8. Groundwater

8. Groundwater

This chapter addresses the existing groundwater environment within and surrounding the project area. In particular, attention has been paid to the location, availability, current use, quality and legislative requirements of groundwater use within the vicinity of the project area. Potential impacts of the JRYUP are identified and mitigation measures are listed.

8.1 Description of environmental values

8.1.1 Groundwater regime

A review of The Geology of Mackay 1:250,000 Map Sheet (Jensen 1972) indicates that the northern portion of the project area is underlain by the sedimentary and volcanic units of the Devonian – Carboniferous age Campwyn Beds truncated mid-project area by the Sarina Fault. The southern section of the area is underlain by the volcanic units of the Permian age Carmila Beds, consisting of conglomerate, greywacke, tuff, acid volcanics and shale.

The project area is characterised by low undulating hills in the north from the Mount Hector Area and from the west where it abuts the Connors Range. To the south and east of the project area the dominant landform becomes coastal plains. The area is dissected by Plane, Elizabeth and Willy Creeks with associated alluvial deposits of limited lateral and vertical extent. Generally the area is overlain by thin alluvial, colluvial and residual soils over a fractured and weathered basement.

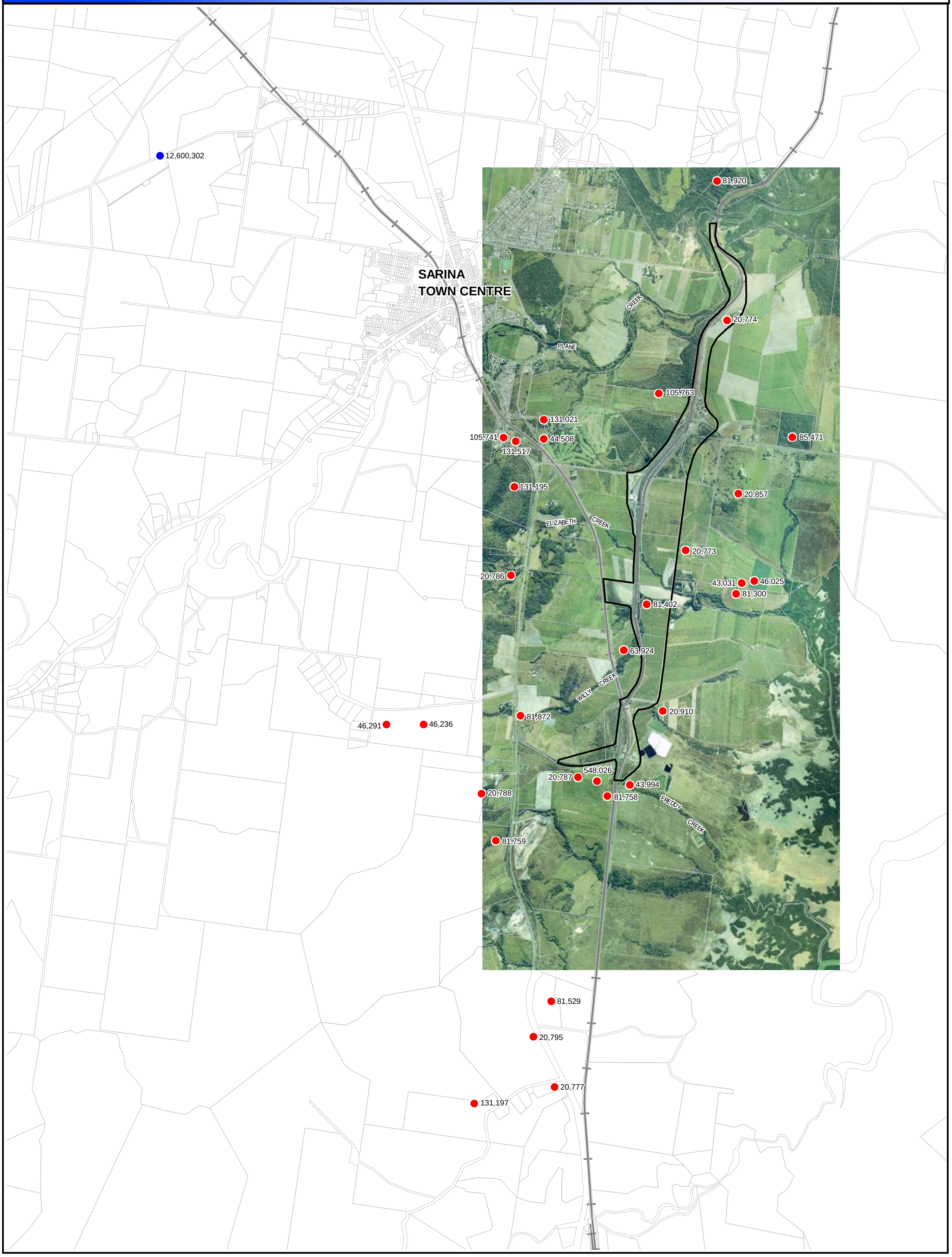
To determine the nature of the groundwater system throughout the project area records from the DNRW groundwater database were accessed and data for all bores within the area adjacent to the project area were analysed. Records were examined for bores located in the area bounded by the western edge of the Bruce Highway corridor in the west, the adjacent coastline to the east, Plane Creek in the north and Tommy Creek to the south of the project area. These records indicate that there are 43 private groundwater bores in the general vicinity of the project area. There are no DNRW groundwater monitoring bores within the Jilalan area and as such water levels and water quality data has not been collected for the area.

Of the 43 recorded private bores, 30 bores have been screened within the fractured bedrock of the area to depths ranging from 5.4 m to 30 m. Five are hand dug wells of depths ranging to approximately 10 m. All wells are terminated at the alluvial/rock interface. A further three bores are recorded as being screened within the alluvial material. Five bores are reported as not being cased and are assumed to have been abandoned at the time of drilling. Locations of all bores are illustrated in Figure 8.1

Hydraulic parameters

The transmissive and storage properties determine the rate and amount of water that can be extracted from an aquifer. The two properties, hydraulic conductivity and storativity are important in characterising the groundwater flow system. These aquifer properties are most reliable when interpreted from pump test data. Other sources such as the interpretation from lithological logs provide data more representative of the site or bore than the aquifer. An interpretation of the fractured rock aquifers of the Carmila Beds and Campwyn Beds within the Pioneer District was undertaken by Bedford (1978). The results of this analysis are summarised in Table 8.1.

Jilalan Rail Yard Upgrade Project



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LEGEND

Rail

Project Area

Cadastre

Groundwater Bore

Groundwater Monitoring Bore

GROUNDWATER BORE LOCATIONS

FIGURE 8.1

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Table 8.1 Hydraulic conductivity of geological units

	Campwyn Beds	Carmila Beds
Average Transmissivity (m^2/d)	145	183
Average Hydraulic Conductivity (m/d)	14	26
Average Thickness (m)	12	8

Source: Bedford 1978

The DNRW groundwater database was reviewed for pump tests undertaken adjacent to the project area. A total of eight bores (44058, 46571, 24702, 46025, 43031, 85471, 81300, and 81872) have pump tests recorded. Four bores had values for Transmissivity and Design yields recorded. No bores had values for Storativity.

Transmissivity is the measure of the amount of water that can be transmitted horizontally through a unit width by the full saturated thickness of the aquifer under a hydraulic gradient of 1. Transmissivity values ranged between 5 and 84 m^2/d.

The design yield of a bore is the volume of water as determined by the pumping test results which can be safely extracted from the bore. Design yields for the area varied form 0.73 L/s at bore 44508 to 26.62 L/s at bore 85471.

Storativity is a dimensionless quantity of water that a permeable unit will absorb or expel from storage per unit surface area per unit change in head. No values have been calculated for the bores in the area due to the short duration of the pumping tests and the lack of observation bore data for these tests.

The consistency of groundwater supplies from the fractured rock aquifer in the vicinity of the project area is variable in nature and appears to be dependent upon the level of fracturing occurring within the rock at any given location. The supplies obtained from the alluvial material associated with Plane Creek and other streams nearby is associated with narrow bands of relatively thin alluvials and is also dependent on specific bore locations.

Seasonal variations

Due to the lack of an existing groundwater monitoring network or water level records for the area it is not possible to determine the sessional variations of groundwater in the immediate project area. However, it can be assumed that monitoring bore (12600302) screened within similar aquifer material in the adjacent Alligator Creek aquifer would reflect a similar seasonal variation. Records for bore 12600302 extend from 31 January 1973 to 4 December 2006. A graph of groundwater elevations for bore 12600302 is illustrated as Figure 8.2.

Water level measurements were recorded biannually until 1992 and from this period on have been taken on a quarterly basis. It should be noted that this sampling pattern is most likely to miss short lasting extreme highs and lows. The records should however, provide sufficient information to determine a steady state aquifer sample. This bore was observed to have a seasonal variation on average of 1.49 m/y, a maximum of 3.04 m in a calendar year and a minium seasonal fluctuation of 0.01 m/y.

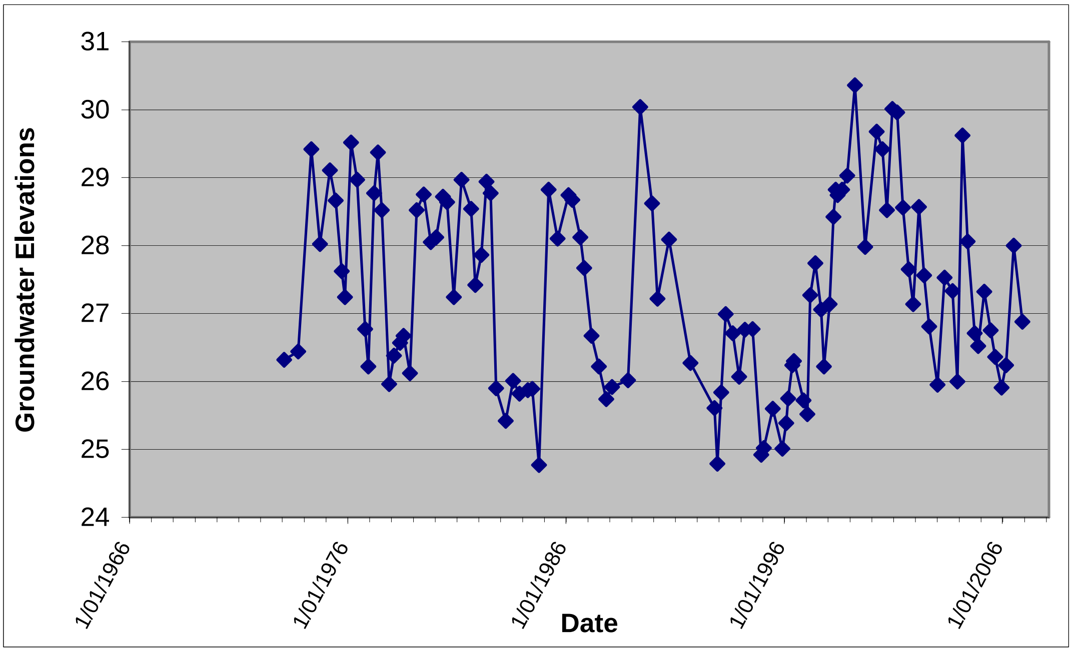


Figure 8.2 Water elevations – Bore 12600302

Groundwater flow directions

There are insufficient records throughout the project area to construct contour plots of the project area or the surrounding area. The water levels available for the bores existing in the project area are limited to a single record at the time of the construction of the individual bores. To produce a contour plot using this information will be inaccurate and misleading.

Groundwater flow is assumed to be in a general easterly direction with localised variations in flow towards Plane Creek in the northern section of the project area, towards Willy and Elizabeth Creeks in the central area, and towards the east and south east in the southern section.

Recharge sources

Wang *et al* (2006) reports that the comparison between rainfall residual mass curves and groundwater level trends in both alluvial and fractured rock observation bores in the adjacent Alligator Creek aquifer indicates that the main source of aquifer recharge throughout most of the area is the direct infiltration of rainfall and infiltration of overland flow water from leakage through the soil profile. This conclusion is supported by a strong correlation between rainfall trends and groundwater level behaviour together with isotopic analyses.

Murphy and Sorensen (2000) presented results from isotopic analyses undertaken on groundwater samples drawn from coastal alluvial bores between Mackay and Sandy Creek. The report concluded that the groundwater found in the alluvial aquifers of the Pioneer Valley was relatively modern in age (less than 30 years old) and that aquifer recharge occurs rapidly, indicating that most recharge is from direct infiltration of rainfall or infiltration from flooded streams. The nature of the aquifers in the project area and their close proximity to both the Pioneer Valley and Alligator Creek catchments supports the conclusion that recharge is of a similar nature within the project area.

8.1.2 Groundwater quality

The Australian and New Zealand Environment and Conservation Council (ANZECC) Guidelines provide guideline values or descriptive statements for different indicators to protect aquatic ecosystems and human uses of waters (eg primary recreation, human drinking water, agriculture, stock watering). The ANZECC Guidelines have been used for comparison of water quality levels in all cases except for the determination of Total Petroleum Hydrocarbons (TPH) in which case the Dutch Cleanup Levels "C" (Ministry of Housing, Spatial Planning and Environment 1998) have been adopted.

There is no current groundwater quality data available for the project area from the DNRW groundwater database, a groundwater quality survey was conducted for a series of bores adjacent to the project area with the intent of establishing a snapshot of current groundwater conditions.

A total of eight groundwater samples were obtained from pre-existing groundwater bores within the area surrounding the project area. As no monitoring bores are present on the existing Jilalan Rail Yard nor within the area adjacent to the project area, private irrigation and domestic bores were used to obtain groundwater samples to characterise the water quality within the area. The location of these bores is illustrated in Figure 8.3.

Four bores (20787, 105763, 81920 and Keat1) are located to the west of and in an upgradient direction of the project area. Water samples collected from these bores are representative of groundwaters entering the project area.

The four bores selected as downgradient sample locations were bore numbers 81402, 65471, 20857 and 46025. These bores are located between the project area and the coastline. Due to the lack of water level data, it is difficult to determine if these bores are all within the direct flow path of groundwater existing in the Jilalan Rail Yard and/or the project area. As a result, it has been assumed that they are representative of the current downgradient groundwater regime at this time.

All groundwater bores examined and sampled are currently in use by the landholders for irrigation or for domestic supplies and were equipped with pumps and pipe works. Access to the bores was limited to the sampling of groundwater through the use of the existing pumps and pipework with the exception of borehole Keat1 where samples were obtained through the limited use of a bailer.

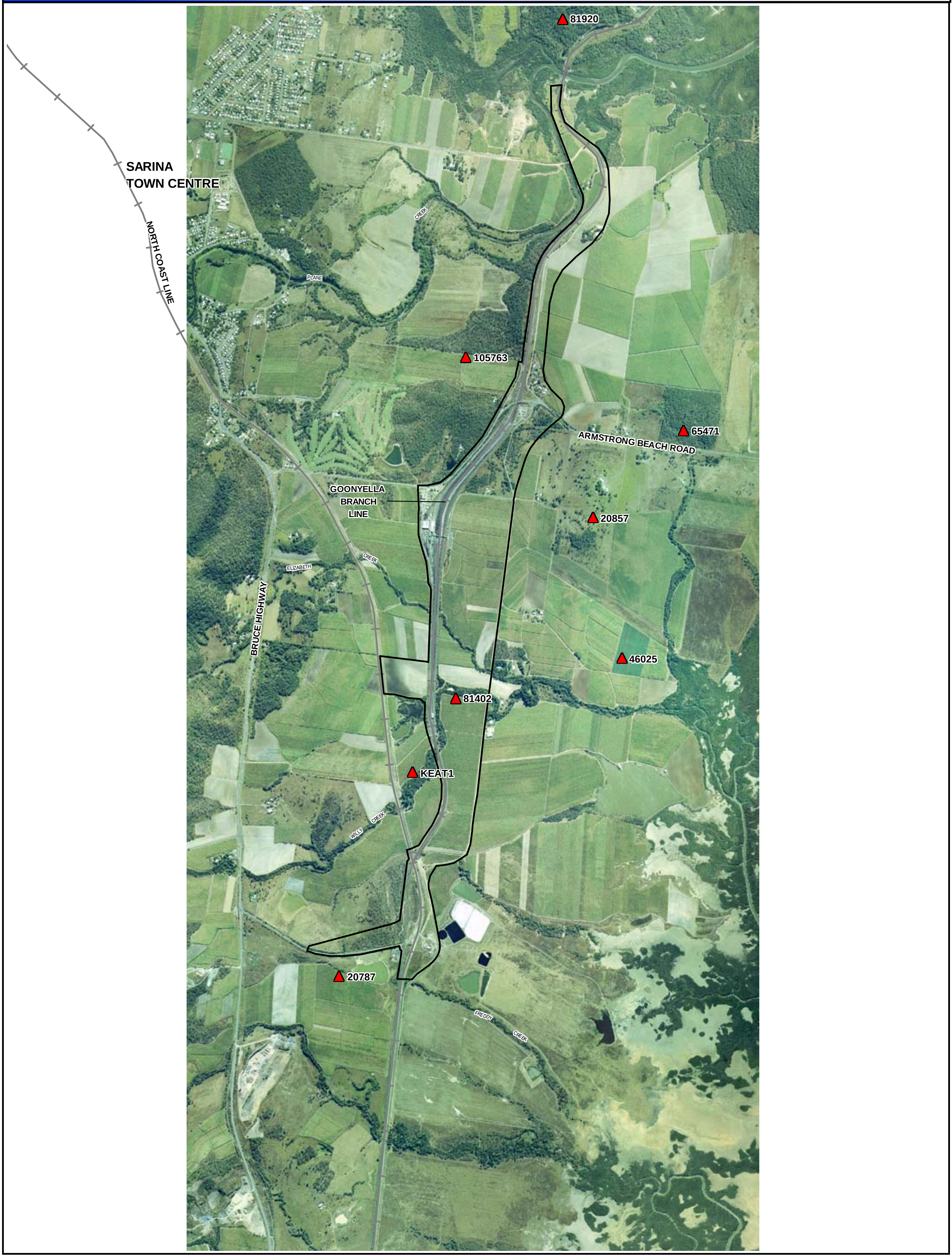
No groundwater level data was obtained due to the inability to gain direct access to the boreholes. The exception to this was borehole Keat1 which was 'flowing' at the time of sampling. Anecdotal information obtained from the land holder revealed that this artesian flow occurs for periods of one to two weeks following periods of substantial rainfall.

Field quality tests for pH, electrical conductivity, redox, dissolved oxygen and temperature were conducted for all bores at the time of sampling. The results of these tests are summarised in Table 8.2.

Water quality was found to be variable across the project area with electrical conductivities ranging from 280 µS/cm to 3,050 µS/cm. The recorded pH for all samples, except bore no 20787, was within the ANZECC Guidelines 2000. The recorded pH for waters sampled from bore number 20787 is outside the recommended drinking water range and may present a corrosion problem to pumps and pipework with long term use. Oxidising conditions were noted in all bores and indicating fresh water recharge to the aquifer.

In addition, water samples from all bores were analysed for total dissolved solids, major ions, dissolved metals (As, Cd, Cr, Cu, Pb, Ni, Hg and Zn), Polychlorinated Biphenyls, Organochlorine and Organophosphorus pesticides, Polynuclear Aromatic Hydrocarbons, Total Petroleum Hydrocarbons (TPH), and BTEX (Benzene, Toluene, Ethylbenzene and Xylene). A full transcript of the analytical results is presented in Appendix I3.

Jilalan Rail Yard Upgrade Project



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LEGEND

Rail

Project Area

Groundwater Sample Bore Location

GROUNDWATER SAMPLE BORE LOCATIONS

FIGURE 8.3

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Table 8.2 Groundwater field quality

Bore	pH	Electrical conductivity (µS/cm)	Dissolved oxygen (ppm)	Redox potential (mv)	Temperature (°C)
20787	5.68	295	2.24	38	21.9
20857	7.51	553	6.95	53	17.1
46025	7.71	1725	6.49	55	22.9
65471	6.84	280	3.73	21	21.1
81402	7.33	3050	3.5	41	23.3
81920	7.27	975	5.12	81	17.8
105763	7.45	2230	3.25	37	23.6
Keat 1	7.16	1600	0.31	75	23.7

Four samples (Bore numbers 20857, 65471, 81402 and 105763) were recorded as having positive results for metals. A summary of results is shown in Table 8.3. All results were below established ANZECC Guidelines 2000 background levels for fresh or estuarine waters. It should be noted that the results for bores 20857, 65471 and 105763 are likely a result of the process of sampling from equipped bores and reflect the interaction of the waters with the pumps and pipework.

The sample from bore number 81402 registered an arsenic concentration of 0.001 mg/L. This concentration is equivalent to the laboratory Limit of Reporting (LOR) and is below ANZECC Guidelines 2000 background levels, and as such does not represent an appreciable environmental risk. Further testing in the area of this bore may be warranted should the opportunity occur.

Samples from bores 20787 and 46025 were reported to have concentrations of TPH of 60 µg/L (C_{29} – C_{36}) and 100 µg/L (C_{15} – C_{28}), respectively. As investigation levels for Total Petroleum Hydrocarbon (TPH) fractions have not been specified in the ANZECC Guidelines 2000 the Dutch Cleanup Levels "C" (Ministry of Housing, Spatial Planning and Environment 1998) have been adopted. These guidelines recommend action for levels of 600 µg/cm or greater for the combined totals of TPH fractions of C_{15} – C_{28} and C_{29} – C_{36}. These levels have not been exceeded in this case. However, the cause of the contaminant has not been identified and could be an indication of the presence of further contamination issues.

Table 8.3 Summary of groundwater positive analytical results

Bore	As (mg/L)	Cu (mg/L)	Pb (mg/L)	Zn (mg/L)	TPH (C15 – C28) (µg/L)	TPH (C29 – C36) (µg/L)
20787						60
20857		0.002	0.001	0.017		
46025					100	
65471		0.013		0.117		
81402	0.001					
105763				0.048		

8.1.3 Groundwater use

The majority of groundwater extracted from within the area is for the production of sugar through sugar cane cultivation. Groundwater is also used in the region for aquaculture, horticulture, pastoral and domestic uses. There is no data available for the quantification of groundwater use throughout the area. Current legislative requirements do not require the measurement of groundwater use in the area.

Groundwater legislative requirements

In Queensland, a number of areas have been declared as subartesian areas under the *Water Act 2000*. Some subartesian areas have been declared within water resource plans, while most have been declared under the *Water Regulation 2002*. The *Water Regulation 2002* and water resource plans are subordinate legislation to the *Water Act 2000*.

The project area is located outside of the Pioneer Valley Declared Subartesian Area and the Pioneer Valley Water Resource Plan area and as such is only subject to general conditions as required under the *Water Act 2000*, the *Water Regulation 2002* and the IP Act.

The *Water Act 2000* requires that a water licence is obtained from DNRW for taking or interfering with artesian water anywhere in the state. Artesian water is underground water that, when tapped by a bore, flows naturally to the surface. A water licence is also required to take or interfere with subartesian water (underground water that has to be pumped to the surface) in declared subartesian areas or in areas defined in a water resource plan. Generally, subartesian water can be taken for non-intensive stock and domestic purposes without a licence within a declared subartesian area. It is necessary to contact the local office of the DNRW and the Sarina Shire Council prior to the development of any groundwater resource to ensure that no additional restrictions or requirements have been instigated.

The IP Act applies as part of the Integrated Development Assessment System (IDAS), under the concept of a:

- Self-assessable development
- Code assessable development
- Impact assessable development

Schedule 8 of the IP Act specifies the operational works that are assessable development. Assessable development includes:

- All work in a watercourse (eg pump, gravity diversion, stream redirection, weir or dam)
- All artesian bores anywhere in the state, no matter what their use
- Subartesian bores in declared groundwater areas used for purposes other than stock and/or domestic purposes
- Subartesian bores in certain declared groundwater areas that are used for stock and/or domestic purposes

All water bores in Queensland are required to be constructed by a licensed water bore driller to meet the “Minimum Construction Requirements for Water Bores in Australia” (Land and Water Biodiversity Committee 2003).

Proposed groundwater sources

Groundwater supplies within the project area and immediate surrounds are almost exclusively sourced from within the underlying fractured rock aquifers of the Carmila Bed and Campwyn Bed aquifers. Groundwater may however, be sourced from the alluvial deposits associated with Plane, Elizabeth and Willy Creeks. These alluvial aquifers are narrow and shallow in nature and supplies from these alluvial aquifers will be limited. There may be isolated zones where higher yields can be sourced from the alluvium. The clay content can also be high in some areas of the catchment leading to the conclusion that groundwater supplies are best sought from the underlying weathered and fractured bedrock.

The limited information available for current groundwater resource extraction points indicates a highly variable fracture pattern within the aquifer. It is recommended that an exploratory bore be located so that it may intersect the Sarina Fault zone to investigate the possibility of increased permeability associated with this geological feature. The location of other potential sites should be determined based on zones of increased permeability as to be determined by an exploratory drilling programme guided by the locations of existing high yielding bores and surface conditions as determined by a site visit.

Fractured rock aquifers often produce groundwater of variable quality due to water/rock interaction processes. Wills and Baker (1988) reviewed the quality of groundwater within the Campwyn Beds and the Carmila Beds, state water within the Campwyn Beds was variable in quality but was good to fair when encountered within fractured zones. Wills and Baker (1998) also found that water within the Carmila Beds was fair to poor quality and suitable for stock watering and observed that fractured zones within the volcanics of the unit produced good quality water. The results of the water quality survey undertaken as a part of this Project found that water qualities in both the Carmila Beds and the Campwyn Beds to be highly variable. Water qualities from both geological units ranged from good to poor.

Existing groundwater extraction bores (RN 81402 and Keat 1) are within the project area and have suitable water quality for construction water supply. The bore RN 81402 is in good condition and operational at the time of the field visit. Bore Keat 1 appears to be functional though the pump has been disconnected and the foot valve remains in place. The condition of the bore casing is unknown. The sustainable yield for these bores is currently unknown but can be determined through a pump test.

8.2 Potential impacts

This section addresses the potential impacts to the groundwater system through the construction and operational phases of the Project. Potential impacts on the groundwater include the physical interaction with the underlying groundwater through extraction, excavation and construction, and the deterioration of quality through contamination.

Potential groundwater impacting contaminants on construction sites and railway facility sites include petroleum hydrocarbons, heavy metals, pesticides, phenyls, polychlorinated biphenyls, and non metallics including arsenic, cyanide, sulphur, sulphides and sulphates.

8.2.1 Potential construction impacts

Potential groundwater impacts during construction include:

- The potential for groundwater contamination from fuel and chemical storage and use.
- Contamination of the exposed groundwater through spills, leaks and surface runoff entering the excavations.
- Infiltration of impacted leachate from stockpiled soil originating from the excavations.
- The intersection or interaction with the groundwater table of building foundations, cut and fill earth works and embankments.

- The extraction of groundwater for the provision of water for site works may lead to the depletion of surface water bodies and the inducement of seawater intrusion. The significant lowering of the water table and the depletion of surface water bodies may have a negative impact on groundwater dependant ecosystems (GDEs).

8.2.2 Potential operational impacts

Potential groundwater impacts during operation include:

- The potential for groundwater contamination from fuel and chemical storage and use.
- The use of pesticides and herbicides for weed and vermin control.
- The potential impacts of metals from the train refurbishment activities on site.
- The use of chemicals for the cleaning and maintenance of trains on site.
- The extraction of groundwater for the provision of facility water may lead to seawater intrusion, negative effects on surface water bodies and effect GDEs.

8.3 Mitigation measures

8.3.1 Design phase

Areas used for the storage, use and processing of potential contaminants shall be designed to allow the containment of leakages, spills and use. Storage facilities designs should include bunded areas to ensure that no potential leaks or spills can propagate to the groundwater. Facilities where potential contaminants are used will be designed to prevent the propagation of contaminants to the environment though the use of separators and wastewater treatment facilities. Attention should be paid to the potential transfer of contaminants during rainfall events and facility cleaning.

Fuel and chemical storage areas should be designed with suitable bunding, in accordance with the appropriate standards, and where possible incorporate roofing to prevent rainfall accumulating within the bunding. It is recommended that the bund be designed to contain spillages and leaks from liquids used and stored, and to facilitate clean-up operations. The net capacity of a bunded compound in a storage facility should be at least 120% of the net capacity of the largest tank. If the material to be bunded, is contained in drums (or other small containers), the bunded area should contain at least 25% of the total volume of the stored products.

The bund floor and wall must be built of materials impervious to the contents of any tank or container within the bund. The bunded area must be capable of preventing the migration of any spillage or leakage to the surrounding environment. A collection sump should be provided in the bund floor to make it easy to remove liquids, and the floor must be graded in such a way that liquids collect in the sump.

Site structure design should account for the presence of groundwater on the site with respect to potential embankment stability, floor heave and corrosive water issues. Significantly, the proposed cuttings, to approximately 17 m depth, for the provisioning, by-pass and wagon maintenance tracks require special attention and monitoring of groundwater conditions needs to be implemented prior to construction. Monitoring bores must be placed during the geotechnical investigation phase and water levels monitored until construction begins. Aquifer tests will need to be undertaken to determine the quantity of groundwater on site to assist with the design and construction of the cuttings.

The proposed rail alignment cuttings are likely to intersect the groundwater table to a depth of several metres, potentially having a localised effect on groundwater levels in the surrounding area by causing some dewatering to occur. Monitoring of the current groundwater conditions through a monitoring bore network and the conducting of aquifer tests will give a greater understanding of the current nature of the aquifer and allow the prediction of conditions during the construction and operational phases.

8.3.2 Construction phase

Potential impacts to the groundwater during the construction phase of the Project will be managed through the implementation of the following measures:

- All fuels and chemicals used during the construction phase of the Project will be stored in bunded facilities that prevent spills, leakage, or over topping of the facility. The facility will prevent any migration of fuels or chemicals to surface water bodies or the underlying groundwater.
- All excavated soil will be stockpiled with appropriate bunding.
- Excavations that will remain open for any considerable time and that intercept the groundwater will be bunded to prevent any impact on the exposed groundwater through ingress of potentially contaminated surface water runoff from surrounding areas.
- Groundwater within the area of structures be tested for corrosive nature and design changes implemented to reflect results if necessary.
- Groundwater levels and quality be monitored to ensure that significant depletion of the resource does not occur, with specific emphasis on the monitoring of potential seawater intrusion and the effects of stream/aquifer interaction such as stream depletion.
- Groundwater can be expected to be encountered during the construction of the rail alignment cuttings, provision should be made for the control of water entering the construction area, its containment and control to prevent silt entrainment to streams, and the removal of water from the site.
- Some dewatering of the groundwater within the nearby area can be expected during the construction phase. This can not be quantified at this time but would be expected to be fairly limited in its extent and in the change to water levels. Aquifer tests to be conducted will enable the quantification of the expected changes. No detrimental effects are expected on known groundwater bores (those recorded in the DNRW groundwater database or observed in during the field visit) outside of the proposed alignment.

8.3.3 Operational phase

The mitigation of potential groundwater impacts during the operational phase of the Project can be achieved by the controlled use of potential groundwater contaminants. Potential contaminants will be stored within suitably bunded areas. Where possible, use should be limited to areas where spill or leakage containment is possible, such as concrete work surfaces with runoff containment and water treatment facilities.

Should an uncontrolled spill occur it will be contained as soon as is possible and clean up commenced immediately. All fuel and chemical spills should be dealt with in a manner consistent with relevant health and safety guidelines.

Groundwater resources should be periodically monitored for levels and quality, ensuring that the resource integrity is maintained. Use of groundwater, particularly during periods of low rainfall may induce effects such as seawater intrusion and lead to dewatering of surface water bodies and negative effects on GDEs.

8.3.4 Groundwater monitoring

The project area consists of an area of pre-existing railway operations and a proposed area for extension of the existing operations. Connell Hatch personnel have conducted an initial site visit and reported that no existing groundwater monitoring bores are present within the project area. The project area is of an elongated shaped that potentially runs perpendicular to the general groundwater flow direction.

A groundwater monitoring network will be installed to establish a baseline groundwater condition in the short term prior to construction. This monitoring network will include bores that establish the quality of groundwater entering the site from upgradient and groundwater quality exiting the site under current conditions. Additionally, monitoring bores should be located within the area of current operations targeting sites of potential contaminant sources.

Further, additional monitoring bores will be placed throughout the expansion area such that predevelopment groundwater quality can be established and groundwater gradients and flow direction can be calculated from monitoring results.

Initial analysis of groundwater samples collected from the monitoring network will include pH, electrical conductivity, major ions, metals (Cd, Co, Cr, Cu, Hg, Ni, Pb, and Zn), non-metals (As, CN, S, sulphides and sulphates), total hydrocarbons, Benzene, Ethel benzene, Toluene, Xylene (BTEX), organochlorines and organophosphates, and phenyls.

The groundwater monitoring network will consist of three to four monitoring bores along the western boundary of the project area to establish groundwater inflows. A similar number of bores should be established along the eastern extent to establish the groundwater flow direction and allow the collection of samples for analysis. A number of monitoring bores should be placed adjacent to potential contaminant sources within the established site for the monitoring of current groundwater conditions. Additionally, a number of bores should be strategically placed within the proposed expansion areas so that they will remain in place to form part of a monitoring network post development.

All monitoring bores should be surveyed to the Australian Height Datum (AHD) at establishment. Water levels for all monitoring bores should be recorded on a weekly basis for a period of a month to establish a short term groundwater flow condition. Water level monitoring should then be reviewed and the long term monitoring period established based on initial results.

A baseline sampling round of all monitoring bores will be conducted for the above analytes as soon as possible after the establishment of the network. Analytical results will then be reviewed and a monitoring plan established based on the results.

8.3.5 Additional groundwater supply

A review of the preliminary geotechnical drilling programme and the emplacement of a groundwater monitoring network will be highly beneficial in characterising the project area hydrogeology and will greatly assist in the placement of potential groundwater extraction bores. As groundwater supplies throughout the project area are limited to zones of fracturing within the underlying Carmila Beds and Campwyn Beds the quantity of any supply will be dependent on the permeability of the individual zones. The water quality is also variable and dependent on the water/rock interaction within the individual zone of increased permeability. Water quality observations and testing will be an integral part of any preliminary drilling programme.

8.3.6 Other issues

In coastal areas, the extraction of groundwater from an aquifer can induce the inland movement of the seawater interface and associated dispersion zone. Under natural conditions, aquifer discharge is in equilibrium with the seawater front and therefore there is no net movement of the seawater interface. However, reduction in the net rate of groundwater discharge from increased pumping can, on a regional scale, cause landward movement of the seawater interface. Pumping from individual bores near the dispersion zone can also produce local seawater intrusion effects such as up-coning. The siting of additional extraction bores within this area will need to be placed with awareness of this issue.

8.4 Conclusions

The following conclusions are based on the information from the DNRW groundwater database and the groundwater sampling conducted as a part of this Project:

- Groundwater resources are limited to fracture zones within the underlying Carmila Beds and Campwyn Beds with minor resources associated with limited alluvial deposits associated with Plane, Elizabeth and Willy Creeks.
- Groundwater flow is in a generally easterly direction with localised variations towards intersecting streams.
- Groundwater quality is variable across the project area and dependent on water/rock interaction within higher permeability fracture zones of the underlying geological units. Water electrical conductivity varies from 280 µS/cm to 3,860 µS/cm.
- Existing groundwater extraction bores (RN 81402 and Keat 1) are within the project area and are of suitable water quality for construction water supply. The sustainable yield for these bores is currently unknown but can be determined through a pump test.
- Suitable groundwater supplies may also be found through the targeting of larger scale fracture zones within the underlying geology. Utilisation of information gained from the geotechnical drilling programme at the commencement of construction planning will assist in targeting suitable locations for water supply bores.
- The installation of a monitoring bore network will enable the confirmation of groundwater flow directions and allow the sampling of groundwater within the project area.
- Site structure design should account for the presence of groundwater on the site with respect to potential embankment stability, floor heave, and corrosive water issues.
- The proposed cuttings, to approximately 17 m depth, require the placement of monitoring bores and the implementation of a groundwater monitoring programme. Monitoring bores will be placed during the geotechnical investigation and water levels monitored until construction begins.
- Aquifer tests will need to be undertaken to determine the quantity of groundwater on site to assist with the design and construction of the cuttings and to determine the impact of the cuttings on the water table.

There is substantial use of groundwater in the area for the irrigation of crops, stock watering and domestic supplies. The implementation of the suggested mitigation measures during construction and operation will ensure that the existing groundwater is protected.