



The importance of water to the Exmouth Peninsula's environmental, heritage and social values

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Acknowledgement of Country

The Department of Water and Environmental Regulation acknowledges the Traditional Owners and custodians of the Exmouth Peninsula and their deep and continuing connection to the land and waters on which we all rely.

We pay our respects to Elders past, present and emerging, and to all members of the Aboriginal communities in the area and their cultures. We acknowledge that the Traditional Owners have been custodians of Country for countless generations and that water is integral to life.

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Summary

Aboriginal people are the Mid West Gascoyne region's first water managers and Traditional Owners of their Country, as recognised in the region's native title determinations. The Traditional Owners have been managing their Country for countless generations and have an enduring connection to, and comprehensive knowledge of, groundwater and surface water and the ecosystems they support.

There is a growing body of work being driven by Aboriginal people on cultural science, knowledge and values. The department acknowledges the importance and uniqueness of this work, which provides greater depth to our understanding of ecological values across the catchment. Yet it is not appropriate or respectful for us to present the cultural science and values studies, projects and records of the Traditional Owners in this report. However, such knowledge should be considered alongside this report to gain an integrated understanding of the places, people and spirit that needs to be protected from the impacts of water use.

This report focuses on the heritage places and environmental values that are listed for protection under legislation, policy and environmental guidance. It does not intend to provide a record of all the water-related values held by the Traditional Owners or to place the listed values as more important than those of Aboriginal people.

An outline of this report

This report describes the Exmouth Peninsula's environmental, social and heritage values listed under legislation, policy and guidance. It also considers the:

- ecological values of water-dependent ecosystems and the current understanding of how they are supported by groundwater
- registered cultural values including Aboriginal culture and heritage that relate to water
- social values of tourism, commercial fishing, recreation, and management and research that relate to water.

Environmental and heritage values

The Exmouth Peninsula's environmental and heritage values are identified in the following legislation, policy and guidance:

- Matters of national environmental significance listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). These include places of world and national heritage including Aboriginal cultural heritage, wetlands of international importance, listed threatened species and ecological communities, and migratory species.
- Aboriginal heritage places listed under the *Aboriginal Heritage Act 1972* (WA).
- Sites and places of significant cultural or natural heritage registered under the *Heritage Act 2018* (WA).

- Threatened species under the *Biodiversity Conservation Act 2016* (WA) – note the formal listing of threatened and priority ecological communities is not yet in force.
- Environmental values defined in the Environmental Protection Authority's environmental factor guidelines. These include social surroundings, flora and vegetation, terrestrial fauna, subterranean fauna, inland waters, marine fauna, benthic communities and habitats, marine environmental quality, and coastal processes, in accordance with Part 4 and Part 5 of the *Environmental Protection Act 1986* (WA).
- Areas of high conservation significance identified in Part B of *Environmental guidance for planning and development – Guidance statement 33* (EPA 2008).
- Conservation reserves managed under the *Conservation and Land Management Act 1984* (WA).
- Environmental values that are internationally and nationally significant including the *Directory of important wetlands in Australia* (Environment Australia 2001) and *International Union for Conservation of Nature red list* (IUCN).

There are also regional and local sites of ecological significance that may be identified during site-specific investigations (in areas where few or no mapping projects or surveys have been undertaken). These include but are not limited to:

- wetlands and waterways that persist during the dry season and provide refuges for aquatic and terrestrial fauna
- water-dependent ecosystems that are resilient to climate change
- ecosystems (or natural places) that provide a link to other water-dependent habitats and drought refuges
- springs and permanent river pools, particularly in arid areas.

1 Introduction

1.1 Purpose of this report

The Department of Water and Environmental Regulation (the department) has prepared this report to support water allocation planning in the Exmouth Peninsula. We will consider the information gathered for and presented in this report to determine the water that needs to stay in the environment to support aquifer integrity, water-dependent ecosystems and their ecological, heritage and social values.

In this report, we introduce water allocation planning for the Exmouth Peninsula and provide important background information. We then identify the environmental and heritage values listed under legislation, policy and guidance that depend on water (surface water and/or groundwater). We also consider the available information to describe groundwater-dependent ecosystems and the current understanding of how groundwater supports them. Finally, we identify threats to the region's groundwater-dependent ecosystems along with the current knowledge gaps and recommend further work to address them. We also describe social values, such as tourism and recreation.

Furthermore, we provide an overarching review of the Exmouth Peninsula's groundwater-dependent ecosystem types and then give more detailed information about their values by groundwater subarea.

Work on Aboriginal cultural science, traditional knowledge and values of freshwater places and Sea Country of the Exmouth Peninsula is underway. We acknowledge the importance and uniqueness of this work, which provides a more complete and holistic understanding of ecological values across the catchment.

While this work is ongoing, we have focused on heritage places that are recorded in the register maintained under the *Aboriginal Heritage Act 1972* (WA). We understand that not all Aboriginal heritage is listed in the register, and we do not intend for this report to provide a record of all the water-related values held by the Traditional Owners or to position the listed values at a higher level than those of Aboriginal people.

The cultural knowledge and values studies, projects and records gathered so far belong to the Traditional Owners and are not published in this report. Such knowledge should be considered alongside this report to gain a full understanding of the places, people and spirits to be protected from the impacts of water use.

1 Background

1.1 Exmouth Peninsula and water allocation planning

The Exmouth Peninsula is in the Mid West Gascoyne region, 1,260 km north of Perth (Figure 1). The peninsula extends 96 km north to south and 21 km across, with a maximum elevation of about 315 mAHD. It features Cape Range, the Ningaloo Coast along the west side, and the Exmouth Gulf along the east.

The Exmouth Peninsula is covered by the *Groundwater allocation plan – Exmouth groundwater subarea* (WRC 1999), which for management purposes divides the area into five groundwater subareas. This values report talks to six subareas, proposing to split the existing Exmouth South subarea into two subareas – Badjirrajirra and Exmouth Salt flats (Figure 1).

Each subarea contains three groundwater resources – the Cape Range Limestone aquifer (generally fresh), the Cape Range saline aquifer (saline) and the Birdrong Sandstone aquifer (saline). The Cape Range Limestone aquifer is the main aquifer supplying water to the town of Exmouth and its surrounding industries. Interest in the Cape Range saline resource has increased during the past decade, with licensees using it for aquaculture, dust suppression and desalination purposes. The Birdrong Sandstone aquifer is situated more than 1 km below ground and is unlikely to be targeted for use.

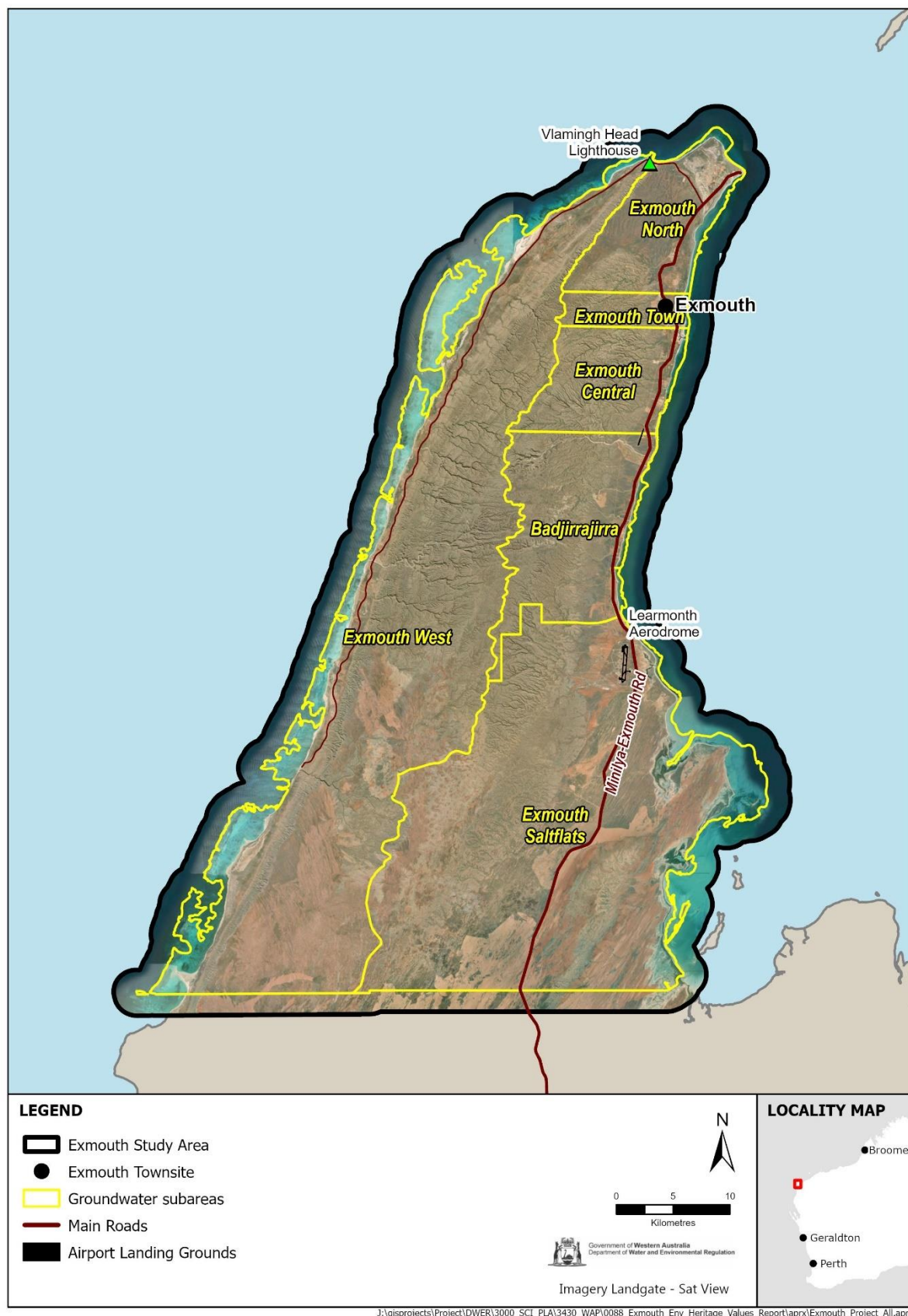


Figure 1 Groundwater subareas of the Exmouth Peninsula

1.2 Ecology

Fauna

The Exmouth Peninsula's most significant terrestrial conservation values are the cave and aquifer ecosystems known as the Cape Range subterranean waterways. These support animals – mostly invertebrates – restricted to groundwater habitats (stygo fauna) or those in caves kept humid by groundwater (troglota fauna). Western Australia is a global hotspot for subterranean fauna and at least 69 species occur on the Exmouth Peninsula, including nine conservation-listed species (Bennelongia 2021) (Appendix A; Section 5.1). Two conservation-listed fish species also occur in the habitat supported by groundwater. Nine conservation-listed troglota fauna have also been recorded on the peninsula (Bennelongia 2021).

Significant terrestrial fauna values also include a high diversity of birds (240 species), reptiles (150 species) and numerous endemic invertebrates including Camaenid land snails (18 species) (Sutton & Shaw 2021).

The Ningaloo Marine Park on the peninsula's western side and the Exmouth Gulf to the east support a great diversity of marine fauna. This includes the iconic whale shark (*Rhincodon typus*) and humpback whale (*Megaptera novaeangliae*), both listed as vulnerable under the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) and as specially protected under the Western Australian *Biodiversity Conservation Act 2016* (BC Act). Other high conservation species include the endangered loggerhead turtle (*Caretta caretta*) (BC Act, EPBC Act); the vulnerable green turtle (*Chelonia mydas*) (BC Act) and hawksbill turtle (*Eretmochelys imbricata*) (BC Act, EPBC Act); and leatherback turtle (*Dermochelys coriacea*) (endangered under the EPBC Act; vulnerable under the BC Act). Thirty-nine species of bird recorded from the Exmouth Peninsula are listed as conservation significant (Appendix A).

Vegetation and flora

The Exmouth Peninsula supports an unusually diverse and rich range of flora for an arid area (Keighery & Gibson 1993). While the flora is like that found on the Burrup Peninsula and Barrow Island, the Exmouth Peninsula has more than twice the number of recorded species (Keighery & Gibson 1993).

Twenty-seven species are listed as priority flora by the Department of Biodiversity Conservation and Attractions (Western Australian Herbarium) under the BC Act (Appendix A). The flora of highest conservation significance is the priority 1-listed *Calytrix* sp. Learmonth (S. Fox EMopp 1). There are five priority 2, five priority 3 and three priority 4 species likely to be associated with creeks or other watercourses.

Although not listed, four vegetation types were identified in a survey of the Qualing area on the peninsula's eastern side (Oceanwise Australia 2022). These communities had not been found in this area previously and are considered of high conservation significance. One of these has been nominated as a threatened

ecological community (TEC) and is undergoing assessment (Long & Aylmore 2021). Qualing Pool is discussed further in Section 7.2.

Threatened and priority ecological communities

Camerons Cave supports the only known occurrence of the Camerons Cave Troglobitic Community (obligatory cave inhabitants), including multiple listed species (DEC 2012). The community is listed as a critically endangered TEC under the BC Act.

The Cape Range remipede community which occurs at Bundera Sinkhole is listed as a vulnerable TEC under the EPBC Act. The sinkhole supports two species of fauna listed as threatened under the BC Act: *Kumonga exleyi* (Cape Range remipede) and *Milyeringa veritas* (blind gudgeon). Both species are also listed as vulnerable under the EPBC Act. *K. exleyi* is only known from the Bundera Sinkhole.

As noted above, a potential occurrence of the subtropical and temperate coastal saltmarsh TEC has been identified in the Qualing area (Long & Aylmore 2021).

1.3 Climate

In summer (December–February), the Exmouth Peninsula (recorded at Learmonth Airport) has daytime temperatures between 25°C and 37°C and in winter (June–August) between 12°C and 25°C. Over the period 1975–2022, temperatures have been increasing by around 0.02°C/year (DWER 2025).

The Exmouth Peninsula lies in a rainfall transition zone. It is far enough north to receive some rainfall from tropical systems, but it is also far enough south to receive rain from north-west cloud bands associated with late autumn/winter frontal systems (BoM 2021). Generally, rainfall is highest between January and July, with June having the highest mean monthly rainfall and the highest mean number of rainy days.

The topography of the Cape Range influences where rain falls on the Exmouth Peninsula. For example, the range shadows the Learmonth Airport station (BoM Station 005007) to some extent, and Exmouth station (BoM Station 005051) less so, from moisture coming from the west-northwest (DWER 2025).

The infrequent nature of large rain events means that rainfall may be very low for several consecutive years. Consecutive dry years can reduce groundwater recharge.

Major rainfall events in recent history include tropical cyclone Vance in March 1999, when Western Australia's highest-ever wind gust of 267 km/hour was recorded, and 207 mm of rain fell at Learmonth Airport. In winter 2002 Western Australia's wettest June day ever was recorded, when 305 mm of rain fell at Exmouth in 24 hours.

1.4 Hydrogeology and hydrology

Hydrogeology

The groundwater system of the Exmouth Peninsula, including Cape Range and the coastal plain, is hosted in calcareous sediments which contain both fresh and saline water resources.

The main freshwater-bearing formations of the Exmouth Peninsula are the Cape Range Group (Trealla, Tulki and Mandu limestone formations) and the Quaternary sediments of the coastal plain, all of which have karstic features (Figure 2). This unconfined aquifer consists of a thin lens of fresh water in delicate balance with the underlying seawater interface. The Cape Range subterranean wetlands occur within the Cape Range Group.

Groundwater recharge is mainly through direct infiltration after heavy rain. As the limestones are highly transmissive, groundwater flow towards the coast occurs relatively rapidly following rainfall. Discharge is likely to be through discrete subsea springs rather than diffuse oceanic discharge (Allen 1972).

Other known discharge points are the pools in Yardie Creek, and Qualing Pool (on an unnamed creek) near the coast. Both hold permanent surface water, and it is likely that vegetation has direct access to the aquifer or to the discharge in the pools. There is evidence that some other creek lines, or sections of them, may also be groundwater dependent. As it is unclear which other creeks may rely on groundwater for all or part of the year, all larger creeks for which we have some information are considered in this report. A permanent spring – recorded at the Tulki/Mandu limestone boundary in the creek within Shothole Canyon in the 1970s – has dried, however other springs may occur in the area.

Depth to groundwater is shallow at the coast and increases rapidly in the inland direction towards Cape Range. As a result, most of the water abstracted for public water supply (Water Corporation) and private use occurs near the coast, above the seawater interface (Figure 2). Abstraction at depth or high rates could lead to the upward migration of saline water, and the overall inland movement of the interface.

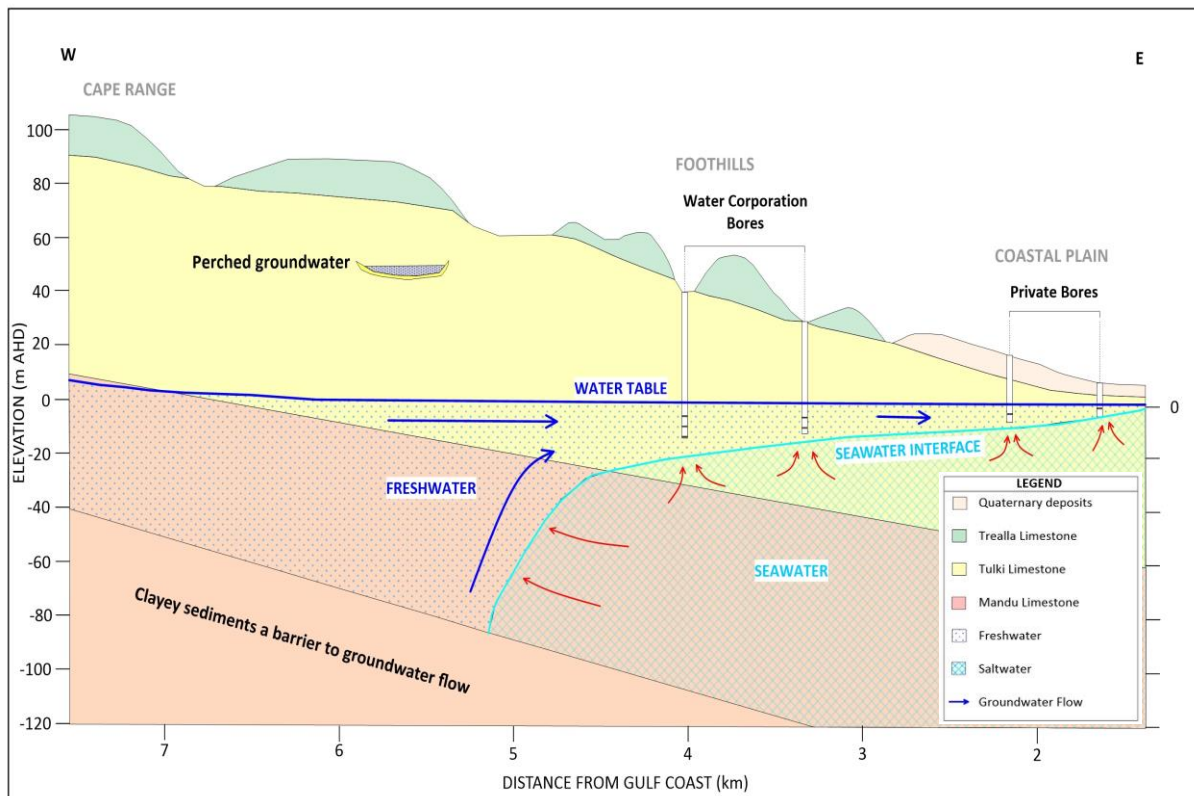


Figure 2 Hydrogeological cross section

Hydrology

The crest of Cape Range forms a regional divide with drainage systems flowing to the east and west (Allen 1993). In the northern two-thirds of the range the creeklines are deeply incised, whereas in the south they are shallower and partly buried by a sand sheet. On the north-east side of the range, the drainage lines are branched. In the north-west they are diagonally crisscrossed or trellised, and in the south they are mainly branched with some long fault-controlled reaches, such as in Yardie Creek (Allen 1993).

All surface water catchments on the eastern side of the range have been mapped and the extent of peak flooding modelled at Qualing (unnamed creek), Shothole, Badjirrajirra and Wapet creeks (Hyd2o 2014).

The modelled catchments vary considerably in size, ranging from 150 ha to 16,640 ha. The two largest of these are Shothole Creek (6,980 ha) and Wapet Creek (16,640 ha). See Section 7 for further information on the individual catchments.

2 Legislation to protect environmental and heritage values

2.1 Broad categories of environmental and heritage values

The Exmouth Peninsula's environmental and heritage values are identified in the following legislation, policy and guidance:

- Matters of national environmental significance listed under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth). These include places of world and national heritage including Aboriginal cultural heritage, wetlands of international importance, listed threatened species and ecological communities, and migratory species.
- Aboriginal heritage places listed under the *Aboriginal Heritage Act 1972* (WA).
- Sites and places of significant cultural or natural heritage registered under the *Heritage Act 2018* (WA).
- Threatened species under the *Biodiversity Conservation Act 2016* (WA) – note the formal listing of threatened and priority ecological communities is not yet in force.
- Environmental values defined in the Environmental Protection Authority's environmental factor guidelines. These include social surroundings, flora and vegetation, terrestrial fauna, subterranean fauna, inland waters, marine fauna, benthic communities and habitats, marine environmental quality, and coastal processes, in accordance with Part 4 and Part 5 of the *Environmental Protection Act 1986* (WA).
- Areas of high conservation significance identified in Part B of *Environmental guidance for planning and development – Guidance statement 33* (EPA 2008).
- Conservation reserves managed under the *Conservation and Land Management Act 1984* (WA).
- Environmental values that are internationally and nationally significant including the *Directory of important wetlands in Australia* (Environment Australia 2001) and *International Union for Conservation of Nature red list* (IUCN).

There are also regional and local sites of ecological significance that may be identified during site-specific investigations (in areas where few or no mapping projects or surveys have been undertaken). These include but are not limited to:

- wetlands and waterways that provide dry-season refuges for aquatic and terrestrial fauna
- ecosystems that are resilient to climate change
- groundwater-dependent ecosystems

- ecosystems (or natural places) that provide a link to other water-dependent habitats and drought refuges
- springs and permanent pools, particularly in arid areas.

2.2 Legislation and international listings

This section provides a short explanation of the legislation, policies and guidance that we have used to describe the Exmouth Peninsula's environmental and heritage places, including Aboriginal cultural heritage.

UNESCO World Heritage Convention

The World Heritage Convention is an international treaty which was adopted by the General Conference of UNESCO on 16 November 1972. The convention defines which sites can be considered for inscription on the World Heritage list with the primary goals of nature conservation and the preservation of cultural properties.

The convention sets out the duties of each country's governments to identify potential sites and to protect and preserve them, and how the World Heritage Fund is to be used and managed. Signatory countries pledge to conserve the World Heritage sites situated in their territory, and report regularly on the state of their conservation.

Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The EPBC Act is the Australian Government's central piece of environmental legislation. The Act provides a legal framework for the protection and management of nationally and internationally important species, ecological communities and heritage places. These are defined in the Act as matters of national environmental significance and include:

- national heritage places
- listed threatened flora and fauna
- threatened ecological communities
- Ramsar-listed wetlands
- migratory bird species protected under international agreements (CAMBA, JAMBA, ROKAMBA, Bonn Convention).¹

The listing of species, ecological communities or heritage places under the EPBC Act is not necessarily more important than listings under Western Australian state legislation (see below). Instead, the EPBC Act establishes assessment and approval requirements that are to be considered in addition to existing approvals required

¹ Agreements between the government of Australia and the governments of Japan ([JAMBA](#)), China (CAMBA) and The Republic of Korea (ROKAMBA), and the Bonn Convention, relating to the protection of migratory birds.

under state law. This means that an action still needs to be approved under all applicable state laws as well as under the EPBC Act.

Western Australian *Aboriginal Heritage Act 1972* (AH Act)

Aboriginal heritage holds significant value to Aboriginal people for their traditional, social, spiritual, historical, scientific or aesthetic importance. All Aboriginal heritage sites in Western Australia are protected by law, regardless of whether they are a registered site. Under Aboriginal heritage laws, proponents are required to seek consent for any activity that will knowingly damage an Aboriginal heritage site.

Aboriginal heritage places can be listed in the Aboriginal Cultural Heritage Inquiry System (ACHIS).

Western Australian *Heritage Act 2018*

The Heritage Act promotes understanding and appreciation of Western Australia's cultural and historical heritage sites. It provides for the identification and documentation of places of heritage significance and for their conservation, use, development and adaptation.

International Union for Conservation of Nature (IUCN) red list

The IUCN red list, founded in 1964, is the world's most comprehensive inventory of the conservation status of fauna and flora. It evaluates the extinction risk to species using set criteria. As of 2023 more than 44,000 threatened species were classified as vulnerable, critical or endangered (IUCN 2024).

The EPBC Act and Western Australia's *Biodiversity Conservation Act 2016* (see below) have adopted the IUCN conservation categories but have applied separate listings: this can lead to species being included in all three lists with three different conservation codes. Although the IUCN list is important to consider, there is no legislative power associated with it.

Western Australian *Environmental Protection Act 1986* (EP Act)

The EP Act established the Environmental Protection Authority (EPA) and made provisions for it to undertake environmental impact assessments of significant proposals. Assessments must consider key environmental factors such as sea, land, inland waters, air and people (EPA 2018).

Significant ecosystems covered under the guideline for the inland water environmental factor (EPA 2018) and relevant to the Exmouth Peninsula include:

- wetlands listed in the *Directory of important wetlands in Australia* (Environment Australia 2001)
- springs and pools
- ecosystems which support significant flora, vegetation and fauna species or communities, including migratory waterbirds

- ecosystems which support significant amenity, recreation and cultural values
- saline lakes, estuaries and nearshore ecosystems reliant on groundwater or surface water inputs.

Part V of the EP Act and the Environmental Protection (Clearing of Native Vegetation) Regulations 2004 regulate the clearing of native vegetation. Under the EP Act, clearing is generally not permitted where native vegetation supports biodiversity values, land conservation and water resource protection. This includes native vegetation that is significant habitat for threatened species and communities or is associated with a wetland or watercourse.

The *Redbook recommended conservation reserves* contains the boundaries of areas the EPA recommends for conservation.

The *Native vegetation policy for Western Australia* (DWER 2022)² provides the whole-of-government approach to achieving better outcomes for native vegetation and improved clarity and certainty for stakeholders.

Western Australian *Biodiversity Conservation Act 2016* (BC Act)

The BC Act provides for listing protected species and threatened ecological communities, including key threatening processes (such as land degradation) and critical habitats.

The BC Act also establishes recovery plans and other modern features of biodiversity conservation and management. Like the EPBC Act, the BC Act has adopted the IUCN conservation categories but has applied separate listings.

The EPBC Act and BC Act provide for a statutory process whereby the Minister for Environment can identify and list a threatened ecological community (TEC). No formal statutory TECs are listed under the BC Act at present. However, decision-makers continue to use a non-statutory TEC list endorsed by the Western Australian Minister for Environment for guidance.

Although priority ecological communities (PECs) are not listed in the BC Act, they are maintained under the Department Biodiversity, Conservation and Attraction's conservation codes. PECs are possible threatened ecological communities that do not meet survey criteria or that are not adequately defined.

Western Australian *Conservation and Land Management Act 1984* (CALM Act)

The CALM Act provides for the protection of public lands and water which includes national parks, nature reserves, marine reserves and conservation parks. These reserves mostly consist of areas of crown land set aside for the protection and conservation of biodiversity and/or natural or cultural heritage values.

² <https://www.wa.gov.au/government/publications/native-vegetation-policy-western-australia>

3 Listed heritage values

In this section we discuss the Exmouth Peninsula's listed heritage values.

World Heritage list

The Ningaloo Coast, which runs along the Exmouth Peninsula's western side, was listed as a World Heritage site in 2011. Covering 7,050 km² of marine and terrestrial environments, the site includes one of the longest nearshore reefs in the world (DEWHA 2010) (Figure 3). The marine area supports numerous listed marine mammals, fish and reptiles, including humpback whales, coastal dolphins, dugongs and marine reptiles (including turtles and sea snakes).

The terrestrial part of the site features subterranean waterbodies with an extensive karst system and a network of underground caves and groundwater streams (DEWHA 2010). These support a variety of rare species that contribute to the exceptional biodiversity of the marine and terrestrial site.

The Ningaloo Coast was nominated for inclusion on the World Heritage list for containing:

- superlative natural phenomena and areas of exceptional natural beauty and aesthetic importance
- outstanding examples representing major stages of the earth's history, including the record of life, significant ongoing geological processes in the development of landforms, and significant geomorphic or physiographic features
- the most important and significant natural habitats for in situ conservation of biological diversity, including those containing threatened species of outstanding universal value from the point-of-view of science or conservation (DEWHA 2010).

National heritage and Commonwealth heritage lists under the Commonwealth *Environmental Protection and Biodiversity Conservation Act 1999*

The national heritage list is established under the EPBC Act. It includes natural, Indigenous and historic places of outstanding value to the nation.

The Commonwealth heritage list is also established under the EPBC Act. This includes natural, Indigenous and historic places on Commonwealth lands and waters or under Australian Government control, which are identified as having Commonwealth heritage values by the federal Minister for the Environment.

The Ningaloo Coast was listed as a national heritage site in 2010. The 8,000 km² site includes a marine area of about 5,500 km², incorporating the Ningaloo Marine Park and the state-managed Muiron Islands Marine Management Area (Figure 3).

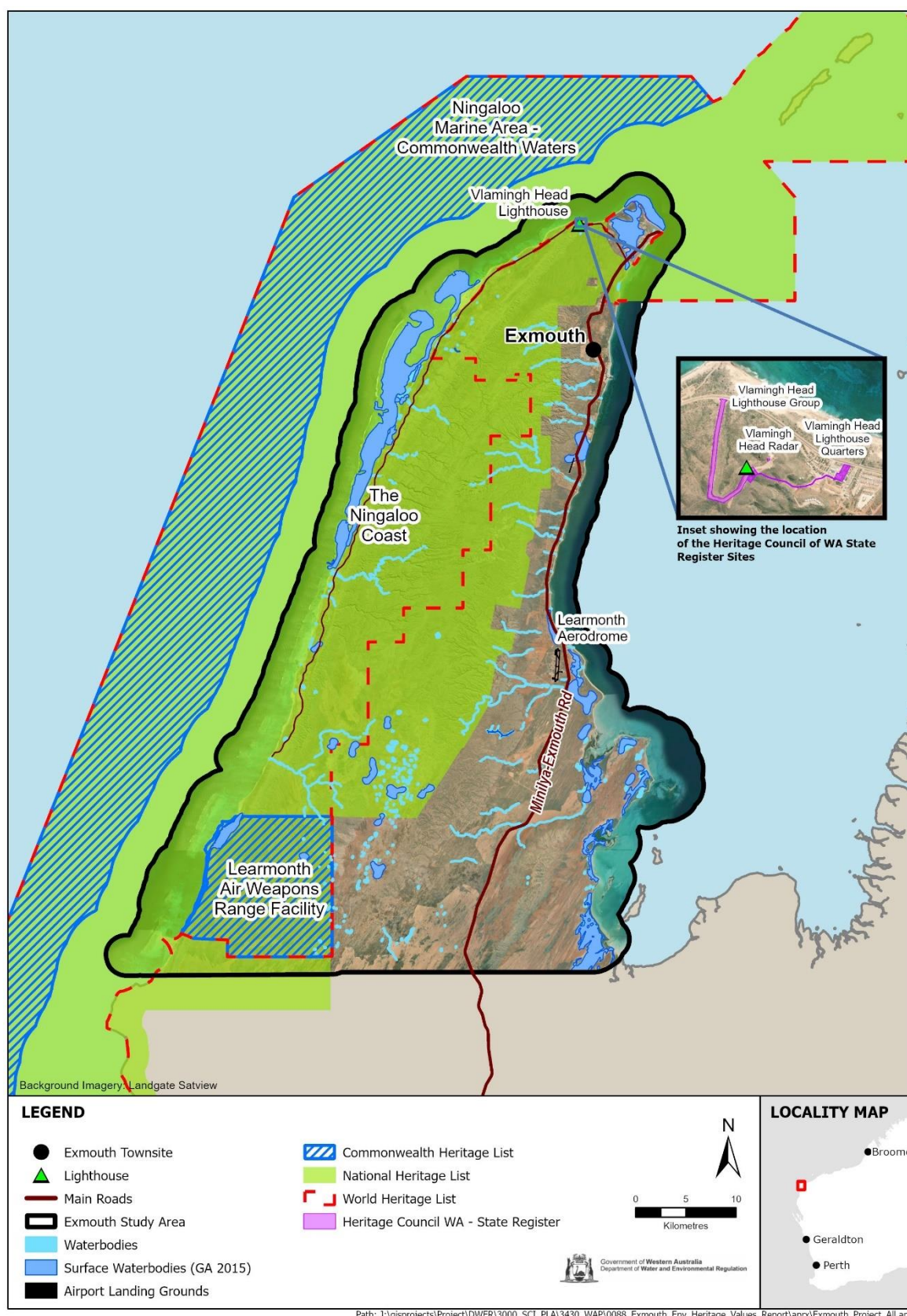


Figure 3 World, Commonwealth and national heritage sites and Heritage Council WA sites.

The inland extent of the Ningaloo Coast encompasses the Cape Range, conservation reserves and areas of pastoral leases. The listed Commonwealth heritage sites are:

- Learmonth Air Weapons Range
- Harold E Holt Naval Communications Station
- Department of Defence's Learmonth Air Base.

These Commonwealth heritage sites are within the Ningaloo Coast national heritage site (Figure 3).

Historical heritage places listed under the Western Australian *Heritage Act 2018*

The Exmouth Peninsula has four heritage sites listed under the Heritage Act (Figure 3). All were part of the Vlamingh Head lighthouse, which was a significant feature of the peninsula's north-west coast for 50 years until 1967. The Operation Potshot site, associated with World War II defences and listed under the municipal inventory, is also located at the Vlamingh Head site.

The sites have aesthetic, historic, social, scientific and cultural heritage significance and are notable pieces of architecture in a very remote location.

Numerous other sites are listed for their local heritage. Example of these include Charles Knife Road and Wapet Jetty.

These sites are unlikely to relate to groundwater.

Aboriginal heritage places listed under the Western Australian *Aboriginal Heritage Act 1972*

Close to 100 sites are registered under the AH Act in the Exmouth Peninsula. All listed sites are located within the registered Warnangura (Cape Range) cultural precinct, which covers 3,000 km² of the peninsula (Figure 4). Sites may be of ceremonial or mythological significance; recognised as a water source; or contain artefacts, middens, engravings, caves and rock shelters (e.g. Mandu Mandu, Yardie Creek, Sandy Point).

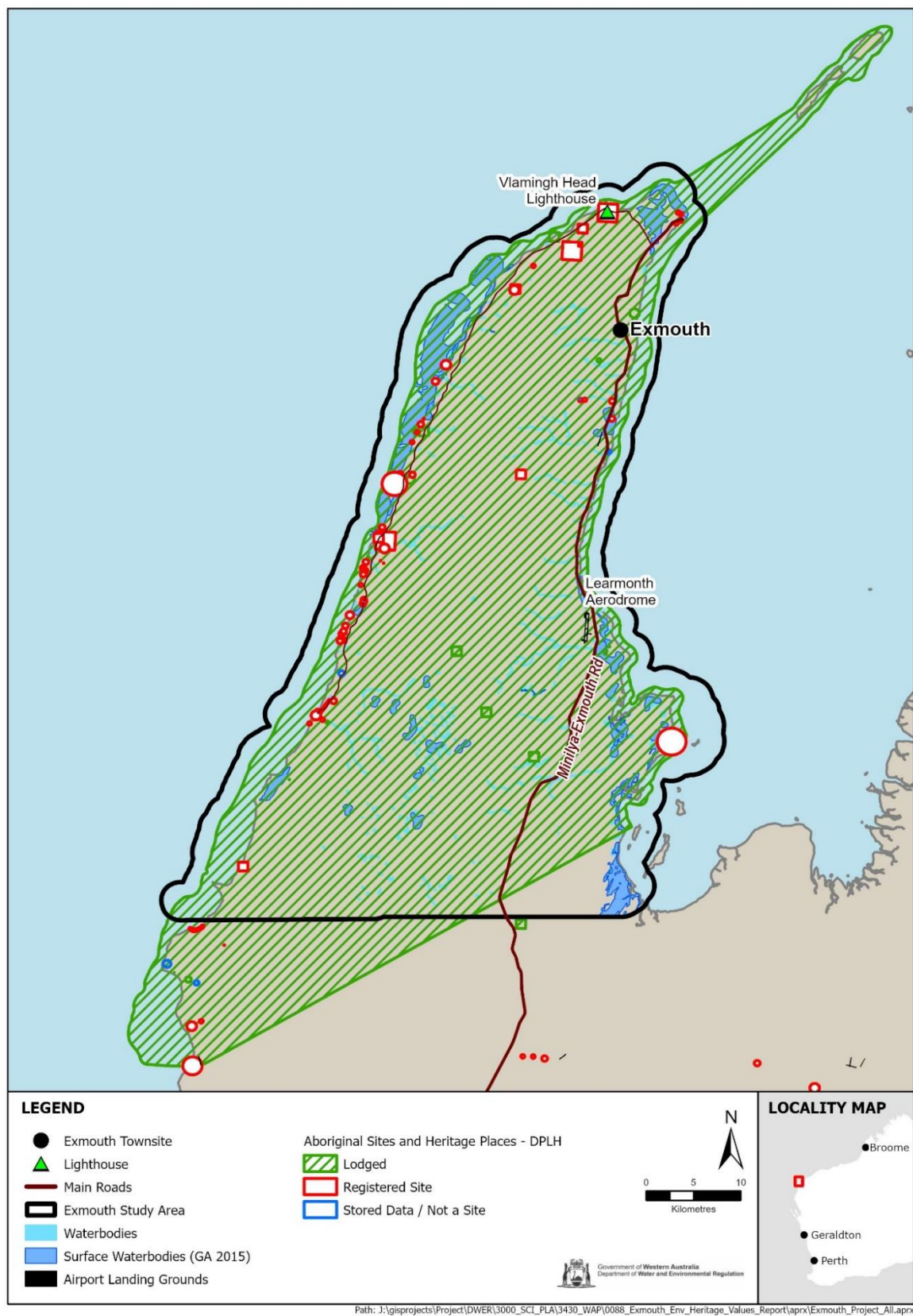


Figure 4 Registered Aboriginal heritage places in the Exmouth Peninsula, Aboriginal Heritage Act 1972 (as of April 2024)

Conservation Estate listed under the Western Australian *Conservation and Land Management Act 1986*

The Conservation Estate listed under the CALM Act covers about 870 km² of the Exmouth Peninsula (Figure 5) and includes:

- national parks – managed jointly by the Baiyungu, Thalanyji and Yinnigurrura (Yinigurdira) people and the Department of Biodiversity, Conservation and Attractions (DBCA)
 - Cape Range National Park
 - Nyinggulara National Park (ex-Ningaloo)
- marine parks – Baiyungu, Thalanyji and Yinikurtura people have responsibilities for Sea Country in the parks
 - Ningaloo Marine Park – outer park in Commonwealth waters managed by Australian Marine Parks
 - Ningaloo Marine Park – inner park in state waters managed by DBCA
- conservation reserves
 - Cape Range Conservation Park – managed by DBCA
- recreational and coastal management parks – managed jointly by the Exmouth Shire Council and DBCA
 - Bundegi Coastal Park
 - Jurabi Coastal Park
- nature reserves – managed by DBCA
 - Whitmore, Roberts, Doole Islands and Sandalwood Landing Nature Reserve
 - Muiron Islands Nature Reserve.

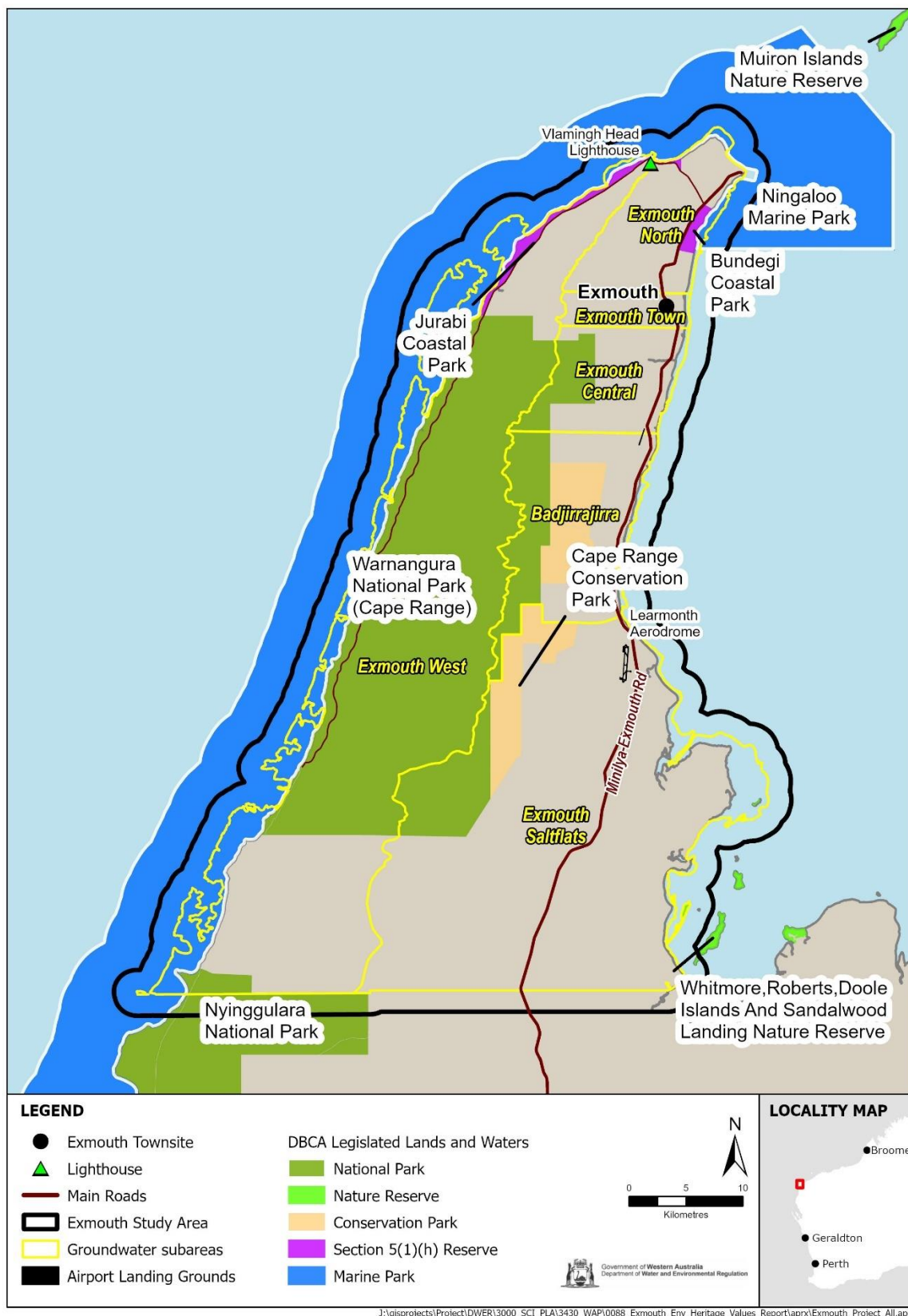


Figure 5 Conservation Estate managed by the Department of Biodiversity, Conservation and Attractions (as of June 2023)

4 Traditional Owner cultural values of water

4.1 Traditional Owners of the Exmouth Peninsula

Traditional Owners have custodial responsibilities for land and waters in the Exmouth region. The Gnulli native title claim was determined in December 2019 and gave recognition to the Baiyungu, Yinnigurrura and/or Thalanyji people over a 71,354 km² area of the Mid West–Gascoyne region, including the Exmouth Peninsula.

The people represented by the Nganhurra Thanardi Garrbu Aboriginal Corporation (NTGAC) have a deep cultural connection with water and there are cultural sites across the Exmouth Peninsula. Under traditional lore (law), the Baiyungu and Yinnigurrura people have responsibilities to care for Country and keep culture strong. The cultural heritage, spiritual and religious values of the Exmouth Peninsula and its surrounding environment are of paramount importance to the Traditional Owners.

4.2 Freshwater cultural values

Work on Aboriginal cultural science, traditional knowledge and the location and values of Sea Country of the Exmouth Peninsula is underway. A separate project to identify culturally important freshwater places is also proposed. We acknowledge the importance and uniqueness of this work, which will provide a more complete and holistic understanding of ecological values across the catchment.

In this report, we have focused on heritage places that are recorded in the register maintained under the AH Act. We understand that not all Aboriginal heritage is listed in the heritage register and we do not intend for this report to provide a record of all the water-related values held by the Traditional Owners or to position the listed values at a higher level than those of Aboriginal people.

Any new information about cultural values and associated mapping would be an important part of informing groundwater allocation and licensing processes.

Based on the cultural importance of water, we make the assumption that all freshwater places have some cultural value, unless otherwise advised by the Traditional Custodians of that place.

5 Recognised environmental values

In this section we identify and discuss both the listed (legislated) environmental values and those included in the EPA factor guidelines across the Exmouth Peninsula. This includes the Ningaloo Reef and nearshore marine zone. For the purposes of this report, we have defined this zone as the area extending 2 km from the coast into the Exmouth Gulf (Figure 1).

We have presented the Exmouth Peninsula's environmental values using a range of groundwater-dependent ecosystem types (Figure 6):

- subterranean (karstic features) and aquifer ecosystems (freshwater and brackish zone)
- wetland ecosystems (creeklines and pools)
- nearshore marine ecosystems (mangroves, seagrass communities)
- springs
- terrestrial vegetation.

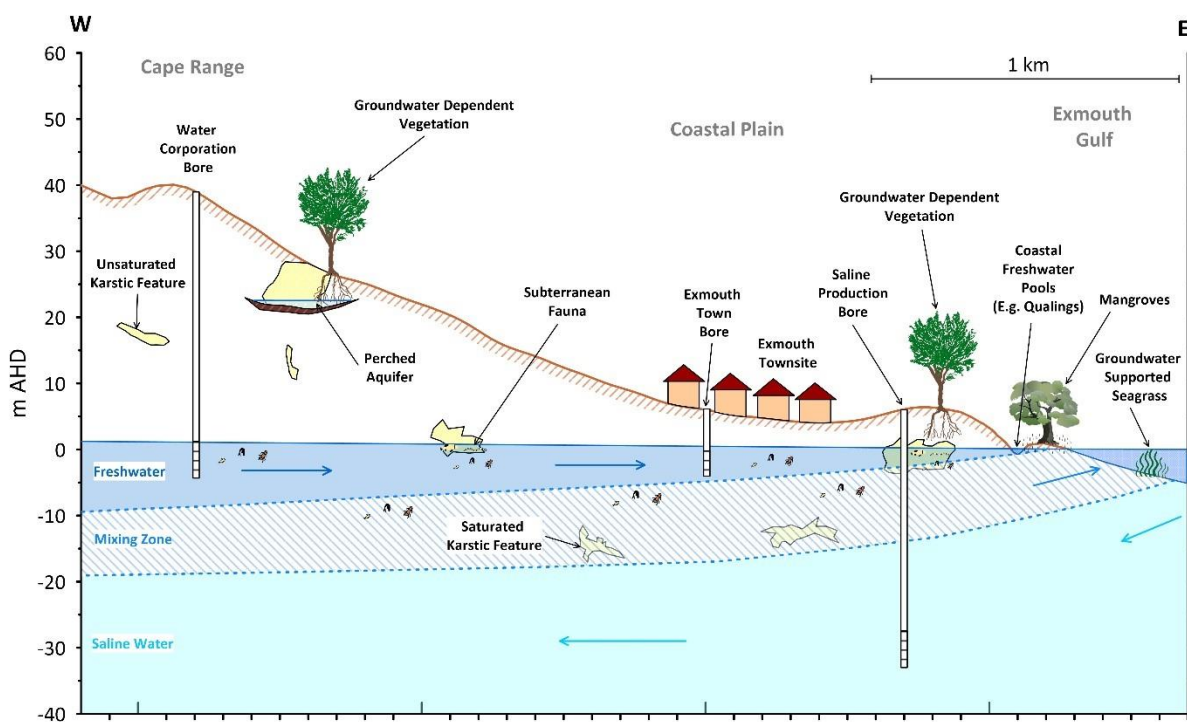


Figure 6 Groundwater-dependent ecosystem types of the Exmouth Peninsula

5.1 Subterranean and aquifer ecosystems

Subterranean and aquifer ecosystems in northern Western Australia support a globally significant diversity of fauna that are adapted to life below the earth's surface. The fauna belongs to two groups:

- stygofauna – aquatic and living in groundwater
- troglofauna – air breathing and living in voids and caves above the watertable, dependent on humid conditions caused by proximity to groundwater (Tomlinson & Boulton 2010) and/or recharge from the surface (Bennelongia 2021).

The occurrence of stygofauna in general is influenced by abiotic habitat characteristics including hydrological connectivity, salinity, dissolved oxygen levels and geology (Gibson 2018). In groundwater, oxygen and nutrients generally decrease with depth. As a result, stygofauna are often most abundant and diverse in the upper part of the aquifer, closer to the watertable. Richness and abundance then generally decrease with distance below the watertable (Korbel et al. 2019).

On the Exmouth Peninsula, suitable stygofauna habitat is determined by the physical characteristics (lithology) of the limestones and conglomerates (Bennelongia 2021). Lithology may influence habitat availability in terms of spaces and voids and by limiting the recharge of energy and nutrients as depth from the watertable increases.

Suitable habitat for troglofauna is shaped by humidity in caves, the presence of voids and fissures, and a source of carbon and energy (Bennelongia 2021). More than 800 caves have been mapped on the Exmouth Peninsula (Brooks 2015). These include karst voids, chutes, fissures and interstitial spaces containing fresh through to brackish and saline waters (Oceanwise 2022). The Tulki Limestone is the main cave-bearing feature (Brooks 2015). However, caves also form in the Trealla limestones, Mowbowra conglomerates, and various sedimentary environments (Oceanwise 2022).

Most caves within the Cape Range are vertical solution pipes extending to a maximum depth of 90 m. Galleries are small and inaccessible, and the caves are dry (Allen 1993). However, the caves on the coastal plain are partially or filled with water.

Significant subterranean and aquifer ecosystems

Significant ecosystems listed in the *Environmental factor guideline: Inland Waters* (EPA 2018) that are relevant to the Exmouth Peninsula include:

- wetlands listed in the *Directory of important wetlands in Australia* (DIWA) (Environment Australia 2001)
- ecosystems which support significant flora, vegetation and fauna species or communities, including migratory waterbirds.

DIWA-listed Cape Range Subterranean Waterways

The Cape Range Subterranean Waterways (Figure 8) are the only wetlands listed in the directory principally for subterranean aquatic fauna values (Humphreys 2000). They are a good example of a subterranean karst wetland system and the only system (apart from Barrow Island) in arid north-western Australia. They meet two Ramsar criteria for listing as a Wetland of International Importance (Jaensch & Watkins 1999) and are recommended as a World Heritage site (Hamilton-Smith et al.

1998). The karst area and rock shelters of Cape Range contain many Aboriginal artworks (Hamilton-Smith et al. 1998).

A wetland may be considered nationally important if it meets one or more of the following criteria:

1. It is a good example of a wetland type occurring within a biogeographic region in Australia.
2. It is a wetland which plays an important ecological or hydrological role in the natural functioning of a major wetland system/complex.
3. It is a wetland which is important as the habitat for animal taxa at a vulnerable stage in their life cycles or provides a refuge when adverse conditions such as drought prevail.
4. The wetland supports one per cent or more of the national populations of any native plant or animal taxa.
5. The wetland supports native plant or animal taxa or communities which are considered endangered or vulnerable at the national level.
6. The wetland is of outstanding historical or cultural significance (DCCEEW 2023b).

The Cape Range Subterranean Waterways meet criteria 1, 2, 3, 4 and 6. The wetlands are described as subterranean waterways, sinkholes, general groundwater and artificial wells of the coastal plain and foothills of Cape Range (DCCEEW 2023b).

Threatened ecological communities

Bundera Sinkhole (Figure 7 and Figure 8) hosts the Cape Range remipede TEC, listed as a vulnerable under the BC Act. Bundera is listed as a DIWA wetland under criteria 1 and 5 (Environment Australia 2001). The sinkhole is described as an inland marine cave, having a freshwater layer overlying sea water (anchialine habitat). As a result, it has a stratified sunlight and physico-chemical profile (Humphreys 1999a). The cave is influenced by marine tides but has no direct surface connection with the open sea (Black et al. 2001).

The sinkhole supports multiple endemic stygofauna listed as threatened under the BC Act, including the Cape Range remipede (*Kumonga exleyi*) and blind gudgeon (*Milyeringa veritas*). All stygofauna are totally dependent on groundwater. Both species are also listed as vulnerable under the EPBC Act. The Cape Range remipede is significant as Australia's only known species of the ancient crustacean order Remipedia and it is restricted to the Bundera Sinkhole.

The sinkhole supports few flora species. The predominant vegetation is the thick aquatic algal community, which can cover the surface and extend to several metres below the water level (Black et al. 2001) (Figure 7). See sections 5.1 and 8.6 for further information.

The Camerons Cave Troglobitic Community (Figure 8) is listed as a critically endangered TEC under the BC Act. This community contains a unique assemblage of troglofauna, of which at least eight species are only found in this cave and are likely dependent on the humidity from groundwater at the base of the cave. Parts of the cave extend below the watertable, believed to be the unconfined Cape Range aquifer (DEC 2012).



Figure 7 Bundera Sinkhole (photo courtesy of R Loomes)

Listed threatened species include troglofauna such as the endemic Camerons Cave millipede (*Stygiochiropus peculiaris*) and Camerons Cave pseudoscorpion (*Indohya damacles*). Blind gudgeon also occur in the cave and at other sites.

Camerons Cave is currently unprotected and the area around the cave is subject to various proposed developments. However, Class A reserves have been proposed for the protection of local areas of significance including Camerons Cave (EPA 2021). See sections 5.1 and 7.2 for further information.

Threatened and priority flora and fauna

The Cape Range Subterranean Waterways support a rich and entirely endemic subterranean community mostly of relictual marine (Tethys Sea) fauna. Many species share similarities with those from similar habitats in the Caribbean and

Canary Islands. The fauna includes the only southern hemisphere representatives of entire classes, orders, families and genera of crustaceans (DCCEEW 2023a).

Bennelongia (2020) reviewed available subterranean fauna datasets (WA Museum, internal database), monitoring records (Water Corporation), recent sampling and recent scientific literature. The study estimated that 69 species of invertebrate stygofauna occur on the Exmouth Peninsula, including 10 threatened species and one priority species. In addition, they found at least 59 species likely to be troglotauna, including eight threatened species and one priority species (Bennelongia 2020) (Appendix A).

In addition to macroinvertebrates, two fish species listed as vulnerable (EPBC) occur within the waterways – blind gudgeon and blind cave eel (*Ophisternon candidum*). Both species inhabit and move between markedly stratified waters (Humphreys 1999b; Humphreys et al. 2006; Seymour et al. 2007), ranging from fresh water at the surface to full seawater salinity at depth.

Figure 9 shows the general location of listed flora and fauna and Section 7 provides further information by subarea. Appendix A provides a full list of listed flora and fauna.

Threats to subterranean and aquifer habitats and knowledge gaps

Threats

Maintenance of water quality, natural hydrological regimes and the anchialine spectrum within the Cape Range Subterranean Waterways is particularly important for the conservation of subterranean fauna (DEC 2010). Potential threats to subterranean and aquifer ecosystems in the Exmouth plan area include:

- unsustainable water abstraction which can draw salt water into brackish or freshwater habitat
- alterations to natural water drainage patterns that may be associated with recreation, infrastructure development or limestone extraction
- pollution by sediment, nutrients, herbicides, insecticides, industrial wastes, bacteria and per- and polyfluoroalkyl substances (PFAS)
- extractive industry impacts – mining activities such as dewatering of aquifers or 'waste' water reinjection altering subterranean habitat quality and availability (pH, temperature, habitat fragmentation)
- mining
- exotic aquatic organisms, particularly aquarium fish and invertebrates
- disturbance of relationships between surface and aquifer environments through clearing of vegetation, and erosion and compaction of overlying soils and landforms, resulting in a reduction in organic matter that subterranean fauna feed on, or sedimentation of habitat

- climate change induced rainfall declines, and increased temperatures, may increase the incidence of fires, which may break down limestone surfaces and destroy karstic features, increase sediment runoff and alter water and nutrient flows (DEC 2010).
- uncontrolled visitor access disturbing cave ecosystems and damaging troglofaunal habitats.

Knowledge gaps

We recommend the following targeted surveys to further knowledge about the Exmouth Peninsula's subterranean and aquifer ecosystems and better inform the assessment of development proposals:

- identify, describe and map potential stygofauna (aquifers) and troglofauna habitat (e.g. caves with permanent standing water, suitable subsurface voids)
- stygofauna
 - detailed surveys of aquifers to identify stygofauna species and their location within the watertable (if possible) and distributions
 - intensive water quality sampling of the entire water column
 - define any relationship between water quality and depth with stygofauna species and/or communities
- troglofauna
 - survey of suitable habitat (e.g. caves) to identify troglofauna species and their distributions and habitat requirements, to ensure no isolation of species occurs
 - determine the relationship between humidity and the presence of troglofauna.

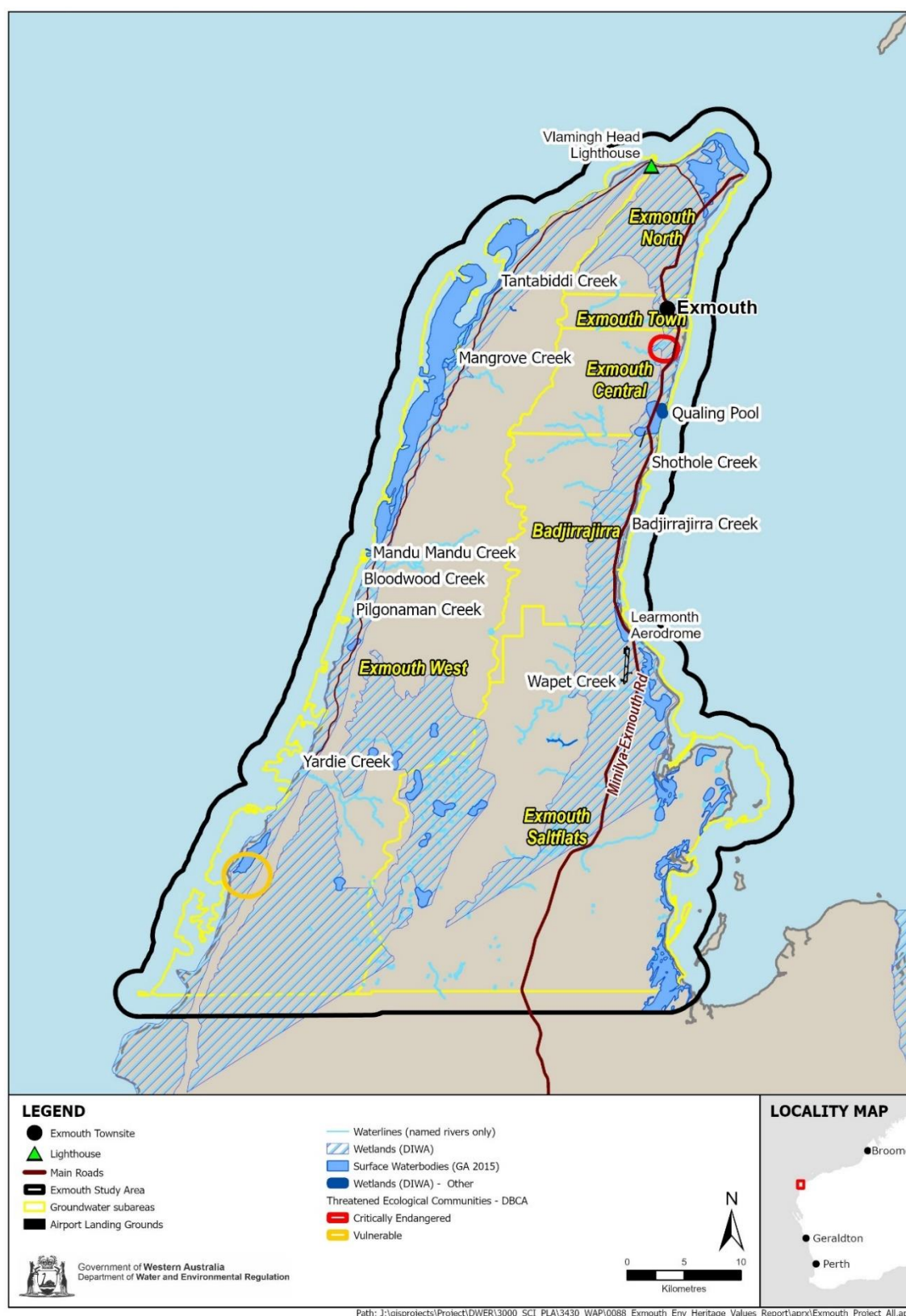


Figure 8 DIWA-listed wetlands (including Subterranean Waterways), threatened ecological communities and surface water bodies of the Exmouth Peninsula

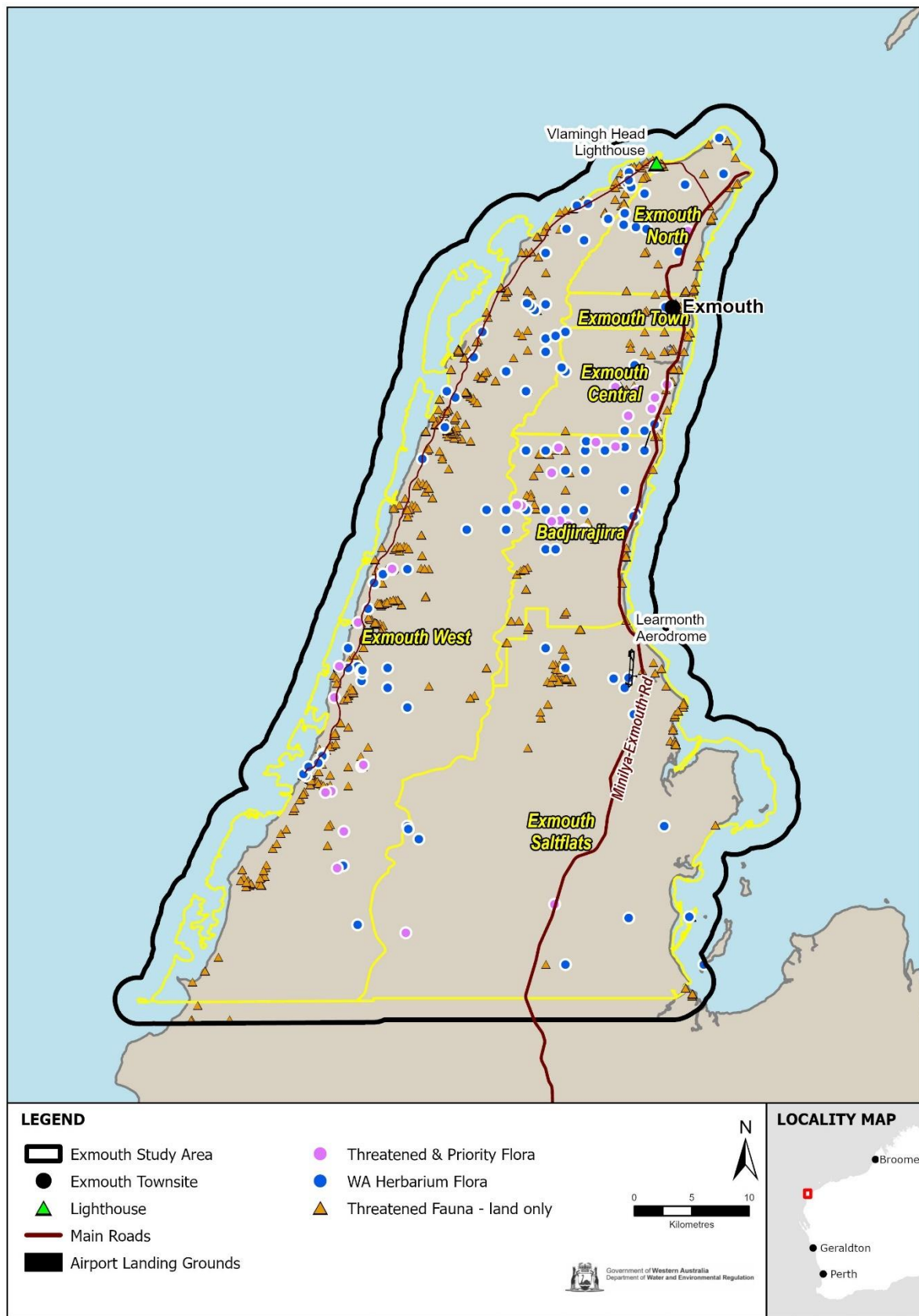


Figure 9 Threatened flora and fauna of the Exmouth Peninsula

5.2 Wetlands and waterways

In addition to the Cape Range Subterranean Waterways discussed in Section 5.1, a series of surface water bodies are mapped across the Exmouth Peninsula. These include a number of creeklines and ephemeral swamps (Figure 8) (see Section 1.4).

Permanent freshwater pools are found on a small number of these systems. The pools provide summer refuge for fauna and flora including conservation-significant waterbirds, mammals and reptiles. It is important that any larger, deeper pools are protected as they will persist even after a limited wet season and provide habitat during the following protracted dry period.

Yardie Creek is the main surface water feature on the peninsula and the only permanent groundwater-fed watercourse (Allen 1993; DEC 2010) (see Section 7.6). Qualing Pool near the mouth of an unnamed creek is also considered permanent and groundwater-fed (Allen 1993) (see Section 7.2).

Groundwater-dependence is largely inferred, based on the permanence of fresh water, the presence of groundwater-dependent riparian and aquatic flora, and – at Qualing Pool – the proximity of the Tulki and Trealla limestones (Oceanwise 2022).

Six creeks with a total catchment area of 45.4 km² flow in an easterly direction from the crest of Cape Range to discharge into the Exmouth Gulf (Sutton & Shaw 2021). The largest of these is the unnamed creek near the light industrial area that flows into Qualing Pool. Badjirrajirra and Wapet creeks are the only named creeks flowing into the gulf. The ephemeral Mangrove and Mandu Mandu creeks flow in a westerly direction from the crest of the range to discharge into the Ningaloo Marine Park north of Yardie Creek. These creeks are discussed further in Section 7.

Significant wetland and waterways ecosystems

Significant ecosystems that are listed in the *Environmental factor guideline: Inland Waters* (EPA 2018) and relevant to the Exmouth Peninsula include:

- wetlands listed in the *Directory of Important Wetlands in Australia* (DIWA) (Environment Australia 2001)
- ecosystems which support significant flora, vegetation and fauna species or communities, including migratory waterbirds.

Directory of important wetlands in Australia (DIWA)

The DIWA-listed Learmonth Air Weapons Range – Saline Coastal Flats wetland is located on the peninsula's western side, north of Bundera Sinkhole. It is listed as a DIWA wetland under criteria 1 (see Section 6.1). Typically the vegetation found there has low species richness, but its floristic composition and structure is highly distinctive and supports habitat-specific fauna (Department of Environment 2000).

Threatened and priority flora, fauna and potential TEC

There are 13 priority (P) flora listed under the BC Act that may be associated with creeks, swamps and watercourses. These include:

- herbs – *Acanthocarpus rupestris* (P2), *Calandrinia* sp. Cape Range (F. Obbens FO 10/18) (P2), *Crinum flaccidum* – Darling lily (P2), *Stackhousia umbellata* (P3)
- climbers – *Tinospora esiangkara* (P2)
- shrubs – *Harnieria kempeana* subsp. *rhadinophylla* (P2), *Acacia alexandri* (P3), *Acacia startii* (P3), *Lysiandra fuernrohrii* – sand sponge (P3), *Eremophila youngii* subsp. *lepidota* (P4), *Rhynchosia bungarensis* (P4)
- palms – *Livistona alfredii* – Millstream fan-palm (P4)
- trees – *Grevillea calcicola* (P3).

Although not listed, four vegetation types of high conservation significance were identified in a recent survey of the Qualing area on the peninsula's eastern side (Oceanwise 2022). These are also potential TECs with one nominated and undergoing assessment. The vegetation types are:

- dense matted *Sporobolus virginicus* grassland
- Nardoo ephemeral herbland
- *Marsilea hirsuta* (an aquatic amphibious fern), *Pluchea rubelliflora* ephemeral and annual herbland over scattered to open *Sporobolus virginicus* tussock grassland
- *Samolus* sp. Shark Bay low shrubland over *Schoenoplectus subulatus* sedgeland with *Cyperus vaginatus* (Oceanwise 2022).

Conservation-significant waterbirds, mammals and reptiles are also associated with creeks, swamps and watercourses. These are discussed further in Section 7.2.

Wetlands and waterways with regional and local environmental value

Yardie Creek, the Learmonth Air Weapons Range and Qualing wetlands have regional and local environmental value because they provide dry season refuges. Yardie Creek also supports populations of emergent aquatic flora that occur well away from their normal ranges. These include *Typha domingensis* and *Schoenoplectus littoralis* (Keighery & Gibson 1993).

Threats to wetlands and waterways and knowledge gaps

Threats

Threats to wetlands and waterways on the Exmouth Peninsula are associated with water resource development, land use changes, and broader phenomena such as climate change and invasive species.

Groundwater abstraction could reduce wetland depth and persistence in the permanent pools of Yardie Creek and Qualing. This would significantly reduce refuge habitat and disrupt food webs. Groundwater decline at the wetlands could also lead to the degradation and loss of dependent native vegetation and increased weed invasion.

Alterations to natural water drainage patterns that may be associated with recreation infrastructure development may lead to pollution of wetlands by sediment, nutrients, herbicides, insecticides, industrial waste and bacteria.

Extractive industry (mining) activities such as dewatering of aquifers or 'waste' water reinjection may alter water quality and availability.

Invasive fish species from aquarium dumping pose a significant threat to native species. Ornamental fish like the guppy and sailfin molly have been introduced to local waterbodies and can be aggressive to native fish, compete for food and carry parasites.

Climate change may result in higher temperatures and a greater variation in rainfall, leading to more consecutive dry years. This could reduce groundwater recharge and cause wetlands to dry out during the dry season or completely.

Threats may also interact or compound. For example, groundwater use may exacerbate the drying of wetlands, which may increase fire penetration into these ecosystems and/or the frequency and intensity of fires, which would likely have substantial implications for wetland biota.

Knowledge gaps

We recommend the following targeted surveys to further knowledge about the Exmouth Peninsula's wetlands and waterways and better inform the assessment of development proposals:

- identify and describe potentially groundwater-dependent systems, which may include:
 - groundwater and surface water analysis to identify the groundwater source
 - installing surface water loggers to describe water depth and seasonality
- targeted surveys of dependent wetlands to identify fauna and flora species
- ongoing water depth and water quality monitoring to define the relationship with dependent fauna and flora.

5.3 Nearshore marine ecosystems

Groundwater discharge near the shore and into the marine environment provides fresh water and nutrients for mangroves (Hayes et al. 2018), seagrass (Carruthers et al. 2005), coral (La Valle et al. 2020) and saltflat communities (Pollino et al. 2018).

Mangroves act as a buffer between sea and land, playing an important role in nutrient and carbon recycling, stabilisation of coastal foreshores and providing both below and above ground level habitat (Gibson 2014) (Figure 10). There is increasing evidence that freshwater inputs, such as groundwater, rain and/or river flow are important for above-ground growth in mangroves and that the trees use this water in preference to saline water (Green & Short 2003; Hayes et al. 2018).

An extensive area of mangroves has been mapped in Gales Bay and the Bay of Rest in the Exmouth Saltflats subarea (Figure 11). This area is also on the EPA's list of recommended conservation reserves. The tidal component of Wapet Creek, adjacent to the Learmonth air base, also supports 35 ha of mangroves. Smaller areas of mangroves are known from the Exmouth West subarea, including in the Mangrove Sanctuary zone at Mangrove Bay (Figure 10).

Seagrass meadows provide significant ecosystem services in coastal waters, including primary productivity, habitat (360 Environmental 2017a), carbon storage and sediment stabilisation (McMahon et al. 2017). Dugong (*Dugong dugon*) feed exclusively on seagrass and several species of turtle, including the green turtle (*Chelonia mydas*), include seagrass in their diets. The Exmouth Peninsula's entire coastline is mapped as an important breeding area for dugongs (Figure 11).

In the Exmouth Gulf seagrass is abundant in waters less than 2.5 m deep (Hayes et al. 2018; 360 Environmental 2017a) and has been mapped in Gales Bay in the south-east corner of the plan area (Figure 11).

Saline coastal flats (salt flats) or foreshore flats can support cyanobacterial mats, which are made up of microbial cyanobacterial communities. When flooded the mats are consumed by invertebrates and other marine organisms and play a significant part in supporting marine food webs in adjacent ecosystems (Hickey & Lovelock 2022). Carbon and nutrient exchange with the marine environment occur at high tides or through groundwater flows.

A recent review of salt flats in the Exmouth Gulf found them to occur on the landward edge of the intertidal zone, often bordered by mangroves on the seaward side and landward by dunes (Hickey & Lovelock 2022). Salt flats are most prominent on the gulf's western coast, although some areas also occur in the Exmouth Saltflats subarea (Figure 11).

Recent work by the department in the La Grange area of northern Western Australia used geochemical tracers, specifically radon isotopes (Rn^{22}), to identify hot spots of groundwater discharge into the nearshore marine environment. Short-lived radon isotopes are not present in marine seawater in significant concentrations, so their presence in nearshore waters indicates groundwater input (Antao et al. 2020). Early results show that fresh groundwater can occur on land within 80 m of the ocean and that persistently green areas near the coast can be an indicator of groundwater use (K Kilminster, DWER, pers. comm.).

The results of this work will be of interest to groundwater management in the Exmouth Peninsula. As well as increasing our knowledge of groundwater inputs into the nearshore marine environment in the La Grange area, it will be relevant to water licensing and managing groundwater use to protect the groundwater-dependent ecosystems in the Exmouth Peninsula's marine and estuarine environments.



Figure 10 Small area of mangroves at Mangrove Bay (photo courtesy of R Loomes)

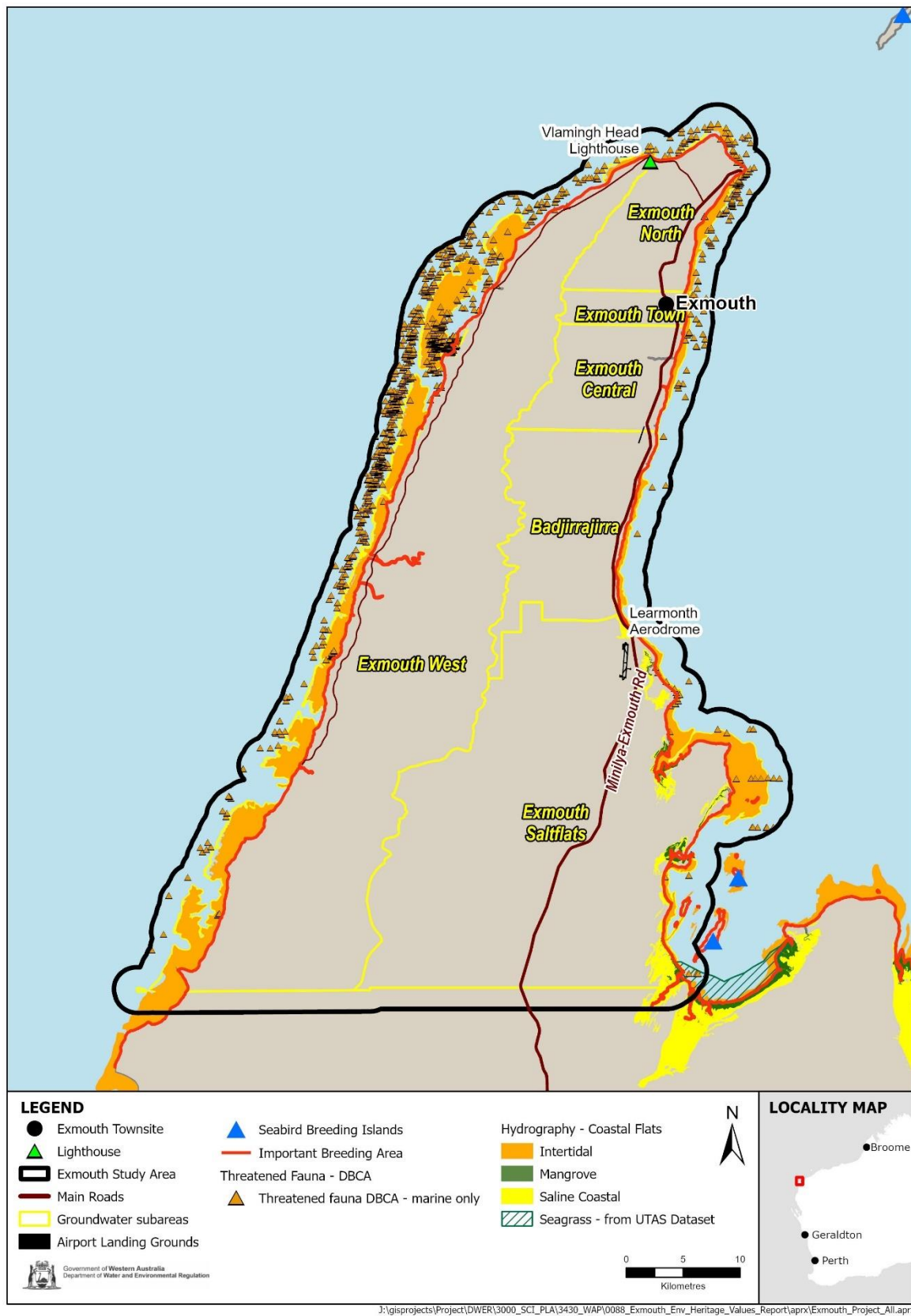


Figure 11 Nearshore marine ecosystems and threatened fauna of the Exmouth Peninsula plan area

Significant nearshore marine ecosystems

Significant ecosystems that are listed in the *Environmental factor guideline: Inland Waters* (EPA 2018) and relevant to nearshore marine ecosystems on the Exmouth Peninsula include:

- saline lakes, estuaries and nearshore ecosystems reliant on groundwater or surface water inputs
- ecosystems which support significant amenity, recreation and cultural values
- ecosystems which support significant flora, vegetation and fauna species or communities, including migratory waterbirds.

Threatened flora and fauna

The Ningaloo Reef National Park dominates the Exmouth Peninsula's western shore. The reef supports diverse habitats including coral reef and intertidal coastal zones (Collins & Stevens 2010), which in turn support a vast array of fauna and flora.

Marine fauna include the iconic whale shark (*Rhincodon typus*) and humpback whale (*Megaptera novaeangliae*), both listed as vulnerable under the EPBC Act and as specially protected under the BC Act. Other threatened species include the endangered loggerhead turtle (*Caretta caretta*) (BC Act, EPBC Act); the vulnerable green turtle (*Chelonia mydas*) (BC Act) and hawksbill turtle (*Eretmochelys imbricata*) (BC Act, EPBC Act); and leatherback turtle (*Dermochelys coriacea*) (endangered under the EPBC Act; vulnerable under the BC Act).

Thirty-nine bird species recorded from the Exmouth Peninsula are listed as conservation significant (Appendix A). Most of these are identified as migratory under international (MI) agreements (CAMBA, JAMBA, ROKAMBA, Bonn Convention).

Listed bird species include the critically endangered eastern curlew (*Numenius madagascariensis*) (BC Act; EPBC Act, MI), curlew sandpiper (*Calidris ferruginea*) (BC Act; EPBC Act, MI) and the great knot (*Calidris tenuirostris*) (BC Act). When visiting northern Australia all three species are found on intertidal mudflats, mangroves and lagoons. Islands important to seabird breeding are located in the gulf's southern area (Figure 11).

Threats to nearshore marine habitats and knowledge gaps

Threats

Threats to the Exmouth Peninsula's estuarine and nearshore marine habitats are associated with water resource development, land use changes, and broader phenomena such as climate change.

Groundwater abstraction could reduce freshwater discharge into the nearshore marine environment. This could negatively affect temperature regulation for turtle nesting or delivery of the nutrients found in groundwater to seagrass and coral habitats. Reduced groundwater discharge may also impact on nearshore mangrove communities as they also use the nutrients in groundwater.

Changes in land use could lead to increased runoff of nutrients, sediment and/or pesticides into the Exmouth Gulf and the Ningaloo Coast.

Knowledge gaps

We recommend the following targeted surveys to further knowledge about the Exmouth Peninsula's nearshore and marine ecosystems and better inform the assessment of development proposals:

- identify, describe and map potentially groundwater-dependent mangroves, seagrass, coral and saltflat ecosystems, which may include:
 - groundwater and marine water analysis to identify the groundwater source, following the approach of Kilminster et al. (in prep)
 - installing water loggers to describe and monitor water temperature and salinity and seasonal variation in both.

5.4 Springs

In arid and semi-arid environments, springs are critically important sources of water supporting terrestrial fauna, and aquatic and riparian habitat. Springs are often important places to Traditional Owners and are a source of water for pastoralists.

Springs were known to occur on the boundary of the Tulki/Mandu limestones in the creek within Shothole Canyon and in the headwaters of Yardie Creek. The Shothole Canyon spring was described as “...a *freshwater spring...emerging at the contact between the lower impermeable part of the Mandu Formation and the upper friable chalky strata. The spring is perennial....flows for several hundred metres and then disappears...*” (Forth 1972) (Figure 12).

Fresh to brackish springs were known to occur near the coastline (Forth 1972; 1973) and a cluster of submarine springs has been observed offshore at Mangrove Bay, discharging fresh water into the marine environment (Collins & Stevens 2010). Forth (1972) also mapped two soaks and a gnamma hole in the Mowbowra Creek area (Figure 12). It was noted that Mowbowra bore/well to the south of the gnamma holes supported stygofauna before it was decommissioned and filled in (Oceanwise 2022; Brooks 2015).

Springs are listed as significant ecosystems in the *Environmental factor guideline: Inland Waters* (EPA 2018).

Threats to spring habitats and knowledge gaps

Threats

The small number of springs that have been mapped on the Exmouth Peninsula are under threat from water resource development and climate change.

Groundwater abstraction could reduce water levels or pressure in aquifers that support terrestrial and coastal springs. This would significantly reduce refuge habitat and disrupt food webs.

Climate change may result in higher temperatures and a greater variation in rainfall, leading to more consecutive dry years. This could reduce groundwater recharge and cause springs to dry out during the dry season or cease flowing completely.

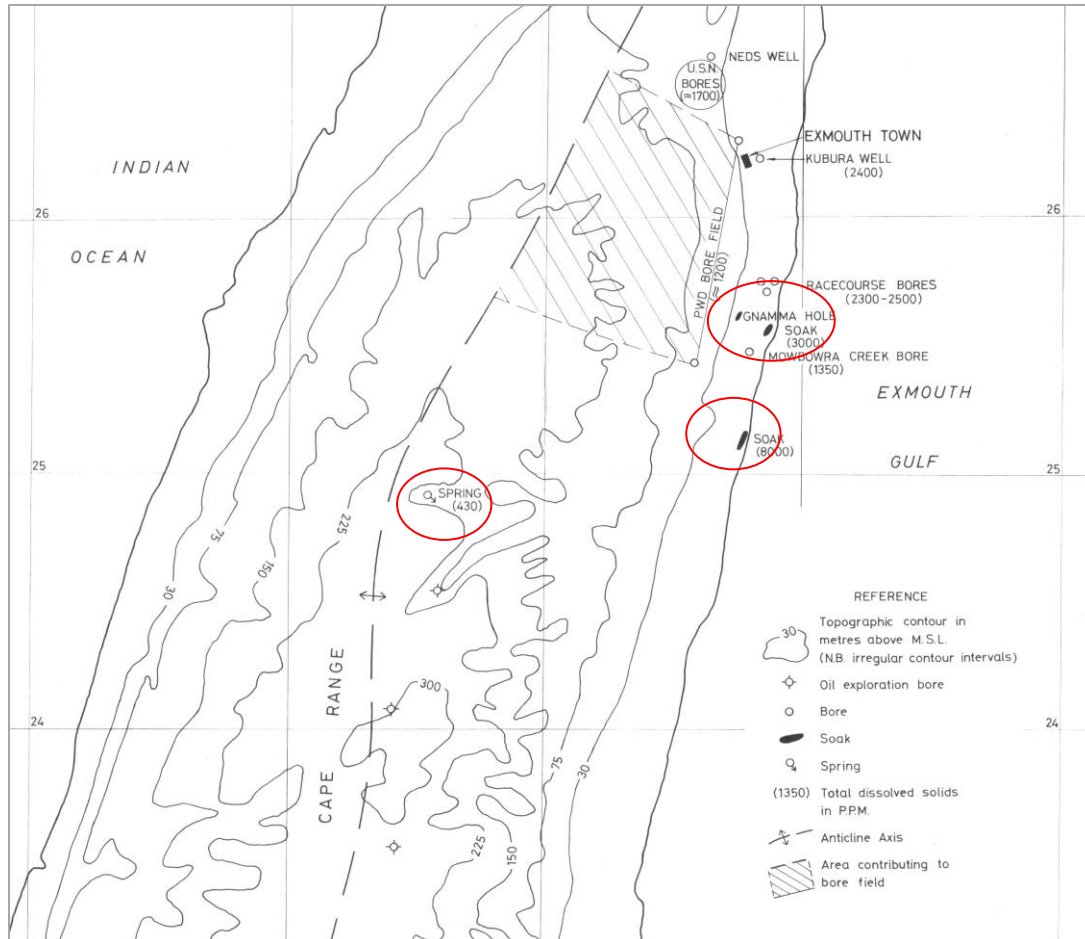


Figure 12 Location of the spring in Shothole Canyon, coastal soaks and gnamma hole mapped in Forth 1972

Climate change may lead to more frequent and intense fires and degradation and/or loss of habitat. Too-frequent fires and grazing or clearing impacts may also lead to invasive flora and fauna species competing with and replacing native species.

Threats may also interact or compound. For example, water resource development may exacerbate the drying of springs, which may increase fire penetration into these ecosystems and/or the frequency and intensity of fires. This would likely have substantial implications for springs, including the invasion of weedy grasses and plant disease.

Knowledge gaps

We recommend the following targeted surveys to further knowledge about the Exmouth Peninsula's spring ecosystems and better inform the assessment of development proposals:

- identify and describe terrestrial and marine springs, including:
 - groundwater and surface water analysis to identify groundwater source
 - installation of surface water loggers to describe water depth and seasonality
- targeted surveys of dependent wetlands to identify fauna and flora species
- ongoing water depth and water quality monitoring to define the relationship with dependent fauna and flora.

5.5 Terrestrial phreatophytic vegetation

Plants that establish and mature using groundwater can become dependent on this water source and consequently may be impacted by changes to groundwater levels (Canham et al. 2021).

Eucalyptus camaldulensis (river red gum), generally considered to be at least partially groundwater-dependent (phreatophytic) in arid environments, was identified on the east coastal plain and described by Forth (1972). Oceanwise (2022) also described the species as occurring on the coastal plain north of Mowbowra Creek. During a site visit in May 2024, the department's staff tentatively identified river red gums near the disused Mowbowra well in the same area. A potential stand of the gums was also noted at a disused well at the Yardie Creek Caravan Park on the western coastal plain. Further work is required to fully identify these species.

Water sources used by river red gums include fresh to moderately saline groundwater and flooding, which can replenish local groundwater (Mensforth et al. 1994; Doody et al. 2015). Given river red gums on the Exmouth Peninsula occur in areas of shallow fresh to brackish groundwater with potential for surface flooding, it is highly likely the species is groundwater-dependent in these areas.

Ficus brachypoda (rock fig) has been recorded at the opening of numerous caves where their deep roots can directly access groundwater (Collins & Stevens 2010; Brooks 2015). Rock figs also occur along the rocky edges of creeklines, including Qualing Pool and Yardie Creek. On the Exmouth Peninsula the rock figs may be an indicator of groundwater (Collins & Stevens 2010).

A small number of the priority 4-listed Millstream fan palm (*Livistona alfredii*) occur near the Yardie Creek springs and may be associated with karst features (Humphreys et al. 1990). These fan palms are otherwise found in the Pilbara region – predominantly in the Millstream-Chichester National Park along the edges of permanent pools and creek beds.

Threats to terrestrial vegetation and knowledge gaps

Threats

Groundwater-dependent (phreatophytic) vegetation on the Exmouth Peninsula is potentially under threat from water resource development and climate change.

Groundwater abstraction could reduce water levels or pressure in aquifers that support groundwater-dependent vegetation on the coastal plain.

Climate change may result in higher temperatures and a greater variation in rainfall, leading to more consecutive dry years. This could reduce groundwater recharge and cause groundwater levels to drop below a depth accessible to vegetation.

Knowledge gaps

We recommend the following targeted surveys to further knowledge about the Exmouth Peninsula's terrestrial phreatophytic vegetation and better inform the assessment of development proposals:

- identify, describe and map areas where potentially groundwater-dependent species occur (e.g. river red gum, rock fig, Millstream palm)
- define the relationship between water depth and quality and the presence of phreatophytic vegetation
- define the level of groundwater-dependence of vegetation communities and/or specific species.

6 Water-dependent social values and public benefits

The Exmouth Peninsula makes up a large portion of the Ningaloo Coast World Heritage Area. This includes the Ningaloo Marine Park (state and Commonwealth waters), Cape Range National Park, Jurabi and Bundegi coastal parks, and areas of unallocated crown and defence land (Section 4).

The natural beauty, ecological significance and low levels of development of the Ningaloo Coast and wider Exmouth Peninsula make it a unique place: a 'jewel in the ocean' (Delliotte 2020). The area attracts growing numbers of tourists each year.

In addition to cultural and heritage values (sections 4 and 5), there are social values and other public benefits that depend on the presence of water in the environment. These include:

- recreation and tourism
- educational and scientific values
- landscape and aesthetics.

Tourism

As discussed in Section 5.3, groundwater inputs into the marine ecosystem can be an important source of nutrients supporting seagrass and coral communities, which in turn support marine fauna and flora.

The Ningaloo Reef is one of Western Australia's most noteworthy tourist attractions. Ningaloo Marine Park is one of only a few places in the world where the vulnerable whale shark (*Rhincodon typus*), the world's largest fish, appears regularly in numbers. In the nearshore waters, individuals are easily accessible to observers. Swimming with whale sharks when they visit between March and July each year has become a major drawcard for visitors to the Exmouth Peninsula.

Popular activities undertaken by tourists in the region include camping (98%), swimming (90%) and snorkelling/diving (82%). Other popular activities include fishing from the shore, walking/hiking and sightseeing (Delliotte 2020).

In addition to the list above, local residents undertake recreational activities including boating, fishing and sailing (Delliotte 2020). Fishing off the beach at the Qualing and Mowbowra creek mouths is particularly popular, and the nearshore environment is likely to be directly supported by groundwater inputs. Boat tours of Yardie Creek are also popular and only possible due to the persistent pools found in the gorge.

Educational and scientific values

Ningaloo Reef, Exmouth Gulf, and the Exmouth Peninsula's cave ecosystems are the subject of significant and ongoing scientific and educational work. As described in sections 5.1 and 5.3, groundwater inputs support some of the communities of

interest. Current groups working on the peninsula and surrounding marine environment include:

- region-specific environmental groups
 - Western Australian Speleological Group Inc.
 - Australian Marine Conservation Society – Protect Ningaloo (NGO)
 - Cape Conservation Group (NGO)
 - Rangelands WA NRM
 - Ningaloo Turtle Program (DBCA).
- universities and organisations active in the area
 - Western Australian Marine Science Institution (WAMSI) – Marine Research Program
 - Minderoo Foundation
 - Great Barrier Reef Foundation in collaboration with UNESCO, The Nature Conservancy's Reef Resilience Network, Columbia University's Center for Resilient Cities and Landscapes, Resilient Cities Catalyst and AECOM
 - Edith Cowan University
 - The University of Western Australia
 - Western Australian Museum
 - CSIRO.

Landscape and aesthetics

The economic and tourism values described above do not entirely reflect the Exmouth Peninsula's total contribution to the welfare of society. The area also holds intrinsic (non-use) value. This is likely to include knowing that people can experience Ningaloo Reef and its environs (corals, mangroves, creeks and other wetlands) now and in the future, and valuing it simply because it exists.

The groundwater-dependent ecosystems are also valued for the ecosystem services they provide. These include nutrient cycling (salt flats), habitat provision (creeks, aquifers, reefs) and coastal protection (mangroves).

The peninsula's landscape and aesthetic values are a major tourism drawcard. The pristine nature of the marine environment and places such as Yardie Creek and Shothole Canyon could be considered groundwater-dependent to some extent.

7 Groundwater-dependent values of subareas

Groundwater-dependent ecosystems are those parts of the environment where the species composition and natural ecological processes are determined by the permanent or temporary presence of groundwater (ARMCANZ & ANZECC 2000).

This section describes the environmental, heritage and social values of each of the groundwater subareas – Exmouth Town, Exmouth Central, Exmouth North, Exmouth West and Exmouth South (referred to below as the proposed Badjirrajirra and Exmouth Saltflat subareas). We focus on those values which relate to, or depend on groundwater in each subarea.

7.1 Exmouth Town subarea

The Exmouth Town subarea covers 36.3 km² running west from the crest of Cape Range, a regional drainage divide, to the coast. As the name suggests, the subarea incorporates the Exmouth townsite, however only the northern section of the Exmouth marina is included (Figure 13).

Environmental, heritage and social values

Subterranean and aquifer ecosystems

On the Exmouth Peninsula's coastal plain, the cave system in the sediments and the underlying Tulki Limestone is partially or totally filled with water. This may also extend for some distance below sea level and offshore (Allen 1993). It is in this area that the DIWA-listed Cape Range Subterranean Waterways are mapped. They occur within 2–3 km of the east coast of the Exmouth Town subarea, excluding areas overlain by the Exmouth townsite and marina (Figure 13).

Four conservation-listed subterranean species are mapped in the waterways (Figure 13): two invertebrates (*Draculoides brooksi* and *Stygiocaris stylifera*) and two fish (blind cave eel, *Ophisternon candidum* and blind gudgeon, *Milyeringa veritas*). The blind gudgeon has previously been recorded in water ranging from fresh to sea water in numerous habitats – caves with water depths up to 33 m, anchialine pools, wells and bores with a watertable up to 50 m below the ground surface (Humphreys 1999b). An additional invertebrate, *Stygiochironomus isolatus*, is recorded at one of the unnamed creeks.

Wetlands and waterways

The wetlands are intersected by two unnamed creeks: one flows through the town's southern area and the other is the headwater of a system flowing north-east out of the subarea. No further information is available on either of these systems.

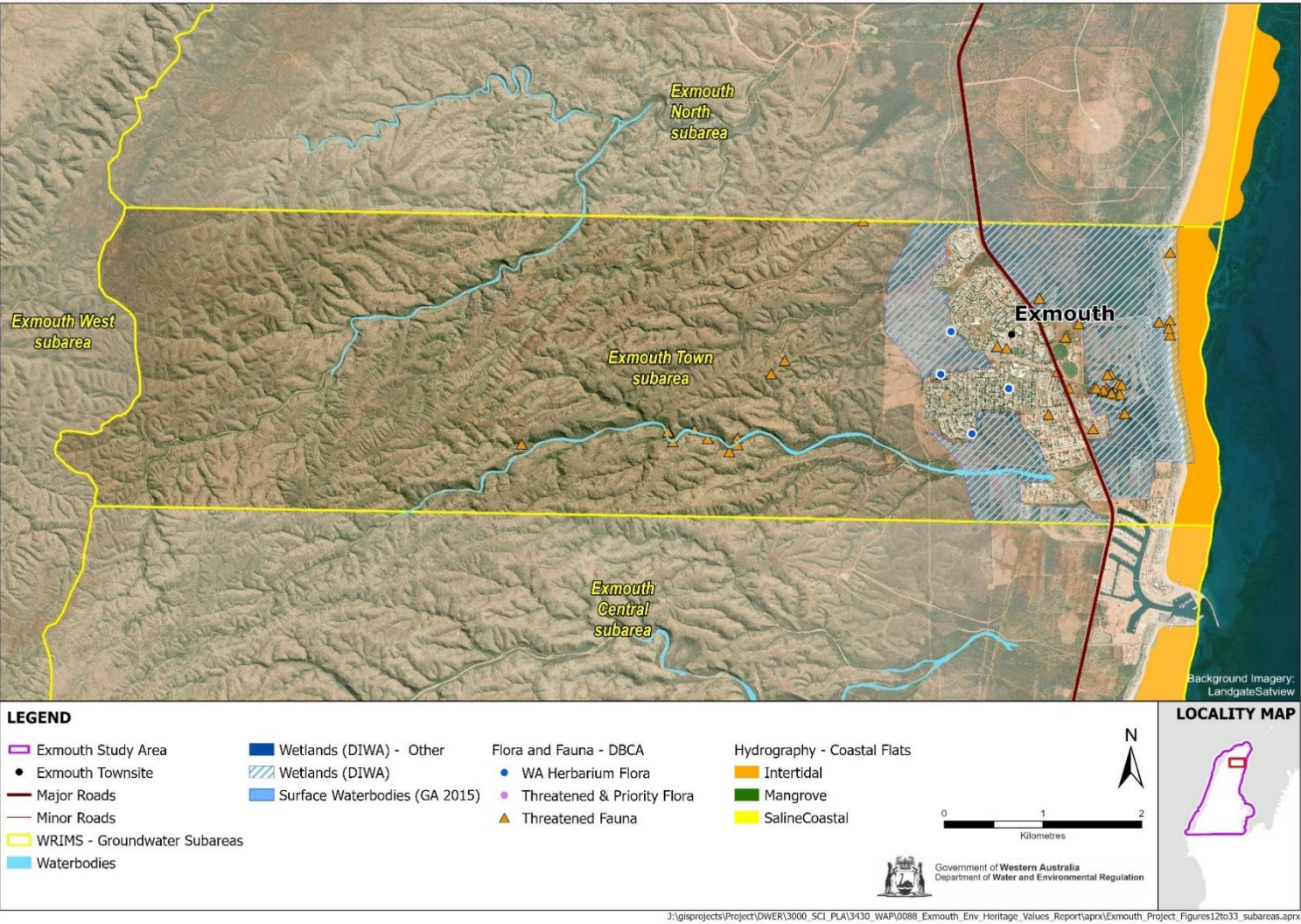


Figure 13 Wetlands, coastal habitats and conservation-listed flora and fauna of the Exmouth Town subarea

Flora and fauna

Eight priority flora were recorded in a recent survey (360 Environmental 2021), with five related to wet environments: *Acacia alexandri*, *Acanthocarpus rupestris*, *Grevillea calcicola*, *Harnieria kempeana* subsp. *rhadinophylla* and *Tinospora esiangkara*.

The endangered black-footed rock wallaby (*Petrogale lateralis lateralis*) has been recorded at the southern creek. Although not dependent on creekline habitats, the presence of the priority 4 western pebble-mound mouse (*Pseudomys chapmani*) has recently been confirmed in the area, along with the peregrine falcon (*Falco peregrinus*) and Cape Range slider (*Lerista allochira*) (GHD 2022).

Nearshore and marine ecosystems

The conservation-listed Australian humpback dolphin (*Sousa sahulensis*) has been recorded in the nearshore environment of Exmouth Town subarea. These dolphins eat a wide variety of coastal, estuarine and inshore reef fish from variety of habitats, including mangroves and seagrass meadows (Figure 13), which may benefit from groundwater discharge.

The Exmouth golf course supports 12 listed bird species identified as migratory under international agreements (CAMBA, JAMBA, ROKAMBA, Bonn Convention). The grey-tailed tattler (*Tringa brevipes*) is listed as priority 4. Migratory species are often found feeding in intertidal mudflats, mangroves and lagoons.

Aboriginal and heritage places

All of the Exmouth Town subarea falls within the Warnangura (Cape Range) cultural precinct (Figure 14). The precinct is listed because it has artefacts/scatter, ceremonial importance, engravings, middens/scatter, mythological significance, rock shelters, named places and water sources.

Two heritage sites occur east of the townsite: a waterhole listed for artefacts/scatter and as a water source, and a skeletal material/burial site on the coast.

Local heritage places include Cape Range no. 1 oil well, the first trees planted in Exmouth and buildings of historic significance.

Social values

The Exmouth Town subarea's western half falls within the national heritage-listed Ningaloo Coast area (Figure 15).

Exmouth is a small resort town serving as a gateway to the Ningaloo Marine Park and Exmouth Gulf. The town is a service centre for the area, supporting tourism (Section 7) and local businesses.

The Exmouth marina, located 2 km south of the town centre, supports local fishing, charter and recreational industries and resources projects. The town beach is a popular swimming spot and has four-wheel drive access.

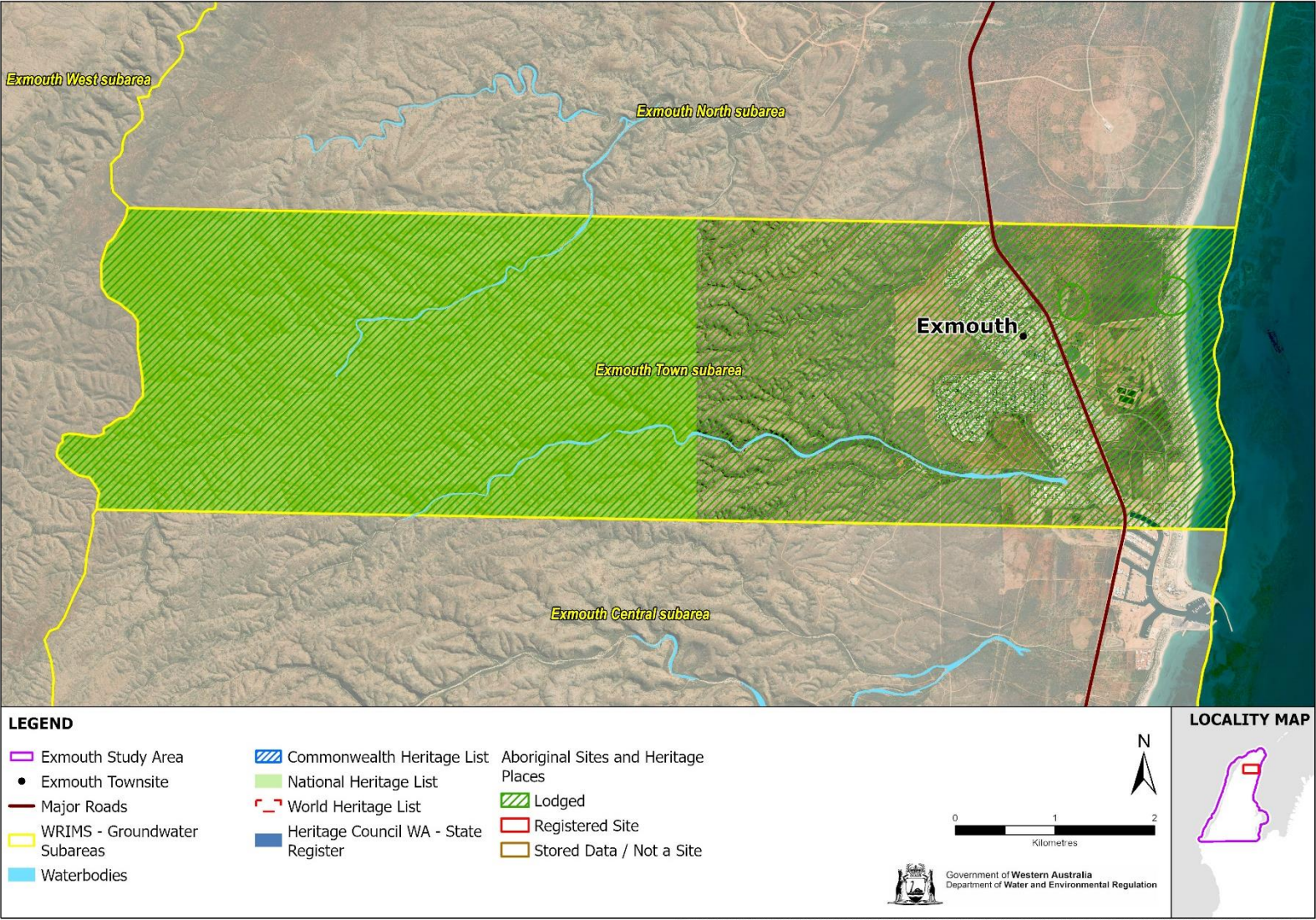
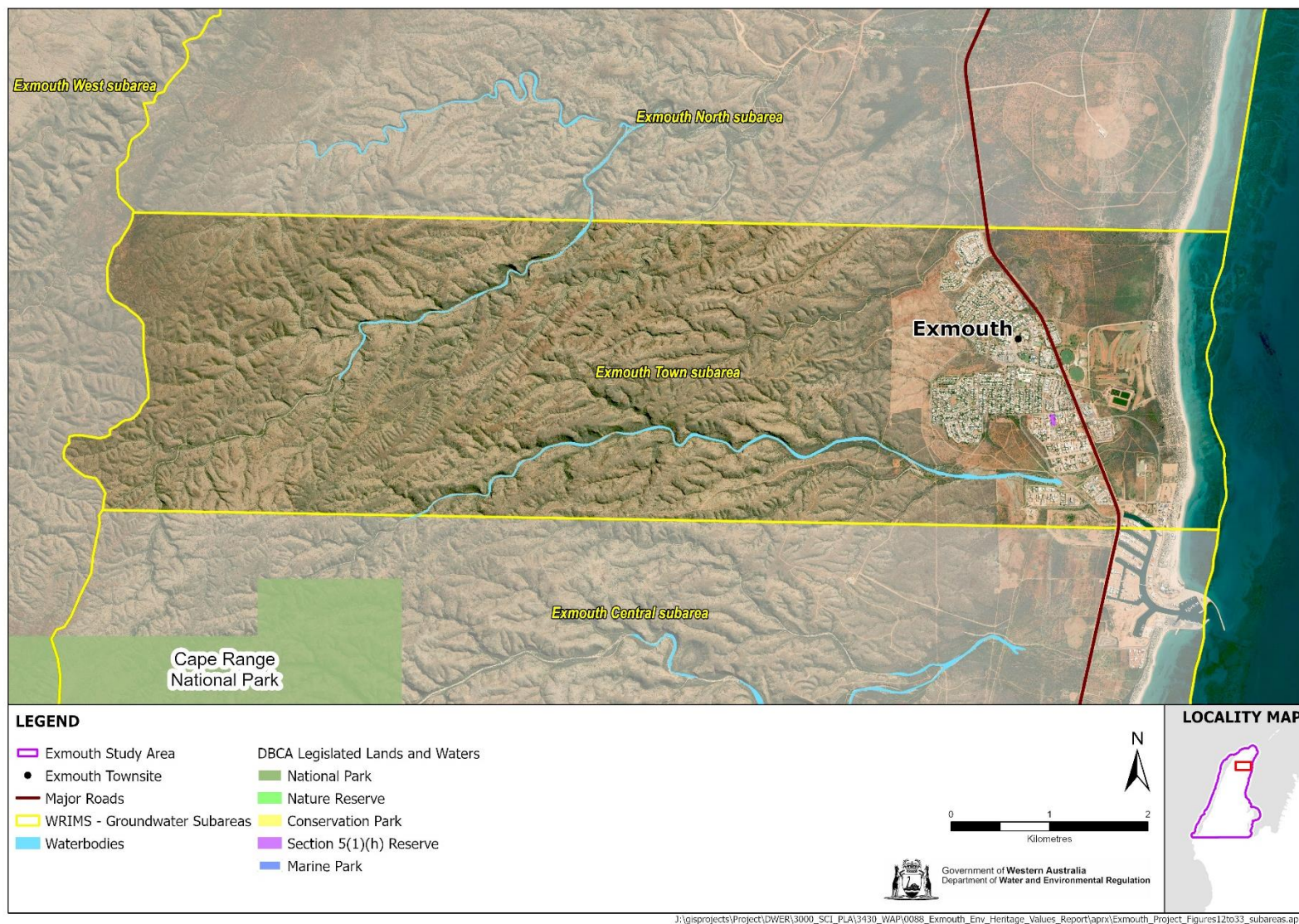


Figure 14 Aboriginal, national and world heritage places of the Exmouth Town subarea



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Figure 15 DBCA-managed lands in the Exmouth Town subarea

7.2 Exmouth Central subarea

The Exmouth Central subarea covers 115 km² running west from the crest of Cape Range to the coast (Figure 16). The Exmouth marina marks the subarea's northern boundary and Exmouth Aerodrome the southern.

Environmental, heritage and social values

Subterranean and aquifer ecosystems

The Exmouth Central subarea supports an area of the DIWA-listed Cape Range Subterranean Waterways (Oceanwise 2022) (Figure 16). This includes aquifers, waterways, sinkholes and artificial wells, with 11 significant karst limestone surface features known in the area (Long & Aylmore 2021).

The waterways are mapped as occurring within 1.5 and 2.5 km of the east coast of the subarea, excluding the marina.

Camerons Cave forms part of the subterranean waterways system. The cave supports the only known occurrence of the critically endangered Camerons Cave Troglotic Community TEC, listed under the BC Act. The troglotic community is a unique assemblage of subterranean species, of which at least eight are known only from this location (DEC 2012). The community's terrestrial components live in small spaces in the limestone next to the cave (DEC 2012). Critical aquatic habitats include the water in the cave, the groundwater feeding it and its catchment.

Threatened stygofauna species of Camerons Cave include the blind cave eel and blind gudgeon. Listed troglotauna include the critically endangered Camerons Cave millipede (*Stygiochiroplus peculiaris*) and Camerons Cave pseudoscorpion (*Indohya damocles*).

Heavy rainfall in 2008 caused rapid recharge and significant flooding in the cave, with the water rising about 1.0 m and taking some time to recede (DEC 2012). Data loggers in bores closest to the cave (30 m and 80 m away) showed groundwater levels responded within two hours of the rainfall, rising by more than 1.0 m. This suggests the cave and the aquifer are well connected. After three months the level of the interface between saline water and fresh water in the cave (saltwater interface) returned to its original position (DEC 2012).

Nearby Dozer Cave also supports stygofauna. However, the cave has been subject to vandalism, fish introductions and pollution and is considered a potential source of contamination for Camerons Cave (DEC 2012). The potential for a hydrological linkage between the caves suggests the need for particular controls and management at this site.

Stygofauna including the blind gudgeon and blind cave eel were noted in the disused Mowbowra well (on the northern side of Mowbowra Creek) before it was filled in (Brooks 2015).

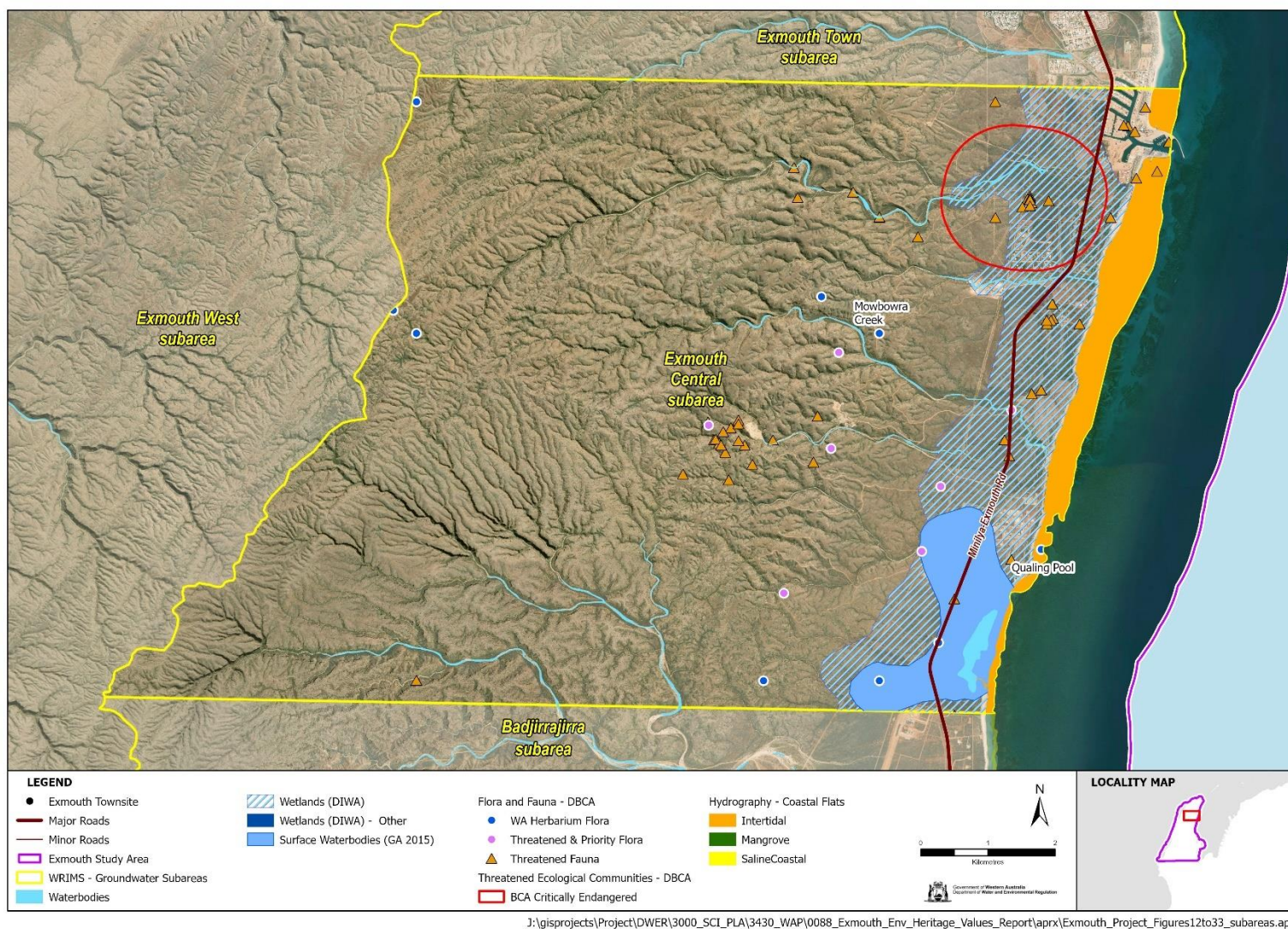


Figure 16 Conservation-listed values and waterbodies of the Exmouth Central subarea

Wetlands and waterways

Five non-perennial creeks intersect the Cape Range Subterranean Waterways (Figure 16). The creeks run from the top of Cape Range to the coast, or flow south out of the subarea.

Mowbowra Creek is the main drainage line overlaying the subterranean waterways system (Oceanwise 2022). It runs eastwards from the range across the waterways, discharging to the coast 700 m north of the Exmouth industrial area. At the coast any surface water is brackish to saline (Allen 1993). This was demonstrated through sampling of surface water quality in a persistent pool towards the mouth of Mowbowra Creek in February 2023 (Sinclair & Vitale 2023) (see Appendix B for all results). Salinity (mS/cm) was slightly lower than oceanic readings in the pool's lower reaches, becoming brackish and then fresh moving upstream (Figure 17). This suggests fresh groundwater may be discharging into the pool.

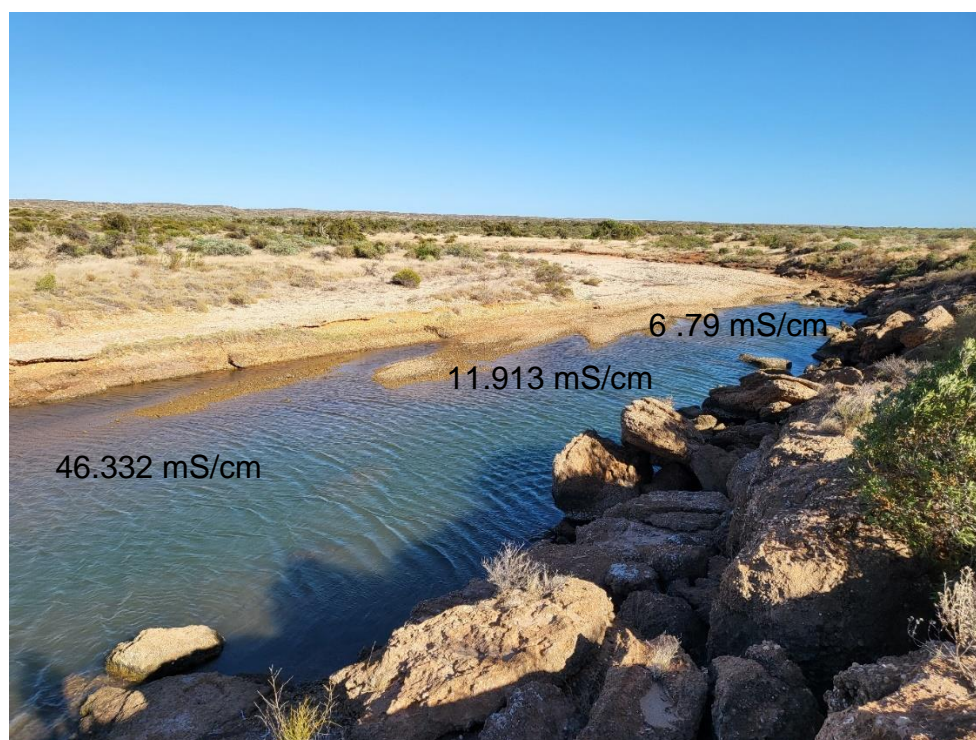


Figure 17 Salinity readings in Mowbowra Pool, February 2023 – moving upstream left to right

Qualing Pool also overlies the subterranean waterways system. It is formed by a series of groundwater-fed pools supporting a permanent wetland at the mouth of an unnamed creek (Allen 1993) (Figure 18). Groundwater input was supported by the results of surface water quality samples taken in February 2023 (Sinclair 2023) and May 2024 (Appendix B). Three pools were sampled on both occasions: two shallow upstream pools and a third at the creek mouth (estuary). In February 2023 water in all pools was fresh but became fresher moving away from the coast (Figure 18). In May 2024 the estuary pool was brackish to saline, however the upstream pools were fresh and had higher levels of dissolved oxygen. These gradients indicate a source of fresh groundwater coming from upstream.

The unnamed creek has a catchment area of 720 ha (Hyd2o 2014) and flows intermittently into the gulf. Note that the expression of fresh water at Qualing Pool is rare on the peninsula, with most water found at the surface having a similar composition to Mowbowra Creek – brackish to saline (Oceanwise 2022). The freshness of Qualing Pool is linked to the area’s geology, including the proximity of the Tulki and Trealla limestones (Oceanwise 2022).

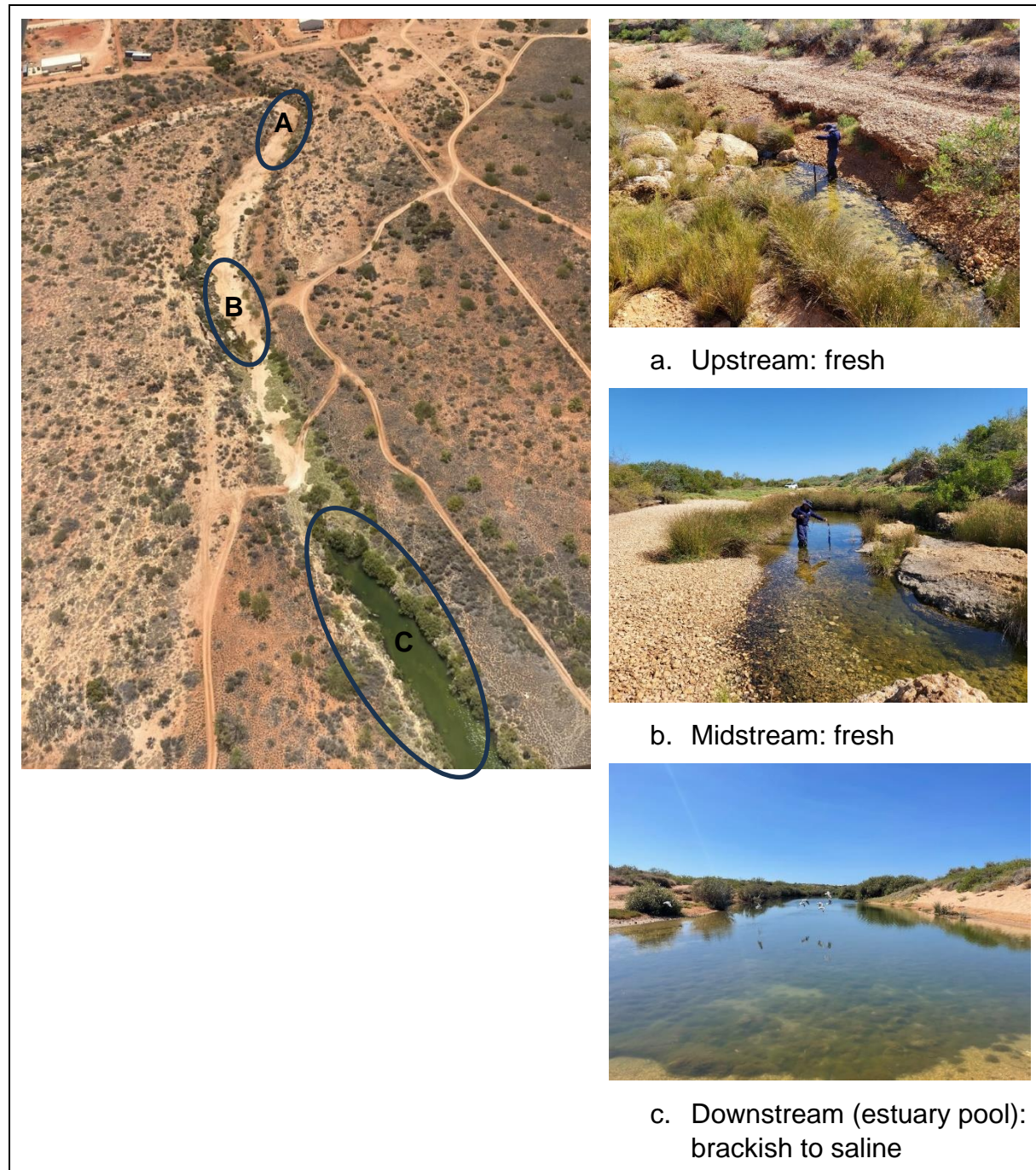


Figure 18 Salinity readings from Qualing pool(s), February 2023 – moving downstream top to bottom (see Appendix B)

Flood modelling by Hyd2o (2014) suggests the area of inundation at the downstream end of Qualing Creek (on an unnamed creek) is influenced by tidal condition. The width of the floodplain is narrowest (60 m) near the coast where the channel banks are incised. Near the Minilya–Exmouth Road the flood width is 350 m, due to the shallow right bank allowing for overtopping and flooding of a comparatively wide low-lying area.

The pools support conservation-significant vegetation, birds, mammals and reptiles. Qualing Pool also supports a small population of grey mangroves (*Avicennia marina*), which are important for maintaining mangrove communities along the western shores of Exmouth Gulf (Oceanwise 2022).

In December 2021 the Western Australian Government announced that a Class A reserve would be established to protect local areas of significance, including Qualing Pool, following the EPA's recommendations in *Potential cumulative impacts of proposed activities and developments on the environmental, social and cultural values of the Exmouth Gulf* (EPA 2021). At the time of writing this report, DBCA was progressing work to establish the reserve.

Between the Mowbowra and Qualing creeks, some smaller unnamed creeks flow to the coast. Multiple occurrences of a troglifauna species, the eastern Cape Range bamazomus (*Bamazomus subsolanus*), have been recorded near the headwaters of one of these creeks. Other unnamed creeks flow south out of the subarea to join Shothole Canyon before flowing out to the gulf.

An ephemeral wetland occurs in an interdunal swale south of Qualing Pool (Long & Aylmore 2021). The wetland is about 1 km long and supports invertebrates, Main's frogs (*Cyclorana maini*) and northern burrowing frogs (*Neobatrachus aquilonius*) that emerge after heavy rainfall events. Although not listed, four vegetation types of high conservation significance, previously unidentified in this area and not currently mapped, were identified in a recent survey of the Qualing area (Oceanwise 2022). Fauna and flora of the wetland are likely to be disjunct populations with the nearest 'relatives' occurring in ecosystems hundreds of kilometres away (Oceanwise 2022).

Nearshore and marine ecosystems

A remote sensing project on the Ningaloo Coast found a strong probability of submarine groundwater discharge associated with karst conduits, alluvial fan systems and offshore paleochannels (Collins & Stevens 2010). It is highly likely that a paleochannel identified immediately offshore of Qualing Pool (Figure 19) (Oceanwise 2022) is an indicator of groundwater discharge.

Dugongs (*Dugong dugon*) have been observed feeding on seagrasses offshore of Mowbowra Creek, while humpback whales (*Megaptera novaeangliae*) and their calves have been seen very close to shore. Conservation-listed Australian humpback dolphins (*Sousa sahulensis*) and green sea turtles (*Chelonia mydas*) have also been recorded in the subarea's nearshore environment.



Figure 19 Qualing Pool and offshore paleochannel (from Oceanwise 2022)

Terrestrial vegetation

Department staff have noted a small stand of possible *Eucalyptus camaldulensis* (river red gum) to the north of Mowbowra Creek near the disused Mowbowra well. Although this species was previously identified on the coastal plain by Forth (1972), further sampling is required to confirm its identification.

Flora and fauna

Twelve priority flora – six related to wet environments – have been recorded in the area: *Acacia alexandri*, *Acacia startii*, *Acanthocarpus rupestris*, *Grevillea calcicola*, *Stackhousia umbellate* and *Tinospora esiangkara*.

In addition to the fauna associated with subterranean waterways, the subarea supports two migratory birds – the crested tern (*Thalasseus bergii*) and eastern Osprey (*Pandion cristatus*) – which are often found feeding in intertidal mudflats, mangroves and lagoons. The black-footed rock wallaby (*Petrogale lateralis lateralis*) has also been recorded in the area.

Aboriginal and heritage places

All of the Exmouth Central subarea falls within the Warnangura (Cape Range) cultural precinct (Figure 20). The precinct is listed because it has artefacts/scatter, ceremonial importance, engravings, middens/scatter, mythological significance, rock shelters, named places and water sources.

Qualing Pool, the unnamed creek and Mowbowra Creek are of significant social and cultural value for Aboriginal people (EPA 2021). Numerous Aboriginal heritage sites associated with the creeks have been listed as they contain artefacts, scatter,

middens and/or rock shelters (Figure 20). The pools are also listed as campsites, while grinding patches/grooves are found at Mowbowra Pool only.

Social values

The Exmouth Central subarea's western half falls within the world and national heritage-listed Ningaloo Coast area and the Cape Range National Park (Figure 21).

The Exmouth marina, located at the top of the subarea, supports local fishing, charters, recreational industries and resources projects. Holiday accommodation is also available. Beach fishing, swimming and other beach activities are also popular on the coast.

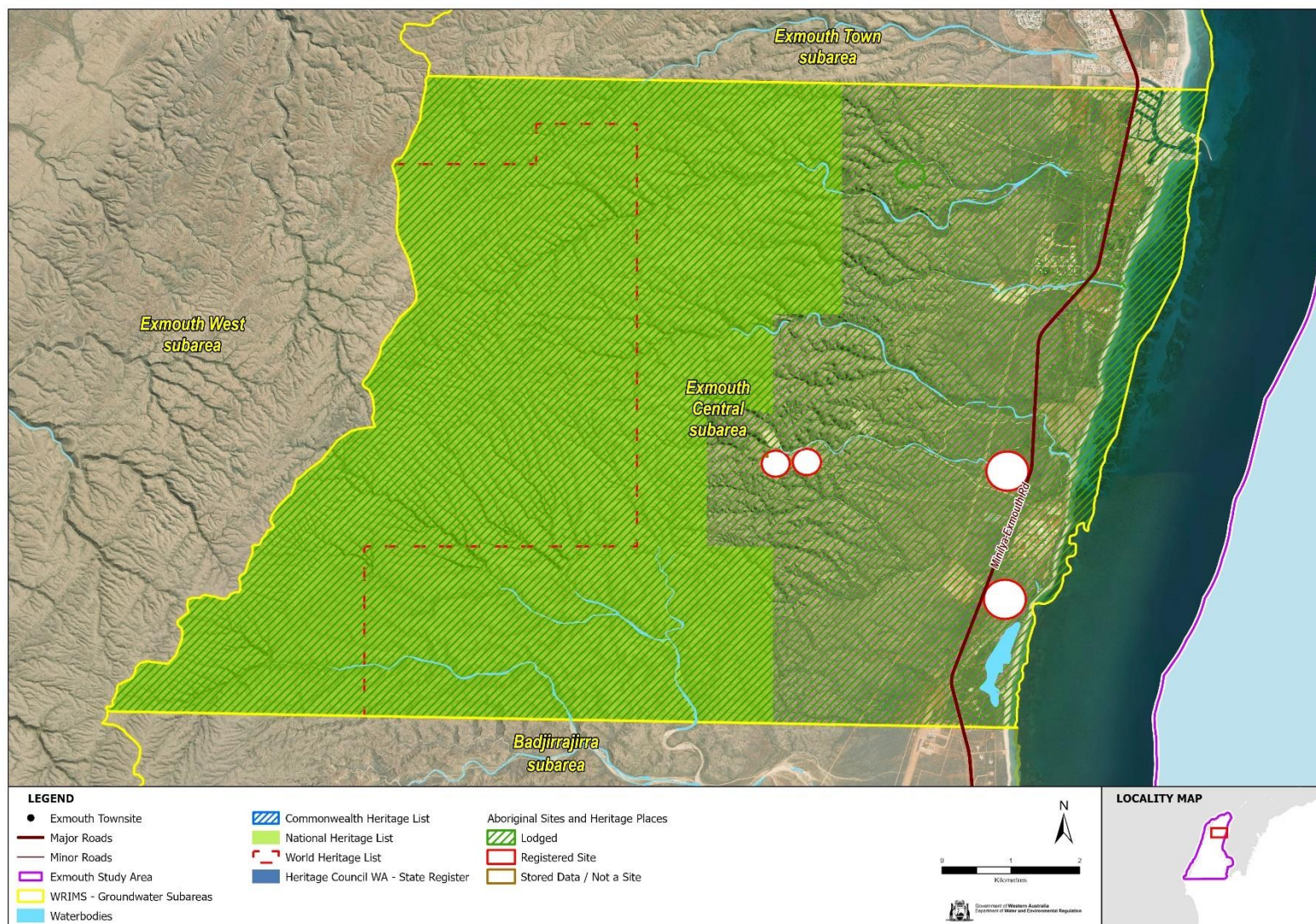
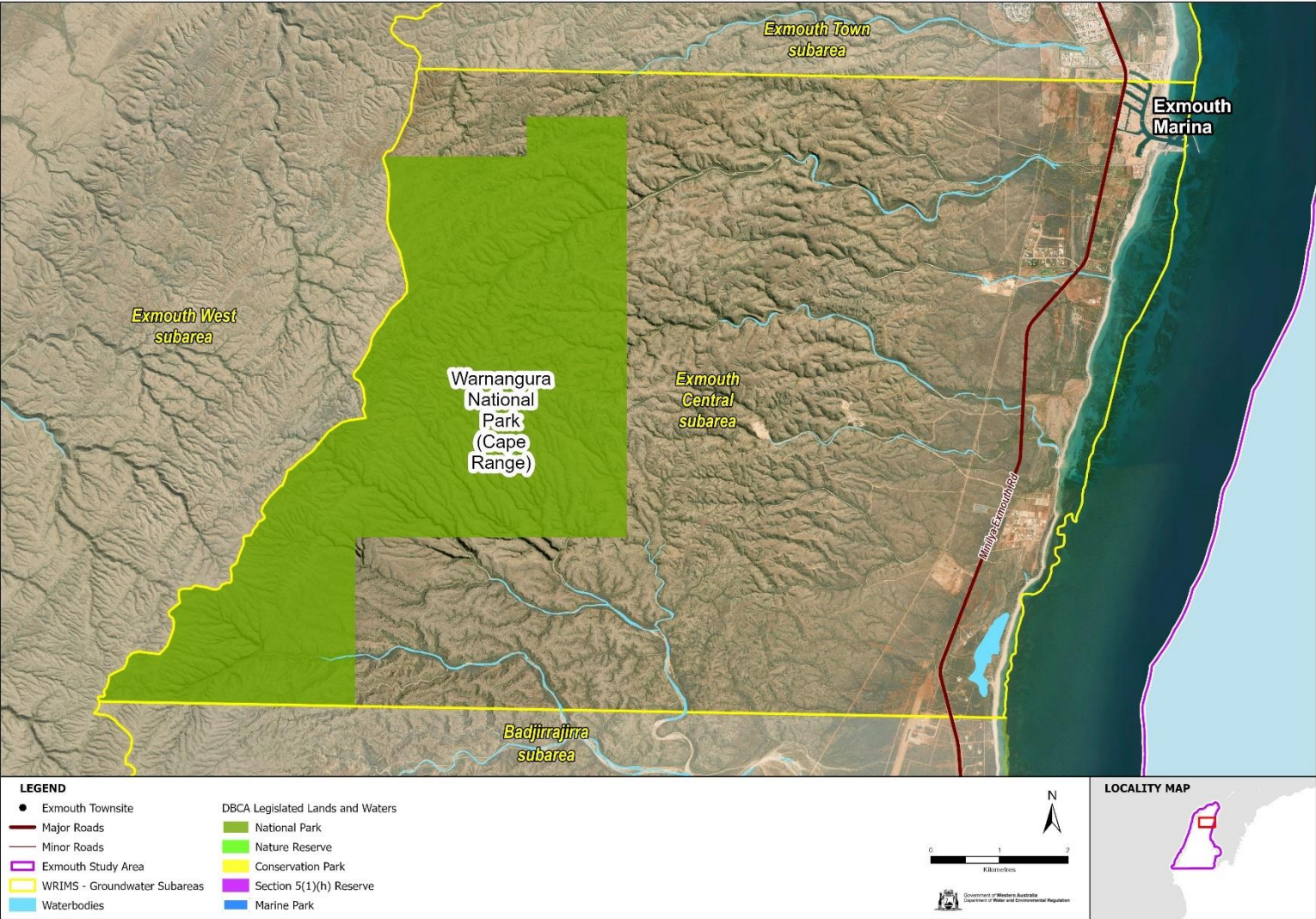


Figure 20 Aboriginal, national and world heritage places of the Exmouth Central subarea



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Figure 21 DBCA-managed lands in the Exmouth Central subarea

7.3 Badjirrajirra subarea

The proposed Badjirrajirra subarea is part of the existing Exmouth South subarea. The proposed subarea covers about 200 km² running east from the crest of Cape Range to the coast (Figure 22). On the coast, Exmouth Aerodrome marks the northern boundary, while the southern boundary is about 2.5 km north of Learmonth Airport. The northern extent of the Exmouth Gulf pastoral station covers some of the subarea.

Environmental, heritage and social values

Subterranean and aquifer ecosystems

The DIWA-listed Cape Range Subterranean Waterways are mapped as occurring along the length of the Badjirrajirra subarea, lying within 2.2 and 3.5 km of the Exmouth Gulf (Figure 22).

Two conservation-listed troglofauna species are known from the area: the eastern endangered Cape Range bamazomus (*Bamazomus subsolanus*) and the priority 4 Cape Range blind cockroach (*Nocticola flabella*). Although stygofauna have also been recorded at sites across the subarea (Bennelongia 2020), species names were not available.

Wetlands and waterways

The Cape Range Subterranean Waterways are intersected by 14 non-perennial creeks running from the top of Cape Range to the coast (Figure 22). Hyd2o (2014) mapped and determined the area of all the surface water catchments within the subarea. Catchment areas range from 150 ha to 6,980 ha.

Shothole Canyon/Creek is the largest of the catchments (Hyd2o 2014), however a number of the creek's tributaries flow south from the Exmouth Central subarea. The main creek flows about 15 km from its headwaters near the top of Cape Range through the Cape Range National Park to the coast. A persistent pool can be seen at the mouth of one of the tributaries.

A perennial freshwater spring is known from the canyon's headwaters (Figure 12) (Forth 1972). The spring was described as feeding a creek which ran for several hundred metres before reaching more permeable strata and disappearing (Forth 1972).

Deeper soils in the bottom of the canyon are described as supporting markedly different vegetation to the rocky slopes (Keighley & Gibson 1993; CALM 1986). At least three species of eucalyptus have been recorded at this site (CALM 1986). Of note is that *Eucalyptus coolabah* was recorded in the area. It has also been recorded on the peninsula's western side (DBCA 2023). *E. coolabah* occurs on occasionally flooded heavy soils and over accessible fresh groundwater and may be an indicator of good water availability.

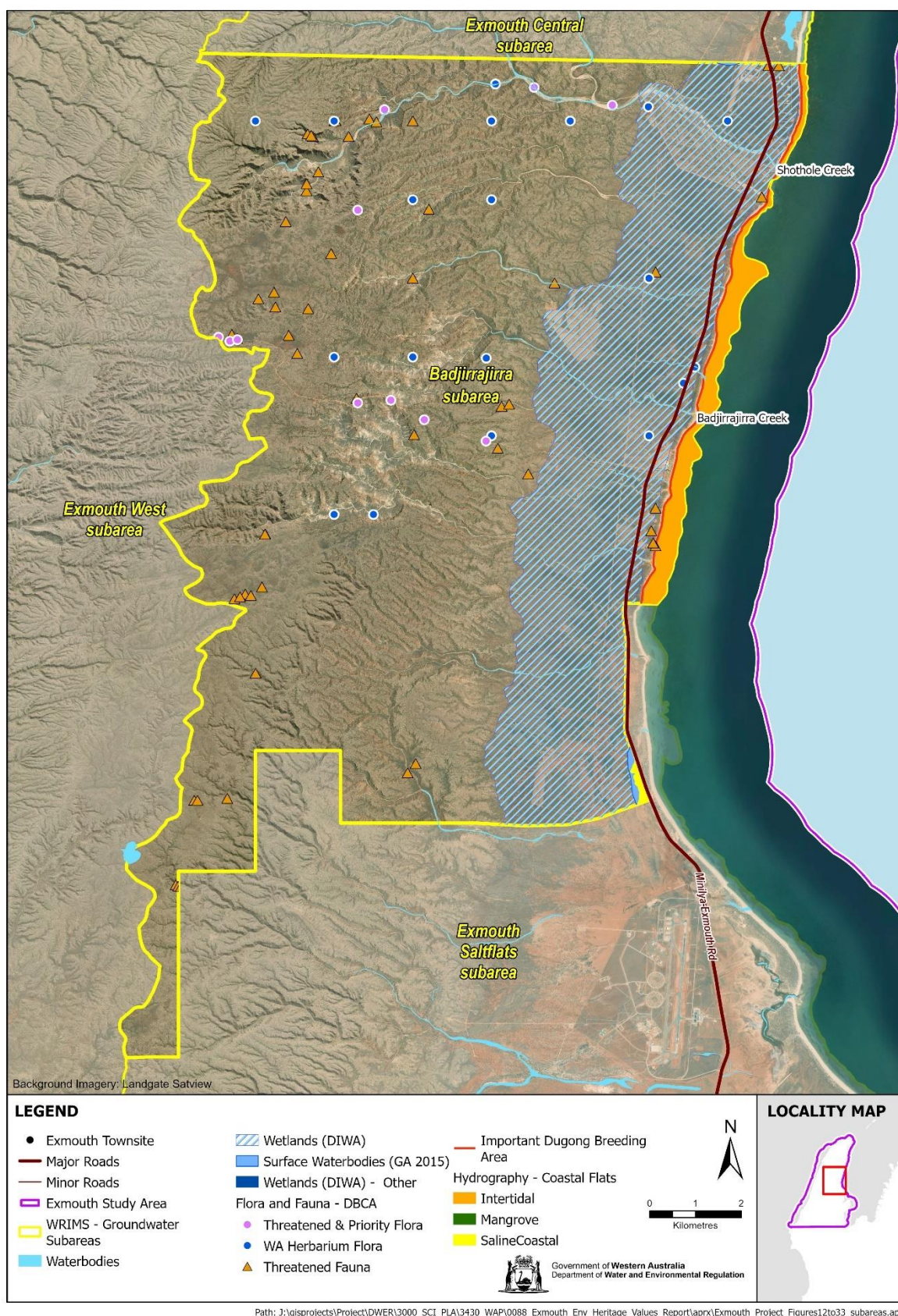


Figure 22 Conservation-listed values and waterbodies of the Badjirrajirra subarea

A highly disjunct population of *Melaleuca bracteata* (river teatree) has also been recorded at Shothole Canyon (Keighery & Lilburn 2019). This species occurs in alluvium along small watercourses and is tolerant of waterlogged conditions.

Badjirrajirra Creek has a catchment area of 1,520 ha (Hyd2o 2014). The creek flows about 10 km from its headwaters near the top of Cape Range through the Cape Range National Park and Conservation Reserve to the coast. The modelled flood width of Badjirrajirra Creek downstream of the Minilya–Exmouth Road ranges 90 to 110 m (Hyd2o 2014). Upstream of the powerline corridor the flood width is estimated to be 320 m. There are several ephemeral streams which may receive floodwaters from the main channel during large events.

Ficus brachypoda, an indicator of fresh groundwater, has been recorded in the upper reaches of Badjirrajirra Creek (DBCA 2023). The creek may also support eucalyptus species as described above for Shothole Canyon.

A surface water feature mapped as a swamp sits on the coast at the subarea's southern end (Figure 22). Satellite imagery suggests this may be a saltflat.

Nearshore and marine ecosystems

The subarea supports four migratory birds – the eastern osprey (*Pandion cristatus*), Caspian tern (*Hydroprogne caspia*), ruddy turnstone (*Arenaria interpres*) and bar-tailed godwit (*Limosa lapponica*) – all often found feeding in intertidal mudflats (Figure 22).

Dugongs (*Dugong dugon*) have been observed off the subarea's coast.

Flora and fauna

Ten priority flora – four related to wet environments – have been recorded in the subarea: *Acacia alexandri*, *Acanthocarpus rupestris*, *Grevillea calcicole* and *Stackhousia umbellata*.

Fig trees (*Ficus brachypoda*) occur at Monajee Cave on Cape Range, indicating a source of freshwater. Of special note is the discovery of Tasmanian tiger (*Thylacinus cynocephalus*) remains in the cave in 1965 (Kendrick & Porter 1973). Finds in other caves have extended the known historic ranges of several other mammal species (Kendrick & Porter 1973).

Five listed terrestrial mammal species are recorded in the subarea. Species with the highest listed conservation value are the endangered northern quoll (*Dasyurus hallucatus*) and black-footed rock wallaby (*Petrogale lateralis lateralis*) (Figure 22).

Aboriginal and heritage places

All of the Badjirrajirra subarea falls within the Warnangura (Cape Range) cultural precinct (Figure 23). The precinct is listed because it has artefacts/scatter, ceremonial importance, engravings, middens/scatter, mythological significance, rock shelters, named places and water sources. Three other heritage sites are listed as containing artefacts and/or scatter.

The Badjirrajirra subarea's western half sits within the national heritage-listed Ningaloo Coast area (Figure 23), the Cape Range National Park and the Cape Range Conservation Reserve (Figure 24). A smaller area, also in the west, falls within the World Heritage-listed Ningaloo Coast area (Figure 23).

Social values

Some of the Exmouth Peninsula's most scenic areas are located in the Cape Range National Park within the Badjirrajirra subarea. Shothole Canyon and Charles Knife Canyon scenic drives are accessible by four-wheel-drive vehicles. A picnic area and short walking trail can be found at Shothole, while Charles Knife has several lookouts (Figure 25). The Badjirrajirra Loop Trail begins at the Thomas Carter Lookout, off Charles Knife Road, with views of Shothole Canyon and Exmouth Gulf (CALM 1986). Shothole Canyon and Charles Knife roads are listed as local heritage places.

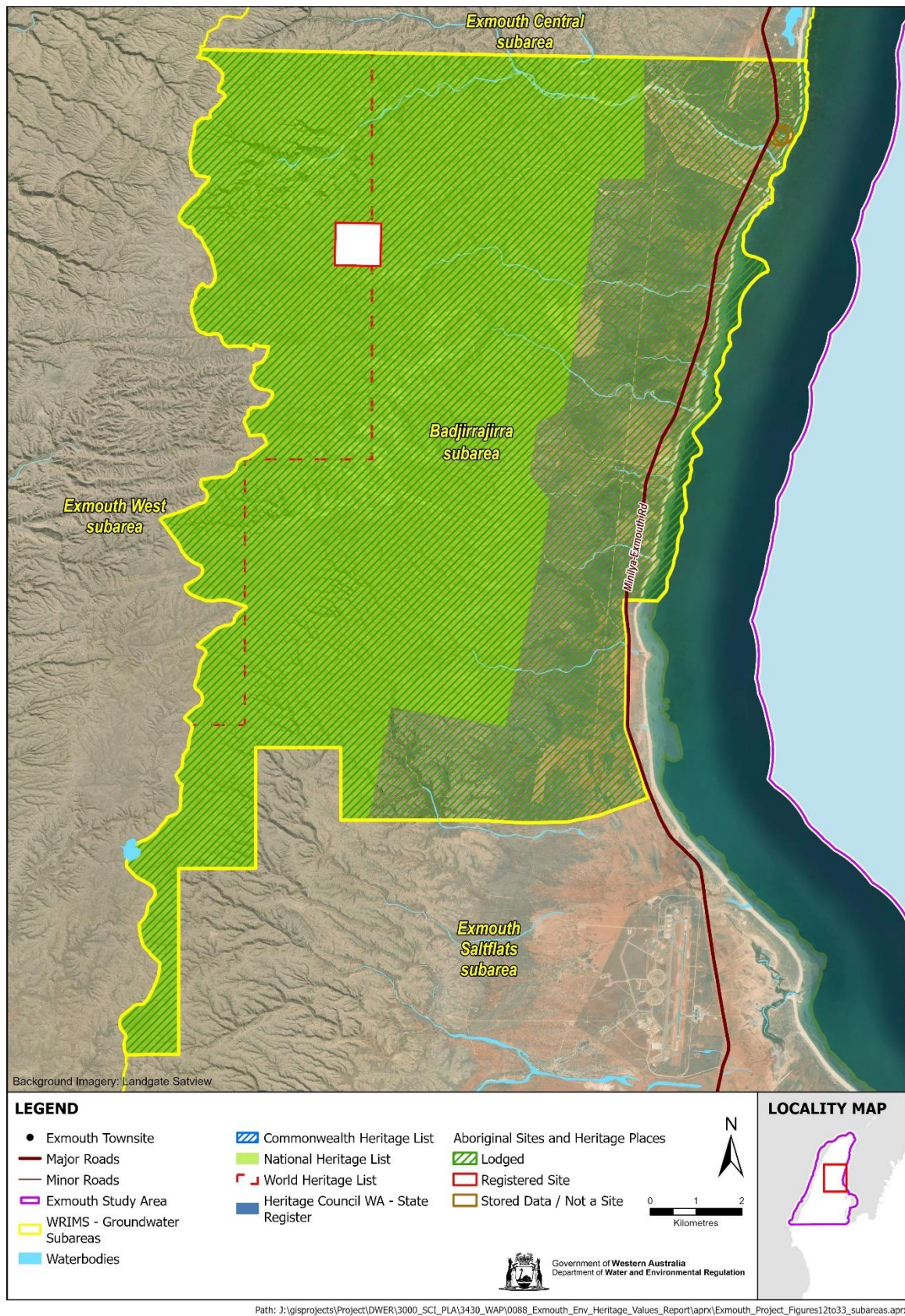


Figure 23 Aboriginal and other heritage places of the Badjirrajirra subarea

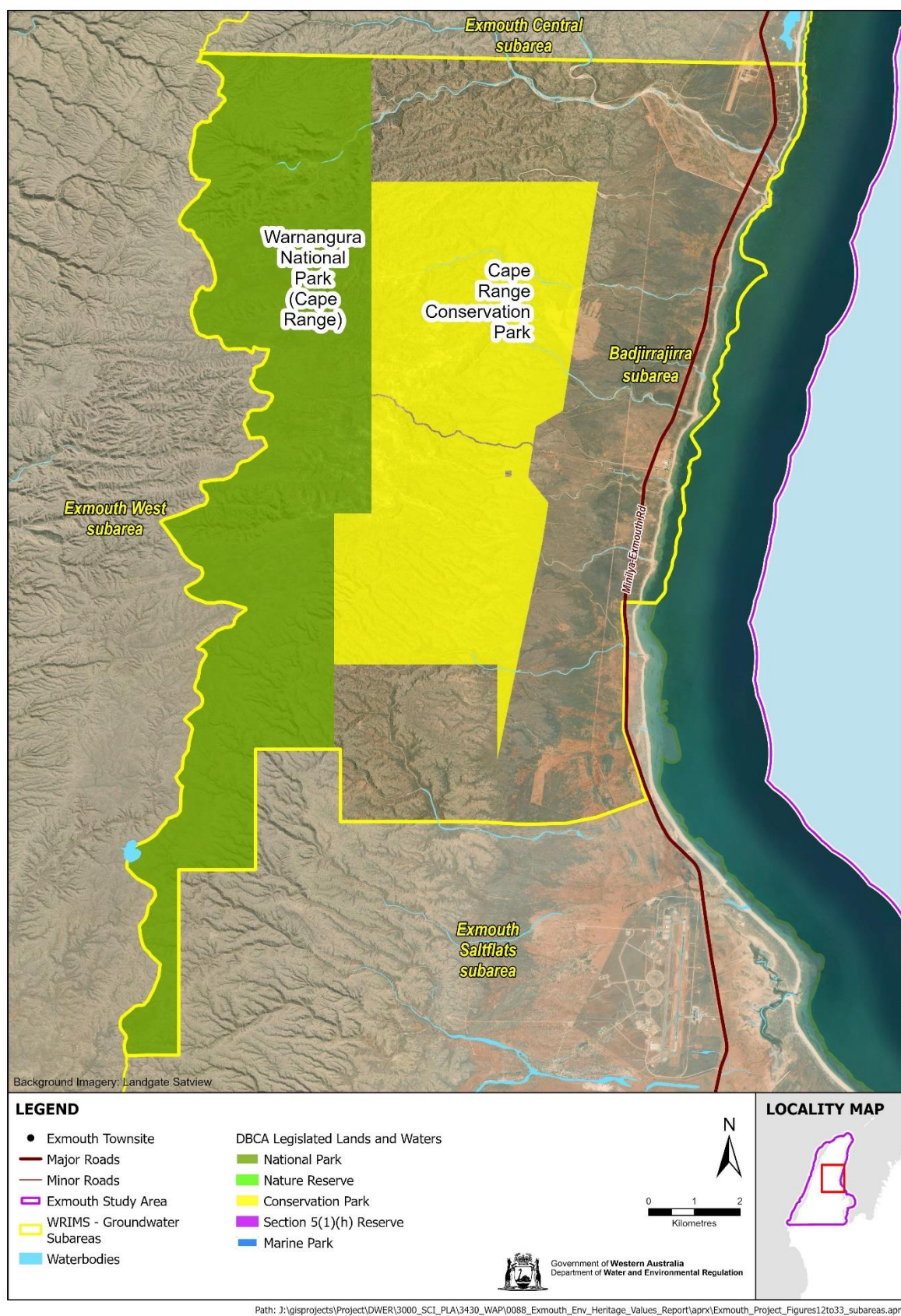


Figure 24 DBCA-managed lands in the Badjirrajirra subarea



Figure 25 Charles Knife Canyon (photo courtesy of R Loomes)

7.4 Exmouth Saltflats subarea

The proposed Exmouth Saltflats subarea is part of the existing Exmouth South subarea. The proposed subarea covers about 800 km² running west from the crest of Cape Range to the coast (Figure 26). The subarea extends from Learmonth Airport in the north to Bullara Station's northern boundary in the south. The Exmouth Gulf pastoral station covers much of the subarea.

In October 2018, as part of a proposal to construct a pipeline fabrication facility, 20 bores were installed to the south of Learmonth between Heron Point and the southern extent of the Bay of Rest (GHD 2019). Groundwater was shallowest (1.0–3.3 mbgl) in coastal dune sand closer to the coast and deepest at the western extent of the drilling (25.2–32.5 mbgl), some 7 km from the coast. Salinity measured in October 2018 and February 2019 was found to decrease with distance from the coast. The highest salinity (73,700 mg/L) was recorded in a bore on the tidal flats near the coast and the lowest in bores to the west (887–1120 mg/L) (GHD 2019). The results confirmed the existence of only a limited freshwater lens on the coastal plain in the Exmouth Saltflats subarea (A Mahon, pers. comm.).

Environmental, heritage and social values

Subterranean and aquifer ecosystems

Occurrences of the DIWA-listed Cape Range Subterranean Waterways are mapped along the coast and below the Cape Range itself (Figure 26). Sections of two creeklines, including Wapet Creek, flow across this area. Forth (1972) inferred that aquifer recharge could occur through direct infiltration and preferential recharge along drainage lines such as Wapet Creek.

Despite this, only one conservation-listed troglofauna species has been recorded from the area: the endangered eastern Cape Range bamazomus (*Bamazomus subsolanus*). Stygofauna have also been recorded at sites across the subarea, but only the spear-beaked cave shrimp (*Stygiocaris stylifera*) has been named in available reports (Bennelongia 2020).

Sixteen of the 20 bores installed in 2018 (see above) were designated stygofauna monitoring bores (GHD 2019), but the project was discontinued and thus it appears no monitoring has occurred.

Wetlands and waterways

The Cape Range Subterranean Waterways are intersected by a small number of non-perennial creeks running from the top of Cape Range to the coast (Figure 26). Wapet Creek is the largest of these, with a catchment area of 16,640 ha. It only has a single outlet to the coast, which results in a large low-lying area being inundated during flooding (Hydr2o 2014). Modelling indicates a very wide area of the Minilya–Exmouth Road would be inundated in this catchment.

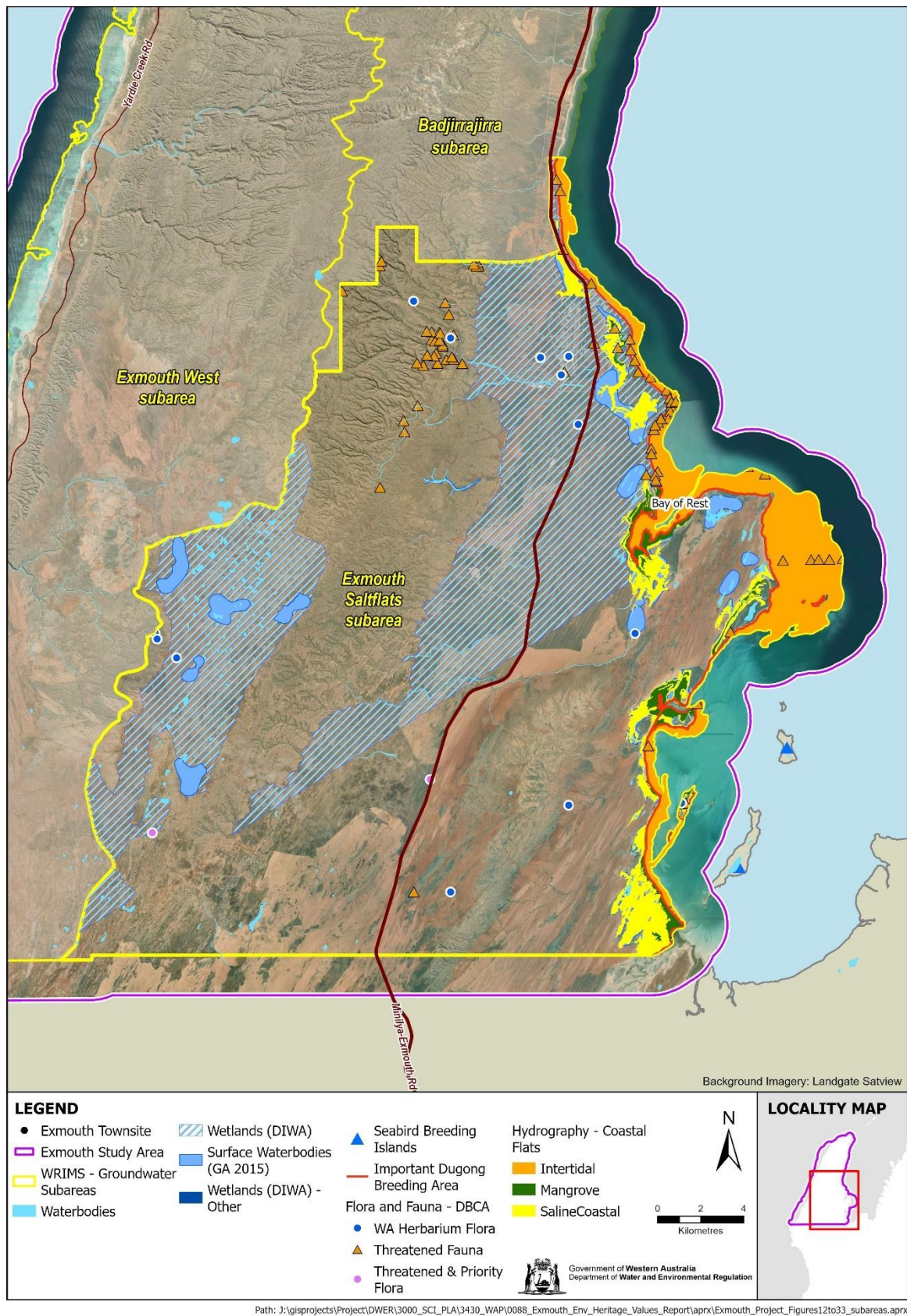


Figure 26 Conservation-listed values and waterbodies of the Exmouth Saltflats subarea

The section of creek mapped as a subterranean waterway flows from the base of the range towards Learmonth Airport. From there it flows into another mapped subterranean waterway located between the airport and the coast. This undescribed wetland appears to be a large saltflat fringed by mangroves on its eastern edge (Figure 26).

Nearshore and marine

Eighteen conservation listed-bird species have been recorded in the area (Figure 26). Species with the highest conservation values are the critically endangered curlew sandpiper (*Calidris ferruginea*), great knot (*Calidris tenuirostris*) and eastern curlew (*Numenius madagascariensis*), as well as the vulnerable greater sand plover (*Charadrius leschenaultii*) and fairy tern (*Sternula nereis nereis*). The remainder are listed under international agreements as migratory species, with the exception of the priority 4 listed grey-tailed tattler (*Tringa brevipes*).

Three listed marine mammals have been recorded offshore: the vulnerable humpback whale (*Megaptera novaeangliae*), priority and internationally listed Australian snubfin dolphin (*Orcaella Heinsohn*), and migratory dugong (*Dugong dugon*). Anecdotally, whales move to the bottom of the Exmouth Gulf where diluted seawater helps remove parasites.

Several mangrove species have been recorded fringing the Bay of Rest: the white mangrove (*Avicennia marina*), spotted-leafed red mangrove (*Rhizophora stylosa*) and club mangrove (*Aegialitis annulata*) (360 Environmental 2017a). Seagrass species (*Halodule uninervis* and *Halophila ovalis*) has also been recorded in the area. Both mangrove and seagrass communities are known to use fresh groundwater discharged in nearshore and marine environments.

Flora and fauna

Ten priority flora have been recorded in the Exmouth Saltflats subarea, with six related to wet environments: *Acacia alexandri*, *Acacia startii*, *Grevillea calcicola*, *Livistona alfredii*, *Lysiandra fuernrohrii* and *Tinospora esiangkara*.

Flora was surveyed across 534 ha within the footprint and close to a proposed onshore pipeline fabrication facility near Point Lefroy in 2017 (360 Environmental 2017b). Seventy-four taxa (including species, subspecies, varieties, and forms) were recorded, including only three introduced species.

Fig Tree Cave/Owls Roost is located near the headwaters of Wapet Creek in the Cape Range National Park. The cave's entrance is marked by a large fig (*Ficus brachypoda*), the roots of which extend deep into the cave (Brooks 2015).

The black footed rock wallaby (*Petrogale lateralis lateralis*, EN) is the only listed terrestrial mammal species recorded in the subarea – The Cape Range slider skink (*Lerista allochira*) is the only listed reptile.

Aboriginal and heritage places

The vast majority of the Exmouth Saltflats subarea falls within the Aboriginal Heritage listed Warnangura (Cape Range) cultural precinct (Figure 27). The precinct is listed as it has artefacts / scatter, ceremonial importance, engravings, middens / scatters, mythological significance, rock shelters, named places and water sources.

Sites within the precinct include Billy Wells listed as a ceremonial water source site, North west cape site located on a creekline in Cape Range and listed as an artefacts/ scatter and, camp site and Exmouth Station on the coast, listed as a skeletal material / burial site. Three other sites south-west of Learmonth Airport and the salt flats are listed as artefacts/ scatter sites.

Although not listed as an Aboriginal heritage site, Monajee Cave contains aboriginal artifacts (Kendrick & Porter 1973) and likely to be of cultural value.

Social values

The subarea's western part sits within the national heritage-listed Ningaloo Coast area and a small area in the south-west falls in the Learmonth Air Weapons Range Commonwealth heritage area (Figure 27). Much of the area falls within the Cape Range National or Conservation parks (Figure 28).

Recreational fishing occurs along the coast, including at the Wapet Creek entrance.

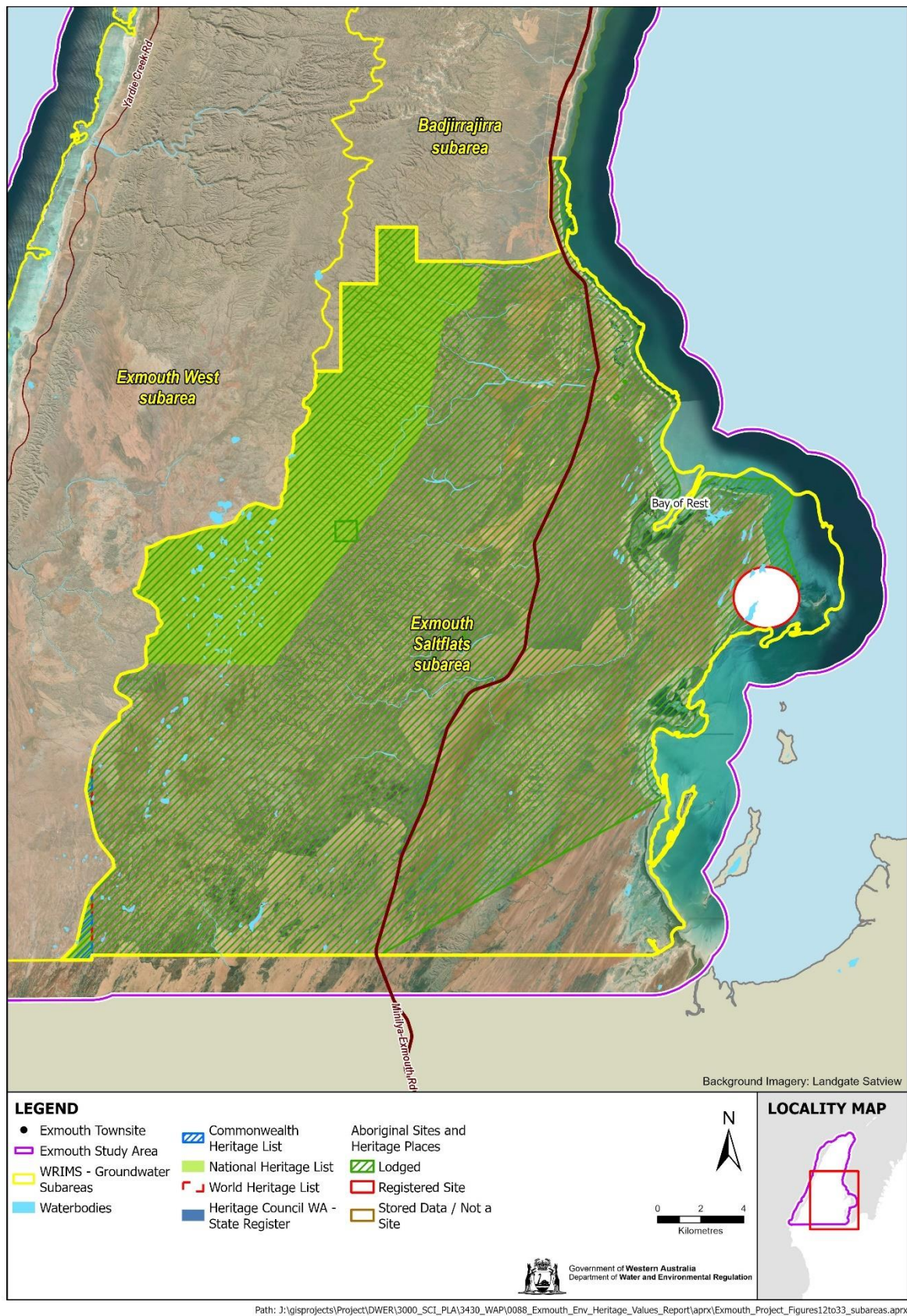


Figure 27 Aboriginal and other heritage places of the Exmouth Saltflats subarea

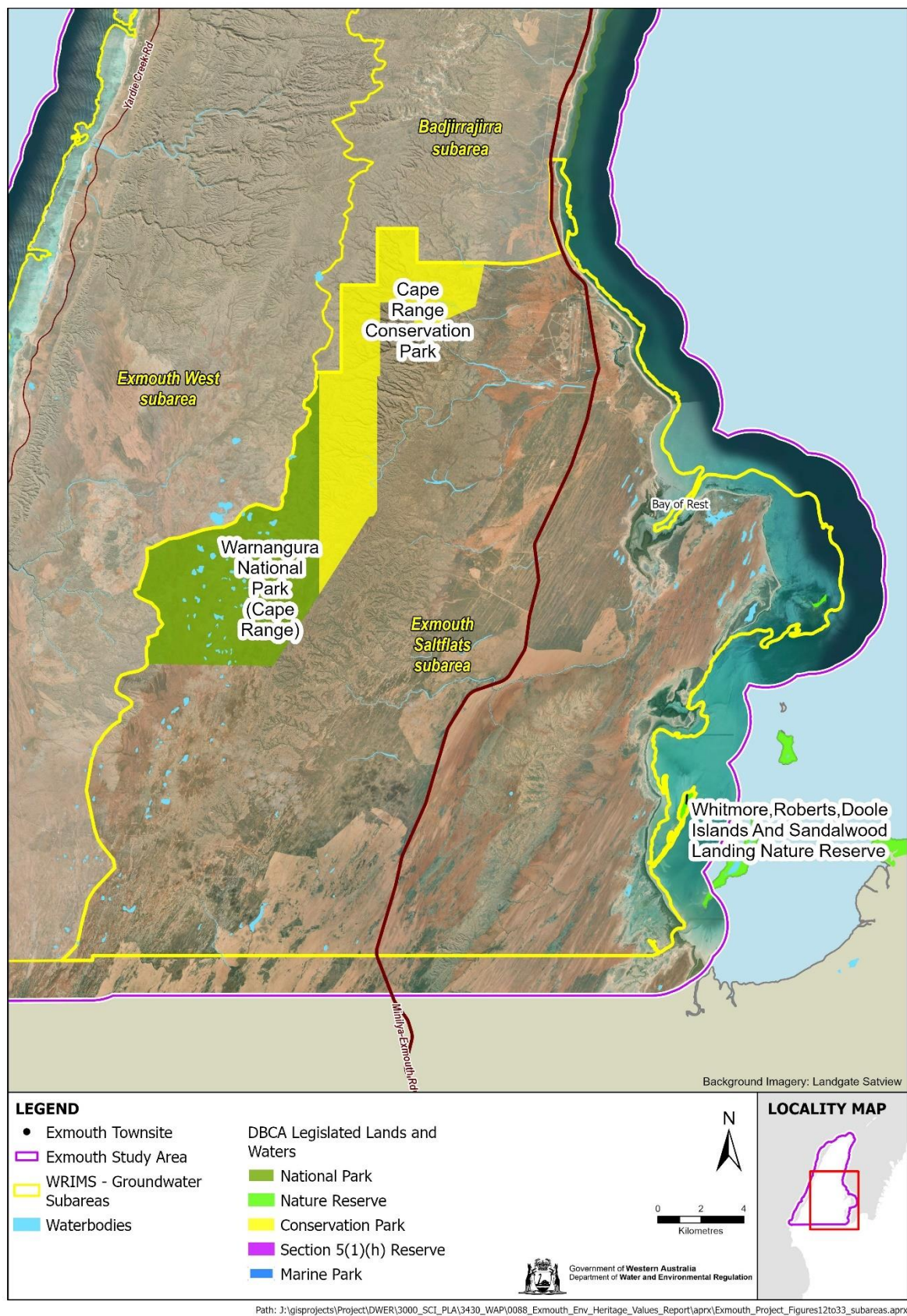


Figure 28 DBCA-managed lands in the Exmouth Saltflats subarea

7.5 Exmouth North subarea

The Exmouth North subarea covers about 52 km². It extends south from the northern tip of North West Cape to the northern boundary of the Exmouth Town subarea (Figure 29).

Environmental, heritage and social values

Subterranean and aquifer ecosystems

Most of the subarea is mapped as DIWA-listed Cape Range Subterranean Waterways (Figure 29).

The endangered northern Cape Range draculoides (*Draculoides brooksi*) is known from the centre of the subarea and vulnerable blind gudgeon (*Milyeringa veritas*) and blind cave eel (*Ophisternon candidum*) from the south.

Bennelongia (2021) recorded a further 13 stygofauna species from bores sampled near the Ningaloo Lighthouse Resort and north-east of the Exmouth townsite. Of those species, only the priority 4 spear-beaked cave shrimp (*Stygilocaris stylifera*) is currently conservation listed.

Wetlands and waterways

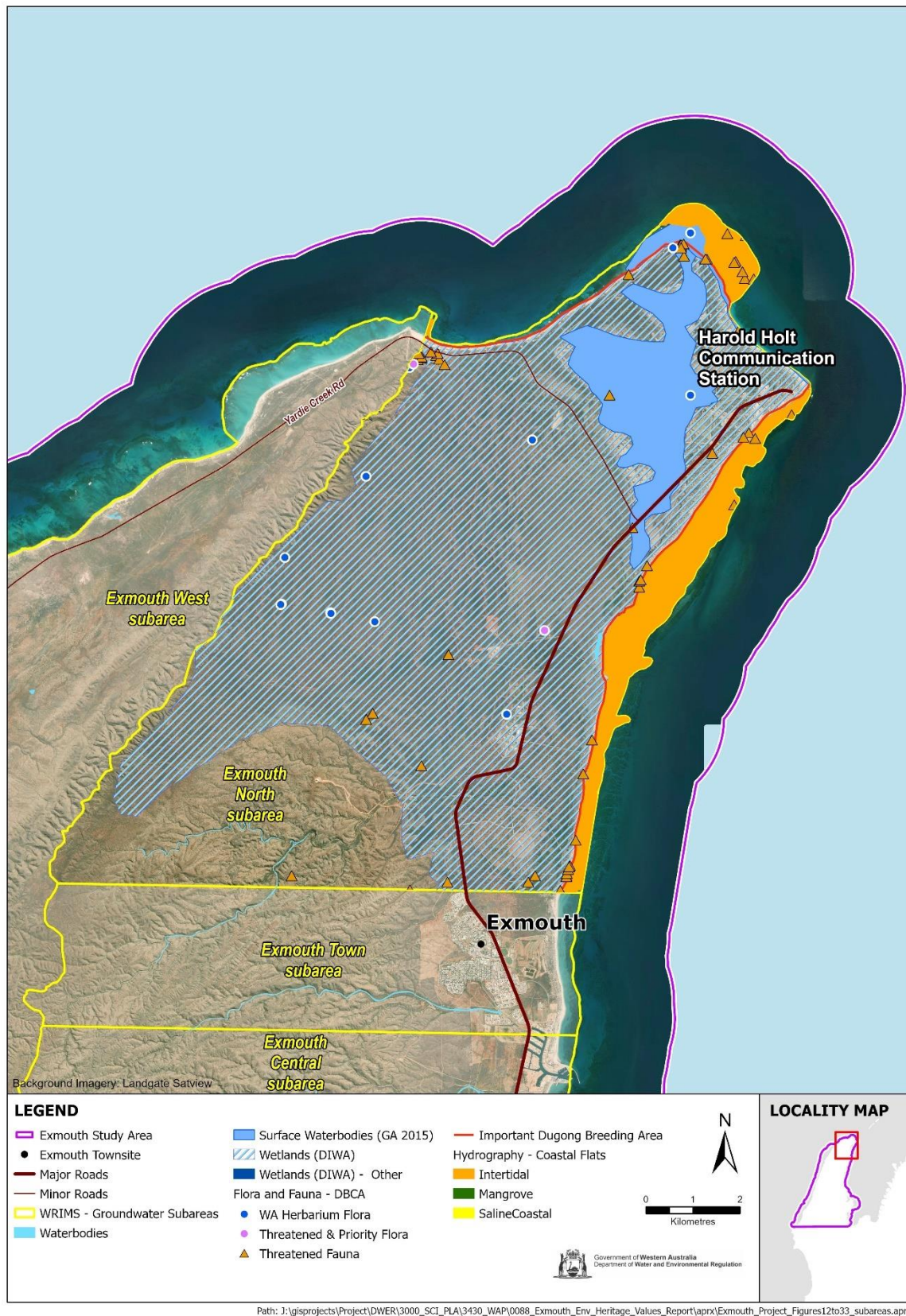
A large area of North West Cape, including the very low frequency antennae site of the Harold E Holt Naval Communications Station, is mapped as a surface water feature. Satellite imagery suggests it is a large saltflat.

There are no named creeks within the Exmouth North subarea. Only one unnamed system occurs in the area's south.

Nearshore and marine ecosystems

Thirteen conservation-listed migratory bird species have been recorded in the area (Figure 29). The species with the highest conservation value is the vulnerable greater sand plover (*Charadrius leschenaultii*). The remainder are listed under international agreements as migratory species, except for the priority 4-listed grey-tailed tattler (*Tringa brevipes*).

The green turtle (*Chelonia mydas*) is listed as vulnerable and a migratory species and is the only conservation-listed reptile recorded onshore, while the priority and migratory Australian humpback dolphin (*Sousa sahalensis*) is the only marine mammal recorded offshore.



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Figure 29 Conservation-listed values and waterbodies of the Exmouth North subarea

Aboriginal and heritage places

The entire subarea falls within the Warnangura (Cape Range) cultural precinct (Figure 30). The precinct is listed because it has artefacts/scatter, ceremonial importance, engravings, middens/scatter, mythological significance, rock shelters, named places and water sources. Within the subarea, Vlamingh Head is a ceremonial, mythological site.

Fives sites containing artefacts/scatter and/or middens/scatter are known at Point Murat, with an additional site that has a skeletal material/burial site and a camp. A site north-east of the Exmouth townsite contains artefacts/scatter.

There are four European heritage sites in the subarea. All are associated with the Vlamingh Head lighthouse, which was a significant feature of the peninsula's north-west coast for 50 years until 1967 (Heritage Council 2023). The sites have aesthetic, historic, social, scientific and cultural heritage significance and are notable pieces of architecture in a very remote location.

Social values

The northern coastal region of the North West Cape is within the World Heritage-listed Ningaloo Coast site (Figure 30 and Figure 31) and the DBCA-managed Ningaloo Marine Park. Most of the subarea, excluding the very low frequency antennae site and the Harold E Holt Naval Communications Station, is within the national heritage-listed Ningaloo Coast area. Part of the DBCA-managed Jurabi Coastal Park runs along the top of the subarea, covering the Ningaloo Lighthouse Resort, while Bundegi Coastal Park sits on the east coast south of the antennae site (Figure 31).

The following places and activities are popular with tourists and local people:

- Surfers Beach – surfing
- Bundegi – snorkelling, swimming, boating
- Jurabi interpretive centre – learn about turtles
- Vlamingh Head lighthouse – scenic lookout (caravan park currently closed)
- Mildura wreck – lookout
- rifle range (near Harold E Holt Naval Communications Station).

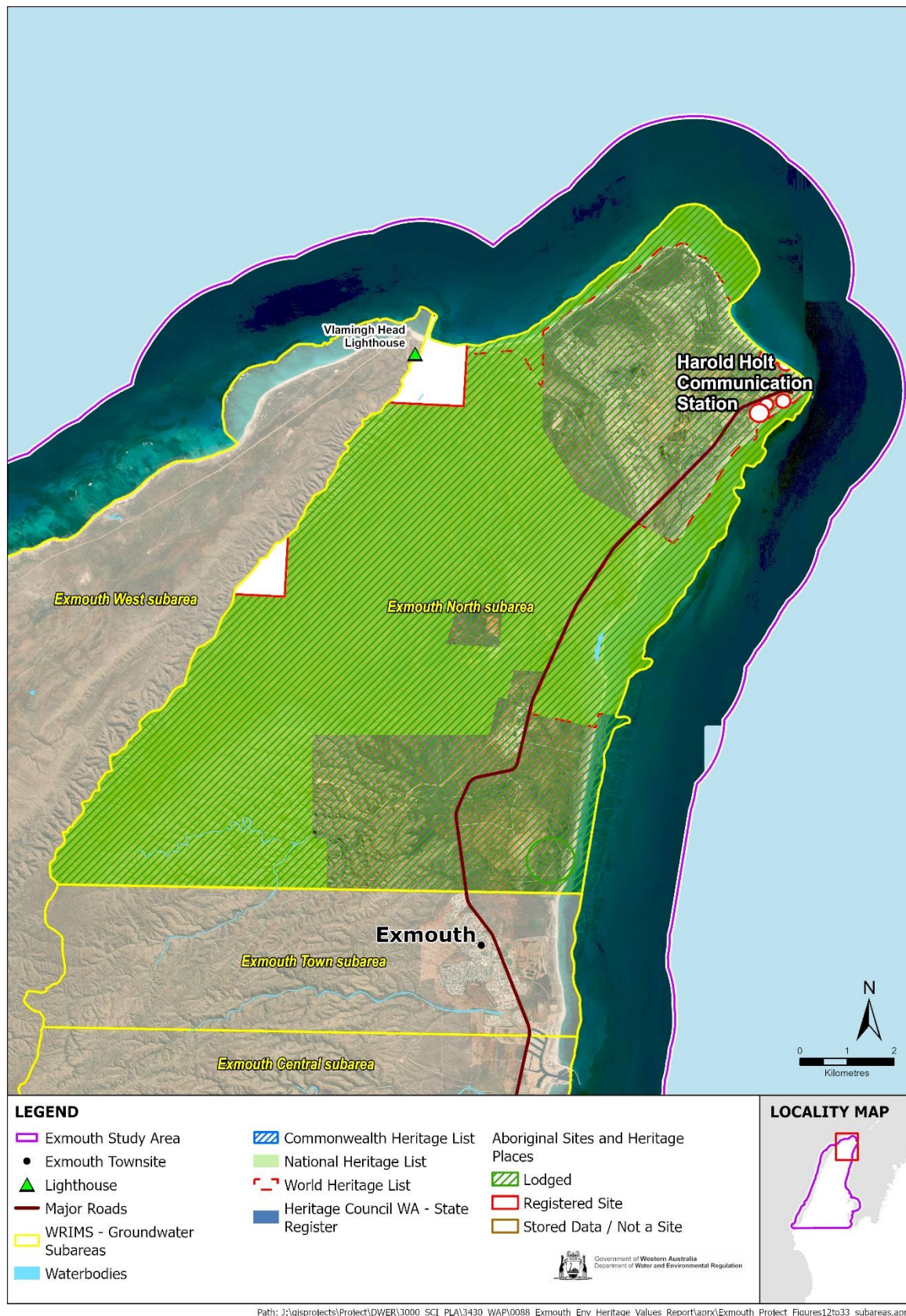


Figure 30 Aboriginal and other heritage places of the Exmouth North subarea

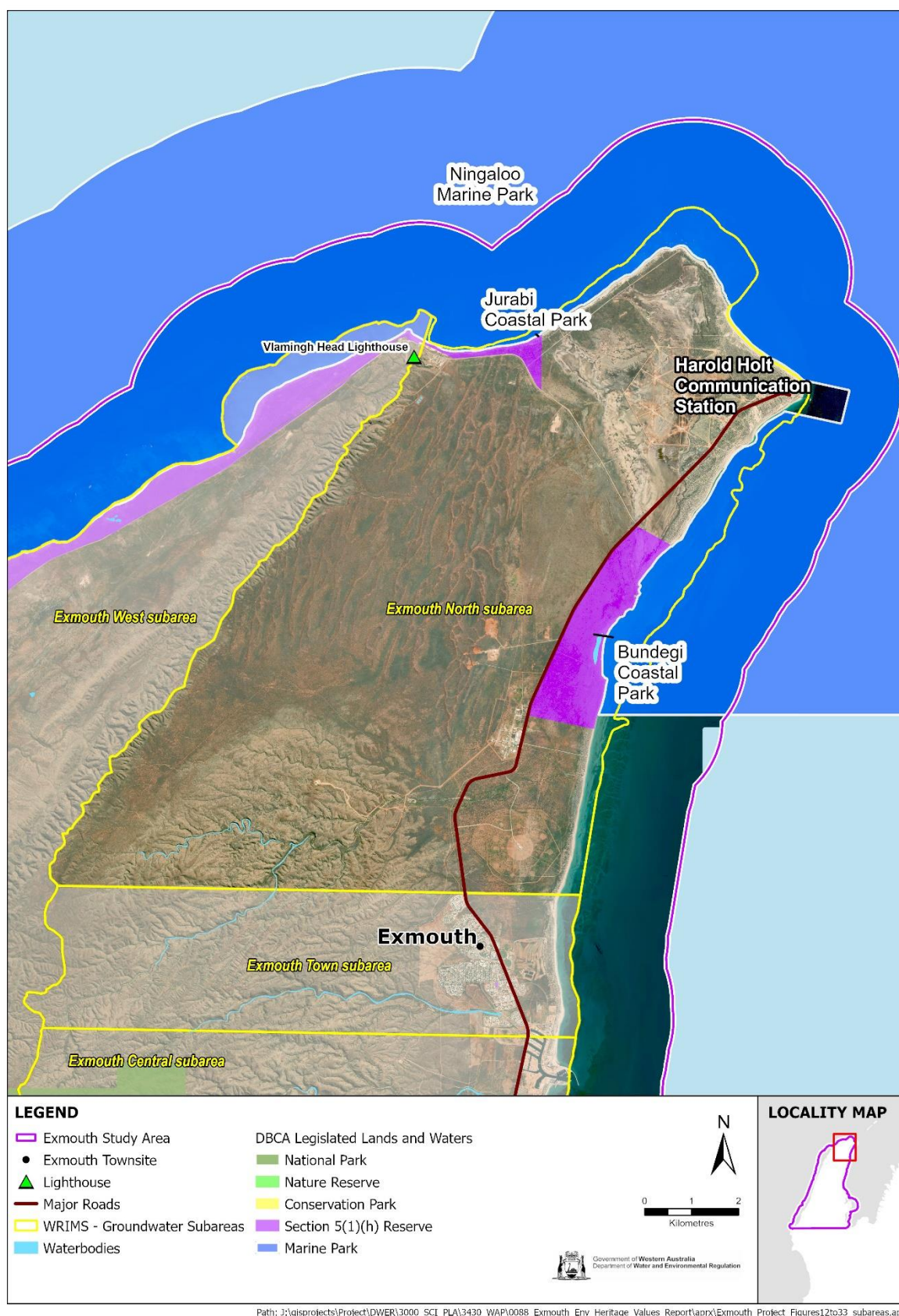


Figure 31 DBCA-managed lands in the Exmouth North subarea

7.6 Exmouth West subarea

The Exmouth West subarea covers about 1,000 km² running south from Vlamingh Head lighthouse to Winderbandi Point (Figure 32).

Environmental, heritage and social values

Subterranean and aquifer ecosystems

A band of DIWA-listed Cape Range Subterranean Waterways wetland from 1.0 to 3.0 km wide is mapped along the full length of the subarea along the Ningaloo Coast. A large area also occurs inland across the southern half of the subarea (Figure 32).

Bundera Sinkhole is located towards the southern end of the subarea (Figure 7, Figure 8) and hosts the Cape Range remipede community TEC, listed as vulnerable under the BC Act. Bundera is a DIWA-listed wetland under criteria 1 and 5 (Environment Australia 2001). The sinkhole supports multiple endemic stygofauna listed as threatened under the BC Act including the Cape Range remipede (*Kumonga exleyi*) and blind gudgeon (*Milyeringa veritas*). All the stygofauna are totally dependent on groundwater. Both species are listed as vulnerable under the EPBC Act. The Cape Range remipede is significant as Australia's only known species of the ancient crustacean order Remipedia and is restricted to the Bundera Sinkhole.

Other conservation-listed subterranean species recorded in the subarea include the vulnerable blind cave eel (*Ophisternon candidum*), the Cape Range millipede (*Stygiochiropus sympatricus*) and lance-beaked cave shrimp (*Stygiocaris lancifera*); the endangered Western Cape Range bamazomus (*Bamazomus vespertinus*) and Western Cape Range draculoides (*Draculoides julianneae*); and the priority 4 Cape Range blind cockroach (*Nocticola flabella*) and spear-beaked cave shrimp (*Stygiocaris stylifera*).

Wetlands and waterways

A number of surface water bodies are mapped across the subarea. These include the Learmonth Air Weapons Range DIWA-listed wetland (Section 6.2) and non-perennial lakes and swamps along the coast and inland of Yardie Creek gorge (Figure 32). No further information is available for these sites.

The DIWA-listed Cape Range Subterranean Waterways are intersected by a number of creeks running west from the top of Cape Range to the coast (Figure 32). Named creeks include the Tantabiddi, Mangrove, Mandu Mandu, Pilgonaman and Yardie creeks.

Yardie Creek is the longest and likely the largest system on the Exmouth Peninsula. The headwaters of its longest tributary are high in Cape Range and flow south and then south-west for about 25 km to the coast. Other tributaries are much shorter and run west for some 13 km from Cape Range to the coast. All tributaries flow into Yardie Creek Canyon.

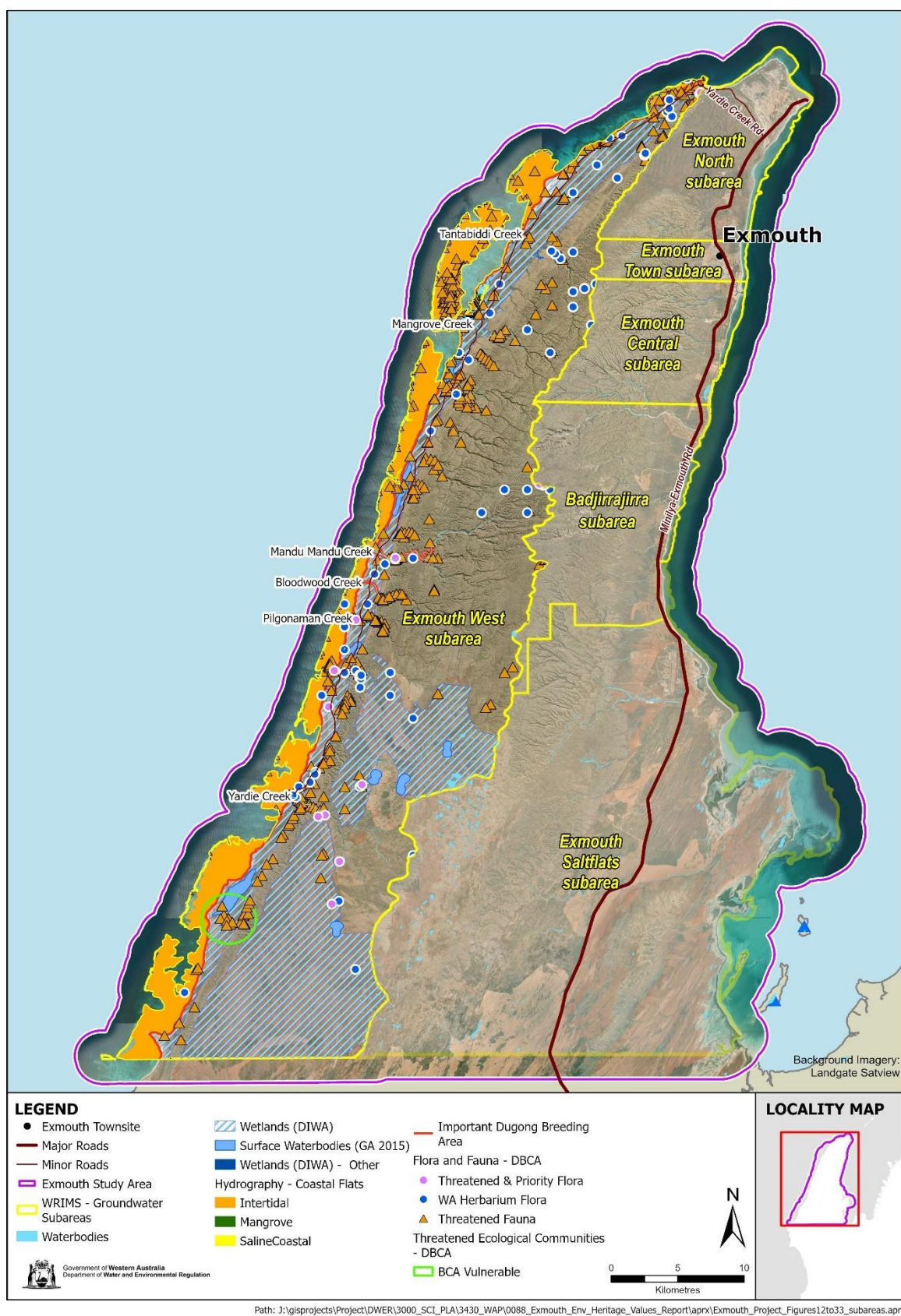


Figure 32 Wetlands, creeks flora and fauna and TEC of the Exmouth West subarea

Although influenced by tides even when the mouth is closed, Yardie Creek is thought to be supported by groundwater discharge (Allen 1993; Collins & Stevens 2010) where the canyon intersects the watertable (A Mahon pers. comm.) Evidence includes the persistence of the pool, which is up to 1.5 km long; the presence of *Ficus brachypoda*, known to rely on fresh groundwater; and the remotely sensed offshore discharge points and alluvial fans (Collins & Stevens 2010).

In addition, Keighery and Gibson (1993) described various flora species at a permanent freshwater pool at Yardie Creek. These included emergent aquatics such as the native bullrush (*Typha domingensis*) and *Schoenoplectus subulatus*, which were hundreds of kilometres from their main ranges. It is not known if these species still occur at Yardie Creek, but they have been identified in the area (Keighery & Lilburn 2019). The Yardie Creek morning glory (*Ipomoea yardiensis*) is endemic to the creek (DEWHA 2010).

At the top of the Yardie Creek system is a stand of the relictual, conservation-listed Millstream palms (*Livistonia alfredii*) (Humphreys et al. 1990; Keighery & Lilburn 2019), also a considerable distance from their main area of occurrence (Millstream). Significant weed invasion has also occurred in the Yardie Creek gorge with infestations of doublegee (*Rumex hypogaeus*) and onion weed (*Asphodelus jistulosus*) (Keighery & Gibson 1993). It has been proposed that the entire system be listed as a wetland of national significance (Keighery & Lilburn 2019).

Yardie Creek Canyon is described as unique because it contains many unusual habitats and acts as a significant refuge for plants and animals. For example, it hosts the endangered West Kimberley black-footed rock wallaby (*Petrogale lateralis lateralis*, West Kimberley), which inhabit steep escarpments, rocky outcrops and overhangs, and the migratory osprey (*Pandion cristatus*) and other local and migratory bird species (DEC 2010).

Pilgonaman Creek is located to the north of Yardie Creek. A much smaller/shorter system, it does not appear to hold water for long periods of time. However, the presence of *Ficus brachypoda* suggests fresh groundwater is accessible. Further evidence that fresh groundwater occurs at Pilgonaman Well is the presence of the vulnerable blind cave gudgeon (*Milyeringa veritas*). The black-footed rock wallaby (*Petrogale lateralis lateralis*) is also found in Pilgonaman Gorge.

28 Mile/Bloodwood Creek and Camp 17 creeks are located between Pilgonaman and Mandu Mandu creeks. Both flow for about 15 km west from Cape Range. Neither appear to hold water for long periods of time, although the gorges of both creeks support black-footed rock wallabies.

The headwaters of Mandu Mandu Creek sit high in Cape Range to the east. Two main tributaries flow for about 15 km to the coast: one south-west from the range and the other west. Mandu Mandu Creek supports *Ficus brachypoda* (Collins & Stevens 2010) along with the conservation-listed priority 2 shrub *Harnieria kempeana* subsp. *rhadinophylla*. Mandu Mandu Gorge supports black-footed rock wallabies. The conservation-listed Cape Range blind cockroach has been recorded near the

headwaters of the creek. Although ephemeral, Mandu Mandu Creek shows evidence of offshore discharge (Collins & Stevens 2010).

Tantabiddi Creek flows north-west for 12 km from the top of Cape Range to the coast into a small, likely estuarine pool. The blind cave eel has been recorded at Tantabiddi Well 3 km to the south of the creek. This indicates the presence of fresh to brackish groundwater in the area.

Nearshore and marine ecosystems

Collins and Stevens (2010) investigated the presence of freshwater indicators in the Exmouth West subarea. They considered *Ficus brachypoda*, karst systems and constructed wells as onshore indicators. Known drainage outlets, springs and marine channels along with remotely sensed offshore discharge points and alluvial fans were considered as offshore indicators (Figure 33a). Figure 33b shows areas identified as having a high probability for groundwater discharge to the marine environment: near Bundera (area 1), Yardie Creek (area 2), Mandu Mandu Creek (area 3), Turquoise Bar (area 4), Lakeside (area 5) and Mangrove Bay (area 6) (Collins & Stevens 2010) (Figure 33b).

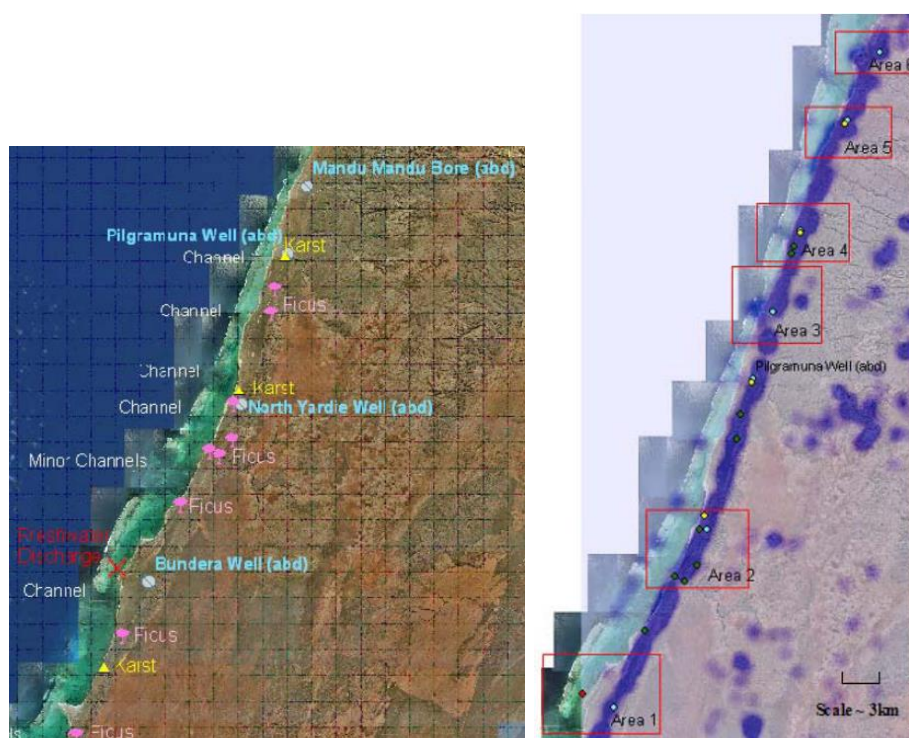


Figure 33 a) Location of freshwater indicators, b) areas with a high probability of groundwater occurrence offshore (from Collins & Stevens 2010)

Mangrove Creek flows north-west from Cape Range to the coast where it spills onto a saltflat before running into a series of small lagoons at Mangrove Bay, described as perennial lakes and swamps. *Avicennia marina* is the dominant species with some *Rhizophora stylosa* also occurring (Hickey et al. 2021). Work in the Kimberley region has recently suggested that dense perennial vegetation, as can be seen in satellite

imagery of this area, could indicate groundwater discharge near the coast (Kilminster et al. in prep).

The saline coastal flats that form the Learmonth Air Weapons Range DIWA-listed wetland are located to the north of Mandu Mandu Creek. This is described as a marine and coastal zone wetland comprising brackish to saline lagoons and marshes with one or more relatively narrow connections with the sea (Environment Australia 2001). It is subject to inundation and ponding (DCCEEW 2023b). Given the wetland covers 300 ha it is likely to possess a relatively diverse flora community (DCCEEW 2023b). As a saltflat with brackish to saline water, the wetland may receive groundwater inputs (see Section 6.3).

Four conservation-listed turtles have been recorded onshore: the endangered loggerhead turtle (*Caretta caretta*); and the vulnerable green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricata*) and leatherback turtle (*Dermochelys coriacea*). Two conservation-listed marine mammals have been recorded offshore within the subarea boundary: the vulnerable humpback whale (*Megaptera novaeangliae*) and the priority 4 Australian humpback dolphin (*Sousa sahalensis*) (Figure 32).

Terrestrial vegetation

Department staff noted a small stand of *Eucalyptus camaldulensis* (river red gum) and an introduced palm species around a disused well/windmill at Yardie Creek Caravan Park. River red gums use shallow fresh to brackish groundwater where it is accessible.

Flora and fauna

In addition to the flora and fauna species discussed in relation to the specific habitats above, there are numerous other conservation-listed species in the Exmouth West subarea (Figure 32). This includes 27 migratory bird species, the highest conservation listings of which are the critically endangered eastern curlew (*Numenius madagascariensis*); endangered Hutton's shearwater (*Puffinus huttoni*), lesser sand plover (*Charadrius mongolus*) and red knot (*Calidris canutus*); and the vulnerable greater sand plover (*Charadrius leschenaultii*). The remainder are listed under international agreements as migratory species, with the exception of the priority 4-listed grey-tailed tattler (*Tringa brevipes*).

Other listed terrestrial species are the priority 4 long-tailed dunnart (*Sminthopsis longicaudata*), priority 4 reptile Cape Range slider (*Lerista allochira*), priority 1 splendid blind snake (*Anilius splendidus*) and priority 4 Ningaloo worm-lizard (*Aprasia rostrata*).

Twenty-three priority flora have been recorded in the Exmouth West subarea, 12 of which are related to wet environments: the priority 2 *Acanthocarpus rupestris*, *Calandrinia* sp. Cape Range (F. Obbens FO 10/18), Darling lily (*Crinum flaccidum*), *Tinospora esiangkara* and *Harnieria kempeana* subsp. *rhadinophylla*; the priority 3 *Grevillea calcicola*, sand sponge (*Lysiandra fuernrohrii*), *Stackhousia umbellata*,

Acacia alexandri and *Acacia startii*; and priority 4 *Rhynchosia bungarensis* and Millstream fan-palm (*Livistona alfredii*).

Aboriginal and heritage places

All of the subarea falls within the Warnangura (Cape Range) cultural precinct (Figure 34). The precinct is listed because it has artefacts/scatter, ceremonial importance, engravings, middens/scatter, mythological significance, rock shelters, named places and water sources.

There are 65 listed Aboriginal heritage sites in the Exmouth West subarea. Ten sites are associated with Yardie Creek. These include artefacts/scatter sites, middens/scatter sites and rock shelters. Human activity in the rock shelters dates back 10,000 years before the present time. Six sites of a similar nature are associated with Mandu Mandu Creek, six with 28 Mile Creek/Bloodwood Creek and seven with Camp 17 Creek (near Turquoise Bay), including the Tulki Well midden. Five sites near the mouth of a series of creeklines at Milyering also include artefacts/scatter sites, middens/scatter and a hunting place.

Padjari Manu Cave and Chugori Rockhole in Cape Range in the subarea's north are listed as water sources.

Social values

The entire Exmouth West subarea falls within the Ningaloo Coast national heritage area, with the vast majority also within the World Heritage-listed area (Figure 35). Learmonth Air Weapons Range in the subarea's south is also listed as a Commonwealth heritage site.

Cape Range National Park also covers most of the subarea with the Jurabi Coastal Park running along the north-western edge to Vlamingh Head.

The natural beauty, ecological significance and low levels of development of the Ningaloo Coast make it a unique place: a 'jewel in the ocean' (Deloitte 2022). The area attracts growing numbers of tourists each year.

Camping within Cape Range National Park is the most popular activity on the Exmouth Peninsula. Campgrounds within the Exmouth West subarea include Boat Harbour, One K, Yardie Creek, Osprey Bay, Kurrajong, Mandu, Tulki Beach, Mesa and Neds.

Other popular places to visit include the Milyering Discovery Centre, observation bird hide and Tantabiddi boat ramp. Walk trails and lookouts at Yardie Creek, Mandu Mandu and Bloodwood Creek also attract visitors as do the favourite swimming and snorkelling sites at Oyster Stacks, Turquoise Bay and Lakeside.

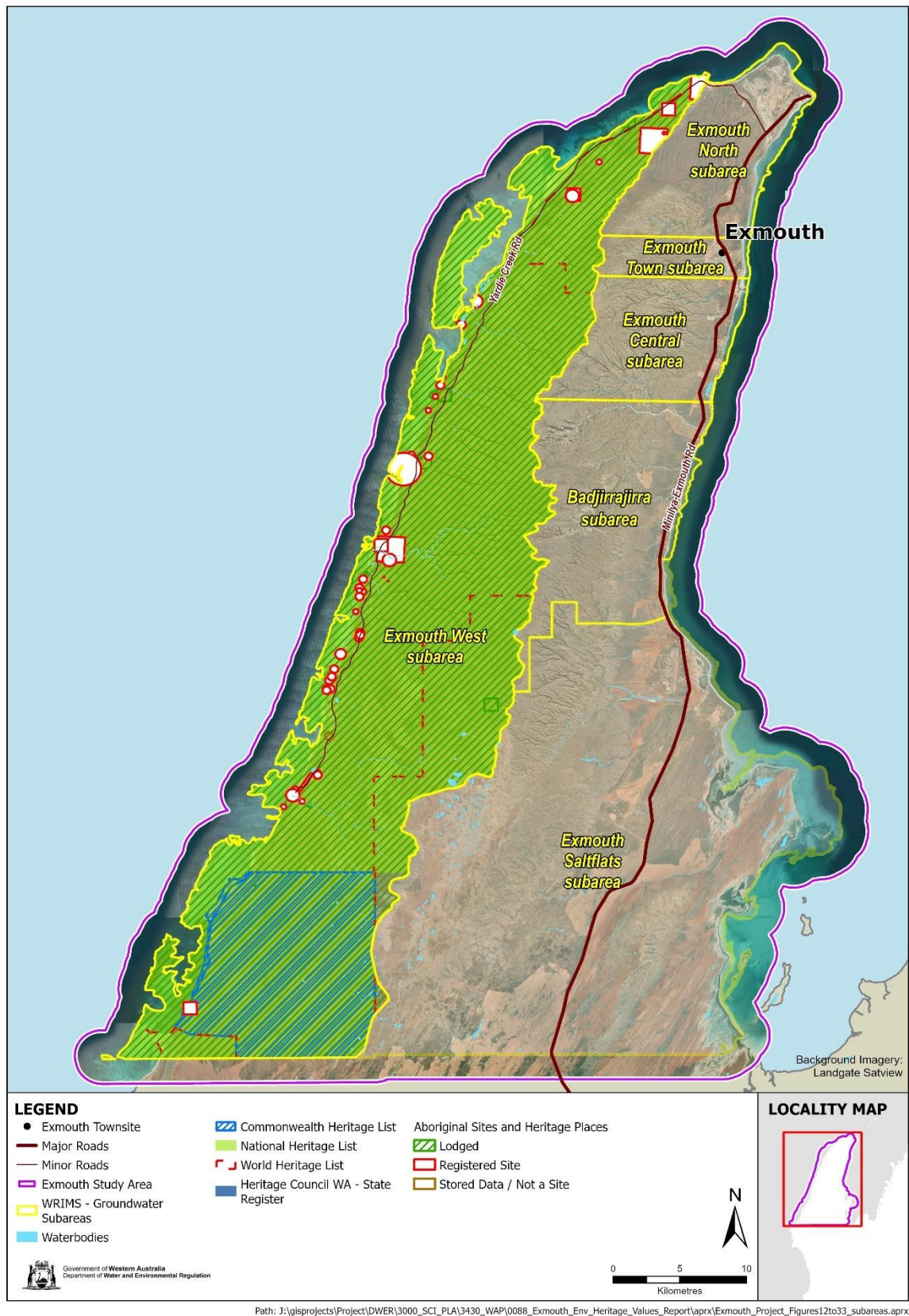


Figure 34 Aboriginal and other heritage places of the Exmouth West subarea

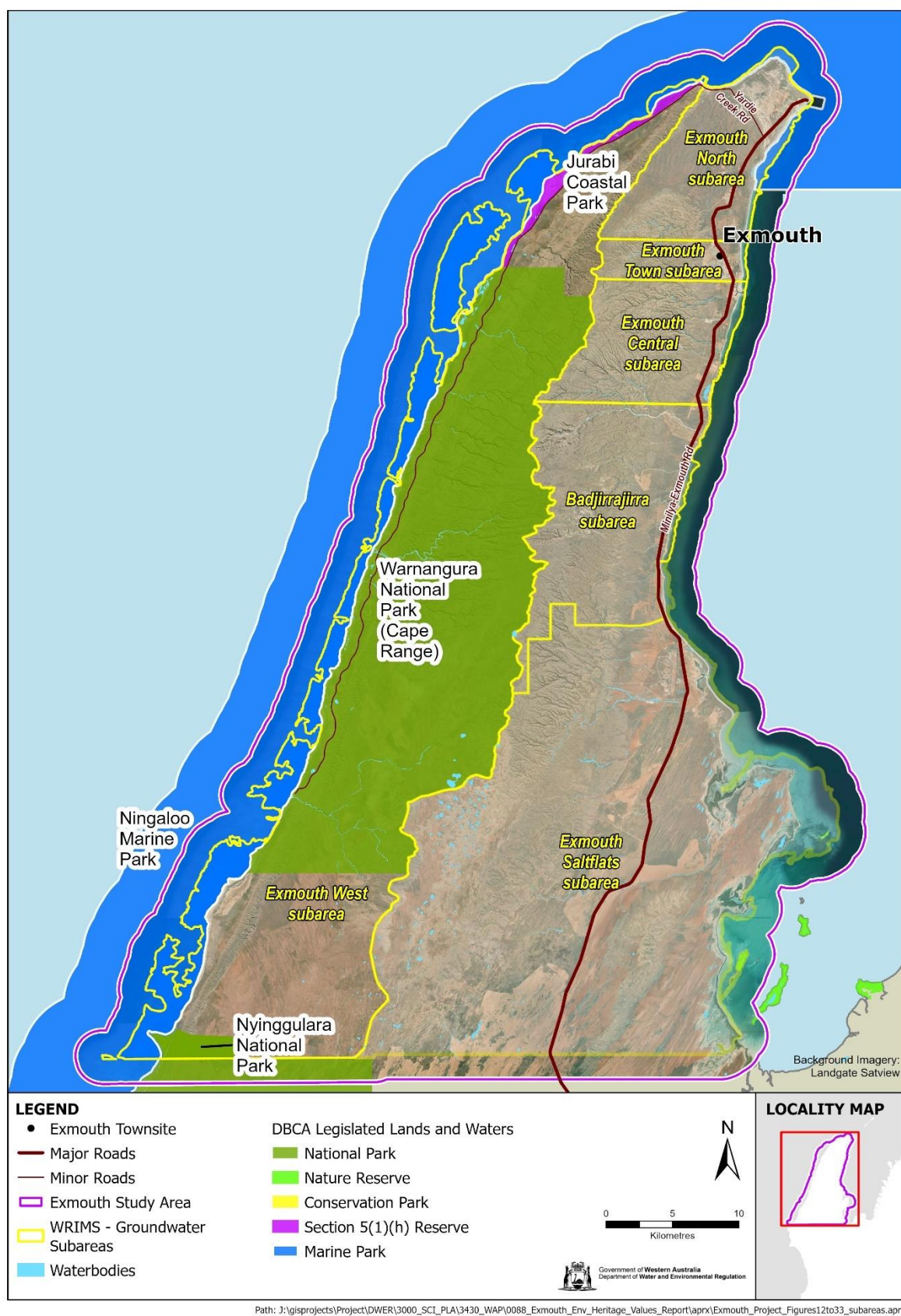


Figure 35 DBCA-managed lands in the Exmouth West subarea

Appendices

Appendix A Listed fauna and flora of the Exmouth Peninsula

Table A1 Listed fauna and their habitats in the Exmouth Peninsula and the Exmouth Gulf

LISTED FAUNA: <i>Scientific name</i>	Common name	Class	Conservation category code		Terrestrial	Marine	Mudflat	Freshwater	GDE	Surface water habitat	Cave/ aquifer
			WA	National							
<i>Actitis hypoleucos</i>	Common sandpiper	Bird	MI	MI			X	X	X	X	
<i>Ardenna pacifica</i>	Wedge-tailed shearwater	Bird	MI	MI							
<i>Arenaria interpres</i>	Ruddy turnstone	Bird	MI	MI			X			X	
<i>Calidris acuminata</i>	Sharp-tailed sandpiper	Bird	MI	MI			X	X	X	X	
<i>Calidris alba</i>	Sanderling	Bird	MI	MI			X			X	
<i>Calidris tenuirostris</i>	Great knot	Bird	CR	CR & MI							
<i>Calidris canutus</i>	Red knot	Bird	EN	EN & MI			X			X	
<i>Calidris ferruginea</i>	Curlew sandpiper	Bird	CR	CR & MI			X	X	X	X	
<i>Calidris ruficollis</i>	Red-necked stint	Bird	MI	MI			X	X	X	X	
<i>Calidris subminuta</i>	Long-toed stint	Bird	MI	MI			X	X	X	X	
<i>Charadrius leschenaultii</i>	Greater/large sand plover	Bird	VU	VU & MI			X	X	X	X	
<i>Charadrius mongolus</i>	Lesser sand plover	Bird	EN	EN & MI			X	X	X	X	
<i>Chlidonias leucopterus</i>	White-winged black tern	Bird	MI	MI		X	X	X	X	X	
<i>Gallinago stenura</i>	Pin-tailed snipe	Bird	MI	MI				X	X	X	
<i>Gelochelidon nilotica</i>	Gull-billed tern	Bird	MI	MI		X	X	X	X	X	
<i>Glareola maldivarum</i>	Oriental pratincole	Bird	MI	MI	X		X	X	X	X	
<i>Hydroprogne caspia</i>	Caspian tern	Bird	MI	MI		X	X			X	
<i>Limosa lapponica</i>	Bar-tailed godwit	Bird	MI	MI			X			X	
<i>Limosa limosa</i>	Black-tailed godwit	Bird	MI	MI			X			X	

LISTED FAUNA: <i>Scientific name</i>	Common name	Class	Conservation category code		Terrestrial	Marine	Mudflat	Freshwater	GDE	Surface water habitat	Cave/ aquifer
			WA	National							
<i>Numenius madagascariensis</i>	Eastern curlew	Bird	CR	CR & MI			X			X	
<i>Numenius minutus</i>	Little curlew; little whimbrel	Bird	MI	MI			X	X	X	X	
<i>Numenius phaeopus</i>	Whimbrel	Bird	Mi	MI			X	X	X	X	
<i>Onychoprion anaethetus</i>	Bridled tern	Bird	MI	MI							
<i>Pandion cristatus</i>	Osprey, eastern osprey	Bird	MI	MI	X	X	X	X		X	
<i>Phaethon lepturus</i>	White-tailed tropic bird	Bird	MI	MI							
<i>Pluvialis fulva</i>	Pacific golden plover	Bird	MI	MI			X			X	
<i>Pluvialis squatarola</i>	Grey plover	Bird	MI	MI			X			X	
<i>Puffinus huttoni</i>	Hutton's shearwater	Bird	EN								
<i>Sterna hirundo</i>	Common tern	Bird	MI	MI		X					
<i>Sterna dougallii</i>	Roseate tern	Bird	MI	MI		X	X				
<i>Sternula albifrons</i>	Little tern	Bird	MI	MI		X					
<i>Sternula nereis neries</i>	Fairy tern	Bird	VU	VU			X				
<i>Thalasseus bergii</i>	Crested tern	Bird	MI	MI		X	X				
<i>Tringa breviceps</i>	Grey-tailed tattler	Bird	MI & P4	MI			X				
<i>Tringa glareola</i>	Wood sandpiper	Bird	MI	MI			X	X	X	X	
<i>Tringa nebularia</i>	Common greenshank, greenshank	Bird	Mi	MI			X	X	X	X	
<i>Tringa stagnatilis</i>	Marsh sandpiper; little greenshank	Bird	Mi	MI			X	X	X	X	
<i>Xenus cinerus</i>	Terek sandpiper	Bird	MI	MI			X				
<i>Falco peregrinus</i>	Peregrine falcon	Bird	OS								

LISTED FAUNA: <i>Scientific name</i>	Common name	Class	Conservation category code		Terrestrial	Marine	Mudflat	Freshwater	GDE	Surface water habitat	Cave/ aquifer
			WA	National							
<i>Ophisternon candidum</i>	Blind cave eel	Fish	VU	VU					X	X	X
<i>Milyeringa veritas</i>	Cave gudgeon, blind gudgeon	Fish	VU	VU							X
<i>Carcharias taurus</i>	Grey nurse shark	Fish	VU	VU		X					
<i>Rhincodon typus</i>	Whale shark	Fish	MI	VU & MI		X					
<i>Dasyurus hallucatus</i>	Northern quoll	Mammal	EN	EN	X				X	X	
<i>Leporillus apicalis</i>	Lesser stick-nest rat	Mammal	EX	EX							
<i>Mesembriomys macrurus</i>	Golden-backed tree-rat	Mammal	P4		X						
<i>Petrogale lateralis lateralis</i>	Black-footed rock-wallaby	Mammal	EN	EN	X				X	X	
<i>Potorous platyops</i>	Broad-faced potoroo	Mammal	EX	EX							
<i>Sminthopsis longicaudata</i>	Long-tailed dunnart	Mammal	P4								
<i>Dugong dugon</i>	Dugong	Mammal	MI	MI		X					
<i>Megaptera novaeangliae</i>	Humpback whale	Mammal	CD & MI	MI		X					
<i>Orcaella heinsohni</i>	Australian snubfin dolphin	Mammal	MI & P4	MI		X					
<i>Sousa sahalensis</i>	Australian humpback dolphin	Mammal	MI & P4	MI		X					
<i>Stennella longirostris</i>	Spinner dolphin	Mammal	MI & P4	MI		X					
<i>Caretta caretta</i>	Loggerhead turtle	Reptile	EN	EN & MI		X					
<i>Chelonia mydas</i>	Green turtle	Reptile	VU and IA			X					
<i>Dermochelys coriacea</i>	Leatherback turtle	Reptile	VU	EN & MI		X					

LISTED FAUNA: <i>Scientific name</i>	Common name	Class	Conservation category code		Terrestrial	Marine	Mudflat	Freshwater	GDE	Surface water habitat	Cave/ aquifer
			WA	National							
<i>Eretmochelys imbricata</i>	Hawksbill turtle	Reptile	VU	VU & MI							
<i>Aprasia rostrata</i>	Ningaloo worm-lizard, monte bello worm-lizard	Reptile	P3		X						
<i>Anilius splendidus</i>	Splendid blind snake (north west cape)	Reptile	P2		X						
<i>Diplodactylus capensis</i>	Cape Range stone gecko	Reptile	P2		X						
<i>Lerista allochira</i>	Cape Range slider	Reptile	P3		X						
<i>Stygiochiropus sympatricus</i>	A stygiochiropus millipede (Cape Range)	Invertebrate – troglafauna	VU								X
<i>Stygiochiropus isolatus</i>	A stygiochiropus millipede (Cape Range)	Invertebrate – troglafauna	VU								X
<i>Prionospio thalanj</i>	Bundera sinkhole worm	Invertebrate – stygoafauna	CR						X		X
<i>Stygiochiropus peculiaris</i>	Camerons Cave millipede	Invertebrate – troglafauna	CR						X		X
<i>Indohya damocles</i>	Camerons Cave pseudoscorpion	Invertebrate – troglafauna	CR								X
<i>Nocticola flabella</i>	Cape Range blind cockroach	Invertebrate – troglafauna	P4								X
<i>Bamazomus subsolanis</i>	Eastern Cape Range bamazomus	Invertebrate – troglafauna	EN								X
<i>Welesina kornickeri</i>	Kornicker's Bundera sinkhole ostracod	Invertebrate- stygoafauna	CR						X		X
<i>Stygiocaris lancifera</i>	Lance-beaked cave shrimp	Invertebrate - stygoafauna	VU						X		X
<i>Draculoides brooksi</i>	Northern Cape Range draculoides	Invertebrate – troglafauna	EN								X

LISTED FAUNA: <i>Scientific name</i>	Common name	Class	Conservation category code		Terrestrial	Marine	Mudflat	Freshwater	GDE	Surface water habitat	Cave/ aquifer
			WA	National							
<i>Bamazomus vespertinus</i>	Western Cape Range bamazomus	Invertebrate – troglofauna	EN								X
<i>Stygiocaris stylifera</i>	Spear-beaked cave shrimp	Invertebrate-stygofauna	P4						X		X
<i>Draculoides julianneae</i>	Western Cape Range draculoides	Invertebrate – troglofauna	EN								X
<i>Kumonga exleyi</i>	Cape Range remipede	Invertebrate – stygofauna	CR	VU					X		X
<i>Bunderia misophaga</i>	A copepod (Bundera Sinkhole)	Invertebrate – stygofauna	CR						X		X
<i>Stygocyclopia australis</i>	A copepod (Bundera Sinkhole)	Invertebrate – stygofauna	CR						X		X
<i>Speleophria bunderae</i>	A copepod (Bundera Sinkhole)	Invertebrate – stygofauna	CR						X		X
<i>Liagoceradocus branchialis</i>	Cape Range liagoceradocus amphipod	Invertebrate – stygofauna	EN						X		X

IA – international agreements

T – threatened – critically endangered, endangered or vulnerable

EN – endangered

CR – critically endangered

VU – vulnerable

P1, P2 and P3 – maybe threatened or near threatened but are data deficient and have not yet been adequately surveyed to be listed

P4 – rare, near threatened and others in need of monitoring.

Table A2 Listed flora of the Exmouth Peninsula and their habitat

LISTED FLORA	Cons. code (Status) (WA Herbarium)	Habitat (Florabase)
Scientific/ common name		
<i>Calytrix</i> sp. Learmonth (S. Fox EMopp 1)	1	-
<i>Abutilon</i> sp. Quobba (H. Demarz 3858)	2	sand
<i>Acacia ryaniana</i>	2	white or red sand, coastal sand dunes
<i>Acanthocarpus rupestris</i>	2	red sand, limestone, along creeks
<i>Calandrinia</i> sp. Cape Range (F. Obbens FO 10/18)	2	water course, creekline
<i>Crinum flaccidum</i> – Darling lily	2	loam, clay, sandstone, swamps, creeks
<i>Cucumis</i> sp. Barrow Island (D.W. Goodall 1264)	2	-
<i>Daviesia pleurophylla</i>	2	sand dunes
<i>Eremophila occidens</i>	2	orange/brown sand., limestone ranges, dunes
<i>Harnieria kempeana</i> subsp. <i>rhadinophylla</i>	2	amongst limestone rocks, creek banks
<i>Tephrosia</i> sp. North West Cape (G. Marsh 81)	2	
<i>Tinospora esiangkara</i>	2	pebbly orange-brown calcareous loam. limestone outcrops or ridges, near creek bank
<i>Verticordia serotina</i>	2	red sand, sand dunes
<i>Acacia alexandri</i>	3	limestone, stony creeks, steep rocky slopes, related to creek courses
<i>Acacia startii</i>	3	calcareous loam with limestone pebbles, stony hills, watercourses.
<i>Carpobrotus</i> sp. Thevenard Island (M. White 050)	3	coarse white sand, dune tops, disturbed areas
<i>Corchorus congener</i>	3	sand, red sandy loam with limestone, sand dunes, plains
<i>Corynotheca flexuosissima</i> - Compact zigzag lily	3	red or white sand, limestone, coastal sand dunes
<i>Eremophila forrestii</i> subsp. <i>capensis</i> - Cape Range poverty bush	3	brown rocky soils, limestone, ridges
<i>Grevillea calcicola</i>	3	limestone hilltops, creekline
<i>Gymnanthera cunninghamii</i>	3	sandy soils
<i>Lysiandra fuernrohrii</i> - Sand spurge	3	creek beds
<i>Stackhousia umbellata</i>	3	sandy soils on limestone, creek bed
<i>Brachychiton obtusilobus</i>	4	skeletal soils, rocky limestone ranges, gorges, occasionally sandplains

LISTED FLORA		Cons. code (Status) (WA Herbarium)	Habitat (Florabase)
Scientific/ common name			
<i>Eremophila youngii</i> subsp. <i>lepidota</i>		4	stony red sandy loam, flats plains, floodplains, semi-saline, clay flats
<i>Livistona alfredii</i> - Millstream fan-palm		4	edges of permanent pools, creek beds
<i>Rhynchosia bungarensis</i>		4	pebbly, shingly coarse sand amongst boulders, banks of flow line in the mouth of a gully in a valley wall

P1, P2 and P3 – maybe threatened or near threatened but are data deficient and have not yet been adequately surveyed to be listed, P4 – rare, near threatened and others in need of monitoring.

Appendix B Surface water quality - Qualing/ Mowbowra area

Table B1 Water quality data (Sinclair & Vitale 2023)

Site	Time	DO %	pH	NTU	DEP m	SPC- mS/cm
Qualing	15:26:29	243.1	8.55	0.91	0.363	10.291
Qualing	15:28:38	193	8.51	1.34	0.458	10.308
Qualing	15:30:12	199.2	8.51	0.01	0.317	10.316
Qualing	15:32:45	195.2	8.5	0.05	0.289	10.283
Qualing	15:36:12	198.8	8.48	0.27	0.289	10.268
Qualing	15:38:23	187.8	8.44	0.42	0.666	10.226
Qualing	15:44:11	299.5	8.66	6.74	0.299	7.761
Qualing	15:46:42	98.5	7.58	3.39	0.29	5.906
Qualing	15:48:14	144.6	7.89	6.64	0.291	5.781
Qualing	15:50:54	142.8	8	-0.92	0.288	6.464
Qualing Beach	16:44:06	108.6	8.07	0.88	0.291	53.999
Qualing Beach	16:45:22	113.5	8.1	1.24	0.428	54.006
Qualing Beach	16:47:02	112	8.11	2.53	0.397	54.043
Qualing Beach	16:48:20	109.8	8.12	3.92	0.334	54.065
Qualing Beach	16:49:19	114.7	8.15	1.39	0.36	54.079
Estuary 3	17:09:25	122.5	8.17	7.62	0.378	54.863
Qualing	8:00:02	111	8.37	0.39	0.332	10.2
Mowbowra	8:28:45	68.4	7.91	3.18	0.603	46.278
Mowbowra	8:29:10	68.9	7.92	3.4	0.34	46.282
Mowbowra	8:32:13	77.5	7.95	4.01	0.558	46.332
Mowbowra	8:35:58	35.6	7.82	0.6	0.51	46.096
Mowbowra	8:38:17	34.7	7.73	5.05	0.34	24.842
Mowbowra	8:40:21	63.8	7.98	1.74	0.339	11.913
Mowbowra Swamp	8:46:21	95.3	8.55	27.93	0.336	80.143

Site	Time	DO %	pH	NTU	DEP m	SPC- mS/cm
Aquaculture Farm	9:16:57	84.3	8.48	-0.06	0.337	55.467
Estuary 0	9:25:24	74.7	7.93	68.95	0.335	40.902
Estuary 0	9:27:06	101.5	8.2	1.43	0.334	56.416
Estuary Y	10:40:19	139.3	8.61	2.76	0.332	66.666
Estuary 4	15:04:45	152.1	8.17	35.46	0.301	82.899
Estuary 4	15:06:20	164.9	8.18	63.05	0.386	82.58
Estuary 4	15:07:43	171.4	8.19	40.82	0.565	82.48
Estuary 4	15:10:40	160.2	8.19	45.73	0.307	82.345
Estuary 4	15:13:13	167.2	8.19	41.35	0.313	82.868
Estuary 5	15:56:19	162.8	8.54	0.39	0.305	80.187

Table B2 Water quality data (DWER, May 2024)

29/05/2024		Temp °C	DO%	DO mg/L	SPC ms/cm	SAL ppt	pH	NTU (turbidity)
Pool 1	1	22.9	79	5.76	41.107	28.48	7.61	602
(estuary)	2	22.9	90.5	6.5	44.135	28.51	7.6	247
	3	23.3	101	7.38	44.071	28.46	7.64	
	4	22.4	71.2	5.21	42.8	27.55	7.7	
Pool 2	5	23.5	134.7	9.4	11.156	6.32	8.27	2.8
	6	23.7	126	10.34	11.2	6.37	8.22	1.1
	7	24.9	187	15.02	8.84	4.94	8	4.3
	8	25.9	97.1	7.66	7.343	4.03	7.69	281
Pool 3	9	21.9	57.4	4.77	14.109	8.2	7.61	1.36
	10	23.7	176	14.43	13.21	7.61	8.44	7.2
	11	22.4	55	3.8	14.76	8.61	7.32	6.8

Glossary

Term	Meaning
Abstraction	The permanent or temporary take of water from any source of supply, so that it is no longer part of the resources of the locality.
Aboriginal cultural value	This report does not provide a definition of Aboriginal cultural value. This term has many definitions for Aboriginal people and when we use it we mean it in the widest-possible use of the term.
Anchialine	Condition where oceanic water mixes with fresh water in a coastal aquifer, characterised by a stratified (layered) water column.
Aquifer	A geological formation or group of formations capable of receiving, storing and transmitting significant quantities of water. Usually described by whether they consist of sedimentary deposits (sand and gravel) or fractured rock. Aquifer types include unconfined, confined, and artesian aquifers.
Biodiversity	Biological diversity or the variety of organisms, including species themselves, genetic diversity and the assemblages they form (communities and ecosystems). Sometimes includes the variety of ecological processes within those communities and ecosystems.
Bore	A narrow, normally vertical hole drilled in soil or rock to monitor or withdraw groundwater from an aquifer.
Catchment	The area of land from which rainfall runoff contributes to a single watercourse, wetland or aquifer.
Confined aquifer	An aquifer lying between confining layers of low-permeability strata (such as clay, coal or rock) so that the water in the aquifer cannot easily flow vertically.
Country (when used in connection to Aboriginal people)	Country means the lands, waterways, seas and skies to which Aboriginal peoples are intrinsically linked. The wellbeing, law, place, custom, language, spiritual belief, cultural practice, material sustenance, family and identity are all interwoven as one.
Cultural value	Cultural values are the core principles and value systems that underpin a community, a society or, in the case of Traditional Owners, a nation, clan or language group. They may be associated with a site of cultural significance or associated with the living, historical and traditional observances, practices, customs, beliefs, values, knowledge, relationships and skills of Aboriginal people. Cultural values of Traditional Owners can only be determined by them and are expressed in many ways such as narratives, songlines, art and maps.
Discharge	The water that moves from the groundwater to the ground surface or above, such as a spring. This includes water that seeps onto the ground surface, evaporation from unsaturated soil, and water extracted from groundwater by plants (see Evapotranspiration) or engineering works.
Discharge rate	Volumetric outflow rate of water, typically measured in cubic metres per second.

Term	Meaning
Dissolved oxygen	The concentration of oxygen dissolved in water normally measured in milligrams per litre (mg/L).
Ecological values	The natural ecological processes occurring within water-dependent ecosystems and the biodiversity of these systems.
Ecological water requirement	The water regime needed to maintain the ecological values (including assets, functions and processes) of water-dependent ecosystems at a low level of risk.
Ecosystem	A community or assemblage of communities of organisms, interacting with one another, and the specific environment in which they live and with which they also interact (e.g. a lake), including all the biological, chemical and physical resources and the interrelationships and dependencies that occur between those resources.
Environment	Living things, their physical, biological, cultural and social surroundings, and interactions between all of these as defined under section 3, <i>Environmental Protection Act 1986</i> (WA).
Evaporation	Loss of water from the water surface or from the soil surface by vaporisation due to solar radiation.
Evapotranspiration	The combined loss of water by evaporation and transpiration. It includes water evaporated from the soil surface and water transpired by plants.
Flow	Streamflow in terms of m ³ /a, m ³ /d or ML/a. May also be referred to as discharge.
Groundwater	Water which occupies the pores and crevices of rock or soil beneath the land surface.
Groundwater area	The boundaries that are proclaimed under the <i>Rights in Water and Irrigation Act 1914</i> (WA) and used for water allocation planning and management.
Groundwater-dependent ecosystem	An ecosystem that is at least partially dependent on groundwater for its existence and health.
Groundwater recharge	The rate at which infiltration water reaches the watertable.
Hydrogeology	The hydrological and geological science concerned with the occurrence, distribution, quality and movement of groundwater, especially relating to the distribution of aquifers, groundwater flow and groundwater quality.
Hydrograph	A graph showing the height of a water surface above an established datum plane for level, flow, velocity, or other property of water with respect to time.
Licence	A formal instrument granted under the <i>Rights in Water and Irrigation Act 1914</i> (WA) that entitles a licensee to take water (the licensed entitlement) from a water resource in accordance with the specified terms, conditions and restrictions on the licence.

Term	Meaning
Native title	The recognition that a group of Aboriginal people have rights and interests to land and waters according to their traditional law and customs as set out in Australian law – <i>Native title Act 1993</i> (Cth).
Native title party	In relation to an area of land where a water licence or permit is applied for the relevant native title party has the meaning given in section 24HA(7)(a) of the <i>Native title Act 1993</i> (WA), including: <ul style="list-style-type: none"> • a representative Aboriginal/Torres Strait Islander body • a registered native title body corporate, or • a registered native title claimant.
Recharge	Water that infiltrates into the soil to replenish an aquifer.
Salinity	The measure of total soluble salt or mineral constituents in water. Water resources are classified based on salinity in terms of total dissolved salts (TDS) or total soluble salts (TSS). Measurements are usually in milligrams per litre (mg/L) or parts per thousand (ppt).
Social value	Social values are the behaviours and beliefs that people share within a community or social group that contribute to wellbeing, sustainability, society and diversity.
Soak	An excavation below ground level that usually intercepts groundwater. Where a wall is also constructed above ground, a combination of surface runoff and groundwater may be captured. Soaks may also be constructed close to a watercourse to obtain water. Other names for soaks may include excavations, dugouts or sumps.
Spring	As defined in s 2(1) of the <i>Rights in Water and Irrigation Act 1914</i> , a spring means a spring of water naturally rising to and flowing over the surface of land, but does not include the discharge of underground water directly into a watercourse , wetland , reservoir or other body of water.
Surface water	Water flowing or held in streams, rivers and other wetlands on the surface of the landscape.
Stygofauna	Aquatic animals, usually invertebrates, living in groundwater.
Traditional Owner	An Aboriginal person/s is a Traditional Owner if they are: <ul style="list-style-type: none"> • a native title holder • a registered native title claimant or claim group • a member of a Regional Aboriginal Corporation established under a settlement agreement with the government • a knowledge holder as defined by the <i>Aboriginal Cultural Heritage Act 2021</i> (WA), or • a person who is recognised as having the cultural authority to speak for a place.
Troglofauna	Air breathing invertebrates living in voids and caves above the water table, dependent on humid conditions caused by proximity to groundwater and/or recharge from the surface.
Watercourse	(a) Any river, creek, stream or brook in which water flows;

Term	Meaning
	<p>(b) Any collection of water (including a reservoir) into, through or out of which any thing coming within paragraph (a) flows;</p> <p>c) Any place where water flows that is prescribed by local by-laws to be a watercourse.</p> <p>A watercourse includes the bed and banks of any thing referred to in paragraph (a), (b) or (c).</p>
Water-dependent ecosystems	Those parts of the environment, the species composition and natural ecological processes of which are determined by the permanent or temporary presence of water resources, including flowing or standing water and water within groundwater aquifers.
Water regime	A description of the variation of flow rate or water level over time. It may also include a description of water quality.
Watertable	The saturated level of the unconfined groundwater. Wetlands in low-lying areas are often seasonal or permanent surface expressions of the watertable.
Waterways	All streams, creeks, stormwater drains, rivers, estuaries, coastal lagoons, inlets and harbours.
Well	An opening in the ground made or used to obtain access to underground water. This includes soaks, wells, bores and excavations.
Wetland	<p>As defined in section 2 of the <i>Rights in Water and Irrigation Act 1914</i>, a wetland is a natural collection of water, whether permanent or temporary, on the surface of any land and includes —</p> <ul style="list-style-type: none"> a) any lake, lagoon, swamp or marsh; and b) a natural collection of water that has been artificially altered but does not include a watercourse.

Volumes of water

One litre	1 litre	1 litre	(L)
One thousand litres	1000 litres	1 kilolitre	(kL)
One million litres	1 000 000 litres	1 Megalitre	(ML)
One thousand million litres	1 000 000 000 litres	1 Gigalitre	(GL)

Units of measure

°C	degrees centigrade, a unit of measure for temperature
DEP m	water depth in metres
DO%	percentage of dissolved oxygen in water
km ²	kilometres squared
m	meters
mm	millimetres
mS/cm	millisiemens per centimetre, a unit of measure used for salinity
mbgl	meters below ground level
NTU	measure of turbidity in water

Shortened forms

AH Act	<i>Aboriginal Heritage Act 1972</i>
ARMCANZ	Agriculture and Resource Management Council of Australia and New Zealand
ANZECC	Australian and New Zealand Environment and Conservation Council
BC Act	<i>Biodiversity Conservation Act 2016 (WA)</i>
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DBCA	Department of Biodiversity, Conservation and Attractions
DPLH	Department of Planning, Lands and Heritage
DWER	Department of Water and Environmental Regulation
EP Act	<i>Environmental Protection Act 1986 (WA)</i>
EPA	Environmental Protection Authority
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999 (Cth)</i>
IUCN	International Union for Conservation of Nature
PEC	priority ecological community
TEC	threatened ecological community

Map information

Disclaimer

The maps in this report are a product of the Department of Water and Environmental Regulation. These maps were produced with the intent that they be used for information purposes within this document and at the scale shown when printing. While the department has made all reasonable efforts to ensure the accuracy of this data, the department accepts no responsibility for any inaccuracies and persons relying on this data do so at their own risk.

Compilation date: August 2024

File path:

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Map sources

The Department of Water and Environmental Regulation is custodian of the following datasets used in production of the maps in this report:

- Towns – DWER, **DWER**.
- WRIMS – Groundwater subareas (DWER-083), **DWER**.
- WA Coastline – WRC (poly), **DWER**.

Other sources

(name, custodian, source, source link)

- Roads (LGATE_012), **Landgate**, SLIP:
<https://catalogue.data.wa.gov.au/dataset/roads-lgate-012>
- Hydrography – Inland Waters – Water Polygons (LGATE-016), **Landgate**, SLIP: <https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-water-polygon-lgate-016>
- Hydrography WA 250K - Surface Waterbodies (GA 2015), **Geoscience Australia**,
<https://ecat.ga.gov.au/geonetwork/srv/eng/catalog.search#/metadata/83135>
- Geonoma (LGATE-013), **Landgate**, SLIP:
<https://catalogue.data.wa.gov.au/dataset/geographic-names-geonoma>
- Airport Landing Grounds, **Landgate**, Landgate supplied.
- Heritage Council WA - State Register (DPLH-006), **DPLH**
<https://catalogue.data.wa.gov.au/dataset/heritage-council-wa-state-register>
- National Heritage List Spatial Database, **DCCEEW**,
<https://fed.dcceew.gov.au/datasets/erin::national-heritage-list-spatial-database-nhl-public/about>
- Commonwealth Heritage List Spatial Database, **DCCEEW**,
<https://fed.dcceew.gov.au/datasets/erin::commonwealth-heritage-list-1/about>
- Aboriginal Sites and Heritage Places, **DPLH**,
<https://catalogue.data.wa.gov.au/dataset/aboriginal-heritage-places>
- DBCA Legislated Lands and Waters, **DBCA**,
<https://catalogue.data.wa.gov.au/dataset/dbca-legislated-lands-and-waters>
- Threatened Ecological Communities, **DBCA**,
<https://catalogue.data.wa.gov.au/dataset/threatened-ecological-communities>

- Hydrography - Inland Waters - Waterlines (named rivers only), **Landgate**, <https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-water-line-lgate-018>
- Wetlands DIWA updated (DBCA), **DBCA**, <https://catalogue.data.wa.gov.au/dataset/directory-of-important-wetlands-in-western-australia>
- Wetlands DIWA 2018 (Repealed version), **DCCEEW**.
- Threatened and Priority Fauna – Planning, **DBCA**, DBCA supplied.
- Threatened and Priority Flora – Planning, **DBCA**, DBCA supplied.
- WA Herb - Planning Data, **DBCA**, DBCA supplied.
- Seabird Breeding Islands, externally supplied under license.
- Dugong Habitat, externally supplied under license.
- Hydrography – Coastal Flat (LGATE-122), **Landgate**, <https://catalogue.data.wa.gov.au/dataset/medium-scale-topo-coastal-flat-polygon-lgate-122>
- Seagrass, AU_seagrass05_POLY, **IMAS**, <https://metadata.imas.utas.edu.au/geonetwork/srv/api/records/61F2E4F8-96DB-4723-AADE-08274DAF2268>

Background imagery

- SatviewWA(LGATE-317),17/04/2024, **Landgate**, SLIP:
https://services.slip.wa.gov.au/arcgis/rest/services/Landgate_Restricted_Imagery/SatViewWA/MapServer

References

- 360 Environmental 2017a, *Australian bundle site; Learmonth habitat surveys*, prepared for Subsea 7, Perth.
- 2017b, *Australian bundle site; detailed flora and vegetation assessment*, prepared for Subsea 7, Perth.
- 2021 *Lots 284, 505, 550 and reserve 51970, Exmouth biological survey*, report prepared for Horizon Power.
- Allen AD 1993, *Outline of the geology and hydrogeology of the Cape Range, Carnarvon Basin, Western Australia*, Geological Survey of Western Australia, Perth.
- Antao M, Kilminster K, Adams K, McGivern M & Howles D 2020, *La Grange and Walyarta (Mandora Marsh) groundwater dependent investigation, SGIP project: scoping document*, Department of Water and Environmental Regulation, Perth.
- ARMCANZ and ANZECC 1996, *National principles for the provision of water for ecosystems, occasional paper SWR No. 3*, Sustainable land and water resource management committee, subcommittee on water resources, Commonwealth of Australia, Canberra.
- Bennelongia 2020, *Ningaloo Lighthouse Resort: subterranean fauna desktop assessment*, prepared for Tattarang, Perth.
- 2021, *Ningaloo Lighthouse Resort: stygofauna survey report*, prepared for Tattarang, Perth.
- Black S, Burbidge AA, Brooks D, Green P, Humphreys WF, Kendrick P, Myers D, Shepard R & Wann J 2001, *Cape Range remipede community (Bundera Sinkhole) and Cape Range remipede interim recovery plan 2000–2003*, Department of Conservation and Land Management, Threatened species and communities unit, Wanneroo.
- Brooks D 2015, 'An introduction to Cape Range caving and (very brief and very basic) geology'; in *Proceedings of the 30th ASF Conference, Exmouth 2015*, Australian Speleological Federation.
- CALM (Department of Conservation and Land Management) 1986, *Cape Range National Park; Charles Knife – Shothole walk trail*, CALM, Perth.
- Canham CA, Duvert C, Beesley LS, Douglas MM, Setterfield SA, Freestone FL, Clohessy S & Loomes RC 2021, 'The use of regional and alluvial groundwater by riparian trees in the wet-dry tropics of Northern Australia', *Hydrological Processes*, vol. 35 e14180.
- Carruthers TJB, van Tussenbroek BI & Dennison WC 2005, 'Influence of submarine springs and wastewater on nutrient dynamics of Caribbean seagrass meadows', *Estuarine, Coastal and Shelf Science*, vol. 64, pp 191–199.

- Collins LB & Stevens A 2010, *Assessment of coastal groundwater and linkages with Ningaloo Reef – final report*, a report for Western Australian Marine Science Institution, Curtin University of Technology, Perth.
- DBCA (Department of Biodiversity, Conservation and Attractions) 2023, [Florabase - the Western Australian Flora, DBCA, Perth \(dbca.wa.gov.au\)](https://www.dbca.wa.gov.au/Florabase), accessed 13/12/2023.
- DCCEEW (Department of Climate Change, Energy, the Environment and Water), 2023a, [Australian Heritage Database \(environment.gov.au\)](https://www.environment.gov.au/australian-heritage-database), Australian Government, accessed 19/07/2023.
- 2023b, [Australian Wetlands Database - Directory Wetland Information Sheet \(environment.gov.au\)](https://www.environment.gov.au/australian-wetlands-database).
- DEC (Department of Environment) 2010, *Cape Range National Park management plan*, DEC and Conservation and the Conservation Commission of Western Australia, Perth.
- 2012, *Camerons Cave Troglobitic Community, Camerons Cave millipede and Cameron Cave's pseudoscorpion interim recovery plan 2012–2017*, Plan no. 324, Department of Environment and Conservation, Perth.
- Deloitte Access Economics 2020, *Economic contribution of Ningaloo: one of Australia's best kept secrets*, a report to the Department of Biodiversity, Conservation and Attractions, Perth.
- DEWHA 2010, *Ningaloo Coast, world heritage nomination, Commonwealth of Australia*, Department of Environment, Water, Heritage and the Arts, Canberra.
- Doody TM, Colloff MJ, Davies M, Koul V, Benyon RG & Nagler PL 2015, 'Quantifying water requirements of riparian river red gum (*Eucalyptus camaldulensis*) in the Murray-Darling Basin, Australia – implications for the management of environmental flows', *Ecohydrology* 8, pp. 1471–1487.
- DWER (Department of Water and Environmental Regulation) 2022, *Native vegetation policy for Western Australia*, DWER, Joondalup.
- 2025, *Exmouth groundwater allocation limits review*, DWER, Joondalup.
- Environment Australia 2001, *A directory of important wetlands in Australia, third edition*, Environment Australia, Canberra.
- EPA (Environmental Protection Authority) 1993, *Red Book status report*, EPA, Perth.
- 2008, *Environmental guidance for planning and development: Guidance statement no. 33*, Environmental Protection Authority, Perth.
- 2018, *Environmental factor guideline – Inland Waters*, Government of Western Australia, Environmental Protection Authority, [Environmental factor guideline – Inland Waters | EPA Western Australia](https://www.epa.wa.gov.au/inland-waters).
- 2021, *Potential cumulative impacts of proposed activities and developments on the environmental, social and cultural values of the Exmouth Gulf*, Environmental Protection Authority, Perth.

- Exmouth Gulf Taskforce 2023, *Interim report to the Minister for Environment*, Department of Water and Environmental Regulation, Joondalup.
- Forth J 1972, *Exmouth water supply, Hydrology report 961*, record 1972/16, Geological survey of Western Australia, Perth.
- 1973, *Exmouth water supply, Geological survey of Western Australia annual report 1972*, Geological survey of Western Australia, Perth.
- GHD 2019, *Learmonth pipeline fabrication facility surface and groundwater investigation*, report prepared for Subsea 7 Contracting PL.
- 2022, *Exmouth renewable power infrastructure flora and fauna survey*, report prepared for Horizon Power.
- Gibson LA 2014, 'Biogeographic patterns on Kimberley islands', Western Australia, *Records of the Western Australian Museum* 81, pp. 245–280.
- 2018, *Shedding new light, A research program for Western Australia*, Western Australian Biodiversity Science Institute, Perth.
- Green E & Short F 2003, *World atlas of seagrasses*, prepared by the UNEP World Conservation Monitoring Centre, University of California Press, Berkeley, USA.
- Hamilton-Smith E, Kiernan K & Spate A 1998, *Karst management considerations for the Cape Range karst province, Western Australia*, report prepared for the Department of Environmental Protection, Perth.
- Hayes M, Jesse A, Welte N, Tabet B, Lockington D & Lovelock C 2018, 'Groundwater enhances above-ground growth in mangroves', *Journal of Ecology*, British Ecological Society.
- Heritage council 2023, *Vlamingh Head Lighthouse*, Government of Western Australia, accessed 19/7/2023, [inHerit - State Heritage Office](#).
- Hickey SM & Lovelock CE 2022, *The salt flats of Exmouth Gulf: ecological functions and threats*, the University of Western Australia, Perth.
- Hickey SM, Radford B, Callow N, Phinn S, Duarte C & Lovelock C 2021, 'ENSO feedback drives variations in dieback at a marginal mangrove site', *Scientific reports, naturereportfolio*, www.nature.com/scientificreports.
- Humphreys WF 1999a, 'Physico-chemical profile and energy fixation in Bundera Sinkhole, an anchialine remipede habitat in north-western Australia', *Journal of the Royal Society of Western Australia*, 82, pp. 89–98.
- 1999b, 'The distribution of Australian cave fishes', *Records of the Western Australian Museum*, vol. 19, pp. 146–472.
- 2000, 'Major climatic change – an example from arid tropical Western Australia', In *Biodiversity in wetlands: assessment, function and conservation*, vol. 1, pp. 227–258, Eds. B Gopal, WJ Junk & JA Davis, Backhuys Publishers, Leiden, The Netherlands.

- Humphreys WF, Brooks RD & Vines B 1990, 'Rediscovery of the palm *Livistona alfredii* on the North West Cape Peninsula', *Records of the Western Australian Museum*, vol. 14, 4, pp. 647–650.
- Humphreys WF, Shiao JC, Lizuka Y & Wann-NianTzeng WN 2006, 'Can otolith microchemistry reveal whether the blind cave gudgeon, *Milyeringa veritas* (Eleotridae), is diadromous within a subterranean estuary?', *Environmental Biology of Fishes*, vol. 75, pp. 439–453.
- Hyd2o Hydrology 2014, *Exmouth hydrological study report to the Shire of Exmouth*, Perth.
- IUCN 2024, *The IUCN Red List of Threatened Species*, Version 2023-1, International Union for Conservation of Nature Natural Resources, [IUCN Red List of Threatened Species](#).
- Jaensch R & Watkins D 1999, *Nomination of additional Ramsar wetlands in Western Australia, final report to the Western Australian Department of Conservation and Land Management*, Wetlands International – Oceania.
- Keighery G & Gibson N 1993, 'Biogeography and composition of the flora of the Cape Range peninsula, Western Australia', *Records of the Western Australian Museum*, vol. 45, pp. 51–8.
- Keighery G & Lilburn L 2019, *Cape Range bush blitz, vascular plants*, Perth.
- Kendrick G & Porter J 1973, 'Remains of a thylacine (Marsupialia: Dasyuroidea) and other fauna from caves in the Cape Range, Western Australia', *Journal of the Royal Society of Western Australia*, vol. 56, pp. 116–122.
- Kilminster K, Bennett, K et al (in prep), *Groundwater connections: Investigating links to the nearshore marine ecosystems in the La Grange Region*, Department of Water and Environmental Regulation, Western Australia
- Korbel K, Stephenson S & Hose G 2019, 'Sediment size influences habitat selection and use by groundwater macrofauna and meiofauna', *Aquatic Sciences*, vol. 81, p. 39.
- La Valle FF, Kantar MB & Nelson CE 2020, 'Coral reef benthic community structure is associated with the spatiotemporal dynamics of submarine groundwater discharge chemistry', *Limnology and Oceanography*.
- Long V & Alymore P 2021, *Mowbowra precinct, Western Australia flora and fauna surveys final report*, Perth.
- McMahon K, Hernawan U, Dawkins K, van Dijk K & Waycott M 2017, *Population genetic diversity, structure and connectivity of two seagrass species, *Thalassia hemprichii* and *Halophila ovalis* in the Kimberley*, report of project 1.1.3 – project 1.1.3.2 prepared for the Kimberley Marine Research Program, Western Australian Marine Science Institution, Perth.

- Mensforth L, Thorburn P, Tyerman S & Walker G 1994, 'Sources of water used by riparian *Eucalyptus camaldulensis* overlying highly saline groundwater', *Oecologia* 100, pp. 21–28.
- Oceanwise Australia Pty Ltd 2022, *Review of the environmental values of the Qualing Pool and Mowbowra Creek areas*, prepared for Protect Ningaloo – Australian Marine Conservation Society, Perth.
- Pollino C, Barber E, Buckworth R, Cadiegues M, Deng A, Ebner BC, Kenyon R, Liedloff AC, Merrin L, Moeseneder C, Morgan DL, Nielsen D, O'Sullivan J, Ponce Reyes R, Robson BJ, Stratford D, Stewart-Koster B & Turschwell M 2018, *Synthesis of knowledge to support the assessment of impacts of water resource development to ecological assets in northern Australia: asset analysis*; a technical report to the Australian Government from the CSIRO northern Australia water resource assessment, part of the National Water Infrastructure Development Fund: water resource assessment, Canberra.
- Seymour JR, Humphreys WF & Mitchell JG 2007 'Stratification of the microbial community inhabiting an anchialine sinkhole', *Aquatic Microbial Ecology*, vol. 50, pp. 11–24.
- Sinclair T & Vitale S 2023, Exmouth surface water field reconnaissance (Feb 2023), Unpublished file note, Exmouth Gulf Taskforce.
- Sutton AL & Shaw JL 2021, *Cumulative pressures on the distinctive values of Exmouth Gulf*, first draft report to the Department of Water and Environmental Regulation by the Western Australian Marine Science Institution, Perth.
- Tomlinson M & Boulton AJ 2010, 'Ecology and management of subsurface groundwater dependent ecosystems in Australia – a review', *Marine and Freshwater Research*, vol. 61, pp. 936–949.
- WRC 1999, *Groundwater allocation plan: Exmouth groundwater subarea*, Water resource and allocation planning series, report no. 9, Water and Rivers Commission, Perth.
- 2000a, *Exmouth water reserve water source protection plan: Exmouth town water supply*, Water source protection series, report no. WRP 26, Water and Rivers Commission, Perth.
- 2000b, *Environmental water provisions policy for Western Australia*, Statewide policy no. 5, Water and Rivers Commission, Perth.

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