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Hydrogeological Assessment

Integrated Live Export Facility (ILEF)

Report Number 23919.80231

Prepared for

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This document provides information to address the intent of Project Number 23919 as agreed to by Wellard Rural Exports.

Executive Summary

EnviroAg Australia Pty Ltd has been engaged by Wellard Rural to conduct a hydrogeological investigation for the proposed Livingstone Integrated Live Export Facility (ILEF), 2658 Stuart Highway, Livingstone NT. The proposed development is immediately adjacent to the "Santavan" PEQ yard which is on the northern neighbouring property.

The objectives of this project were to;

a) Define the hydrogeology of the site; and,

b) Provide data critical to the design of the ILEF and allow the delivery of detailed design of the proposed key infrastructure.

The assessment has included;

a) Desktop assessment;

b) Drilling test bore holes to define the site hydrogeology;

c) Excavation of fourteen (14) test pits; and,

d) Compilation and assessment of the data obtained.

The site was divided into three zones in accordance with their proposed purposes;

Zone 1. Export Facility

Zone 2. Irrigable Area

Zone 3. Waste Systems

The bedrock geology consists of dolomite, carbonate rocks, sandstone, shale, siltstone, schist, granite and metamorphic rocks.

A hydrogeological assessment of the site identified that shallow ground waters associated with the swamp below the site and potential discharges to the headwaters of the Berry Springs Creek is replenished by the shallow aquifer (the first aquifer encountered during drilling).

The highest yielding bedrock aquifers are the dolomites and carbonate rocks. Lesser yielding aquifers are found in the fractured sandstones and siltstone. Schist, granite and metamorphic rocks are low yielding aquifers.

The installed bore draws water from the deeper dolomite aquifer therefore will not impact on the Berry Creek Spring resource.

Limitations Assessment

The hydrogeological modelling and recommendations presented within this report are based on a limited number of test pits and a test borehole with limited site coverage. It must be noted that variations in ground conditions occur over relatively short distances and with depth.

Table of Contents

List of Tables

List of Figures

List of Appendices

1. Introduction

1.1 Hydrogeological Study

The purpose of the hydrogeological study is to investigate the subsurface hydrologic and geologic conditions of an area or site.

Data includes the thickness of the geologic materials, the soil properties, the occurrence and flow of groundwater, the quality of groundwater and the water levels at local groundwater wells.

1.2 Site Description

EnviroAg Australia Pty Ltd (EnviroAg) was engaged by Wellard Rural Pty Ltd (Wellard) to undertake a Hydrogeological Study at the proposed Livingstone Integrated Live Export Facility (ILEF) site in Darwin. The property is referred to as “Livingstone Valley” and is located on Lot 5544 Hundred of Strangways, 2658 Stuart Highway (Figure 1).

The site of the proposed ILEF is located adjacent to Stuart highway as shown in Figure 1 below. It is near the eastern boundary of the Berry Spring Creek catchment, a tributary of the Blackmore River which feeds into the Middle Arm of Darwin Harbour in the north-west (Figure 2). Berry Springs is fed from dolomite aquifers and is a major source of water for the rural community.

The site is relatively flat and has been cleared, ploughed and sown to improved pasture. The land is currently used for grazing stock and pasture production. The site has an east to west slope of about 1.5% and a cross fall of about 0.5%.

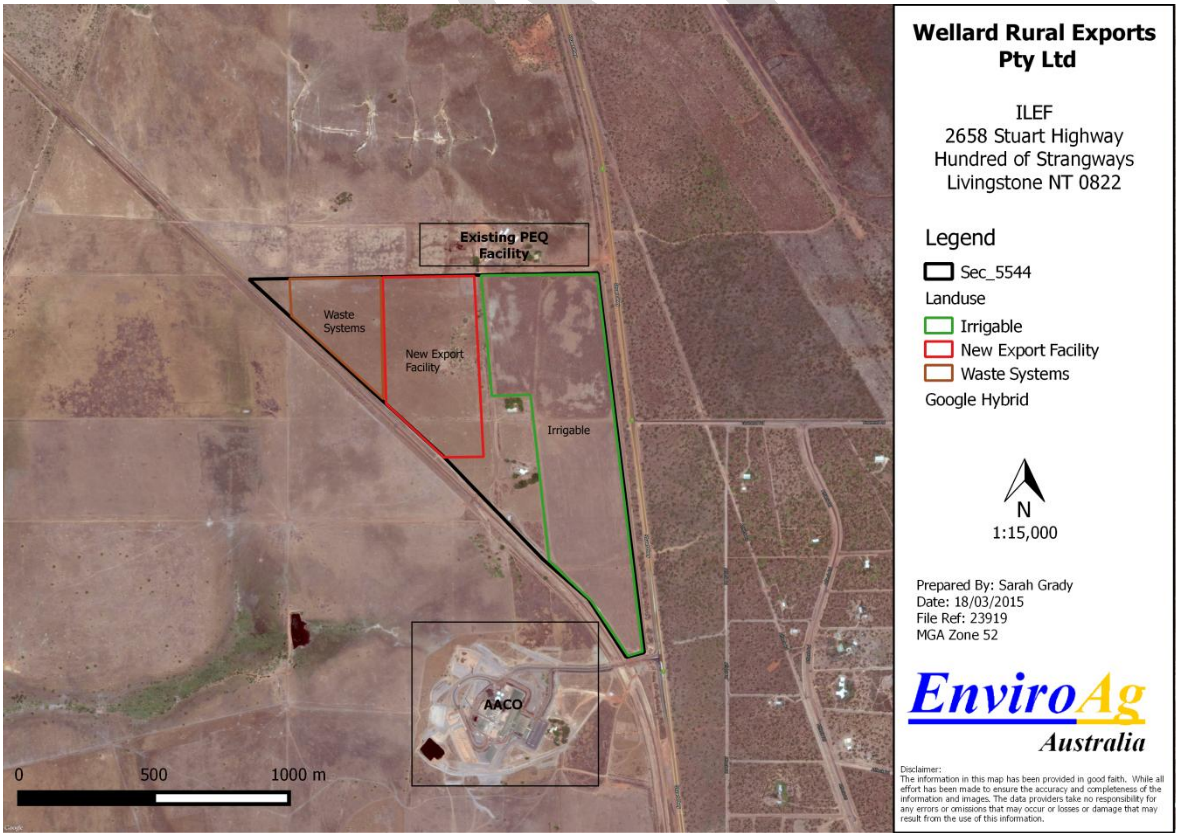

Figure 1 "Livingstone Valley" ILEF Site Satellite Image

A hydrogeological investigation assessment has been undertaken on the site. Key information and findings gathered through tests conducted are detailed within this report.

1.3 Site Details

Site details are presented in the Table 1 below.

Table 1 Wellard ILEF Site Details

Site Name	Integrated Live Export Facility (ILEF)
Site Address	Livingstone, NT 0822
Property Description	Lot 5544 Hundred of Strangways
County	Livingstone, Northern Territory
Current Land Use	Agriculture
Site Area	90.5ha

2. Review of Site Geology

2.1 Regional Geology

The geology of the region has been described by the Department of Infrastructure, Planning and Environment in "*An understanding of the groundwater and surface water hydrology of the Darwin Harbour Plan of Management area*" (Haig & Townsend, 2003).

The elevation in the catchment ranges from 20 Australian Height Datum (AHD) to 60 AHD (Figure 6). It is positioned at the top of a foothill adjoining a plateau on which the Stuart Highway is positioned.

The majority of the Darwin Harbour region is covered by a 10m layer of Cainozoic aged laterite, below which there are 30-60 metres of Cretaceous aged sandstones and claystone. The regional unconfined aquifer system recharges during the wet season and is comprised of shallow sediments. Cretaceous sediments act as a source of recharge and storage to the deeper bedrock aquifers.

The following provides a summary of the regional geology as described by Haig and Townsend (2003):

- The bedrock geology consists of dolomite, carbonate rocks, sandstone, shale, siltstone, schist, granite and metamorphic rocks. The highest yielding bedrock aquifers are the dolomites and carbonate rocks. Lesser yielding aquifers are found in the fractured sandstones and siltstone. Schist, granite and metamorphic rocks are low yielding aquifers.
- Most of the region is covered with 20 to 50 metres of more recent sandstone, siltstone and claystone. There is a 5 to 10 metre thick layer of laterite i.e. a residual clayey layer mainly consisting of hydroxides of iron and aluminium formed under tropical climatic conditions by the weathering of igneous rocks that forms a capping layer over most of the area.
- Recharge to the regional aquifers is a result of direct infiltration of rain through the surface deposits. The average annual rainfall in the region is 1,700 mm, as much as 200 mm is recharged to some of the more transmissive areas in the catchment.
- Groundwater flows are determined by topography and the capacity of the aquifer to transmit water horizontally and vertically.
- Approximately 50% of the catchment area has moderately to severely water logged soils. Following the periods of high rainfall and runoff, the wetlands that form during the wet season will gradually dry up as shallow groundwater drains. Some wetlands which are "perched" above clay layers persist through the dry season.
- Perennially flowing springs, which are fed from deeper dolomite aquifers, are found at Howard Springs and Berry Springs.
- Compared to undeveloped areas, the groundwater levels at the end of the dry season in the developed rural area have lowered 6 to 10 metres over the last 20 years.
- The additional lowering of water levels at the end of the dry season is due to water extraction associated with rural development.
- Following the cycle of natural drainage and extraction of groundwater, the aquifer system is fully recharged each wet season.

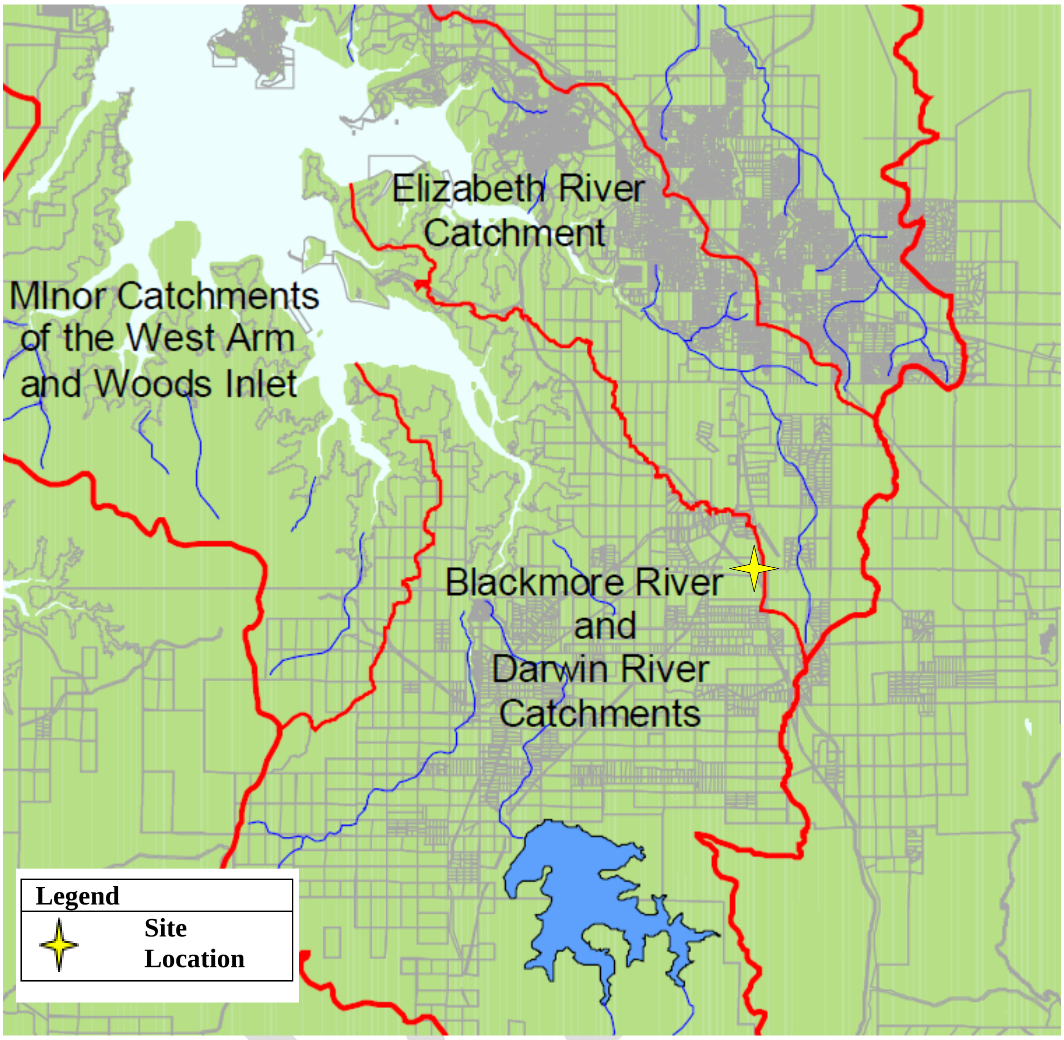

Figure 2 Catchments of the Darwin Harbour Region (Haig & Townsend, 2003)

2.2 Local Hydrogeology

2.2.1 Stratigraphy

A search of bores in the vicinity was undertaken. The location of the bores is shown in Figure 3 below. The bore cards for these bores and found in Appendix A.

The key attributes of the bores are summarised in Table 2 below. Bores 000079 and 000030 are found on “Livingstone Valley”.

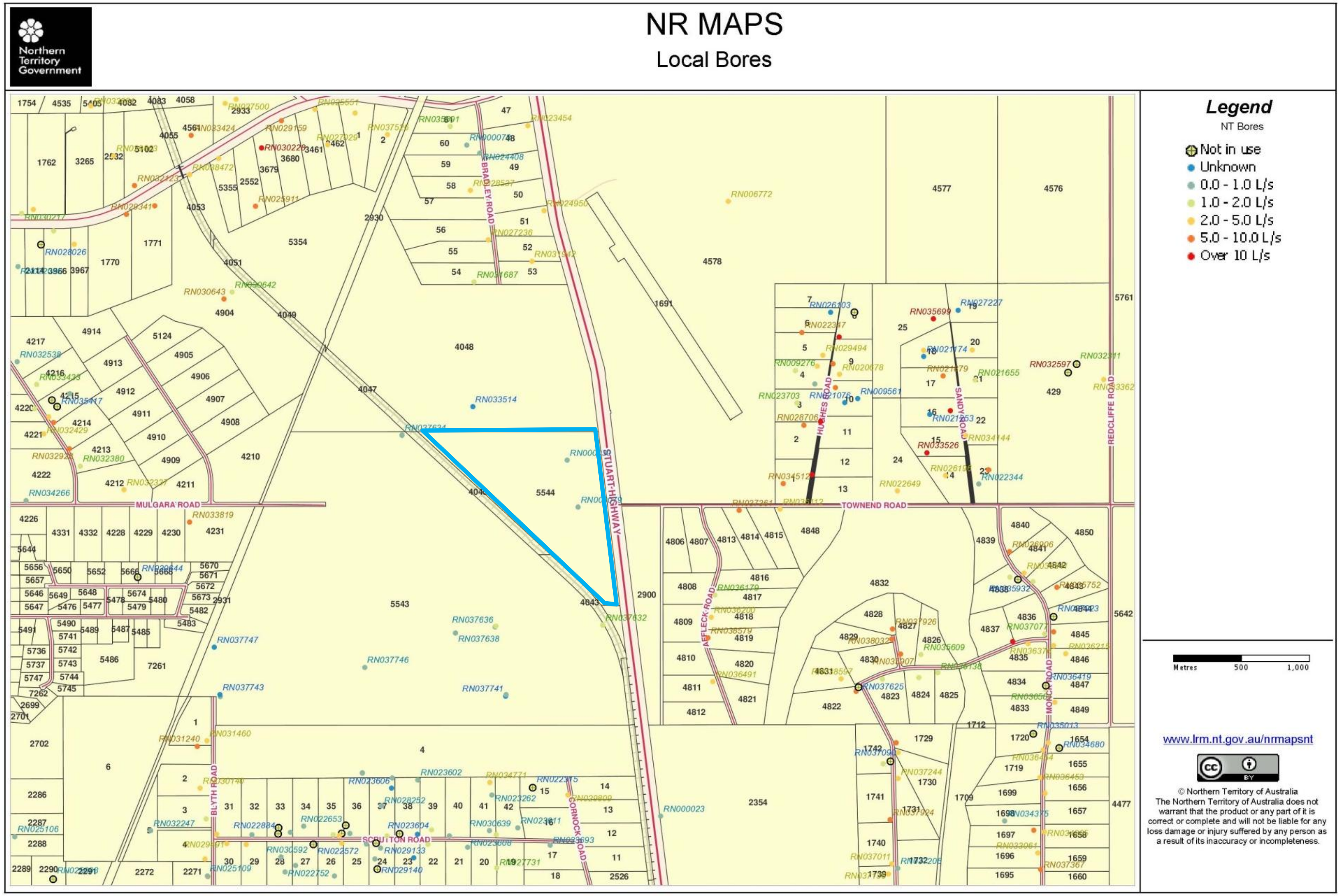

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Figure 3 Rural well locations surrounding the property lined in blue (DLRM, 2015)

Table 2 Summary of Bores Local to Site (DLRM, 2015)

RN of Bore	Name	Date of Bore Completion	Depth (m) dbgl	Estimated Depth AHD (m)	SWL (m)	Water Bearing Zone screened (m)	Yield (L/s)	Quality	Use
037632	AA Co.	2012	40	11	5.8	5-10 16-24 28-32	2	EC 49.4, pH 8.51	Monitoring
037636	AA Co.	2012	40	0	2.4	5-8 28-40	0.2	EC 109.4, pH 8.45	Monitoring
037638	AA Co.	2012	40	-3	1.4	5-8 24-30	0.2	EC 87.2, pH 8.09	Monitoring
037634	AA Co.	2012	47	-9	2.2	0.5-10 20-40	0.75	EC 89.5, pH 8.43	Monitoring
033514	Santavan	1982 (registered 2002)	43	1	2	Unknown	Unknown	Unknown	Prod/ Domestic
030642	Santana	1996	40	-11		26-40	1.2	Good	Explorat^{N} test
031687	McGuffog	1998	121	-70	18	104-121	1.5	EC 143, pH 8.2	Agri
031942	Chin	1992	133	-80	17	48-80 85-? 130-133	2.8	Unknown	Agri
037361	Malgorze-wicz	2011	53	-2	13	47.5-52	10	EC 338, pH 7.29	Domestic

The existing registered bores in the locality were drilled and constructed between 1996 and 2012 for monitoring, domestic and agricultural production purposes. Most bores were drilled to depths of approximately 40 metres with standing water levels of 1 – 6 metres below ground level.

Yields were mostly sufficient for domestic and production bores – less than 2 litres/second. The main water bearing zones are recorded as being from approximately 5 – 10 metres in depth in the near surface aquifers; and most generally at a depth of 20 – 40 metres, whilst the deepest aquifer is approximately 104 – 130 m in depth.

Soil drill logs where recorded for the majority of these bores in the immediate vicinity of the proposed development.

The majority of borehole/drill logs exhibited the following information:

- Topsoil to 0.5 – 1.0 metre depth;
- Sandy surface soil is underlain by sandy clay and clay layers to ~20 – 30 metres in;
- Depth providing a barrier to the groundwater aquifer;
- Deeper layers generally included grey clay, brown and grey “shale”; and,
- Siltstone with gravelly seams.

2.2.2 Ground Water Model

Haig and Townsend (2003) present a W-E cross section from Howard Springs to Black Jungle Lagoon. This cross section shows the Whites formation on the east and beds of sedimentary materials to the west. The cross section is shown below in Figure 4.

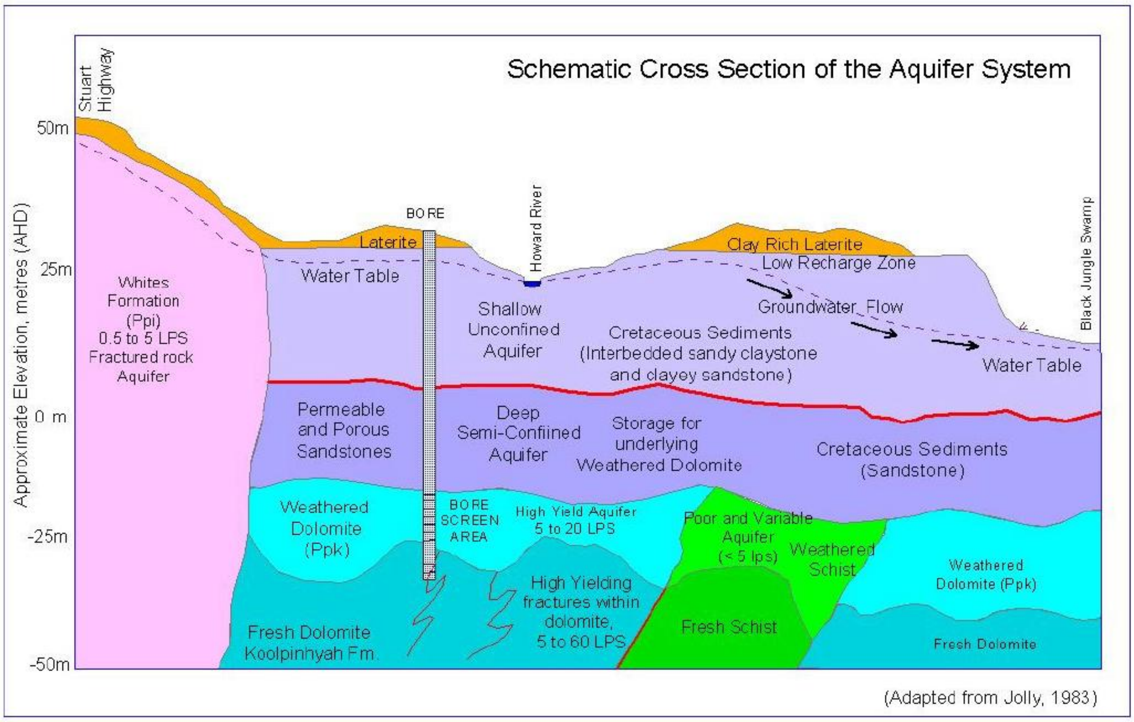

Figure 4 Schematic Cross Section of the Aquifer System (Haig and Townsend, 2003)

2.2.3 Site Drainage

Based on the available literature shallow groundwater at the 'Livingstone Valley' site are likely to fluctuate with the season. Further low areas are likely to become inundated during the 'wet season' (Haig and Townsend, 2003).

The local rural community utilise water from Berry Creek and its springs. The sustainability of Berry Creek and its springs are relied upon as a source of water for the rural and recreation operations within the area. Groundwater discharge sourced predominantly from the lower dolomite aquifers and overland flows replenish Berry Spring Creek. The sustainability of the "base flow" into the creek can be directly linked to the rate extraction of the numerous stock and domestic bores in its catchment and the surrounding areas. These extract water from the sediments overlying the lower dolomite sediments. Excessive surface extraction reduces recharge rates to the deeper aquifers. Overland flow will only replenish Berry Spring Creek during the wet season.

Groundwater levels at the end of the dry season have been documented to have dropped six to ten metres over the last 20 years.

2.2.4 Water Quality

The water quality is determined by the time period in which it has spent in contact with the aquifer material, the type of aquifer, distance from the sea and the distance from the recharge source. Deeper dolomite aquifers tend to yield harder alkaline waters and the shallower cretaceous aged sandstone produces fresh non-carbonate water with more acidic properties.

3. Site Hydrogeological Assessment

A field study was undertaken in January and June 2015. In January 2015 the complete site was traversed and assessment of drainage was undertaken in parallel with a topographic site survey.

Advices were sought from the NT Government and local drilling companies that had drilled stock, domestic and production bores in the vicinity. Anecdotal advices were obtained that suggested the Whites Formation would be found on the eastern most area of the property and it would abut sedimentary formations.

In June 2015 a test bore was drilled and the location of existing bores was established and past bore holes were inspected (see Figure 5). This test bore was drilled at the same time as the soil survey. The soil survey is reported by EnviroAg Australia in the Soil Survey report in Appendix L of the Environmental Assessment.

Figure 5 Test bore location in relation to existing bores.

3.1 Surface Soils Characteristics

The soil characteristics of the site are described in the report (23870.150703 Soil Assessment and Land Capability) in Appendix L of the Environmental Impact Assessment.

The soils in the upper areas of the “Livingstone Valley” are a classic “Darwin Lateritic Red Kandosol”. Kandosols have gravelly sandy to loamy surface soil, gradually changing to sandy clay or clay subsoils with really poor structure, low fertility and (generally) poor water holding capacity. The poor structure and laterite can lead to seasonal waterlogging and this has been extensively observed on site.

3.2 Groundwater Characterisation

A test borehole (1) was drilled using the following drilling method:

- Open hole Rotary Air Blast (RAB) drilling with a 300mm drill to a depth of 5.1 m to establish a surface case to hold loose surface material;
- Open hole drilling with a 200mm drill to a depth of 72m; and
- RAB drilling with a 150mm drill, through a 152mm ID casing, to 112m.

The soil strata was sampled and logged at 0.5m intervals. The assessment of consistency and density was based on soil textural characteristics, the relative difficulty of penetration by the drill rig. The drilling method employed clearly identified the horizon from which samples were taken. The bore logs for the installation of the bore are provided in Appendix B.

3.3 Bore Installation

Table 4 summarises the bore construction properties of the deep aquifer bore installed for the supply of the ILEF facility. As shown, the bore installed extracts water from the 4th (deep) aquifer, and will therefore not lower of the water levels within the near surface aquifer.

Drilling was conducted by Bores NT according to *Minimum Construction Requirements for Water Bores in Australia* (LWBC 2003). Soil sampling and logging was performed at strata changes and is detailed in Table 3.

Table 3 Summary of Drilling Observations

Type	Depth (m)	**Description**
Natural	0 - 0.5	Topsoil
Natural	0.5 - 5	Laterite; weathered laterite (ferricrete) based materials
	5 - 19	Clays, silts and decomposed siltstones / claystones
Natural	19 - 28	Weathered brown siltstone
Natural	28 - 40	Firm brown siltstone
Natural	40 - 90	Firm multi-coloured shades, good fracturing
Natural	90 - 98	Soft grey dolomite (mineralised; fine grained)
Natural	98 - 114	Soft grey dolomite (course crystals)

Table 4 Bore Construction Summary

Aquifer Depth	Aquifer 1 (Sandstone / Siltstone) – 25-36m (sealed off) Aquifer 2 (Sandstone / Siltstone) – 45-53m Aquifer 3 (Siltstone) – 62-73m Aquifer 4 (Dolomite; fine graduating to course grained) – 98-114m
Total Bore Depth	114m below ground level 115m below top of casing
Head Works	158mm casing 1m above ground level
Standing Water Level	13m below top of casing
Screen Construction	4.8m slotted casing (158mm Dia) 67-71.2 6m 115mm slotted casing 6m 115mm s/s wire wound screen: 107.2-113.2m

3.4 Ground Water Model

Based on the desktop assessment; bore logs and onsite drilling a ground water model was developed. Figure 6 depicts a cross section of the Livingstone site illustrating the movement of groundwater and the interaction of the newly implemented bore with the aquifer with the deepest aquifer.

It is noted that transient downslope flow occurs in the A2-B2 horizons. Where there is a reduction in slope the soil water is forced to the surface. It is at this change in slope that surface waters start to accumulate. These two processes lead the waterlogged areas shown in the maps presented by Haig and Townsend (2003).

Below the site these waters generate a swamp. A proportion of this accumulated water filters down through the ferricrete and travels into Berry Creek and its springs via the surface aquifers.

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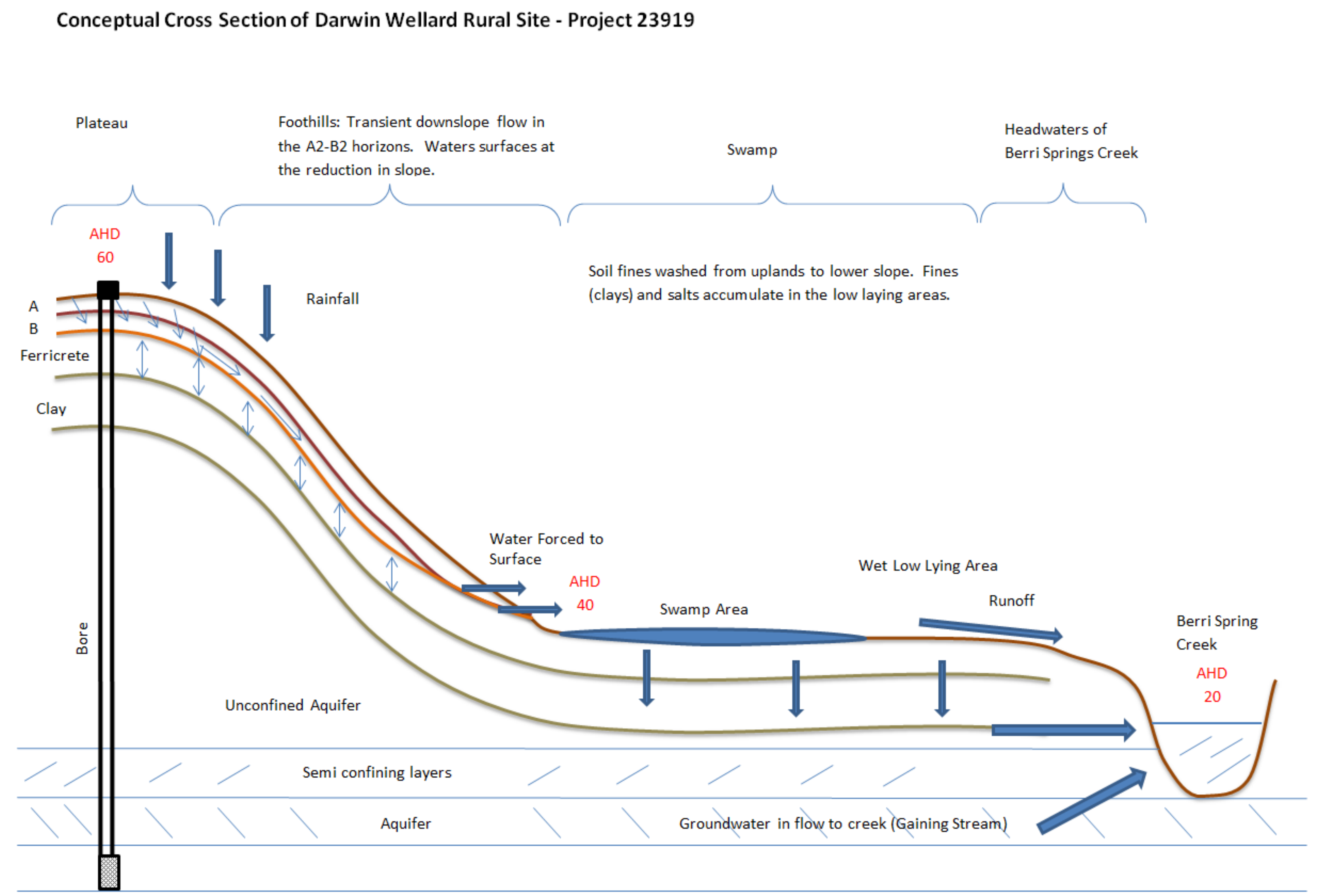

Figure 6 **Conceptual Cross Section of the Hydrological Properties pertaining to the ILEF Darwin Site**

4. Conclusions and Recommendations

The hydrogeological assessment of the site has confirmed that it has a stratigraphy aligned with the findings of Haig and Townsend (2003).

The site is underlain by a layer of ferricrete below which is found interbedded siltstones and clay stones. The claystone is likely to be relatively impermeable and confine aquifers within this stratigraphic series. This aquifer is a relatively shallow aquifer and it is the source of much of the local stock and domestic supplies.

Below these materials more porous sandstones are located.

The bore constructed on "Livingstone Valley" the Wellard ILEF site will extract water from the deeper sandstone and dolomite aquifers and as such will not impact on the near surface aquifers. It has been constructed so that the near surface aquifers are excluded from the screen zone and pump take.

The following recommendations apply:

- The holding and storage ponds will need to be lined to prevent groundwater inflows and or be built above ground.
- The pond lining will need to be "reinforced" to prevent the lining is not 'pushed out' by the subsurface flow. To reduce the risk of structural failure of pond walls and flooring a rock armouring will be implemented to improve stability during periods of heightened transient groundwater flow.
- Shallow near surface ground waters at the "toe" and bottom of the slope can adversely affect the construction of infrastructure in the wet season or immediately thereafter if not correctly managed. Controls must be implemented into the design at an early stage.
- A piezometer should be placed above and below the site to monitor shallow groundwater depth and quality.
- Monitoring of the water levels and extraction from the deep water should be undertaken.

5. References

Australian Standard 1289 -1997 (Methods for testing soils for engineering purposes)

Australian Standard 1726 - 1993 (Geotechnical Site Investigations)

Casagrande, A. (1948). Classification and identification of soils. *Transactions of the American Society of Civil Engineers*, 113(1), 901-930.

Department of Land and Resource Management (DLRM) (2015). NT NR Maps. Northern Territory Government. Available from http://www.lrm.nt.gov.au/spatial-lrm/nrmapsnt (Accessed 10.08.2015).

Haig, T., & Townsend, S. (2003). An understanding of the groundwater and surface water hydrology of the Darwin Harbour Plan of Management area. *Proceedings: Darwin Harbour Region: current knowledge and future needs*, 122-149.

6. Appendices

Appendix A. Records of Bores in the Vicinity of the Site

Appendix B. Bore Completion Report