HYDROGEOLOGICAL ASSESSMENT

EXTRACTIVE INDUSTRIES APPROVAL

For

JOHN FORREST

Lots 3 and 237 Ludlow Park Road, Ludlow

Water Direct Pty Ltd

PO Box 3135
East Perth WA 6892
Phone: 08 9325 3966
Facsimile: 08 9325 3988
www.wdl.com.au

Job No. JSF/PEI/312
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1. INTRODUCTION

1.1 Location

The proposed extractive industry is on Lots 3 and 237 Ludlow Park Road, Ludlow located approximately 11 kilometres west southwest of Busselton, Western Australia (Figure 1). The site also forms the south-eastern edge of the Wonnerup Estuary and associated Ramsar wetlands and forms the north-western boundary of the Tuart Forest National Park.

1.2 Proposed Development & Project Particulars

The proposed extractive industry, crushed limestone for road building, will be located on 63 hectares of existing pastoral and horticultural land consisting of Lots 3 and 237 Ludlow Road, Ludlow (Figure 2).

The development plan is to initially remove and stockpile between 100mm and 150mm of topsoil on up to individual 5,000 m2 areas. Any sand will then be removed and stockpiled. The underlying limestone will be extracted to a maximum depth of 2m below natural land surface.

The sands will then be replaced on the pit floor to raise the surface to a relative level of 0.8m AHD. Up to 150mm of topsoil will be reinstated on top of the sands and then sown with grasses for pasture.

A cross-section of the proposed extractive industry is shown on Figure 3. The height at the lowest point on the western side at the end of the project will be 0.8m AHD.

2. LOCALITY DESCRIPTION

2.1 Topography

The proposed extractive industry site is located on the Swan Coastal Plain which is bounded to the north-west by the Geographe Bay and to the south-east by the Whicher Scarp. The Swan Coastal Plain is generally flat and in the vicinity of the proposed extractive industry site has an elevation varying from 0 (Wonnerup Estuary) to approximately 5m AHD (Tuart Forest National Park).

The proposed extractive industry site slopes very gradually to the west north-west into the Wonnerup Estuary and the surface elevation varies from 1.9m AHD on the north-western side to just over 3.5m AHD on the south-eastern side.

2.2 Drainage

The proposed extractive industry site is to the south-eastern side of the Wonnerup Estuary. The Ludlow River catchment, located to the north and east, discharges into the Wonnerup Estuary prior to the estuary water entering the Geographe Bay. Floodgates installed in the early 1900's to stop saline water from Geographe Bay entering the estuary during high tides and assist in maintaining a steady water level unaffected by tidal influences in the associated wetlands. The floodgates work by allowing fresh water to flow out of the Wonnerup Estuary when the estuary water level is higher than the Geographe Bay level and shut stopping saline inflow when the tide raises the Geographe Bay level above the estuary water level. The Wonnerup Estuary water level can therefore be below 0m AHD during the summer and autumn months when the Ludlow River is not flowing.

The proposed extractive industry site has no natural drainage on it although the Ludlow River channel passes to the immediate north of Lot 3 prior to entering the estuary. The high porosity of the surface lithologies of the proposed extractive industry site (limestone and sand) and a thin sandy soil profile, results in non-existent surface runoff during normal rainfall events. Rainfall (or excess irrigation) drains directly through the surficial sediments to the water table.

2.3 Vegetation

The vegetation of the Swan Coastal plain varies considerably over its length. In the Ludlow area the proposed extractive industry site sits between two iconic vegetation types. The Wonnerup Estuary consists of the estuary and the associated wetlands which are Ramsar listed. On the south-eastern side of the site is the Tuart Forest National Park.

The proposed extractive industry site has been cleared for several decades and used for farming, mainly horticulture and grazing. A thin strip of trees is to be retained on the eastern edge of the extractive industry.

2.4 Climate/Rainfall

The Ludlow area experiences a typically Mediterranean climate, characterised by cool, wet winters and warm, dry summers. The nearest long term meteorological station is at Busselton Shire (009515), located 11km to the west southwest of Lot 3, for which a reliable rainfall recording commenced in 1877.

The average annual rainfall at Busselton Shire is approximately 811 mm with most rainfall being recorded during the months of May through to September. Rainfall exceeds potential evaporation only during May to August. The monthly rainfall averages and the monthly rainfall for 2016 for Busselton Shire are presented in Table 1.

Table 1
Rainfall Data – Busselton Shire (9515)

Month	Average (mm)	2016
January	10.1	72.5
February	10.2	11.0
March	20.7	52.3
April	41.4	50.1
May	115.6	104.7
June	167.1	92.7
July	163.0	149.6
August	115.4	137.8
September	74.9	62.8
October	49.4	47.7
November	24.6	4.9
December	12.7	7.5
Total	811.4	793.6

Busselton Shire (9515) rainfall figures, as supplied by the Bureau of Meteorology, for 2016 indicate that it was a nearly average year with a total of 793.6mm of rainfall.

3. HYDROGEOLOGY

3.1 Local Geology

The proposed extractive industry site and the surrounding area is part of the southern Perth Basin. Structurally the site is in the Bunbury Trough to the west of the Dardanup Scarp.

The proposed extractive industry site is underlain by three significant aquifer systems. These are from the surface the Superficial Formations aquifer, the Leederville Formation aquifer and the Yarragadee Formation aquifer. The Leederville Formation aquifer extends to a depth in excess of 150m below ground level in the Bunbury Trough and the Yarragadee Formation exists at greater depths.

The base of the Superficial Formations aquifer at the proposed extractive industry site varies from about 3m below ground level on the north-western side to about 5m below ground level on the south-eastern side (Figure 3). Immediately below the Superficial Formations aquifer is the Leederville Formation aquifer.

In the Busselton area the Superficial Formations aquifer consists of mainly the Tamala Limestone. At the proposed extractive industry site the Tamala Limestone is overlain by weathered Tamala Limestone sands and underlain at a shallow depth by the Leederville Formation. Associated with the limestone are some discontinuous thin layers and bands of sands and minor clays.

Lithological logs from water bores around the general area and test pits on the site indicate that the geology immediately below the ground surface consists of a thin veneer of top-soil sands between 0.25 and 0.6m in thickness underlain by up to 0.8m of limestone. Immediately below may be up to 1m of yellow sand then up to 2.8m of limestone all of which is underlain by orange to orange-brown clays. The clays at the site are understood to be the top of the Leederville Formation. Figure 3 shows a hydrogeological cross-section through the site with the lithologies encountered at four excavation sites.

In the immediate vicinity of the proposed extractive industry site the Leederville Formation consists of sandy clays which act as an aquitard. The very transmissive limestones and sands of the Superficial Formations aquifer would result in most

groundwater flowing horizontally westwards the Wonnerup Estuary and a very flat groundwater level gradient (Figure 2). The limestones and sands of the Tamala Limestone form a very transmissive lithology with hydraulic conductivities estimated to between 0.5 and 5m per day (Hirschberg, 1989).

Hirschberg indicates that the Leederville Formation discharges into the Superficial Formations aquifer in this area.

3.2 Groundwater Investigations

Twelve test pits have been excavated on site to determine the suitability of the limestone for extractive purposes, to identify lithologies and to determine standing water levels. The locations and water levels, including contours, are shown on Figure 2. Some of the test pits have been surveyed for location and ground surface. Were possible the standing water level has been surveyed using differential GPS. Most of the water level data was surveyed in February, March and April of 2017. These are considered to be the lowest standing water levels (minimum seasonal groundwater level). A cross-section showing the lithologies the ground surface and recorded water levels is shown in Figure 3.

The groundwater level has been measured in production bore PB3, to the north of the extractive industry site, on 7 October 2016 and 7 February 2017. On both occasions the water level was measured at 0.27m AHD.

The water levels measured at the site and their locations are shown in Table 2 and on Figure 2.

Table 2
Site Water Level Measurements

Site ID	Easting	Northing	Water Level	Date Measured	Type
	m	m	m AHD		
1	357120	6280952	-0.041	27-Apr-17	Sample pit
2	357015	6281010	-0.046	27-Apr-17	Sample pit
3	356958	6280711	-0.085	27-Apr-17	Sample pit
4	356798	6280732	-0.088	27-Apr-17	Sample pit
5	356671	6280510	-0.118	27-Apr-17	Sample pit
Warners Dam	357090	6280530	0.152	07-Feb-17	Excavation 2
	357298	6280884	0.236	07-Feb-17	Trench
	357408	6281103	0.248	07-Feb-17	Trench
PB3	357771	6281872	0.27	7-Oct-16 & 7-Feb-17	Production bore
Sand Pit	356727	6280184	0.032	07-Feb-17	Sand pit

3.3 Depth – Maximum Seasonal Groundwater Level

The Maximum Seasonal Groundwater Level is the highest normal water level in an annual cycle period. In the Busselton region this is generally experienced in the Superficial Formations between September and November and is the result of rainfall recharge raising the water level in the shallow aquifer. In the Superficial Formations aquifer near the Whicher Scarp, clayey lithologies with a low hydraulic conductivity, where the groundwater cannot be easily transmitted away, have annual variations in the order of 2 to 5m (Hirschberg 1989) with the highest water level being caused by rainfall recharge. Close to the coast of Geographe Bay the higher hydraulic conductivity sandy and limestone lithologies have smaller recorded annual variations in the order of 0.5 to 1m.

At this site all water levels except one have been measured February and April 2017 when the water levels would be at their lowest. One exception is the water levels measured in October 2016 and February 2017 at production bore PB3. The water level on both occasions was 0.27m AHD. This shows that the annual variation in this location may be significantly lower than 0.7m such as BN5S and probably in the order of less than 0.4m, similar to BN9S. The long term water levels of these two bores are shown in Figure 4. In the late 1990's the annual variation in BN9S was close to 0.1m.

Therefore the limited water table variation at the proposed extractive industry site is controlled by the high hydraulic conductivity of the sands and the limestone and the flood-gate system at the exit of the Wonnerup Estuary regulating the water level. After the winter/spring inflows from the Ludlow River into the Wonnerup Estuary the water level continues to decline as the flood waters flow into Geographe Bay. The water levels recorded in the western parts of the site in April 2017 are below average sea level (-0.041 to -0.118m AHD).

The Maximum Seasonal Groundwater Level is therefore likely to be in the order of 0 to 0.1m AHD on the western parts of the site near the Wonnerup wetlands and in the order 0.2 to 0.3m AHD in the eastern parts of the site near the Tuart Forest National Park.

3.4 Flow Direction

The Superficial Formations aquifer groundwater flow direction in the proposed extractive industry site is from the east (Tuart Forest National Park) to the west towards the Wonnerup Estuary Ramsar listed wetlands (Figure 2). Under normal conditions the groundwater would end its journey in Wonnerup Estuary however in periods of a high water inflow from the Ludlow River some of the groundwater may continue west and north-west into Geographe Bay.

Figure 2 shows contours constructed from water levels measured within the property in February and April 2017. The low gradients (<0.0005) indicate a high transmissivity of the underlying Tamala Limestone. The flood gate controlled water level in the Wonnerup Estuary is likely to be very similar to the groundwater level across the proposed extractive industry site.

3.5 Groundwater Chemistry

The groundwater in at the site has also been sampled since 2014, for regulatory reasons, and analysed for groundwater chemistry which is shown below in Table 3. This site is on the upstream side of the property and reflects the chemistry of the groundwater entering the site from the Tuart Forest National Park. The analytical data shows that the groundwater is slightly alkaline (7 - 8) with a brackish quality that is generally between 1,000 and 2,000mg/L.

Table 3
Superficial Groundwater Chemistry

Analyte/ID	Historical Range (pre Jan-14)	Excavation 2 (Warners Dam)						Department of Water Triggers
Date		30-Oct-14	30-Apr-15	28-Oct-15	6-Jan-16	26-Apr-16	8-Mar-17	
pH	7.4 – 7.6	7.7	7.4	7.0	7.6	7.5	8.0	<4
Electrical Conductivity (µS/cm)	2,200 – 2,800	2,950	2,750	2,210	3,770	3,540	2,000	
Total Dissolved Salts	1,300 – 1,500	1,600	1,500	1,200	2,400	1,950	1,000	1000
Total Nitrogen	-	23.6	14.8		33	44.4	21	>5
Nitrate/Nitrite as N	-	20	14		33	44	19	
Ammonia as N	-	4.1	1.5		0.6	<0.1	<0.005	
Total Phosphorus	-	<0.01	0.11		0.02	0.06	<0.05	>0.1
Phosphate as P	-	<0.01	0.03		<0.01	0.06	<0.005	
Sulphate	-	190	160		190	210	96	
Chloride	-	690	670		860	790	390	
Total Acidity	-	<5	5		5	2	<5	<2

Total Alkalinity	-	205	115		250	230	210	>100
Iron	<0.10 – 0.35	0.011	0.0062		0.072	0.13	0.03	<30
Aluminium		0.075	0.0073		0.012	0.081	<0.01	<4

All results in mg/L unless otherwise stated. Figures in bold are analyses exceeding the Department of Water guidelines.

The groundwater analyses show that the groundwater also contains significant nitrogen levels mainly in the form of nitrate, due to horticultural practices, but low to negligible phosphorus. The sulphate and chloride levels are similar to those analysed in BN4S in 1984 and therefore considered normal. The low iron and low aluminium levels are typical of this area.

4. EXISTING GROUNDWATER USE

The existing Superficial Formations Licence to Take Water (GWL62779(6)) for these properties has been most recently been used for the growing of market garden vegetables. This was done on a third party basis with an Approval of Agreement to Take Water (AGR178162(1)) that has now ceased. The GWL allows for the abstraction of up to 240,000kL per annum. The water was abstracted from three excavations and trenches into the very transmissive limestone underlying the property and from two shallow (5m) deep bores (PB2 and PB3) that are located about 800m to the northeast of the extractive industry site.

A small amount of water from irrigation would normally return back to the aquifer beneath irrigated areas. A similar sized Yarragadee aquifer Licence to Take Water exists on the property and this would also add to the irrigation recycling. The Yarragadee bore has not been used for over twelve months.

4.1 Groundwater Dependent Ecosystems

Environmentally there are two groundwater users in the area. To the southeast is and bordering the property is the Tuart Forest National Park (Figure 1). The Tuart trees and associated flora of this forest derive a small amount of water from groundwater. The bulk of the area to the immediate southeast is mapped as Zone 5 – Mature tall tuart woodland with a smaller area to the south being mapped as Zone 1 – Vasse-Wonnerup riparian woodland. The tuart woodlands require well drained soils and therefore are not a groundwater dependent ecosystem.

The major groundwater dependent ecosystem is the Ramsar listed Vasse-Wonnerup wetlands. These are the western and north-west boundaries of the extractive industry properties. The wetlands are very dependent on the groundwater from the Tamala Limestone maintaining the brackish water supply especially in the summer/autumn months when a lack of flow from the Ludlow River and high evaporation would increase salinity levels in the estuary. Brackish groundwater flowing westwards would reduce the salinity on the fringes maintaining plant growth.

5. RISK ASSESSMENT

As mentioned previously the proposed extractive industry site is located between the Ramsar listed Vasse-Wonnerup wetlands and the Tuart Forest National Park and groundwater flows westwards from the forest to the wetlands. Therefore any activity that affects the water table, the water quantity or the water quality could have potential effects on these ecosystems. This section discusses the potential risks of the activity.

The proposed extractive industry activity will involve the lowering of the ground surface level during extraction of the limestone to the water table (+0.1m AHD). Following extraction of the limestone the floor will be raised at least 0.5m back to (+0.6m AHD) using sands and then the about 100mm of topsoil will be reinstated. During the extraction and after the rehabilitation there is potential to cause groundwater related impacts on the two important ecosystems in the vicinity.

The Tuart Forest National Park is located up-gradient of the proposed extractive industry site and therefore least likely to be affected by any activities at the proposed extractive industry site. During the extraction phase the water level will not be lowered or altered and groundwater dependent ecosystems within the forest reliant on the water level and /or water quantity would be unaffected. The groundwater flow is to the west any changes in the water quality will be moving away from the forest.

The Ramsar listed Vasse-Wonnerup wetlands are located in the northwest to west of the activity site and the following points are related to the extraction and rehabilitation.

1. During the extraction phase the water level will not be lowered or altered and groundwater dependent ecosystems within the wetlands reliant on the water level would be unaffected.
2. The extraction being mainly above water table will result in no change to the quantity of water flowing through to the wetlands during the extraction phase.
3. During the extraction phase there is potential to have some ponding of groundwater/rain water. Evaporation of the ponded water may increase the salinity of the water although the amount would be minimal. The extraction will

take place over small areas (0.5ha) and therefore the potential increase in salinity would be minimal.

4. The other source of water quality problems would be failure of earthmoving equipment which could be the cause of pollution due to equipment lubricants and fuels. This is possible and earthmoving contractors are required to carry spill kits etc. to contain and recover any spilled lubricants or fuels. Any lost lubricants or fuels would be diluted significantly before reaching the wetlands.
5. As part of the rehabilitation of each small extractive area the floor of the area would be deep ripped to break up any compaction caused by the earthmoving equipment. This will assist in maintaining rainfall recharge into the aquifer and therefore water quantity and quality following rehabilitation.
6. Following rehabilitation there is potential for some ponding of water following significant rainfall events. There is no evidence of ponding currently and as the existing topsoil will be reinstated on sands the potential for ponding is limited. The site will have a slight southeast to northwest slope to it with a capture area along the north-western edge of the rehabilitated capture area.

The above information demonstrates that the potential risk of impact on the groundwater dependent ecosystems of the proposed extractive industry is acceptable and manageable with a suitable water management plan.

6. MANAGEMENT APPROACH

The previous sections have shown that the proposed extractive industry at Lot 3 and 237 Ludlow Road are likely to have minimal no negligible impacts on the groundwater system and that the potential risk of impact on the groundwater dependent ecosystems of the Tuart Forest National Park and the Ramsar listed Vasse-Wonnerup wetlands will be low.

6.1 Water Management Plan

The following plan is proposed to monitor the groundwater quality and levels at the proposed extractive industry site.

A borefield of five shallow monitoring bores will be excavated and constructed using 50 mm PVC casing slotted for the final metre. There will be three bores located on the western boundary (down gradient), one near each corner and one in the centre. The other two bores will be located on the eastern boundary (up gradient) will be located at each corner. All five monitoring bore locations and a relative level at the top of the PVC casing are to be surveyed. The following table indicates suggested locations and preferred total depths and slotted casing depths.

Table 4
Proposed Monitoring Bores

Site ID	Easting	Northing	Total Depth	Slotted Depth
	m	m	m BGL*	m BGL*
MB1	356,900	6,281,300	3	2 - 3
MB2	356,700	6,280,820	3	2 – 3
MB3	356,530	6,280,500	3	2 - 3
MB4	357,070	6,280,390	4.5	3.5 – 4.5
MB5	357,580	6,281,050	4.25	3.25 – 4.25

* m BGL = metres below ground level

Using the proposed monitoring bores a water level and quality monitoring program is proposed to determine the Maximum Seasonal Groundwater Level for the site and to identify the up gradient and the down gradient salinity and down gradient water chemistry. This program will be commenced immediately that the proposed extractive industry is approved.

Table 5

Proposed Monitoring Program

Bores to be monitored	Parameters being monitored	Monitoring Frequency
MB1 – MB5	Water Level below top of casing	Monthly on the last working day of the month
MB1 – MB5	Electrical conductivity, pH	Monthly bailed sample on the last working day of each month
MB2	Chemical analysis including: pH, Electrical conductivity, total dissolved salts, total nitrogen, nitrate/nitrite as N, ammonia as N, total phosphorus, phosphate as P, sulphate, chloride, total acidity, total alkalinity, Iron and aluminium.	September/October and March/April each year to be submitted to a laboratory using NATA certified methods

The data is to be submitted on a quarterly basis to the Department of Water.

7. CONCLUSIONS

- An extractive industry site is being proposed for Lots 3 and 237 Ludlow Road, Ludlow where it is proposed to excavate limestone for road building purposes.
- The limestone is shallow and will be extracted from above the water table (0.1m AHD). The pit floor (0.1m AHD) will then be backfilled using sands during rehabilitation back to a level of approximately 0.8m AHD.
- The Superficial Formations aquifer consisting mainly of the Tamala Limestone extends from the surface to about -1m AHD.
- The Maximum Seasonal Groundwater Level has not been measured at the site but is estimated to be approximately 0.1m AHD on the western side of the site and approximately 0.3m AHD on the eastern side of the site. The annual water level variation is estimated to be about 0.1m.
- The potential impacts of the proposed extractive industry on the Tuart Forest National Park groundwater dependent ecosystems are considered to be low and therefore acceptable.
- The potential impacts of the proposed extractive industry on the Vasse-Wonnerup wetlands and the associated groundwater dependent ecosystems are also considered to be low but because of the high environmental value of the wetlands the impact is considered manageable.
- A water management plan has been proposed to enable monitoring of the groundwater table and quality before, during and after the extractive industry is in operation to assist in the management.

8. REFERENCES

Hirschberg, K-J.B., 1989. *Busselton shallow-drilling groundwater investigation, Perth Basin*, Geological Survey of Western Australia. Professional Papers, Report 25, pp17 – 37.

9. LIMITATIONS OF REPORT

LIMITATIONS ON INTERPRETATION, USE AND LIABILITY OF THIS REPORT

Water Direct Pty Ltd has prepared this report exclusively for John Forrest, in accordance with generally accepted consulting practice. The work has been undertaken for the client and for review by regulatory agencies.

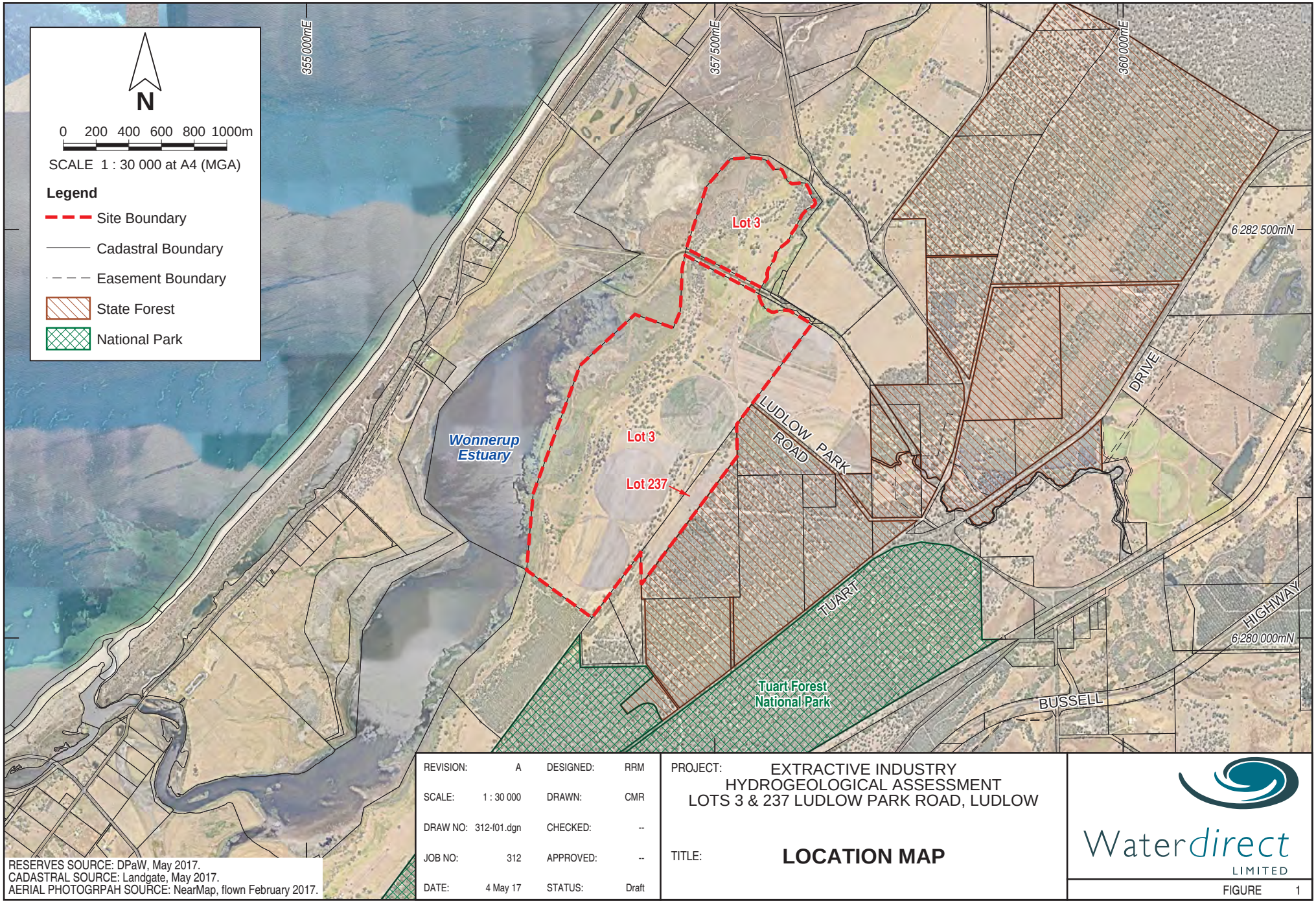
Aquifer materials and groundwater flow systems are a product of continuing natural and manmade processes and thus exhibit a variety of characteristics and properties that vary from place to place and can change with time. Geology/hydrogeology involves gathering and assimilating limited facts about these characteristics and properties in order to understand and predict the behaviour of the ground on a particular site under certain conditions. This report may contain such facts obtained by inspection, drilling, excavation, probing, sampling, testing or other means of investigation, particularly pumping and drawdown data. If so, they are directly relevant only to the groundwater system at the place where, and the time when the investigation was carried out. Any groundwater modelling predictions presented should not be regarded as matters of fact.

This report and other reports referred to may contain comments on works being carried out by others. The Company cannot and will not take responsibility for works carried out by others on site to date. We do not guarantee the performance of the project in any respect, only that our work and judgement meet the standard of care of our profession at this time.

Any interpretation or recommendation given in this report shall be understood to be based on judgement and experience, not on greater knowledge of facts other than those reported.

FIGURES

PINPOINT CARTOGRAPHICS (08) 9562 7136 312-f01.dgn



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CADASTRAL SOURCE: Landgate, May 2017.
AERIAL PHOTOGRPAH SOURCE: NearMap, flown February 2017.

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JOB NO:	312	APPROVED:	--
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PROJECT: EXTRACTIVE INDUSTRY
HYDROGEOLOGICAL ASSESSMENT
LOTS 3 & 237 LUDLOW PARK ROAD, LUDLOW

TITLE: **LOCATION MAP**

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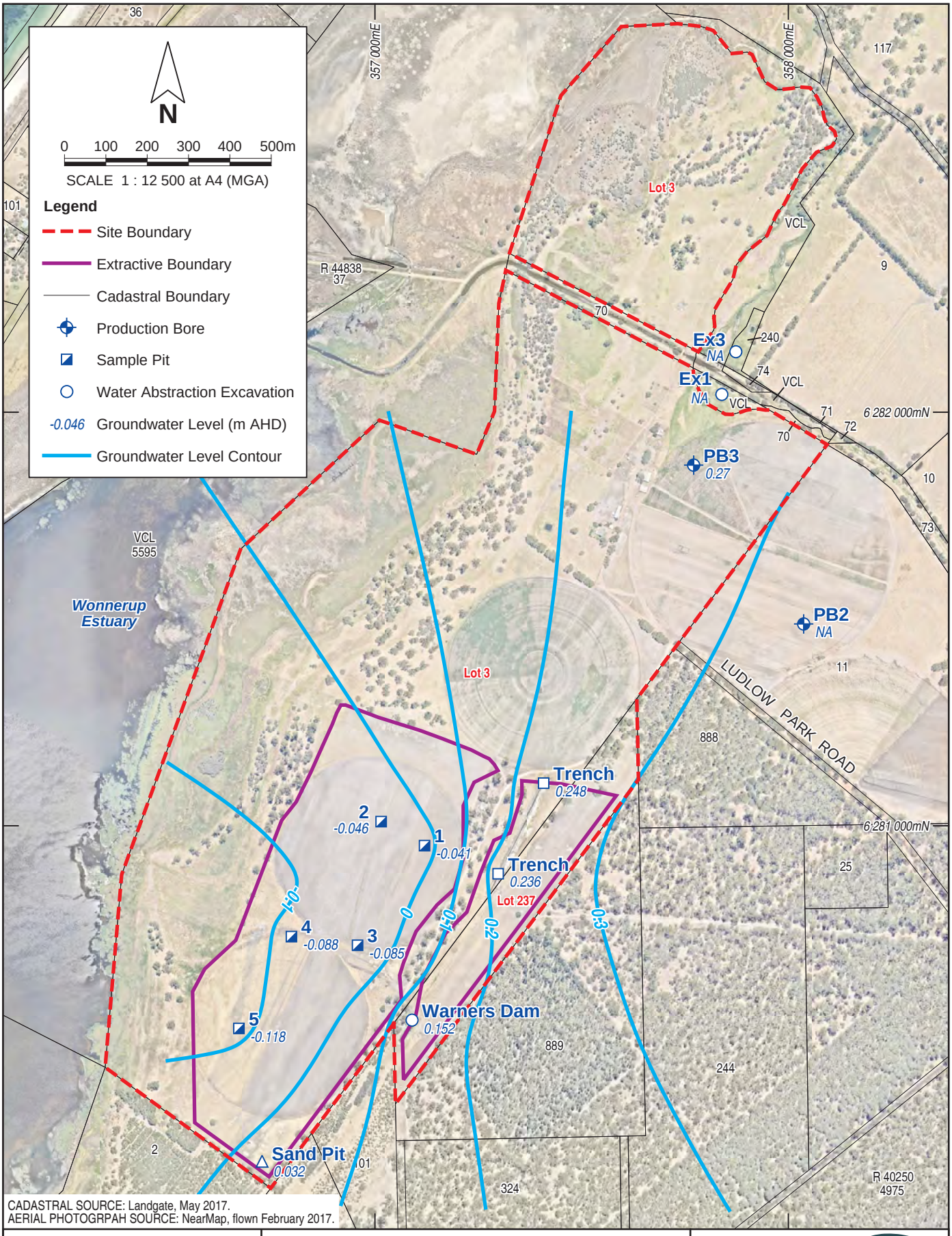
FIGURE 1



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PROJECT: EXTRACTIVE INDUSTRY
HYDROGEOLOGICAL ASSESSMENT
LOTS 3 & 237 LUDLOW PARK ROAD, LUDLOW

TITLE: **SITE MAP**

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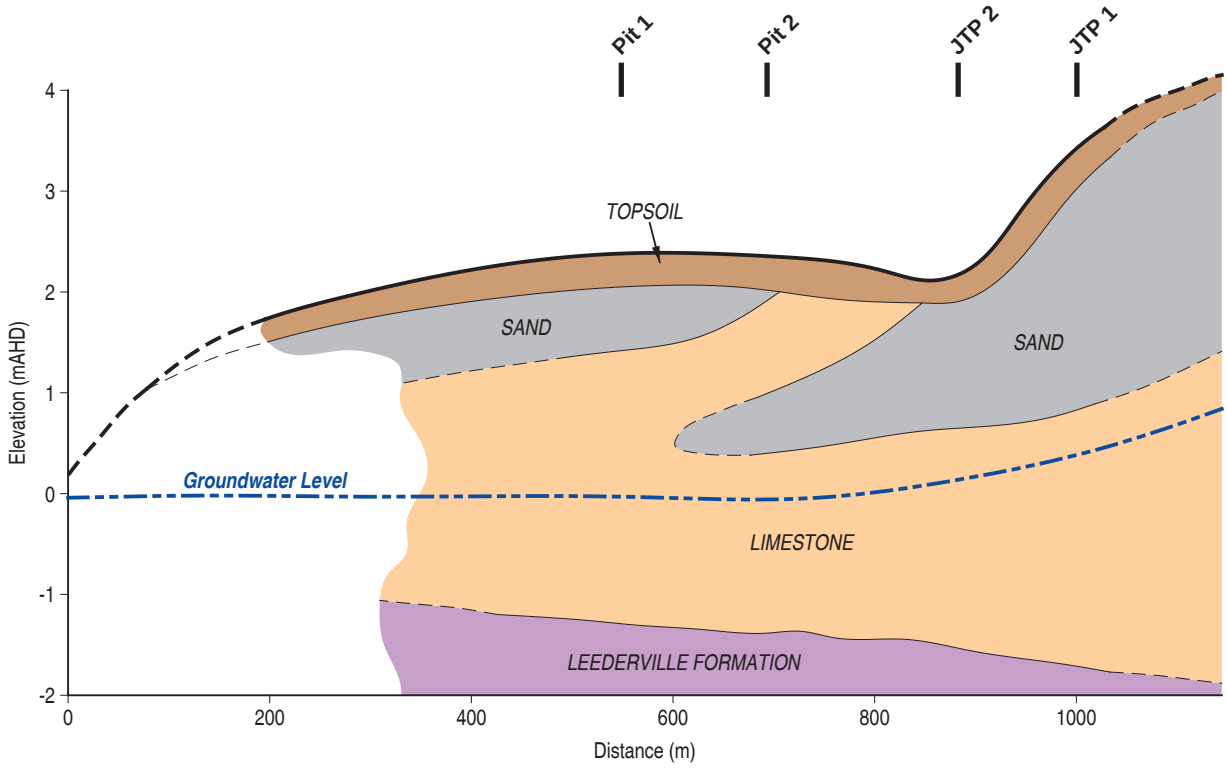
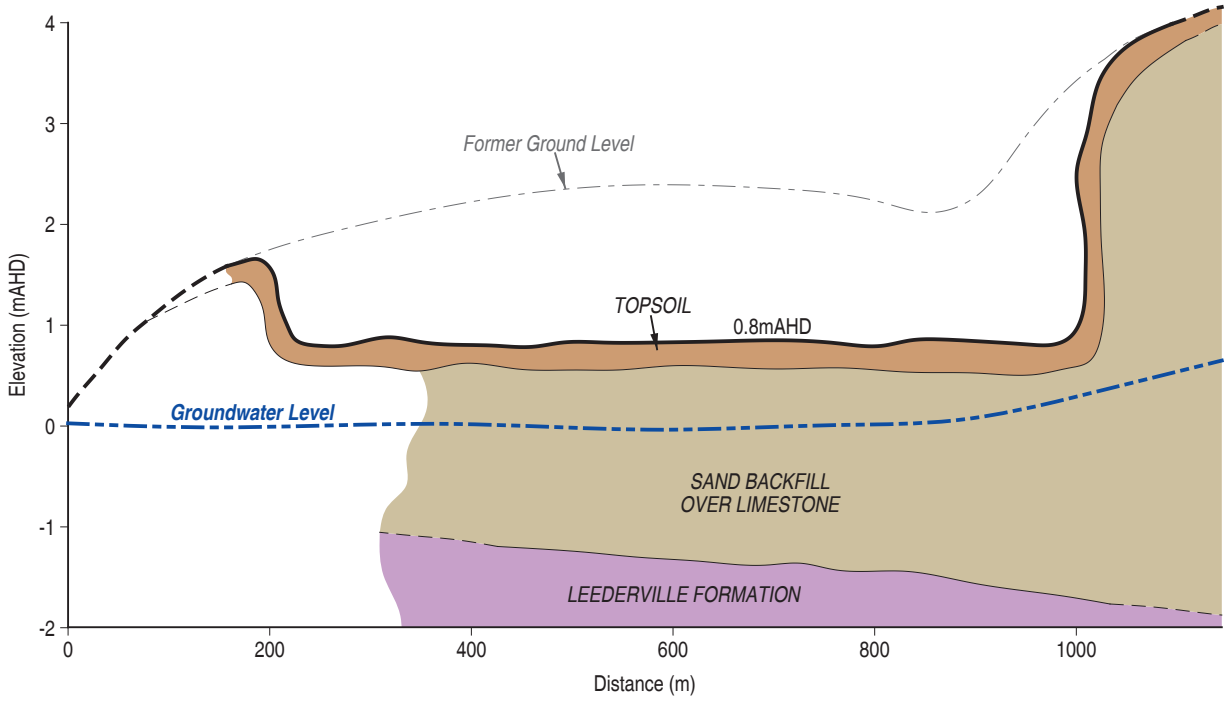
FIGURE 2





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PROJECT: EXTRACTIVE INDUSTRY
HYDROGEOLOGICAL ASSESSMENT
LOTS 3 & 237 LUDLOW PARK ROAD, LUDLOW

TITLE: **HYDROGEOLOGICAL CROSS-SECTION**

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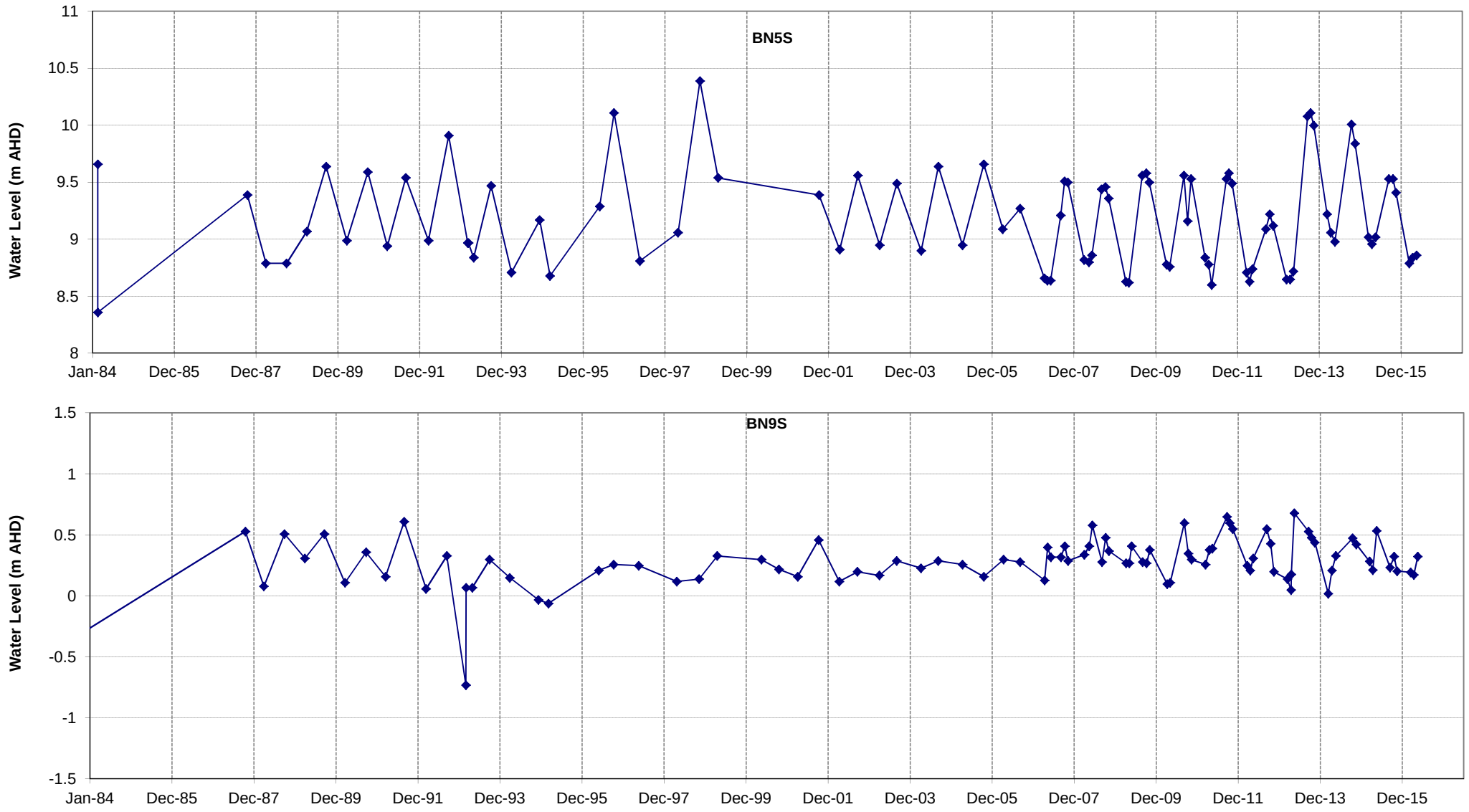
FIGURE 3



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PROJECT: **Proposed Extractive Industry**

Lots 3 and 237 Ludlow Road, Ludlow

TITLE: **BN5S & BN9S Monitoring Data**

FIGURE 4

Waterdirect Pty Ltd