	0.07	0.00	0.000	0.005	0.000	1.35	0.000	id
	20th	46	30	40	31	23	29	131	15	114	55	3	1	0.20	0	648	196	7.0	109.6	29.2	0.09	0.00	0.000	0.005	0.000	1.43	0.043	id
	30th	51	31	45	31	26	30	141	17	126	57	5	1	0.25	0	720	218	7.2	115.8	32.0	0.10	0.01	0.005	0.010	0.015	1.48	0.054	id
	40th	59	32	54	33	31	31	148	27	167	60	6	2	0.30	0	844	268	7.3	122.2	34.0	0.10	0.01	0.332	0.010	0.015	1.59	0.065	id
	50th	69	34	59	34	34	32	153	29	200	66	10	2	0.50	0	975	287	7.5	125.5	38.0	0.11	0.01	0.420	0.015	0.015	1.69	0.109	id
	60th	85	36	69	34	39	33	158	34	248	69	15	2	1.50	0	1200	333	7.8	132.4	39.0	0.11	0.01	0.520	0.020	0.015	1.79	0.326	id
	70th	106	38	84	35	48	34	169	38	353	75	22	3	5.50	1	1535	414	7.9	139.2	40.7	0.12	0.01	0.694	0.030	0.015	1.85	1.196	id
	80th	122	40	109	36	64	35	179	42	474	82	26	5	14.00	1	1800	533	8.0	148.0	46.0	0.12	0.03	0.910	0.030	0.015	2.72	3.043	id
	90th	156	41	155	39	102	37	192	45	690	87	37	6	16.50	2	2315	871	8.3	158.7	50.0	0.14	0.04	1.500	0.105	0.015	2.97	3.587	id
16 - Northern Granite Outcrops	Insufficient data																											
Cainozoic deposits																												

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
1 - Petrie Basin	Insufficient data																											
2 - Central Tertiary Sediments	Insufficient data																											
3 - Sediments Overlying Coal Measures	Insufficient data																											
4 - Amberley Basin	Insufficient data																											
5 - Beaudesert Beds	Insufficient data																											
6 - Duricrust Main Range	Insufficient data																											
7 - Minor Northern Tertiary Deposits	Insufficient data																											
8 - Northern Tertiary Remnants	Insufficient data																											
9 - Sandy Creek Saline Weathered Alluvium	Sam.	48	48	48	48	48	48	33	33	48	48	33	33	34	34	49	48	36	48	25	31	10	10	8	8	48	34	0
	10th	51	21	49	7	62	22	353	6	78	22	9	1	0.03	0	898	376	7.2	267.3	12.4	0.08	id	id	id	id	1.10	0.007	id
	20th	114	24	69	15	77	31	381	8	271	53	10	1	0.68	0	1580	531	7.5	307.0	15.8	0.10	id	id	id	id	1.92	0.148	id
	30th	151	27	112	19	95	33	408	10	450	68	13	2	1.77	0	2044	660	7.7	326.4	24.2	0.10	id	id	id	id	2.47	0.385	id
	40th	210	34	123	21	115	33	435	19	686	76	14	2	3.52	0	2944	775	7.7	357.4	26.6	0.13	id	id	id	id	3.04	0.765	id
	50th	280	40	138	23	150	37	445	21	881	84	70	3	4.00	0	3600	1024	7.8	369.0	29.0	0.20	**0.01**	**0.010**	**0.040**	**0.020**	3.85	0.870	id
	60th	455	43	163	24	200	40	455	32	1349	90	93	4	5.16	0	4686	1258	7.9	379.4	29.4	0.27	id	id	id	id	5.32	1.122	id
	70th	574	48	184	25	261	43	482	43	1918	99	149	5	6.23	0	7176	1554	8.0	411.8	30.8	0.40	id	id	id	id	6.55	1.354	id
	80th	836	50	266	28	305	45	575	65	2501	100	278	7	13.90	1	7824	1938	8.2	487.8	34.4	0.50	id	id	id	id	8.02	3.022	id
	90th	1477	68	300	32	451	53	743	80	3527	100	380	8	33.35	1	10888	2311	8.3	578.1	44.2	0.50	id	id	id	id	16.05	7.250	id
10 - Minor Weathered Tertiary Deposits	Sam.	95	95	95	95	95	95	72	72	95	95	60	60	59	59	95	95	72	95	55	65	19	19	16	16	95	59	2
	10th	35	20	22	6	18	16	202	13	47	19	3	0	0.05	0	584	159	7.5	186.0	20.0	0.10	id	id	id	id	0.94	0.011	id
	20th	58	23	34	12	32	24	310	31	72	22	5	1	0.23	0	867	229	7.6	296.8	27.0	0.10	id	id	id	id	1.29	0.050	id
	30th	68	25	53	17	45	31	383	41	105	27	5	1	0.94	0	1080	330	7.7	345.0	30.2	0.16	id	id	id	id	1.41	0.204	id
	40th	81	27	69	23	55	34	427	53	145	36	9	2	1.60	0	1190	415	7.8	378.4	34.0	0.20	id	id	id	id	1.68	0.348	id
	50th	113	30	78	29	65	37	506	63	197	47	11	2	3.50	0	1450	461	7.9	415.0	37.0	0.20	**0.01**	**0.015**	**0.005**	**0.015**	1.92	0.761	id
	60th	148	37	90	33	77	38	570	70	242	63	20	2	6.00	1	1594	519	7.9	470.0	39.0	0.29	id	id	id	id	2.59	1.304	id
	70th	188	50	102	34	90	41	600	74	312	87	32	3	8.00	1	1800	580	8.0	489.8	41.8	0.35	id	id	id	id	4.09	1.739	id
	80th	252	60	121	37	113	43	656	77	474	100	60	4	13.00	1	2234	754	8.1	528.4	48.0	0.40	id	id	id	id	6.24	2.826	id
	90th	939	74	178	42	187	45	739	80	1784	100	185	7	18.60	3	6484	1147	8.3	597.6	51.2	0.53	id	id	id	id	17.40	4.043	id
Lower GAB aquifers and aquitards																												
1 - Southeastern Hutton Outcrop (cont)	Sam.	609	609	610	610	606	606	606	605	606	605	578	577	412	411	595	607	571	605	354	562	234	216	22	22	606	412	41
	10th	81	29	16	5	9	5	152	10	116	32	3	1	0.00	0	870	88	7.3	132.8	11.0	0.10	0.00	0.000	0.000	0.000	1.97	0.000	0.000
	20th	124	37	28	9	15	9	234	16	158	39	8	1	0.00	0	1100	145	7.5	200.0	13.0	0.10	0.00	0.000	0.001	0.002	2.85	0.000	0.000
	30th	161	44	40	11	24	14	314	22	210	47	11	1	0.40	0	1305	216	7.6	270.2	15.0	0.17	0.01	0.010	0.005	0.010	3.55	0.087	0.000
	40th	205	51	52	15	39	19	373	29	288	54	14	2	0.50	0	1506	310	7.8	317.6	17.0	0.20	0.02	0.010	0.005	0.012	4.86	0.109	0.000
	50th	250	57	66	18	53	24	420	36	368	60	20	2	0.80	0	1780	399	7.9	351.0	20.0	0.30	0.02	0.010	0.010	0.015	5.65	0.174	0.000
	60th	301	62	80	20	67	29	470	43	495	68	25	3	1.16	0	2154	479	8.0	395.0	23.0	0.30	0.04	0.020	0.020	0.018	7.05	0.252	0.000
	70th	365	69	100	22	89	34	522	51	694	75	35	3	2.50	0	2900	625	8.1	445.0	26.1	0.40	0.05	0.040	0.025	0.020	8.17	0.543	0.000
	80th	509	77	140	26	145	41	585	59	1035	81	55	4	3.90	0	3806	960	8.2	487.2	30.0	0.50	0.10	0.080	0.046	0.025	10.25	0.848	0.016
	90th	781	87	205	31	253	47	671	66	1875	86	135	5	8.90	1	5700	1573	8.4	563.0	38.0	0.60	0.20	0.370	0.172	0.039	15.07	1.935	0.033
2 - Central Huttons	Insufficient data																											

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
3 - Laidley Creek Sandstones	Sam.	55	55	55	55	55	55	55	55	55	55	54	54	46	46	55	55	55	55	39	55	28	27	13	13	55	46	7
	10th	30	22	19	2	14	2	252	10	36	16	7	1	0.05	0	528	91	7.5	210.2	16.4	0.01	0.00	0.000	id	id	0.87	0.011	id
	20th	33	23	39	7	25	17	265	16	39	17	11	1	0.20	0	552	200	7.8	220.8	34.4	0.10	0.00	0.010	id	id	0.98	0.043	id
	30th	40	26	42	13	28	22	275	26	46	19	12	2	0.50	0	650	219	7.9	231.6	37.0	0.16	0.01	0.010	id	id	1.23	0.109	id
	40th	58	28	44	22	30	34	362	34	55	20	17	2	0.50	0	878	239	8.0	302.2	41.2	0.20	0.01	0.010	id	id	1.34	0.109	id
	50th	81	30	51	33	42	36	430	52	95	22	26	3	1.80	0	1143	298	8.1	357.0	43.0	0.20	0.01	0.010	**0.020**	**0.010**	2.03	0.391	id
	60th	175	42	66	35	52	37	524	72	630	65	33	4	2.70	0	2540	360	8.1	431.4	44.8	0.20	0.02	0.013	id	id	3.31	0.587	id
	70th	720	66	84	36	69	38	562	74	1196	71	44	5	4.50	1	4770	505	8.2	464.8	46.6	0.20	0.03	0.020	id	id	12.20	0.978	id
	80th	1561	76	159	37	126	39	724	76	2230	81	80	7	7.50	1	7884	968	8.3	593.8	47.4	0.30	0.05	0.020	id	id	23.73	1.630	id
	90th	2264	93	230	38	374	40	832	79	4068	89	139	10	31.00	5	12508	2145	8.4	696.2	50.0	0.35	0.06	0.480	id	id	42.01	6.739	id
4 - Southeastern Marburgs	Sam.	11	11	11	11	11	11	11	11	11	11	11	11	10	10	11	11	11	11	6	11	5	6	5	5	11	10	5
	50th	**747**	**88**	**63**	**7**	**11**	**3**	**285**	**13**	**1100**	**83**	**63**	**3**	**0.60**	**0**	**4100**	**216**	**7.9**	**256.0**	id	**0.10**	id	id	id	id	**27.46**	**0.130**	id
5 - South East Walloons (cont)	Sam.	707	707	706	706	674	674	703	703	707	707	630	630	490	490	665	703	646	705	386	640	321	294	93	93	674	490	81
	10th	91	31	5	2	1	1	171	12	68	21	1	0	0.00	0	731	24	7.5	184.0	11.0	0.05	0.00	0.000	0.000	0.000	2.11	0.000	0.000
	20th	122	43	10	3	4	2	278	27	110	27	4	0	0.05	0	930	49	7.7	249.6	12.0	0.10	0.00	0.000	0.005	0.010	3.05	0.011	0.000
	30th	159	54	18	6	8	5	342	35	140	35	7	1	0.50	0	1142	98	7.8	300.0	14.0	0.12	0.01	0.000	0.005	0.010	4.77	0.109	0.000
	40th	200	64	30	8	18	8	403	42	189	41	10	1	0.60	0	1350	168	8.0	350.0	16.0	0.20	0.01	0.010	0.005	0.015	6.63	0.130	0.033
	50th	255	73	43	11	29	13	455	49	265	47	14	2	1.00	0	1640	251	8.1	395.0	18.0	0.25	0.01	0.010	0.010	0.015	8.99	0.217	0.065
	60th	325	82	53	14	45	20	513	55	374	54	23	3	1.70	0	2000	330	8.2	458.8	21.0	0.30	0.01	0.010	0.012	0.015	11.70	0.370	0.082
	70th	408	89	72	18	60	26	596	63	501	61	34	3	2.60	0	2484	421	8.3	517.8	25.0	0.40	0.03	0.020	0.024	0.015	15.60	0.565	0.082
	80th	555	93	96	23	91	33	688	70	794	71	51	4	5.40	0	3300	579	8.4	589.0	31.0	0.45	0.05	0.030	0.046	0.015	23.17	1.174	0.082
	90th	1024	96	145	30	140	44	788	77	1539	85	106	7	13.10	1	5726	925	8.7	686.0	38.5	0.63	0.16	0.110	0.126	0.030	38.71	2.848	0.082
6 - Logan Albert Walloons	Insufficient data																											
7 - Lockyer Valley Sandstones	Sam.	183	183	183	183	182	182	173	173	183	183	165	165	149	149	173	183	172	183	144	169	104	102	47	47	182	149	1
	10th	42	30	13	2	10	11	89	11	50	26	2	0	0.00	0	512	81	7.2	106.0	14.0	0.05	0.00	0.000	0.000	0.000	1.54	0.000	id
	20th	67	38	19	4	18	13	226	19	90	36	5	1	0.25	0	642	132	7.4	221.6	20.0	0.10	0.00	0.005	0.005	0.000	2.21	0.054	id
	30th	128	48	25	6	23	16	318	24	180	41	8	1	0.50	0	1165	173	7.7	291.0	23.0	0.10	0.01	0.010	0.010	0.004	2.73	0.109	id
	40th	185	56	34	9	32	19	403	30	224	48	10	1	0.76	0	1508	246	7.8	355.6	28.2	0.17	0.01	0.010	0.010	0.010	4.00	0.165	id
	50th	237	64	42	12	64	23	500	39	317	60	14	2	1.50	0	1863	419	8.0	425.0	32.0	0.20	0.01	0.010	0.020	0.015	7.12	0.326	id
	60th	315	69	60	17	99	26	581	51	473	69	18	2	3.00	0	2303	577	8.1	481.8	36.0	0.23	0.02	0.026	0.020	0.015	8.22	0.652	id
	70th	478	75	74	21	114	29	670	58	838	74	30	2	5.12	0	3657	666	8.2	549.6	39.0	0.30	0.03	0.047	0.020	0.015	11.64	1.113	id
	80th	1113	81	97	24	158	35	838	63	1630	83	58	3	10.82	1	6120	825	8.3	698.6	45.0	0.40	0.06	0.100	0.038	0.020	19.64	2.352	id
	90th	1767	86	134	30	217	43	1039	73	3336	90	126	4	21.60	1	10394	1165	8.4	869.4	55.7	0.51	0.13	0.229	0.132	0.025	29.29	4.696	id
8 - Lockyer Valley Southern Headwaters	Sam.	116	116	116	116	116	116	89	89	115	115	88	88	83	83	115	116	94	116	73	87	18	17	7	6	116	83	4
	10th	133	21	53	6	74	16	342	9	422	50	10	0	0.50	0	2304	493	7.2	288.0	10.4	0.10	id	id	id	id	1.73	0.109	id
	20th	214	26	83	9	124	23	380	12	641	66	20	1	2.00	0	3000	696	7.4	326.0	19.0	0.10	id	id	id	id	2.37	0.435	id
	30th	317	29	107	12	161	36	435	14	942	72	33	2	3.30	0	3654	1000	7.5	365.0	27.6	0.20	id	id	id	id	3.32	0.717	id
	40th	406	32	140	17	195	38	458	16	1213	76	54	3	7.80	0	4524	1151	7.5	390.0	30.0	0.20	id	id	id	id	4.33	1.696	id
	50th	495	37	173	21	234	39	482	19	1380	80	79	4	16.00	1	5010	1445	7.6	425.5	32.0	0.25	**0.05**	**0.020**	id	id	4.90	3.478	id
	60th	570	43	212	25	280	43	579	23	1700	82	104	5	25.00	1	5730	1732	7.7	500.0	34.0	0.30	id	id	id	id	6.13	5.435	id
	70th	712	50	256	27	307	45	643	27	1848	85	158	7	41.20	1	6040	1945	7.8	534.0	36.4	0.40	id	id	id	id	7.62	8.957	id
	80th	820	62	325	28	354	49	787	31	2156	100	236	7	54.60	2	6652	2217	7.9	627.0	40.0	0.50	id	id	id	id	11.81	11.870	id
	90th	1033	79	400	31	432	53	1289	58	2515	100	335	8	65.60	2	7820	2602	8.1	889.0	44.8	0.54	id	id	id	id	16.70	14.261	id
9 - Lockyer Sandstones Recharged Area	Sam.	228	228	228	228	228	228	172	172	228	228	163	163	157	157	223	228	176	228	137	159	56	55	28	28	228	157	2
	10th	43	20	34	14	33	30	180	21	55	22	4	0	0.36	0	634	227	7.5	205.7	21.6	0.10	0.00	0.000	0.004	0.000	0.99	0.078	id
	20th	60	21	42	19	43	35	270	28	99	28	6	1	0.82	0	943	296	7.7	235.4	28.0	0.10	0.01	0.009	0.005	0.004	1.24	0.178	id
	30th	69	23	50	21	53	39	312	35	142	34	8	2	1.70	0	1100	361	7.7	278.1	32.0	0.10	0.01	0.010	0.005	0.010	1.40	0.370	id
	40th	86	26	60	24	64	41	366	48	181	43	10	2	2.50	0	1250	418	7.9	310.8	35.0	0.10	0.01	0.010	0.009	0.010	1.60	0.543	id
	50th	97	28	72	26	78	43	418	55	214	53	13	3	4.30	1	1450	495	8.0	350.5	38.0	0.12	0.01	0.010	0.010	0.015	1.82	0.935	id
	60th	116	33	85	28	92	45	440	60	320	65	18	3	7.16	1	1650	597	8.0	378.2	40.0	0.16	0.01	0.020	0.010	0.015	2.06	1.557	id
	70th	141	37	100	30	105	47	504	66	380	75	45	4	10.20	1	1914	681	8.1	417.0	42.2	0.20	0.02	0.038	0.019	0.015	2.56	2.217	id

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
	80th	181	45	121	32	127	51	548	72	506	100	68	7	19.80	2	2256	841	8.2	454.0	45.0	0.20	0.03	0.162	0.026	0.015	3.45	4.304	id
	90th	283	54	159	34	164	52	641	79	777	100	103	9	34.00	3	3240	1029	8.3	527.5	49.4	0.30	0.05	0.914	0.053	0.025	5.19	7.391	id
Basal GAB Formations																												
1 - Eastern Evergreen Outcrop (cont)	Sam.	28	28	28	28	28	28	28	28	28	28	28	28	20	20	27	28	28	28	20	28	19	19	2	2	28	20	0
	10th	196	42	9	1	4	1	228	9	201	24	3	0	id	id	1368	50	7.0	245.9	id	0.30	id	id	id	id	3.52	id	id
	20th	239	43	13	1	5	1	373	16	308	39	3	0	id	id	1400	65	7.5	366.4	id	0.30	id	id	id	id	4.34	id	id
	30th	298	66	15	2	7	1	513	25	381	39	4	0	id	id	1448	77	7.6	421.7	id	0.31	id	id	id	id	14.06	id	id
	40th	452	72	15	2	11	6	519	30	399	50	5	0	id	id	2050	85	7.8	443.6	id	0.50	id	id	id	id	15.46	id	id
	50th	933	88	20	5	12	6	523	41	466	58	11	1	**1.00**	**0**	2950	85	8.0	447.0	**15.0**	0.67	**0.02**	**0.020**	id	id	18.41	**0.217**	id
	60th	1002	90	28	6	84	18	622	48	808	69	20	1	id	id	4105	534	8.2	522.0	id	0.84	id	id	id	id	23.39	id	id
	70th	1287	97	82	13	98	19	630	60	1004	74	24	2	id	id	5286	610	8.3	526.5	id	1.85	id	id	id	id	58.50	id	id
	80th	1507	98	89	18	150	38	819	60	1482	81	32	2	id	id	5524	789	8.4	691.2	id	2.02	id	id	id	id	60.64	id	id
	90th	1990	98	344	20	292	40	3021	76	3844	89	237	4	id	id	7294	2059	8.4	2495.5	id	3.19	id	id	id	id	66.02	id	id
2 - Eastern Central Area (cont)	Sam.	78	78	76	76	76	76	78	78	78	78	73	73	50	50	68	76	68	78	28	66	31	27	2	2	75	50	17
	10th	132	54	1	0	0	0	232	52	56	12	0	0	0.00	0	777	5	7.6	226.3	13.1	0.20	0.00	0.000	id	id	3.39	0.000	id
	20th	180	94	2	1	0	0	336	57	60	17	2	0	0.00	0	946	7	7.7	315.0	14.5	0.30	0.00	0.000	id	id	20.67	0.000	id
	30th	240	97	2	1	0	0	501	62	76	19	4	1	0.00	0	1120	10	8.0	439.2	16.1	0.50	0.00	0.000	id	id	26.38	0.000	id
	40th	288	97	3	1	1	0	558	70	96	21	8	1	0.00	0	1158	11	8.2	483.8	17.8	0.70	0.01	0.000	id	id	30.10	0.000	id
	50th	306	98	3	1	1	1	620	72	108	25	14	2	0.25	0	1260	14	8.3	548.0	20.0	0.93	0.01	0.000	id	id	36.39	0.054	**0.000**
	60th	320	98	4	2	1	1	650	73	120	28	18	4	0.50	0	1362	25	8.4	558.4	23.2	1.60	0.03	0.008	id	id	39.49	0.109	id
	70th	343	99	7	3	3	2	668	77	150	30	31	5	0.80	0	1550	32	8.5	565.0	24.9	2.30	0.12	0.010	id	id	48.76	0.174	id
	80th	397	99	11	3	5	3	684	82	191	34	35	6	1.05	0	1742	41	8.7	582.2	28.8	3.60	0.18	0.010	id	id	58.03	0.228	id
	90th	439	99	32	24	11	19	775	84	238	41	64	10	1.90	0	1900	120	8.8	658.3	39.0	4.13	0.40	0.030	id	id	83.80	0.413	id
3 - Southeastern Evergreen (cont)	Sam.	104	104	104	104	104	104	103	103	104	104	98	98	81	81	100	104	94	104	78	96	47	47	20	20	104	81	7
	10th	70	45	6	2	2	1	117	10	73	27	0	0	0.00	0	749	30	7.2	106.5	11.0	0.10	0.00	0.000	id	id	3.76	0.000	id
	20th	158	60	10	3	6	3	202	14	165	36	1	0	0.00	0	1047	44	7.4	173.2	14.0	0.20	0.00	0.001	id	id	5.63	0.000	id
	30th	244	69	14	6	11	7	236	21	255	45	5	1	0.00	0	1585	88	7.5	211.5	16.1	0.21	0.00	0.009	id	id	6.87	0.000	id
	40th	317	73	27	9	17	11	338	26	339	57	10	2	0.30	0	1940	161	7.7	306.0	19.0	0.30	0.01	0.010	id	id	8.39	0.065	id
	50th	379	76	40	11	29	14	454	34	475	61	21	3	0.50	0	2325	231	7.9	382.0	26.0	0.30	0.01	0.020	**0.020**	**0.008**	10.11	0.109	id
	60th	460	78	53	12	37	16	496	41	588	71	27	4	0.80	0	2658	280	8.0	419.8	30.0	0.40	0.02	0.050	id	id	12.34	0.174	id
	70th	568	85	78	14	62	18	554	50	783	75	53	5	1.60	0	3085	478	8.1	476.4	33.0	0.55	0.02	0.130	id	id	17.48	0.348	id
	80th	721	94	123	17	87	23	608	62	959	82	69	5	3.00	0	3788	672	8.2	537.0	41.2	0.90	0.07	0.174	id	id	25.44	0.652	id
	90th	926	97	165	24	123	30	725	71	1635	88	160	6	6.20	0	5785	936	8.3	647.5	47.9	1.80	0.19	0.408	id	id	39.00	1.348	id
4 - Beuaraba Woogaroo	Sam.	395	395	397	397	396	396	368	363	384	380	352	347	323	318	379	397	369	380	304	348	263	254	160	159	394	323	28
	10th	25	39	4	7	4	12	13	12	31	31	1	0	0.00	0	209	27	5.8	15.0	11.0	0.02	0.01	0.005	0.005	0.015	1.69	0.000	0.000
	20th	34	50	8	10	5	14	37	21	48	37	2	1	0.25	0	274	41	6.5	38.0	13.0	0.05	0.01	0.010	0.005	0.015	2.02	0.054	0.000
	30th	48	58	12	14	7	16	65	29	64	42	4	1	0.25	0	394	59	6.8	65.0	16.0	0.10	0.01	0.020	0.010	0.015	2.27	0.054	0.000
	40th	67	61	16	16	10	17	99	35	80	46	5	2	0.25	0	559	83	7.1	93.2	21.0	0.10	0.01	0.062	0.020	0.015	2.71	0.054	0.000
	50th	85	64	22	18	14	19	137	44	110	54	7	2	0.25	0	683	116	7.4	128.0	28.0	0.11	0.01	0.090	0.020	0.015	3.18	0.054	0.025
	60th	105	66	31	20	19	21	195	51	139	61	8	3	0.50	0	868	166	7.6	194.0	32.0	0.14	0.01	0.188	0.040	0.015	3.93	0.109	0.163
	70th	130	69	43	22	25	23	293	55	184	68	10	4	0.70	0	1050	209	7.8	257.2	36.0	0.18	0.02	0.301	0.050	0.015	4.27	0.152	0.163
	80th	158	72	52	26	39	27	354	60	225	78	13	5	1.40	0	1250	289	7.9	310.2	43.0	0.20	0.05	0.548	0.070	0.017	4.96	0.304	0.163
	90th	229	76	73	31	52	32	439	65	395	92	17	6	5.04	2	1780	408	8.1	370.0	56.0	0.30	0.58	0.914	0.202	0.050	6.84	1.096	0.163
5 - Gatton Sandstone Southwestern Headwaters	Sam.	86	86	86	86	86	86	73	73	80	80	67	67	59	59	79	86	67	79	58	61	19	17	0	0	86	59	3
	10th	103	26	4	1	1	0	365	7	184	26	3	0	0.00	0	1420	14	7.3	297.0	4.0	0.20	id	id	id	id	1.80	0.000	id
	20th	119	29	8	2	4	2	447	32	244	34	6	1	0.08	0	1600	36	7.4	367.4	7.4	0.20	id	id	id	id	2.03	0.017	id
	30th	266	55	12	3	7	2	470	36	288	44	9	1	0.50	0	1670	58	7.7	392.6	9.1	0.30	id	id	id	id	6.37	0.109	id
	40th	348	65	17	3	14	4	500	41	322	50	11	1	1.00	0	1752	101	7.8	412.6	10.0	0.30	id	id	id	id	12.97	0.217	id
	50th	385	85	26	5	22	9	530	45	337	55	20	2	1.10	0	1850	151	7.9	437.0	11.0	0.30	**0.16**	**0.010**	id	id	17.88	0.239	id
	60th	450	93	56	14	65	21	582	48	361	59	22	2	2.18	0	1990	407	8.1	476.2	13.0	0.40	id	id	id	id	23.20	0.474	id
	70th	520	95	77	16	91	30	660	56	408	62	25	3	4.64	0	2300	606	8.2	544.6	18.7	0.50	id	id	id	id	29.45	1.009	id
	80th	688	97	101	23	106	43	732	66	621	76	47	4	10.00	0	2920	681	8.4	651.6	20.0	0.60	id	id	id	id	35.84	2.174	id
	90th	1350	98	283	28	209	47	916	74	1840	90	600	9	14.00	1	7240	1591	8.5	743.6	23.6	0.80	id	id	id	id	51.85	3.043	id

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
6 - Gatton Sandstone Saline Area	Sam.	843	843	843	843	843	843	730	715	788	773	720	705	671	656	744	843	728	774	693	706	328	322	100	98	843	671	38
	10th	151	25	21	3	10	2	293	9	200	18	4	0	0.00	0	1833	108	7.2	295.0	9.0	0.10	0.00	0.000	0.000	0.000	2.24	0.000	0.000
	20th	215	31	33	4	17	3	418	13	310	25	10	1	0.50	0	2196	167	7.4	360.0	11.0	0.10	0.01	0.010	0.000	0.000	2.94	0.109	0.000
	30th	300	37	46	6	37	11	474	19	389	47	13	1	1.00	0	2600	256	7.5	400.0	13.0	0.20	0.01	0.010	0.005	0.010	3.85	0.217	0.000
	40th	407	43	67	9	86	21	521	25	465	56	20	1	2.00	0	3000	541	7.6	441.4	16.0	0.20	0.01	0.010	0.005	0.010	5.84	0.435	0.000
	50th	532	56	88	13	114	29	592	33	633	65	34	2	2.60	0	3740	711	7.7	494.5	23.0	0.27	0.03	0.020	0.010	0.015	8.50	0.565	0.000
	60th	650	68	110	17	147	36	705	42	871	73	50	3	4.50	0	4370	864	7.8	575.8	28.0	0.30	0.06	0.020	0.010	0.015	11.46	0.978	0.000
	70th	800	83	144	20	195	42	947	53	1250	78	84	4	7.70	0	5100	1165	7.9	756.1	32.0	0.40	0.18	0.050	0.020	0.015	20.53	1.674	0.000
	80th	1050	92	210	23	270	47	1310	77	1862	85	146	6	21.00	1	6258	1671	8.0	1066.6	37.0	0.60	0.37	0.090	0.030	0.030	27.84	4.565	0.163
	90th	1300	94	292	27	377	52	2201	81	2500	91	265	9	37.30	1	8070	2223	8.3	1845.0	42.0	0.90	0.85	0.551	0.050	0.030	38.06	8.109	0.163
7 - Lower Lockyer Recharged Area	Sam.	649	649	649	649	649	649	608	608	649	649	606	606	581	581	636	649	609	649	546	593	341	333	166	166	649	581	7
	10th	50	19	30	10	33	28	258	23	64	23	4	1	0.00	0	730	240	7.5	236.0	26.0	0.09	0.00	0.000	0.000	0.000	1.13	0.000	id
	20th	68	22	43	16	45	35	320	30	110	30	7	1	0.25	0	980	320	7.7	274.6	31.0	0.10	0.01	0.005	0.005	0.010	1.37	0.054	id
	30th	76	25	53	20	60	38	361	37	167	37	9	1	0.70	0	1200	390	7.8	310.0	34.0	0.10	0.01	0.010	0.005	0.010	1.51	0.152	id
	40th	93	27	64	23	71	41	400	43	205	43	12	2	1.50	0	1400	450	7.9	340.0	37.0	0.10	0.01	0.010	0.005	0.015	1.66	0.326	id
	50th	110	30	73	25	86	43	440	48	287	48	15	2	3.00	0	1650	527	8.0	373.0	39.0	0.11	0.01	0.010	0.010	0.015	1.92	0.652	id
	60th	138	34	83	27	100	46	475	55	381	54	21	3	6.00	1	1900	615	8.0	400.0	42.0	0.16	0.02	0.010	0.010	0.015	2.34	1.304	id
	70th	161	37	98	29	119	48	517	61	469	61	30	4	10.00	1	2205	743	8.1	439.6	44.0	0.20	0.03	0.020	0.010	0.015	2.88	2.174	id
	80th	217	44	124	31	151	51	583	67	592	69	50	5	18.00	2	2600	911	8.2	495.4	47.0	0.20	0.05	0.020	0.020	0.020	3.45	3.913	id
	90th	330	55	178	35	205	55	683	74	944	83	72	6	40.50	3	3900	1277	8.4	577.4	51.0	0.21	0.08	0.148	0.030	0.025	5.07	8.804	id
8 - Logan Albert Sandstones	Insufficient data																											
9 - Albert River Woogaroo	Insufficient data																											
10 - Clarence Moreton Nambour Connection	Sam.	9	9	9	9	9	9	8	8	9	9	9	9	6	6	9	9	9	7	4	9	6	4	2	2	9	6	1
	50th	**184**	**77**	**19**	**9**	**17**	**20**	**5**	**28**	**394**	**81**	**14**	**2**	id	id	**1380**	**239**	**5.9**	id	id	**0.13**	id	id	id	id	**7.36**	id	id
11 - Nambour Basin	Sam.	60	60	60	60	60	60	60	60	60	60	59	59	59	59	60	60	60	56	59	60	60	60	0	0	60	59	0
	10th	8	33	1	2	2	10	2	1	8	16	1	1	0.50	0	94	12	4.6	1.5	7.0	0.00	0.00	0.019	id	id	0.70	0.109	id
	20th	11	39	1	5	2	13	3	3	10	25	2	2	0.72	0	119	16	5.1	2.0	8.0	0.00	0.00	0.020	id	id	0.88	0.157	id
	30th	14	49	1	7	3	14	4	5	17	31	2	2	2.04	2	145	22	5.4	6.0	9.0	0.10	0.02	0.020	id	id	1.00	0.443	id
	40th	17	54	2	8	4	16	10	9	19	33	2	3	4.22	4	158	27	5.6	14.0	9.2	0.10	0.02	0.030	id	id	1.21	0.917	id
	50th	22	59	4	11	5	19	23	23	22	37	2	3	13.00	9	192	33	6.0	20.0	12.0	0.10	0.02	0.040	id	id	1.65	2.826	id
	60th	24	63	6	16	6	22	49	34	28	45	2	3	17.98	22	217	40	6.2	41.0	16.4	0.10	0.02	0.060	id	id	1.94	3.909	id
	70th	35	69	9	22	6	26	60	50	34	51	3	4	25.70	45	294	57	6.3	53.0	22.6	0.10	0.02	0.122	id	id	2.15	5.587	id
	80th	38	76	19	31	8	36	106	59	44	60	5	5	39.50	56	369	84	6.7	90.0	34.4	0.20	0.02	0.260	id	id	3.39	8.587	id
	90th	82	83	60	41	13	50	202	70	88	73	13	7	58.28	63	533	170	7.3	167.5	41.4	0.30	0.03	0.637	id	id	4.54	12.670	id
12 - Eudlo Creek Nambour Formation	Insufficient data																											
13 - Kin Kin Beds	Insufficient data																											
14 - Noosa River Sandstone	Insufficient data																											
15 - Tarong Basin	Insufficient data																											
16 - Southern Moreton Bay and Barrier Islands	Insufficient data																											
Earlier sedimentary basins underlying the GAB																												

Chemistry zone	%ile	Na		Ca		Mg		HCO_3		Cl		SO_4		NO_3 (ion)		EC	Hard	pH	Alk	SiO_2	F	Fe	Mn	Zn	Cu	SAR	TN	TP
		mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	mg/L	%	µS/ cm	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L		mg/L	mg/L
1 - Logan Coal Measures	Sam.	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57	57	55	57	57	57	56	25	25	57	57	0
	10th	111	45	12	3	2	4	1	2	75	21	7	1	0.00	0	861	96	5.4	24.4	18.6	0.10	0.00	0.005	0.010	0.007	2.73	0.000	id
	20th	161	56	16	5	16	10	44	4	183	46	14	2	0.05	0	1105	123	5.9	75.2	25.0	0.12	0.01	0.020	0.018	0.010	4.95	0.011	id
	30th	195	72	24	6	20	12	124	7	333	60	26	3	0.50	0	1436	160	6.7	120.4	27.6	0.20	0.01	0.100	0.024	0.020	7.77	0.109	id
	40th	232	77	40	7	23	13	193	7	438	86	39	4	0.50	0	1646	242	6.9	184.6	33.4	0.20	0.02	0.290	0.040	0.023	9.08	0.109	id
	50th	284	78	49	7	29	14	235	7	482	87	58	5	0.60	0	2150	307	7.1	244.0	35.0	0.42	0.03	0.425	0.080	0.025	12.00	0.130	id
	60th	425	79	72	8	47	14	303	10	791	87	106	6	1.00	0	2736	452	7.2	255.0	37.6	0.50	0.07	0.800	0.112	0.044	12.68	0.217	id
	70th	824	80	95	10	83	15	325	32	1477	88	158	6	2.50	0	5099	517	7.4	301.6	44.2	0.54	0.10	1.210	0.222	0.050	16.50	0.543	id
	80th	1506	83	128	31	164	16	395	45	2814	92	250	8	2.50	0	8940	892	7.6	343.4	55.0	0.60	0.49	1.540	0.544	0.060	21.83	0.543	id
	90th	1829	87	145	39	203	20	434	55	3215	97	299	18	5.00	0	10228	1177	8.7	358.6	72.6	0.70	2.64	3.220	1.328	0.118	24.29	1.087	id
2 - Brisbane Coal Bearing Beds	Insufficient data																											
3 - Ipswich Coal Deposits	Insufficient data																											
4 - Kholo Sediments and Volcanics	Insufficient data																											

Notes

1. Abbreviations: Sam.: Number of samples, Na: Sodium, Ca: Calcium, Mg: Magnesium, HCO_3: Bicarbonate, Cl: Chloride, SO_4: Sulfate, NO_3: Nitrate (expressed as the ion), EC: Electrical conductivity, Hard: hardness, Alk: alkalinity, SiO_2: Silica, F: Fluoride, Fe: Iron, Mn: Manganese, Zn: Zinc, Cu: Copper, SAR: Sodium adsorption ratio, TN: total nitrogen, TP: total phosphorus, mg/L: milligrams per Litre, µS/cm: microsiemens/centimetre

2. Percentiles are provided in most cells where samples are available for a particular indicator. The Queensland Water Quality Guidelines (section 4) contains information on recommended minimum sample size when deriving percentiles for use in deriving water quality guidelines. For this table, where less than 8 samples were available, cell shows insufficient data ('id'); where 8–20 samples were available, 50th percentile values are provided (in bold). Where greater than 20 samples were available, the full percentile ranges are provided. The intent is to maintain current water quality (20th, 50th and 80th percentile ranges) where water quality is in natural condition. Where there is evidence of anthropogenic disturbance in groundwater quality, a long term goal to improve water quality may be established and reflected by adoption of an alternative (e.g. 40th percentile) value.

3. Na, Ca and other ion % columns: The percentages of major cations (Na, Ca and Mg) were evaluated for each sample, as were the major anions (Cl, HCO_3, SO_4 and NO_3). Then the ion % columns were compiled by calculating the percentiles of these percentages independently of each other. For instance, in the Alluvium zone 1 – North Coast Alluvium, the 50th percentile of Na is 61, while the 20th–80th percentile range is 37–93. This means that half of the samples contain at least 61% of dissolved Na, with the balance being made up of Ca and Mg in any proportions. Because of this, the sum of the 50th percentiles in Alluvium Zone 1 – North Coast Alluvium – is near to 100%, with Ca contributing 18% and Mg contributing 16%. However, the 20th and 80th percentiles of each of the major cations is based on ranges of that cation, and add up to less or more than 100% respectively.

4. Low TP values (e.g. recordings of zero) may be due to concentrations below detection limits. Concentrations of TP are usually low in Queensland groundwaters, because most of the phosphorus binds to particles in the soil and unsaturated zone, restricting its movement to the aquifer (Holman et al. 2008).

5. Refer to accompanying figures (maps) for locations of chemistry zone. In some locations (mainly within the alluvial aquifer class) a chemistry zone is identified by entire zone and the 'near stream' (within 1.5km of stream channel) component of the zone, where near stream water quality characteristics may be different from overall zone. Percentiles are provided in each case. Overall zone includes near stream and other areas. Near stream zone is shown on large scale plans accompanying this report, available on the department's website.

Reference: Holman, IP, Whelan, MJ, Howden, NJK, Bellamy, PH, Willby, NJ, Rivas-Casado, M & McConvey, P. 2008, 'Phosphorus in groundwater – an overlooked contributor to eutrophication?'. Hydrological Processes, vol. 22, no: 5121–5127.

10 Glossary

Terms as used in this document

Al – Aluminium

Alkalinity – ability to neutralize acids to the equivalence point of carbonate or bicarbonate

Alluvium – loose, friable material eroded and reshaped by water

Anion – A negatively charged ion (e.g. Cl^-).

ANZG – Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Aquiclude – An aquiclude or confining layer is a bed of rock or sediment which, although porous and capable of storing water, can only transmit it at negligible rates. If a confined aquifer is penetrated by a bore, the water will rise to the potentiometric surface, which is an elevation related to the height of the recharge source and hydraulic gradient. This may be above the local water table or even the ground surface.

Aquifer – permeable underground water-bearing material, from which groundwater can be extracted. There are two main aquifer types, confined and unconfined. In an unconfined aquifer, the groundwater surface is a water table, which rises or falls freely according to recharge and discharge. On the other hand, a confined aquifer is overlain by an impermeable layer, which confines the water below the elevation of the recharge beds. If the pressure is released, as in a bore, the water level rises above the aquifer to its natural level in relation to recharge.

Aquifer class – a classification system for major aquifer types, including division of large systems such as the GAB, to avoid difficulties in mapping overlapping units. The aquifer types occurring in Queensland have been subdivided into nine major classes for mapping purposes. Seven of these classes occur in the Fitzroy/Burdekin region. Each aquifer class is subdivided into chemistry zones, with boundaries mapped around distributions of similar water chemistry and a consistent suite of aquifers.

Aquitard – a relatively impermeable layer which retards but does not prevent the flow of water to or from an underlying aquifer. The aquifer underlying the aquitard may be referred to as a semi-confined, or leaky aquifer.

Artesian (or confined) – groundwater at a lower elevation than its recharge source, which is confined under pressure by overlying impervious beds. Water level will rise when a bore penetrates the impervious layer. Aquifer may be ‘semi-confined’ if overlying material allows some leakage.

Basin – Australia was divided into drainage divisions through the work of The Australia's River Basins 1997 project by the Australian Water Resources Management Committee (1997). The drainage divisions are further sub-divided into water regions and then into river basins, which represent discrete catchments such as the Fitzroy or Pioneer, which have outlets to either the sea, or an inland drainage area. Larger basins such as the Fitzroy or Murray Darling are divided into **Sub-basins**, based on the catchments of major tributaries.

B – Boron

Basalt – extrusive volcanic rock formed from rapid cooling of lava

Baseflow – stream flow derived from deep subsurface flow and delayed shallow subsurface flow

Baseline quality – The most common water quality across a zone, under present conditions

Bedrock – native consolidated rock underlying the surface, usually overlain by weathered material. Sometimes referred to as **Basement**.

Bore – A bore or well is described by USGS (2018) and (NUDLC 2012) as an artificial excavation, constructed by any method, to abstract, observe or explore groundwater or other resources. The depth of the excavation is greater than the largest surface dimension, and it may be an open hole, or more usually lined with a casing containing slots or screens to allow for the entry of water from the desired aquifer level. Some bores contain more than one pipe, to access groundwater at different levels. Bores in Queensland are issued with a unique Registration Number (RN) with separate pipes being referred to alphabetically. Information and data for these bores can be accessed through the QDNRME Groundwater Database via the RN.

Ca – Calcium ion (major cation)

Carbonates – dissolved calcium and magnesium bicarbonates, or rocks such as limestone or dolomite which were formed or cemented by their precipitation.

Catchment – A catchment, as used here, is a less formal term than basin. It can refer to any area of land where all run-off flows through a common network of rivers and creeks to the main stream which has a terminal outlet such as a larger body of water or the ocean. Catchments are bordered and separated by elevated and often hilly areas known as watersheds.

Cation – A positively charged ion (e.g. Na^+).

Chemical type – chemistry of a groundwater, characterised by particular ionic equivalence; the major chemical types identified for the South East Queensland Region are:

1. Moderately saline with even cations
2. Mg rich
3. Low to moderate salinity, sodium chloride and bicarbonate with low magnesium
4. Highly saline Sodium chloride
5. Very fresh (<200 mS/cm) sodium and calcium chloride with low pH

Ck – Creek

Cl – Chloride ion (major anion)

CO_3 – Carbonate (anion)

Consolidated – Aquifers composed of solid rocks such as granite, sandstone, basalt or limestone. Ground water enters, flows and is stored in fractured or weathered zones, pore spaces, or voids caused by solution, as in limestone. Such aquifers have limited porosity or storage capacity, and may be hydrologically discontinuous.

Craton – The surface of the earth is divided into a series of tectonic plates. The term craton or shield refers to an ancient, stable continent land mass, usually in the interiors of a tectonic plate, as opposed to the more geologically active regions near the edges.

Cu – Copper

DRDMW – Department of Regional Development, Manufacturing and Water, the Queensland Government Department which is custodian of the states, ground and surface water databases. The department was referred to as **DNRME** from 2018, **DNRM** from 2015 to 2018, and **DERM** or other titles prior to 2012.

D/S – Downstream of

DO – Dissolved oxygen. Usually given in mg/L, but at times as percent saturation.

EC – Electrical conductivity, a measure of salinity measured in µS/cm

EH – Redox potential

EP Act – Environmental Protection Act 1994 (Qld.)

Equivalence – amount of a substance which will either – react with or supply one mole of hydrogen ions (H^+) in an acid–base reaction; or react with or supply one mole of electrons in a redox reaction

Evenly proportioned cations – water chemistry where the major cations (Na, Ca and Mg) are in roughly even proportions in terms of equivalents, although in Queensland groundwaters sodium is usually slightly in excess of each of the others.

F – Fluoride ion

Fe – dissolved iron, either ionic or in other chemical combinations.

Formation – or **geological formation** is the fundamental geological unit. It consists of a body of rock with comparable lithology, and is usually named, e.g. 'Hooray Sandstone'.

GAB – Great Artesian Basin

GAB Cap – relatively impermeable layer of shallow marine sediments overlying the GAB

GABSPM – Great Artesian Basin Strategic Management Plan

GDE – Groundwater dependant ecosystem

Geological Time Scale – divides the time from formation of the Earth to the present, into a series of units that are useful for comparing geological formations of space and time. These units are measured in millions of years (MYA), but defined according to significant geological changes or events on a world wide scale, and therefore vary greatly in length. Those most relevant to this study are summarized here.

Period		MYA before present	Description
Precambrian		4600–541	Began with formation of the Earth. Divided into several units, the most recent being the Proterozoic, which represents the oldest surface rocks in Queensland.
	Proterozoic	2,500–541	When the Proterozoic began, the Earth had liquid water, oxygen in the atmosphere, and single celled organisms, with soft bodied multicellular forms evolving later. The early geology consists of heavily metamorphosed rocks and granites, which were followed in Queensland by relatively undeformed sediments.
Paleozoic		541– 252	Divided into the Cambrian, Ordovician, Silurian, Devonian, Carboniferous, and lastly the Permian. The Paleozoic in Queensland is

Period		MYA before present	Description
Paleozoic (continued)			dominated by a **subduction zone** which formed offshore of the Precambrian craton towards the end of the Proterozoic. The subduction trench became filled with deep water marine sediments and volcanics. It remained active throughout the Paleozoic, but with compression intervals where the sediments were folded into stable continental crust. The new crust was eroded to form shallow marine or terrestrial basins while the trench reopened further to the east. The Great Dividing Range (GDR) is formed from the trench sediments and associated granites. An 'explosion' in biodiversity on land and water during the Paleozoic allowed the formation of coal and oil in the shallow marine and terrestrial basins.
Mesozoic		252– 66	Divided into the Triassic, Permian and Cretaceous. It began with the final phases of the Paleozoic subduction-compression cycles, referred to as the Hunter-Bowen Orogeny, which had greatly extended the landmass. Changing patterns of subsidence and uplift caused the Palaeozoic sedimentary basins such as the Bowen and Galilee to be uplifted, eroded, and be replaced by newer drainage patterns including the Great Artesian Basin (GAB). The formation of the GAB was completed by a relatively impermeable cap of marine sediments laid down by the Eromanga Sea. The end of the Mesozoic saw the breakup of Gondwanaland, and the Hunter-Bowen Orogeny landmass being split by the opening of the Tasman and Coral Seas. The landward side rose, while the eastern bloc sank, with remnants now in New Zealand and the Solomon and nearby Islands.
Cainozoic		66– 0	Most recent, divided into the Tertiary and Quaternary.
	Tertiary **Tertiary** (continued)	66– 2.6	The first and longest period of the Cainozoic, divided into the Paleocene, Eocene, Oligocene, Miocene and Pliocene. It saw many changes in Queensland that affected present groundwaters. At the end of the Mesozoic, Queensland was mainly flat lying, and the GAB was a subartesian aquifer system with exposures in the east providing recharge. The rising of the east coast, associated with the opening of the Tasman Sea, created the GDR and tilted the GAB to the west, creating artesian conditions. The opening of the sea also stretched the crust, leading to floods of basaltic lava, potential aquifer systems, but covering much of the GAB recharge areas. The modern drainage pattern was formed by the rise of the GDR, with short, steep, coastal basins and drier, low gradient, westerly basins with extensive floodplains. The headwaters of the western streams were progressively 'captured' by the greater erosive power of the coastal streams, leading to greatly reduced inland discharge. After separating from Antarctica, Australia drifted north to its present location, changing to a drier climate with extensive weathering and duricrust formation.
Cainozoic (continued)	**Quaternary**	2.6–0	The Quaternary may be further subdivided into the **Pleistocene**, which covers the Ice Age (2.6 MYA-11,700 thousand years ago), and the **Holocene**, or **Recent**, which is the current period, in which most active floodplains were deposited. The most significant feature of the Quaternary was the Ice Age, which caused large water level fluctuations along the Queensland coast, as well as episodic climate change. This is the age when human impacts occurred. The modern alluvial systems of Queensland developed, within the more extensive Tertiary systems, particularly in inland basins. The GBR also formed during this period, while sand dunes were built in the southwest, as well as on the coast. These included the large sand deposits of North Stradbroke, Moreton and Fraser Islands. Several major deltas were formed by large rivers, and acid sulphate soils were deposited in low lying coastal areas.

GDR – Great Dividing Range

GIS – Geographic information system

GMU – Groundwater management unit

Granitic Rock – an **igneous** rock formed from the molten state at depth, where slow cooling gave it a coarse granular texture. True **granites** have a narrow range of chemical composition, but the term is used broadly here to include all rocks of similar appearance and origin.

Groundwater – water that is stored below the plant root zone in soil pore spaces or in porous or fractured rocks. The **water table** is the depth at which all available space is saturated.

Group – Groundwaters with similar types of chemistry.

GW – groundwater

GWDB – The DRDMW Groundwater Database, which contains most of the chemical and hydrological data for groundwater in Queensland.

Hardness – Hardness is a water quality parameter caused primarily by calcium and magnesium ions in solution. It is expressed as $CaCO_3$ in mg/Ll. Hard water increases the amount of soap or detergent required for washing, and also deposits mineral scale or incrustation on kettles, boilers and pumping equipment. Harder water can, however, reduce the toxicity to the ecosystem of certain trace substances. In terms of guidelines, ANZECC and ARMCANZ (2000) advise that <60 is possibly corrosive, 60–200 can be considered good quality, 200–500 requires softening with an increasing likelihood of scale, and >500 can cause severe scaling.

HCO_3 – Bicarbonate ion (anion)

Igneous – rocks such as basalt or granite that were formed from solidified lava or magma

Hydraulic conductivity – a property of aquifer material that describes the rate at which water can move through fractures pore spaces. It depends on the permeability and degree of saturation of the material, and determines the travel time of the water between two points.

Intrusion – an igneous rock formed where molten magma was **intruded** under pressure into the overlying rocks, and subsequently cooled.

Ion – An atom or molecule which has either an excess or shortage of electrons, giving it a negative charge (anion) or positive charge (cation) respectively. Dissolved salts are generally in ionic form, with cations being metallic (i.e. Na, Ca, Mg) and anions non-metallic (i.e. Cl, SO_4, HCO_3).

K – Potassium (cation)

Lithology – the term 'lithology' is used loosely in this document to comment on the origin, formation, mineral composition and classification of rock or stratigraphic unit. The primary lithological division is into igneous, metamorphic and sedimentary rocks.

Magma – molten rock, from deep in the earth's crust, which forms igneous rock on cooling, and **lava** if it reaches the surface through volcanoes.

Metamorphic – rocks where minerals and structure have been altered after emplacement, due to the heat and pressure exerted by deep burial or earth movements. The rock are then said to be **metamorphosed**

Mg – Magnesium ion (cation)

Mn – Manganese (cation)

Na – Sodium ion (cation)

NaCl – Sodium chloride

NO_3 – Nitrate (anion)

NTU – Nephelometric turbidity units

NWQMS – National Water Quality Management Strategy

Orogeny – a mountain building process that occurs when deep, oceanic trenches, formed in subduction zones, become filled by sediments. These sediments are deformed by continuing compressional forces within the subduction zone, becoming folded, faulted and squeezed upward to form mountain ranges. **Metamorphism** and **Igneous** rocks are usually associated with orogenies.

pH – measure of how acidic or alkaline a water is by the concentration free hydrogen ions in solution. The pH scale ranges from 0 to 14, with a pH of 7 being neutral, values lower than 7 being acidic, and pH values higher than 7 being alkaline (basic). For instance, approximate pH values are orange juice 3, coffee 5, rainwater 6, freshly distilled water 7, seawater 8, and a baking soda solution 9 (Decelles 2002).

PO_4 – Ortho-phosphate (anion)

R – River

RAH – Residual alkali hazard

Recharge – hydrologic process where water moves downward from surface water to groundwater

Salinity – the dissolved salt content in water. In most Queensland natural waters this includes the cations Na, Ca Mg, and to a lesser extent K, and the anions Cl and HCO_3, with usually smaller amounts of SO_4 and NO_3. These are known as the major ions. Salinity can be measured in several ways, although these are not exactly comparable: Total Dissolved Ions (TDI) is a measure of the major ions in solution expressed in mg/L. This is most needed by catchment managers because it can be used to measure mass transport of salts. An alternative measure is Electrical Conductivity (EC) which is the ability of the solution to conduct an electric current in mS/cm. Although EC is influenced by the type as well as quantity of salts, as well as by factors such as temperature, pressure and suspended matter, it is often used as a substitute for TDI because it is easily measured. Salinity categories in this document are based on median EC in µS/cm:

- EC <200 very low
- EC <200–500 low
- EC <500–1500 moderate
- EC <1500–5000 high
- EC >5000 very high
- Salinity is classified variable if the range is more than twice the median.

SAR – Sodium adsorption ratio is used to measure the dominance of sodium (Na) in the water chemistry, and to determine whether Na levels in irrigation water will cause soil structure to deteriorate.

Sediments – or **Sedimentary rocks**, are those formed when the weathered, fragmented, or dissolved remains of previous rocks or biological materials are accumulated in layers, often having been transported there by wind or water. They may be **unconsolidated**, but become hardened if compressed by subsequent layers, or cemented by solutions of dissolved **silica** or **carbonates.** Examples are sandstone, shale, alluvium, limestone, coal.

SiO_2 – Silicon dioxide (or **silica**)

SO_4. – Sulphate ion (anion)

Sodic – waters where sodium dominates the cations in terms of proportion.

Subduction zone – The surface of the earth (crust) is broken into a series of plates, and a subduction zone occurs where two collide, forming a deep trench where one is thrusting under the other. The trench is filled with deep water sediments, and an **Orogeny** occurs when these are later deformed by compressional forces, resulting in folding, faulting, metamorphosis and uplifting to form mountain ranges.

Surface water – water collecting on the ground or in a stream, river, lake, wetland, or ocean

SW – Surface water

SWDB – Surface water database

SYSTAT – A statistical and graphical software package.

TDI – Total dissolved ions

TDS – Total dissolved solids

Tectonics – The surface of the earth (crust) is broken into a series of plates. Tectonics describes the very large-scale processes through which these plates interact to reshape continental or oceanic features, for instance through Subduction zones.

Unconsolidated – Sedimentary rocks with a loose, friable structure, because they have not been significantly compressed by subsequent layers, or cemented.

U/S – Upstream of

UA – Unincorporated (groundwater) areas, not included in a GMU

Volcanics – Rocks of volcanic origin, consisting of lava flows, volcanic ash, and sometimes layers of sediment composed mostly of volcanic materials. Examples are basalt and andesite.

Water table – the surface where the groundwater pressure head equals atmospheric pressure

Zn – Zinc (cation)

Zone – Geographically delineated area that is likely to contain groundwater of a particular type at one or more individual depth classes.

References:

NUDLC 2012, '*Minimum construction Requirements for water bores in Australia*', 3rd ed. National Uniform Drillers Licensing Committee, 146p.

USGS 2018, '*Water Science Glossary of Terms*', https://water.usgs.gov/edu/dictionary.html#W, accessed: 17/10/2018.