



# Galilee Basin

## Report on the Hydrogeological Investigations

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## Executive Summary

### Introduction

The Galilee Basin Operators' Forum (GBOF) is a group of petroleum companies exploring the Galilee Basin for commercial quantities of hydrocarbons. Exploration activities include the search for conventional hydrocarbons, and increasingly non-conventional hydrocarbon sources such as coal seam gas (CSG). The CSG target is the Permian coal measures as shown in Figure 1.1.

Understanding and protecting groundwater is a key issue and community concern. As part of the early exploration activities in the Galilee Basin, the GBOF companies have initiated this study to assist in developing a regional and consistent subsurface description, and to document the existing data for the groundwater systems in the Galilee Basin study area. RPS, as an independent company, was contracted to perform the study and prepare a report.

This initial study should not be confused with a "baseline assessment" or "underground water impact report" which are specific requirements under the *Water Act 2000*, triggered once production testing is underway or production has commenced. This study gathers and assembles all the base historical data which may be used in further studies. For the Galilee Basin study area, this investigation is specifically designed to:

- Review stratigraphy and identify possible aquifers beneath the GBOF member company tenures;
- Delineate aquifers that warrant further monitoring; and
- Obtain and tabulate current Department of Environment and Resource Management Groundwater Database (DERM GWDB)( now the Department of Environment and Heritage EHP)registered bore data including:
  - » Water bore location and summary statistics;
  - » Groundwater levels and artesian flow data; and
  - » Groundwater quality.

Data sources for this report include:

- Groundwater data available in the DERM GWDB;
- Petroleum exploration wells recorded in Queensland Petroleum Exploration Data (QPED);
- DERM groundwater data logger/tipping bucket rain gauge program;
- Springs of Queensland Dataset (version 4.0) held by DERM;
- PressurePlot Version 2 developed by CSIRO and linked to a Pressure-Hydrodynamics database; and
- Direct communication with GBOF members.

Data was sourced in January 2011. Since then there has been considerable additional drilling by GBOF members, which is not incorporated in this report. All data has been used by RPS as provided without independent investigations to validate the data. It is recognised that historical data may be subject to inaccuracies, however, as work progresses in the region, an improvement in data integrity should be realised.

RPS identified approximately 3,300 registered water bores within the GBOF tenements. Fewer than 150 petroleum wells have been drilled within a GBOF member tenement at the time of data extraction.

Broadly speaking, within the study area, the Eromanga Basin overlies the Galilee Basin, except in the east near the basin margin, where the Eromanga Basin sequence is not present. The Eromanga Basin sequence is overlain by Tertiary and/or Quaternary sediments. Older basins underlie the Galilee Basin as shown on Figure 1.3. The relationship between these geological basins and the hydrogeological basin, the Great Artesian Basin (GAB), is shown on Figures 3.3 and 3.4. The GAB encompasses the Eromanga Basin sequence and the top of the Galilee Basin sequence to the base of the Clematis Sandstone, as described in the *Water Resource (Great Artesian Basin) Plan 2006*.

Groundwater within the Galilee Basin study area is most frequently derived from the shallow unconfined aquifers in Quaternary alluvium and Tertiary sediments. Of the water bores attributed to an aquifer, 25% are screened in or open to the Quaternary alluvial and Tertiary sediment aquifers. Although these shallow systems are important, bore densities are quite low, often in the range of one bore per square kilometre.

Within the Eromanga Basin sequence, the most significant groundwater resources are in the Hutton Sandstone, the Hooray Sandstone and the Cadna-owie Formation aquifers. Water resources are also produced from aquifers hosted within the relatively shallow Rolling Downs Group.

Additionally locally important volumes of water are produced from units more traditionally considered as confining units or aquitards. It is common to find records of bores screened in water-producing zones within the Westbourne, Moolayember and Rewan Formations. Regionally, the Permian Betts Creek beds and the Aramac Coal Measures (and their equivalents) yield sufficient groundwater to be classified as water-bearing sediments. In these cases, the groundwater is produced from the coal seams and interbedded sandstones, varying in thickness from less than 10cm to more than 21m.

The study identified and described the following aquifer systems (in bold font where regionally important) in the Galilee Basin study area:

- Eromanga sedimentary basin aquifers or water-bearing sediments:
  - » Cretaceous age Rolling Downs Group;
  - » Cretaceous age Gilbert River Formations;
  - » Jurassic to Cretaceous age Ronlow beds;
  - » Cretaceous age Cadna-owie Formation;
  - » Cretaceous age Hooray Sandstone;
  - » Jurassic age Injune Creek Group;
  - » Jurassic age Hutton Sandstone; and
  - » Jurassic age Precipice Sandstone (rarely identified in the study area).
- Galilee sedimentary basin aquifers or water-bearing sediments:
  - » Triassic to Jurassic age Warang Sandstone;
  - » Triassic age Clematis Sandstone;
  - » Triassic age Dunda beds;
  - » Permian age Betts Creek beds;
  - » Permian age Colinlea Sandstone;

- » Permian age Aramac Coal Measures; and
- » Late Carboniferous to Early Permian age Joe Joe Group.

There are five major structural provinces within the Galilee Basin study area where sediments and rocks produce minor amounts of water for local use (Figure 1.3):

- Adavale Basin—locally important production from sediments and minor volcanic beds;
- Drummond Basin—small volumes of groundwater are produced from the Late Devonian to early Carboniferous sequence beneath the Koburra Trough portion of the study area;
- Mt. Isa Inlier—a feature of the eastern Galilee Basin, this is a geologically complex mineral province consisting of intensely folded and faulted Precambrian age sedimentary and igneous rocks to Mesozoic age sedimentary rocks;
- Cape River Province—minor water production from Early Palaeozoic metamorphic rocks within this area, which is not widely reported in bore logs;
- Maneroo Platform—this feature is regionally important because of the contact between the Hutton Sandstone and the Permian coal measures along its northern boundary.

Typically, thick regional confining units such as the Moolayember Formation and the Rewan Formation, inhibit hydraulic connection between the Hutton Sandstone and the Permian coal measures. However, these confining units thin toward the Maneroo Platform, creating an area where the Hutton Sandstone and Permian coal measures are in close contact, identified as a “zero edge” (Figure 3.10). In this area, groundwater within the Hutton Sandstone aquifer may be influenced by depressurising the Permian coal measures. The absence of these normally thick confining sequences means that the overlying Cadna-owie Formation/Hooray Sandstone aquifer systems are also stratigraphically in closer proximity to the Permian coal measures.

In areas where the Moolayember Formation, the Dunda beds and the Rewan Formations are thin or absent, depressurisation of the Permian coal measures may potentially impact regional aquifers or water-bearing sediments. This is especially important along portions of the northern edge of the Maneroo Platform, where the Hutton Sandstone is stratigraphically in contact with the Permian coal measures.

The following Eromanga and Galilee basin aquifers (bolded where regionally important) may locally occur in close stratigraphic contact with the Permian coal measures and could potentially be impacted by depressurisation of the coal measures:

- Jurassic age Hutton Sandstone;
- Late Triassic to Early Jurassic age Warang Sandstone;
- Triassic age Clematis Sandstone;
- Triassic age Dunda beds; and
- Late Carboniferous to Early Permian Jochmus Formation (upper Joe Joe Group).

Groundwater-level data are available for over 4,400 Galilee Basin water bores. This study evaluated groundwater levels for both the entire Galilee Basin study area and within specific active GBOF member tenements. Groundwater levels were found to be consistent with the GAB in general, with groundwater levels ranging from deeper than 300m bGL to artesian conditions. The major groundwater recharge areas are located in the north and east where the Eromanga and Galilee basin aquifers outcrop or subcrop under alluvial sediments. The bores located in the recharge areas are generally subartesian.

The major artesian bores are located in the south, suggesting a general groundwater discharge area in the south. The wide band of artesian bores in the north-west near Richmond may also correspond to an area of groundwater discharge at the western Galilee Basin boundary.

Contouring of groundwater level data from the Rolling Downs Group aquifers, Cadna-owie/Hooray Sandstone aquifers and the Hutton Sandstone aquifer was undertaken to gain an understanding of changes in the groundwater potentiometric surface. In many areas, there were insufficient data to complete a contour map from the groundwater level data. However, several features are noteworthy:

- The Rolling Downs Group shows two large-area groundwater lows over the Maneroo Platform and at the southern end of the Lovelle Depression in the west. These lows parallel the Thomson River (south-west of Longreach) and the Diamantina River, respectively, suggesting that regional groundwater flow in the Rolling Downs Group is toward the major river systems;
- The Cadna-owie/Hooray Sandstone aquifer flow trends are very similar to the overlying Rolling Downs Group. The aquifers are recharged in the north, east and over the Springsure Shelf. There is a notable groundwater high north of Hughenden and east of Aramac;
- The Hutton Sandstone groundwater flow is not well defined due to a lack of data over the Maneroo Platform. Groundwater flow over the Springsure Shelf suggests that the Hutton Sandstone aquifer discharge area is located to the south and south-west of the study area.

Time-series plots of groundwater level data from the DERM GWDB were undertaken to attempt to identify long-term water level trends. However, the GWDB contained only 14 water bores with more than 10 measurements. The small number of bores with repeat time-series data was surprising given the large number of water bores in the study area and the over 40,000 groundwater-level measurements available in the GWDB.

RPS received groundwater flow and static groundwater level data for over 2,000 bores within the Galilee Basin study area from DERM. Nearly 1,100 water bores were compiled with groundwater flow data (Table 6.4), including groundwater discharge, static groundwater level and calculated static groundwater level. The water bore discharge peaked in the early 1900s at over 100L/s per bore for a small number of bores. The peak measured groundwater flow declined to about 40L/s per bore around 1975. Groundwater flow continues to slowly decline to approximately 30L/s per bore around the year 2000. The increase in the number of recorded observations reflects the increasing number of bores tapping the Eromanga and Galilee basin aquifers and water-bearing sediments. This decrease in groundwater flow predates any lowering of the water pressure in Permian coals by CSG exploration.

The DERM GWDB groundwater quality data represents a wide range of groundwater samples collected over many decades. Drillers typically obtained groundwater quality samples at the time a water bore was drilled and other samples were collected as part of various sampling programs. Sampling protocols are not always recorded, so the value and integrity of some of the data is not clear. The constituents analysed from the individual water bores varied considerably, so a comprehensive set of results are not available for all of the aquifers sampled. Nevertheless, groundwater quality in the Galilee Basin study area is generally good and both the Eromanga and Galilee basin aquifers generally yield water of sufficient quality for livestock and, in some areas, for domestic use. Both the Hutton Sandstone and the Clematis Sandstone host significant groundwater resources with regard to both groundwater availability and the suitability for domestic and stock watering uses.

Of the 265 registered GAB springs within the Galilee Basin study area, 38 springs are in the Barcardine Region and the remaining 227 are in the Springsure Region. The majority of the GAB springs are active (192) and only a small number have been bored or dammed. The distribution of the springs gives a strong indication of the source aquifer for the springs—almost all within the Eromanga basin aquifers north of Barcardine and within the Galilee sedimentary basin aquifers over

the eastern Springsure Shelf. The springs north of Barcaldine occur in two distinct bands, one that is associated with the Hutton Sandstone aquifer and another that is likely associated with the Cadnawowie Formation/Hooray Sandstone aquifer systems. Springs are not present west of the first outcrop of the Toolebuc Formation and possibly the Wallumbilla Formation.

It is apparent from this report that notwithstanding the seemingly large number of bores represented in the GWDB, and the number of existing petroleum wells, data quality and reliability is variable. There are significant data gaps in terms of time-series data, and groundwater quality data must be viewed with caution given the probable variable sampling techniques and methodologies. Additionally, it is not possible to assign single water sources to a large number of bores, which therefore makes them less useful for reliable interpretation and mapping.

The report has identified two key regions where groundwater impacts will need close monitoring once production testing or production are underway, including the eastern margin of the Galilee Basin, where deeper stratigraphic units come to the surface and are more frequently tapped as water sources; and the Maneroo Platform area, where thinning or absence of the Triassic sequence means the Hutton Sandstone is in contact or close proximity to the Permian coal measures. For most of the study area however, the Permian coal measures are well separated from aquifers or water-bearing sediments by the thick Triassic sequences.

The regulatory regime now in place under the *Water Act 2000*, will address these issues, with requirements to undertake baseline assessments of bores, undertake modelling of the groundwater regime and undertake targeted monitoring in areas where modelling predicts both short-term and long-term impacts may be seen. It is not the role of this report to pre-empt the results of underground water impact modelling, a requirement which has not yet been triggered for most of the GBOF tenements. This report provides a foundation on which the GBOF members can build a common understanding of the hydrogeology of the area, which will ultimately be to the benefit of all stakeholders.

## Glossary of Terms

Word	Definition
aGL	Above ground level. Typically used in this report to refer to the calculated groundwater level at a bore under artesian pressure.
Acidity	Having a pH less than 7.
AHD	Australian Height Datum.
Alkaline	Having a pH greater than 7.
Alluvial	Sediment transported by water.
Alluvium	Sediments deposited by water in rivers, streams or sheetwash.
Anticline	A convex fold in rocks, forming an arch. The antonym is a syncline.
Aquifer	A zone, bed or formation of water-bearing permeable rock or unconsolidated material (gravel, sand or silt) from which groundwater can be usefully extracted.
Aquifer system	Interlayered permeable and poorly permeable materials that comprise two or more permeable units separated by aquitards, which impede vertical groundwater movement but do not affect the regional hydraulic continuity of the system.
Aquitard	A zone, bed or formation that restricts the flow of groundwater from one aquifer to another, comprising layers of clay or non-porous rock with low hydraulic conductivity. An aquitard can store water but is not an effective transmitter of water. Also called a confining unit.
Artesian aquifer	A confined aquifer where the piezometric head rises above the ground surface such that the pressure causes water to flow freely from bores drilled into the aquifer, without pumping.
ATP	Authority to Prospect for Petroleum. A resource authority given under Queensland petroleum legislation to carry out exploration for petroleum or coal seam gas in Queensland (see EPP).
Basal Jurassic Unconformity	The unconformity marks the base of the Eromanga Basin sedimentary sequence and the top of the Galilee Basin sedimentary sequence. The basal Jurassic unconformity is a very important stratigraphic marker in the Galilee Basin.
Basement	Basement is used in this report to mean the undifferentiated complex of rocks that underlies the rocks of interest. In this report the rocks of interest are the Galilee and Eromanga sediments and overlying Quaternary alluvium and Tertiary sediments and basalt.
Basin	A depression of large size, which may be structural or depositional in origin, in which sedimentary rocks have accumulated to a substantial thickness.
Bedrock	A general term for the unweathered rock that lies underneath the soil and other unconsolidated material.
bGL	Below Ground Level. With respect to groundwater depth, measurements documented as below ground level are noted as negative (e.g. -45 m bGL equals 45 m below ground surface). Measurements of drilling depth and other subsurface depths are recorded as positive (e.g. 2,700 m bGL).
bKB	Below the kelly bushing or kelly table on a drill rig
Bore	In the context of this report, bore refers to a hole drilled into the ground and completed to access groundwater.
Calculated static water level	The depth to groundwater derived from the modified Sternberg methodology. A



Word	Definition
(CSWL)	calculated static water level may give a truer value than the maximum pressure recorded during a pumping test.
Casing	Steel, fibreglass, or other type of pipe placed in a well or bore as drilling progresses to prevent the bore wall from caving in during drilling, to prevent seepage of gas and/or fluids, and to provide a way to extract gas and/or fluid. The design of the casing must withstand a variety of forces, such as collapse, burst, and tensile failure, as well as chemically aggressive gas and/or fluids. Casing is commonly permanently cemented or grouted in place.
Catchment	The total area of land potentially contributing to water flowing through a particular point.
Clay	Detrital mineral particle of any composition having a diameter less than 0.0004 mm
Claystone	Sedimentary rock of indurated clay-sized silicate material having the texture and composition of shale, but lacking its lamination.
Coal seam	A stratified layer, or deposit of coal.
Coal seam gas (CSG)	Natural gas contained within coal. Typically in Queensland this natural gas is predominately methane.
Completion or completed	The physical equipment installed in a well or bore to facilitate and control its use after drilling.  In this report, indicates where an individual well or bore has been screened or perforated to access groundwater, natural gas or petroleum.
Conglomerate	Coarse-grained sedimentary rock composed of more or less rounded fragments at least gravel size (2mm in diameter) set in a fine textured matrix of sand or silt, and may be cemented by calcium carbonate, silica iron oxide or hardened clay.
Contour	A line on a map connecting points that are the same height above sea level .
Darcy's law	An empirical law that describes the flow of groundwater through a porous medium (i.e. sediments and sedimentary rocks).
DERM	Department of Environment and Resource Management, Queensland  Note that since the commencement of this report, and following the 2012 Queensland Government election, environmental regulation is carried out by the Department of Environment and Heritage Protection (DEHP)
DERM GWDB	DERM Groundwater Database.
DEEDI	Department of Employment, Economic Development and Innovation, Queensland.  Note that since the commencement of this report, and following the 2012 Queensland Government election, resource regulation is carried out by the Natural Resources and Mines (NRM)
Discharge	Water that moves from a groundwater body to the ground surface (or into a surface water body such as a lake or the ocean). Discharge typically leaves aquifers directly through seepage (active discharge) or indirectly through capillary rise (passive discharge). The term is also used to describe the process of water movement from a body of groundwater.
Discharge area	Where significant amounts of groundwater come to the surface, either as liquid water or as vapour by evaporation.
Drawdown	A lowering of a water table, or a change in hydraulic head in an aquifer, typically

Word	Definition
	due to pumping a well or bore.
Drill stem test (DST)	The controlled flowing of the fluids from a reservoir in a well to provide estimates of the flow rate and fluid pressure.
EC	An abbreviation for electrical conductivity, a measure of the ability of a medium to conduct electricity. EC is used often as a surrogate measure of salinity levels in water or soil since conductivity of a solution generally increases in proportion with its salt content. Its unit of measurement is microSiemens per centimetre ( $\mu\text{S}/\text{cm}$ )
EPP	Exploration Permit for Petroleum (see ATP).
Exploration well	A well drilled to determine geology, stratigraphy and presence or absence of hydrocarbons or mineral resources in a particular area or structure.
Fault	(a) A fracture in the Earth's crust along which the rocks on one side are displaced relative to those on the other. (b) A fracture that has experienced translation or movement of the fracture walls parallel to the plane of the fracture
Flow rate	The amount of surface water or groundwater flowing past a given point or line over a defined period of time. Measured as volume, depth or area of water per unit time (i.e. L/s or $\text{m}^3/\text{s}$ ).
Flow system	Local flow system transporting groundwater where discharge and recharge occur within a few kilometres of each other. Flows may be permanent or temporary and the water is typically transported down a hill-slope through an unconfined aquifer that is relatively thin (<20 m) and close to the surface.
Flow velocity	The speed at which surface water or groundwater flows. Measured as a distance per unit time (e.g. mm/hr, or m/day).
Fluvial, fluvatile	Having originated by deposition within riverine environments (see Alluvial). Referring to processes occurring in a river.
Formation	(a) A unit in stratigraphy defining a succession of rocks of the same type. (b) A body of rock strata that consists of a certain lithology or combination of lithologies.
Fresh water	Water characterised by having low concentrations of dissolved salts and other total dissolved solids; drinkable or potable water is implied. In this report, refers to water with a salinity < 1,500 mg/l TDS.
Galilee Basin study area	Refers to the limit of the area covered by this investigation.
GDE	Groundwater Dependent Ecosystem.
GABCC	Great Artesian Basin Consultative Council.
Gravel pack, filter pack	Graded sand or gravel placed in the annular space of a groundwater installation to protect the screens or slotted casing adjacent to selected aquifer horizons.
Groundwater	Water stored below the ground surface that saturates (in available porosity) the soil or rock and is at greater than atmospheric pressure and will therefore flow freely into a bore or well.
Groundwater elevation	Groundwater elevation is the height of water table or piezometric surface in metres above or below the Australian Height Datum (m AHD). Groundwater elevation should not be confused with groundwater level, which is measured in metres below ground level (m bGL).

Word	Definition
Groundwater flow	The movement of water through openings in sediment and rock that occurs in the zone of saturation. Lateral groundwater flow - movement of groundwater in a non-vertical direction. Lateral groundwater flows are usually, although not always, more or less parallel to the ground surface.
Groundwater level	Groundwater level is the depth below the ground surface of the water table for unconfined aquifers or the standing water level in a well for a confined aquifer. The measurement is presented in metres below ground level (m bGL). Groundwater level should not be confused with groundwater elevation, which is the height of water table or piezometric surface in metres above or below the Australian Height Datum (m AHD).
Group	The lithostratigraphic unit next in rank above formation, consisting partly or entirely of named geological formations.
GSQ	Geological Survey of Queensland, part of Mines and Energy within the Department of Employment, Economic Development and Innovation.
Head (hydraulic head, static head)	The energy contained within a column of water resulting from elevation or pressure. The static head is the height at which the surface of a column of water could be supported against the action of atmospheric pressure.
Hydraulic conductivity	(a) A measure of the potential rate of flow of a fluid through soil or rock. Hydraulic conductivity is expressed in units of length per unit time, typically millimetres per hour (mm/hour) or metres per day (m/day). (b) A coefficient of proportionality describing the rate at which a fluid can move through the interconnected pore spaces in a porous medium.  The density and viscosity of the fluid must be considered in determining conductivity. (c) The volume of fluid that flows through a unit area of porous medium for a unit hydraulic gradient normal to that area;
Hydraulic gradient	(a) The slope of the water table or potentiometric surface. The hydraulic gradient is determined from the decline in groundwater level at two measuring points divided by the distance between them. (b) The change in hydraulic head with direction.
Hydraulic head	The elevation in a well in reference to a specific datum; the mechanical energy per unit weight of water.
Hydrocarbons	Naturally-occurring organic compounds containing only the elements hydrogen and carbon that may exist as solids, liquids or gases.
Hydrogeology	The study of groundwater movement through soil, sediment or rock under natural or induced conditions.
Impermeable	Describes the nature of solid material that will not allow fluids to pass freely.
Infiltration	The process where water enters the soil through its surface. The downward movement of water into the soil profile.
Leakage	A flux of fluid from or into an aquifer or reservoir. This commonly refers to cross-formational flow.
Lithology	The physical and mineralogical characteristics of a rock.
Lacustrine	Pertaining to, formed in, growing in, or inhabiting lakes.

Word	Definition
LOR	Limit of Reporting. The limit of reporting is the lower threshold for reporting constituent concentrations at which a numerical value can be assigned for a specified analytical method.
Member	A lithostratigraphic unit, a division of a formation, generally of distinct lithologic character and often of only local extent.
Metamorphic rock	Rock of any origin altered in mineralogical composition, chemical composition or structure by heat, pressure, or movement at depth in the Earth's crust.
mg/L	Milligrams per litre or parts per million A measure of the amount of dissolved solids in a solute in terms of milligrams of solute per litre of solution.
Migration	The movement of a fluid (water, gas or oil) from regions of higher to lower pressure.
milli darcies (mD)	A unit of measure of permeability. A porous medium has a permeability of 1 darcy when differential pressure of 1 atmosphere across a sample 1 centimetre long and 1 square centimetre in cross section will force a liquid of 1 centipoise of viscosity through the sample at the rate of 1 cubic centimetre per second.
milli-eq/L	The equivalent (symbol: eq or Eq), sometimes termed the molar equivalent is a measure of the concentration of a solute in solution; obtained by dividing the concentration in milligrams per liter by equivalent weight of the ion.
ML	Megalitre or one million litres.
Mudstone	Mudstone is the result of grains of clay and silt having been deposited layer upon layer, compacted by the weight of overlying material and cemented together over millions of years to form a hard rock. They are similar to shales but lack the feature of a layered structure.
Outcrop	(a) The part of a rock formation that appears at the surface of the ground. (b) The part of a geologic formation or structure that appears at the surface of the earth; also, bedrock that is covered only by surficial deposits such as alluvium. (c) To appear exposed and visible at the earth's surface; to crop out.
Perched aquifer (perched water table)	An aquifer in that infiltrating water remains separated from an underlying main body of groundwater, with an unsaturated zone existing between the two. Usually perching occurs due intermediate impermeable or low permeability layer. Where the perched aquifer is unconfined, a perched water table exists.
Perforation	A series of holes in a casing to provide access to a resource (i.e. groundwater, petroleum liquids or gas). Hole created in casing and cement/grout through to the target formation. Perforations allow gas and/or fluid flow to and from the casing and formation. Perforations are commonly made by a perforating gun that is lowered into the hole and fires high-powered jets or shoots steel projectiles.
Permian Unconformity	The Permian unconformity marks the contact between the early Permian Aramac Coal Measures and the Permian Betts Creek Beds. This unconformity is an important stratigraphic marker in the Galilee Basin.
Permeability	A measure of the capacity of rock or stratum to allow water or other fluids such as oil to pass through it (i.e. the relative ease with which a porous medium can transmit a fluid). Typically measured in darcies or millidarcies.
pH	A measure of the acidity or alkalinity of water. It is related to the free hydrogen ion

Word	Definition
	concentration in solution pH = 7 is neutral; pH < 7 acidic; pH > 7 alkaline.
Piezometric head	The elevation to which water will rise in a piezometer connected to a point in an aquifer. Differences in piezometric head determine the hydraulic gradient and therefore the direction of groundwater flow.
Piezometric surface	A surface of equal hydraulic heads or potentials, typically depicted by a map of equipotentials such as a map of water-table elevations. See potentiometric surface.
Piper diagram	A graphical means of displaying the ratios of the major ionic species in water.
Pore water pressure	Pressure exerted by fluid in the void space of soil or rock. It is usually expressed with respect to atmospheric pressure so that positive pressures indicate that the porous medium is saturated and negative pressures indicate that it is unsaturated.
Porosity	The volume of the voids divided by the total volume of porous medium (the percentage of a rock or soil that is represented by open voids or spaces).
Porous	Having porosity.
Potable	Drinkable. Potable waters can be consumed safely without treatment.
Potentiometric surface	A surface of equal hydraulic heads or potentials, typically depicted by a map of equipotentials such as a map of water-table elevations.
Production bore	A bore from which extraction of groundwater may take place, at commercial rate, either through pumping or artesian flow.
psia	Pounds per square inch absolute (including atmospheric pressure).
psi	A unit of pressure or pounds per square inch or 6.895 kilopascals.
QDEX	Queensland Digital Exploration Reports.
QPED	Queensland Petroleum Exploration Data.
Recharge	The water that moves into a groundwater body to replenish or increase sub-surface storage. Recharge typically enters an aquifer by rainfall infiltrating the soil surface and then percolating through the zone of aeration (unsaturated soil). Recharge can also come via irrigation, the leakage of surface water storage or leakage from other aquifers. Recharge rate is expressed in units of depth per unit time (e.g. mm/year).
Recharge area	A defined area of land where a significant amount of groundwater recharge occurs.
Recovery	The rate at which the water level in a pumped bore rises once extraction has ceased, after the pump has been shut off. It is the inverse of drawdown.
Saline (water)	A term used to describe water that has high salinity levels (TDS >5,000 mg/L) that limit its suitability for many uses.
Salinity	A measure of the salts usually sodium chloride (NaCl) dissolved in water, expressed in TDS mg/L or EC $\mu$ S/cm.
Sand	Sedimentary mineral grains deposited by wind or water action having a particle size of between 1/16 and 2 mm diameter.
Sandstone	A sedimentary rock composed predominantly of consolidated sand-sized grains (i.e. 1/16 to 2 mm).

Word	Definition
Saturated zone	The part of a body of soil or rock where the voids and spaces are filled with water.
Screen	A portion of a well or bore casing that is pre-perforated or slotted to allow water to flow through it. The screen and associated filter packing (sand) act as a filtering device to permit the flow of liquid or air but prevents the passage of sediments or backfill particles.
Screen, slotted section	See perforation.
Seal	(a) A largely impermeable rock (usually mudstone, claystone or shale) that retards the passage of fluids (including water, gas or oil). (b) Seal is also used to refer to the cement placed in the bore annulus outside of the casing.
Sediment	(a) Solid material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity, or ice and has come to rest on the Earth's surface either above or below sea level. (b) Solid material, whether mineral or organic, which has been moved from its position of origin and redeposited.
Sedimentary rock	Any rock that has formed from the consolidation of sediment (for example, sandstone, conglomerate, mudstone).
Seep	Point at where seepage occurs.
Seepage	Occurs where the water table intersects the ground surface and water flows out. This is active discharge and is driven by the hydraulic gradient.
Shale	A fine-grained sedimentary rock comprised of layers of clays and other fine sized mineral particles.
Silt	Silts are sedimentary grains having a particle size of between 0.002 to 0.05 mm in diameter.
Siltstone	A sedimentary rock comprised of silt-size particles cemented together.
Shut-in pressure	Formation pressure as recorded at the well head when all valves are closed to the surface.
Spring	A place where groundwater discharges to the ground surface
Standing water level (static water level, SWL)	The depth to groundwater measured at any given time when pumping or recovery is not occurring.
Strata	Beds or layers of sedimentary rock.
Structure	Used to describe the overall relationship of rock masses e.g. folding, faulting or unconformities, any of which could act as traps for migrating gas or fluids.
Sub-artesian aquifer	An aquifer that requires artificial pumping to raise water to the surface, because the confining pressure is insufficient to raise the water to ground level.
Subcrop	The intersection of a plane representing the unconformity and a geological surface below that unconformity is the subcrop limit of the older surface. It represents the boundary between a region where the older surface is preserved below the unconformity and a region where it is not preserved.
Surface flow	A term used to describe the movement of water across the ground surface as run-off or stream flow.
Syncline	A concave fold in rocks, forming a trough. The antonym is an anticline.
Throw	Distance of movement, vertical or horizontal, along a fault plane.

Word	Definition
Total dissolved solids (TDS)	An expression of the total soluble mineral content of water determined by either measuring the residue on evaporation or the sum of analysed chemical constituents. Usually quoted in milligrams per litre (mg/L) or the equivalent parts per million (ppm), TDS may also be approximated from electrical conductivity (EC) measurements using the conversion $EC (\mu\text{S}/\text{cm}) \times 0.68 = \text{TDS (mg/L)}$ (see Electrical Conductivity).
Transmissivity	The rate of horizontal groundwater flow through the full saturated thickness of an aquifer across a unit width. Transmissivity may be quoted as $\text{m}^3/\text{day}/\text{m}$ [ $\text{L}^3/\text{T}/\text{L}$ ], but is more commonly expressed as $\text{m}^2/\text{day}$ [ $\text{L}^2/\text{T}$ ]. Transmissivity is related to the hydraulic conductivity of the aquifer by the equation $T=Kb$ .
Unconfined aquifer (water table aquifer)	An aquifer where the surface of the saturated zone is at atmospheric pressure. See aquifer.
Unconformity	A surface between successive strata representing a missing interval in the geologic record of time; produced either by an interruption in deposition or by the erosion of strata followed by renewed deposition.
Underlain	Term that refers to the relative position of a rock unit, formation, or geological material. Synonymous with lies below the ground surface or overlying strata.
Water-bearing strata	A formation or lithology that locally yields usable quantities of groundwater for use (i.e. stock watering), but is typically considered a non-water-bearing unit or aquitard.
Water table	(a) The upper surface of a body of groundwater occurring in an unconfined aquifer. At the water table, pore water pressure equals the atmospheric pressure. (b) The surface of a body of groundwater within an unconfined aquifer at which the pressure is atmospheric.
Well	In the context of this report, well, refers to a hole drilled into the ground and completed to access liquid petroleum resources.
Yield	The discharge of well or bore at (nearly) steady flow [ $\text{L}^3/\text{t}-1$ ].
Zero Edge	The edge or end of a formation or rock unit at depth. Often the point where a formation subcrops under younger rocks.

## Geological Time Scale

YEARS Myr (rounded)	ERA	PERIOD	EPOCH	
0-2.6	Cainozoic	Quaternary	Holocene	
			Pleistocene	
2.6-23		Tertiary		Pliocene
				Miocene
				Oligocene
				Eocene
23-65			Palaeocene	
65-145	Mesozoic	Cretaceous		
145-199		Jurassic		
199-251		Triassic		
251-299	Palaeozoic	Permian		
299-359		Carboniferous		
359-416		Devonian		
416-444		Silurian		
444-488		Ordovician		
488-542		Cambrian		
>542		Pre-Cambrian		

Source: International Commission on Stratigraphy



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