## AUSTRALIA BUNDLE SITE

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# Subsea 7 Australia Contracting Pty Ltd

## Learmonth Pipeline Fabrication Facility

## Surface and Groundwater Investigation

March 2019

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# 1. Introduction

## 1.1 Project background

Subsea 7 is investigating the option to build a new Pipeline Fabrication site in Learmonth, Western Australia. The proposal will involve a fabrication facility and associated amenities, along with a 10.5 km bundle track, launchway, and access road.

As part of the Environmental Protection Agency (EPA) submission for the project, GHD has undertaken a surface water and groundwater investigation to:

- Establish the baseline and future catchment hydrological processes,
- Establish the baseline hydrogeological regime; and
- Identify and mitigate potential impacts.

The proposed development site is located at Learmonth, approximately 40 km south of Exmouth. The site location is shown in Figure 1.


Figure 1 - Project site location

## 1.2 Purpose and scope

The objectives of this study is the address the surface water and groundwater aspects of the EPA's Environmental Scoping Document (ESD). The ESD included numbered recommendations for 'required work'. These items form the broad Scope of this this report and are reproduced below as Table 1-1, which includes the relevant sections in this report where each ESD requirement is met.

Table 1-1 - Environmental Scoping Document - Required work

| ESD Required work | Section of this report |
|---|---|
| **59)** Characterisation of the baseline hydrological and hydrogeological regimes and water quality and quantity, both in a local and regional context, including, but not limited to, water levels including the fluctuation of the aquifer system in response to tides and storm events, water chemistry, presence of acid sulphate soils, stream flows, flood patterns, spatial characteristics of the fresh/saline groundwater interface, aquifer characteristics and recharge potential. | Sections 2, 3 and 4 |
| **60)** Identification of the location of abstraction bores for water requirements and identify and discuss any associated impacts of groundwater abstraction including from drawdown | Sections 7.3 and 7.4 |
| **61)** Provision of a detailed description of the design and location of the proposal with the potential to impact surface and ground water, including the extent of discharges and/or reinjection, and the disturbance of acid sulphate soils, if present. | Section 2 |
| **62)** Hydrological investigations to determine the effects of any proposed surface discharge, reinjection and modified drainage will have on the surface and ground water quality and quantity of the likely direct and indirect impact areas taking into account cyclonic conditions, cumulative impacts and a range of climatic scenarios including probable maximum precipitation. | Sections 5, 6 and 7 |
| **63)** Prediction of the residual impacts on hydrological processes and inland waters environmental quality, for direct, indirect and cumulative impacts, after considering avoidance and minimisation measures. | Sections 6 and 7 |
| **64)** Identification of the management, mitigation and monitoring methods to be implemented for the proposal to ensure residual impacts are not greater than predicted | Sections 7 |
| **65)** Where significant residual impacts remain, and relate to MNES, propose an appropriate offsets package that is consistent with the Environment Protection and Biodiversity Conservation Act 1999 Environmental Offsets Policy. Spatial data defining the area of significant residual impacts should also be provided | NA |

To achieve these objectives, modelling of the 10-year Average Recurrence Interval (ARI) flood (design event), 50–year ARI flood (climate change event), 100–year ARI flood (check event) and Probable Maximum Precipitation Design Flood (PMP-DF, ultimate event) of existing and future (with bundle track infrastructure in place) conditions was completed. This report presents the findings of this work.

To achieve the hydrogeological based objectives, groundwater investigations were completed incorporating drilling, monitoring bore installation, water level monitoring and water quality sampling.

## 1.3 Limitations and assumptions

The following assumptions and limitations in the methodology are noted:

- There are uncertainties associated with catchment boundaries and flow paths, however, they were derived using the best available elevation data. The datasets used were SRTM Digital Elevation Model (Geoscience Australia 2003) as well as the detailed survey data collected for the site, using CatchmentSIM software.
- Australian Rainfall & Runoff (Pilgrim, 1987) (ARR 87) guidelines were used for this project, with the exception of the next bullet point. This included rainfall intensity-frequency-duration data obtained from Bureau of Meteorology, temporal patterns, areal reduction factors and the general approach for identification of the critical storm.
- Australian Rainfall & Runoff (Ball *et al*, 2016) (ARR 16) draft guidelines were used for the climate change component. This was done because ARR 87 does not provide any guidance on climate change.

## 1.4 About this report

This report: has been prepared by GHD for Subsea 7 Australia Contracting Pty Ltd and may only be used and relied on by Subsea 7 Australia Contracting Pty Ltd for the purpose agreed between GHD and Subsea 7 Australia Contracting Pty Ltd as set out in Section 1.2 of this report.

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The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

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# 2. Available data

## 2.1 Topography

The following topographical data was obtained for the study:

- SRTM Digital Elevation Model with 30 m resolution (Geoscience Australia, 2010);
- Detailed survey data collected for the site from previous work; and
- A LiDAR (25 cm resolution) and aerial imagery (10 cm pixel size) survey scoped for this study and provided by Platinum Surveys Pty Ltd, the extent of which is shown in Figure 2.

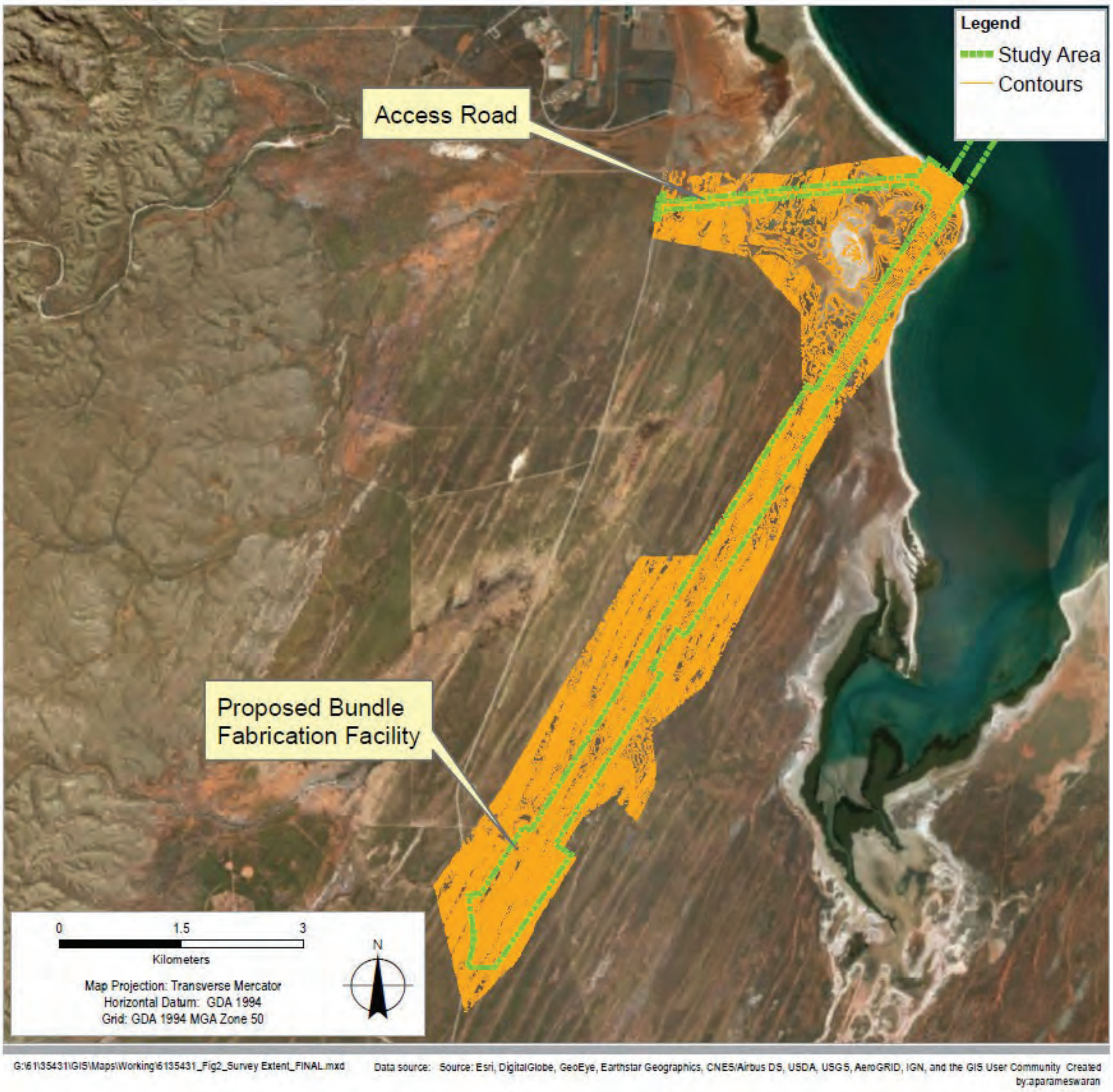



Figure 2 - Survey extent

## 2.2 Climate and rainfall

The proposal site is located in a hot, semi-arid climatic zone (Cardno, 2011) that is occasionally impacted by tropical cyclones. The wet season is from January to July.

Average monthly and annual rainfall data was obtained at Learmonth rainfall gauge (ID 005007) from the Bureau of Meteorology's (BOM) climate data online website[1]. The gauge is located

[1] http://www.bom.gov.au/climate/data/index.shtml?bookmark=200

slightly north of the proposal site and is expected to be representative of catchment rainfall. This data is tabulated and graphed in Table 2-1 and Figure 3 respectively, showing that on average the area receives relatively low rainfall throughout the year, with the driest months being August to December. The annual average is approximately 260 mm.

Table 2-1 - Average Monthly and Annual Rainfall at Learmonth Station (ID 005007)

| Month | Average Rainfall (mm) |
|---|---|
| January | 31.0 |
| February | 40.9 |
| March | 40.8 |
| April | 17.6 |
| May | 42.2 |
| June | 43.2 |
| July | 22.0 |
| August | 11.6 |
| September | 1.9 |
| October | 1.6 |
| November | 1.8 |
| December | 6.1 |
| **Annual** | **259.6** |

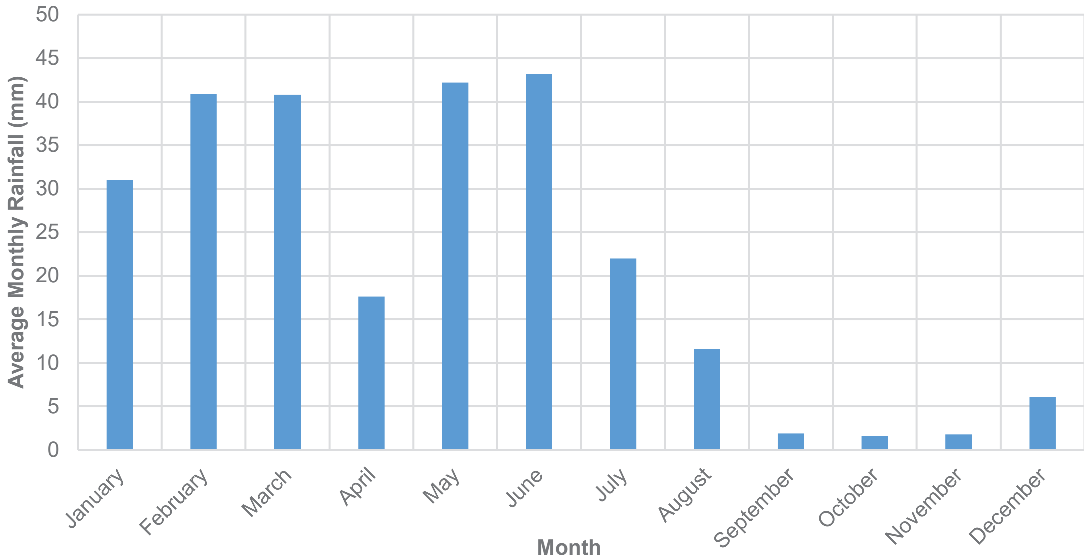



Figure 3 - Average Monthly Rainfall at Learmonth Station (ID 005007)

Inspection of monthly and daily data by Eliot *et al* (2012) found that daily totals of intense local rainfall events far exceed long-term averages. This is reflected in the Rainfall intensity-frequency-duration (IFD) data obtained from the Bureau of Meteorology from their ARR 87 website[2]. The coordinates used were 22.325 South, 114.100 East and the retrieved data is presented in Table 2-2.

[2] http://www.bom.gov.au/hydro/has/cdirswebx/cdirswebx.shtml

Table 2-2 - Rainfall IFD for site area (mm)

| Duration | 1 Year | 2 Years | 5 Years | 10 Years | 20 Years | 50 Years | 100 Years |
|---|---|---|---|---|---|---|---|
| 5 min | 6.1 | 8.1 | 11.6 | 13.8 | 16.7 | 20.5 | 23.6 |
| 6 min | 6.8 | 9.1 | 13.0 | 15.5 | 18.7 | 23.1 | 26.5 |
| 10 min | 9.2 | 12.3 | 17.7 | 21.3 | 25.7 | 31.8 | 36.7 |
| 20 min | 13.4 | 18.0 | 26.2 | 31.6 | 38.3 | 47.7 | 55.0 |
| 30 min | 16.2 | 21.9 | 32.1 | 38.8 | 47.2 | 59.0 | 68.0 |
| 1 hour | 21.2 | 28.8 | 43.0 | 52.6 | 64.5 | 81.3 | 94.8 |
| 2 hours | 25.8 | 35.6 | 55.0 | 68.2 | 85.0 | 108.8 | 128.2 |
| 3 hours | 28.4 | 39.6 | 62.4 | 78.6 | 98.7 | 128.1 | 152.1 |
| 6 hours | 33.1 | 46.7 | 76.8 | 99.0 | 127.2 | 168.0 | 202.2 |
| 12 hours | 39.2 | 55.8 | 95.6 | 124.8 | 163.2 | 219.6 | 267.6 |
| 24 hours | 47.8 | 68.2 | 119.3 | 157.9 | 207.1 | 280.8 | 345.6 |
| 48 hours | 57.6 | 82.6 | 145.4 | 193.4 | 254.9 | 347.5 | 427.7 |
| 72 hours | 61.1 | 88.6 | 157.7 | 211.0 | 279.4 | 383.0 | 473.0 |

## 2.3 Tidal data

Long term water level observations were sourced from Department of Transport's Exmouth tidal gauge (GHD, 2017b). These characteristics are shown in Table 2-3.

Table 2-3 - Tidal Plane at Exmouth (GHD, 2017b)

| Tidal Plane | m CD | m AHD |
|---|---|---|
| Highest Astronomical Tide (HAT) | 2.89 | 1.49 |
| Mean High Water Spring (MHWS) | 2.35 | 0.95 |
| Mean High Water Neap (MWHN) | 1.74 | 0.34 |
| Mean Sea Level (MSL) | 1.47 | 0.07 |
| Mean Low Water Spring (MLWN) | 1.2 | -0.2 |
| Mean Low Water Neap (MLWS) | 0.58 | -0.82 |
| Lowest Astronomical Tide (LAT) | 0 | -1.4 |

## 2.4 Soil infiltration

No detailed data or investigations were available to define soil infiltration characteristics in the study area. General data on horizon saturated hydraulic conductivity was obtained from a CRC for Catchment Hydrology publication (2004-06). Whilst this data does not directly provide infiltration values, it does allow estimates to be made on relative levels of infiltration per area, as this is correlated with hydraulic conductivity.

GHD geotechnical engineers visited the site and noted an adjacent area that appears to be subject to regular ponding which is likely to have less infiltration than adjacent land. This is supported by data from Geoscience Australia (2017) and a swamp classification by Bureau of Meteorology (2015). The area is shown in Figure 4.

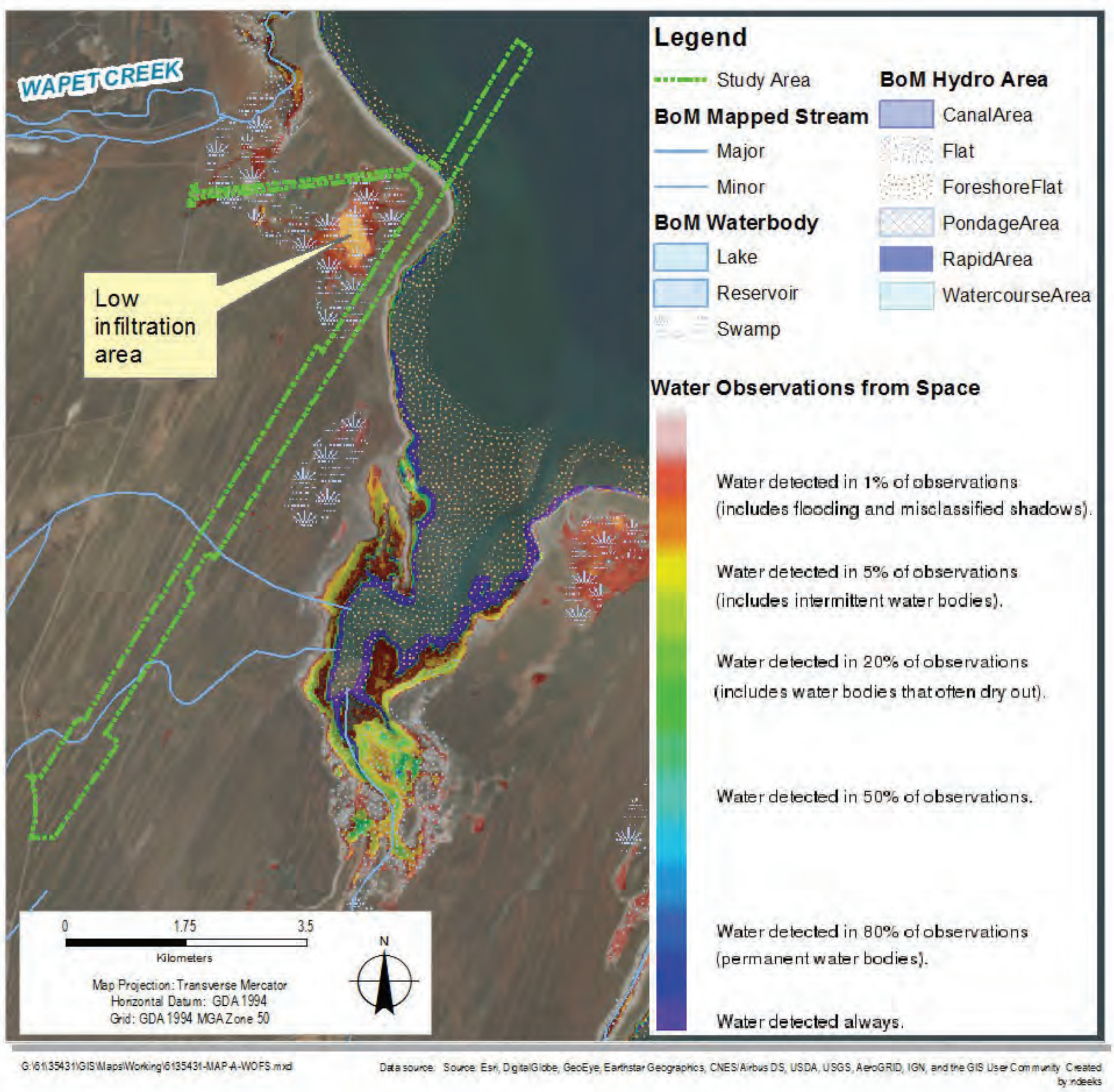



Figure 4 - Area of lower infiltration

## 2.5 Previous studies

There are two flood related reports published for the cape area:

- Exmouth Floodplain Management Study (SKM, 2007); and
- Exmouth Hydrological Study (hyd$_2$0, 2014).

All of the catchments studied in the SKM report are to the north of the project site, near Exmouth town. A related but unpublished modelling report that SKM produced fully describes the modelling approach and catchment delineation.

The southernmost catchment in the hyd$_2$0 report overlaps with the northernmost catchment in this project, however the hydrology was completed using the rational method and therefore cannot be validly compared. The rational method estimates peak discharge from a small catchment, however, it is a simplistic approach and in some cases it may provide overly conservative results.

## 2.6 Calibration data

The Exmouth area does not have any streamflow gauging available for calibration of the model. Therefore, Regional Flood Frequency Estimation (RFFE) (Rahman *et al*, 2012) results were not obtained due to inaccurate representation of the hydrological characteristics of rivers in the study area.

# 3. Site characteristics

## 3.1 Topography and soils

The elevation of the site ranges from about 25 m Australian Height Datum (AHD) at the inland end to 0 m AHD at the coast and generally slopes from the south west end to the north east. Based on available topographical data (Section 2.1), the site appears to drain internally, with a coastal dune preventing discharge to the ocean.

The Phase 3 Geotechnical Desk Study (GHD, 2017c) reported the majority of the site to be built on an area characterised by a series of parallel network dunes and residual sand plains made up of red brown to yellow quartz sand. The dunes are approximately 5 m in height and are stabilised by light vegetation comprising grasses and small shrubs. The dunes generally trend north north east – south south west. The sand within the dunes could be expected to vary from loose to medium dense.

Closer to the coast the alignment crosses areas of beach and coastal dunes (containing some quartzose calcarenite beachrock) and areas of supratidal flats which contain mixes of mud and silt where regularly inundated and calcareous clay, silt and sand with some deposits of gypsum and salt where the inundation is more sporadic (limited mainly to high storm surges). Materials in these areas are expected to be moist to wet and to be soft if saturated.

## 3.2 Geological setting

The Project area is located on the coastal plains within a minor syncline between Cape Range in the west and Rough Range in the south east. Within the main project footprint (east of Minilya-Exmouth Road) the site surface geology is typically residual sand plains forming longitudinal dunes, with intertidal flats (calcareous clay, silt and sand) and supratidal flats (calcareous clay, silt and sand with authigenic gypsum and salt) identified in the far north east of the project area along the coastal fringes (GSWA, 1980).

The Cape Range foothills are located approximately 4 km west of the site and coincide with the area proposed for groundwater supply bores. Within this area, the surface geology is typically Exmouth Sandstone, and Bundera Calcarenite. Higher in the range, Trealla Limestone and Tulki Limestone are exposed (GSWA, 1980).

## 3.3 Hydrogeological setting

Based on an interpretation of the surface geology, it is inferred that minor sandstone and calcarenite underlie the surface sands, with a succession of limestone beneath (see further comment in Section 4: Groundwater investigation). Where saturated, the sandstone and limestone units are considered a regionally important aquifer and are currently utilised for Exmouth Town water supply, Learmonth RAAF base water supply, together with various stock and domestic supply bores (see Section 3.4).

Groundwater within the limestone aquifer is generally found to flow eastwards, from the Cape Range (source of groundwater recharge) towards the Exmouth Gulf where it discharges (Department of Water, 2011). Local groundwater flow patterns are likely to be significantly affected by karstic features. Due to the highly permeable nature of the limestone aquifer, the saline interface is known to extend by up to 5 km inland, this is further discussed with regard the Project drilling results summarised in Section 4. It is noted that the saltwater wedge coincides with, and is controlled by, the presence of highly transmissive karstic features. As a result, any water supply bores are sensitive to over pumping and bores are generally throttled to minimise saline up-coming (DoW, 2011).

The freshwater aquifer thickens to the west, with distance from the coast, and is known to be up to 150 in depth, however the aquifer permeability may also decrease with aquifer thickness.

## 3.4 Existing groundwater users

As noted in Section 3.3 above, there are groundwater uses identified within close proximity of the project area. These include licensed groundwater abstraction user and non-licensed users. A summary of which is provided in the following sections:

### 3.4.1 Licensed groundwater users

Abstraction of groundwater within Western Australia is licensed under the Rights in Water and Irrigation Act 1914 by the Department of Water and Environmental Regulation (DWER). The site is located within the Exmouth South groundwater sub-area, with the licensed aquifer being the Cape Range Limestone. An enquiry was made to the DoW with regard to the availability of groundwater for the Cape Range Limestone aquifer. The DoW indicated that the aquifer is currently only 2% allocated.

A review of existing groundwater licences was made though assessment of the DWER Water Register (Water Register, 2018). The Water Register provides a summary of existing licenses but does not provide details on the location or number of bores used for a licence. A summary of the current licences is provided below as Table 3-1.

In summary, the licensed abstraction within close proximity of the Project is for relatively small groundwater volumes. The licenses held by Rough Range Oil and Main Roads are expected to be for bores areas some distance from the Project (i.e. more than 5 km).

Table 3-1 - Existing groundwater abstraction licenses

| Licence ID | Holder | Aquifer | Volume per annum (expiry) | Comment |
|---|---|---|---|---|
| 175966 | Rough Range Oil Pty Ltd | Carnarvon - Cape Range Limestone | 550 kL (2012-2019) | Very large area covering their Exploratory petroleum permit. Location of bores unknown. |
| 201409 | Main Roads | Carnarvon - Cape Range Limestone | 20000 kL (2018-2028) | Along the road alignment of Minilya-Exmouth Road. Location of bores unknown.. |
| 47187 | M G Kailis Pty. Ltd | Carnarvon - Cape Range Limestone | 100000 kL (2013-2023) | Coastal area 8 km from the Project site. |
| 159169 | M G Kailis Pty. Ltd | Saline Resource | 30000 kL (2017-2027) | |

### 3.4.2 Unlicensed groundwater users

Domestic and stock use are except from groundwater licensing, and as such there is no formal requirement for the locations of stock or domestic abstraction bores to be recorded, providing that abstraction is limited to less than 1500 kL per bore/per annum. Whilst not licensed, the location of many stock bores is recorded on the DWER Water Information Reporting database (DWER, 2018 b).

Data from the WIR database, in addition to data gathered whilst on site and in discussion with the owner of Exmouth Gulf Station, identified a number of stock bores, within close proximity of the Project site. These are identified on Figure 6. The stock bores tend to be equipped with either a solar powered pump, or wind powered pump. In general they supply low volumes of groundwater and only target water of suitable quality for stock use.

In addition to stock bores, information on groundwater abstraction within federal land is also not publically available. It is known that groundwater is abstracted at RAAF Learmonth, located immediately to the North of the Project. Historic data on the bore locations for RAAF Learmonth is include in the WIR database. The WIR data indicates around a dozen bores, predominately located in the area to the west of the site towards the foothills of the limestone ranges. Information on how much groundwater is abstracted at the site is unknown.

## 3.5 Surface water catchments

The floodplain has very few defined flow paths based on aerial imagery and available topographical data, making it difficult to determine exact catchment boundaries. The catchment areas draining to the proposed infrastructure were delineated using CatchmentSim v3.5 software and are shown in Figure 5. From the figure, there are three catchments with associated areas as follows: Catchment A – 108.3 $km^2$, Catchment B – 36.9 $km^2$ and Catchment C – 59.8 $km^2$. Catchment A drains to the access road, whereas B and C drain toward the access road, fabrication facility and bundle track alignment.

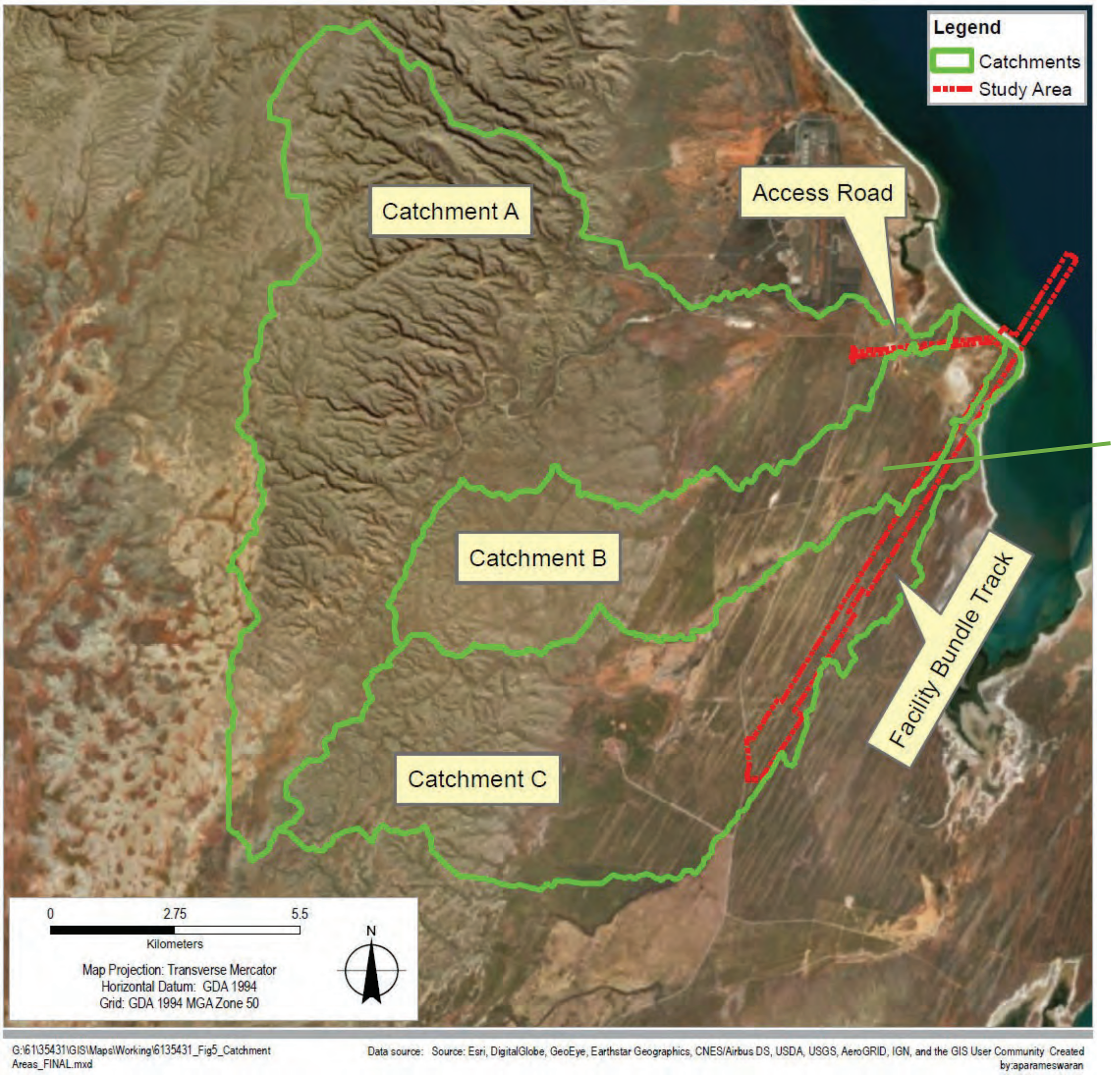



Figure 5 - Catchment areas (Source: Aerial Imagery from ESRI ArcGIS Basemap, 2018)

# 4. Groundwater investigation

## 4.1 Drilling program aims

A drilling program was completed for the project to achieve two main aims:

- Determination of a suitable location for groundwater supply bores.
- Establishment of a stygofauna monitoring bore network

The requirements for each aim are summarised in the following sections.

### 4.1.1 Groundwater supply options

Groundwater assessment drilling was required to demonstrate a suitable groundwater supply target for the Project. A raw water demand of 12,000 kL/annum is required. If non-fresh groundwater were to be used, this volume demand would increase to account for desalinisation (See Section 4.2 for drilling summary highlighting the fresh groundwater source to be used for supply). The drilling program was to be an investigatory drilling program only, with water supply bores constructed at a later stage and following the outcomes of the PER.

Prior to commencement of the drilling program, two groundwater supply options were proposed:

- Offsite (area of Little Bore)
- Onsite - within western margin of project envelope

Due to the sites proximity to the coast, and consequently the likelihood of more saline groundwater/thinner fresh water aquifer being present towards the east, the most prospective groundwater supply area (in terms of groundwater quality) was identified in the area west of the Minilya Exmouth Road towards the base of the Range and proximate to creek outflows near the area of Little Bore (i.e. outside of the original project envelope).

An onsite source would be preferred to the above as this would minimise the need for a water pipeline and maintain site operations within a small area. No existing data was available to demonstrate on-site water quality, therefore a number of targets were chosen within the project envelope, located as close to existing drainage to determine if any onsite sources could provide fresh groundwater.

### 4.1.2 Stygofauna monitoring bore network

The extent and bore locations for the stygofauna monitoring network would be dependent on the outcomes of the groundwater supply assessment. That is, the location of the stygofauna monitoring bores would need to target areas where groundwater abstraction was to occur (in addition to locations targeting mapped areas of potential subterranean fauna habitat (Bennelongia, 2017)).

A total of 20 stygofauna monitoring bores would be required for the project. The location for these, based on the two potential water supply options were determined by 360 Environmental in their Proposed Subterranean Fauna Sampling Plan (360 Environmental, 2018).

## 4.2 Drilling results summary

Drilling commenced within the Project footprint at ST01. Being the most western site, this offered the highest likelihood of a fresh onsite groundwater supply (see Figure 6).

An air-core / reverse circulation drilling method was chosen in order to be able to assess groundwater quality/groundwater flow during drilling. As such, during drilling of ST01 field water quality samples were taken and it was established that the groundwater quality was saline at this site, and by implication, saline within the general project envelope. This resulted in pursuing the 'Offsite' (area of Little Bore) water supply option. Subsequent drilling in the area west of the site and around Little Bore confirmed that an offsite source would provide suitable groundwater for the project (i.e. relatively fresh groundwater and good groundwater yields).

Drilling and monitoring bore installation continued in accordance with the Proposed Subterranean Fauna Sampling Plan. A summary of the completed monitoring bores is provided below as Table 4-1, and completed bore logs, including monitoring bore installation details are included as Appendix E.

### Table 4-1 - Monitoring bore installation summary

| Site ID | Location | Purpose | Drilled depth (mbgl) | Screen interval (mbgl) | Depth to ground-water*(mbgl) |
|---|---|---|---|---|---|
| ST01 | Fabrication area | Project area - water supply assessment | 25.8 | 18-24 | 17.1 |
| S09 | Fabrication area | Stygofauna monitoring | 26 | 18-24 | 14.6 |
| S16 | Fabrication area | Stygofauna monitoring | 24 | 13.9-16.9 | 11.8 |
| S10 | Fabrication area | Stygofauna monitoring | 27 | 13.9-19.9 | 11.8 |
| S01 | Footprint - Central | Stygofauna monitoring | 17 | 9-15 | 4 |
| S05 | Footprint - Central | Stygofauna monitoring | 6 | 2-6 | 1 |
| S04 (North) | Footprint - Central | Stygofauna monitoring | 6 | 2-6 | 1.1 |
| S04 (South) | Footprint - Central | Stygofauna monitoring | 6 | 1.7-5.7 | 1 |
| S02 | Footprint - Central | Stygofauna monitoring | 12 | 3.9-9.9 | 2.8 |
| S08 | Footprint - Down gradient | Stygofauna monitoring | 9 | 2.5-8.5 | 1.8 |
| S03 | Footprint - Down gradient | Stygofauna monitoring | 9 | 2.45-8.45 | 1.8 |
| S06 (North) | Footprint - Down gradient | Stygofauna monitoring | 9 | 1.5-7.5 | 1.5 |
| S06 (South) | Footprint - Down gradient | Stygofauna monitoring | 9 | 2.7-8.7 | 1.5 |
| S07 | Footprint - Down gradient | Stygofauna monitoring | 12 | 4.77-10.77 | 3.3 |
| S15 | Water supply area - Up gradient | Stygofauna monitoring | 42 | 35.7-41.7 | 28 |
| S14 | Water supply area - Up gradient | Stygofauna monitoring | 45 | 39.8-44.8 | 32.5 |
| S11 | Water supply area - Up gradient | Stygofauna monitoring | 50 | 27-33 | 24.5 |
| S22 | Water supply area - Up gradient | Offsite - water supply assessment | 48 | 34.7-46.7 | 25.2 |
| S24 | Water supply area - Up gradient | Offsite - water supply assessment | 52.5 | 40.5-52.5 | 26.5 |
| S25 | Water supply area - Up gradient | Offsite - water supply assessment | 44 | 31-43 | 22 |

** depth to groundwater as meters below ground level measured 22-23rd October 2018*

## 4.3 Interpreted geology / hydrogeological units

In general drilling confirmed the expected site geology (as described in Section). A summary of the site geology and hydrogeological units is presented below as Table 4-2, and sketched in cross section on Figure 7.

### Table 4-2 - Summary of lithology

| Unit | Thickness | Comment |
|---|---|---|
| Sand | 0-3 m | Coastal dune sand. Present across the main project area at surface, thickest in the West, absent in the water supply area, and thin or absent in coastal flats. Generally not saturated. |
| Sandstone (Exmouth Sandstone) | 5-20 m | An interbedded sequence of pale red to yellow sandstone, varying from well cemented to poorly cemented. Was found throughout the Project area. In some areas, the sandstone was interbedded with more calcareous sediments. Some minor clay bands were also noted.<br>The sandstone, where found in lower elevation areas, was found to be saturated and offered reasonable groundwater flow. |
| Calcarenite/limestone (Bundera Calcarenite, and possibly Trealla Limestone in the west at depth). | >40 m | An interbedded sequence of white to brown, well to poorly cemented Calcarenite/limestone was found throughout the Project area where drilling continued deep enough. Shell fragments and minor clays were noted, particularly in the western areas at depth.<br>The calcarenite/limestone was found to be saturated and offered reasonable to good groundwater flow.<br>***Note:*** *The sandstone and calcarenite/limestone units are considered to represent a single connected aquifer, with no discernible separation between the two.* |

## 4.4 Groundwater levels

Understanding of groundwater levels and groundwater flow (direction and velocity) is required in order to determine the baseline groundwater conditions, including identifying seasonal variations and pathways/receptors for potential contaminants.

Following completion of the monitoring bore installation, all bores were surveyed to determinate accurate location and elevation datums. An initial groundwater level monitoring round was then completed on all bores by 360 Environmental (22-23 October 2018). A subsequent groundwater level monitoring rounds was completed in February 2019 to allow assessment of seasonal variability.

The groundwater monitoring allowed the determination of the potentiometric surface. The potentiometric surface was generated using the groundwater level from the October 2018 monitoring round, and assuming an elevation of zero mAHD for the coastline. This is plotted on Figure 6, and also illustrated on the cross section produced as Figure 7. The following key observations area noted regarding groundwater levels:

- The groundwater flow direction is largely consistent with the topography, with a general easterly flow direction, with groundwater discharging along the coast. It is noted the within the fabrication area, groundwater appears to be flowing in an east south-easterly direction, whereas in the area closer to the proposed slipway, groundwater is flowing in a more easterly direction. Some caution should be noted in the recorded contours due to lack of control points outside of the project area.

- The data suggests a slight groundwater mound in the area of S04 and S05. The reason for this apparent mound is unclear but may be related to measurement error, tidal fluctuations or an area of higher recharge.
- The greatest depth to groundwater is found in the western bores where groundwater occurs at an approximate elevation of around 1.6 mAHD, equivalent to a depth to groundwater from ground level of between 22-32 m depending on location.
- The shallowest depth to groundwater is found in the low lying bores located closest to the coast (e.g. S04 North and South, S05 and S06 North and South) where groundwater occurs at a depth of less than 1.5 metres below ground level (mbgl), equivalent to less than 0.5 mAHD.
- In the main fabrication area, groundwater is found to occur at a depth of between 12 and 17 mbgl depending on location.
- Groundwater level seasonal variability was noted between the October 2018 and February 2019 monitoring rounds. On average, the groundwater levels reduced by 0.2 m over this period. The largest reduction in groundwater levels was seen at S04, S05 and S10 where a reduction of around 1 m was noted. The reduction may possibly be attributed in part to tidal variation as well as seasonality.

## 4.5 Groundwater quality

Groundwater sampling was required in order to demonstrate the baseline groundwater quality at the site. Two groundwater quality sampling rounds have been undertaken, one to represent groundwater quality at the end of the winter period (October 2018), and a subsequent round will to represent summer groundwater quality (February 2019).

The monitoring rounds were completed by 360 Environmental on a selection of bores. The selection was made to provide representative baseline data for the Project area. The bores sampled included the following:

- S01 – To represent the central area of the rail alignment
- S03 - – To represent the down gradient area of the rail alignment
- S06 (north) - To represent off site / site boundary down gradient area of the Project
- S09 - To represent the fabrication area of the Project
- S14 - To represent the upgradient area of the site
- S24 - To represent the proposed borefield area / upgradient of the site
- S25 - To represent the proposed borefield area / upgradient of the site

A groundwater analysis suite was chosen to provide broad range of parameters to allow baseline assessment. A summary of the groundwater quality results is provided in tabular format as Appendix F. The monitoring report completed by 360 Environmental, including the laboratory results is included as Appendix G. For comparative purposes, the tabulated results presented in Appendix F compare the data to the Australian Drinking Water Guidelines (ADWG) for aesthetic and health based parameters, and to the ANZG (2018) – Marine water (95% level of species protection). The ADWG was chosen to reflect that groundwater utilised for the project may be used for potable supply. The ANZG marine guideline was used to reflect that groundwater from the site will discharge to the marine environment.

The following observations are made with reference to the two (October 2018 and February 2019) sampling groundwater quality results:

- The groundwater quality at the site is typified by two distinct groundwater signatures:

  - Salt dominant groundwater (hypersaline i.e. higher salinity than sea-water) in bores located in the main project footprint: and
  - Fresh to slightly brackish groundwater for those bores sampled in the western area (S24 and S25) and representing the proposed groundwater supply area.
- All four bores sampled in the main project footprint recorded salinities (as Total Dissolved Solids) of between 41,300 mg/L (S09 in February 2019) to 73,700 mg/L (S06 in October 2018). The least saline groundwater within the project main footprint was sampled at S09 which is the furthest from the coast. The most saline groundwater within the project main footprint was sampled at S06 which is located in an area identified as tidal flats/salt plain.
- The high salinity of the project area is likely caused by the concentration of salts in areas of tidal flats. These areas would have historically occurred further inland of the current flats as a result of sea-level changes.
- As highlighted by the conceptual cross section presented as Figure 7, the location of the saline wedge and interface between fresh groundwater in the west and saline groundwater in the east is not accurately known, due to an absence of drilling data between water supply area and the fabrication area. Based on the topography, it could be expected that salt flats could have extended as far inland as the area noted as a break of slope, just west of Minilya-Exmouth Road. As such, it is possible that the salt wedge may be located in this area. It is noted that the bores in the water supply area were drilled and installed through at least 12 m of saturated aquifer. No change in salinity was noted with depth at these locations, implying that the interface is some distance east of here.
- The relatively fresh groundwater found in the western area (S24 and S25) indicates that the groundwater is suitable for Project water supply with salinities measured between 887 and 1120 mg/L. The groundwater quality has a very similar signature to the Exmouth Town Water Supply water (DoW, 2011).
- Groundwater quality data is consistent between each sampling round for each monitoring site, demonstrating no significant seasonal variability during the period of monitoring.
- The low concentrations of nutrients and biological components indicate that the site wide groundwater is un-impacted by its current use for sheep grazing.

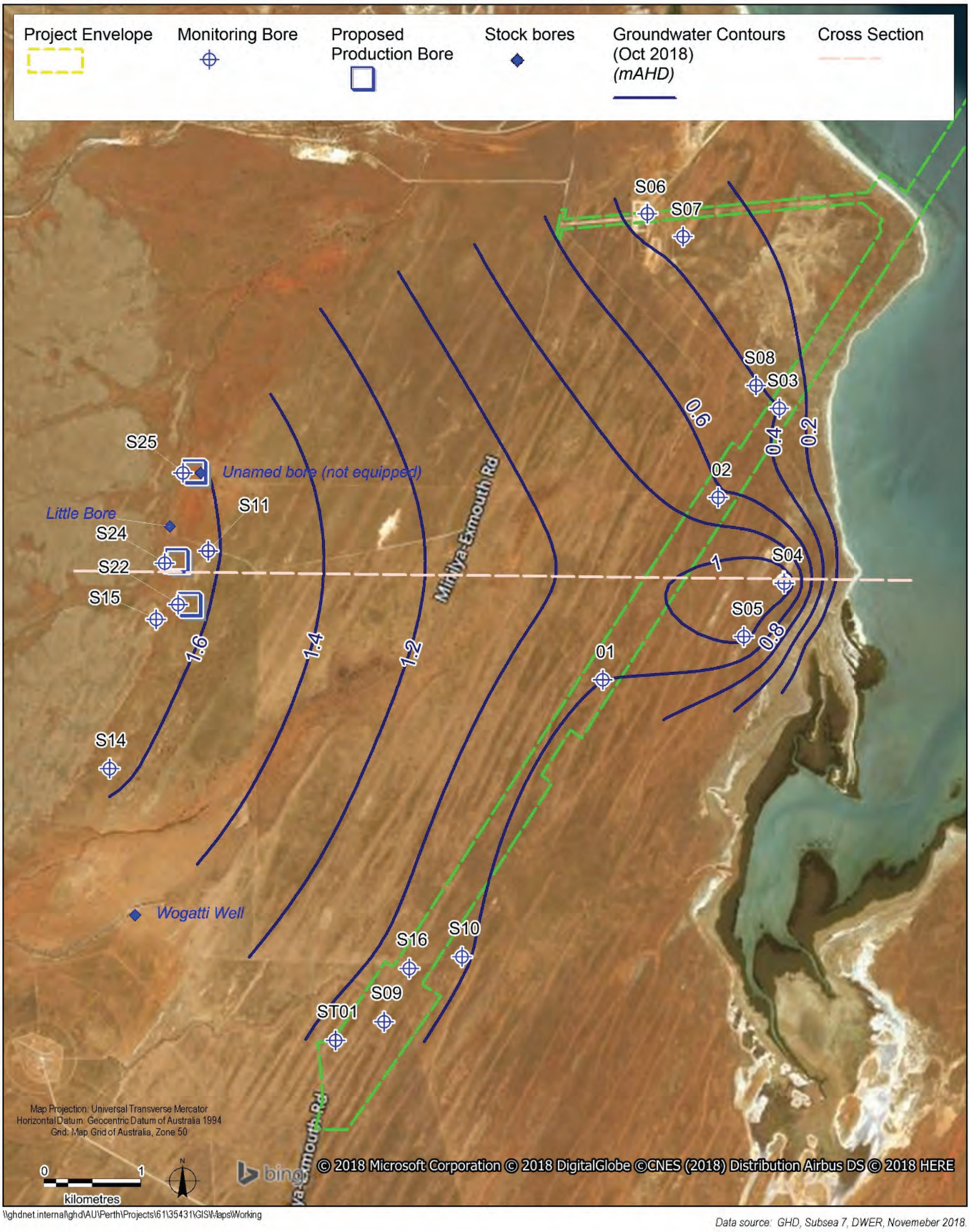



Figure 6 - Bore locations and groundwater contours (October 2018 data)

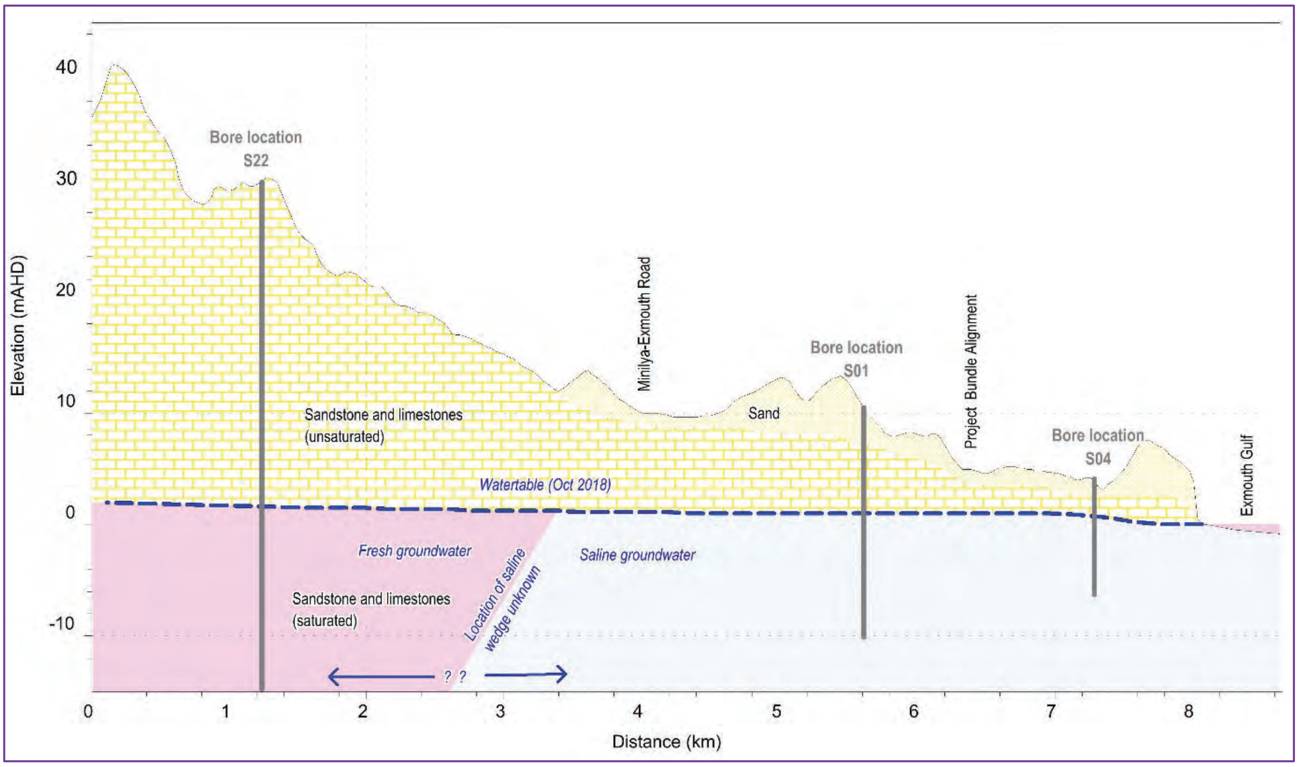



Figure 7 - Hydrogeological cross section (See Figure 6 for alignment)

# 5. Surface water model set-up

## 5.1 Approach

Each catchment has a hilly upper reach that drains to a complex floodplain where, based on aerial imagery and low resolution 30 m grid topographical data, there are very few defined flow paths. Given the difficulty of establishing sub-catchments, a rain-on-grid 2D approach was adopted for the flood modelling.

## 5.2 Design events

The design events to be run included the:

- 10-year ARI, which is the design case and sets the size and serviceability of the surface water infrastructure such as culverts, channels and floodways.
- 100-year ARI is the event used to design flood damage protection, avoid damage to infrastructure and property and avoid discharge to the environment of associated materials
- Probable Maximum Precipitation Design Flood, which is typically used to assess the worst case scenario of a future closure scenario. In this study it has been used to demonstrate how the development could modify flood behaviour in a worst case flood.
- 50-year ARI (see Appendix A, Section A-1) to determine the potential risk that climate change poses to the infrastructure, and whether there is a need to model climate change projections.

## 5.3 Design rainfall

The IFD data shown in Table 2-2 was adopted as the design rainfall. Catchment A has a very large area (108.3 $km^2$) that also required application of areal reduction factors to convert point rainfall values to areal estimates (discussed further in Appendix A, Section A-2).

The durations that were run were as follows: 30 min, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, 24 hours, 48 hours and 72 hours.

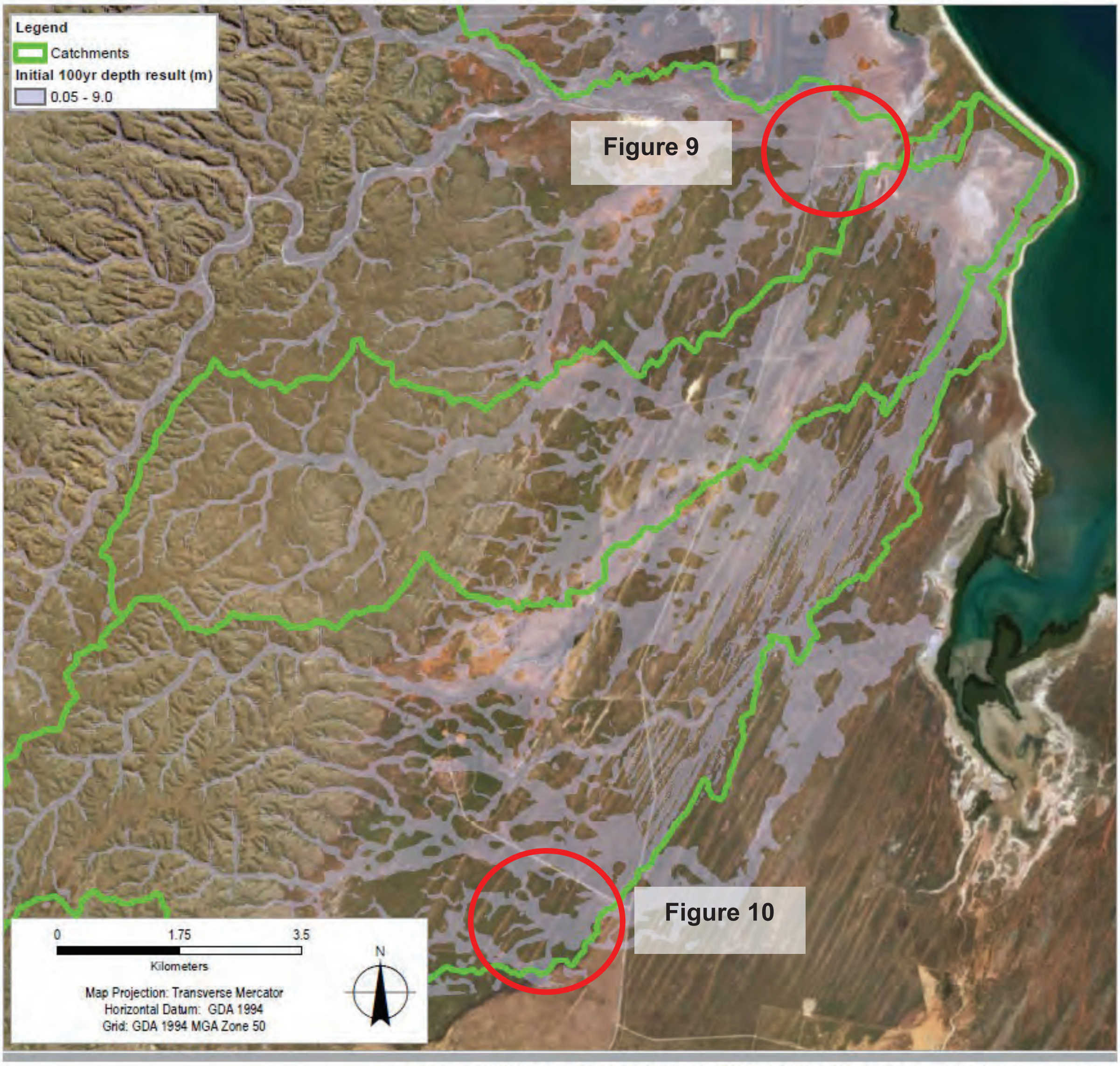
Standard ARR 87 temporal patterns were used for the Indian Ocean Division, Zone 7.

Derivation of the PMP was done using Bureau of Meteorology Guidelines and is fully discussed in Appendix A, Section A-3.

## 5.4 Model geometry

### 5.4.1 Existing case

The model surface consisted of a combination of the 30 m SRTM data and the detailed survey data, with the detailed survey taking precedence in areas of overlap. As the model extent was very large, a 15 m cell size was applied. Initial runs showed that modifications to the coarse part of the model were required in three places, as shown on Figure 8. These modifications were implemented to account for known hydraulic structures that were not represented by the coarse topographic data.




Data source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community Created by:aparameswaran

## Figure 8 – Modifications to model geometry

The first modification was at the intersection of a flow path and the Minilya-Exmouth Road (Figure 9), where the coarse grid showed flows spreading southwards and crossing the road to drain to the low-lying area adjacent to the site. Due to the presence of a floodway that was not replicated in the data, flows are expected to remain within the floodway, which directs runoff to northern model outlet. The portion of road without the floodway was raised so that flows cross the road at the floodway.

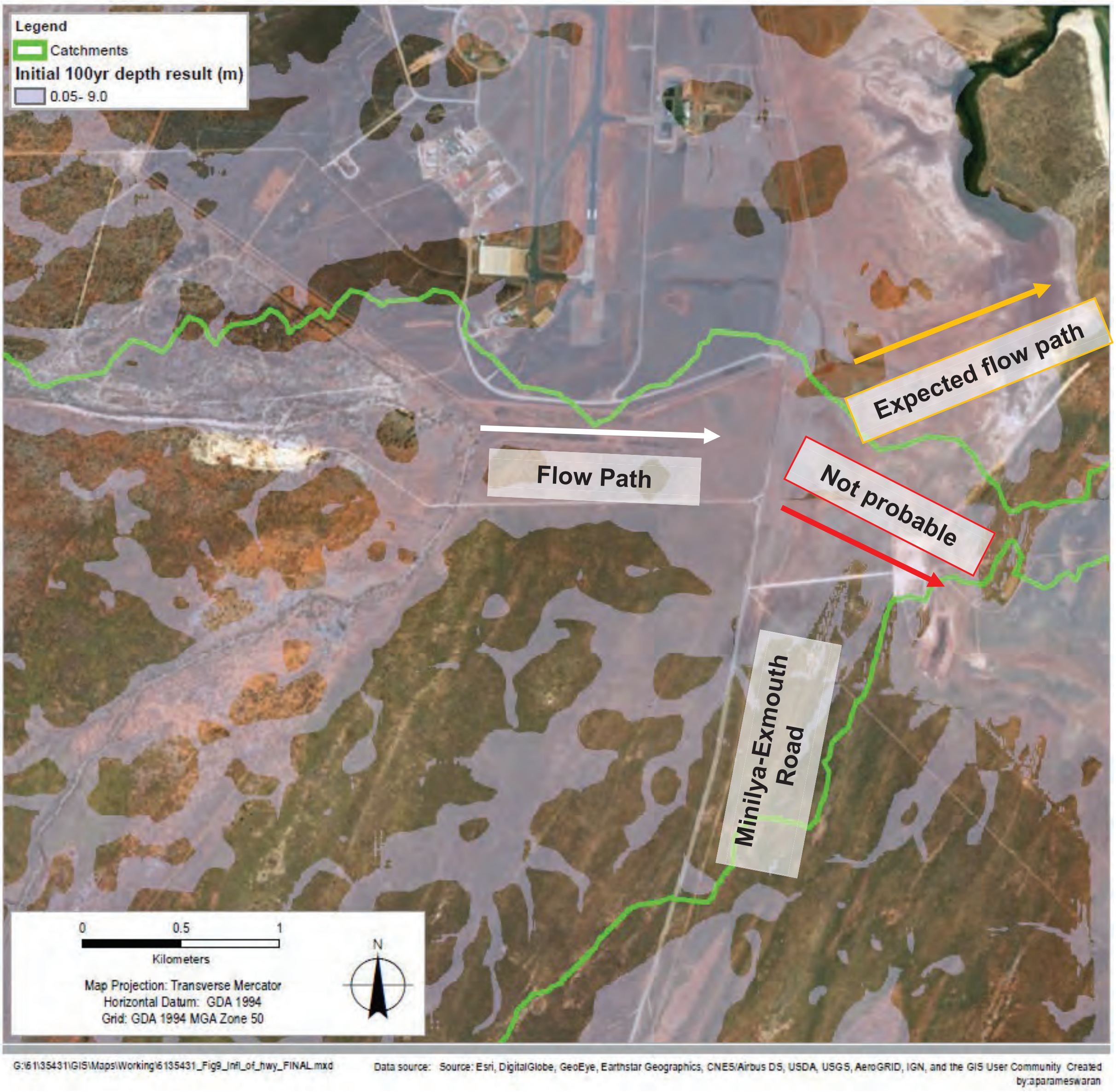



Figure 9 - Influence of the highway

In the southern portion of the study area, the expected flow path is not followed due to the absence of a series of north-south running dunes in the coarse topographic data. This is shown in Figure 10 and was resolved by cutting a channel to direct flow to the creek line. In addition, there is a crossing of the Minilya-Exmouth Road where culvert data is not available (Figure 10). At this location, the road model was lowered to allow flows to pass unobstructed.

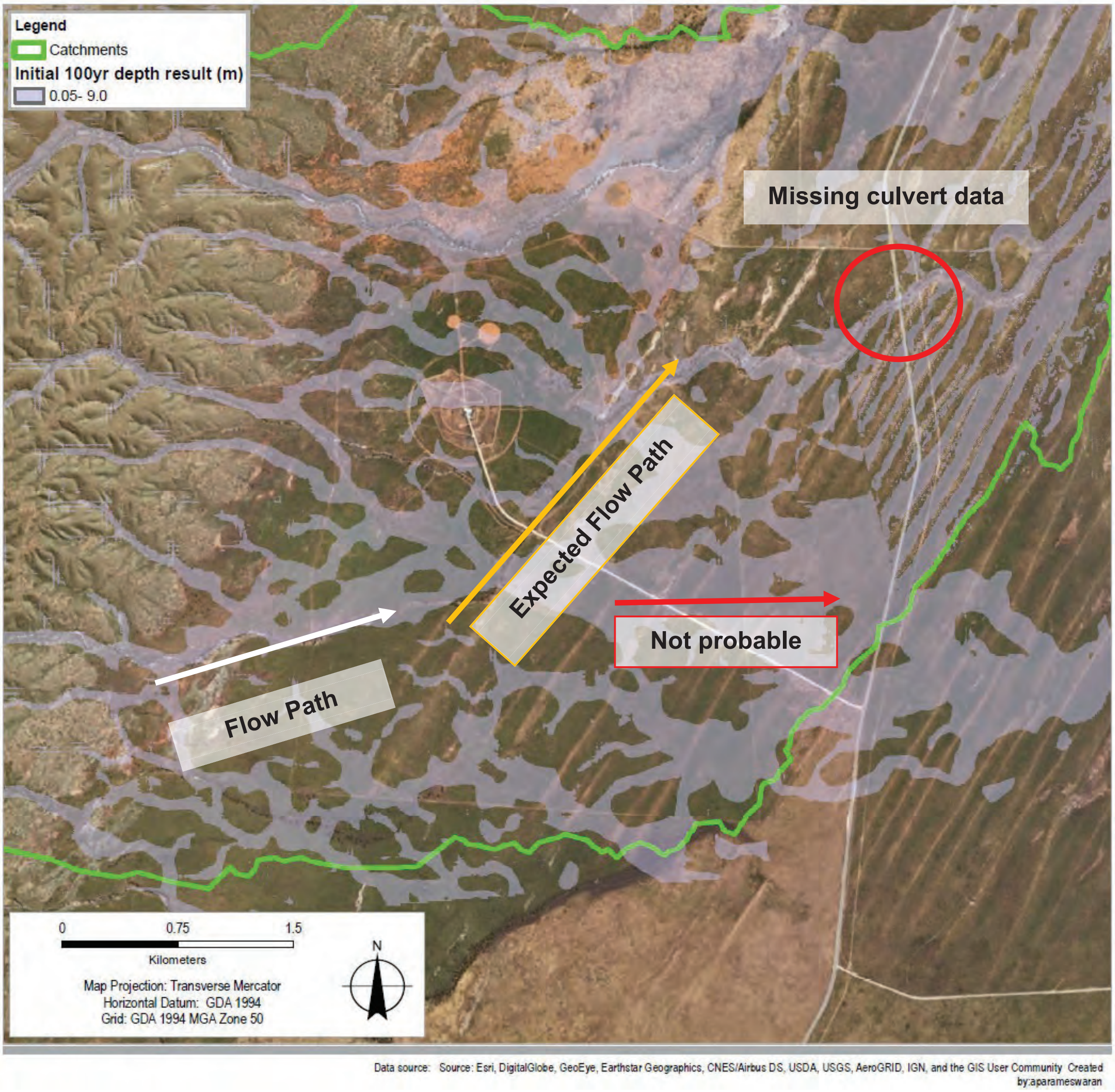



Figure 10 - Break-out flows and missing culvert data

### 5.4.2 Future case

The access road and bundle track alignment were directly input in the model based on available design. The following changes were also applied to the existing geometry to produce the future case:

- Inclusion of a new culvert at the waterway marked in Figure 11; and
- Inclusion of an open drain adjacent to the bundle track alignment to prevent flows from crossing the bundle track multiple times, as shown in Figure 11. This removes the need for multiple culverts under the bundle track.

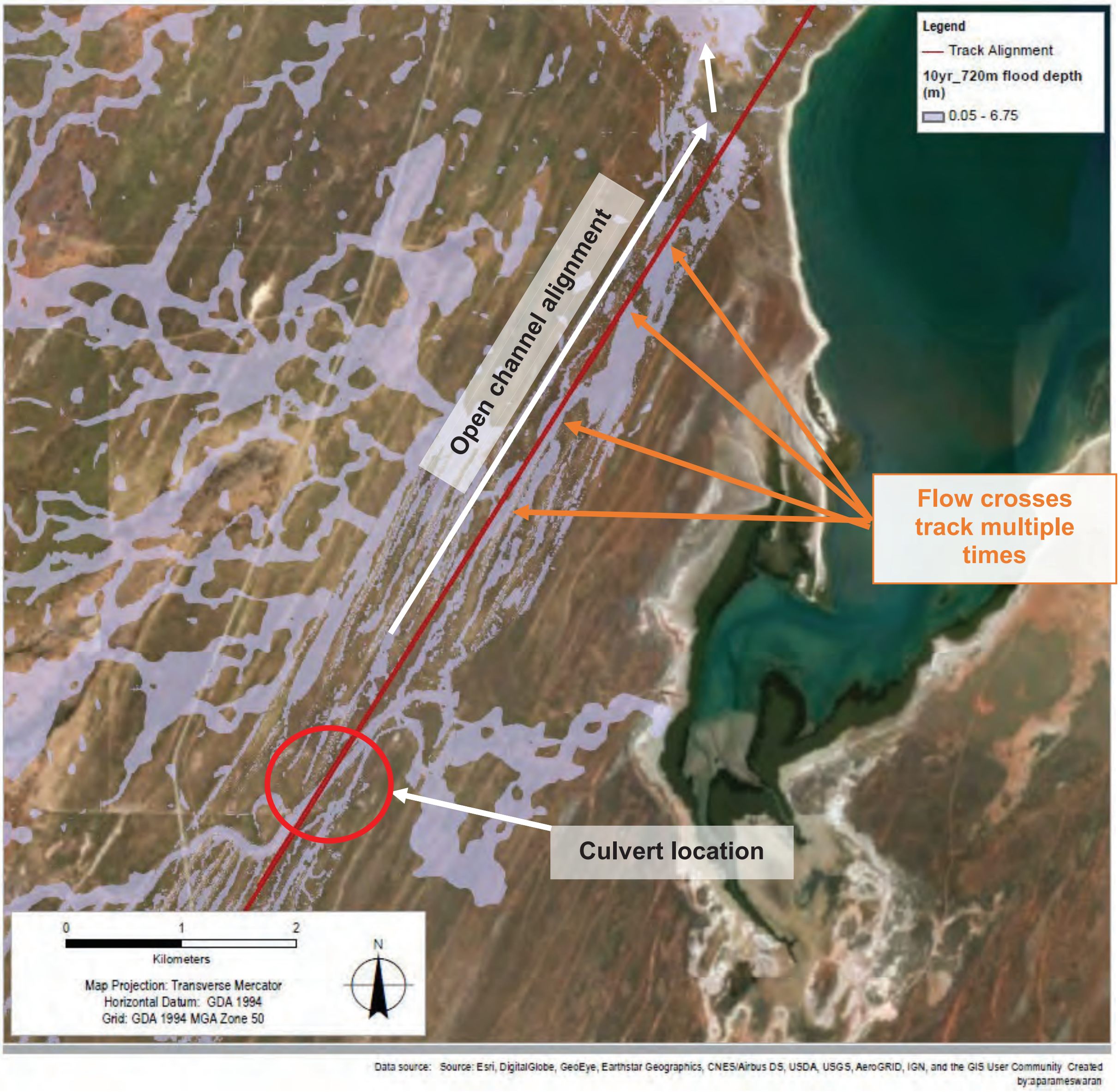



Figure 11 – Future geometry modifications

## 5.5 Boundary conditions

Two types of boundary conditions were applied in the model:

- Tidal boundaries where the model extent ended next to the ocean. This was based on the highest astronomical tide from Table 2-3, which was kept constant throughout the model run.
- Normal slope boundaries where the model extent ended on land.

## 5.6 Manning's roughness values

Manning's roughness values were assigned to the cells of the model using a combination of:

- Interactive supervised imagery classification in the area covered by aerial imagery (shown in Figure 2); and
- Polygons with assigned material roughness.

The area was split into heavy (n=0.035) and light (n=0.030) vegetation, bare earth (n=0.025), asphalt (n=0.012), and sand (n=0.026).

## 5.7 Soil losses

Soil infiltration losses were set based on CRC for Catchment Hydrology (2004-06) horizon saturated hydraulic conductivity layers. The initial and continuing loss approach was used, where initial loss was varied based on areas shown in Figure 12, and the continuing loss was fixed. Note that the area identified as subject to frequent ponding in Section 2.4 was assigned a lower loss value independent of Figure 12, which was based on site observations by GHD geotechnical engineers. The final values are shown in Table 5-1.

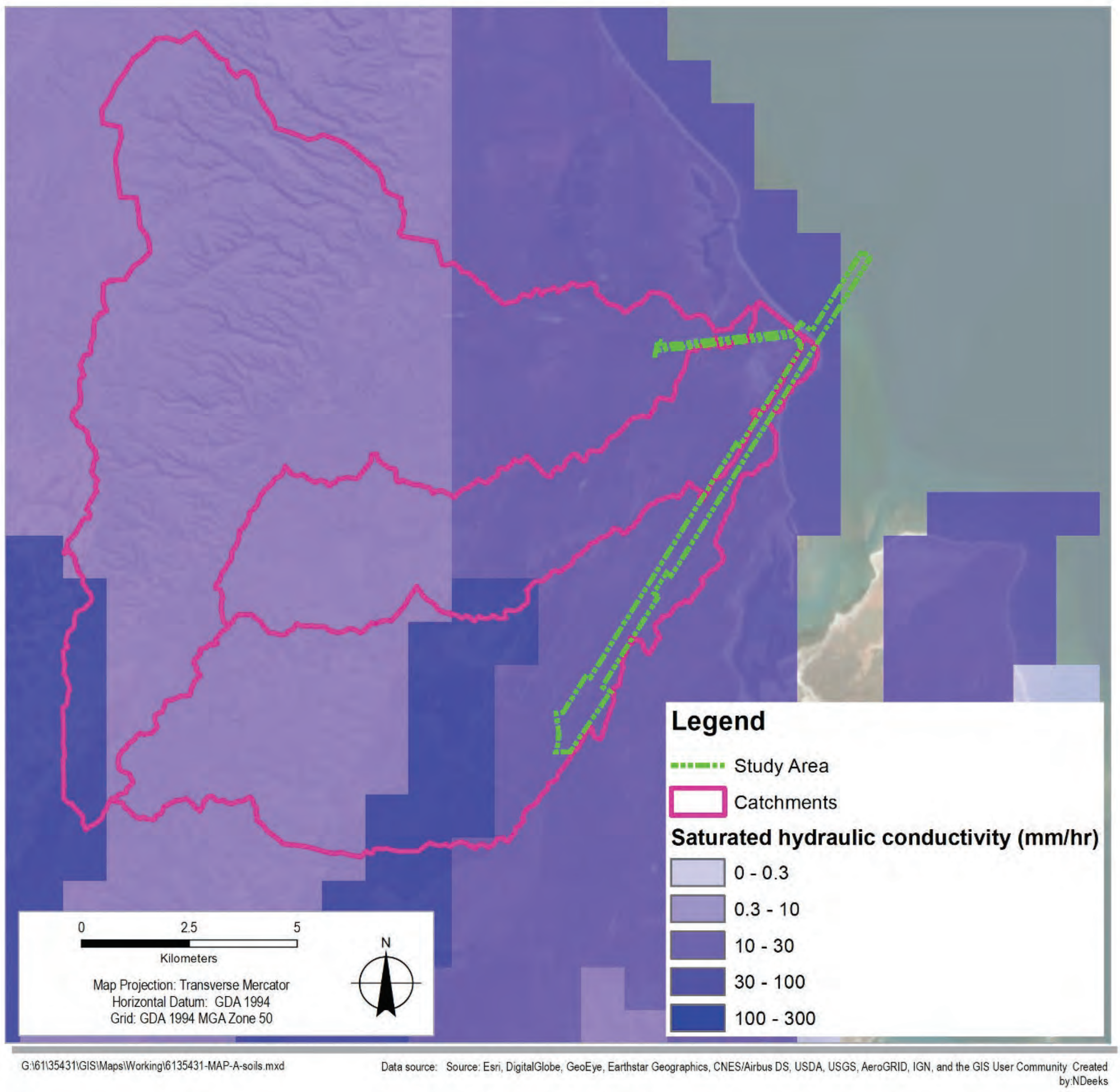



Figure 12 - Horizon saturated hydraulic conductivity layers (CRC for Catchment Hydrology, 2004-06)

Table 5-1 - Soil infiltration values

| Horizon saturated hydraulic conductivity | Initial Loss / Continuing Loss |
|---|---|
| Area of low infiltration (refer Section 2.4) | 40 mm, 5 mm/hr |
| 0 to 10 | 50 mm, 5 mm/hr |
| 10 to 100 | 60 mm, 5 mm/hr |
| 100 to 300 | 70 mm, 5 mm/hr |

# 6. Surface water model analysis

## 6.1 Model results

The critical storm, being that which results in the maximum water level and flow, was determined by selecting three points of interest and finding the duration with the highest flow and/or water level at those locations. The points and the reasons for their selection are identified below and in Figure 13:

- Point 1: location identified for a culvert in Figure 11. This is a point of interest as it is the point where a well-defined creek crosses the proposed facilities.
- Point 2: location at the beginning of the proposed open channel alignment in Figure 11. This is a point of interest because it is where the flow path begins multiple crossings, back and forth, of the bundle track alignment.
- Point 3: area subject to frequent ponding shown in Figure 4, selected because this ponding may inundate the bundle track line.

The resultant maximum flow and water levels per Average Recurrence Interval (ARI) and case are shown in Table 6-1. The existing and future case flood maps are presented in Appendix B.

Table 6-1 – Maximum flows and water depths at points of interest

| Point of interest | 10 Year ARI | 50 Year ARI | 100 Year ARI | PMP |
|---|---|---|---|---|
| Point 1, flow<br>- Existing<br>- Future | <br>45.5 $m^3/s$<br>48.1 $m^3/s$ | <br>100.6 $m^3/s$<br>101.2 $m^3/s$ | <br>151 $m^3/s$<br>154.9 $m^3/s$ | <br>397.8 $m^3/s$<br>400.4 $m^3/s$ |
| Point 2, flow<br>- Existing<br>- Future | <br>25.2 $m^3/s$<br>26.1 $m^3/s$ | <br>168.8 $m^3/s$<br>171 $m^3/s$ | <br>247.8 $m^3/s$<br>248.2 $m^3/s$ | <br>1,681.6 $m^3/s$<br>1,782.5 $m^3/s$ |
| Point 3, water level<br>- Existing<br>- Future | <br>2.47 mAHD<br>2.53 mAHD | <br>3.35 mAHD<br>3.47 mAHD | <br>3.66 mAHD<br>3.70 mAHD | <br>5.32 mAHD<br>5.35 mAHD |

## 6.2 Climate change exposure

A comparison of the 10 and 50-year future case results show that the expected flows at the points of interest for the 50-year case ranges from two to six times greater than the 10-year case. Although the drainage design event is the 10-year flood, the bundle track drainage and alignment elevations will be designed such that floods up to the 100-year ARI event will not inundate the track alignment or bundle facility. Therefore, the potential risk of climate change is not considered significant enough to proceed to analysing future climate projections.

# 7. Response to Environmental Scoping Document (ESD)

## 7.1 Baseline hydrology summary (ESD Item 59)

There are three surface water major catchments (refer Section 3.5) draining to the proposed works (pad, bundle track and access road alignment). The upper reach of each is hilly and the stream flow paths are well defined, whereas based on available data, the floodplain has poorly defined streams.

There are many north-south running dunes in the floodplain, including a major dune along the coast that is likely to exacerbate flooding by preventing outflow from the site. The presence of the coastal dune is characteristic of the Exmouth gulf coast as a whole (Eliot *et al*, 2012).

Whilst the catchments are large, the average rainfall (Figure 3) in the area is low and therefore the waterways are ephemeral in nature, with no baseflow. They are classified as Inland Waters under EPA's Environmental Factor Guideline (2018), but are not likely to support any significant ecosystems, nor would they have any significant beneficial uses.

The area is also known to be at high risk of flooding because of (Eliot *et al*, 2012):

- High intensity events, and/or
- When impacted by a series of rainfall events resulting in a high catchment antecedent moisture condition, and/or
- If bushfires have reduced vegetation cover, and/or
- If discharges are constrained at the catchment outlet by a coastal dune.

According to a 360 Environmental report (2018), the site is within the Carnarvon bioregion and the Cape Range subregion of the Eremaean Botanical province. As it is in an arid zone with a desert climate, there is no assured growth season. From north to south, there is:

- Dry spinifex grassland (Triodia and Plectrachne) in the north where summer rainfall peaks,
- Deserts with intermittent rainfall, and
- Low Acacia-Eucalyptus woodlands receiving evenly distributed rains.

The site area consists of samphire and saltbrush low shrublands, Bowgada low woodland on sandy ridges and plains, Snakewood shrubs on clay flats and tree to shrub steppe over hummock grasslands between red sand dune fields.

The major land cover modifications are (i) Learmonth Airport, which borders the northern boundary of the catchments draining to the proposed facilities, and (ii) Exmouth-Minilya Highway, which has a north-south alignment. Due to these two features, water quality may exhibit minor concentrations of hydrocarbons. No other surface water quality data is known to be available. Flood levels and flow rates at Learmonth Airport and the Highway are not directly or indirectly impacted by the development. Whilst the airport may generate additional runoff compared to the natural environment, the runoff does not drain to the study area and therefore there are no cumulative impacts on flow rates or flood levels."

Based on surface water modelling results for the existing case, flood flows generally drain as follows:

- Catchment A: flows will largely follow an outflow path to the ocean that is to the north of the facilities and east of Learmonth Airport.

- Catchment B: flows will generally pond at the lower end of the catchment in an area subject to frequent inundation. A small portion of the end of the catchment also ponds in the other low area marked in Figure 4.
- Catchment C: Flows will pass through the proposed bundle track facilities, either crossing it to discharge to the southeast or travel north along the alignment to the low area marked in Figure 4. Water will pond there until the depth is great enough to begin flowing over the proposed access road alignment to the outlet (Wapet Creek) to the east of Learmonth Airport.

Figure 13 annotates the comments made in the preceding paragraphs.

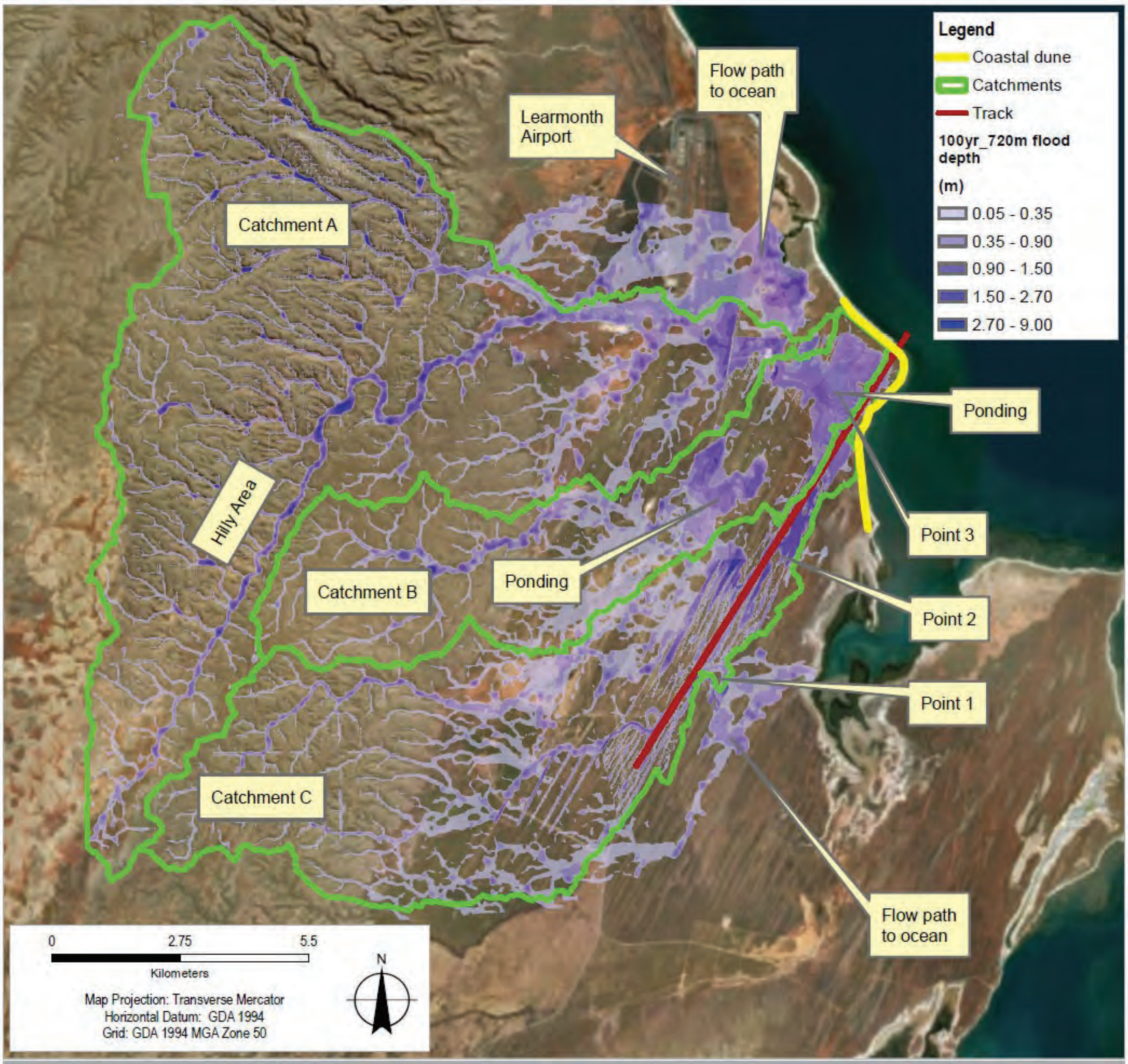



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Figure 13 - Baseline surface water hydrology

## 7.2 Effects on surface water and groundwater

### 7.2.1 Potential impact of proposed facilities to surface water (ESD 61)

The proposal consists of a pipeline facility located on a pad, with a bundle track alignment to provide transport to the launch site and an access road from Exmouth-Minilya Highway to the launch site. The bundle track will follow the contours of the land wherever possible to minimise earthworks, though due to the presence of dune formations, there are locations where this is not possible and existing features will be disturbed. This is especially the case where the alignment is designed to cut through the coastal dune to reach the ocean.

There are three **receiving environments** for surface water:

1. The superficial groundwater aquifer, which flows towards the ocean;
2. The natural depression illustrated in Figure 4, where surface water evaporates or infiltrates to groundwater; and
3. The ocean (Exmouth Gulf).

With reference to EPA's Inland Waters Environmental Factor Guideline (2018), the **potential impacts** of the proposed development activities are as follows:

1. In areas where the proposed facilities bisect existing waterways, runoff may be obstructed or redirected from natural waterways. This is possible near Point 1 where a creek crosses the proposed alignment, or Point 2 where the flow path is on or adjacent to large stretches of the alignment.
2. In areas subject to frequent inundation, the duration and extent of inundation could be altered. This is possible near Point 3 where inflows could be altered by the proposed facilities.
3. Where the bundle track cuts through the coastal dune, a new flow path could be formed from the ponded area to the ocean. This would result in a potential impact to water quality and quantity through erosion and silt transport to the coastal environment. Runoff from cut slopes could also drain to the ocean.
4. Impact to surface water quality and subsequently receiving environments due to the exposure of soils (risk of erosion and elevated suspended solids) during construction and operations, which will result in increased sediment transport in stormwater.
5. Discharge of treated wastewater via spray field to surface water systems and groundwater aquifers via infiltration, resulting in impact to surface water and groundwater quality
6. Impact to surface water and groundwater quality due to leak or spill of chemicals, including hydrocarbons, during operations.

### 7.2.2 Effects of spray field on surface water quality and quantity (ESD 62)

The report *'Pipeline Bundle Fabricating Facility – Water Supply and Treatment Options'* (GHD, 2017a) outlines the proposed methodology for addressing waste water disposal through the use of a spray field. As detailed in the report, the proposed system will ensure that nutrients concentrations and loads are minimised to avoid potential impacts to surface water and groundwater.

In summary, the facility will require amenities for up to 140 workers on site and it is assumed that the per-capita greywater nutrient concentrations will be in the range of 25-50% of the typical per-capita load in greywater from typical residential households. This reduction was applied to account for the absence of washing machines and their associated laundry detergent nutrient load.

The wastewater generated by the workers will be managed by:

- Blackwater (all wastewater from toilets, urinals and the mess area [sinks and dishwashers]) will be collected in storage tanks and disposed of via (periodic) tanker transfer to the Water Corporation's Exmouth WWTP; and

- Greywater (wastewater from showers plus wash basins in ablution/shower block areas) will be treated and disposed of onsite via spray irrigation of landscaped areas around the facility.

Spray fields use sprinklers to spray Treated Waste Water (TWW) onto fields where it evaporates or infiltrates into soil. Disinfection is required where TWW is being sprayed. (GHD, 2017a). As outlined above, the TWW for this project will be for treated greywater only.

The proposed location of the spray field is southeast of the fabrication site. The sprinklers are expected to mix, pump and spray TWW at  rate of up to 26 $m^3$/day, or 18 litres/min over a nominal 11,000 $m^2$ area. This is equivalent to 2.4 mm/day, or 0.1 mm/hr.

Nutrient concentrations and loads vary with the treated greywater volumes and adopted treatment system. As detailed in the Water Supply and Treatment Options report (GHD, 2017a), the treatment system will reduce nitrogen and phosphorus levels to concentrations similar to those achieved by the sole residential scale greywater treatment system currently approved for use in Western Australia. The estimated concentrations of nitrogen and phosphorous in the treated grey water are expected to be in the region of 7 and 1 mg/L respectively. Noting that in the absence of any surface water features near the spray field, mobilisation of nutrients via surface water is improbable.

As outlined in the Water Supply and Treatment Options report (GHD, 2017a), it is reasonable to assume that the majority of the irrigation water will be lost via evapotranspiration from the plants and soil surface, with only relatively minor volumes leaching through the soil profile to the water table. In view of the low nutrient loads, and receiving environment, the impacts are considered as negligible.

Conservatively assuming a moderate infiltration soil type, the Horton loss model suggests a final (ultimate) infiltration rate of 13 mm/hr. Therefore, the spray field rate of discharge is two orders of magnitude lower than the soil infiltration capacity, and no surface runoff is expected. There is a buffer area allotted in the proposed spray area to prevent humans or livestock from being exposed to the TWW, as well as fencing around the field. It should be noted that groundwater in the area of the spray field occurs at a depth of around 15 metres below existing ground level. The groundwater at this location is hypersaline.

If the spray field is placed in a flow path, this will potentially result in surface water contamination with bacteria that is harmful to humans. The location was overlayed with the 100 year flood extent in Figure 14 which shows that the spray field is outside of the zone of inundation.

In summary, the above information indicates that the spray field is unlikely to have a significant impact on either surface water quality or groundwater quality. The presence of monitoring bores within the area will allow the ongoing monitoring of groundwater quality, and confirmation of the lack of impacts from the spray field.

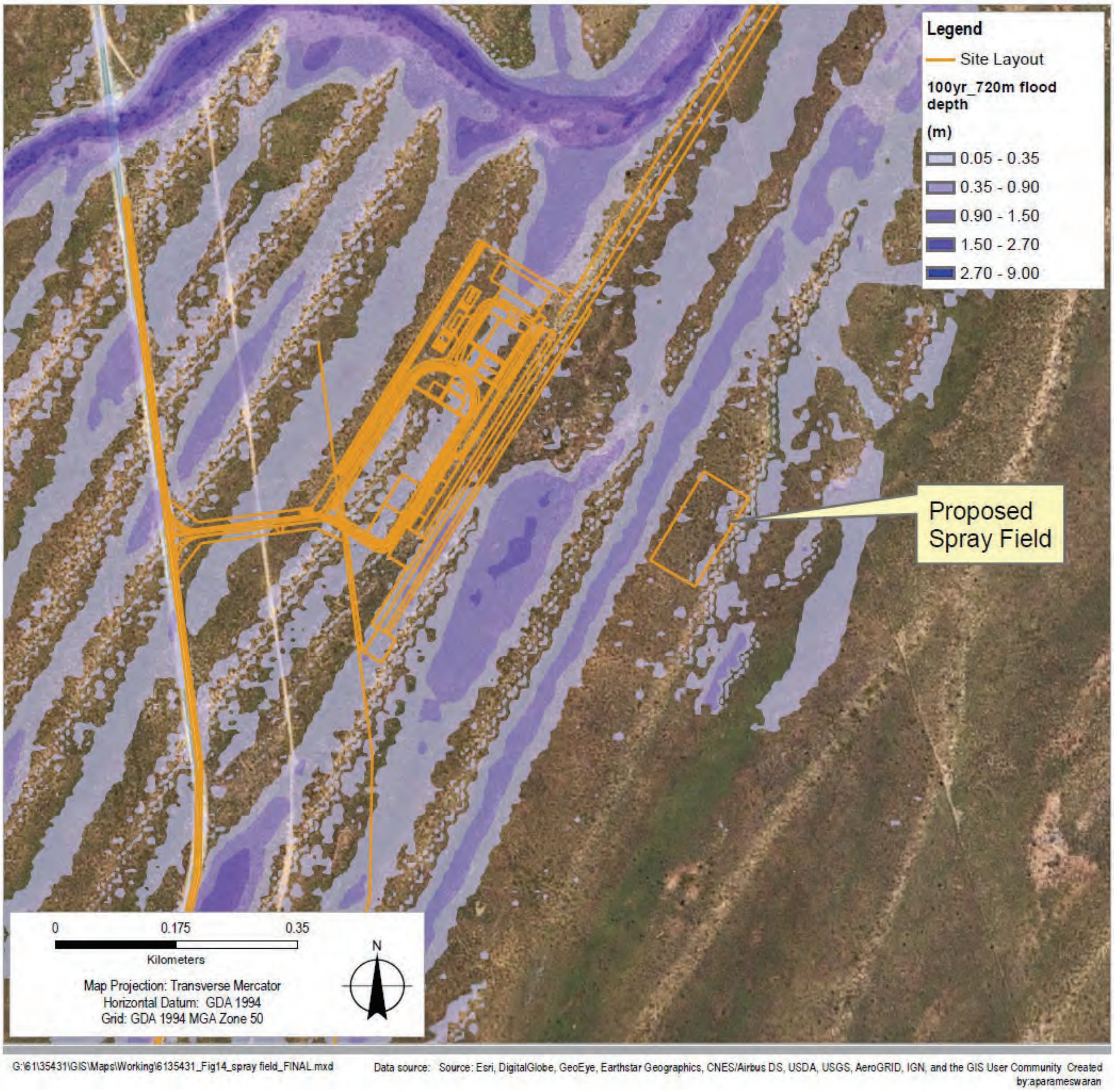


Figure 14 - Proposed spray field overlayed with 100 year flood extent

### 7.2.3 Predicted residual impacts after minimisation measures (ESD 63)

To alleviate the potential impacts 1 to 3, the following was proposed and tested in the modelling (Section 5.4.2):

- A culvert at Point 1 to allow flows to continue down the existing path; and
- Inclusion of an open drain beginning at Point 2 that will run adjacent to the bundle track alignment to safely and efficiently convey flows to the natural depression.

A comparison of the existing and future case modelling scenarios at the identified points of interest in Section 6.1 and Table 6-1 show that there is very little change to maximum flows or water levels at Points 1 to 3 due to the proposed facilities. This is because water is allowed to pass through the railway at Point 1 and the open drain conveys flows along the alignment to the same end location.

Maps of flood level difference (Appendix C) and velocity (Appendix D) per return period were prepared, with positive values showing a decrease in water level or velocity in the future, and negative values showing an increase (i.e. existing case subtract future case). The following residual impacts were noted:

- A general increase in flood level and velocities along the western side of the bundle track from the facility to just before the beginning of the open drain alignment. The highest velocity increases, reaching 1.0 m/s in the 100-year ARI, are at the culvert crossing (Figure 15), which is a scour risk. This will be mitigated with appropriate scour protection works during design.
- An increase in velocities of over 1.0 m/s along the proposed open drain alignment (Figure 15), which is expected and will be mitigated with appropriate scour protection works.
- A general decrease in flood levels on the eastern side of the bundle track, due to the proposed open drain diverting water, of over 0.80 m (10-year ARI). There may be some corresponding impacts to vegetation due to reduced inundation extent and duration.
- An expected increase in flooding in the natural depression from Figure 4 in the 50-year ARI event, where it reaches 0.10 m. This is caused by the discharge of the open drain. The extent of ponding remains the same. Given the area is already subject to frequent inundation and has very little vegetation, there are no additional implications.
- Other than what is mentioned above, velocity changes are generally insignificant and will not alter any natural scour or sediment deposition characteristics of the area.

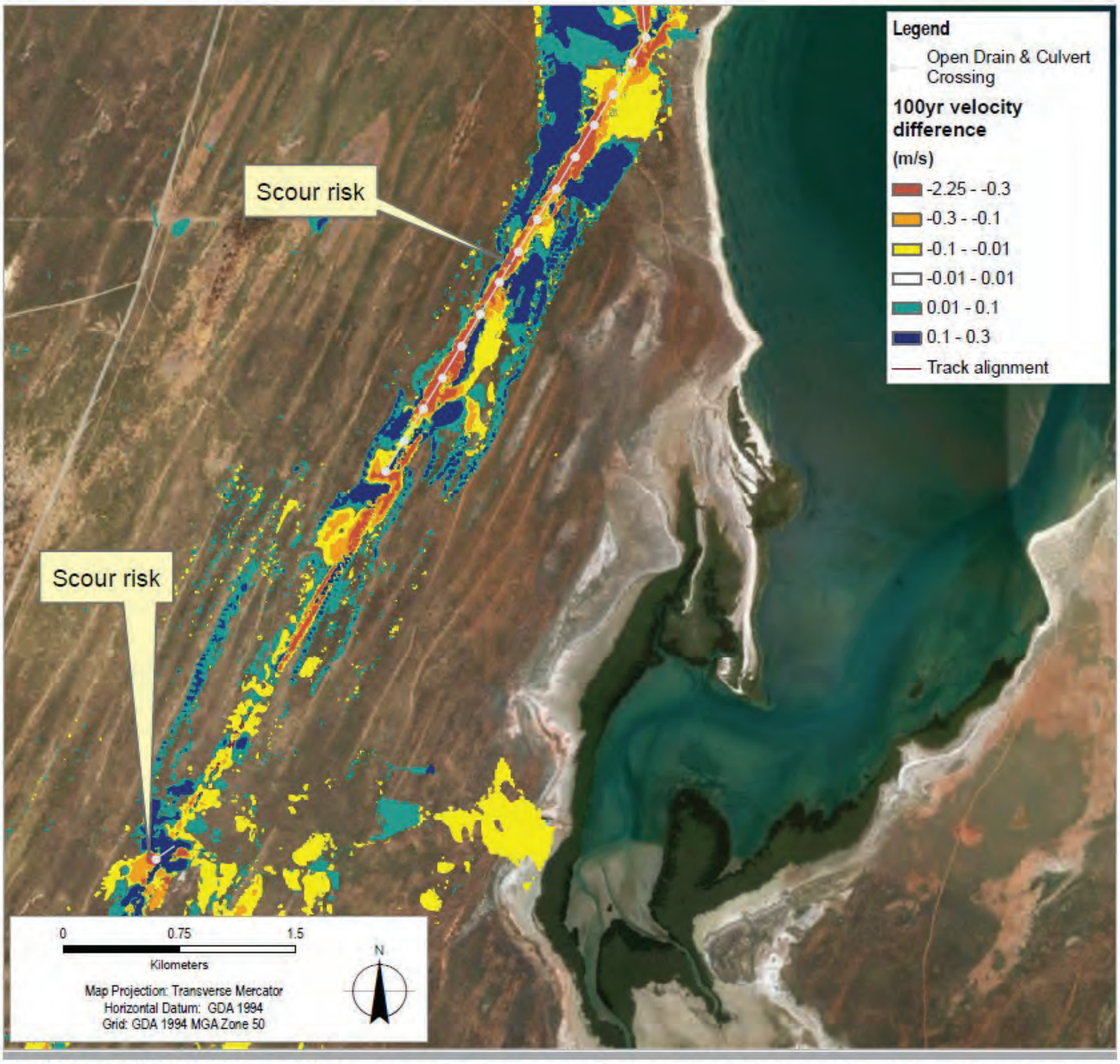


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Figure 15 - Changes to flood levels and velocities

Figure 16 shows changes to flows in two locations along the proposed open drain (LOC 1, LOC 2), and at the exit of flows from the site (LOC 3). The 50 year ARI has the largest increase.

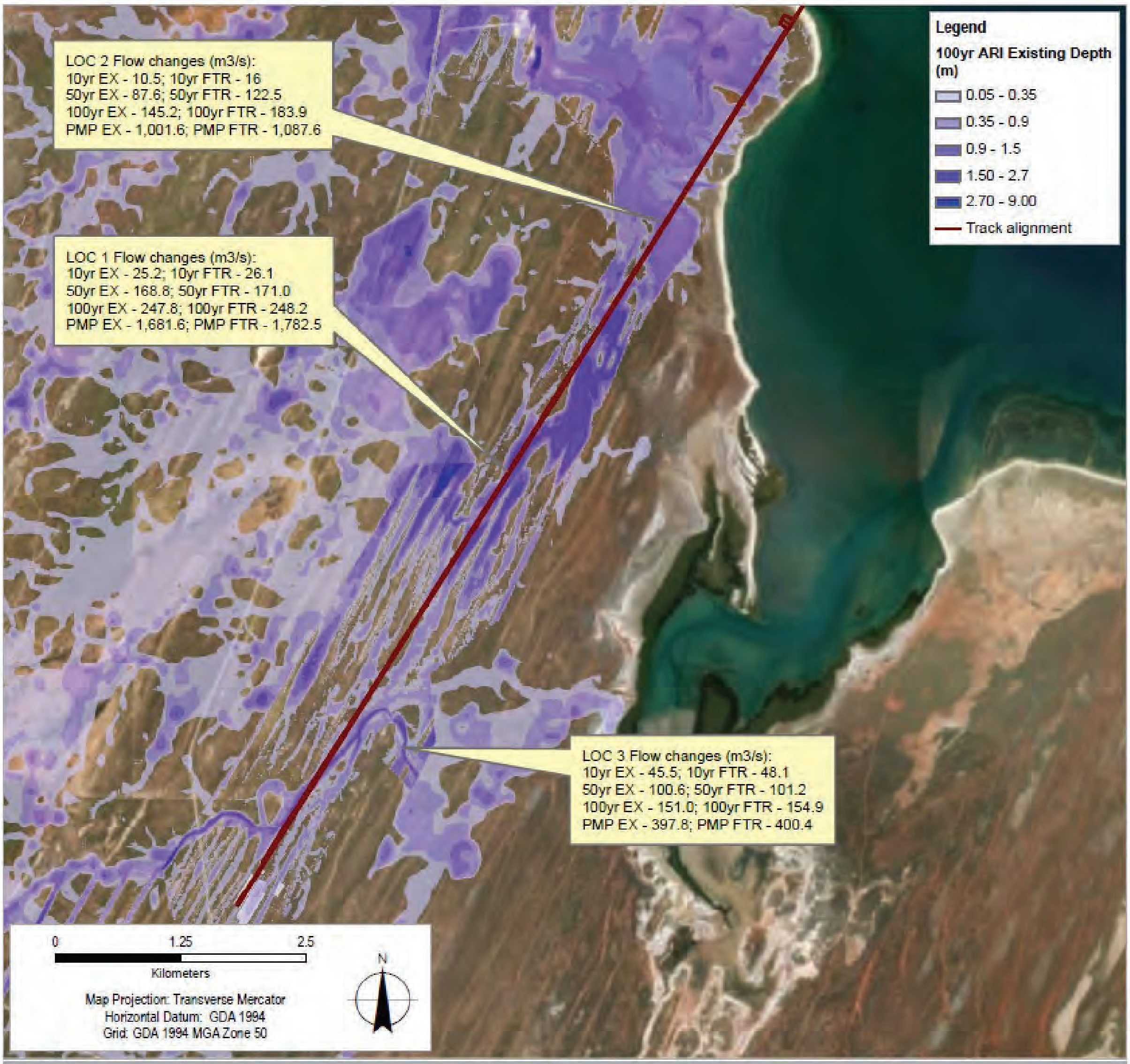


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Figure 16 - Changes in flows (EX: Existing; FTR: Future)

The new flow path to the ocean along the rail alignment does not convey water in the 10-year ARI. It does however begin to do so in more infrequent events, beginning somewhere between the 10-year and 50-year ARI. Some pollutants and sediments during construction or site operation may also be mobilised by these flows to the ocean receiving environment, however, it is important to note that (i) the bundle track will have sediment basins placed along the alignment to control this, and (ii) during construction, bunding will be used to safely contain pollutants. A channel with a spillway structure will be designed with a lower elevation than the bundle track to safely convey the flows. Depending on velocities, scour protection will also be included.

Potential impact 4 (Section 7.2) is only relevant to the ocean receiving environment. Mobilised sediment that percolates to groundwater will be filtered through soil layers. Mobilised sediment that travels to the natural depression will inherently settle in the depression.

### 7.2.4 Management, mitigation and monitoring methods – ESD 64

During construction, stormwater quality will be controlled with use of an environmental management plan that will identify locations for appropriate control measures. Drainage management will likely consist of temporary cut-off drains leading to sediment basins that will settle out fines before discharge to the environment. Subsea7 have committed to undertaking regular inspections to ensure that the cut-off drains are holding shape and functioning as intended. In addition, clearing will be minimised and cleared surfaces will be stabilised.

For the proposed drainage infrastructure, ongoing monitoring is important. This will involve regular inspection and maintenance of the culvert and open channel to ensure the drainage lines are sediment and debris free so that the design capacity is maintained. In addition, groundwater monitoring should be incorporated to identify any changes to groundwater quality as a result of drainage changes.

During operations, chemical and hydrocarbon storage vessels will be bunded appropriately. Staff will be trained in refuelling procedures and management of chemicals. Oil spill kits and equipment will be available on site.

## 7.3 Proposed water abstraction (ESD 60)

As highlighted by Section 4, the drilling and groundwater quality testing has demonstrated that the area near Little Bore has the potential to meet the project water demands, subject to an abstraction licence and the installation of production bores.

The site is located within the Exmouth South groundwater sub-area, with the licensed aquifer being the Cape Range Limestone. The DWER have noted that due to the sensitivity of the Cape Range Limestone to saline intrusion, any groundwater abstraction licence is likely to be issued with the following conditions:

- pump rates for each bore are not to exceed 0.3 litres per second
- salinity should not be greater than 467 milli-siemens per meter measured at 25$^{0}$C (2500 mg/L TDS).

Based on the expected total water demand for the project (12,000 kL/annum) and the pumping rate restriction condition, a total of three production bores would be required. The proposed location for these three bores are shown on Figure 6 with the proposed bores located within the same drill pad/cleared areas of the monitoring bores S22, S24 and S25. Locating the bores adjacent to the existing monitoring bores provides numerous advantages, namely:

- The geology and groundwater occurrence (flow and quality) at these locations is known. All bores were relatively fresh (either based on laboratory results for S24 and S5, or for the field results – see bore logs Appendix E). All three bores provided an air-lift yield of around 0.3 L/s. This indicates that production bores located here would easily meet the supply demands.
- The existing monitoring bores can be used during pump testing of the proposed production bores to monitor drawdown and allow the determination of aquifer storage parameters.
- The existing monitoring bores can be used during operation to provide data on groundwater level drawdown affects from pumping.
- The extended depth of the monitoring bores, with a total screen length of 12 m, will allow the vertical profiling of the aquifer during borefield operation which can assist in the early detection of potential saline upconing.

## 7.4 Potential impacts from abstraction (ESD 61)

### 7.4.1 Potential receptors

As summarised above, the groundwater investigation completed to date has demonstrated that the area near Little Bore has the potential to meet the project water demands. A conceptual borefield incorporating three abstraction bores is proposed, with the production bore locations highlighted on Figure 6. Whereas current data indicates a relatively thick freshwater profile (i.e. only fresh groundwater intersected in this area, after drilling up to 20 m of saturated thickness), due to the potentially karstic nature of the aquifer, the risk from potential saline intrusion will remain, and should be considered during project development.

Little Bore, an existing stock bore, is located between two of the proposed abstraction bores at a distance of 600 m from PB01 and 400 m from PB02. Another stock bore, Wogatti Well, is located around 3.5 km south of PB03. Both stock bores are equipped with solar powered submersible pumps, which maintain water in storage tanks for stock watering. Consideration of potential drawdown impacts on the stock bores will need to be assessed.

In addition to potential drawdown impacts on the existing stock bores, drawdown impacts on reducing the available stygofauna habitat will also need to be considered.

### 7.4.2 Drawdown model set-up

In order to assess the drawdown influence the borefield may have, the drawdown characteristics have been modelled using a wellfield model using Aqtesolv software. Aqtesolv allows various predictive methods to model cumulative impacts from multiple abstraction bores, and produces the resultant drawdown at the location of the abstraction bores and any additional receptor locations (in this scenario, impacts on nearby stock bores). Conceptual production bore data was used based on the proposed location of the bores and the expected depths based on the monitoring bore drilling. Abstraction rates were modelled based on the maximum groundwater volume expected for the Project. The range of parameters used for modelling are summarised in Table 7-1.

It should be noted that all parameters used are conservative, including using an over-estimation of the pumping rate. A more accurate model could be produced following completion of the production bores (site specific aquifer properties will be available).

Table 7-1 - Aquifer properties and results for simplified drawdown model

| *Parameters* | *Value* | *Comment* |
|---|---|---|
| Pumping rate | 36 kL/day (0.14 L/s per bore) | Total project demand of 12,000 kL per annum, with abstraction taken over a period of 330 days (i.e. to account for higher abstraction rate than needed). |
| Saturated thickness | 20 m | Conservative estimate based on drilling data (i.e. total of over 20 m of saturated freshwater was drilled. Base of freshwater unknown). |
| Hydraulic conductivity | 0.5 to 5 m/day | Conservative range estimate for hydraulic conductivity of a sandstone unit (Domenico, & Schwartz, 1990). |
| Transmissivity | 10 to 100 $m^2$/day | Based on the above hydraulic conductivity and aquifer thickness. |
| Aquifer storativity | 0.001 | Conservative estimate for sandstone |

### 7.4.3 Model results - Predicted drawdown

The modelling results are presented as Appendix H, which shows the drawdown at the location of the production bores, and nearby stock bores for a total period of 10,000 days (~27 years). As highlighted by the parameters listed in Table 7-1, results are shown for two scenarios highlighting drawdown effects under a range of conservatively plausible transmissivity values of 10 $m^2$/day and 100 $m^2$/day.

Drawdown at Little bore (between abstraction bores PB01 and PB02) is shown on Figure 17. The model outputs as drawdown contours are presented for the 10 $m^2$/day transmissivity scenarios as Figure 18 and Figure 19 for 1 year and 10 years of abstraction respectively, and for the 100 $m^2$/day transmissivity scenarios as Figure 20 and Figure 21 for 1 year and 10 years of abstraction respectively. Key modelled drawdown results are presented as Table 7-2. Key observations are the following:

- Under the most conservative scenario (over estimation of drawdown), modelled with a transmissivity value of 10 $m^2$/day, maximum drawdown in the immediate location of the pumping bores is up to 2.5 m after 10 years of continuous abstraction. It should be noted that the model does not include any recharge to the aquifer over this period. The modelled scenario with a transmissivity value of 100 $m^2$/day shows a maximum drawdown in the area of the borefield of up to 0.32 m after 10 years.
- Drawdown at Little Bore is modelled as being up to 0.82 m under the most conservative scenario, and as low as 0.15 m. Both these ranges could be within the seasonal groundwater level variation.
- Minimal groundwater level drawdown is predicted at Wogatti Well, and at any distances from the production bores. For example, under the most conservative scenario, and with no recharge over a 10 year period, the 0.5 m drawdown contour extends to a maximum distance of around 500 from the borefield.

Table 7-2 – Modelled drawdown results

| Location | Time | Drawdown* |
|---|---|---|
| Pumping bore PB02^ | 1 year | 0.25 – 1.94 m |
| | 5 years | 0.30 – 2.33 m |
| | 10 years | 0.32 – 2.52 m |
| Little Bore | 1 year | 0.08 – 0.25 m |
| | 5 years | 0.13 – 0.63 m |
| | 10 years | 0.15 – 0.82 m |
| Wogatti Well | 1 year | 0 m |
| | 5 years | 0 – 0.02 m |
| | 10 years | 0.02 – 0.04 m |

* Range based on transmissivity values of 10 $m^2$/day and 100 $m^2$/day
^ Pumping bore PB02 used as this has the most drawdown due to interference effects from the other pumping bores.

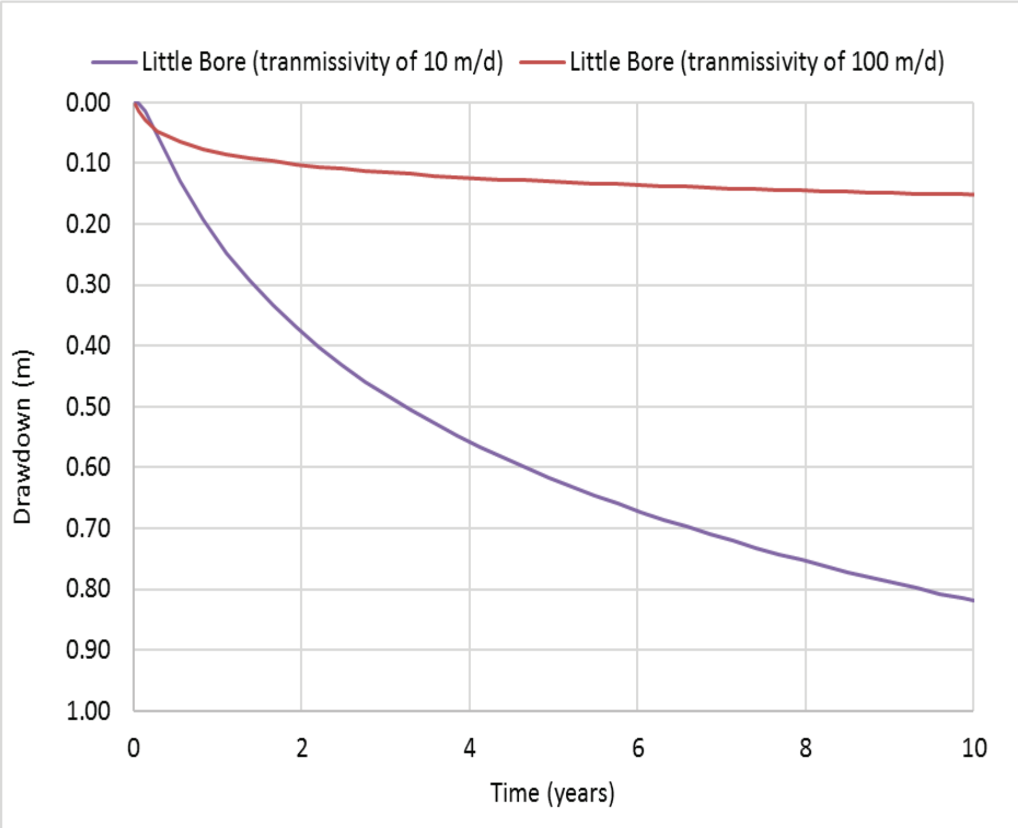


Figure 17 - Drawdown at Little Bore after 1 year (transmissivity of 10 $m^2/d$)

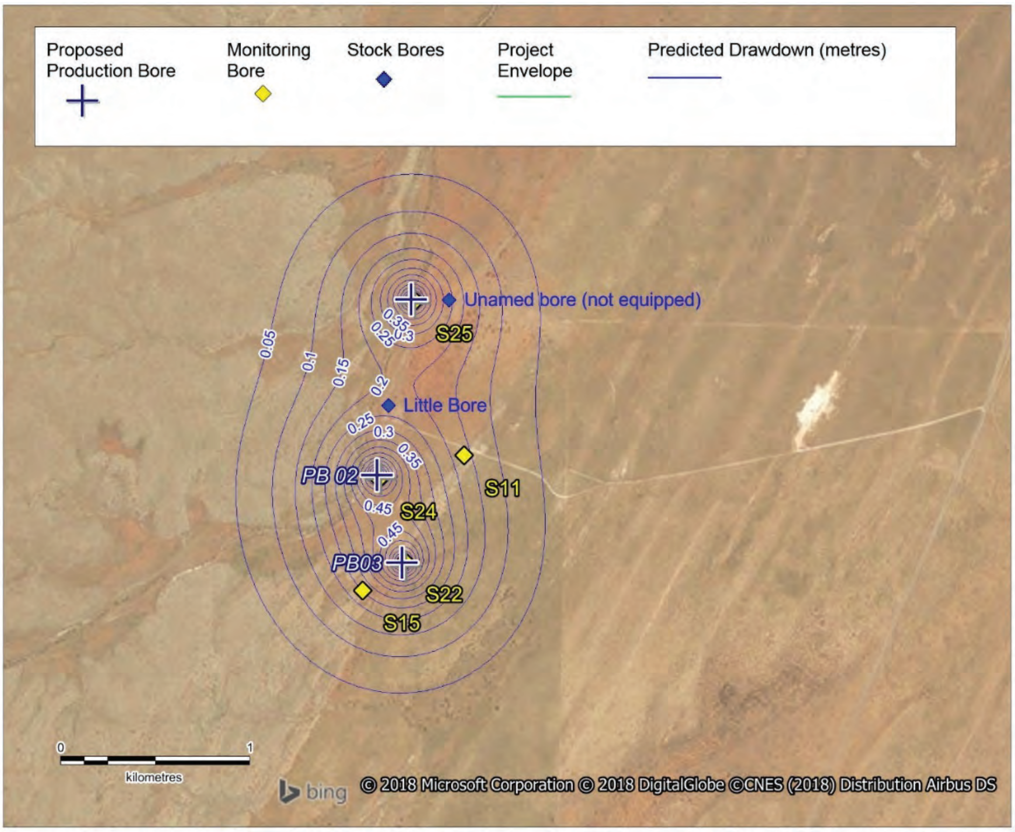


Figure 18 - Drawdown after 1 year (transmissivity of 10 $m^2/d$)

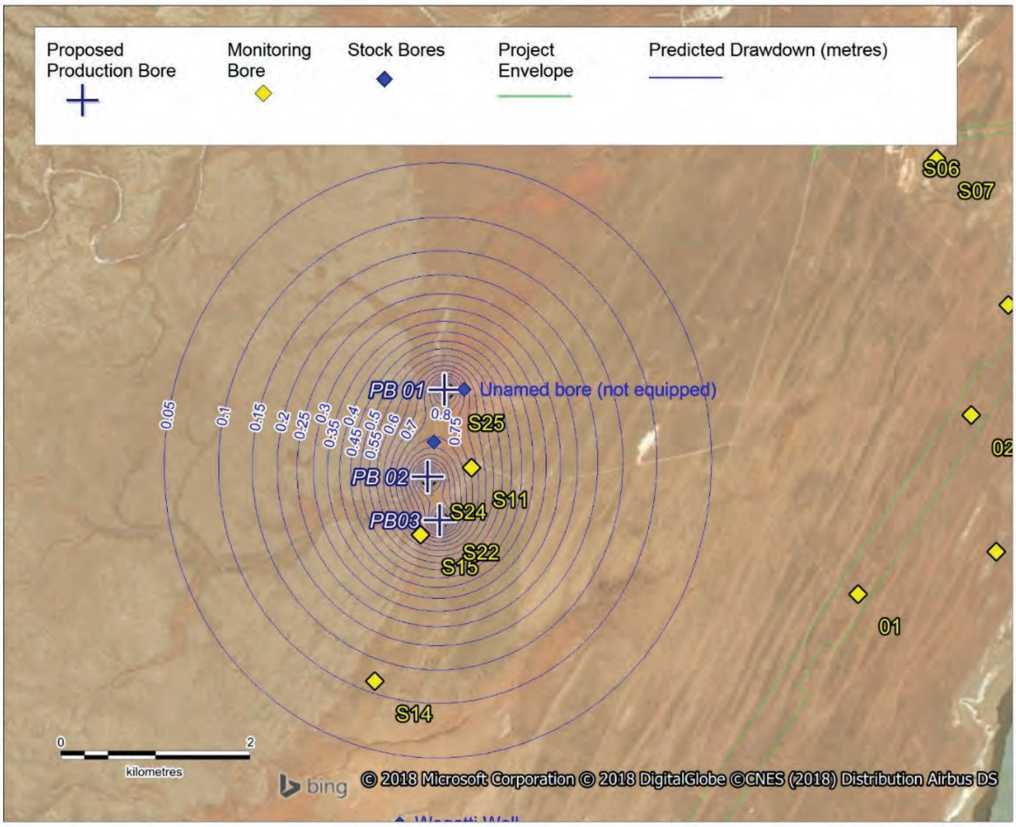


Figure 19 - Drawdown after 10 year (transmissivity of 10 $m^2$/d)

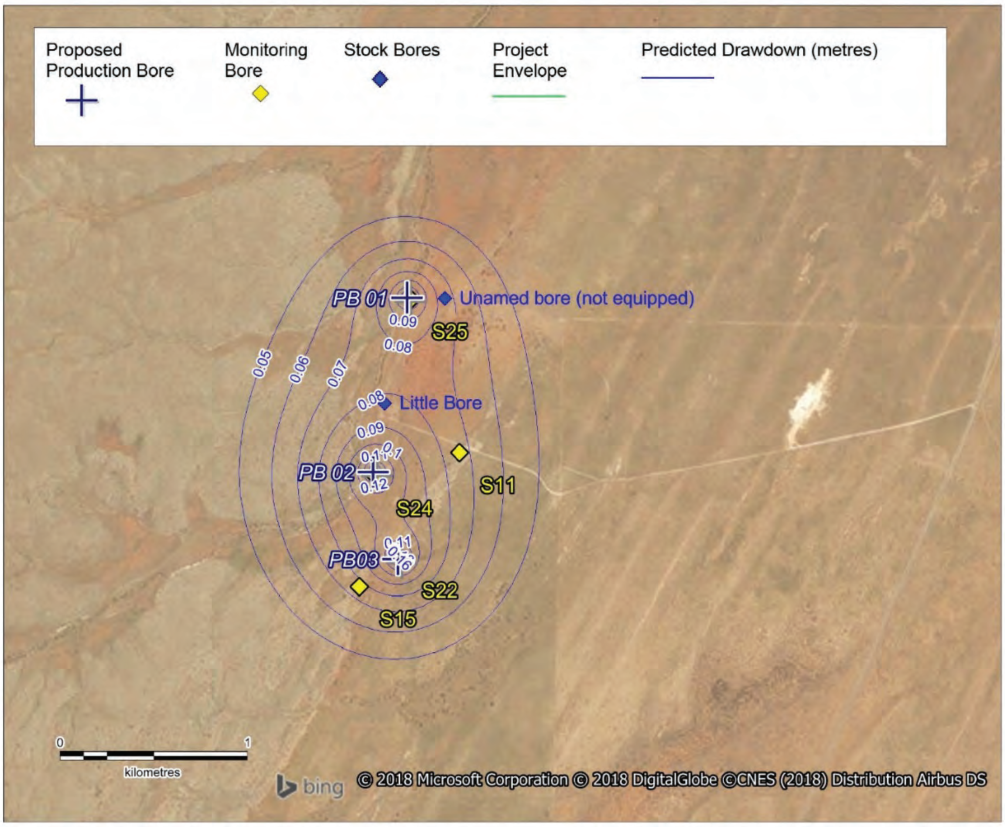


Figure 20 - Drawdown after 1 year (transmissivity of 100 $m^2$/d)

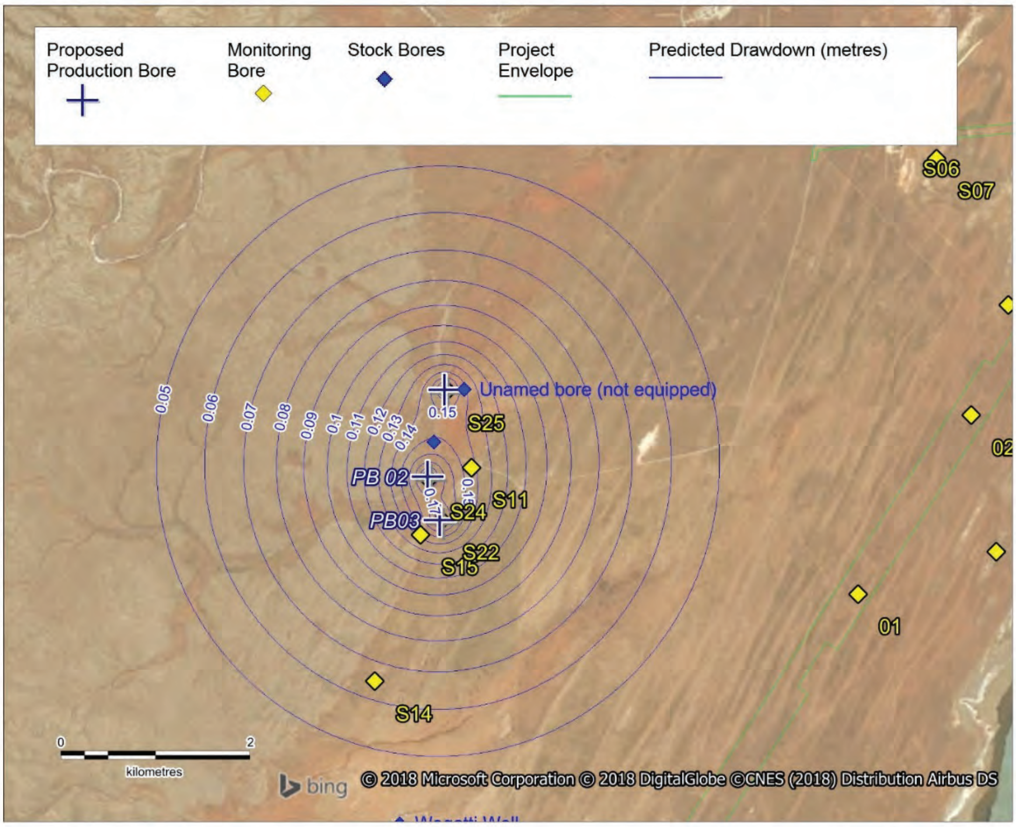


Figure 21 - Drawdown after 10 year (transmissivity of 100 $m^2$/d)

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