4. Water Resources

4.1 Surface Water Resources – Existing Environment

The Clermont mining leases are located on Gowrie Creek. Gowrie Creek forms a part of the Wolfang Creek catchment, which has an area of approximately 830 square kilometres (km^2) (**Figure 4-1)**. Surface water hydrology in the region is dominated by Wolfang Creek, which drains to Sandy Creek. The waterways of the Wolfang Creek catchment include Gowrie Creek, Apsley Creek and Teatree Creek. The confluence of Gowrie Creek and Wolfang Creek occurs approximately two kilometres downstream of the boundary of the Clermont MLs. Wolfang Creek and Gowrie Creek are both ephemeral waterways that drain to Sandy Creek, Theresa Creek and into the Mackenzie River, one of the major rivers in the Fitzroy River basin.

The Wolfang Creek catchment is bounded by Peak Range to the north-east boundary and Drummond Range to the north-west. Land uses in the catchment, including grazing and cultivation, and clearing, have already contributed to the degradation of the waterways. Only limited stands of remnant vegetation exist in areas of steeper terrain and along some creek banks.

4.1.1 Regional Surface Water Hydrology

Hydrological characteristics (stream length and catchment area) of significant waterways in the vicinity of the Project are presented in **Table 4-1**.

Table 4-1 Hydrological Characteristics of Significant Waterways in the Vicinity of the Project

Stream Name	Stream Length (km)	Catchment Area (km^2)
Sandy Creek	87	2497
Wolfang Creek	53	866
Apsley Creek	14	53
Gowrie Creek	19	88
Teatree Creek (part of Gowrie Ck catchment)	12	36
Gowrie Creek (within Mining Leases)	8.5	19

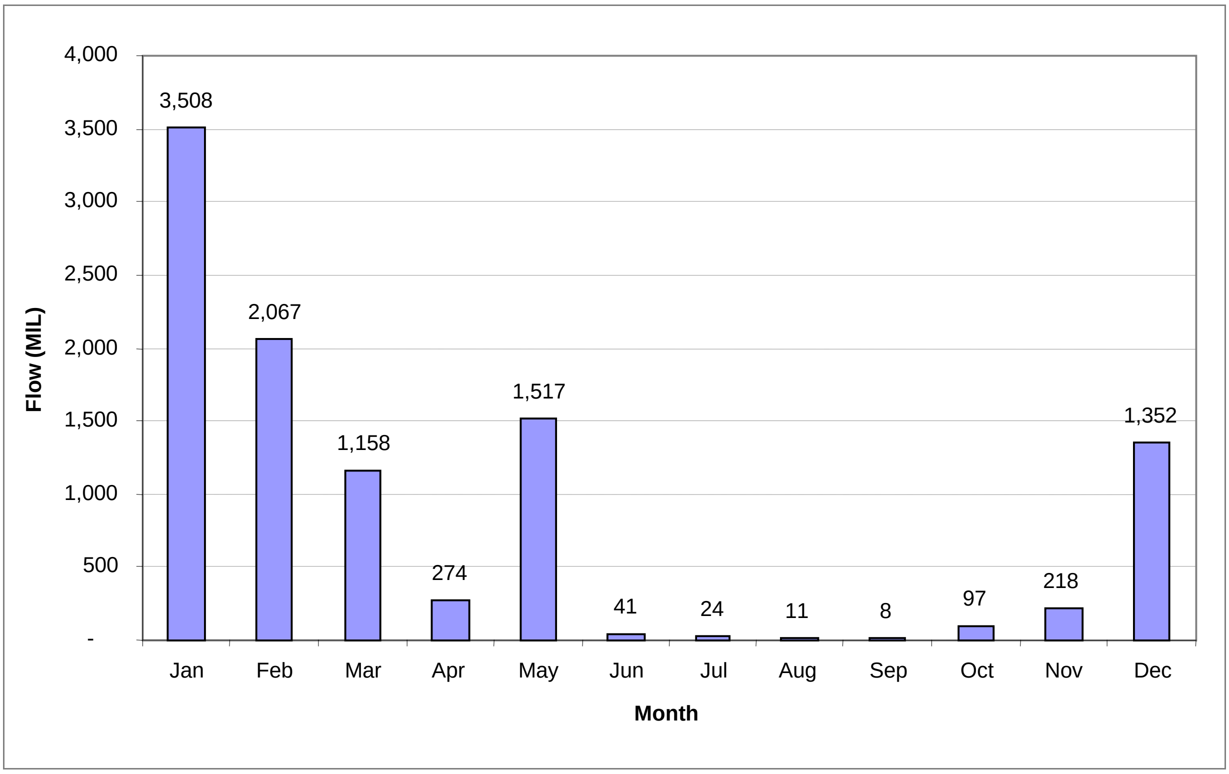
DNRME has monitored the hydrology of the region on Wolfang and Sandy Creeks. **Figure 4-2** shows the locations of the DNRME gauges. The flow gauge on Sandy Creek remains active but the Wolfang Creek gauges ceased recording in 1988. No historical monitoring exists for the Gowrie Creek catchment.

Details of DNRME Gauging Stations on Wolfang Creek and Sandy Creek are provided in **Table 4-2**.

The Wolfang Creek gauges form a continuous hydrological data series of 17 years for a site approximately 15 km upstream of the confluence of Wolfang and Gowrie Creeks. **Figure 4-3** provides a summary of the mean monthly total flows in Wolfang Creek over the period of record. It shows a clear seasonal pattern with a summer wet season. The average monthly flows in Wolfang Creek range from 8 ML in winter/spring to 3,508 ML in January, the wettest month.

Table 4-2 DNRME Gauging Station Details

DNRME Station 130211A - Wolfang Creek at Innisfree	
Site Commenced	15/10/1971
Site Ceased	01/10/1976
Grid Reference	Zone - 55 E574593 N7492543
Max gauged stage in metres (m)	0.590 on 14/01/1974
Catchment Area	438km²
DNRME Station 130211B - Wolfang Creek at Innisfree	
Site Commenced	01/10/1976
Site Ceased	01/10/1988
Grid Reference	Zone - 55 E559414 N7478587
Max gauged stage (m.)	0.260 on 09/08/1976
Catchment Area	438km²
DNRME Station 130207A - Sandy Creek at Clermont	
Site Commenced	21/01/1965
Site Ceased	Current
Grid Reference	Zone - 55 E574593 N7492543
Max gauged stage (m.)	2.410 on 15/05/1977
Catchment Area	409km²



Source: DNRME "Watershed" Internet (2004) - http://www.nrm.qld.gov.au/watershed/precomp/130211b/fsr.htm

Figure 4-3 Wolfang Creek Average Monthly Total Flow (1971 – 1988)

The Proponent provided the output of a RAFTS model for the hydrology of the region. The model was calibrated to recorded stream flow data for the five largest recorded flood events, which are outlined in **Table 4-3**. This model was used to predict flow from ungauged subcatchments of the Wolfang Creek catchment, including Gowrie Creek.

Table 4-3 Wolfang Creek Largest Recorded Flood Flows

Date of Event	Peak Flow Rate (m^3/s)	Volume (ML)	Duration (hours)
April 1983	234	16,390	160
May 1983	228	7,840	52
January 1983	215	7,170	67
February 1978	212	15,540	118
January 1974	176	7,000	118

The model was also used to predict creek flow during design flow events. The 1% and 2% annual exceedance probability (AEP) flood flows at pertinent locations are presented in **Table 4-4**. The RAFTS model predicted peak 1% AEP instantaneous flows of 378 m^3/s in Gowrie Creek (at the confluence with Apsley Creek). The same model predicted 1% AEP flows of 1645 m^3/s in Wolfang Creek at the confluence with Gowrie Creek.

Table 4-4 Wolfang Creek and Gowrie Creek Design Flood Flows

Location	1% AEP (1 in 100 year) Flood Peak Flood Flow (m^3/s)	2% AEP (1 in 50 year) Flood Peak Flood Flow (m^3/s)
Gowrie Creek at Teatree Creek confluence (upstream end of mining leases)	322	268
Gowrie Creek at Apsley Creek confluence (downstream end of mining leases)	378	315
Wolfang Creek at Gowrie Creek Confluence	1,645	1,385

4.1.2 Gowrie Creek Catchment Hydrology

Gowrie Creek dominates the local drainage regime of the 32 km^2 Clermont mining leases (ML 1904 and ML 1884). Teatree Creek drains into Gowrie Creek at the upstream end of the mining leases and Apsley Creek drains into Gowrie Creek immediately downstream of the mining leases as shown in **Figure 4-1**. The Wolfang Creek floodplain forms the downstream control to flows in Gowrie Creek. The total Gowrie Creek catchment is approximately 90 km^2, 11% of the Wolfang Creek catchment.

The mining leases are generally cleared for grazing and cropping and has stands of remnant vegetation. The majority of remnant vegetation is along the western side of the mining lease. The Peak Downs Highway forms a significant hydraulic control to flood flow.

The mining leases generally slope to the south east to Gowrie Creek with terrain elevations ranging between 315 m AHD to 260 m AHD. The soils are dominated by dark, cracking clays that have a high soil moisture storage capacity. Rainfall runoff modelling undertaken by the Proponent showed that a very low proportion of rainfall results in runoff. On an annualised basis, only 3.5% of rainfall on the catchment becomes creek flow.

4.1.3 Existing Flooding Characteristics

Flooding on the mining lease is dominated by the local drainage of Gowrie Creek in conjunction with the floodplain flow of Wolfang Creek. The floodplains of the two creeks intersect at the southern end of the mining leases, where flood flows inundate a large area.

Regional flooding characteristics were determined using the hydraulic model, MIKE21. MIKE21 is a fully two-dimensional model based on the terrain model of the site. No historical flood level data were available for calibration of the model so conservative parameters were adopted. Freeboards have been applied to design levels to account for lack of calibration.

Hydraulic modelling showed that the existing flooding situation of the site is extensive. Gowrie Creek channel has limited capacity and the 100 year flood (1% AEP) quickly spills into the floodplain.

Wolfang creek also spills out of the primary channel very early in a flood event and both floodplains are broad relative to their primary channel.

Within the mining leases, Gowrie Creek inundates a large proportion of the lower land as shown in **Figure 4-4**. The floodplains of Gowrie and Wolfang Creek intersect approximately 2 km from the southern end of the mining lease. The 1% AEP inundation in Gowrie Creek achieves approximately 276 m AHD at the northern end of the ML and Wolfang Creek and Gowrie form a combined water surface at 263 m AHD at the southern end of the ML.

4.1.4 Creek Geomorphology

4.1.4.1 Creeks and Flow Characteristics

The proposed open cut pit will be located within the central section of Gowrie Creek, and it will be necessary to divert approximately 8.5 km of the creek to establish the pit.

The creeks are ephemeral with flows generally occurring after summer storms. Some ponding occurs within the creek bed in the lower reaches of Gowrie Creek for a limited period after these storms. An analysis of the stream flow records for Wolfang Creek at the stream flow gauging station at Innesfree demonstrates that:

- 80% of the annual flow occurs in the period from December to March;
- evaporation and infiltration losses are high, with only 3.5% of rainfall within the catchment being converted into surface runoff; and
- there is limited baseflow in the creeks, with almost the entire flow occurring during storm events and with baseflow comprising only 1.5% of the mean annual flow.

Gowrie Creek has a catchment area of 90 km^2 and rises 7.5 km north east of the site. The average bed slope grade is 0.3%.

Teatree Creek is a tributary of Gowrie Creek and its confluence occurs within the mining leases. Teatree Creek has a catchment area of 33 km^2 and rises 8.4 km to the north of the site. The average bed slope grade is 0.4%.

4.1.4.2 Geomorphological Reaches and Fluvial Characteristics

The structure of the creek system can generally be described in terms of four distinct reaches. These are:

- **Gowrie Creek Upper Reach** – describes the creek from the headwaters to the confluence with Teatree Creek;
- **Teatree Creek Upper Reach** – typical of the creek from the headwaters to the confluence with Gowrie Creek;
- **Gowrie Creek Mid Reach** – describes the characteristics of the creek from the confluence to 1 km south of the Peak Downs Highway; and
- **Gowrie Creek Lower Reach** – typical of the section of the creek from south of the highway to the confluence with Wolfang Creek.

Within the four distinct reaches, the river types (Chang, 1988) transition from a sinuous braided creek in the Gowrie Creek and Teatree Creek upper reaches to sinuous canal-form creek lines further to the south.

4.1.4.3 Gowrie Creek – Upper Reach

Gowrie Creek upstream of the junction with Teatree Creek has a highly modified low-flow channel. The majority of riparian vegetation has been cleared for grazing and cropping, and only isolated stands of mature trees remain on the creek banks. The low-flow channel is sinuous with evidence of recent lateral channel migration of between 2 and 10 m. The typical creek cross-section is:

- a two metre wide low-flow channel incised to a depth of approximately 0.8 m;
- an active flow channel that is approximately six metres wide; and
- a high-flow channel that is approximately 11 m wide.

The bed of the creek is mobile and consists of deep alluvial sediments. There is no aquatic vegetation, however the benches on the inside bends of the meanders are well-grassed and relatively stable. There is evidence of significant lateral migration on the outside bends of the meanders in the channel, indicating that the main channel of the upper reaches may move sideways from season to season.

A photograph of a typical section of the upper reach of Gowrie Creek is presented in **Plate 4-1**.

Plate 4-1 View of Gowrie Creek Low-Flow Channel, Looking Downstream

4.1.4.4 Teatree Creek – Upper Reach

Teatree Creek has a meandering incised low-flow channel in a broad, flat, alluvial floodplain. The majority of the native riparian vegetation has been cleared for grazing or cropping. There is a narrow band of mature trees on the banks of the creek, with pasture dominating in the riparian zone.

The typical creek cross section is:

- Three to five metres wide low-flow channel;
- a steep, almost vertical, bank one to two metres high on the outside bend of the meander, with some undercutting at the toe;
- a low bench on the inside bend of the creek about three to six metres wide; and
- a high-flow channel 13-20 m wide.

There is active erosion at the toe of the outside bend and there is evidence of significant lateral migration of the creek. There is significant aggradation in the active channel of sediment eroded from the creek banks and floodplain. Some of these characteristics are shown in a photograph of the upper reach of Teatree Creek (**Plate 4-2)**.

Plate 4-2 Teatree Creek – View Of Low-Flow Channel Looking Upstream

4.1.4.5 Gowrie Creek – Mid Reach

The low-flow channel is more structured in the reaches downstream of the junction and the riparian vegetation is continuous and relatively dense on both banks. The horizontal alignment of the low-flow channel is relatively stable with the trees increasing bank stability and limiting the lateral migration of the meanders and the erosion of the creek banks.

The active flow channel is braided, with summer flows creating braided high-flow channels. Typical dimensions of the creek cross section in this reach are:

- a high-flow channel is incised two to three metres into the surrounding floodplain;
- a two to three metres wide low-flow channel;
- a 13-15 m wide active-flow channel with benches on both sides of the creek and flood runners on both benches; and
- a 25-30 m high-flow channel with a dense tree cover and some alternate high-flow channels.

The banks, benches and floodplains are well vegetated. The creek bed is mobile and there is limited aquatic vegetation with the low-flow channel. Summer flows mobilise the deep alluvial sediment within the creek and results in significant aggradation and scouring of sediments within the creek bed.

In the areas where the bed is scoured, ephemeral ponds occur after the summer storms. A photograph of a typical section of the mid-reach of Gowrie Creek is presented in **Plate 4-3**.

4.1.4.6 Gowrie Creek – Lower Reach

The creek becomes more sinuous and braided with multiple low-flow channels and flood runners. The width of the riparian zone varies significantly. In some areas there are as many as three low-flow channels and the riparian zone is approximately 400 m wide. In other sections, there is a single low-flow channel and the riparian zone is approximately 100 m wide.

A typical cross section for this reach comprises:

- a shallow low-flow channel some 16 m wide with scattered trees within the low-flow channel and extensive areas of ephemeral ponding;
- an active flow channel of 40-50 m wide with multiple benches on both banks. The active flow channel is well vegetated and relatively and stable the major channel adjustments occur during larger floods; and

Â a high-flow channel that is 60-100 m wide with a linearly continuous riparian zone.

Plate 4-4 shows a typical example of this reach.

Plate 4-3 View of Gowrie Creek – Mid Reach Looking Downstream from the Left Bank

Plate 4-4 View of Anabranch of Gowrie Creek – Lower Reach Looking Downstream

4.1.4.7 Sediment Characteristics and Fluvial Dynamics

The sediment characteristics of Gowrie Creek vary between the upper to lower reaches. Samples taken at four locations showed similar specific gravity values (averaging 2.66). Soil type and consistency in the bed of the creek varied from a medium dense sand (SP), sandy clay (CL) to sandy silty clay (CL-CH).

Particle size distribution analyses of the creek bed sediment showed that, in the upper reaches, over 30% of sediment was finer than 0.4 micrometre (σm) diameter. In the mid-and lower reaches, over 80% of the material was larger than 0.4 σm diameter. The particle size distribution indicates a high proportion of silt (50-60%), with lower proportions of clay (20-30%) and sand (10-20%).

The median sediment size over the reaches of Gowrie Creek varied from 1-20 σm, indicating a consistently fine material consistent with observed evidence of bed movement. In finer sediments, relatively moderate water velocities of 0.6 m/s to 1 m/s, corresponding to frequent rainfall events during summer, are expected to cause observable sediment movement.

Baseline results indicate that the highest bed movement and channel bank erosion are likely to occur seasonally at the upper reach of Gowrie Creek. Flows entering Gowrie Creek from Teatree Creek are expected to contribute high volumes of alluvial silts to the sediment load in Gowrie Creek, exacerbated by the fine sediments and the slightly steeper bed slope of this tributary.

Towards the lower reaches of Gowrie Creek, undulations in the bed invert level result in pools of water being retained after storm events. Water velocities in this reach are consequently slower and deposition of the coarser sediments occur in this area.

4.1.5 Surface Water Quality

4.1.5.1 Water Quality Monitoring

Surface water quality has been monitored in several creeks in the local area by past and present mining lease holders and the DNRME.

RTCA (and previous lease holders) have undertaken sampling on Gowrie Creek, Wolfang Creek as well as Cement Hill pit and Spring Creek, which are upstream from the proposed mining operation. Water sampling included the collection of rising stage samples and grab samples from 1981 to 2004. **Figure 4-2** shows the locations of water quality monitoring points. The samples were analysed for an extensive suite of parameters.

DNRME has undertaken monitoring of water quality in Wolfang and Sandy Creeks as part of its State-wide surface water monitoring program (referred to in **Section 4.1.1** and shown **Figure 4-2**). Sampling by DNRME was sporadic over the 17 year period of the record. The samples were analysed for an extensive suite of parameters.

4.1.5.2 Data Analysis and Comparison

Data collected from water quality analyses over the period 1981 to 2004 were reviewed for data quality. The following criteria were applied before finalising the historic dataset:

- values for certain analytes (e.g. metals, some nutrients) were omitted if it was not clear whether analysis had been performed on a filtered or unfiltered sample;
- rising stage sampling results were averaged for each event in cases where bias would otherwise be introduced into statistical analyses; and
- suspended solids values over 30 000 mg/L were omitted from rising stage sampler results as they were considered to result from sampler malfunction.

Uncertainty exists regarding the DNRME sampling and analysis procedures, particularly for samples that may require filtering (e.g. metals and some nutrients). Consequently, results for analytes requiring filtering have mostly been removed from the dataset.

In summarising surface water quality data, sampling locations within each catchment were pooled. The RTCA and DNRME datasets for Wolfang Creek were combined.

Summary tables of surface water quality were compiled and compared against the following guidelines:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000):
  - aquatic ecosystems: protection of upland river aquatic ecosystems in tropical Australia, and using the 90% protection trigger levels for metal toxicants due to the degraded nature of the catchment (see **Section 5.6.8**);
  - water quality for irrigation and general water use; and
  - livestock drinking water quality.

Statistical measures provided in the summary tables include median values, 20th and 80th percentiles (for aquatic ecosystem protection value comparison), minimum and maximum (for stockwater and irrigation value comparison); and

Filtered metals data were used in comparisons against aquatic ecosystems protection guidelines since these reflect the bioavailable component of metals that are more able to directly affect aquatic biota. Total metals data were compared against irrigation and stockwater guidelines since both bioavailable and bound (non-bioavailable) metals can be ingested by livestock or irrigated onto crops.

Overview of Surface Water Quality

Surface water quality of Gowrie, Wolfang and Sandy Creeks is compared to irrigation and stockwater guidelines in **Table 4-6** and compared to aquatic ecosystems protection guidelines in **Table 4-7**. There is limited surface water quality data for Cement Hill and Spring Creek. These data are presented in **Appendix I**.

In general, water quality in creeks in the area is suitable for irrigation and stockwater use, although phosphorus, iron and or aluminium concentrations may occasionally be elevated beyond the relevant guideline levels.

All creeks exhibit degraded conditions for the protection of aquatic ecosystems. In general, the creeks show levels of most forms of nitrogen and phosphorus above guideline levels. Copper is also elevated.

The pH of creeks is generally alkaline, with pH levels ranging up to 8.5. Total suspended solids concentrations are high, indicating a turbid environment influenced by the agricultural development in the catchment. Electrical conductivity is highly variable and typically exceeds ANZECC (2000) guideline criteria, with values ranging up to 3 090 σS/cm in Wolfang Creek (**Table 4-6**).

Cement Hill pit water quality is generally of better quality than that of the creeks and is generally suitable for irrigation, stockwater and aquatic ecosystems protection.

4.1.6 Existing Water Uses

A list of existing agricultural users of Gowrie Creek and Wolfang Creek surface water resources was compiled by the Proponent through a search of the DNRME database on surface water extraction licences and through interviewing local residents.

Seven surface water extraction licences exist on Sandy Creek and only three of these licences are downstream of the Wolfang Creek confluence. The details on these licences are contained in **Table 4-5**.

Table 4-5 Details of Existing Surface Water Extraction Licences

Lot / DP	Purpose
5CLM403	Domestic use, stock watering
2RP618200	Domestic use, stock watering
2RP618200	Irrigation

Gowrie and Wolfang Creeks have very limited recreational values as they do not contain any permanent water or water holes. The Project will not affect any recreational values in these creeks.

Table 4-6 Summary of Water Quality for Surface Waters Compared Against the ANZECC (2000) Guidelines for Irrigation and Stockwater

Parameter	Total / Filtered	Unit	ANZECC Irrigation	ANZECC Stockwater	WOLFANG CREEK (RTCA & DNRME)				GOWRIE CREEK (RTCA)				SANDY CREEK (DNRME)			
					Count	Min	Median	Max	Count	Min	Median	Max	Count	Min	Median	Max
Electrical Conductivity		σS/cm	1250	-	27	67	370	3090	46	106	211	456	80	61	445	1176
pH			-	-	27	6.9	7.9	8.9	46	7.2	7.9	9.9	80	6.1	7.7	8.4
Suspended Solids		mg/L	-	-	23	20	154	10800	38	105	5380	29167	50	2	30	1760
TDS		mg/L	**-**	2500	19	87	210	1490	23	40	138	820	78	33	230	683
Turbidity		NTU	-	-	1	-	100	-	0	-	-	-	21	1	47	910
Total Kjeldahl Nitrogen as N		mg/L	-	-	7	0.6	1.50	2.50	11	1.0	3.0	9.6	2	0.8	1.7	2.6
Ammonia		mg/L	-	-	9	0.04	0.06	0.2	19	<0.01	0.05	0.53	0	-	-	-
Nitrate as N		mg/L	-	90	19	0.02	0.40	3.70	18	0.02	0.31	1.35	26	<0.01	0.16	0.58
Nitrite as N		mg/L	-	9	8	<0.01	<0.01	0.02	15	<0.01	<0.01	0.06	0	-	-	-
Total Nitrogen as N		mg/L	5	-	9	0.46	1.5	3.0	14	0.4	2.2	11.0	5	0.2	0.7	0.9
Total Phosphorus as P		mg/L	**0.05**	-	7	0.05	**0.45**	1.21	11	0.24	**2.22**	5.58	7	0.02	**0.07**	0.75
Calcium		mg/L	-	1000	2	20	21	22	19	10	17	39	78	2	20	64
Chloride		mg/L	175	-	27	2	48	760	48	0	10	37	78	5	62	197
Fluoride		mg/L	1	2	24	0.02	0.20	0.62	19	0.10	0.30	0.50	74	0.04	0.14	0.50
Hardness as CaCO3		mg/L	**60**	-	21	45	**302**	524	3	44	50	72	78	13	**123**	303
Magnesium		mg/L	-	-	2	7.0	7.5	8.0	30	0.1	7.2	92	0	-	-	-
Potassium		mg/L	-	-	20	0.8	2.2	8.5	28	<1	2	11	66	2	3	28
Sodium		mg/L	-	-	21	7	100	400	30	10	20	37	78	3	35	129
Sulphate		mg/L	-	1000	16	2	27	64	30	1	2	7	68	2	25	175
Alkalinity as CaCO3		mg/l	-	-	21	24	130	474	22	84	99	255	78	13	91	208

Note: Bold indicates median values in exceedance of guideline value for ANZECC Irrigation or Stockwatering.

Table 4-6 (continued) Summary of Water Quality for Surface Waters Compared Against the ANZECC (2000) Guidelines for Irrigation and Stockwater

Parameter	Total / Filtered	Unit	ANZECC Irrigation	ANZECC Stockwater	WOLFANG CREEK (RTCA & DNRME)				GOWRIE CREEK (RTCA)				SANDY CREEK (DNRME)			
					Count	Min	Median	Max	Count	Min	Median	Max	Count	Min	Median	Max
Aluminium	Total	mg/L	**5**	**5**	0	-	-	-	3	2.21	**6.71**	26.00	0	-	-	-
Arsenic	Total	mg/L	0.1	0.5	0	-	-	-	0	-	-	-	0	-	-	-
Boron	Total	mg/L	0.5	5	2	0.100	0.180	0.260	0	-	-	-	19	<0.1	<0.1	0.2
Cadmium	Total	mg/L	0.01	0.01	0	-	-	-	0	-	-	-	2	<0.01	<0.01	0.01
Chromium	Total	mg/L	0.1	1	0	-	-	-	1	<0.01	<0.01	<0.01	2	0.002	0.006	0.010
Copper	Total	mg/L	0.2	0.4	0	-	-	-	0	-	-	-	2	0.002	0.013	0.023
Iron	Total	mg/L	**0.2**	-	0	-	-	-	3	<0.01	<0.01	<0.01	2	0.65	**4.38**	8.10
Lead	Total	mg/L	2	0.1	0	-	-	-	0	-	-	-	2	<0.001	<0.001	0.008
Manganese	Total	mg/L	0.2	-	0	-	-	-	0	-	-	-	2	0.020	**0.505**	0.990
Mercury	Total	mg/L	0.002	0.002	0	-	-	-	4	<0.0001	<0.0001	<0.0001	0	-	-	-
Molybdenum	Total	mg/L	0.01	0.15	0	-	-	-	0	-	-	-	0	-	-	-
Nickel	Total	mg/L	0.2	1	0	-	-	-	0	-	-	-	2	0.000	0.008	0.015
Selenium	Total	mg/L	0.02	0.02	0	-	-	-	0	-	-	-	0	-	-	-
Zinc	Total	mg/L	2	20	0	-	-	-	0	-	-	-	0	-	-	-

Note: Bold indicates median values in exceedance of guideline value for ANZECC Irrigation or Stockwatering.

Table 4-7 Summary of Water Quality from Surface Waters Compared Against ANZECC (2000) Aquatic Ecosystems Protection Guideline Values

Parameter	Total / Filtered	Unit	ANZECC Aquatic Ecosystems	WOLFANG CK (RTCA & DNRME)				GOWRIE CK (RTCA)				SANDY CK (DNRME)			
				Count	20th %ile	Median	80th %ile	Count	20th %ile	Median	80th %ile	Count	20th %ile	Median	80th %ile
Electrical Conductivity		σS/cm	**250**	27	227	**370**	1774	46	175	211	269	80	158	**445**	669
pH			**6.0-7.5**	27	7.71	**7.94**	8.36	46.0	7.8	**7.9**	8.5	80	7.1	**7.7**	8.0
Suspended Solids		mg/L	-	23	26	154	698	38	1164	5380	12700	50	7	30	304
TDS		mg/L	-	19	138	210	895	23	100	138	286	78	102	230	380
Turbidity		NTU	**15**	1	-	**100**	-	0	-	-	-	21	5	**47**	200
Total Kjeldahl Nitrogen as N		mg/L	-	7	0.98	1.50	1.74	11	1.10	3.00	6.30	2	1.13	1.69	2.25
Ammonia		mg/L	**0.006**	9	0.05	**0.06**	0.10	19	0.02	**0.05**	0.16	0	**-**	-	-
Nitrate as N		mg/L	**0.030**	19	0.143	**0.400**	1.281	18	0.100	**0.305**	0.982	26	0.045	**0.158**	0.316
Nitrite as N		mg/L	0.030	8	<0.01	<0.01	<0.01	15	<0.01	<0.01	0.03	0	-	-	-
Total Nitrogen as N		mg/L	**0.150**	9	0.58	**1.50**	1.98	14	1.06	**2.20**	6.44	5	0.26	**0.73**	0.83
Total Phosphorus as P		mg/L	**0.010**	7	0.132	**0.450**	0.496	14	0.4	**2.2**	11.0	5	0.2	**0.7**	0.9
Reactive Phosphorus as P	Filtered	mg/L	**0.005**	6	0.03	**0.035**	0.04	11	0.02	**0.03**	0.04	0	-	-	-
Calcium	Filtered	mg/L	-	25	13.6	18	36	19	13	17	25	78	9	20	32
Chloride		mg/L	-	27	13	48	397	48	6	10	15	78	21	62	120
Hardness as Ca CO3		mg/L	-	21	66	302	455	3	46	50	63	78	52	123	208
Magnesium	Filtered	mg/L	-	25	6.0	11.7	82.6	30	3.3	7.2	16.4	78	7.0	17.5	30.2
Potassium		mg/L	-	20	1.7	2.2	4.5	28	1.4	1.8	2.9	66	2.8	3.0	3.5
Sodium		mg/L	-	21	40	100	248	30	14	20	26	78	15	35	61
Sulphate		mg/L	-	16	6	27	38	30	2	2	3	68	8	25	50
Total Alkalinity		mg/l	-	21	97	130	275	22	91	99	136	78	45	91	110

Note: Bold indicates median values in exceedance of the guideline value.

Table 4-7 (cont.) Summary of Water Quality from Surface Waters Compared Against ANZECC (2000) Aquatic Ecosystems Protection Guideline Values

Parameter	Total / Filtered	Unit	ANZECC Aquatic Ecosystems	WOLFANG CK (RTCA & DNRME)				GOWRIE CK (RTCA)				SANDY CK (DNRME)			
				Count	20th %ile	Median	80th %ile	Count	20th %ile	Median	80th %ile	Count	20th %ile	Median	80th %ile
Toxicant 90% protection guideline value															
Aluminium	Filtered	mg/L	0.08	6	0.016	0.038	0.460	22	0.005	0.014	0.060	2	0.009	0.010	0.011
Antimony	Filtered	mg/L	-	6	<0.001	<0.001	0.001	19	<0.001	<0.001	<0.001	0	-	-	-
Arsenic	Filtered	mg/L	0.042	6	<0.001	<0.001	0.002	19	<0.001	<0.001	<0.001	0	-	-	-
Barium	Filtered	mg/L	-	6	0.007	0.0075	0.01	19	0.005	0.007	0.014	0	-	-	-
Beryllium	Filtered	mg/L	-	6	<0.001	<0.001	<0.001	19	<0.001	<0.001	<0.001	0	-	-	-
Boron	Filtered	mg/L	0.68	6	<0.1	<0.1	<0.1	19	<0.1	<0.1	<0.1	0	-	-	-
Cadmium	Filtered	mg/L	0.0004	6	<0.0001	<0.0001	0.0001	19	<0.0001	<0.0001	<0.0001	0	-	-	-
Chromium	Filtered	mg/L	0.006	6	<0.01	<0.01	<0.01	19	<0.01	<0.01	<0.01	0	-	-	-
Cobalt	Filtered	mg/L	-	6	<0.001	<0.001	<0.001	19	<0.001	<0.001	<0.001	0	-	-	-
Copper	Filtered	mg/L	**0.0018**	6	0.0030	**0.0030**	0.0040	19	0.002	**0.003**	0.005	11	<0.001	**0.010**	0.060
Iron	Filtered	mg/L	-	7	0.05	0.06	0.86	19	0.01	0.07	0.14	21	0.03	0.20	0.62
Lead	Filtered	mg/L	0.0056	6	<0.001	<0.001	<0.001	19	<0.001	<0.001	<0.001	0	-	-	-
Manganese	Filtered	mg/L	2.5	7	0.001	0.002	0.008	19	0.001	0.001	0.001	8	<0.001	0.010	0.016
Mercury	Filtered	mg/L	0.0019	6	<0.0001	<0.0001	<0.0001	19	<0.0001	<0.0001	<0.0001	0	-	-	-
Molybdenum	Filtered	mg/L	-	6	<0.001	<0.001	<0.001	19	<0.001	<0.001	<0.001	0	-	-	-
Nickel	Filtered	mg/L	0.013	6	0.003	0.003	0.003	19	0.002	0.003	0.004	0	-	-	-
Selenium	Filtered	mg/L	0.018	6	<0.01	<0.01	<0.01	19	<0.01	<0.01	<0.01	0	-	-	-
Silver	Filtered	mg/L	0.0001	6	<0.001	<0.001	<0.001	19	<0.001	<0.001	<0.001	0	-	-	-
Zinc	Filtered	mg/L	0.015	6	0.001	0.002	0.006	19	0.001	0.001	0.002	9	0.006	0.010	0.020

Note: Bold indicates median values in exceedance of the guideline value.

4.2 Surface Water Resources – Potential Impacts

Project activities that may affect surface water include:

- changes to catchment hydrology due to containment of mine site runoff;
- operation of dams associated with the site water management system including the Mine Water Dam and Process Water Dam;
- release of surplus groundwater to Wolfang Creek (via Gowrie Creek); and
- diversion of Gowrie Creek around the pit.

4.2.1 Impacts on Catchment Hydrology

Local runoff from disturbed areas of the site will be controlled to ensure that this water will not discharge from the site without adequate treatment. The maximum reduction in catchment flowing directly to Gowrie Creek and Apsley Creek would be 15 km^2 and 0.5 km^2 respectively. Hydrological modelling indicates that this would result in:

- a reduction of Gowrie Creek flows of approximately 16%;
- a reduction of Wolfang Creek flow of less than 2%; and
- a reduction of flow in Apsley Creek of approximately 1%

4.2.2 Site Water Management System

Management of site rainfall runoff will require operation of a series of storages intended to separate clean runoff from disturbed areas. Water from disturbed areas will be used preferentially for coal processing and handling. Subsequent sections describe the process of predicting the operation of the site water management system. A schematic of the system is presented in **Figure 2-15**.

4.2.2.1 Water Balance Model

A water balance model was developed to predict the operation of the site water management system and determine its capacity to manage weather extremes. The water balance model was constructed on a monthly resolution over 17 years of Project life.

The water balance model was used to:

- predict the security of water supply for operations;
- predict storage requirements on the site; and
- ensure that water management system operation did not exceed receiving water quality criteria.

The control variables for the water balance model are summarised in **Table 4-8**.

The model clearly showed that the climate has a strong influence on the water balance. Under average conditions, mine demands exceed rainfall runoff during the dry winter months. During the wet season, rainfall runoff exceeds mine demands. Therefore, the system was developed to allow for both storage and release.

The model was run to assess whether the proposed infrastructure and water management arrangements would satisfy operational requirements and downstream environmental values. The environmental values to be protected were those of a highly disturbed aquatic ecosystem used for stock watering (see **Section 5.6.8**). It was determined that these values would be adequately protected if the releases from the Mine Water Dam were controlled to ensure that the receiving water (Wolfang Creek) did not exceed its 80th percentile EC value (i.e. 1 774 µs/cm – see **Table 4-7**). Hence, 1 774 µs/cm was adopted as the receiving water quality criteria to be achieved during such releases.

Table 4-8 Water Balance Modelling Inputs

	Variable	Description
INPUTS	Rainfall	Recorded rainfall from Clermont town gauge was used. The following scenarios were tested: Â monthly average rainfall repeated over 21 years; Â minimum total 21 year rainfall sequence; Â median total 21 year rainfall sequence; and Â maximum total 21 year rainfall sequence.
	Runoff	Rainfall converted to runoff via runoff coefficients dependant on land uses on the site.
	Pit Water	Seepage to pit increasing from 15 L/s to 30 L/s. Assumed steady state for water balance at 25 L/s.
	Advanced Pit Dewatering	Water used to supplement mine site runoff during prolonged dry periods.
DEMANDS	Evaporation	Monthly averages from Clermont town.
	Storage seepage	Ignored for conservatism.
	Construction	Demand during opening of box-cut only.
	Coal Processing Plant	Demand commences at start of Year 1 Production. Assumed constant at 34 ML/month for life of mine.
	Haul Roads and Dust Suppression	Demand commences at opening of box-cut and increases linearly with length of haul road developed to 750 ML/a.
	ROM Stockpile	2.3 ML/month.
	Potable Water	7 ML/month allows for drinking water demands and potable demands to the CPP. Water to be supplied from advanced dewatering.
CONTROLS	Wolfang Creek water quality	Releases from the mine water management system was set so that it could only occur during flow events in Wolfang or Gowrie Creeks. Releases could only occur if the resulting EC in Wolfang Creek did not exceed a nominated value (refer **Section 4.2.5**).
	System discharge capacity	Limited to the capacity of a 600 mm diameter pipe running under 2 m head.

Modelling suggested that the Mine Water Dam could be operated according to the defined criteria under a median 20 year climate. The target EC level was not exceeded, with Wolfang Creek remaining below this EC criteria during flow events. The model showed that approximately 1 000 ML per annum would need to be released in an average of four events per annum under median climatic conditions. Further assessment using a wet (80^{th} percentile) climatic pattern and a dry (20^{th} percentile) climatic pattern found little variation from this result.

Some of the storages required for management of site water will be relocated during the mine life (refer **Figures 2-6** to **Figure 2-10**) however this does not affect their sizing nor function.

Security of Operations and Storage Sizing

Table 4-9 provides a summary of the results from the water balance modelling. The table shows the sum of demands at various stages of mine life and how it is anticipated that the demands can be met. The results are for the median climate scenario.

In the year prior to coal production, the box-cut will be underway, resulting in a high demand for water for construction and dust suppression. Runoff from disturbed surfaces will be collected and used to meet demands. Water from the advanced dewatering process will be used to make up shortfalls in prolonged dry periods and will supply demands for potable water and for the BAM.

In Production Year 1, construction demands cease. Coal processing operations are underway and demand for water from the BAM is maintained.

In Production Year 3, the demands of mining and processing operations have stabilised and will not vary greatly throughout the remaining life of the mine. The disturbed area will gradually increase until commencement of rehabilitation. This results in a greater catchment area and therefore a greater proportion of the mine demands can be met by the stored runoff. The demand from the BAM has ceased.

Table 4-9 Water Balance Model Result Summary

	Box-cut development	Production Year 1	Production Year 3
Losses			
Storage evaporation and seepage	784	784	784
Mine Demands			
Construction	800	0	0
Coal processing plant	0	408	408
Haul Roads and Dust Suppression	700	750	750
ROM Stockpile	0	28	28
Clean Water Demands			
Potable Water	84	84	84
Blair Athol Mine	473	473	0
Total Demands (ML)	**2 841**	**2 527**	**2 054**
Supply from runoff	1 212	1 250	1 546
Supply from Advanced Dewatering to operations	1 072	720	424
Supply from Advance Dewatering to clean water demands	557	557	84
TOTAL SUPPLY (ML)	**2 841**	**2 527**	**2 054**

The water balance model was used to test mine operation during periods of extreme dry weather and extreme wet weather. Mine water security was assured in dry weather as advanced dewatering volume is greater than the mine demand. Therefore, water can always be routed to mine operations as required.

Mine operation would be possible in extreme wet weather given the release criteria. The Mine Water Dam would be sized to provide adequate storage to ensure that releases occur only during flow events in Wolfang Creek or Gowrie Creek. The capacity to recommence mining after wet weather will be limited by the capacity to pump rainfall runoff water from the pit.

The Mine Water Dam storage capacity is proposed to be 2000 ML. This volume was determined through testing all of the available 21 year recorded rainfall sequences through the water balance model with the aim of having no uncontrolled releases from the Mine Water Dam. Under none of the available recorded sequences did an uncontrolled release occur. Therefore this volume would be more than adequate to provide security to mining operations while conforming to water quality release criteria.

The Pit Water Dam capacity is proposed to be 500 ML. This approximates to the 100 year 24 hour runoff volume from the pit. It is intended that this storage would be kept empty, ready to receive runoff generated by storm events. Water would be pumped from this storage to the Process Water Dam or the Mine Water Dam.

4.2.2.2 Process Water Management

The key elements of the process water management (shown in **Figure 2-15**) are:

- Raw Water Dam;
- Process Water Dam;
- Environmental Dam; and the
- Workshop Dam

Process Water Dam

The Process Water Dam was sized to ensure reliable supply to the CPP. The dam will take supply from the Raw Water Dam and also receive water decanted from the Coal Washery Waste Disposal Area. The volume required for the Process Water Dam for operational purposes is about 30 ML.

The capacity of the Process Water Dam will be 130 ML, to provide a freeboard capacity of 100 ML. This freeboard capacity is necessary to enable the Process Water Dam to collect the runoff from the Coal Washery Waste Disposal Area as the Process Water Dam has the potential to be a 'hazardous dam' according to EPA criteria (refer **Section 4.2.6.3**). The 100 ML freeboard capacity is equivalent to the runoff from the 100 year ARI 1 day event. The Process Water Dam spillway will have a design capacity equal to the 1 in 1000 year ARI critical storm.

Coal Washery Waste Area

The Process Water Dam will be operated so that if a rainfall event causes the Process Water Dam to fill beyond 30 ML, the excess stored water will be used preferentially to meet mine and coal processing demands until the 100 ML freeboard is restored. The Process Water Dam will have a spillway designed with a 1 in 1 000 year ARI critical storm. Releases from the Process Water Dam flow to the Environmental Dam.

Environmental Dam

The Environmental Dam will be maintained empty during normal operation. It will collect runoff from the coal processing area and will be used to meet mine demands until it is empty. The storage has been sized to store the runoff from a 100 year ARI 1 day runoff event. In extreme rainfall events creating a volume greater than the 100 year 1 day event, the overflow from the Environmental Dam will pass over a spillway to the Pit Water Dam. The Environmental Dam spillway will have a design capacity equal to the 1 in 1 000 year ARI critical storm.

Workshop Dam

Runoff from the workshop area reports to the Workshop Dam. The storage has been sized to contain the 100 year ARI 1 day critical storm. Runoff will be collected in the Workshop Dam and this water will be released via the Process Water Dam. In extreme rainfall events excess water will pass via a spillway to the Pit Water Dam.

Summary

The storages have been sized either for operational or runoff control depending on their purpose. A summary of the storages and their sizing is shown in **Table 4-10**.

Table 4-10 Summary of Storages

Storage	Design Criteria	Volume (ML)
Raw Water Dam	Operation	8
Process Water Dam	Operation Runoff control Catchment = 0.6km² Design Storm = 0.01AEP 24hr	30 100
	Total	*130*
Environmental Dam	Runoff control Catchment = 0.26km² Design Storm = 0.01AEP 24hr	35
Workshop Dam	Runoff Control Catchment = 0.1km² Design Storm = 0.01AEP 24hr	16

4.2.2.3 Sediment Management

The mine will require a number of sediment dams to treat runoff from disturbed areas, including waste rock dumps. The purpose of the dams will be to remove the bulk of suspended sediment from runoff that would otherwise cause sedimentation downstream.

Water quality monitoring results for the existing land uses show that the waterways in the region have high suspended solids concentrations and are naturally turbid (**Section 4.1.5.2**). Using this as an indication of baseline values, the proposed design criteria of the sediment dams are therefore:

- retain the flow from a 10 year ARI (0.1 AEP) critical duration storm for the catchment for sufficient time to settle 0.05 mm diameter (coarse silt) particles;
- retain the flow from a 1 year ARI (1 AEP) critical duration storm for the catchment for sufficient time to settle 0.02 mm diameter (fine silt) particles; and
- maximise the length of the dam relative to the width of the dam to maximise hydraulic retention time and deposition.

Sediment dams will be wet basins (i.e. spillway operated) with the only losses arising from seepage and evaporation. Flow will be passed from the dams via engineered spillways to adjacent waterways. Dams will be de-silted when required.

4.2.2.4 Embankment Protection

All dams will be provided with spillways to protect the dam embankment during flows up to the design flood event. The following dams will have spillways with a design capacity equal to the 1 in 1 000 year ARI critical storm:

- the Process Water Dam;
- the Environmental Dam; and
- the Pit Water Dam.

All other dams will have a spillway with a design capacity equal to the 1 in 100 year ARI critical storm.

4.2.2.5 Depth of Storages

Site storages will all be more than 60 cm deep, the minimum depth recommended to minimise mosquito breeding (Queensland Health, 2002). Wave action within the storages will also suppress mosquito breeding.

4.2.3 Surplus Groundwater Release

The advance dewatering process will create a surplus of groundwater during normal climatic and operating conditions.

The total amount of groundwater taken will comprise groundwater extracted from advance dewatering bores installed in the Tertiary basalt and Tertiary sediment aquifers, and groundwater that seeps into the pit through the pit walls and floor. The water balance model used assumes that all of the groundwater extracted from advance dewatering bores is from the Tertiary basalt and Tertiary sediment aquifers, and that all of the groundwater that seeps into the pit is from the Permian units.

Water balance modelling suggests that an excess will not occur for an average of 1.2 months per annum from Production Year 2 onwards under median climatic conditions.

Wherever possible, water extracted from the advance dewatering borefield will be used to supply demands of mining operations. This demand will reduce as the mine area increases and more rainfall runoff from disturbed land is intercepted for reuse.

Figure 4-5 shows the annualised profile of groundwater extracted from the advanced dewatering borefield and mine demands on that dewatering water under median climatic conditions. Surplus groundwater from the advance dewatering borefield will be available for use by others in sustainable and feasible projects. However, potential use of the surplus is limited by the following factors:

- decreasing volume over the life of mine;
- inconsistent surplus as mine demands would take priority in periods of dry weather;
- no surplus during extended dry periods;
- surplus would continue and need to be accepted in periods of wet weather to avoid release; and
- excess will end with end of coal production.

Potential use by others, if any, cannot yet be quantified and therefore the effects of releasing the surplus groundwater from the advance dewatering borefield to local creek systems have been investigated using flow modelling (refer **Section 4.2.3.2**).

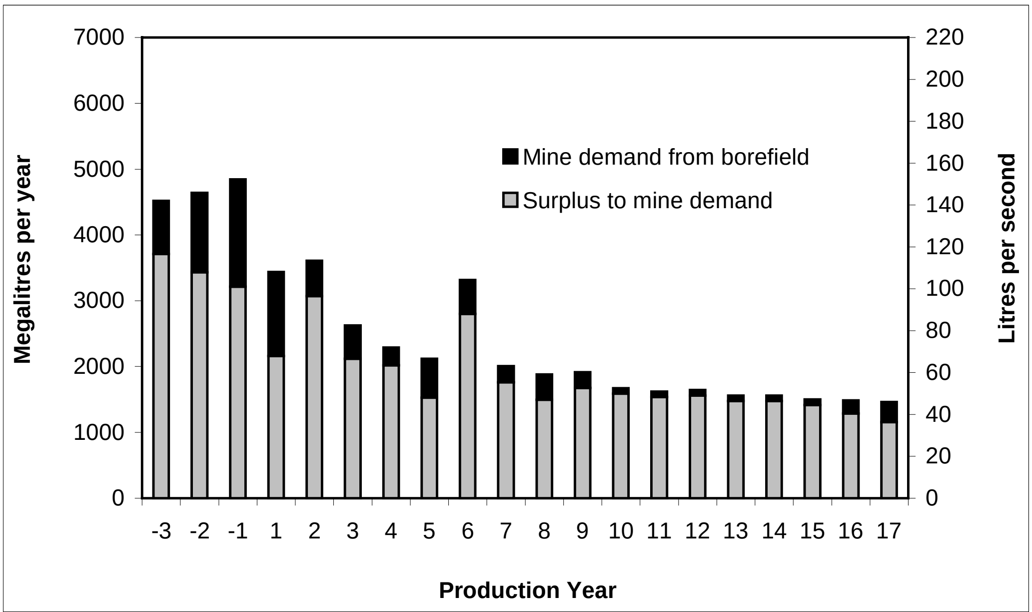


Figure 4-5 Annualised Chart of Dewatering Volume and Demands

4.2.3.1 Release Rates and Location

Release of groundwater from the advance dewatering borefield that is stored in the advance dewatering dam would occur into the Gowrie Creek diversion (**Figure 4-6)**. The volume of surplus groundwater to be discharged varies between approximately 140 L/s and 15 L/s for any given month where a continuous discharge is expected. Under the median rainfall conditions modelled, zero discharges may occur on about 1-2 months per year, on average. The frequency of zero discharges would increase in drier years.

As the mine progresses further to the south and the dewatering borefield moves in concert with the advancing pit, the discharge location is expected to move south along Gowrie Creek. The nature of this discharge is likely to result in a perennial low flow in Gowrie Creek, Wolfang Creek and Sandy Creek downstream of the mine.

4.2.3.2 Flow Modelling

A flow model was constructed to estimate the rate of advance of the downstream extremity of the perennial low. The flow model developed was a simple one-dimensional model that used available topographical information, measured hydraulic conductivity values in creek beds and particle size distributions of creek bed material to determine the width, depth, sinuosity and downstream extent of the resulting low flow wetting front.

The flow model assumed that wet season flows in the creek would temporarily override the perennial low flow, which would re-establish itself several days following a wet season flow without lasting effects caused by the flushing of the channel by larger flows. Consequently, discharges caused by rainfall events were not modelled.

The low flow model utilised void moisture replenishment, bed seepage and evaporation losses to estimate the rate of advance of the low flow wetting front. Immediate seepage losses occur due to the saturation of near-surface pores, with ongoing losses influenced by saturated and unsaturated hydraulic conductivity. The flow model allowed for known zones of water retention, which comprised visually assessed in-stream waterholes and the known presence of the Sandy Creek aquifer that once formed a water supply source for the township of Clermont. Losses in these zones were modelled using approximations of storage potential.

Monthly water discharges determined using a water balance model (refer **Section 4.2.2.1**) were averaged and applied as a continuous and constant water discharge rate within each year. Year-to-year changes in this average were modelled.

Model Creek Bed Material Parameters

Four creek bed material samples were taken at four separate locations within Gowrie Creek. Soil type and consistency in the bed of the creek varied from a medium dense sand (SP), sandy clay (CL) and sandy silty clay (CL-CH), and particle size analyses showed that over 80% of bed material was larger than 0.4 micrometers in the middle and lower reaches of Gowrie Creek. This indicated that, within Gowrie Creek at least, a perennial low flow is likely to create a well-defined, meandering low-flow channel if similar bed material exists in the Gowrie Creek diversion.

Field tests were undertaken on these samples by the University of Queensland for dry density and wet density. Laboratory analyses were undertaken on these samples for gravimetric moisture content, matric suction, specific gravity and saturated hydraulic conductivity. From these results, unsaturated hydraulic conductivity was also assessed.

Hydraulic conductivity values for Sandy Creek were drawn from DNRME information relating to aquifer permeability and particle size distribution tests carried out for the Sandy Creek aquifer that was originally used to supply the Clermont township.

These tests indicated that the material in Gowrie Creek was consistently impermeable, with saturated hydraulic conductivity values of lower than 10^{-10} m/s and unsaturated hydraulic conductivity values of as low as 10^{-14} m/s. These values are similar to an impermeable clay, and indicate that ongoing seepage losses into the bed of Gowrie Creek would be very low.

Visual inspections indicate that Wolfang Creek possesses similar bed material characteristics to Gowrie Creek, and that similar hydraulic behaviour would exist for the channel created by the perennial low flow within Wolfang Creek.

Sandy Creek material showed more permeable characteristics, with saturated hydraulic conductivity values ranging from 10^{-4} to 10^{-6} m/s, synonymous with a coarser, more particulate aggregate such as sand or gravel. Unsaturated hydraulic conductivity values were not available from past testing, so an estimate was made in the model.

Qualitatively, these results indicated that the wetting front of the low flow is expected to progress rapidly through Gowrie and Wolfang Creeks, with significant retention of water at the surface and relatively minor seepage losses once pore spaces close to the surface were filled with water. Consequently, very little recharge to the underlying aquifers would occur from this low flow. Once Sandy Creek is reached, the wetting front would slow down considerably, and a much higher seepage loss would be incurred. Visual evidence after periods of rainfall in the area supports this, with surface water still evident in Gowrie and Wolfang Creeks after surface water in Sandy Creek has dissipated.

Model Results - Geomorphology

The size of the existing natural channel has been formed over time by runoff contributed by the Gowrie Creek, Wolfang Creek and Sandy Creek catchments. In the upper sections of Gowrie Creek, the existing low-flow channel is approximately 2 m wide and the main channel is around 6m wide. The upper sections of Gowrie Creek show evidence of seasonal lateral migration (see **Section 4.1.4.3**). These channel dimensions increase further downstream in response to the larger catchment, and the extent of lateral seasonal migration reduces further downstream as sediments become less mobile (see **Sections 4.1.4.5** and **4.1.4.6**).

Modelling predicted that the discharge of surplus groundwater would cut a small (low flow) channel into the bed of the Gowrie Creek and Wolfang Creek. This low-flow channel is likely to meander between 10 cm and 2 m off the centerline of the main channel, with a wavelength of around 4 to 5 times the meander width. The meander pattern is expected to be relatively consistent, but the magnitude of the meander will vary depending on the bed slope and local materials in the bed. The meander pattern will also change from year to year, within the above ranges, as the discharge flow rate varies.

The size of the low-flow channel will average around 40-50 cm wide by 15-20 cm deep in most natural sections of Gowrie and Wolfang Creeks, and the material in the creek bed will erode naturally under the discharge flows to create a small, stable channel whose overall bed slope will be similar to or less than the existing average bed slope. The engineered section of the Gowrie Creek diversion could be constructed to vary this as required. Velocities vary from 0.4 m/s to around 0.7 m/s in the low-flow channel within the natural material. Erosion of creek banks is unlikely, as the meander pattern is expected to remain well within the confines of the natural channel, predominantly near the lowest points of the creek bed. Notwithstanding variations in bed material and average longitudinal bed slopes, smaller meanders would tend to form in the narrower upstream sections of the creeks and wider meanders would form preferentially in wider sections of the creeks.

In areas prone to holding water (eg in-stream waterholes, or intermittent fluctuations in bed profile height), permanent waterholes are expected to form, particularly along Gowrie and Wolfang Creeks.

As the low flow exits Wolfang Creek and enters the Sandy Creek system, the greater infiltration loss and the coarser sediments are expected to result in some braiding of the low-flow channel. The low-flow channel structure within Gowrie and Wolfang Creek bed sediments would lose some of its definition within Sandy Creek, particularly at the tail end of the wetting front. A more braided pattern would be seen, located approximately within the confines of a 50-75 cm wide envelope. This braiding is expected to be removed during the wet season, and re-established further downstream seasonally as the wetting front progresses.

Model Results - Wetting Front

The downstream extremity of the low flow (wetting front) is likely to be well defined in Gowrie and Wolfang Creeks, with little subsurface evidence of moisture occurring ahead of the limit of surface water. Within Sandy Creek, a higher moisture content in creek bed sediments (a damp zone) may be perceived up to 2-3 m in front of the limit of surface water, depending on the depth of sandy sediments directly beneath the creek bed.

The low flow model undertook calculations at 100 m intervals, and did not model the distinction between surface water and damp sediments.

Figure 4-7 shows the progression of the wetting front over the life of the mine. In the first year, the wetting front is expected to progress rapidly downstream, above the relatively impermeable sediments in the bed of Gowrie and Wolfang Creeks, and reach Sandy Creek. Because the discharge rate of surplus groundwater into Gowrie Creek would vary considerably from year to year, the wetting front is expected to regress slightly whenever there are significant reductions in the discharge rate. It is estimated that about 95% of the surplus groundwater released would enter Sandy Creek, whereupon it would recharge the Sandy Creek alluvial aquifer.

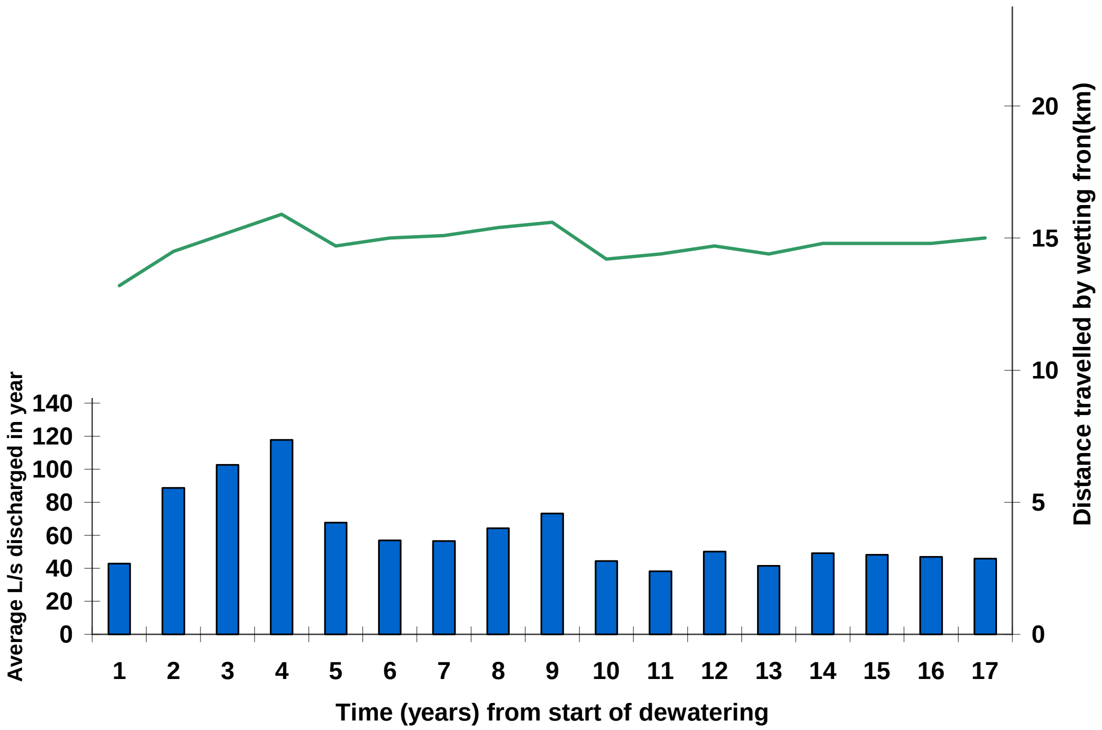


Figure 4-7 Progression of Wetting Front Over the Life of the Mine

During periods of zero discharge in dry weather, the wetting front would contract. When zero discharge occurs for over four to five days, most of the surface water in the low-flow channel is expected to be removed, primarily by evaporation in Gowrie and Wolfang Creeks, and primarily through seepage losses in Sandy Creek. Intermittent in-stream waterholes, located along undulating sections of the creek bed, could still remain after 1 or 2 month periods of zero discharge.

At the end of mine life, the wetting front is expected to have progressed around 15 km downstream of its original discharge location (see **Figure 4-7**). The model has not simulated a downstream migration of the original discharge location as the mine advances southwards. If a progressive southward relocation of the discharge point were to occur, a corresponding downstream progression of the end-of-mine wetting front would be expected, but with some damping (ie a 1km southward relocation of the discharge point would generally result in less than a 1 km progression of the end-of-mine wetting front along Sandy Creek).

Once continuous discharges into Gowrie Creek cease, the wetting front is expected to contract quickly upstream along Sandy Creek, and more slowly upstream along Gowrie and Wolfang Creeks. Simultaneously, upper reaches of the Gowrie Creek low-flow channel would begin to dry out, with the process taking days in upstream sections and several months in undulating sections. Following permanent cessation of discharges into Gowrie Creek, a dry creek bed is expected to be restored in most areas except larger waterholes within one dry season, and would be expected to be permanently restored within two consecutive dry seasons.

4.2.4 Gowrie Creek Diversion

In order to permit mining of the full coal resource, it is proposed to divert the Gowrie Creek from its current course to allow development of the pit. The proposed diversion is approximately 8.5 km in length and will replace an existing sinuous reach of river of similar length. The diversion will be constructed to the east of the existing creek and will be excavated to a depth of 700 mm below natural surface. The diversion will be excavated with side batters at a grade of one vertically to four horizontally with a base width of 3 m and a top width of 8.5 m. The longitudinal slope adopted for the design is 0.2% and the diversion is designed to accommodate the 1% AEP. In addition to the diversion, two levee banks are proposed to be constructed: one on the western side of the diversion, which will be approximately 8 km in length; and one on the eastern side, which will be in the order of 1.5 km in length.

The waterway diversion has been designed to:

- protect the pit from flooding;
- balance the cut and fill requirements for earthworks;
- provide a stable channel;
- limit or eliminate any increase in upstream flooding as a result of the proposed diversion;
- maintain similar flow velocities in Gowrie Creek downstream of the proposed diversion;
- develop a sinuous low-flow channel in order to prevent erosion and scour; and
- provide a low-flow channel with similar length to the existing Gowrie Creek.

Conceptual designs have been prepared for the diversion. The proposed design incorporates the following measures to prevent adverse impacts:

- a sinuous low-flow channel with a stream length similar to the existing creek to minimise velocities that cause erosion and scour;
- a select clay or lime stabilised liner in the channel to limit channel instability and prevent excessive sediment loads being generated; and
- construction of two levees adjacent to the diversion which will have the effect of substantially reducing the floodplain width when compared against natural conditions.

The design has taken into account the findings of the ACARP study on the maintenance of geomorphic processes in stream diversions (ACARP, 2000).

4.2.4.1 Geomorphological Impacts

A natural stream flowing in alluvium is unlikely to be stable. The channel is poorly defined with evidence of significant lateral migration. It is generally 1 m deep and more deeply incised on the outside bend of meanders, and shallower in the flatter reaches near the Peak Downs Highway. In these sections there is significant deposition of alluvium sediments within the channel bed.

Channel morphology represents a dynamic equilibrium that reflects the range of flows, sediment loads and vegetation to which the waterway is subjected. In a 'mature' river system such as Gowrie Creek, the size, shape and planform of the waterway is well adjusted to the history of the flows. Gradual changes would be expected in the natural waterway as a response to varying flow regimes or to other changes in the physical environment. The natural channel would not be completely stable in an engineering sense.

The size, shape, planform and geometric variability of the Gowrie Creek diversion will provide stability, habitat diversity, aesthetic impact and functionality of the diverted Gowrie Creek.

Whilst various geomorphic models can analyse limited sets of hydrologic and hydraulic conditions, there is no deterministic design process that can be employed to generate an optimum geomorphic design. Rather the geomorphic design will be a synthesis of a number of inputs that will be driven by a priority setting process.

Design and implementation of a diversion channel which is geomorphologically stable and which contains a near natural and robust ecology is challenging as there are numerous inter-related elements in the river system which need to be considered. These include:

- the flow regime, i.e. the magnitude of discharge (across the full range of flows from low flows to flood design events), and the temporal distribution on daily and seasonal timeframes;
- flow hydraulics which relates to depth, velocity and turbulence;
- distribution, transport, deposition, movement and disturbance of sediment and gravels;
- aquatic and riparian vegetation;
- geomorphic features such as sinuosity, bed substrate, scour pools, bed gradient and floodplain features;
- fauna including aquatic invertebrates;
- longitudinal and horizontal connectivity; and
- water quality aspects.

Key design parameters for the Gowrie Creek diversion are discussed below.

Bankfull Capacity

The diversion design should provide a geomorphically robust waterway design, with low risk of major waterway instabilities for a range of flow events likely to be encountered in the life of the diversion. In this respect the proposed diversion should remain relatively stable in events up to the 20 year ARI flood event.

Experience with flood damage assessments has found that significantly greater stream scour associated with floods greater than the 20 year ARI event over lesser and more frequent flood events. Significant waterway scour should be anticipated in Australian river systems, including Gowrie Creek in flood events greater than the 20 year ARI. The 100 year ARI event has been adopted for design of the diversion channel to minimise the potential for broad scale scour of the diversion and deposition of material into Wolfang Creek.

Bed Grade

The proposed bed grade of the diversion is 0.2% which is similar to the existing bed grade. A sound geomorphological principle is to mimic a stable natural system where possible. The adopted bed grade is considered appropriate. Eventually the channel will provide localised undulations in the bed grade which will lead to small pools being formed. No grade controls are required for this design.

Bed Width

The adopted bed width developed in the proposed diversion is three metres which is similar to the existing conditions. The bed width in the actual constructed diversion should be varied, ranging from two metres to four metres. This should be undertaken in association with varying batter slopes to ensure the minimum waterway area is achieved along any cross section. This will also enhance the visual aspect of the diversion and provide for a more natural appearance.

Stream Power

Stream power analysis using HEC-RAS modelling has been undertaken for the 100 year ARI design flows in both the natural and proposed diversion channel. Stream power of 35 W/m^2 has been identified (Brookes, 1998) as a threshold for stability in constructed channels. According to Gippel and Stewardson (1998), bankfull stream power of less than 10 W/m^2 is likely to be associated with deposition, stream power between 10 and 35 W/m^2 should be stable, between 35 and 100 W/m^2 streams will tend to be actively meandering and above 100 W/m^2 may be eroding and become braided or straight.

Bankfull flow for the 100 year event in the modelled diversion has yielded maximum stream powers of 28 W/m^2, well below the threshold of 35 W/m^2 with the average stream power in the diversion being in the order of 18 W/m^2. The steam power calculations show that the diversion values are generally higher than the natural condition however this is to be expected as the proposed levee banks are constraining the floodwaters to a more confined area. The values indicate that the proposed channel design is suitable and does not increase stream power values to an unacceptable level.

A stream power analysis of the natural reaches of Gowrie Creek, above the proposed diversion, has shown that the values for some sections of this waterway are in the order of 60 W/m^2. This would indicate that the waterway is still in the process of adjusting and will provide sediment loads that will be transported downstream through the diversion channel. This also confirms the observations of the fieldwork that the bed in the upper reaches is still mobile.

Geomorphology Impacts Summary

It is acknowledged that it would not be possible to reconstruct a creek and not incur localised stream erosion and deposition. Some erosion and deposition would occur that would be similar to that occurring in other waterways in the area. However some adjustments would occur as a result of adjustments to channel shape and form within the new diversion. A program of adaptive waterway management within the diversion would be undertaken to address these adjustments through its design life. Adaptive waterway management, i.e. intervention management, will be undertaken as a result of a monitoring program, which will be part of the mines normal environmental monitoring program for the site.

4.2.4.2 Flooding Impacts

The regional flooding impacts of the diversion channel was assessed using the MIKE21 hydraulic modelling package as discussed in **Section 4.1.3**. Levees and the diversion channel were added to the terrain and the model re-run. The diversion channel is designed for the 100 year ARI flood event and the Gowrie Creek flood is contained in the flood levees. The resulting inundation is shown in **Figure 4-8**. Shades of blue represent various depths of flooding with contouring showing the resultant water surface level (m AHD)

The impact of the levees on regional flooding is shown in **Figure 4-9**. In this figure, areas shown in shades of red are where flood levels have increased by more than 100 mm. It can be seen that the diversion creates higher flood levels east of the channel and into Wolfang Creek. The increase in flood depth outside the mining leases is minimal. The downstream impacts on flood depth do not extend past the Gowrie Creek and Wolfang Creek confluence.

The upstream impacts on Gowrie Creek do not extend beyond the mining leases. Hence, there are no risks to farmland from contaminated surface water flow in such events.

In the unlikely event of failure of the levee banks, flood waters would spill into the mine pit, and be contained without release. There would be no risk to farmland from such an event.

The design of the diversion has considered the need to prevent excessive sediment loads being generated. Flood mitigation measures will not have any effect on salinity or the emission of any substance of a hazardous or toxic nature.

4.2.4.3 Probability of Filling Final Void

An assessment was made to predict if flooding would cause the final void to overtop. The Gowrie Creek diversion channel levees will divert flow in the 100 year ARI flood event. Although there will be some additional freeboard, assessment was undertaken that assumed the levees would overtop for events greater than the 100 year ARI, and that a portion of this water would enter the final void.

The Gowrie Creek diversion will not change the flood immunity of existing and proposed roads.

Flood levels in the area of the void are dominated by flow in Wolfang Creek and its floodplain. The methodology adopted for the assessment was:

- produce flood hydrographs for the 500 year ARI and the Probable Maximum Flood (PMF) events;
- quantify the volume in each hydrograph greater than the 100 year ARI peak flow rate;
- predict the volume greater than the 100 year ARI flood that will enter the final void;
- develop a relationship between flood probability and the volume of water that will enter the final void; and
- predict the probability of the final void filling. That is, predict the probability of the volume entering the final void equalling the volume available in the final void.

The PMF of Wolfang Creek was assessed to have a probability of 0.0001% (1 in 1,000,000 year ARI). The volume of water that may enter the final void was predicted and a simple water balance was developed using the following assumptions:

- flow will overtop the levees for discharges greater than the 100 year ARI peak flow rate;
- the levees will be at their design levels at the time of flooding;
- the levee structure will remain intact during the flood event;
- 25% of Gowrie Creek flood volume greater than 100 year ARI would enter the final void. The remainder will be conveyed past the ML;
- 50% of the Wolfang Creek flood volume greater than the 100 year ARI event would make it to the final void. The remainder would be conveyed past the ML; and
- the standing water level at the flood event would be 15 m below the top of the final void. This was predicted to occur approximately 290 years post-mining (refer **Section 4.4.2**). This equates to an approximate final void freeboard volume of 54 300 ML.

Table 4-11 shows the estimated volumes entering the final void for different return recurrence intervals. By interpolation, it was concluded that the probability of the final void filling was approximately 0.03%, which is approximately a 1 in 3 300 year flood event. This provides an indication that the likelihood of overtopping of the final void is low.

Table 4-11 Flood Probability and Final Void Flooding

Flood ARI	Peak Flow in Wolfang Creek (m^3/s)	Volume Entering Final Void (ML)
100	1 286	0
500	1 900	30 500
PMF (1,000,000)	6 500	237 000

4.2.5 Surface Water Quality Impacts

The impacts of the mining operation on downstream water quality will be minimised by:

- releasing from the Mine Water Dam only during times of flow in Wolfang or Gowrie Creeks;
- releasing from the Mine Water Dam only if the resultant EC and pH in Wolfang Creek does not exceed the defined criteria; and
- ensuring all runoff from disturbed areas passes through sediment dams before entering local creeks.

The EC level that will not be exceeded in downstream waters in Wolfang Creek due to release from the Mine Water Dam, has been set at 1774 σS/cm, the 80^{th} percentile EC of Wolfang Creek as measured by monitoring over the period 1981 to 2004.

The pH range that will be maintained has been set at 6.0 – 8.5, the range monitored over the same period.

The release of surplus groundwater to Gowrie Creek would have little impact on the water quality of Gowrie or Wolfang Creeks during natural storm flow events due to the low rate of release. However, such release would change the nature of the receiving environment from an ephemeral stream to a perennial stream. The effects of this change in water quality on aquatic biology is discussed in **Section 5.7.1**.

4.2.6 Regulatory Requirements

4.2.6.1 Water Act 2000

Relevant Queensland legislation is the *Water Act 2000*. A primary purpose of this Act is to advance sustainable management and efficient use of water and other resources by establishing a system for the planning, allocation and use of water. One of its main provisions is the development and implementation of Water Resource Plans for river basins in Queensland.

The Project is located in the north-west of the Fitzroy River Basin. The Fitzroy River Basin was the first major river basin in Queensland to have a Water Resource Plan finalised. At the time of its finalisation in 1999 it preceded declaration of the *Water Act 2000* and was initially known as a Water Allocation and Management Plan. To be formally consistent with the *Water Act 2000* after its declaration the plan was renamed the Water Resource (Fitzroy Basin) Plan 1999, which will be referred to here as the Fitzroy Basin WRP.

The stated objectives of the Fitzroy Basin WRP are integrated and sustainable water management that seeks to achieve a balance in providing:

- security for water users in the plan area;
- security for holders of resource operations licences (ROLs) in the plan area;
- for further water-related development in the plan area; and
- for environmental water requirements for natural ecosystems in the plan area.

The plan area encompasses the entire river basin, and therefore applies to the Project. ROL holders are the operators of major water supply infrastructure, such as SunWater, which operates the Nogoa Mackenzie Water Supply Scheme based on supplemented water supply from Fairbairn Dam. Gowrie Creek, which is directly affected by the proposed mine operations, flows into Wolfang Creek, which flows into Sandy Creek, which flows in turn into Theresa Creek which is a tributary of the Nogoa River downstream of Fairbairn Dam.

The control of runoff from active mining operations is expected to decrease total flow volume in Wolfang Creek by approximately 2%, equivalent to a decrease of 200 ML in a median year. Data available from DNRM internet site website (www.nrme.qld.gov.au/watershed/) shows that Mean Annual Flow at station 130211 (Wolfang Creek at Innisfree) is less than 5% of the Mean Annual Flow at station 130206 (Theresa Creek at Gregory Highway). The impact of the project on flow volumes in the Nogoa River will therefore be very minor and will have negligible impact on water supply security for the Nogoa Mackenzie Water Supply Scheme. The impact on flow volumes would be further reduced if disposal of some of the groundwater pumped in the Advance Dewatering System is discharged to surface streams.

The WRP deals with principles and objectives of the planning and management of water resources in the river basin. Details of how water management will be implemented to achieve those objectives is the subject of the Fitzroy Basin Resource Operations Plan 2003, which will be referred to here as the ROP. It declares: *A ROP defines the rules that guide the allocation and management of water to achieve the objectives set in the WRP*.

Much of the Fitzroy Basin ROP deals with rules for water allocation and management in specified Water Supply Schemes (for supplemented water) and Water Management Areas (for unsupplemented water) – of which the Nogoa Mackenzie Water Supply Scheme (WSS) and the associated Water Management Area (WMA) are the nearest examples. The Clermont mining lease falls well outside the Nogoa Mackenzie WSS and WMA, and therefore the rules relevant to WSSs and WMAs do not apply directly to this development.

Water Licence Requirements

In relation to water licences, sections 204 and 206 of the *Water Act 2000* state that a water licence is required for taking water and/or interfering with the flow of water (surface or subsurface).

The Proponent would require a water licence to take water from the aquifers, and a licence to interfere with Gowrie Creek due to the proposed diversion. The decision to grant a water licence will be made by the Chief Executive administering the Fitzroy Basin ROP, currently through the agency of DNRME. The criteria used in deciding applications are outlined in Section 210 of the *Water Act 2000*.

Referable Dams

Sections 480 to 493 of the *Water Act 2000* define referable dams and the criteria for requiring failure impact assessments. Any dam requiring failure impact assessment is referable under the *Water Act 2000*. One set of criteria relate to the height, storage capacity and catchment area of a dam. Under this set of criteria the dams proposed for the Project do not require failure impact assessments because they will not exceed 8 m in height. A failure impact assessment would still be required however, if the Chief Executive (currently through the agency of DNRME) considers that such an assessment would assign a category 1 or category 2 failure impact rating – in other words, that a population of two or more would be at risk downstream in the event of a dam failure. All dams will be studied more than 8 km from the nearest population and breach flows would pass through large flood plains before reaching populations.

Overland Flow

Capture or harvesting of overland flow is not currently subject to provisions of the Fitzroy Basin WRP; however the Government issued a notice of its intention to amend the Act to cover overland flow in September 2001 and placed a moratorium on development of new works for storage of overland flow. Mining activities are exempted from the moratorium. The draft amendment to the Fitzroy Basin WRP is scheduled for release for public comment in the second half of 2004. It will then become clear if on-site storages on Mining Leases will be subject to new regulation under this amendment.

4.2.6.2 Fisheries Act 1994

The *Fisheries Act 1994* applies to all land within Queensland, and the adjacent marine environment. The purpose of the Act is *to provide for the use, conservation and enhancement of … fisheries resources and fish habitats* consistent with ecologically sustainable development.

Sections 111 to 116 are concerned with waterway barrier works that may impede fish movement in waterways, and specifies a requirement for application for approval to build waterway barrier works. This would apply to any barrier constructed on Gowrie Creek associated with the proposed creek diversion if creek flow was inhibited. Works associated with the construction of the diversion will not include a barrier.

4.2.6.3 Environmental Protection Act

The *Environmental Protection Act* provides guidance for determining if a dam will contain hazardous wastes. The definition of hazardous waste is defined in the *Code of Environmental Compliance for Environmental Authorities for High Hazard Dams Containing Hazardous Waste*. The definition of a hazardous waste is 'any substance whether liquid, solid, or gaseous, derived by or resulting from, the processing of minerals that tends to destroy life or impair or endanger health'. The EPA information sheet on hazardous waste dams defines the purpose of hazardous waste storages as 'primarily used for storing process water, recycling treatment liquors and for tailings disposal.'

Using this definition, only the Process Water Dam could be interpreted as requiring assessment as a hazardous dam, by virtue of the fact that it will receive water from the Coal Washery Waste disposal. The Process Water Dam will receive runoff from the coal washery waste disposal area. Due to the nature of the coal washery wastes, the runoff may have the potential to exceed some criteria as hazardous liquor under the EPA Guidelines. The storage is expected to have a surface area greater than two hectares so it would then also trigger the 'High Hazard' classification.

To mitigate any environmental risk posed by overflow from the Process Water Dam, the storage will be designed and operated to maintain a freeboard volume, under normal operating conditions, equal to runoff from a 100 year ARI 1 day duration storm event.

4.3 Groundwater Resources – Existing Environment

4.3.1 Groundwater Hydrology

The Project area is located within the Highlands Subartesian Area (DNRM, 2000). Groundwater investigations have been conducted at the Clermont Mining Leases and immediate surrounds dating back to the late 1970s. More than 10 groundwater related field assessments have been conducted over this time as well as more than 14 separate desktop studies.

More recently (since 2001) groundwater assessment of the Mining Leases has been undertaken using a combination of field surveys and groundwater modelling. Groundwater modelling has been used to simulate the current groundwater environment and to assist in prediction of regional impacts on groundwater users and the environment resulting from mine related groundwater extraction.

Field assessments have included:

- drilling and installation of water bores;
- undertaking pumping tests within bores;
- groundwater sampling for chemical analysis;
- surveying of bore locations and groundwater usage on neighbouring properties; and
- monitoring of water level fluctuations within bores and rainfall events.

Desktop studies have included:

- reviewing groundwater potential for area;
- interpreting results of ongoing groundwater monitoring;
- assessing potential of groundwater as a source of water supply for Blair Athol Mine;
- assessing impact of groundwater extraction within the Mining Leases on surrounding aquifers;
- assessing boxcut groundwater dewatering issues;
- modelling of boxcut groundwater dewatering requirements;
- modelling of pit groundwater inflows for life of mine; and
- modelling of final void water quality.

A summary of these studies is contained in **Table 4-12**.

Table 4-12 Summary of Groundwater Related Studies, Clermont Mining Leases and Surrounds

Period	Activity
Mid 1960s	Hydrogeological field assessment of aquifers near Clermont township for water supply.
Early 1970s	Further field assessment of aquifers near Clermont township for water supply potential.
Late 1970s	Exploration drilling within Clermont Mining Leases in search of gold. Drilling locates coal.
Early 1980s	Extensive geological, geotechnical and hydrogeological field assessment of Wolfang deposit.
Late 1980s	Further geological, geotechnical and hydrogeological field assessment of Wolfang deposit.
Early 1990s	Review of previous hydrogeological investigations. Final void water quality modelling.
Late 1990s	Extensive resource delineation drilling program. Review of previous hydrogeological work.
Early 2000s	Extensive hydrogeological field assessments. Resource delineation drilling program. Extensive numerical modelling of groundwater behaviour and potential impacts of mine dewatering.

4.3.1.1 Relevant Legislation

The ‘taking’ of water from an aquifer under land is regulated by the Queensland *Water Act 2000* and Queensland *Water Regulation 2002* and requires a licence. Development of bores required to extract water from an aquifer is an assessable development under the *Integrated Planning Act 1997*.

RTCA currently holds DNRME issued Water Licences to extract 1400 ML of water per year from the Tertiary gravel aquifer and 100 ML of water per year from the Tertiary basalt aquifer within the Clermont Mining Lease 1884 to supply water to the BAM.

Water Licences for the taking of groundwater for the Clermont Coal Mine Project will have to be obtained by the Proponent from DNRME. The licences will stipulate a maximum annual take from each relevant aquifer. Under the *Water Act 2000*, the DNRME has authority to direct the licensee to provide and maintain access to alternative water supplies for other water entitlement holders who would be affected by the granting of the licence. This authority is similar to the old “make good” provisions of the now repealed *Water Resources Act 1989*. The *Water Act 2000* does not authorise directions to be made with respect to alternative supplies for persons without other water entitlements. An application for a Water Licence is publicly advertised.

4.3.1.2 Aquifers

Four distinct aquifers occur beneath the Clermont Mining Leases, and a Quaternary alluvial aquifer also occurs in the region but not within the Mining Leases.

The five regional aquifers are:

- Quaternary alluvial aquifer;
- Tertiary basalt aquifer;
- Tertiary sediment aquifer;
- Permian sedimentary rock aquifer; and
- Early Cambrian metamorphic rock aquifer.

The four aquifers beneath the Clermont Mining Leases are illustrated in **Figure 4-10**.

Quaternary Alluvial Aquifer

Quaternary alluvial deposits occur predominantly along creeks in the region. Within the Mining Leases the alluvial deposits are clay rich and do not yield significant quantities of water. Quaternary alluvial deposits within the Mining Leases do not constitute an aquifer.

Outside of the Mining Leases, the Quaternary alluvial deposits typically vary in thickness between zero to 15 m and consist of varying proportions of clay, silt, and minor sand and gravel material. Potential for groundwater exists within sandy and gravely sections of the alluvium, and represents an unconfined aquifer. Groundwater occurs within several metres of the ground surface. Groundwater yields within this aquifer are likely to vary from nil up to 5 L/s. The Quaternary alluvial aquifers are not regionally extensive and, accordingly, groundwater extraction at high rates is not sustainable in the long term.

Tertiary Basalt Aquifer

The Tertiary basalt aquifer varies in thickness between zero and 90 m within the Clermont Mining Leases boundary, and between zero and in excess of 120 m outside of the Mining Leases boundary. The aquifer is semi-confined to confined and consists of multiple individual basalt layers separated by several metres of clay. Groundwater typically occurs within the fractured and vesicular horizons of the basalt at a depth of approximately 30 m below ground surface. Groundwater yields from bores within this aquifer vary from nil up to 10 L/s, with an average yield of approximately 3 to 5 L/s.

The Tertiary basalt aquifer represents a major aquifer within the region due to its large aerial extent and relatively shallow depth to groundwater.

Tertiary Sediment Aquifer

Regionally, the Tertiary sediment aquifer consists of gravel, sand and clay layers. Beneath the Mining Leases, the aquifer comprises a highly permeable gravel and sand layer located at the base of the Tertiary pile. The gravel and sand material has been deposited within discrete paleochannels carved into the underlying Permian sedimentary rock units. Beneath the Mining Leases the aquifer is up to 30 m thick and depth to the top of the aquifer ranges between approximately 50 and 110 m below the ground surface.

Within the Mining Leases, the Tertiary sediment aquifer is a confined aquifer. Groundwater yield from bores within this aquifer is up to 20 L/s. The gravel layers are separated from the overlying basalt aquifer by up to 30 m of relatively impermeable clay. Testing of the Tertiary sediment aquifer indicates that the gravel deposits hosting groundwater within the Mining Leases are not laterally extensive, and may not extend beyond the Mining Leases boundary. It is anticipated that similar discrete gravel deposits are located outside of the Mining Leases, however these gravel deposits are poorly connected or unconnected to the gravels located within the Mining Leases boundary.

Outside of the Mining Leases, groundwater bearing gravel units have been identified within a paleochannel located beneath Sandy Creek near the Clermont Township (Heidecker, 1965). At this location the aquifer is up to 20 m thick and depth to top of the aquifer is approximately 10 m below the ground surface. The gravel unit is overlain by Quaternary alluvium consisting predominantly of silt and clay with some areas of gravel. Historical reports indicate the gravel unit is of limited lateral and vertical extent and is recharged at several locations along Sandy Creek. This aquifer is unconfined (directly beneath Sandy Creek) to confined (further from Sandy Creek). Groundwater yield from bores installed within this aquifer is up to 20L/s.

The Tertiary sediment aquifer is not considered a major regional aquifer due to the isolated nature of the gravel deposits and poor interconnection of these units. Prolonged groundwater extraction from these aquifers at high rates is not envisaged to be sustainable.

Permian Sedimentary Rock Aquifer

The Permian sedimentary rock aquifer is a semi-confined to confined aquifer. Water bearing units of this aquifer consist of sandstone, coal and conglomerate rock types within the Mining Leases, and sandstone and conglomerate outside of the Mining Leases boundary. The water bearing units are interbedded with less permeable rock units such as mudstone, siltstone and shale.

Within the Mining Leases the Permian sedimentary rock units hosting the aquifer are up to 200 m thick and the top of the aquifer is typically intercepted at approximately 100 m depth below ground surface. Groundwater yields from bores measured within this aquifer are generally less than 1 L/s.

Outside of the Mining Leases, the aquifer is up to 150 m thick. Permian sedimentary rock is exposed at the surface in some parts of the region while in other areas the top of the unit is intercepted at up to 120 m below ground surface. Bores installed within sandstone in areas outside of the Mining Leases generally provide limited supplies of water of mediocre quality (Heidecker, 1965). The depth required to intercept this aquifer also limits its practical usefulness for water supply.

Early Cambrian Metamorphic Rock Aquifer

The Early Cambrian metamorphic rock aquifer consists predominantly of schist. The metamorphic rock units represent the basement upon which Permian sedimentary rocks, Tertiary sediments and Tertiary basalt units have been deposited. Water is present within the rock units along fractured and weathered zones, however the clayey nature of the rock type when weathered tends to limit the ability of this unit to transmit groundwater. Limited testing of this potential aquifer has been conducted due to the rare occurrence of groundwater intersected within this aquifer during drilling programs. This aquifer does not represent a major water bearing unit within the region.

4.3.1.3 Groundwater Use

A total of 161 groundwater bores have been identified by RTCA within a radius of 10 km of the Mining Leases boundary. The bores were located during field surveys undertaken in January 2002, January 2003 and December 2003. Ninety-nine of these bores are neighbouring landholder bores, eight are existing RTCA groundwater extraction bores and the remaining 54 are RTCA groundwater monitoring bores.

Bore locations are shown in **Figure 4-11** and bore uses (based on interviews with neighbouring landholders) are summarised in **Table 4-12**.

Table 4-13 Groundwater Use

Groundwater Use	Number of Bores
Stockwater	43
Domestic	5
Domestic and Stockwater	10
Domestic and Chemical Mixing	1
Not Used	39
Industrial (Mining)	8
RTCA Groundwater Monitoring	54
Chemical mixing	1

The highly permeable nature of the basalt terrain in the Clermont area means that farm dams do not hold water and hence landholders rely on groundwater as their primary water source for stockwater and domestic purposes. All neighbouring farm properties surveyed have groundwater extraction bores located on the property.

Bore construction details are not available for the majority of landowner bores, and accordingly, it is not certain from which aquifer these bores extract water. The majority of these bores extend to depths of approximately 30 to 40 m. Reference to geological information for the area indicates that due to the shallow depth of the majority of these bores, it is likely that they are extracting water from the Tertiary basalt aquifer. A summary of which aquifer individual bores are installed within is contained in **Table 4-14**.

Table 4-14 Number of Bores Installed Within Each Aquifer

	Tertiary Basalt	Tertiary Gravel/ Sediments	Permian Sedimentary Rock	Early Cambrian Metamorphic Rock	Unknown
Bores	24	17	17	13	90

No landholder bores were located to the west of the Mining Leases. This is consistent with the limited groundwater supply in this area and the poor quality of water intersected.

Bores vary in age from 12 months through to approximately 50 years. Ninety-four of the bores were not equipped with pumping apparatus at the time of the surveys, and were accordingly not used for water extraction purposes at the time of the surveys. Some of these bores may be equipped in the future. Approximately 37 bores are equipped with windmills and pump less than 1 L/s when the wind is blowing. The remaining 30 bores are equipped with various types of pumps, with landholder bores extracting water at rates of between 0.5 L/s and 9 L/s, and RTCA bores extracting water at rates of up to 15 L/s. Methods used for groundwater extraction from each bore is summarised in **Table 4-15**.

Table 4-15 Method of Groundwater Extraction Within Bores

	Windmill Operated	Windmill Operated (requires repair)	Electric or Fuel Powered Pump	Bore Not Equipped
Number of bores	31	6	30	94

Impacts of Current Pumping

The rate at which groundwater can be extracted from a bore is dependant upon the extraction capacity of the pump and the rate at which groundwater moves into the bore column. Similarly, the impact that extracting groundwater from a bore has on the surrounding groundwater resource is related to how much water has been removed, and the length of time it takes the aquifer to recover.

The majority of landholder bores are equipped to extract groundwater at rates of less than 1 L/s and are only pumped for a few hours each day. Assuming these bores are installed within the Tertiary basalt aquifer, this extraction rate is likely to have negligible impact on the regional groundwater resource. At this rate and frequency of pumping, drawdown within the aquifer would be limited to the immediate vicinity of the bore, and can vary from as little as tens of centimetres through to tens of metres depending upon the characteristics of the Tertiary basalt aquifer immediately surrounding the bore. The aquifer is likely to recover within several hours following cessation of pumping.

Bores which are heavily utilised for water supply can have a greater impact on groundwater resources, particularly groundwater levels in close proximity to the bore. This is particularly the case for bores which are pumped constantly (24 hours per day), and/or at rates of greater than 1 L/s. Constant groundwater extraction from bores leads to a local depression of the potentiometric surface of up to tens of metres and can lower the potentiometric surface in a radius of several hundred metres surrounding the extraction bore. Recovery of the potentiometric surface occurs on cessation of pumping activities and recharge of the aquifer and can take several months or even years depending on the duration of pumping, the extraction rate and recharge to the aquifer. This is the situation for bores installed within the Tertiary sediment aquifer within the Clermont Mining Leases.

Drought conditions typically result in a decrease in aquifer recharge. Reduced aquifer recharge subsequently results in a drop in groundwater levels within extraction and monitoring bores, because water held in the aquifer is not being replenished.

Since January 2002, RTCA has extracted approximately 845 ML of groundwater from within the Clermont Mining Leases for use at the Blair Athol Mine. This equates to an average extraction rate of approximately 10.5 L/s from the Tertiary sediment aquifer and approximately 1.3 L/s from the Tertiary basalt aquifer. The groundwater is required to supplement the Blair Athol Mine site water supply, which has been decreased by a prolonged period of drought. Effects of groundwater extraction from within the Clermont Mining Leases on surrounding aquifers and groundwater users is monitored by RTCA as a requirement of their DNRME Water Licences. Results of monitoring are discussed in following sections.

Existing Groundwater Monitoring Network

RTCA currently has an extensive groundwater monitoring network in place both on and surrounding the Clermont Mining Leases. The bores were installed in 1983, 1988, 1996, 2001 and 2003 and are screened within Tertiary basalt, Tertiary sediments, Permian units or metamorphic rock units. The locations of existing monitoring bores are illustrated on **Figure 4-11**.

Groundwater level fluctuations are currently monitored within 12 bores on a monthly basis and a further 23 monitoring bores on a 3 monthly basis. Groundwater extraction volumes are monitored on a monthly basis within 8 bores used for Blair Athol Mine water supply purposes. Groundwater chemistry is monitored within eight bores on a six monthly basis.

This monitoring network and program is in accordance with the conditions of the DNRME Water Licences and will be continued while those licences are still current.

4.3.1.4 Groundwater Levels

Groundwater levels have been monitored within RTCA groundwater monitoring bores since 1983. RTCA has also monitored landowner bores surrounding the proposed mine on an annual basis since January 2002.

A contour map has been created of regional groundwater level elevations measured within bores installed within the Tertiary basalt aquifer (see **Figure 4-12**). The water levels within the bores reflect the regional potentiometric surface, i.e. the level to which water will rise in tightly cased well. In the Clermont area, the potentiometric surface is typically more than 10 m above the top of the aquifer (due to confining pressures). Overall groundwater movement is from the north-east to south, in accordance with topographic fall of the regional terrain.

The Tertiary basalt aquifer represents the shallowest regionally extensive aquifer in the study area. Field testing indicates this aquifer is typically "confined" to "semi-confined" meaning that water held within the aquifer is held under pressure. Water levels within bores installed into the confined and semi-confined sections of the aquifer will rise above the top of the aquifer to a level consistent with the pressure within the aquifer. In areas which lack a confining layer above the aquifer, water within the aquifer is not under pressure and the aquifer is classified as "unconfined".

Water level fluctuation within bores installed in confined aquifers indicates a change in pressure within the aquifer. This can be due to aquifer depletion (resulting in a drop in water level within the bore) or aquifer recharge (resulting in a rise in water level within the bore). The saturated thickness of the aquifer remains the same.

Water level fluctuation within bores installed in unconfined aquifers occurs as a result of aquifer depletion or recharge. Changes in water level within an unconfined aquifer reflect a change in saturated thickness of the aquifer.

Within Mining Leases Boundary

Groundwater levels within the Tertiary basalt aquifer on site fluctuate in response to pumping from this aquifer and climatic influences. Water levels within bores drilled into the basalt aquifer rise to within approximately 10 m from the ground surface due to confining pressures exerted on the aquifer. During heavy usage, water levels within individual bores can drop significantly in the immediate vicinity of the bore. Representative water level fluctuations within Tertiary monitoring bores (basalt and sediments) within the Mining Leases are illustrated in **Figure 4-13**. A rainfall residual mass curve is also included on the figure, to demonstrate the response of the aquifer to climatic events. Rainfall residual mass curves are explained in the glossary of terms.

Groundwater levels within bores installed within the Tertiary sediment aquifer fluctuate in response to continued groundwater extraction from this aquifer within the Clermont Mining Leases. Water levels within monitoring bores installed within the Tertiary sediment aquifer respond immediately to pumping from any of the extraction bores located within this aquifer on site regardless of proximity to the bore. This response is illustrated on **Figure 4-13** during the periods of May 2002 to December 2002 and between June 2003 and October 2003. This response demonstrates the confined nature of the aquifer. Water levels within bores installed within the Tertiary sediment aquifer rise to within approximately 15 m of the ground surface when not being pumped, however this can take several years of no groundwater extraction, and steady aquifer recharge. Water levels within monitoring bores installed within this aquifer are currently between 40 to 95 m below ground level as a result of pumping to Blair Athol Mine. Greatest depth to groundwater (95 m) is currently experienced within close proximity to extraction bores.

Water levels within bores installed in the Permian coal measures rise to within approximately 20 to 25 m of the ground surface due to confining pressures exerted on the aquifer. Water levels in bores installed within the weathered upper units of the Permian coal measures respond to current groundwater extraction from within the Mining Leases. The weathered Permian coal measures directly underlie gravel beds (Tertiary sediment aquifer), and accordingly are directly connected and respond in a similar way to groundwater extraction from the Tertiary sediment aquifer at this location.

Outside Mining Leases Boundary

Water levels within bores installed in aquifers outside of the Mining Leases rise to within approximately 3 to 30 m of the ground surface due to confining pressures exerted on the aquifers. Groundwater levels with monitoring bores installed within Tertiary basalt, Permian sedimentary rock and metamorphic rock aquifers surrounding the Mining Leases have fluctuated up to 10 m since 1983 (see **Figure 4-14**). The monitoring bores located to the north, east and south of the Mining Leases display a similar fluctuation in water level over time regardless of screened lithology. The water levels within these bores correlate directly with periods of rainfall and drought events. Under typical climatic conditions, water levels may fluctuate 1 to 3 m in any single year. Bores located within metamorphic rock units to the west of the proposed mine show negligible fluctuation in groundwater level over time. Limited groundwater occurs within these units.

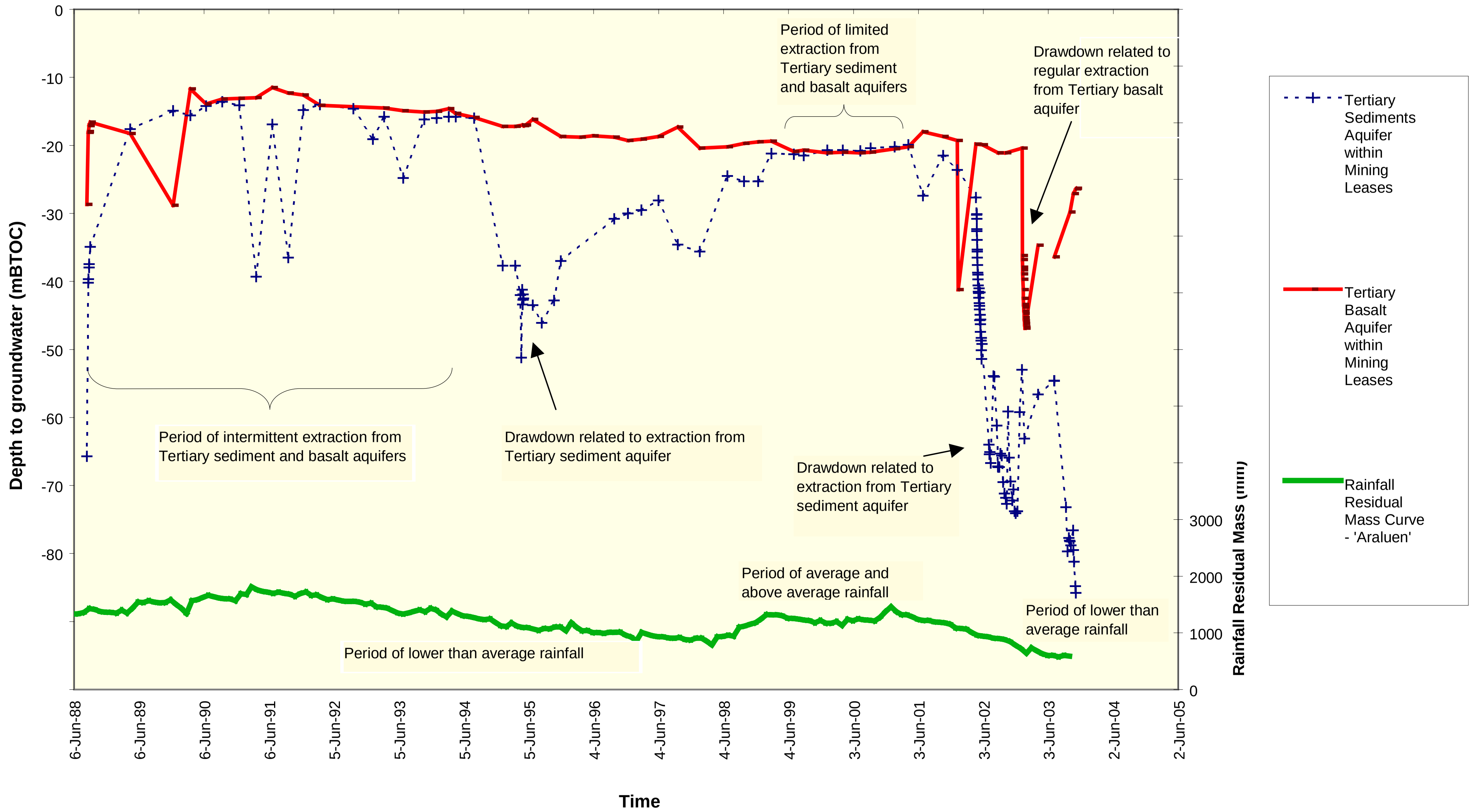


Figure 4-13

Representative Water Level Fluctuation within Tertiary Monitoring Bores within Mining Lease

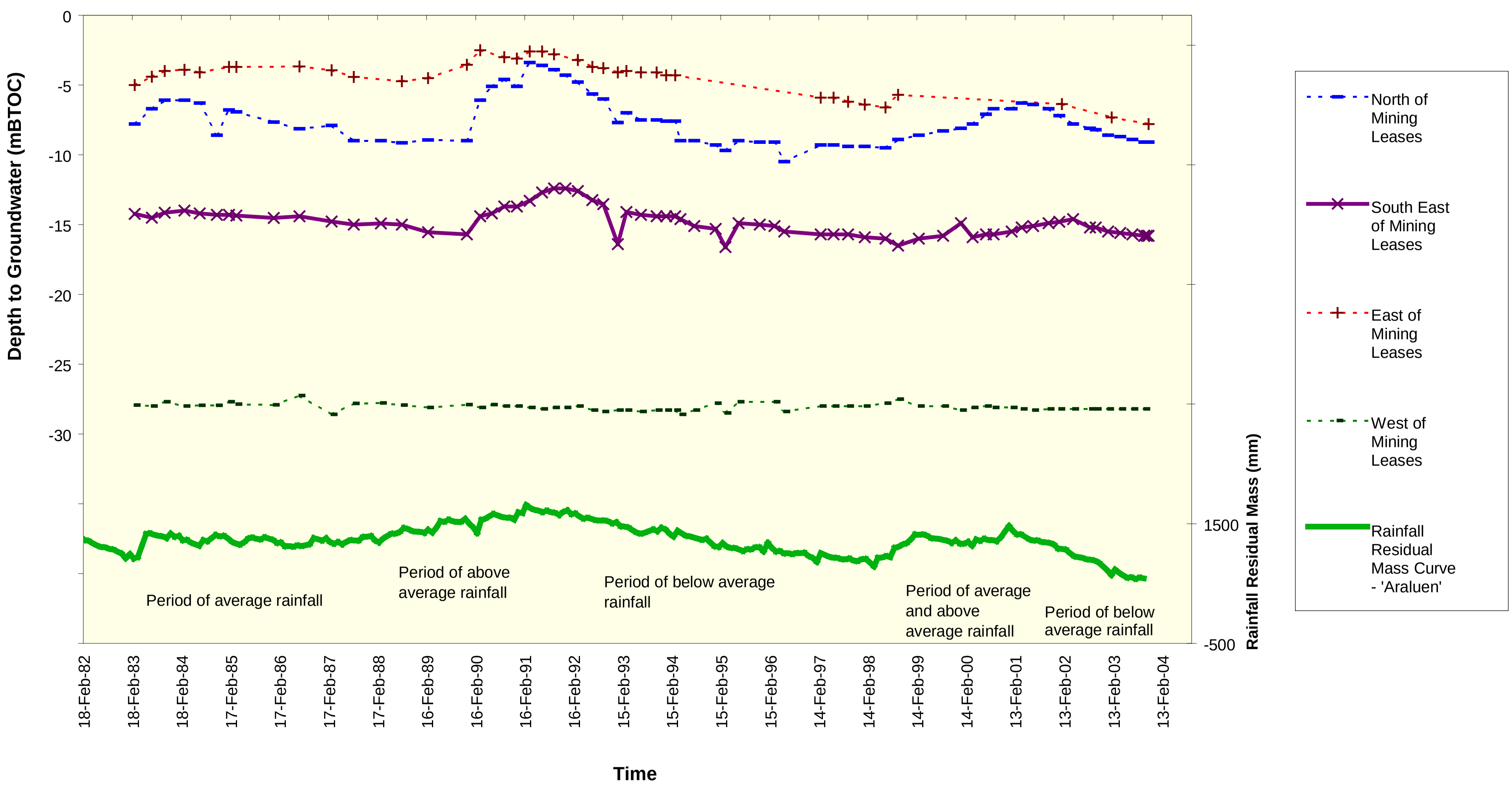


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Figure 4-14

Representative Water Level Fluctuation within Monitoring Bores Surrounding the Mining Lease Since 1983

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Figure 4-15 displays representative groundwater level fluctuation within monitoring bores to the north, east and south of the Mining Leases since January 2001. The displayed period corresponds with the period of extensive groundwater extraction within the Mining Leases for use at neighbouring Blair Athol Mine. Water levels within the monitoring bores surrounding the Mining Leases do not appear to be affected by historical groundwater extraction from the Tertiary basalt or Tertiary sediment aquifers within the Mining Leases.

4.3.1.5 Aquifer Recharge

Recharge of the groundwater system occurs via surface water infiltration into the groundwater system. Recharge to the aquifers in the region occurs predominantly in the topographically higher areas and along creek beds during and immediately following rainfall events. This is discussed below.

Recharge to the Tertiary basalt aquifer typically occurs in areas of thin soil cover or out crop (typically upland areas) where groundwater can readily move downwards into the aquifer via permeable zones including fractures, joints and vesicles. Recharge also occurs along creek beds, where basalt crops out, and enables direct infiltration of surface water into the aquifer during and following rainfall events.

The Tertiary sediment aquifers (multiple discrete aquifers) recharge via leakage from the overlying Tertiary basalt aquifer, adjoining highly weathered Permian or metamorphic units and via direct surface water infiltration in regions where the Tertiary sediments subcrop. Recharge of the gravel aquifer beneath Sandy Creek occurs at several locations along Sandy Creek (Heidecker, 1965) where the creek base cuts the top of the aquifer.

The Permian sedimentary rock aquifer receives recharge at locations where the unit outcrops or subcrops. In addition to this, the aquifer receives recharge via leakage from overlying, adjoining and in some instances, underlying aquifers. These recharge processes are also true for water bearing zones within the Early Cambrian metamorphic units.

The distribution of recharge assumed for groundwater modelling purposes is shown in **Appendix H**. Regional direction of groundwater flow is illustrated on **Figure 4-12**.

A rise in water levels within bores during successive wet years and a fall in water levels during successive dry years is evident in **Figure 4-14**, and demonstrate aquifer recharge and depletion due to climatic variation.

Pumping activities on the Clermont Mining Leases have masked any response of the Tertiary sediment aquifer to rainfall events.

4.3.2 Groundwater Quality

4.3.2.1 Water Quality Data Collection Programs

RTCA currently has an extensive groundwater monitoring network in place both on and surrounding the Clermont Mining Leases. The locations of existing monitoring bores are illustrated on **Figure 4-11**.

Groundwater chemistry is monitored within eight bores on a six monthly basis. Monitoring also exists for samples taken by previous Mining Lease holders going back to 1981.

4.3.2.2 Data Analysis and Comparison

Data collected from water quality analyses over the period 1981-2004 was reviewed for suitability and data quality.

Values for certain analytes (e.g. metals, some nutrients) were omitted if it was not clear whether the analysis had been performed on a filtered or unfiltered sample.

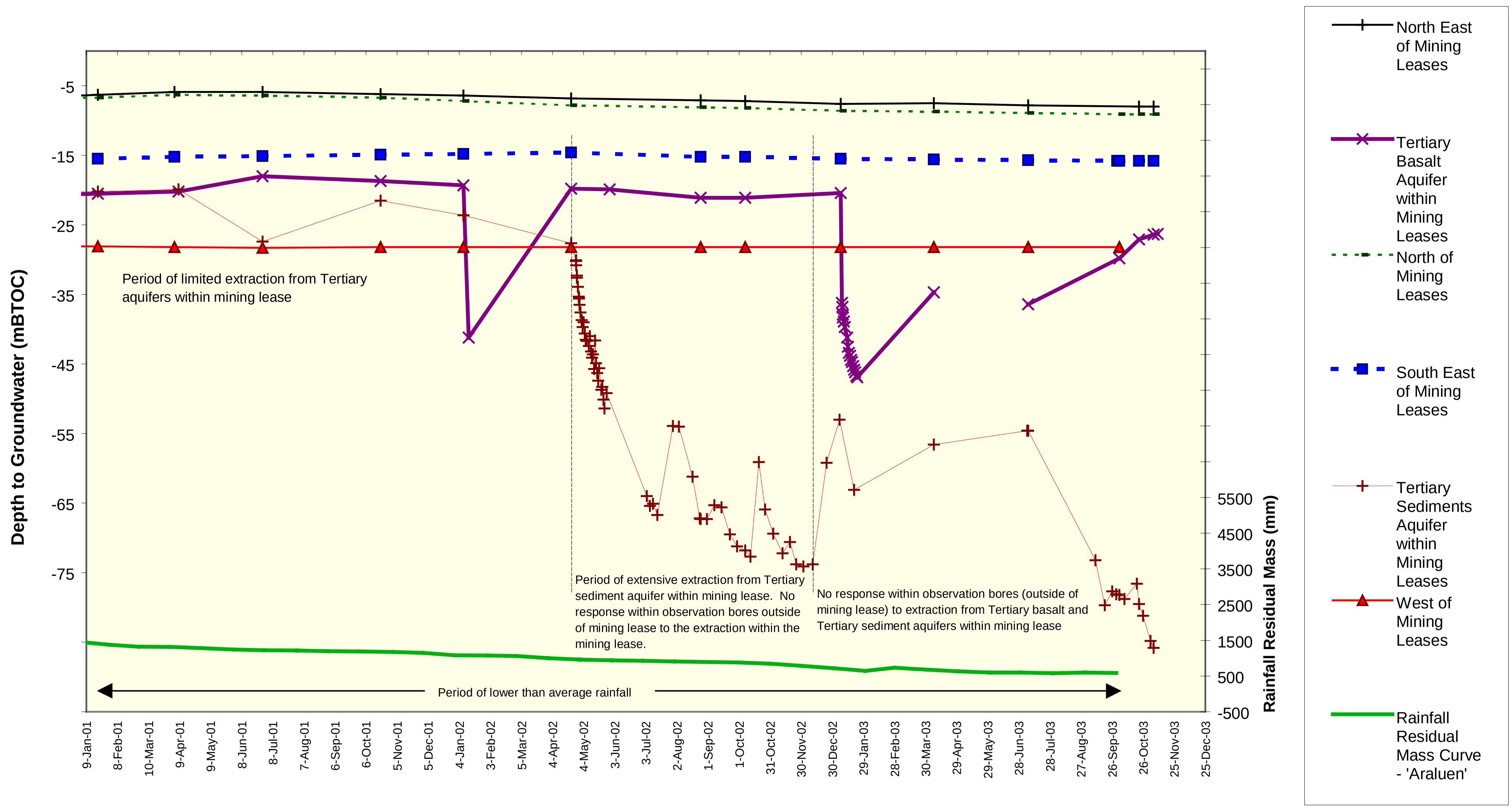

Figure 4-15

Representative Water Level Fluctuations of Monitoring Bores within Mining Lease Compared to Fluctuations within Monitoring Bores Surrounding the Mining Lease Since 2001

Summary tables of groundwater quality were compiled and compared against the following guidelines:

- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC, 2000).
  - Aquatic ecosystems: Protection of upland river aquatic ecosystems in tropical Australia, and using the 90% protection levels for toxicants due to the degraded nature of the catchment (see **Section 5.6.8**). Guideline levels for dissolved oxygen were converted from percentage saturation to mg/L;
  - Water quality for irrigation and general water use; and
  - Livestock drinking water quality;
- Australian Drinking Water Guidelines (NHMRC and ARMCANZ 1996).

Median values of the Clermont groundwater set were compared against the guideline values, except for drinking water which compares maximum values of the Clermont groundwater dataset.

Other statistical values are also presented in the tables:

20^{th} and 80^{th} percentile values are provided in the aquatic ecosystems protection summary-comparison table to provide distributional data similar to that recommended by ANZECC (2000).

Minimum and maximum values are provided in the drinking water, irrigation and stockwater quality summary table to provide an overall range for the data.

Filtered metals data were used in comparison against aquatic ecosystems protection guidelines since these reflect the bioavailable component of metals that are more able to impact on aquatic biota. Total metals data were compared against drinking water, irrigation and stockwater guidelines since both bioavailable and bound (non-bioavailable) metals can be ingested by livestock, people or irrigated onto crops.

4.3.2.3 Summary of Groundwater Quality

The groundwater data demonstrate that water quality is similar for all aquifers. This is illustrated by the pH and EC data in **Table 4-16**. The data for the three aquifers was pooled to provide an overall groundwater quality summary.

Table 4-16 pH and Electrical Conductivity of Aquifers

Aquifer	pH range	pH median	EC range (σS/cm)	EC median (σS/cm)
Tertiary basalt	7.0 - 8.5	7.6	539 - 1560	922
Tertiary sediments	7.1 – 8.3	8.0	665 - 1450	798
Permian sedimentary units	7.3 – 8.1	7.6	590 - 1650	1060

Comparison of median background groundwater quality against aquatic ecosystems guideline levels (**Table 4-17**) indicates that EC, pH, total phosphorus, reactive phosphorus and copper levels are elevated. Total nitrogen and ammonia levels are also elevated. However, a comparison of groundwater with existing surface water quality indicates that pH, total nitrogen, total phosphorus, reactive phosphorus and copper in groundwater are lower than in surface waters (**Table 4-17**). Ammonia in groundwater is higher than in surface waters, but it is not at concentrations that are toxic to aquatic organisms (see **Section 5.7.1**) if released into surface waters.

EC is generally higher in groundwater than in surface waters. Nevertheless, the levels are not extreme and are well within the range found in local creeks. The 80^{th} percentile EC of Wolfang Creek is nearly double the median groundwater EC. Release to surface waters is not likely to affect aquatic organisms (see **Section 5.2.3.1**).

Table 4-17 Summary of Groundwater Quality Compared to ANZECC Aquatic Ecosystems Protection Guideline Values

Parameter	Total /Filtered	Unit	ANZECC Aquatic Ecosystems	Count	20th %ile	Median	80th %ile
Electrical Conductivity		σS/cm	**250**	98	718	**908**	1176
pH			**6.0-7.5**	119	7.5	**7.7**	8.0
Suspended Solids		mg/L		16	<1	2	5
TDS		mg/L		88	422	542	678
Turbidity		NTU	15	18	3.3	15.5	244
Dissolved Oxygen		mg/L	7.0-9.5	6	5.1	7.0	8.2
Nitrate as N		mg/L	0.030	6	<0.01	<0.01	0.02
Nitrite as N		mg/L	0.030	6	<0.01	<0.01	<0.01
Total Nitrogen as N		mg/L	**0.150**	6	0.1	**0.2**	0.3
Organic Nitrogen as N		mg/L		5	0.1	0.8	2.6
Total Kjeldahl Nitrogen as N		mg/L		11	0.2	0.2	1.0
Ammonia as N		mg/L	**0.006**	11	0.05	**0.20**	0.26
Total Phosphorus as P		mg/L	**0.01**	6	0.04	**0.09**	0.31
Reactive Phosphorus as P		mg/L	**0.005**	6	0.02	**0.02**	0.03
Toxicant 90% protection guideline value							
Aluminium	Filtered	mg/L	0.08	9	<0.01	0.01	0.03
Antimony	Filtered	mg/L		3	<0.001	<0.001	<0.001
Arsenic	Filtered	mg/L	0.042	10	<0.001	0.001	0.002
Barium	Filtered	mg/L		3	0.0298	0.043	0.046
Beryllium	Filtered	mg/L		9	<0.001	<0.001	<0.001
Boron	Filtered	mg/L	0.68	9	<0.1	<0.1	<0.1
Cadmium	Filtered	mg/L	0.0004	10	<0.0001	<0.0001	<0.0001
Chromium	Filtered	mg/L	0.006	9	<0.001	<0.001	<0.001
Cobalt	Filtered	mg/L		9	<0.001	<0.001	<0.001
Copper	Filtered	mg/L	**0.0018**	10	<0.001	**0.002**	0.006
Iron	Filtered	mg/L		9	<0.01	0.05	0.10
Lead	Filtered	mg/L	0.0056	10	<0.001	<0.001	0.0022
Manganese	Filtered	mg/L	2.5	9	0.0106	0.013	0.015
Mercury	Filtered	mg/L	0.0019	8	<0.0001	<0.0001	<0.0001
Molybdenum	Filtered	mg/L		9	<0.001	0.001	0.0014
Nickel	Filtered	mg/L	0.013	10	<0.001	0.002	0.0034
Selenium	Filtered	mg/L	0.018	9	<0.01	<0.01	<0.01
Zinc	Filtered	mg/L	0.015	10	0.0038	0.0055	0.0106

Note: Bold indicates median values in exceedance of the guideline value.

Table 4-18 Comparison of Groundwater with Existing Surface Water Quality

Parameter	Total /Filtered	Unit	ANZECC Aquatic Ecosystems	Groundwater Median	Wolfang Creek Median	Gowrie Creek Median
Electrical Conductivity		σS/cm	250	908	370	211
pH			6.0-7.5	7.7	7.9	7.9
Ammonia as N		mg/L	0.006	0.20	0.06	0.05
Total Nitrogen as N		mg/L	0.150	0.20	1.50	2.20
Total Phosphorus as P		mg/L	0.010	0.09	0.45	2.22
Reactive Phosphorus as P		mg/L	0.005	0.02	0.035	0.03
Copper	Filtered	mg/L	0.0018	0.002	0.010	0.003

When compared to irrigation and stock watering guidelines (**Table 4-19**), all analytes, except for total phosphorus, were within guideline levels. While total phosphorus levels were elevated, they were significantly lower than total phosphorus levels recorded in local creeks (0.09 mg/L in groundwater compared with 0.45 mg/L and 2.2 mg/L in Wolfang Creek and Gowrie Creek; refer **Table 4-6**).

Groundwater exhibits typical characteristics of hard water, with maximum values for TDS, hardness and chloride exceeding Australian Drinking Water guidelines (**Table 4-19**). However, median values for these parameters are much closer to guideline values. Maximum values for a range of metals (e.g. aluminium, iron, manganese, nickel) exceeded guideline values. However, these elevated levels were due to the presence of particulate matter, as filtered samples showed much lower concentrations (see **Table 4-19**). Conventional potable water treatment methods would produce acceptable drinking water from groundwater.

4.4 Ground Water Resources – Potential Impacts

4.4.1 Impacts on Groundwater – During Mine Dewatering and Operation

The BAM will continue to use groundwater sourced from the Tertiary sediments aquifer and Tertiary basalt aquifer beneath the Clermont Mining Leases until the BAM ceases production in about 2009. Under average climatic conditions the BAM will require approximately 475 ML per annum from the Clermont Mining Leases.

Approximately eighteen months prior to commencement of mining at Clermont, the Proponent will undertake an advance dewatering program within the vicinity of the initial boxcut. The aim of the advance dewatering program will be to draw groundwater levels down to the base of the Tertiary sediments prior to onset of mining to reduce the risk of slope instability and ensure a safe mining environment. This will require extensive pumping from a borefield installed in the Tertiary basalt and Tertiary sediment aquifers in close proximity to the boxcut.

Continued groundwater extraction will be required throughout the operational phase of the project, as the pit development progresses in a southerly direction from the boxcut. New bores will be installed ahead of the mining path as older bores are overtaken by the pit.

Following cessation of mining, groundwater extraction related to mining operations will cease, and water levels within surrounding aquifers will begin to recover.

Predictive numerical groundwater modelling has been conducted to determine the potential magnitude and extent of impact of mining on the surrounding groundwater system. Impacts include the potential impact on neighbouring groundwater users.

Table 4-19 Summary of Groundwater Quality Compared to Drinking Water, Irrigation and Stockwater Guidelines

Parameter	Total /Filtered	Unit	ADWG Drinking Water	ANZECC Irrigation	ANZECC Stockwater	Count	Min.	Median	Max.
Electrical Conductivity		µS/cm		1250		98	539	908	1650
pH			6.5-8.5			119	7.0	7.7	8.5
Suspended Solids		mg/L				16	<1	2.0	820
TDS		mg/L	**500**		2500	88	120	542	**1100**
Turbidity		NTU	**5**			18	0.6	15.5	**680**
Dissolved Oxygen		mg/L	**6.5**			6	**4.3**	7.0	8.9
Nitrate as N		mg/L	10		90	6	<0.01	<0.01	0.08
Nitrite as N		mg/L	9		9	6	<0.01	<0.01	0.02
Total Nitrogen as N		mg/L		5		6	<0.1	0.2	0.3
Organic nitrogen as N		mg/L				5	<0.1	0.8	3.3
Total Kjeldahl Nitrogen as N		mg/L				11	<0.1	0.2	3.5
Ammonia as N		mg/L	0.5			11	0.03	0.20	0.34
Total Phosphorus as P		mg/L		**0.05**		6	0.02	**0.09**	0.31
Reactive Phosphorus as P		mg/L				6	0.01	0.02	0.04
Sodium Adsorption Ratio						57	1.4	2.1	156
Alkalinity as CaCO3		mg/L				70	237	320	580
Chloride		mg/L	**250**	175		98	12	88	**255**
Calcium		mg/L			1000	87	3	40	103
Fluoride		mg/L	1.5	1	2	16	<0.01	0.30	0.90
Magnesium		mg/L				85	<1	38	100
Potassium		mg/L				73	<1	3	24
Sodium		mg/L				82	12	102	176
Sulphate		mg/L	250		1000	80	<1	15	52
Hardness as CaCO3		mg/L	**200**	60		92	46	243	**579**
Aluminium	Total	mg/L	**0.2**	5	5	15	<0.01	0.03	**10.7**
Antimony	Total	mg/L	0.2	5	5	7	<0.001	<0.001	0.003
Arsenic	Total	mg/L	**0.007**	0.1	0.5	15	<0.001	0.002	**0.067**
Barium	Total	mg/L	0.7			7	0.015	0.048	0.081
Beryllium	Total	mg/L		0.1		9	<0.001	<0.001	<0.001
Boron	Total	mg/L	0.3	0.5	5	9	<0.1	<0.1	<0.1
Cadmium	Total	mg/L	0.002	0.01	0.01	15	<0.0001	<0.0001	0.002
Chromium (VI)	Total	mg/L	0.05	0.1	1	9	<0.01	<0.01	0.01
Cobalt	Total	mg/L		0.05	1	9	<0.001	<0.001	0.002
Copper	Total	mg/L	2	0.2	0.4	15	<0.001	0.003	0.044
Iron	Total	mg/L	**0.3**	0.2		10	<0.01	0.06	**1.82**
Lead	Total	mg/L	0.01	2	0.1	15	<0.001	<0.001	0.008
Manganese	Total	mg/L	**0.1**	0.2		15	0.008	0.015	**2.130**
Mercury	Total	mg/L	0.001	0.002	0.002	15	<0.0001	<0.0001	0.0002
Molybdenum	Total	mg/L	**0.05**	0.01	0.15	14	<0.001	0.001	**0.062**
Nickel	Total	mg/L	**0.02**	0.2	1	15	<0.001	0.003	**0.123**
Selenium	Total	mg/L	0.01	0.02	0.02	14	<0.01	<0.01	<0.01
Silver	Total	mg/L	0.1			7	<0.001	<0.001	0.005
Zinc	Total	mg/L	3	2	20	15	0.001	0.009	0.232

Note: Bold ADWG Drinking Water values indicate maximum value is in exceedance of Drinking Water Guideline value.
Note: Bold ANZECC values indicate median values in exceedance of guideline value for ANZECC Irrigation or Stockwatering.

4.4.1.1 Numerical Computer Modelling Methodology

A predictive numerical groundwater model was constructed using geological and hydrogeological data that has been collected during site assessments over the past 25 years. A summary of these investigations is included in **Table 4-12**. An outline of the modelling process is presented in **Appendix H**.

The groundwater model has been used to predict potential impacts on the regional groundwater system during:

- operational stages of the Project. This includes impacts caused by dewatering of aquifers ahead of mining, and;
- post-mining phase of the Project. This includes impacts on the aquifers during recovery of the aquifer after mining has ceased.

The outcomes of the predictive modelling are discussed in **Sections 4.4.1.2**, **4.4.1.4**, **4.4.1.5**, **4.4.2.1** and **4.4.2.3**.

4.4.1.2 Impacts on Regional Groundwater Levels – During Mine Dewatering and Operation

The total amount of groundwater taken will comprise groundwater extracted from bores plus groundwater that seeps into the pit through the pit walls. Groundwater removal rates required to adequately dewater the pit throughout the mine life are illustrated in **Figure 4-16**. Removal rates begin at approximately 150 L/s at the onset of advance dewatering, increase to approximately 180 L/s during early mining and drop to approximately 70 L/s by the end of mine life. The reduction in water extracted from bores is largely due to mining out of a large percentage of the Tertiary sediment aquifer during pit progression, and the progressive dewatering of the local groundwater aquifers.

Groundwater sourced from the Tertiary sediment aquifer accounts for approximately 80% of the required groundwater dewatering volume in the first year of bore field operation and reduces to approximately 50% of total groundwater dewatering volume by the end of mine life.

Groundwater sourced from the Tertiary basalt aquifer accounts for approximately 25% of total groundwater dewatering volume during early stages of the dewatering program and reduces to approximately 15% towards the end of mine life.

Groundwater extracted from Permian units accounts for the remaining 5% (early stage) to 35% (late stage) of total groundwater volume removed as a result of the Project.

During the mine life, the rate of groundwater extraction from Tertiary basalt, Tertiary sediment and Permian aquifers within the Mining Leases will significantly exceed the rate that these aquifers can recharge from surrounding rock units. This will lead to a depression or “drawdown” of the potentiometric surface in the vicinity of the mine when compared to pre-mining levels at this location.

The impact of mining related groundwater extraction on surrounding aquifers has been simulated within a computer based numerical groundwater modelling package. The impact is illustrated via a series of drawdown contours at three stages through the mine life (**Figure 4-17**, **Figure 4-18** and **Figure 4-19**). The drawdown contours represent the vertical distance in metres that the potentiometric surface has been lowered from its initial level. The initial potentiometric surface is taken as average pre-mining water levels within bores in the region based on RTCA groundwater level monitoring in 2002. Hence, the 2 m drawdown contour represents the location where a 2 m drop in water level (compared to pre-mining levels) is predicted for bores installed within the Tertiary basalt aquifer.

The extent of impact on regional aquifers caused by groundwater extraction within the Mining Leases increases from the onset of advance dewatering through to cessation of mining. At the end of mine life, the 2 m drawdown contour is predicted to be located up to 3.5 km to the north, 3.75 km to the east and 2.5 km to the south of the Mining Leases boundary. Groundwater drawdown impacts of less than 2 m will not significantly affect the groundwater environment as this drawdown is well within the natural fluctuation of water levels within aquifers in the region.

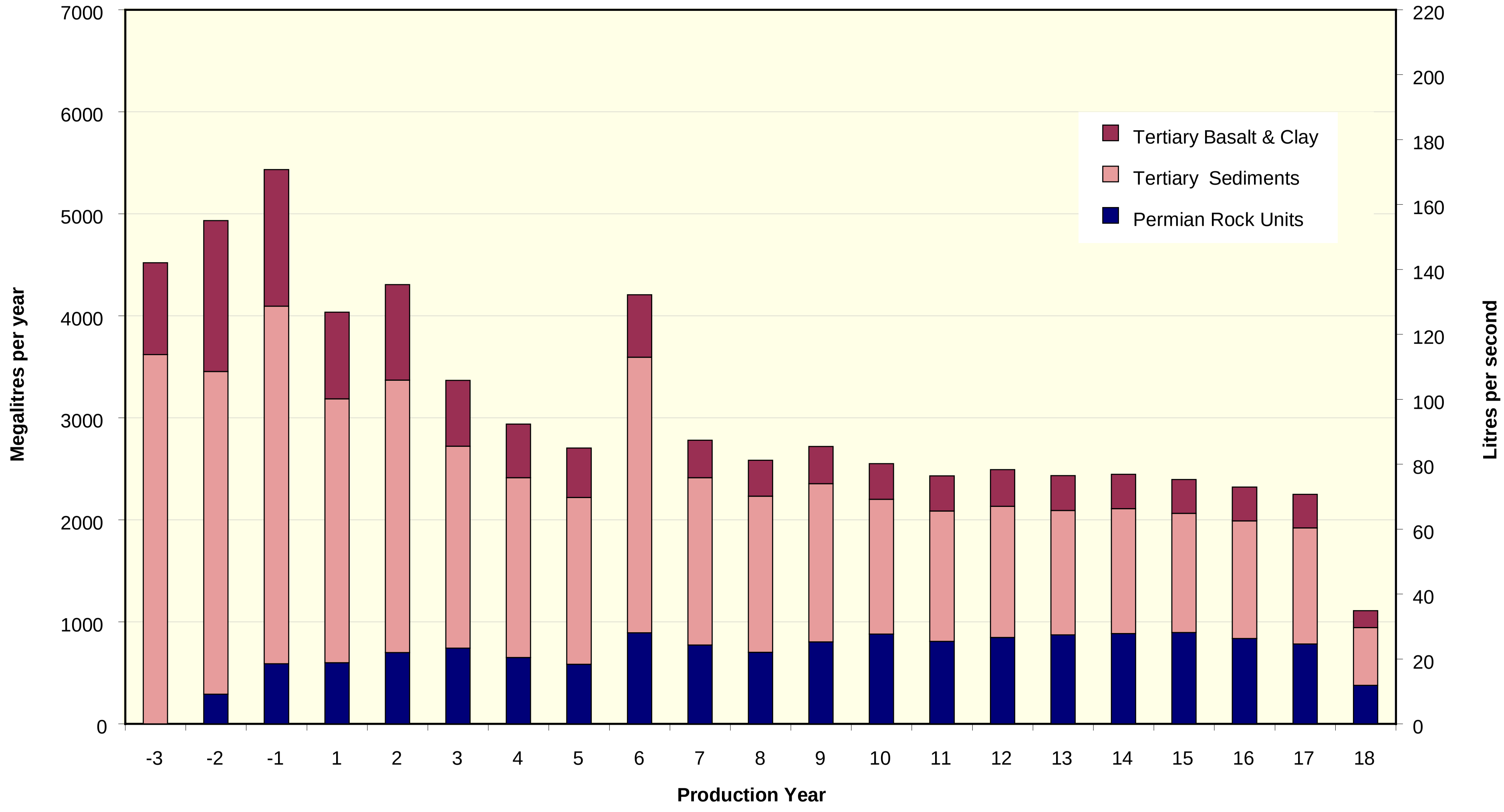

Figure 4-16

Groundwater Removal Rates Throughout Life of Mine

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4.4.1.3 Impacts on Groundwater Quality During Mine Dewatering and Operation

During advance dewatering and mine operation, water quality within aquifers surrounding the Mining Leases are expected to remain the same as pre-mining water quality for these aquifers (see **Section 4.3.2**). No change in water quality during advance dewatering and mine operation (as compared to pre-mining) is expected for the following reasons:

- during advance dewatering and mine operation, groundwater will be continually extracted within the Mining Leases to ensure a safe working environment within the pit. Extraction of groundwater within the Mining Leases will create a depression in the potentiometric surface at this location, and groundwater surrounding the Mining Leases will travel towards this depression from the north and east, and to a lesser extent, the south and west. The net movement of groundwater towards the pit during advance dewatering and mine operation will stop the movement of potentially poorer quality water (that may have been impacted by mining) from moving out of the Mining Leases boundary and into the surrounding aquifers; and
- aquifers outside of the Mining Leases will continue to receive recharge via the same processes that occurred pre-mining.

During mine operation, water quality within aquifers surrounding the Mining Leases will continue to be suitable for the same purposes applicable during the pre-mining era.

4.4.1.4 Impacts on Groundwater Users During Mine Dewatering and Operation

The groundwater drawdown impact of 2 m will progressively expand from within the Mining Leases boundaries (during advance dewatering) to cover parts of eight neighbouring properties by the end of mine operation. By end of mining, 24 landholder bores will be impacted (**Figure 4-19**). Properties would experience up to 25 m drawdown (as compared to pre-mining) close to the Mining Leases boundary, reducing to less than 2 m drawdown at a distance of approximately 3.75 km from the Mining Leases boundary.

The potential impact on groundwater users on these properties is discussed below:

- the pressure head within aquifers surrounding the Mining Leases will reduce, which will result in an increased depth to water surface within bores located within the area of impact;
- reduced pressure head within aquifers will potentially reduce the rate at which groundwater can be extracted from bores due to reduced head of water above the pump;
- inlet valves within bores may have to be lowered in order to maintain sufficient head of water above the pump when the pump is operational. This may increase the cost of extracting groundwater from within bores;
- new pumps may be required if existing pumps are not powerful enough to lift groundwater from the increased depth beneath the surface; and
- in some situations, bores may need to be deepened or relocated in order to ensure sufficient long term water supply for stockwatering and domestic purposes.

RTCA is currently undertaking assessments to quantify the impact of groundwater drawdown on the groundwater supplies of neighbouring groundwater users potentially affected by the mine dewatering program. RTCA has held initial meetings with the landholders of each of the eight potentially affected properties to discuss their groundwater supply and demand, the location and characteristics of bores, and the management of each property and the implications this has for demand. Further hydrogeological evaluations are programmed by RTCA to assess the potential availability of alternative groundwater supplies that would be unaffected by the mine dewatering program. Based on the results of these assessments and discussions with relevant landholders, options to ensure access to adequate alternative water supplies will be developed and discussed with the affected parties. Discussions with landholders indicate that the provision of alternative supplies from deepened bores and/or replacement bores would be considered to provide a more secure and independent supply than would be achieved by pumping surplus groundwater from the mine to properties.

RTCA will continue discussions with relevant landholders with a view to reaching mutually agreeable arrangements for the provision of alterative supplies throughout the mine life, and after mine closure. The quantity and reliability of the alternative supply arrangements will be at least equal to that required to maintain the existing productive capacity of each property.

4.4.1.5 Other Impacts

All streams within the study area are ephemeral and there are no perennial water holes present. Under average conditions, groundwater does not contribute to surface water flow within these creeks and streams. In exceptionally wet years it is possible that perched aquifers may contribute groundwater to the surface water system along creeks and at the toe of slopes (ie a natural spring may appear). One occurrence of an ephemeral spring has been reported in the upper reaches of Gowrie Creek, to the north-west of the Mining Leases.

The drawdown of the potentiometric surface associated with mining is unlikely to have an impact on the discharges from perched aquifers as these aquifers sit above, and are poorly connected to, the aquifers below.

Historical monitoring of regional aquifers indicates that the regional potentiometric surface is typically 15-30 m below the natural ground surface on elevated topography and typically 5-15 m below ground surface on broad drainage lines. Aquifers across the majority of the region are confined to semi-confined. Water within a confined and semi-confined aquifer is held under pressure, and water levels within bores installed into these aquifers will rise above the top of the aquifer to a level consistent with this pressure (which defines the regional potentiometric surface). This means that the shallowest water bearing strata (aquifer) in this region typically occurs at a greater depth than the regional potentiometric surface for the same location. Drill logs for the study area indicates the shallowest aquifer is typically intercepted at depths of greater than 20 m below ground surface.

The effect of drawing down the potentiometric surface on the availability of soil moisture for plants is discussed below.

Soil moisture is held within the pores between soil particles as a result of capillary action, and a soil moisture zone occurs whether or not an aquifer is present. Where an aquifer is connected to a soil moisture zone, such as occurs in unconfined aquifers, the soil moisture zone extends from the top of the potentiometric surface (where the pores between soil particles are fully or almost completely saturated) up to ground level (where the amount of moisture in the soil is highly dependent on rainfall conditions, and may be close to zero in sustained dry conditions). The soil moisture zone is deeper where ground elevations are higher, and shallower near the main drainage lines in lower topography. The root zone of most plants in semi-arid or arid climates is generally well above the top of the water table within unconfined aquifers.

In most cases, extraction of water from the confined and semi-confined Tertiary basalt and Tertiary sediment aquifers will have a limited drawdown effect on perched water tables and smaller, unconfined aquifers nearer the surface because of the presence of the intervening confining/semi-confining layer. In these aquifers, drawdown is likely to be minor or in some cases, where laterally extensive confining layers exist, negligible.

A drawdown of the water table has the effect of stretching the soil moisture zone vertically, with saturated or near-saturated conditions continuing to occur immediately above the drawn down water table, and rainfall-dependent soil moisture contents occurring at ground level. Within the Project area, the soils are typically heavy, with small particle sizes and high clay content, which tend to hold moisture well. Consequently, the stretched soil moisture zone is expected to hold water efficiently in the upper part of the zone, and decreases in soil moisture content within the root zone are not expected to be close to thresholds that may threaten plant life. The relatively minor variations in average soil moisture content are expected to fall within the seasonal ranges currently experienced. Impacts on vegetation are further discussed in **Section 5.7.2**.

Land disturbance caused by mining activities has the potential to have an impact on the local groundwater regime in the following ways:

- reduced aquifer recharge along historical path of Gowrie Creek (within Mining Leases) due to creek diversion during mine operation;
- reduced recharge of aquifers located immediately south of the Mining Leases due to reduction in the upgradient surface catchment area available as a recharge source; and
- increased water infiltration rates through the waste rock dumps and into the groundwater system due to their fractured nature.

The potential impacts caused by land disturbance through mining are minor relative to those caused by dewatering drawdown in the vicinity of the mine activities.

Subterranean waters may contain aquatic invertebrates called stygofauna, particularly in karst geological systems. Aquifers in the Project area have not been surveyed to determine the presence or absence of stygofauna. It is proposed to conduct a stygofauna survey to establish if stygofauna are present and if so, the range of taxa present. This survey is planned to occur once the regional monitoring bore network is installed (see **Section 4.6.2**). Selected bores both within and outside the anticipated zone of groundwater drawdown will be sampled.

4.4.1.6 Impact Mitigation During Mine Dewatering and Operation

The Proponent will seek to reach mutually agreeable arrangements with affected neighbouring groundwater users for the provision of alterative supplies throughout the mine life, and after mine closure (see **Section 4.4.1.4**). Alternative supplies will be put in place before supplies from relevant existing landholder bores are adversely affected. Due to the progressive nature of drawdown within the aquifers, the provision of alternative supplies is likely to be staged. Options for alternative supplies include:

- installation of new pumps capable of extracting groundwater from greater depth within existing bores;
- deepening of existing bores;
- installation of a new bore at another location on the property; and
- provision of piped water sourced from the mine (surplus water from the mine dewatering program).

The specific arrangements for affected properties will be discussed with each relevant landholder with a view to reaching a mutually acceptable agreement. The arrangements will include adherence to the proposed monitoring programme so that the actual water table impacts can be compared to those predicted by the groundwater model. If monitoring shows that drawdown varies by more than 2 m from the modelled drawdown the groundwater model will be reviewed to determine whether (a) an adjustment to the model is required, and (b) additional monitoring is required. Regular review of the groundwater model is important to ensure that the model can continue to reliably predict ongoing impacts on the regional groundwater system, given that such predictions are used to determine the extent and timing of mitigation actions.

4.4.2 Impacts on Groundwater – Post-Mining

4.4.2.1 Groundwater Levels – Post-Mining

After mining of the Clermont deposit is complete, groundwater extraction within the Mining Leases will cease. The regional groundwater system will begin immediately to re-adjust to the new aquifer conditions within the Mining Leases. Water levels/pressures within the regional aquifers will eventually attain a new equilibrium level (steady state).

The new equilibrium groundwater system will have a different potentiometric surface than was present pre-mining due to:

- the presence of a final void in the southern extent of the coal deposit; and
- backfilled material having different hydraulic properties than the coherent rock units that existed pre-mining.

A final void will remain in southern extent of the deposit (refer **Figure 2-11**). Surface water runoff from the waste rock dumps will be directed into the final void to assist groundwater recovery. In addition, rainfall over the final void and groundwater inflow from surrounding aquifers will slowly raise the water level in the final void. The high levels of evaporation experienced within central Queensland will slow the rate of recovery by constantly removing water from the final void water surface. Average evaporation in the region is approximately three times the average annual rainfall.

Final Void Water Levels

The final void will be up to 2.8 km long, 2.0 km wide and have an average depth of 120 m below the surface (with a maximum depth of 175 m below the surface). Immediately following cessation of mining, there will be a steep hydraulic gradient between the water level within the final void and water levels within surrounding aquifers. As the water level within the final void rises, the hydraulic gradient between the void and surrounding aquifers will flatten, slowing the rate of groundwater inflow into the final void. Final void water level recovery modelling is described in **Appendix H**.

The final void represents a location at which the Tertiary basalt, Tertiary sediment and Permian coal measure aquifers have been removed through mining and replaced by a void. The final void will receive groundwater inflow from the Tertiary basalt aquifer, Tertiary sediment aquifer and remaining Permian coal measures via inflow through the walls of the final void. Groundwater inflow will also occur from areas of backfill material into the void. **Figure 4-20** illustrates water inflow and losses from the final void, post-mining.

When water levels within the void have risen to a sufficient elevation, the final void will represent a location where all three of these aquifers are connected and have the same potentiometric head. A permanent depression in the potentiometric surface will be present at this location due to the high rate of evaporation from the final void water surface, for which surface run-off and groundwater inflow to the pit cannot fully compensate.

The post-mining regional groundwater flow pattern will re-establish itself, but some groundwater from the north, north-east and to a lesser extent from the south, will gravitate into the final void. The permanent depression of the potentiometric surface around the void acts like a sink and will not permit water within the final void to flow outwards into the regional system (illustrated in **Figure 4-21**).

Water levels within the final void reach 85 % of their final stable water level (post-mining equilibrium level) within 100 years of cessation of mining. This is equivalent to 219 m RL. Water levels within the final void attain their post-mining equilibrium level (of approximately 245 m RL) after 290 years. This level is approximately 10 m lower than the pre-mining potentiometric surface at this location, and about 15 m lower than the crest of the void.

Without flooding inflows, the void will never entirely fill, and therefore will never overflow to the downstream environment. The void waters will essentially remain isolated from the other surface waters of the area.

Regional Groundwater Levels – Post-Mining

The potentiometric surface within areas that have more than 10 m of drawdown (as illustrated in **Figure 4-19**) begins to recover immediately following cessation of mining. These areas are within and immediately surrounding the Mining Leases boundary. The initial rise in the potentiometric surface at these locations is related to the rise in water levels within the final void and backfilled areas of the pit.

In contrast, outside the Mining Leases, the potentiometric surface will continue to drop up to 3.5 m following cessation of mining as the groundwater system adjusts to the new regional aquifer conditions. The slight drop in water level experienced outside of the Mining Leases (post-mining) occurs as a result of a flattening of the regional hydraulic gradient, as the groundwater system moves towards its new equilibrium state. Maximum aerial extent of groundwater drawdown surrounding the Mining Leases (based on 2 m drawdown contour) occurs 50 years after cessation of mining (see Figure 4-22). Groundwater drawdown impacts of 2 m extend beyond the boundary of the Mining Leases by approximately 4.6 km to the north, 4 km to the east and 2.5 km to the south.

The waste rock material backfilled in the pit to the north of the final void has significantly different hydrogeological parameters to that of the *in situ* rock of the pre-mining aquifer in this area. The different hydrogeological parameters of the backfill material combined with the high rate of evaporation within the final void will create a different final equilibrium potentiometric surface than was present prior to mining. This will result in a residual drawdown within and immediately surrounding the Mining Leases boundary when the potentiometric surface reaches an equilibrium level.

Water levels within regional aquifers are expected to recover from maximum drawdown to within approximately 50% of their pre-mining level within 140 years after cessation of mining.

The regional potentiometric surface after aquifers have attained final equilibrium conditions (**Figure 4-21**) has a similar general direction of groundwater flow from north-east to south as the pre-mining flow direction (**Figure 4-12**). The regional residual drawdown post-mining is shown in **Figure 4-23**. The potentiometric surface within an area approximately 2 km to the north of the Mining Leases boundary and 0.6 km to the east of the Mining Leases boundary are expected to continue to show a residual drawdown of between 2 m and 3.5 m. Impacts to the south and west are confined to within the Mining Leases boundary.

4.4.2.2 Groundwater Quality – Post-Mining

Final void water quality is discussed in **Section 4.5**.

Although water quality within the final void is expected to deteriorate over time post-mining, this reduction in water quality in not expected to impact the surrounding aquifers. Water present within the final void (post-mining) will not flow out of the final void and into the regional aquifer for the following reasons:

- the final void represents a location at which each of the regional aquifers is in direct hydraulic connection within one another;
- high evaporation rates over the final void result in the final void water level being lower than potentiometric heads within the surrounding aquifers. Evaporation over the surface of the final void water body has a similar effect to operation of several large pumps at this location and causes a permanent sink in the regional potentiometric surface within the vicinity of the final void;
- water will flow under pressure towards the final void along a hydraulic gradient, from areas of high pressure head to areas of low pressure head (final void). A similar hydraulic gradient is present in all aquifers. Water will always flow in the direction of the hydraulic gradient. Accordingly, the permanent depression of the potentiometric surface within the void acts like a sink and will not permit water within the final void to flow outwards into the regional system (as illustrated in **Figure 4-20** and **Figure 4-21**);
- the equilibrium water level achieved within the final void (approximately 245 m RL) is low enough that at all times, there will be a flow of groundwater from the regional aquifers into the final void. This occurs even after waste rock is reshaped to direct some surface water runoff into the pit; and
- the local and regional aquifers will be replenished by rainfall on groundwater recharge zones, and are not expected to change in quality from pre-mining levels.

Post-mining water quality within all aquifers surrounding the Mining Leases is expected to remain the same as pre-mining water quality.

4.4.2.3 Impact on Groundwater Users – Post-Mining

Post-mining, the potential impacts on groundwater users are:

- water levels in 30 of the 99 landholder bores identified on properties surrounding the Mining Leases would be lowered by 2m or more from their pre-mining water levels;
- water levels within 26 of the 30 affected landholder bores would recover to their pre-mining levels; and
- the potentiometric surface beneath three properties surrounding the Mining Leases would have a permanent residual drawdown of more than 2 m compared to pre-mining levels. Maximum residual drawdown is predicted to be approximately 3.5m.

Lowering of pump intake valves within some bores may have been required during mine operation due to mining related aquifer drawdown. The pump intake valves of these impacted bores can potentially be raised again as the water level within individual bores begins to rise, post-mining.

The water quality within landholder bores is not expected to change from pre-mining conditions.

The Proponent will seek to reach mutually agreeable arrangements with affected neighbouring groundwater users for the provision of alterative supplies throughout the mine life, and after mine closure. The provision of alternative supplies from deepened bores and/or replacement bores would provide the most secure and most independent supply after mine closure.

4.5 Final Void Water Quality Assessment

The main features of the final landform after mining ceases will consist of waste rock dumps in the north-west and south-west, and a final void in the south (see **Figure 2-11**).

The void will collect and accumulate water only from groundwater ingress, direct rainfall into the void, and from overland surface flows from those slopes of the north-west waste dump draining into the void. All other surface flows from the vicinity of the final void will be diverted around the void, including Gowrie Creek, except for a flood that exceeds the design event for the levee bank as discussed in **Section 4.2.4.3**.

Final void water quality was predicted through the use of a mass balance model to estimate the Total Dissolved Solids (TDS) concentrations in the void and through qualitative description.

The final void water quality model was used to predict salinity levels in the final void over the long-term (**Figure 4-24**). It does not model the effects of flooding to the void, which would essentially add freshwater to the storage and have a diluting effect on the water quality. The inputs to the model are provided in **Appendix J**.

In the base-case scenario, the model predicts that upon mine closure the TDS of void water is expected to be about 500 mg/L, which reflects the dominance of groundwater inflows. Salinity increases at a relatively constant rate after equilibrium, taking approximately 340 years to reach the ANZECC (2000) stockwater guideline level of 2 500 mg/L and taking about 6 300 years to reach the seawater salinity levels (36 000 mg/L). The water is not expected to be suitable for potable water.

Worst-case scenario analysis shows an identical pattern but with stockwater TDS levels being achieved in 276 years and seawater salinity levels being reached in approximately 5 400 years.

The large volume of water predicted to occur within the void at equilibrium (approximately 140 000-150 000 ML) will provide buffering against significant fluctuations in salinity, which can occur in shallow voids where salinities can change significantly between years depending on whether it is a wet or dry year. In the long term, the final void is expected to contain waters that increase in salinity at a relatively constant rate over time.

Figure 4-24 Salinity of Final Void Waters Following Cessation of Mining

Continual turnover of void waters is likely, driven by evaporation at the water surface. Evaporation produces waters at the surface that are more saline (and therefore more dense) than waters below resulting in the more dense surface waters sinking through the water column toward the bottom of the void. This results in continual turnover of void waters and homogenous water quality through the water column.

Continual mixing of void waters has positive benefits for general water quality. Oxygen levels are anticipated to penetrate well below the surface, possibly to the bottom of the void. Nutrients, anions and cations are also likely to be well mixed through the water column.

This trend of continual mixing may be disrupted temporarily in years when there are significant freshwater inflows via incident rainfall on the pit or pit walls. In this situation, a less dense layer of freshwater can persist as a layer on top of the more dense saline waters in the void. This stratification may possibly last for up to a year until the freshwater layer is evaporated. During this time there may be gradual oxygen depletion in the bottom waters. There could also be the potential for algal blooms to occur on occasions.

4.6 Monitoring

4.6.1 Surface Water Resources

4.6.1.1 Surface Water Quality

The monitoring of flowing waters to be undertaken when water is released from the Mine Water Dam to Wolfang and/or Gowrie Creek is described in **Table 4-20**. The water sampling locations described in **Table 4-20** have been selected for flow event monitoring because they can generally be accessed during wet weather conditions.

Routine monitoring of key water storages within the Project site will be undertaken to provide information on the operation of the mine water management system. Locations and parameters to be monitored regularly are described in **Table 4-21**.

Table 4-20 Proposed Flow Event Surface Water Quality Monitoring Program

Location	Parameter
Release point from Mine Water Dam	pH, EC, turbidity, TDS, suspended solids, Sulphate, Total Alkalinity, Arsenic, Cadmium, Copper, Lead, Mercury and Selenium.
Wolfang Creek, upstream of the mine water dam release point (WCK10)	pH, EC, DO, turbidity, TDS, suspended solids, Ammonia, Nitrate as N, Total Nitrogen as N, Total Phosphorous as P, Sulphate, Total Alkalinity, Arsenic, Cadmium, Copper, Lead, Mercury and Selenium.
Gowrie Creek, upstream of the mine water dam release point (GCK10)	pH, EC, DO, turbidity, TDS, suspended solids, Ammonia, Nitrate as N, Total Nitrogen as N, Total Phosphorous as P, Sulphate, Total Alkalinity, Arsenic, Cadmium, Copper, Lead, Mercury and Selenium.
Wolfang Creek at the Gregory Highway Bridge Crossing (WCK30)	pH, EC, DO, turbidity, TDS, suspended solids, Ammonia, Nitrate as N, Total Nitrogen as N, Total Phosphorous as P, Sulphate, Total Alkalinity, Arsenic, Cadmium, Copper, Lead, Mercury and Selenium.

Table 4-21 Proposed Routine Surface Water Quality Monitoring Program

Location	Parameter	Frequency
Mine Water Dam	pH, EC, turbidity, TDS, suspended solids, Sulphate, Total Alkalinity, Arsenic, Cadmium, Copper, Lead, Mercury and Selenium.	Quarterly
Advance Dewatering Dam - release point	Electrical Conductivity, pH, Total Nitrogen, Ammonia, Total Phosphorus, copper	Quarterly

All sampling will be undertaken in accordance with the *Water Quality Sampling Manual, Third edition* (EPA, 1999). The frequency of monitoring and range of parameters analysed during flow and routine monitoring will be reviewed after the first two years of mine operation.

4.6.1.2 Geomorphology

Upon completion of the construction phase of the proposed diversion a quantitative monitoring and evaluation program will be put in place to ensure that the diversion is working as intended by the designer

The aim of the monitoring and evaluation program will to determine if problems are occurring, such as bank erosion. The program will follow the principals and procedures outlined in the Australian Coal Association Research Program (ACARP) Project “Monitoring and Evaluation Program for Bowen Basin River Diversions” (Project Number C9068). The two basic types of monitoring recommended in the ACARP project include:

- pre-determined frequency modelling which is where a certain timeframe is set down for routine monitoring; and
- event based monitoring which is usually undertaken after a certain design flood has passed down the diversion and is undertaken to check the survival of any waterway structures, including levees, and the stability of the bed and banks of the waterway.

More specifically, the Proponents propose that a combination of pre-determined frequency and event based monitoring be implemented at this site. A suggested combination could comprise sampling at the following intervals:

- pre-determined frequency at 1, 2, 5, 7 and 10 years after construction. A review should be conducted following the 10 year inspection to determine the ongoing frequency of monitoring; and
- event based monitoring at flood events greater than the 5 year ARI flood event. The height of this flood event can be predetermined and marked within the channel to make it easier to determine if the trigger event has been exceeded.

It is proposed that the level of monitoring for this site should be the bronze level (as defined in Rutherford *et al*., 2000) which includes unreplicated, controlled, sampling after implementation and qualitative evaluation. This should provide a moderate level of confidence in the outcomes required from the design of the waterway diversion.

A detailed monitoring program will be developed as part of the detail design of the waterway diversion.

4.6.2 Groundwater Resources

4.6.2.1 Mine Dewatering and Operational Mining Phase

A groundwater monitoring program will be undertaken during the operation of the dewatering borefield. The aim of monitoring will be to confirm the extent of impact that mine progression has on the surrounding groundwater environment.

Monitoring will provide early warning of any variation in response of the groundwater system to that predicted by the groundwater model. This will enable the Proponent to undertake mitigation measures to minimise impact on surrounding groundwater users.

It is proposed that a network of up to 23 additional monitoring locations will be progressively added to the existing monitoring network of 12 locations upon project approval. These bores will be installed in two phases:

- phase one will be installed prior to the installation and operation of advanced dewatering bores on site; and
- phase two bores will be installed within 12 months of project approval.

Proposed locations for monitoring sites are indicated in **Figure 4-25**. At each proposed location, separate monitoring bores will be installed within Tertiary basalt, Tertiary sediment, Permian sedimentary rock and Early Cambrian metamorphic rock units, depending upon which aquifers are present. Not all aquifers will be present at each location.

Groundwater level fluctuation and water chemistry monitoring will be undertaken of groundwater bores within major aquifers surrounding the Mining Leases (ie. Tertiary basalt, Tertiary sediment, Permian sedimentary rock and Early Cambrian metamorphic rock aquifers). The proposed operational phase groundwater monitoring program is as follows:

- near field monitoring –
  - water levels will be monitored on a monthly basis at 12 new monitoring sites (Near field 1 to 12) and 11 existing bore locations (WC6, WP1, WP2, WP3, WP4, WP5, WP6, WP7, WP9, WP10, and WP11) within 4 km of the Mining Leases boundary. Monitoring locations are illustrated on **Figure 4-25**. It is expected that many of these monitoring bores will detect a drop in water level within the first few years of the operational phase, hence they will be monitored on a monthly basis from onset of advance dewatering. Once drawdown within these bores is confirmed as matching model predictions, monitoring frequency will be reduced to a quaterly basis;
  - groundwater samples will be collected on an annual basis from each bore present at six of the ***near field*** monitoring locations (Near field 1, 4, 6, 8, 9 and 11). Locations for near field groundwater sample collection are illustrated in **Figure 4-25**. The total number of bores to be installed is unknown until drilling is conducted, as each site may intercept up to four separate aquifers. Groundwater samples will undergo laboratory analysis for pH, electrical conductivity, total dissolved solids, cations, anions, nutrients (Total Nitrogen, Ammonia, Total Phosphorous and Reactive Phosphorous) and selected metals (Arsenic, Cadmium, Copper, Lead, Mercury, Selenium and Zinc).

- regional monitoring:
  - water levels will initially be monitored on a quarterly basis at 11 new monitoring sites (Regional 1 to 11) and one existing bore (bore WC1). Each of these monitoring locations is more than 4 km from the Mining Leases and it is unlikely that these monitoring sites will ever detect impacts from groundwater extraction and are deliberately located outside of the predicted extent of impact to confirm this limit. The monitoring frequency of these bores will be reduced to a half-yearly basis during early years of mine operation once seasonal fluctuations have been analysed to confirm that negligible drawdown impacts occur in the first few years. Frequency of monitoring will be increased again to quarterly towards the end of mine life to monitor any possible late-stage drawdown influences; and
  - groundwater samples will be collected on an annual basis from each bore present at seven ***regional monitoring*** locations (Regional 1, 3, 5, 7, 8, 10 and 11). Locations for regional groundwater sample collection are illustrated in **Figure 4-25**. The total number of bores to be installed is unknown until drilling is conducted, as each site may intercept up to four separate aquifers. Groundwater samples will undergo laboratory analysis for pH, electrical conductivity, total dissolved solids, cations, anions, nutrients (Total Nitrogen, Ammonia, Total Phosphorous and Reactive Phosphorous) and selected metals (Arsenic, Cadmium, Copper, Lead, Mercury, Selenium and Zinc).

Monitoring results (water level and chemistry) will be entered into the existing RTCA groundwater database which will be regularly updated.

Table 4-22 Proposed Groundwater Monitoring Program

Parameter	Near Field Bores	Regional Bores	Frequency
Standing water level	Near field 1-12, WC6, WP1-7, WP9-11	Regional 1-11, WC1	Near field: Monthly then quarterly. Regional: Quarterly, then half yearly, then quarterly
pH, EC, TDS	Near field 1, 4, 6, 8, 9, 11	Regional 1, 3, 5, 7, 8, 10, 11	Annual
Cations, Anions	Near field 1, 4, 6, 8, 9, 11	Regional 1, 3, 5, 7, 8, 10, 11	Annual
Total Nitrogen, Ammonia, Total Phosphorous, Reactive Phosphorous	Near field 1, 4, 6, 8, 9, 11	Regional 1, 3, 5, 7, 8, 10, 11	Annual
Al, As, Cd, Cu, Pb, Hg, Se, Zn	Near field 1, 4, 6, 8, 9, 11	Regional 1, 3, 5, 7, 8, 10, 11	Annual

4.6.2.2 Post Closure

After mining has ceased and decommissioning and rehabilitation works are complete, the Proponent will seek to relinquish its Clermont Mining Leases. Prior to relinquishment, the Proponent will discuss with the parties with whom it has had alternative water supply arrangements the nature, scope and resourcing of an on-going groundwater monitoring programme. This programme may be a continuation of that outlined for operational mining, or an agreed variation, depending on circumstances at the time. It is anticipated that continuation of the agreed on-going programme would become a condition of Mining Lease relinquishment.

Post-mining groundwater monitoring will be undertaken within monitoring bores that were installed during the operational phase of the project.

Post-mining groundwater monitoring will be subject to detailed closure / relinquishment conditions. It is expected that by the end of the operational phase of the Project, the groundwater model for the region will be sophisticated enough (through incorporation of operational phase responses) to accurately predict long-term behaviour of the aquifer. This will assist the refinement of post-mining groundwater monitoring programs.