Bennelongia Environmental Consultants

Subsea 7 Pipeline Fabrication Facility: Stygofauna Survey

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Subsea 7

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Final Report

Short-Range Endemics I Subterranean Fauna

Waterbirds I Wetlands

Subsea 7 Pipeline Fabrication Facility: Stygofauna Survey

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EXECUTIVE SUMMARY

Subsea 7 plans to construct a pipeline fabrication facility (the project), located south of Learmonth on the western side of Exmouth Gulf and approximately 35 km south of the township of Exmouth. The project includes the construction of a fabrication shed, a storage area and two 10 km long bundle tracks which lead to a bundle launchway. The bundle launchway will span 380 m across the beach into the nearshore subtidal area where each bundle will be launched upon completion.

Desktop studies were conducted to investigate the potential for subterranean fauna to be found within the project area. Subterranean fauna communities can be divided biologically into two distinct groups: stygofauna and troglofauna. Troglofauna are air-breathing animals that live below the land surface, usually at depth greater than 2-3 m, with a distribution that extends down to the water table. Stygofauna are aquatic animals that live in groundwater and Cape Range supports a rich stygofauna community.

The desktop assessment concluded that, owing to an absence of habitat, troglofauna are unlikely to occur within the project envelope and are unlikely to be impacted by borefield operations even if they are present in the borefield. However, the occurrence of stygofauna is highly likely in both the borefield and development footprint. As a result, a three phase stygofauna survey was conducted to document the stygofauna species present and to determine whether stygofauna may be impacted by the planned project. Two potential impacts were identified: 1) loss of habitat as a result of groundwater abstraction to supply water for pipe testing and for on-site amenities, and 2) increased groundwater nutrient loads and reduced salinity as a result of spray field operation to dispose of treated grey water.

A total of 180 specimens belonging to 11 species were collected during the stygofauna survey. Of the 11 species identified, three were collected from the proposed borefield west of the Exmouth-Minilya road. They also occur in other parts of the Cape Range Peninsula. Eight species were collected within, or adjacent to, the project envelope east of the Exmouth-Minilya road, but all eight species were found close to the coast in supratidal habitat. No species were collected from the sand plain area covering most of the project envelope and in which the spray field is located. Two of the coastal species occur in other parts of Cape Range Peninsula and elsewhere.

Four species collected near the coast are of scientific interest and their stygofauna status is uncertain. These are the copepods *Ameira* 'BHA250', *Ectinosoma `BHA244`*, *Apodopsyllus `BHA255`* and *Speleophria `BCA002`* (the latter species has many anchialine relatives).

Given the relatively small drawdown associated with borefield operations and the widespread distributions of the stygofauna species collected in the borefield, it is concluded that borefield operations will not adversely affect stygofauna. Given the lack of stygofauna species on the sand plain, the small size of the spray field and small volume of water being disposed of, with various factors likely to minimise changes to groundwater conditions resulting from nutrients in the water and its low salinity, it is concluded that disposal of greywater will also not adversely affect stygofauna.

Accordingly, it is considered the Subsea 7 Pipeline Fabrication Facility poses no significant threat to either troglofauna or stygofauna species.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

1. INTRODUCTION

Subsea 7 plans to construct a pipeline fabrication facility (the project) south of Learmonth on the western side of Exmouth Gulf and approximately 35 km south of the township of Exmouth. The project includes construction of a fabrication shed, a storage area and two 10 km long bundle tracks that lead to a bundle launchway for the bundles of pipes being manufactured (Figure 1). The bundle launchway will span 380 m across the beach into the nearshore subtidal area where each bundle will be launched upon completion.

The project will require abstraction of groundwater for a potable water supply and for hydrotesting of the bundles. Groundwater will be sourced from up to three wells located west of the Minilya-Exmouth road (the other infrastructure is east of the road) and treated to make it potable. The greywater generated will be disposed of on-site, after treatment to reduce nutrients, in a small spray field (up to 1.5 ha) that irrigates vegetation. This report is designed to assess the significance of any impact that project construction and operations may have on subterranean fauna.

Subterranean fauna can be divided into two distinct groups: stygofauna and troglofauna. Troglofauna are air-breathing animals that live below the land surface, usually at depth greater than 2-3 m, with a distribution that extends down to the water table. Stygofauna are aquatic animals that live in groundwater. The vast majority of subterranean fauna in Western Australia are invertebrates, although stygofaunal fish and troglofaunal reptiles have been recorded (Aplin 1998; Whitley 1945). Subterranean fauna usually show morphological modifications to life underground that include loss (or reduction) of eyes and skin pigmentation, elongation of appendages and sensory setae, and development of a vermiform body shape.

Many coastal sections of the Cape Range Peninsula are known to support rich stygofauna communities, while Cape Range itself and the associated foothills, which runs north-south along the centre of the peninsula, are known to support a rich troglofauna community (Eberhard *et al.* 2005; Hamilton-Smith *et al.* 1998; Harvey *et al.* 1993). The occurrence and distribution of subterranean fauna is closely related to geology. Both stygofauna and troglofauna inhabit subterranean spaces that comprise interstices, voids, vugs, cavities or fissures. Geologies that contain many such spaces represent potential habitat. Both vertical and lateral connectivity of spaces are factors that contribute to determining the distribution of subterranean fauna. In Western Australia, karst, calcretes and shallow alluvial aquifers are prospective habitat for stygofauna, while air-breathing troglofauna are particularly common in karst and some iron formations.

1.1. The Cape Range Peninsula

The Cape Range Peninsula contains a diverse set of land uses, including Cape Range National Park and Ningaloo Marine Park (which together form the Ningaloo World Heritage Area), as well as pastoral stations, a defence base and various recreational and commercial areas.

The nationally important wetland 'Cape Range Subterranean Waterways' occurs partially within the Project area. This wetland was listed because of its known or potential values for subterranean fauna. More generally, the occurrence of globally important subterranean fauna values in parts of the Cape Range Peninsula were among the reasons for nominating the area as part of the Ningaloo World Heritage site (DEWHA 2010), although subterranean species do not occur necessarily across the whole peninsula.

1.1.1. Stygofauna on the Cape Range Peninsula

There have been many studies of stygofauna on the Cape Range Peninsula (e.g. Humphreys and Adams 1991; Knott 1993; Page *et al.* 2016; Page *et al.* 2008), as well as intensive monitoring of the stygofauna in the Exmouth water supply borefield (e.g. Goater 2007; Tang 2006). It has been shown that the coastal

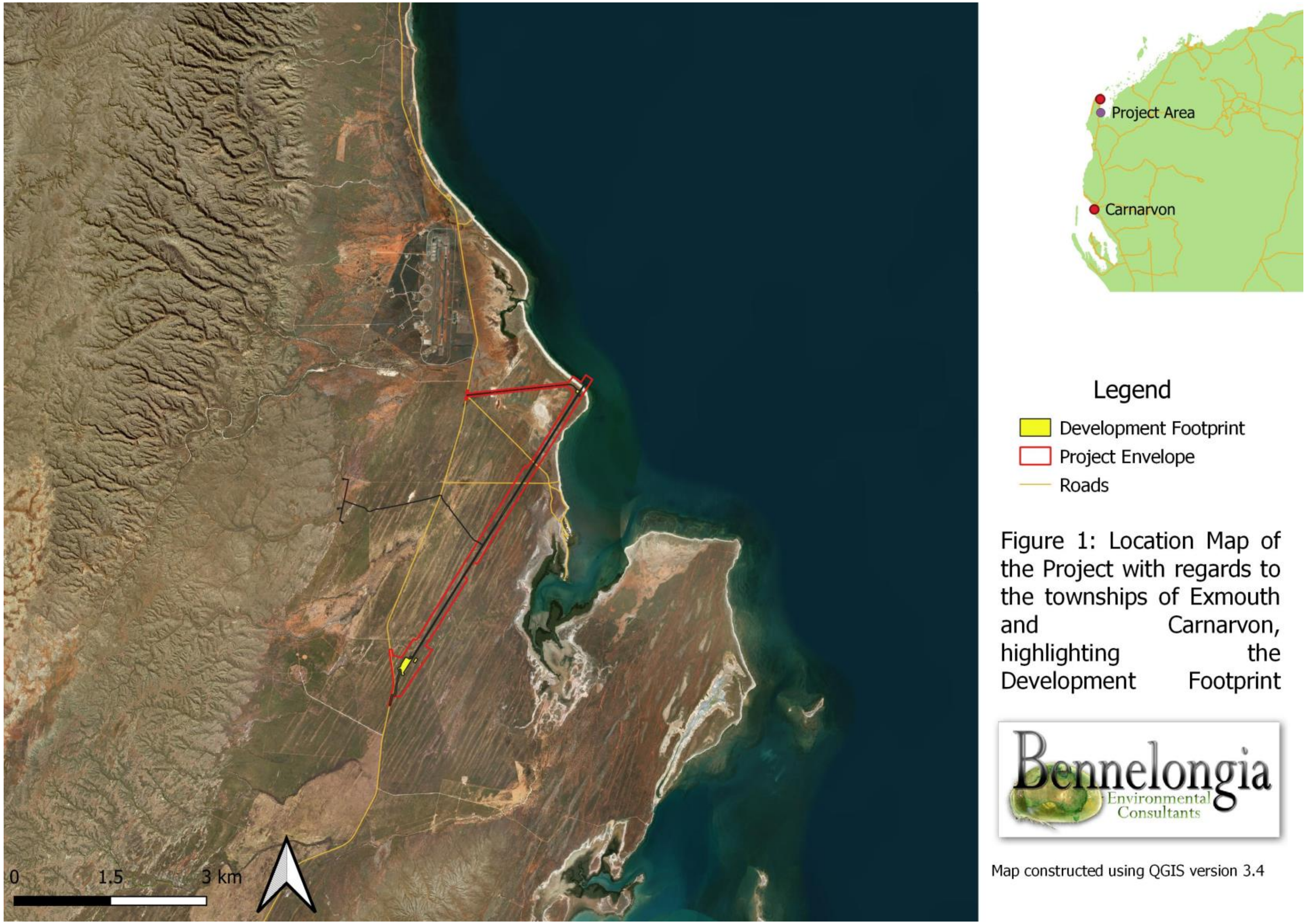

Figure 1. Proposed location of the pipeline fabrication facility.

plain habitats are rich in stygofauna. Perhaps the most significant site for stygofauna is Bundera Sinkhole, on the western side of the peninsula, which supports a well described anchialine community (e.g. Black *et al.* 2001; Humphreys 1999). The term anchialine refers to coastal systems where fresh or brackish water overlays marine water in a stratified system. Where anchialine systems occur in limestone caves, such as at Bundera Sinkhole, the fauna often contains relictual or otherwise interesting crustaceans (e.g. Jaume *et al.* 2001; Yager and Humphreys 1996).

1.1.2. Troglofauna on the Cape Range Peninsula

Many species of troglofauna have been collected from caves in Cape Range and its foothills (Gray and Thompson 2001; Harvey 1998; Humphreys and Adams 1991), whereas few species have been collected from the coastal plain.

The occurrence of troglofauna east of the Exmouth-Minilya road, where most of the project is located (Figure 2), is considered unlikely in the more inland sandplain comprising a dune network of quartz sand, with occasional small patches of nodular calcrete (Appendix 1). It is even more unlikely in the silt and clay-dominated areas closer to the coast. Depth to groundwater is up to 20 m near the road but is reduced to 4 m at bore S01 midway along the bundle track and is about 2 m near the coast. Soils are saline in the sandplain because they receive large amounts of aerosol salts from Exmouth Gulf, and even saltier near the shore because of past marine inundation as well as aerosol salts.

Troglofauna are most abundant in karstic and fractured rock habitats (including situations where voids are the result of weathering or chemical processes). Sandplain has low prospectivity for troglofauna because pore spaces are too small for most species and the occurrence of troglofauna is highly unlikely in supratidal flats near the coast because the silt/clay substrate does not have large enough pore spaces and the depth to groundwater is only a couple of metres. Furthermore, surface-soil species exclude troglofauna from shallow soils and, as a consequence, troglofauna are unlikely to occur in supratidal flats and much of the sandplain area because of shallow groundwater, irrespective of the availability of suitable pore spaces. An additional constraint on occurrence is that troglofauna only occur in environments where air is fully saturated with water vapour and they become desiccated if high concentrations of salt are present (see Howarth and Moldovan 2018). On the basis of these constraints, it is considered unlikely that troglofauna occur within the project area east of Exmouth-Minilya road, even though small areas of nodular calcrete are present.

More favourable habitat for troglofauna occurs in the borefield, where the depth to groundwater is 20-30 m and there is some karstic habitat present (Invertebrate Solutions 2018) but operation of the borefield will not affect the occurrence of troglofauna.

Based on the lack of suitable habitat for troglofauna east of the Exmouth-Minilya road (as well as minimal impacts, see section 1.1.3) and the absence of any impact to troglofauna in the proposed borefield, the likely impacts of the Project on troglofauna are not considered further in this report.

1.1.3. Impacts on Stygofauna

Development projects may potentially impact subterranean fauna in two ways. These are by removal of habitat through ground excavation or removal of groundwater and by reducing the quality (or carrying capacity) of habitat. Habitat removal is a direct impact and is more likely to result in the complete loss of animals from an area than loss of habitat quality. The latter is often called an indirect impact and result from reduced recharge and energy input as a result of project developments. The effects of polluting events, such as petroleum spills, salinisation and nutrient release, are usually treated as indirect impacts although, in extreme cases, they may result in total loss of habitat for some species.

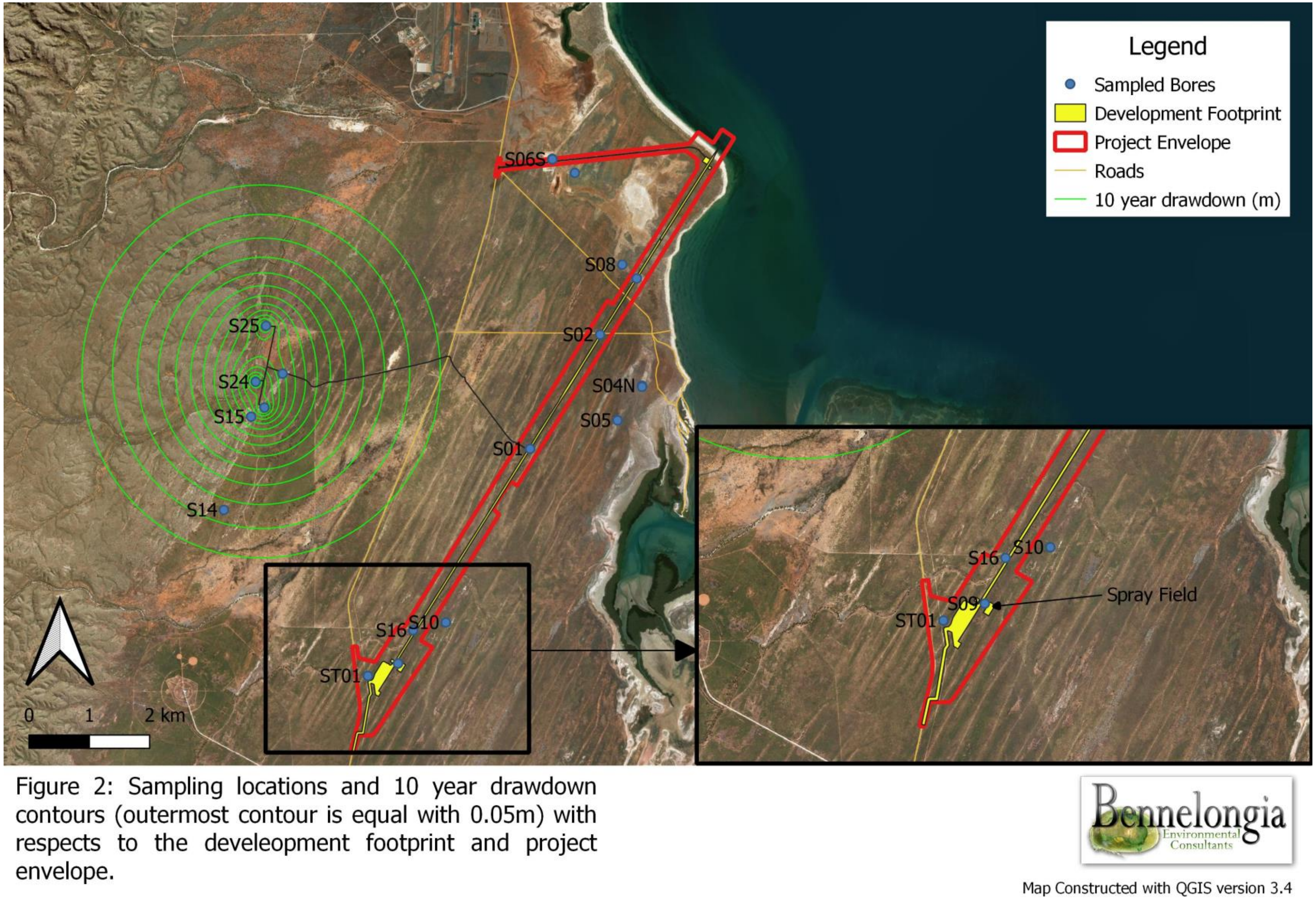

Figure 2. Proposed project infrastructure and locations of the bores sampled for stygofauna.

It is useful to consider construction and operations of the pipeline fabrication facility separately when identifying potential impacts of the project on subterranean fauna:

1) Construction will cause surface disturbance in limited areas in the form of road construction (up to 6.9 ha), bundle track construction (35 ha), erection of buildings and staff facilities etc (8 ha), spray field (1.5 ha), drainage sump and hydrotesting pond(1 ha), groundwater borefield and supply pipeline (2.6 ha) and miscellaneous drains, access tracks and earthworks area (120 ha) (Figure 2). Excavations will not exceed 1 m in depth (note that surface species exclude troglofauna from such shallow habitat). Petroleum products and other chemicals will be used in construction.

2) Operations will include managing a borefield to supply hydrotesting water and a potable water supply to support staff (12 ML/annum), disposal of greywater from staff facilities (2.5ML/annum), and the storage and use of hydrocarbons and other chemicals used for bundle manufacture, transport etc. In addition, there will be on-going reduction of infiltration of rainwater and plant matter (carbon for energy) as a result of the creation of hard surfaces (roads, building etc) in the project area.

The most likely impacts, other than a hydrocarbon or chemical spill, on stygofauna will be:

1) Loss of habitat - groundwater abstraction to provide water for bundle pipe testing and amenities at the fabrication site will lower the watertable and reduce the volume of stygofauna habitat available.

Water is required for onsite potable water use in kitchens, showers and washbasins, as well as for hydro-testing of the constructed bundle pipes. This water requirement is anticipated to be no more than 12 ML/annum. Water will be sourced from three bores located to the west of the Exmouth-Minilya road (Figure 2) and will be treated to make it potable. The drawdown associated with 10 years of abstraction has been modelled by GHD (2019a). Most assessments in Western Australia assume that drawdowns of <2 m do not affect stygofauna significantly and, on this basis, there is essentially no drawdown impact associated with the borefield.

2) Altered groundwater conditions – disposing of treated greywater is likely to increase nutrient concentrations and decrease salinity of groundwater.

Greywater generated on site through showers, washbasins etc will be treated on site. This greywater (2.5 ML/annum) will be disposed of in a small vegetated spray field. Some of the sprayed water will evaporate and a substantial proportion of the nutrients in it will be taken up by plants or will adhere to soil particles above the watertable (GHD 2019b). The remaining water, salt and nutrients will recharge groundwater. The expected increase in nutrients (mainly nitrogen) in groundwater as a result of sprayfield operation is expected to be small and occur over a limited area; the expected freshening of groundwater is also expected to be localised.

As described above, it is anticipated that only very minor loss, or deleterious change, in habitat will occur as a result of project operations. However, owing to the known richness and scientific importance of subterranean fauna communities occurring on the coastal plain of Cape Range Peninsula, stygofauna surveys were conducted to document the stygofauna species present, or likely to occur, within the project area and to assess the likely impact of the project on stygofauna conservation values.

2. FRAMEWORK

The environmental impact assessment process in relation to state government approvals in Western Australia is largely managed under the *Environmental Protection Act 1986* (EP Act). The Environmental Protection Authority (EPA), which administers the EP Act has put out a position statement '*Environmental Protection of the Cape Range Province*' on the Exmouth peninsula area that identifies stygofauna and troglofauna as a major value of the Cape Range area and laid out policies to underpin environmental assessment and decision-making in the area (EPA 1999). More recently, they provided a framework for the assessment of subterranean fauna. These are: EPA (2016a) that describes how subterranean fauna should be treated as a factor in assessment, and EPA (2016b, 2016c) that provide technical guidance on survey design and sampling methods.

The proposed pipeline fabrication facility is currently being reviewed by the EPA under Part IV of the EP Act at a public environmental review (PER) level of assessment. Subterranean Fauna is deemed to be a preliminary key environmental factor in the assessment. This report provides the results of a field survey of stygofauna in the project area and provides an assessment of the likely impact of the project on subterranean fauna.

3. SAMPLING FOR STYGOFAUNA

A three-phase survey program was conducted to assess the presence of stygofauna within the project. The surveys were conducted in accordance with EPA technical guidance for survey and sampling methods (2016b, 2016c).

3.1. Sampling effort and methods

Twenty bores distributed across the proposed development envelope were sampled, with each bore being sampled three times. The locations of bores are shown in Figure 2 and a list of bores is provided in Appendix 2. Bores were sampled with modified plankton nets of either 32 or 90 mm diameter, depending on the diameter of the bore (Invertebrate Solutions 2019). Each bore was hauled six times (three times with a 150 µm mesh net and three times with a 50 µm mesh net). Nets were lowered to the base of the bore and agitated at the bottom to mix sediment into the water column to increase likelihood of capturing benthic species. The nets were then hauled through the entire water column of the bore. Samples were transferred into polycarbonate vials containing 100 % ethanol and kept in a cool environment (esky with ice bricks or refrigerator) for preservation purposes. Samples that contained large volumes of sediment were elutriated prior to sample preservation. Nets were washed in decontamination solution between each site to avoid cross-contamination. Depth to water table, depth to end of hole, temperature, dissolved oxygen, electrical conductivity, pH and oxygen-reduction potential were recorded using a Hanna HI 9298194 water quality meter.

3.2. Sampling in Relation to Project Impacts

The sampling design had two objectives: 1) to compile a list of species that occur, or are likely to occur, within the borefield and project development envelope, and 2) to assess the conservation significance of any possible changes in stygofauna communities associated with the potential project impacts on stygofauna habitat (albeit these impacts will be small). As such, sampling occurred in two distinct areas, the freshwater drawdown area associated with abstraction and the saline/coastal area that is potentially influenced by infrastructure development and operations, including by the potential spread of a nutrient and freshwater plume from the treated greywater spray field (although this impact is likely to be very small).

At the time of sampling, the exact location of the spray field and extent of the borefield were not known and sites were selected to maximise the likelihood of identifying species that occur within the general areas of the borefield and project envelope (including adjacent areas that reflect conditions inside the envelope). The sprayfield site has now been selected (see Figure 1). Sample effort is assigned to general areas in Table 1, with more detail about locations given in Appendix 2.

3.3. Personnel

Field work and sample sorting was conducted by Timothy Moulds of Invertebrate Solutions. Samples were sorted by Jane McRae, and Melita Pennifold and animals identified by Jane McRae, with advice on some copepod identifications from Prof. Tomislav Karanovic. The report was written by Huon Clark and reviewed by Stuart Halse.

Table 1. Sampling effort for stygofauna in different parts of the project.

Location	No of bores	No. of samples
Borefield	6	18
Project envelope	10	30
Outside envelope	4	12
Total	**20**	**60**

4. SAMPLING RESULTS

4.1. Groundwater Salinity

Salinity of groundwater near the watertable varied across the project, being fresh in the borefield (approximately 800-1,200 mg/L) and of marine salinity levels, or slightly higher, in the project envelope (Appendix 3). Salinity in the vicinity of the spray field was 30,000-34,000 mg/L and this may represent the salinity of the upper layer of groundwater across most of the sand plain until the supralittoral, although the salinity in bore S04 in the middle of the plain was approximately 43,000 mg/L and at the S06 bores (assumed to be on the seaward edge of the sand plain) it was about 50,000 mg/L. These higher salinities may reflect fine-scale variation in groundwater salinity. Salinity in supralittoral areas near the coast was 48,000-52,000 mg/L. No salinity profiling was undertaken.

4.2. Stygofauna

A total of 180 specimens belonging to 11 species were collected during the three phases of stygofauna survey. All species collected are crustaceans and comprise two amphipods and nine copepods (Table 2).

Eight species were collected from the project envelope and its surrounds east of the Minilya-Exmouth road, while three species were collected from the borefield. Six of the eight species east of the road are known only from the project envelope or its immediate vicinity. The exceptions are the widespread copepod *Stygoridgwayia trispinosa*, which is found widely in the Pilbara (Tang *et al.* 2008), and the copepod *Phyllopodopsyllus wellsi*, which occurs elsewhere on the Cape Range Peninsula and on Barrow Island. In contrast to the situation east of the road, all animals identified within the borefield are known to occur in other parts of the Cape Range Peninsula or further afield.

Six of the eight species collected from the project envelope and close surrounds were represented by only one individual despite three phases of sampling (Table 2). Despite this high proportion of species collected as single animals, the species estimating algorithms (see Colwell 2013) suggest that approximately 70% of stygofauna species at the project have been documented (Figure 3). This is at the lower end, but within the range, of the efficiency of most subterranean fauna assessments.

Interestingly, stygofauna were not collected from any of the bores in the sand plain. In contrast, 66% of the borefield bores (4 of 6 sampled, Figure 4) and 75% of the supratidal bores yielded stygofauna (3 of 4 sampled, Figure 5). This suggests the sandplain at the project does not provide suitable habitat for stygofauna, although a general habitat analysis considered it to be prospective (Invertebrate Solutions 2017) and stygofauna have been collected 40 km north at Exmouth at similar groundwater depths and salinities to those of the sand plain.

Table 2. Stygofauna species collected during three rounds of sampling.
Blue highlighting indicates high order identifications that of species that are probably already listed in the table. Grey highlighting indicated the species is known only from the development envelope.

Higher Order Identification	Lowest Identification	Number of Specimens	Located within drawdown impact zone	Located within sprayfield impact zone	Located outside of impact zones	Comment
Arthropoda						
Crustacea						
Malacostraca						
Eumalacostraca						
Amphipoda						
Eriopisidae	Nedsia `sculptilis Cape Range`	1	Yes	No	Yes	Elsewhere on Cape Range peninsula
	Nedsia sp.	1	NA	NA	NA	Only a partial animal found, probably N. 'sculptilis'.
Decapoda						
Atyidae	Stygiocaris stylifera	19	Yes	No	Yes	Also located at the northern end of Cape Range Peninsula
Maxillopoda						
Copepoda						
Calanoida						
Ridgewayiidae	Stygoridgewayia trispinosa	1	No	Unlikely	Yes	Widespread throughout the Pilbara
Cyclopoida						
Cyclopidae	Diacyclops humphreysi s.s.	6	Yes	No	Yes	Occurs elsewhere on Cape Range peninsula
	Neocyclops `BCY058`	20	No	Unlikely	Probably	Known from S08 outside project
	Neocyclops sp.	1	NA	NA	NA	From S03, probably N. 'BCY060'
Harpacticoida						
Ameiridae	Ameira `BHA250`	5	No	Unlikely	Probably	Known from S03 in development envelope
	Nitokra `BHA251`	123	No	Unlikely	Probably	Known from S08 outside project
Ectinosomatidae	Ectinosoma `BHA244`	1	No	Unlikely	Probably	Known from S03 in development envelope
Paramesochridae	Apodopsyllus `BHA255`	2	No	Unlikely	Probably	Known from S04 outside project
Tetragonicipitidae	Phyllopodopsyllus wellsi	1	No	Unlikely	Yes	Occurs elsewhere on Cape Range peninsula and Barrow Island
Misophrioida						
Speleophriidae	Speleophria `BCA002`	3	No	Unlikely	Probably	Known from S03 in development envelope
Grand Total		**184**				

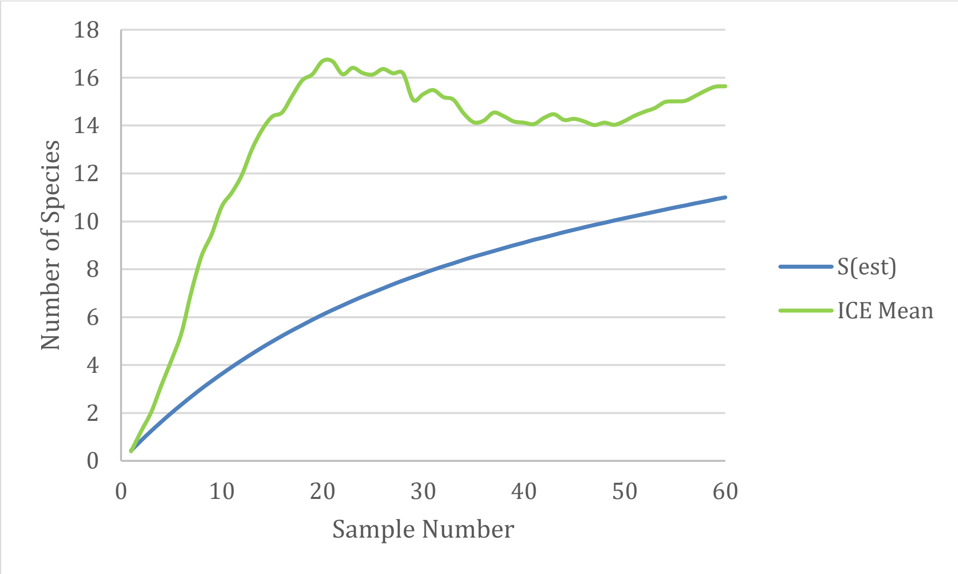

Figure 3. Stygofauna species accumulation curve based on sampling results and ICE estimate of the actual number of species present (using EstimateS, Colwell 2013).

4.3. Nationally Important Wetland

The three bores in or near the nationally important wetland (S06N, S06S, S07) did not yield any animals, despite this area being considered potentially important for subterranean fauna. These bores were in sandplain and results from near the bundle track suggest nearby supratidal areas may comprise a more prospective part of the wetland for stygofauna.

4.4. Species of Interest

4.4.1. Species of Scientific Interest

While none of the stygofauna species collected is considered likely to be impacted by project development or operations, four of the species collected are of scientific interest.

***Ameira* `BHA250`**

Five individuals of *Ameira* 'BHA250' were identified in bore S03, which is located 7.5 km from the spray field (Figure 5). The nearest record of an *Ameira* is from Lake MacLeod, just to the south of the Cape Range Peninsula. It is currently not possible to state whether these two species are the same or how closely they are related.

It should also be noted that the subterranean status of *Ameira* 'BHA250' is unclear. The family Ameiridae has a marine origin but has successfully colonised fresh water, especially in subterranean habitats (Conroy-Dalton and Huys 1996) and Ameira 'BHA250' may be an inland record of a marine species or may be a stygofaunal species adapted to saline coastal areas. Whichever is the case, the availability of apparently suitable supratidal habitat north and south of the project, and the distance of this species from the spray field, mean that its conservation status is unlikely to be affected by the project.

***Ectinosoma* `BHA244`**

Only one individual of *Ectinosoma* 'BHA244' was collected from bore S03 (Figure 5). *Ectinosoma* is predominantly a marine genus, although it has been collected from wells in Florida (Bruno *et al.* 2005). As with *Ameira* "BHA250', its status as stygofauna is uncertain. However, owing to the availability of apparently suitable habitat north and south of the project, and the distance of this species from the spray field, its conservation status is unlikely to be affected by the project.

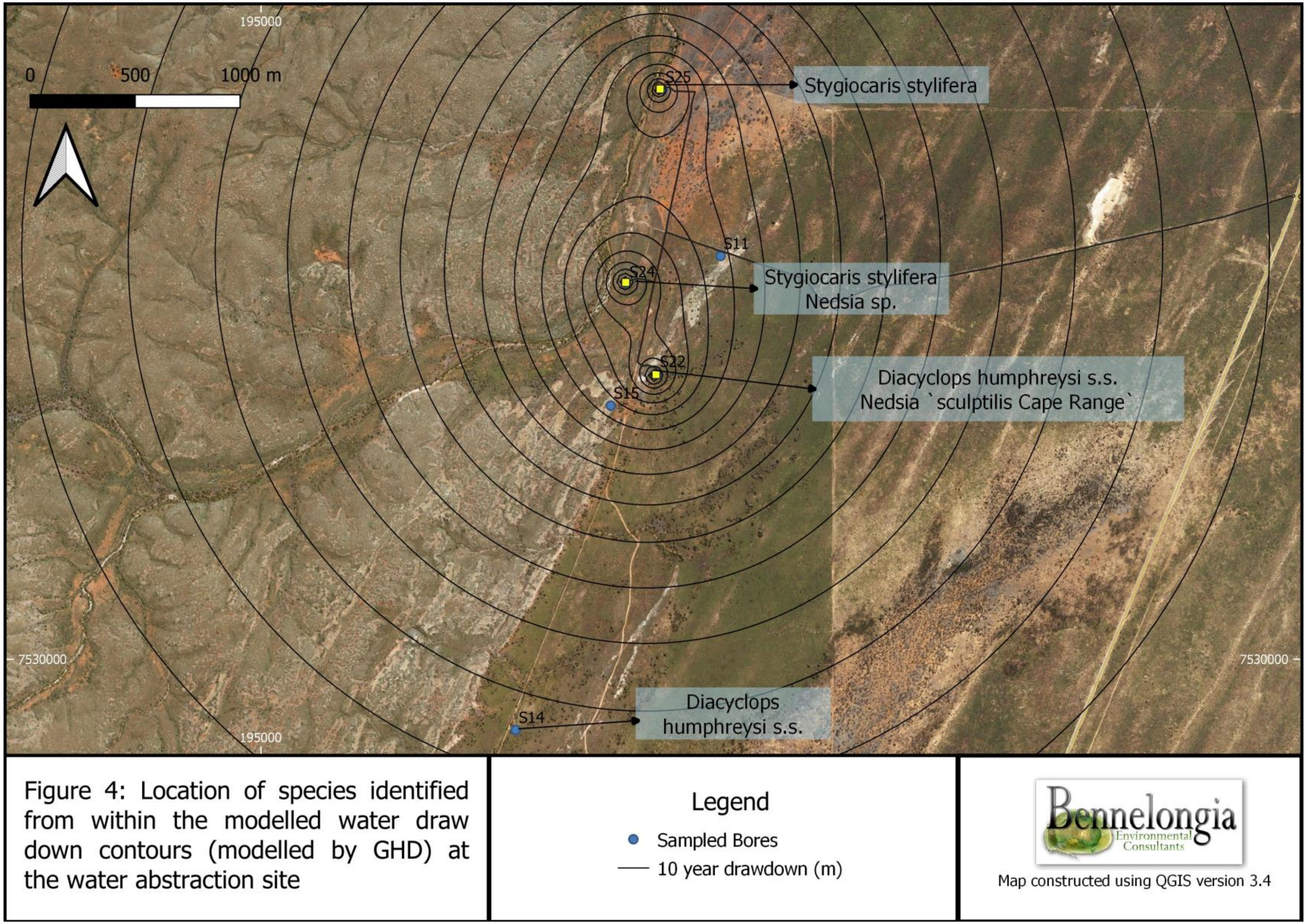

Figure 4: Location of species identified from within the modelled water draw down contours (modelled by GHD) at the water abstraction site

Figure 4. Locations of stygofauna species collected within the borefield.

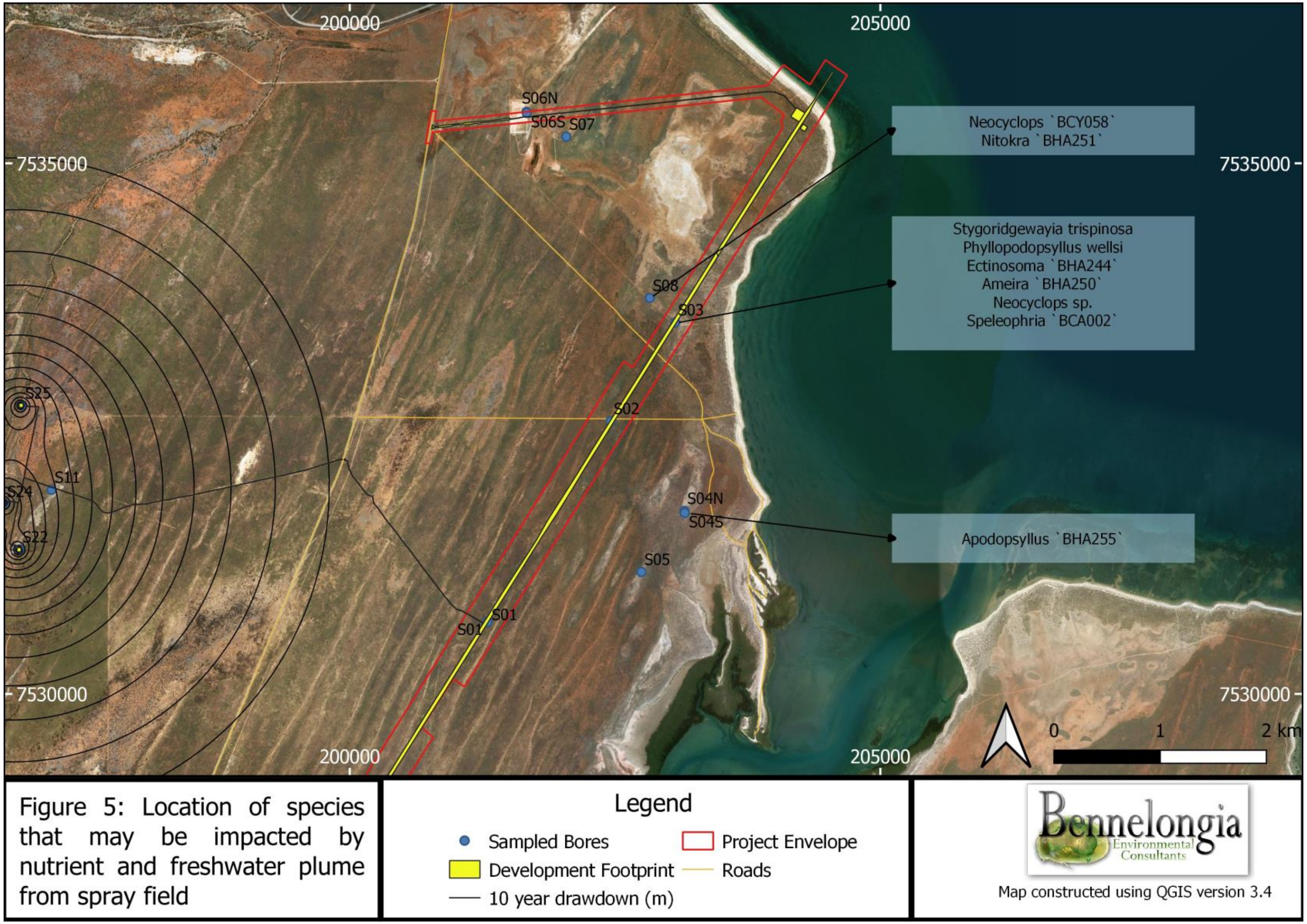

Figure 5. Locations of stygofauna species collected in and near to project envelope.

***Apodopsyllus* `BHA255`**

Two individuals of *Apodopsyllus* 'BHA255' were identified in Bore S04 North, which is located 6.1 km from the spray field and outside the development envelope. *Apodopsyllus* 'BHA255' is likely to be an interstitial marine species. Similar *Apodopsyllus* species have been found throughout Western Australia and are linked to interstitial marine environments (Tomislav Karanovic, pers. comm, May 2019). However, stygobiont species of *Apodopsyllus* occur in Italy (Pesce 1985). Whether *Apodopsyllus* 'BHA255' is an interstitial species of the upper shore, or stygofauna, it is not expected to be significantly affected by project development and operations.

Speleophria `BCA002`

Three individuals of *Speleophria* 'BCA002' were collected from bore S03 in the third phase of sampling after quite heavy rainfall. This species is closely related to the critically endangered *Speleophria bunderae,* which is known from the Bundara Sinkhole on the western side of the Exmouth peninsula (Jaume *et al.* 2001). Other species of *Speleophria* were collected on Barrow Island in 2012 (Jane McRae, pers. comm., May 2019) and in the Nullarbor Plain caves (Karanovic and Eberhard 2009). *Speleophria* species usually occur in anchialine habitats – closed pools located near the coast that have fresh water overlying seawater. The ecological significance of the record of *Speleophria* 'BCA002' at bore S03 is unclear, although it suggests that perhaps some copepod species utilise the fresh and saline water interface of groundwater along the coast of the southern part of Exmouth Gulf. This may mean the other copepods discussed above are also best regarded as stygofauna. It may also mean their ranges are relatively restricted, although the availability of apparently suitable habitat north and south of the project means that project development and operations are unlikely to threaten any species.

4.4.2. Listed Species

Stygiocaris stylifera

A total of 19 specimens of *Stygiocaris stylifera* were collected during the three field surveys at the Project. They came from two bores within the drawdown area. *Stygiocaris stylifera* is a Priority 4 species that occurs on the northern and eastern sides of the Cape Range Peninsula and on Barrow Island (Page *et al.*, 2008). While collections of *Stygiocaris stylifera* demonstrate that suitable habitat for this and some stygobytic species occurs within the project borefield, the wider range of the species as documented by Page *et al*. (2008) means the project itself will not have significant conservation impact on the species, irrespective of the groundwater changes that occur.

Ophisternon candidum* and *Milyeringa veritas

The current survey did not collect either the blind cave eel (*Ophisternon candidum)* or the blind gudgeon *(Milyeringa veritas)*. Both species are listed as Vulnerable under the Western Australian *Biodiversity Conservation Act 2016* and *Commonwealth Environment Protection and Biodiversity Conservation Act 1999* and occur on the western and eastern sides of Cape Range. The previous most southern known location on the eastern side of the Cape Range Peninsula was at Mowbowra Well, approximately 10 km south of Exmouth (Humphreys and Adams 1991). Based on known geology and salinity levels, it is not expected that the blind cave eel and blind gudgeon will be present in the Project Envelope. The fresher water, observed presence of karst on the surface and collection of *Stygiocaris stylifera* are indications that habitat in the project borefield is similar to that farther north on the peninsula where the eel and gudgeon are known to occur. Thus, although not collected during the three field surveys, it remains possible the eel and gudgeon occur in the borefield or its vicinity. However, as is the case with *Stygiocaris stylifera*, the wider range of the two species means the project itself will not have significant conservation impact on either species, irrespective of the groundwater changes that occur.

5. DISCUSSION

No subterranean species will be directly threatened by habitat loss as a result of the project. The shallow excavation (up to 1 m) that will occur in parts of the project envelope are in areas that are unlikely to support troglofauna. The absence of troglofauna is made more certain by the fact that soil invertebrates, which are usually widespread species, are likely to exclude troglofaunal species to depths of about 2 m. There will be a small reduction in groundwater habitat as a result of borefield production but the lowering of the watertable will be <20 cm, which is highly unlikely to be biologically meaningful.

Indirect impacts on species through the reduction of habitat quality as a result of increased nutrient concentrations or freshening of groundwater are also unlikely. Additionally, no stygofauna species were recorded in the vicinity of the spray field. The species recorded in the supratidal area are 6-7 km from the spray field and unlikely to be in the path of any plume (which would be expected to dissipate within a short distance because of the relatively small quantities of water and nutrients being sprayed).

The lack of threat from nutrients is highlighted by comparing existing groundwater concentrations with those expected in greywater. Nitrogen levels in a range of bores ranged from 0.2-2.4 mg/L. Treated grey water released at the spray field will have a nitrogen concentration of 7 mg/L (GHD 2019b). Phosphorus concentrations in groundwater at the project site ranged between <0.01 mg/L and 0.08 mg/L. Treated greywater will be released at the spray field at concentrations of 1 mg/L (GHD 2019b). The nutrient levels in treated greywater are comparable to those from wastewater treatment plants designed to achieve a high level of nutrient reduction (GHD 2019b). The treated greywater will be sprayed over an appropriately designed and vegetated area and it is possible that most of the nutrients to be bound by soil or taken up by the vegetation and converted to plant biomass (GHD 2019b). Groundwater concentrations under the spray field will be further reduced as groundwater flows through the area.

The extent to which greywater freshens the groundwater below and downstream of the spray field will be influenced by the volume of greywater, the amount of evaporation and groundwater flow rates. In theory, impacts on stygofauna may also be dependent on the extent of salinity stratification in the groundwater aquifer and whether this is altered by spray field operation. However, given that the sprayfield will occupy no more than 1.5 ha, the likelihood of changes in groundwater conditions extending over distances of more than a few hundred metres are probably low. It is highly unlikely that any stygofauna species in a uniform sand plain environment, without strong barriers, would have a range this small (Halse et al. 2014). Currently, no stygofauna species are known to occur in the vicinity of the spray field.

6. CONCLUSIONS

Desktop studies of the project site were conducted to assess the possibility of the presence of subterranean fauna within the project area of the Learmonth pipeline fabrication facility. Owing to a lack of identified suitable habitat, it was considered that troglofauna are unlikely to occur at the project. Furthermore, it was considered that project development would not affect troglofaunal habitat if any was present. In contrast, it was considered that suitable habitat for stygofauna was present and that two activities might impact any stygofauna species present. These are: 1) water drawdown west of the Exmouth-Minilya road as a result of groundwater abstraction, and 2) infiltration of nutrients and freshwater when treated greywater is released at a specifically designed sprayfield. The desktop study found sufficient information to conclude the project will not threaten the conservation status of troglofauna species but it was considered that field survey of stygofauna was needed to assess the potential impact of the project on this group of animals.

A total of 180 specimens belonging to 11 species were collected during the stygofauna survey. Of the 11 species identified, three were collected from the proposed borefield west of the Exmouth-Minilya road or the development envelope east of the road. They also occur in other parts of the Cape Range Peninsula. Eight species were collected within, or adjacent to, the project envelope but all eight species were found close to the coast in supratidal habitat. No species were collected from the sand plain area covering most of the project envelope and in which the spray field is located. Two of the coastal species occur in other parts of Cape Range Peninsula and elsewhere.

Four species collected near the coast are of scientific interest and their stygofauna status is uncertain. These are the copepods *Ameira* 'BHA250', *Ectinosoma* `BHA244`, *Apodopsyllus* `BHA255` and *Speleophria* `BCA002` (the latter species has many anchialine relatives).

Given the relatively small drawdown associated with borefield operations and the widespread distributions of the stygofauna species collected in the borefield, it is concluded that borefield operations will not adversely affect stygofauna. Given the lack of stygofauna species on the sand plain, the small size of the spray field and small volume of water being disposed of, with various factors likely to minimise changes to groundwater conditions resulting from nutrients in the water and its low salinity, it is concluded that disposal of greywater will also not adversely affect stygofauna.

Accordingly, it is considered the Subsea 7 Pipeline Fabrication Facility poses no significant threat to either troglofaunal or stygofauna species.

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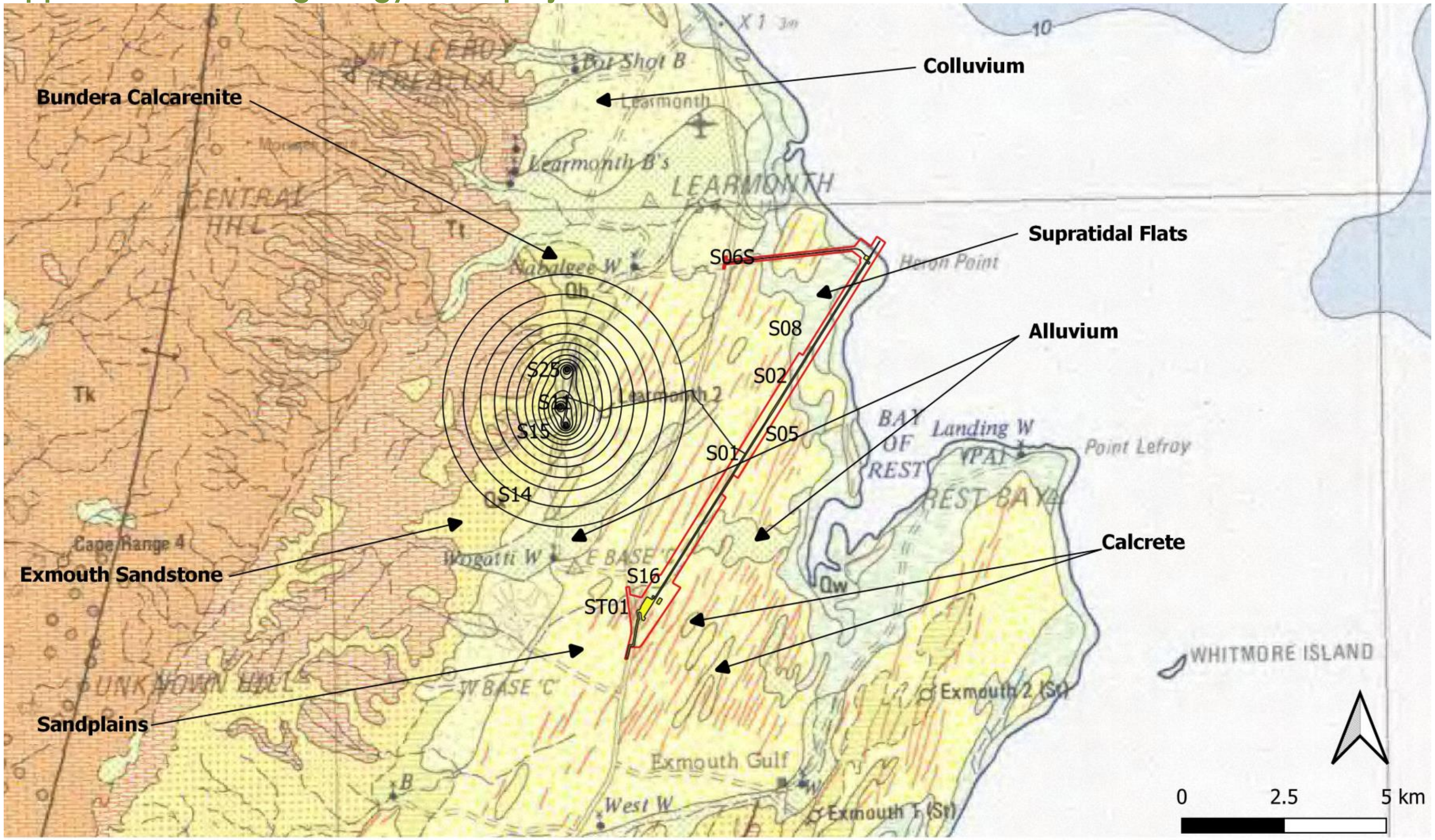
Appendix 1. Surface geology of the project area and surrounds



Appendix 1: Surface geology of the area surrounding the Project
GSWA 250k Yanrey-Ningaloo 2003
Author: Huon Clark
Date: 20/05/2019

Legend
Development Footprint
Project Envelope
10 year drawdown (m)

Appendix 2. Bores sampled during three phases of the stygofauna survey and their locations

Name	Location	Latitude	Longitude
S01	Bundle track	22.30379	114.10085
S02	Bundle track	22.28692	114.11247
S03	Bundle track	22.27863	114.11853
S04N	Near coast, outside development envelope	22.29467	114.11904
S04S	Near coast, outside development envelope	22.29484	114.11906
S05	Near coast, outside development envelope	22.29979	114.11501
S06N	Access road, important wetland area	22.26048	114.10531
S06S	Access road, important wetland area	22.26056	114.10533
S07	Near important wetland area	22.26266	114.1089
S08	Near bundle track, outside development envelope	22.27651	114.11625
S09	Near spray field	22.33552	114.07893
S10	?downstream of spray field	22.32952	114.08674
S11	Borefield	22.29184	114.06126
S14	Borefield	22.31205	114.05137
S15	Borefield	22.29818	114.05605
S16	Bundle track	22.33059	114.08147
S22	Borefield	22.29686	114.05822
S24	Borefield	22.29298	114.05689
S25	Borefield	22.28463	114.05873
ST01	Near fabrication site	22.33728	114.07404

Appendix 3. Salinity (TDS mg/L) and depth to groundwater (m) at bores in the three phases of sampling.

Highlighted TDS values in April reflect recent rainfall and either recharge or rainfall leakage around bore.
TDS values are calculated from electrical conductivity using the conversion of Williams (1986).

Bore	October 2018		January 2019		April 2019		No. of species
	TDS	Depth	TDS	Depth	TDS	Depth	
S01	42300	3.6	42300	4.2	42500	4.2	
S02	33500	4.2	33500	4.22.4	35700	3.0	
S03	49600	1.8	49600	1.8	48800	2.4	7
S04N	50700	1.8	50700	1.8	51300	1.8	1
S04S	52700	1.8	52700	1.8	48600	1.8	
S05	44500	1.8	44500	2.4	**18800**	1.8	
S06N	50700	1.8	50700	1.8	46700	1.8	
S06S	52600	1.8	52600	1.8	43200	1.8	
S07	41300	3.0	41300	3.0	36500	3.6	
S08	51300	1.8	51300	1.8	51900	1.8	3
S09	34500	12.6	34500	15.0	**16800**	14.4	
S10	33800	13.2	33800	13.2	**16800**	12.0	
S11	2222	25.8	2222	24.0	2576	23.4	
S14	1241	32.3	1241	32.4	1016	31.2	1
S15	911	28.5	911	28.2	352	28.2	
S16	30600	12.0	30600	12.6	**14500**	12	
S22	939	24.0	939	25.2	985	25.2	2
S24	1004	27.6	1004	28.2	958	25.8	2
S25	788	22.2	788	22.2	843	21.6	1
ST01	29200	18.6	29200	18.6	28500	18.0	

Appendix 4. Results of stygofauna sampling.

Bore	Sample Date	Species	No. of animals
S01	22/10/2018	No species	-
S01	9/01/2019	No species	-
S01	10/04/2019	No species	-
S02	22/10/2018	No species	-
S02	19/01/2019	No species	-
S02	10/04/2019	No species	-
S03	22/10/2018	*Stygoridgewayia trispinosa*	1
S03	22/10/2018	*Phyllopodopsyllus wellsi*	1
S03	22/10/2018	*Ectinosoma `BHA244`*	1
S03	22/10/2018	*Ameira `BHA250`*	1
S03	9/01/2019	*Ameira `BHA250`*	2
S03	10/04/2019	*Ameira `BHA250`*	2
S03	10/04/2019	*Neocyclops sp.*	1
S03	10/04/2019	*Speleophria `BCA002`*	3
S04 North	22/10/2018	No species	-
S04 North	9/01/2019	No species	-
S04 North	8/04/2019	*Apodopsyllus `BHA255`*	2
S04 South	22/10/2018	No species	-
S04 South	9/01/2019	No species	-
S04 South	10/04/2019	No species	-
S05	22/10/2018	No species	-
S05	9/01/2019	No species	-
S05	10/04/2019	No species	-
S06 North	22/10/2018	No species	-
S06 North	9/01/2019	No species	-
S06 North	10/04/2019	No species	-
S06 South	22/10/2018	No species	-
S06 South	9/01/2019	No species	-
S06 South	10/04/2019	No species	-
S07	22/10/2018	No species	-
S07	9/01/2019	No species	-
S07	10/04/2019	No species	-
S08	22/10/2018	*Neocyclops `BCY058`*	5
S08	22/10/2018	*Nitokra `BHA251`*	100
S08	9/01/2019	*Neocyclops `BCY058`*	3
S08	9/01/2019	*Nitokra `BHA251`*	17
S08	10/04/2019	*Neocyclops `BCY058`*	12
S08	10/04/2019	*Nitokra `BHA251`*	6
S09	22/10/2018	No species	-
S09	9/01/2019	No species	-
S09	10/04/2019	No species	-
S10	22/10/2018	No species	-

Bore	Sample Date	Species	No. of animals
S10	9/01/2019	No species	-
S10	10/04/2019	No species	-
S14	22/10/2018	No species	-
S14	8/01/2019	*Diacyclops humphreysi s.s.*	1
S14	9/04/2019	*Diacyclops humphreysi s.s.*	4
S15	22/10/2018	No species	-
S15	9/01/2019	No species	-
S15	10/04/2019	No species	-
S16	22/10/2018	No species	-
S16	9/01/2019	No species	-
S16	10/04/2019	No species	-
S22	24/10/2018	*Nedsia `sculptilis* Cape Range`	1
S22	9/01/2019	No species	-
S22	9/04/2019	*Diacyclops humphreysi s.s.*	1
S24	23/10/2018	*Stygiocaris stylifera*	4
S24	8/01/2019	*Stygiocaris stylifera*	1
S24	8/01/2019	*Nedsia sp.*	1
S24	9/04/2019	*Stygiocaris stylifera*	7
S25	23/10/2018	*Stygiocaris stylifera*	3
S25	8/01/2019	*Stygiocaris stylifera*	2
S25	9/04/2019	*Stygiocaris stylifera*	2
ST01	22/10/2018	No species	-
ST01	9/01/2019	No species	-
ST01	10/04/2019	No species	-