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BIOREGIONAL ASSESSMENTS

CSIRO

Protected matters for the Beetaloo GBA region

Technical appendix for Geological and Bioregional Assessment: Stage 2

2020

A scientific collaboration between the Department of Agriculture, Water and the Environment, Bureau of Meteorology, CSIRO and Geoscience Australia

The Geological and Bioregional Assessment Program

The Geological and Bioregional Assessment Program will provide independent scientific advice on the potential impacts from development of selected unconventional hydrocarbon plays on water and the environment. The geological and environmental data and tools produced by the Program will assist governments, industry, landowners and the community to help inform decision making and enhance the coordinated management of potential impacts.

The Program is funded by the Australian Government Department of the Environment and Energy. The Department of the Environment and Energy, Bureau of Meteorology, CSIRO and Geoscience Australia are collaborating to undertake geological and bioregional assessments. For more information, visit http://www.bioregionalassessments.gov.au.

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Authorship is listed alphabetically after first author.

On 1 February 2020 the Department of the Environment and Energy and the Department of Agriculture merged to form the Department of Agriculture, Water and the Environment. Work for this document was carried out under the then Department of the Environment and Energy. Therefore, references to both departments are retained in this report.

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Cover photograph

Mataranka Thermal Pools, Beetaloo GBA extended region, October 2018
Credit: Alf Larcher (CSIRO)
Element: GBA-BEE-2-381

Executive summary

Expansion of the shale, tight and deep coal gas industries in Australia has potential to impact on environmental matters. There is a need to examine impacts on Matters of National Environmental Significance (MNES) (i.e. *Environmental Protection and Biodiversity Conservation Act* (EPBC Act) matters) at a regional level and enable regulators to assess cumulative impacts of development on these matters. The Strategic Assessment process does this task. While a Strategic Assessment is not planned for the Beetaloo GBA region the current report describes a review of MNES, other matters protected by the EPBC Act, Matters of Territory Environmental Significance (MTES), other matters of environmental significance in the NT, and landscape classes. It does this for the Beetaloo GBA region and the broader Beetaloo GBA extended region.

MNES that occur, or potentially occur, in the Beetaloo GBA region are 14 threatened species, 13 migratory species and one species that is both threatened and migratory. Within the Beetaloo GBA extended region there are one threatened ecological community, 15 threatened species, 15 migratory species and two species that are both threatened and migratory.

Other protected matters in the Beetaloo GBA region consist of 21 listed marine species. Within the Beetaloo GBA extended region are located 23 listed marine species, and five areas of Commonwealth lands.

Among territory matters of environmental significance, one territory reserve, Bullwaddy Conservation Reserve, occurs entirely within the Beetaloo GBA region. A further four reserves are outside the Beetaloo GBA region but have 100% of their area within the Beetaloo GBA extended region. Four species that are classified as threatened under the NT's *Territory Parks and Wildlife Conservation Act* but not under the Commonwealth's EPBC Act have been recorded in the Beetaloo GBA region since 1990 and are considered likely to still occur there; a further two Territory-listed threatened species occur in the Beetaloo GBA extended region. Also, of environmental significance in the NT are nationally important wetlands. Two of these occur in the Beetaloo GBA extended region; Mataranka Thermal Pools and Lake Woods.

Among groundwater-dependent ecosystems (GDEs), springs do not occur within the Beetaloo GBA region but are present within the Beetaloo GBA extended region to the north-north-east and east as discharge complexes from the major northward flowing groundwater systems of the CLA. The springs at Mataranka Thermal Pools sustain dry-season flows in the Roper River system and support terrestrial and wetland GDEs. Connectivity between surface water and groundwater is limited within the Beetaloo GBA region because of the depth to groundwater (typically >40 m). Terrestrial GDEs are mostly limited to shallow perched aquifer systems that are fed by groundwater.

Key threatening processes operating in the Beetaloo GBA region include competition and land degradation by rabbits and unmanaged goats, predation by European red fox and feral cats, predation, habitat degradation, competition and disease transmission by feral pigs, novel

biota and their impact on biodiversity (e.g. feral horse, donkey, camel) and biological effects, including lethal toxic ingestion, caused by cane toads.

No socio-economic or cultural assets were identified in the EPBC Act protected matters searches. The searches did not identify any world heritage properties, national heritage places or Commonwealth heritage places in either the Beetaloo GBA region or the Beetaloo GBA extended region. A search of the NT heritage register identified 13 declared heritage places within the Beetaloo GBA extended region. A search of the NT archaeological sites database identified 39 Aboriginal archaeological sites within the Beetaloo GBA region and a further 80 within the GBA extended region.

To determine how impacts caused by shale, tight and deep coal gas exploration and development may affect ecosystems at a landscape scale in the Beetaloo GBA region, a landscape classification of six landscape classes was developed based on Queensland's Land Zones, (provided by the NT Government Department of Environment and Natural Resources). The landscape classification was developed to provide a basis for systematic assessment of the potential impacts on landscape function and the protected matters nested in each landscape class. The landscape classification showed that the region is dominated by loamy and sandy plains and clay plains.

A prioritisation process identified the following matters as being of the highest priority (priority 1) for assessment in Stage 3 of the project: four species listed as MNES, one species listed as a MTES, two wetlands of national importance, and all GDEs.

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- Technical Peer Review Group: Andrew Boulton, Peter McCabe, Catherine Moore, Jenny Stauber
- State Government Science Technical Review: This group includes scientists from the Northern Territory state government.

Abbreviations and acronyms

Abbreviation/acronym	Definition
ABS	Australian Bureau of Statistics
AIATSIS	Australian Institute of Aboriginal and Torres Strait Islander Studies
BI	Brittleness index
CSG	Coal seam gas
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
GBA	Geological and Bioregional Assessment
GDE	Groundwater-dependent ecosystem
IBRA	Interim Biogeographic Regionalisation of Australia
ILUA	Indigenous Land Use Agreement
MNES	Matters of National Environmental Significance
LGA	Local government area

Units

Unit	Description
cm	Centimetre
g	Gram
ha	Hectare
km	Kilometre
km^2	Kilometre squared
m	Metre

The Geological and Bioregional Assessment Program

The $35.4 million Geological and Bioregional Assessment (GBA) Program is assessing the potential environmental impacts of shale and tight gas development to inform regulatory frameworks and appropriate management approaches. The geological and environmental knowledge, data and tools produced by the Program will assist governments, industry, landowners and the community by informing decision making and enabling the coordinated management of potential impacts.

In consultation with state and territory governments and industry, three geological basins were selected based on prioritisation and ranking in Stage 1: Cooper Basin, Isa Superbasin and Beetaloo Sub-basin. In Stage 2, geological, hydrological and ecological data were used to define 'GBA regions': the Cooper GBA region in Queensland, SA and NSW; the Isa GBA region in Queensland; and the Beetaloo GBA region in NT. In early 2018, deep coal gas was added to the assessment for the Cooper GBA region, as this play is actively being explored by industry.

The Program will assess the potential impacts of selected shale and tight gas development on water and the environment and provide independent scientific advice to governments, landowners, the community, business and investors to inform decision making. Geoscience Australia and CSIRO are conducting the assessments. The Program is managed by the Department of the Environment and Energy and supported by the Bureau of Meteorology.

The Program aims to:

- inform government and industry and encourage exploration to bring new gas supplies to the East Coast Gas Market within five to ten years
- increase understanding of the potential impacts on water and the environment posed by development of shale, tight and deep coal gas resources
- increase the efficiency of assessment and ongoing regulation, particularly through improved reporting and data provision/management approaches
- improve community understanding of the industry.

The Program commenced in July 2017 and comprises three stages:

- **Stage 1 Rapid regional basin prioritisation** identified and prioritised geological basins with the greatest potential to deliver shale and/or tight gas to the East Coast Gas Market within the next five to ten years.
- **Stage 2 Geological and environmental baseline assessments** is compiling and analysing available data for the three selected regions to form a baseline and identify gaps to guide collection of additional baseline data where needed. This analysis includes a geological basin assessment to define structural and stratigraphic characteristics and an environmental data synthesis.
- **Stage 3 Impact analysis and management** will analyse the potential impacts to water resources and matters of environmental significance to inform and support Commonwealth and Territory management and compliance activities.

The PDF of this report and the supporting technical appendices are available at https://www.bioregionalassessments.gov.au/geological-and-bioregional-assessment-program.

About this report

Presented in this technical appendix are the protected matters for the Beetaloo GBA region. It provides more detailed information regarding environmental and cultural protected matters, landscape classification, ecohydrological conceptualisation, and the prioritisation and screening process for protected matters in the Beetaloo GBA region. The structure and focus of the synthesis report and technical appendices reflect the needs of government, industry, landowners and community groups.

Technical appendices

Other technical appendices that support the geological and environmental baseline assessment for the Beetaloo GBA region are:

- Kirby JK, Golding L, Williams M, Apte S, Mallants D, King J, Otalega I and Kookana R (2020) Qualitative (screening) environmental risk assessment of drilling and hydraulic fracturing chemicals for the Beetaloo GBA region.
- Orr ML, Bernardel G, Owens R, Hall LS, Skeers N, Reese B and Woods M (2020) Geology of the Beetaloo GBA region.
- Hall LS, Wang L, Bailey AHE, Orr ML, Owens R, Jarrett, A, Lech ME, Skeers N, Reese, B and Woods M (2020) Petroleum prospectivity of the Beetaloo Sub-basin.
- Evans TJ, Radke BM, Martinez J, Buchanan S, Cook SB, Raiber M, Ransley TR, Lai ÉCS, Skeers N, Woods M, Evenden C, Cassel R and Dunn B (2020) Hydrogeology of the Beetaloo GBA region.
- Kear J and Kasperczyk D (2020) Hydraulic fracturing and well integrity review for the GBA regions.

All maps for the Beetaloo GBA region use the Map Grid of Australia (MGA) projection (zone 53) and the Geocentric Datum of Australia 1994 (GDA 1994)

1 Protected matters

Matters of National Environmental Significance (MNES) that occur, or potentially occur, in the Beetaloo GBA region are 14 threatened species, 13 migratory species and one species that is both threatened and migratory. Within the Beetaloo GBA extended region there are one threatened ecological community, 15 threatened species, 15 migratory species and two species that are both threatened and migratory.

Other protected matters in the Beetaloo GBA region consist of 21 listed marine species. Within the Beetaloo GBA extended region are located 23 listed marine species, and five areas of Commonwealth lands.

Among Matters of Territory Environmental Significance (MTES), 1 territory reserve, Bullwaddy Conservation Reserve, occurs entirely within the Beetaloo GBA region. A further four reserves are outside the Beetaloo GBA region but have 100% of their area within the Beetaloo GBA extended region. Four species that are classified as threatened under the NT's *Territory Parks and Wildlife Conservation Act* but not under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act* (EPBC Act) have been recorded in the Beetaloo GBA region since and are considered likely to still occur there; a further two Territory-listed threatened species occur in the Beetaloo GBA extended region. Also of environmental significance in the NT are two nationally important wetlands: Mataranka Thermal Pools and Lake Woods.

Among groundwater-dependent ecosystems (GDEs), springs do not occur within the Beetaloo GBA region but are present within the Beetaloo GBA extended region to the north-north-east and east as discharge complexes from the major northward flowing groundwater systems of the CLA. The springs at Mataranka Thermal Pools sustain dry-season flows in the Roper River system and support terrestrial and wetland GDEs. Twenty springs occur within the Beetaloo GBA extended area but none are in the Beetaloo GBA region. Both the Beetaloo GBA region and extended region contain areas of aquatic and terrestrial GDEs. Connectivity between surface water and groundwater is limited within the Beetaloo GBA region because of the depth to groundwater (typically >40 m), therefore, terrestrial GDEs are mostly limited to shallow perched aquifer systems that are fed by groundwater.

Key threatening processes operating in the Beetaloo GBA region include competition and land degradation by rabbits and unmanaged goats, predation by European red fox and feral cats, predation, habitat degradation, competition and disease transmission by feral pigs, novel biota and their impact on biodiversity (e.g. feral horse, donkey, camel) and biological effects, including lethal toxic ingestion, caused by cane toads.

1.1 Matters of National Environmental Significance

The EPBC Act protected matters search identified the following Matters of National Environmental Significance (MNES) in the Beetaloo GBA region (Figure 1): 14 threatened species, 13 migratory species and one species that is both threatened and migratory. No other MNES were identified

from the Beetaloo GBA region. A list of these MNES together with a summary of each species' biology, distribution and habitat is given in Table 1.

Methods snapshot: Identifying protected matters

Most matters considered in this report were identified in the Beetaloo GBA region and Beetaloo GBA extended region (Figure 1) based on the EPBC Act protected matters reports run by the Department of the Environment and Energy on 6 September 2018. This search was re-run on 15 March 2019 to validate the original report and assess if any matters had either been added or removed from the list. An additional search was run on 23 September 2019 when the boundary of the Beetaloo GBA extended region was modified. The protected matters reports run for the Beetaloo GBA region and extended region searched for the following MNES: world heritage properties, wetlands of international importance, threatened species, threatened ecological communities, and migratory species. The report also searched for other matters protected under the EPBC Act that are not listed as MNES. These are Commonwealth lands, listed marine species, critical habitats, and Commonwealth reserves.

The EPBC Act protected matters reports also identified territory reserves and nationally important wetlands. Species classified as threatened under the NT's *Territory Parks and Wildlife Conservation Act* but not under the Commonwealth's *Environmental Protection and Biodiversity Conservation Act* (EPBC Act) were identified by examining data downloads provided by the NT government's Fauna and Flora Division on 10 June 2018 and again on 26 September 2019 (for the new extended boundary).

Groundwater-dependent ecosystems (GDEs) were identified by interrogating NT databases, specifically NT terrestrial ecosystem data for terrestrial GDEs and NT aquatic ecosystem data for aquatic GDEs. Springs data were obtained by combining the NT aquatic ecosystem data with the NT springs data to create a new layer containing all springs common to both datasets. This analysis was untaken on 30 September 2019.

The EPBC Act protected matters search identified the following MNES in the Beetaloo GBA extended region (Figure 1): one threatened ecological community, 15 threatened species, 15 migratory species and two species that are both threatened and migratory. The threatened and migratory species within the Beetaloo GBA extended region included all the species identified as being of national environmental significance in the Beetaloo GBA region plus *Acrocephalus orientalis*, *Polytelis alexandrae*, *Pristis pristis*, and *Tringa nebularia*. A list of these MNES together with a summary of each species' biology, distribution and habitat is given in Table 1.

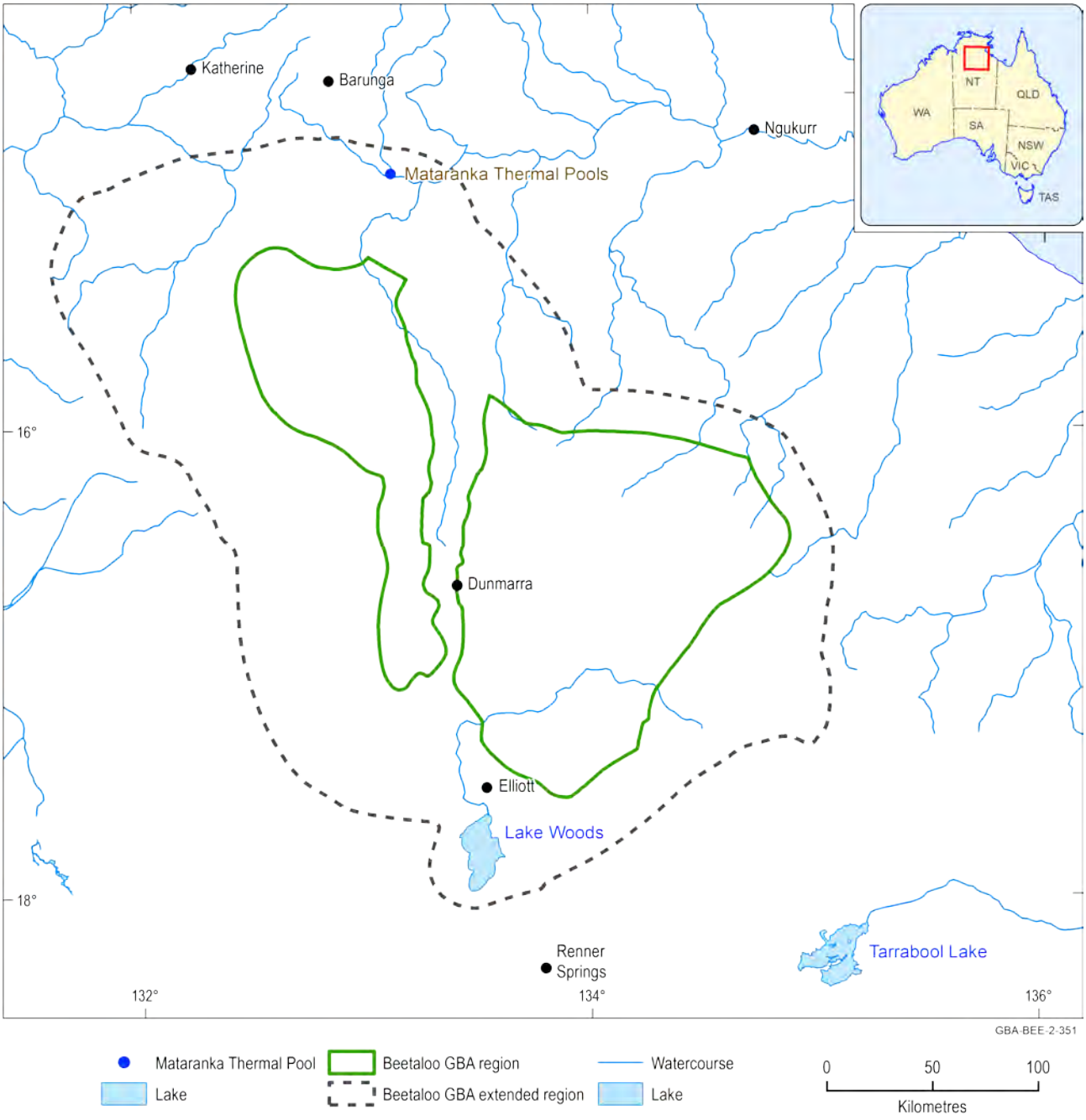

Figure 1 Map of the Beetaloo GBA region and extended Beetaloo GBA region

Data: Department of the Environment and Energy (2010)
Element: GBA-BEE-2-351

1.1.1 Nationally listed threatened species and threatened ecological communities

In total, 15 species listed as threatened (being either critically endangered, endangered or vulnerable) occur or potentially occur within the Beetaloo GBA region based on reports run by the Department of the Environment and Energy on 6 September 2018. These include birds (eight species), mammals (five species) and reptiles (two species). No fish, frogs, invertebrates or plants that are listed as threatened under the EPBC Act occur, or may occur, in the Beetaloo GBA region.

In total, 17 species are listed as threatened within the Beetaloo GBA extended region. These include birds (nine species), mammals (five species), reptiles (two species) and a freshwater fish. No frogs, invertebrates or plants that are listed as threatened under the EPBC Act occur, or are likely to occur, in the Beetaloo GBA extended region. The threatened species within the Beetaloo GBA extended region included all the species identified in the Beetaloo GBA region in addition to the princess parrot (*Polytelis alexandrae*) and freshwater sawfish (*Pristis pristis*).

The threatened ecological community that potentially occurs within the Beetaloo GBA extended region is the Arnhem Plateau sandstone shrubland complex (Figure 2). This community occurs to the north-east of the Beetaloo sub-basin on the Arnhem Plateau (within Djelk and Warddeken Indigenous Protected Areas) and on sandstone outliers at Ubirr, Nawurlandja and Burrunggui in Kakadu National Park and the Marawal Plateau in Nitmiluk National Park (Commonwealth of Australia 2011). The threatened ecological community has not been recorded in the Beetaloo GBA region. The community may occur in the north-east portion of the Beetaloo GBA extended region, but this has not been confirmed. If present in the Beetaloo GBA extended region, the community will be at the extreme southern edge of its range and is likely to cover a limited area.

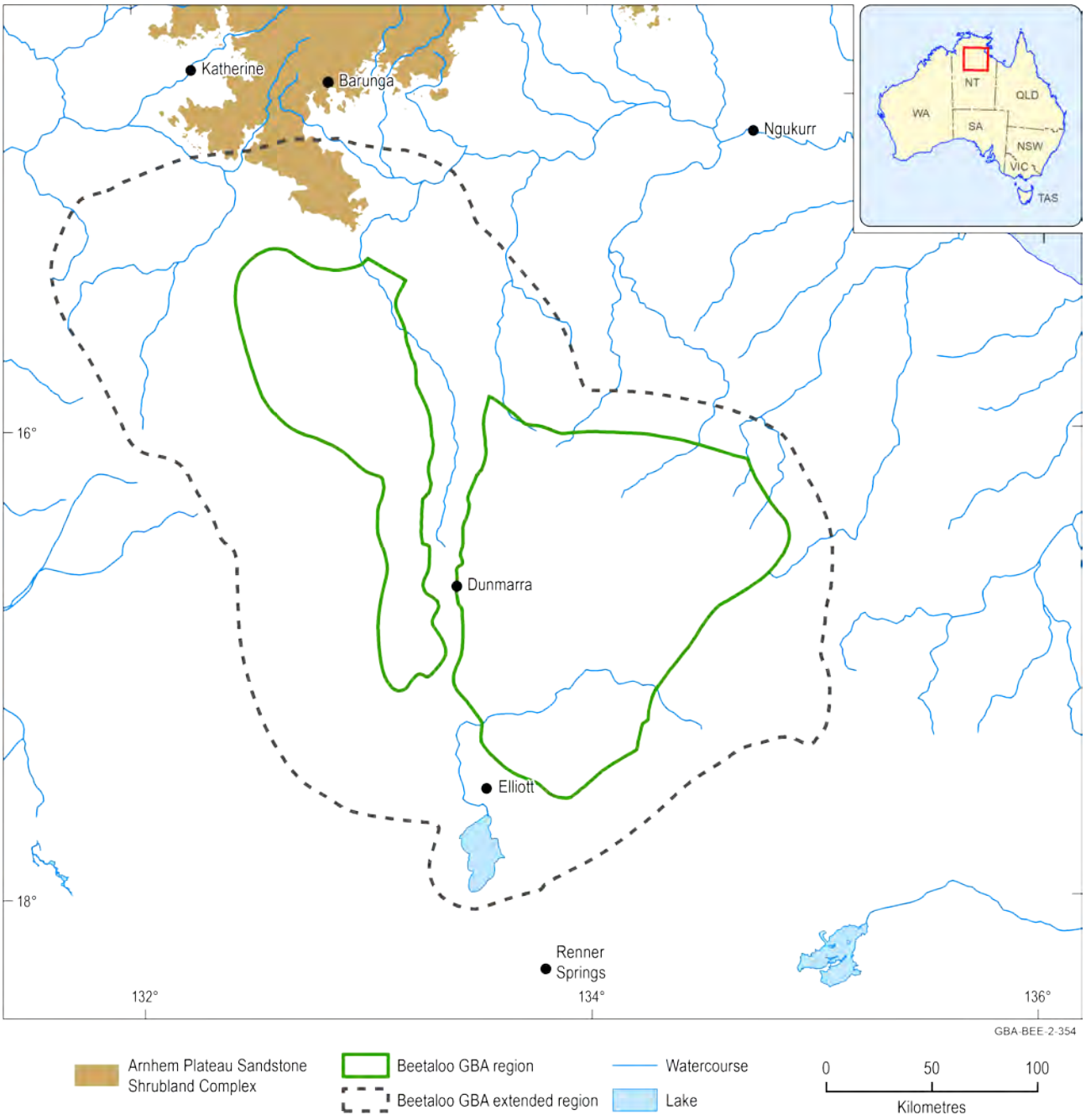

Figure 2 Potential distribution of the threatened ecological community, Arnhem Plateau Sandstone Shrubland Complex

Data: Department of the Environment and Energy (2018a)
Element: GBA-BEE-2-354

1.1.2 Nationally listed migratory species

In total, 14 species are listed as migratory under the EPBC Act and occur, or may occur, in the Beetaloo GBA region. This total includes one species, *Calidris ferruginea*, that is also listed as threatened.

In total, 17 species are listed as migratory under the EPBC Act and occur, or may occur, in the Beetaloo GBA extended region. This total includes two species, *Calidris ferruginea* and *Pristis pristis*, that are also listed as threatened. The migratory species within the Beetaloo GBA extended region include all the species identified in the Beetaloo GBA region plus three additional species: *Acrocephalus orientalis*, *Pristis pristis*, and *Tringa nebularia*.

Migratory species are those that are protected under bilateral international agreements. The EPBC Act list of migratory species is assembled from four bilateral agreements. These agreements are:

- China-Australia Migratory Bird Agreement (CAMBA)
- Japan-Australia Migratory Bird Agreement (JAMBA)
- Republic of Korea-Australia Migratory Bird Agreement (ROKAMBA)
- Bonn Convention (Convention on Conservation of Migratory Species of Wild Animals).

The International Union for Conservation of Nature's (IUCN) classification of the global conservation status of each of the 15 migratory species that are not classified as threatened in Australia under the EPBC Act is given in Table 1. Many of these species have both a large global population size and a large population size in Australia. Each of the 15 species has an IUCN global concern status of 'least concern' – the status with the lowest level of concern in the IUCN classification system.

Table 1 Species classified as Matters of National Environment Significance under the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* that protected matters searches have identified as occurring, or potentially occurring, in the extended Beetaloo GBA region together with a summary of biology, distribution and habitat

For those species that are migratory, but not threatened, information is also provided on IUCN global conservation status and global population trend. The fourth column indicates whether protected matters searches have identified the species as occurring, or potentially occurring, in the Beetaloo GBA region (if so, then listed as 'yes') or whether it is restricted to the extended Beetaloo GBA region (listed as 'no').

Status	Scientific name	Common name	Present in GBA region	Summary of biology, distribution and habitat
Critically endangered	*Calidris ferruginea*[a, b]	Curlew sandpiper	Yes	Migratory shorebird. Breeds mainly in Siberian Arctic. Non-breeding migrant during Austral summer to Africa, Asia and Australasia. Large numbers visit Australia mostly on intertidal mudflats in sheltered coastal areas (estuaries, bays, inlets, lagoons). Less common inland on lakes, dams and bore drains. Global population estimate between 1.085 and 1.285 million birds. Numbers declining globally.

Status	Scientific name	Common name	Present in GBA region	Summary of biology, distribution and habitat
Endangered	*Dasyurus hallucatus*	Northern quoll	Yes	Carnivorous marsupial. Nocturnal. Endemic to northern Australia (eastern Queensland, Top End of NT to Kimberley and Pilbara in WA). Occupies savanna woodland and patches of rainforest and favours rocky escarpments. Numbers declining.
	Elseya lavarackorum	Gulf snapping turtle	Yes	Freshwater turtle. Endemic to northern Australia. Limited range covering upper and middle reaches of the Nicholson and Gregory rivers in north-west Queensland/north-east NT and upper reaches of Calvert River, NT. Occurs in deep water pools of permanent spring-fed rivers. Numbers stable. Not considered threatened in the NT (listed as near threatened).
	Erythrura gouldiae	Gouldian finch	Yes	Passerine bird. Endemic to northern Australia from inland north Queensland across Top End of NT to Kimberley in WA. Occupies open woodland close to water; it feeds on seeding grasses and nests in hollows in eucalypts. Evidence that numbers recovering.
	Pezoporus occidentalis	Night parrot	Yes	Parrot. Nocturnal, terrestrial. Endemic to arid zone; records in south-west Queensland, north-east SA and northern WA. Occupies mature spinifex grassland feeding on short-lived herbs and grasses. Trends in abundance unknown.
	Rostratula australis[c]	Australian painted snipe	Yes	Resident shorebird. Endemic to Australia. Occupies shallow freshwater wetlands. Recorded across mainland but its area of occupancy is comparatively small, estimated at about 2000 km^2. Numbers appear to be stable.
Vulnerable	*Acanthophis hawkei*	Plains death adder	Yes	Venomous snake. Endemic to northern Australia from north-east of WA across Top End and Barkly Tableland of NT/Queensland border and Mitchell Grass Downs in south-west Queensland. Occupies floodplains with cracking clay soils. Numbers may be declining due to consumption of cane toads.
	Erythrotriorchis radiatus	Red goshawk	Yes	Bird of prey. Endemic to Australia with patchy range across coastal and interior regions of Queensland, NT and north-east of WA and north-east NSW. Occurs in open forest and woodland and along rainforest edges. Numbers appear to be stable.
	Falcunculus frontatus whitei	Crested shrike-tit (northern)	Yes	Passerine bird. Occurs in northern Australia across Top End of NT to Kimberley in WA. Populations fragmented. Forages for invertebrates on trees within woodland. Numbers stable. Not considered threatened in the NT (listed as near threatened).

Status	Scientific name	Common name	Present in GBA region	Summary of biology, distribution and habitat
	Grantiella picta	Painted honeyeater	Yes	Passerine bird. Specialised on fruit of mistletoes. Wide distribution across eastern Australia extending to the tropics in north-west Queensland and north-east NT. Exhibits seasonal movement in response to food availability. Occupies acacia-dominated woodlands preferring those with mature trees. Numbers appear to be stable.
	Macroderma gigas	Ghost bat	Yes	Bat (largest insectivorous bat in Australia with body mass up to 165 g). Endemic to tropical northern Australia from Rockhampton, central Queensland across Top End of NT to Kimberley and Pilbara in WA. Daytime roosts in caves and disused mines, forages in woodland. Recent declines in numbers. Listed as threatened in 2016.
	Macrotis lagotis	Greater bilby	Yes	Ground-dwelling marsupial. Nocturnal. Endemic to arid Australia in south-western Queensland and across western deserts of NT and WA. Occurs in variety of habitats, favouring spinifex sandplains and paleodrainage areas in NT. Numbers appear to be stable although fluctuate naturally as resources fluctuate.
	Phascogale pirata	Northern brush-tailed phascogale	Yes	Carnivorous marsupial. Nocturnal. Endemic to Top End of NT. Occurs mostly in tall open forest dominated by eucalypts. Little is known about this species. Numbers may be declining.
	Polytelis alexandrae	Princess parrot	No	Parrot. Endemic to the western arid zone of Australia occurring in north-west SA and across the western deserts of NT and WA. Forages on flowers, seeds and other plant material on spinifex sandplains and woodlands and nests in hollows of large trees. Exhibits nomadic movements in response to pulses in food resources following rainfall. Numbers appear to be stable.
	Pristis pristis[a]	Freshwater sawfish	No	Freshwater fish (largest freshwater fish in Australia reaching maximum body length of 5.82 m). Occupies river (up to 400 km inland) and estuarine environments and up to 100 km offshore in northern and western Australia as well as in North and South America, Africa, Asia and New Guinea. In Australian rivers during dry-season habitat is a series of isolated waterholes. Numbers appear to be declining.
	Saccolaimus saccolaimus nudicluniatus	Bare-rumped sheath-tailed bat	Yes	Insectivorous bat. Occurs in northern Australia (Townsville to Iron Range in Queensland and Top End of NT) and in New Guinea, Timor, Indonesia and elsewhere in south-east Asia. Forages in open space above woodland and roosts during day in colonies of up to 100 bats in tree hollows. Recent status change from critically endangered because of new information on distribution.

Status	Scientific name	Common name	Present in GBA region	Summary of biology, distribution and habitat
	Tyto novaehollandiae kimberli	Masked owl (northern)	Yes	Owl. Occurs across northern Australia from the coast of north Queensland across Top End to Kimberley in WA. Forages in tall open eucalypt forest and along margins of agricultural fields. Nests and roosts in hollows in large trees within forest patches. Numbers appear to be stable.
Migratory	*Acrocephalus orientalis*[b]	Oriental reed-warbler	No	Passerine bird. Breeds in Russia, Mongolia and northern Asia. Non-breeding migrant to equatorial areas during the Austral summer. Very rare vagrant in Australia. IUCN global status is least concern; however, numbers may be decreasing.
	Actitis hypoleucos[b]	Common sandpiper	Yes	Shorebird. Global population estimated at 2.6 to 3.2 million birds. Breeds in Europe and Asia. Non-breeding migrant in Austral summer in large numbers along all coastlines and in many inland areas of Australia. Mapped extent of potential habitat covers entire Australian continent. IUCN global status is least concern; however, numbers may be decreasing.
	Apus pacificus[b]	Fork-tailed swift	Yes	Swift. Breeds in south-east China and adjacent countries. Non-breeding migrant in Austral summer across Australia. Mapped extent of potential habitat covers most of Australia. IUCN global status is least concern and numbers are stable.
	Calidris acuminata[b]	Sharp-tailed sandpiper	Yes	Shorebird. Breeds in northern Siberia. Non-breeding migrant in Austral summer in large numbers along all coastlines and in inland areas of Australia. Population estimated at up to 140,000 birds (global population estimate is >160,000 birds). Mapped extent of potential habitat covers entire continent. IUCN global status is least concern and numbers are stable.
	Calidris melanotos[b]	Pectoral sandpiper	Yes	Shorebird. Breeds in northern Russia and North America. Non-breeding migrant in Austral summer in low numbers along coastlines and inland areas of Australia. Global population estimate is 25,000 to 100,000 birds. Mapped extent of potential habitat covers entire continent. IUCN global status is least concern and numbers are stable.
	Cecropis daurica[b]	Red-rumped swallow	Yes	Passerine bird. Widespread and abundant (global population estimate of 10 million to 50 million). Breeds in Russia, Mongolia, western Asia, northern Africa, Middle East and southern Europe. Non-breeding migrant to the tropics in the Austral summer. A vagrant in Australia with less than ten birds typically present in any given year. IUCN global status is least concern and numbers are stable.

Status	Scientific name	Common name	Present in GBA region	Summary of biology, distribution and habitat
	Charadrius veredus[b]	Oriental plover	Yes	Shorebird. Breeds in Mongolia and adjacent Russia. Approximately 90% of global population migrates to Australia in Austral summer occupying coastal and inland areas. Non-breeding in Australia. 144,000 birds at Eighty Mile Beach, WA, in February 2010. Occupies a wide range of marine, freshwater and terrestrial habitats. IUCN global status is least concern. The population trend is unclear.
	Crocodylus porosus[b]	Saltwater crocodile	Yes	Aquatic reptile. Occurs in Bangladesh, Brunei, Cambodia, India, Sri Lanka, Malaysia, Myanmar, Papua New Guinea, Philippines, Solomon Islands, Vanuatu, Vietnam, Timor and Indonesia. Occupies inland lakes, swamps and marshes and coastal brackish waters and tidal sections of rivers. In Australia occupies rivers and estuarine areas from Kimberley across northern Australia to southern coastal Queensland. IUCN global status is least concern with numbers increasing.
	Cuculus optatus	Oriental cuckoo	Yes	Cuckoo. Large global distribution including breeding range across the Palearctic region. Non-breeding migrant to the Top End of NT and eastern Australia in the Austral summer. Global population is estimated at between 5 and 15 million birds. IUCN global status is least concern and numbers are stable.
	Glareola maldivarum[b]	Oriental pratincole	Yes	Shorebird. Breeds in eastern China and Russia and parts of south-east Asia. Non-breeding migrant in Austral summer mainly in the north of WA and across Top End of NT to north-west Queensland. Occupies a wide range of marine, freshwater and grassland habitats. IUCN global status is least concern; however, numbers may be decreasing.
	Hirundo rustica[b]	Barn swallow	Yes	Passerine bird. One of the world's most widespread birds (global population estimate between 290 and 500 million) occurring across all continents except Antarctica. Rare summer visitor across north of Australia. IUCN global status is least concern. The population trend is unclear.
	Motacilla cinerea	Grey wagtail	Yes	Passerine bird. Widespread in the Northern Hemisphere and tropics with some populations breeding in Europe and Asia then migrating to tropical Africa and Asia. Global population estimate of 6.9 million to 19.8 million birds. A non-breeding vagrant in Australia. Occupies riverine areas. IUCN global status is least concern and numbers are stable.

Status	Scientific name	Common name	Present in GBA region	Summary of biology, distribution and habitat
	Motacilla flava[b]	Yellow wagtail	Yes	Passerine bird. Extremely large range from Europe to Siberia to west Asia and China south to Egypt. Global population estimate of 64 to 107 million birds. A non-breeding vagrant in Australia. Occupies terrestrial and freshwater habitat. IUCN global status is least concern. The population trend is unclear.
	Pandion haliaetus[b]	Osprey	Yes	Bird of prey. Occurs in all continents except Antarctica. Breeding resident along the entire coast of mainland Australia (but not Tasmania). The global population is between 100,000 and 499,999 birds and is increasing. IUCN global status is least concern and numbers are increasing.
	Tringa nebularia[b]	Common greenshank	No	Shorebird. Breeds in Scandinavia and across Russia. Non-breeding migrant in Austral summer in small numbers along most coastlines and in many inland areas of Australia. Australian population estimated at 18,000 to 19,000 birds (global population estimate of 440,000 to 1.5 million). Occupies a range of wetland types. IUCN global status is least concern with numbers stable.

[a]Also listed as migratory
[b]Also listed as marine
[c]Listed as marine under the name *Rostratula benghalensis*

1.2 Other matters protected by the EPBC Act

The protected matters search in the EPBC Act identified 23 listed marine species as occurring or potentially occurring in the extended Beetaloo GBA region. Of these, 21 listed marine species were identified for the Beetaloo GBA region with an additional two species only listed for the extended GBA region. In addition, the extended area held four Commonwealth lands.

1.2.1 Listed marine species

Listed marine species are those that occur in Commonwealth marine areas. A total of 21 listed marine species were identified as occurring or potentially occurring in the Beetaloo GBA region with an additional two species identified only from the Beetaloo GBA extended region. Of the 23 species, 16 species have already been covered as MNES (Table 1). The curlew sandpiper (*Calidris ferruginea*) is threatened and migratory, the painted snipe (*Rostratula benghalensis*) is threatened (although listed as the Australian painted snipe – see Table 1) and 14 other species are migratory. Only seven of the species that are listed marine species are not migratory or threatened or both (i.e. they are not MNES).

A brief profile of each of these seven listed marine species is given in Table 2 together with information on each species' biology, distribution, habitat, IUCN global conservation status and global population trend. All species were listed for both regions. Each of the seven species has an IUCN global concern status of least concern – the status with the lowest level of concern in the IUCN classification system.

1.2.2 Commonwealth lands

Five areas of Commonwealth land are located within the Beetaloo GBA extended region but outside of the Beetaloo GBA region. These areas are not managed for conservation; four locations are managed by the Department of Defence for defence purposes. These assets are the Delamere Weapons Range, Willeroo Station Radar Site, Killarney Station Radar Site and an un-named site adjacent to the Delamere Weapons Range. These four sites are in the extreme north-west portion of the Beetaloo GBA extended region. The final area is an un-named property within the town of Elliott. Because of the location of these areas, none are considered to be at risk from the development of a shale gas industry.

Table 2 Listed marine species classified as other matters protected by the Commonwealth's *Environment Protection and Biodiversity Conservation Act 1999* that occur, or potentially occur, in the Beetaloo GBA region and the Beetaloo GBA extended region, together with a summary of biology, distribution, habitat, IUCN global conservation status and global population trend. Species that are also Matters of National Environmental Significance are not covered in this list

Scientific name	Common name	Biology, distribution and habitat
Anseranas semipalmata	Magpie goose	Waterbird. Occurs in Australia and southern regions of the island of New Guinea. Nomadic, congregating in large numbers in wetlands or wet grasslands. In Australia occurs from the Kimberley region of WA across Top End of NT down east coast to northern NSW. Also recorded from southern Victoria and SA. Populations appear to be stable and IUCN conservation status is least concern.
Ardea alba	Great egret	Waterbird. Massive global distribution including North and South America, Africa, Asia and Europe. Global population estimated at 41.5 to 69.9 million birds. Occupies wide range of inland and coastal wetlands. Mapped extent of potential habitat covers entire Australian continent. IUCN conservation status is least concern.
Ardea ibis	Cattle egret	Waterbird. Massive global distribution including North and South America, Africa, Asia and Europe. Global population estimated at 4 to 9.85 million birds. Occupies open grassy areas and some wetlands. Mapped extent of potential habitat covers most of Australian continent. Populations appear to be increasing and IUCN conservation status is least concern.
Chrysococcyx osculans	Black-eared cuckoo	Cuckoo. Breeding resident in Australia, southern regions of the island of New Guinea and in Timor and Indonesian islands. Occupies woodland and shrubland, mostly in inland Australia although mapped extent of potential habitat covers most of Australian continent. Populations appear to be stable and IUCN conservation status is least concern.
Haliaeetus leucogaster	White-bellied sea-eagle	Bird of prey. Range includes coastal India, Sri Lanka, south-east Asia, Philippines, Indonesia and Papua New Guinea. In Australia, occurs along coast and extends inland along some of the larger rivers. Australian population size estimated at >500 pairs. Populations appear to be decreasing but IUCN conservation status is least concern.
Merops ornatus	Rainbow bee-eater	Bee-eater. Outside Australia occurs in Indonesia, Timor-Leste, Papua New Guinea and Solomon Islands. The population is estimated to number at least 1 million birds. Mapped extent of potential habitat covers entire Australian continent. Populations appear to be stable and IUCN conservation status is least concern.
Crocodylus johnstoni	Freshwater crocodile	Aquatic reptile. Endemic to northern Australia where it occurs in the Kimberley region of WA across the Top End of the NT across northern Queensland. It occupies freshwater wetlands. Populations appear to be stable and IUCN conservation status is least concern.

Information is sourced from: IUCN (2019). Refer to Table 1 for a listing of threatened species and migratory species.

1.3 Species accounts

The accounts provided in this section are intended to provide a summary of scientific understanding of each species as at 30 June 2019. Information has been sourced from review documents such as recovery plans wherever possible. The assessment of water dependency refers to the species itself not its food species. If a species lives in water, needs to drink water to survive or depends on nest or roost sites that are in trees that are water dependent it has been classified as water dependent. The assessment of the likelihood of being impacted by gas development in the Beetaloo GBA region refers to unconventional gas development and is specific to the Beetaloo GBA region. That is, a species may have a high likelihood of being impacted by unconventional gas development in other regions but a low likelihood in the Beetaloo GBA region. Such a situation arises if the species has a limited distribution in the Beetaloo GBA region that does not include areas that will be impacted by gas development. A dichotomy of 'low' and 'high' is used to assess this category. The knowledge of species' distributions within the Beetaloo GBA region is based on searches carried out 6 September 2018. This search was re-run on 15 March 2019 to validate the original report and assess if any matters had either been added or removed from the list. An additional search was run on 23 September 2019 when the boundary of the Beetaloo GBA extended region was modified.

Curlew sandpiper, *Calidris ferruginea*

Overview

The curlew sandpiper is listed as critically endangered and as a migratory and marine species under the EPBC Act. The curlew sandpiper is a migratory shorebird that breeds mainly in the Arctic region of northern Siberia and spends the Austral summer in a non-breeding phase distributed across Africa, Asia and Australasia (Figure 3). The species does not breed in Australia, but significant numbers spend the non-breeding season here. In Australia the curlew sandpiper mainly occurs on the coast particularly intertidal mudflats in sheltered coastal areas such as estuaries, bays, inlets and lagoons. Non-tidal coastal areas include swamps, lakes and lagoons and ponds in sewage farms and saltworks. The curlew sandpiper occurs less commonly inland. Here it occupies lakes, dams and bore drains.

The global population of the curlew sandpiper is estimated to number between 1.085 million and 1.285 million.

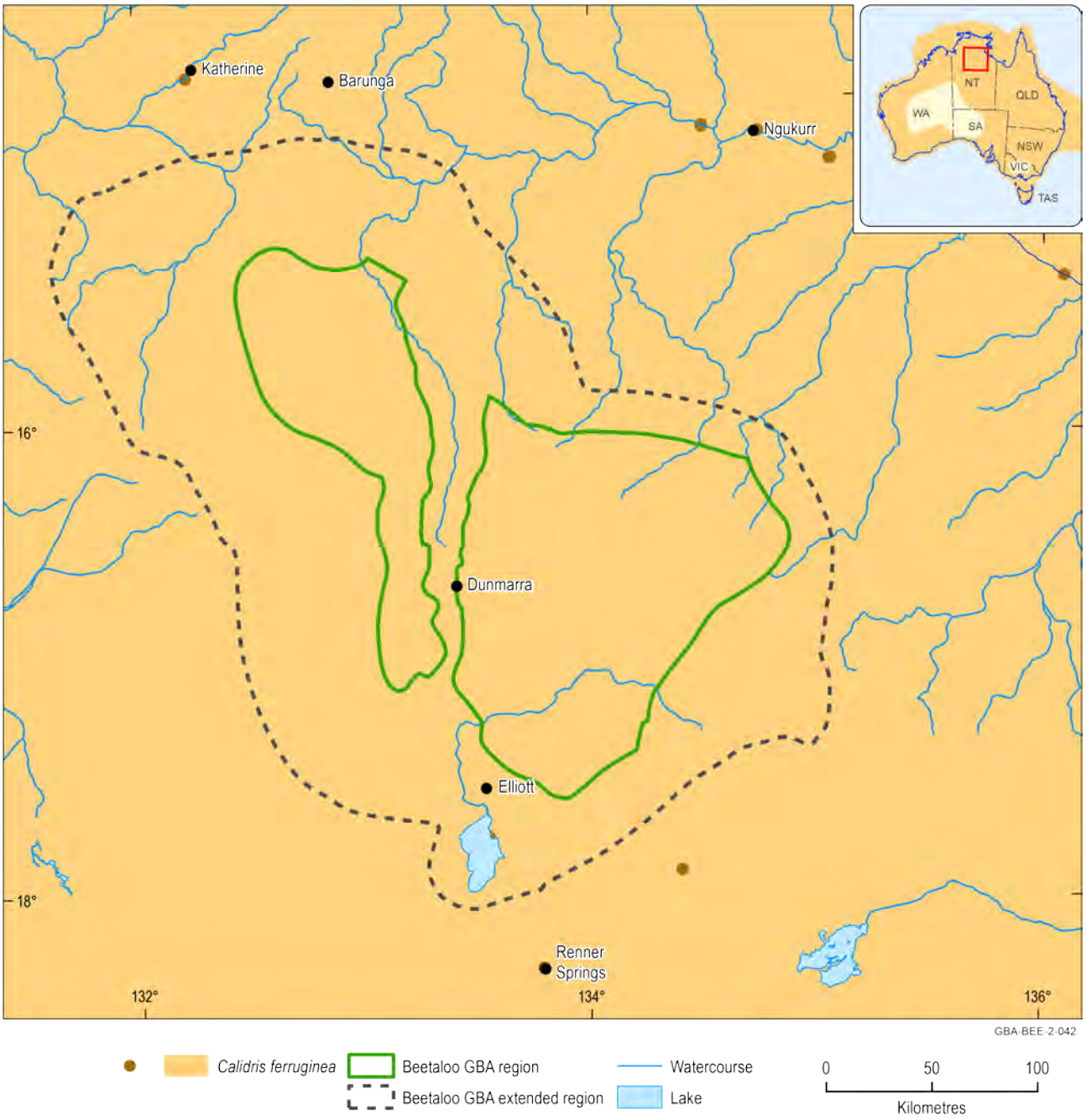

Figure 3 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the curlew sandpiper, *Calidris ferruginea*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-042

Water dependency

The curlew sandpiper is water dependent. It will not occur in an area unless suitable foraging habitat in the form of wetlands with bare edges of mud or sand with water to a depth up to 60 mm is available.

Impacts from shale and other unconventional gas development

The key areas of the landscape are shallow freshwater wetlands and estuarine environments.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination;
- changed surface water quality and/or flows; and
- contamination of estuarine waters.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on a moderate likelihood of occurrence in the region based on available knowledge. If present, the species will be in low numbers.

Information sources

Department of Environment and Energy (2019)

IUCN (2019)

Red goshawk, *Erythrotriorchis radiatus*

Overview

The red goshawk is a large hawk that has a wingspan of up to 1.35 m and a length of 45 to 60 cm. The sexes differ in size; females attain a maximum body mass of 1.1 kg compared to maximum body mass of 0.6 kg for males. The red goshawk has a wide but patchy distribution across coastal and interior regions of Queensland, the NT and the north-east of WA. It also occurs in north-east NSW (Figure 4). The species mainly occurs in open forest and woodland but also is present along the edges of rainforest. It mostly feeds on medium to large birds.

The red goshawk is currently listed nationally as vulnerable.

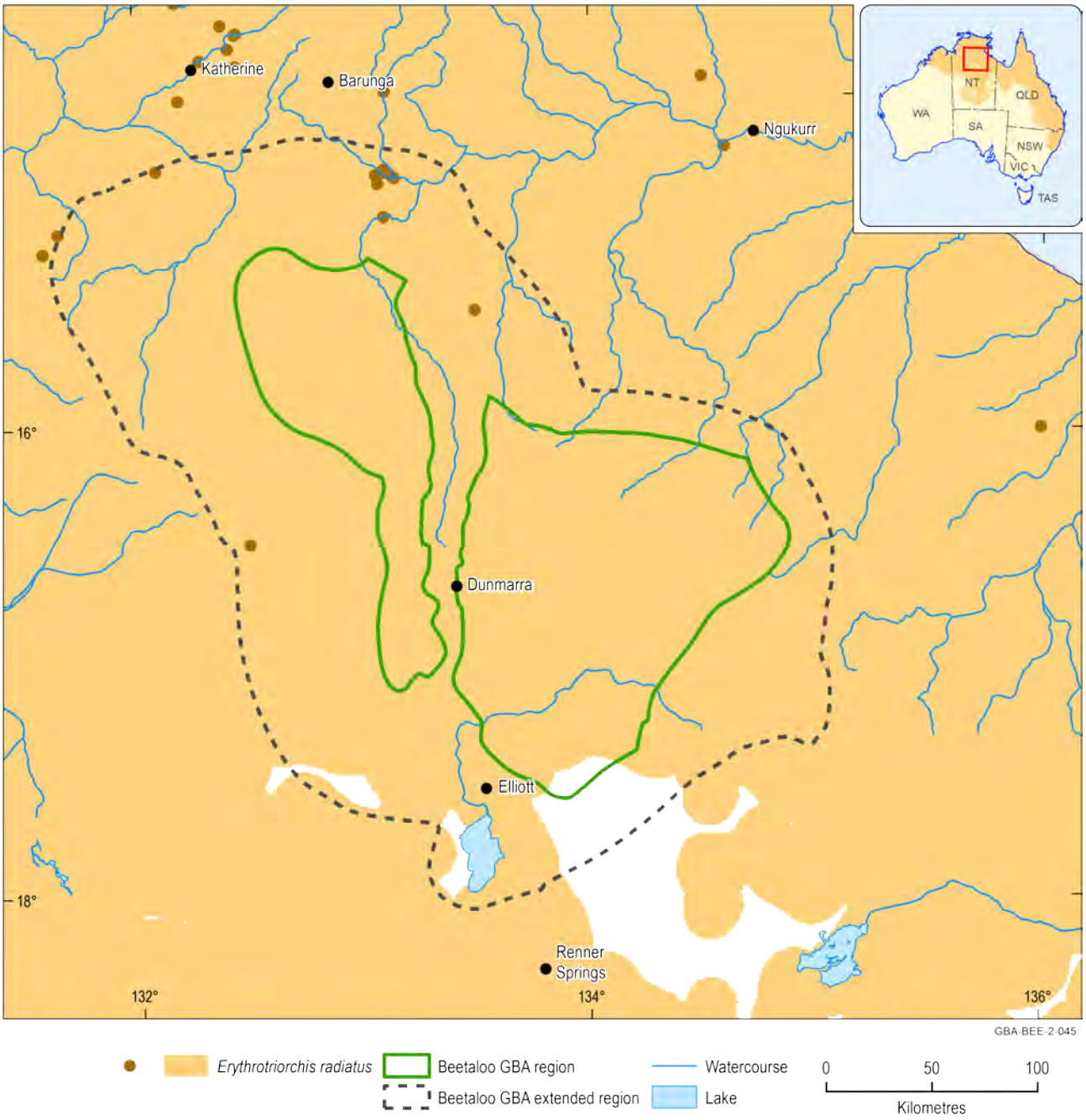

Figure 4 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the red goshawk, *Erythrotriorchis radiatus*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-045

Water dependency

The species is classed here as water dependent because of the likely water dependency of its nest sites. Nests are constructed in tall trees (mean height of 31 m) that are located within 1 km of, and commonly beside, permanent water. Water sources include rivers, swamps and pools (Department of Environment and Resource Management, 2012).

Impacts from shale and unconventional gas development

The key areas of the landscape for the species are likely to be riverine/gallery forest that support mature trees suitable for breeding.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows
- changed groundwater quality and/or levels
- bank instability and erosion.

Likelihood of being impacted by gas development in Beetaloo GBA region

High. Although the species is not known from the GBA region it breeds in the GBA extended region around Mataranka Thermal Pools. Nesting trees are likely to be within terrestrial GDEs which are connected to groundwater systems in the GBA region. Consequently, there is potential for some activities to negatively affect breeding habitat.

Information sources

Department of Environment and Energy (2019)

Department of Environment and Resource Management (2012)

Garnett et al. (2011)

Gouldian finch, *Erythrura gouldiae*

Overview

The Gouldian finch is a bird that occurs across northern Australia from inland north Queensland across the Top End of the NT to the Kimberley of WA (Figure 5). The species is multi-coloured with a combination of vivid colours. It is small with a body mass of 14 to 15 g. The Gouldian finch occupies open woodland that is relatively close to water; it feeds on seeding grasses and nests in hollows in eucalypts.

The species is endangered nationally. There is mounting evidence that populations are recovering (Garnett et al., 2011).

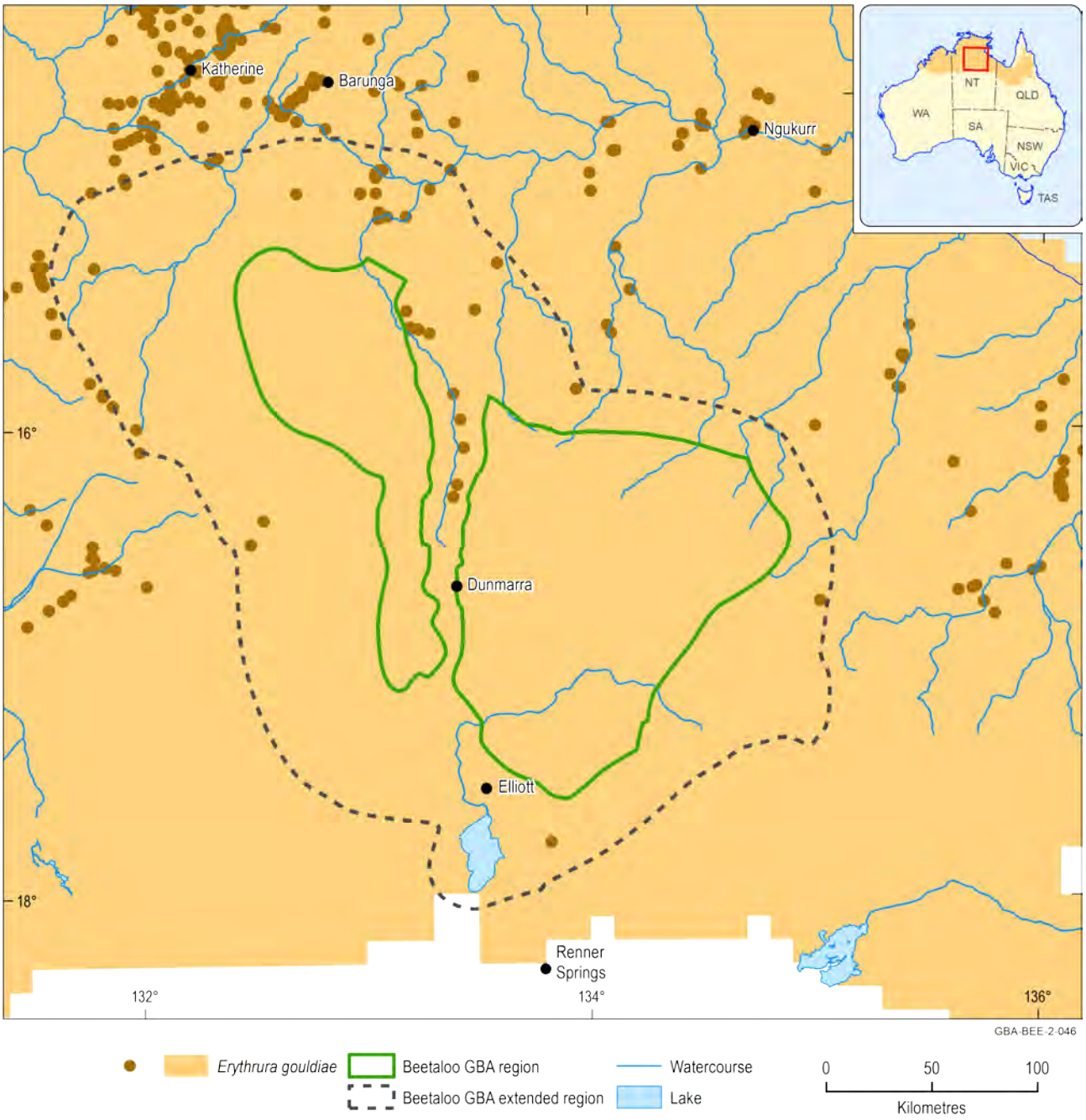

Figure 5 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the Gouldian finch, *Erythrura gouldiae*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-046

Water dependency

The Gouldian finch is water dependent. It relies on surface water sources, which it will visit daily. These typically occur in waterholes in creeks. Birds breed within 2 to 4 km of perennial waterholes or springs.

Impacts from shale and unconventional gas development

The key areas of the landscape for the species are waterholes and springs (on which it relies for water) and hollow-bearing trees in which it nests.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- introduction of invasive plants
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows
- bank instability and erosion.

Likelihood of being impacted by gas development in Beetaloo GBA region

High. Assessment is based on known occurrence in the region and potential of activities to negatively affect habitat, disrupt breeding and decrease size of the population.

Information sources

Department of Environment and Energy (2019)

Garnett et al. (2011)

Crested shrike-tit (northern), *Falcunculus frontatus whitei*

Overview

The northern subspecies of the crested shrike-tit is currently listed nationally as vulnerable. It is a small species of bird with a body mass of 20 to 30 g. It occurs in a range of different *Eucalyptus*-dominated woodlands in northern Australia. The northern subspecies of the crested shrike-tit forages for invertebrates in the foliage, branches, trunk and bark of trees. It is endemic to north-western Australia from the Kimberley region of WA to Borroloola in the north-east of the NT (Figure 6).

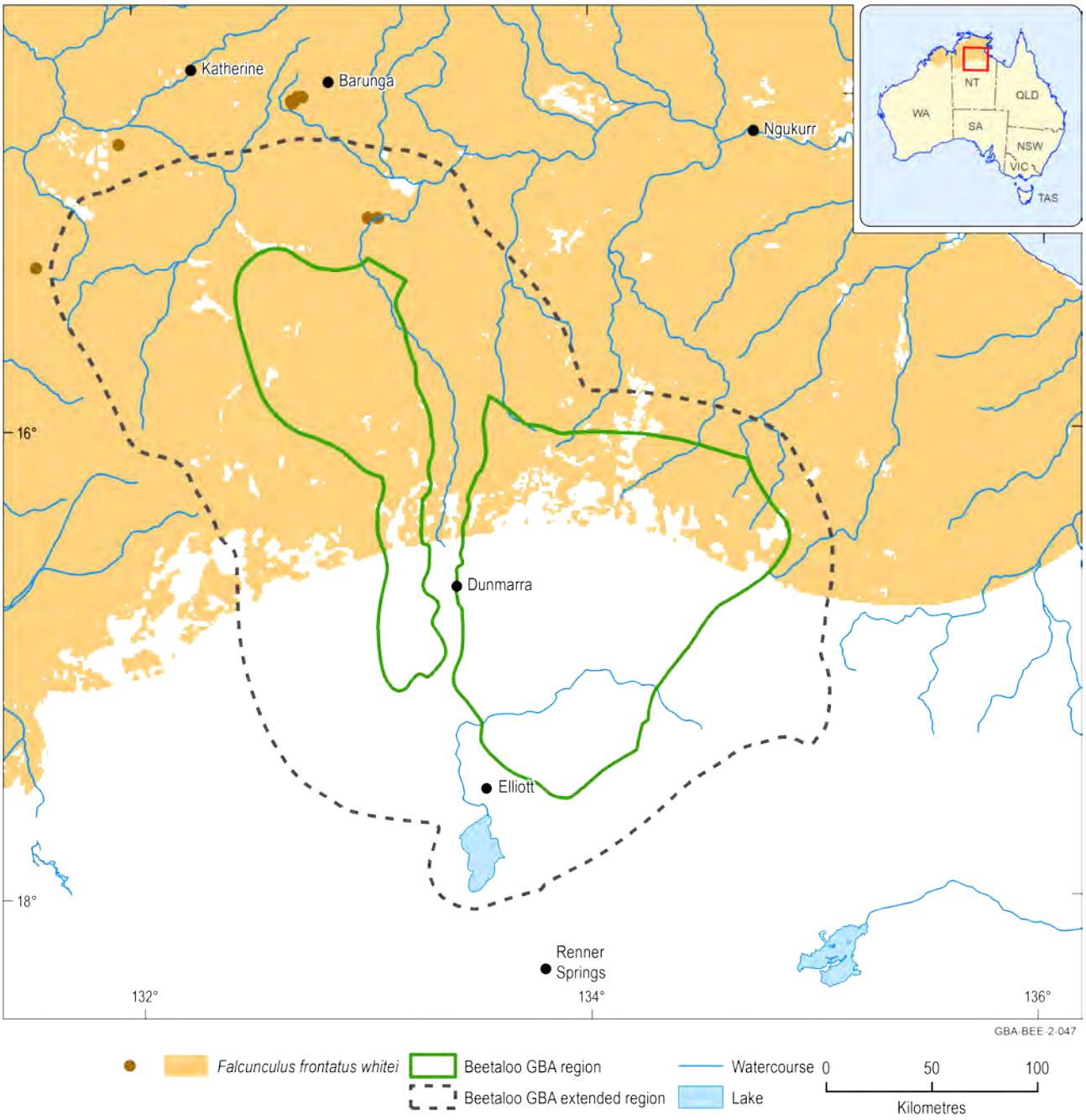

Figure 6 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the crested shrike-tit (northern), *Falcunculus frontatus whitei*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-047

Water dependency

The crested shrike-tit is assessed here as being water dependent requiring daily access to surface water to drink.

Impacts from shale and unconventional gas development

The key areas of the landscape for the species are eucalypt-dominated woodlands.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- introduction of invasive plants
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

High. Assessment is based on known occurrence in the region and potential of activities to negatively affect habitat, disrupt breeding and decrease size of the population.

Information sources

Department of Environment and Energy (2019)

Painted honeyeater, *Grantiella picta*

Overview

The painted honeyeater is a small species of bird (body mass 18 to 25 g) that has a wide distribution across eastern Australia extending to the tropics in north-west Queensland and north-east NT (Figure 7). It is a specialised bird feeding mainly on the fruit of mistletoes and exhibits seasonal movements in response to food availability. The painted honeyeater occupies acacia-dominated woodlands showing a preference for those with mature trees (Garnett et al., 2011). Many birds move to semi-arid regions in northern Australia following the completion of breeding in late summer/early autumn.

The painted honeyeater is listed nationally as vulnerable.

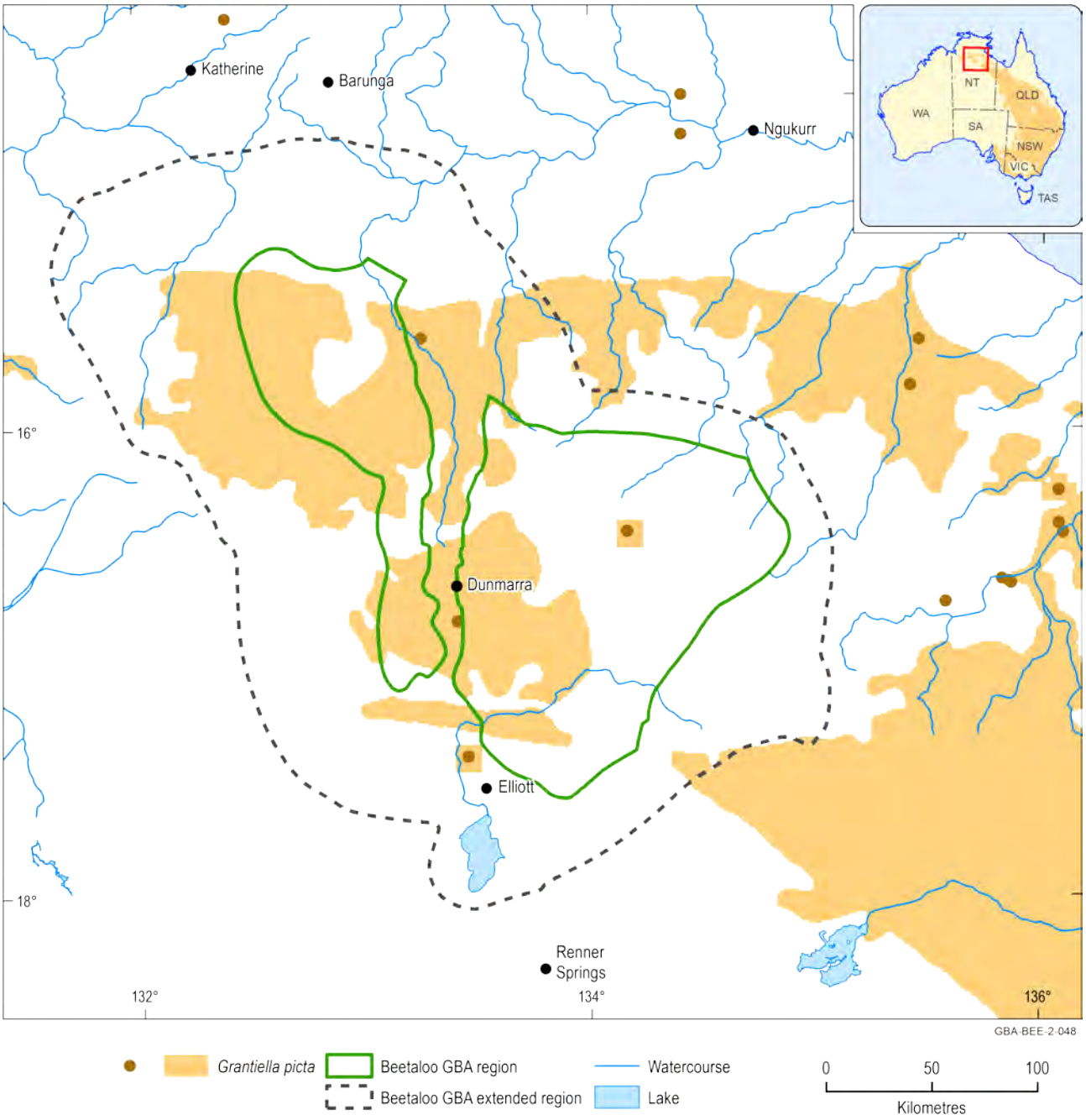

Figure 7 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the painted honeyeater, *Grantiella picta*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-048

Water dependency

The painted honeyeater is assessed here as being water dependent requiring daily access to surface water to drink.

Impacts from shale and unconventional gas development

The key areas of the landscape for the species are those that support mature trees with good numbers of mistletoes.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- introduction of invasive plants
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Although known to occur in the region; it is a non-breeding visitor. Numbers in the region are likely to be low (last record was in 2002) and the region represents a small portion of its geographic range.

Information sources

Department of Environment and Energy (2019)

Garnett et al. (2011)

Night parrot, *Pezoporus occidentalis*

Overview

The night parrot is a ground-dwelling bird that has a body mass of about 100 g. It is an enigmatic species that has only been regularly sighted, although in a small geographic range, since 2013. The night parrot is endemic to the Australian arid zone where it occurs in south-west Queensland, north-east SA and WA. In Queensland it occurs near Diamantina Lakes National Park and further to the north (Figure 8). It is cryptic and nocturnal. It shelters during the day in mature spinifex (*Triodia*) hummocks and flies up to 10 km to nearby feeding grounds soon after dusk. The diet is likely to be dominated by short-lived herbs and grasses. The species is currently listed as endangered.

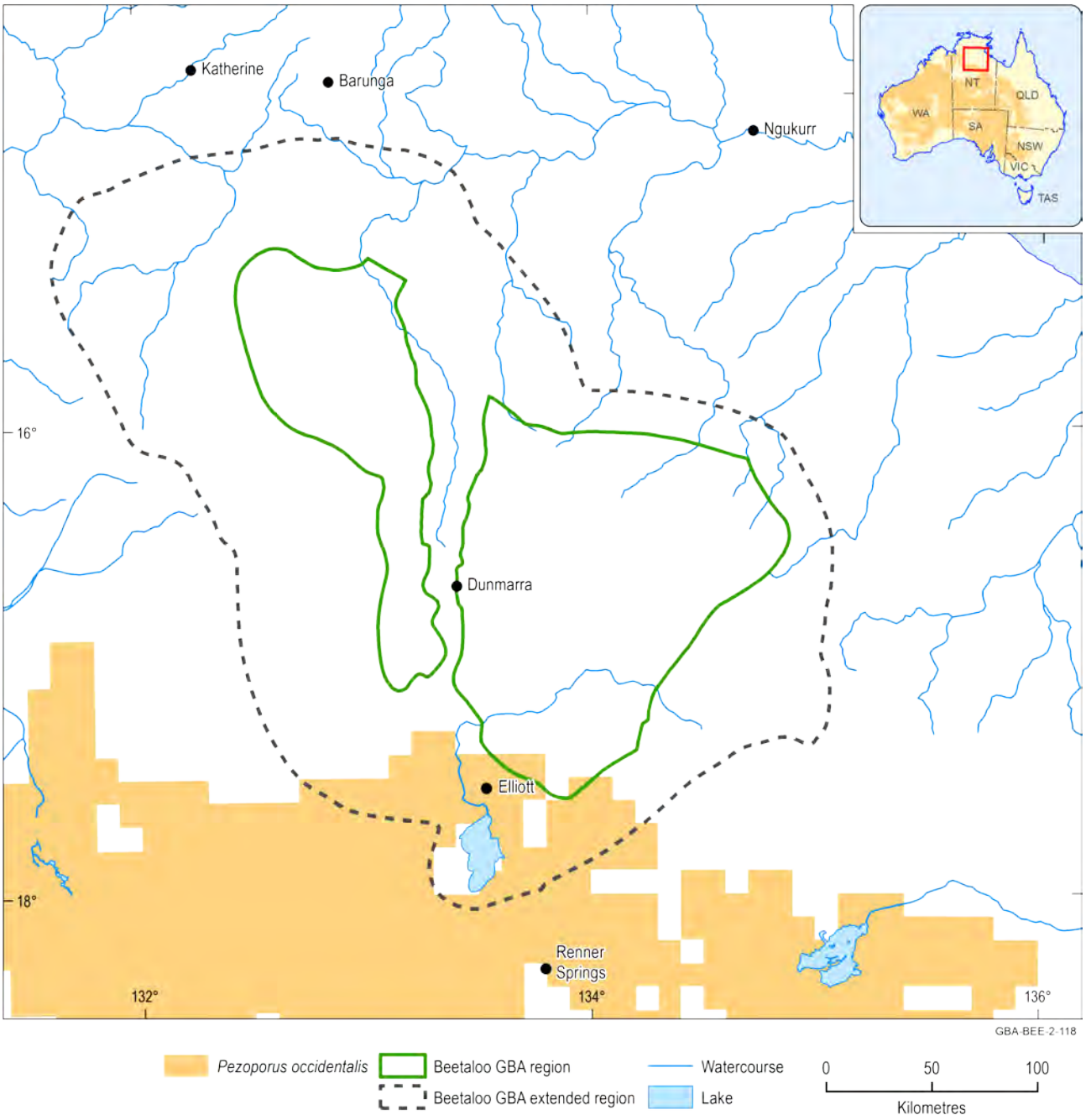

Figure 8 Potential distribution of the night parrot, *Pezoporus occidentalis*

Data: Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-118

Water dependency

The night parrot is not considered to be water dependent.

Impacts from shale and unconventional gas development

The key areas of the landscape for the species are those that support mature spinifex in which it roosts during the day and its foraging habitat which is in broad, shallow depressions that are fed from local runoff supporting cracking clay soils and mixed herb-grasslands.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- introduction of invasive plants
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on low likelihood of occurrence in the region. There are no historical records from the region and there is a lack of suitable habitat.

Information sources

Department of Environment and Energy (2019)

Princess parrot, *Polytelis alexandrae*

Overview

The princess parrot is endemic to Australia's arid zone. It occurs in the western arid zone from north-west SA across the western deserts of the NT and WA (Figure 9). The species forages on flowers, seeds and other plant material on spinifex sandplains and woodlands and nests in the hollows of large trees. Princess parrots exhibit nomadic movements in response to pulses in primary productivity. The species is listed as vulnerable under the EPBC Act. Numbers appear to be stable.

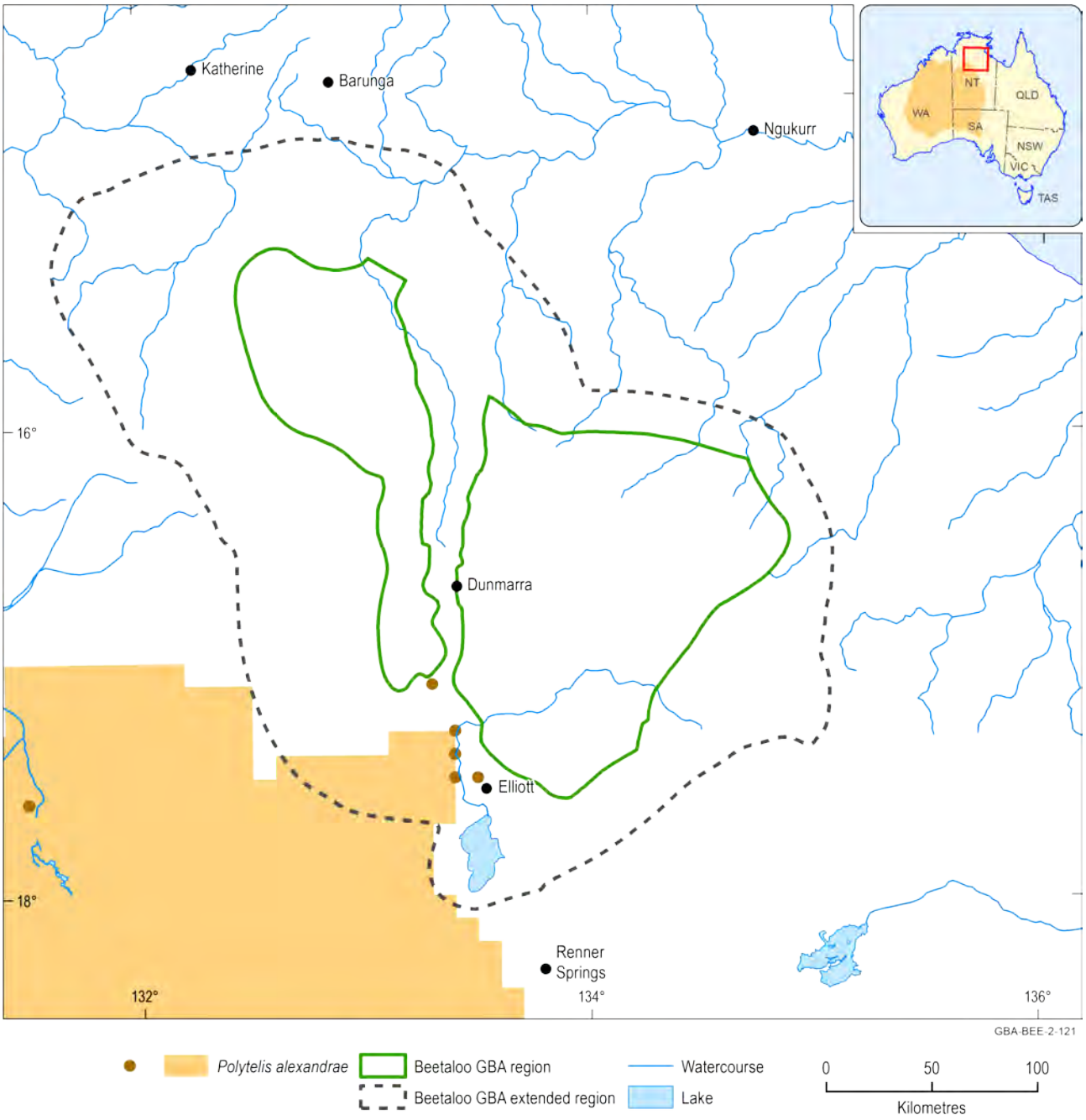

Figure 9 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the princess parrot, *Polytelis alexandrae*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-121

Water dependency

The princess parrot is not water dependent.

Impacts from shale and unconventional gas development

The key areas of the landscape for the species are spinifex sandplains and woodlands especially those that support large hollow-bearing trees that are used as nests.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- introduction of invasive plants
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on low likelihood of the species regularly occurring in the region. The most recent record is from 1976 and the records are considered to have low locational reliability.

Information sources

Department of Environment and Energy (2019)

Australian painted snipe, *Rostratula australis*

Overview

The Australian painted snipe (*Rostratula australis*) is a species endemic to Australia that occupies shallow freshwater wetlands. It is listed as endangered and as a marine species under the EPBC Act. Although the species has been recorded across the Australian continent, the area of occupancy is comparatively small and was estimated at about 2000 km^2 by (Garnett et al., 2011) (Figure 10).

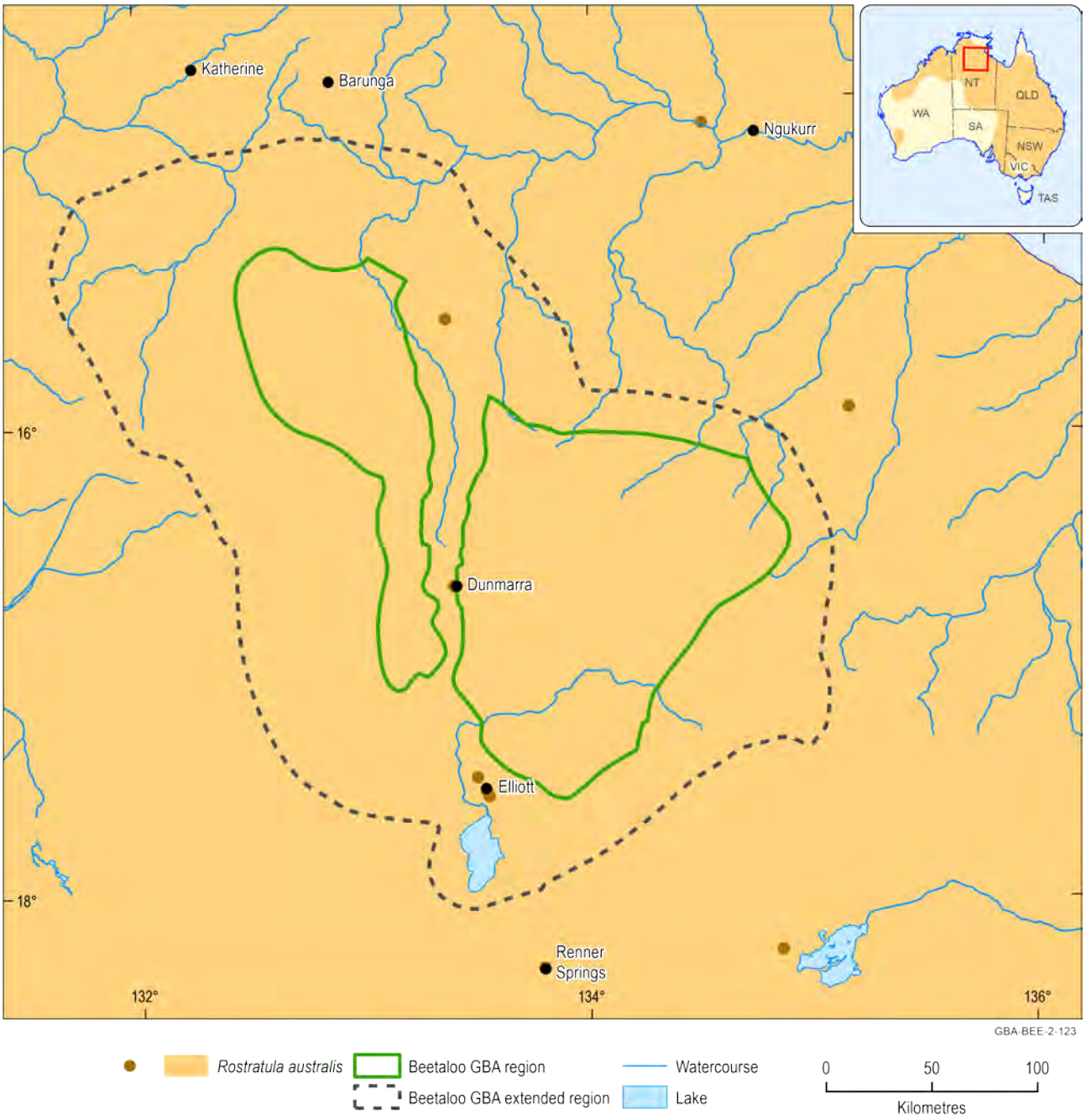

Figure 10 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the Australian painted snipe, *Rostratula australis*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-123

Water dependency

The Australian painted snipe is a water-dependent species. The main habitat of this species is shallow freshwater wetlands. Suitable habitat includes lakes, swamps, claypans, inundated or waterlogged grassland and saltmarsh and artificial wetlands including dams, rice crops, sewage farms and bore drains.

Impacts from shale and other unconventional gas development

The key areas of the landscape for this species are shallow freshwater wetlands.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

High. Assessment is based on known occurrence in the region and potential of activities to negatively affect habitat and disrupt breeding.

Information sources

Department of Environment and Energy (2019)

Garnett et al. (2011)

Masked owl (northern), *Tyto novaehollandiae kimberli*

Overview

The northern subspecies of the masked owl occurs across northern Australia from the coast of north Queensland across the Top End to the Kimberley region in WA (Figure 11). It is a large bird (body mass 400 g) with a distinctive heart-shaped facial disc. The masked owl (northern) typically forages in tall open forests of eucalypts and along the margins of agricultural fields. Here it captures rodents and other small mammals. Masked owls nest and roost in hollows in large trees within forest patches.

The northern subspecies of the masked owl is listed nationally as vulnerable.

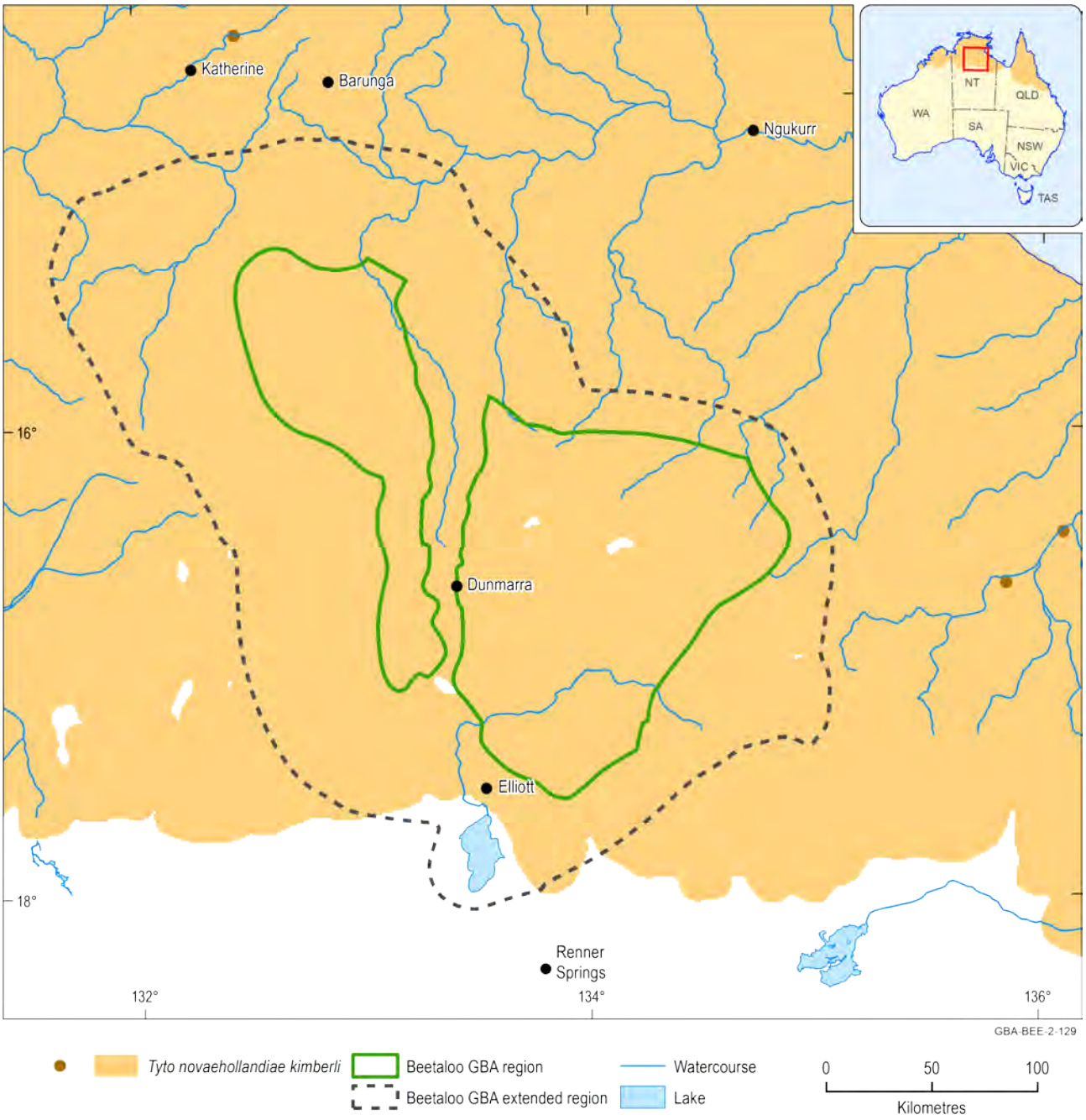

Figure 11 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the masked owl (northern), *Tyto novaehollandiae kimberli*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-129

Water dependency

The masked owl (northern) is not considered to be water dependent.

Impacts from shale and other unconventional gas development

The key areas of the landscape for the species are likely to be forest patches that support mature trees with hollows that are used for breeding and roosting.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows
- changed groundwater quality and/or levels
- bank instability and erosion.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on lack of records and low likelihood of occurrence in the region.

Information sources

Department of Environment and Energy (2019)

Garnett et al. (2011)

Northern quoll, *Dasyurus hallucatus*

Overview

The northern quoll is a medium-sized carnivorous marsupial. The sexes differ in size; males attain a maximum body mass of 1.12 kg compared to maximum body mass of 0.69 kg for females. The species is an omnivore feeding on fruits, invertebrates and some vertebrates including mammals, birds, reptiles and frogs. Northern quolls shelter during the day in rock crevices, tree hollows, termite mounds and similar structures. At night they forage both on the ground and in trees in savanna woodland and patches of rainforest and appear to favour rocky escarpments.

The northern quoll is the largest remaining carnivorous marsupial in most of northern Australia. The range of the species includes eastern and northern Queensland, the Top End of the NT and the Kimberley and Pilbara regions of WA (Figure 12). The northern quoll is listed nationally as endangered.

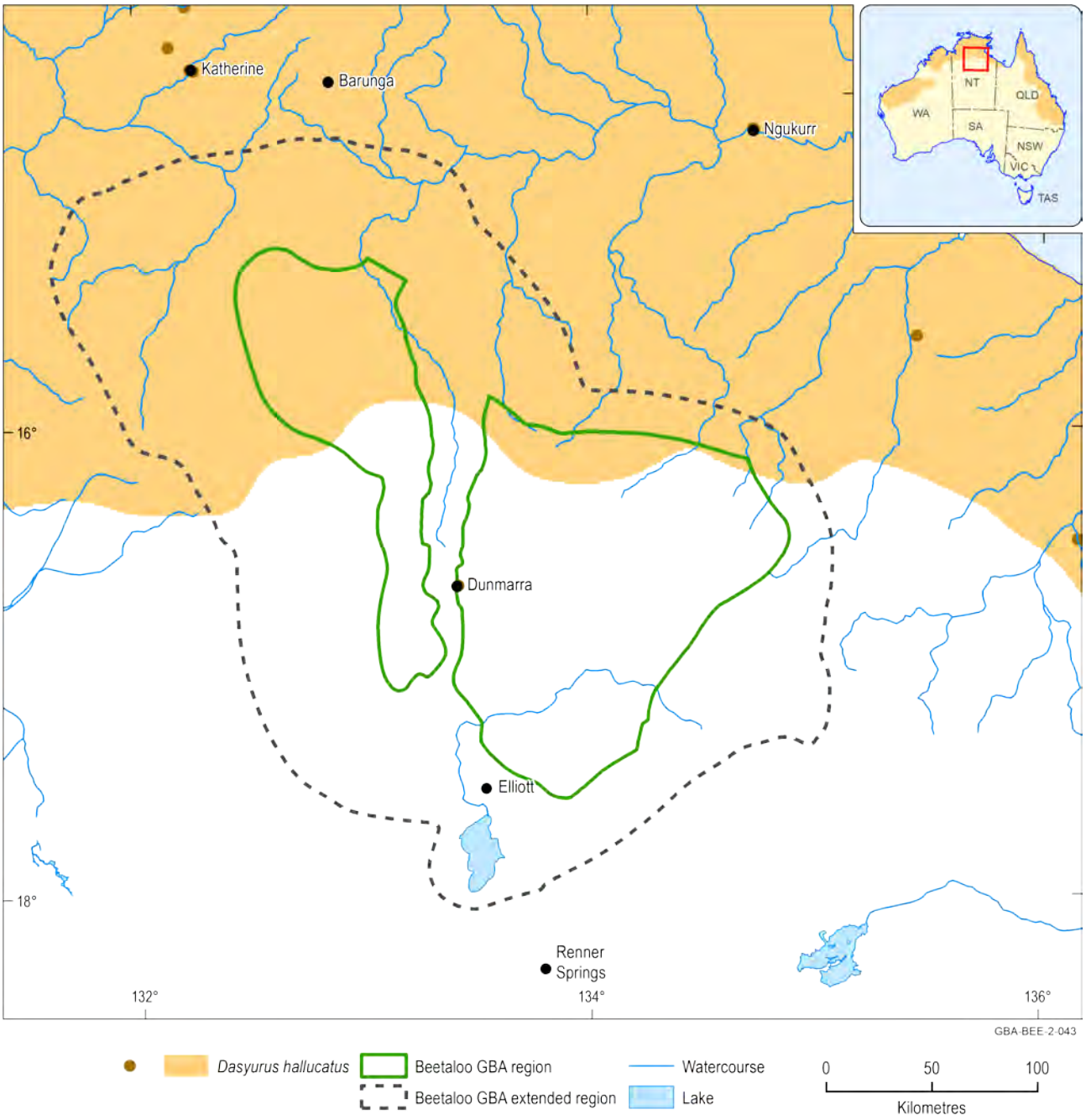

Figure 12 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the northern quoll, *Dasyurus hallucatus*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-043

Water dependency

The northern quoll is not considered to be water dependent. It will drink water when it is available but appears able to obtain enough moisture from its food when surface water sources dry up towards the later stages of the dry season in northern Australia (van Dyck and Strahan, 2008).

Impacts from shale and other unconventional gas development

The species has broad habitat requirements in terms of foraging and shelter sites. Rocky habitats are of importance. The northern quoll is known to be at risk from predation by cats and dingoes

and by ingesting cane toads. Therefore, it is imperative that activities undertaken as part of the development of a shale gas industry do not encourage these species. Specifically, sources of resource subsidies for predators of quolls (such as open rubbish dumps and accessible sources of water) should be avoided.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on the low likelihood of the species occurring in the region as represented by the post 1999 distribution of the species given in Hill and Ward (2010). If the species was present it is expected that population size in the region would be very low.

Information sources

Hill and Ward (2010)

van Dyck and Strahan (2008)

Northern brush-tailed phascogale, *Phascogale pirata*

Overview

The northern brush-tailed phascogale is a carnivorous marsupial, with a body mass of 150 to 230 g. Northern brush-tailed phascogales mostly occur in tall open forests dominated by species of *Eucalyptus*. They feed on the ground and in trees and shelter during the day in tree hollows. The species is endemic to the Top End of the NT occurring from Litchfield National Park across to West Island (Figure 13).

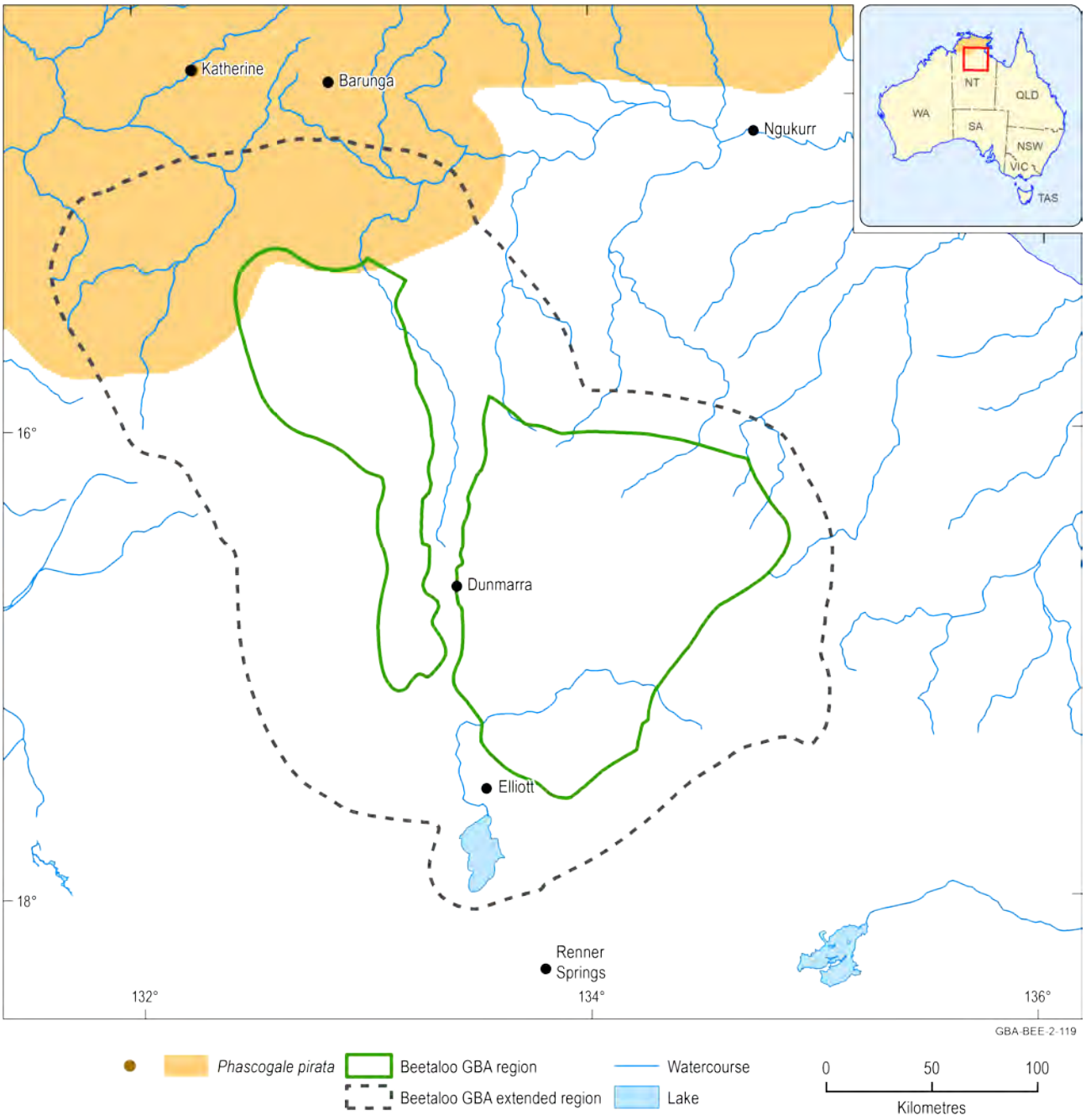

Figure 13 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the northern brush-tailed phascogale, *Phascogale pirata*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-119

Water dependency

This species is not considered to be water dependent.

Impacts from shale and other unconventional gas development

The key areas of the landscape are areas of tall open forests dominated by eucalypts.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- introduction of invasive plants
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on a lack of records of the species in the region, the lack of suitable habitat, and the likelihood that, if it does occur, numbers will be very low as the Beetaloo GBA area is at the extreme south of its potential range.

Information sources

Department of Environment and Energy (2019)

van Dyck and Strahan (2008)

Greater bilby, *Macrotis lagotis*

Overview

The greater bilby is a medium-sized ground-dwelling native marsupial (body mass 600 to 2500 g) that is the only surviving member of the sub-family Thylacomyinae within the bandicoot family (Peramelidae). Although its range has declined considerably since European settlement of Australia it is still found in south-western Queensland and across the western deserts of the NT and WA (Figure 14). It is a nocturnal species that shelters during the day in burrows that it digs itself. It has an omnivorous diet. It occupies a wide range of vegetation assemblages including hummock grassland and acacia shrublands.

The greater bilby is an iconic desert marsupial that has become a flagship species for conservation in Australia. It is listed nationally as vulnerable. The species is considered to play an important role as an ecosystem engineer by digging the soil and facilitating nutrient cycling.

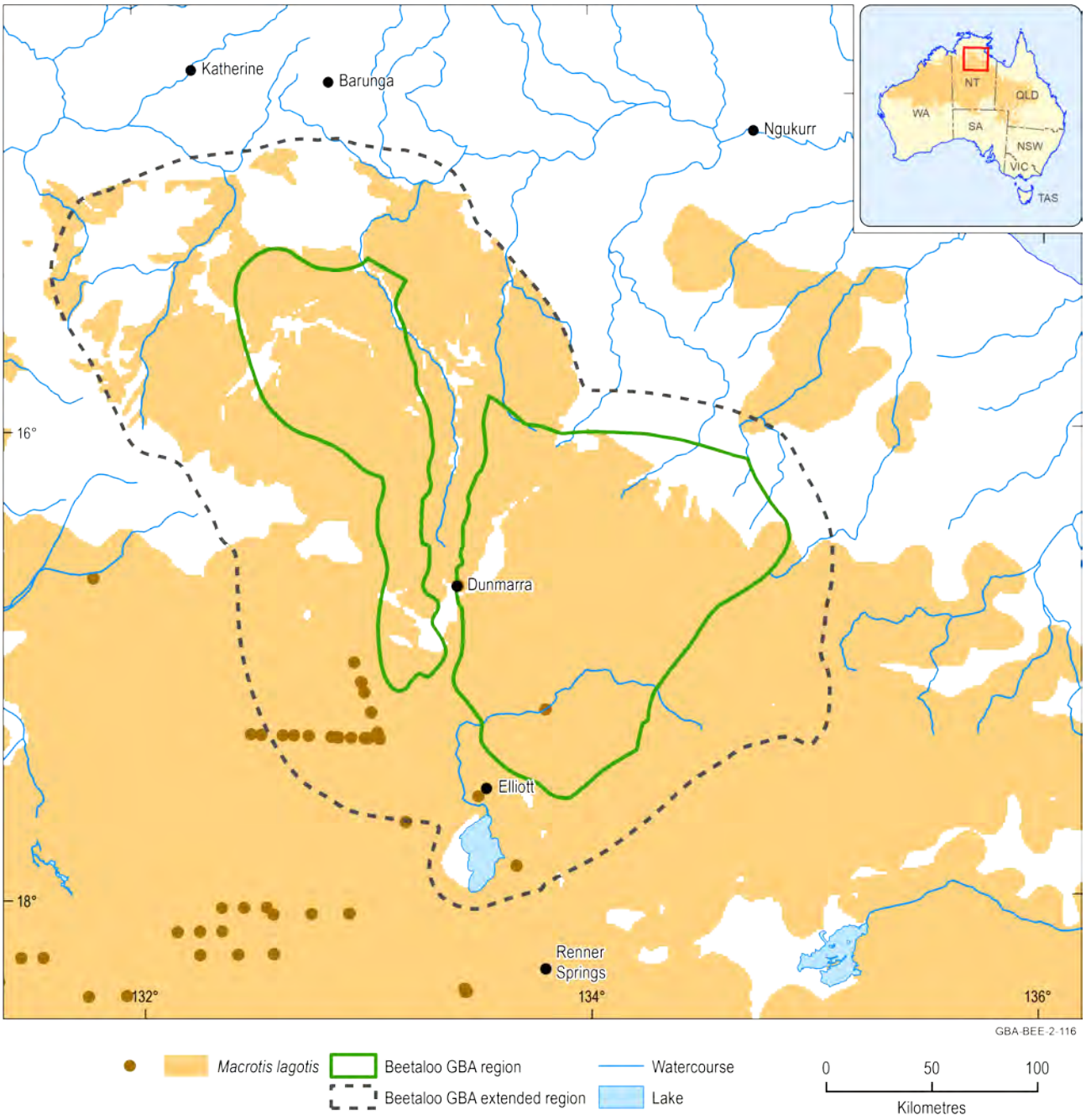

Figure 14 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the greater bilby, *Macrotis lagotis*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-116

Water dependency

This species is not considered to be water dependent. The species obtains most of its water from its food.

Impacts from shale and other unconventional gas development

The key areas of the landscape are areas of tall open forests dominated by eucalypts.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

High. The greater bilby is known to occur in the Beetaloo GBA region and is regularly sighted in some areas. There is the potential for activities to negatively affect habitat and disrupt breeding.

Information sources

Department of Environment and Energy (2019)

van Dyck and Strahan (2008)

Ghost bat, *Macroderma gigas*

Overview

The ghost bat is the largest species of microchiropteran bat that occurs in Australia. It has a head-body length of 10 to 13 cm, a wingspan of up to 60 cm and a body mass of up to 165 g. The ghost bat is a spectacular looking animal with a prominent noseleaf and large ears. The species is confined to the tropical north of Australia although formerly (till the 1960s) it was patchily distributed in central Australia and, historically when the climate was warmer and wetter, it occurred as far south as the Nullarbor Plain (Figure 15).

The ghost bat spends the day in subterranean roosts, usually caves, rocky overhangs and disused mine adits and shafts. Therefore, it has distinct roosting and foraging sites. Foraging takes place in woodland with individuals foraging over an area of up to 61 ha.

The species has recently undergone decreases in population size. The exact cause(s) are unclear at this stage. The conservation status of the ghost bat was elevated to vulnerable in 2016.

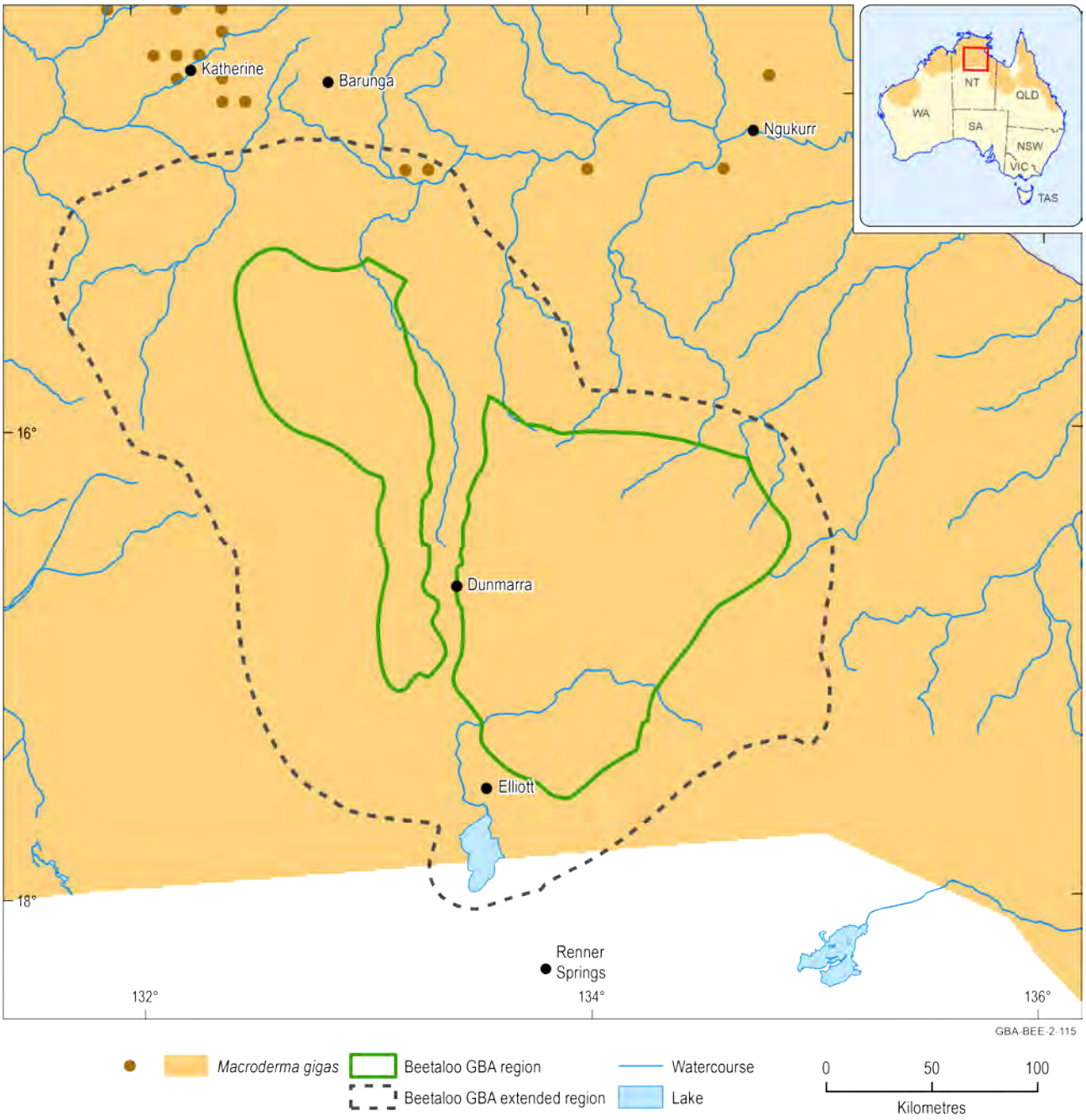

Figure 15 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the ghost bat, *Macroderma gigas*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-115

Water dependency

The ghost bat is not considered to be water dependent. It is likely to access surface water to drink while foraging at night when it is available.

Impacts from shale and other unconventional gas development

The key areas of the landscape for this species are likely to be subterranean (caves, disused mines) roost sites (which may suffer unintentional disturbance) and surface water (used for drinking). Extensive foraging habitat in eucalypt forest and woodland exists for this species.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

No. Assessment is based on a low likelihood of its continued occurrence in the region with last record in 1987 and the stated decline of the species throughout its range. No important roost sites for the species are known in the Beetaloo GBA region or in the Beetaloo GBA extended region.

Information sources

Department of Environment and Energy (2019)

Bare-rumped sheath-tailed bat, *Saccolaimus s. nudicluniatus*

Overview

The bare-rumped sheath-tailed bat is a large microchiropteran bat that occurs in northern Australia and New Guinea, Timor, Indonesia and elsewhere in south-east Asia. It has a body mass up to 55 g and a head-body length of up to 95 mm. The species feeds on insects at night that it captures while foraging in open space. It has fast, direct flight. During the day the bare-rumped sheath-tailed bat roosts in colonies of up to 100 individuals located in tree hollows.

Until recently, it was listed as critically endangered, but the species is now classified nationally as vulnerable. In Australia it has been recorded along the east coast of Queensland from Townsville up to Iron Range on Cape York Peninsula and across the Top End of the NT (Milne et al., 2009) (Figure 16).

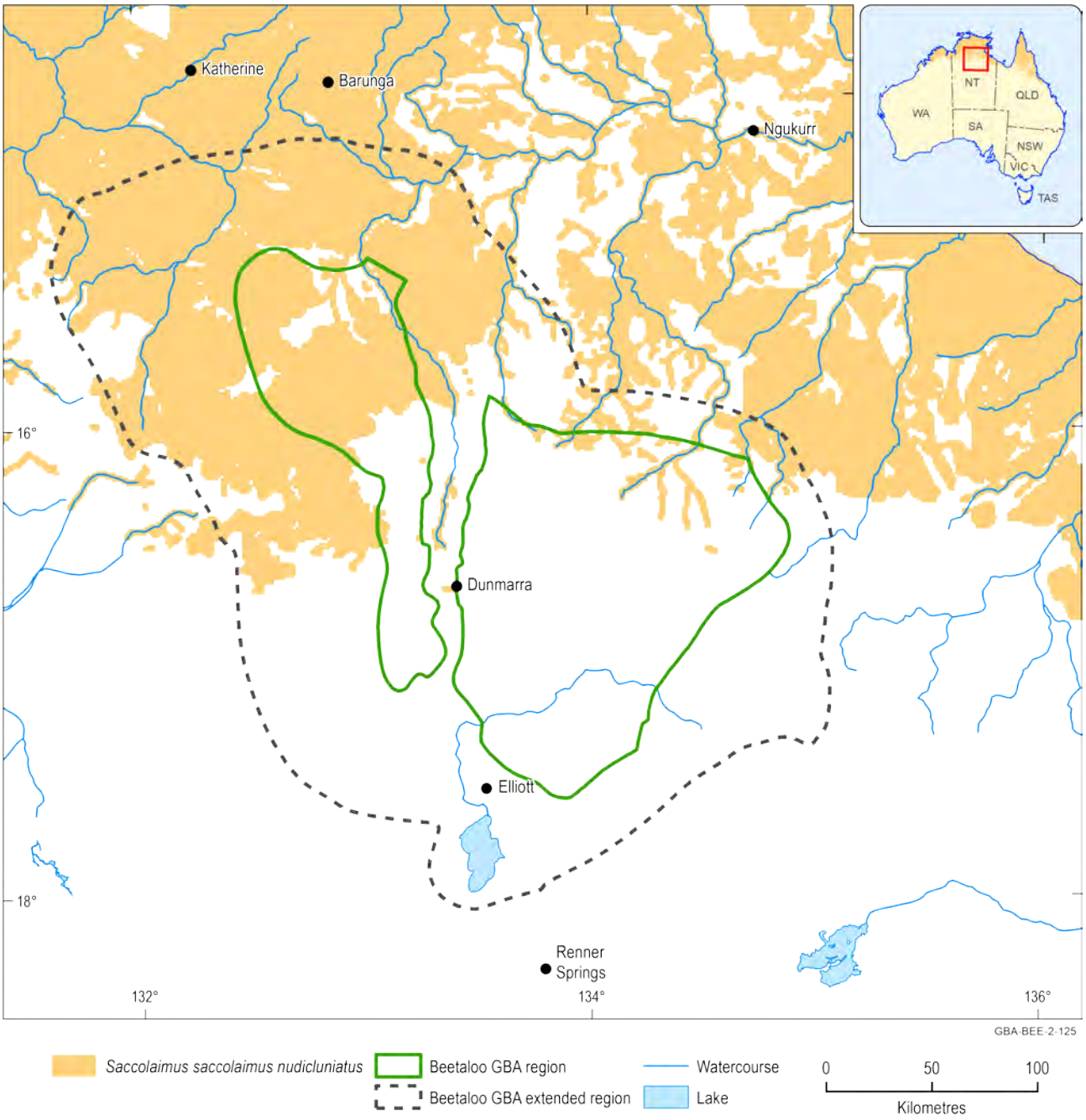

Figure 16 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the bare-rumped sheath-tailed bat, *Saccolaimus s. nudicluniatus*

Data: Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-125

Water dependency

The bare-rumped sheath-tailed bat is not considered to be water dependent.

Impacts from shale and other unconventional gas development

The key areas of the landscape are likely to be roosts in hollows of large trees. Extensive foraging habitat in eucalypt forest and woodland exists for this species.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows
- changed groundwater quality and/or levels
- bank instability and erosion (which may impact roost trees).

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on lack of records and low likelihood of occurrence in the region.

Information sources

Department of Environment and Energy (2019)

Milne et al. (2009)

Schulz and Thomson (2007)

Plains death adder, *Acanthophis hawkei*

Overview

The plains death adder is a small (body length of about 0.6 m), stout-bodied terrestrial snake. It occurs across northern Australia from the extreme north-east of WA, across the Top End and Barkly Tableland of the NT/Queensland border and the Mitchell Grass Downs in south-west Queensland (Figure 17). The plains death adder occurs on floodplains that have cracking clay soils. The conservation status of this species is vulnerable. Populations have declined because of cane toad invasion in to northern Australia; the species readily captures toads but is highly susceptible to the toad's toxins.

The plains death adder feeds on reptiles, frogs and small mammals, especially rodents. Reptiles and frogs are taken when the snakes are young. The species is like other death adders in being an ambush predator.

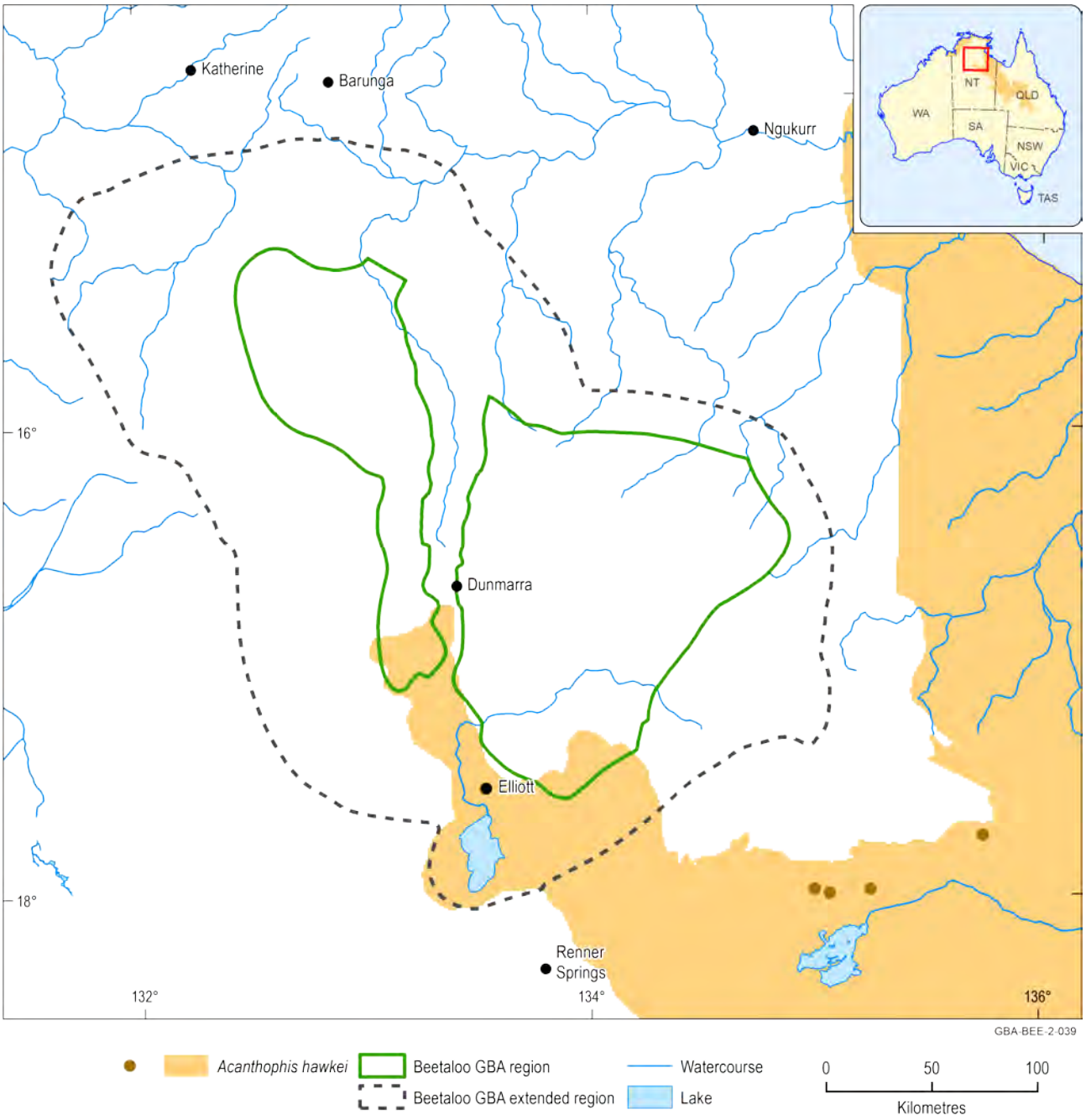

Figure 17 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the plains death adder, *Acanthophis hawkei*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-039

Water dependency

The water dependency of the species is poorly understood but it is considered unlikely to be water dependent.

Impacts from shale and other unconventional gas development

The key areas of the landscape for this species are likely to be floodplains that have cracking clay soils.

Potential effects likely to be experienced by this species include:

- habitat loss and fragmentation
- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on moderate likelihood of occurrence in the region and relatively small portions of suitable habitat for the species.

Information sources

Department of Environment and Energy (2019)

Ward and Phillips (2012)

Gulf snapping turtle, *Elseya lavarackorum*

Overview

The gulf snapping turtle is a species of freshwater turtle that was first described from fossils found at Riversleigh Station and was subsequently discovered to be extant. The gulf snapping turtle has a short neck and grows to a maximum length of 35 cm. It is an aquatic species that is entirely herbaceous and is confined to riverine habitat. It nests by laying eggs in the soil near the edge of the water.

Based on current understanding of species boundaries in the genus, the gulf snapping turtle appears to have a limited distribution that encompasses the upper and middle reaches of the Nicholson and Gregory Rivers in north-west Queensland and north-east NT and the upper reaches of the Calvert River in the NT (Freeman et al., 2014) (Figure 18). These areas are characterised by stony hills and escarpments. The gulf snapping turtle occurs in deep water pools of permanently flowing spring-fed rivers and occurs in highest densities where the riparian vegetation is undisturbed (Freeman et al. 2014). The gulf snapping turtle is listed nationally as endangered. However, in the NT it is listed as being of least concern.

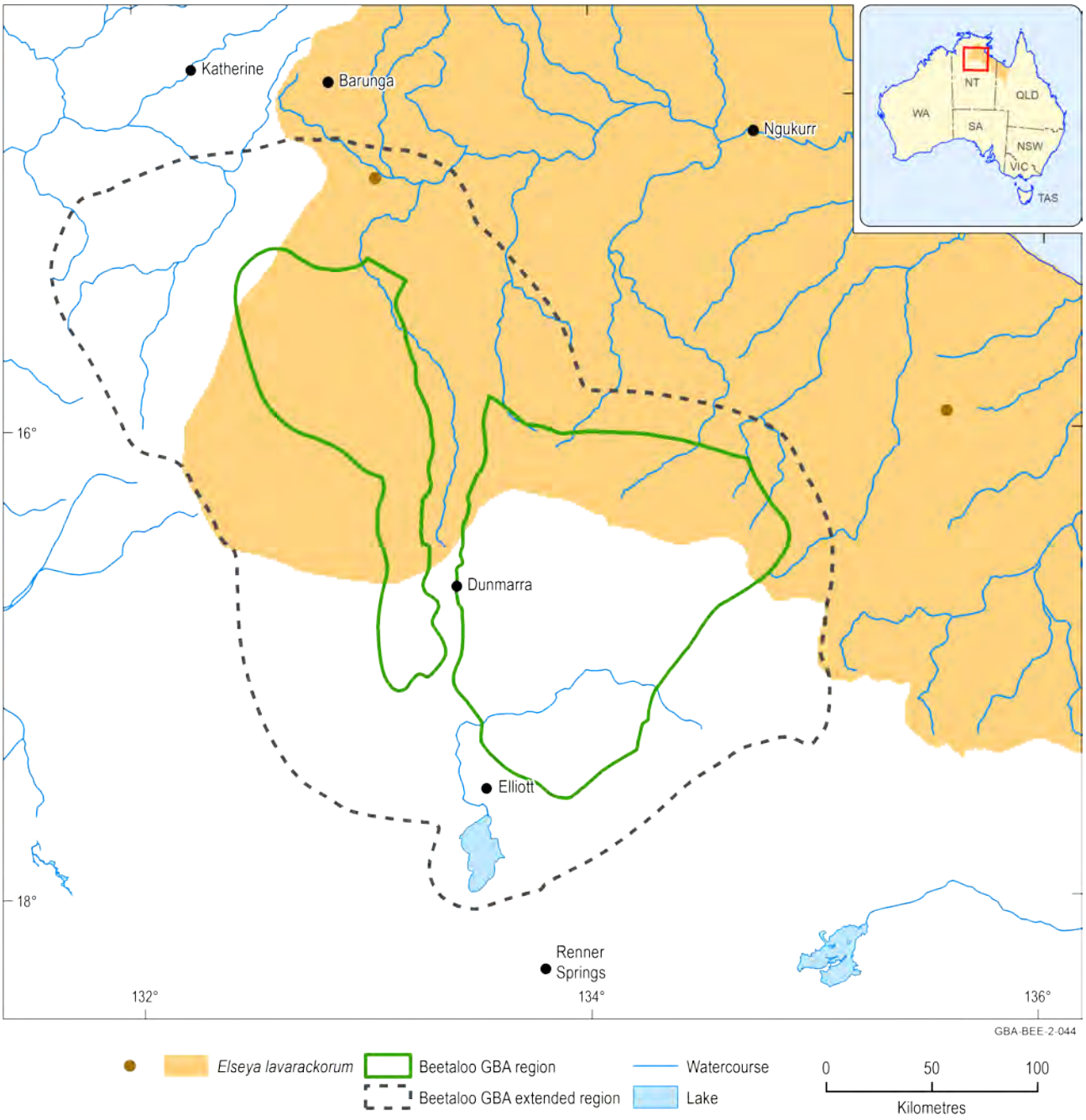

Figure 18 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the gulf snapping turtle, *Elseya lavarackorum*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-044

Water dependency

This species is water dependent throughout its life.

Impacts from shale and other unconventional gas development

Key areas for the gulf snapping turtle are deep water pools of permanently flowing spring-fed rivers especially where the riparian vegetation is largely undisturbed.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows
- changed groundwater quality and/or levels
- bank instability and erosion
- changed groundwater composition.

Likelihood of being impacted by gas development in Beetaloo GBA region

Uncertain. Occurrence in the region is uncertain because of taxonomic confusion. If present there is the potential of activities to decrease population size, reduce area of occupancy and negatively affect habitat.

Information sources

Department of Environment and Energy (2019)

Woinarski (2006)

Freeman et al. (2014)

Freshwater sawfish, *Pristis pristis*

Overview

The freshwater sawfish is a large, slender fish. It is the largest freshwater fish found in Australia reaching a maximum body length of 5.82 m (Commonwealth of Australia 2015a). The species lives in river and estuarine environments and up to 100 km offshore in northern and western Australia as well as in North and South America, Africa, Asia and New Guinea (Figure 19). The species is classified as vulnerable nationally and is also listed as migratory under the EPBC Act.

Freshwater sawfish inhabit the sandy or muddy floors of shallow coastal waters, estuaries and river mouths and have been recorded up to 400 km inland in the central and upper reaches of freshwater rivers and in isolated waterholes. Freshwater bodies and estuaries are occupied by neonates and juveniles whereas adults occur mainly in estuaries and coastal marine environments. In Australian rivers, nursery areas fragment during the dry season and turn in to a series of isolated waterholes that are reconnected during the subsequent wet season.

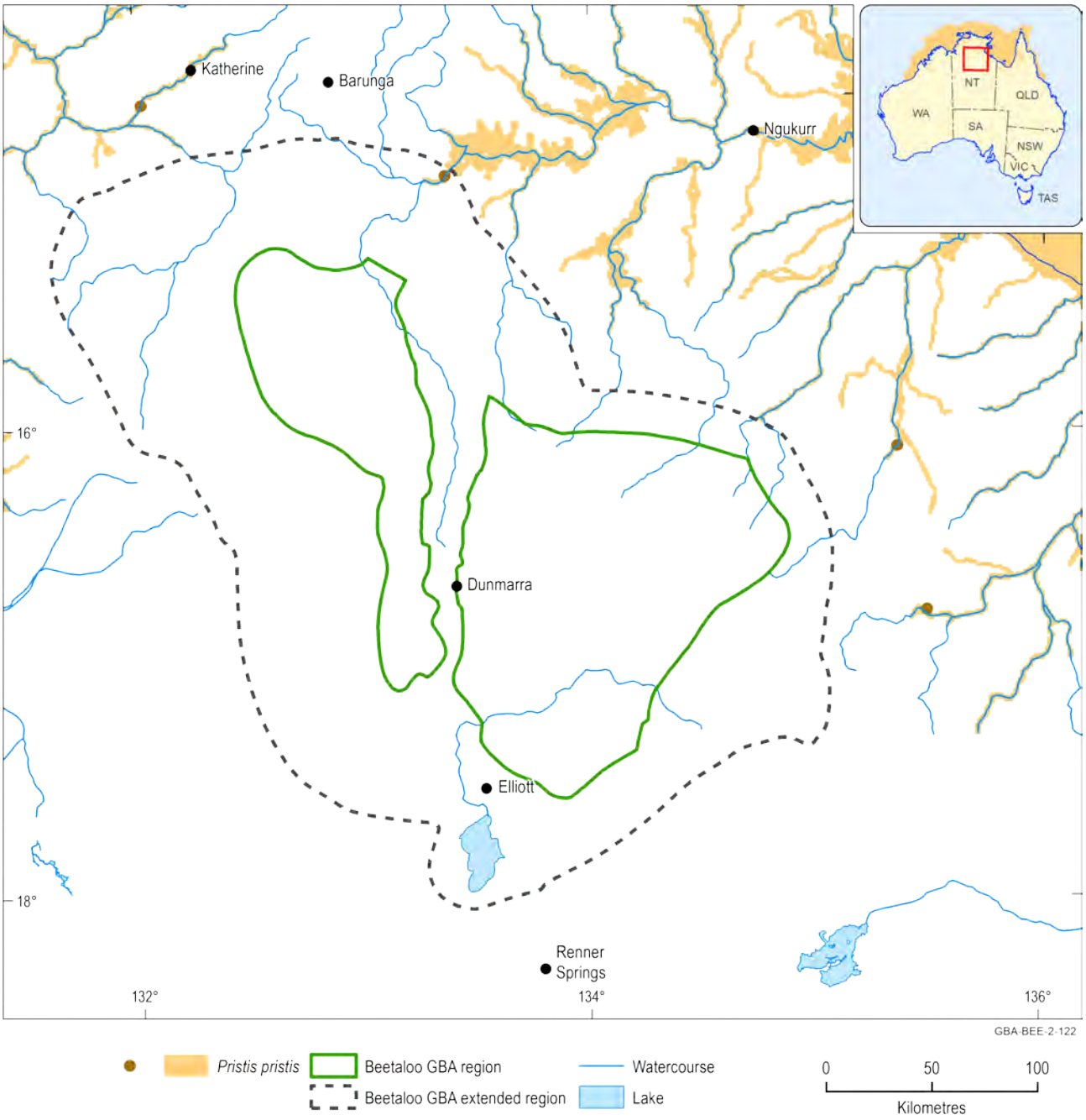

Figure 19 Potential distribution (solid colour) and Atlas of Living Australia observations (dots) of the freshwater sawfish, *Pristis pristis*

Data: Atlas of Living Australia (2019); Department of the Environment and Energy (2018b)
Element: GBA-BEE-2-122

Water dependency

This species is aquatic.

Impacts from shale and other unconventional gas development

Key areas in tropical rivers for freshwater sawfish are likely to be the central and upper reaches of freshwater rivers and isolated waterholes.

Potential effects likely to be experienced by this species include:

- exposure to soil, groundwater and/or surface water contamination
- changed surface water quality and/or flows
- changed groundwater quality and/or levels
- bank instability and erosion
- changed groundwater composition
- contamination of estuarine waters.

Likelihood of being impacted by gas development in Beetaloo GBA region

Low. Assessment is based on a very low likelihood of the species occurring in the region. There is a possibility that if changes in groundwater flows affect discharge at springs such as at Mataranka the species will be impacted. This will be addressed in Stage 3 of the project.

Information sources

Commonwealth of Australia (2015a)

Commonwealth of Australia (2015b)

1.4 Matters of Territory Environmental Significance

Two matters of environmental significance classified under NT legislation are potentially relevant to the Beetaloo GBA region and extended region. These matters are:

1. parks and reserves (listed under the *Territory Parks and Wildlife Conservation Act*)
2. species listed as threatened (i.e. critically endangered, endangered, vulnerable) under the Territory Parks and Wildlife Conservation Act but not under the Commonwealth's EPBC Act.

In addition to matters listed under NT legislation, the GBA Program also considered the following two categories as being of environmental significance within the NT:

3. nationally important wetlands identified in the *Directory of Important Wetlands in Australia* (DIWA) (Department of the Environment and Energy, 2010)
4. groundwater-dependent ecosystems.

1.4.1 State and territory reserves

One territory reserve, Bullwaddy Conservation Reserve, occurs entirely within the Beetaloo GBA region (Table 3). A further four reserves are outside the Beetaloo GBA region but have 100% of their area within the Beetaloo GBA extended region (Table 3).

Table 3 List of national parks, reserves and conservation covenants under the *Territory Parks and Wildlife Conservation Act* located in the Beetaloo GBA region and the Beetaloo GBA extended area, together with a summary of key attributes

Location	Name of reserve	Details
Beetaloo GBA region	Bullwaddy Conservation Reserve	Only reserve within the Sturt Plateau IBRA region. Contains stands of bullwaddy, Macropteranthes kekwickii.
Beetaloo GBA extended region	Elsey National Park	Protects Mataranka Thermal Pools. Refugium for endemic plants.
	Frew Pond	A waterhole along the route of the Overland Telegraph Line named by explorer John McDouall Stuart in 1862.
	Lake Woods Conservation Covenant	Covers Lake Woods. Significant wetland.
	Longreach Waterhole Protected Area	Protects part of the Lake Woods system.

1.4.2 Territory-listed threatened species

Four species of vertebrate animal, that have been classified as threatened in the NT but not nationally, have been recorded within the Beetaloo GBA region since 1990 and are considered to possibly still occur there (Table 4). These species are: grey falcon (*Falco hypoleucos*), pale field-rat (*Rattus tunneyi*), Merten's water monitor (*Varanus mertensi*), and floodplain monitor (*Varanus panoptes*). A further two species has been recorded from the extended GBA region since 1990: Mitchell's water monitor (*Varanus mitchelli*) and the land snail, *Trachiopsis victoriana*. Each of these species is classified as vulnerable in the NT.

Table 4 Fauna species recorded from the Beetaloo GBA extended region that are listed as threatened under TPWCA, but not listed under EPBC Act, also indicating if recorded within the Beetaloo GBA region

Scientific name	Common name	Conservation status	Present in GBA region
Falco hypoleucos	Grey falcon	Vulnerable	Yes
Rattus tunneyi	Pale field-rat	Vulnerable	Yes
Trachiopsis victoriana	land snail	Vulnerable	No
Varanus mertensi	Mertens' water monitor	Vulnerable	Yes
Varanus mitchelli	Mitchell's water monitor	Vulnerable	No
Varanus panoptes	Floodplain monitor	Vulnerable	Yes

1.4.3 Nationally important wetlands

Two wetlands in the Beetaloo GBA extended region are listed as nationally important wetlands (Department of the Environment and Energy, 2010). These wetlands are Lake Woods and Mataranka Thermal Pools. Lake Woods is an ephemeral freshwater wetland that is located south

of the Beetaloo GBA region. It typically occupies an area of 350 km^2 but has expanded up to 850 km^2 during major floods (1993, 2001). When inundated the Lake Woods system consists of a diversity of wetland environments including open water and large areas of Lignum (*Duma florulenta*) swamp and holds over 100,000 waterbirds. Mataranka Thermal Pools is a series of perennial spring wetlands fed by groundwater in the upper Roper River system. The area has 10 species of plants endemic to the NT and often supports a large roost of flying-foxes (*Pteropus* spp.). It lies to the north of the Beetaloo GBA region.

1.4.4 Groundwater-dependent ecosystems

The Beetaloo GBA region and extended region both contain important groundwater-dependent ecosystems (GDEs) (Figure 20). The identification of springs for this report combines two datasets to obtain a more complete springs spatial dataset of springs (Geological and Bioregional Assessment Program (2019c) and Department of Environment and Natural Resources (NT) (2013)). There are 20 likely or confirmed spring locations in the Beetaloo GBA extended region but none within the Beetaloo GBA region. Both the Beetaloo GBA region and the extended region support areas of aquatic GDEs and terrestrial GDEs (Table 5).

Table 5 Groundwater-dependent ecosystems in the Beetaloo GBA region and the Beetaloo GBA extended region

Type of GDE	Area within GBA region	Area within extended GBA region	Number within GBA region	Number within extended GBA region
Springs	NA	NA	NA	20
Aquatic GDEs	1007	3401	35	147
Terrestrial GDEs	7115	34895	9	153

Data: Geological and Bioregional Assessment Program (2019d)

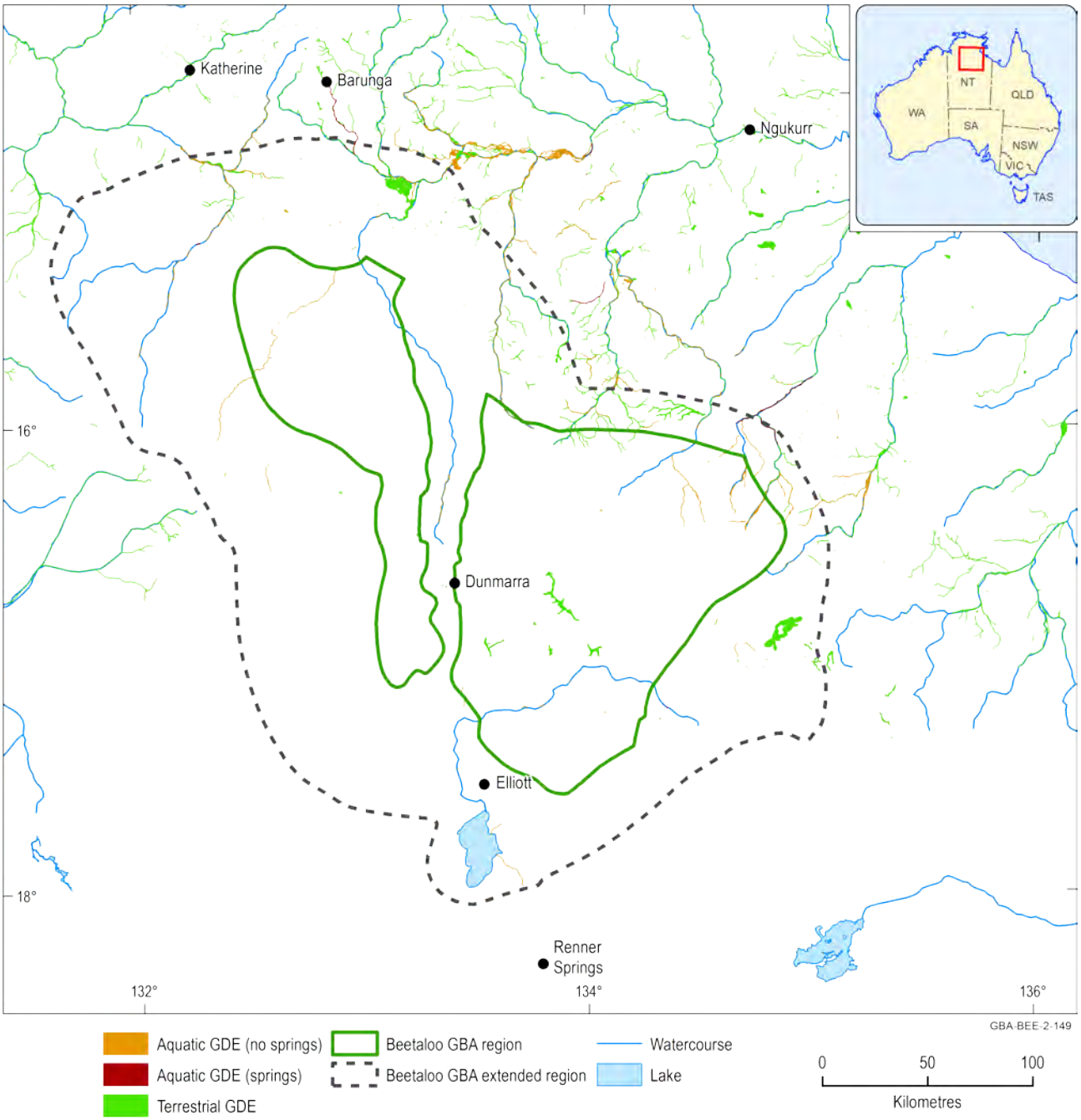

Figure 20 Groundwater-dependent ecosystems in the Beetaloo GBA region and Beetaloo GBA extended region

Data: Geological and Bioregional Assessment Program (2019a, 2019d, 2019b)
Element: GBA-BEE-2-149

2 Cultural baseline synthesis

No cultural assets were identified in the EPBC Act protected matters searches. The searches did not identify any national heritage places or Commonwealth heritage places in either the Beetaloo GBA region or the Beetaloo GBA extended region.

A search of the Northern Territory heritage register identified 13 declared heritage places within the Beetaloo GBA extended region (but none within the Beetaloo GBA region). A search of the NT archaeological sites database identified 119 Aboriginal archaeological sites within the Beetaloo GBA extended region, of which 39 are within the Beetaloo GBA region.

No cultural assets were identified in the EPBC Act protected matters searches. The searches did not identify any national heritage places or Commonwealth heritage places in either the Beetaloo GBA region or the Beetaloo GBA extended region.

Cultural assets were searched for in EPBC Act protected matters searches run by the Australian Government Department of the Environment and Energy. A search was run on 16 September 2018 and re-run on 15 March 2019 to validate the original report and assess if any matters had either been added or removed from the list. An additional search was run on 23 September 2019 when the boundary of the Beetaloo GBA extended region was modified. The search looked for national heritage places and Commonwealth heritage places.

Territory-listed Aboriginal archaeological sites and declared heritage places, listed under the *Heritage Act 2011* NT, were identified during searches of the NT archaeological sites database and NT heritage register, respectively. The searches were carried out on 8 October 2019.

A total of 13 sites listed on the NT heritage register occur within the Beetaloo GBA extended region. These sites are:

- Birdum historic township
- Daly Waters aviation complex
- Daly Waters flying fox
- Elsey memorial cemetery
- Frew Ponds overland telegraph poles
- Murranji track, Murranji bore and waterhole
- Murranji track, number 11 bore
- Newcastle Waters township
- Ucharonidge Station number 1 bore and windmill
- Union Camp (Gurindgi walk-off headquarters)
- WWII Gorrie airfield precinct
- WWII Larrimah telephone repeater station and powerhouse
- Warloch Ponds road bridge.

None of these are within the Beetaloo GBA region.

The search of the NT archaeological sites database identified 39 sites within the Beetaloo GBA region. An additional 80 Aboriginal archaeological sites were within the Beetaloo GBA extended region. Further details are not provided here because this information is deemed to be sensitive and is not publicly available.

3 Landscape classification and ecohydrological conceptualisation

To determine how hydrological and other changes caused by shale and tight gas development may affect ecosystems at a landscape scale, six landscape classes have been identified, based on Queensland's Land Zones. The Beetaloo GBA region is dominated by loamy and sandy plains, and by clay plains. There are also substantial areas of floodplain and alluvium, and undulating country on fine-grained sedimentary rocks. There are only traces of tablelands and duricrusts, and basalt plains and hills.

3.1 Description of landscape classes

The methodology for defining landscape classes is based on submethodology M03 for assigning receptors to water-dependent assets from the Bioregional Assessment Technical Programme (O'Grady et al., 2016), with modifications that reflect the broader purpose of the Geological and Bioregional Assessment Program. A landscape classification approach was used to systematically define geographical areas into landscape classes that are similar in physical and/or biological and hydrological character.

Conceptually, landscape classes can be considered as bundles of ecosystem assets (Bureau of Meteorology, 2013; United Nations et al., 2014), that produce ecosystem services that provide benefit to humanity. Landscape classification aims to:

- reduce ecosystem and landscape complexity to a limited number of regional-scale landscape classes that are mutually exclusive and comprehensive
- guide the development and review of conceptual models, including their spatial and temporal scope
- where possible, use existing data sources and existing classifications or typologies
- provide a natural aggregation for reporting potential impacts
- be applicable to data-poor regions.

Inputs into the landscape classification were based on existing classification schemes wherever possible and can be purely physical, biological or predictive (Linke et al., 2011). Choice of approach depends on the availability of data at an appropriate scale, as well as the expertise and resources for undertaking the assessment. Landscape classifications should be credible, transparent, logical and consistently applied; where possible, match other classifications (or at least some of their classes); and be feasible within available resourcing.

The landscape classification developed for the Beetaloo GBA region is based on the Queensland Land Zones (Wilson and Taylor, 2012). Consistent with the principles outlined above, it sought to use existing data sources and classifications, and to leverage the extensive effort already expended to develop highly relevant conceptual models at both landscape scale and wetland scale

by the Queensland Government as part of its Wetlands Program (Department of Environment and Science (Qld), 2017).

A detailed landscape classification, based on Queensland's Land Zones, was provided by the NT Government Department of Environment and Natural Resources (Department of Environment and Natural Resources (NT), 2019). The areas of each Land Zone (Queensland) and corresponding landscape class (GBA) are given in Table 6, along with descriptions of the landscape classes.

Table 6 Landscape classes of the geological and bioregional assessment in the Beetaloo GBA region, and corresponding Land Zones. The area of each landscape class is also given

Landscape class (GBA)	Land Zones (Qld)	Geological description	Area (km²)
Loamy and sandy plains	Tertiary-early Quaternary loamy and sandy plains and plateaus	Tertiary-early Quaternary extensive, uniform near level or gently undulating plains with sandy or loamy soils. Includes dissected remnants of these surfaces. Also includes plains with sandy or loamy soils of uncertain origin, and plateau remnants with moderate to deep soils usually overlying duricrust. Excludes recent Quaternary alluvial systems, exposed duricrust, and soils derived from underlying bedrock. Soils are usually Tenosols and Kandosols, also minor deep sandy surfaced Sodosols and Chromosols. There may be a duricrust at depth.	19,979
Clay plains	Tertiary-early Quaternary clay plains	Tertiary-early Quaternary clay deposits, usually forming level to gently undulating plains not related to recent Quaternary alluvial systems. Excludes clay plains formed *in-situ* on bedrock. Mainly Vertosols with gilgai microrelief but includes thin sandy or loamy surfaced Sodosols and Chromosols with the same paleo-clay subsoil deposits.	4,937
Floodplain and alluvium	Recent Quaternary alluvial systems	Recent Quaternary alluvial systems, including closed depressions, paleo-estuarine deposits currently under freshwater influence, inland lakes and associated wave-built lunettes. Excludes colluvial deposits such as talus slopes and pediments. Includes a diverse range of soils, predominantly Vertosols and Sodosols; also with Dermosols, Kurosols, Chromosols, Kandosols, Tenosols, Rudosols and Hydrosols; and Organosols in high rainfall areas.	1,809
Undulating country on fine-grained sedimentary rocks	Fine-grained sedimentary rocks	Fine-grained sedimentary rocks, generally with little or no deformation and usually forming undulating landscapes. Siltstones, mudstones, shales, calcareous sediments, and labile sandstones are typical rock types although minor interbedded volcanics may occur. Includes a diverse range of fine textured soils of moderate to high fertility, predominantly Vertosols, Sodosols, and Chromosols.	1,406
Tablelands and duricrusts	Cainozoic duricrusts	Cainozoic duricrusts formed on a variety of rock types, usually forming mesas or scarps. Includes exposed ferruginous, siliceous or mottled horizons and associated talus and colluvium, and remnants of these features, for example low stony rises on downs. Soils are usually shallow Rudosols and Tenosols, with minor Sodosols and Chromosols on associated pediments, and shallow Kandosols on plateau margins and larger mesas.	383

Landscape class (GBA)	Land Zones (Qld)	Geological description	Area (km²)
Basalt plains and hills	Cainozoic igneous rocks	Cainozoic igneous rocks, predominantly flood basalts forming extensive plains and occasional low scarps. Also includes hills, cones and plugs on trachytes and rhyolites, and associated interbedded sediments, and talus. Excludes deep soils overlying duricrust. Soils include Vertosols, Ferrosols and shallow Dermosols.	7
	Total		28,521

Source: Department of Environment and Natural Resources (NT) (2019) adapted from Wilson and Taylor (2012)

The total area of Beetaloo GBA region is 28,521 km² (Table 6). It is dominated by loamy and sandy plains (19,979 km²) and by clay plains (4937 km²), mainly associated with the Sturt Plateau IBRA region (Table 7), although the southern-most clay plains are associated with Mitchell Grass Downs IBRA region (Table 7).

The 1809 km² of Floodplain and alluvium is mainly within the Sturt Plateau IBRA region but also within the Gulf Fall Uplands IBRA region (Table 7). The Sturt Plateau watercourses are generally short and braided and include Western and Birdum Creeks in the north-west of the region and Newcastle Creek in the south.

The landscape class, undulating country on fine-grained sedimentary rocks, comprises an area of 1406 km² in the Beetaloo GBA region. This is in the north and is associated with headwaters of creeks and rivers in both the Gulf Fall Uplands and Sturt Plateau IBRA regions (Table 7).

There are very small areas of tablelands and duricrusts (383 km²) and basalt plains and hills (7 km²) in the Beetaloo GBA region. Sandstone ranges, and hills and lowlands on metamorphic rocks, occur just outside the Beetaloo GBA region (Figure 21). No springs occur in the Beetaloo GBA region, but Mataranka Springs are situated in the Roper River Catchment in Elsey National Park, some 40 km north of the Beetaloo GBA region, and other springs occur in the Beetaloo GBA extended region.

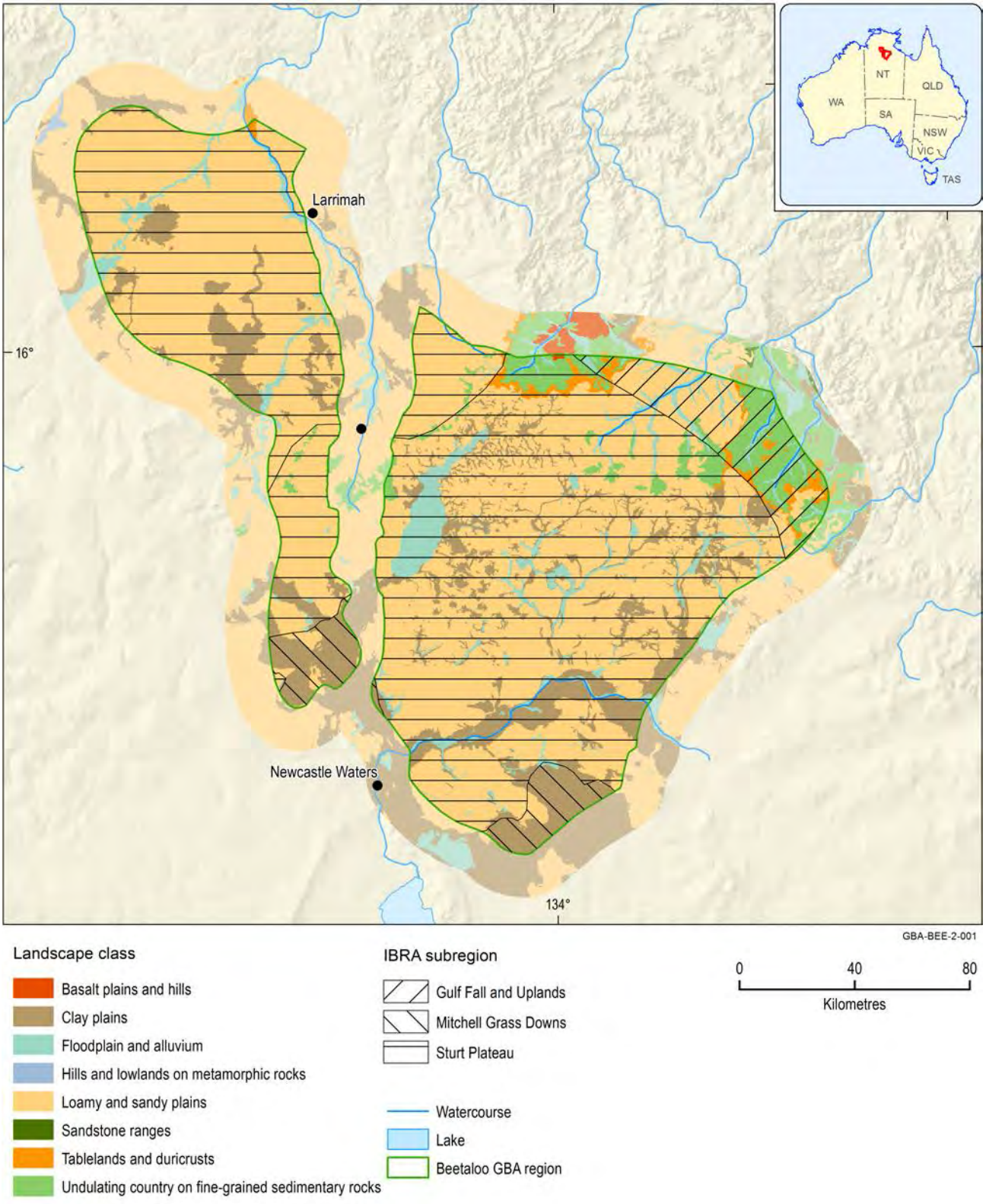

Figure 21 Landscape classes with the Beetaloo GBA region. IBRA regions are also indicated. Note that the landscape classification extends slightly outside the GBA boundary for context

Data: Department of Environment and Natural Resources (NT) (2019)
Element: GBA-BEE-2-001

Table 7 IBRA regions in the Beetaloo GBA region

IBRA region	Area (km²)
The **Sturt Plateau** region mostly comprises a gently undulating plain on lateritised Cretaceous sandstones. Soils are predominantly neutral sandy red and yellow earths. The most extensive vegetation is eucalypt woodland with tussock grass or Triodia understorey, but there are also large areas of lancewood (*Acacia shirleyi*) thickets, and bullwaddy (*Macropteranthes kekwickii*) woodlands. Elevation ranges from 100 to 300 m above sea level and falls gently from south to north. The Sturt Plateau lies over the Dunmurra, Daly, Wiso, and McArthur Basins, where Tertiary formed laterites of the Birdum Creek Beds and Cainozoic deposited sands occur. There are two major catchment areas: The Roper drainage system captures all streams east of, and including the Western Creek system, while the Dry River catchment in the west eventually contributes to the Daly River. The drainage systems are weakly developed. Channel incision is poor in the southern and central areas and it is not until the lower reaches of the Dry River and Elsey Creek are approached that some maturity is observed. Within the Roper drainage system, Newcastle Creek flows south into Lake Woods. Generally, less than 5% of rainfall will contribute eventually to streamflow as a result of the flat terrain, the apparent high storage capacity of waterholes and swamps and the existence of sinkholes.	25,155
The Barkly Tableland subregion of the **Mitchell Grass Downs** region is dominated by *Astrebla pectinata* grasslands on the extensive Tertiary clay plains overlying limestone beds. A variety of mulga (*Acacia aneura*), eucalypt and chenopod open woodland to shrubland communities occur on swamps or sand sheets associated with deposits from the adjacent Northwest Highlands bioregion. Intermittent drainage lines and associated alluvial plains supporting eucalypt woodland, grasslands or open herblands are scattered across the Barkly Tableland (as they are across all provinces in the Mitchell Grass Downs bioregion).	1,338
The McArthur subregion of the **Gulf Fall and Uplands** region is composed almost entirely of low hills and plateaus on gently deformed pre-Cambrian sediments, overlain in places by Mesozoic sediments of the Carpentaria Basin forming residual plateaus and scarps. Folded pre-Cambrian sediments underlie most of the subregion, and outcrop mainly along its eastern margin. Sandy alluvia are common along the larger watercourses. Sandstone areas sometimes contain springs and other areas of permanent or near-permanent water. This is a remote subregion and its biology is poorly known. It drains largely into a series of rivers including the Roper, Towns, Cox, Arnold and Limnen Bight Rivers, and then into the Gulf of Carpentaria.	2,027

Source: Baker et al. (2005); Wilson (1999); Morgan (1999); Yin Foo (2002)

3.2 Landscape classes and associated conceptual models

Loamy and sandy plains

There are extensive areas of loamy and sandy plains within the Beetaloo GBA region; mainly associated with the Sturt Plateau IBRA subregion, which is characterised by undulating plain on lateritised Cretaceous sandstones and Cainozoic deposited sands (Table 6). Loamy and sandy plains may be formed by redeposition of colluvium or be formed in-situ from 'old' alluvial processes (Wilson and Taylor, 2012). They may also result from prolonged, intense, deep weathering of parent rock material high in iron and/or aluminium oxides and kaolin clays. Landforms are flat to gently undulating plains, plateaus and dissected tablelands.

Within the Beetaloo GBA region, the vegetation is dominated by woodlands and open forests of *Corymbia* and *Acacia*, with some areas of *Macropteranthes* woodlands and tussock grasslands.

Figure 22 shows a schematic of this landscape class based on the 'sandy plains' conceptual model (Queensland Government, 2015).

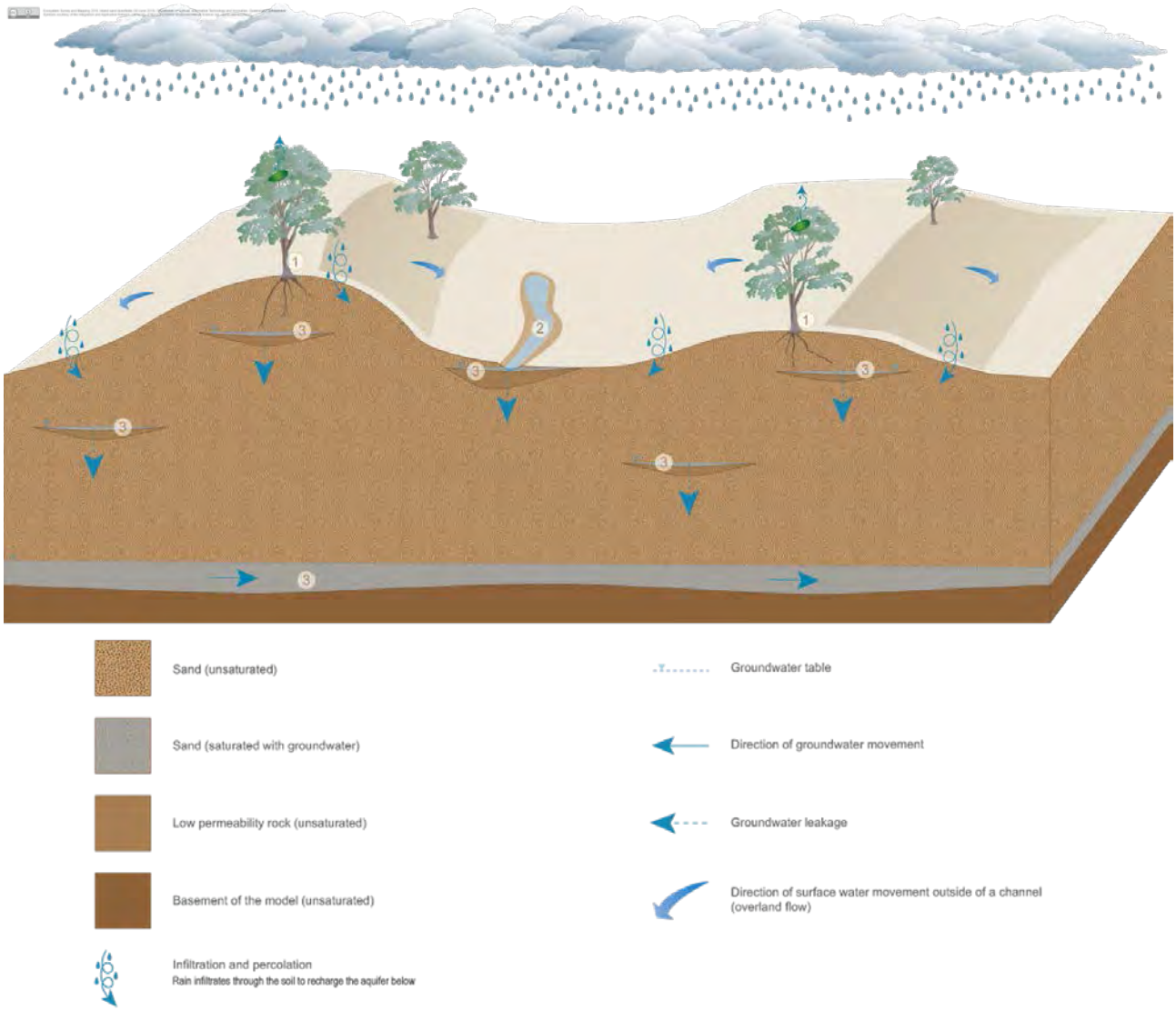

Figure 22 Sandy plains ecohydrological conceptual model

1. Terrestrial GDEs. Regional ecosystems and riverine wetlands may depend on the subsurface presence of groundwater within the capillary zone for some or all of their water requirements.
2. Subterranean GDEs. Aquifer and cave subterranean wetlands may depend on the subterranean expression of groundwater for some or all of their water requirements.
3. Surface expression GDEs. Lacustrine wetlands, palustrine wetlands and riverine water bodies may depend on the surface expression of groundwater for some or all of their water requirements.

Source: Pictorial conceptual models, WetlandInfo, Department of Environment and Science, Queensland, viewed 19 March 2019 (Queensland Government, 2015)

Element: GBA-BEE-2-150

Clay plains

Clay plains are mainly associated with the Sturt Plateau IBRA region although the southern-most clay plains are associated with Mitchell Grass Downs IBRA region. Clay plains are either on relict drainages or associated with modern creeks such as Newcastle Creek.

Clay plains are typically gently undulating plains, with clay soils and texture-contrast soils derived from fine-grained sediments. Clay plains includes paleo-clay unconsolidated sediments originating from 'old' alluvial processes and aeolian clays, forming predominantly level to gently undulating plains, but includes lesser rises and low hills particularly in arid areas. These paleo-clay deposits are now elevated above and usually isolated from the alluvial valleys and floodplains (Wilson and

Taylor, 2012). As a result, this is now an erosional landscape with poorly defined drainage. Soils are dominated by Vertosols with gilgai microrelief. Larger gilgai may provide ephemeral wetland habitat as a result of ponding of rainfall. Soils usually have restricted rooting depth due to the adverse effects of high sodium levels.

Within the Beetaloo GBA region, vegetation is dominated by *Eucalyptus* and *Corymbia* woodlands, and by *Melaleuca* low woodland.

This landscape class is represented by the 'high-level alluvia' conceptual model (Queensland Government, 2017a). The term 'high-level alluvia' refers to alluvia deposited in ancestral valleys, which are located above the channels in the current landscape in the form of inverted relief. Over time a channel will erode through older alluvial deposits resulting in older alluvia appearing in the banks above the channel.

Figure 23 shows a schematic of this landscape class based on the 'high-level alluvia' conceptual model (Queensland Government, 2017a).

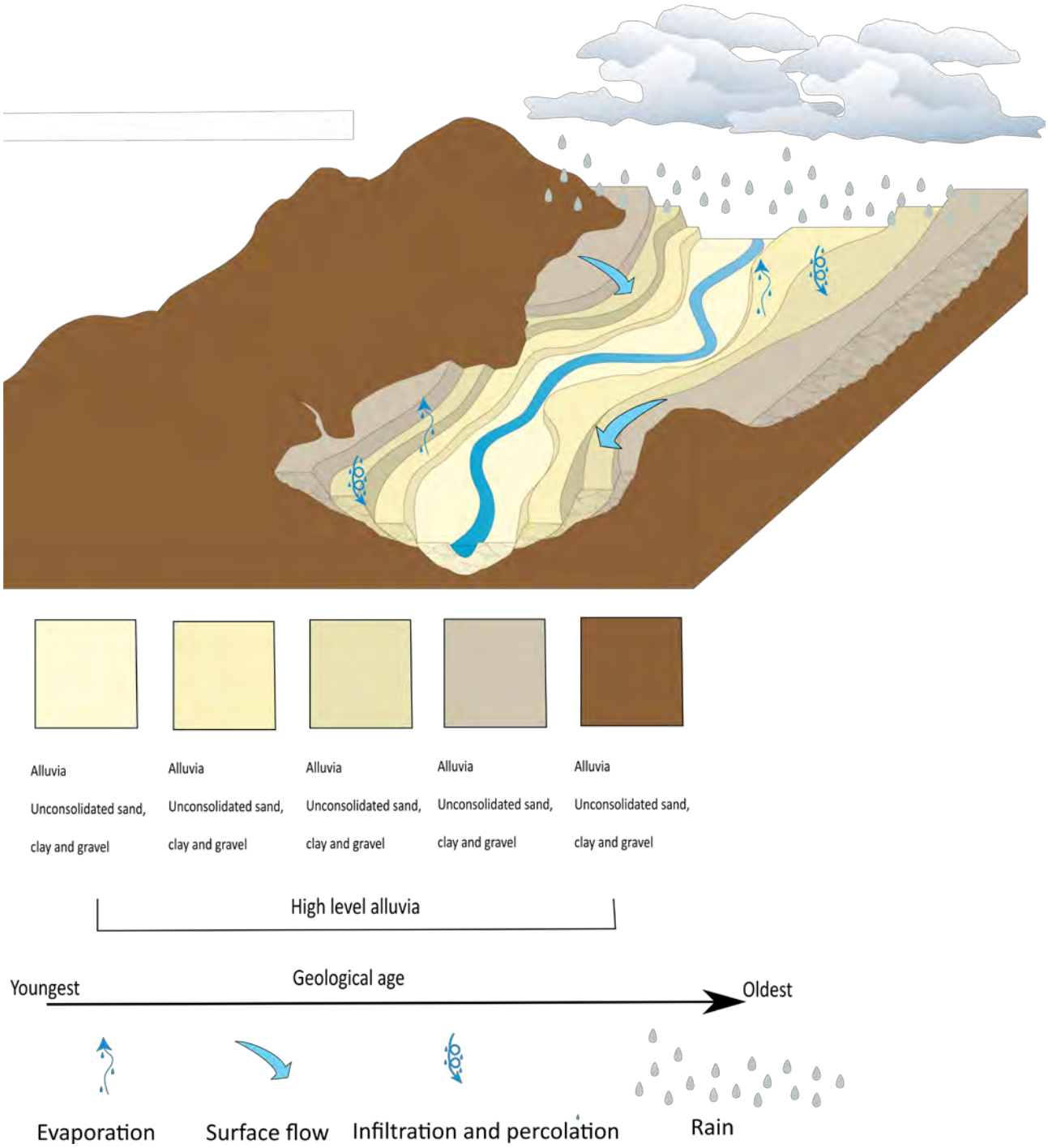

Figure 23 Clay plains conceptual model, based on the 'high-level alluvia' conceptual model

Source: Pictorial conceptual models, WetlandInfo, Department of Environment and Science, Queensland, viewed 19 March 2019 (Queensland Government, 2017a)
Element: GBA-BEE-2-151

Floodplain and alluvium

Floodplain and alluvium are associated with numerous creeks (Birdum, Sunday, Western, Elsey, Cow, Middle, Bucket, Ross, Newcastle) in the Sturt Plains IBRA region, with several rivers (Arnold, Hodgson, Cox) and the creeks that feed them in the Gulf Fall and Uplands IBRA regions, and with their associated floodplains (Figure 21).

Floodplain and alluvium include a wide variety of landforms including, but not limited to, fans, plains, flats, banks, benches, bars, channels and streams, depressions, lakes, playa, swamps and terraces (Wilson and Taylor, 2012). In all these landforms, there may be frequent active erosion and aggradation by channelled and overbank streamflow, or the landforms may be relict from these processes (National Committee on Soil and Terrain, 2009).

Floodplain and alluvium landforms are mostly flat to gently undulating with levées, bars, streambed and banks creating minor local relief (Wilson and Taylor, 2012). Soils are very diverse and are dominated by Vertosols and Sodosols but include a diverse range of other soils. They are usually fertile and often cleared or developed for agriculture or pastoralism. Riparian vegetation adjacent to watercourses is generally more biodiverse than that of the surrounding landscape and is often denser due to greater water availability.

Within the Beetaloo GBA region, vegetation is dominated by *Melaleuca*, *Eucalyptus* and *Corymbia* woodlands and low woodlands.

Figure 24 shows a schematic of the landscape class 'Floodplain and alluvium' based on the Alluvia—mid-catchment conceptual model (Queensland Government, 2017a).

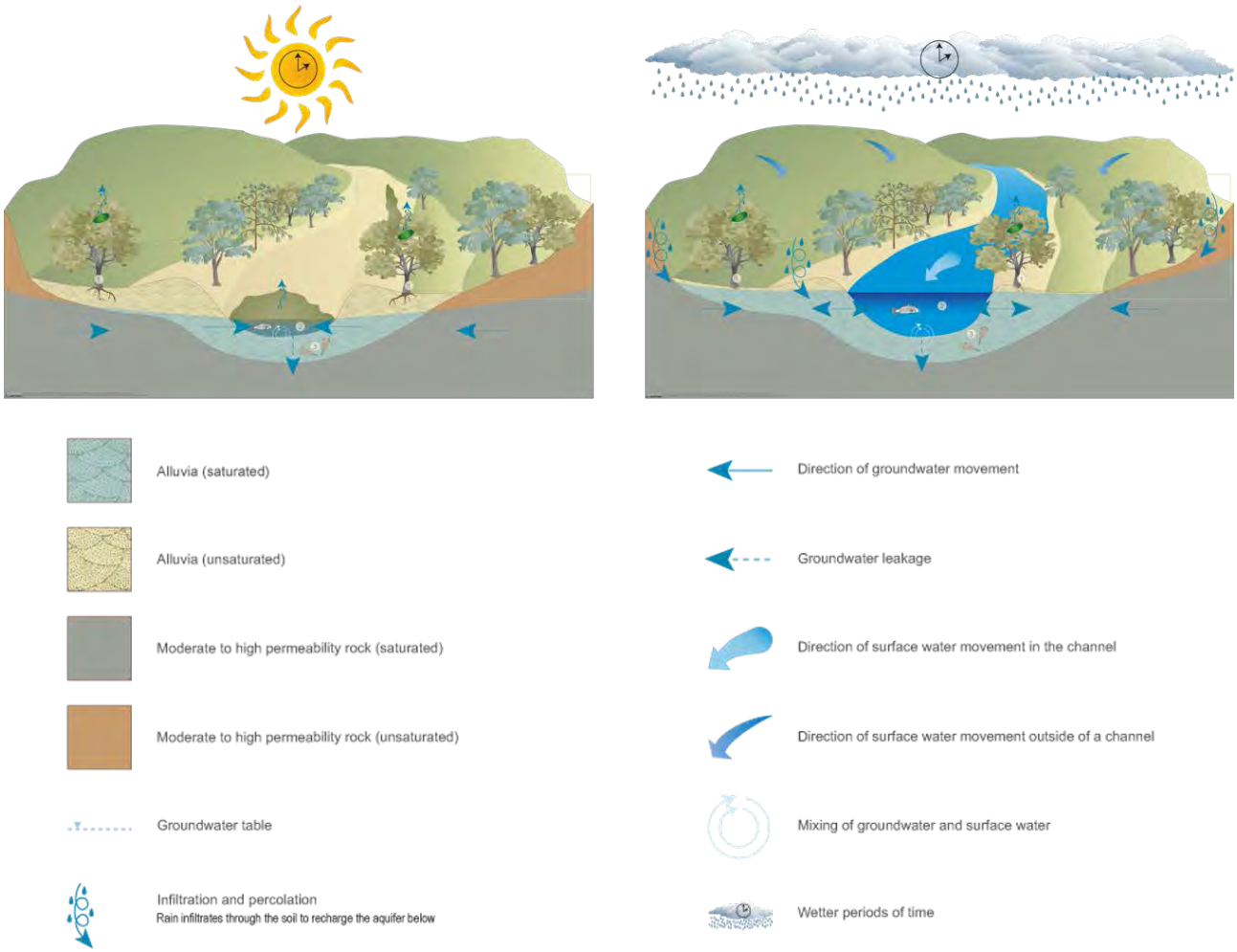

Figure 24 Floodplains and alluvia ecohydrological conceptual model based on the Alluvia—mid-catchment conceptual model

1. Terrestrial GDEs. Regional ecosystems and riverine wetlands may depend on the subsurface presence of groundwater within the capillary zone for some or all of their water requirements.
2. Subterranean GDEs. Aquifer and cave subterranean wetlands may depend on the subterranean expression of groundwater for some or all of their water requirements.
3. Surface expression GDEs. Lacustrine wetlands, palustrine wetlands and riverine water bodies may depend on the surface expression of groundwater for some or all of their water requirements.

Source: Pictorial conceptual models, WetlandInfo, Department of Environment and Science, Queensland, viewed 19 March 2019 (Queensland Government, 2017a)

Element: GBA-BEE-2-152

Undulating country on fine-grained sedimentary rocks

Undulating country on fine-grained sedimentary rocks in the Beetaloo GBA region is found mainly in the Gulf Fall and Uplands IBRA subregion, which is composed almost entirely of low hills and plateaus on gently deformed pre-Cambrian sediments, overlain in places by Mesozoic sediments of the Carpentaria Basin forming residual plateaus and scarps.

Fine-grained sedimentary rocks include siltstones, mudstones and shales. Depending on the lithology (mineral composition) of the lithic fragments, these fine-grained sedimentary rocks formed clayey soils or soils with clay subsoils (Wilson and Taylor, 2012). Due to the general 'soft' nature of the sedimentary rocks and the readily weathered nature of the lithology, the landforms are dominated by gently undulating plains and rises, many of which have been extensively developed or cleared for pasture. Soils are predominantly Vertosols, Sodosols, and Chromosols.

The vegetation in the Beetaloo GBA region is dominated by *Eucalyptus* and *Corymbia* woodland, with areas of tussock grassland, *Melaleuca* low woodland and *Acacia* open forest.

Figure 25 shows the landscape class 'undulating country on fine-grained sedimentary rocks' represented by the 'exclusion zones' conceptual model (Queensland Government, 2017b).

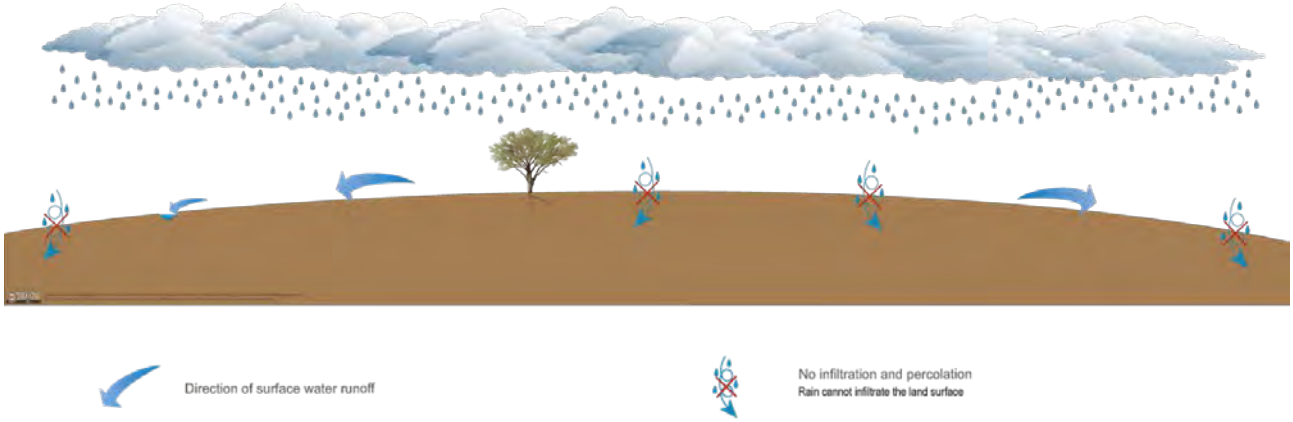

Figure 25 Undulating country on fine-grained sedimentary rocks conceptual model based on the exclusion zones ecohydrological conceptual model

Source: Pictorial conceptual models, WetlandInfo, Department of Environment and Science, Queensland, viewed 19 March 2019 (Queensland Government, 2017b)
Element: GBA-BEE-2-153

Tablelands and duricrusts

Tablelands and duricrusts occur in the north-west of the Beetaloo GBA region, mainly in the Gulf Fall and Uplands IBRA subregion (Table 7), which are composed almost entirely of low hills and plateaus on gently deformed pre-Cambrian sediments, overlain in places by Mesozoic sediments of the Carpentaria Basin, forming residual plateaus and scarps.

Tableland and duricrust areas are also known as dissected residuals, breakaways or ironstone jump-ups. They are characterised by a silcrete or ferricrete surface that has been eroded to form low but steep escarpments, mesas and buttes (Santos, 2015) with colluvial slopes (talus) with shallow soils (<0.5 m) over deeply weathered rock (Wilson and Taylor, 2012). Soils are either absent (exposed rock) or dominated by shallow (<0.5 m) Rudosols and Tenosols, with Kandosols on plateau and tableland margins. They may have gibber-covered foot slopes. Permanent surface water is scarce on elevated areas of tablelands (Santos, 2015).

Within the Beetaloo GBA region, the vegetation is dominated by *Acacia* woodland and low woodlands, with some areas of *Corymbia*, *Eucalyptus* and *Melaleuca* woodland, and some areas of tussock grassland.

This landscape class is represented by the 'exclusion zones' conceptual model (Queensland Government, 2017b) and is shown in Figure 25.

Basalt plains and hills

Basalt plains and hills are lava plains and associated volcanic cones and plugs (Wilson and Taylor, 2012). The extensive undulating plains are broken occasionally by low scarps, hills, and plateaus.

Vegetation on basalt plains and hills in the Beetaloo GBA region is dominated by *Melaleuca* low woodland.

This landscape class is represented by the 'exclusion zones' conceptual model (Queensland Government, 2017b) and is shown in Figure 25.

4 Protected matters prioritisation and screening

4.1 Protected matters prioritisation and screening approach

A prioritisation and screening process was adopted to identify individual protected matters that were likely to be impacted by potential shale and tight gas development within the Beetaloo GBA region. The approach reviewed each matter identified in relation to its potential extent and distribution within the Beetaloo GBA region. The steps in the prioritisation and screening process are outlined below.

4.1.1 Step one: identify matters

There are five categories of Matters of National Environmental Significance (MNES) identified under the EPBC Act that are potentially relevant to the Beetaloo GBA region and extended region. These are:

1. world heritage properties
2. national heritage places
3. wetlands of international importance (listed under the Ramsar Convention)
4. listed threatened species and threatened ecological communities
5. migratory species listed under international agreements.

Another two categories of protected matters identified under the EPBC Act that are potentially relevant to the Beetaloo GBA region and extended region:

1. listed marine species
2. Commonwealth lands.

These matters were identified from the Protected Matters Search Tool (PMST). In addition to these matters, the landscape classes defined by the GBA Program were also included, although these are not protected by the EPBC Act. A summary of the MNES identified and their data sources is given in Table 8.

Table 8 Matters that are considered to be of national importance in the Beetaloo GBA region and extended region consisting of Matters of National Environmental Significance (MNES) and other protected matters listed under the EPBC Act and landscape classes together with the source of data

Category of matter	Data source
Matters of National Environmental Significance	
World heritage properties	PMST
National heritage places	PMST
Wetlands of international significance (Ramsar)	PMST
Nationally listed threatened species	PMST
Nationally listed threatened ecological communities	PMST
Migratory species protected under international agreements	PMST
Other matters protected by the EPBC Act	
Listed marine species	PMST
Whales and other cetaceans	PMST
Commonwealth lands	PMST
Matters not protected by the EPBC Act	
Landscape classes	GBA

Three categories of Matters of Territory Environmental Significance (MTES) that are classified under NT legislation are also potentially relevant to the Beetaloo GBA region and extended region. These matters are:

1. parks and reserves (listed under the *Territory Parks and Wildlife Conservation Act*)
2. species listed as threatened (i.e. critically endangered, endangered, vulnerable) under the *Territory Parks and Wildlife Conservation Act* but not under the Commonwealth's EPBC Act
3. cultural heritage areas including NT heritage places.

In addition to matters listed under NT legislation, the GBA Program also considered the following two categories as being of environmental significance within the NT:

- nationally important wetlands identified in the *Directory of Important Wetlands in Australia* (DIWA) (Department of the Environment and Energy, 2010)
- groundwater-dependent ecosystems.

A summary of these matters and their data sources is given in Table 9.

Table 9 Matters of Territory Environmental Significance (MTES) and other matters of significance in the Northern Territory relevant to the Beetaloo GBA region and extended region

Category of matter	Description	Data source
Parks and reserves	Parks and reserves listed under the *Territory Parks and Wildlife Conservation Act 2006*	PMST
Threatened species	Plant and animal species identified as threatened wildlife under the *Territory Parks and Wildlife Conservation Act 2006*	NT Fauna Atlas NT Flora Atlas
Heritage areas	Heritage places and objects listed under the *Heritage Act 2011*. These include: • boriginal archaeological sites • eritage places.	NT Heritage Register NT Archaeological Sites Database
Nationally important wetland	Wetlands that are of national significance and that are listed in the *Directory of Important Wetlands in Australia* (DIWA)	Australian Wetlands Database
Groundwater-dependent ecosystems (GDEs)	All groundwater-dependent ecosystems including springs, aquatic GDEs and terrestrial GDEs	NT terrestrial ecosystem database NT aquatic ecosystem database NT springs database

4.1.2 Step two: prioritise matters

To identify individual matters that were likely to be impacted by potential shale and tight gas development within the Beetaloo GBA region, each matter was reviewed in relation to its extent and distribution within the region. Landscape classes were also included. Matters were assigned to one of three priorities:

Priority 1. Importance of the region to the matter warrants a detailed level of assessment. Future assessment of the matter will endeavour to provide the following assessments:

- Spatial extent and quantification of possible impacts where possible
- Scale of impact relative to national and territory values (e.g. EPBC significant impact guidelines, Table 11)
- Field or remote sensing data validation of occurrence and areas of impact
- Details of direct and indirect impact causes and effects that may result (expressed as a narrative table and conceptual model)
- Recommended specific and standard mitigation measures.

Priority 2. Importance of the region to the matter warrants a high-level assessment. Future assessment will endeavour to provide the following assessments:

- spatial extent of potential impacts where possible
- description of possible direct and indirect impact causes and effects.

Priority 3. Importance of the region to the matter does not warrant further assessment. Impacts on these matters will not be assessed but it is anticipated that general mitigation and avoidance measures will provide some level of protection to biodiversity.

MNES, MTES and other matters were initially categorised as shown in Table 10.

Table 10 Initial categorisation of protected matters

	Priority
MNES	
World heritage properties	Not present
National heritage places	Not present
Internationally important (Ramsar) wetlands	Not present
Nationally listed threatened species	1
Nationally listed threatened ecological communities	1
Nationally listed migratory species protected under international agreements	1
Other matters protected by the EPBC Act	
Listed marine species	2
Whales and other cetaceans	Not present
Commonwealth lands	2
Other matter not protected by the EPBC act	
Landscape classes	2
MTES	
Territory parks, reserves and conservation covenants	2
Territory-listed threatened species – Critically Endangered, Endangered, Vulnerable	1
Territory-listed species - Near Threatened and Data Deficient	3
Heritage areas & Aboriginal archaeological sites	2
Other matters	
Nationally important wetlands	1
GDEs	1

4.1.3 Step three: further screening of priority 1 and priority 2 matters

Following initial categorisation, matters categorised as priority 1 or 2 were subject to additional screening.

The first stage of this approach was applied to species and threatened ecological communities where it was uncertain whether they occurred in the Beetaloo GBA region. In other words, the protected matters searches identified that these species/communities were 'likely to occur' or 'may occur' in the region as opposed to being 'known to occur'. Additional information on distribution, to ascertain whether the matters were likely to be present within the Beetaloo GBA region, was obtained both from additional modelling undertaken as part of a NESP Northern Australian Hub project and by seeking expert opinion. At this stage multiple species/communities were excluded from further assessment because it was determined that they did not occur within the Beetaloo GBA region. These species/communities were:

- Arnhem Plateau Sandstone Shrubland Complex (Threatened Ecological Community)

- Northern quoll
- Gulf snapping turtle
- Northern brush-tailed phascogale
- Princess parrot
- Freshwater sawfish.

Next, matters categorised as priority 1 or 2 were screened further using the significant impact guidelines (Commonwealth of Australia, 2013) (Table 11). Where the protected matter was a *place*, e.g. a wetland of national significance, the matter was included if the area:

- partially or wholly intersected with areas licenced for exploration and within areas deemed to be prospective for shale and tight gas development, or
- could be deemed to be hydrologically connected to these areas from a surface water or groundwater perspective, or
- was thought to contain potential habitat for an identified species protected matter.

Matters that were not retained were assigned to priority 3. Landscape classes were assessed using the same criteria as for the *place* protected matters.

Where the protected matter was a *species*, species occurrence records were downloaded from the Atlas of Living Australia. In addition to these records the spatial data associated with the predicted distribution of each EPBC-listed species were reviewed (Figure 2 to Figure 19). The presence of each species within the Beetaloo GBA region, based on known records and predicted distributions, was assessed in relation to its national distribution and potential for significant impact assessed using the significant impact guidelines (Table 11), species recovery plans, conservation advices and threat abatement plans.

For critically endangered and endangered species, the species was retained as priority 1 if it was known or expected to occur in the Beetaloo GBA region and there was a possibility of negative impacts occurring to the species in the region as outlined in Table 10. Otherwise the species was classed as priority 2. This approach moved species to priority 2 if there was little suitable habitat in the region resulting in it only occurring as a vagrant.

For vulnerable and migratory species, the species was retained as priority 1 only if the Beetaloo GBA region supported an important population of the species. Otherwise the species was moved to priority 2.

Those protected matters that occurred or potentially occurred in the extended Beetaloo GBA region but not in the Beetaloo GBA region were given a score of 3. However, if in Stage 3 (impact analysis and management) of this work there is evidence that impacts from shale and tight gas development will extend beyond the Beetaloo GBA region, these assessments will be reconsidered.

Protected matters and landscape classes that remained after this screening process were matters that are potentially exposed to significant impacts associated with development within the region and are to be considered further as part of the impact assessment.

Table 11 Significant impact guidelines for assessing Matters of National Environmental Significance

Class	Status	Criteria
Listed threatened species and ecological communities	Extinct in the wild species	N/A
Listed threatened species and ecological communities	Critically endangered or endangered species	An action is likely to have a significant impact on a critically endangered or endangered species if there is a real chance or possibility that it will: • lead to a long-term decrease in the size of a population • reduce the area of occupancy of the species • fragment an existing population into two or more populations • adversely affect habitat critical to the survival of a species • disrupt the breeding cycle of a population • modify, destroy, remove, isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline • result in invasive species that are harmful to a critically endangered or endangered species becoming established in the endangered or critically endangered species' habitat • introduce disease that may cause the species to decline, or • interfere with the recovery of the species.
Listed threatened species and ecological communities	Vulnerable species	An action is likely to have a significant impact on a vulnerable species if there is a real chance or possibility that it will: • lead to a long-term decrease in the size of an important population of a species • reduce the area of occupancy of an important population • fragment an existing important population into two or more populations • adversely affect habitat critical to the survival of a species • disrupt the breeding cycle of an important population • modify, destroy, remove or isolate or decrease the availability or quality of habitat to the extent that the species is likely to decline • result in invasive species that are harmful to a vulnerable species becoming established in the vulnerable species' habitat • introduce disease that may cause the species to decline, or • interfere substantially with the recovery of the species.
Listed threatened species and ecological communities	Critically endangered or endangered communities	N/A[1]

Class	Status	Criteria
Listed migratory species		An action is likely to have a significant impact on a migratory species if there is a real chance or possibility that it will: • substantially modify (including by fragmenting, altering fire regimes, altering nutrient cycles or altering hydrological cycles), destroy or isolate an area of important habitat for a migratory species • result in an invasive species that is harmful to the migratory species becoming established in an area of important habitat for the migratory species, or • seriously disrupt the life cycle (breeding, feeding, migration or resting behaviour) of an ecologically significant proportion of the population of a migratory species
Wetlands of international importance (Ramsar)		N/A[1]
The Commonwealth marine environment		N/A[1]
World heritage properties		N/A[1]
National heritage places		N/A[1]

[1]for the sake of brevity and clarity, guidelines (Commonwealth of Australia, 2013) are only reproduced for matters that are present in the Beetaloo GBA region or Beetaloo GBA extended region

4.2 Screening matters for Stage 3

4.2.1 Priority 1 matters

Four species of national environmental significance were identified as being potentially at risk from future unconventional gas development and thus will be assessed as priority 1 matters in Stage 3 (impact analysis and management). These include:

- the endangered species
  - *Erythrura gouldiae* (Gouldian finch)
  - *Rostratula australis* (Australian painted snipe)
- and the vulnerable species
  - *Falcunculus frontatus whitei* (Crested shrike-tit (northern))
  - *Macrotis lagotis* (Greater bilby).

In addition, one species, *Falco hypoleucos* (Grey falcon) that is a matter of territory environmental significance was identified as being potentially at risk from future unconventional gas development and will be assessed as a priority 1 matter in Stage 3. It is listed as vulnerable in the NT.

The two nationally important wetlands, Mataranka Thermal Pools and Lake Woods, were assessed as priority 1 matters. Although outside the Beetaloo GBA region there is sufficient evidence, for both these wetlands, of hydrological connectivity to areas within the Beetaloo GBA region that are

deemed to be prospective for shale and tight gas development to warrant their inclusion as priority 1 matters. Mataranka Thermal Pools show evidence of groundwater connectivity and Lake Woods of surface water connectivity to areas within the Beetaloo GBA region. Several Territory parks, reserves and conservation covenants are included within the area of these two wetlands. Specifically, Elsey National Park covers Mataranka Thermal Pools and Lake Woods includes Lake Woods conservation covenant and Longreach Waterhole protected area. Hence these three matters will not be assessed separately.

In addition to these matters, all GDEs were identified as priority 1 matters for assessment in Stage 3.

4.2.2 Priority 2 matters

The critically endangered *Calidris ferruginea* (curlew sandpiper) may occur within the Beetaloo GBA region hence the species will be assessed as priority 2 matters in Stage 3 (impact analysis and management).

Six additional Matters of National Environmental Significance were identified as being potentially at some risk from future unconventional gas development, although this risk will not be experienced by an important population of the species. Hence the species will be assessed as priority 2 matters in Stage 3 (impact analysis and management). These include:

- the endangered species *Peroporus occidentalis* (night parrot), and
- the vulnerable species
  - *Acanthophis hawkei* (plains death adder)
  - *Grantiella picta* (painted honeyeater)
  - *Macroderma gigas* (ghost bat)
  - *Saccolaimus saccolaimus nudicluniatus* (bare-rumped sheat-tailed bat)
  - *Tyto novaehollandiae kimberli* (masked owl (northern)).

In addition, four species that are Matters of Territory Environmental Significance were identified as being potentially at some risk from future unconventional gas development, although this risk will not be experienced by an important population of the species. Hence the species will be assessed as priority 2 matters in Stage 3. Each species is listed as vulnerable in the NT. These include:

- *Rattus tunneyi* (pale field-rat)
- *Varanus mertensi* (Merten's water monitor)
- *Varanus mitchelli* (Mitchell's water monitor)
- *Varanus panoptes* (Floodplain monitor).

Bullwaddy Conservation Reserve was identified as a priority 2 matter for assessment in Stage 3.

In addition, each landscape class, except 'basalt plains and hills', was identified as a priority 2 matter for assessment in Stage 3.

5 Knowledge gaps

Adequate understanding of the geographic distribution and ecology, including diet, habitat use and breeding season, of Matters of National Environmental Significance (MNES) and other protected matters and Matters of Territory Environmental Significance are key knowledge gaps for the study area. The knowledge gaps in this case represent understanding of both where matters occur in relation to potential unconventional petroleum resource development and how the ecological requirements of species and ecological communities may be impacted by the resource development pathway. Currently, the majority of protected matters are identified as 'likely to occur' or 'may occur' rather than 'known to occur' within the Beetaloo GBA region. Resolving whether individual matters occur (or did occur) within the GBA region and, if so, when and where, is necessary to identify those matters that may be impacted by future unconventional petroleum resource development. Likewise, understanding the ecological requirements (including diet, habitat use and breeding season) and life histories of individual species is essential information for assessing how each will respond to environmental change resulting from the unconventional petroleum development pathway in a region. This is an important knowledge gap.

Another important knowledge gap relates to the interaction between existing key threatening processes in the region and causal pathways that will eventuate during resource development. As an example, road construction during the establishment phase of unconventional petroleum resource development may facilitate the movement of invasive species (both animals and plants) in to new areas. Knowledge of the nature and extent of these interactions and how they may differ across landscape classes is scarce.

The landscape classification is limited by the quality of available datasets, including surface geology, elevation, vegetation and landform mapping, and extent and quality of ground observations. Additional information of these types will assist in refining and increasing the accuracy of the landscape classification.

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Glossary

The register of terms and definitions used in the Geological and Bioregional Assessment Program is available online at https://w3id.org/gba/glossary (note that terms and definitions are respectively listed under the 'Name' and 'Description' columns in this register). This register is a list of terms, which are the preferred descriptors for concepts. Other properties are included for each term, including licence information, source of definition and date of approval. Semantic relationships (such as hierarchical relationships) are formalised for some terms, as well as linkages to other terms in related vocabularies. Many of the definitions for these terms have been sourced from external glossaries – several from international sources; spelling variations have been preserved to maintain authenticity of the source.

abandonment: a process which involves shutting down the well and rehabilitating the site. It includes decommissioning the well.

accumulation: in petroleum geosciences, an 'accumulation' is referred to as an individual body of moveable petroleum

activity: for the purposes of Impact Modes and Effects Analysis (IMEA), a planned event associated with unconventional gas resource development. For example, activities during the exploration life-cycle stage include drilling and coring, ground-based geophysics and surface core testing. Activities are grouped into ten major activities, which can occur at different life-cycle stages.

anticline: an arch-shaped fold in rock in which rock layers are upwardly convex. The oldest rock layers form the core of the fold and, outward from the core, progressively younger rocks occur.

aquifer: rock or sediment in a formation, group of formations, or part of a formation that is saturated and sufficiently permeable to transmit quantities of water to bores and springs

aquitard: a saturated geological unit that is less permeable than an aquifer, and incapable of transmitting useful quantities of water. Aquitards commonly form a confining layer over an artesian aquifer.

artesian aquifer: an aquifer that has enough natural pressure to allow water in a bore to rise to the ground surface

asset: an entity that has value to the community and, for the purposes of geological and bioregional assessments, is associated with a GBA region. An asset is a store of value and may be managed and/or used to maintain and/or produce further value. An asset may have many values associated with it that can be measured from a range of perspectives; for example, the values of a wetland can be measured from ecological, sociocultural and economic perspectives.

bed: in geosciences, the term 'bed' refers to a layer of sediment or sedimentary rock, or stratum. A bed is the smallest stratigraphic unit, generally a centimetre or more in thickness. To be labeled a bed, the stratum must be distinguishable from adjacent beds.

biogenic gas: hydrocarbon gases (which are overwhelmingly (greater than or equal to 99%) methane) produced as a direct consequence of bacterial activity

bore: a narrow, artificially constructed hole or cavity used to intercept, collect or store water from an aquifer, or to passively observe or collect groundwater information. Also known as a borehole or piezometer.

brittleness: a material is brittle if, when subjected to stress, it breaks without significant plastic deformation

brittleness index: brittleness index (BI) is used to calculate the ease at which a shale rock breaks. It can be estimated from the normalised Young's modulus and Poisson's ratio

casing: a pipe placed in a well to prevent the wall of the hole from caving in and to prevent movement of fluids from one formation to another

casing string: steel pipe used to line a well and support the rock. The casing extends to the surface and is sealed by a cement sheath between the casing and the rock. Often, multiple casings are used to provide additional barriers between the formation and well.

charge: in petroleum geoscience, a 'charge' refers to the volume of expelled petroleum available for entrapment

cleat: the vertical cleavage of coal seams. The main set of joints along which coal breaks when mined.

coal: a rock containing greater than 50 wt.% organic matter

coal seam gas: coal seam gas (CSG) is a form of natural gas (generally 95% to 97% pure methane, CH_4) extracted from coal seams, typically at depths of 300 to 1000 m. Also called coal seam methane (CSM) or coalbed methane (CBM).

compression: lateral force or stress (e.g. tectonic) that tends to decrease the volume of, or shorten, a substance

conceptual model: an abstraction or simplification of reality that describes the most important components and processes of natural and/or anthropogenic systems, and their response to interactions with extrinsic activities or stressors. They provide a transparent and general representation of how complex systems work, and identify gaps or differences in understanding. They are often used as the basis for further modelling, form an important backdrop for assessment and evaluation, and typically have a key role in communication. Conceptual models may take many forms, including descriptive, influence diagrams and pictorial representations.

confined aquifer: an aquifer saturated with confining layers of low-permeability rock or sediment both above and below it. It is under pressure so that when the aquifer is penetrated by a bore, the water will rise above the top of the aquifer.

consequence: synonym of impact

conventional gas: conventional gas is obtained from reservoirs that largely consist of porous sandstone formations capped by impermeable rock, with the gas trapped by buoyancy. The gas can often move to the surface through the gas wells without the need to pump.

Cooper Basin: the Cooper Basin geological province is an Upper Carboniferous – Middle Triassic geological sedimentary basin that is up to 2500 m thick and occurs at depths between 1000 and 4400 m. It is overlain completely by the Eromanga and Lake Eyre basins. Most of the Cooper Basin is in south-west Queensland and north-east SA, and includes a small area of NSW at Cameron Corner. It occupies a total area of approximately 130,000 km^2, including 95,740 km^2 in Queensland, 34,310 km^2 in SA and 8 km^2 in NSW.

crude oil: the portion of petroleum that exists in the liquid phase in natural underground reservoirs and remains liquid at atmospheric conditions of pressure and temperature. Crude oil may include small amounts of non-hydrocarbons produced with the liquids.

crust: the outer part of the Earth, from the surface to the Mohorovicic discontinuity (Moho)

dataset: a collection of data in files, in databases or delivered by services that comprise a related set of information. Datasets may be spatial (e.g. a shape file or geodatabase or a Web Feature Service) or aspatial (e.g. an Access database, a list of people or a model configuration file).

deep coal gas: gas in coal beds at depths usually below 2000 m are often described as 'deep coal gas'. Due to the loss of cleat connectivity and fracture permeability with depth, hydraulic fracturing is used to release the free gas held within the organic porosity and fracture system of the coal seam. As dewatering is not needed, this makes deep coal gas exploration and development similar to shale gas reservoirs.

deformation: folding, faulting, shearing, compression or extension of rocks due to the Earth's forces

deposition: sedimentation of any material, as in the mechanical settling of sediment from suspension in water, precipitation of mineral matter by evaporation from solution, and accumulation of organic material

development: a phase in which newly discovered oil or gas fields are put into production by drilling and completing production wells

discovered: the term applied to a petroleum accumulation/reservoir whose existence has been determined by its actual penetration by a well, which has also clearly demonstrated the existence of moveable petroleum by flow to the surface or at least some recovery of a sample of petroleum. Log and/or core data may suffice for proof of existence of moveable petroleum if an analogous reservoir is available for comparison.

dome: a type of anticline where rocks are folded into the shape of an inverted bowl. Strata in a dome dip outward and downward in all directions from a central area.

ecosystem: a dynamic complex of plant, animal, and micro-organism communities and their non-living environment interacting as a functional unit. Note: ecosystems include those that are human-influenced such as rural and urban ecosystems.

ecosystem asset: an ecosystem that may provide benefits to humanity. It is a spatial area comprising a combination of biotic and abiotic components and other elements which function together.

effect: for the purposes of Impact Modes and Effects Analysis (IMEA), a change to water or the environment, such as changes to the quantity and/or quality of surface water or groundwater, or to the availability of suitable habitat. An effect is a specific type of an impact (any change resulting from prior events).

Eromanga Basin: an extensive geologic sedimentary basin formed from the Early Jurassic to the Late Cretaceous that can be over 2500 m thick. It overlies several older geological provinces including the Cooper Basin, and is in part overlain by the younger Cenozoic province, the Lake Eyre Basin. The Eromanga Basin is found across much of Queensland, northern SA, southern NT, as well as north-western NSW. The Eromanga Basin encompasses a significant portion of the Great Artesian Basin.

erosion: the wearing away of soil and rock by weathering, mass wasting, and the action of streams, glaciers, waves, wind, and underground water

exploration: the search for new hydrocarbon resources by improving geological and prospectivity understanding of an area and/or play through data acquisition, data analysis and interpretation. Exploration may include desktop studies, field mapping, seismic or other geophysical surveys, and drilling.

extraction: the removal of water for use from waterways or aquifers (including storages) by pumping or gravity channels. In the oil and gas industry, extraction refers to the removal of oil and gas from its reservoir rock.

fault: a fracture or zone of fractures in the Earth's crust along which rocks on one side were displaced relative to those on the other side

field: in petroleum geoscience, a 'field' refers to an accumulation, pool, or group of pools of hydrocarbons or other mineral resources in the subsurface. A hydrocarbon field consists of a reservoir with trapped hydrocarbons covered by an impermeable sealing rock, or trapped by hydrostatic pressure.

floodplain: a flat area of unconsolidated sediment near a stream channel that is submerged during or after high flows

flowback: the process of allowing fluids and entrained solids to flow from a well following a treatment, either in preparation for a subsequent phase of treatment or in preparation for cleanup and returning the well to production. The flowback period begins when material introduced into the well during the treatment returns to the surface following hydraulic fracturing or refracturing. The flowback period ends when either the well is shut in and permanently disconnected from the flowback equipment or at the startup of production.

fold: a curve or bend of a formerly planar structure, such as rock strata or bedding planes, that generally results from deformation

formation: rock layers that have common physical characteristics (lithology) deposited during a specific period of geological time

formation water: water that occurs naturally in sedimentary rocks

fracking: see hydraulic fracturing

fracture: a crack or surface of breakage within rock not related to foliation or cleavage in metamorphic rock along which there has been no movement. A fracture along which there has been displacement is a fault. When walls of a fracture have moved only normal to each other, the fracture is called a joint. Fractures can enhance permeability of rocks greatly by connecting pores together, and for that reason, fractures are induced mechanically in some reservoirs in order to boost hydrocarbon flow. Fractures may also be referred to as natural fractures to distinguish them from fractures induced as part of a reservoir stimulation or drilling operation. In some shale reservoirs, natural fractures improve production by enhancing effective permeability. In other cases, natural fractures can complicate reservoir stimulation.

free gas: the gaseous phase present in a reservoir or other contained area. Gas may be found either dissolved in reservoir fluids or as free gas that tends to form a gas cap beneath the top seal on the reservoir trap. Both free gas and dissolved gas play important roles in the reservoir-drive mechanism.

gas cap: part of a petroleum reservoir that contains free gas

geological formation: stratigraphic unit with distinct rock types, which is able to mapped at surface or in the subsurface, and which formed at a specific period of geological time

groundwater: water occurring naturally below ground level (whether stored in or flowing through aquifers or within low-permeability aquitards), or water occurring at a place below ground that has been pumped, diverted or released to that place for storage there. This does not include water held in underground tanks, pipes or other works.

groundwater-dependent ecosystem: ecosystems that require access to groundwater on a permanent or intermittent basis to meet all or some of their water requirements

groundwater system: see water system

hazard: an event, or chain of events, that might result in an effect (change in the quality and/or quantity of surface water or groundwater)

hydraulic fracturing: also known as 'fracking', 'fraccing' or 'fracture simulation'. This is a process by which geological formations bearing hydrocarbons (oil and gas) are 'stimulated' to increase the flow of hydrocarbons and other fluids towards the well. In most cases, hydraulic fracturing is undertaken where the permeability of the formation is initially insufficient to support sustained flow of gas. The process involves the injection of fluids, proppant and additives under high pressure into a geological formation to create a conductive fracture. The fracture extends from the well into the production interval, creating a pathway through which oil or gas is transported to the well.

hydraulic fracturing fluid: the fluid injected into a well for hydraulic fracturing. Consists of a primary carrier fluid (usually water or a gel), a proppant such as sand and chemicals to modify the fluid properties.

hydrocarbons: various organic compounds composed of hydrogen and carbon atoms that can exist as solids, liquids or gases. Sometimes this term is used loosely to refer to petroleum.

hydrogeology: the study of groundwater, including flow in aquifers, groundwater resource evaluation, and the chemistry of interactions between water and rock

hydrological connectivity: a descriptive measure of the interaction between water bodies (groundwater and/or surface water)

hydrostatic pressure: equal pressure in all direction, equivalent to the pressure which is exerted on a portion of a column of water as a result of the weight of the fluid above it

impact: the difference between what could happen as a result of activities and processes associated with extractive industries, such as shale, tight and deep coal gas development, and what would happen without them. Impacts may be changes that occur to the natural environment, community or economy. Impacts can be a direct or indirect result of activities, or a cumulative result of multiple activities or processes.

impact cause: an activity (or aspect of an activity) that initiates a hazardous chain of events

impact mode: the manner in which a hazardous chain of events (initiated by an impact cause) could result in an effect (change in the quality and/or quantity of surface water or groundwater). There might be multiple impact modes for each activity or chain of events.

Impact Modes and Effects Analysis: a systematic hazard identification and prioritisation technique based on Failure Modes and Effects Analysis

injection: the forcing or pumping of substances into a porous and permeable subsurface rock formation. Examples of injected substances can include either gases or liquids.

kerogen: insoluble (in organic solvents) particulate organic matter preserved in sedimentary rocks that consists of various macerals originating from components of plants, animals, and bacteria. Kerogen can be isolated from ground rock by extracting bitumen with solvents and removing most of the rock matrix with hydrochloric and hydrofluoric acids.

known accumulation: the term accumulation is used to identify an individual body of moveable petroleum. The key requirement to consider an accumulation as known, and hence contain reserves or contingent resources, is that each accumulation/reservoir must have been penetrated by a well. In general, the well must have clearly demonstrated the existence of moveable petroleum in that reservoir by flow to surface or at least some recovery of a sample of petroleum from the well. However, where log and/or core data exist, this may suffice, provided there is a good analogy to a nearby and geologically comparable known accumulation.

Lake Eyre Basin: a geologic province containing Cenozoic terrestrial sedimentary rocks within the Lake Eyre surface water catchment. It covers parts of northern and eastern SA, south-eastern NT, western Queensland and north-western NSW. In the Cooper GBA region, the basin sedimentary package is less than 300 m thick.

landscape class: for the purposes of geological and bioregional assessments (GBA), a collection of ecosystems with characteristics that are expected to respond similarly to changes in groundwater and/or surface water due to unconventional gas resource development. Note that there is expected to be less heterogeneity in the response within a landscape class than between landscape classes. They are present on the landscape across the entire GBA region and their spatial coverage is exhaustive and non-overlapping. Conceptually, landscape classes can be considered as types of ecosystem assets.

life-cycle stage: one of five stages of operations in unconventional gas resource development considered as part of the Impact Modes and Effects Analysis (IMEA). These are exploration, appraisal, development, production, and rehabilitation. Each life-cycle stage is further divided into major activities, which are further divided into activities.

likelihood: probability that something might happen

lithology: the description of rocks, especially in hand specimen and in outcrop, on the basis of characteristics such as colour, mineralogic composition and grain size

material: pertinent or relevant

mature: a hydrocarbon source rock that has started generating hydrocarbons

metamorphic rock : a rock formed from pre-existing rock due to high temperature and pressure in the Earth's crust, but without complete melting

methane: a colourless, odourless gas, the simplest parafin hydrocarbon, formula CH_4. It is the principal constituent of natural gas and is also found associated with crude oil. Methane is a greenhouse gas in the atmosphere because it absorbs long-wavelength radiation from the Earth's surface.

migration: the process whereby fluids and gases move through rocks. In petroleum geoscience, 'migration' refers to when petroleum moves from source rocks toward reservoirs or seep sites. Primary migration consists of movement of petroleum to exit the source rock. Secondary migration occurs when oil and gas move along a carrier bed from the source to the reservoir or seep. Tertiary migration is where oil and gas move from one trap to another or to a seep.

Moho: the Mohorivicic discontinuity (seismic reflector) at the base of the crust

natural gas: the portion of petroleum that exists either in the gaseous phase or is in solution in crude oil in natural underground reservoirs, and which is gaseous at atmospheric conditions of pressure and temperature. Natural gas may include amounts of non-hydrocarbons.

oil: a mixture of liquid hydrocarbons and other compounds of different molecular weights. Gas is often found in association with oil. Also see petroleum.

oil-prone: organic matter that generates significant quantities of oil at optimal maturity

organic matter: biogenic, carbonaceous materials. Organic matter preserved in rocks includes kerogen, bitumen, oil and gas. Different types of organic matter can have different oil-generative potential.

outcrop: a body of rock exposed at the surface of the Earth

overpressure: occurs when the pore pressure is higher than the hydrostatic pressure, caused by an increase in the amount of fluid or gas in the rock, or changes to the rock that reduce the amount of pore space. If the fluid cannot escape, the result is an increase in pore pressure. Overpressure can only occur where there are impermeable layers preventing the vertical flow of water, otherwise the water would flow upwards to equalise back to hydrostatic pressure.

P10: in terms of petroleum resource classification, P10 indicates a 10% probability that this volume of oil or gas will be found or exceeded

pay: a reservoir or portion of a reservoir that contains economically producible hydrocarbons. The term derives from the fact that it is capable of 'paying' an income. Pay is also called pay sand or pay zone. The overall interval in which pay sections occur is the gross pay; the smaller portions of the gross pay that meet local criteria for pay (such as minimum porosity, permeability and hydrocarbon saturation) are net pay.

pay zone: see pay

permeability: the measure of the ability of a rock, soil or sediment to yield or transmit a fluid. The magnitude of permeability depends largely on the porosity and the interconnectivity of pores and spaces in the ground.

petroleum: a naturally occurring mixture consisting predominantly of hydrocarbons in the gaseous, liquid or solid phase

petroleum system: the genetic relationship between a pod of source rock that is actively producing hydrocarbon, and the resulting oil and gas accumulations. It includes all the essential elements and processes needed for oil and gas accumulations to exist. These include the source, reservoir, seal, and overburden rocks, the trap formation, and the hydrocarbon generation, migration and accumulation processes. All essential elements and processes must occur in the appropriate time and space in order for petroleum to accumulate.

play: a conceptual model for a style of hydrocarbon accumulation used during exploration to develop prospects in a basin, region or trend and used by development personnel to continue exploiting a given trend. A play (or group of interrelated plays) generally occurs in a single petroleum system.

plug: a mechanical device or material (such as cement) placed within a well to prevent vertical movement of fluids

porosity: the proportion of the volume of rock consisting of pores, usually expressed as a percentage of the total rock or soil mass

potential effect: specific types of impacts or changes to water or the environment, such as changes to the quantity and/or quality of surface water or groundwater, or to the availability of suitable habitat

produced water: a term used in the oil industry to describe water that is produced as a by-product along with the oil and gas. Oil and gas reservoirs often have water as well as hydrocarbons, sometimes in a zone that lies under the hydrocarbons, and sometimes in the same zone with the oil and gas. The terms 'co-produced water' and 'produced water' are sometimes used interchangeably by government and industry. However, in the geological and bioregional assessments, 'produced water' is used to describe water produced as a by-product of shale and tight gas resource development, whereas 'co-produced water' refers to the large amounts of water produced as a by-product of coal seam gas development.

producing: a well or rock formation from which oil, gas or water is produced

production: in petroleum resource assessments, 'production' refers to the cumulative quantity of oil and natural gas that has been recovered already (by a specified date). This is primarily output from operations that has already been produced.

production activity: any physical activity associated with drilling and hydraulic fracturing (which may include clearing and/or well construction) pursuant to the granting of production approvals for onshore shale gas on a production licence

production approvals: all operational approvals granted under the Schedule and all environmental approvals granted under the Petroleum Environment Regulations on a production licence for a production activity

production well: a well used to remove oil or gas from a reservoir

proppant: a component of the hydraulic fracturing fluid system comprising sand, ceramics or other granular material that 'prop' open fractures to prevent them from closing when the injection is stopped

reserves: quantities of petroleum anticipated to be commercially recoverable in known accumulations from a given date forward under defined conditions. Reserves must further satisfy four criteria: they must be discovered, recoverable, commercial and remaining (as of the evaluation date) based on the development project(s) applied.

reservoir: a subsurface body of rock having sufficient porosity and permeability to store and transmit fluids and gases. Sedimentary rocks are the most common reservoir rocks because they have more porosity than most igneous and metamorphic rocks and form under temperature conditions at which hydrocarbons can be preserved. A reservoir is a critical component of a complete petroleum system.

reservoir rock: any porous and permeable rock that contains liquids or gases (e.g. petroleum, water, CO_2), such as porous sandstone, vuggy carbonate and fractured shale

ridge: a narrow, linear geological feature that forms a continuous elevated crest for some distance (e.g. a chain of hills or mountains or a watershed)

riparian: within or along the banks of a stream or adjacent to a watercourse or wetland; relating to a riverbank and its environment, particularly to the vegetation

risk: the effect of uncertainty on objectives (ASNZ ISO 3100). This involves assessing the potential consequences and likelihood of impacts to environmental and human values that may stem from an action, under the uncertainty caused by variability and incomplete knowledge of the system of interest.

runoff: rainfall that does not infiltrate the ground or evaporate to the atmosphere. This water flows down a slope and enters surface water systems.

sandstone: a sedimentary rock composed of sand-sized particles (measuring 0.05–2.0 mm in diameter), typically quartz

seal: a relatively impermeable rock, commonly shale, anhydrite or salt, that forms a barrier or cap above and around reservoir rock such that fluids cannot migrate beyond the reservoir. A seal is a critical component of a complete petroleum system.

sediment: various materials deposited by water, wind or glacial ice, or by precipitation from water by chemical or biological action (e.g. clay, sand, carbonate)

sedimentary rock: a rock formed by lithification of sediment transported or precipitated at the Earth's surface and accumulated in layers. These rocks can contain fragments of older rock transported and deposited by water, air or ice, chemical rocks formed by precipitation from solution, and remains of plants and animals.

seismic survey: a method for imaging the subsurface using controlled seismic energy sources and receivers at the surface. Measures the reflection and refraction of seismic energy as it travels through rock.

shale: a fine-grained sedimentary rock formed by lithification of mud that is fissile or fractures easily along bedding planes and is dominated by clay-sized particles

shale gas: generally extracted from a clay-rich sedimentary rock, which has naturally low permeability. The gas it contains is either adsorbed or in a free state in the pores of the rock.

shear: a frictional force that tends to cause contiguous parts of a body to slide relative to each other in a direction parallel to their plane of contact

source rock: a rock rich in organic matter which, if heated sufficiently, will generate oil or gas. Typical source rocks, usually shales or limestones, contain about 1% organic matter and at least 0.5% total organic carbon (TOC), although a rich source rock might have as much as 10% organic matter. Rocks of marine origin tend to be oil-prone, whereas terrestrial source rocks (such as coal) tend to be gas-prone. Preservation of organic matter without degradation is critical to creating a good source rock, and necessary for a complete petroleum system. Under the right conditions, source rocks may also be reservoir rocks, as in the case of shale gas reservoirs.

spring: a naturally occurring discharge of groundwater flowing out of the ground, often forming a small stream or pool of water. Typically, it represents the point at which the watertable intersects ground level.

stress: the force applied to a body that can result in deformation, or strain, usually described in terms of magnitude per unit of area, or intensity

stressor: chemical or biological agent, environmental condition or external stimulus that might contribute to an impact mode

structure: a geological feature produced by deformation of the Earth's crust, such as a fold or a fault; a feature within a rock, such as a fracture or bedding surface; or, more generally, the spatial arrangement of rocks

surface water: water that flows over land and in watercourses or artificial channels and can be captured, stored and supplemented from dams and reservoirs

terrane: an area of crust with a distinct assemblage of rocks (as opposed to terrain, which implies topography, such as rolling hills or rugged mountains)

tight gas: tight gas is trapped in reservoirs characterised by very low porosity and permeability. The rock pores that contain the gas are minuscule, and the interconnections between them are so limited that the gas can only migrate through it with great difficulty.

total organic carbon: the quantity of organic matter (kerogen and bitumen) is expressed in terms of the total organic carbon (TOC) content in mass per cent. The TOC value is the most basic measurement for determining the ability of sedimentary rocks to generate and expel hydrocarbons.

trap: a geologic feature that permits an accumulation of liquid or gas (e.g. natural gas, water, oil, injected CO_2) and prevents its escape. Traps may be structural (e.g. domes, anticlines), stratigraphic (pinchouts, permeability changes) or combinations of both.

unconfined aquifer: an aquifer whose upper water surface (watertable) is at atmospheric pressure and does not have a confining layer of low-permeability rock or sediment above it

unconventional gas: unconventional gas is generally produced from complex geological systems that prevent or significantly limit the migration of gas and require innovative technological solutions for extraction. There are numerous types of unconventional gas such as coal seam gas, deep coal gas, shale gas and tight gas.

water system: a system that is hydrologically connected and described at the level desired for management purposes (e.g. subcatchment, catchment, basin or drainage division, or groundwater management unit, subaquifer, aquifer, groundwater basin)

watertable: the upper surface of a body of groundwater occurring in an unconfined aquifer. At the watertable, pore water pressure equals atmospheric pressure.

weathering: the breakdown of rocks and other materials at the Earth's surface caused by mechanical action and reactions with air, water and organisms. Weathering of seep oils or improperly sealed oil samples by exposure to air results in evaporative loss of light hydrocarbons.

well: typically a narrow diameter hole drilled into the earth for the purposes of exploring, evaluating, injecting or recovering various natural resources, such as hydrocarbons (oil and gas), water or carbon dioxide. Wells are sometimes known as a 'wellbore'.

well barrier: envelope of one or several dependent barrier elements (including casing, cement, and any other downhole or surface sealing components) that prevent fluids from flowing unintentionally between a bore or a well and geological formations, between geological formations or to the surface.

well integrity: maintaining full control of fluids (or gases) within a well at all times by employing and maintaining one or more well barriers to prevent unintended fluid (gas or liquid) movement between formations with different pressure regimes, or loss of containment to the environment

well pad: the area of land on which the surface infrastructure for drilling and hydraulic fracturing operations are placed. The size of a well pad depends on the type of operation (for example, well pads are larger during the initial drilling and hydraulic fracturing than at production).

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