GeoTerra

DELTA COAL PTY LTD

CHAIN VALLEY COLLIERY
GROUNDWATER MANAGEMENT PLAN

CVC3-R4A
15 December 2020

GeoTerra Pty Ltd **ABN 82 117 674 941**

PO Box 220 Canterbury NSW 2193

Phone: 02 9787 9137 Fax: 02 9787 1874 Mobile 0417 003 502 Email: geoterra@iinet.net.au

Authorised on behalf of GeoTerra Pty Ltd:	
Name:	Andrew Dawkins
Signature:	
Position:	Principal Hydrogeologist

Date	Rev.	Comments
21.05.2020		Initial Draft
15.12.2020	A	Final

TABLE OF CONTENTS

1. INTRODUCTION 4

1.1 Objectives 5

1.2 Scope 6

1.3 Definitions 6

1.4 Limitations 6

2. LEGISLATION 8

2.1 Water Management Act 2000 8

2.2 State Groundwater Policy 8

2.2.1 Groundwater Quality Protection 9
2.2.2 Groundwater Dependent Ecosystems 9
2.2.3 Groundwater Quantity Protection 10

3. CURRENT AND PROPOSED OPERATIONS 11

3.1 Adjacent Workings 12

3.2 Predicted Subsidence 12

3.3 Rainfall and Evaporation 13

4. LOCAL GROUNDWATER SYSTEM 14

4.1 Alluvial Aquifers 15

4.2 Lake Macquarie Sediments 15

4.3 Shallow Bedrock 15

4.4 Deep Bedrock 15

4.5 Coal Seams 16

4.6 Structure and Intrusions 16

4.7 Private Bores Within or Adjacent to the Proposed Mining Area 17

4.8 Regional Groundwater Use 18

5. GROUNDWATER IMPACTS FROM PREVIOUS MINING 19

5.1 Wyee State Mine 19

5.2 Private Bores 20

5.3 Potable Mine Water Supply 20

5.4 Licensed Mine Water Discharges 20

5.5 Mine Water Pumping and Mine Groundwater Inflow 20

5.6 Mine Groundwater Quality 21

6. POTENTIAL GROUNDWATER IMPACTS 24
6.1 Hydraulic Connection to Lake Macquarie 24
6.2 Aquifer / Aquitard Interconnection 24
6.3 Regional Groundwater Depressurisation 25
6.4 Private Bore Yields and Serviceability 25
6.5 Groundwater Dependent Ecosystems 26
6.6 Groundwater Quality 26
6.7 Groundwater Seepage to or From Terrestrial Streams 27
6.8 Groundwater Inflow to Mine Workings 27

7. GROUNDWATER MONITORING PLAN 28
7.1 Mine Groundwater Inflow 28
7.2 Private Bore Water Levels 28
7.3 Groundwater Quality 29
7.3.1 Inactive Private Bores 29
7.3.2 Active Private Bores 29
7.4 Groundwater Contamination 30

8. GROUNDWATER ASSESSMENT CRITERIA AND TRIGGERS 31
8.1 Mine Water Extraction and Discharge 31
8.2 Private Bore Groundwater Levels 32
8.3 Private Bore Groundwater Quality 32

9. POTENTIAL GROUNDWATER AMELIORATIVE ACTIONS 33
9.1 Private Bore Yield 33
9.2 Private Bore Groundwater Quality 33

10. CONTINGENCIES 34

11. AUDIT AND REVIEW 34
11.1 Internal Audits 34
11.2 External Audits 35

12. RECORDS 35

13. RESPONSIBILITIES AND ACCOUNTABILITIES 35
13.1 General Manager 35
13.2 Environment and Community Coordinator 35
13.3 Hydrogeologist / Hydrologist 36

14. TRAINING 36

15. REPORTING 36
15.1 Annual Environmental Management Report 36

16. REFERENCES 37

FIGURES

Figure 1 Current and Proposed Workings and Private Bore Locations 7
Figure 2 Local Area Stratigraphy 14
Figure 3 Faulting in the Vicinity of MW S5 17
Figure 4 Annual Mine Dewatering Volumes 21
Figure 5 Mine Water Chemistry 23

TABLES

TABLE 1 Maximum Predicted Subsidence 12
TABLE 2 Maximum Observed Subsidence 13
TABLE 3 Rainfall and Evaporation Summary Data 13
TABLE 4 Registered Local Private Bores 18
TABLE 5 Water Chemistry - Major Ions 22
TABLE 6 Water Chemistry - Metals 22
TABLE 7 Mine Water Chemistry 22
TABLE 8 Suggested Producing Groundwater Bore Water Level Monitoring 29
TABLE 9 Suggested Producing groundwater Bore Water Quality Monitoring 30
TABLE 10 Groundwater Quality Monitoring Parameters 30
TABLE 11 Groundwater Chemistry Criteria (mg/L) 32

1. INTRODUCTION

This revised Groundwater Monitoring Program (GwMP) has been prepared in compliance with Schedule 3 (Condition 18D) of the Delta Coal Pty Ltd (DC) Chain Valley Colliery Extension Project Approval SSD 5465 for the addition of Miniwall S5.

Development Consent (SSD-5465 – as modified) was approved on 23 December 2013 which permits the current and proposed activities.

This report is to be read in conjunction with the Water Management Plan prepared for Chain Valley Colliery (Delta Coal, 2019).

This GwMP includes:

- a groundwater water quality and quantity monitoring program;
- trigger levels for mining impacts on groundwater systems;
- procedures to be followed in the event that monitoring of groundwater indicates an exceedance of trigger levels;
- measures to mitigate, remediate and/or compensate for identified impacts;
- a protocol for the notification of trigger level exceedances, and;
- a contingency plan where, in the event of adverse effects on groundwater quality and/or quantity due to mining impacts, Chain Valley Colliery will provide an equivalent supply until the affected supply is restored, or as agreed with the landowner and the NSW Department of Industry - Water (DPIE).

Groundwater related operations at Chain Valley Colliery include the:

- historic Great Northern and Wallarah seams bord and pillar workings;
- current Fassifern Seam development as well as miniwall workings; and
- water storage and management facilities owned and operated by Chain Valley Colliery.

Operation of the GwMP needs a high level of management input to operate Chain Valley Colliery within the relevant requirements and various water licences, particularly to ensure compliance with the water discharges authorised by Environment Protection Licence (EPL) 1770.

An essential part of the plan is monitoring of all groundwater inflows and extraction into and out of the underground with reliable flow meters, as well as monitoring of groundwater levels and water quality in private bores.

This information is necessary for periodical reviews of the groundwater management system and to support any updates/changes to licences.

The proposed mitigation measures minimise and manage the impacts of any potential adverse effects on local aquifers within the GwMP area.

The proposed mitigation measures minimise, where possible, the impacts of the proposed mining on the various groundwater sources, aquifers or groundwater dependent ecosystems that may be present in the Project Area.

1.1 Objectives

The objective of the GwMP is to operate Chain Valley Colliery so that the subsurface mining operations will be conducted in a manner which minimises the potential impacts on groundwater flow and quality, aquifer integrity, groundwater dependent ecosystems and other off-site groundwater related impacts.

In order to achieve this goal, the GwMP will be used to establish procedures to:

- measure, control, mitigate and repair potential impacts that could, or do, occur to the groundwater system overlying Chain Valley Colliery; and
- identify, measure, minimise or where possible, avoid potential significant adverse impacts that can result from mining and subsidence on the groundwater systems within the Project Area.

In addition, the GwMP will be used to:

- monitor groundwater system changes in relation to the leaseholder's mining activities;
- assess the pre and post-mining condition of groundwater systems in the lease area;
- ensure all relevant groundwater criteria are met;
- minimise and manage any impacts on the availability of groundwater to potentially impacted residents, landholders or other groundwater users;
- minimise adverse changes on groundwater dependent ecosystems, where present;
- provide a forum to record and discuss mining impacts; and
- provide an annual report on the monitoring, observations and actions conducted within the preceding 12 months to the Department of Planning, Industry and Environment (DPIE).

These objectives will be met by:

- monitoring groundwater seepage and groundwater quality in the workings during mining within the mine lease area;
- installation of water monitoring appliance(s) to measure pumped water volumes to and from the mine workings. These appliances will be maintained in good working order. If required the mine will supply a test certificate to certify the current accuracy of the appliance(s) furnished by the manufacturer or by some duly qualified person or organisation. The mine water pumping records will be maintained and supplied to DPIE at the end of the water year;
- ensuring that any tail-water drainage will not be allowed to discharge onto adjoining roads, crown land or other lands, or into any unauthorised stream, or any aquifer, by surface or subsurface drains or pipes or any other means without appropriate approval;
- ensuring that any groundwater extracted from the works will not be discharged into any watercourse or source of groundwater except in compliance with the Protection of the Environment Operations Act (1997);
- any works used for the purpose of conveying, distributing or storing groundwater from the works will not be constructed or installed so as to obstruct the free passage of floodwaters flowing in, to or from a river or lake;
- all groundwater extracted from the works will be used or applied only on such land, and for such purposes, as approved by DPIE, and;
- providing a forum to report, discuss and record impacts to the groundwater system that involves the Chain Valley Colliery, stakeholders and DPIE, as required.

1.2 Scope

The GwMP is to be used to protect, monitor and manage the condition of the groundwater system within the Chain Valley Colliery lease area that may potentially be impacted due to coal mining and mine subsidence.

It applies to persons employed or engaged by Chain Valley Colliery when carrying out activities described by this plan.

This GwMP is to be read in conjunction with the current version of the Water Management Plan (WMP) which outlines the monitoring and management of specific factors relating to surface water and groundwater issues due to the predicted subsidence.

All other water management components not directly related to the GwMP are contained as part of the WMP.

The plan covers mining until completion of Domains 1 and 2, although the plan may be used beyond that benchmark with appropriate modification.

1.3 Definitions

For the purpose of this document, the area addressed in the GwMP is defined as the groundwater systems within the Chain Valley Colliery project approval area. The main features in the GwMP area shown in **Figure 1** include the:

- current Chain Valley Colliery workings in the Fassifern Seam;
- the proposed extraction within Domains 1 and 2; and
- the current and proposed extraction of Miniwalls S2, S3, S4 and S5.

1.4 Limitations

This GwMP is based on current monitoring data and the proposed and approved operational aspects relating to Chain Valley Colliery. The relevant groundwater features have been identified from:

- existing studies;
- data supplied by Chain Valley Colliery representatives; and
- associated consultant's reports in the Lake Macquarie area.

The impacts of mining on the groundwater system have been assessed in previous studies (see references). However, it is recognised that prediction and assessment of changes to, and effects from, operation of the Colliery on the groundwater system can be relied upon only to a certain extent.

The groundwater study prepared for the Chain Valley Colliery Mining Extension 1 Groundwater Assessment (GeoTerra, 2013) determined there is a low potential for the mine's impacts on the groundwater system to exceed the predictions and assessments. However, the possibility of impacts above predictions has been considered in this plan.

The plan will not necessarily prevent impacts from the proposed mining, but does identify appropriate procedures to manage the impacts within tolerable limits and identifies procedures that can be followed should evidence of increased impacts and unacceptable risk emerge.

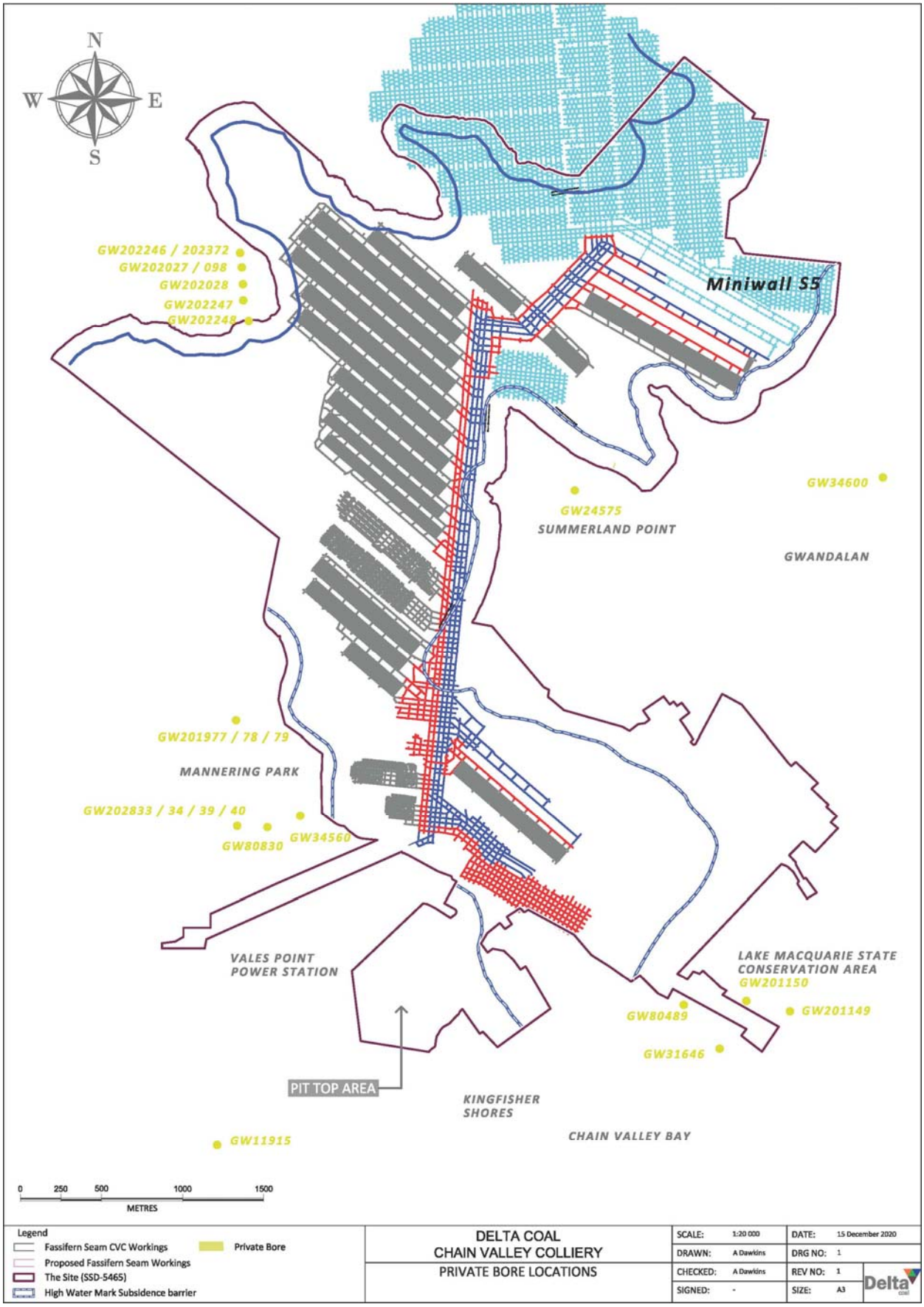

Figure 1 Current and Proposed Workings and Private Bore Locations

2. LEGISLATION

The following sub-sections outline NSW statutory requirements that apply to the mining operation with respect to groundwater.

2.1 Water Management Act 2000

The key legislation for the management of water in the project area is the *Water Management Act 2000* (the Act), which regulates water use for rivers and aquifers where water sharing plans have commenced.

Under the Act, DPIE has prepared a range of statutory water management plans covering aspects such as water sharing, water use, drainage management and floodplain management. In NSW, 36 water sharing plans have commenced, covering 80 percent of water currently extracted. The plans cover most of the regulated river systems (those controlled by major dams for rural water supplies), a number of unregulated river systems and the major inland alluvial aquifers.

The project area is located in the *South Lake Macquarie Water Source* section of the Water Sharing Plan - Hunter unregulated water sources.

The object of the Act is the sustainable and integrated management of the State's water for the benefit of both present and future generations. The Act provides arrangements for controlling land-based activities that affect the quality and quantity of the State's water resources. It provides for four types of approval:

- water use approvals – authorise the use of water at a specified location for a particular purpose, for up to ten years;
- water management work approvals;
- controlled activity approvals; and
- aquifer interference activity approvals – authorise the holder to conduct activities that affect the aquifer. This approval is for activities that intersect groundwater, other than water supply bores and may be issued for up to ten years.

For controlled activities and aquifer interference activities, the Act requires that the activities avoid or minimise impacts on the water resource and land degradation, and where possible the land must be rehabilitated.

2.2 State Groundwater Policy

The *NSW State Groundwater Policy* (Framework Document) was adopted in 1997 and aims to manage the State's groundwater resources to sustain their environmental, social and economic uses. The policy has three component parts:

- The *NSW Groundwater Quality Protection Policy*, adopted in December 1998;
- The *NSW State Groundwater Dependent Ecosystems Policy*, adopted in 2002; and
- The *NSW Groundwater Quantity Management Policy*.

2.2.1 Groundwater Quality Protection

The *NSW Groundwater Quality Protection Policy* (Department of Land and Water Conservation, 1998), states that the objectives of the policy will be achieved by applying the management principles listed below.

- all groundwater systems should be managed such that their most sensitive identified beneficial use (or environmental value) is maintained;
- town water supplies should be afforded special protection against contamination;
- groundwater pollution should be prevented so that future remediation is not required;
- for new developments, the scale and scope of work required to demonstrate adequate groundwater protection shall be commensurate with the risk the development poses to a groundwater system and the value of the groundwater resource;
- a groundwater pumper shall bear the responsibility for environmental damage or degradation caused by using groundwater that is incompatible with soil, vegetation and receiving waters;
- groundwater dependent ecosystems will be afforded protection;
- groundwater quality protection should be integrated with the management of groundwater quality;
- the cumulative impacts of developments on groundwater quality should be recognised by all those who manage, use, or impact on the resource; and
- where possible and practical, environmentally degraded areas should be rehabilitated and their ecosystem support functions restored.

2.2.2 Groundwater Dependent Ecosystems

The *NSW State Groundwater Dependent Ecosystems Policy* (Department of Land and Water Conservation, 2002) is specifically designed to protect valuable ecosystems which rely on groundwater for survival so that, wherever possible, the ecological processes and biodiversity of these dependent ecosystems are maintained or restored for the benefit of present and future generations. The policy defines Groundwater Dependent Ecosystems (GDEs), as *"communities of plants, animals and other organisms whose extent and life processes are dependent on groundwater".*

Five management principles establish a framework by which groundwater is managed in ways that ensure, whenever possible, that ecological processes in dependent ecosystems are maintained or restored. A summary of the principles follows:

- GDEs can have important values. Threats should be identified and action taken to protect them;
- groundwater extractions should be managed within the sustainable yield of aquifers;
- priority should be given to ensure that sufficient groundwater is available at all time to identified GDEs;
- where scientific knowledge is lacking, the precautionary principle should be applied to protect GDEs; and
- planning, approval and management of developments should aim to minimise adverse effects on groundwater by maintaining natural patterns, not polluting or causing changes to groundwater quality and rehabilitating degraded groundwater systems.

2.2.3 Groundwater Quantity Protection

The objectives of managing groundwater quantity in NSW are to:

- achieve the efficient, equitable and sustainable use of the State's groundwater;
- prevent, halt and reverse degradation of the State's groundwater and/or its dependent ecosystems;
- provide opportunities for development which generate the most cultural, social and economic benefits to the community, region, state and nation, within the context of environmental sustainability; and
- involve the community in the management of groundwater resources.

3. CURRENT AND PROPOSED OPERATIONS

Chain Valley Colliery is an underground coal mine operated by Delta Coal Pty Ltd (Delta Coal).

The Colliery is located in the Newcastle Coalfields at the southern end of Lake Macquarie in NSW, and is approximately 60 kilometres south of Newcastle, within the Swansea-North Entrance Mine Subsidence District.

The project area incorporates the relatively flat pit top area, existing ventilation shaft and fan site on Summerland Point, as well as foreshore areas and Lake Macquarie.

The terrestrial land within the GwMP area is gently undulating and drains to Lake Macquarie.

Chain Valley Colliery commenced operation in the 1960's extracting coal from the Wallarah seam, the Great Northern Seam and the Fassifern Seam, and currently conducts mining within leases ML 1051, CCL 721 and ML 1632.

The current Fassifern Seam Miniwalls are located underneath Lake Macquarie, within and to the north of Chain Valley Bay.

The mine has completed extraction of Miniwalls 1 to 12 (MW1 to MW12) and has an approved Extraction Plan for Miniwalls N1 and S1, S2, S3 and S4 in the Fassifern Seam.

At the time of writing, the Chain Valley Colliery has completed miniwall S2.

No current or proposed secondary extraction underlies any terrestrial based surface water catchments, with all secondary extraction proposed to be underneath the saline, tidal region of Lake Macquarie.

Chain Valley Colliery currently has Development Consent (SSD-5465 – as modified) for:

- extraction of up to a maximum of 2.1 million tonnes per annum until 31 December 2027 through continued mining via first workings and miniwall methods within the Fassifern Seam;
- continued coal transport for the surface facilities site;
- continued use of the existing surface facilities, and;
- continuation of passive underground activities within the old workings of the Wallarah seam, Great Northern seam and the Fassifern Seam.

The approved mining area is approximately 200m below the sediments of Lake Macquarie, within a boundary set to exclude secondary extraction within the High Water Mark Subsidence Barrier or the Seagrass Protection Barrier**.**

Bord and pillar mining was commenced in the Fassifern Seam in 2006 and secondary extraction in the form of miniwall mining method in the Fassifern Seam commenced in 2011.

The S3 miniwall panel is being mined at 97m wide (rib to rib) with a 40m wide inter-panel pillar, whilst the proposed miniwall panels S4 and S5 will have the same width.

These panel widths are significantly less than previously proposed for Chain Valley and adjacent mines – for example, at Wyee Colliery Longwalls 17 to 21 were up to 150m wide, and were extracted between 150m and 180m below surface.

Historically, Chain Valley Colliery has mined within the Wallarah and Great Northern seams to the east with via bord and pillar methods, while to the south west and west Wyee State Mine (now named Mannering Colliery) has mined the Great Northern and Fassifern seams using bord and pillar and longwall extraction.

Mining within the Wallarah and Great Northern Seams will not be undertaken as part of the Project.

The maximum water depth within the proposed mining areas is greater than 5m, whilst sediment on the bottom of the lake is less than 5m thick over Miniwall S5.

Above the Fassifern Seam over Miniwall S5, overburden (including the lake sediments), ranges from 144 - 161m with a rock cover thickness of 139 – 157m (Strata^2, 2020).

The maximum height of connective fracturing is predicted to be between 79 to 82m for Miniwall S5 according to the Ditton and Merrick (2014) approach, however, where the spanning influence of the 26 – 30m thick Teralba conglomerate is factored in, the potential height ranges from 45 to 50m above the workings (Strata^2, 2020).

3.1 Adjacent Workings

Chain Valley Colliery is entirely surrounded by the existing Mannering, Myuna and Wallarah Collieries as well as by the historic Newvale and Moonee Collieries.

Mannering Colliery (formerly the Wyee State Mine), has conducted longwall mining in the Great Northern and Fassifern seams since the 1960s. Extraction continued until 2002, when mining became uneconomic. The mine was temporarily shut down until 2004 when it was reopened by Centennial Coal. Since 2004, mining progressed in the Fassifern Seam using bord and pillar methods.

The Myuna Colliery commenced operation in 1981 and is currently mining the Fassifern Seam via bord and pillar techniques.

Wallarah Colliery operated from 1979 until 2002, when it was placed under care and maintenance.

Munmorah, Mandalong and Cooranbong Collieries are also nearby, but are not immediately adjacent to the Chain Valley Colliery holding boundary.

3.2 Predicted Subsidence

The maximum subsidence after completion of mining will be located under Lake Macquarie, with the 20mm subsidence line to be contained within the lake high water mark (Strata^2, 2020).

The maximum predicted subsidence, tilts and strains over the proposed workings (assuming a 170m depth of cover) are summarised in **Table 1**.

TABLE 1 Maximum Predicted Subsidence

Parameter	After Extraction of Miniwall S5
Vertical subsidence	350 mm
Tilt	5 mm/m
Strain (Compressive and Tensile)	2 mm/m

To date, the maximum subsidence has been observed as summarised in **Table 2**.

TABLE 2 Maximum Observed Subsidence

Location	Maximum Subsidence (m)
MW1	0.20
MW2	0.40
MW3	0.70
MW4	0.22
MW5	0.46
MW6	0.80
MW7	0.90
MW8	1.00
MW9	1.20
MW10	0.90
MW11	0.60
MW12	0.30
CVB1	0.45
MW S1	<0.1
MW N1	<0.1
MW S2	<0.1
MW S3	<0.15

It is predicted there will be no observable subsidence at the lake foreshore, lake high water mark, or the sea grass beds (Strata[2], 2020).

3.3 Rainfall and Evaporation

Analysis of climate data from the Bureau of Meteorology (BoM) weather station at Peats Ridge indicates the following rainfall data as shown in **Table 3**.

TABLE 3 Rainfall and Evaporation Summary Data

	Rainfall (mm/year)	Evaporation (mm/year)
Maximum	2186	1420
90th Percentile	1685	1247
75th Percentile	1418	1210
Median	1226	1170
20th Percentile	902	1090
Minimum	567	410

4. LOCAL GROUNDWATER SYSTEM

For management purposes, groundwater within the GwMP area has been divided into the following classes:

- **(Mine water**) groundwater and town water that is pumped into or out of the underground workings;
- (**Groundwater**) water contained within strata overlying the mine workings; and
- (**Seeps and springs**) groundwater that discharges to surface water catchments within the project area.

Groundwater flows from the "terrestrial" recharge areas, outside of Lake Macquarie, as well as from the saline waters of Lake Macquarie into the overburden under a regional hydraulic gradient, with dominantly horizontal confined flow along discrete discontinuities and fractures within bedding planes, and / or above fine grained, relatively impermeable strata within the overburden sequence.

The overburden generally contains low yielding aquifers with low hydraulic conductivities. A schematic of the stratigraphic sequence is shown in **Figure 2.**

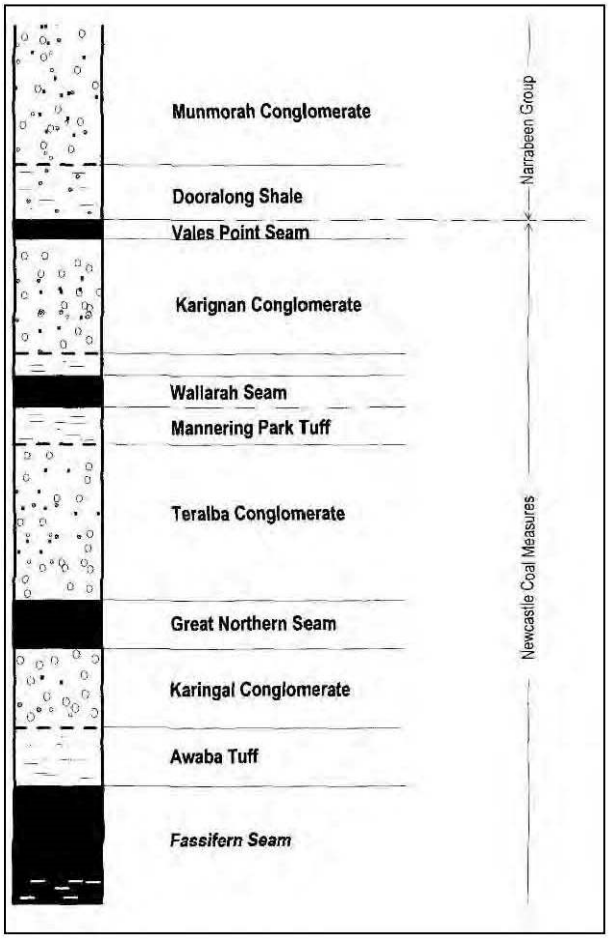

Figure 2 Local Area Stratigraphy

4.1 Alluvial Aquifers

Quaternary to recent alluvial terrestrial sediments comprising sand, gravel, clay and silt are associated with creeks and drainage channels in the local area, to the east, west and south on the shores of Lake Macquarie.

Alluvium in the vicinity of the project area is likely to be present associated with the drainage lines which discharge to Lake Macquarie.

No data is available for the thickness or lithology of alluvium within the project area. However, it is anticipated, if present, to be thin, with limited aerial extent, and no significant water storage or transmitting capacity.

Alluvial sediments within the "terrestrial" areas, outside of the project area, are generally too shallow and limited in extent to be used for groundwater supply.

4.2 Lake Macquarie Sediments

Sediments in the vicinity of MWS2 – S5 within Lake Macquarie consist of unconsolidated sands, clays, silts and gravels from 5 - 23m thick.

4.3 Shallow Bedrock

The shallow bedrock comprises weathered bedrock which potentially contains discontinuous perched aquifers. These have developed at the interface between the soil and bedrock and along zones of locally increased permeabilities caused by weathering of bedrock and faulting.

The depth and permeability of any aquifers is likely to be dependent on the depth of weathering and the extent and frequency of any permeable fracture systems.

Recharge to the shallow bedrock aquifer is primarily through rainfall infiltration, with some infiltration into the underlying basement through fractures, joints and faults.

4.4 Deep Bedrock

The Newcastle Coal Measures are overlain by the Munmorah Conglomerate and the Dooralong Shale of the Triassic Narrabeen Group which comprise the majority of the overburden.

The Munmorah Conglomerate extends to a depth of approximately 120m in the vicinity of the project area and comprises mostly quartz-lithic sandstone interbedded with pebble conglomerate.

The Dooralong Shale is up 20m thick and comprises cross-bedded sandstone intercalated with siltstone and claystone (Forster and Enever, 1992).

Fractured bedrock aquifers would be present within the Narrabeen Group and the Newcastle Coal Measures with discrete water yielding horizons associated with zones of increased permeability i.e. faults and the coal seams.

The overburden and interburden is a low yielding sequence of essentially dry conglomerates and shales.

Joints and fractures associated with fractured bedrock systems tend to be laterally and vertically discontinuous, resulting in poor hydraulic connection and low groundwater yields.

Forster and Enever (1992) state that "*neither the Narrabeen Group nor the Newcastle Coal Measures contain any significant quantities of groundwater and their permeabilities are known to be generally low (<10-7 m/s).*

Any permeable zones which do occur are usually due to jointing, faulting and shearing on bedding planes.

Because of the extremely low permeability of the rock substance, groundwater flow through the overburden strata is almost exclusively by interconnecting defects such as joints and bedding.

For this reason, coal seams with their interconnecting cleat and joint patterns are often found to be 'aquifers' relative to the surrounding strata. Despite this, most underground coal mines on the Central Coast are quite dry, and rarely have any major groundwater problems."

Groundwater in the deep bedrock aquifer is of poor quality with salinity levels ranging from 3000 to 16,000 µS/cm.

Recharge to the deep bedrock aquifer is generally from infiltration of rainfall from overlying aquifers and the flow direction is expected to reflect the local topography.

4.5 Coal Seams

The coal deposits historically or currently mined in the area include the Wallarah, Great Northern and Fassifern seams of the Newcastle Coal Measures which are generally interbedded with tuffaceous claystone.

The coal seams generally have a low primary or inter-granular porosity and permeability, with bedding planes, joints, fractures and cleating imparting an enhanced secondary permeability.

The 4.5 – 5.5m thick Fassifern Seam underlies the Wallarah and Great Northern seams within the project area, and lies between 139 - 157m below surface, with a proposed mining height of up to 3.5m.

4.6 Structure and Intrusions

The overburden dips at approximately two degrees to the south-west.

Superimposed on the regional dip is the Macquarie Syncline, with an axis that runs through the Chain Valley Colliery holding, along with associated faulting and igneous intrusions.

Mapped and inferred geological structures in the project area indicate that MW S5 is expected to extract through the following inferred geological structures:

- at the inbye end, an igneous dyke up to 2m thick, and;
- in the outbye half of the panel, a normal fault with a throw of <1m.

There is also an inferred 3m fault at the outbye end of TG S5, but this is not projected to traverse the MW S5 extraction area.

The fault plane will almost certainly extend upwards through the Fractured and Constrained Zones. However, given that:

- voussoir beam analysis suggests that such a feature would not appreciably impact on the spanning ability of the Teralba Conglomerate; and
- the favourable experiences from previous extraction panels with much greater exposure to major structures,

this fault is considered to be of no material consequence.

Figure 3 shows the major structural features, based on in-seam drilling, mapping in adjacent areas / seams and exploration drilling results. The MW S2 to S4 panels are orientated at 119°, rather than the 134° of earlier CVC panels which is more favourable with respect to the dominant 131° structural direction.

Overall, the structural environment is considered to have no significant adverse implications for S5 panel subsidence and sub-surface fracturing.

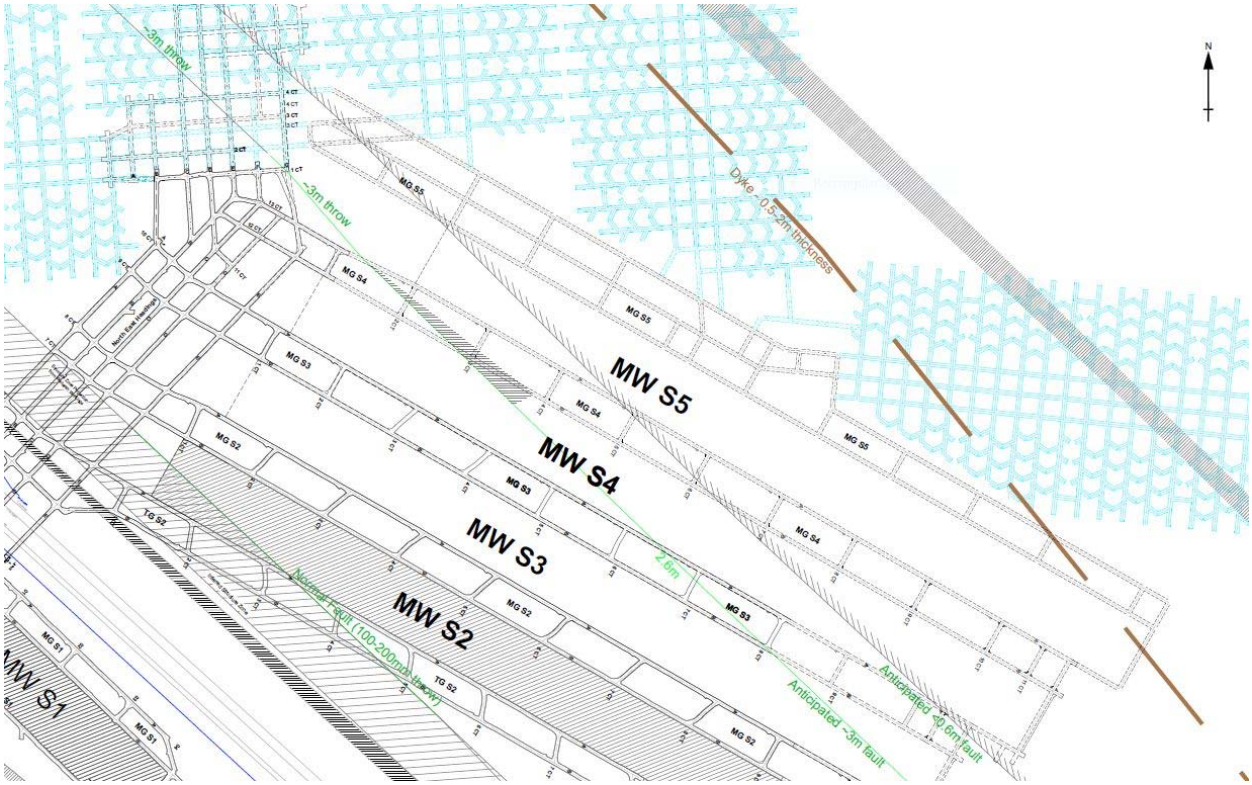

Figure 3 Faulting in the Vicinity of MW S5

4.7 Private Bores Within or Adjacent to the Proposed Mining Area

Twenty three DPIE registered bores are (or were) located within or near the GwMP area as shown in **Figure 1** and **Table 4**.

From the available data, the majority of bores are completed in shallow (<18.3) meters below ground level (mbgl) sandy alluvium with one coal exploration bore converted for use as a domestic water supply (GW31646).

Many shallow (<7 mbgl) deep test bores are present in the area, along with some shallow (<7.2 mbgl) monitoring bores.

Most of the deeper remnant private bores in the GwMP area are potentially used for domestic garden or limited irrigation water supply.

Where the data is available from the DPIE records, groundwater has been obtained from the shallow sandy alluvial / colluvial aquifers with low to moderate yields ranging from 0.13 L/sec to 1.50 L/sec.

TABLE 4 Registered Local Private Bores

GW	E	N	Drilled	Depth (m)	SWL (m)	Aquifer (mbgl)	YIELD (L/s)	Purpose	Bore Currency
11915	363007	6329604	-	5.4	-	-	-	Poultry	no response
24575	365969	6332788	1965	15.2	-	-	-	Domestic	no response
31646	366742	6329317	1960	277.5	3.0	3.0 – 10.6	0.13	Dom. / Coal Explore	not present
34560	364130	6330883	1970	18.3	5.5	5.5	-	Domestic	not present
34600	367678	6332873	1971	61.0	5.7	18.2	0.06	Waste disposal	-
80489	366441	6329674	2003	-	-	-	-	Domestic	no internal access
80830	363757	6330850	2004	-	-	-	-	Test bore	capped / covered
201149	367104	6329608	2006	4.0	1.0	1.0 – 4.0	1.50	Irrigation spear	no response
201150	366840	6329640	2006	4.0	1.0	1.0 – 4.0	1.50	Irrigation spear	no response
201977	363730	6331388	2008	7.1	6.0	6.0 – 7.0	-	Monitoring	-
201978	363712	6331391	2008	7.1	6.0	6.0 – 7.0	-	Monitoring	-
201979	363704	6331405	2008	7.2	6.0	6.0 – 7.0	-	Monitoring	-
202027	363829	6334141	2007	3.7	-	-	-	Test bore	not present
202028	363872	6334034	2007	5.5	1.6	-	-	Test bore	not present
202098	363829	6334141	2007	4.0	0.8	-	-	Test bore	not present
202246	363834	6334174	2007	3.5	1.2	0.6 – 3.5	-	Test bore	not present
202247	363899	6333964	2007	5.0	3.6	2.0 – 5.1	-	Test bore	not present
202248	363918	6333881	2007	5.0	-	2.0 – 5.0	-	Test bore	not present
202372	363834	6334174	2007	4.0	-	-	-	Test bore	not present
202833	363568	6330876	2013	6.5	2.50	2.5 – 3.5	-	Monitoring bore	-
202834	363563	6330861	2013	6.5	2.50	2.5 – 3.5	-	Monitoring bore	-
202839	363574	6330883	2013	7.2	2.5	2.5 - 3.5	-	Monitoring bore	-
202840	363573	6330859	2013	5	2.0	2.0 – 3.0	-	Monitoring bore	-

Note: - no data available SWL = standing water level

4.8 Regional Groundwater Use

Registered bores in the vicinity of the GwMP area are generally installed into the Munmorah Conglomerate to a maximum depth of 61m, with the majority of bores installed to less than 30m.

Groundwater yields are generally less than 1 L/s, with one bore reporting a yield of 5 L/s.

The authorised uses of the bores include:

- stock watering;
- poultry;
- industrial;
- domestic; and
- waste disposal.

While it is recognised that not all existing bores are likely to be registered, the database gives an indication of groundwater usage in the area.

Overall, it is concluded that the importance and reliance on groundwater by local landowners and residents is limited.

5. GROUNDWATER IMPACTS FROM PREVIOUS MINING

The Chain Valley Mine is surrounded by other collieries which have been extracting coal from as early as the 1940s using both longwall and bord and pillar methods.

Historical and current mining operations have resulted in extensive dewatering and depressurisation within and overlying the extracted coal seams.

Water is pumped out of the mines which results in a lowering of the potentiometric surface within the overlying aquifers.

Due to the extent of mining in the region, the subsidence effects would have partly depressurised the overburden.

5.1 Wyee State Mine

An extensive study by Forster and Enever (1992) at the adjacent Wyee State Mine (now called Mannering Colliery) assessed the impact of 150 m wide longwall mining on the hydrogeological properties of the overburden.

The study assessed that longwall mining of the Great Northern Seam resulted in measurable changes in the hydrogeological properties over a large proportion of the overburden as a result of the redistribution of stresses. The changes reported for the overburden were:

- **Upper Strata** (more than 115 m above the Great Northern Seam) –the hydrogeological properties of the strata after mining were generally similar to those measured prior to mining. Some strata reported a temporary drop in piezometric pressure which recovered soon after the completion of mining in that area.
- **Intermediate Strata** (65 to 115 m above the Great Northern Seam) – experienced significant permanent piezometric pressure increases after mining. The cause of the increase in pressure was uncertain, however it was concluded that *"since the intermediate strata have not lost piezometric pressure, it is certain that significant vertical drainage has not occurred from these strata and they have formed an effective barrier against vertical hydraulic connection between the surface and the mine."*
- **Lower Strata** (less than 65 m above the Great Northern Seam) – showed significant increased permeability and permanent decreases in piezometric pressure which indicated that significant cracking has occurred and allowed partial drainage into the workings.

Although measured changes in the lower strata indicate hydraulic connection was generated and groundwater seepage to the workings had occurred, the changes in the intermediate and upper strata was not significant, and were due to minor strata movements and the formation of fractures that were vertically discontinuous.

It was assessed that the intermediate and upper strata would form a barrier to vertical drainage and that aquifers from 65 – 115 m above the workings should not be hydraulically vertically connected to the workings, and should not be drained as a result of subsidence.

Aquifers greater than 115 m above the mine workings should not be impacted at all.

It should be noted that the subsidence studied over the Wyee State Mine related to 150 m wide longwalls, whilst the maximum width of the proposed Chain Valley miniwalls is 97 m, with 30.6 m wide pillars. As a result, the predicted subsidence and the height of fracturing over the proposed workings will be significantly less than was observed over the Wyee State Mine longwalls.

5.2 Private Bores

No adverse changes to bore yields, pumping flow duration or groundwater quality have been observed or reported in private bores within the GwMP area.

5.3 Potable Mine Water Supply

The mine has a potable water supply connection from the Wyong Council town-water system.

Historically, a range of 132 – 162 ML/year of potable water is supplied to Chain Valley Colliery, of which approximately 15% is used for pit top operations and 85% is used for dust suppression in the underground.

As required by Schedule 3, Condition 18(b) of SSD-5465, practical measures to minimise potable water consumption and maximise recycled water use have been implemented and continue to be investigated by Delta Coal, as discussed in the associated WMP. However, the use of non-potable water in all operational activities is not possible due to its quality, work health and safety and equipment requirements.

5.4 Licensed Mine Water Discharges

The discharge of mine water from the sedimentation and pollution control ponds is licensed under the *Protection of the Environment Operations Act* 1997 by the Environment Protection Authority (EPA).

Under EPL No. 1770 there is a single licensed discharge point for Chain Valley Colliery (LDP1), which has a maximum discharge volume of 12,161 kL/day.

The Colliery obtained a 4,443 ML/year groundwater licence (20BL173107) on the 12th March 2013 under the *Water Act, 1912* to enable water to be pumped from the underground workings to the sedimentation and pollution control ponds at the pit top.

5.5 Mine Water Pumping and Mine Groundwater Inflow

Historic data indicates that 1,914 – 2,536.4 ML/year of mine water has been extracted via two pumps in the Great Northern Seam workings sump, with a reduction in extraction volumes being evident over the last 3 years as shown in **Figure 4**.

The net groundwater seepage into the workings is estimated from the difference between the annual potable water intake and the annual water volume extracted from the underground workings.

The latest annual groundwater make (2019) from the mine is estimated at 1,913 ML/yr, or 5.24 ML/day.

Temporary increases in groundwater inflows to the mine have been reported in the vicinity of faults and associated fractures. The increases in inflow are usually short lived as the structures associated with fractured bedrock systems tend to be laterally and vertically discontinuous, resulting in poor hydraulic connection and have low groundwater yields (GeoTerra, 2013).

In general, the Fassifern Seam has to date been the driest seam, whilst mining of the overlying Wallarah Seam has been conducted without major adverse impacts to the overlying aquifers or inflow of water from Lake Macquarie (GeoTerra, 2013).

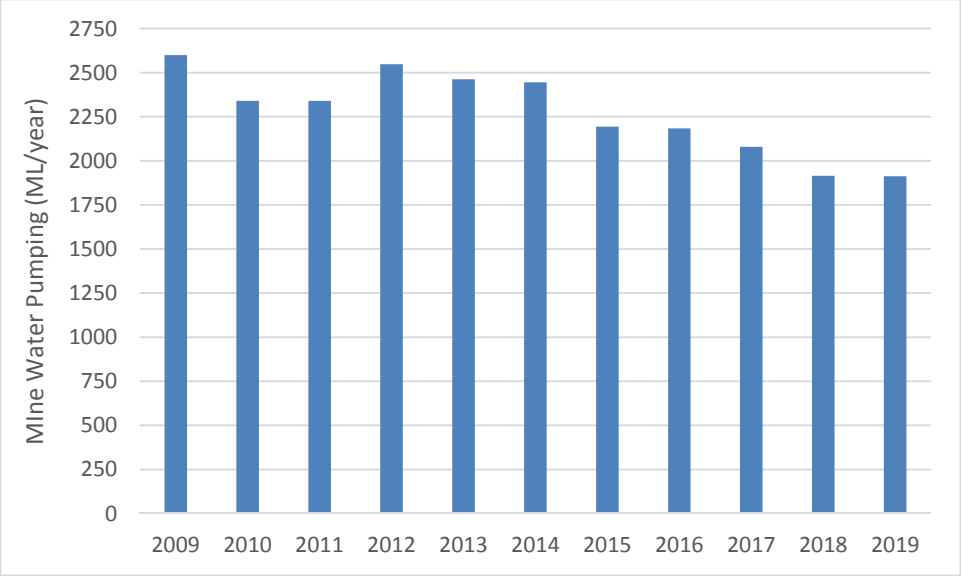

Figure 4 Annual Mine Dewatering Volumes

5.6 Mine Groundwater Quality

Groundwater monitored within the current and historic underground mining areas in the Chain Valley Colliery indicates the inflow water is brackish to relatively saline in subsided areas over the Great Northern Seam workings (11,800 – 28,200 mg/L) with a circum-neutral to mildly alkaline pH (7.30 – 7.76).

Groundwater seepage from a dyke at the northern end of the current Fassifern Seam workings, over the unsubsided main headings, had a brackish salinity of 2,390 mg/L and an alkaline pH of 8.63 as shown in **Tables 5** and **6**.

The data indicates that groundwater within the underground is significantly above the ANZECC (2000) water quality criteria (the default trigger values for physical & chemical stressors in SE Austtralian lowland rivers and 95% protection of freshwater species) for:

- pH (Fassifern dyke);
- electrolytical conductivity (all samples);
- total nitrogen (all samples);
- total phosphorous (Fassifern dyke); as well as,
- filterable copper (Great Northern Seam sump , Fassifern dyke); and
- filterable zinc (all samples except GNS2).

The exceedance in the mine water seepage depends on the guideline applied for the end use of the water.

The groundwater seepage is not generally suitable for potable, livestock or irrigation use, but is suitable for discharge under EPL 1770.

TABLE 5 Water Chemistry - Major Ions

	pH	EC (uS/cm)	TDS	Na	Ca	K	Mg	Cl	F	HCO3	SO4	Total P	Total N	DOC
ANZECC 2000	6.5 -8.0	2,200	-	-	-	-	-	-	-	-	-	0.05	0.5	-
Karignan Ck	6.93	185	100	29	2.2	2.3	3.5	54	0.10	10	6	**0.15**	**0.6**	17
Chain Valley Bay	7.64	47,300	36,100	10500	470	470	1100	19400	1.3	125	2200	**0.06**	0.4	<1
GNS SUMP	7.48	35,600	23,200	7640	590	125	690	13600	0.25	360	1200	0.04	**2.3**	2
GNS1 (roof)	7.30	40,400	28,200	7980	730	80	840	15600	0.47	435	1320	<0.01	**3.4**	<1
GNS2 (pond)	7.76	19,500	11,800	3950	140	38	230	6730	0.57	385	250	0.02	**0.6**	3
Fassifern dyke	**8.63**	3,500	2,390	925	1.9	9.1	2.1	310	5.6	2040	7	**0.65**	**4.1**	3

NOTE: all values in mg/L
samples collected 22/6/2012

TABLE 6 Water Chemistry - Metals

	Fe(T)	Fe	Mn(T)	Mn	Cu	Pb	Zn	Ni	Al	As	Li	Ba	Sr
ANZECC 2000	-	-	1.9	1.9	0.0014	0.0034	0.008	0.011	0.055	0.013 / 0.024	-	-	-
Karignan Ck	1.3	0.82	0.03	0.03	**0.003**	<0.001	**0.014**	<0.01	0.05	<0.01	<0.001	0.026	0.10
Chain Valley Bay	0.10	0.02	0.02	0.01	**0.003**	<0.001	**0.013**	<0.01	0.03	<0.01	0.38	0.041	4.8
GNS SUMP	0.18	0.07	0.06	0.04	**0.004**	<0.001	**0.018**	<0.01	0.04	<0.01	0.98	0.084	31
GNS1 (roof)	0.12	0.07	0.27	0.16	<0.001	<0.001	**0.010**	<0.01	0.03	<0.01	1.3	0.080	44
GNS2 (pond)	0.05	<0.01	<0.01	<0.01	<0.001	<0.001	0.003	<0.01	0.01	<0.01	0.59	0.17	11
Fassifern dyke	2.4	0.08	0.06	0.02	**0.004**	<0.001	**0.019**	<0.01	0.04	<0.01	0.28	0.37	1.0

NOTE: all values in mg/L
metals reported as acidified and 45um filtered samples except where Total (T) values are shown
samples collected 22/6/2012

Analysis of selected areas within the workings and in Lake Macquarie on 14th February 2020 was conducted as summarised in **Table 7** and shown as a Piper Diagram in **Figure ?.**

TABLE 7 Mine Water Chemistry

	pH	EC (uS/cm)	TDS	Na	Ca	K	Mg	Cl	F	HCO3	CO3	SO4	TP
ANZECC 2000	**6.5 - 8.0**	**2,200**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**0.05**
TGS2 (Goaf Fassi)	8.54	13900	6710	3220	28	11	20	4320	n/a	899	82	**40**	**0.17**
S2 Face (Fassi)	8.46	14600	7810	3240	41	10	15	4410	n/a	917	80	**47**	**<0.05**
11KV Switch)Roof GN Conglomerate)	7.73	33000	19600	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	<0.05
Lake Macquarie	8.14	52100	34900	10800	414	389	1300	16000	n/a	106	<1	2680	<0.05

NOTE: all values in mg/L except as shown samples collected on 14/2/2020

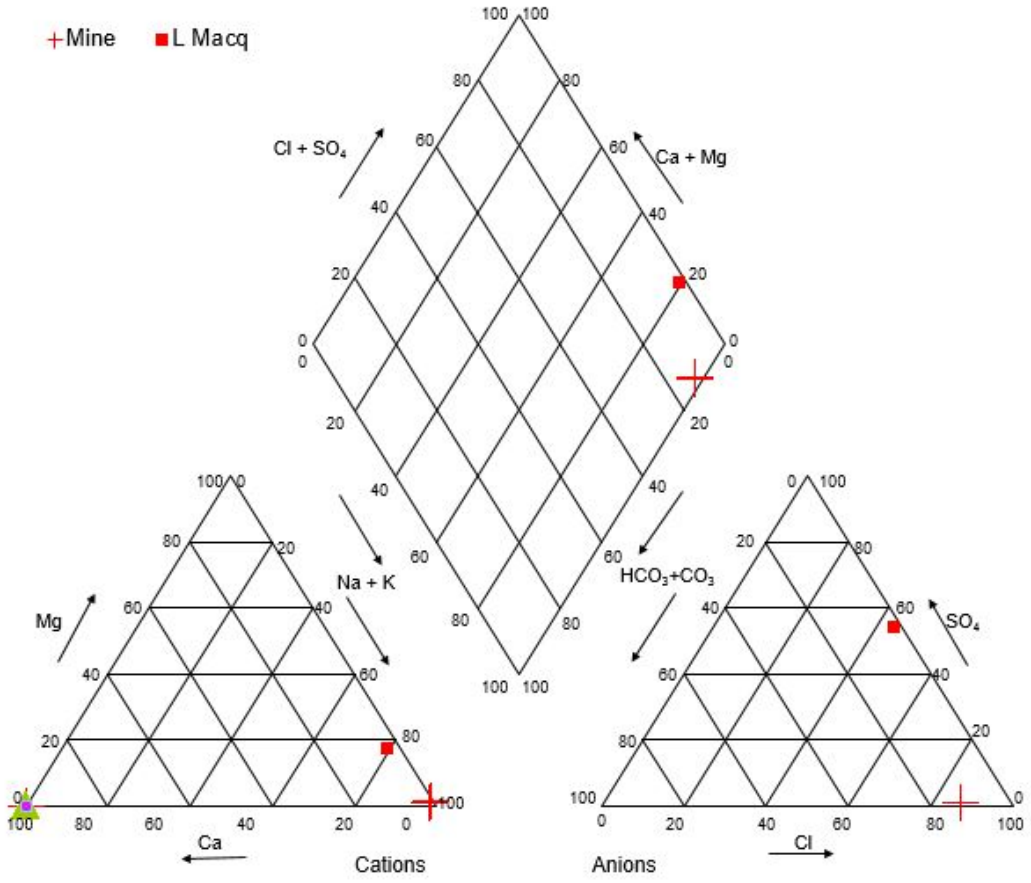

Figure 5 Mine Water Chemistry

6. POTENTIAL GROUNDWATER IMPACTS

It is anticipated that subsidence over the 144 - 161 m deep proposed S5 miniwall workings may affect the overlying groundwater system through:

- surface cracking to approximately 20m below surface;
- height of connective fracturing to less than 50 m above the seam (Strata^2, 2020), with partial loss of groundwater if fracturing extends into an overlying aquifer, which can cause minor groundwater inflow from the goaf to the workings;
- an exponential decrease in overburden permeability with height above the workings;
- connectivity between the mine workings and overlying aquifers within the fractured goaf, which can result in depressurisation of the aquifers;
- dewatering and depressurisation of the Great Northern and Fassifern seams as mining progresses;
- increased aquifer permeability, and, potentially;
- reduced groundwater quality in the overlying aquifers.

6.1 Hydraulic Connection to Lake Macquarie

The Forster and Enever (1992) study at Wyee State Mine, with 150 m wide longwalls, indicated there was no hydraulic connection at heights over 115 m above the extracted workings.

It should be noted that the proposed miniwall has a maximum width of 97 m, which means the height of fracturing would be less than that observed over the 150 m wide Wyee State Mine longwalls.

As a result, hydraulic connection between Chain Valley Colliery and Lake Macquarie over the proposed secondary extraction workings associated with Miniwall S5 is not anticipated as the minimum depth of cover is at least 144 m (including lake bed sediments), or from 139 m of basement (excluding the sediments in Lake Macquarie).

6.2 Aquifer / Aquitard Interconnection

Mining induced cracking and vertical subsidence of strata over the extraction area may potentially extend up to 20 m below surface, with bedding dilation from below the surface zone down to the upper goaf.

In the upper horizons, subsidence can alter the dominance of the pre-mining horizontal flow along or above aquitards to generate a combination of vertical and horizontal flow regimes as aquitards are breached and water drains to lower elevations in the strata.

Vertical flow continues down the strata until the drainage is restricted by intact aquitards, at which the depth the flow then resumes its horizontal dominance.

Below the surface cracked zone, an increase in horizontal flow component can occur due to dilation and bending of strata, even though the layers are not actually breached by vertical cracking. The increased horizontal permeability extends across the subsided area, gradually diminishing as the subsidence and dilation decreases out to the edge of the subsidence zone.

No adverse interconnection of aquifers and aquitards is anticipated within 20 m of the lake bed as there are no recorded aquifers in this interval.

However, there may be an increased rate of recharge into the upper overburden from the lake waters due to the increased secondary porosity and permeability of the subsided, fractured overburden.

6.3 Regional Groundwater Depressurisation

Extensive mining of the Fassifern, Wallarah and Great Northern seams at Chain Valley and surrounding collieries for more than 60 years has significantly depressurised the overburden within the vicinity of the proposed workings.

Groundwater levels within the Fassifern Seam has already been extensively impacted by mining in the area and therefore continued mining is likely to have little additional impact, if any.

The deeper basement lithologies have increased permeability in areas of partial or full extraction due to subsidence induced caving and fracturing over the workings which results in an increased groundwater storage capacity of the overburden through increased secondary porosity.

Groundwater flow rates within the deeper aquifers are likely to increase within the caved and fractured areas due to greater hydraulic connectivity between horizontal and vertical fractures.

A temporary lowering of the regional piezometric surface over the subsidence area of up to 1.0 m due to horizontal dilation of strata may occur due to the increase in secondary porosity and permeability (GeoTerra, 2013). This effect will be more notable directly over the area of greatest subsidence and dilation, and will dissipate laterally out to the edge of the subsidence zone.

Based on similar observations in NSW with similar mining layouts, surficial and mid depth strata groundwater levels may reduce by up to 15m, and may stay at that reduced level until maximum subsidence develops at a specific location. The duration of the reduction depends on the time required to develop maximum subsidence, the time for subsidence effects to migrate away from a location as mining advances to subsequent panels, and the length of time required to recharge the secondary voids.

The degree of groundwater level decline under the lake due to subsidence is predominantly determined by the proximity to a mined panel, however it can also be significantly affected by the rate of lake water infiltration and terrestrial rainfall recharge to an aquifer, as well as changes in the rate or duration of groundwater extraction in any adjacent groundwater bores.

On the basis that the pre-mining circumstances of lake water and rainfall recharge as well as any local bore pumping remain the same, it is anticipated that groundwater levels will recover over a few months as the secondary void space is recharged by lake water and rainfall infiltration.

There is generally no permanent post mining reduction in groundwater levels under the lake, as no new hydraulically connected outflow paths from within the overburden develop.

6.4 Private Bore Yields and Serviceability

Although registered bore sites are located within the predicted 1.0 m groundwater depressurisation area, no private bore yields or serviceability have historically been reported to be, or are predicted to be affected by subsidence or regional groundwater depressurisation associated with the proposed workings, which are entirely located under Lake Macquarie.

No beneficial users of the deep bedrock/coal measures aquifers have been identified in the vicinity of the GwMP Area.

6.5 Groundwater Dependent Ecosystems

Cumulative impacts from the proposed mining are not anticipated to adversely impact on groundwater dependant ecosystems in the 20 mm subsidence area.

This is primarily because no groundwater dependent ecosystems have been identified in the proposed subsidence area within or under Lake Macquarie.

6.6 Groundwater Quality

Previous observations in NSW Coalfields indicates that groundwater quality within the subsided overburden is not generally adversely affected, however there may be increased iron hydroxide precipitation and a lowering of pH if the groundwater is exposed to “fresh” surfaces in the strata with dissolution of unweathered iron sulfide (marcasite) or iron carbonate (siderite).

The degree of iron hydroxide and pH change due to subsidence is difficult to predict, and can range from no observable effect to a distinct discolouration of water pumped out of bores.

The discolouration does not pose a health hazard, however it can cause clogging of pumping equipment and piping in extreme cases.

It should be noted that many bores in the local area can already have significant iron hydroxide levels, and a pre-mining survey of the active bores is required to assess the baseline water quality prior to undermining.

Acidity (pH) changes of up to 1 order of magnitude can occur, however the change can be reduced if the bore has sufficient bicarbonate levels.

The potential for groundwater contamination also exists from spills of fuels, oils and chemicals from both the surface and underground mine workings. Spills may result in the contamination of soil, while the infiltration of rainfall or direct migration of contaminants to the water table has the potential to contaminate shallow aquifers.

The potential for impacts can be minimised through the appropriate storage of fuels and hazardous chemicals, the implementation of appropriate work procedures and regular inspections and maintenance of equipment and plant.

Leaks and spills should be handled in accordance with the PIRMP prepared for the site, and remediated as required on a case by case basis.

Infiltration of potentially contaminated water from the sedimentation dams also has the potential to impact groundwater quality. As the dams receive all site runoff, amenities water and mine water, as well as workshop and wash down water after treatment by an oil separator, there is potential for the water within the dams to be contaminated by dissolved petroleum hydrocarbons and heavy metals. It is understood the dams are not lined with a low permeability layer, and as such, seepage of potentially contaminated water within the dams may be infiltrating alluvial or shallow aquifers.

6.7 Groundwater Seepage to or From Terrestrial Streams

No known springs or streams are present in the GwMP area that would be affected by subsidence and associated regional groundwater depressurisation with the existing and proposed workings.

Overall, the terrestrial streams within the GwMP area will be subjected to no or very low tensile and compressive strains and are not anticipated to be adversely affected by subsidence related stream bed cracking.

No loss of overall stream flow or regional change in stream water quality within the local streams is anticipated to occur.

6.8 Groundwater Inflow to Mine Workings

Loss of lake water or any significant loss of connate groundwater within the overburden to the underlying workings has not been observed in mines in the local area at similar depths of cover to the proposed workings.

Vertical hydraulic connection to the workings is anticipated to be restricted by the Dooralong Shale and the Mannering Park Tuff aquitards, which are not anticipated to be breached by subsidence over the proposed Fassifern Seam workings and are both below the surficial and above the goaf, vertically connected, dilation zones.

The horizontal permeability above and between the aquitards may be enhanced after subsidence, however there is no additional vertical connectivity through or below them to the underlying workings.

Based on available records, the 2019 annual groundwater seepage into the workings was 1,913 ML/yr, or 5.24 ML/day.

No obvious relationship between expansion of the mine and increased groundwater inflow to the workings is evident in the current data, with a reduction in mine water pumping evident over the last three years.

Based on a groundwater modelling assessment (GeoTerra, 2013) the inflow may increase up to 10.5 ML/day as the Colliery expands.

7. GROUNDWATER MONITORING PLAN

The groundwater monitoring program at available (or currently present) locations shown in **Figure 1** is designed to provide a database that enables:

- comparison of anticipated vs observed impacts on the groundwater system through miniwall as well as bord and pillar extraction of the Fassifern Seam at Chain Valley Colliery and any associated subsidence effects; and
- procedures to assess, manage or rehabilitate any adverse effects that exceed specified trigger levels.

As the proposed workings, and the anticipated associated subsidence impacts, are wholly located underneath or within Lake Macquarie, the monitoring plan specifically deals with the following issues.

7.1 Mine Groundwater Inflow

The active underground mining area should be monitored by the underground supervisors to assess whether observable groundwater inflow is occurring to the active panels and if any changes are noted.

Water flow monitoring appliances have been installed to measure pumped water volumes to and from the mine workings. These appliances will be maintained in good working order, and if required, DC will supply a test certificate to certify the current accuracy of the appliances furnished by the manufacturer or by some duly qualified person or organisation.

Daily total mine water pumping records will be maintained, plotted and interpreted annually and will be supplied to DPIE within the Annual Environmental Management Report (AEMR).

7.2 Private Bore Water Levels

Where property access is granted and access inside a producing groundwater bore is possible, water levels within the private bores could be measured at least once before and once after mining is conducted in the GwMP area to assess if any adverse effects due to subsidence have occurred as shown in **Table 8**.

It is suggested that all other shallow monitoring or test bores, or waste disposal bores are not to be included in the monitoring suite.

Where monitoring of groundwater levels is not possible due to installed pump head-works, the mine will assess any reports from landowners in regard to adverse effects on bore water availability that may occur during or after extraction of the proposed workings.

Each property owner may be interviewed before and after the proposed mining to assess the bore's status, pumping rate, and its general duration of pumping as well as the type and set up of the pump.

Where feasible, the bore yield should also be measured, and water levels measured where access inside the bore is possible.

Where private bores are being occasionally or frequently pumped, and could thereby temporarily distort the static regional groundwater levels, the depth to groundwater, where accessible, should be monitored during pump resting periods to assess the regional piezometric surface across the area.

TABLE 8 Suggested Producing Groundwater Bore Water Level Monitoring

GW	Monitoring Frequency	Monitoring Method	Units
11915	Upon access / post mining	Dip meter	mbgl
24575	Upon access / post mining	Dip meter	mbgl
80489	Upon access / post mining	Dip meter	mbgl

Note: mbgl = metres below ground level

7.3 Groundwater Quality

7.3.1 Inactive Private Bores

Where property access is granted and access inside a bore is possible, a pre-mining water sample collection and analysis will be conducted within one month of access being granted and available, and will be repeated at the end of mining in the project area to enable assessment of any subsidence related changes in groundwater quality.

Each bore will be purged prior to sampling until pH and salinity measurements stabilise, which usually involves removal of at least three bore volumes of water.

Samples will be collected, appropriately preserved, kept on ice and transported under chain of custody documentation to arrive at the laboratory within appropriate holding times.

In addition, each piezometer or inactive bore will be monitored in the field for bi-monthly salinity (µS/cm) and pH measurements.

7.3.2 Active Private Bores

Where property access is granted and access to the groundwater bore is possible, an initial water sample collection and analysis will be conducted within one month of access being granted and available, and will be repeated at the end of mining in the project area to enable assessment of any subsidence related changes in groundwater quality.

To date, access to one current bore has been granted (GW80489), however no sample could be obtained as the installed pump was not working.

The use, and any treatment, of the bore water should be ascertained and observations made on the quantum of iron hydroxide precipitating from the pumped water before and after mining.

Each bore will be purged prior to sampling until pH and salinity measurements stabilise, which usually involves removal of at least three bore volumes of water.

Samples will be collected from bores that are current and accessible as shown in **Table 9**, and will be appropriately preserved, kept on ice and transported under chain of custody documentation to arrive at the laboratory within appropriate holding times.

TABLE 9 Suggested Producing groundwater Bore Water Quality Monitoring

GW	Monitoring Frequency	Monitoring Method	Units
11915	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)
24575	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)
80489	Upon access / post mining	In situ pump / bailer	pH EC mg/L (ions, metals, nutrients)

During extraction within the GwMP area, the frequency of monitoring and the parameters to be monitored may be varied in consultation with DPIE once the baseline groundwater quality and its response to mining (if any) is established.

The frequency of post mining monitoring will be reassessed after mining is complete in the GwMP area as it may be possible, depending on results, to lengthen the intervals.

Table 10 presents the physical groundwater quality parameters to be measured.

TABLE 10 Groundwater Quality Monitoring Parameters

SUITE	ANALYTES
Initial monitoring / after mining is completed	Field EC, Eh, pH, temp TDS, Na, K, Ca, Mg, F, Cl, SO4, HCO3, NO3, Total N, Total P Cu, Pb, Zn, Ni, Fe, Mn, As, Se, Cd, Cr, Li, Ba, Cs, Rb, Sr (filtered)

7.4 Groundwater Contamination

In accordance with the sites' EPL and WMP, surface water discharged from the dams is monitored monthly for a range of pollutants.

The range of analysis for surface water also includes oil and grease, which allows the assessment of impact, if any, that these dams may be having on underlying aquifers.

8. GROUNDWATER ASSESSMENT CRITERIA AND TRIGGERS

Management of impacts within predictions follow standard assessment review and response protocols.

Contingent measures are included in this plan to ensure the timely and adequate management of the proposed extraction and subsidence impacts outside of anticipated levels.

Where and if required, specialist hydrogeological / hydrological investigations and reports may include:

- the study scope and objectives;
- consideration of any relevant aspect from this plan;
- analysis of trends;
- assessment of any impacts against prediction;
- assessment of the cause of a change or impact;
- options for management and mitigation;
- assessment for the need for contingency measures;
- any recommended changes to this plan; and
- appropriate consultation with DPIE, DRE and EPA.

Site specific mitigation / remediation action plans may include:

- a description of the impact to be managed;
- results of the specialist investigations;
- aims and objections for the plan;
- specific actions required to mitigate/manage;
- timeframes for implementation;
- roles and responsibilities;
- identification of and gaining appropriate approvals from landholders and government agencies; and
- a consultation and communication plan.

Trigger values for further assessment of potential subsidence effects on groundwater systems within the plan area are discussed in the following sections.

The triggers have been developed to reflect the current variability in relevant parameters and to enable the identification of any changes that may be due to either subsidence effects, landowner impacts and/or natural causes.

If trigger values are exceeded, the cause and effect will be investigated and a management plan developed if it is directly related to mining.

The Environment and Community Coordinator shall be responsible for the implementation of agreed actions and shall communicate such actions to the relevant landowners or authorities.

8.1 Mine Water Extraction and Discharge

Chain Valley Colliery holds a DPIE license (WAL41508) to extract up to 4,443 ML/year from the workings, and currently holds EPL 1770 which permits volumetric discharge of up to 12,161 kL/day via its licensed discharge point.

Mine water extraction will be measured daily and daily discharge volumes will be reported on a monthly basis via the DC website.

As part of the AEMR the average monthly groundwater extraction rates will be determined by assessing the difference between the potable water pumped into the workings and the total water pumped out of the workings. This assumes no hydraulic conductivity with Lake Macquarie,

surface potable water leaks, water theft or measurement error.

A trigger for the groundwater extraction will be where the monthly average extracted underground mine water exceeds **10.5 ML/day** (75th percentile groundwater inflow – refer **Table 3**), and this average continues for at least 2 months.

8.2 Private Bore Groundwater Levels

It should be noted that landowners pumping their own bores, as well as the interference effect from other landholders pumped bores can significantly affect temporary standing water levels in a bore, without any influence from mining or subsidence.

On this basis, if the combined monitoring of the outlined private bores indicates a sustained drawdown of **greater than 2 m over a 2 month period** in a private bore, or, if a landowner reports a lack of groundwater availability in a bore that cannot be accessed internally, then the cause of the exceedance will be investigated to assess whether the >2 m drawdown or lack of supply is due to:

- lack of rainfall recharge, using comparison to the cumulative sum of daily rainfall;
- operation of landowner bores either within or outside an affected bores property;
- subsidence; or
- any or all of the above.

The 2 m drawdown trigger level has been derived through extrapolation of similar mining subsidence related effects in similar mining layouts and geomorphological areas in NSW and to be consistent with the minimal impact considerations of the NSW Aquifer Interference Policy.

8.3 Private Bore Groundwater Quality

If a landowner reports an increase in iron hydroxide precipitation or water salinity, as an initial default, the ANZECC 2000 irrigation and livestock guidelines shown in **Table 11** will be used as trigger levels to assess bore water quality.

As no bores are used for drinking water in the GwMP, drinking water quality criteria and triggers are not specified.

TABLE 11 Groundwater Chemistry Criteria (mg/L)

	pH	**TDS**	**Hardness as CaCO3**	Cu	Pb	Zn	Ni	Fe	Mn	As	Cd
Irrigation	*6 - 8.5*	-	*>60-350*	*5*	*5*	*5*	*2*	*10*	*10*	*2.0*	*0.05*
Livestock	-	*<4000/5000*	-	*1 / 0.4*	*0.1*	*20*	*1*	-	-	*0.5*	*0.01*

NOTE: all metals values are for filtered metals;

irrigation criteria for short term trigger values (< 20 years);

livestock criteria for beef / sheep.

9. POTENTIAL GROUNDWATER AMELIORATIVE ACTIONS

9.1 Private Bore Yield

Although it is not anticipated due to the separation distance from the bores to the proposed subsidence area, should the accessibility, available drawdown or yield of a bore be impacted due to subsidence, Chain Valley Colliery is required to provide an alternative water supply until the bore recovers.

If the level does not sufficiently recover and the effect is due to subsidence rather than regional climatic or anthropogenic factors, repairs or maintenance to a bore can be undertaken after maximum subsidence has developed. At this time the pump intake can be lowered, the bore extended to a greater depth or a new bore can be established.

With these mitigation measures in place it is unlikely that water supply to properties will be significantly impacted by the proposed mining.

In the event of a monitored or reported adverse impacts on the yield or saturated thickness of a private registered bore, the cause will be investigated.

If a groundwater level drop of over 2 m for a period of over 2 months is recorded, and the reduction in bore yield is a consequence of subsidence, the mine will enter into negotiations with the affected landowners and Subsidence Advisory NSW with the intent of formulating an agreement which provides for one, or a combination of:

- re-establishment of saturated thickness in the affected bore(s) through bore deepening;
- establishment of additional bores to provide a yield at least equivalent to the affected bore prior to mining;
- provision of access to alternative sources of water; and/or
- compensation to reflect increased water extraction costs, e.g. due to lowering pumps or installation of additional or alternative pumping equipment.

9.2 Private Bore Groundwater Quality

In the event of an adverse change in groundwater quality to a private bore, particularly in regard to salinity and / or iron levels, the mine will implement an investigation to determine if the cause is due to subsidence.

Although it is not anticipated due to the separation distance from the bores to the proposed subsidence area, if subsidence cracking has caused a notable increase in iron hydroxide precipitates or the landowner reports an adverse change in salinity, and that change exceeds the trigger levels, the mine will enter into negotiations with the affected landowner with the intent of formulating an agreement which provides for one, or a combination of:

- re-establishment of the water supply from a new bore to provide water equivalent to the pre mining status of the bore (on the basis that the landholder has allowed for pre-mining status of the bore to be established);
- provide access to an alternative source of water, or;
- compensate the bore owner to reflect the economic costs incurred due to the subsidence effects on the water quality.

10. CONTINGENCIES

In the event that the proposed monitoring indicates that a trigger has been reached or is being approached, DC will commission a hydrogeologist or hydrologist to review the data, with the outcomes of that review, including any recommendations, being subject to consultation with DPIE.

A trigger of pH or electrical conductivity would initially lead to an increase in the analytes monitored and/or frequency of sampling to confirm the magnitude and extent of the change in groundwater chemistry and verify the change is a consequence of mining.

Should the standing water level trigger be achieved in any bore, the mine staff shall notify the affected landowner(s) and, if it is the hydrogeologist's opinion that the reduction is a consequence of mining, mitigation measures identified in previous sections will be initiated.

An independent authority may also be used where a dispute arises as to the cause of the change, given that groundwater supply and quality can be affected by non-mining related factors such as bore siltation, aquifer depletion by adjoining mining operations, agricultural users, bacterial infection, fertilizer contamination etc.

11. AUDIT AND REVIEW

This document shall be reviewed, and if necessary revised, within 3 months of the following:

- the submission of an Annual Environmental Management Report (AEMR);
- the submission of an incident report;
- the submission of an independent environmental audit; and
- following any modification to the project approval.

Other factors that may require a review of the GwMP are:

- observation of greater impacts on surface features due to mine subsidence than was previously expected;
- observation of fewer impacts or no impacts on surface features due to mine subsidence than was previously expected; and/or
- observation of significant variation between observed and predicted subsidence.

Internal and external audits of this document will be carried out as described below. If possible, audits shall be objective and be conducted by a person or organisation independent of the document being audited.

Audits shall be carried out by personnel who have the necessary qualifications and experience to make an objective assessment of the issues. The extent of the audit, although pre-determined may be extended if a potentially serious deviation from this document is detected.

Any audit non-conformances and/or improvement opportunities will have corrective and preventative actions implemented to avoid recurrence, these actions will be loaded into the site Incident Database to ensure the actions are assigned to the relevant people and completed.

11.1 Internal Audits

Internal audits of this document and all other Environmental Management System documents are to be undertaken every three years. Improvements from the audit are to be incorporated in the site action database to ensure the actions are assigned to the relevant people and completed.

11.2 External Audits

External audits will be conducted utilising external specialists and will consider the document and related documents. External auditors shall be determined based on skills and experience and upon what is to be accomplished. External audits will be periodically at a frequency determined by the site General Manager, or in response to significant environmental incidents for which a systems failure has been determined as a contributor to the incident.

An Independent Environmental Audit (IEA) will be undertaken every three years, or as otherwise required by the Department of Planning, Industry and Environment (DPIE).) the audit will be conducted by an audit team whose appointment has been endorsed by the Secretary of DPIE.

Any actions arising from external audits will be loaded into the site actions database to ensure the actions are assigned to the relevant people and completed.

12. RECORDS

Generally, the site Environment and Community Coordinator will maintain all EMS records, which are not of a confidential nature. Records that are maintained include:

- monitoring data and equipment calibration;
- environmental inspections and auditing results;
- environmental incident reports;
- complaint register; and
- licenses and permits.

All records are stored so that they are legible, readily retrievable and protected against damage, deterioration and loss. Records are maintained for a minimum of 4 years.

13. RESPONSIBILITIES AND ACCOUNTABILITIES

13.1 General Manager

- Ensure that the requisite personnel and equipment are provided to enable this plan to be implemented effectively

13.2 Environment and Community Coordinator

- authorise the Plan and any amendments thereto;
- ensure this plan is reviewed should any changes to the mine plan or if levels of subsidence are greater than predicted. Notify the relevant authorities of any triggers being exceeded;
- reporting in the AEMR;
- ensure that inspections are undertaken in accordance with the schedule;
- ensure that persons conducting the inspection are appropriately trained, understand their obligations and the specific requirements of this plan;
- review and assess monitoring results and inspection checklists;
- promptly notify the General Manager of any identified environmental issue.

13.3 Hydrogeologist / Hydrologist

- assist in compiling and/or reviewing the monitoring to the standard and frequency as outlined in this plan; and
- promptly notify the Environment and Community Coordinator of any identified environmental issue.

14. TRAINING

All personnel who conduct inspections will be trained in the requirements of the plan.

Training will be conducted on maintaining and downloading monitoring equipment, operation of the field testing equipment and sampling procedure for laboratory analysis identification of the various subsidence impacts detailed in this plan.

15. REPORTING

15.1 Annual Environmental Management Report

An Annual Environmental Management Report (AEMR) will be submitted to DPIE each year. As part of the AEMR the groundwater section will include;

- groundwater related activities, and the level of compliance with the GwMP;
- all groundwater monitoring volumes and rates taken by the works;
- the volume groundwater extracted from the works that was discharged via the Licensed Discharge Point;
- all groundwater extraction data;
- the extent of groundwater depressurisation and any groundwater salinity impacts compared with predictions in the Environment Assessment;
- interpretation of the data, discussion of trends and their implications;
- an overall comparison of groundwater performance with predictions for the life of the mine provided in the Environmental Assessment; and
- an outline of proposed adaptive or remediation actions if required.

Notification of the groundwater monitoring results and interpretations will be reported within the required annual period to outline the natural trends and any impacts from mining on the groundwater system.

16. REFERENCES

AECOM, 2011A. Groundwater Impact Assessment, Chain Valley Colliery Continuation of Mining

AECOM, 2011B Mine Water Balance, Chain Valley Colliery Continuation of Mining

AGE Consultants, 2006 Mannering Colliery Continuation of Mining, Environmental Assessment, Groundwater.

ANZECC & ARMCANZ 2000 National Water Quality Management Strategy. Australian and New Zealand Guidelines For Fresh and Marine Water Quality, Vol. 1

DIPNR, 2005 Management of Stream / Aquifer Systems in Coal Mining Developments

Ditton Geotechnical Services, 2013 Subsidence Impact Assessment for the Chain Valley Colliery Mining Extension 1 Project

Forster I.R., 1995 Impact of Underground Mining on the Hydrogeological Regime, Central Coast NSW. From Engineering Geology of the Newcastle Region

Forster I., and Enever J., 1992 Hydrogeological Response of Overburden Strata to Underground Mining – Central Coast, New South Wales, Office of Energy.

GeoTerra, 2013 Chain Valley Colliery Mining Extension 1 Groundwater Assessment, Report LDO2-R1D

GSS Environmental, 2013 Chain Valley Colliery Mining Extension 1 Project – Surface Water Assessment

HLA-Envirosciences, 2002 Mandalong Mine Groundwater Study Stage 1 Preliminary Review. November.

Li, G., Forster, I., Fellowes, M., Myors, A., 2006 A Case Study on Longwall Mining under the Tidal Waters of Lake Macquarie

Mine Subsidence Engineering Consultants, 2018 Miniwalls S2 and S3. Subsidence predictions and Impact Assessments for the Natural and Built Features due to the Extraction of the proposed Miniwalls S2 and S3 in Support of the Extraction Plan

Peabody LakeCoal Pty Ltd, 2008 Annual Environmental Management Report, Chain Valley Colliery, Year Ending 30 June 2008

Peabody LakeCoal Pty Ltd, 2009 Annual Environmental Management Report, Chain Valley Colliery, Year Ending 30 June 2009

Strata^2, 2018 Geotechnical Aspects of S2 and S3 Panel Design

Strata^2, 2019 Lake Coal Chain Valley Colliery, S4 Panel: Geotechnical Environment, Subsidence Estimates and Impacts

Strata^2, 2020 Lake Coal Chain Valley Colliery, S5 Panel: Geotechnical Environment, Subsidence Estimates and Impacts

DISCLAIMER

This report was prepared in accordance with the scope of services set out in the contract between GeoTerra Pty Ltd (GeoTerra) and the client, or where no contract has been finalised, the proposal agreed to by the client. To the best of our knowledge the report presented herein accurately reflects the client's intentions when it was printed. However, the application of conditions of approval or impacts of unanticipated future events could modify the outcomes described in this document.

The findings contained in this report are the result of discrete / specific methodologies used in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site / sites in question. Under no circumstances, however, can it be considered that these findings represent the actual state of the site / sites at all points. Should information become available regarding conditions at the site, GeoTerra reserve the right to review the report in the context of the additional information.

In preparing this report, GeoTerra has relied upon certain verbal information and documentation provided by the client and / or third parties. GeoTerra did not attempt to independently verify the accuracy or completeness of that information. To the extent that the conclusions and recommendations in this report are based in whole or in part on such information, they are contingent on its validity. GeoTerra assume no responsibility for any consequences arising from any information or condition that was concealed, withheld, misrepresented, or otherwise not fully disclosed or available to GeoTerra.

Interpretations and recommendations provided in this report are opinions provided for our Client’s sole use in accordance with the specified brief. As such they do not necessarily address all aspects of water, soil or rock conditions on the subject site. The responsibility of GeoTerra is solely to its client and it is not intended that this report be relied upon by any third party, who should make their own enquiries.

The advice herein relates only to this project and all results, conclusions and recommendations made should be reviewed by a competent and experienced person with experience in environmental and / or hydrological investigations before being used for any other purpose. The client should rely on its own knowledge and experience of local conditions in applying the interpretations contained herein.

To the extent permitted by law, GeoTerra, excludes all warranties and representations relating to the report. Nothing in these terms will exclude, restrict or modify any condition, warranty, right or remedy implied or imposed by any statute or regulation to the extent that it cannot be lawfully excluded, restricted or modified. If any condition or warranty is implied into this license under a statute or regulation and cannot be excluded, the liability of GeoTerra for a breach of the condition or warranty will be limited to the supply of the service again.