# Groundwater Extraction Scenarios

## Arrowsmith Hydrogen Project

CW1183400

Prepared for
Infinite Blue Energy

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# 1 Background

Infinite Blue Energy ("IBE") is developing a hydrogen-production project with associated wind turbines and solar panels in the Arrowsmith area (Site), which is located approximately 320 km north of Perth (Figure 1-1). IBE is evaluating the feasibility of using approximately 900 ML/year site groundwater for the project. IBE has approached Cardno to evaluate the groundwater supply for optimal abstraction while minimising drawdown to the onsite Groundwater Dependent Ecosystems (GDE's). The Site area is considered as low to medium potential for terrestrial GDEs to occur (Ecoscape, 2021). Previous pump tests indicate a suitable pumping rate of approximately 4 L/s. However, flow was determined to be hindered by bore construction. Hence, further literature review and investigation was undertaken to determine the parameters required for understanding the feasibility of the satisfying the anticipated demand via groundwater extraction.

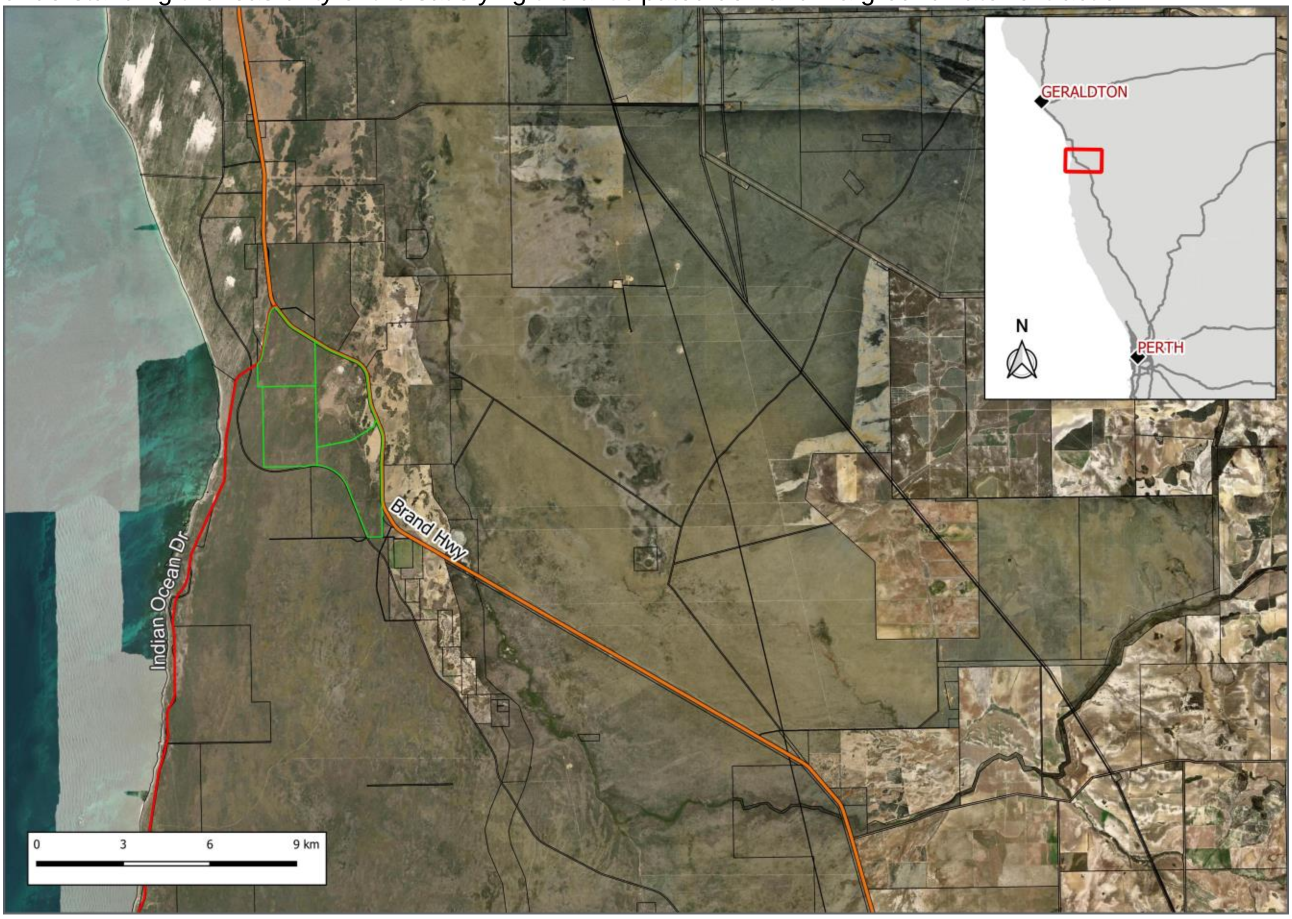



Figure 1-1 Site Location

# 2 Objective

The objective of this project comprised the following elements:

> Evaluation of groundwater supply for optimal abstraction of groundwater from the Site to achieve the desired abstraction volume while minimising drawdown that could adversely impact GDEs onsite. It is to be considered that the preferred production bore location is near the proposed hydrogen plant that will be located in the north-east area of the site.
  - Specifically, evaluation of the drawdown as a result of groundwater extraction from:
    - The Superficial Aquifer
    - The Yarragadee Aquifer
    - Both the Superficial Aquifer and Yarragadee Aquifer

# 3 Scope of Work

The following scope of work was undertaken to fulfil these objectives:

> Reviewed geological and hydrogeological parameters at and surrounding the Site;

> Developed a site-specific conceptual hydrogeological model to simulate the simplified geology and groundwater conditions at the Site and surrounds;

> Used the conceptual model to support construction of a numerical groundwater flow model;

> Calibrated the numerical model with pre-groundwater extraction groundwater conditions by varying key input parameters to generally match the observed representative groundwater levels; and

> Used the numerical model to simulate the following groundwater extraction scenarios and determine the associated drawdown:

- groundwater extraction from multiple bores within the Superficial Aquifer;
- groundwater extraction from one bore within the Yarragadee Aquifer; and
- groundwater extraction from two bores within the Yarragadee Aquifer.

> Consider cumulative impacts with the inclusion of surrounding groundwater uses.

# 4 Setting

## 4.1 Location

The Site is located approximately 320 km north of Perth. As shown on Figure 1-1**Error! Reference source not found.**, the Site is bounded to the east by the Brand highway and to the west by Indian Ocean Road. The shoreline is located approximately 1 km to the west of the western boundary.

## 4.2 Topography

The ground elevation across the site ranges between 8 mAHD and 52 mAHD with the lowest elevation being at the northern boundary of the site and the highest elevation located towards the centre of the western boundary. The site in general has varying ground elevation with a relatively flat, low elevation (16 mAHD) area located to the north-east of the site.

## 4.3 Geology

The following geological summary is synthesised from the Government of Western Australia Department of Water's report *Northern Perth Basin: Geology, hydrogeology and groundwater resources* dated January 2017.

The surface geology around and at the site is predominately Tamala Limestone comprised of calcarenite sand with quartz sand and minor clayey sediments present in varying amounts. Cementation of the calcarenite is most prominent towards the coastal regions with karstic features and cave systems present throughout the formation as a result of carbonate dissolution and recalcification. Regionally, the Tamala Limestone has a typical thickness of 40-50 m with the thickness at the site being only 20 m.

Underlying the Tamala Limestone, the Yarragadee Formation is predominately sand with interbedded sandstone, siltstone, shale and claystone units. The Yarragadee Formation has a maximum thickness of approximately 4000 m, however, at the Site, the maximum thickness is closer to 500 m. To the east of the site, the depth of the Yarragadee increases to -1000 mAHD due to the presence of a fault line.

The Yarragadee contains four distinct units, Unit A, Unit B, Unit C and Unit D, in order from oldest to youngest. The basal portion of the Yarragadee, Unit A, contains of approximately 70% medium to coarse grained, poorly to moderately sorted sandstone. Unit B comprises of 60-70% siltstone and shale/claystone layers. Overlying this siltstone and claystone unit is the predominantly sand (80%) unit, Unit C. The uppermost layer, Unit D, is composed of interbedded sandstone, claystone and siltstone. Both Unit D and Unit C become thinner towards the west. As a result, the upper most Yarragadee layer present at the location of the Site is predominantly Unit B, with Unit C present along the eastern boundary.

South to south-west of the site, the Yarragadee Formation is not present due to the Beagle Ridge Fault. Here, the superficial aquifer is located above the Cattamarra Coal Measures.

## 4.4 Hydrogeology

The two main aquifers present at the Site are the Superficial Aquifer and the Yarragadee Aquifer. The Superficial Aquifer is the upper unconfined aquifer located between the Gingin Scarp to the east, Geraldton to the north, Gingin to the South and the coastline to the west. This aquifer is composed of numerous geological units and is relatively thin vertically (20-30 m thick). At the site, the Superficial Aquifer is comprised predominantly of the highly transmissive Tamala Limestone.

The Yarragadee Aquifer is bound to the south-west of the site by the Beagle Fault which is inferred to act as a no-flow barrier forcing groundwater flow north to north west towards the coast. To the west, the Yarragadee formation continues below the seabed and is bound to the east by the Darling or Urella faults. Comprised of four hydrostratigraphic units, the Yarragadee Aquifers hydrogeological parameters vary throughout the extent of the aquifer. Due to the location of the site, the Yarragadee aquifer is largely composed of Unit B and Unit A where a hydraulic conductivity of 5 m/day has been adopted (Table 4-1).

Table 4-1 Indicative Aquifer Parameters and Characteristics at the Site

| Parameter | Superficial Aquifer | Yarragadee Aquifer | | | |
|---|---|---|---|---|---|
| | - | Unit A | Unit B | Unit C | Unit D |
| Hydraulic Conductivity (k) (m/day) | 50 | 5 | 5 | 0.1 - 5 | 5 |
| Aquifer/Unit Base (mAHD) | 10 | -500 | -200 | - | - |
| Aquifer/Unit Thickness (m) | 20 | 300 | 210 | - | - |

Increased salinity is experienced at the location of the Site due to the presence of a saltwater wedge and the related mixing zone. Salinity across Site ranges from approximately 7000 mg/L (TDS) and 1500 mg/L (TDS) within the both the Yarragadee Aquifer and Superficial Aquifer as shown in (DoW, 2017). This area also experiences upward groundwater movement causing saline water to flow from the underlying Yarragadee Aquifer up into the portions of the Superficial Aquifer.


Figure 4-1 Salinity as TDS (mg/L) within the Yarragadee Aquifer

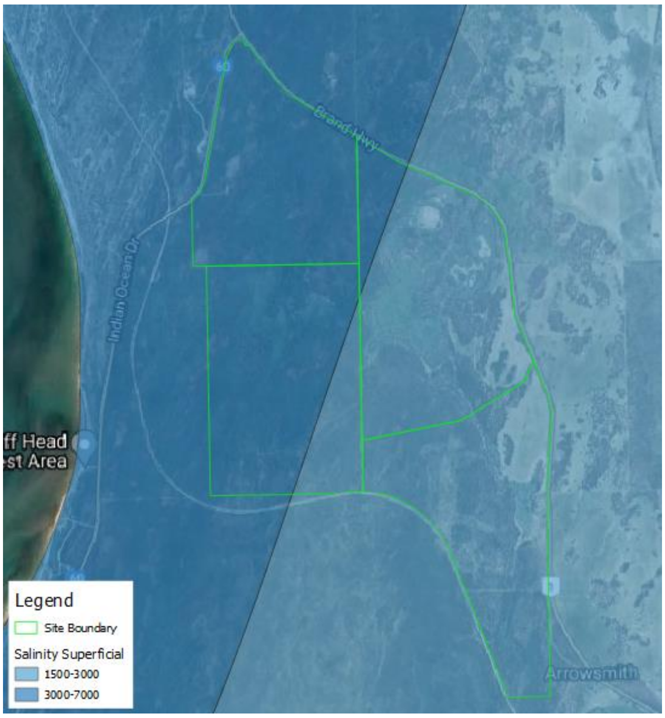



Figure 4-2 Salinity as TDS (mg/L) within the Superficial Aquifer

## 4.5 Groundwater Dependent Ecosystems (GDEs)

A database search of the Bureau of Meteorology's (BOM, 2021) Groundwater Dependent Ecosystems Atlas found both terrestrial and aquatic GDEs onsite and surrounding the site. Majority of the site is classified as a low potential GDE with the western portion classified as moderate potential GDE for terrestrial GDEs. One small portion, located in the north-east section of the site, is classified as a high potential terrestrial GDE. One watercourse located on-site to the south and east is classified as a moderate potential aquatic GDE. An environmental survey conducted onsite (Ecoscape, 2021) found a vegetation species indicative of a GDE, Eucalyptus Camaldulensis. The areas where this vegetation type is located has been considered as a potential GDE. All GDE locations and classifications are displayed in Figure 4-3.

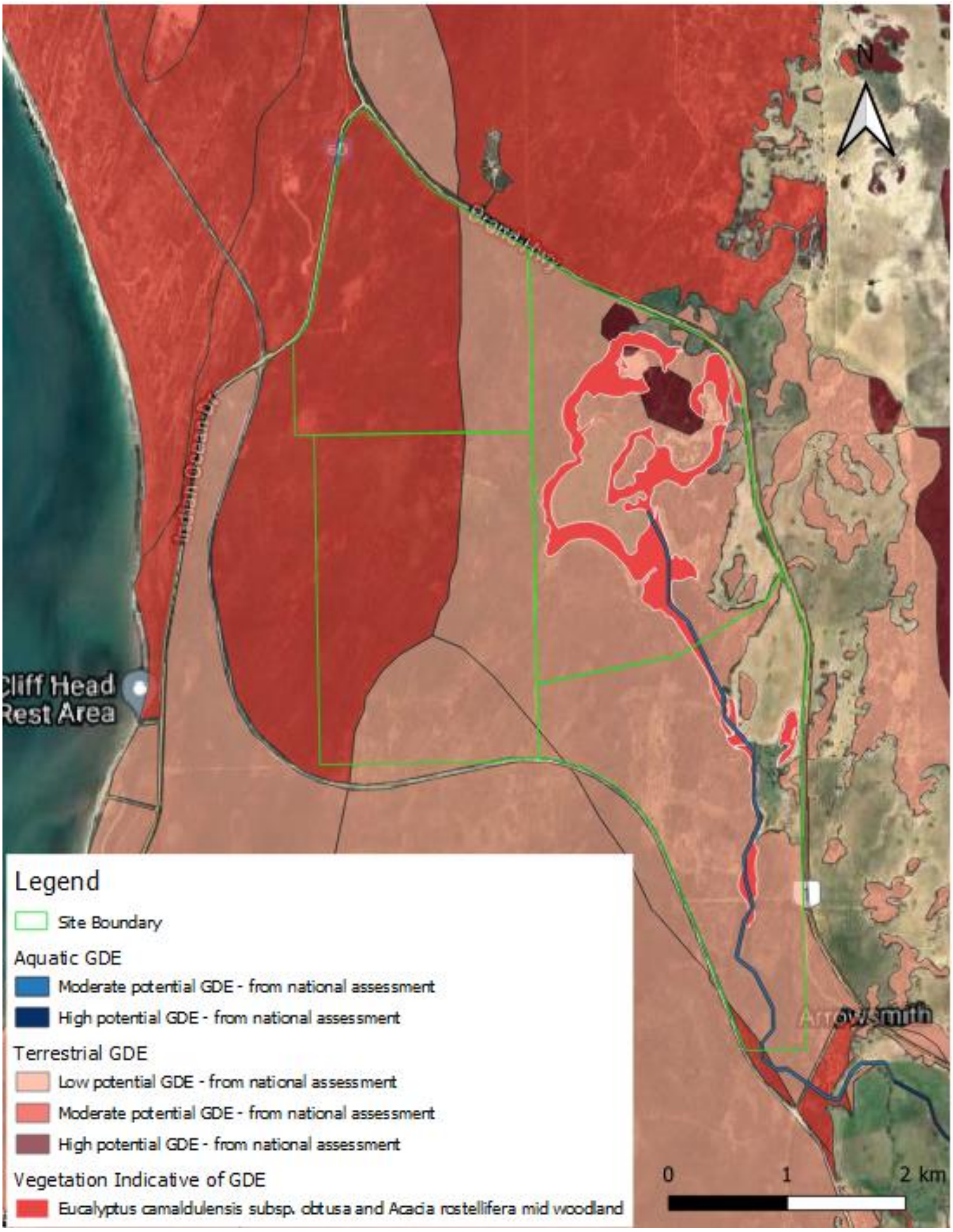



Figure 4-3 Location of GDEs at the Site

# 5 Extraction Feasibility Assessment

## 5.1 Modelling Approach

A model of groundwater flow across the site and surrounds was constructed to assess the feasibility of extracting 900 ML/year of groundwater from the underlying aquifer systems. A numerical model (rather than an analytical model) was used due to complicated geology of the area. A three-dimensional numerical groundwater model (MODFLOW based) was constructed to simulate the groundwater levels at the site. The model was then used to determine drawdown levels under various groundwater extraction scenarios.

## 5.2 Modelling Domain and Discretization

Groundwater flow beneath the site was simulated using a model domain of 40 km by 40 km (Figure 5-1). The model domain was divided into a series of rectilinear cells with sizes ranging from approximately 6 m by 6 m across the area in which potential production bores were located in the various modelling scenarios and 100 m by 100 m away from these areas.

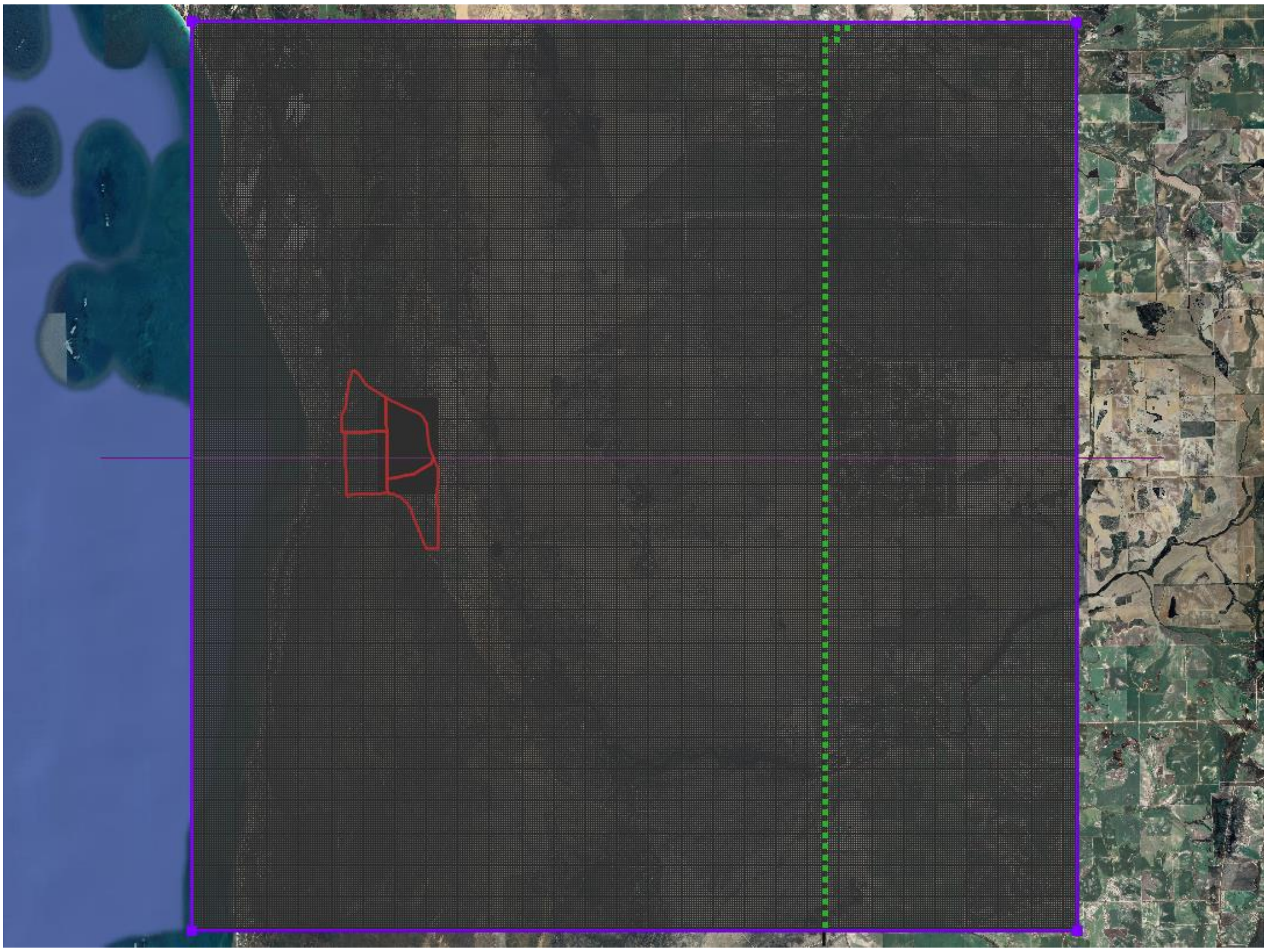


Figure 5-1 Model Domain

Vertically, the superficial aquifer is represented by Layer 1 with the Yarragadee Aquifer represented by Layers 2-5 corresponding to each geological unit of the Yarragadee (Unit D, Unit C, Unit B and Unit A). The top of Layer 1 corresponds to either the land surface or sea level. Elevations vary across the model with the lowest point being sea level in the west of the model (0 mAHD) and the highest ground elevation is approximately 50 mAHD in the eastern portion of the model. The thickness of each layer within the model is presented in Table 5-1.

Table 5-1 Model Layer Thickness

| Layer Number | Thickness (m) |
|---|---|
| 1 | ~20 |
| 2 | 80 |
| 3 | 100 |
| 4 | 100 |
| 5 | 200 |

## 5.3 Modelling Parameters

Hydraulic conductivity is a key input parameter for the steady-state models used to evaluate groundwater levels. Table 5-2 presents horizontal hydraulic conductivity values for each layer. These values were interpreted from information provided by the Department of Water (DoW, 2017).

Table 5-2 Model Layer Hydraulic Conductivities

| Layer Number | Hydraulic Conductivity (m/day) |
|---|---|
| 1 | 50 |
| 2 | 5 |
| 3 | 0.1 - 5 |
| 4 | 5 |
| 5 | 5 |

Layer number 3, correlating to Unit C of the Yarragadee Aquifer, was modelled with a lower hydraulic conductivity (0.1 m/day) where this layer is present as the uppermost layer to the east of the site. All hydraulic conductivities used are the minimum hydraulic conductivity values for each aquifer ensuring the model presents results under the least favourable conditions.

## 5.4 Model Boundaries

### 5.4.1 Constant Heads

Constant-head boundary cells were assigned across the off-shore (western) portion of the model. For cells in Layer 1 located offshore the ocean, a groundwater elevation of 0 mAHD was assigned.

### 5.4.2 Recharge

Diffuse recharge across the model domain was assigned a value equivalent to 30 mm/year. This value was based on information presented in *Northern Perth Basin: Geology, hydrogeology and groundwater resources* (2017).

### 5.4.3 Production Bores

To simulate groundwater extraction three scenarios were executed. The first scenario saw two bores located in the Yarragadee Aquifer (Unit B), one located near the hydrogen plant and the additional bore located south-west of the hydrogen plant, pumping at a rate of 1,233 $m^3$/day each. Scenario two involved a single bore, located near the hydrogen plant, pumping from the Yarragadee Aquifer at a rate of 2,466 $m^3$/day. The third scenario involved four bores located in the Superficial Aquifer, distanced from one another in a north-east to south-west line, pumping at a rate of 616.5 $m^3$/day.

# 6 Modelling Results

Each drawdown scenario was reviewed to evaluate whether drawdown would occur to an extent that could potentially impact the Groundwater Dependent Ecosystems (GDEs) located on-Site or off-Site. To protect sensitive ecosystems, such as GDEs, a 0.2m decline in water levels has been adopted as a trigger which is regularly utilised to indicate when prevention or mitigation options are required under established legal frameworks (NSW DPI, 2012; Queensland Government, 2000; South Australian Arid Lands Natural Resources Management Board, 2009).

## 6.1 Pre-extraction Groundwater Levels

Figure 6-1 displays the Layer 1 (Superficial Aquifer) contours of simulated groundwater levels prior to any Site groundwater extraction. These contours present groundwater levels in alignment with literature groundwater levels of the Superficial Aquifer at and surrounding the Site location. Figure 6-2 displays the contours for Layer 2 (the upper unit of the Yarragadee Aquifer) under the same conditions. These also align with target values and are similar to those of the Superficial Aquifer due to the hydraulic connectivity of the two aquifers at this location.

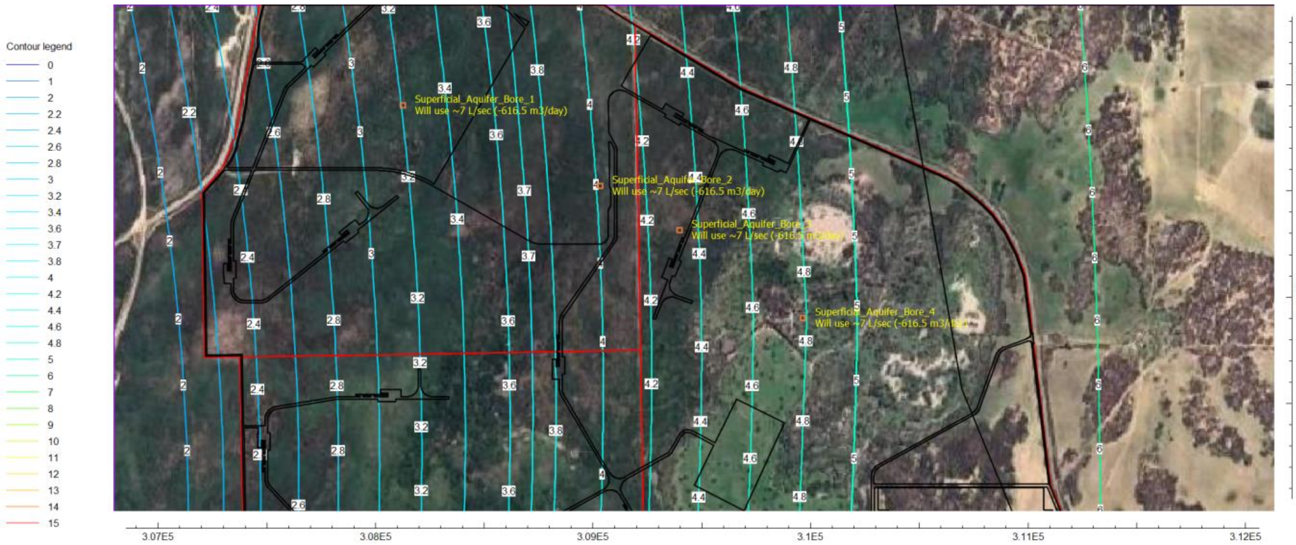



Figure 6-1 Groundwater levels in the Yarragadee Aquifer before groundwater extraction

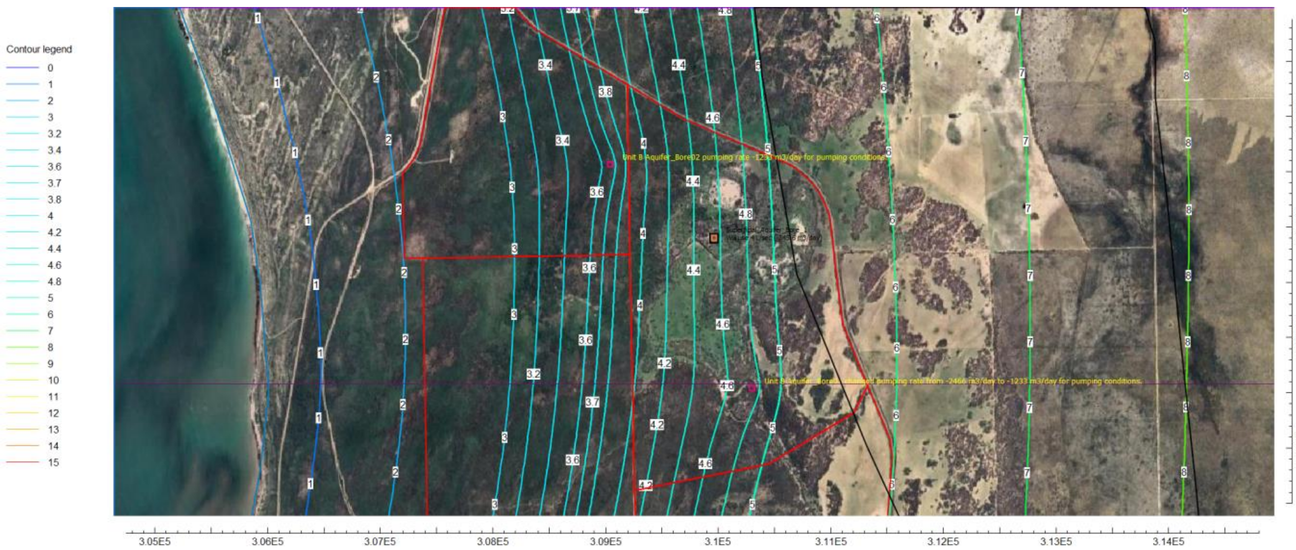



Figure 6-2 Groundwater levels in the Superficial Aquifer whilst pumping from two bores located in the Yarragadee Aquifer at an extraction rate of 1233 m3/day

## 6.2 Scenario 1 - Two Yarragadee Production Bores

Contours presented in Figure 6-3 and Figure 6-4 display the groundwater levels under steady state conditions with groundwater extraction from two Yarragadee Aquifer bores at a rate of 1,233 $m^3$/day per bore. Figure 1, Appendix A presents the drawdown experienced in the Superficial Aquifer under such conditions, indicating a maximum drawdown of 0.2 m. Drawdown occurred to 0.2 m at a radius of 350 m from the most northern bore and 100 m from the south-west bore. A maximum distance to 0.1-m drawdown was approximately 1,500 m, extending off-site to the north-east.

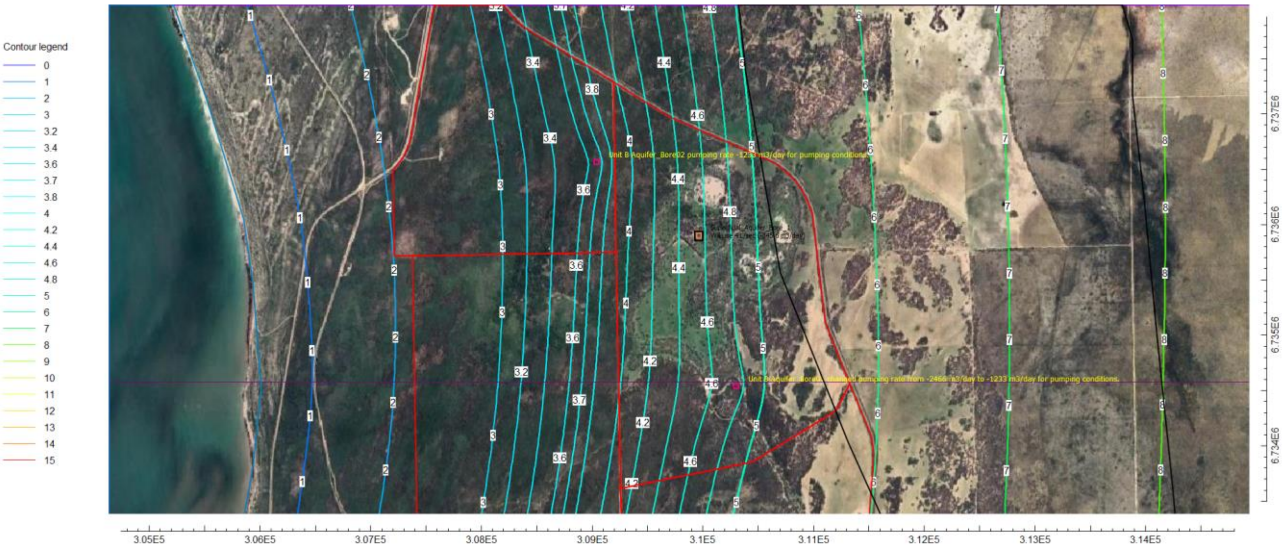



Figure 6-3 Groundwater levels in the Superficial Aquifer whilst pumping from two bores located in the Yarragadee Aquifer at an extraction rate of 1233 $m^3$/day

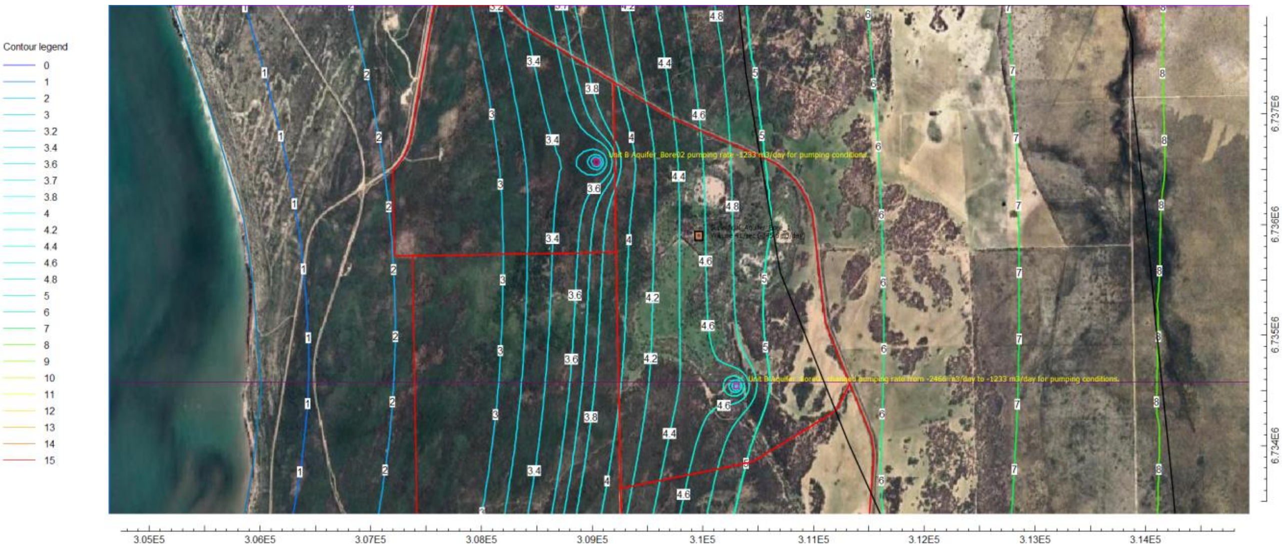



Figure 6-4 Groundwater levels in the upper unit of the Yarragadee Aquifer whilst pumping from two bores located in the Yarragadee Aquifer at an extraction rate of 1233 $m^3$/day

## 6.3 Scenario 2 - Single Yarragadee Production Bore

Scenario 2 contours, provided in Figure 6-5 and Figure 6-6, present the steady state condition groundwater levels while groundwater extraction from one bore located in the Yarragadee Aquifer. The extraction rate at this bore was 2,466 m$^3$/day creating a maximum drawdown in the Superficial Aquifer of 0.4 m (Figure 2, Appendix A). Drawdown occurred off-site to 0.1 m both north-east and north-west of the Site with further drawdown to 0.2 m occurring off-site to the north-east. The distance to the 0.2-m-drawdown contour was 900 m and the distance to the 0.1-m-drawdown contour was 2,500 m.

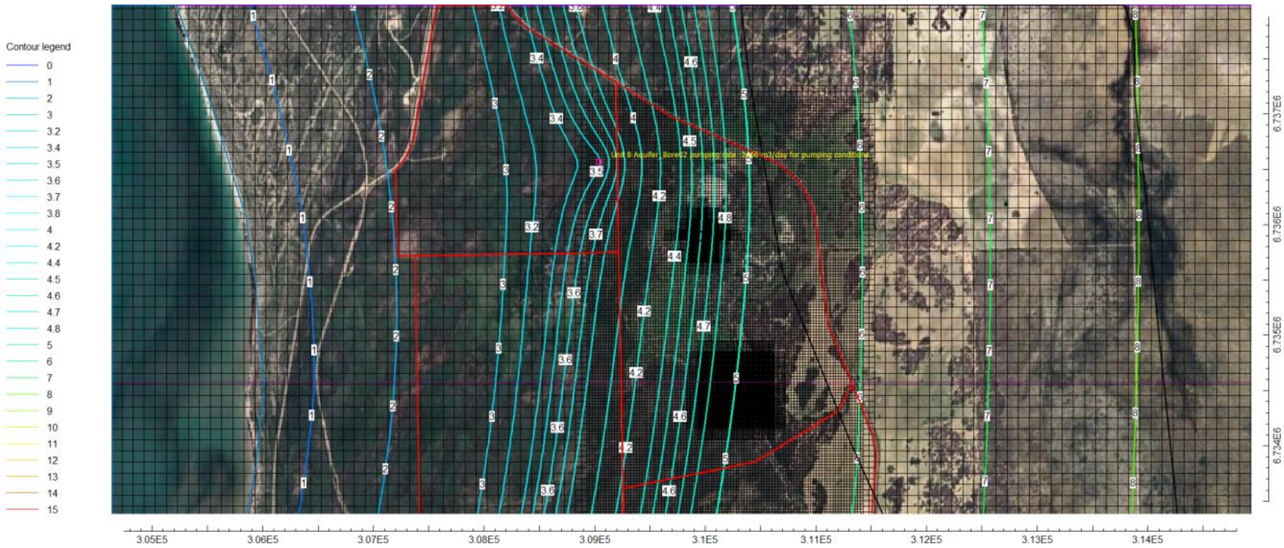



Figure 6-5 Groundwater levels in the Superficial Aquifer whilst pumping from one bore located in the Yarragadee Aquifer at an extraction rate of 2466 m$^3$/day

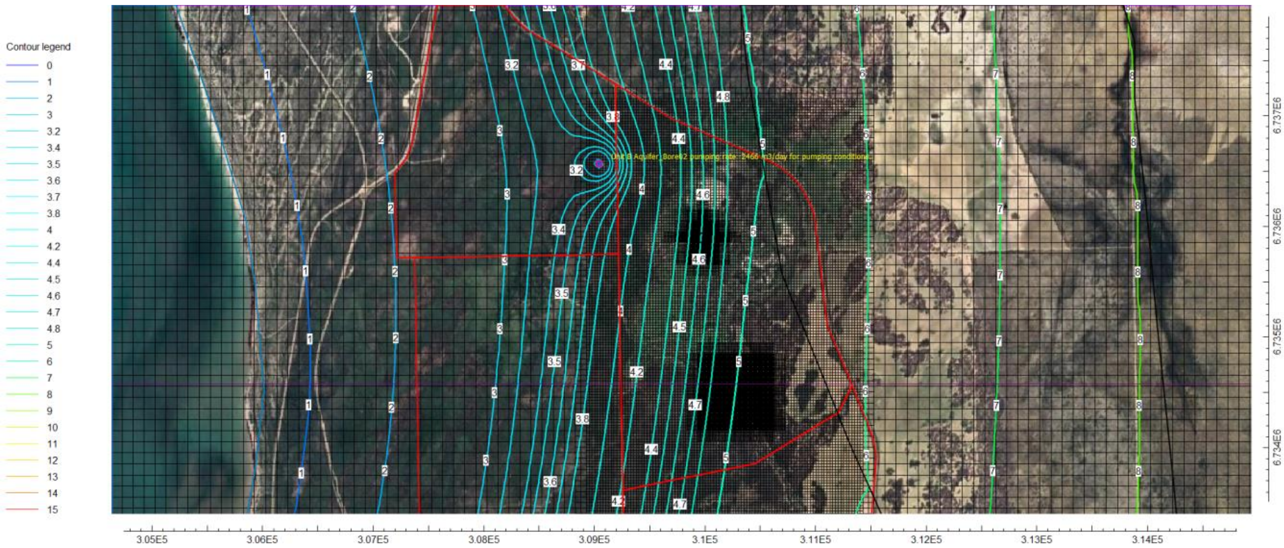



Figure 6-6 Groundwater levels in the upper unit of the Yarragadee Aquifer whilst pumping from one bore located in the Yarragadee Aquifer at an extraction rate of 2466 m$^3$/day

## 6.4 Scenario 3 - Four Superficial Production Bores

Figure 6-7 and Figure 6-8 present the groundwater level contours for Layer 1 and Layer 2 under steady state conditions when extracting groundwater from four bores located in the Superficial Aquifer at a pumping rate of 616.5 $m^3$/day per bore. The drawdown experienced in the Superficial Aquifer under these conditions is presented in Figure 3, Appendix A. A maximum drawdown of 0.5 m occurred to a minimal radius whilst drawdown to 0.1 m occurred at a distance of approximately 2,500 m and 0.2 m drawdown occurred at a maximum distance of approximately 800 m.

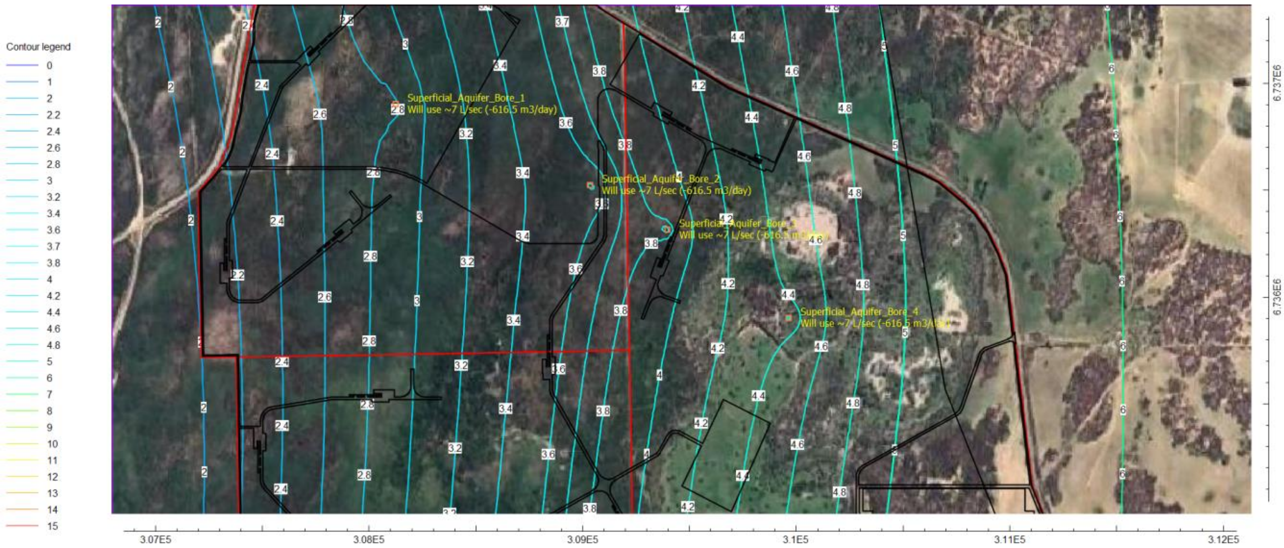



Figure 6-7 Groundwater levels in the Superficial Aquifer whilst pumping from four bores located in the Superficial Aquifer at an extraction rate of 616.5 $m^3$/day

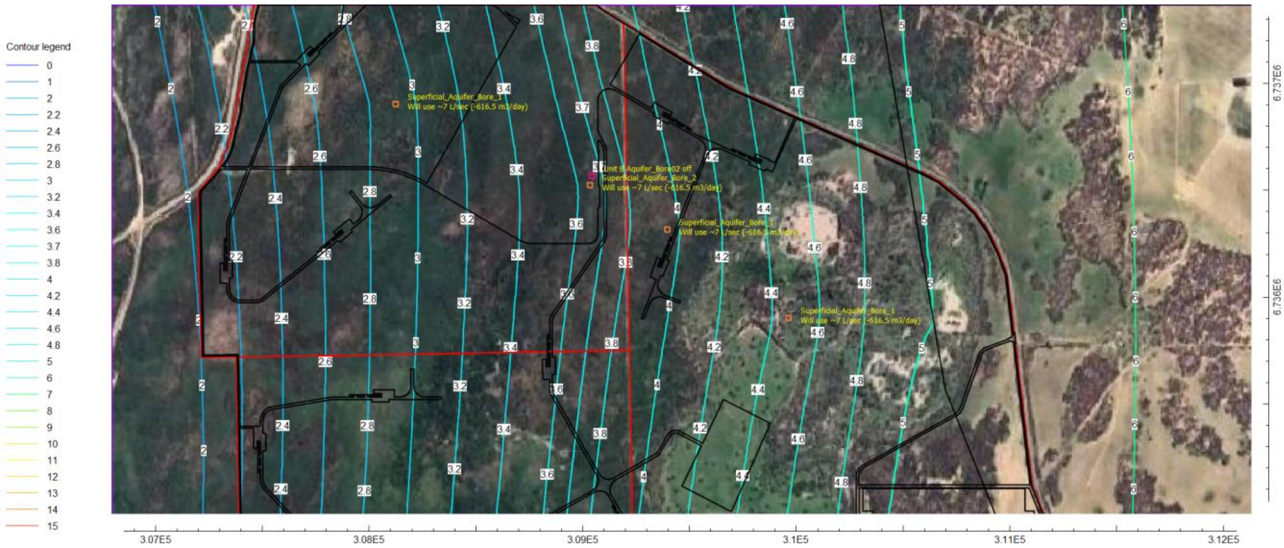



Figure 6-8 Groundwater levels in the upper unit of the Yarragadee Aquifer whilst pumping from four bores located in the Superficial Aquifer at an extraction rate of 616.5 $m^3$/day

## 6.5 Summary

Table 6-1 provides a summary of all drawdown experienced under each groundwater extraction scenario for comparison. Refer to Appendix A for exact bore location and drawdown experienced at each bore.

Table 6-1 Summary of drawdown experienced under each groundwater extraction scenario

| Scenario | Bore | Maximum Drawdown (mAHD) | Drawdown Radius at 0.1 m Drawdown (m) | Drawdown Radius at 0.2 m Drawdown (m) |
|---|---|---|---|---|
| 1 | Northern Yarragadee Bore | 0.2 | 1,500 | 350 |
| | Southern Yarragadee Bore | 0.2 | 1,200 | 100 |
| 2 | Northern Yarragadee Bore | 0.4 | 2,500 | 900 |
| 3 | All Superficial Bores | 0.5 | 2,500 | 800 |

## 6.6 Cumulative Impacts

Consideration has been given to the cumulative impacts of two additional groundwater users within the area:

1. VRX - 0.9GL from the Yaragadee Aquifer.
2. Triangle - 0.01228GL from the Superficial Aquifer.

Due to unknowns with groundwater bore construction and operating strategies, the following assumptions have been made:

> Representation of production bore construction within the model is as per the production bores assumed for the IBE development within each Aquifer.

> Flow rates are averaged across the whole year i.e. 28L/s for VRX and 0.4L/s for Triangle.

> For all scenarios, both the Triangle and VRX bores were included.

The location of the groundwater bores are shown in Figure 6-9.

Table 6-2 provides a summary of all drawdown experienced under each groundwater extraction scenario for comparison. Refer to Figure 7 to 9, Appendix A for exact bore location and drawdown experienced at each bore.

Table 6-2 Summary of drawdown experienced under each groundwater extraction scenario including cumulative impacts.

| Scenario | Bore | Drawdown Radius at 0.2 m Drawdown (m) – without off-site bores. | Drawdown Radius at 0.2 m Drawdown (m) – with off-site bores. | Maximum Drawdown at Eastern Site Boundary (m) |
|---|---|---|---|---|
| 1 | Northern Yarragadee Bore | 350 | 580 | 0.19 |
| | Southern Yarragadee Bore | 100 | 810 | |
| 2 | Northern Yarragadee Bore | 900 | 8,000 | 0.20 |
| 3 | All Superficial Bores | 800 | 8,000 | 0.23 |

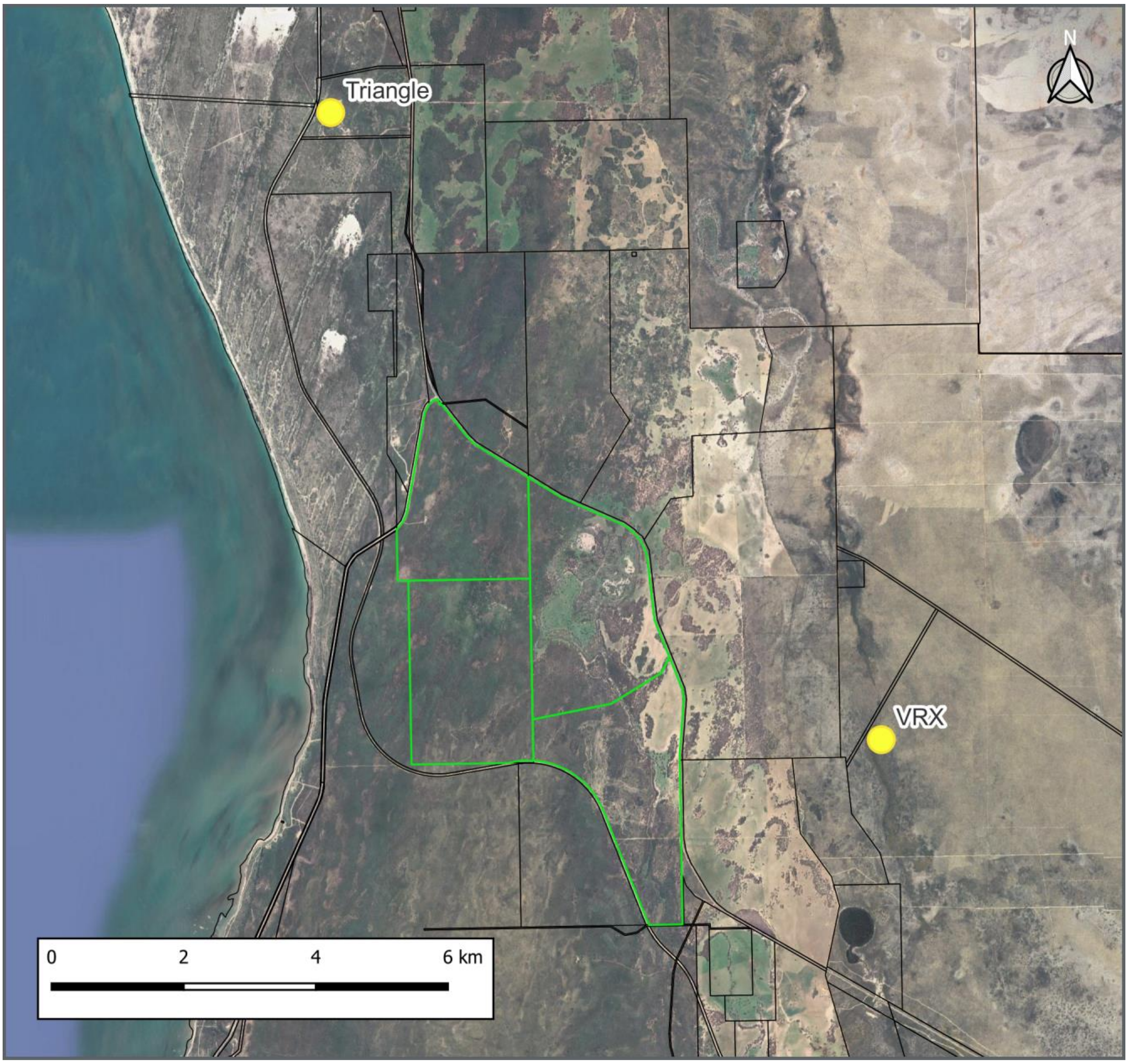



Figure 6-9 Off-site Production Bores

With the inclusion of the off-site production bores, the following can be observed.

> The Triangle production bore to the north of the site does not interact with the drawdown of the site in any of the scenarios.

> In all scenarios, the VRX bores cone of depression (drawdown) meets with the cone of depression of the sites production bore which causes the 0.2m drawdown to extend further.

> Scenario 1 cumulative cone of depression increases the 0.2m drawdown for the site bores but remains within the site boundary. The increase in radius of the 0.2m cone of depression would extend further into the GDE’s on the site.

> Scenario 2 and 3 cumulative cone of depression increases the 0.2m drawdown extent significantly extending east of the VRX bore.

The assumption that VRX are abstracting all their groundwater allocation from a single production bore is causing the 0.2m drawdown contour to extend a significant distance. Further refinement is needed once construction and operation details of the VRX groundwater abstraction scenario can be confirmed.

As per the recommendations of this report, two abstraction bores in the Yarragadee Aquifer, limits the extent of drawdown and a similar outcome at VRX would also limit the interaction of both sites drawdown. The site production bores positioning could also be managed to ensure the 0.2m drawdown is minimised within vicinities of the GDE’s.

# 7 Conclusion

IBE require approximately 900 ML/year of groundwater to use on-site. Cardno constructed a groundwater flow model to simulate current conditions. This model was then used to construct three pumping scenarios. These three scenarios were used to evaluate the most appropriate method for obtaining this water requirement. Extraction from the Yarragadee Aquifer and the Superficial Aquifer were explored with consideration of the GDEs located both on-site and off-site.

To represent the aquifer characteristics of the geological layers identified in literature, a multi-layer three-dimensional model was created. Hydrogeological parameters were determined through desktop research to input into the model. Groundwater levels were determined for conditions prior to groundwater extraction and were found to be consistent with literature values. These levels were then implemented as constant head levels for each of the groundwater extraction models to provide each model with more realistic pre-pumping groundwater levels.

Comparison of each groundwater modelling scenario found that Scenario 1, pumping from two Yarragadee Aquifer bores, provided sufficient groundwater volumes for on-site use whilst limiting the potential impact on the surrounding GDEs. With a constant pumping rate of 1,233 $m^3$/day per bore (2,466 $m^3$/day total), this scenario displayed minimal drawdown (maximum 0.2 m) with a small drawdown radius. As the GDEs are considered to be at risk with drawdown greater than 0.2 m, Scenario 1 provides a solution with little to no impact on the local GDEs whilst providing a solution with constant groundwater extraction assurance. Figure 4, Appendix A indicates the drawdown occurring across both terrestrial and aquatic GDE locations however, the bore locations can be moved to limit impact if necessary.

Figure 6, Appendix A displays the potential location of karst systems located in the Tamala Limestone Formation. Whilst these areas of potential cave locations were not considered in the modelling, the bores were placed at a distance from these locations with minimal drawdown effect to these areas.

In the event of one bore ceasing to extract groundwater for a period of time, the second groundwater bore has the ability to continue to extract groundwater ensuring continuous water supply to the Site. The bores should be constructed to abstract the maximum demand if one bore was to go offline for a period of time to ensure continuity of supply. In this situation, if the functioning bore is required to pump at an increased rate Scenario 2 provides an understanding of the drawdown and potential impact on local GDEs (Figure 5, Appendix A).

Further refinement of the cumulative impact scenario is needed once construction and operation details of the VRX groundwater abstraction scenario can be confirmed. As per the recommendations of this report, two abstraction bores in the Yarragadee Aquifer, limits the extent of drawdown and a similar outcome at VRX would also limit the interaction of both sites drawdown. The site production bores positioning could also be managed to ensure the 0.2m drawdown is minimised within vicinities of the GDE’s once the cumulative impacts are confirmed.

The steps outlined in Appendix B, Project Planning, should be considered for implementation.

# 8 Limitations

Assumptions and limitations applicable for all modelling undertaken include and are not limited to the following:

> The geological layers defined in MODFLOW have been adopted with interpretation of literature values

> Depths of geological layers have been identified with respect to the approximate ground levels. Therefore, it is likely that some elevations and depths of geological layers may not precisely reflect actual depths.

> Base case models have been constructed to reflect literature groundwater levels

> Boundary conditions (as constant-head boundaries) have been specified to create the representative pre-construction site groundwater elevations.

# 9 References

Bureau of Meteorology, 2021, Groundwater Dependent Ecosystems Atlas, accessed at http://www.bom.gov.au/water/groundwater/gde/map.shtml October 2021, Commonwealth of Australia, Bureau of Meteorology.

Department of Water, 2017, Hydrogeological bulletin series Report no. HB1, Northern Perth Basin: Geology, hydrogeology and groundwater resources

Ecoscape (Australia) Pty Ltd (2021) Arrowsmith Wind and Solar Farm Environmental Survey, prepared for Infinite Blue Energy. Ecoscape report number 4562-20R

APPENDIX

# A

FIGURES

Cardno

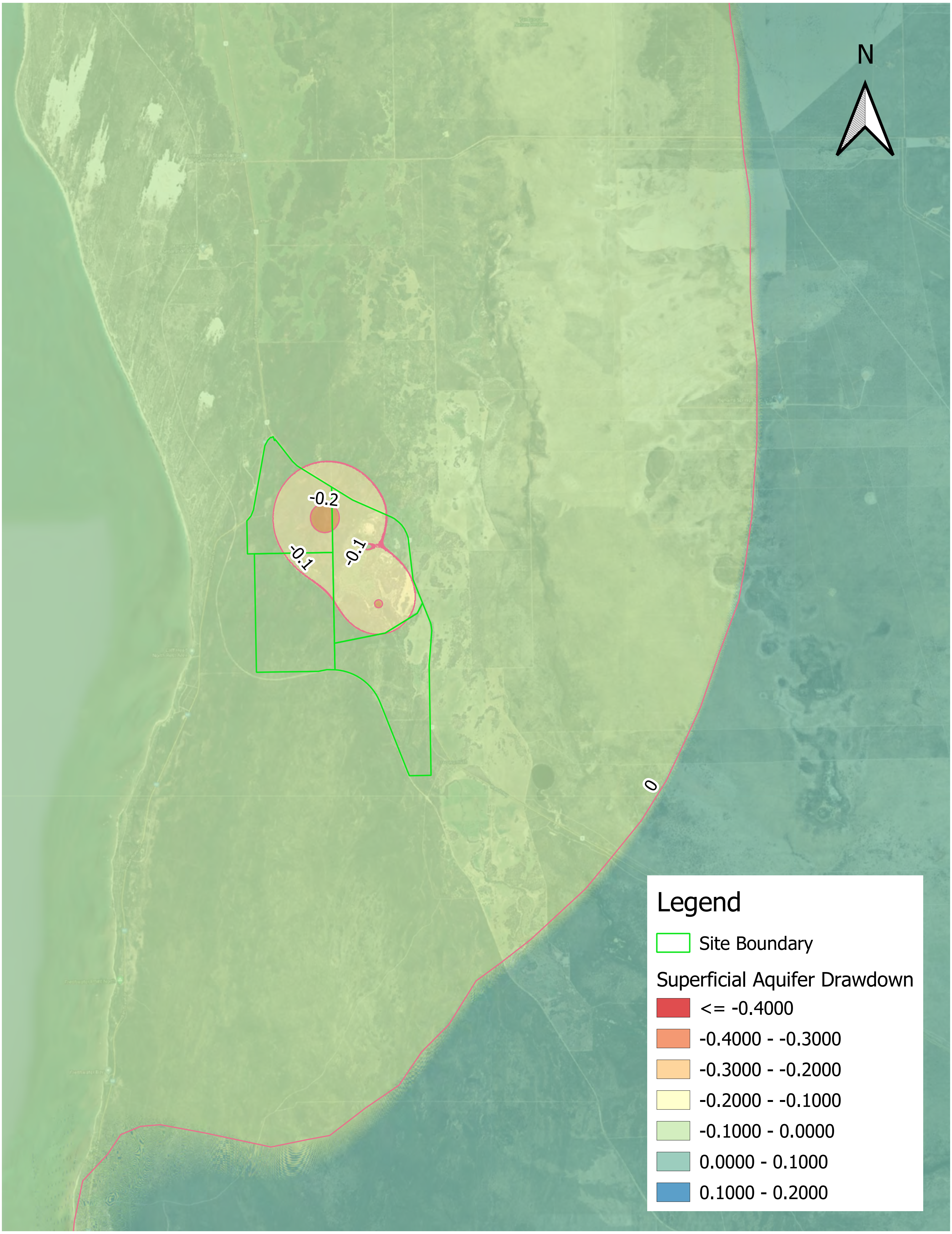



**Figure 1 - Scenario 1: Pumping from Two Yarragadee Aquifer Bores**



Drawdown occurring in the Superficial Aquifer as a result of pumping from two Yarragadee Aquifer Bores at 1,233 m^3/day each

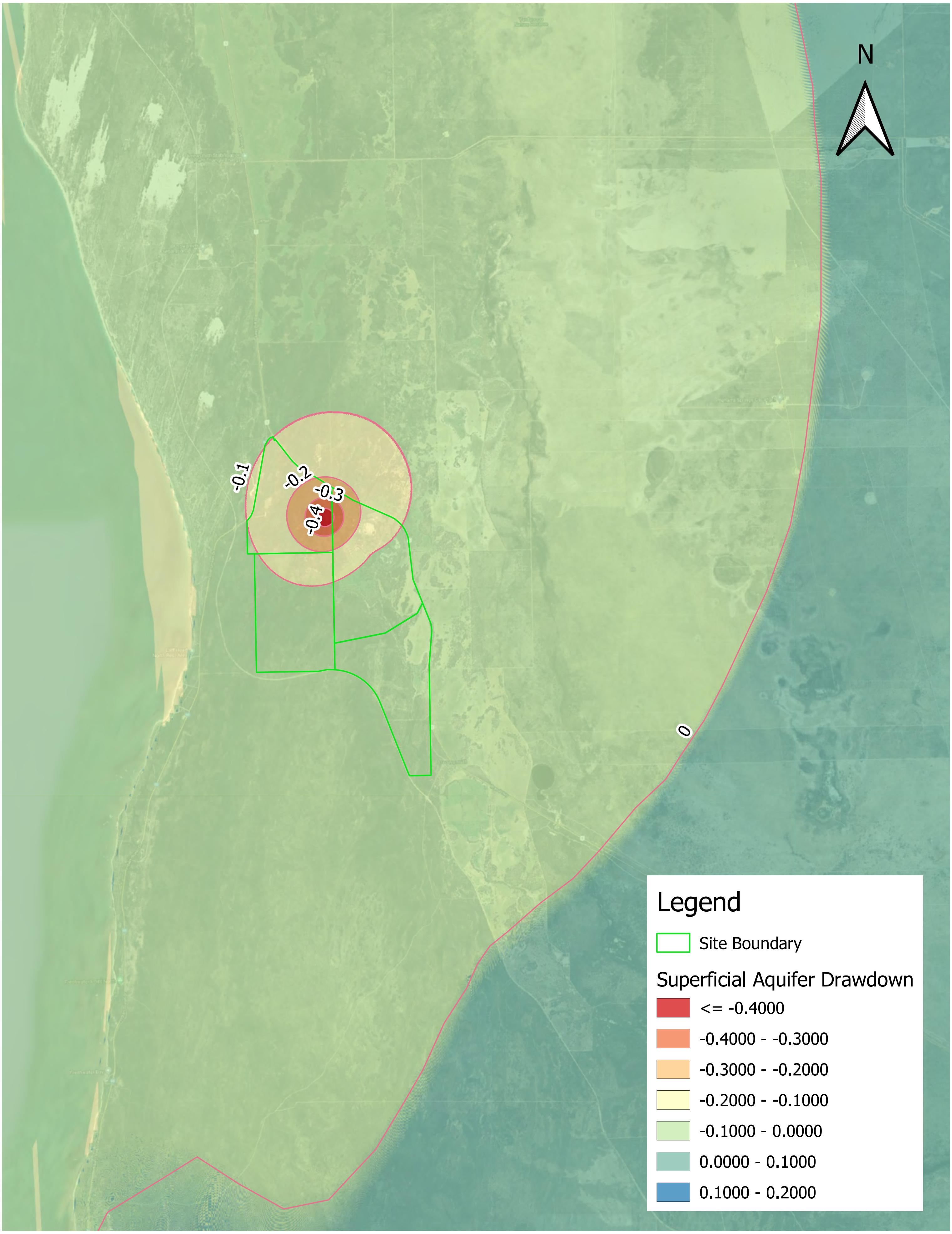
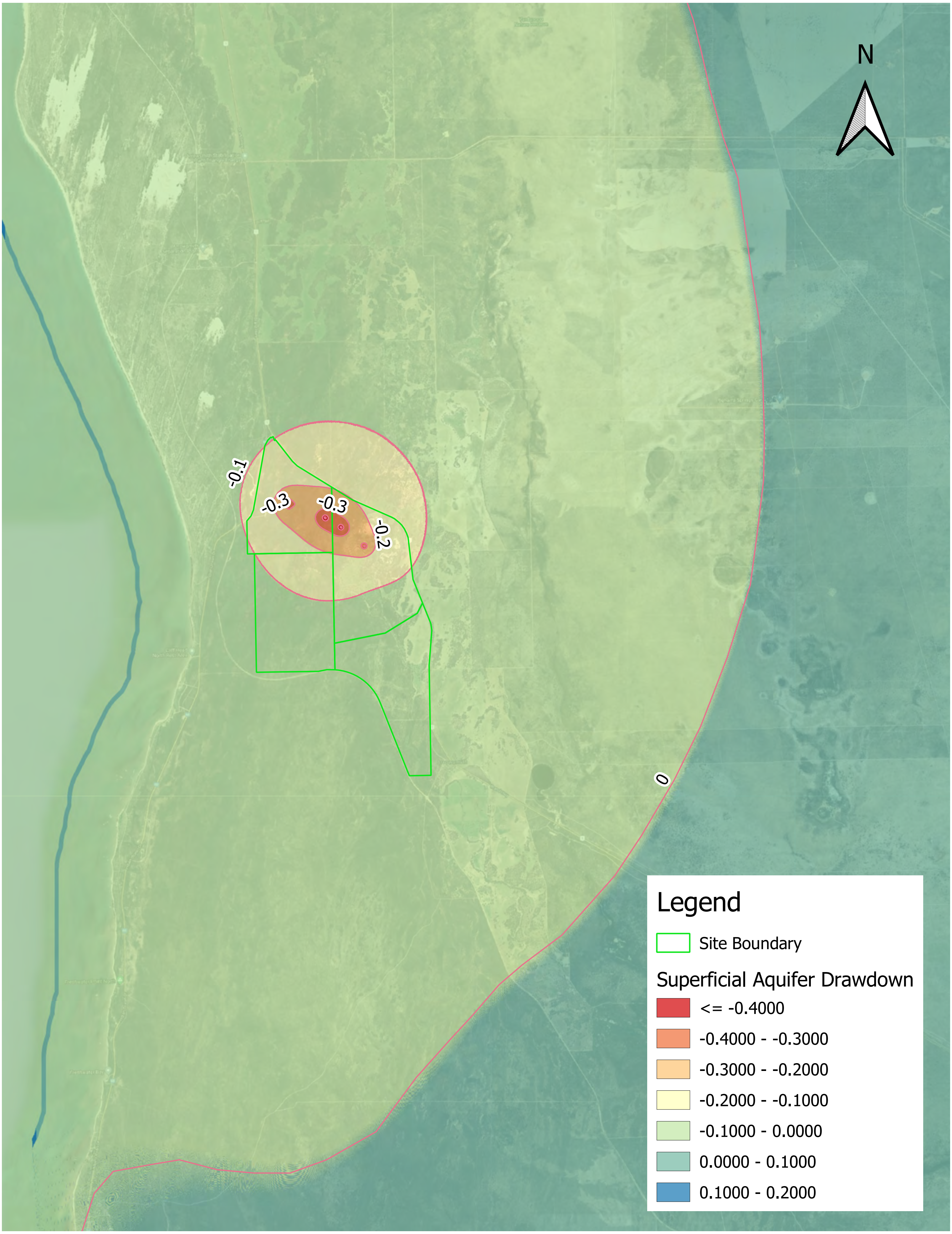



**Figure 2 - Scenario 2: Pumping from One Yarragadee Aquifer Bore**



Drawdown occurring in the Superficial Aquifer as a result of pumping from one Yarragadee Aquifer Bores at 2,466 m^3/day




# Figure 3 - Scenario 3: Pumping from Four Superficial Aquifer Bores

Drawdown occurring in the Superficial Aquifer as a result of pumping from four Superficial Aquifer Bores at 616.5 m^3/day each

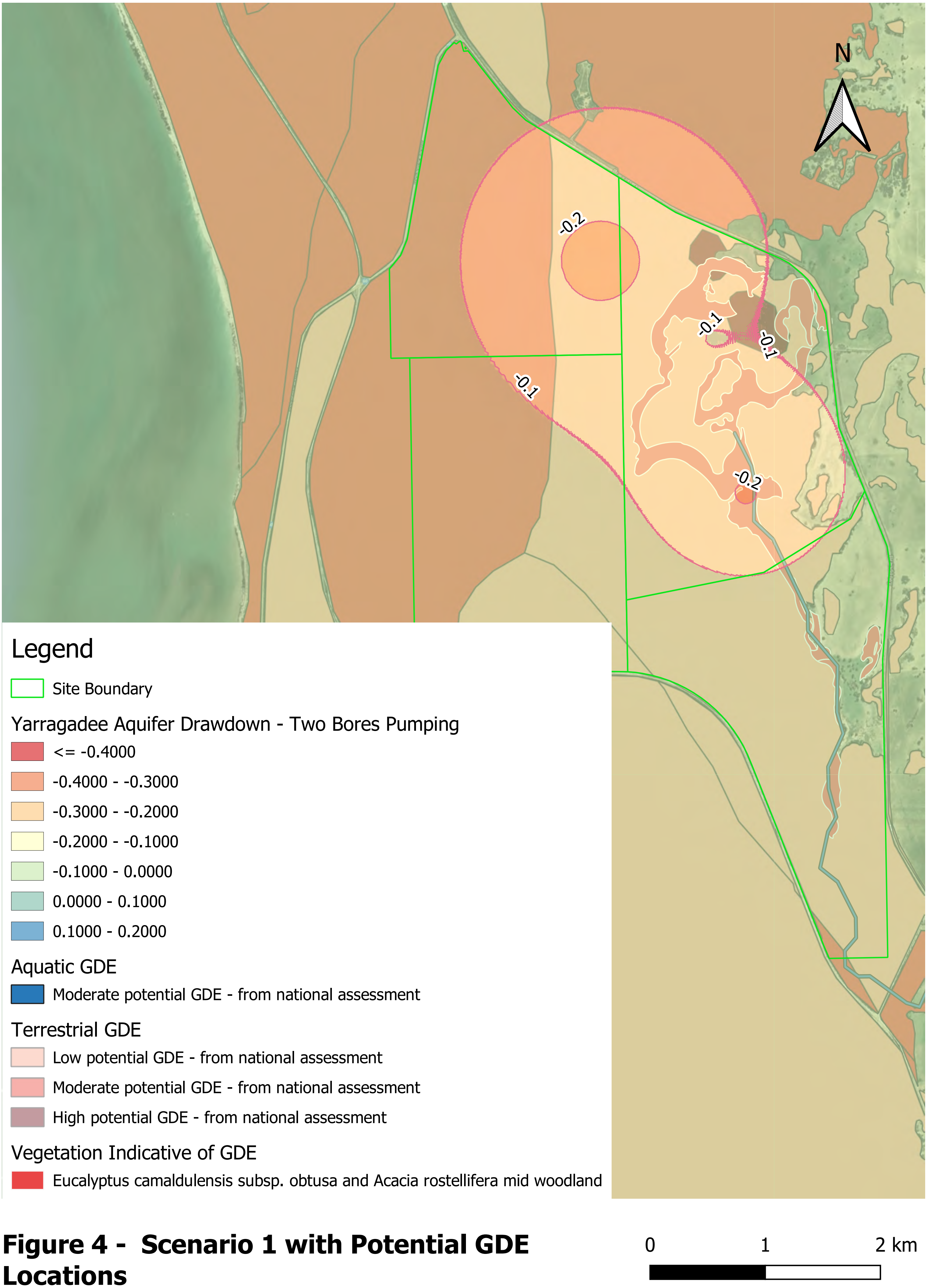



**Figure 4 - Scenario 1 with Potential GDE Locations**

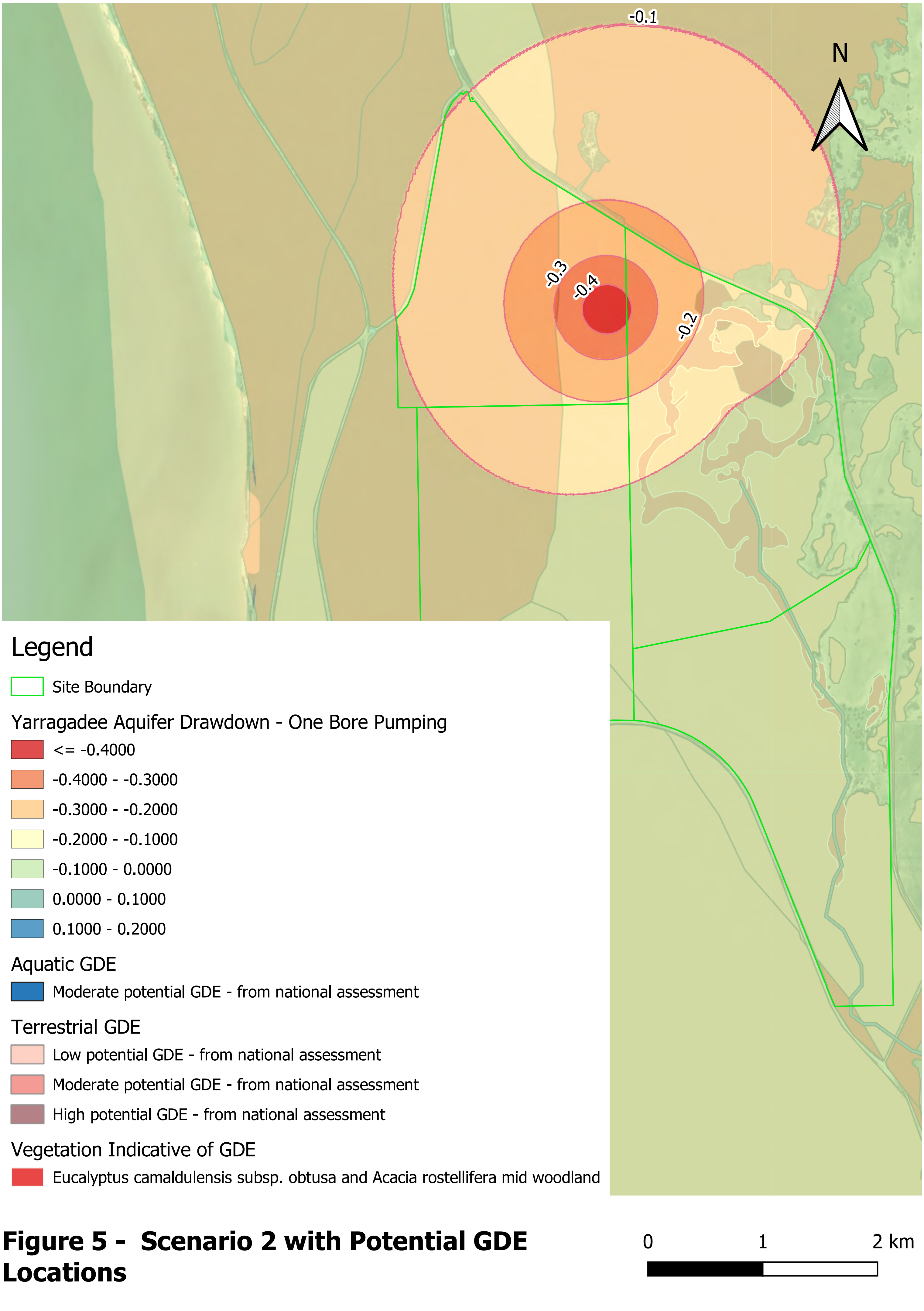



**Figure 5 - Scenario 2 with Potential GDE Locations**

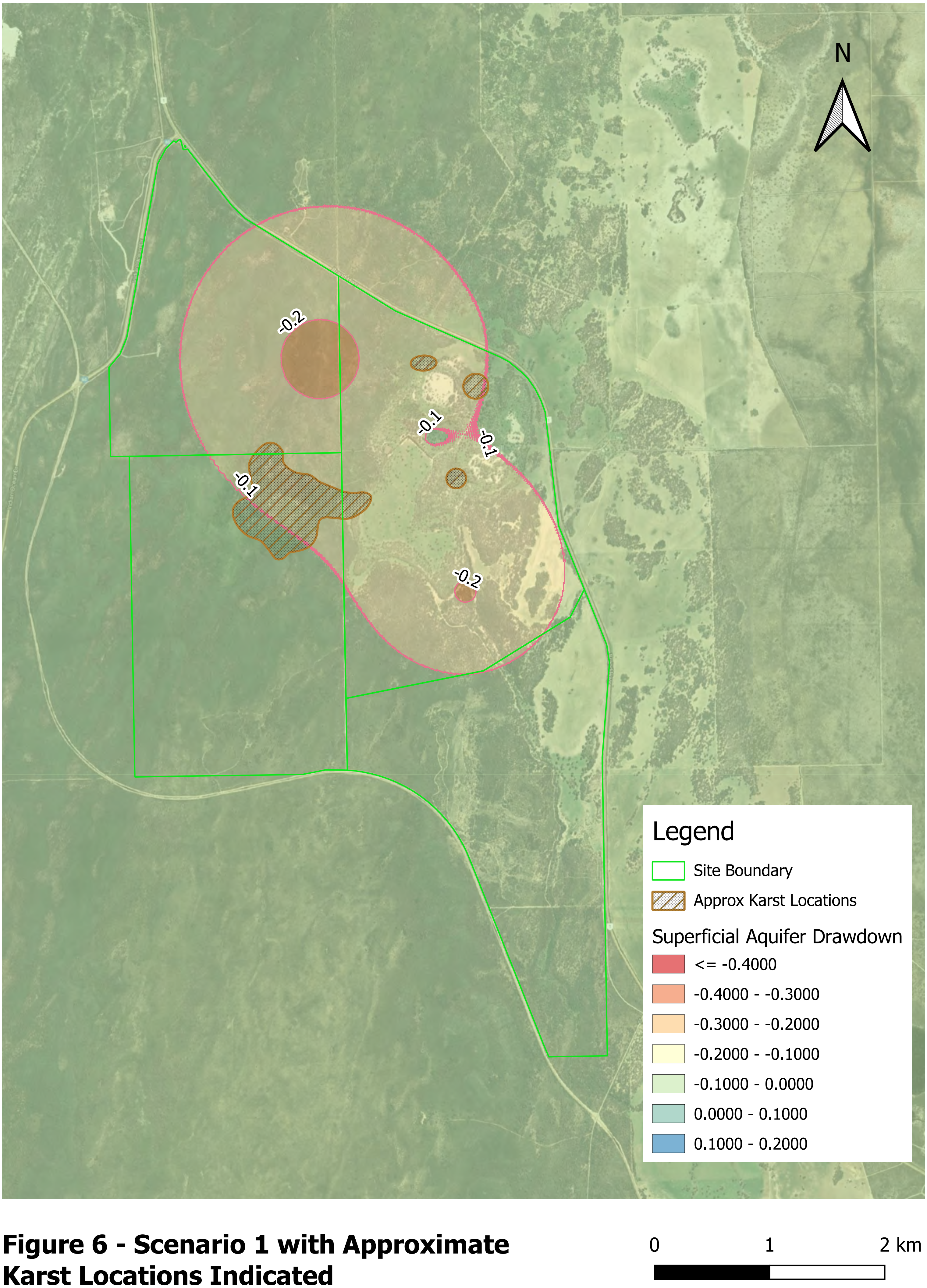



**Figure 6 - Scenario 1 with Approximate Karst Locations Indicated**

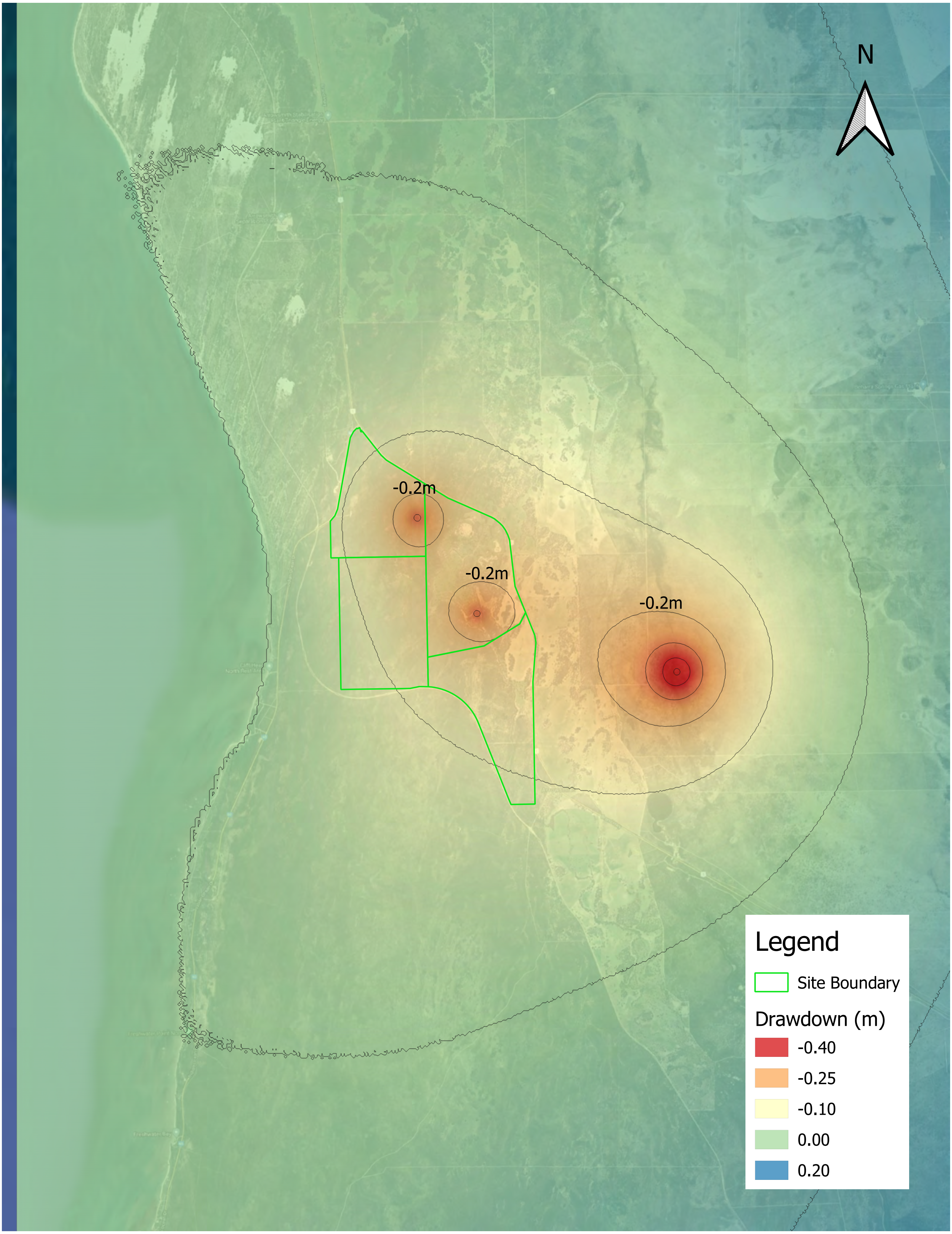



**Figure 7 - Scenario 1 with Off-Site Production Bores Cumulative Impacts**

0 1 2 km

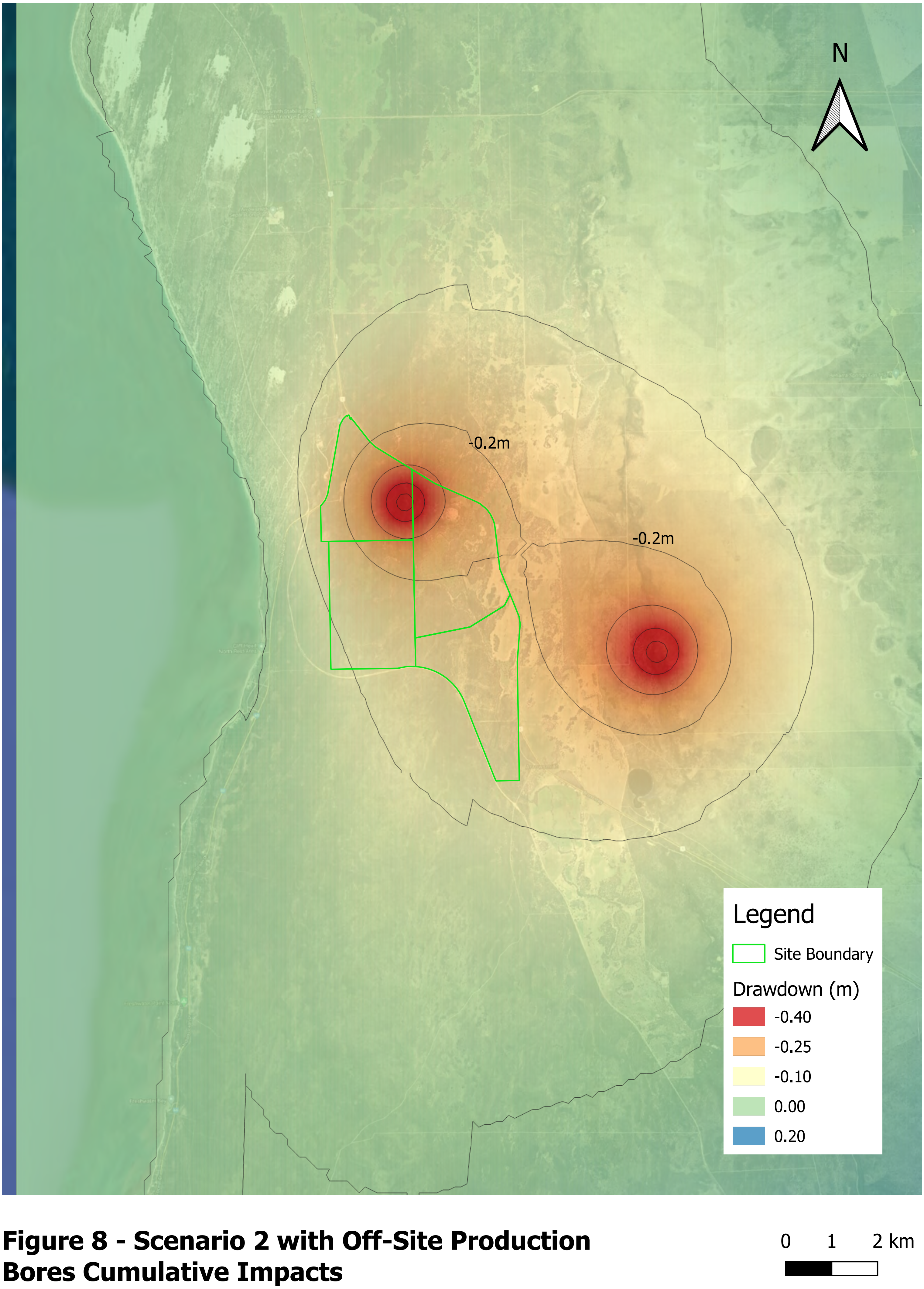



**Figure 8 - Scenario 2 with Off-Site Production Bores Cumulative Impacts**

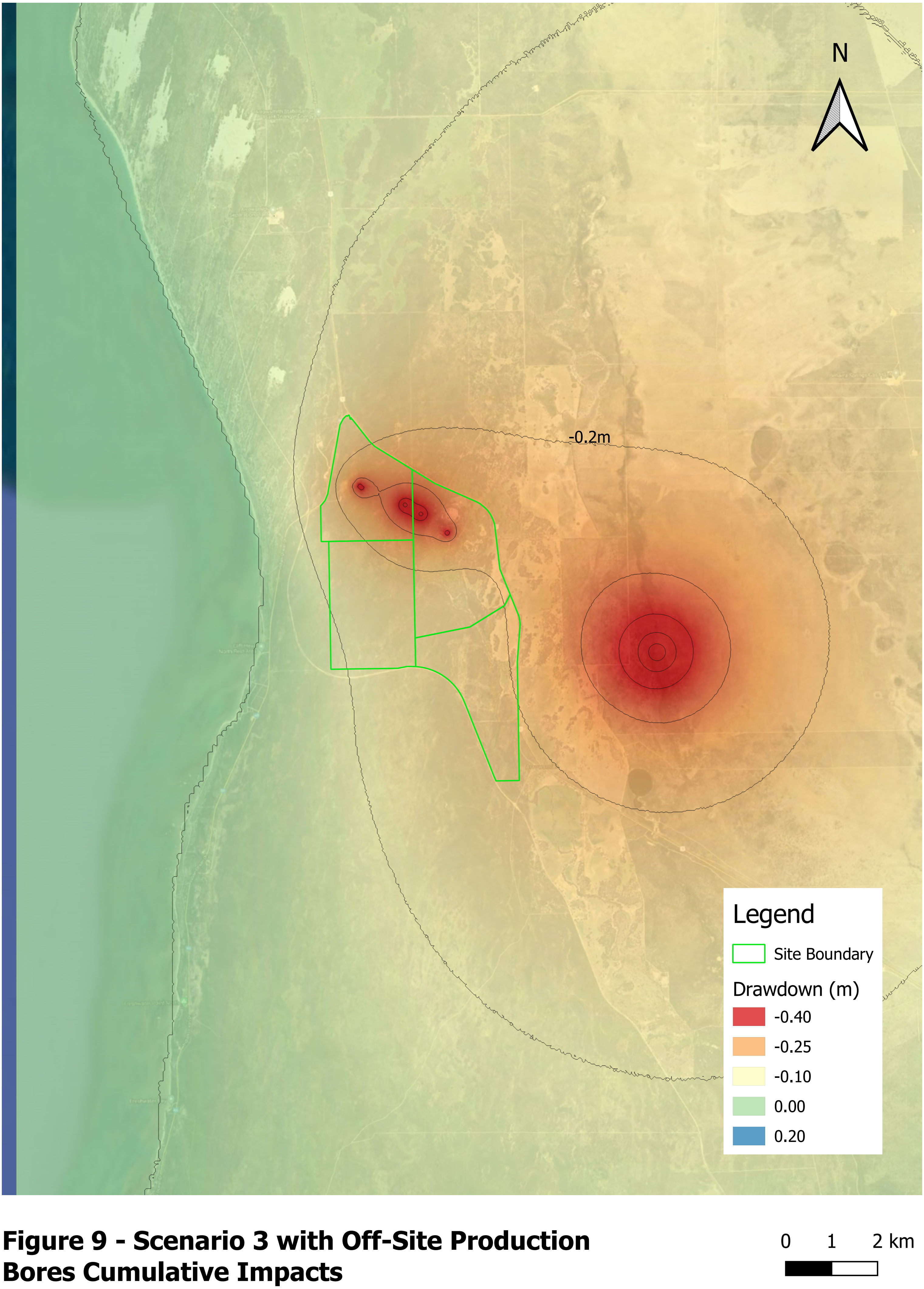



**Figure 9 - Scenario 3 with Off-Site Production Bores Cumulative Impacts**

APPENDIX

# B

PROJECT PLANNING

# 10 Project Planning

The following section provides an overview of the groundwater licensing process and further investigations which are likely required should the project progress.

### 10.1.1 Licencing and Approvals

The abstraction of groundwater will need to be assessed by DWER which will be regulated through:

> Licence to construct or alter a well: section 26D, *Rights in Water and Irrigation Act 1914.*
> Licence to take water: section 5C, *Rights in Water and Irrigation Act 1914.*

A section 26D licence will need to be applied for prior to undertake drilling. The licence will then be issued with conditions which will outline drilling and investigation requirements which will most likely include a detailed hydrogeological assessment in accordance with DWER's *Operational policy 5.12 – Hydrogeological reporting associated with a groundwater well licence*.

### 10.1.2 Assessment

Based on the water requirements and allocation status of the Superficial and Yarragadee Aquifers, it is likely that either a H2 or H3 hydrogeological assessment will be requested by the DWER (2009) as:

> The volume of water requested will be large;

> The level of knowledge regarding the state of the groundwater source is limited;

> The demand for accessing a particular groundwater resource is high (based on proposed surrounding land uses; and

> The potential impacts of taking the water may be considered significant.

A H2 assessment is a basic hydrogeological assessment including drilling and test pumping while a H3 is more detailed and will also require a groundwater model (update to the model described above with site-specific hydrogeological testing) to support the application and reporting.

### 10.1.3 Drilling and Test Pumping (for Hydrogeological Assessment)

#### *10.1.3.1 Bore Design and Installation*

**Pilot Hole**

A pilot hole will be advanced near (within 100m) of the proposed location of the production bore. The objective of the pilot hole is to collect geological, geophysical, and hydrogeological information over the anticipated depth interval of the production bore (nominally 300 m; base of Unit B of the Yarragadee Formation).

Ideally, the pilot bore, which will be nominally 100 mm in diameter, will be advanced using an air-rotary drilling method (with casing hammer). Cuttings collected at approximately 1 m to 2 m intervals will be logged visually and used to prepare a log of the geological materials.

**Geophysics**

After completion of the pilot hole a suite of geophysical survey will be undertaken. It is anticipated that acoustical televiewer, optical televiewer, calliper, fluid temperature, fluid conductivity/resistivity, self-potential (short- and long-scale), fluid flow (ideally heat pulse), and natural gamma tools will be used for the survey.

Based on the findings from the geophysical survey several packer tests will be conducted to evaluate flows from productive intervals identified by interpretations of the geophysical surveys. This information will be used as part of designing the production bore.

**Construction Details**

Due to costs, it is recommended to install a test bore which can be utilised ultimately as the production bore for abstraction should the project progress.

Conceptual construction details for the bore is presented in Table 10-1.

Table 10-1 Production Bore Construction Details

| Detail | Description comments |
|---|---|
| Drilled Depth | 100 m to 300 m |
| Drill diameter – production casing | 400 mm |
| Verticality and Alignment | Boreholes should be drilled and casings set to retain roundness and also be constructed straight and as close to vertical as possible. |
| Drilling Method | To be agreed with the Contractor<br>Ideally, the air-rotary drilling method (with casing hammer) or similar, which minimises the use of liquids. |
| Conceptual Bore Design | To be confirmed, the conceptual design for a 100-m-deep bore is:<br>**Surface Casing**<br>0 - 6 metres Below Ground Level (mBGL): 508 mm nominal ID uPVC or mild steel casing.<br>**Conductor Casing**<br>0 - 20 mBGL (through the Superficial Aquifer and at least one metre into the Yarragadee Formation); annulus grouted up to land surface and cement plug at the bottom of the casing: 400 mm nominal ID uPVC casing.<br>**Production Casing**<br>0 – 81.0 mBGL: 250 mm nominal ID uPVC CL12.<br>**Casing/Screen Cross-Over**<br>uPVC 250/250 mm, connecting screens to casing.<br>**Well Screen**<br>81.0 – 99.0 mBGL: 250 mm nominal ID API 304 grade stainless steel wedge-wire screen, 0.6 mm aperture<br>**Blank screen (Sump) with End Cap**<br>99.0 – 100.0 mBGL: 250 mm nominal ID API 304 grade stainless steel casing<br>Casing centralisers shall be located at no greater than 6 metre intervals along the bore casing and screen. Note that the bore design listed above is preliminary only, and may be subject to variation depending on conditions encountered during construction of the borehole. |
| Filter Pack (FP) | The annulus surrounding the screen shall be packed with an artificial filter pack (graded sand) in the annulus between the sump/screen and production casing using a tremmie pipe of appropriate diameter and using water flushing and mud circulation and withdrawal of the tremmie to prevent bridging and blockage.<br>The top of the filter pack shall be tagged at "top of screen plus 2m" or approx. 79.0m below ground.<br>**Filter Pack Sizing**<br>FP d90 = 0.5 to 0.65 mm<br>**Filter Pack Design Element Check**<br>• Design rules (Driscoll, 1992)<br>o An Artificial Filter Pack is justified where the formation is fine (d40 <0.5mm; d90 <0.25mm) and uniform (UC<2 for d40/d90 % retained), and/or stratified.<br>o Based on previous experience in similar geological setting, a filter pack is justified (assuming 40% retained grain size of 0.5mm)<br>• Filter pack size d70 is 4 or 6 times the aquifer d70 (5 times has been selected for the assumed sand interval at the site).<br>• Filter Pack grading is selected to have UC<2.5.<br>• The screen aperture is selected to be d90 of the filter pack grading.<br>Applying this to PSDs for theses sands (excluding limestone aggregates) the Filter Pack spec is:<br>FP d10 = 1.3 mm<br>FP d40 = 1.0 mm |

| Detail | Description comments |
|---|---|
| | FP d90 = 0.5 to 0.65 mm = screen aperture |
| Production Casing | Shall be 250 mm PN12 SWJ PVC-U piping manufactured in accordance with AS1477:2006 Series 1. . |
| Screen Assembly | **Well Screen**<br>81.0 – 99.0 mBGL: 250 mm nominal ID API 304 grade stainless steel wedge wire screen, 0.6 mm aperture.<br>**Blank screen (Sump) with End Cap**<br>99.0 – 100 mBGL: 250 mm nominal ID API 304 grade stainless steel casing |
| Centralisers | Shall consist of engineered plastic bow centralisers to fit a minimum 150-mm annulus.<br>They should be placed at the top and bottom of the screen and at 6-m intervals. |
| Bore Sealing | A Bentonite cement slurry plug to be placed via the tremmie to provide an initial seal between the casing and borehole to minimise flow of potentially contaminated water from surface waters to the filter pack via the annulus<br>Following minimum 12 hours of setting time, fill the annulus back to surface with cement grout. |
| Bore development | This involves circulation to clean the casing, and combination of jetting, surging and air lift, and repeat, until the water is clear and contains less than 5mg/1000 litres of sediment. |

**Test Pumping**

The test pump shall be capable of maintaining bore discharge of up to 50.0 litres per second from a pump inlet depth of up to 95 m.

A staged test of four different rates (5.0L/s;12.5L/s; 25 L/s; and 50.0L/s), each of one hour duration is required.

Following recovery of the groundwater level a constant rate test, nominally of 72-hour duration and at a flow rate of 28.0 litres per second (rate to be confirmed by superintendent following the staged test), is required.

Manual groundwater level measurement shall also be made in the new production bore in each step of the staged test, and also during the constant rate test at the following times:

- 0 - 5 minutes: 1 minute interval
- 5 - 15 minutes: 5 minute interval
- 20 - 60 minutes: 10 minute interval
- + 60 minutes: 30 minute interval

### 10.1.4 Production Bore Installation

Should a licence be granted, a second groundwater abstraction bore should be installed based on the specifications in Section 10.1.3.

### 10.1.5 Installation of Superficial Aquifer Observation Wells

A series of groundwater monitoring bores will likely be required to be installed within the Superficial Aquifer. Bores should be positioned in close proximity to the nearest GDE’s to confirm drawdown impacts (if present) from the operation of the production bores.

### 10.1.6 Summary of Costs

An estimate of costs for the above works is provided in Table 10-2.

Table 10-2 Estimated Costs

| Item | Estimated Cost (ex GST) |
|---|---|
| Drilling and Installation of an indicative 300-m pilot hole (to be converted to an observation well) | $360,000 |

| Item | Estimated Cost (ex GST) |
|---|---|
| Drilling and Installation of an indicative 100-m Production Bore No. 1 (to be used for pump tests in the first instance) | $150,000 to $450,000 |
| Geophysics | $15,000 |
| Test Pumping | $40,000 |
| Drilling, Installation and geophysical/pump testing of 100 m Production Bore No. 2 | $205,000 to $505,000 |
| Installation of 10 superficial aquifer monitoring bores. | $60,000 |
| Consultant Fees (including H3 hydrogeological report, modelling, licence applications and bore installation supervision) | $150,000 to $250,000 |
| Total | $980,000 to $1,680,000 |