BHP Western Australia Iron Ore

Jimblebar targeted ghost bat survey

June 2021

Executive summary

BHP Western Australian Iron Ore (BHP WAIO) commissioned GHD Pty Ltd (GHD) to undertake a targeted Ghost Bat (*Macrodermis gigas)* survey covering the Jimblebar area. This Study Area is located directly adjacent to the Jimblebar BHP WAIO mining operation.

Recent vertebrate fauna assessments within the area have identified several caves, four showing evidence of Ghost Bat presence. All of the caves with evidence have been located outside of current/ proposed BHP development envelopes; however, future developments may disturb these caves, particularly the ones to the north of Jimblebar. In addition, the proximity of activities involved in the Jimblebar Optimisation Project to Ghost Bat caves has triggered the application of the Programme Matter Outcomes (PMOs) under 'the Assurance Plan' (BHP 2018) for BHP's Pilbara Strategic Assessment. The Assurance Plan was developed to manage impacts to several 'Program Matters', or listed threatened fauna species under the *Environment Protection and Biodiversity Act 1999*, which include the Ghost Bat. Monitoring of Ghost Bat caves in the area is required to the Program Matter Outcome of '*no loss of Ghost Bat Population's due to Program Activities*' is being achieved.

Field surveys targeting Ghost Bats were conducted from the 25 to 31 May 2020 and consisted of the following methods:

- habitat and roost assessments;
- in-situ time lapse video camera surveys; and
- bat call surveys using full spectrum detectors.

Previous historical records and caves within 40 km radius of the survey area where reviewed prior to the survey. Two (Biologic 2019) sites were investigated were outside the targeted search area (CAV-20 and CAV-10). CAV-06, 07 and 08 were also previously known (Biologic 2019) and were assessed in this current assessment. A known cave (SC-01) was also investigated within the survey area that was assessed previously by GHD (GHD 2019a).

GHD investigated 57 locations resulting in 20 sites recorded with known or potential diurnal roosting habitat for Ghost Bat. Of the 20 sites five were confirmed as diurnal roosting sites and three classified as nocturnal feeding/refuge sites for the Ghost Bat. Confirmed diurnal roost sites included:

- SC-01 - categorised as *Diurnal roost ongoing use.* One Ghost Bat was flushed from the roost during the May 2020 survey and evidence of occupation during different times of the year was recorded during the surveys undertaken by GHD during 2020 and 2019 (e.g. large scat pile containing recent and older scats). Bat call surveys were also undertaken for five consecutive nights during May 2020 and although the Ghost Bat was recorded, the timing and frequency of calls suggests the species was not occupying the roost habitat during the day during the survey period. Furthermore, the structure of these roosts is unlikely to support breeding habitat requirements.
- CAV-19 – categorised as *Diurnal roost probably occasional use*. The Ghost Bat from SC-01 was flushed into this site. A detailed habitat assessment was not carried out in order to avoid further disturbance therefore further survey and monitoring is recommended for CAV-19 to determine the type of diurnal roost.
- CAV-09, CAV-11, CAV-12, CAV-16 - categorised as Diurnal roost with occasional use. Evidence of usage in the form of scats and feeding evidence and favourable roost structure for each site support diurnal roost habitat for the Ghost Bat. However the evidence recorded did not support ongoing use (e.g. large scat piles with recent and historical scat).

Bat call surveys were also undertaken for four consecutive nights during May 2020 at CAV-09 and although the Ghost Bat was recorded, the timing and frequency of calls suggests the species was not occupying the roost habitat during the day during the survey period. Furthermore, the structure of these roosts is unlikely to support breeding habitat requirements.

Ghost Bat foraging habitat within the survey area consists of:

- Major Drainagelines
- Plains (Sand and Stony)
- Mulga Woodland
- Breakaway/ Cliff, Hillcrest/Hillslope
- Gorge/Gully.

These foraging habitats are well-represented in the surrounding area. Suitable roosting habitats within the survey area consist of Breakaway/ Cliff, Hillcrest/Hillsope and Gorge/Gully habitats as they contain caves and overhangs.

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1. Introduction

1.1 Project background

BHP Western Australian Iron Ore (BHP WAIO) commissioned GHD Pty Ltd (GHD) to undertake a targeted Ghost Bat (*Macrodermis gigas)* survey covering the Jimblebar area (hereafter referred to as the Study Area). This Study Area is located directly adjacent to the Jimblebar BHP WAIO mining operation and encompasses active/ non-active Geoscience tenure / off tenure and potential mining operational areas.

Recent vertebrate fauna assessments within the area have identified several caves, four showing evidence of Ghost Bat presence. All of the caves with evidence of Ghost Bat presence were located outside the current/ proposed BHP development envelopes; however, future developments may disturb these caves, particularly the ones to the north of Jimblebar. In addition, the proximity of activities involved in the Jimblebar Optimisation Project to Ghost Bat caves has triggered the application of the Programme Matter Outcomes (PMOs) under '*the Assurance Plan*' (BHP 2018) for BHP's Pilbara Strategic Assessment. The Assurance Plan was developed to manage impacts to several 'Program Matters', or listed threatened fauna species under the *Environment Protection and Biodiversity Act 1999*, which include the Ghost Bat. Monitoring of Ghost Bat caves in the area is required to the Program Matter Outcome of '*no loss of Ghost Bat Population's due to Program Activities*' is being achieved.

1.2 Purpose of this report

This targeted Ghost Bat assessment will be used to inform future environmental approvals across the area and Ghost Bat monitoring required under BHP's Federal Strategic Approval; however as requested this survey report is a general report and does not assess any specific development proposed by BHP WAIO.

1.2.1 Limitations and assumptions

This report has been prepared by GHD for BHP and may only be used and relied on by BHP for the purpose agreed between GHD and the BHP as set out in section 1.2 of this report.

GHD otherwise disclaims responsibility to any person other than BHP arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

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.

The opinions, conclusions and recommendations in this report are based on assumptions made by GHD described in this report. GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by BHP and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

1.3 Scope of works

The survey objectives were to:

- document and characterise potential Ghost Bat roosts on and off BHP WAIO tenure around the Jimblebar area;
- map important Ghost Bat habitat;
- record evidence of Ghost Bat; and
- in collaboration with BHP, set up methodology for an on-going monitoring program.

Consistent with these objectives the scope of works involved:

- provision of a comprehensive desktop assessment comprising database search and literature review for the study area, to determine the presence, or likely presence, and location of Ghost Bat;
- undertaking a single season targeted Ghost Bat survey within the survey area;
- producing a technical report (this document) detailing the desktop assessment and the targeted survey method and results; and
- submission of the survey data in accordance with BHP requirements.

1.4 Study Area location

This Study Area is located directly adjacent to the Jimblebar BHP WAIO mining operation and approximately 50 kilometres (km) north of Newman, Western Australia (WA). The Study Area consist of discrete targeted search areas (survey area) derived from a desktop assessment review of previous reports (see Figure 1, Appendix A). For this report, the term Study Area includes the survey area and an additional 40 km radius buffer around the survey area. The Study Area defines the limits of the desktop assessment.

The survey area defines the limits of the targeted field assessment undertaken by GHD for the Ghost Bat.

1.4.1 Regional biogeography and climate

The study area is situated in the Eremaean Botanical Province, within the Pilbara and Gascoyne bioregions as described by the Interim Biogeographic Regionalisation of Australia (IBRA; Thackway and Cresswell 1995).

The Pilbara bioregion is characterised by vast coastal plains and inland mountain ranges with cliffs and deep gorges. Vegetation is predominantly mulga low woodlands or snappy gum over bunch and hummock grasses. Tenure comprises Aboriginal land, leasehold (for grazing cattle) and conservation reserves. The bioregion provides the majority of WA's exports in petroleum, natural gas and iron ore. Major population centres are Karratha, Port Hedland, Newman and Tom Price.

The Gascoyne bioregion is characterised by low, rugged ranges and broad, flat valleys. The vegetation is dominated by open mulga low woodlands. The main land use of this sub-region comprises extensive sheep and cattle grazing on pastoral leasehold. Mining is important for the bioregion's economy. There are no major population centres in the bioregion.

The climate of this region is arid to tropical with very hot summers and mild winters. Rainfall in the Pilbara is spatially and temporally variable. Rainfall in the eastern Pilbara (containing the site) is most influenced by tropical and monsoonal drivers which are predominantly active in the summer and autumn months (December – May) while rainfall in the western Pilbara is also influenced by southern mid-latitude drivers such as frontal systems during autumn and winter (March – August) (Sudmeyer 2016).

During summer and early autumn (December – March), average daily temperatures exceed 30°C across the region, with average daily maxima exceeding 35°C from October – March. During the winter months (June – August), average temperatures are around 20°C across the region.

The closest current weather station to the site is in Newman (Station ID: 007176) located approximately 51 km south of the southern survey area boundary. Climate data from this station indicate:

- mean maximum temperature ranges from 22.8°C in July to 39.1°C in December;
- mean minimum temperature ranges from 6.4°C in July to 24.9°C in January; and
- mean annual rainfall is 334.9 mm with an average of 38.7 rain days per year (BoM 2020).

Rainfall for the previous six month lead up to the survey is presented in Table 1 (based on Newman data Aero Station 007176). The rainfall total for this period was 293.2 mm, which isapproximately 90% of the year's average total for this region.

Table 1 Rainfall 6 months prior to the survey month.

Date	Rainfall (mm)
November 2019	1.4
December 2019	6.6
January 2020	198.2
February 2020	61.8
March 2020	0.4
April 2020	17.4
May 2020	7.4
Total	285.8 mm

During the survey the weather was cool and dry. Temperature and rainfall statistics during the survey period are presented in Table 2.

Table 2 Daily temperature and rainfall statistics during survey period (sourced BoM 2020)

Date	Temperature (°C)		Rainfall (mm)
	Minimum	Maximum	
25 May 2020	12.7	16.1	1.4
26 May 2020	8.0	20.2	6.0
27 May 2020	3.9	20.8	0
28 May 2020	4.9	22.7	0
29 May 2020	8.6	26.2	0
30 May 2020	8.6	25.1	0
31 May 2020	9.2	24.5	0

1.4.2 Geology, land systems and soils

The study area is located within the Warakurna and Fortescue Large Igneous Provinces of the Pilbara Craton (Glikson *et al.* 1996). The Pilbara Craton is a geological formation formed from Archaean crust (3.6-2.7 billion years ago).

The study area forms part of the Hamersley Ranges to the north and west. The Newman region is characterised by Banded Iron Formations (BIFs) and Late Archaean greenstones, in the west giving way to the Early Archaen grantoids and metagabbro intrusive of the Augustus region to the south (Government of Western Australia 2020). The area largely comprises banded jaspilite and chert along with shales (Biologic 2014).

Soils within the study area comprise the following (Bureau of Regional Sciences 2009):

- Mz25: Plains associated with the Fortescue valley; there is a surface cover of stony gravels close to the ranges and hills: chief soils are acid red earths (Gn2.11) with some neutral red earths (Gn2.12); red-brown hardpan is absent. Associated are areas of calcareous earths (Gc) and loams (Um1) on calcrete (kunkar) and some hard red (Dr) soils around creek lines.
- Fa13: Ranges of banded jaspilite and chert along with shales, dolomites, and iron ore formations; some areas of ferruginous duricrust as well as occasional narrow winding valley plains and steeply dissected pediments. This unit is largely associated with the Hamersley and Ophthalmia Ranges. The soils are frequently stony and shallow and there are extensive areas without soil cover: chief soils are shallow stony earthy loams (Um5.51) along with some (Uc5.11) soils on the steeper slopes. Associated are (Dr2.33, Dr2.32) soils on the limited areas of dissected pediments, while (Um5.52) and (Uf6.71) soils occur on the valley plains.
- BE6: Extensive flat and gently sloping plains, which sometimes have a surface cover of gravels and on which red-brown hardpan frequently outcrops: chief soils are shallow earthy loams (Um5.3), with associated (Gn) soils of units My5O and Mz23 of Sheet 6. As mapped, there are inclusions of units Oc47 and BB9.
- Mz36: Pediments with some steep hills on granites; granitic residuals; bosses and tors: chief soils are acid red earths (Gn2.11) overlying a red-brown hardpan. Other soils include (Uc5.11) and (Dr2.32).
- AA16: Low ranges and steep hills on granites, with extensive areas of bare rock; small valley plains are included: chief soils appear to be shallow stony sands (Uc5.1 l) but small areas of (Dr2.32) and (Gn2.12) soils also occur.

The Pilbara region has been surveyed by the Department of Agriculture and Food, Western Australia (DAFWA) and others for the purposes of land classification, mapping and resource evaluation. One hundred and two land systems have been described for the region, which are distinguished on the basis of topography, geology, soils and vegetation (van Vreeswyk *et al.*

2004). The survey area intersects five mapped land systems; details of these land systems are presented in Table 3.

Table 3 Land systems within the survey area

Land system	Description	Land type
Boolgeeda	Stony lower slopes and plains below hill systems supporting hard and soft spinifex grasslands or mulga shrublands	Stony plains with spinifex grasslands
Newman	Rugged jaspilite plateaux, ridges and mountains supporting hard spinifex grasslands.	Hills and ranges with spinifex grasslands
McKay	Hills, ridges, plateaux remnants and breakaways of meta sedimentary and sedimentary rocks supporting hard spinifex grasslands.	Hills and ranges with spinifex grasslands
Sylvania	Gritty surfaced plains and low rises on granite supporting acacia-eremophila-cassia shrublands.	Stony plains with acacia shrublands
Talga	Hills and ridges of greenstone and chert and stony plains supporting hard and soft spinifex grasslands.	Hills and ranges with spinifex grasslands

1.4.3 Hydrology and vegetation

Jimblebar Creek runs through the targeted survey area. Jimblebar Creek is classified as a 'Significant Stream' which flows seasonally. The Caramulla Creek, classified as a 'Major River', is located approximately 6.5 km east of the most eastern targeted area and is also considered seasonal (Desmond *et al*. 2001).

Broad scale (1:1,000,000) pre-European vegetation mapping of the Pilbara region was completed by Beard (1976) at an association level. The mapping indicates there are two vegetation associations present within the survey area including:

- Low woodland, open low woodland or sparse woodland: Mulga *Acacia aneura* and associated species; and
- Low tree-steppe: Hummock grassland with scattered bloodwoods & snappy gum *Triodia* spp., *Corymbia dichromophloia*, *Eucalyptus leucophloia*.

2. Methodology

2.1 Requirements, legislation and background information

2.1.1 BHP requirements

BHP requirements applied to this survey are set out in Guidance for Vertebrate Fauna Surveys in the Pilbara (SPR-IEN-EMS-012 v6). This document outlines BHP's expectations for survey components including the level of survey, desktop assessment, survey design and intensity, timing, habitat assessment and reporting requirements. Biological survey spatial data requirements (SPR-IEN-EMS-015 v9) set out all biodiversity data requirements to standard and consistent format. These standards enable analysis of survey data and comparison between surveys spatially and temporally.

2.1.2 Relevant legislation and background information

In WA all native species and communities are protected under the *Biodiversity Conservation Act 2016* (BC Act). Species of high conservation status (conservation significant species) are further protected under Commonwealth E*nvironment Protection and Biodiversity Conservation Act 1999* (EPBC Act). In addition, regulatory authorities also provide a range of guidance and information on expected standards and protocols for environmental surveys, as referred to in section 2.3.1.

2.2 Desktop assessment

Prior to the field survey a desktop assessment was undertaken to collect relevant environmental and ecological information pertaining to the survey area and wider study area and to assist survey design. This included a review of:

- previous fauna survey reports provided by BHP that cover portions of the survey area and wider study area;
- the DBCA Threatened and Priority Fauna database for the study area;
- the DBCA *NatureMap* database for Ghost Bat activity previously recorded within the study area (DBCA 2007–). This is an integrated database comprising the following relevant databases:
  - Pilbara Threatened Fauna;
  - Fauna Survey Returns Database;
  - Biological Survey - Pilbara Biological Survey (mammals, birds, reptiles);
  - WA Threatened Fauna Database;
  - WA Museum (WAM) databases (mammals, birds, reptiles); and

Aerial photography, geology/soils, land systems and hydrology information to provide background information on the variability of the environment and likely vegetation and habitat types present.

2.3 Field survey

2.3.1 Guiding documents and permits

Guiding documents

The survey methodology and data collection that GHD employed was consistent with:

- Environmental Protection Authority (EPA) Technical Guidance –Terrestrial Fauna Surveys (EPA 2016a);
- EPA Technical Guidance – Sampling methods for terrestrial vertebrate fauna (EPA 2016b);
- Survey Guidelines for Australia's Threatened Mammals (Department of the Environment, Water, Heritage and the Arts (DEWHA) 2010a); and
- Survey Guidelines for Australia's Threatened Bats (DEWHA 2010b).

Bat identification and nomenclature

Bats were identified in the field or office (insitu camera, bat call analysis) using reference books and field guides and electronic guides. Where identification was not possible, photographs of specimens were collected to be later identified (field) or species were identified to genus level (bat call analysis).

Bat call identification was assisted by consulting distribution information for potential species (Armstrong 2011 and McKenzie *et al.* various dates; Churchill 2008; Van Dyck *et al.* 2013; Atlas of Living Australia 2020 and NatureMap 2020) and published call descriptions (e.g. Armstrong and Cole 2007; McKenzie and Bullen 2009; Guppy *et al.* 1985; Hourigan 2011).

Nomenclature used in this report follows that used by WAM as reported on *NatureMap*. This nomenclature is deemed the most up-to-date species information for WA fauna.

2.3.2 Survey timing, effort and method

The field survey consisted of a single season targeted assessment undertaken from 25 to 31 May, 2020. The field survey was led by Principal Zoologist Glen Gaikhorst and assisted by Senior Zoologist Robert Browne-Cooper, Ecologist Madison Roberts and Ecologist Lynnette Greer. The experience of these staff members are presented in Table 4.

Table 4 Personnel experience

Name	Years of experience	Role
Glen Gaikhorst	20+	Principal Zoologist
Robert Browne-Cooper	20+	Senior Zoologist
Madison Roberts	3	Ecologist
Lynnette Greer	2	Ecologist

The following methods were used in the targeted Ghost Bat survey:

- habitat and roost assessments;
- Insitu time lapse video cameras; and
- bat call surveys.

Each method is described below in sections 2.3.3-2.3.5. Figure 3 and Figure 4 displays the targeted search areas and methods used during the survey. Table 5 provides a summary of the survey methods and effort used during the survey (refer to Figure 3 and Figure 4). A helicopter was utilised over three days to extend survey effort and access locations that would otherwise be inaccessible.

Table 5 Survey methods and effort

Method	Sites	Effort
Habitat / roost assessment	20 sites within 23 targeted search areas	20 sites across approximately 1420 ha
Time lapse infrared camera	2 sites Cave ID CAV- 03 for 5 nights and CAV-09 for 4 nights	CAV- 03 for 4 nights and CAV-09 for 5 nights = 9 camera nights for 2 sites
Bat calls surveys (SM4 bat detector)	2 sites Cave ID (SC-01, SM4-1) 5 nights and Cave ID (CAV-09, SM4-6) 4 nights	SC-01 for 5 nights and CAV-09 for 4 nights = 9 detector nights for 2 sites (approximately 99 detector hours)

2.3.3 Survey limitations

EPA Technical Guidance –Terrestrial Fauna Surveys (EPA 2016a, 2016b) states fauna and faunal assemblage survey reports for environmental impact assessment in Western Australia should contain a section describing the limitations of the survey methods used. The limitations and constraints associated with the fauna component of this field survey are discussed in Table 6.

Table 6 Survey limitations

Limitations	Constraints	Impact on survey outcomes
Scope, were target species sampling methods not able to be employed due to constraints i.e. weather conditions?	Minimal	The Ghost Bat was the target species of this survey. The sampling method was able to be employed without constraint as demonstrated in the composite table of data in Results Section 4 and Appendix. Weather conditions were conducive to undertaking target bat survey/bat cave habitat assessment.
Seasonal environmental conditions	Minimal	The survey timing was in Autumn i.e. following the season of predicted maximum rainfall based on EPA guidelines. Bat survey including cave habitat assessments are not affected greatly by normal environmental conditions.
Proportion of fauna identified, recorded and/or collected	Nil	All fauna including target bat species and opportunistic general fauna were identified however a general fauna survey was not the objective of this survey.
Proportion of the task achieved and further work which might be needed	Minimal	The survey was successful and achieved in terms of adequate coverage. The use of helicopter enabled aerial reconnaissance of potential caves and efficient site coverage.
Remoteness and/or access problems	Nil	The survey areas were accessed on foot and vehicle. A helicopter was utilised over three days to extend survey effort and access locations that would otherwise be inaccessible.
Personnel experience	Minimal	The Zoologists involved in the survey both have substantial experience (both over 25 years) having each worked on at least ten target Ghost Bat surveys and bat cave habitat assessments involving survey method design, field survey, habitat assessment, and data analysis.

2.3.4 Habitat assessment

The habitat assessment was undertaken in accordance with the BHP fauna survey guidelines as outlined in section 2.1.1. Field data was collected via the ArcGis Online platform at Ghost Bat record sites and other locations as required to enable delineation and mapping of major Ghost Bat habitat types throughout the survey area. For the purposes of consistency, where appropriate, the habitat type names have been aligned with those of previous reports relevant to the survey area. Broad important habitat types within the survey were delineated by utilising existing mapping and infilling where required. Habitats were then mapped and described based on the following:

- location within study;
- landscape position;
- geomorphology, topography and substrate;
- photos of representative habitat types;
- vegetation description and dominant structure;
- values to Ghost Bat (e.g. refuge, foraging, shelter);
- ecological processes of importance;
- disturbances (weeds, fire, ground disturbance);
- wider extent and connectivity of habitat type based on previous mapping;
- comparison between broad habitat types; and
- evaluation of the likelihood of occurrence of Ghost Bat within the environments present (based on presence of suitable habitats and species recorded).

Caves identified as potentially suitable for Ghost Bat were first observed opportunistically while driving or traversing through the survey area, and then further investigated by foot where accessible. Outcrops not accessible by vehicle but considered to potentially contain caves were accessed by foot and searched thereafter. A helicopter was utilised over three days to extend survey effort and access location that would otherwise be inaccessible. Assessment of suitability for Ghost Bat included cave dimensions, the presence of guano and evidence of feeding. If possible, SongMeters and/or cameras were set at the mouths of caves to collect further evidence of cave use.

2.3.5 Roost categorisation

Unlike the Pilbara Leaf-nosed Bat, the roost habitats of the Ghost Bat are not yet formally categorised in current published guidance. The categorisation approach used here for Ghost Bat roost habitats is consistent with surveys undertaken to date by GHD for other mining projects in the Pilbara and considers the roosting requirements of the Ghost Bat as documented in Threatened Species Scientific Committee (2016). Potential roost records also follow a similar nomenclature however, cannot be definitively categorised due to the absence of some information (e.g. the roost structure appears to be suitable, however Ghost Bat are yet to be recorded in the roost).

Roost categories include:

- *Breeding roost* — evidence of occupation from early September through to mid-February by more than a few individuals. The roost may or may not be occupied all year round. Pregnancy in the Pilbara has been recorded in August and births occurred after late October (Douglas 1967 cited in Armstrong 2000). A study of the Ghost Bat in the Pilbara noted pregnant bats in September 1998 and young attached to the teat in November and December 1998 (Armstrong and Anstee 2000). Parturition occurs over a month commencing in mid-October

and juvenile bats commence flying at seven weeks with young capable of flight by the end of January (Toop 1985). Considered as critical habitat for both the daily and long-term survival of the Ghost Bat.

- *Diurnal roost with ongoing use* — evidence of occupation during different times of the year by one or more individuals however structure of roost unlikely to support breeding habitat requirements. Considered as critical habitat for both the daily and long-term survival of the Ghost Bat.
- *Diurnal roost with occasional use* — roost occasionally used at different times of the year for a few individuals. Structure of roost small and does not support breeding or large colony habitat requirements. Roost could facilitate dispersal in the region. Considered as important habitat for both the daily and long-term survival of the Ghost Bat. In addition to the structural aspect of the roost, an assessment of usage including evidence for feeding, scat deposits and/or presence of Ghost Bat should be used to categorise this roost type. Information including acoustic and visual data may also be required to understand ongoing usage.
- *Diurnal roost probably occasional use* — the structure (e.g. shape and size) may support diurnal roosting for a few individuals, however, insufficient evidence to provide definitive categorisation or cave could not be assessed due to presence of Ghost Bat individual. Further survey and monitoring is recommended to determine the type of diurnal roost.
- *Nocturnal/feeding refuge* — occupied or entered at night for resting, feeding or other purposes. Not considered critical habitat, but are important for persistence in a local area. Nocturnal refuge sites may also be shallow caves, or deeper overhangs that do not offer diurnal roosting opportunities.

2.3.6 Insitu infrared camera

In order to determine roost occupancy and gain an understanding of how diurnal roosts are used, black infrared time lapse video camera (Reconyx HS2X) were placed at known and potential roost sites for a period of three consecutive nights at each site (Figure 3 and Figure 4). Video and still imagery was reviewed following field surveys. Cameras were positioned on the cave floor and aimed at an area of cave ceiling located directly above Ghost Bat scat piles or feeding evidence. This was to maximise detection of bats at locations most frequently utilised by Ghost Bats.

2.3.7 Bat call survey and analysis

Bat calls were recorded during field surveys using in situ (stationary) full spectrum Song Meter (SM4 bat) detectors (Wildlife Acoustics). Detectors were set for a minimum of four consecutive nights at two location (Figure 3 and Figure 4) and programmed to record from 30 minutes pre-sunset to 30 minutes post-sunrise. Bat detectors were positioned at the entrance of known or potential diurnal roost sites. For each detector the time and date deployed and recovered, and the GPS coordinates were recorded.

Data from the bat detectors were downloaded to a computer and analysed for the presence of bat calls following the field survey by Craig Grabham (GHD). Data was processed and analysed using a combination of manual review and automated techniques using Kaleidoscope Pro (Wildlife Acoustic, version 5.1.9) and Anabat Insight (Titley Scientific, version 1.9.4). The analysis process consisted of the following steps:

1. Files were downloaded from the units and saved to external hard drive (back up copy) following the survey for later processing and analysis
2. Using the batch and signal parameter processing features in Kaleidoscope Pro compressed WAV files collected using the Song Meter units were split into 1 second standard WAV files for manual analysis

3. For each night, data was manually reviewed for bat calls using Kaleidoscope Pro viewer from sunset onwards for 1.5 hours by visually comparing the time-frequency graph (spectrogram) and call characteristics (e.g. peak frequency, characteristic frequency and call shape) with species call descriptions from published guidelines (e.g. Armstrong and Cole 2007; McKenzie and Bullen 2009; Guppy *et al.* 1985; Hourigan 2011)
4. Data was then processed using the cluster analysis feature in Kaleidoscope Pro to automatically scan and sort the recorded bat calls into groups of similar calls (clusters). Clusters were then manually reviewed and identified to species or species group
5. For comparison a portion of the data was also processed using customised filters in Anabat Insight for the Pilbara Leaf-nosed Bat and Ghost Bat. Further manual review of some data was completed for validation purposes to accurately identify species.

Call identification was assisted by consulting distribution information for potential species (Armstrong 2011; and McKenzie *et al.* 2009, 2012; Churchill 2008; Van Dyck *et al*. 2013) and records from Atlas of Living Australia (June 2020) and NatureMap (June 2020). No reference calls were collected during the survey, however a sample of calls including identified Ghost Bat calls were sent to recognised bat call analyst Kyle Armstrong for review.

A call (pass) was defined as a sequence of three or more consecutive pulses of similar frequency and shape with the exception of the Pilbara Leaf-nosed Bat where at least two clear pulses was acceptable. Calls with less than three defined consecutive pulses of similar frequency and shape were not unambiguously identified to a species but may be used as part of the bat activity count for the survey area. Due to variability in the quality of calls and the difficulty in distinguishing some species the identification of each call was assigned a confidence rating (see Mills *et al.* 1996 & Duffy *et al.* 2000) as summarised in Table 7.

Table 7 Confidence ratings applied to calls

Identification	Description
D - Definite	Species identification not in doubt.
PR - Probable	Call most likely to represent a particular species, but there exists a low probability of confusion with species of similar call type or call lacks sufficient detail.
SG - Species Group	Call made by one of two or more species. Call characteristics overlap, particularly poor quality calls or mixed species calls making it difficult to distinguish between species e.g. *Chaerephon jobensis* / *Saccolaimus flaviventris* *Taphozous georianus* / *Taphozous hilli* *Nyctophilus* sp. The calls of *Nyctophilus geoffroyi* / *daedalus* / *arnhemensis*.

The semi-automated analysis process does not always capture all 'softer' Pilbara Leaf-nosed Bat (those calls with a lower amplitude) and Ghost Bat calls and sometimes calls with few pulses. Noting these limitations the manual review of all files during step 3 of the analysis process for each night ensured no emergence or early calls were missed. It is also important to note that both the Pilbara Leaf-nosed Bat and Ghost Bat need to be in close proximity to the bat detector to be recorded. The Ghost Bat call in particular is of low intensity making it difficult to detect with a bat detector therefore ultrasonic surveys should not be the primary means of surveying for this species.

3. Desktop assessment

3.1 Ecology of the Ghost Bat

The Ghost Bat (*Macroderma gigas*) is listed as Vulnerable under the EPBC Act and BC Act.

3.1.1 Morphology

The Ghost Bat (family Megadermatidae) is the largest microchiropteran in Australia and one of the largest in the world. Distinguishing factors include pale grey or light brown fur with a lighter coloured belly. The colour of individuals tends to be paler in the more inland populations. Wing membranes are pale cream to brown and the species lacks a tail but retains a full tail membrane. Large ears are joined above the head and the tragus is forked. Eyes are large and a long simple-shaped noseleaf extends along the top of the muzzle (Churchill 2008).

3.1.2 Distribution and habitat

The distribution of Ghost Bat ranges from the Pilbara and Kimberley regions of Western Australia, through the Top End and Gulf Fall country of the Northern Territory, to parts of northern Queensland (Churchill 2008; Woinarski *et al.* 2014). Once distributed throughout most of the continent, it declined in the Holocene and further after European settlement, and now exists as a group of geographically and genetically isolated populations across northern Australia (Molnar *et al.* 1984, Churchill and Helman 1990; Worthington Wilmer *et al*. 1994, 1999). While it shows some variation in morphology and fur colour across its range (Douglas 1962; Hand and York 1990), it does not contain any recognised subspecies (Simmons 2005). An isolated population is persisting in the Pilbara region, and is sensitive to disturbance (Van Dyck and Strahan 2008).

The Ghost Bat inhabits Pilbara ironstone formations with relatively deep caves and iron ore exploration adits, as well as granite boulder rockpiles and disused underground gold and copper mines in the granite-greenstone terrain of the eastern Pilbara (Armstrong and Anstee 2000). They prefer warm, humid roost microclimates, especially when breeding, because of a limited ability to maintain heat and water balance in drier conditions, and are unable to enter torpor (Leitner and Nelson 1967; Churchill 1991; Armstrong and Anstee 2000; Baudinette *et al.* 2000).

Roost sites used permanently are generally deep natural caves or disused mines with a relatively stable temperature of 23°C − 28°C and a moderate to high relative humidity of 50 − 100 percent (Pettigrew *et al.* 1986; Churchill & Helman 1990; Churchill 1991; Armstrong & Anstee 2000). Deeper caves and mines that can support these conditions are relatively uncommon, which limits roosting opportunity, area of occupancy, and results in aggregations in relatively few subterranean structures. Small numbers or individual Ghost Bats are sometimes encountered in smaller caves, with drier or cooler microclimates (Armstrong and Anstee 2000; Woinarski *et al.* 2014).

3.1.3 Diet and foraging

Ghost Bats are carnivorous (flesh eating) and insectivorous (insect eating) and have been recorded eating birds, bats, small mammals, frogs, geckos and a variety of insects (Churchill 2008). Claramunt et al. (2019) found 46 vertebrate taxa were identified from the analysis of the faecal pellets from the Pilbara. Of the 46 taxa, nine species of microbat were identified including species known to co-habit caves with the Ghost Bat (Start *et al.* 2019; Claramunt *et al.* 2019).

Ghost Bats are known to return to their roost with their food and drop the less palatable portions (beaks, feet etc.) on the ground. They use several techniques to capture prey including active hunting with echolocation, passive sit-and-wait hunting using eyesight, and passive hearing. They use what is called ‘whispering’ echolocation to avoid alerting their potential prey.

3.1.4 Breeding

Females give birth to a single young, and most females breed by two years of age (Hoyle et al. 2001). In the Pilbara parturition occurs over a month commencing in mid-October, and young can be shifted to other caves as caves become warmer as summer progresses. Juvenile bats commence flying at seven weeks with all young capable of flight by the end of January (Toop 1985). Generation time is estimated at 8 years (Woinarski *et al*. 2014).

In the Pilbara, most known breeding sites of the ghost bat are confined to underground gold/copper mines that are now collapsing or being open cut, and to caves in banded ironstone strata that may be mined out over the next 30−50 years. On current trends, most of its Pilbara roost sites may be destroyed over the next 30 years (Woinarski *et al.* 2014).

3.2 Review of previous surveys

As part of the desktop assessment fauna survey reports of spatial relevance to the survey area were provided by BHP. These reports have been reviewed and their findings summarised in Table 8 and Table 9.

3.2.1 Previous records

Previous historical records and caves within 40 km radius of the survey area where reviewed prior to the survey. These historical record locations are presented in Figure 2, Appendix A. Two (Biologic 2019) sites investigated were outside the targeted search area (CAV-20 and CAV-10). CAV-06, 07 and 08 were also previously known (Biologic 2019) and were assessed in this current assessment.

A known cave (SC-01) was also investigated within the survey area that was assessed previously by GHD (GHD 2019a).

Table 8 Summary of previous fauna studies

Name of survey	Jimblebar Hashimoto Vertebrate Fauna Assessment	Jimblebar Iron Ore Project Terrestrial Vertebrate Fauna Assessment	Caramulla level 1 Flora and Vegetation Survey and Fauna Assessment	Jimblebar Iron Ore Project Bat Survey and Assessment	Wheelarra Hill North Fauna Assessment ENV Australia	Caramulla Level 1 Vertebrate Fauna Assessment	Jimblebar North Level 1 vertebrate fauna survey report	Jimblebar East and Caramulla Fauna Survey	North Jimblebar Fauna Survey
Consultant	Ecologia (2006)	Outback Ecology (2009)	GHD (2009)	Specialised Zoological (2009)	ENV (2012)	Biologic (2018)	Onshore (2019)	GHD (2019a)	GHD (2019b)
Level of experience of consultant	Senior personnel had specific training and had undertaken at least 15 Pilbara surveys	Survey team were fauna specialists with many years' experience undertaking fauna surveys of this kind in WA	Combined total of 6+ years of fauna survey experience	Dr Kyle Armstrong – over 10 years experience undertaking bat survey and assessment including target species	Level 2 surveys included practitioners that were regarded as suitably qualified in their respective fields	Combined total of 10+ years of fauna survey experience in the Pilbara	Single season Level 1	Combined total of 20+ years of fauna survey experience in the Pilbara	Combined total of 50+ years of fauna survey experience in the Pilbara
Location of survey in relation to this survey	Partial overlap with targeted search areas	Partial overlap with targeted search areas	Located east of the targeted search areas	Located in between targeted search areas	Overlaps with most of the targeted search areas	Located east of the targeted search areas	Small area partially overlaps with targeted search areas	Overlaps with most of the targeted search areas	Overlaps with most of the targeted search areas
Dates of survey	26/8-16/9/2005, 6-15/2/2006	4-15/6/2008, 27/9-3/10/2008	1-8/12/2008	6-11/05/2008	7-18/4/2011 4-13/10/2011	17-21/2/2018	12-17/9/2018	29/04/2019-10/05/2019	29/04/2019-10/05/2019
Summary of relevant survey techniques and survey effort	975 minutes bat recordings (Anabat) from 5 sites	None – includes review of previous efforts including Specialised Zoological (2009) Jimblebar Iron Ore Project Bat Assessment	Opportunistic visual and aural survey – Level 1 habitat assessment	Targeted surveys including 7 day traverse for roost habitat, 2 night traverse with detector, 3 video sessions for emergence surveys (include Hashimoto and Adit 2), 1 sheeting session of Hashimoto adit, 4 harp trap sessions (include Hashimoto and Adit 2), 15 nights Anabat detector for 15 sites	12 hrs nocturnal spot lighting. Bat acoustic detectors (SD1 and SM2) set for one or two nights at 5 locations and searches for caves suitable for bat roosts	Target habitat searches (9 hr), remote pilot drone searches (1.5 hrs). 12 SM4 bat detectors at 6 sites for 2 nights/site for total of 12 recording nights.	Targeted habitat searches, SM4 (locations throughout study area) – effort not documented	Targeted habitat searches, 510 minutes of night searches, 28 nights of Bat detection, 1000 minute of additional active search effort	Targeted habitat searches, 120 minutes of night searches, 10 nights of Bat detection
Conservation significant bat species recorded during survey/ type of evidence / location	Ghost Bat and Pilbara Leaf-nosed Bat calls recorded from mine adit (Site 2) close to Jimblebar Creek. Ghost Bat also observed foraging during surveys (site 4). Site 2 records subsequently determined to be erroneous based on a later study (Specialised Zoological 2009).	None reported form field survey	None reported from field survey	No Ghost Bat or Pilbara Leaf-nosed Bat positively recorded.	None reported from field survey	None reported from field survey	None reported from field survey	Ghost Bat **Cave ID FJ 1** - Partial feeding remains present within an overhang of numerous small birds, mainly Budgies. **Cave ID FJ 2** – Approx. 70 m from feeding overhang is potential roost cave which could not be investigated safely. **Cave ID SC1** – potential day roost, no evidence of current use. **Cave ID SC2** -	Ghost Bat **Cave ID NJ2** – approx. 15 old Ghost Bat Scat, potential day roost. **Cave ID NJ3** – approx. 5 old possible Ghost Bat scat, potential day and feeding roost **Cave ID NJ4** – approx.. 4-5 old possible Ghost Bat scat, potential day and feeding roost

Name of survey	Jimblebar Hashimoto Vertebrate Fauna Assessment	Jimblebar Iron Ore Project Terrestrial Vertebrate Fauna Assessment	Caramulla level 1 Flora and Vegetation Survey and Fauna Assessment	Jimblebar Iron Ore Project Bat Survey and Assessment	Wheelarra Hill North Fauna Assessment ENV Australia	Caramulla Level 1 Vertebrate Fauna Assessment	Jimblebar North Level 1 vertebrate fauna survey report	Jimblebar East and Caramulla Fauna Survey	North Jimblebar Fauna Survey
								Day roost and potential breeding roost. Large deposit of fresh scat recorded.	
Survey and report limitations	No significant survey limitations highlighted in report. No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)	No significant survey limitations highlighted in report.	No limitations listed or addressed in report. Level 1 survey – targeted bat survey techniques not required	No significant survey or report limitations.	No significant limitations highlighted in report No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)	No significant limitations highlighted in report. No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)	Poor seasonal conditions noted for the survey timing in September 2018. No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)	No significant limitations highlighted in report	No significant limitations highlighted in report.

Table 9 Summary of previous fauna studies (continued)

Name of survey	Orebody 31 Fauna Assessment	Orebody 19 Level 2 Vertebrate Fauna Survey	Orebody 31 Vertebrate Fauna Survey	OB31 Jimblebar Access Track VCP Level 1 Flora & Vegetation Survey and Vertebrate Fauna Assessment	Caramulla Level 1 Vertebrate Fauna Assessment	Shearer's West Targeted Vertebrate and Short-range Endemic Invertebrate Fauna Assessement
Consultant	env Australia (2011)	Biologic (2014)	Biologic (2014)	Onshore Environmental (2015)	Biologic (2018)	Biologic (2019)
Level of experience of consultant	Not specified	Combined total of 30+ years experience in the Pilbara region	Combined total of 70+ years experience in the Pilbara region.	11+ years experience as a Zoologist	Combined total of 10+ years of fauna survey experience in the Pilbara	Combined total of 14+ years experience in the Pilbara region
Location of survey in relation to this survey	Orebody 31	Orebody 19 located west of targeted search areas	Orebody 31	Adjacent west of Jimblebar Creek	Adjoins the southern edge of the current survey area	Shearer's West Tenement
Dates of survey	28/02/2011-2/03/2011 and 29/03/2011-1/04/2011	24/05-6/06/2013 and 27/08-6/09/2013	28/02/2011-2/03/2011 and 2-11/10/2013 and 2-6/12/2013	15-16/07/2015	17-21/2/2018	29/04/2019-4/05/2019
Summary of relevant survey techniques and survey effort	Not specified. 7 days total of Level 1 assessment.	48 detector nights using SM2Bat+ detectors (32 nights phase 1, 16 nights phase 2) over 24 locations. Nocturnal surveys, habitat assessments (45 sites)	28 nights of Bat detection, targeted searches throughout survey area, 4 nights of nocturnal searching throughout survey area.	Two person days of targeted transects and opportunistic observations over the survey area.	Target searches (9 hr), remote pilot drone searches (1.5 hrs). SM4 bat detectors at 6 sites for 2 nights/site.	9 nights of Bat detection, targeted searches at most prospective areas in terms of habitat features
Conservation significant bat species recorded during survey/ type of evidence / location	None reported form field survey	Ghost Bat - historical evidence of scat in the form of a c. 50 cm high stalagmite at cave 'obcave3'. The scat was completely decayed and combined into a solid mass. Cave approximately 30 m deep with other bat species present. Likely used by Ghost Bats historically but not in recent times. Seven other sites were classified as potential feed roosts.	None reported from field survey	None reported from field survey	None reported from field survey	None reported from field survey One potential Ghost Bat roost however no evidence of usage or occupation reported.
Survey limitations/ Report limitations	No significant limitations highlighted in report	No significant limitations highlighted in report. No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)	No significant limitations highlighted in report No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)	Report describes cold weather during the survey as affecting reptile activity/detection	No significant limitations highlighted in report No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)	No significant limitations highlighted in report No information available regarding call analysis method or results (e.g. bat call activity or species for each detector site)

4. Survey results

4.1 Habitat assessment

Studies undertaken on Ghost Bat foraging has found that the species will move up to 12 to 15 km from a roost cave to hunt, but most commonly on average only 5 to 6 km to adequate foraging habitat (Bob Bullen pers. comm.). In these studies the most common foraging habitat type included major drainagelines and associated habitat including triodia plains and mulga woodlands that are *Triodia* dominant (Chris Knuckey pers. comm.). Churchill (2008) records gorge, gully and major drainagelines as forgaging habitat for the species. Therefore based on current data Ghost Bat foraging habitat within the survey area (Figure 5 and Figure 6) consists of;

- Major Drainagelines
- Plains (Sand and Stony)
- Mulga Woodland
- Breakaway/ Cliff, Hillcrest/Hillslope
- Gorge/Gully.

These foraging habitats are well-represented in the surrounding area. Suitable roosting habitats within the survey area consist of Breakaway/ Cliff, Hillcrest/Hillsope and Gorge/Gully habitats as they contain caves and overhangs.

4.2 Roost assessment

GHD investigated more than 57 locations (e.g. slopes, gorges and breakaways or cliffs at the tops of ridges or plateaus) on foot and/or by helicopter when undertaking searches for potential day/diurnal roost habitat. Twenty sites were recorded with known or potential diurnal roosting habitat or nocturnal/feeding refuge for Ghost Bat. Figure 5 and Figure 6, Appendix A displays each of the 20 sites described in Table 10 and Table 11 and habitat types. Figure 7, Appendix A displays the Ghost Bat observations. Table 12 display photographs for each site. Summary of key survey results regarding roosting habitat:

- Five of the 20 sites investigated were confirmed as day roosting sites for the Ghost Bat.
  - SC-01 - categorised as *Diurnal roost ongoing use*. Located approximately 6 km south east of the Jimblebar mining area (see Plate 1) is a confirmed day roost as one Ghost Bat was flushed from the roost during survey. The Ghost Bat was observed to fly from within this cave into CAV-19 approximately 200 metres east of SC-01. Furthermore, large amounts of scats (scat count approximately 300) and previous records of occupation justifies this categorisation.
  - CAV-09, CAV-11, CAV-12, CAV-16 - categorised as *Diurnal roost occasional use*. Evidence of Ghost Bat usage included scats and feeding evidence was recorded at each roost. The structure of each roost (e.g. shape and size) was suitable for diurnal roosting.
- Eight of the 20 sites investigated were deemed *potential Diurnal roost, probably occasional* use (CAV-04, 13, 14, 15, 17, 18, 19 and 21). The structure (e.g. shape and size) may support diurnal roosting for a few individuals, however there was insufficient evidence to provide definitive categorisation. A detailed habitat assessment was not carried out at CAV-19 in order to avoid further disturbance to the Ghost Bat in this cave. Further survey and monitoring is recommended for CAV-19 to determine the type of diurnal roost.
- Three of the 20 sites were categorised as *nocturnal/ feeding refuge* (CAV-06, 07 and 20).

- Two of the 20 sites investigated were outside the targeted search area. One cave (CAV-20) investigated was a potential feeding refuge and re-check from a previous survey (Biologic 2019) however no evidence of Ghost Bat was found. The other site (CAV-10) was an old mine adit observed from the helicopter. There was no evidence of Ghost Bat at this cave however two *T. georgianus* were present.
- One other site (CAV-02) was categorised as potential *Diurnal roost* (unknown type) because the habitat assessment determined the roost has potential for the Pilbara Leaf-nosed Bat. It is unlikely that this roost provides ongoing diurnal refuge for the Ghost Bat, however the structural characteristics and microclimate may provide day roosting (albeit transitory) for the Pilbara Leaf-nosed Bat. There was no secondary evidence of Pilbara Leaf-nosed Bat at CAV-02 at the time of the survey.

Table 10 Summary of cave habitat assessment (Caves SC-01 and CAV-02 to CAV-11)

Cave ID	CAV-02	SC-01	CAV-04	CAV-05	CAV-06	CAV-07	CAV-08	CAV-09	CAV-10	CAV-11
Site ID	JB-02	JB-03	JB-04	JB-05	JB-06	JB-07	JB-08	JB-09	JB-10	JB-11
Roost Type	Potential diurnal roost (unknown type)	Diurnal roost ongoing use	Potential diurnal roost, probably occasional use	Potential diurnal roost, probably occasional use	Potential nocturnal/ feeding refuge	Potential nocturnal/ feeding refuge	No signs of GB evidence present	Diurnal roost occasional use	No signs of GB evidence present.	Diurnal roost occasional use
Date cave assessed	29/05/2020	26/05/2020	27/05/2020	26/05/2020	30/05/2020	30/05/2020	30/05/2020	27/05/2020	28/05/2020	28/05/2020
Cave Position	Upper Slope	Upper Slope	Mid Slope	Upper Slope	Upper Slope	Upper Slope	Upper Slope	Mid slope	Mid Slope	Upper Slope
Floor slope	Flat	Incline	Flat	Flat	Flat	Flat	Flat	Incline	Flat	Incline
Aspect	West	North/East	North	North/ West	South/East	South/East	South/East	South	North/ West	East
Cave Exposure	Semi Exposed	Exposed	Sheltered	Semi Exposed	Semi Exposed	Semi Exposed	Sheltered	Sheltered	Semi Exposed	Semi Exposed
Entrance Type	Overhang	Overhang	Cavern	Cavern	Overhang	Cavern	Cavern	Overhang	Cavern	Overhang
Entrance Shape	Round/Oval	Horizontal	Horizontal	Round/ Oval	Horizontal	Round/Oval	Horizontal	Round/Oval	Vertical	Horizontal
Entrance Width (m)	10	2	7	6	4	3	2	1.2	1.2	7
Entrance Height (m)	2	1	2	2	1	1	1	0.7	1.5	4

Cave ID	CAV-02	SC-01	CAV-04	CAV-05	CAV-06	CAV-07	CAV-08	CAV-09	CAV-10	CAV-11
Cave Depth (m)	3	5	12	15	4	8	5	13	15	16
Number of Chambers	2	1	1	1	1	1	1	1	1	3
Height of highest chamber (m)	1	3.5	2.5	2.5	3	1.6	0.9	3	1.5	5
Temperature Entrance	22°C	11°C	21°C	18	-	-	-	15°C	12°C	14
Temperature Back	25°C	27.4°C	28°C	22	-	-	-	29.1°C	23°C	20
Humidity Entrance	50%	30%	38%	28%	-	-	-	0%	30%	30
Humidity Back	60%	67%	-	35%	-	-	-	71%	50%	45
Humidity Roost 1	-	67%	1	-	1	1	1	70%	-	
Light Entrance	1	1	0	1	0	0	0	1	1	1
Light Back	0	1	2	1	1	1	1	1	0	0

Cave ID	CAV-02	SC-01	CAV-04	CAV-05	CAV-06	CAV-07	CAV-08	CAV-09	CAV-10	CAV-11
Water present internal	No	No	None	No	None	None	None	No	No	None
Water present external	No	No	None	No	None	None	None	No	No	None
GB Scat Count	0	300	0	0	0	0	0	15	0	10
Count/ estimate	count	estimate	Count	count	Count	Count	Count	count	count	Count
Scat Age	No scat	Fresh to very old	No scats	No scat	No scats	No scats	No scats	Fresh (<1 month)	No scat	Old (6 mths to 3 yrs)
Evidence of use/ occupation	No evidence of GB, potential for Pilbara Leaf-nosed Bat (PLNB). Potential occasional use for GB. Other micro bat scats present	1 GB flew out of cave and sheltered in CAV-19 (approx 200 m east). Bat detector SM4-1	Revisit from 2019. Light penetrates to back of cave. Likely a feeding refuge but opportunistic ally used	No signs of GB evidence present. Historical record of GB scats from 2019. 3 x *T. georgianus* present. Light present in main chamber	Revisit from 2019. No evidence of use apart from some scattered old feathers, did not appear GB. Lots of Euro scat. Historical record of GB scats from 2019.	Revisit from 2019. This cave lacks internal structure to support long term GB roosting. Potential use for feeding refugia but no evidence was present to support	Revisit from 2019. This cave lacks internal structure to support long term GB roosting. Potential use for feeding refugia but no evidence was present to support	Up to 5 x *V. finlaysoni* seen flying. Dark, high ceiling with extra crevices. Potential PLNB. SM4-6, entrance and insitu camera set up outside.	Old mine adit no GB present 2 x *T. georgianus* present	Scattered scats, old, lots euro, monitor, and echidna. Feeding and roost of owl, lots of pellets.

Cave ID	CAV-02	SC-01	CAV-04	CAV-05	CAV-06	CAV-07	CAV-08	CAV-09	CAV-10	CAV-11
						this. Historical record of GB scats from 2019.	this. 1 x microbat heard. Very low ceiling in chamber			
Monitoring / notes	Yes – monitor, consider further for PLNB	Yes - monitor	No	No	No	No	No	Yes - monitor	No	

Table 11 Summary of cave habitat assessment (Caves CAV-12 to CAV-21)

Cave ID	CAV-12	CAV-13	CAV-14	CAV-15	CAV-16	CAV-17	CAV-18	CAV-19	CAV-20	CAV-21
Site ID	JB-12	JB-13	JB-14	JB-15	JB-16	JB-17	JB-18	JB-19	JB-20	JB-01
Roost Type	Diurnal roost occasional use	Potential diurnal roost, probably occasional use	Potential diurnal roost, probably occasional use	Potential diurnal roost, probably occasional use	Diurnal roost occasional use	Potential diurnal roost, probably occasional use	Potential diurnal roost, probably occasional use	Potential diurnal roost, probably occasional use	Potential nocturnal/ feeding refuge	Potential diurnal roost, probably occasional use
Date cave assessed	28/05/2020	29/05/2020	30/05/2020	26/05/2020	26/05/2020	26/05/2020	27/05/2020	26/05/2020	30/05/2020	27/05/2020
Cave Position	Mid Slope	Mid Slope	Mid Slope	Upper Slope	Upper Slope	Upper Slope	Mid slope	Upper Slope	Upper Slope	Upper Slope
Floor slope	Incline	Flat	Incline	Flat	Flat	Flat	Flat	Flat	Flat	Incline
Aspect	North/ West	North/ West	West	East	East	East	South	South/West	West	South/ West
Cave Exposure	Semi Exposed	Semi Exposed	Sheltered	Semi Exposed	Semi Exposed	Semi Exposed	Semi Exposed	Sheltered	Exposed	Semi Exposed
Entrance Type	Overhang	Cavern	Cavern	Overhang	Overhang	Cavity	Overhang	Cavity	Cavity	Cavern
Entrance Shape	Horizontal	Horizontal	Vertical	Horizontal	Horizontal	Round/Oval	Round/Oval	Horizontal	Horizontal	Round/Oval
Entrance Width (m)	8	1	1.6	5	2	3	6	2	7	5

Cave ID	CAV-12	CAV-13	CAV-14	CAV-15	CAV-16	CAV-17	CAV-18	CAV-19	CAV-20	CAV-21
Entrance Height (m)	1.8	6	2	2	1.5	2	3	1	1.4	4
Cave Depth (m)	12	15	22	6	4	5	7	-	5	15
Number of Chambers	1	2	2	2	2	2	2	-	1	1
Height of highest chamber (m)	4	3.5	4	5	1.5	4	3	-	2.5	5
Temperature Entrance	22.5	14	24.2	15°C	11	15°C	12°C	-	16	18°C
Temperature Back	26.6	26.3	28.4	15°C	21	15°C	14°C	-	15	25°C
Humidity Entrance	34	31	34	-	0	0%	0%	-	25	-
Humidity Back	44	83	72	0%	40	0%	10%	-	34	60%
Humidity Roost 1				-	45	-	-			-
Light Entrance	1	1	1	1	1	1	1	-	1	1
Light Back	1	0	0	0	1	0	0	-	0	0

Cave ID	CAV-12	CAV-13	CAV-14	CAV-15	CAV-16	CAV-17	CAV-18	CAV-19	CAV-20	CAV-21
Water present internal	None	None	None	No	None	No	No	None	None	No
Water present external	None	None	None	External within 50 m	None	External within 50 m	No	None	None	No
GB Scat Count	10	0	0	0	2	0	0	0	0	0
Count/ estimate	Count	Count	Count	count	Count	count	count	Count	Count	count
Scat Age	Old (6 mths to 3 yrs)	No scats	No scats	No scat	Old (6 months to 3 years)	No scat	No scat	No scats	No scats	No scat
Evidence of use/ occupation	Some old feathers and scat, only opportunistic use or used for feeding	No GB evidence. Good cave, may lack large dome roof cavity, good temp and humidity	Chamber to back of cave maybe too small for GB to enter, great cave internally for GB. Pitch black but no evidence of use	Chamber 1 - only dark last meter but could still see faintly with human eye. Other chamber 1.5 m high and quite light	Foraging evidence (feathers), no guano. Small size entrance allowing some additional light	Foraging evidence (owl pellets) in one cave, (series of 3 caves). No other evidence of GB. High and narrow chambers but relatively small	*T. georgianus* scat present, feathers present, established owl roost at entrance. Dark inside but not pitch black, crevice at the back about 2	The GB from SC-01 flew into this cave however a thorough assessment of this cave was not conducted due to it already being disturbed	Revisit Biologic 2019 cave. Potential feeding refuge with opportunistic use only Receives too much light during the day.	Few scattered feathers (GB forage). *T. georgianus* present, Olive Python scat

Cave ID	CAV-12	CAV-13	CAV-14	CAV-15	CAV-16	CAV-17	CAV-18	CAV-19	CAV-20	CAV-21
							m in height which is pitch black.			
Monitoring / notes	No	No	Yes - monitor	No	No	No	No	Yes - monitor	No	Wooden artefact (significant heritage site). Do not monitor

Table 12. Representative photos for each site

Cave ID	Pictures	
CAV-21		
CAV-02		
SC-01		
CAV-16		

Cave ID	Pictures	
CAV-05		
CAV-15		
CAV-17		
CAV-18		
CAV-09		

Cave ID	Pictures	
CAV-10		
CAV-11		
CAV-12		
CAV-13		

Cave ID	Pictures	
CAV-14		
CAV-06		
CAV-04	No image available	
CAV-07		
CAV-08	No image available	
CAV-19		

4.3 Review of camera data

No Ghost Bats were recorded using this method.

4.4 Bat call analysis

Nine survey nights recording approximately 11 hours each night recorded 5563 full spectrum WAV files (all sites all nights combined). Six species were positively identified (Definite) of the 15 or so species that are known to occur from the locality of the study area. As many as two other species may also have been recorded, but poor data quality and/or interspecific call similarities precluded reliable identification of additional species.

The Ghost Bat was recorded at each site during the survey. However, the time of the first Ghost Bat call for each night was recorded at least 1 hour past sunset and the time of the last call recorded was at least 2 hours before sunrise. The absence of calls over consecutive nights during the emergence period indicates that Ghost Bats were not occupying the roost during the time of the survey. Furthermore the number and frequency of calls recoded throughout the night suggests that each site was regularly visited by Ghost Bats during the survey (see Table 13 and Chart 1).

Table 14 and Table 15 provides a list of definite and probable species recorded for each night. Plate 1 provides an example spectrogram for echolocation call of Ghost Bat identified as a result of call analysis.

Table 13 Summary of first species/Ghost Bat calls for each night per detector per site

Site/ unit / date	Time first Ghost Bat call	Time last Ghost Bat call
SC-01 / SM4-1 26-27/5/20	9:50 pm	1:20 am
SC-01 / SM4-1 27-28/5/20	7:55 pm	-
SC-01 / SM4-1 28-29/5/20	10:41 pm	4:28 am
SC-01 / SM4-1 29-30/5/20	7:53 pm	1:29 am
SC-01 / SM4-1 30-31/5/20	9:16 pm	10:54 pm
CAV-09 / SM4-6 27-28/5/20	12:45 am	-
CAV-09 / SM4-6 28-29/5/20	9:27 pm	4:06 am
CAV-09 / SM4-6 29-30/5/20	-	-
CAV-09 / SM4-6 30-31/5/20	10:41	12:59 am

Note: Sunset time for the survey period c. 5:20 pm, Sunrise time for the survey period c. 6:32 am. Source: TimeandDate.com for Jimblebar - https://www.timeanddate.com/sun/@2069071?month=5&year=2020

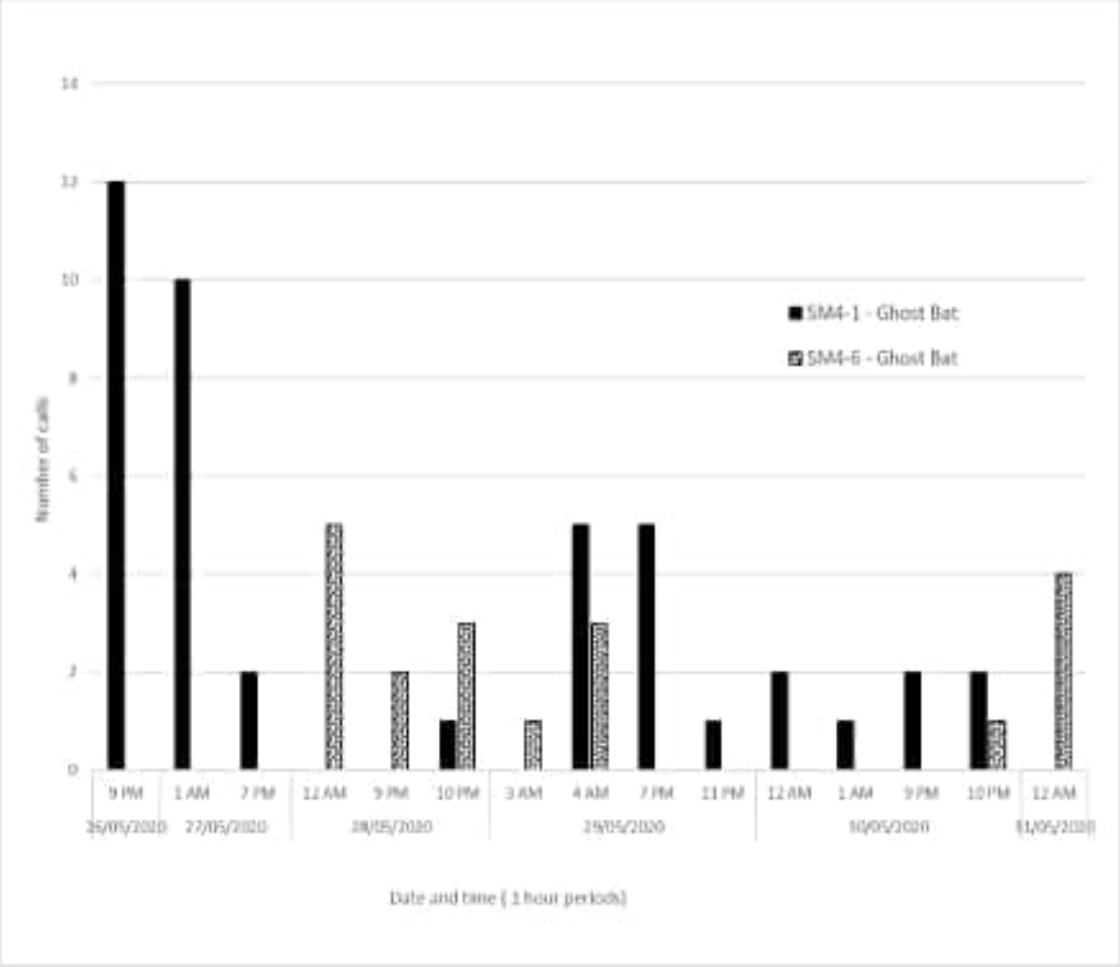


Chart 1 Number of Ghost Bat echolocation calls recorded per hour for each night for each detector site (SM4-1, SC-01 and SM4-6, CAV-09). Note: periods of time without data removed.

Table 14 Bat call analysis results for SC-01 (SM4 unit 1)

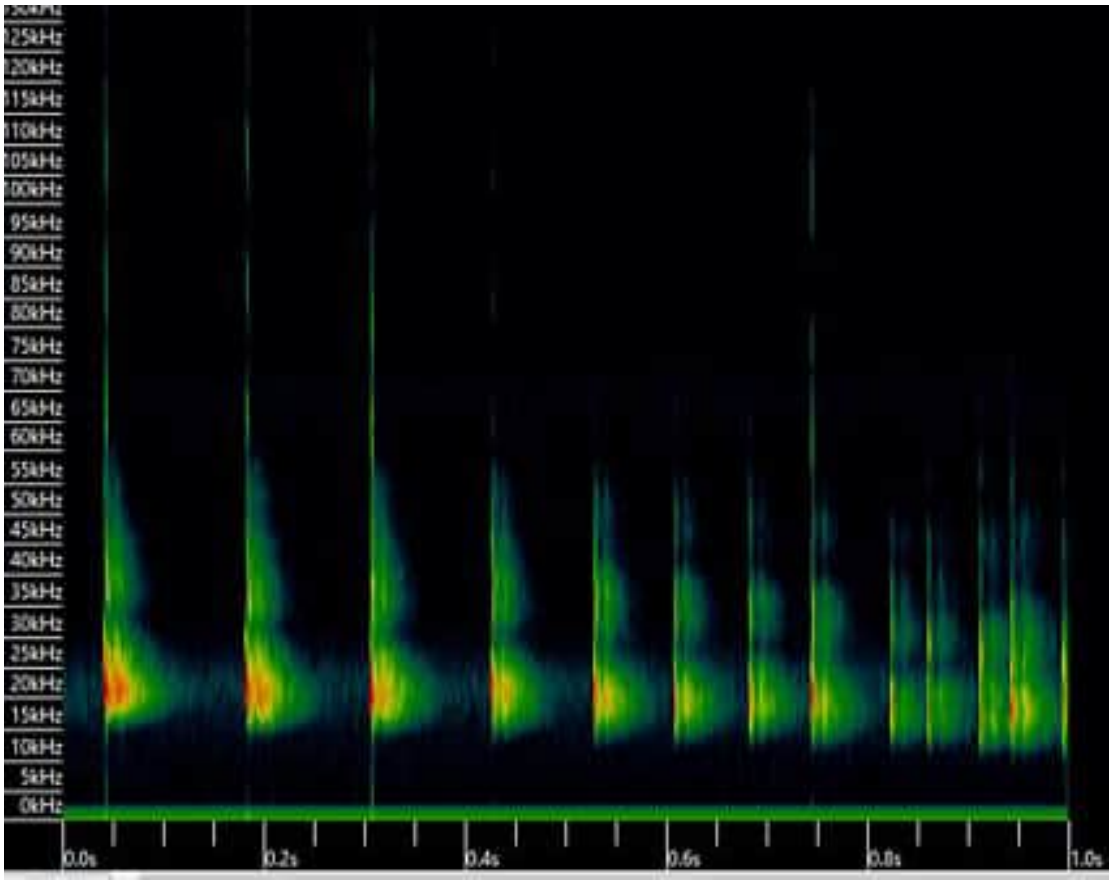
Species/ Species Group	SC-01 (SM4-1)				
	26-27/05/20	27-28/05/20	28-29/05/20	29-30/05/20	30-31/05/20
Austronomus australis	D	D	D	D	D
Chalinolobus gouldii	D	-	D	D	D
Macroderma gigas (Vu v)	D	D	D	D	D
Scotorepens greyii	-	D	D	D	D
Taphozous georgianus	D	D	D	D	D
Vespadelus finlaysoni	D	D	D	D	D
Austronomus australis/ Saccolaimus flaviventris	SG	SG	SG	SG	SG
Macroderma gigas/ Taphozous georgianus	SG	SG	SG	SG	SG
Number of species	5	5	6	6	6

Table 15 Bat call analysis results for CAV-09 (SM4 unit 6)

Species/ Species Group	CAV-09 (SM4-6)			
	27-28/05/20	28-29/05/20	29-30/05/20	30-31/05/20
Austronomus australis	D	D	D	D
Chalinolobus gouldii	-	D	D	-
Macroderma gigas (Vu v)	D	D	PR	D
Scotorepens greyii	D	D	D	D
Taphozous georgianus	D	D	D	-
Vespadelus finlaysoni	D	D	D	D
Austronomus australis/ Saccolaimus flaviventris	SG	SG	SG	SG
Macroderma gigas/ Taphozous georgianus	SG	SG	SG	SG
Number of species	5	6	5	4

Table Notes: Total number of species recorded for each night/site is based on definite (D) identification only. See Table 1 for confidence rating e.g. D, PR or SG. Vu – species listed as Vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*. v - species listed as vulnerable under the *WA Biodiversity Conservation Act 2016*

Plate 1 Example spectrogram for echolocation call of a Ghost Bat identified as a result of call analysis 27/5/2020.



5. Discussion

5.1 Summary of key survey findings

GHD investigated 57 locations resulting in 20 sites recorded with known or potential diurnal roosting habitat or nocturnal/feeding refuge for Ghost Bat. Of the 20 sites five were confirmed as day roosting sites for the Ghost Bat. No breeding roosts were recorded during this survey. Given the level of survey effort and previous surveys completed in the study area, it is unlikely that any additional significant roosts (e.g. breeding or other diurnal roosts) occur within the targeted search areas. Information gathered from the literature review and recent surveys was used in the categorisation process for each site:

- SC-01 - categorised as *Diurnal roost-ongoing use.* One Ghost Bat was flushed from the roost during the May 2020 survey and evidence of occupation during the surveys undertaken by GHD May of 2019 (e.g. large scat pile containing recent and older scats) was recorded. This information in addition to the historical record supplied by BHP (unknown source) at this site demonstrates ongoing usage of the roost. Bat call surveys were also undertaken for five consecutive nights during May 2020 and although the Ghost Bat was recorded the timing and frequency of calls suggests the species was not occupying the roost habitat during the day during the survey period. Furthermore, the structure of the roost is unlikely to support breeding habitat requirements.
- CAV-19 – categorised as *Diurnal roost probably occasional use*. The Ghost Bat from SC-01 was flushed into this site. A detailed habitat assessment was not carried out in order to avoid further disturbance to the Ghost Bat therefore further survey and monitoring is recommended for CAV-19 to determine the type of diurnal roost. Other caves categorised as *Diurnal roost probably occasional use* are CAV-04, CAV-05, CAV-13, CAV-14, CAV-15, CAV-17, CAV-18, CAV-19 and CAV-21.
- CAV-09, CAV-11, CAV-12, CAV-16 - categorised as *Diurnal roost-occasional use.* Evidence of usage in the form of scats and feeding evidence and favourable roost structure for each site supports the categorisation of these caves as diurnal roost habitat for the Ghost Bat. However the evidence recorded did not support ongoing use . Bat call surveys were also undertaken for four consecutive nights during May 2020 at CAV-09 and although the Ghost Bat was recorded the timing and frequency of calls suggests the species was not occupying the roost habitat during the day during the survey period. Furthermore, the structure of these roosts is unlikely to support breeding habitat requirements.
- Three of the 20 sites were categorised as *potential nocturnal/ feeding refuge* (CAV-06, 07 and 20).

During the development of this report, GHD received correspondence from BHP regarding Ghost Bat survey effort and records for the area known as Orebody 19. The report written by Biologic (2014) noted historical evidence of scat in the form of a c. 50 cm high stalagmite at cave ‘obcave3’. The scat was completely decayed and combined into a solid mass. The cave was reported to be approximately 30 m deep with other bat species present. It is likely that this cave was used by Ghost Bats historically but not in recent times. In addition, seven other sites were classified as potential feed roost with no evidence (e.g. bat, scat or feed remains) recorded. Cave ‘obcave3’ is located approximately 15.2 km west of CAV-09 and 22.8 km north-west of SC-01. It is feasible that these caves form part of the same usable cluster of caves in the general region due to the distances involved (Bat Call WA 2020).

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Appendices

Appendix A - Figures

Figure 1 Study Area Locality

Figure 2 Ghost Bat Historical Records and Known Caves 40km Radius

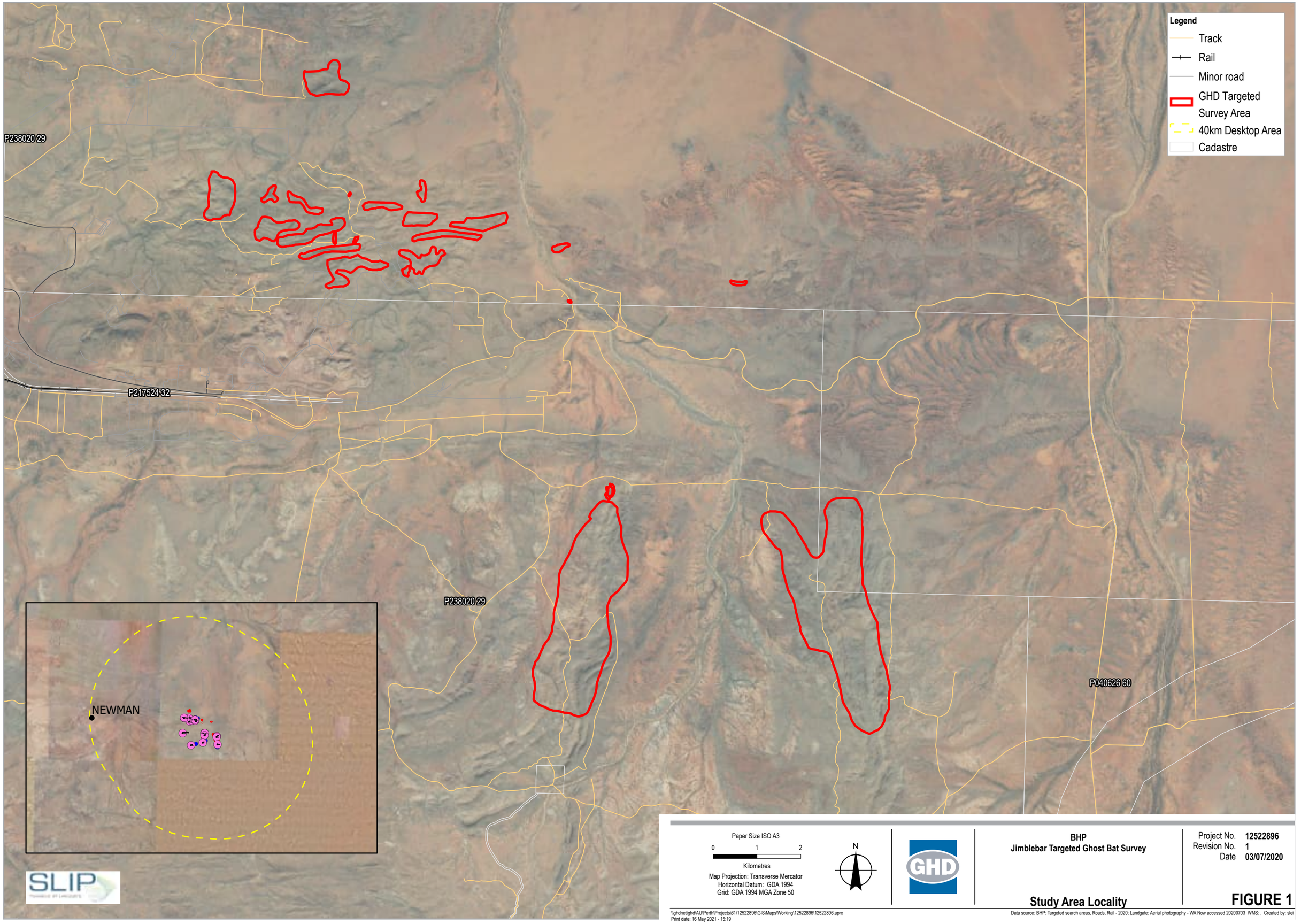
Figure 3 GHD Survey Methods

Figure 4 GHD Survey Methods

Figure 5 GHD Survey Results

Figure 6 GHD Survey Results

Figure 7 GHD Ghost Bat Observations



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GHD

BHP
Jimblebar Targeted Ghost Bat Survey

Study Area Locality

Project No. **12522896**
Revision No. **1**
Date **03/07/2020**

FIGURE 1

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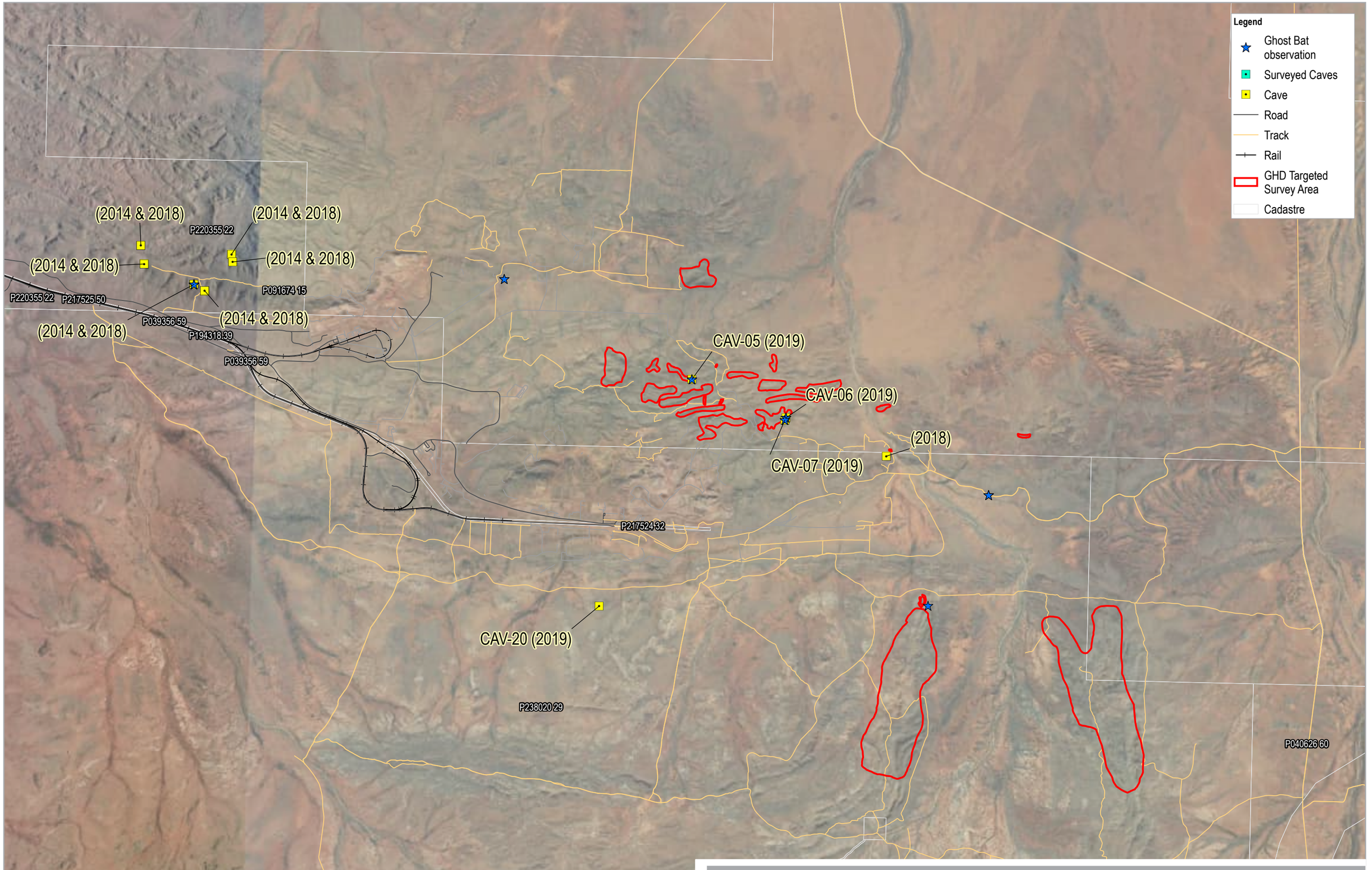

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BHP
Jimblebar Targeted Ghost Bat Survey

Ghost Bat Historical Records and Known Caves 40km Radius

Project No. **12522896**
Revision No. **2**
Date **22/07/2020**

FIGURE 2

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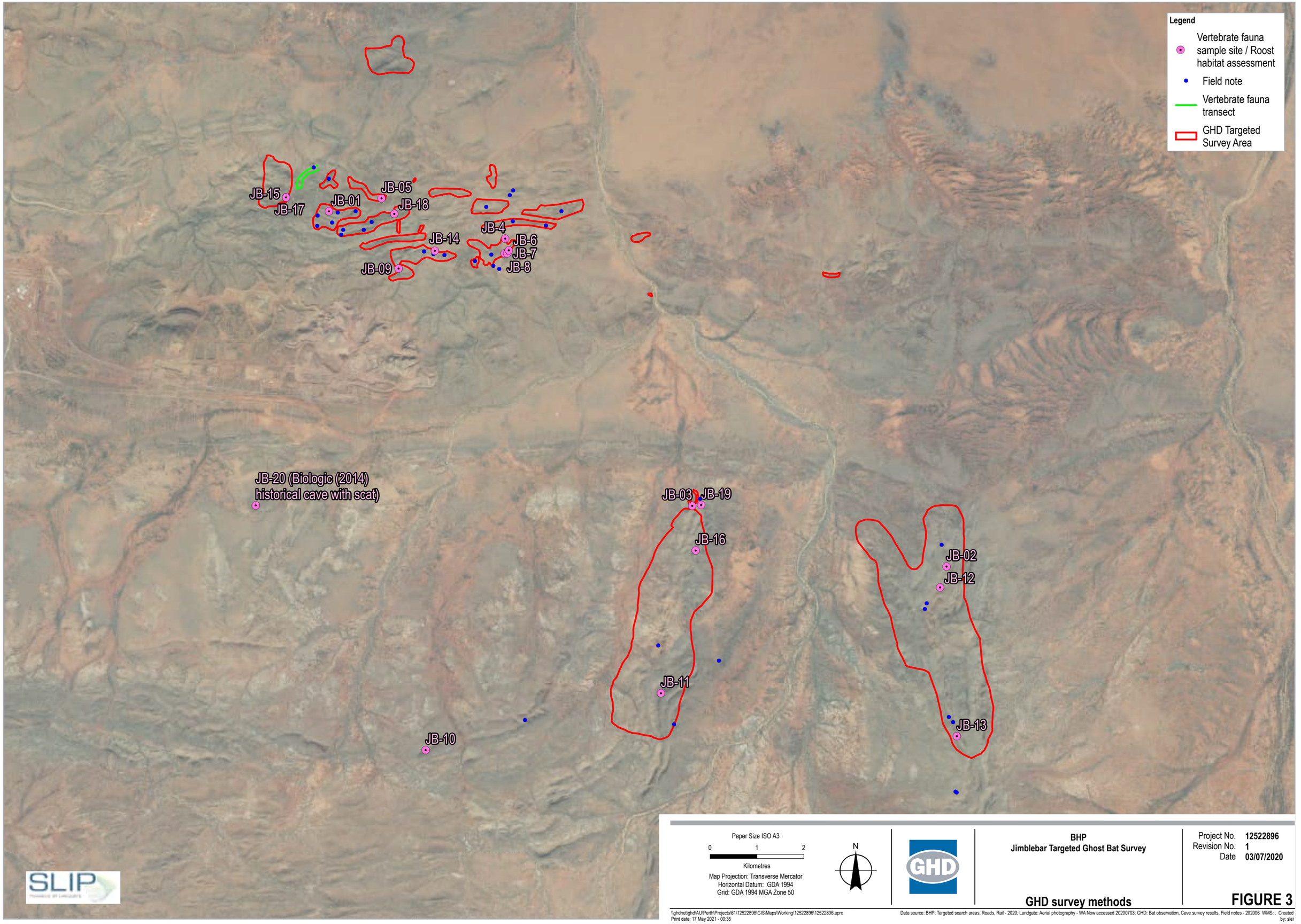

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GHD

BHP
Jimblebar Targeted Ghost Bat Survey

GHD survey methods

Project No. **12522896**
Revision No. **1**
Date **03/07/2020**

FIGURE 3

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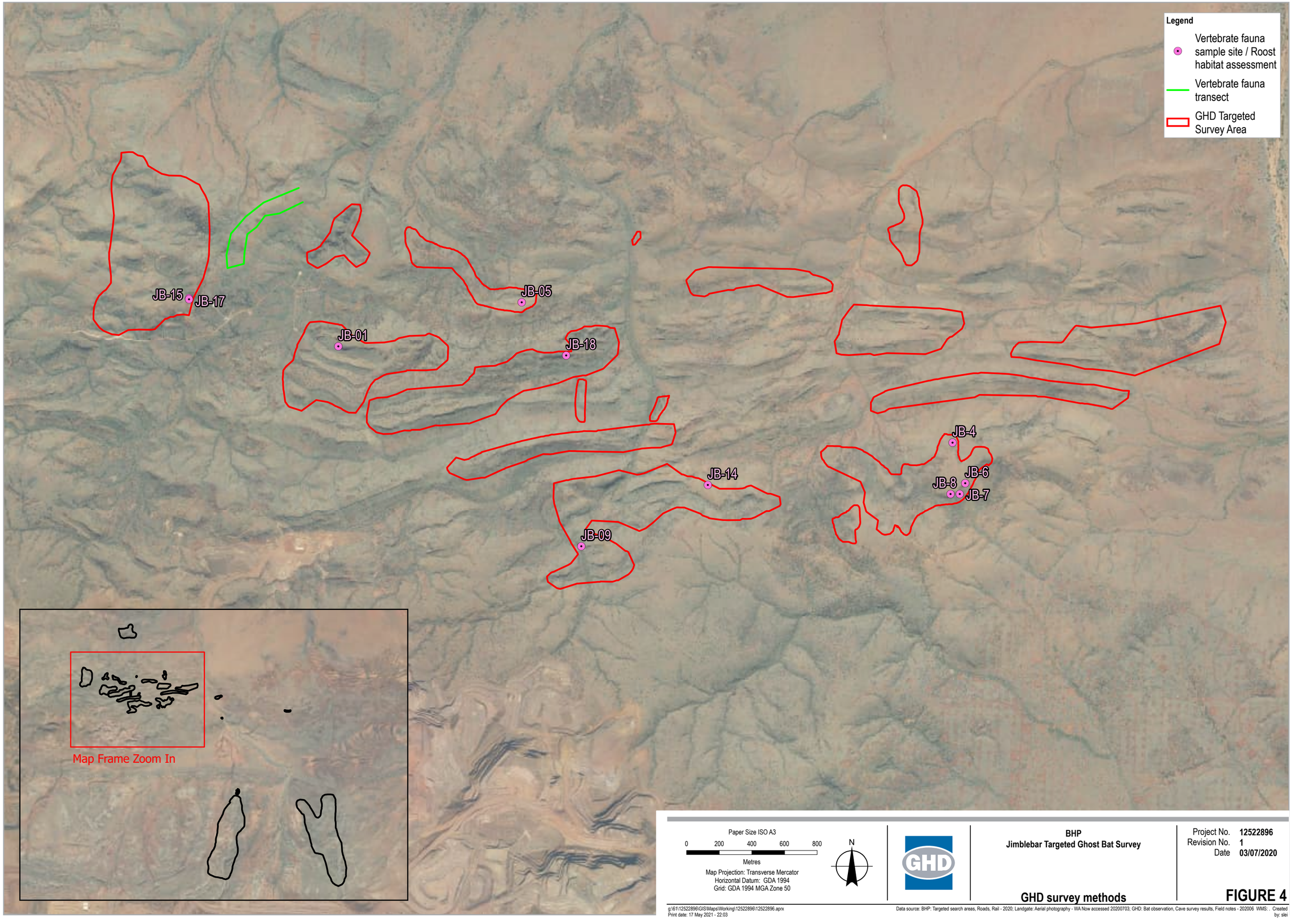

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Metres

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BHP
Jimblebar Targeted Ghost Bat Survey

GHD survey methods

Project No. 12522896
Revision No. 1
Date 03/07/2020

FIGURE 4

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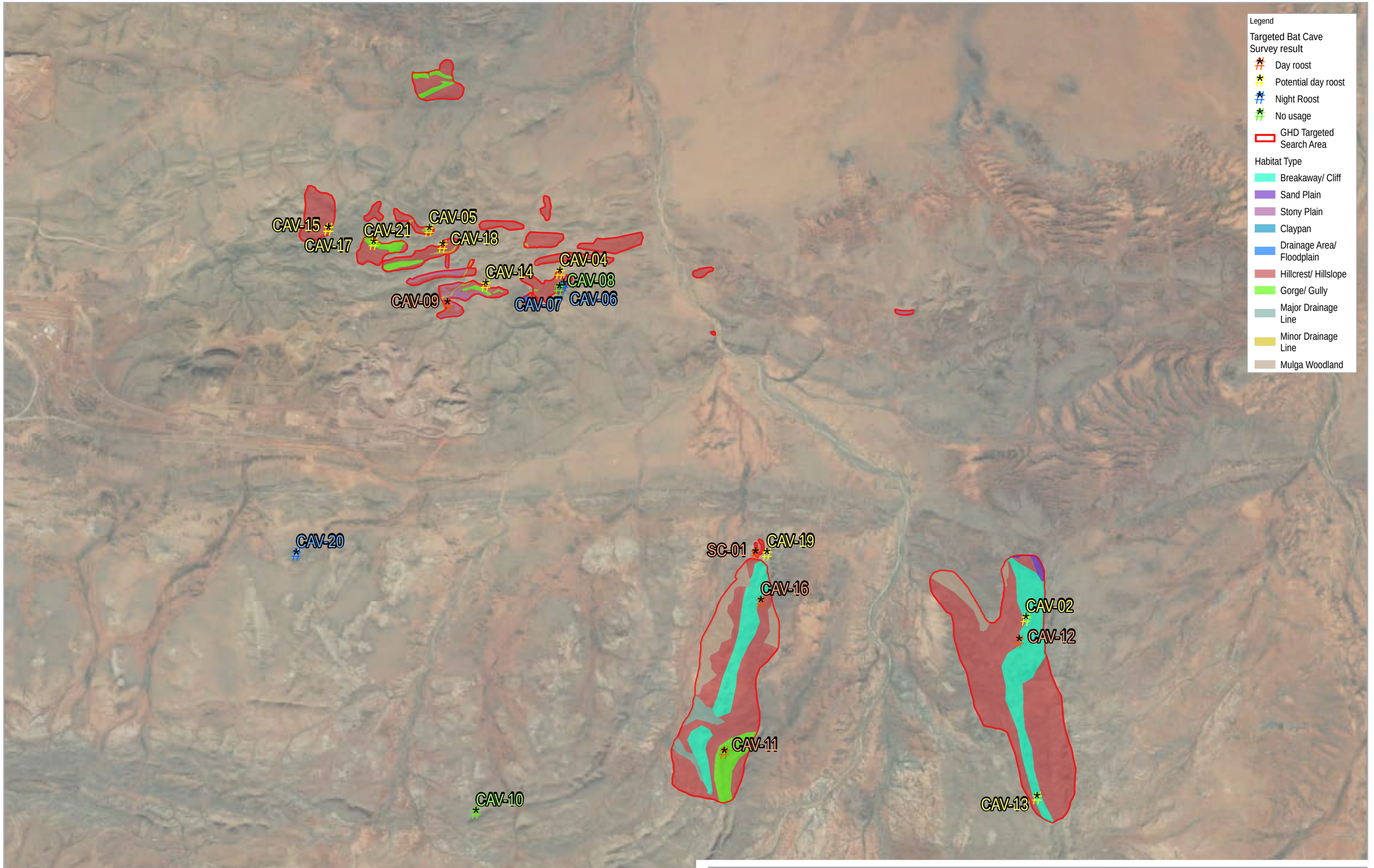

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Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

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BHP
Jimblebar Targeted Ghost Bat Survey

GHD Survey Results

Project No. 12522896
Revision No. 4
Date 03/07/2020

FIGURE 5

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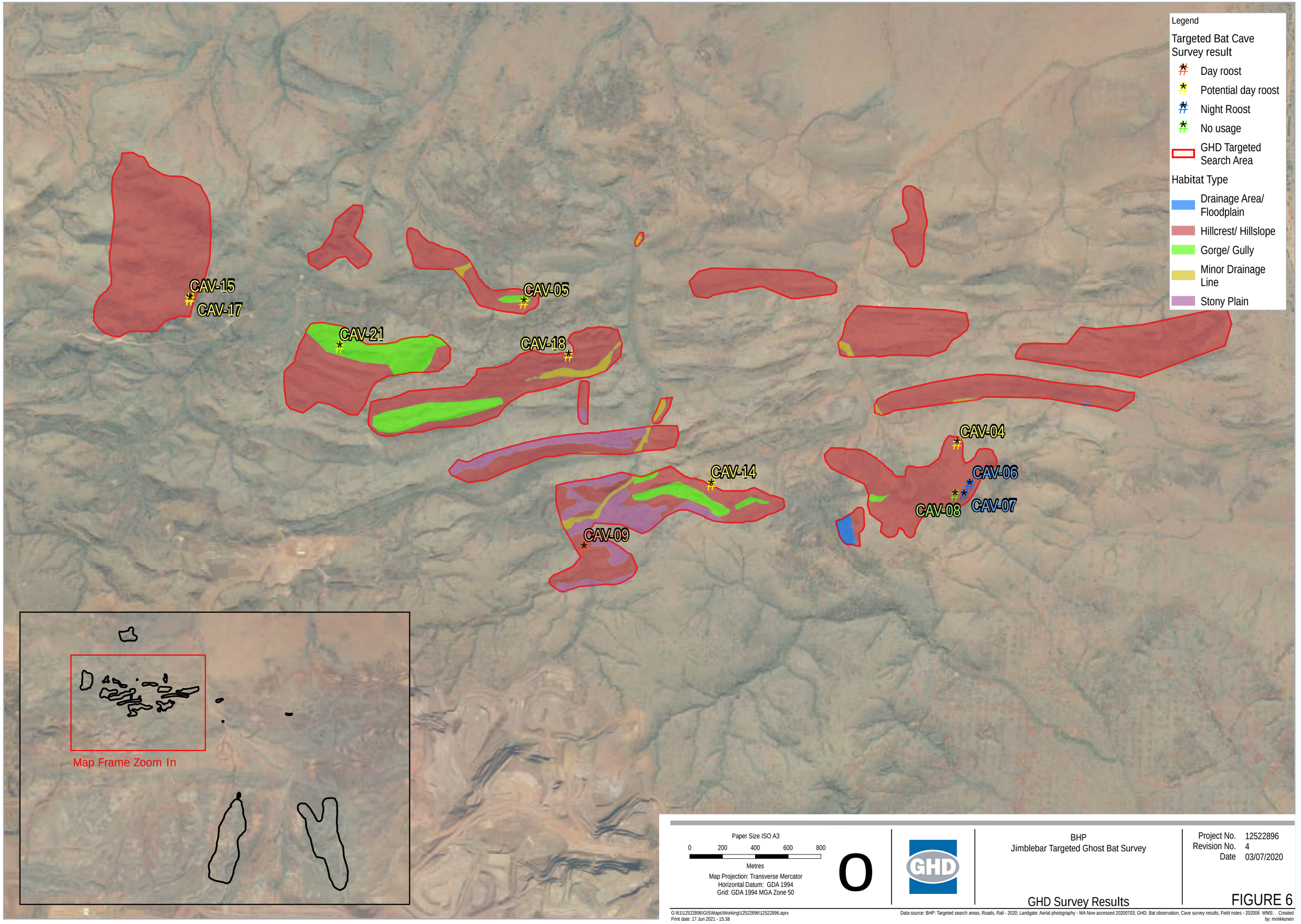

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BHP
Jimblebar Targeted Ghost Bat Survey

GHD Survey Results

Project No. 12522896
Revision No. 4
Date 03/07/2020

FIGURE 6

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Paper Size ISO A3

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Kilometres

Map Projection: Transverse Mercator
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BHP
Jimblebar Targeted Ghost Bat Survey

GHD Ghost Bat Observations

Project No. 12522896
Revision No. 1
Date 03/07/2020

FIGURE 7

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Print date: 17 May 2021 - 01:09

Data source: BHP: Targeted search areas, Roads, Rail - 2020; Landgate: Aerial photography - WA Now accessed 20200703; GHD: Bat observation, Cave survey results, Field notes - 202006 WMS: . Created by: slei

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12522896-41442-31/https://projectsportal.ghd.com/sites/pp18_02/jimblebartargetedgho/ProjectDocs/12522896-REP-Rev 2 Final Jimblebar targeted ghost bat survey.docx

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Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
0	M Roberts, C Grabham G Gaikhorst	J Collins		J Collins		31/3/2021
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