Department of Regional Development, Manufacturing and Water

Groundwater Monitoring Network Review Methodology Guideline

February 2022

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Queensland Government

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1.0 Executive Summary

The 'Groundwater Monitoring Network Review Methodology Guideline' (the Review Methodology) outlines the methodology for the review of the current departmental groundwater monitoring bore network across the State. The Review Methodology will be applied to 190 individual groundwater units across the State and recommendations made for each unit. Where relevant groundwater units have similar groundwater unit priority categories, then recommendations have been combined. The Review Methodology provides the basis for a transparent, consistent and repeatable review of the groundwater monitoring network and the department's information needs for individual groundwater units.

A major update to the Review Methodology from previous groundwater network monitoring reviews has been the introduction of a risk assessment approach to prioritising resource risk to the 190 individual groundwater units. This has been a significant process that was not part of the original scope, requiring the original Statewide Risk Assessment methodology to be reviewed and adapted for groundwater. The risk assessment methodology developed (Section 3.1.1.1) will form the basis for future Statewide Risk Assessments.

Consultation with a range of stakeholders has been undertaken regionally, internally through the Water Monitoring Team, Water Policy and Divisional Support and externally (Department of Environment and Science - DES) to develop and refine the Review Methodology. A significant component of the consultation was undertaken with the Water Policy group, particularly in relation to the 'Statewide Risk Assessment Criteria'.

The Review Methodology relates to the collection of water level data only. Water quality was the subject of a separate review in 2019 and is out of scope for this review. The purpose of the review is two-fold:

- Firstly, the collection of groundwater data by DRDMW is administered under a Quality Management System (QMS) certified to ISO 9001:2015 standards. The QMS requires that a review of the network be completed every five years. The previous groundwater monitoring network review was completed in 2014
- Secondly, it is good management practice and appropriate to review the monitoring network in the context of changes to water planning requirements and other stakeholder needs.

Groundwater monitoring data collected across the network supports a range of groundwater planning, management, and investigation activities. For the purposes of this review, the following strategic objectives for groundwater monitoring have been adopted as follows:

a) Support the management of underground water

b) Establish a baseline of information to understand changes within the groundwater resource

c) Monitor aquifers at an appropriate scale – for the purposes of this review, this is defined as a groundwater unit.

A groundwater unit is defined by a region and is relative to hydrogeology, level of risk to the resource, and management actions applied to the groundwater unit by the region i.e., managed and non-managed groundwater units

The Review Methodology has three distinct parts.

Part A - Prioritising Groundwater Units

Four criteria have been identified in the process of prioritising groundwater units. These criteria are identified as follows:

- Resource Risk – an assessment of the risk to the resource
- Water Management – consideration of existing management
- Resource Assessment – Planning – data (groundwater level) requirements for assessment purposes
- Specific Management Requirements – local issues impacting data requirements

There is a scoring process associated with each of the four criteria which results in an overall score of up to 12 for each groundwater unit.

Part B - Monitoring Bore Assessment

The following seven criteria have been developed to rank the individual importance of each bore relative to other monitoring bores in the same groundwater unit. Two levels of criteria are presented with those in Level 1 having a higher weighting and therefore attracting higher points. The majority of the criteria are based on previous reviews and are described in more detail below.

Level 1 criteria include:

- Is the monitoring bore representative of the aquifer?
- What purposes the bore is monitored for? and:
- Bore construction

Level 2 criteria include.

- Is the bore 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

As a result of Part B each bore within a groundwater unit receives a score of up to a maximum of 27. Following this process, recommendations about the future of each bore in the network are made. This is predominantly a subjective process and is based on the priority of the groundwater unit, demand profile and the ranking of individual bores, assessed using the groundwater system knowledge of experienced regional operatives. Where changes i.e., removal, addition, replacement are recommended, justification will be provided. Recommendations for measurement frequencies and loggers are also addressed.

Part C – Recommendations for Proposed Network in each Groundwater Unit

The final part of the process is to summarise the recommendations 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.

This part of the process identifies the number of sites currently monitored in the groundwater unit and those proposed to be monitored under the recommendations of this review. The number of sites is further split into those manually monitored and those equipped with loggers, both before and after the review. A discussion of the reasoning for the need for loggers and telemetry in each groundwater unit is included.

This part of the process identifies the range of scoring under Part B for each bore in the groundwater unit and a data gap analysis for each groundwater unit.

A 'Gap Analysis' is undertaken for each groundwater unit and recommendations are made for additional sites or amendment of sites as required. It is recommended that a 'Statewide Gap Analysis' is undertaken using the outcomes of the Review methodology to identify the relative priorities for new bores across the State, in the event that funding for new priority monitoring bores becomes available.

2.0 Ambient Groundwater Monitoring Network Operational Review

2.1 Purpose of this Document

The purpose of this document is to detail the proposed methodology for the review of the current departmental ambient groundwater monitoring bore network. The driver for this review is two-fold:

- Firstly, the collection of groundwater data by DRDMW is administered under a Quality Management System (QMS) certified to ISO 9001:2015 standards. The QMS requires that a review of the network be completed every five years. This ensures the network produces data that are appropriate for contemporary sustainable resource management.
- Secondly, it is good practice and appropriate to review the monitoring network in the context of changes to water planning requirements and other stakeholder needs. Since the last network review in 2014, requirements have potentially changed both in terms of measured data and measurement frequency, along with the measurement technology used. This review will underpin a more robust monitoring environment for the future.

The methodology developed provides the basis for a transparent, consistent and repeatable review of the groundwater monitoring network and the department's information needs at individual sites. The review will guide DRDMW to determine whether groundwater data collected is meeting stakeholder requirements, and if the DRDMW network has suitable site density and placement (resolution) to allow the department to fulfil its legislative, management and other identified requirements

Note: Water level is treated as a separate entity to water quality (chemistry of natural waters) (WQ) information which may be collected in monitoring bores. WQ was the subject of a separate review in 2019 and is out of scope for this review.

2.2 Objectives for Groundwater Monitoring

Groundwater monitoring data collected across the network supports a range of groundwater planning, management, and investigation activities. For the purposes of this review, the following strategic objectives for groundwater monitoring are described as follows:

a) Support the management of underground water – data to support the assessment, management, and planning activities, and to understand and manage risk associated with use and development of the resource.

b) Establish a baseline of information – to understand baseline conditions in a groundwater resource for future development and establish a long-term dataset to gauge management responses, or other external drivers i.e., climate change, land use that potentially influence resource behaviour

c) Monitor aquifers at an appropriate scale – for the purposes of this review this is defined as a groundwater unit scale. A groundwater unit is defined by a region and is relative to hydrogeology, level of risk to the resource, and management actions applied to the groundwater unit by the region i.e., managed and non-managed groundwater units. Examples of managed groundwater units are the Callide Valley Alluvium, Surat Gubberamunda or Atherton Basalts. Examples of non-managed groundwater units are Wet Tropics Coastal Alluvial Aquifers, Bribie Island and Mary River Alluvium.

2.3 Purpose of the Network

The department's groundwater monitoring network has evolved over more than 120 years from principally a resource management and assessment network to one which underpins a variety of decisions relating to the state's water resources and their use. As a result, in some cases, the distribution and location of monitoring sites may no longer be commensurate with the current management or assessment requirements.

The purpose of the departments groundwater level monitoring network is driven by the fundamental requirements for groundwater monitoring. That is, to monitor the quantity or quality of groundwater resources, which is primarily done to understand the status or trends in the following:

- groundwater storage (monitored by measuring groundwater levels and pressures in bores at a groundwater unit scale)
- response of groundwater systems to stress and management actions, i.e., pumping or water extraction, capping and piping of bores. This includes monitoring of groundwater to surface water interaction and impacts on water users and ecosystems.
- changing groundwater gradients and potential quality of water in aquifers (while quality is not part of this review, changing groundwater gradients can influence quality e.g sea water intrusion)
- groundwater processes including recharge and natural groundwater discharges (such as spring flows or baseflows in watercourses).
- evaluation of the effectiveness of management arrangements introduced through Water Plans
- data to support management rules introduced through Water Plans

Secondary reasons for monitoring groundwater are for understanding the following, noting these information needs are often not solely reliant on groundwater monitoring:

- the hydraulic characteristics of groundwater systems
- the degree of confinement of aquifers
- the areal extent of aquifers

There are other matters that relate to groundwater including ground subsidence, earthquakes, land salinisation not identified in this review.

2.4 Use and Demands for the Departments Groundwater Monitoring Data

Aside from the requirements for groundwater monitoring data by the department, there is an increasing demand from both groundwater users and 3rd party users (e.g., other government department, consultants, industry, and catchment groups). There is greater community expectation in respect to the purpose and location of monitoring sites, particularly as this data can be viewed via Queensland Globe. In 2020/21, Queensland Globe metadata identified typical monthly hits of 200 to 800 water level plots being produced on the Globe with a high of 1840 plots produced in May 2021 after rainfall events. Departmental uses of the collected data include:

- Understanding aquifer responses to management or seasonal factors at a groundwater unit scale i.e., condition and trend analysis

- Aquifer assessment, conceptualisation and modelling (groundwater models are generally calibrated to water level responses due to the uncertainty associated with recharge)
- Monitoring compliance against water plan outcomes and objectives
- Informing decisions on routine resource management (e.g. announced entitlement)
- Monitoring seawater intrusion and rising groundwater tables
- Impact assessment and management associated with resource industries
- Other contractual/client arrangements (e.g., Murray-Darling Basin Authority)

Groundwater monitoring practices have been evolving with the advent of technology such as increasing access to cost effective telemetry (the process of recording and transmitting instrument readings in real time).

2.4.1 Alternative Data Collection Technologies

There has been a significant advancement in data gathering technologies in recent times as the availability of cellular networks expand to remote areas. Coinciding with this expansion, NB-IoT and other low-cost telemetry solutions have enabled a seemingly cost-effective way of transmitting collected data from a remote site to the office environment.

Future reviews must consider the drivers for higher resolutions of data, which might only be cost effectively gathered through the installation of some of these technologies. Currently, a standardised departmental bore logger will cost the department in the order of $16,000 to purchase and install. For a specific monitoring bore, the use of alternative low-cost telemetry solutions that are available in 2021, allows the same functionality as the current standard equipment for approximately one fifth of the cost.

In this review, recommendations have been made to increase the resolution of data in some groundwater units i.e., installation of additional loggers. To cost effectively implement this, it is recommended the department trial the use of these alternative technologies to evaluate effectiveness and potential cost savings.

2.5 Policy/Legislative Settings

The department administers the *Water Act 2000*. The purpose of the Act in relation to the management of water includes:

– Providing a framework for the sustainable management of Queensland’s water resources by establishing a system for the planning, allocation and use of water

The sustainable management of water includes management that:

– Allows for the allocation and use of water resources within limits that can be sustained indefinitely.
– Sustains the condition of ecosystems, water quality, water-dependent ecological processes and biological diversity associated with watercourses, lakes, springs, aquifers and other natural water systems.
– Builds confidence regarding the availability and security of water entitlements.
– Promotes the efficient use of water through the regulation of water use if there is a risk of land or water degradation.

- Recognises the interests of Aboriginal people and Torres Strait Islanders and their connection with water resources.
- Integrates both long and short term environmental considerations, such as climate change into decision making processes.

A robust, targeted, long-term groundwater monitoring network is integral to the department delivering outcomes in accordance with the purpose of the *Water Act 2000*. A quality assured network also ensures accountability of external monitoring networks. Without monitoring data, the department would not be able to sustainably manage water.

Specific legislative requirements to monitor groundwater include:

- *Section 38 of the Act* - requires the department to provide information for planning purposes by regularly measuring and keeping publicly available records of the volume and quality of water in Queensland; and collecting information on the water requirements of, and impacts of water management on natural ecosystems, including for example, from the department in which the *Environmental Protection Act 1994* is administered.
- *Water Plans and Water Management Protocols* – outline catchment specific water plan outcomes and measures for achieving plan outcomes. This may include the development of a monitoring, evaluation and reporting strategy.

Water Sharing Rules – for water management areas regulated under the *Water Regulation 2016* may specify particular monitoring requirements.

The need for groundwater monitoring data is also supported by the Water Planning Science Plan 2020 - 2030. The DRDMW Strategic Plan further defines what success looks like for the department.

The legislative setting guides the groundwater monitoring network review by providing a framework to establish the purpose of monitoring for each groundwater unit and its priority or ranking.

2.6 Consultation

Consultation with a range of stakeholders has been undertaken internally and externally to develop and refine the Review Methodology. A significant component of the consultation was undertaken with the Water Policy group, particularly in relation to the 'Statewide Risk Assessment Criteria' (Section 3.1.1.1). The other internal groups consulted with include water monitoring, management and planning staff in Northern and Southern region, Statewide Water Management Team and Divisional Support.

The Department of Environment and Science (DES) was consulted in relation to monitoring requirements for modelling purposes (Section 5.3).

3.0 Review Methodology

The Review Methodology needs to consider the variable requirements, demand and availability of information, as well as the significant hydrogeological and management diversity in groundwater units that are currently monitored throughout the State. A three-step methodology has been developed to address these issues as follows:

1. Review the priority and determine the specific purposes for monitoring in each groundwater unit where monitoring is currently occurring and other units where a risk is identified, and monitoring is not currently occurring (Part A)
2. Review the priority of each currently monitored bore within the groundwater unit (Part B)
3. Provide recommendations based on the assessment under Part A and B, including a Gap Analysis and reasoning for frequency for manual measurements and loggers/telemetry sites (Part C)

3.1 Part A – Groundwater Unit Assessment

3.1.1 Prioritising Groundwater Units

Four criteria have been identified in the process of prioritising groundwater units. These criteria are identified as follows:

- Resource Risk – an assessment of the risk to the resource
- Water Management – consideration of existing management
- Resource Assessment – Planning – data (groundwater level) requirements for assessment purposes
- Specific Management Requirements – local issues impacting data requirements

The criteria are all weighted equally and are scored as outlined in Table 2. The individual score for each criterion is then totalled providing a maximum score of 12 for an individual groundwater unit. Each groundwater unit is then ranked from highest priority to lowest priority. Following Part B (Section 4.0), where the importance of each bore is rated, the overall ranking in Part A provides support for the decisions made regarding the appropriate number of bores required in each groundwater unit and monitoring frequency.

3.1.1.1 Resource Risk

The resource risk assessment criteria identified in Table 1 is based on the ‘Statewide Risk Assessment’ method to assess Resource Risk. The methodology has been adapted to better describe risks to the groundwater units across the State and will form a basis for future groundwater unit risk assessments. Table 1 has been developed in consultation with Water Policy. The Resource Risk categorises the risk 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.

Table 1 - Considerations for Determining Resource Risk Categories based on Water Resource Pressure*

Risk category	Considerations
Low	Low level of development or low numbers of bores accessing the aquifer, low water use in comparison to what the system appears capable of delivering as evidenced by groundwater levels being maintained well above bottom of aquifer or from anecdotal information. Apparent low demand for water. Aquifer appears predominantly at full supply (possible evidence of groundwater discharge to SW, GDE's etc) There are no or very few complaints or compliance activities.
Medium	Medium level of development, moderate water use and demand in comparison to what the system appears capable of delivering or increased numbers of bores or higher levels of use known i.e., irrigation (in comparison to low risk areas). Aquifer storage is depleted in extended drought periods but recovers in moderate to higher groundwater recharge events. An increase in water use is considered sustainable. Limited complaints or compliance activities in relation to take of water.
High	Highly developed aquifer with water use consistently similar to water available. Competition for the resource, demand for additional bores and or water use. Groundwater levels may have long term downward trends and/or extended periods (typically between major recharge events) of low to very low available supplies in landholder bores, in parts of the area. Potential for changed groundwater gradients to cause saltwater intrusion or (in inland areas) significant mobilisation of local saline groundwater on a regular basis. Regular complaint/ compliance issues in relation to the unauthorised take of water. In areas with a water plan in place there may be some water trading and/or a history of overuse by individual users. Alternatively, it may be an area where rising groundwater levels either pose salinity problems and or threaten cropping.
Very High	Very high level of development and use, over utilised system, high level of competition for resources, significant complaints/ compliance issues relating to unauthorised take. History of aquifer overuse. Long term water level declines and long-term reduction in the available pumping rates in bores. Significant management intervention is indicated to avoid system failure by limiting take. Additionally, there may be a specific threat to the resource, such as, rising groundwater levels creating salinity problems and is impacting cropping, or the aquifer is at risk of major saltwater intrusion issues or there is a high value groundwater dependant ecosystem under threat.

* Note: The purpose of the water resource pressure rating is to understand and describe the pressure each groundwater unit is under in terms of the level of water resource development

Table 1 applies to all groundwater units. For alluvial aquifers, Appendix 1 provides a description of the aquifer storage methodology to be used in conjunction with Table 1.

Table 2 provides the mechanism for prioritising all groundwater units, using the four criteria previously described and including the Resource Risk Criteria as detailed in Table 1. Table 2 outlines the scoring system for prioritisation for groundwater units with an accompanying colour code.

Table 2 – Criteria for Ranking Priority of Groundwater Units

Criteria		Score			
		0	1	2	3
1	Resource Risk	Low	Medium	High	Very high
2	Water Management	Nil	Limited management	Managed	Intensively managed
3	Resource Assessment - Planning	Nil	Low Required in the longer term	Medium Identified – required in the short to medium term	High Groundwater assessment occurred/ occurring or Modelled
4	Specific management requirement	Nil	Low	Medium	High

Discussion of the criteria is as follows:

3.1.1.2 Resource Risk

As assessed in Section 3.1.1.1

3.1.1.3 Water Management

Intensively managed can be represented by those managed areas where a higher level of management is in place. Typically, these areas would have volumetric entitlements and water sharing rules such as announced entitlements in place.

A medium level of management (managed) is typified by groundwater units where entitlements or authorisations to take exist. No announced entitlement or allocation process is in place; however, the resource is likely managed by volumes or by limiting works.

Limited management describes a groundwater unit where currently there are some management actions undertaken, however, they are fairly limited in scope. An example of this level of management is where a Water Plan has identified a requirement to monitor groundwater trends in the area.

If a groundwater unit is not identified in the *Water Regulation 2016* as an underground water area or identified in a Water Plan, then Nil management applies.

While not specific to the criteria, information in the 'Subcatchment Risk Assessment' spreadsheet could be used as a background resource for management issues in some units.

3.1.1.4 Resource Assessment - Planning

A high requirement here is represented by a groundwater assessment that has recently occurred or is currently occurring. A groundwater model may have been developed or is in development or a detailed manual groundwater assessment has been or is to be undertaken e.g., water balance assessment.

A medium level is where a groundwater assessment is identified as being required, within the next 5 – 10 years based on commitments in a Water Plan, or commitments to a user community or similar. Data from the network may have already been used in some preliminary assessment work. A medium level may also be represented by an area where there has been a detailed, well calibrated groundwater model developed and there is unlikely to be a significant review or update of this model required.

Low level is where assessment is likely in the longer term.

Nil is where an assessment is unlikely to occur in the foreseeable future.

3.1.1.5 Specific Management Requirement

This relates to a specific issue within the unit in this area. The area may or may not be currently managed.

Examples of these Specific Management Requirements are:

1/ Connection with Identified Significant Groundwater Dependant Ecosystems

2/ Impact Assessment associated with CSG, Mining, Feedlots, PFAS or other Similar issues

3/ Sea Water Intrusion or Inland Groundwater Gradients for Water Quality (natural) control

This includes coastal areas where increased groundwater use can influence the movement of sea water into the aquifer or in other areas where changing groundwater level gradients can influence the movement of existing poor quality groundwater from one area to another.

4/ Town Water Supply

Is the groundwater in this unit being used for town water supply or potentially may be used for town water supply? Is there some other linkage between the use of water from this unit and the reliability of town water supplies?

5/ Groundwater/Surface Water Connectivity

Is there significant connectivity of surface water and groundwater in this area? If so, is it important in understanding the impact of groundwater take on surface water reliability and vice versa e.g. Is this a surface water scheme area where the alluvial groundwater is managed but not part of the scheme? Or is the flow of water important to support water-related aesthetic, cultural and recreational values?

6/ Pressure Head Management – GAB Aquifers only

Is the GAB groundwater unit artesian and is maintenance of pressure an important component of stakeholder access to water within the aquifer? Has there been significant investment through programs such as GABSI, IGABIIP to cap and pipe works in the groundwater unit to maintain or restore pressure?

7/ Unique Regional Management Consideration

Is there a unique regional management criteria that needs to be identified?

If a groundwater unit has multiple specific management requirements or one particular management requirement is considered critical in the unit, then the unit would score higher in this category. If none of the specific management requirements apply, then a Nil weighting is applied.

Once a score has been determined for each criterion for a groundwater unit, the unit is given a total score and ranking at the top of the groundwater unit assessment sheet for that unit. The total scoring, ranking and associated colour coding is as defined in Table 3.

Table 3 – Part A Total Score Ranking and Colour Codes

Total Score	Ranking
0 - 3	Low
4 - 6	Medium
7 - 9	High
10 - 12	Very High

3.2 Part A Example – Central Condamine Alluvium

Central Condamine Alluvium

	Groundwater Unit Assessment Overall Rank : Total Score 9/12 – High

Facts:

- Aquifer Type: Alluvium
- Water Plan – Condamine and Balonne
- SDL area under the Murray Darling Basin Water Plan
- Managed groundwater area since the 1960's
- Area: 4453 km^2
- 315 individual water licences / 40 841 ML in entitlement

Purpose of monitoring:

- Groundwater levels – selected sites have loggers/ telemetry; manual readings 4 readings per annum
- Water quality measurement – selected sites, 3 yearly
- Water Plan identified trigger sites to determine announced entitlements
- Highly managed system
- Highly utilised system
- Model
- Trading rules

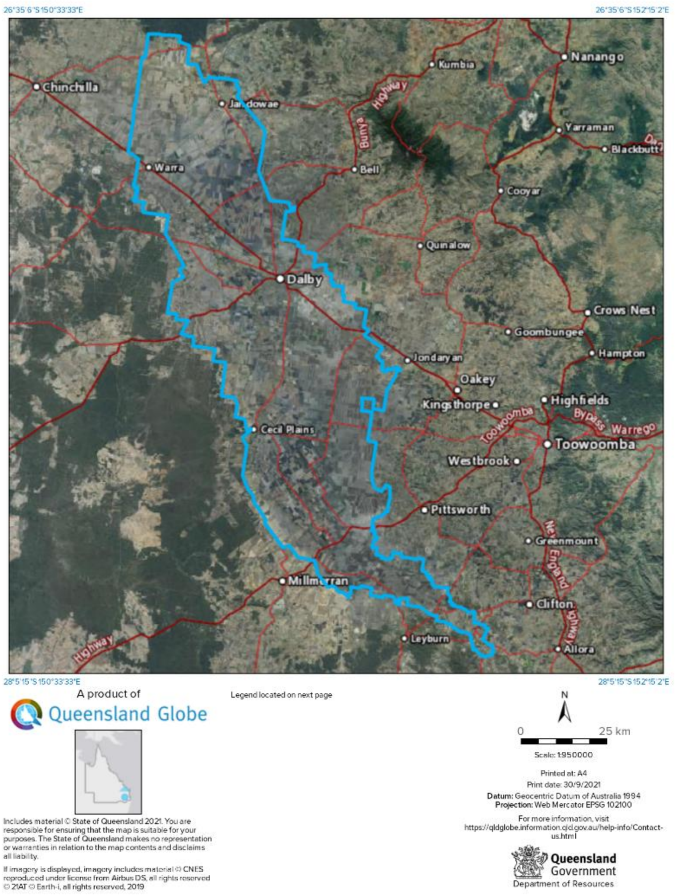

Figure 1 – Central Condamine Alluvium

Assessment against Criteria

Criteria		Weighting			
		0	1	2	3
1	Resource Risk	Low	Medium	High	Very high
2	Water Management	Nil	Limited management	Managed	Intensively managed
3	Resource Assessment - Planning	Nil	Low Required in the longer term	Medium Identified – required in the short to medium term	High GW Assessment occurred/ occurring or Modelled
4	Specific management requirement	Nil	Low	Medium	High

Supporting Information

Resource Risk

- Highly developed aquifer with water use similar to water available.
- Approximately 46 000 ML (MDB BDL) - no water available in General Reserve in the Qld Water Plan area; no water in MDB SDL; recent Commonwealth buyback has resulted in entitlements reduced to approximately 41 000 ML.
- An increase in water use is not considered sustainable – competition for the resource.
- High demand for water – trading is available (last 4 quarters: average price / ML was $5100, with a high of $7000 / ML); seasonal water assignments are available.
- A previously over-allocated resource with long term water level reductions since the 1960's. Early indications are that the storage appears to be responding positively to entitlement and use reductions

Resource Risk Score	High

Water Management

- Water licences with volumetric entitlements exist for all non stock and domestic take
- Currently, there are a significant number of monitoring sites to measure water levels in this groundwater unit to support management – There are a number of Water Plan trigger monitoring bores
- An annual Announced Entitlements regime is used to manage the resource – dependent on average water level per zone in a selection of trigger bores in a zone (Water Management Protocol).
- Groundwater unit has Water Sharing Rules, Seasonal Water Assignment Rules and extraction has been metered since 1979

Water Management Score	Intensively Managed

Resource Assessment - Planning and Future Development

- This groundwater unit has a model that needs to be reviewed or updated at Plan review.
- This groundwater unit is included in the Surat UWIR model that is updated every 3 years.
- Trading rules include impact assessment criteria for construction of new works (Bores).

Resource Assessment – Planning Score	High

Specific Management Requirements

- One specific management requirement associated with this aquifer:
  - Source of Town Water Supply for the towns of Dalby, Pittsworth and Millmerran

Specific Management Requirements Score	Low

4.0 Part B – Monitoring Bore Assessment

The following seven criteria have been developed to rank the individual importance of each bore relative to other monitoring bores in the same groundwater unit. Two levels of criteria are presented with those in Level 1 having a higher weighting and therefore attracting higher points. The majority of the criteria are based on previous reviews and are described in more detail below.

Level 1 criteria include:

- Is the monitoring bore representative of the aquifer
- What purposes the bore is monitored for, and.
- Bore construction

Level 2 criteria include:

- Is the bore 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

Using the methodology described below the bores are ranked individually within the groundwater unit. Following the ranking process for each monitoring bore, recommendations about the future of each bore in the network are made. This is predominantly a subjective process and is based on the priority of the groundwater management unit and the ranking of individual bores, assessed using the groundwater system knowledge of experienced regional operatives. Where changes i.e., removal, addition, replacement are recommended, justification will be provided. Recommendations for measurement frequencies and loggers are also addressed based on the methodology presented in Section 5.0.

The team from the department's Information Systems Management (Water) who manage the Groundwater Database, developed a website at the request of the Working Group, which accepts a list of Registered Number/s (RN) and then identifies the nearest other bore and distance to each bore in the list. The output file displays the drilled date, casing material and distance to the nearest bore for each RN in the specified list. These output files have been used to provide some automation efficiencies in the Part B process.

4.1 Level 1 Criteria

4.1.1 Monitoring Bore Data Representative of Aquifer

This criterion ensures that data collected from monitoring bores is indicative of the conditions of the majority of the aquifer or in some marginal areas where understanding connectivity with the main aquifer is considered important.

Score	Description of Situation
5	**Bore Data Representative of Aquifer:** available historical data collected from this bore (strata log, water level, water quality etc.) shows results and/or trends typical of data from other bores in the same aquifer in the area
3	**Bore Data Representative of Aquifer with some qualification:** Typically, some data like the strata log may raise questions as to whether the bore is representative but the overall data including water level and quality if available indicates the data collected from the bore is typical of data from other bores in the same aquifer in the area. Alternatively, the bore has been dry or blocked for sufficient periods to only allow some part of the record to be representative of the aquifer
1	**Bore Data not considered Representative of Aquifer.** A review of data available including strata log, water level and water quality indicates the data from the bore is not typical of data from other bores in the same aquifer in the area or possibly in multiple aquifers

4.1.2 Bore Purpose

This criterion relates to the level of use of the data collected from the bore for making groundwater management decisions. Examples of data uses include:

- GWM - Groundwater Modelling either existing (or would now be used in an update of the model). Generally representative of the aquifer and would provide good data for contouring of groundwater levels
- GWSW - Groundwater – Surface water connection. These bores are generally close to the potential recharge source (watercourse) and the data will assist with our understanding of groundwater-surface water connection, particularly in development and running of groundwater models
- WSHAR – Used in water sharing rules, e.g Announced Entitlement or allocation, management decision bores listed in a Water Plan or Water Management Protocol
- WPF - Weir performance (adjacent weirs u/s and d/s)
- REP – Representative bore used for some purpose, groundwater storage determination, is or has been used for providing groundwater trends in area i.e., section 29 limitations or used in newspaper, newsletter or something similar
- WQGRAD - Where poor quality groundwater meets good within the groundwater unit, Water Level Gradients important (not a coastal saltwater intrusion issue)
- WLGRAD – Used to assess water level gradients, groundwater flow directions and recharge sources
- WQINFL- Taking WQGRAD one step further where a combination of groundwater quality and proximity of groundwater level to surface indicates poor groundwater in one groundwater unit may affect good quality groundwater in another groundwater unit. (Use in NAP Bores)
- WLT - Monitoring base line water level trends
- QUAL- Bore is used for water quality issues, GWAN or sea water intrusion monitoring.
- WLRI – Bore is used to monitor rising groundwater levels
- LTHS – valuable Long-Term Historic Site, can include nearby replacement bores. The site should be representative of the aquifer and existed for more than 30 years
- SNMB – Shared Network Monitoring Bores (3rd party interests)
- QA – Quality assurance or compliance. Eg are these monitoring bores installed to allow compliance of an external network (could be a department bore in the same area as a mine’s monitoring network)

Score	Description
5	**Multiple Purpose Bore:** this bore is used for at least 3 different purposes as listed above **or** is listed in a Water Plan, Water Management Protocol or Water Sharing Rules
3	**Dual Purpose Bore:** this bore is used for only 2 purposes as listed above
1	**Single Purpose Bore:** this bore is only used for 1 particular purpose, likely to be WLT

4.1.3 Construction

This criterion relates to any potential or known issues associated with the construction of the monitoring bore. These issues include:

- Age of the bore
- History of blockage
- History of being dry
- Integrity of the casing
- Depth in comparison to nearby bores in areas where bores may go dry

From a starting score of 5, points are deducted in the following manner.

- For non GAB bores, if the bore is more than 40 years old reduce by 1 point. If date drilled is unknown (e.g private bore being utilised and no drilled date details.) assume greater than 40 years old. This rule does not apply to GAB bores
- Bore has been blocked at least once, reduce by 1 point, regularly blocked over its life, e.g tree roots or deteriorating casing 2 points. If the blockage issues are such that they have impacted at least one third of the record since blockage began and it is considered to be greatly impacting data obtained give a total score either 1 or 2 depending on quality of data now available
- The bore is dry for a cumulative period of 1 – 5 years reduce by 1 point. If dry for a greater period reduce by 2 points. If the dry issues are such that they have impacted at least one third of the record and it is considered to be greatly impacting data obtained score either 1 or 2 depending on quality of data now available. Note if the bore was dry because of blockages, deal with it under the blockage guideline above
- The bore is considerably shallower than nearby bores and although not having gone dry yet is likely to in the foreseeable future, reduce by 1 point

- Regardless of the considerations listed above if there are serious construction or headworks issues assign a score of 1

Examples

Non GAB bore drilled in 1973 no record of being dry or blocked. No other issues. Reduce by 1 point (more than 40 years old), score 4.

Bore drilled in 1995. Dry record for cumulative period of 5 years. No other issues. Reduce by 1 point (dry for 1 – 5 years). Score 4.

Non GAB bore drilled in 1975. Reduce by 1 point (more than 40 years old). Additionally, bore became blocked in 2003. Tree roots have been removed but grown back. Bore has been dry for about 10 years since 2003 because of blockage. Water levels in these drier periods drop below the blockage. Some useful data has been obtained in recharge periods. Overall score adopted was 2.

4.2 Level 2 Criteria

4.2.1 Level of Groundwater Demand in the General Area

This criterion relates to the level of take from production bores (e.g., irrigation, intensive animal production) or level of entitlement in the general area of the monitoring bore. Whilst it is not ideal for a monitoring bore to be adjacent an irrigation bore, it is necessary to locate a percentage of monitoring bores in those parts of an area experiencing higher groundwater use and therefore higher stress to understand aquifer behaviour in these areas. The scoring in this criterion is as follows:

Score	Description
3	**High Use area:** Majority of properties in this area have a high level of groundwater take or high level of entitlement
2	**Moderate Use area:** Moderate groundwater take or level of entitlement in the area but not high compared to some other areas or limited knowledge of the location of groundwater take in the area
1	**Low Use area:** Very low level of groundwater take or entitlement in this area

A groundwater unit might have monitoring bores with up to 3 different scores in this criterion because of the variation in use throughout the area.

4.2.2 Influence of Bore via Pumping

This criterion identifies where bores that are directly and unduly influenced by factors such as nearby high use production bores will rate lower than those that are not.

Score	Description
3	**Bore Generally Free of Influence:** data collected from the bore is not noticeably impacted by pumping nearby or is rarely impacted
2	**Limited impact:** data collected from this bore may be impacted occasionally and generally drawdowns are no more than moderate in size. Or may be significantly impacted however the bore is equipped with a data logger, thus pumping influence can be accounted for. Or in the case of a GAB artesian bore, the testing regime accounts for the impacts of antecedent conditions on the measurement of head in the bore
1	**Significant Impact:** data collected from this bore is regularly impacted by pumping nearby and drawdown impacts are moderate to high

4.2.3 Bore Accessibility

This criterion ranks each bore according to its accessibility with regard to wet weather conditions, cropping etc. It also acknowledges the greater likelihood of a landowner withdrawing access to a private bore by scoring private bores as either 2 or 1.

Score	Description
3	**Department Bore Good Access:** typically located adjacent a reliable formed road which could also be a road into a farm house
2	**Moderate Accessibility:** Department Bore where access is occasionally restricted by wet tracks or cropping, locked gates etc. Private bore where access is either good or moderate
1	**Poor Accessibility:** Department or Private bore where access can often be restricted or there may be safety concerns (e.g. adjacent to busy road)

4.2.4 Distance to Nearest Groundwater Level Monitoring Bore

This criterion ranks groundwater level monitoring bores according to their proximity to the nearest monitoring bore within the same aquifer. Lower rankings are given to bores that are separated by the smallest distances or are clustered together, however, consideration is given to a bore on the same bore line.

In some cases, the bores within a bore line may be located relatively closely to one another in order to collect data on cross-alluvium groundwater trends. This may result in low rankings being given to all bores within a bore line. If bores have been drilled in lines the best bore on the line, based on the other criteria, will first be measured from the nearest other monitoring bore in the same aquifer, not on this line. Other bores on the line will be simply measured to the closest monitoring bore in the same aquifer.

Score	Description
3	**Bore Highly Isolated:** bore greater than 1000m from nearest groundwater level monitoring bore in the same aquifer
2	**Bore Moderately Isolated:** bore 200m - 1000m from nearest groundwater level monitoring bore in the same aquifer
1	**Bore Within Cluster:** bore less than 200m from nearest groundwater level monitoring bore in the same aquifer

These distances are set up to reflect smaller to moderately sized alluvial areas (e.g Lockyer Valley) and will need some adjustment for larger alluvial areas and non alluvial areas. In these other cases, the adjusted distances should be identified as part the assessment.

5.0 Frequency of Measurement Methodology

In a general sense, the greater the variation in water levels and the greater the responsiveness of an aquifer to the recharge and discharge components of the local and regional water balance, the greater the requirement for increased frequency of measurement of groundwater levels in a monitoring bore.

5.1 Manual Measurements

Historically, the department has aimed to measure groundwater levels in monitoring bores at a minimum of 4 times per year in most sub artesian groundwater units across the state. This is considered to provide a basic understanding of the variation in water levels caused by seasonal variations in both recharge and water use patterns. However, depending on the storage behaviour, variation to this frequency may be required.

5.1.1 Long Term Water Level Trends

One of the first requirements of a groundwater monitoring system is to determine long term trends of groundwater levels which is a reflection of long term storage and whether the system is in balance. i.e., is recharge, water use and discharge in balance or is the storage under stress because they are not.

In some geologic units, where recharge and use are not large, the water level responses to seasonal events are not likely to be large or rapid. Hence 2 measurements per year might be ample to provide a guide to long term groundwater levels.

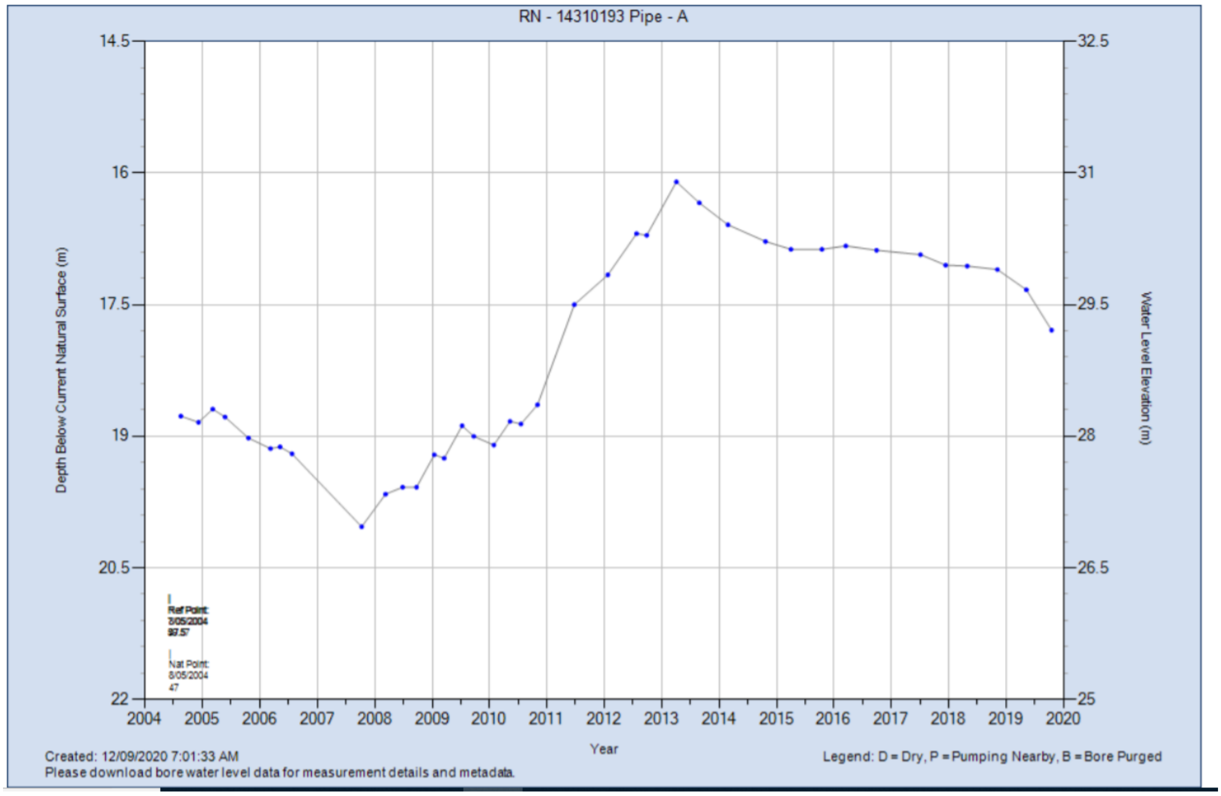

Figure 1 – Water Level Plot for a **Monitoring Bore in the Walloon Coal Measures - Rosewood**

Note the trends in this Walloon Coal Measures bore in the Rosewood area (Figure 1). Measurement frequency is up to four times per year up to 2010. From 2010 onwards reducing measurement frequency from four times a year to two times a year has reduced the ability to observe the impacts of seasonal variation, however, two readings annually allow for an understanding of long term storage trends to be maintained.

In other geologic units like alluvium, water level responses are often more seasonal. Traditionally, the department has used a minimum of four measurements per year to capture the general responses to seasonal conditions. Seasonal variations occur generally as increased recharge in high rainfall years and increased use in low rainfall years.

However, even in alluvium, if nothing more was required of the network but to obtain long term trends, the measurement of water levels 2 or 3 times a year is generally adequate to determine those long term trends.

5.2 Requirement for Continuous and/or Real Time Measurement (Loggers)

In some circumstances, it is desirable to have at least some representative bores in an area equipped with data loggers where daily water level measurements can be obtained. Some of the circumstances where such additional data might be warranted can be described as follows.

In an area where water levels rise and fall quickly in response to recharge and discharge events. These include:

- upstream areas of alluvial aquifers where recharge occurs quickly in response to rainfall and stream flow events. Water levels then drop quickly after stream flows recede and drainage of groundwater either back to the stream or down or across valley flow occurs
- water levels on sand islands where recharge after rainfall, directly through the ground surface is high and discharge to streams and the sea is also significant and constant
- basalt aquifers where recharge is responsive to rainfall, generally in upland areas through soils that have high internal drainage characteristics

Figure 2 provides a plot of groundwater levels in a monitoring bore in an upstream alluvial area of the Lockyer Valley. The water levels respond quickly to stream flows and drop sharply after flows recede and down valley groundwater flow impacts storage. In some periods the extended baseflows in the adjacent creek, following major rainfall events, maintains groundwater levels for longer periods. Similar monitoring results can be obtained via very regular manual measurements if staff are based nearby. Otherwise, a logger will capture the full cycle. The other advantage of a logger in such circumstances is when high stream flow events can hinder access for manual measurements.

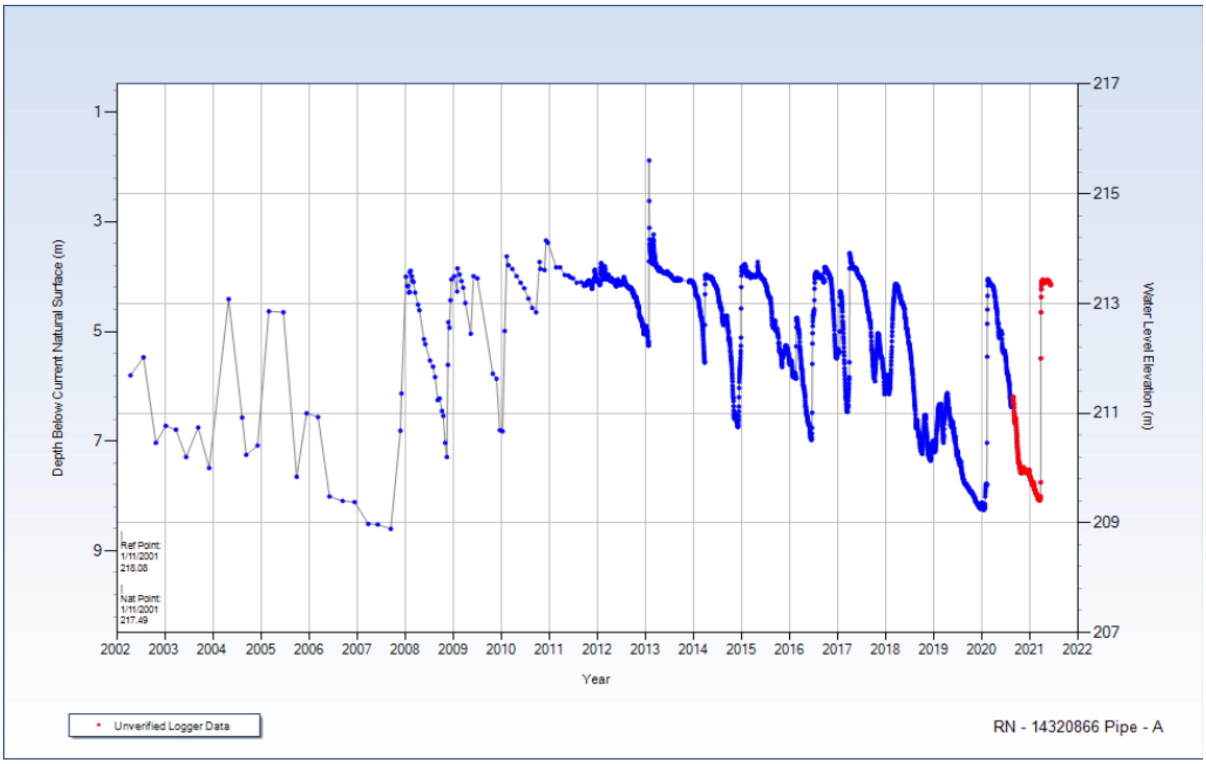

Figure 2 – Water Level Plot for Monitoring Bore in Shallow Alluvium upstream of Tenthill Creek – Lockyer Valley

Loggers are also effective in areas where pumping nearby greatly impacts monitoring bores. This issue is exaggerated in confined aquifers. The loggers on some bores in the Mulgildie South area are a good example, where the Precipice Sandstone aquifer is confined to semi confined and pumping rates from production bores are as high as 50 litres per second. Loggers provide an understanding of recovered groundwater levels in the bore over time. An example is provided in Figure 3 where a monitoring bore in a confined aquifer in the Precipice Sandstone near Mundubbera was equipped with a logger after a number of years of manual measurements. The logger allows a much better understanding of those water levels not significantly impacted by pumping nearby and hence a better indication of the storage trends over time in the aquifer.

Similarly bores in unconfined aquifers can be greatly impacted by pumping of high volumes in irrigation bores which are very close to monitoring bores. If a better site for the monitoring bore can not be found a logger again provides an understanding of recovered groundwater levels.

In some instances, loggers and telemetry can be required for reasons other than the variation in groundwater levels. An example is where water levels in representative bores are being used to inform the public or make water sharing decisions. In these cases, the water levels in bores may vary only small amounts over time but a commitment has been given to make the data available.

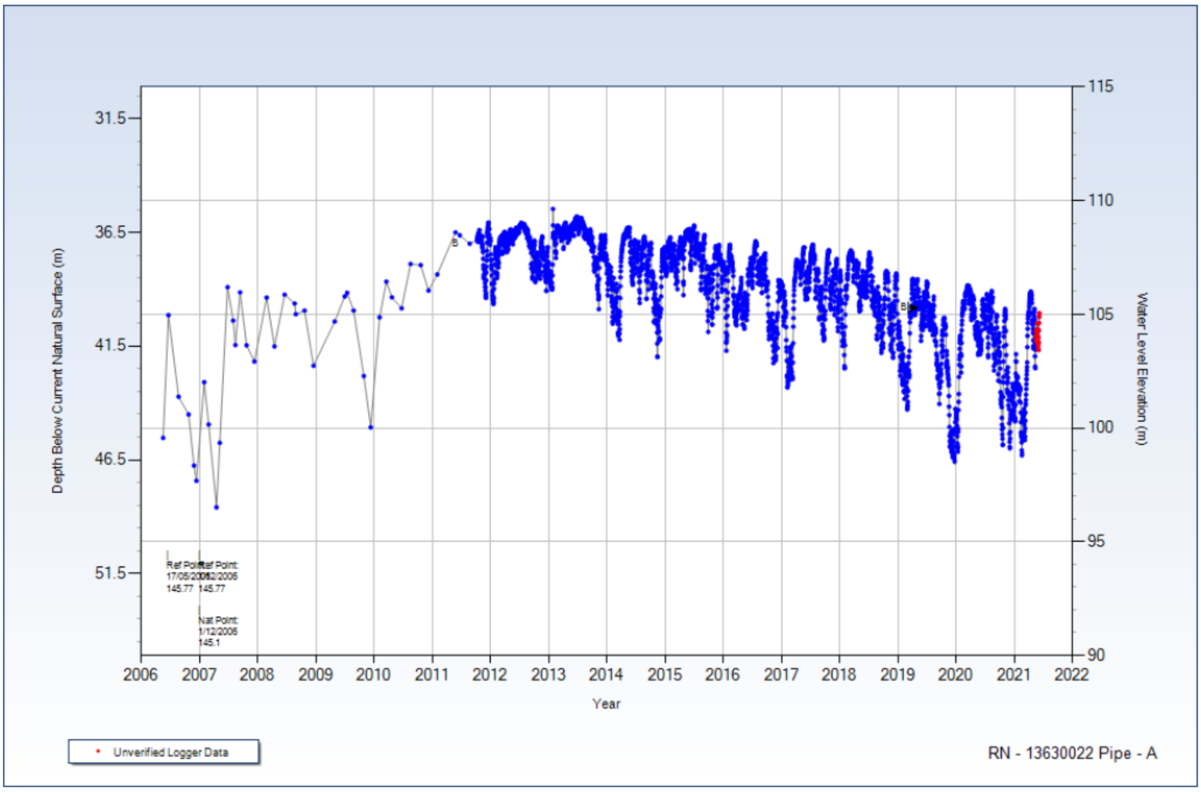

Figure 3 – Water Level Plot for Monitoring Bore in a Confined Aquifer (Precipice Sandstone) near Mundubbera

5.3 Frequency of Monitoring Requirements - Modelling

Comments were sought from the DES in relation to frequency of monitoring requirements for groundwater modelling. Without referencing a specific groundwater unit, the response provided some general principles of monitoring for groundwater modelling requirements. They include:

1) *'Even, spatially distributed monitoring within the aquifer (or area of interest) including the boundary areas*
2) *Where multiple aquifers exist (e.g., layers), spatial coverage for each aquifer, even if not regularly accessed by pumping*
3) *Consistent temporal monitoring data, at a frequency of at least monthly. The length of records needs to cover a range of climatic variations (typically, records in excess of seven years without break)*
4) *Representative monitoring bores with high-frequency records (dataloggers) to observe daily variability and effects of localised impacts (e.g., pumping, flooding, GW-SW interaction, responses to rainfall events) – these bores to represent different parts of the aquifer, including higher use areas.*
5) *Monitoring to cover areas of future/proposed development if possible*
6) *In coastal areas, monitoring that adequately covers the coastal boundary, including a range of depths that may enable assessment of seawater interface positions.*
7) *High-resolution monitoring bores close to gauging stations provide good value in understanding GW-SW interaction, where possible'.*

The biggest issues in modelling are dealing with inconsistent monitoring data for calibration purposes. Not just spatial/temporal coverage but data quality as well. So in addition to modelling, we would seek good accurate records of specific bore information (casing, elevation, location, etc)'

The recommendations for frequency of manual groundwater monitoring have been determined as outlined in Section 5. While it is not practicable to have monthly manual readings for all bores in a modelled area, recommendations for additional loggers have been made for monitoring sites in priority areas.

6.0 Part C – Recommendations for Proposed Groundwater Monitoring Network

The final part of the process is to provide recommendations (Part C) for each groundwater unit, incorporating a summary of the priority ranking identified in Part A and the recommended sites to be monitored as determined through the Part B process. A discussion of the reasoning for the need for loggers and telemetry in each groundwater unit is included. Additionally, data gaps are identified for the groundwater unit and recommendations for additional monitoring sites have been made.

For each groundwater unit, a map is provided identifying the sites to be retained or removed or where bores are to be added or where data gaps are identified.

This part of the process identifies the number of sites currently monitored in the groundwater unit and those proposed to be monitored under the Review Methodology recommendations. The number of sites is further split into those manually monitored and those equipped with loggers, both before and after the Review Methodolgy is applied.

Additionally, the range of scoring under Part B for each bore in the groundwater unit is provided.

A Gap Analysis is undertaken for each groundwater unit and recommendations are made for additional sites or amendment of sites as required

There are a number of groundwater units where the resource risk has been assessed as High or Very High mainly as a result of development occurring with limited monitoring in place to understand background levels. It is recommended that following the finalisation and endorsement of the Review Methodology recommendations, a 'Statewide Gap Analysis' is undertaken using the outcomes of the review to identify the relative priorities for new bores across the State, in the event that funding for new priority monitoring bores becomes available.

6.1 Part C Example – Recommendations for the Central Condamine Alluvium Groundwater Unit

Recommended Monitoring Frequency and Measurement Numbers		
Summary	**Current Network**	**Proposed Network**
Number of sites	173	147
Manual measurements per year	644	546
Sites monitored manually	149	123
Loggers with Telemetry	24	24

GROUNDWATER UNIT ASSESSMENT

Part A Assessment

Groundwater Unit Assessment Overall Rank : 9 /12 – High

Facts:

- Aquifer Type: Alluvium
- Water Plan areas – Condamine and Balonne.
- SDL area under the Murray Darling Basin Water Plan
- Managed area since the 1960's - GWMA
- Area: 4453 km^2
- 315 licences / 40 841ML in entitlement

Purpose of Monitoring:

- Groundwater levels – selected sites have loggers/ telemetry; manual readings 4 readings per annum
- Water quality measurement – selected sites 3 yearly
- Water Plan identified trigger sites to determine announced entitlements
- Highly managed system
- Highly utilised system
- Current Model
- Trading rules

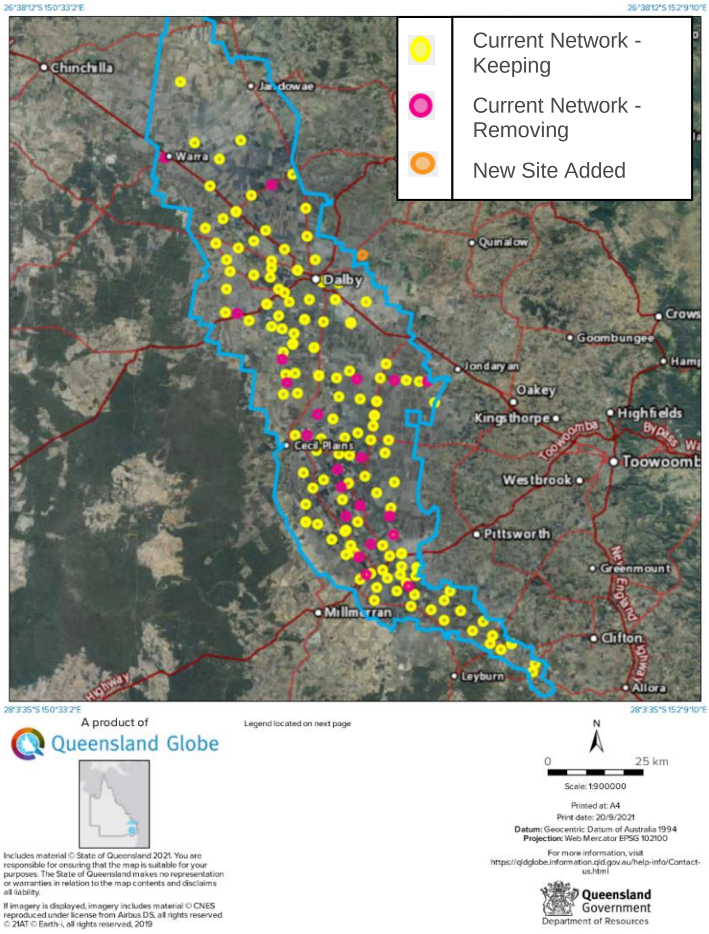

Figure 1 – Central Condamine Alluvium

Part B Assessment

Assessment Summary	
Total number of sites on current GWAN	173
Sites – Abandoned and Destroyed	0
Score range for existing sites (maximum possible score 27)	16 - 27

Recommendation (Part C)

Changes to Network	
Remove (abandoned & destroyed)	0
Remove (other reasons*)	27
New or reinstated sites	1

* Eight (8) because they appear blocked or are dry

Six (6) as the SWL in the shallower pipe is linked to the deeper pipe

Thirteen are close to other sites and are showing similar responses to nearby sites and are therefore surplus

Five (5) of these are in important locations within the aquifer and may need to be replaced

One site requires more detailed investigation to determine if the water levels are still representative of the aquifer.

Monitoring Schedules including Recommendations for Loggers/Telemetry

The existing network identifies 173 sites with total manual measurements of 644 measurements per year. The proposed network has 147 sites with total manual measurements of 546 manual measurements per year.

There are currently 24 loggers on sites in this area. It is recommended 24 loggers remain in this area however, some loggers will need moving to a new location.

Data Gaps

There are areas of CCA Zone 4 where there is limited monitoring bore coverage, however, there is limited development in that area and is not considered a priority at this time.

Comments

The recommended network is considered to meet the monitoring requirements as defined in Part A and is considered appropriate for the priority of this groundwater unit.

7.0 Appendices

Appendix 1: Guide to Assessing Alluvial Aquifers using Aquifer Storage

The following examples are provided as a guide to determining the lowest recorded level of aquifer storage in an area and then using that information to assist in understanding the risk to the groundwater resource. At this time, it is only suggested to use this in alluvial aquifers, but it may have wider applications.

The methodology to determine the lowest aquifer storage is to first select some representative monitoring bores in the area being considered. Often about 5 bores, spaced throughout the area and typical of those areas where most extraction is likely to be occurring, should be sufficient.

The following pieces of information are required from each bore:

Bottom of the aquifer in metres below ground level. If the depth to the base of the aquifer at the monitoring bore in question is considered shallower than other landholder bores around it, use the typical depth of those surrounding bores to determine base of aquifer.

Highest water level (WL) on record in metres below ground level.

Lowest WL on record in metres below ground level.

When using water levels in metres below ground level, be aware of potential changes in ref point elevation over time and adjust measurements accordingly. (Check the elevation table in the GWDB).

Firstly, a range of potential water levels is calculated in each bore. The range equals the base of the aquifer figure minus the assessed highest water level on record.

Then to determine the percent volume in storage in the aquifer at the lowest water level on record the following equation is used:

(base of aquifer (m bgl)) - (lowest recorded WL (m bgl)) /range (m) x 100

Initially the following interpretation of the results is proposed:

- If the lowest calculated storage for representative bores in an area generally remain above 60% this would be a low risk area.
- If the lowest calculated storage for representative bores in an area generally fall below 60% but remain above 40% this would be a medium or moderate risk area.
- If the lowest calculated storage for representative bores in an area generally fall below 40% this would be a high or very high risk area, and additional factors would need to be considered for final determination.

Examples of storage determinations using representative bores within groundwater units are shown in the following Tables and Figures. Note the vertical scales of all 3 plots are the same. The red line on the bottom of each plot approximates the depth to the base of the aquifer in the area of each bore.

Low Risk Area Example - Stanley River and Tributaries Alluvium

Table 10

RN	Depth to base of Aquifer m (bgl)	Highest WL m (bgl)	Date highest	Lowest WL m (bgl)	date	Range (m) depth to base - highest WL	Storage level % at lowest WL	Comments
14330007	13.7	0.79	30/03/2015	4.58	15/06/2016	12.91	**71**	
14330016	12.5	1.96	21/12/2010	6.05	17/03/1987	10.54	**61**	pumping nearby impacts
14330024	13.1	1.64	2/03/1976	4.37	2/05/2008	11.46	**76**	
14330026	14.8	2.19	21/12/2010	5.94	11/12/2019	12.61	**70**	
14330029	13.4	3.72	21/12/2010	6.44	9/10/2006	9.68	**72**	

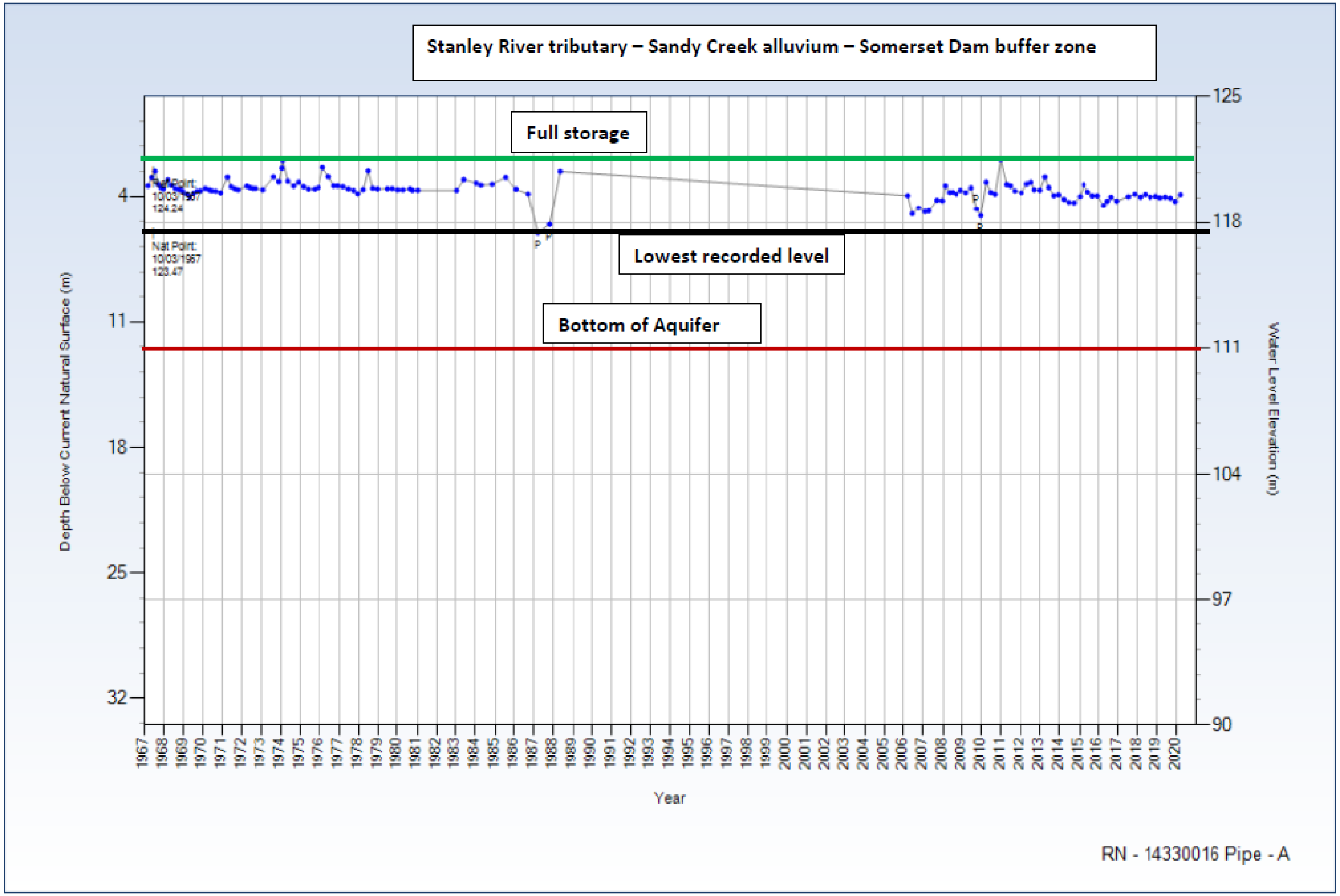

Figure 4: Water Level Plot for Representative Bore Stanley River and Tributary Alluvium

Moderate Risk Area Example – Teviot Brook Alluvium

Table 11

RN	Depth to base of Aquifer m (bgl)	Highest WL m (bgl)	Date highest	Lowest WL m (bgl)	date	Range m depth to base - highest WL	storage level % at lowest WL	Comments
14500110	13.7	2.36	16/02/2011	6.29	28/09/1995	11.34	**65**	
14500117	16.1	0.37	24/04/1990	7.72	1/02/1995	15.73	**53**	Some low measurements ignored because of pumping nearby
14500105	19.4	3.96	28/03/1991	11.67	28/01/2003	15.44	**50**	base of aquifer based on log for 14500108
14500099	20.9	3.84	1/03/2011	11.84	26/10/1995	17.06	**53**	short sharp peaks ignored
14500096	20.3	3.34	10/05/1989	10.57	1/10/2003	16.96	**57**	

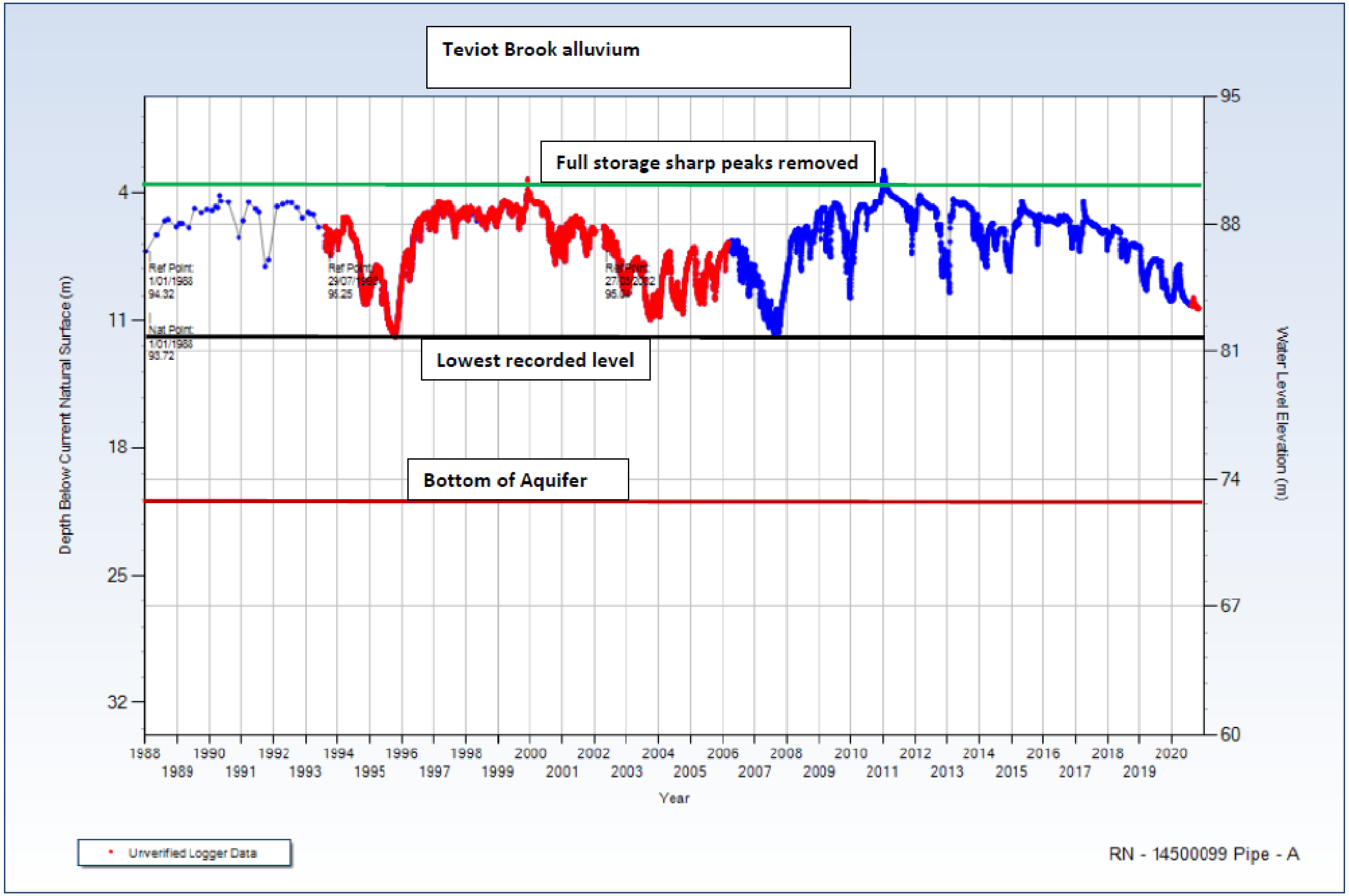

Figure 5: Water Level Plot for Representative Bore Teviot Brook Alluvium

High or Very High Risk Area Example - Lockyer Valley – Tenthill Creek Alluvium

Table 12

RN	Depth to base of Aquifer m (bgl)	Highest WL m (bgl)	Date highest	Lowest WL m (bgl)	date	Range (m) depth to base - highest WL	storage level % at lowest WL	Comments
14320979	11	2.44	7/12/2010	7.01	24/07/2007	8.56	**47**	
14320989	15.2	4.28	27/03/2013	10.9	19/09/2007	10.92	**39**	
14320865	20.7	8.2	20/01/2011	20.33	31/08/2007	12.5	**3**	Base of aquifer based on old bore 0268
14320925	26.2	9.95	5/04/2011	25.33	6/12/2007	16.25	**5**	
14320477	29	10.59	29/04/2013	27.53	29/10/2007	18.41	**8**	Base of aquifer based on nearby bores
14320464	34	11.14	27/06/2013	30.36	29/05/2006	22.86	**16**	

*Note: Bores 14320979 and 14320989 are located in upstream areas and the other bores further downstream where more irrigation occurs

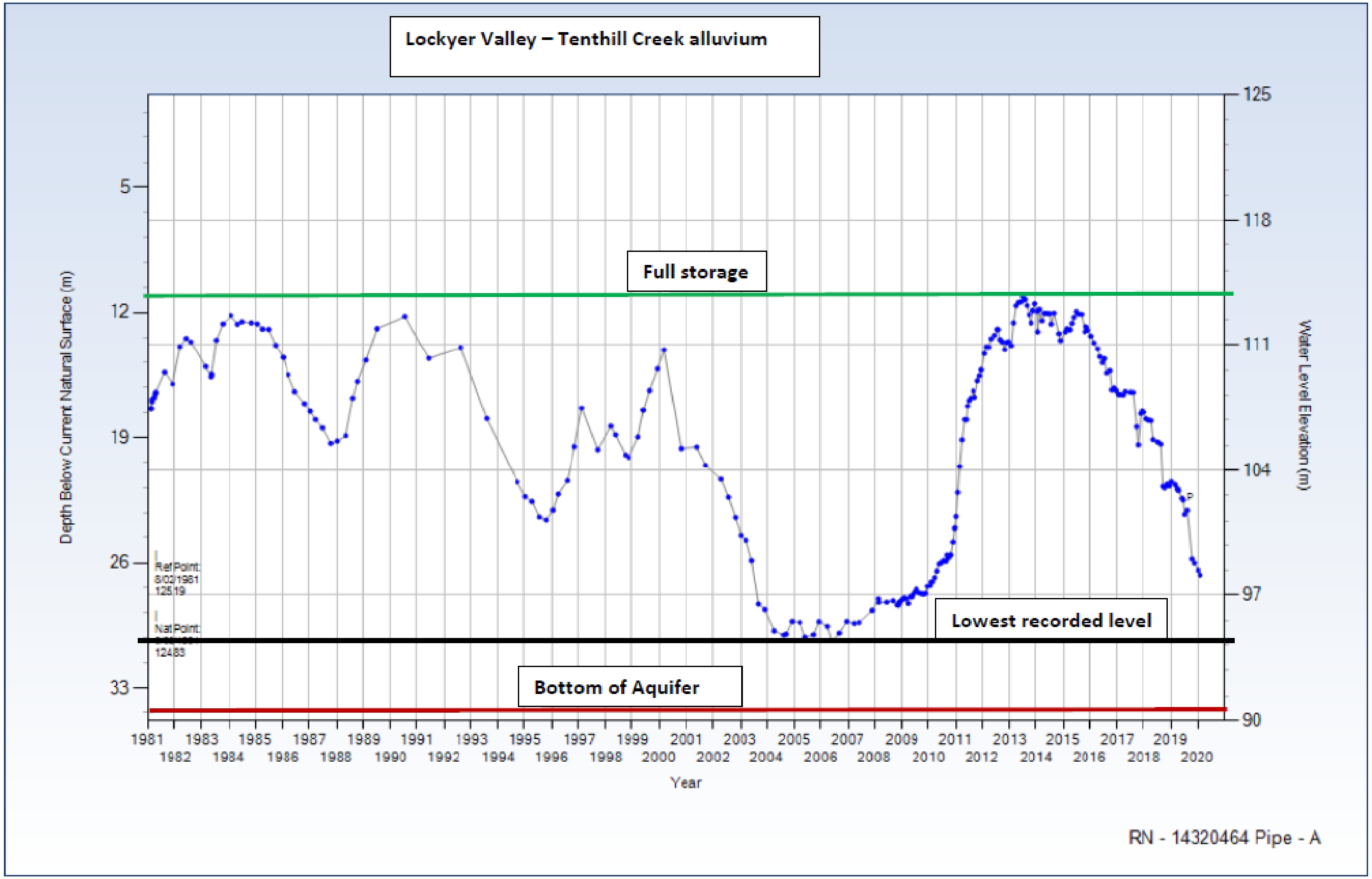

Figure 6: Water Level Plot for Representative Bore Upper Lockyer Alluvium (Tenthill Creek)

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