Hammersley Iron Railway

Hammersley Iron Railway

Hammersley Iron Railway

Tom Price Railway Rd

Nanutarra Rd

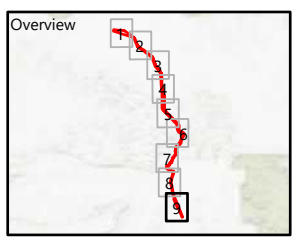
Vegetation

- M1 - *Acacia aptaneura* (*A. pruinocarpa*) low woodland over *Triodia epactia* (*T. melvillei*) very open hummock grassland over *Chrysopogon fallax* scattered tussock grasses.
- M2 - *Acacia ?macraneura*, *A. aptaneura* over *Triopia epactia* scattered hummock grasses.

Figure 8 Vegetation Types

Legend

- Roads
- Railways
- Rivers and Creeks
- Disturbance Footprint
- Development Envelope



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Kilometres

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JACOBS, 263 Adelaide Terrace, Perth WA 6000
Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

541800 546000 550200

7606200 7602000 7597800

Hammersley Iron Railway

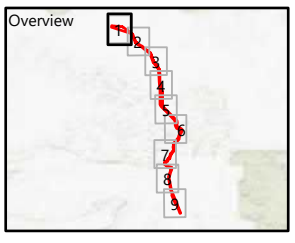
Roebourne-Wittenoom Rd

Tom Price Railway Rd

Vegetation Condition
- Excellent
- Very Good
- Good
- Poor
- Cleared

Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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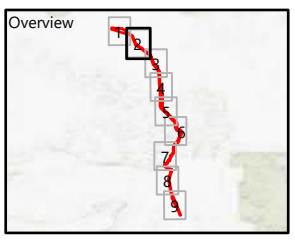
Hammersley Iron Railway
Tom Price Railway Rd

Vegetation Condition
- Excellent
- Excellent to Very Good
- Very Good
- Good
- Good to Poor
- Poor
- Cleared

Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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Hammersley Iron Railway

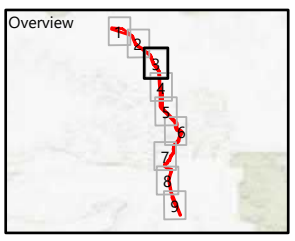
Tom Price Railway Rd

Tom Pric

Vegetation Condition
- Excellent
- Very Good
- Good
- Good to Poor
- Poor
- Cleared

Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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Kilometres

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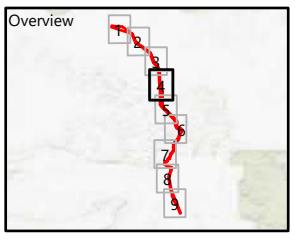
Tom Price Railway Rd
Hammersley Iron Railway

Vegetation Condition
- Excellent
- Very Good
- Good
- Cleared

Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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Tom Price Railway Rd
Hammersley Iron Railway
Vegetation Condition
- Excellent
- Excellent to Very Good
- Very Good
- Very Good to Good
- Good
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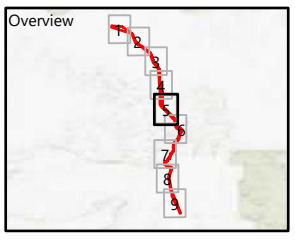
Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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Tom Price Railway Rd
Hammersley Iron Railway

Vegetation Condition
- Excellent
- Excellent to Very Good
- Very Good
- Very Good to Good
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- Good to Poor
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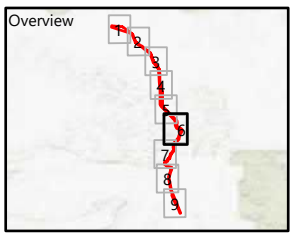
- Cleared

Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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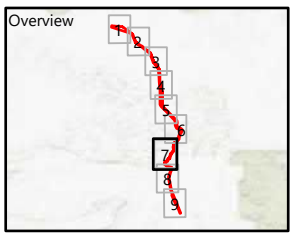
Tom Price Railway Rd
Hammersley Rd
Hammersley Iron Railway
Vegetation Condition
Excellent
Very Good
Very Good to Good
Good
Good to Poor
Cleared

Figure 9 Vegetation Condition

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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Hammersley Rd
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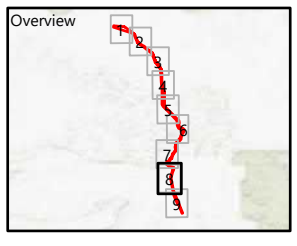
Tom Price Railway Rd
Vegetation Condition
- Excellent
- Excellent to Very Good
- Very Good
- Very Good to Good
- Good
- Good to Poor
- Cleared

Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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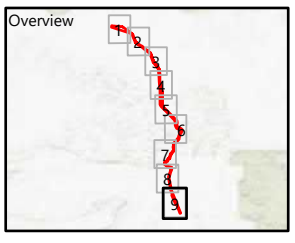
Hammersley Iron Railway
Hammersley Iron Railway
Hammersley Iron Railway
Tom Price Railway Rd
Nanutarra Rd

Vegetation Condition
- Excellent to Very Good
- Very Good
- Good
- Cleared

Figure 9 Vegetation Condition

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Rivers and Creeks



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Inset Map

Hammersley Iron Railway

Roebourne-Wittenoom Rd

Tom Price Railway Rd

Flora Observation

- P2 - *Euphorbia inappendiculata* var. *inappendiculata*
- P2 - *Euphorbia inappendiculata* var. *queenslandica*
- P3 - *Dolichocarpa* sp. Hamersley Station (A.A. Mitchell PRP 1479)
- P3 - *Euphorbia australis* var. *glabra*
- P3 - *Gymnanthera cunninghamii*
- P3 - *Swainsona thompsoniana*
- P3 - *Themeda* sp. Hamersley Station (M.E. Trudgen 11431)
- P4 - *Goodenia berringbinensis*
- P4 - *Goodenia nuda*

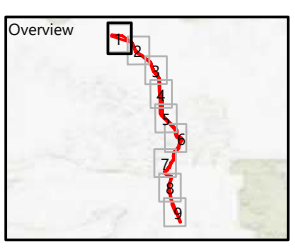
Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened



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Hammersley Iron Railway

Tom Price Railway Rd

Flora Observation

P4 - *Goodenia nuda*

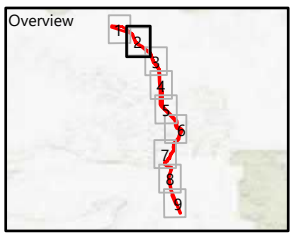
Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened



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Kilometres

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Inset Map

Hamilton-Tom Price Iron Railway

Tom Price Railway Rd

Tom Price

Flora Observation

- P3 - *Euphorbia australis* var. *glabra*
- P4 - *Goodenia nuda*

Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened

Overview

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Kilometres

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Inset Map

Hammersley Iron Railway

Flora Observation

- P1 - *Josephinia* sp. Woodstock (A.A. Mitchell PRP 989) PN
- P4 - *Goodenia nuda*

Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened

Overview

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Kilometres

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Tom Price Railway Rd
Hammersley Iron Railway
Flora Observation
P4 - *Goodenia nuda*

Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened

Overview

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Kilometres

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Tom Price Railway Rd

Hammersley Iron Railway

Flora Observation

- P1 - *Hibiscus* sp. Mt Brockman (E. Thoma ET 1354)
- P3 - *Triodia basitricha*
- P4 - *Goodenia nuda*

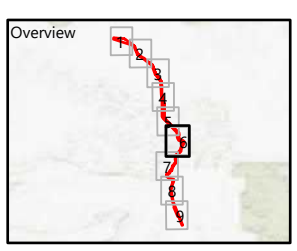
Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

562800 567000 571200

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Inset Map

Tom Price Railway Rd

Hammersley Rd

Hammersley Iron Railway

Flora Observation

- P1 - *Hibiscus* sp. Mt Brockman (E. Thoma ET 1354)
- P2 - *Aristida lazaridis*
- P3 - *Glycine falcata*
- P3 - *Sida* sp. Hamersley Range (K. Newbey 10692)
- P3 - *Themeda* sp. Hamersley Station (M.E. Trudgen 11431)
- P4 - *Eremophila magnifica* subsp. *magnifica*
- P4 - *Goodenia nuda*
- T - *Seringia exastia*

Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened

Overview

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Kilometres

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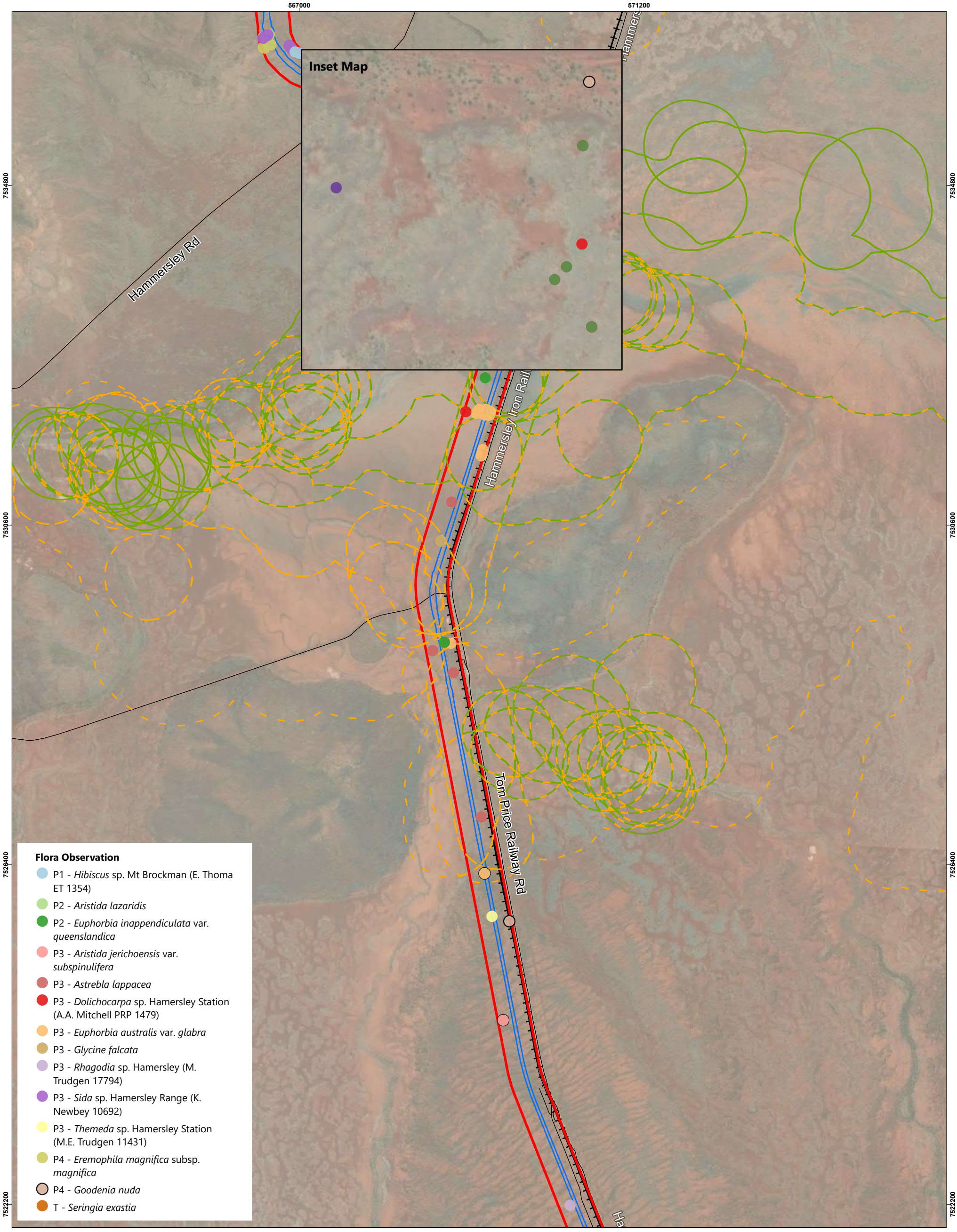


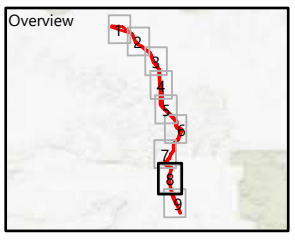
Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened



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Hammersley Iron Railway
Hammersley Iron Railway
Tom Price Railway Rd
Nanutarra Rd

Flora Observation

- P1 - *Vittadinia* sp. Coondewanna Flats (S. van Leeuwen 4684)
- P3 - *Aristida jerichoensis* var. *subspinulifera*
- P3 - *Rhagodia* sp. Hamersley (M. Trudgen 17794)
- P3 - *Sida* sp. Hamersley Range (K. Newbey 10692)
- P3 - *Themeda* sp. Hamersley Station (M.E. Trudgen 11431)
- P4 - *Goodenia nuda*

Figure 10 Conservation Significant Flora

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

State Listd TECs and PECs

- Priority
- Threatened

Overview

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Kilometres

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Hammersley Iron Railway

Roebourne-Wittenoom Rd

Tom Price Railway Rd

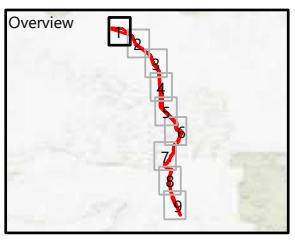
Weed Species

- Cenchrus ciliaris
- Cenchrus setiger
- Cynodon dactylon
- Echinochloa colona
- Flaveria trinervia
- Malvastrum americanum
- Portulaca pilosa s. lat
- Tribulus terrestris
- Vachellia farnesiana

Figure 11 Invasive Flora Species

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope



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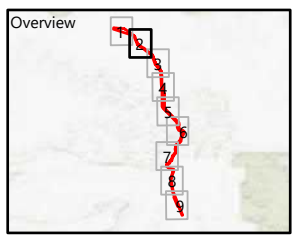
Hammersley Iron Railway
Tom Price Railway Rd

Weed Species
- Bidens bipinnata
- Cenchrus ciliaris
- Cenchrus setiger
- Echinochloa colona
- Vachellia farnesiana

Figure 11 Invasive Flora Species

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope



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Hammersley Iron Railway

Tom Price Railway Rd

Weed Species

- Aerva javanica
- Bidens bipinnata
- Cenchrus ciliaris
- Cenchrus setiger
- Echinochloa colona
- Flaveria trinervia
- Malvastrum americanum
- Portulaca pilosa s. lat
- Setaria verticillata
- Sonchus oleraceus
- Vachellia farnesiana

Figure 11 Invasive Flora Species

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Overview

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Kilometres

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Tom Price Railway Rd

Hammersley Iron Railway

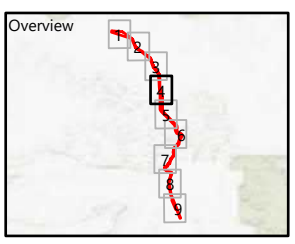
Weed Species

- Aerva javanica
- Bidens bipinnata
- Cenchrus ciliaris
- Cenchrus setiger
- Flaveria trinervia
- Malvastrum americanum
- Portulaca pilosa s. lat
- Setaria verticillata
- Sonchus oleraceus

Figure 11 Invasive Flora Species

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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Tom Price Railway Rd

Hammersley Iron Railway

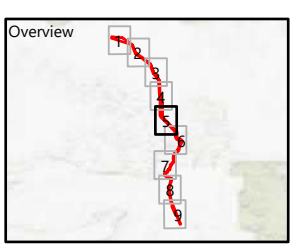
Weed Species

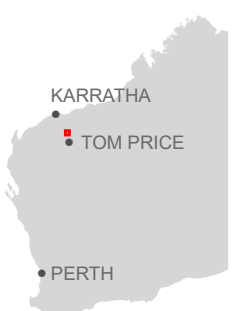
- Cenchrus ciliaris
- Cenchrus setiger
- Flaveria trinervia
- Malvastrum americanum
- Vachellia farnesiana

Figure 11 Invasive Flora Species

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope





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Tom Price Railway Rd

Hammersley Iron Railway

Weed Species
- Aerva javanica
- Cenchrus ciliaris
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- Cynodon dactylon
- Echinochloa colona
- Flaveria trinervia
- Malvastrum americanum
- Rumex vesicarius
- Setaria verticillata
- Tribulus terrestris
- Vachellia farnesiana

Figure 11 Invasive Flora Species

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope

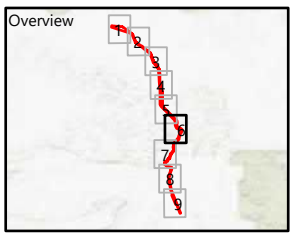

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Figure 11 Invasive Flora Species

Legend
- Roads
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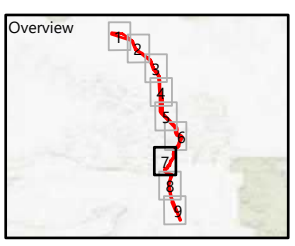
- Disturbance Footprint
- Development Envelope



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Kilometres

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Jacobs

JACOBS, 263 Adelaide Terrace, Perth WA 6000
Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

567000
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Hammersley Rd
Hammersley Iron Railway
Tom Price Railway Rd

Weed Species
- Bidens bipinnata
- Cenchrus ciliaris
- Cenchrus setiger
- Datura leichhardtii subsp. leichhardtii
- Echinochloa colona
- Malvastrum americanum
- Setaria verticillata
- Tribulus terrestris
- Vachellia farnesiana

Figure 11 Invasive Flora Species

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Overview

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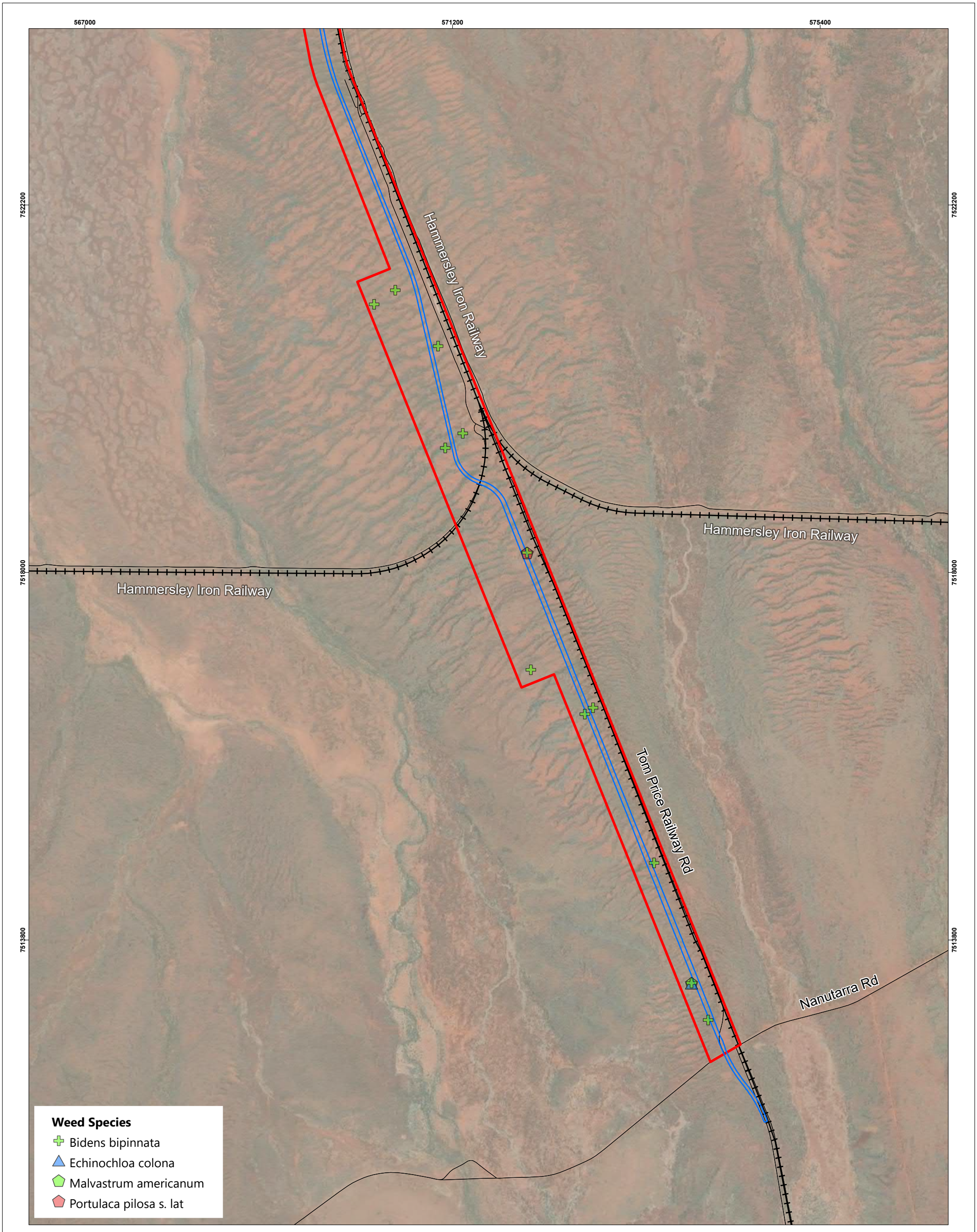
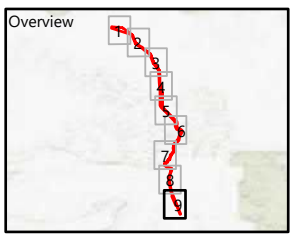


Figure 11 Invasive Flora Species

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope



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541800 546000 550200

7606200 7602000 7597800

Hammersley Iron Railway

Roebourne-Wittenoom Rd

Tom Price Railway Rd

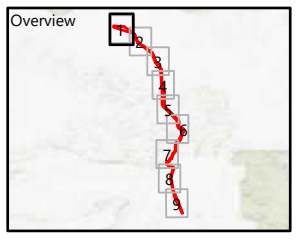
Fauna Habitat

- ASCC - *Acacia xyphophylla* shrublands over cracking clay
- ASM - Mixed Acacia shrublands
- MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 12 Fauna habitats

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tom Price Railway Rd

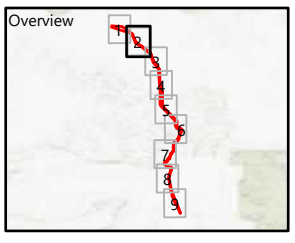
Fauna Habitat

- ASCC - *Acacia xyphophylla* shrublands over cracking clay
- ASM - Mixed Acacia shrublands
- CP - Floodplain
- MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 12 Fauna habitats

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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7593600 7589400 7585200 7581000

Hammersley Iron Railway

Tom Price Railway Rd

Rhinonicteris aurantia Pilbara FormRhinonicteris aurantia Pilbara Form

Tom Price

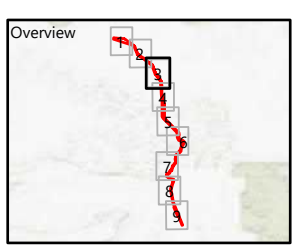
Fauna Habitat

- ASM - Mixed Acacia shrublands
- CP - Floodplain
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MWP - Mulga woodland plain

Figure 12 Fauna habitats

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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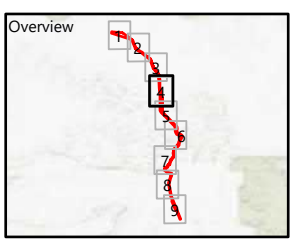
Tom Price Railway Rd
Hammersley Iron Railway

Fauna Habitat
- ASM - Mixed Acacia shrublands
- CP - Floodplain
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MMW - Man made water bodies
- MWP - Mulga woodland plain

Figure 12 Fauna habitats

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tom Price Railway Rd
Pseudomys chapmani
Hammersley Iron Railway

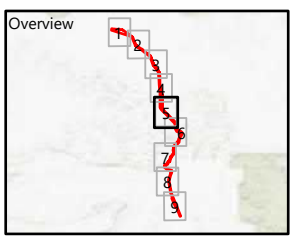
Fauna Habitat

- ASM - Mixed Acacia shrublands
- CP - Floodplain
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MDM - Melaleuca forest/major drainage lines
- MMW - Man made water bodies
- RHS - Rocky hills and slopes with low open spinifex and scattered trees

Figure 12 Fauna habitats

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Kilometres

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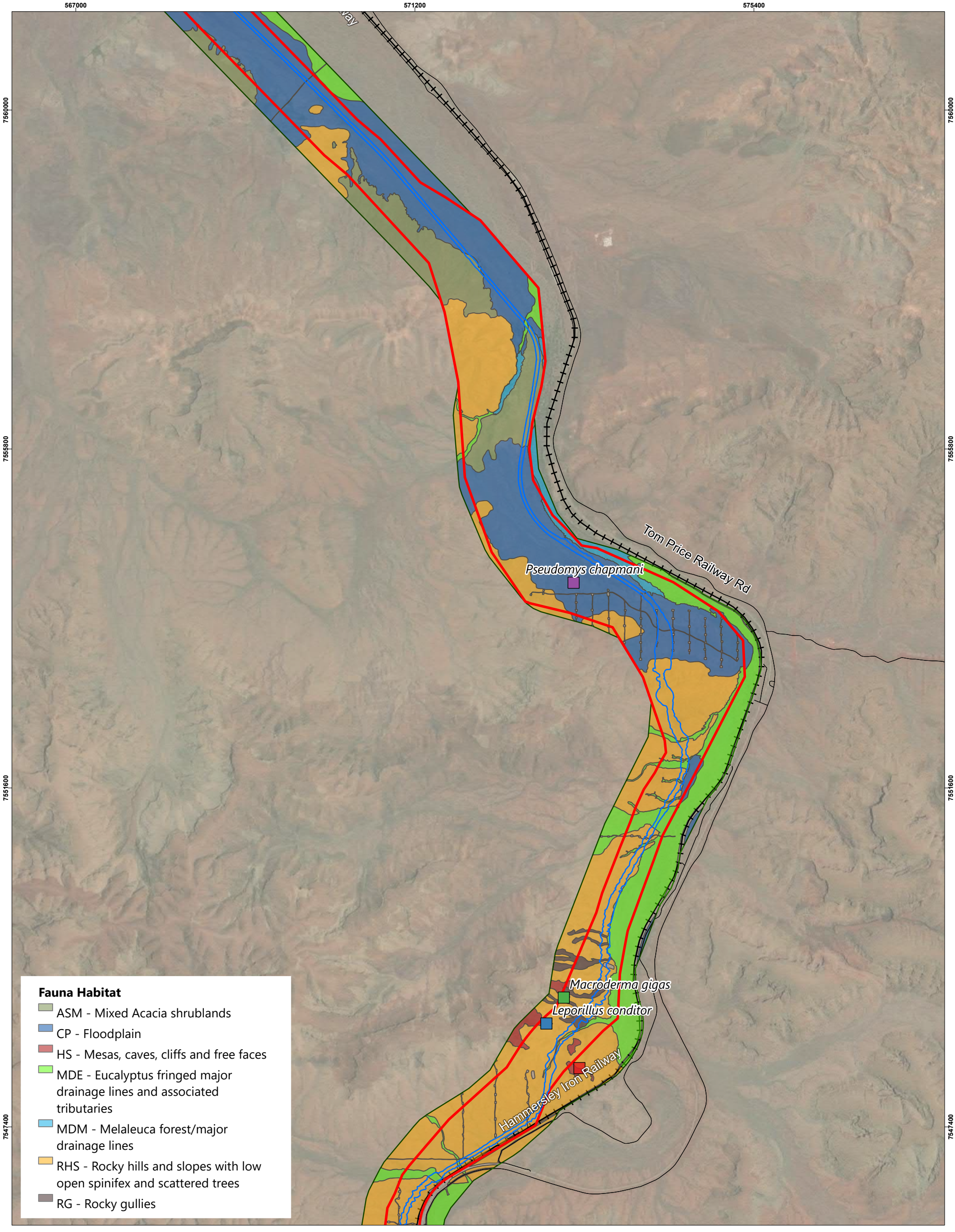
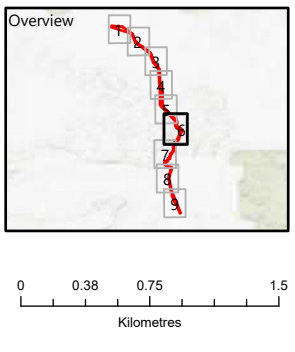


Figure 12 Fauna habitats

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tom Price Railway Rd
Hammersley Rd
Hammersley Iron Railway
Macroderma gigas
Macroderma gigas
Pseudomys chapmani
Pseudomys chapmani

Fauna Habitat

- ASM - Mixed Acacia shrublands
- CP - Floodplain
- GPCC - Grassland plains with cracking clay
- HS - Mesas, caves, cliffs and free faces
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MG - Grove Mulga
- MWP - Mulga woodland plain

Figure 12 Fauna habitats

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary

Overview

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Kilometres

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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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7534800 7530600 7526400 7522200

Macroderma gigas

Pseudomys chapmani

Hammersley Rd

Hammersley Iron Railway

Tom Price Railway Rd

Rhinonicteris aurantia Pilbara Form

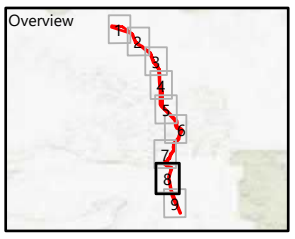
Fauna Habitat

- ASM - Mixed Acacia shrublands
- GPCC - Grassland plains with cracking clay
- HS - Mesas, caves, cliffs and free faces
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MG - Grove Mulga
- MMW - Man made water bodies
- MWP - Mulga woodland plain

Figure 12 Fauna habitats

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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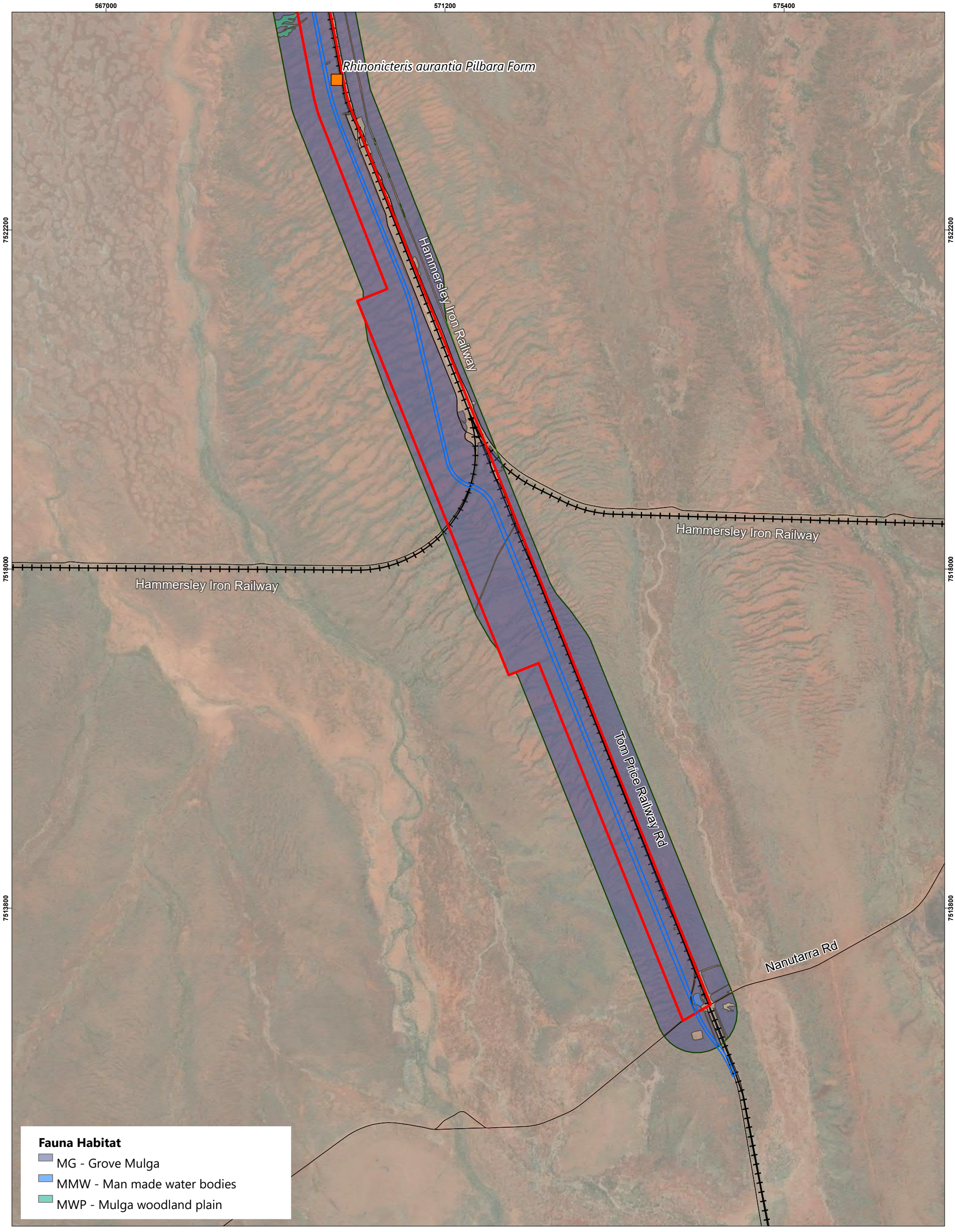

Figure 12 Fauna habitats

Legend

- Roads
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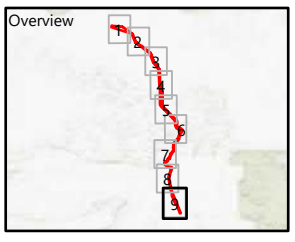
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Hammersley Iron Railway

Roebourne-Wittenoom Rd

Tom Price Railway Rd

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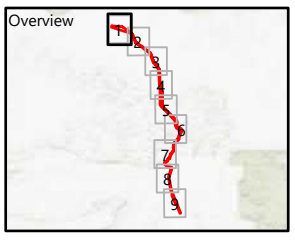
Supporting Northern Quoll Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tom Price Railway Rd

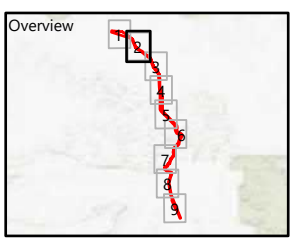
Supporting Northern Quoll Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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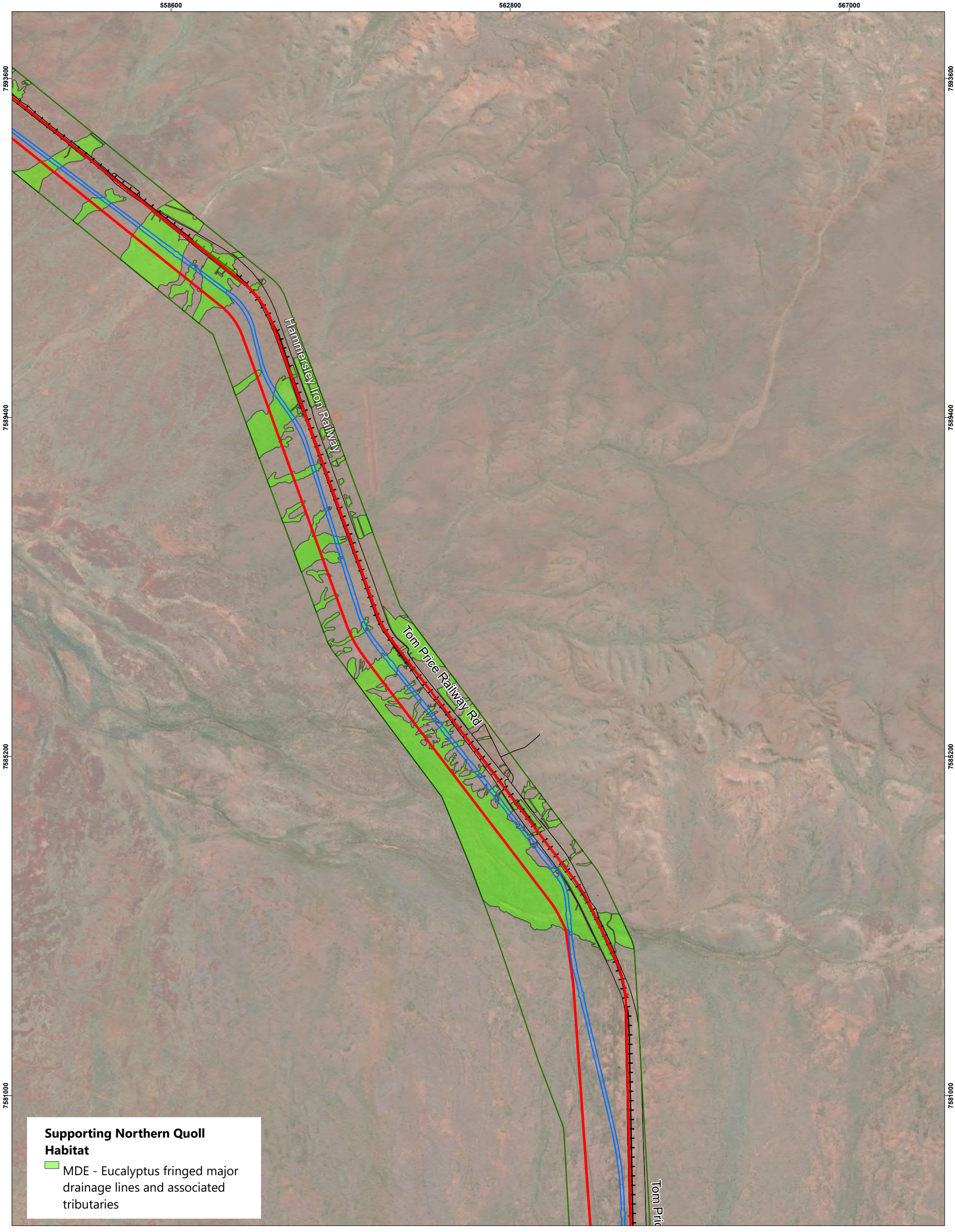
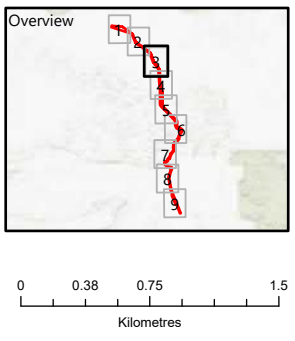


Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

562800
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Tom Price Railway Rd
Hammersley Iron Railway

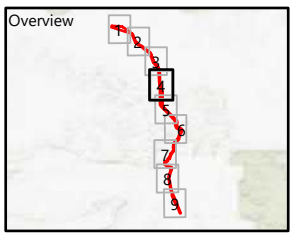
Supporting Northern Quoll Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Kilometres

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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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Tom Price Railway Rd

Hammersley Iron Railway

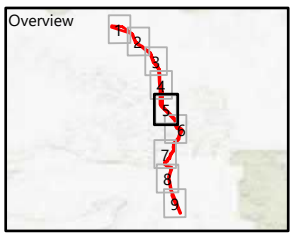
Supporting Northern Quoll Habitat

- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MDM - Melaleuca forest/major drainage lines
- RHS - Rocky hills and slopes with low open spinifex and scattered trees

Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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Tom Price Railway Rd

Hammersley Iron Railway

Habitat Critical to the Survival of the Species

- HS - Mesas, caves, cliffs and free faces
- RG - Rocky gullies

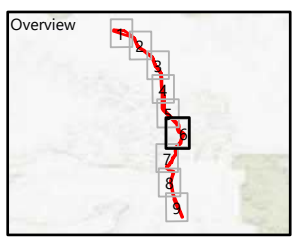
Supporting Northern Quoll Habitat

- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MDM - Melaleuca forest/major drainage lines
- RHS - Rocky hills and slopes with low open spinifex and scattered trees

Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tom Price Railway Rd
Hammersley Rd
Hammersley Iron Railway

Habitat Critical to the Survival of the Species

HS - Mesas, caves, cliffs and free faces

Supporting Northern Quoll Habitat

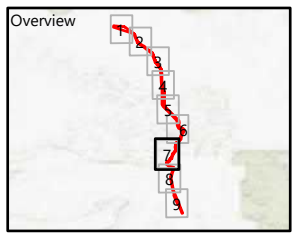
MDE - Eucalyptus fringed major drainage lines and associated tributaries

RHS - Rocky hills and slopes with low open spinifex and scattered trees

Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Hammersley Rd
Hammersley Iron Railway
Tom Price Railway Rd

Habitat Critical to the Survival of the Species

HS - Mesas, caves, cliffs and free faces

Supporting Northern Quoll Habitat

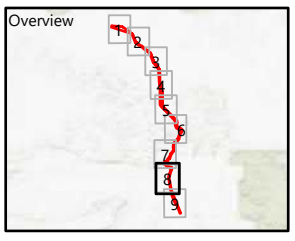
MDE - Eucalyptus fringed major drainage lines and associated tributaries

RHS - Rocky hills and slopes with low open spinifex and scattered trees

Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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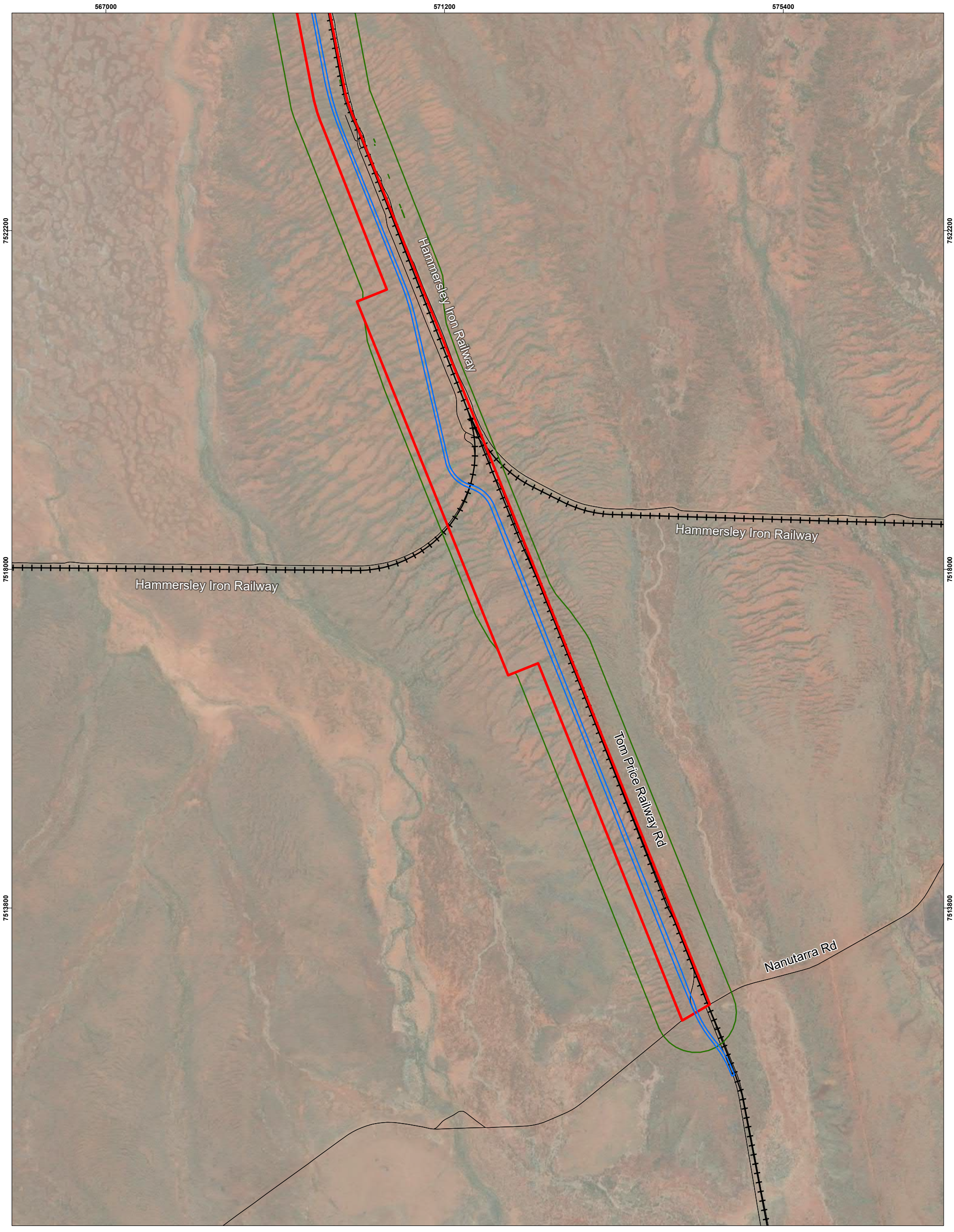
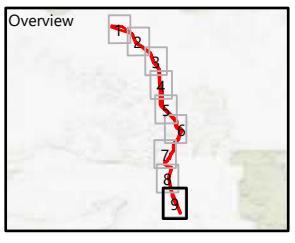


Figure 13 Northern Quoll Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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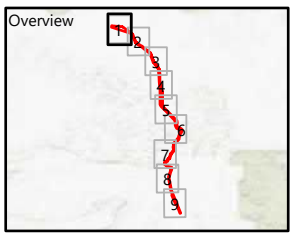
Pilbara Leaf-nosed Bat Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Kilometres

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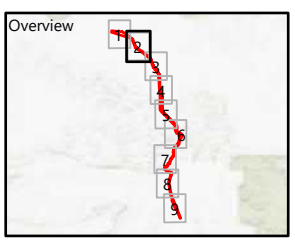
Pilbara Leaf-nosed Bat Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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Rhinonicteris aurantia Pilbara Form

Pilbara Leaf-nosed Bat Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

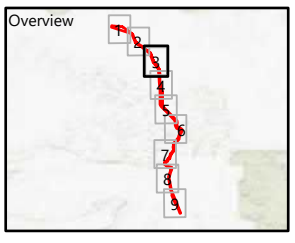
Fauna Observation

Rhinonicteris aurantia Pilbara Form, VU

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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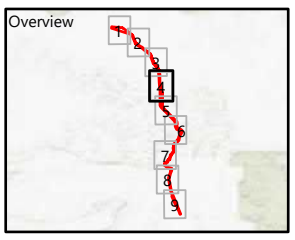
Pilbara Leaf-nosed Bat Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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JACOBS, 263 Adelaide Terrace, Perth WA 6000
Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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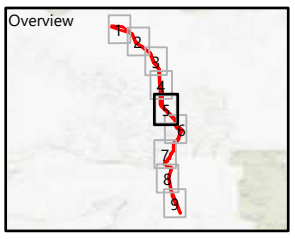
Pilbara Leaf-nosed Bat Habitat

- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MDM - Melaleuca forest/major drainage lines
- RHS - Rocky hills and slopes with low open spinifex and scattered trees

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Kilometres

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JACOBS, 263 Adelaide Terrace, Perth WA 6000
Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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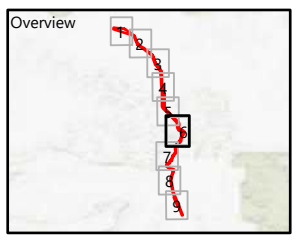
Pilbara Leaf-nosed Bat Habitat

- HS - Mesas, caves, cliffs and free faces
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MDM - Melaleuca forest/major drainage lines
- RHS - Rocky hills and slopes with low open spinifex and scattered trees
- RG - Rocky gullies - Important Habitat

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Pilbara Leaf-nosed Bat Habitat

- HS - Mesas, caves, cliffs and free faces
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
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Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
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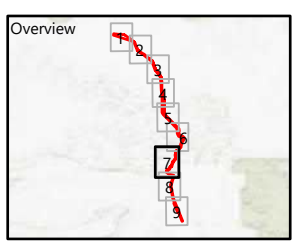
- Fauna Habitat Survey Boundary



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Rhinonicteris aurantia Pilbara Form

Pilbara Leaf-nosed Bat Habitat

- HS - Mesas, caves, cliffs and free faces
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- RHS - Rocky hills and slopes with low open spinifex and scattered trees

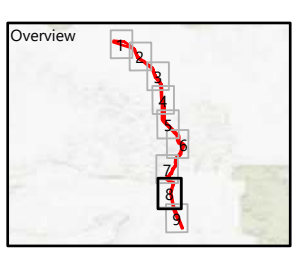
Fauna Observation

- *Rhinonicteris aurantia* Pilbara Form, VU

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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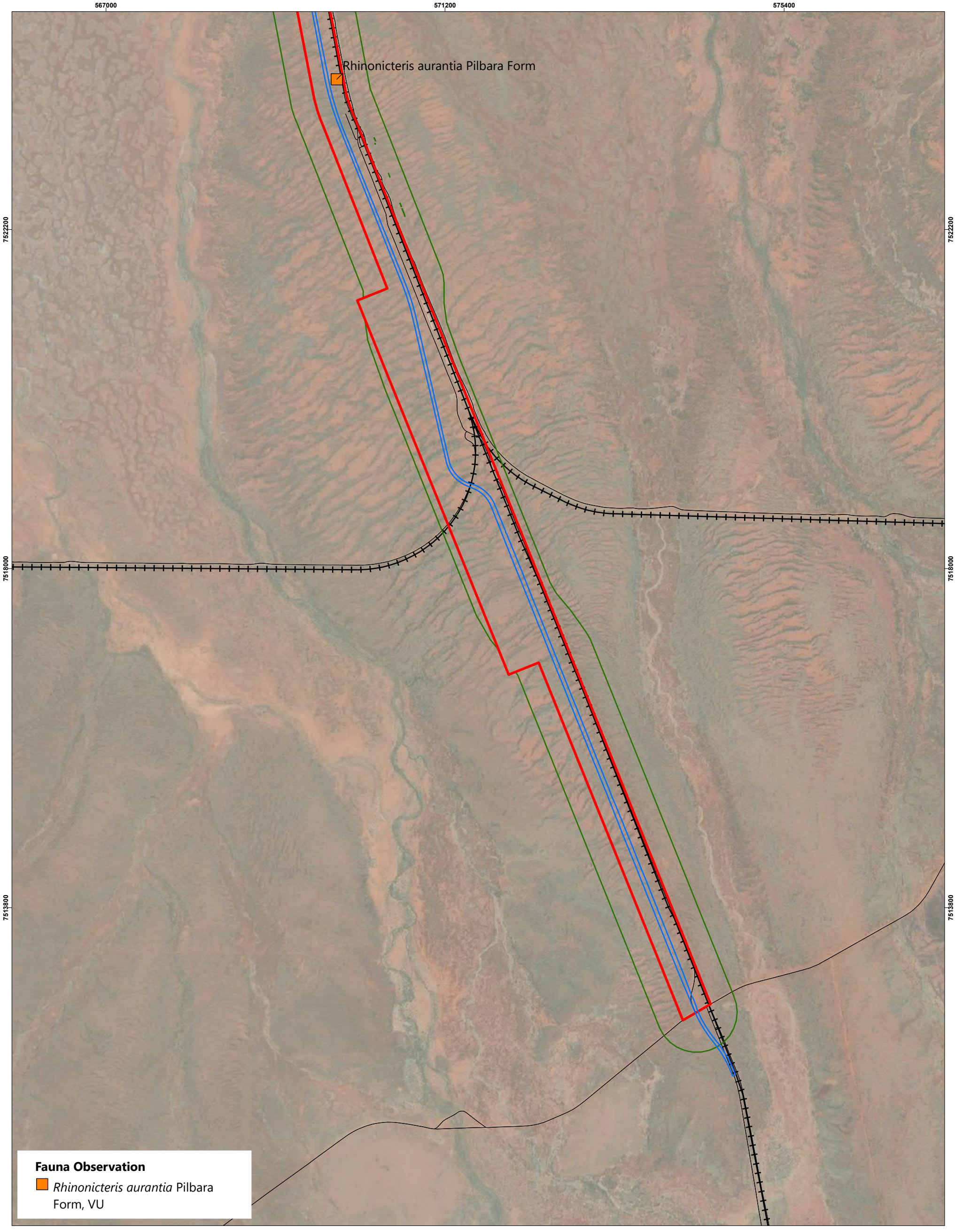

Figure 14 Pilbara Leaf-nosed Bat Habitat

Legend

- Roads
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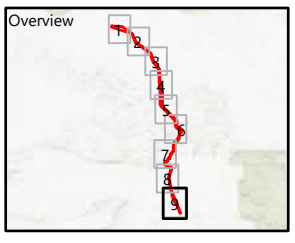
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Hammersley Iron Railway

Roebourne-Wittenoom Rd

Tom Price Railway Rd

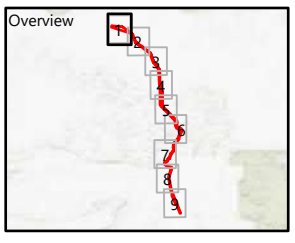
Ghost Bat Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries - Important Habitat

Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tom Price Railway Rd

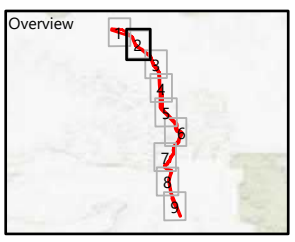
Ghost Bat Habitat

- CP - Floodplain - Other Suitable Habitat
- MDE - Eucalyptus fringed major drainage lines and associated tributaries - Important Habitat

Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Hammersley Iron Railway

Tom Price Railway Rd

Tom Price

Ghost Bat Habitat

- CP - Floodplain - Other Suitable Habitat
- MDE - Eucalyptus fringed major drainage lines and associated tributaries - Important Habitat

Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
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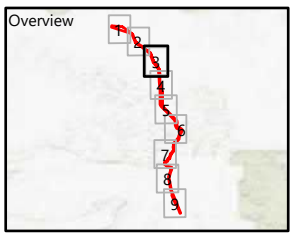
- Fauna Habitat Survey Boundary



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Hammersley Iron Railway

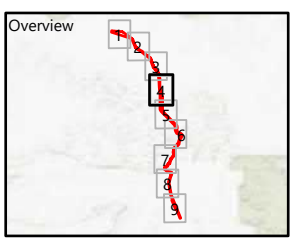
Ghost Bat Habitat

- CP - Floodplain - Other Suitable Habitat
- MDE - Eucalyptus fringed major drainage lines and associated tributaries - Important Habitat
- MMW - Man made water bodies

Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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Tom Price Railway Rd

Hammersley Iron Railway

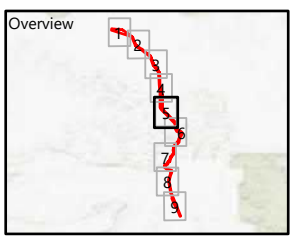
Ghost Bat Habitat

- CP - Floodplain - Other Suitable Habitat
- MDE - Eucalyptus fringed major drainage lines and associated tributaries - Important Habitat
- MDM - Melaleuca forest/major drainage lines - Important Habitat
- MMW - Man made water bodies
- RHS - Rocky hills and slopes with low open spinifex and scattered trees - Important Habitat

Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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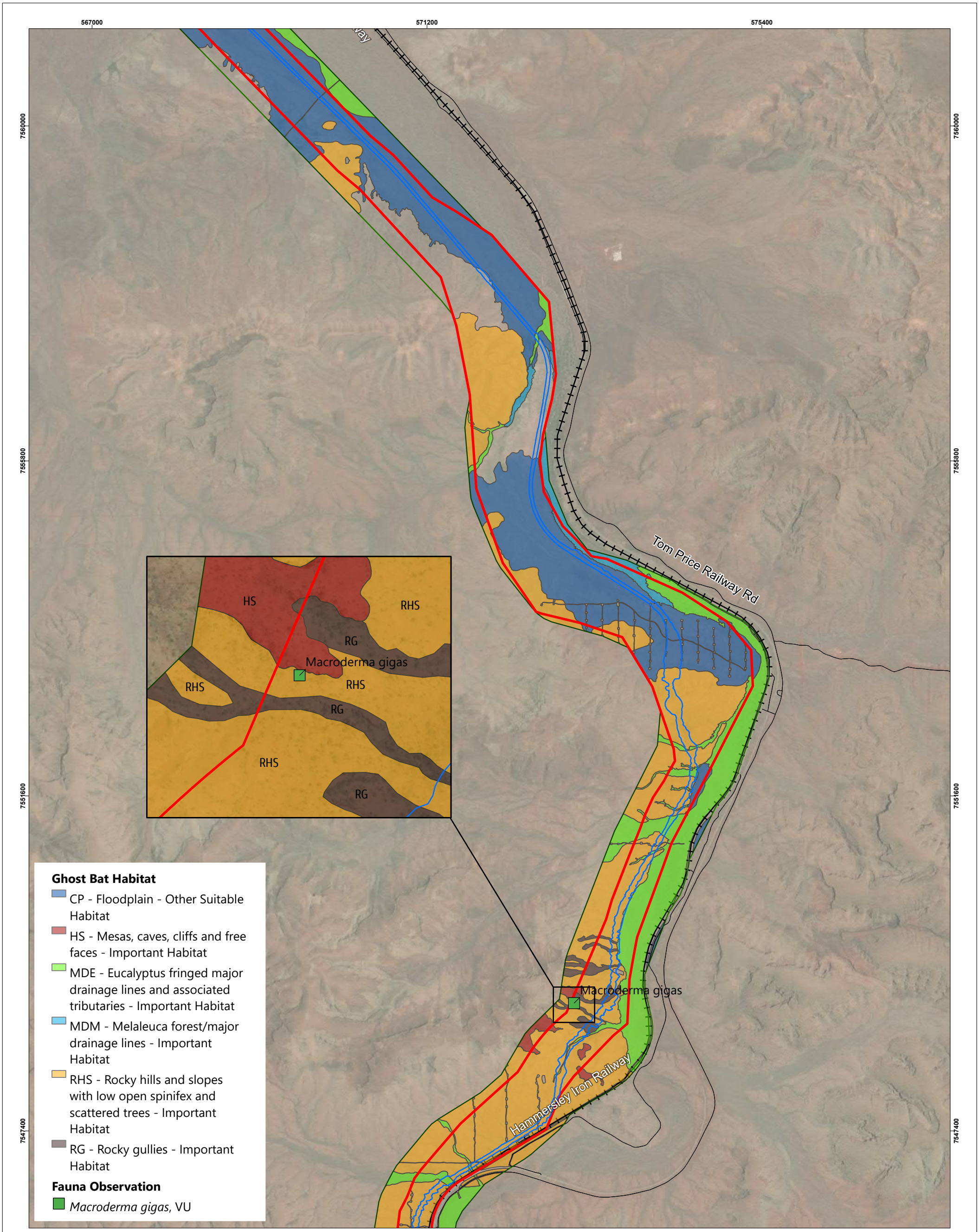

Figure 15 Ghost Bat Habitat

Legend

- Roads
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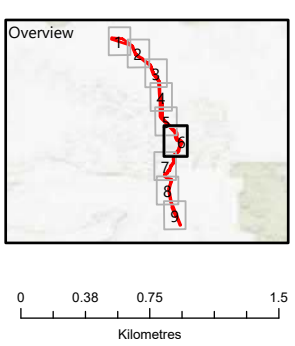
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Tom Price Railway Rd
Hammersley Rd
Hammersley Iron Railway

RHS
Macroderma gigas
RHS
Macroderma gigas
RHS
HS

Macroderma gigas
Macroderma gigas

Ghost Bat Habitat

- CP - Floodplain - Other Suitable Habitat
- HS - Mesas, caves, cliffs and free faces - Important Habitat
- MDE - Eucalyptus fringed major drainage lines and associated tributaries - Important Habitat
- RHS - Rocky hills and slopes with low open spinifex and scattered trees - Important Habitat

Fauna Observation

- *Macroderma gigas*, VU

Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary

Overview

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Kilometres

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Jacobs

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Macroderma gigas

Hammersley Rd

Hammersley Iron Railway

Tom Price Railway Rd

Ghost Bat Habitat

- HS - Mesas, caves, cliffs and free faces - Important Habitat
- MDE - Eucalyptus fringed major drainage lines and associated tributaries - Important Habitat
- MMW - Man made water bodies
- RHS - Rocky hills and slopes with low open spinifex and scattered trees - Important Habitat

Fauna Observation

- *Macroderma gigas*, VU

Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary

Overview

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Kilometres

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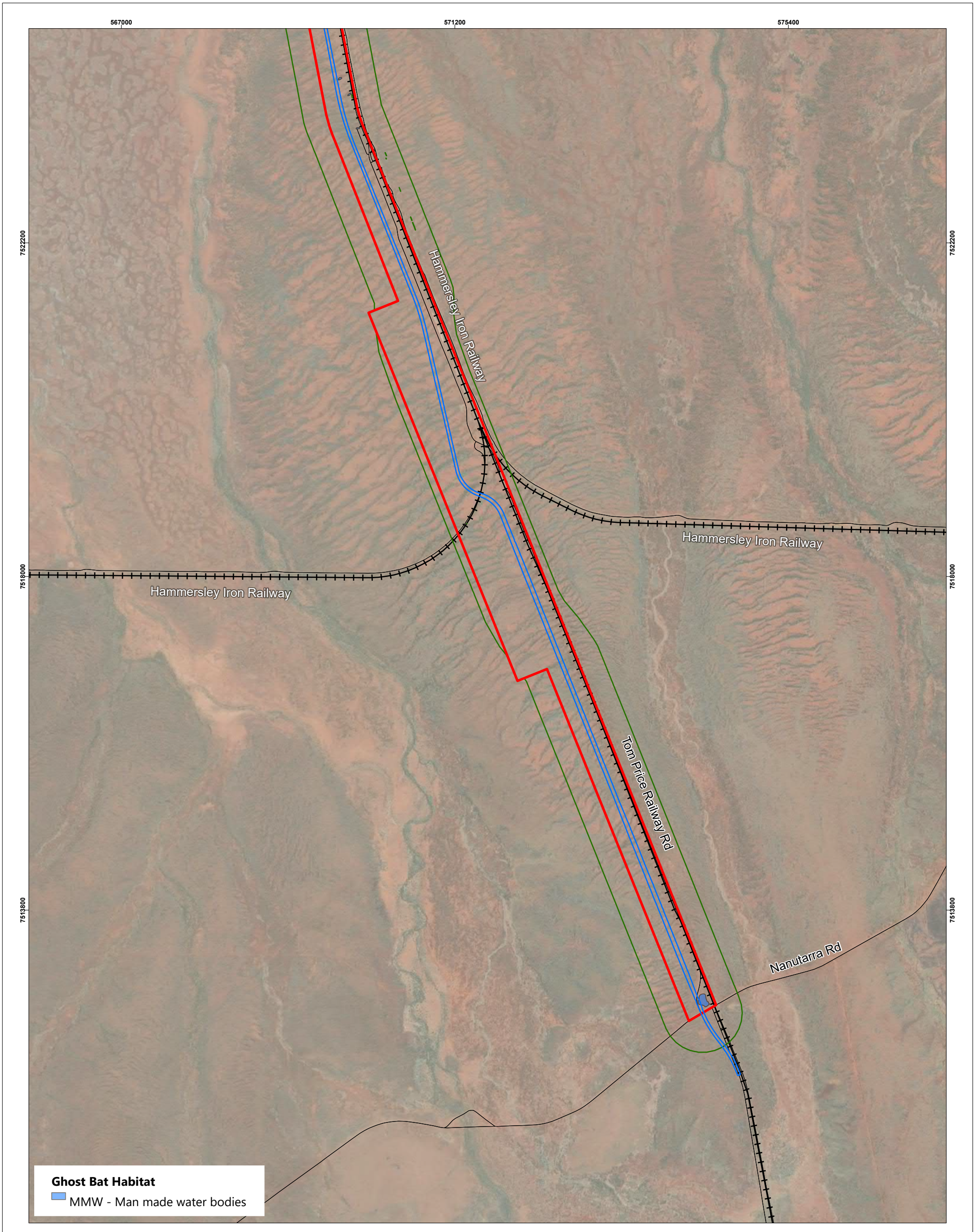
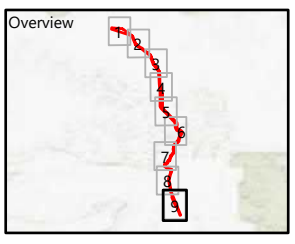


Figure 15 Ghost Bat Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Hammersley Iron Railway

Roebourne-Wittenoom Rd

Tom Price Railway Rd

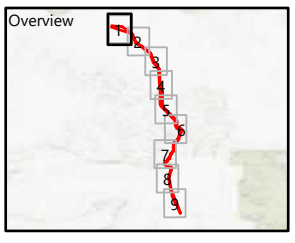
Pilbara Olive Python Habitat

MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 16 Pilbara Olive Python Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Pilbara Olive Python Habitat
- CP - Floodplain
- MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 16 Pilbara Olive Python Habitat

Legend
- Roads
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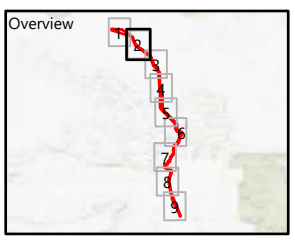

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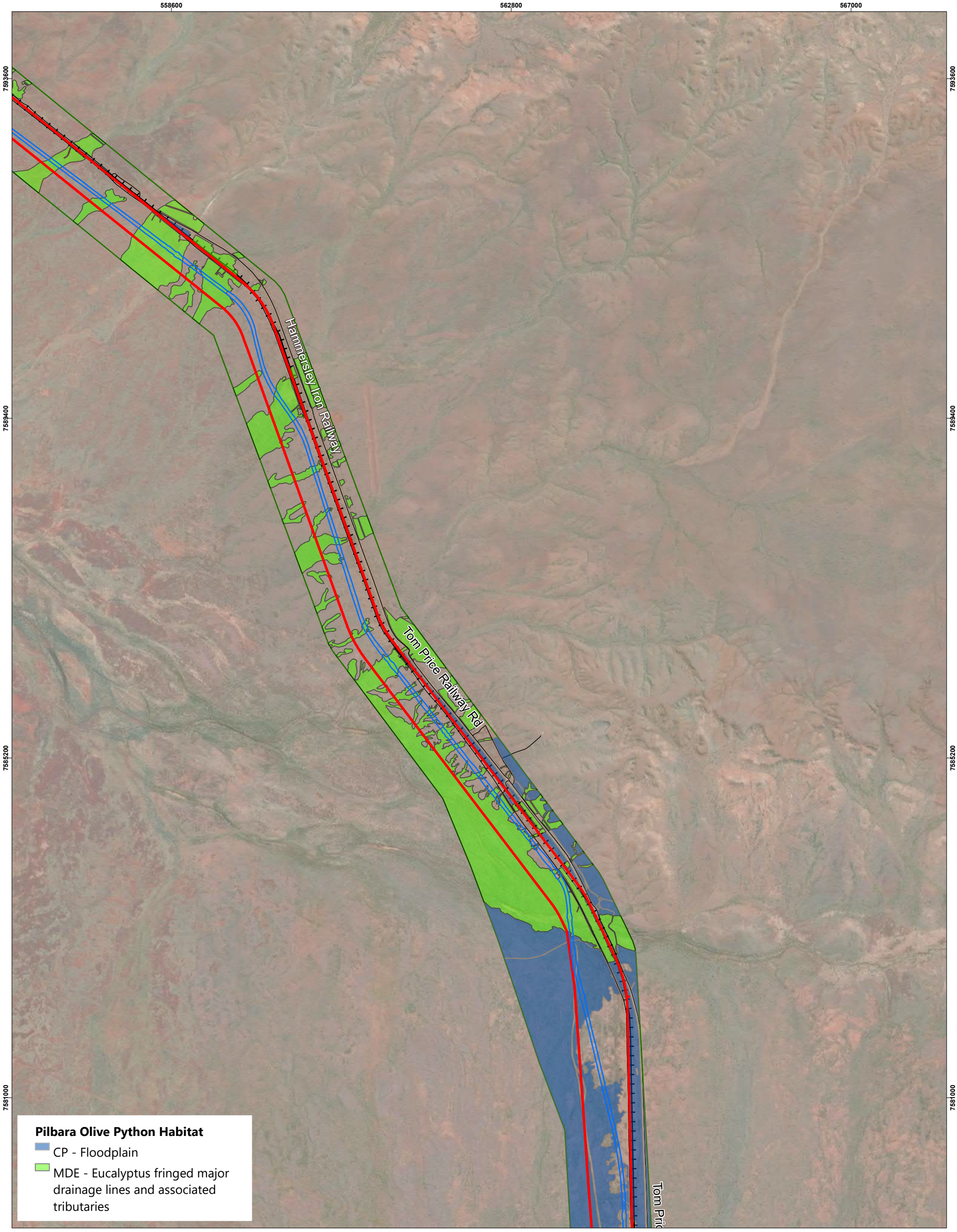

Figure 16 Pilbara Olive Python Habitat

Legend

- Roads
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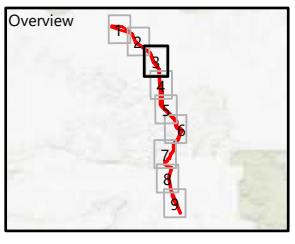

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Hammersley Iron Railway

Pilbara Olive Python Habitat
- CP - Floodplain
- MDE - Eucalyptus fringed major drainage lines and associated tributaries

Figure 16 Pilbara Olive Python Habitat

Legend
- Roads
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- Disturbance Footprint
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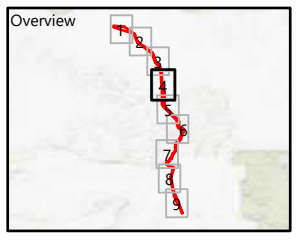

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Hammersley Iron Railway

Pilbara Olive Python Habitat

- CP - Floodplain
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
- MDM - Melaleuca forest/major drainage lines
- RHS - Rocky hills and slopes with low open spinifex and scattered trees

Figure 16 Pilbara Olive Python Habitat

Legend

- Roads
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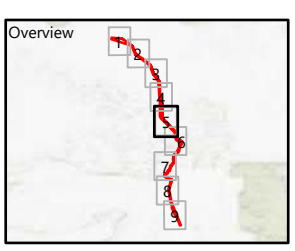
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Hammersley Iron Railway

Pilbara Olive Python Habitat

- CP - Floodplain
- HS - Mesas, caves, cliffs and free faces
- MDE - Eucalyptus fringed major drainage lines and associated tributaries
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Figure 16 Pilbara Olive Python Habitat

Legend

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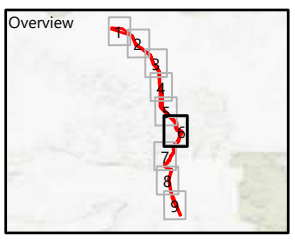

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Pilbara Olive Python Habitat

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Figure 16 Pilbara Olive Python Habitat

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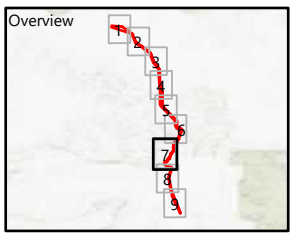

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Pilbara Olive Python Habitat

- HS - Mesas, caves, cliffs and free faces
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Figure 16 Pilbara Olive Python Habitat

Legend

- Roads
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- Disturbance Footprint
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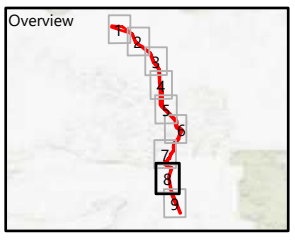
- Fauna Habitat Survey Boundary



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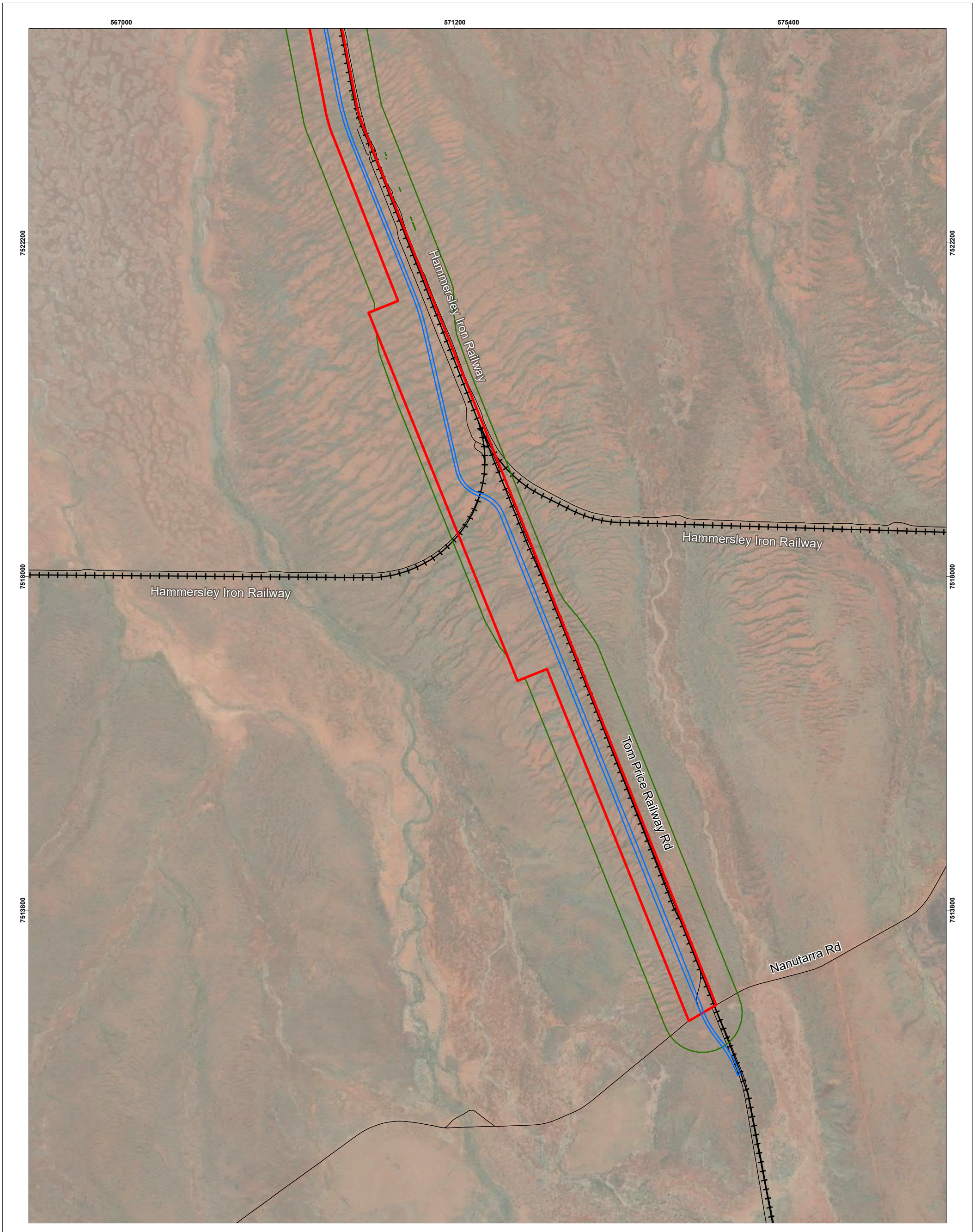

Figure 16 Pilbara Olive Python Habitat

Legend

- Roads
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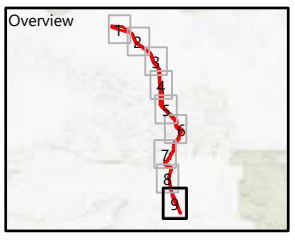

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Hammersley Iron Railway

Roebourne-Wittenoom Rd

Tom Price Railway Rd

Figure 17 Night Parrot Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary

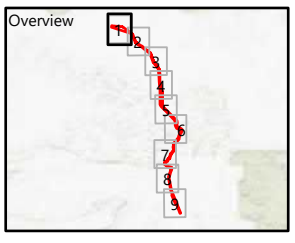

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Figure 17 Night Parrot Habitat

Legend

- Roads
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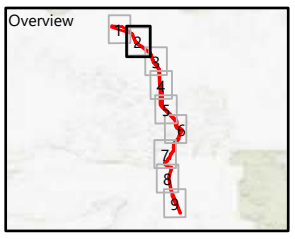
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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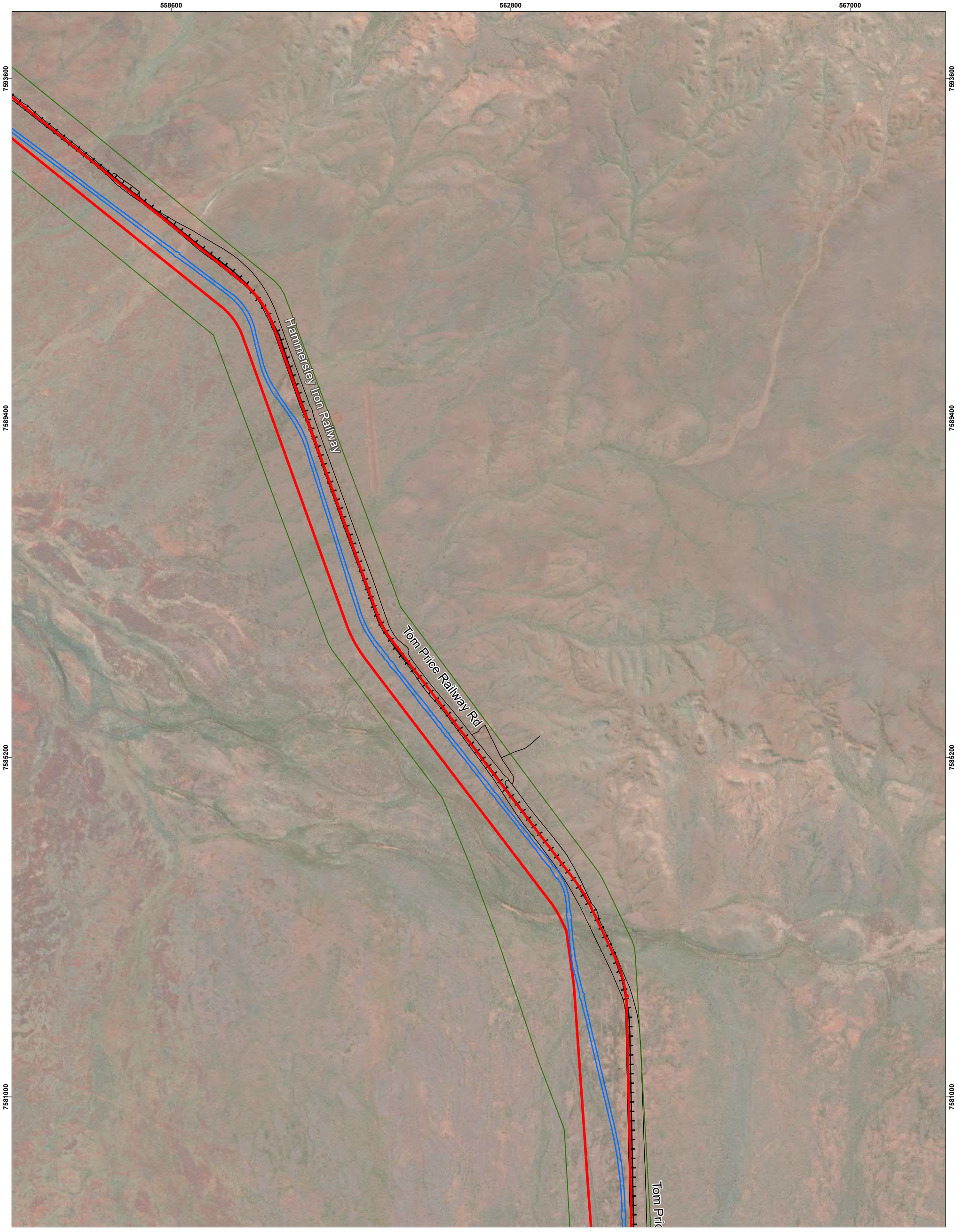
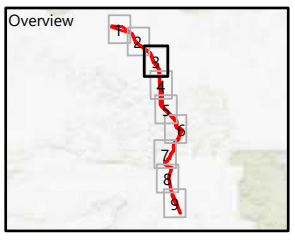


Figure 17 Night Parrot Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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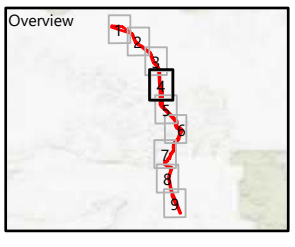
Tom Price Railway Rd
Hammersley Iron Railway

Figure 17 Night Parrot Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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JACOBS, 263 Adelaide Terrace, Perth WA 6000
Tel: +61 8 9469 4400 Fax: +61 8 9469 4488

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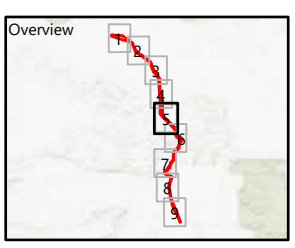
Tom Price Railway Rd

Hammersley Iron Railway

Figure 17 Night Parrot Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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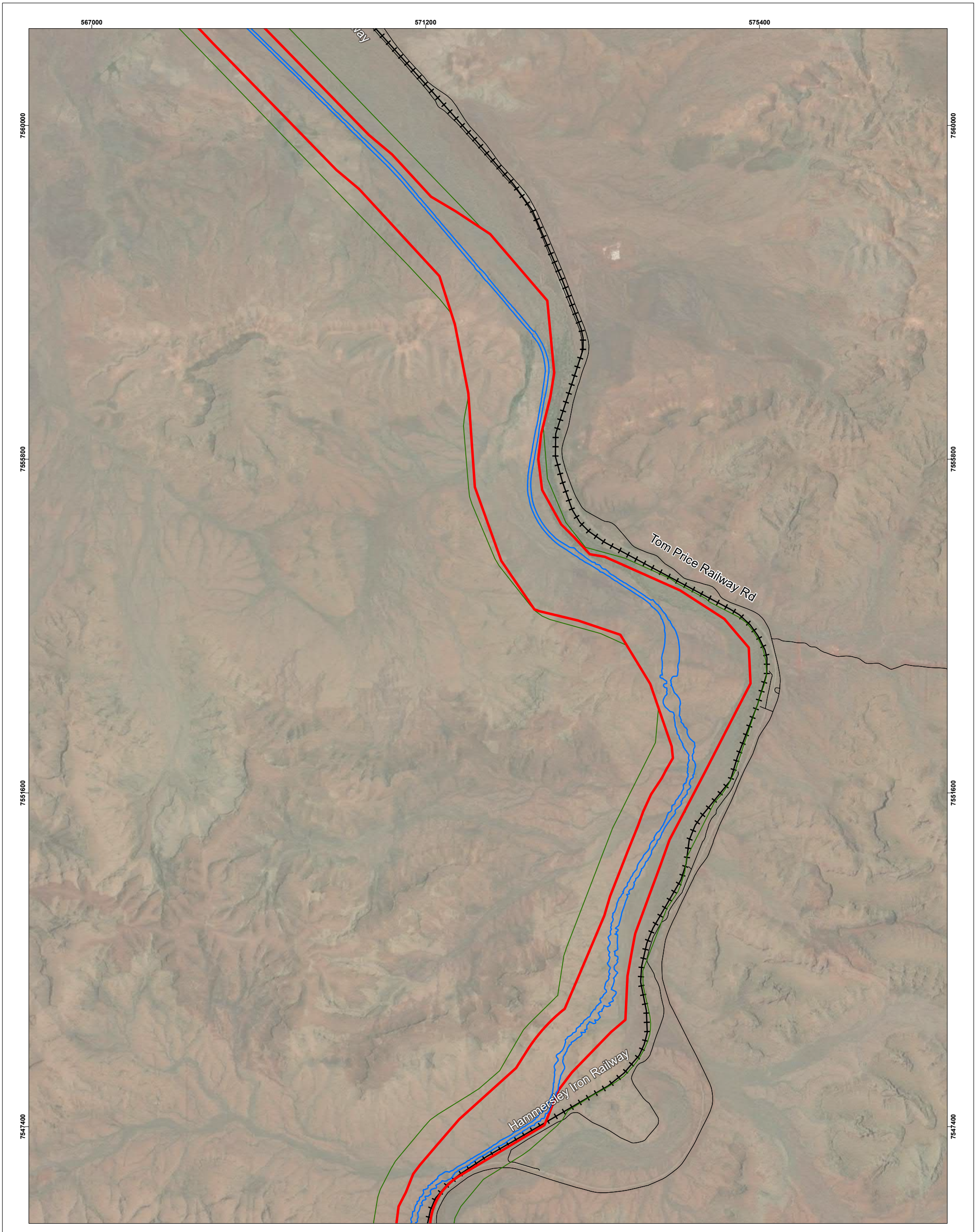
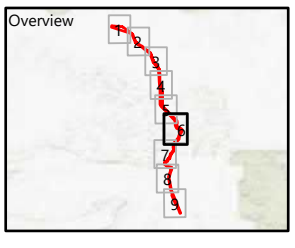


Figure 17 Night Parrot Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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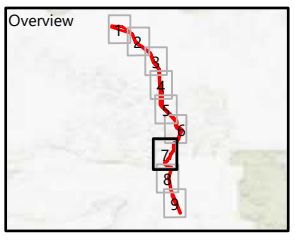
Hammersley Iron Railway
Night Parrot Habitat
GPCC - Grassland plains with cracking clay

Figure 17 Night Parrot Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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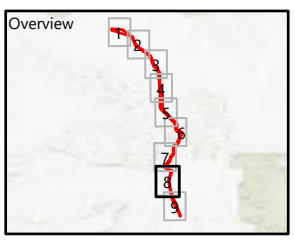
Hammersley Iron Railway
Tom Price Railway Rd

Night Parrot Habitat
GPCC - Grassland plains with cracking clay

Figure 17 Night Parrot Habitat

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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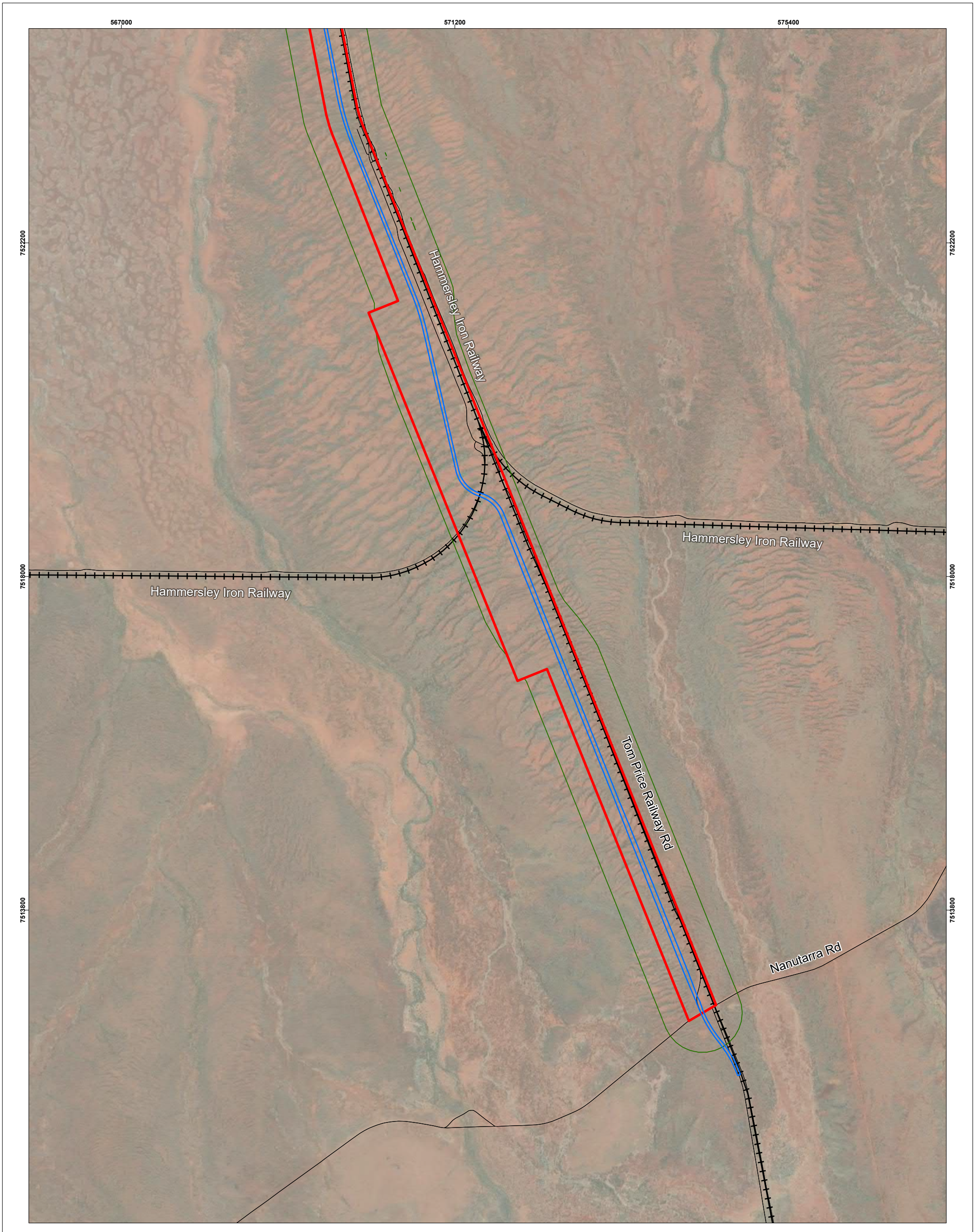
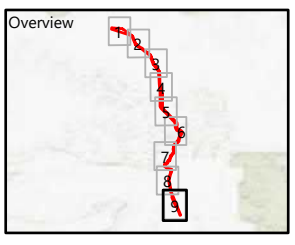


Figure 17 Night Parrot Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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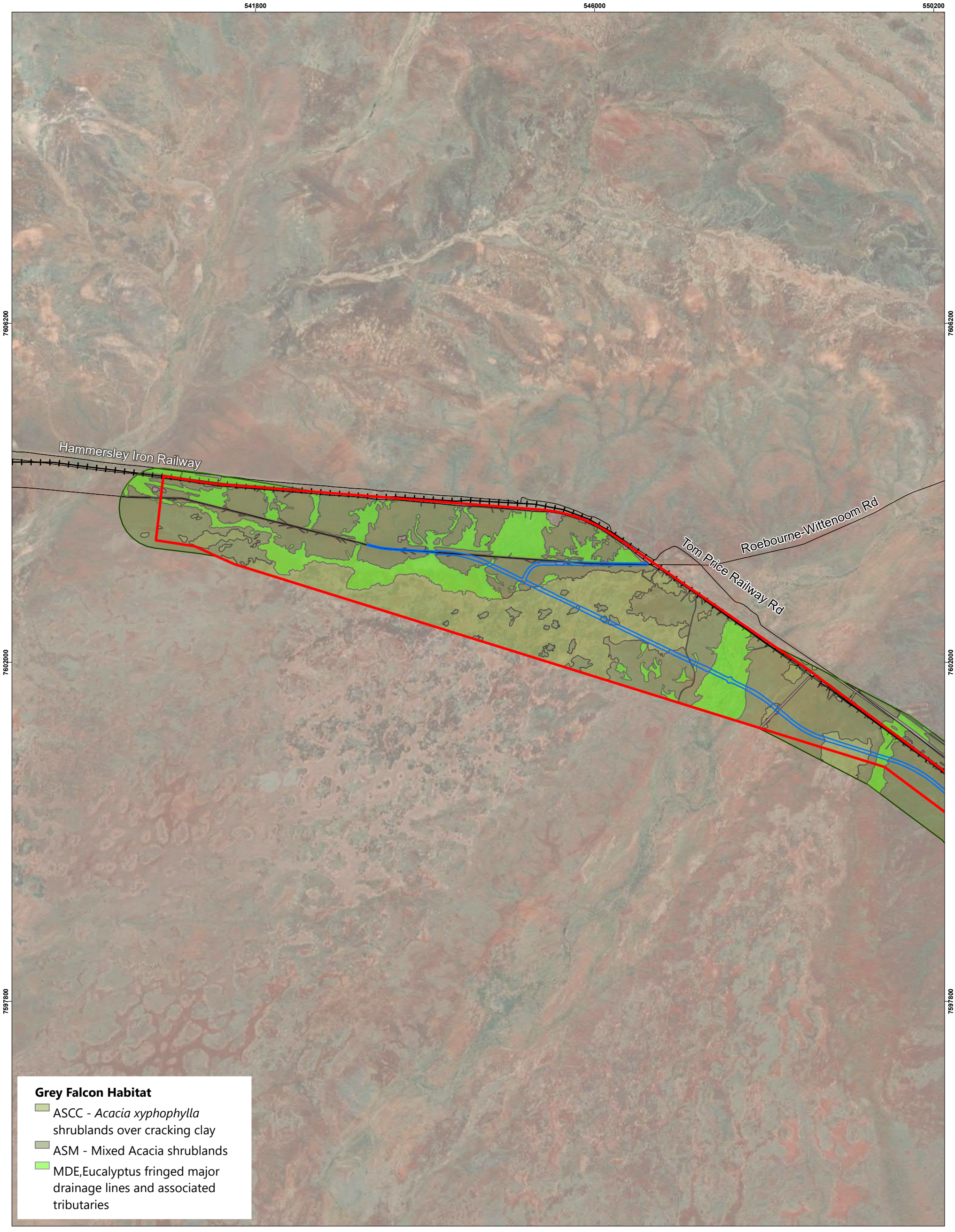
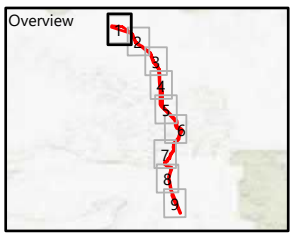


Figure 18 Grey Falcon Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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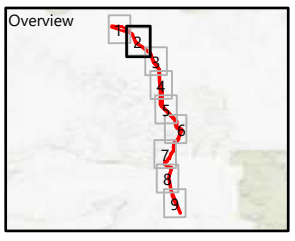
Grey Falcon Habitat

- ASCC - *Acacia xyphophylla* shrublands over cracking clay
- ASM - Mixed Acacia shrublands
- CP - Floodplain
- MDE,Eucalyptus fringed major drainage lines and associated tributaries

Figure 18 Grey Falcon Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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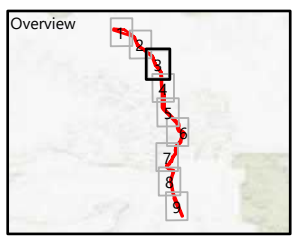
Grey Falcon Habitat
ASM - Mixed Acacia shrublands
CP - Floodplain
MWP - Mulga woodland plain
MDE,Eucalyptus fringed major drainage lines and associated tributaries

Figure 18 Grey Falcon Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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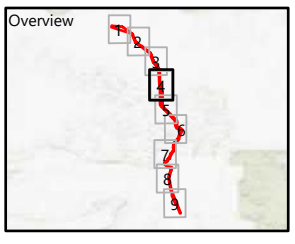
Hammersley Iron Railway

Grey Falcon Habitat
- ASM - Mixed Acacia shrublands
- CP - Floodplain
- MMW - Man made water bodies
- MWP - Mulga woodland plain
- MDE,Eucalyptus fringed major drainage lines and associated tributaries

Figure 18 Grey Falcon Habitat

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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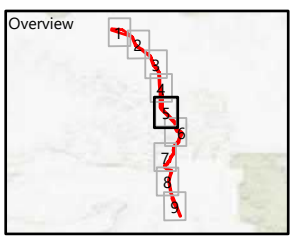
Hammersley Iron Railway

Grey Falcon Habitat
- ASM - Mixed Acacia shrublands
- CP - Floodplain
- MMW - Man made water bodies
- RHS - Rocky hills and slopes with low open spinifex and scattered trees
- MDE,Eucalyptus fringed major drainage lines and associated tributaries
- MDM,Melaleuca forest/major drainage lines

Figure 18 Grey Falcon Habitat

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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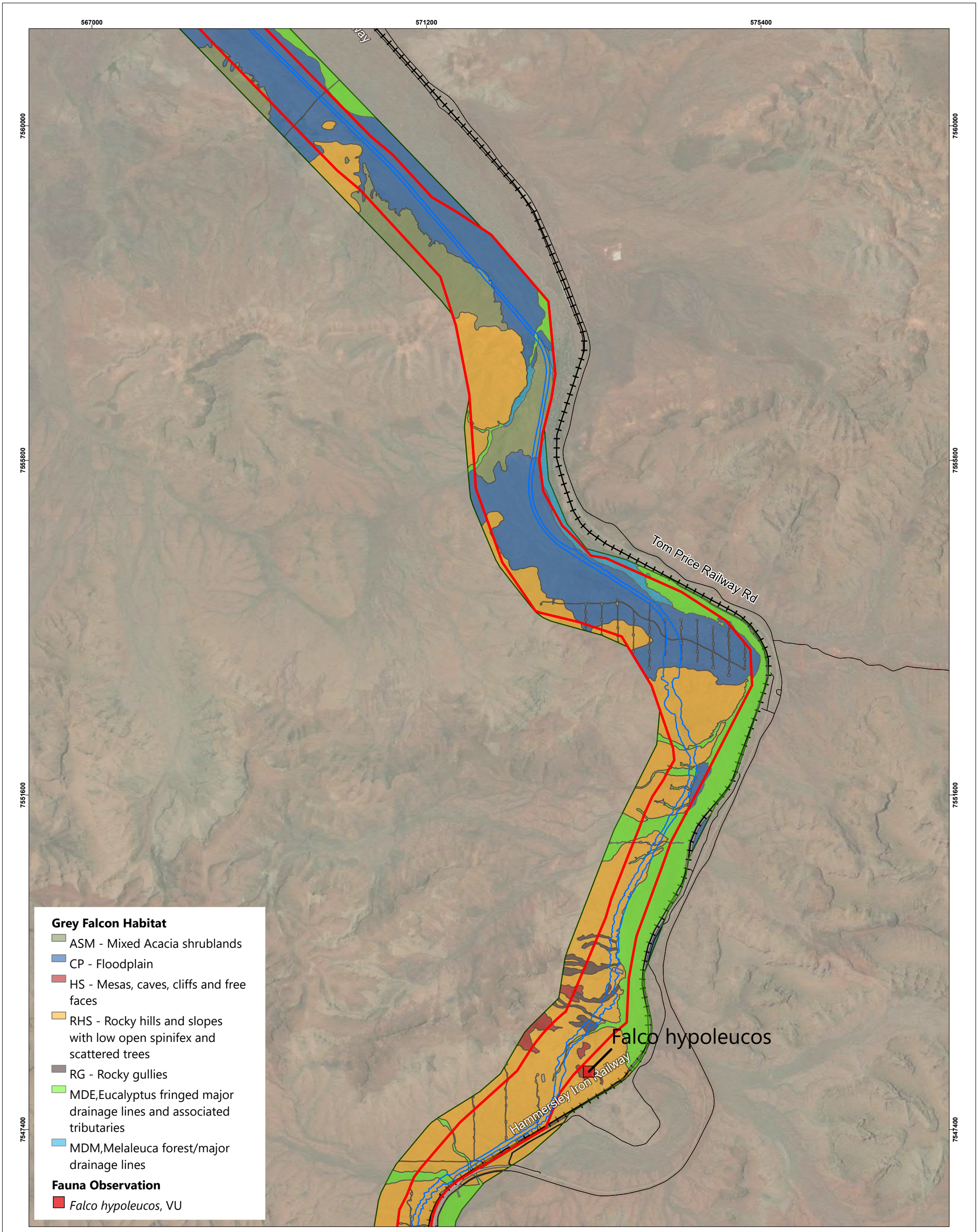
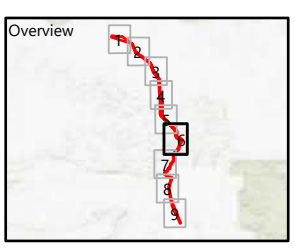


Figure 18 Grey Falcon Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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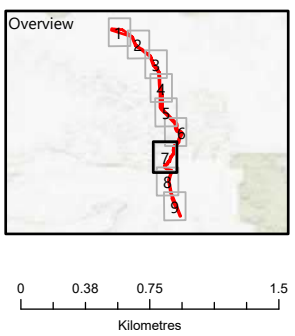
Hammersley Rd
Hammersley Iron Railway

Grey Falcon Habitat
- ASM - Mixed Acacia shrublands
- CP - Floodplain
- GPCC - Grassland plains with cracking clay
- HS - Mesas, caves, cliffs and free faces
- MG - Grove Mulga
- MWP - Mulga woodland plain
- RHS - Rocky hills and slopes with low open spinifex and scattered trees
- MDE,Eucalyptus fringed major drainage lines and associated tributaries

Figure 18 Grey Falcon Habitat

Legend
- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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Hammersley Rd

Hammersley Iron Railway

Tom Price Railway Rd

Grey Falcon Habitat

- ASM - Mixed Acacia shrublands
- GPCC - Grassland plains with cracking clay
- HS - Mesas, caves, cliffs and free faces
- MG - Grove Mulga
- MMW - Man made water bodies
- MWP - Mulga woodland plain
- RHS - Rocky hills and slopes with low open spinifex and scattered trees
- MDE,Eucalyptus fringed major drainage lines and associated tributaries

Figure 18 Grey Falcon Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary

Overview

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Kilometres

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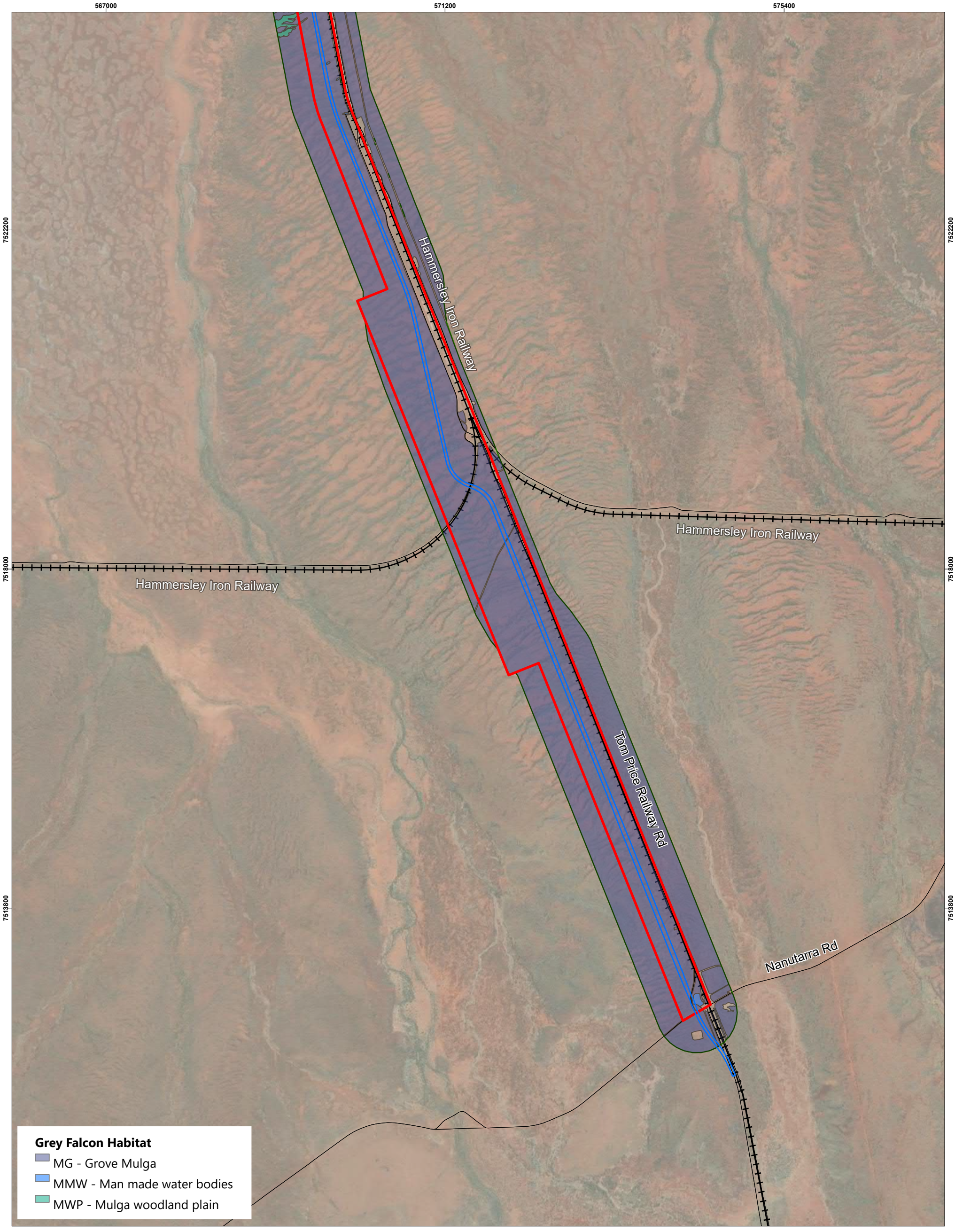
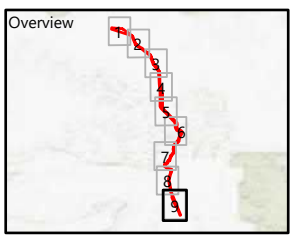


Figure 18 Grey Falcon Habitat

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- Fauna Habitat Survey Boundary



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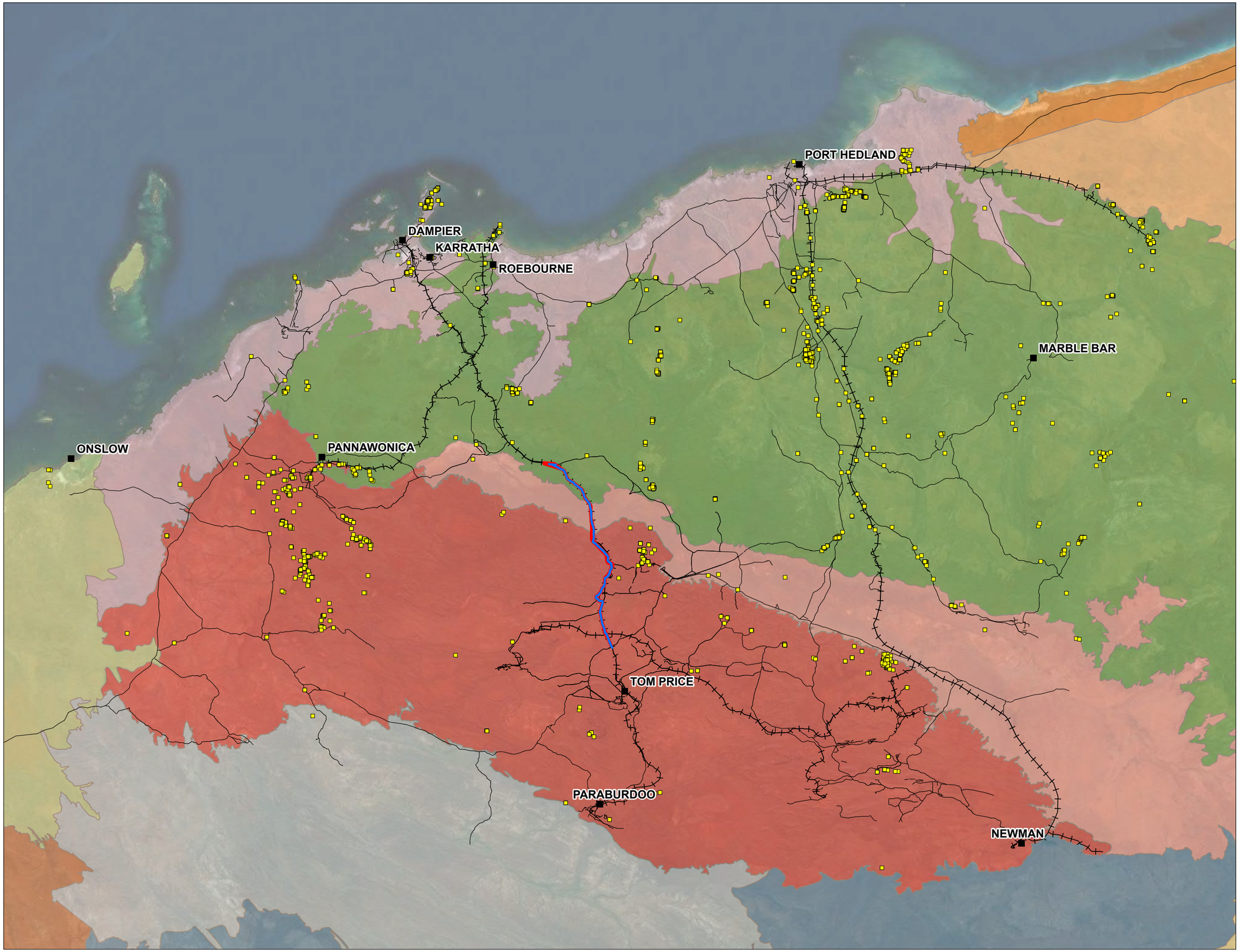

Legend

- Northern Quoll Occurences (DBCA)
- Roads
- Railways
- Disturbance Footprint
- Development Envelope

IBRA Subregions

- Ashburton
- Augustus
- Cape Range
- Mackay
- Chichester
- Fortescue
- Hamersley
- McLarty
- Pindanland
- Roebourne
- Trainor
- Wooramel

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Figure 19 Northern Quoll Regional Distribution

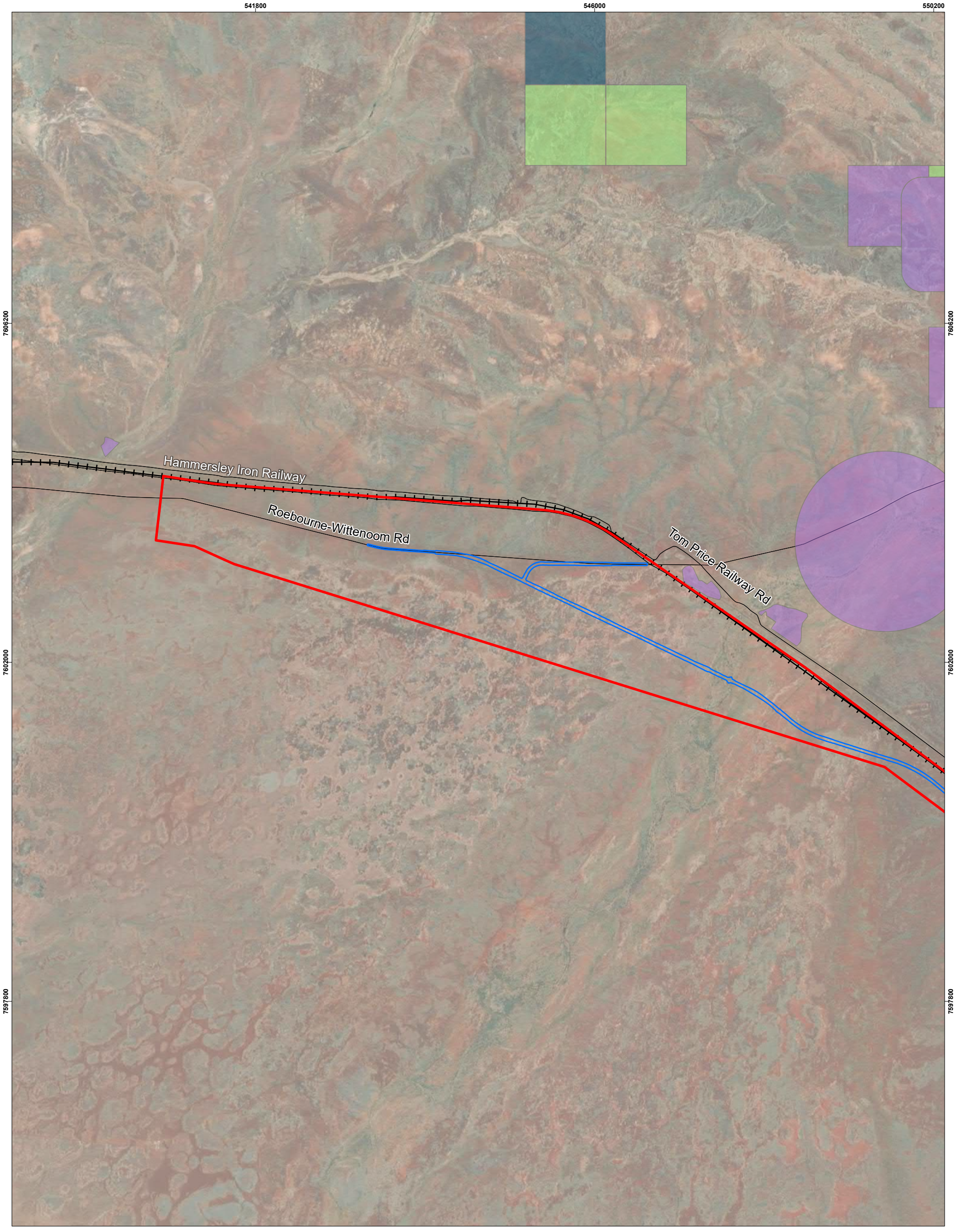

Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Aboriginal Heritage Places

- Lodged
- Registered Site
- Stored Data / Not a Site

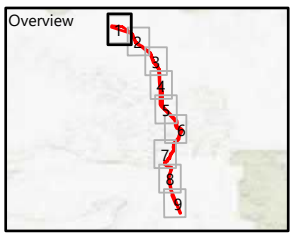

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Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Aboriginal Heritage Places

- Lodged
- Registered Site

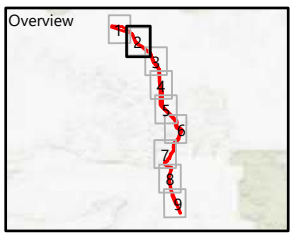

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Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- **Aboriginal Heritage Places**
- Lodged

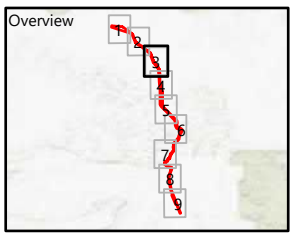

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Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope
- **Aboriginal Heritage Places**
- Stored Data / Not a Site

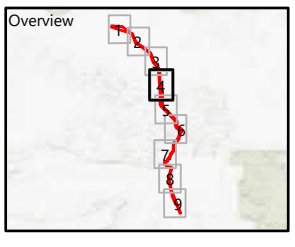

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Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Aboriginal Heritage Places

- Lodged
- Registered Site
- Stored Data / Not a Site

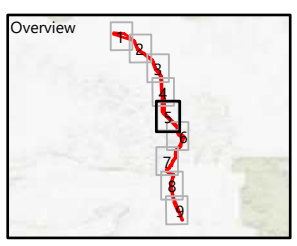

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Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Aboriginal Heritage Places

- Lodged
- Registered Site
- Stored Data / Not a Site

Overview

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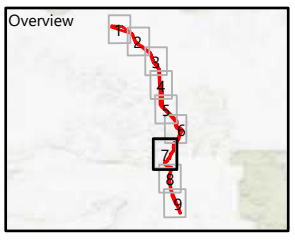
Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Aboriginal Heritage Places

- Lodged
- Registered Site
- Stored Data / Not a Site



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Hammersley Iron Railway

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Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
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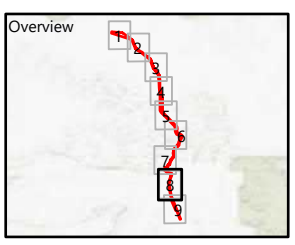
- Disturbance Footprint
- Development Envelope

Aboriginal Heritage Places

- Lodged
- Registered Site
- Stored Data / Not a Site



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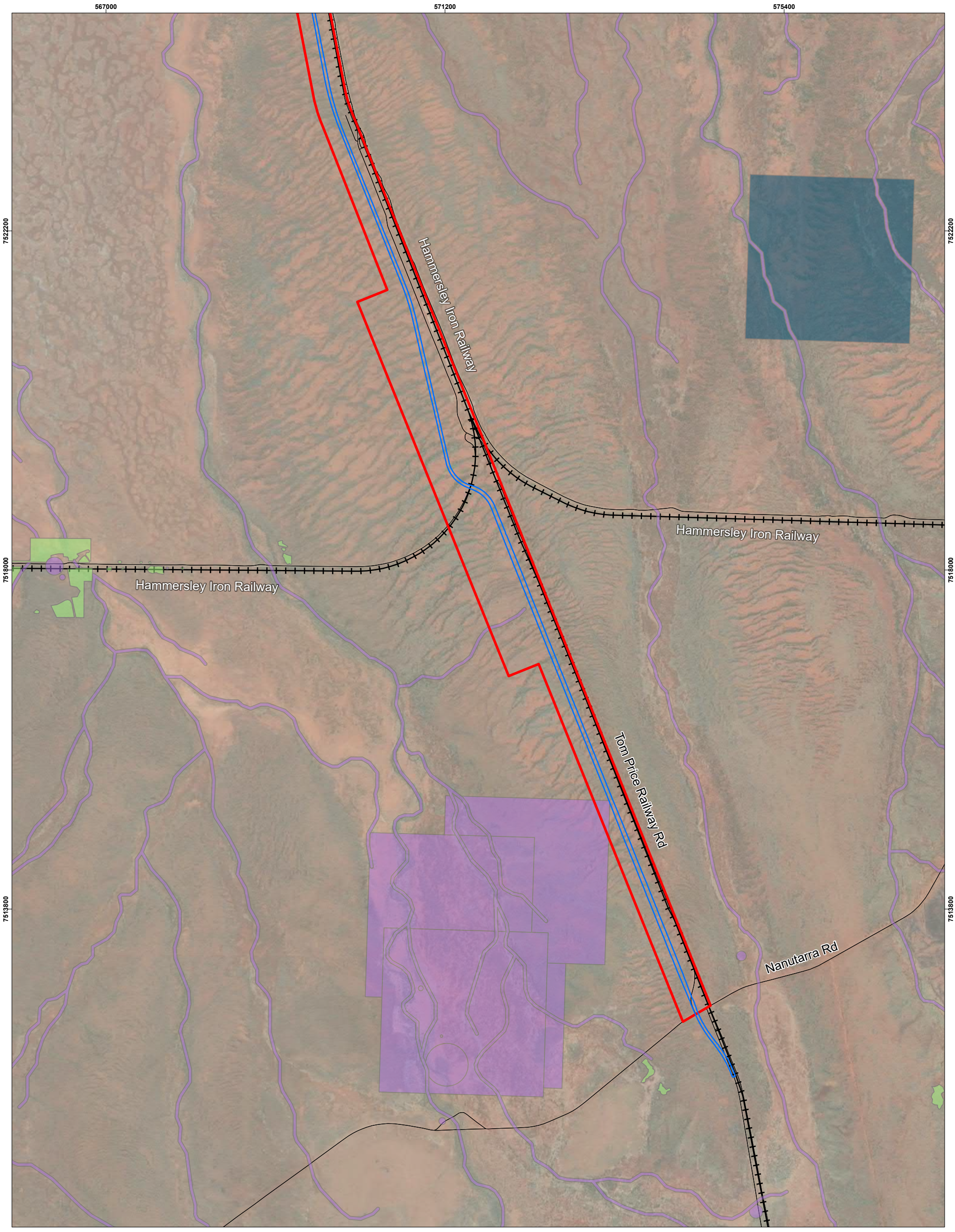


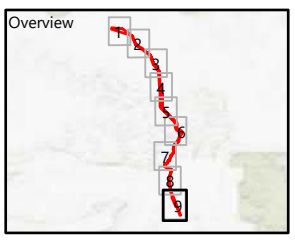
Figure 20 Registered Aboriginal Heritage Sites

Legend

- Roads
- Railways
- Disturbance Footprint
- Development Envelope

Aboriginal Heritage Places

- Lodged
- Registered Site
- Stored Data / Not a Site



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Jacobs

JACOBS, 263 Adelaide Terrace, Perth WA 6000
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13 APPENDICES

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Appendix 1 Additional Information Request

Australian Government
Department of Agriculture, Water and the Environment

EPBC Ref: 2020/8725

Ms Martine Scheltema
Manager Environment
WA Main Roads
1 Waterloo Cres
EAST PERTH WA 6004

Dear Ms Scheltema,

Decision on referral
Karratha - Tom Price Road Stage 4, WA

Thank you for submitting a referral under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act). I am writing to you in relation to your proposed action to complete Stage 4 of the Karratha – Tom Price Road upgrade, constructing 107 km of new two-lane, undivided and sealed carriageway between the end of Stage 3 Road at Wallyinya Pool to Nanutarra Rd, ~26 km north of Tom Price.

On 3 September 2020, a delegate of the Minister for the Environment decided that the proposed action is a controlled action and that it will be assessed by preliminary documentation. Further information will be required to be able to assess the relevant impacts of the proposed action. Details outlining the further information required are at Attachment A. Please note that the Department may request additional information later on as part of the ongoing assessment of the proposal under the *Environment Protection and Biodiversity Conservation Act 1999*.

Details on the assessment process and the responsibilities of the proponent are set out in the enclosed fact sheet. Further information is available from the Department's website at http://www.environment.gov.au/epbc.

If you have any questions about the assessment process or the further information required, please contact Zac Taylor by email to zac.taylor@environment.gov.au and quote the EPBC reference number shown at the beginning of this letter.

Yours sincerely

Daniel Rothenfluh
Acting Director
Project Assessments West Section
Environment Approvals Division
September 2020

REQUEST FOR ADDITIONAL INFORMATION

ASSESSMENT BY PRELIMINARY DOCUMENTATION

Karratha - Tom Price Road Stage 4, WA (EPBC 2020/8725)

This document sets out the specific information required by the Minister under section 95A of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the assessment of the relevant impacts of the proposed action (hereafter referred to as the 'preliminary documentation').

The preliminary documentation for the proposed action must include:

- the information contained in the original referral.
- the additional information provided on the impacts of the proposed action and the measures you propose to avoid, mitigate and/or offset those impacts.
- any other relevant information on the matters protected by the EPBC Act.

The preliminary documentation must contain sufficient information to allow the Minister (or delegate) to make an informed decision on whether or not to approve, under Part 9 of the EPBC Act, the taking of the action for each controlling provision.

The preliminary documentation must address the matters set out below.

General content, format and style

The preliminary documentation should be provided as one document with attachments and provided in a format that is objective, clear and succinct. It must contain sufficient information to avoid the need to search out previous or supplementary reports and be written so that any conclusions reached can be independently assessed.

The preliminary documentation must include a reference table demonstrating where in the documentation the additional information requirements have been addressed.

Where appropriate, the preliminary documentation must be supported by:

- evidence-based conclusions based on the best available peer-reviewed scientific literature with supporting references cited or expert opinion provided.
- relevant maps, plans, diagrams and technical information (e.g. specifications, schematics) – any images provided must be clearly annotated, in colour and of high resolution.
- scientifically-robust methodologies that are appropriate for purpose, including a description of the methodology used and justification of why the methodology was selected.

The preliminary documentation must reference all relevant standards, policies and other guidance material published by the Department. Any instances where published guidance is not followed must be justified. Where no Commonwealth standards exist, state government and/or industry standards may be appropriate.

The contact details of Departmental officers should be redacted from the preliminary documentation. The preliminary documentation should not contain any commercial in confidence markings. If the preliminary documentation contains sensitive information, please discuss this with the assessment officer.

RELEVANT MATTERS OF NATIONAL ENVIRONMENTAL SIGNIFICANCE

From the information provided to date, the Department considers that the following protected matters that may be significantly impacted by the proposed action include, but are not limited to[1]:

Listed threatened species and communities

- Northern Quoll (*Dasyurus hallucatus*) – Endangered
- Ghost Bat (*Macroderma gigas*) – Vulnerable
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) – Vulnerable
- Olive Python (*Liasis olivaceus barroni*) – Vulnerable
- Night Parrot (*Pezoporus occidentalis*) - Endangered
- Grey Falcon (*Falco hypoleucos*) - Vulnerable

The preliminary documentation must include the following specific information:

1. Description of the action

This should include the location of all works to be undertaken (including plans and maps) and elements of the action that may have impacts on MNES. The description of the action must also include details on how the works are to be undertaken (including stages of development and their timing) and design parameters for any structural elements of the action that may have impacts on MNES.

A description of the proposed action must include:

- A summary of all components of the proposed action.
- The activities associated with the proposed action.
- The location, boundaries and size (in hectares) of the proposed action area, any discrete disturbance areas, and any adjoining areas which may be directly or indirectly impacted by the proposed action, including nearby habitat and areas for stockpiles, laydowns/storage, construction camps, substations, temporary transmission lines, vehicle access and associated activities.
- A layout plan (or plans) for the project, including but not limited to key infrastructure, laydown areas and construction camps, new access tracks, conservation areas and heritage agreements the project corridor passes through.

[1] Please note, any protected matter listed under the EPBC Act at the time of the controlled action decision may be considered relevant to the assessment of the proposed action and should be addressed, as appropriate, in the preliminary documentation.

- The anticipated timing and duration (including start and completion dates) for construction and operation of the proposed action.
- A description of operational requirements of the action including any anticipated maintenance works.
- A description and likely timing of rehabilitation activities associated with the proposed action; and
- A discussion and details of any feasible alternatives to the proposed action that were considered, including the alternative of taking no action, a comparative description of the impacts of each alternative on MNES and detail to make clear why any alternative is preferred to another. Short, medium and long-term advantages and disadvantages of the options should be discussed.

2. Description of the environment and matters of national environmental significance

The preliminary documentation must provide a general description of the environment impacted by and surrounding the proposed action area, in both the short and long term. Specific matters this section must address include, but are not limited to:

- A description of the protected matters, including but not limited to those listed above, that are, or have the potential to be in the proposed action area and surrounds.
- A description of the current land use, topography, surface and groundwater bodies, waterways and vegetation communities within the proposed action area and surrounds.
- For listed threatened species and communities that are known or have the potential to be present within the proposed action area and surrounds, and are likely to, or may be significantly impacted by the proposed action, a minimum of:
    - Information on the abundance, distribution, ecology and habitat preferences for each listed species or community.
    - Quantification of the extent of habitat and the number of individuals likely to be impacted, or historical patterns of use by those species, within the proposed action area and surrounds (including mapping identifying known and/or potential habitat).
    - Assessment of the quality and importance of known or potential habitat for the relevant listed species or communities within the proposed action area and surrounds.
    - Information detailing known occurrences of listed ecological communities within a 1km radius of the proposed action area and the size of these occurrences.
    - Information detailing known populations or records of individuals of listed species within a 1 km radius of the proposed action area and the size of these populations, if available. For mobile species such as birds and bats, population information and records of individuals must be considered at a relevant radius from the proposed action area.
    - An assessment of the adequacy of any surveys undertaken (including survey effort and timing). In particular, the extent to which these surveys were appropriate for the

listed species or community and undertaken in accordance with relevant Departmental survey guidelines.

The preliminary documentation should include all potential impacts to MNES and associated avoidance and mitigation measures outlined in the referral information plus the additional information listed below.

Species and Communities specific information

Based on the referral documentation, the proposed action is likely to have a significant impact on the below listed species and communities. However, given the lack of information provided, the Department also notes the possibility that other species may be present which were not identified in the desktop analysis. If environmental surveys identify additional listed species or communities not mentioned here, please provide additional information about these matters in addition.

The preliminary documentation should address the general considerations listed in this document for the following species and any other MNES which are noted during the surveys. As a minimum address all the points of section 2, 3, 4 and where applicable section 5 of this document for the following species:

- Northern Quoll (*Dasyurus hallucatus*) – Endangered
- Ghost Bat (*Macroderma gigas*) – Vulnerable
- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*) – Vulnerable
- Olive Python (*Liasis olivaceus barroni*) – Vulnerable
- Night Parrot (*Pezoporus occidentalis*) – Endangered
- Grey Falcon (*Falco hypoleucos*) - Vulnerable

Habitat Quality Guidance Note

Please note that a methodology suitable for each individual listed species or community (i.e. approved by the Department or supported by literature) must be used to assess habitat or vegetation quality, noting that the same scoring system must be used at both impact and offset sites, where relevant (see Section 5 of this document). The quality score for an area of habitat must relate directly to the habitat requirements of the species. There are three components that must be considered when calculating habitat quality: site condition, site context and species stocking rates.

Relevant guidance material (such as survey guidelines, conservation advices, recovery plans, threat abatement plans and policy statements) is available on the Department's public website. It is your responsibility to ensure that you have identified the relevant documents.

3. Assessment of impacts

The preliminary documentation must include an assessment of potential impacts (including direct, indirect, consequential and cumulative impacts) that may occur as a result of all elements and project phases of the proposed action on MNES that are likely to be present within the proposed action area and surrounds. The impacts of the proposed action should be considered at the broadest scope: all components of the proposed action should be considered, including any associated supporting infrastructure. The Department considers the proposed action may result in, but not be limited to, the following impacts:

- Increased predation from introduced species.
- Increased risk of vehicle strike.
- Vegetation clearing and loss of habitat.
- Increase light and noise pollution.
- Habitat degrading processes such as weed invasion.
- Illegal rubbish dumping and litter.

The impact assessment should identify and take into account the scale, duration and intensity of the proposed action, and:

- For each listed species and/or community, identify the amount and quality of habitat or vegetation likely to be impacted (directly and indirectly).
- Identify the number of affected individuals and/or habitat features (e.g. number of potential breeding trees or hollows, etc.) relevant to each listed species.
- Characterise the nature of impacts, including timing and whether the impact is temporary or permanent.
- Include a risk assessment of the potential impacts of the proposed action, including whether the nature and/or scale of the potential impacts are unknown, unpredictable or irreversible, and what confidence is placed on the predictions or relevant impacts; and
- Include details of any relevant policy guidelines, studies, surveys, management plans or consultations with subject-matter experts which were not included in the original referral.

4. Avoidance and mitigation measures

The preliminary documentation must provide information on specific measures proposed to avoid, mitigate and manage impacts to the relevant protected matters from the proposed action. Documentation should clearly set out the following measures for each environmental issue and protected matter likely to be impacted by the proposed action. Measures including, but not limited to, the following items must be outlined in the documentation:

- A consolidated list of impact avoidance and mitigation measures based on best available practices that will be implemented to reduce impacts on protected matters (including any additional to those proposed in the original referral). This must include a description of each measure proposed, relevant protocols, the name of the agency responsible for each measure, as well as the location and timing for each measure.
- Describe contingencies for events, such as the identification of protected matters during construction searches (e.g. translocation management protocols for specific species).
- Details of any rehabilitation or revegetation measures to be implemented, including objectives, target species, timing of relevant stages, methodology, maintenance and monitoring.
- For each proposed mitigation measure, please also include:

  - performance and completion criteria
  - monitoring and reporting arrangements
  - potential risks/threats, including residual risks, and any measures that would be implemented to mitigate against these risks, and any proposed monitoring to confirm the effectiveness of these measures

- Discussion of the likely residual impacts to the protected matter after proposed avoidance and/or mitigation measures are taken into account.

Management commitments by the person proposing to take the action must be clearly distinguished from recommendations or statements of best practice made by the document author or other technical expert. It is preferable to provide a consolidated table of management commitments, including details on funding, roles and responsibilities and measurable performance criteria. Commitments should be made using unambiguous language, i.e. use 'will' and 'must' when committing to actions instead of 'where possible', 'where practicable', 'as required', 'to the greatest extent possible', and 'should' or 'may'.

Where an action management plan is to be prepared to manage impacts to protected matters, the action management plan must be submitted as part of the preliminary documentation unless the Election to have an Action Management Plan Approved after Approval of the Taking of an Action form at Attachment B is completed and returned to the Department.

Any action management plan submitted as part of the preliminary documentation must be prepared in accordance with the Action Management Plan Criteria at Attachment C.

The Department notes that some action management plans required as a condition of approval may be eligible for acceptance through a third-party Quality Assurance Review process in place of Ministerial-approval. Please notify the Departmental project officer if you would like to discuss this option.

5. Offsets

The preliminary documentation must also provide details of the likely residual impacts on MNES discussed at Section 3 that are likely to occur after all avoidance and/or mitigation measures are taken into account. If applicable, include the reasons why avoidance or mitigation of impacts cannot be reasonably achieved.

The preliminary documentation must draw a conclusion on the need for an offset and, where an offset is required, include the following information:

- An offset package consisting of an offset proposal (strategy) and key commitments and management actions for delivering and implementing a proposed offset (e.g. an Offset Management Plan). The proposed offset must meet the requirements of the Department's *EPBC Act Environmental Offsets Policy* (October 2012) available at: www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy. The package must include, but not be limited to, the following:
  - A description of the offset site(s) including location, size, condition and environmental values present.
  - Justification of how the offset meets the *EPBC Act Environmental Offsets Policy.*

- An assessment (and justification for each input used) of the offset site(s) using the Department's *Offset Assessment Guide* available at: www.environment.gov.au/epbc/publications/epbc-act-environmental-offsets-policy.
- Details on how the offset will be secured, managed and monitored, including management actions, responsibility, timing and performance criteria. This should include the specific environmental outcomes to be achieved from management measures.
- The anticipated cost (financial and other) of delivery of the offset(s).

6. Economic and social matters

The preliminary documentation must address the economic and social impacts (both positive and negative) of the proposed action. This may include:

- An indication of the financial investment the project represents.
- Details of any public and/or Indigenous stakeholder consultation activities, and their outcomes.
- Projected costs and benefits of the proposed action, including the basis for their estimation through cost/benefit analysis or similar studies, e.g. employment opportunities expected to be generated by the project (including construction and operational phases).

Economic and social impacts should be considered at the local, regional and national level.

7. Ecologically sustainable development

The preliminary documentation should include a discussion of how the proposed action meets the principles of ecologically sustainable development, as defined in s. 3A of the EPBC Act.

8. Environmental record of the person proposing to take the action

If the person proposing to take the action is a corporation, this extends to the executive officers of the corporation as well and details of the corporation's environmental policy and planning framework must also be included.

The preliminary documentation must include details of any proceedings under a Commonwealth, State or Territory law for the protection of the environment or the conservation and sustainable use of natural resources against:

a) The person proposing to take the action.

b) For an action for which a person has applied for a permit, the person making the application.

9. Other approvals and conditions

The preliminary documentation must include information on any other requirements for approval or conditions that apply, or that the proponent reasonably believes are likely to apply, to the proposed action. This must include:

- A description of any approval that has been obtained or is required to be obtained from a state, territory or commonwealth agency or authority (other than an approval under the EPBC Act), including any conditions that apply (or are reasonably expected to apply) to the action.

- A description of the monitoring, enforcement and review procedures that apply, or are proposed to apply, to the action.

Outcomes-based conditions

Outcomes-based conditions can provide approval holders with greater flexibility and autonomy while still holding them accountable for achieving sound environmental outcomes. The Department promotes the use of outcomes-based conditions where possible, in accordance with its *Outcomes-based Conditions Policy* (2016).

Please advise the Department if you would like to pursue this approach. If so, the preliminary documentation would need to:

- Thoroughly document the baseline condition of the relevant protected matter(s).
- Identify conservation objectives (outcomes) for the relevant protected matters, preferably with reference to any applicable conservation advices, recovery plans and threat abatement plans, and the likely impact the proposed outcome will address.
- Detail the proposed management to achieve the outcome, including, but not limited to: performance indicators; periodic milestones; proposed monitoring and adaptive management and; record keeping, publication and reporting processes.

10. Relevant policies and publications

Various policy statements and other publications that may be relevant to your assessment can be found on the Department's website and must be referenced.

For each protected matter, the preliminary documentation must include a statement of whether or not the proposed action is inconsistent with any relevant recovery plan and threat abatement plan. Statements of whether or not relevant conservation advices have been considered must be included for those protected matters that do not have recovery plans.

11. Information sources

The preliminary documentation must state for the information provided, the following:

a) The source and currency (date) of the information.

b) How the reliability of the information was tested.

c) The uncertainties (if any) in the information.

d) Guidelines, plans and/or policies considered.

ELECTION TO HAVE AN ACTION MANAGEMENT PLAN APPROVED

Note: Pursuant to section 132B of the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act), this election must be given to the Minister before the Minister grants an approval of the proposed action under section 133 of the EPBC Act.

PERSON PROPOSING TO TAKE ACTION

1. Name and Title:
2. Organisation (if applicable):
3. EPBC Referral Number (if known):
4. ACN/ABN (if applicable):
5. Postal Address:
6. Telephone:
7. Email:
8. Name of designated proponent (if not the same person named at item 1 above and if applicable):
9. ACN/ABN of designated proponent (if not the same person named at item 1 above):

□ I elect to submit an action management plan(s) for approval in accordance with section 132B of the *Environment Protection and Biodiversity Conservation Act 1999*. I understand that a fee of $2,690 may apply under the cost recovery arrangements.

Declaration:

□ I declare that to the best of my knowledge the information I have given on this form is complete, current and correct.

□ I understand that giving false or misleading information is a serious offence.

Signature _____ **Date:** _____

Action Management Plan Criteria
1. Includes (in the plan itself) a declaration of accuracy signed by the proponent/approval holder when submitting the plan: *<u>Declaration of Accuracy</u>* *I declare that to the best of my knowledge, all the information contained in, or accompanying this document is complete, current and correct. I am duly authorised to sign this declaration on behalf of the proponent/approval holder. I am aware that:* a. *giving false or misleading information is a serious offence under section 137.1 of the Criminal Code Act 1995 (Cth)* b. *section 137.2 of the Criminal Code Act 1995 (Cth) makes it an offence for a person to produce a document to another person in compliance or purported compliance with a law of the Commonwealth where the person knows that the document is false or misleading;* c. *section 490 of the Environment Protection and Biodiversity Conservation Act 1999 (Cth) (EPBC Act) makes it an offence for an approval holder to provide information in response to an approval condition where the person is reckless as to whether the information is false or misleading; and* d. *section 491 of the EPBC Act makes it an offence for a person to provide information or documents to specified persons who are known by the person to be performing a duty or carrying out a function under the EPBC Act or the Environment Protection and Biodiversity Conservation Regulations 2000 (Cth) (EPBC Regulations) where the person knows the information or document is false or misleading.* *Signed:* *Full name (please print):* *Organisation (please print):* *EPBC Referral Number:* *Name of Action Management Plan this document and declaration refers to:* *Date:*

2. Outlines the plan's purpose and provides contextual information including, but not limited to:
    a. location and nature of relevant action activities;
    b. a schedule of action phases (e.g. commencement, construction, operation and decommissioning);
    c. information on protected matters to:
        i. guide management approach; and
        ii. establish 'baseline' condition prior to commencement of the action, quantified using the relevant protected matter attribute (e.g. quality score for area of habitat, no. of individuals or water quality);
    d. location of protected matters (and/or their habitat) in relation to the action location/boundary; and
    e. management objectives for protected matters and strategies to manage key risks to achieving those objectives.

3. Establishes SMART[2] 'performance standards' used to evidence achievement of management objectives and which are comprised of:
    a. ***performance indicators***, used to measure performance against a management objective, and specify physical, chemical or biological parameters that will be measured to assess environmental health and/or condition; and
    b. ***performance criteria,*** which are the numerical values for ***performance indicators*** established as one or more of the following functional types:
        i. ***threshold criteria***, acceptable numerical level(s) beyond which there is likely to be an unacceptable impact to protected matters and if breached will require ***corrective actions***;
        ii. ***trigger criteria***, numerical level(s) to forewarn of approaching unacceptable impacts to protected matters and, if breached, require mitigation activities (***trigger action response plan or TARPs***) to avoid realisation of that impact; or
        iii. ***completion criteria,*** numerical level(s) to achieve and maintain specified management objectives.

4. Assesses the risk that the plan's objectives will not be met and identifies the sources of those risks and strategies for managing them. Includes a risk assessment which must:
    a. identify events that will, may, or are likely to prejudice attainment of 'performance standards';

[2] *Specific, Measurable, Achievable, Relevant and Time-bound*. For detail on SMART see page 11 of the Draft *Outcomes-based conditions guidance* available at https://www.environment.gov.au/system/files/consultations/7c4a2b5b-2282-45c4-8e67-f0b5155ab12a/files/draft-outcomes-based-conditions-guidance.pdf

b. assess the likelihood and consequences of those events, and characterise residual risk levels[3] (assuming management activities are implemented) using the risk matrix below:

RISK MATRIX	
Qualitative measure of likelihood (how likely is it that this event/circumstance will occur after management activities are implemented)	
Highly likely	Is expected to occur in most circumstances
Likely	Will probably occur during the life of the project
Possible	Might occur during the life of the project
Unlikely	Could occur but considered unlikely or doubtful
Rare	May occur in exceptional circumstances
Qualitative measure of consequences (what will be the consequence/result if the issue does occur)	
Minor	Minor incident of environmental damage that can be reversed (*e.g. short-term delays to achieving plan objectives, implementing low-cost, well-characterised corrective actions*)
Moderate	Isolated but substantial instances of environmental damage that could be reversed with intensive efforts (*e.g. short term delays to achieving plan objectives, implementing well-characterised, high-cost/effort corrective actions*)
High	Substantial instances of environmental damage that could be reversed with intensive efforts (*e.g. medium-long term delays to achieving objectives, implementing uncertain, high-cost/effort corrective actions*)
Major	Major loss of environmental amenity and real danger of continuing (*e.g. plan objectives are unlikely to be achieved, with significant legislative, technical, ecological and/or administrative barriers to attainment that have no evidenced mitigation strategies*)
Critical	Severe widespread loss of environmental amenity and irrecoverable environmental damage (*e.g. plan objectives are unable to be achieved, with no evidenced mitigation strategies*)

		Consequence				
		Minor	**Moderate**	**High**	**Major**	**Critical**
Likelihood	**Highly Likely**	**Medium**	**High**	**High**	**Severe**	**Severe**
	Likely	**Low**	**Medium**	**High**	**High**	**Severe**
	Possible	**Low**	**Medium**	**Medium**	**High**	**Severe**
	Unlikely	**Low**	**Low**	**Medium**	**High**	**High**
	Rare	**Low**	**Low**	**Low**	**Medium**	**High**

[3] The risk assessment may also include the risk level prior to any management, however, this is not necessary for the purpose of the plan

c. state the level of uncertainty and apply a 'margin of safety' where uncertainty is high (i.e. enhance monitoring and management activities until uncertainty is reduced to an acceptable level); d. identify additional management activities that will be implemented (i.e. through *TARPs*) if *trigger criteria* are realised, to avoid unacceptable impacts to protected matters; e. include a 'stop work' response if *TARPs* are not effective; and f. identify effective *corrective actions* that will be implemented to repair/mitigate unacceptable impacts to protected matters that are project attributable.
5. Specifies management activities that will be implemented to ensure the plan's 'performance standards' are met. Each management activity must: a. include timeframes for implementation; b. be clearly related to meeting 'performance standards'; and c. be derived from recognised and demonstrably appropriate principles, practice, or guidelines, and be justified - technically, scientifically and/or legally (e.g. by recommendation in an EPBC Act protected matter conservation advice, recovery plan and threat abatement plan).
6. Includes an 'adaptive management' and review program to ensure uncertainty will reduce over time, and 'performance standards' are efficiently met. The program must: a. require frequent review of the effectiveness of management activities with high levels of uncertainty; b. ensure new information is collected and incorporated into the plan, as a result of implementing the plan and from relevant external sources (e.g. literature, EPBC Act policy statements); c. include a schedule and triggers for internal auditing of the plan's implementation and its effectiveness in meeting 'performance standards'; and d. require periodic review and technical evaluation (i.e. by a suitably qualified ecologist or relevant expert), and revision of the plan: i. according to approved timeframes; ii. in response to changing circumstances; and iii. to address learnings from implementing *corrective actions and/or TARPs*.
7. Includes a monitoring program adequate to inform 'adaptive management' and to demonstrate 'performance standards' have been, will be, or are likely to be met and maintained. The monitoring program must: a. engage suitably qualified persons to design and conduct monitoring, and analyse monitoring data; and b. describe the monitoring methodology that will be implemented including, but not limited to: i. monitoring area/site selection;

ii. sampling technique and intensity over space and time; iii. the statistical analyses that will be employed; and iv. an assessment of effectiveness and constraints to use, including but not limited to: o consistency with relevant Commonwealth, State or Territory guidelines; o capability of detecting change in environmental condition due to management interventions, taking into consideration effects of seasonal and climatic variability; and o statistical power.
8. Includes a program for handling and storing information/data for the purpose of 'adaptive management', reporting, publishing and auditing in accordance with conditions of the approval (e.g. for compliance purposes).
9. Includes as an appendix to the plan quantitative and qualitative 'baseline' data from on-ground surveys and photo-point monitoring sites within the action boundary or offset site(s) and data from 'benchmark', 'control' or reference sites outside the action boundary or offset site(s).
10. Includes a program to report on plan implementation. The program must: a. identify EPBC Act approval reporting obligations and how those obligations will be met; b. include reporting template/s; and c. include a schedule and triggers for reporting types (e.g. annual compliance, environmental incidents and non-compliance).
11. Specifies roles, responsibilities and accountabilities for implementing the plan.
12. Ensures maps and diagrams used are clearly legible when printed on A4 and that they: a. show the project area in a regional context; b. show areas with differing environmental condition or habitat quality, protected areas, management zones and buffer or 'no-go' zones'; c. show the location (or general location) of monitoring plots and management activities that will be undertaken, and are scaled to enable the reader to clearly identify local landmarks (e.g. fences, tracks, buildings) d. include a legend, metric graphic bar scales, north point, local grid lines and a title block showing: EPBC Act number; project name; author; datum; scale (e.g. 1:25 000); source and date of data/imagery.
13. References scientific, legal or other claims or statements that support the effectiveness of the plan (e.g. literature, published guidelines, legislation, conservation advice, recovery plans and threat abatement plans).
14. Makes clear, firm commitments. Uses 'will' and 'must' when committing to actions and not: 'where possible'; 'where practicable'; 'as required'; 'to the greatest extent possible; 'should'; or 'may'.

15. Includes a glossary of terms comprised of: acronyms; terms open to different interpretations, not in common use; technical; or terms used as defined in the approval conditions.

Appendix 2 Construction Water Strategy Data Review and Gap Analysis (Jacobs 2020)

Karratha Tom Price Road Stage 4

Construction Water Strategy

Data Review and Gap Analysis

KTP4 WS0001 | V1

4 Aug 2020

Main Roads Western Australia

112/17

Document history and status

Revision	Date	Description	Author	Checked	Reviewed	Approved
0	11/06/2020	Draft Report for Client Review	PM	PM	CC	DM
1	04/08/2020	Final	PM	PM	CC	DM

Distribution of copies

Revision	Issue approved	Date issued	Issued to	Comments
0		11/06/20	MRWA	Comments provided. Final Report updated.

Karratha Tom Price Road Stage 4

Project No:	IW217831
Document Title:	Construction Water Strategy
Document No.:	KTP4 WS0001
Revision:	V1
Document Status:	Issued
Date:	4 Aug 2020
Client Name:	Main Roads Western Australia
Client No:	112/17
Project Manager:	Brian Hartley
Author:	Pride Mangeya
File Name:	IW217831-KTP Stage 4-Data Review and Gap Analysis-FINAL.docx

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Contents

1. Introduction

Main Roads Western Australia (MRWA) engaged Jacobs to develop a water supply strategy for the proposed Stage 4 of the Karratha to Tom Price Stage 4 (KTP4) road construction. KTP4 comprises a 107 km road alignment that extends from the Rio Tinto rail line crossing of the Roebourne-Wittenoom Road (south of Millstream Chichester National Park) to the Nanutarra-Munjina Road at Mt Sheila (Figure 1.1).

Water is required for the construction phase of the project, namely for dust suppression and material conditioning (substrate engineering/compaction). It is proposed that water is sourced primarily from underground sources along the alignment. The scope of this phase of the investigation includes the assessment of prospective groundwater sources via the following tasks:

- Environmental setting review - Collect and review site background data and information (topography/ELVIS data, climate, land use, etc.), geology and hydrogeology of the area, groundwater use, groundwater dependent ecosystems (GDEs) and other sensitive receptors. This will allow further development of our understanding of the water availability in the region. This review will allow the assessment of other potential water sources in the region.
- Water allocation and licensing (high level) review - in order to assess water resource availability and access regulation, the following tasks have been undertaken:
  - Review information on water availability and allocation, licensing conditions, water allocation plan requirements of groundwater resources in the study area
  - Interrogate water licencing databases to assess potential yields in the catchment
  - Review groundwater quality information from public sources (BOM Groundwater Explorer and the Pineena water bore database for adjacent water users
- Water and infrastructure availability review - to assess the current access to groundwater via existing infrastructure, the following tasks have been undertaken:
  - Review information regarding existing water supply bores – we understand that the KTP4 will run along a similar alignment to the Rio Tinto rail corridor. Water supply bores were installed along the Rio Tinto rail corridor during construction and we have engaged with Rio Tinto (via MRWA) to access information related to these bores. WA state regulatory databases have also been interrogated for collect information on bores in the region
  - Review potential yields for bores and aquifers as targeted by the Rio Tinto supply bores
  - Review current and historical groundwater drawdown and impacts
  - Review the locations of existing bores and their relative position to the road alignment. Bores located on the opposite side of Rio Tinto rail corridor, relative to KTP4, will likely not be available to the KTP4 project, due to rail traffic and access
  - Strategy and reporting - the outcomes of the above reviews and assessment are summarised in this report. This report also includes a water supply strategy and way forward, including a summary of water supply options from existing bores and the potential need for new groundwater source points, water licensing requirements and recommendations

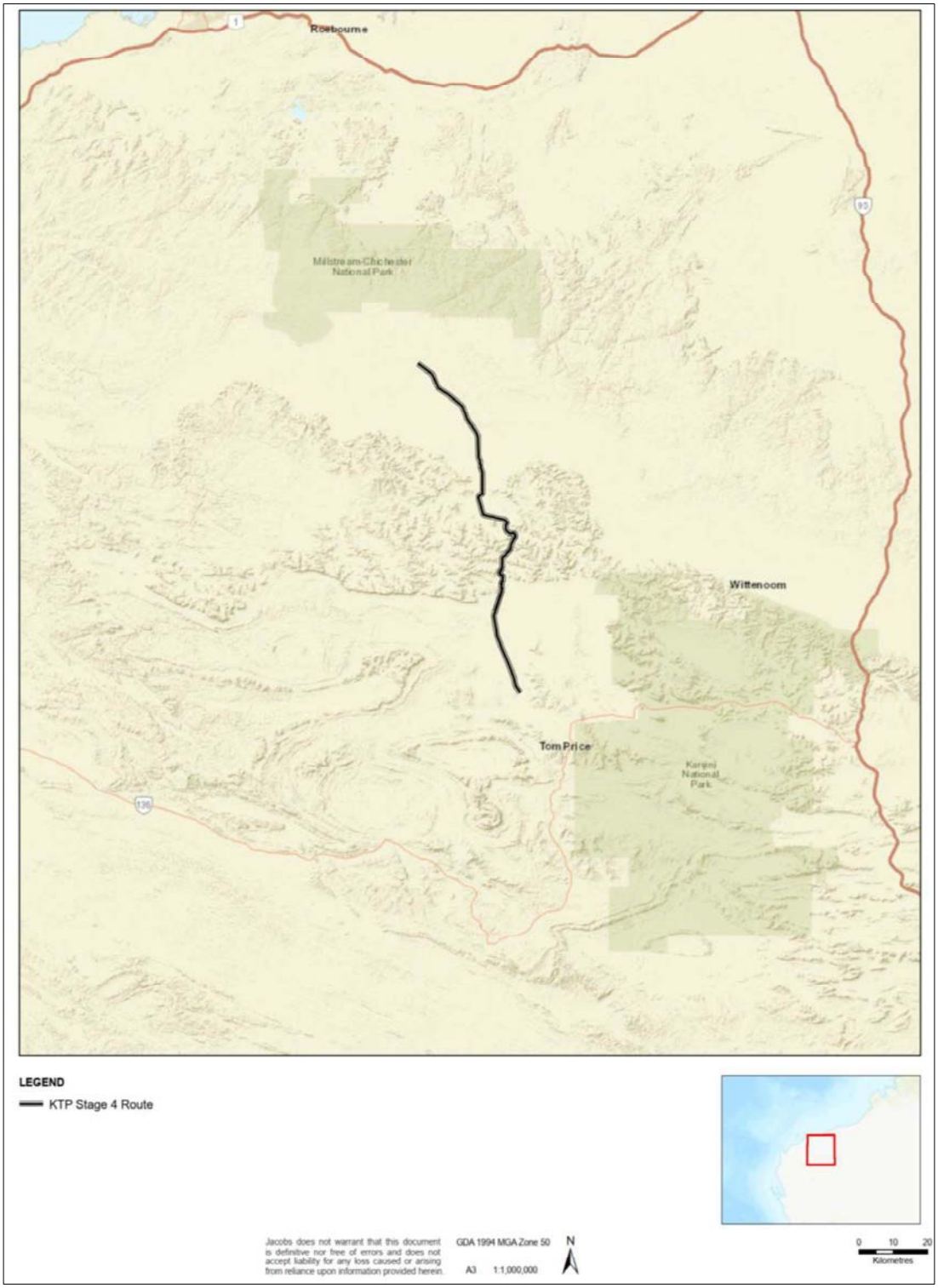

Figure 1.1: Location Map

2. Climate

The climate of the study area is described as an arid tropical climate with annual rainfall of 398.5mm (Bureau of Meteorology (BoM) Station - Tom Price, No. 005072). Summers are hot with average temperatures of 30.8˚C and winters are mild with average temperature of 15.9 ˚C. Rainfall is highest in summer months and lowest in spring.

2.1 Rainfall

The BoM holds climate data for the study area with data collected at:

- Station No. 005072 (Tom Price), located south of the study area, has rainfall data records from 1972 to 2011
- Station No. 005005 (Hamersley), located close to the middle of the study area, has rainfall data records from 1912 to 2015
- Station No. 005012 (Millstream), located north of the study area, has rainfall data from 1897 to present

Mean annual rainfall and seasonal rainfall trends along the study alignment are comparable. The rainfall data is presented in Figure 2.1 and summarised in Table 2.1.

Table 2.1: Monthly Rainfall Statistics

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Tom Price BoM station No. 005072													
Mean	82.3	95.5	60.4	30.9	20.4	25.3	16.8	10.8	2.4	4.4	10.9	40.7	398.5
Lowest	1.7	1.4	2.2	0	0	0	0	0	0	0	0	0	207.9
Median	58.4	75.2	35.4	20.2	12.7	15.4	8.8	1.8	0	0.5	4	23.6	324.2
Highest	231.5	335.9	184.4	135.8	90	128.6	95.4	98.2	31.6	62.3	59.4	152	745.9
Hamersley BoM station No. 005005													
Mean	85.8	83.7	68.5	26.7	24.1	25	10.2	6.8	2.1	4.9	11.5	36.1	384.5
Lowest	0	0	0	0	0	0	0	0	0	0	0	0	69.3
Median	62.8	61.3	38.5	9.9	9.7	6.8	2.9	0	0	0	2.5	23.1	350.3
Highest	356.6	399.4	399.4	280.3	199.4	192.1	76	47	42.9	92.8	97.1	418.6	1090
Millstream BoM station No. 005012													
Mean	77.1	88.2	67.2	24.6	26.8	29.9	12.3	7.5	1.9	2.8	6.6	28.7	369.8
Lowest	0	0	0	0	0	0	0	0	0	0	0	0	128.8
Median	63.2	76.7	37.4	9.4	14.2	14.9	3	0	0	0	1.1	20.8	338.2
Highest	368.5	388.1	423.8	255.3	175	197.4	194.1	119.4	54.4	80.3	50	136	898.7

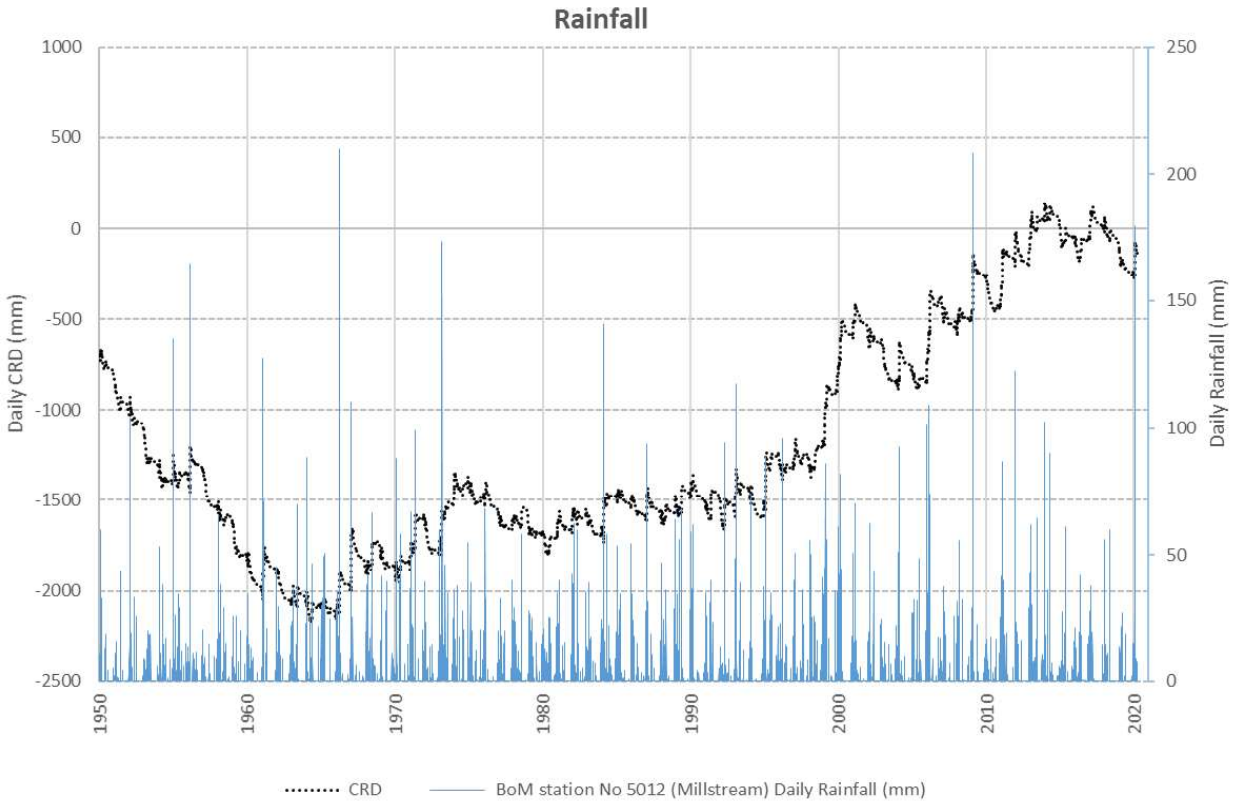

Figure 2.1: Millstream Rainfall (1950 to 2020)

Figure 2.1 shows the daily and the Cumulative Rainfall Departure (CRD) for the Millstream Station (BoM station No. 005012) for the period from 1950 to 2020. It is apparent from the CRD trend that from 1966 to 2014, there was a long period of predominately above average rainfall (seen in the upward trending CRD plot). Following this, from 2014 there was a short trend of predominately below average rainfall (downward trending plot). Short term cycles of above and below average rainfall are super-imposed on the longer-term trends.

Figure 2.2 presents a 20-year snapshot for the Millstream station for the most recent rainfall data from 2000 to 2020. A strong seasonal pattern is evident in the plot.

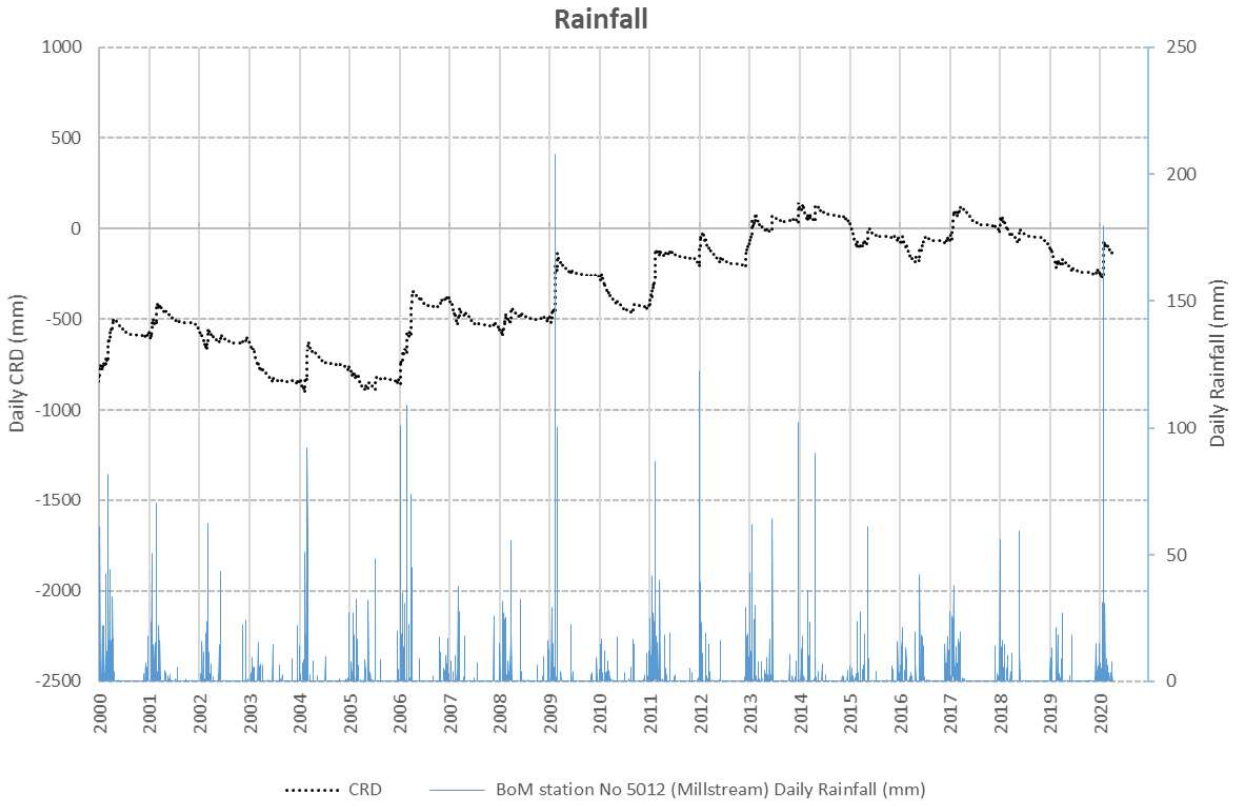

Figure 2.2: Millstream Rainfall (2000-2020)

2.2 Evaporation

Daily Class A Pan evaporation has been recorded at Wittenoom (BoM station No. 005026) from 1967 to 2019. The average daily evaporation rate is presented in Table 2.2. The average annual daily Pan A evaporation is 8.6 mm/day. Wittenoom is the closest monitoring station to the study area, and it is approximately 70 km to the north-east. Mean monthly rainfall data is also provided for comparison. Wittenoom annual rainfalls are approximately 90 mm higher than Millstream.

Table 2.2: Evaporation - BoM Station 5026 (Wittenoom)

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Wittenoom BoM station No. 005026													
Mean Monthly Rainfall (mm)	115.9	103.1	68.9	27.3	26.7	29.3	13.7	7.7	2.9	3.9	9.5	48.4	461.8
Mean Daily Evaporation (mm)	11.3	9.8	9	7.7	5.7	4.5	4.8	6.1	8.6	11.1	12.4	12.4	8.6

3. Geology

3.1 Overview

The proposed KTP4 alignment is located within the Hamersley Basin of the Pilbara Craton. The Hamersley Basin consists of volcanic-sedimentary rocks of the Mount Bruce Supergroup (2,770 Ma to near 2,350 Ma) that unconformably overlie a granite-greenstone terrane (Figure 3.1).

Erosion and deposition in the Cenozoic formed deep paleochannels, which contain Channel-in-Iron Deposits (CID). More recent shallow alluvial deposits coincide with the modern stream network. Valleys and paleovalleys in the Hamersley Basin show a common sequence: CIDs at the bottom, overlain by calcrete, lacustrine clay, and varying alluvium from gravel to clay, with an upper layer of calcrete (Rojas. et. al., 2018).

3.2 Mount Bruce Supergroup

The Mount Bruce Supergroup is divided into the Fortescue, Hamersley and Turee Creek groups which are described below. The descriptions of the groups are based on information from Thorne and Trendall (2001).

3.2.1 Fortescue Group

The Fortescue Group (2,775 Ma - 2,630 Ma) is the stratigraphically lowest group within the Mount Bruce Supergroup. The Fortescue Group is a thick sequence of mafic lava flows and associated clastic and volcaniclastic sedimentary rocks. Table 3.1 provides a summary of formations within the Fortescue Group.

Table 3.1: Summary of geological formations in the Fortescue Group.

Formation	Description
Jeerinah Formation	Argillite, sandstone, dolomite, chert, and a variety of volcanic rocks including basalt flows, pillow lava, fine- to coarse-grained mafic volcaniclastic, and felsic volcaniclastic rocks.
Bunjinah Formation	Consists mainly of basalt flows, pillow lava, fine-to coarse-grained and mafic volcaniclastic rocks. Non-volcanic sedimentary rocks, including carbonate, quartz sandstone, conglomerate, and argillite are also recorded locally.
Pyradie Formation	Pyroxene spinifex-textured basalt flows and pillow lava, hyaloclastite, komatiite, and minor chert and tuffaceous argillite.
Boongal Formation	Consists mainly of basalt flows, pillow lava, fine- to coarse-grained mafic volcaniclastic rocks, and sedimentary carbonate rocks
Hardey Formation	Comprises a diverse suite of non-volcanic sedimentary rocks and volcanic rocks. The former include clast- and matrix-supported conglomerate, feldspathic quartz sandstone and pebbly sandstone, and argillite. Volcanic rocks include felsic and mafic volcaniclastic deposits, basaltic flows, and local pillow lava. Dolerite and layered mafic sills form a significant part of the stratigraphy in the northwest Pilbara and south Pilbara sub-basins
Mount Roe Basalt	Consists mainly of basaltic flows and local pillow lava interbedded with minor tuff, hyaloclastite, and epiclastic rocks; subordinate non-volcanogenic sedimentary rocks include clast- and matrix-supported conglomerate, feldspathic quartz sandstone, and argillite
Bellary Formation	Massive basalt and basaltic breccia, vesicular basalt, and mafic tuff occur in lower and upper levels interbedded with both subaerial and subaqueous fan-delta deposits.

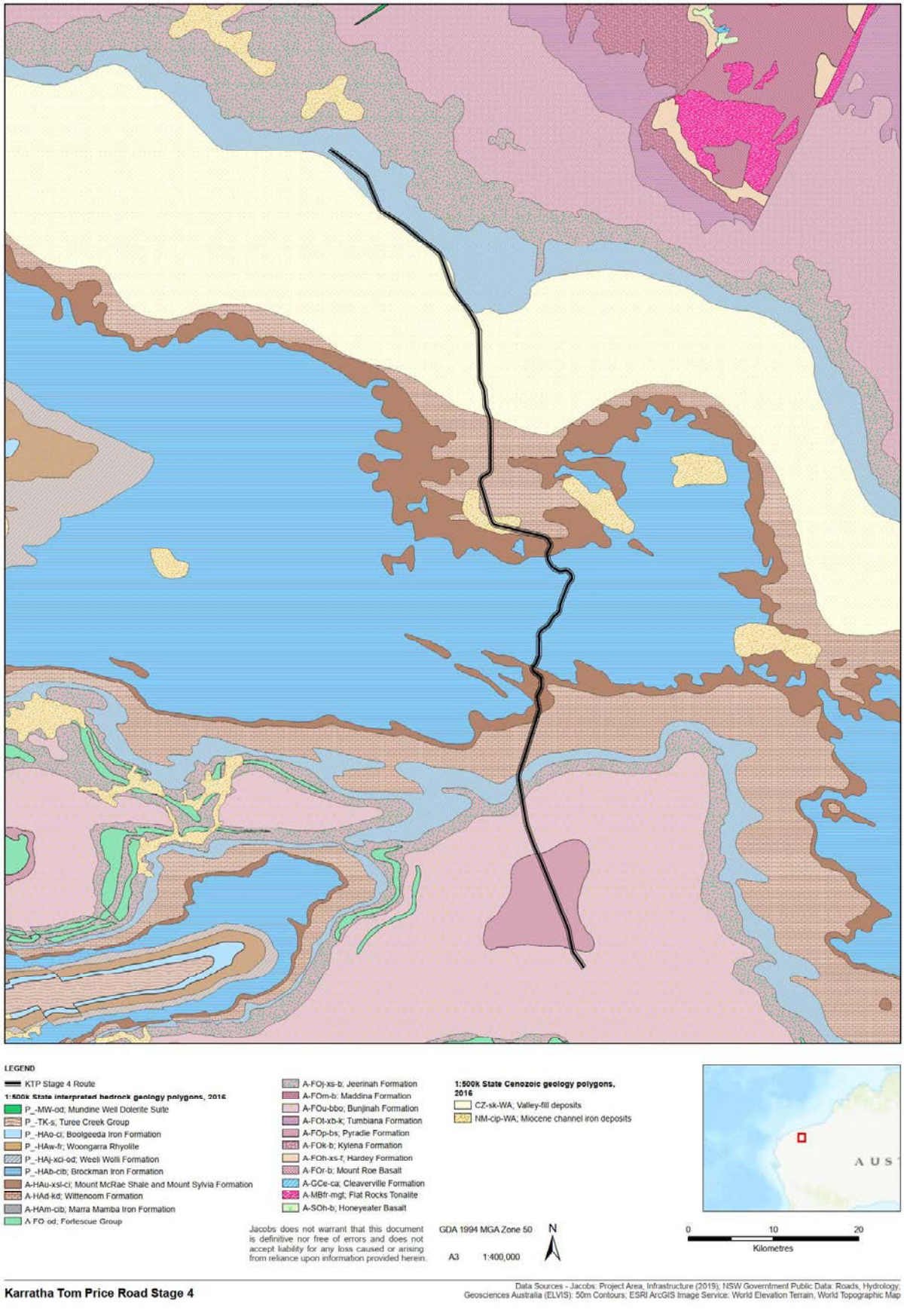

Figure 3.1: Geology of study area.

3.2.2 Hamersley Group

The Hamersley Group (2,630 Ma - 2,445 Ma) is about 2.5 km thick and is characterised by abundant banded iron-formations (BIFs), which have acted as the host rocks for large bodies of high-grade iron ore. The BIF units are separated by thinner 'shales', which are also iron-rich. Many of the BIFs have a volcanogenic component. The Wittenoom Formation, in the lower part of the Hamersley Group, consists largely of dolomitic rocks. The Woongarra Rhyolite is a thick intrusive rhyolitic unit in the upper part of the Hamersley Group. The Boolgeeda Iron Formation is the uppermost formation of the Hamersley Group.

3.2.3 Turee Creek Group

The Turee Creek Group (2,445 – 2,208 Ma) unconformably overlies the Hamersley Group. The Turee Creek Group consists largely of epiclastic sedimentary rocks and its outcrop is confined to a few separate localities within the southern outcrop area of the Mount Bruce Supergroup. The Kungarra formation is the lowest formation of the Turee Creek Group.

4. Hydrogeology

4.1 Groundwater Systems in Study Area

Rojas et al. (2018) categorised the groundwater systems in the Pilbara region into the following:

- CID aquifers
- inland alluvial systems and paleovalleys, including calcrete and valley-fill aquifers
- karstifed dolomites underlying inland valleys within the Hamersley Range
- Permian and Cenozoic paleochannels in the northeast of the study area
- fractured rocks comprising mineralised BIF of locally high yields and limited storage
- fractured bedrock formations

Figure 4.1 shows the location of the main aquifer types within the greater Pilbara Region. Aquifer types occurring along and surrounding the proposed KTP4 alignment include CIDs aquifers, valley-fill aquifers, karstifed dolomites aquifers and fractured rock aquifers.

The sections below provide brief descriptions of the four main aquifer types in the KTP4 area, based on Rojas et al. (2018). Table 4.1 summarises information on the thickness, salinity and bore yields for aquifers in the study area. Table 4.2 provides hydraulic property summary statistics for the aquifer types for the Pilbara region.

4.1.1 Channel Iron Deposits Aquifers

CIDs aquifers are concealed iron-rich highly porous and permeable deposits underlying current valleys and paleovalleys. CID aquifers are composed of basal ferruginous sediments derived from BIFs of the Hamersley Group, highly porous and permeable, capable of significant yields up to 1,500 m^3/day and show thicknesses of up to 100 m and typical widths of less than 1 km (refer Table 4.1) in the Robe River area (refer Figure 4.1).

CID aquifers are normally overlain by leaky aquifers and can behave as unconfined aquifers when in hydraulic connection with overlying sediments, and also as confined aquifers when overlain by poorly transmissive sediments. Table 4.2 provides a summary of hydraulic properties for CID aquifers within Pilbara Region.

The main recharge mechanism is downward leakage from overlying aquifers. Conceptually, in most cases, CIDs are hydraulically connected with overlying valley-fill sediments forming inland alluvial aquifer systems and they exchange downward fluxes to underlying karstifed/fracture dolomite aquifers of regional extent.

The CID aquifer total dissolved solids concentration in the Robe River area (refer Figure 4.1) is generally below 200 mg/l (Table 4.1), which is typical of freshwater conditions.

4.1.2 Valley-fill and Inland Alluvial Aquifers

Valley-fill aquifers occur along the Fortescue River valley channel. Valleys and paleovalleys in the Hamersley Basin show a common sequence of CIDs at the bottom, overlain by calcrete, lacustrine clay and varying alluvium from gravel to clay, with an upper layer of calcrete commonly developed in the zone of watertable fluctuation.

Valley-fill aquifers develop high transmissivity and secondary porosity in calcrete deposits and groundwater usually occurs in interconnected karstified dolomites, CID, calcrete, and gravel aquifers. Hydraulic connectivity of these aquifers, however, depends on local conditions and the presence of confining units. Table 4.2 provides a summary of hydraulic properties for valley-fill aquifers within Pilbara Region.

The aquifers vary from unconfined to confined given the complex nature of layering in the deposits. Ground water recharge takes place through streamflow infiltration in those river sections cutting valley-fill sediments or the outcrops of calcrete/CID deposits, and through scree on the valley flanks. Estimates of recharge in the valley-fill

aquifers in the central Pilbara Region vary from 0.09 Mm3/year/km to 17 Mm3/year/km length of valley (approximately 250 m3/day/km to 46,500 m3/day/km) and depend on factors such as frequency, flow volume, and duration of surface flows (Johnson and Wright 2001).

The main discharge mechanisms correspond to outflows to river springs and pools, evapotranspiration, and direct evaporation where the water table is close to the surface. The valley-fill aquifers support relevant spring-fed groundwater dependent ecosystems around the Weeli Wolli Creek and in the Millstream aquifer area.

Groundwater in the valley-fill aquifers is usually fresh to brackish, with exception of the Fortescue Marsh, a closed basin in the Upper Fortescue Valley, where hypersaline groundwater has been reported (Table 4.1). Valley-fill aquifers show the largest potential when hydraulically connected with underlying fractured bedrocks or karstified dolomites. The calcrete aquifer around Millstream in the Lower Fortescue valley is one of the most significant water resources for this type of aquifer.

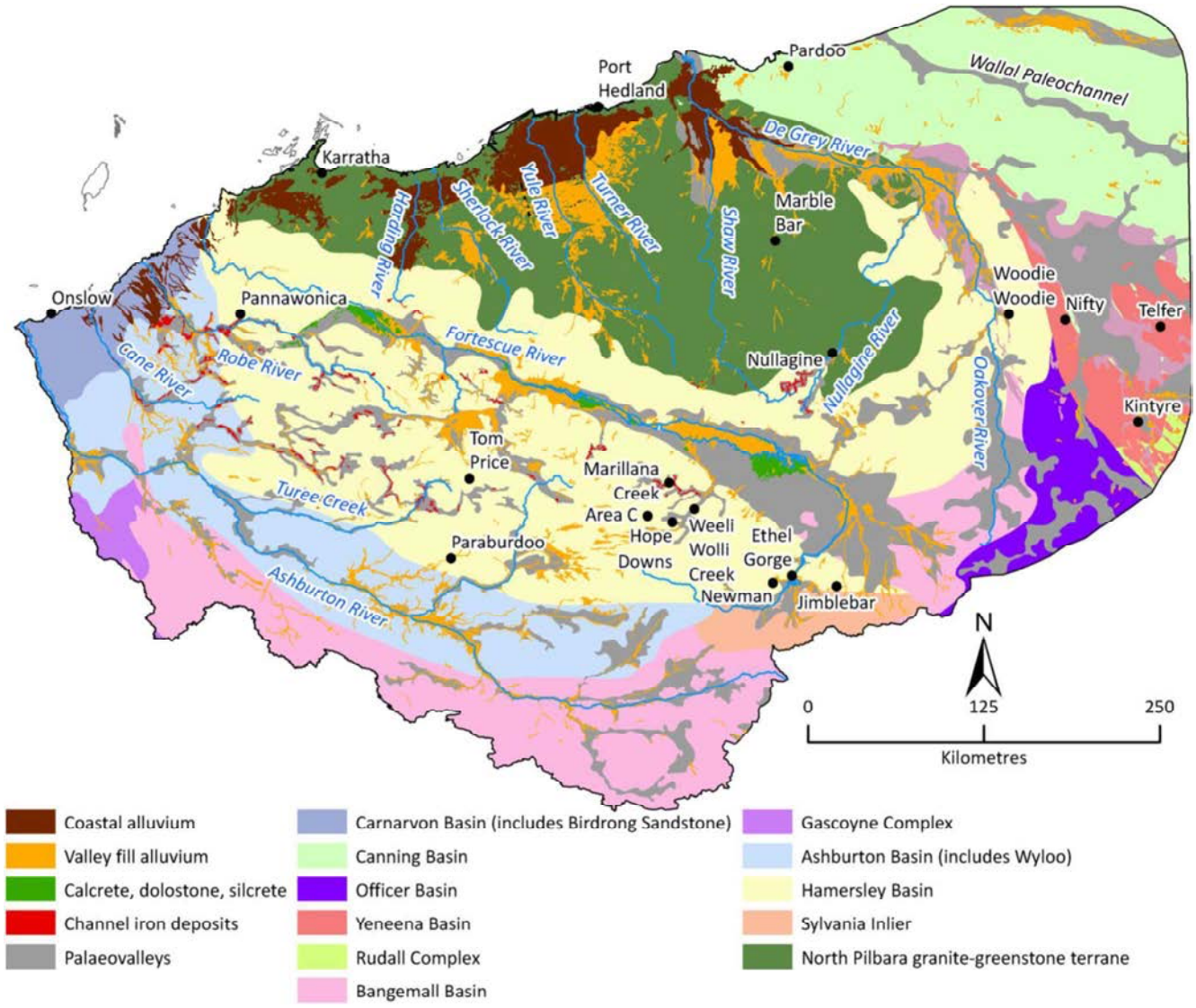

Figure 4.1: Main aquifer types in the Pilbara Region. Source: Rojas et al. (2018)

Table 4.1: Summary information on aquifers within the study area. Source:Rojas et al. (2018)

Aquifer Type	Area	Thickness (m)	Total Dissolved Solids (mg/L)	Bore Yields	
				(m^3/day)	L/s
CID	Robe River	40 - 100	<200	1,500	17
Valley-fill	Lower Fortescue Valley	Up to 150 [45][a]	200 - 1500	100-500 [<1,500][b]	1-6[<17]
	Upper Fortescue Valley	60 [up to 150][c]	<60,000[d]	-	-
	Hamersley Range	<90	500-550	860	10
Karstified/weathered dolomite	Lower Fortescue Valley (around Millstream)	150	150–1,500	<2,000–5,500	<23 - 63
Fractured rock	Mine sites at Tom Price	51	480–3,000	1,000	12
	Mineralised BIFS at Tom Price	-	200–1400	500	6

[a] Value in brackets corresponds to the calcrete aquifer in the Lower Fortescue Valley around Millstream.

[b] Values can reach high bore yields depending on the connectivity of aquifer (calcrete, conglomerate, and alluvium).

[c] Some creeks of the Upper Fortescue Valley can reach up to 150 m depth of alluvial sediments (e.g., Upper Weeli Wolli Creek).

[d] Hypersaline groundwater recorded in the vicinity of the Fortescue Marsh.

Table 4.2: Summary of hydraulic properties for aquifer types within Pilbara Region. Source:Rojas et al. (2018)

Aquifer Type	Statistic	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)	Storativity (-)
CID	Mean	14.85	1449.88	1.05×10^{-2}
	Median	15.9	740	8.75×10^{-4}
	Range	305.86	20,992	1.9×10^{-1}
	No. of observations	122	177	124
Valley-fill	Mean	7.44	931	4.17×10^{-3}
	Median	8.8	274	4×10^{-4}
	Range	375	10,000	8.9×10^{-2}
	No. of observations	87	125	81
Karstified/weathered dolomite	Mean	1.56	1,329	4.02×10^{-2}
	Median	2.14	380	2×10^{-3}
	Range	390	24,992	3×10^{-1}
	No. of observations	46	75	39
Fractured rock	Mean	2.26	638	1.27×10^{-2}
	Median	6.04	140	6×10^{-4}
	Range	420	10,500	6.4×10^{-1}
	No. of observations	322	407	212

Aquifer Type	Statistic	Hydraulic Conductivity (m/day)	Transmissivity (m^2/day)	Storativity (-)
Mineralised BIF	Mean	3.42	951	3.31×10^{-2}
	Median	5.17	427	3×10^{-3}
	Range	769	10,000	5×10^{-1}
	No. of observations	940	1,243	730

4.1.3 Karstified/Weathered Dolomite Aquifers

The karstified dolomite of the Wittenoom Formation underlie the major valleys of the Hamersley Range, and is prospective for groundwater where it underlies thick sequences of valley-fill. Dolomite in the study area is highly variable in nature, from massive to highly karstifed.

The Wittenoom Formation of the Millstream aquifer reaches thicknesses of up to 150 m and can have cavities up to 0.5 m thick, thus, having high transmissivities and bore yields up to 5,500 m^3/day (Table 4.1). Table 4.2 provides a summary of hydraulic properties for karstified/weathered dolomite aquifers within Pilbara Region.

The Total Dissolved Solids (TDS) concentrations in the Wittenoom Formation around the Millstream area suggest that groundwater in this aquifer is fresh (Table 4.1). The main recharge mechanism corresponds to vertical leakage from overlying inland alluvial aquifers.

4.1.4 Fractured Rock Aquifers

Fractured rock aquifers occur across the greater part of the study area, but do not contain regionally substantial groundwater resources. They can, however, locally provide water supply and feed springs and pools supporting GDEs.

Fractured rock aquifers occur within the upper weathered zone of granite basement rocks where secondary porosity has been developed due to weathering, fractures, joints, and quartz veining or in greenstone rocks where brittle deformation has occurred. These fractured rock aquifers are commonly unconfined.

Fractured rock aquifers also occur in BIFs where weathering and/or ore mineralisation has enhanced well-developed solution features. Groundwater in orebodies is commonly compartmentalised and stand-alone water supplies have been developed.

Given the importance mining has in the Pilbara Region, Rojas et al. (2018) further sub-divided this type of aquifer into those occurring in rocks of the granite–greenstone terrane and in iron-rich deposits showing well-developed fractures due to ore mineralisation (mineralised BIFs).

Available data on TDS indicate that these aquifers are classified as fresh to brackish in the study area (Table 4.1).

Table 4.2 provides a summary of hydraulic properties for fractured rock aquifers and mineralised BIFs within Pilbara Region.

5. Water Licensing

Water users in the Pilbara require a water licence issued under *section 5C of the Rights in Water and Irrigation Act 1914 Act* to lawfully take groundwater, unless exempt. A licence is also required to construct or alter wells (including drilling and testing), which is issued under section 26D of the Act.

Under *Rights in Water and Irrigation Exemption (Section 26C) Order 2012*, a licence is not required for the construction or alteration of, or the taking of water from, non-artesian wells that are used solely to monitor water levels and/or water quality.

When submitting 26D and 5C applications, proponents will need to:

- outline their investigation program and timelines
- demonstrate a clear use for the water
- provide the usual information associated with a 5C application once investigations are complete – such as legal access to land, operating strategy (if required) and hydrogeological report
- advertise the application/s if the requested volume is for 100,000 kL or more

5.1 Test Pumping Licence

The Department of Water and Environmental regulation (DWER) usually allows a cumulative total take of up to 50 ML per bore for the purpose of test pumping and commissioning. Proponents requiring a volume above this amount should discuss it with the DWER. Proponents completing large-scale or long-term pump-testing may require a 5C licence and/or other approvals.

5.2 Assessing Licences for Fractured Rock Aquifers

For fractured rock aquifers such as the Ashburton – Hamersley-Fractured Rock Resource, applicants are required to:

- demonstrate their ability to abstract water
- identify and demonstrate their ability to manage any impacts on groundwater-dependent values over the life of the project
- assess the potential impacts on overlying or nearby alluvial aquifers
- provide an appropriate level of hydrogeological reporting, as specified in Operational policy no 5.12 (DoW, 2009c)

6. Groundwater Allocation

The groundwater resources occurring along the proposed KTP4 alignment are covered by the Pilbara groundwater allocation plan (Department of Water, 2013). The study area falls under the Ashburton administrative sub-area of the Pilbara groundwater allocation plan (Plan).

The Plan defines four groundwater resources within Ashburton administrative sub-area covering the study area. The groundwater resources (shown in Figure 6.1) are as follows:

- Ashburton – Hamersley-Millstream resource
- Ashburton – Wittenoom-Wittenoom resource
- Ashburton – Hamersley-Fractured Rock
- Ashburton – Hamersley-Fortescue

Table 6.1 provides a summary of the allocation for each groundwater resource area. Information on the allocation levels for the groundwater resources is based on the Pilbara groundwater allocation plan (Department of Water, 2013).

6.1 Ashburton – Hamersley-Millstream Resource

The Ashburton – Hamersley-Millstream Groundwater Resource is one of the nine target aquifers specified in the groundwater allocation plan. Target aquifers have allocation limits set by DWER to provide more certainty around the volume of water available for nearby ports and coastal towns.

The Ashburton – Hamersley-Millstream Groundwater Resource includes aquifers within Millstream Dolomite (Millstream Aquifer), shales, gravelly-clay and chert.

The allocation limit for the Ashburton – Hamersley-Millstream Groundwater Resource is 15,682,500 kL/year (Table 6.1). Information provided by the DWER indicates that, as of 9 April 2020, the Ashburton – Hamersley-Millstream Resource was fully allocated and there are seven active licences. Details of the active licences are summarised in Table 6.2.

The public supply allocation limit of 15,000,000 kL/yr for the Ashburton – Hamersley -Millstream Groundwater Resource is the maximum volume the Water Corporation's borefield can supply to the scheme when supply from Harding Dam is not available. The amount of water available from the aquifer in any one year depends on how recently recharge has occurred. This is because Millstream aquifer is in a national park and supports high cultural, social and environmental values and taking water from the aquifer, if not managed carefully, poses a risk to these values.

6.2 Ashburton – Wittenoom-Wittenoom Resource

The Ashburton – Wittenoom-Wittenoom Resource consists mainly of the karstic dolomite aquifers of the Wittenoom Formation. According to the Rojas et al. (2018) classification, the Wittenoom Formation dolomite aquifers fall into karstified/weathered dolomite aquifer-type. The Ashburton – Wittenoom-Wittenoom Resource is a non-target aquifer (i.e. water supply potential and demand is low or being investigated).

The allocation limit for the Ashburton – Wittenoom-Wittenoom Resource is 20,000,000 kL/year (Table 6.1). Information provided by the DWER indicates that as of 9 April 2020, there was 12,721,300 kL/year allocated to 24 licences with 7,278,700 kL/year available for allocation from the Ashburton – Wittenoom-Wittenoom Resource. Details of the active licences are summarised in Table 6.3.

6.3 Ashburton – Hamersley-Fortescue Resource

The Ashburton – Hamersley-Fortescue resource refers to groundwater within the valley-fill deposits along the Fortescue River. The resource is a non-target aquifer.

There is no allocation limit for the Ashburton – Hamersley-Fortescue resource and licence applications are assessed on a case-by-case basis.

Information provided by the DWER indicates that as of 9 April 2020 154,092,000 kL was allocated to 16 licences. Details of the active licences are summarised in Table 6.4.

6.4 Ashburton – Hamersley-Fractured Rock Resource

The Ashburton – Hamersley-Fractured Rock Resource is a non-target aquifer. The groundwater resource does not have an allocation limit because the DWER has not set an allocation limits for fractured rock aquifers because fractured rock aquifers have complex and irregular structures and characteristics, such as water availability, recharge and storage and the sustainable amount of water that can be taken each year is very localised.

Fractured rock aquifers are managed solely through case-by-case licensing. For these aquifers, the groundwater allocation plan provides the department's approach and policy for licence assessments rather than setting out detailed management and allocation limits. Information on active licences was not available to Jacobs at the time of preparing this report.

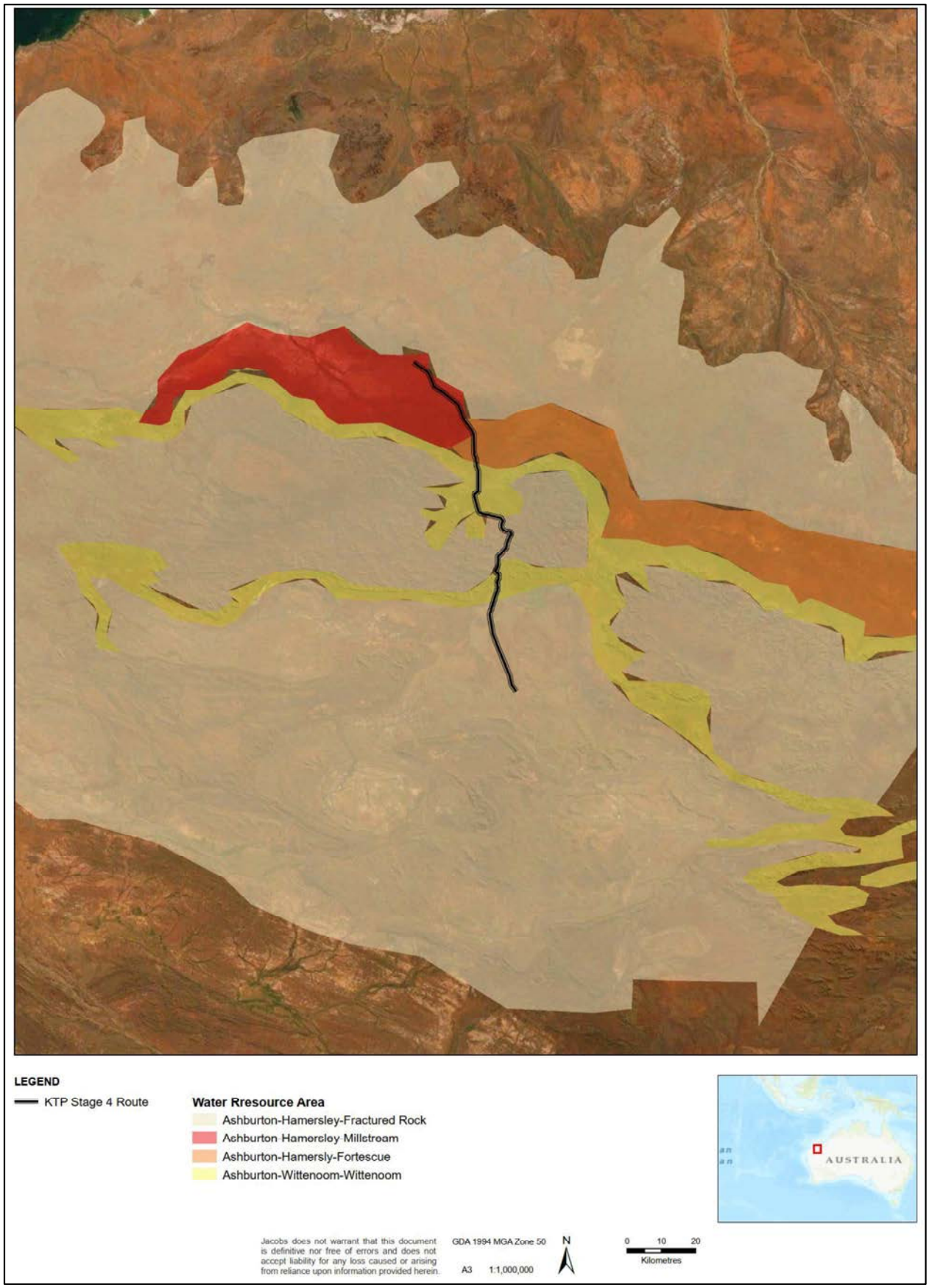

Figure 6.1: Groundwater resources within study area.

Table 6.1: Allocation limits for groundwater resources

Resource (Subarea – aquifer)	Allocation Limit (kL/yr)	Allocation limit component (kL/yr)				Status of water availability for licensing (as at 9 April 2020)
		Licensable		Unlicensable	Reserved Water	
		General licensing	Public water supply	Unlicensed use	Public water supply	
Ashburton – Hamersley-Millstream	15,682,500 [a]	682,500	15,000,000	0	0	Fully Allocated
Ashburton – Wittenoom-Wittenoom	20,000,000	19,980,000	20,000	0	0	7,278,700
Ashburton – Hamersley-Fortescue	Not set	Not set	Not set	Not set	Not set	Case-by-case
Ashburton – Hamersley-Fractured Rock	Not set	Not set	Not set	Not set	Not set	Case-by-case

[a] 15,000,000 kL/yr is the maximum amount that can be taken from the Water Corporation's borefield, provided management conditions are met and Harding Dam cannot be used. The long-term reliable allocation for Ashburton – Hamersley-Millstream is an average of 6,000,000 kL/yr. The general component is mostly for temporary use away from the borefield and the component will be reduced as this use ceases.

Table 6.2: Summary of licence information for Ashburton- Hamersley Millstream Resource

Licence WRI Number	Issue Date	Expiry Date	Allocation (kL/year)	Licence Holder
105696	22/10/2018	11/05/2024	15,000,000	Water Corporation
156125	9/04/2013	1/04/2023	300,000	Pilbara Iron Company (Services) Pty Ltd
177274	10/04/2019	23/06/2023	220,000	Pilbara Iron Company (Services) Pty Ltd
179791	23/08/2017	22/08/2027	31,500	Shire of Ashburton
181138	8/10/2018	7/10/2028	20,000	Fortescue Metals Group Limited
183492	20/10/2016	19/10/2021	100	Rio Tinto Exploration Pty Limited
204173	31/03/2020	30/03/2030	1,500	API Management Pty Limited

Table 6.3: Summary of licence information for Ashburton-Wittenoon-Wittenoon Resource

Licence WRI Number	Issue Date	Expiry Date	Allocation (kL/year)	Licence Holder
105695	17/10/2018	28/09/2027	20,000	Water Corporation
162582	3/09/2013	2/09/2023	200,000	Pilbara Iron Company (Services) Pty Ltd
172106	24/09/2012	23/09/2022	50,000	BHP Billiton Iron Ore Pty. Ltd.
172447	28/10/2015	27/10/2025	10,000	Fortescue Metals Group Limited
172581	6/08/2013	5/08/2023	60,000	Pilbara Iron Company (Services) Pty Ltd
173187	16/12/2015	15/12/2025	40,000	Fortescue Metals Group Limited
173395	10/03/2016	9/03/2026	45,000	Hamersley Iron Pty. Limited
173556	1/06/2016	31/05/2026	70,000	Fortescue Metals Group Limited
174095	19/06/2019	1/11/2025	1,300,000	Fortescue Metals Group Limited
176259	8/06/2015	22/05/2023	10,000	Pilbara Iron Company (Services) Pty Ltd
177974	12/02/2020	11/02/2030	8,100,000	Fortescue Metals Group Limited
178305	22/11/2017	22/11/2027	5,000	API Management Pty Limited
179439	30/06/2014	29/06/2024	60,000	Fortescue Metals Group Limited
179579	28/07/2014	27/07/2024	67,500	DDG Fortescue River Pty Ltd
179706	13/08/2018	12/08/2028	20,000	Fortescue Metals Group Limited
180966	30/04/2015	29/04/2025	1,000	Rio Tinto Exploration Pty Limited
180991	29/04/2015	30/04/2025	1,000	Rio Tinto Exploration Pty Limited
182763	9/05/2016	8/05/2026	10,000	Rio Tinto Exploration Pty Limited
201832	14/08/2018	13/08/2028	800	Hamersley Iron Pty. Limited
202543	11/03/2019	10/03/2029	70,000	Pilbara Iron Company (Services) Pty Ltd
202549	12/03/2019	11/03/2029	1,500,000	Pilbara Iron Pty Ltd
203398	19/09/2019	18/09/2029	1,000	Auski Holdings Pty Ltd
203627	20/11/2019	19/11/2029	80,000	Main Roads
203967	11/02/2020	10/02/2030	1,000,000	Fortescue Metals Group Limited

Table 6.4: Summary of licence information for Ashburton-Hamersly-Fortescue Resource

Licence WRI Number	Issue Date	Expiry Date	Allocation (kL/year)	Licence Holder
158473	4/09/2013	3/09/2023	45,000	Pilbara Iron Company (Services) Pty Ltd
161717	22/09/2014	21/09/2024	100,000	Fortescue Metals Group Limited
166200	6/10/2016	5/10/2026	150,000,000	Chichester Metals Pty Ltd
167113	10/08/2012	9/08/2022	750,000	BHP Billiton Iron Ore Pty. Ltd.
168125	5/04/2019	23/06/2023	220,000	Pilbara Iron Company (Services) Pty Ltd
172221	5/10/2010	21/09/2020	15,000	BHP Billiton Iron Ore Pty. Ltd.
174242	2/09/2013	1/09/2023	15,000	Hamersley Iron Pty. Limited
174412	25/09/2014	24/09/2024	100,000	Fortescue Metals Group Limited
175224	14/12/2016	14/12/2026	20,000	Fortescue Metals Group Limited
176596	4/05/2016	2/05/2026	80,000	Hancock Prospecting Pty Ltd
178646	6/02/2015	5/02/2025	1,100,000	Chichester Metals Pty Ltd
179578	28/07/2014	27/07/2024	67,500	DDG Fortescue River Pty Ltd
179792	10/10/2014	9/10/2024	31,500	Shire of Ashburton
202096	2/11/2018	1/11/2028	8,000	Hancock Prospecting Pty Ltd
202550	12/03/2019	11/03/2029	1,500,000	Pilbara Iron Pty Ltd
203599	14/11/2019	13/11/2029	40,000	Main Roads

7. Water and Infrastructure Availability Review

The proposed KTP4 alignment will run along a similar alignment to the Rio Tinto rail corridor (Figure 7.1). Rio Tinto installed water supply bores along the corridor for railway construction purposes. Figure 7.1 shows the location of the Rio Tinto water supply bores located within 5 km of the proposed KTP4 alignment. The following sections summarise the available information on the water supply bores supplied by Rio Tinto.

7.1 Airlift Yields

An airlift yield is the rate at which groundwater is removed from a bore during drilling with an air flushed drilling method and is an estimate of the potential pumping rate of a bore (pumping capacity). Airlift yields are usually lower than the pumping rates that can be achieved during bore production pumping (in-use pumping capacity). From professional experience, the in-use pumping capacity is 1/4 to 1/2 of the air lift test yield in fractured rock aquifers. Table 7.1 and Figure 7.2 present a summary of the available airlift yields information obtained during the drilling of the Rio Tinto water supply bores.

The highest airlift yields were obtained from bores drilled into the dolomites of the Wittenoom Formation (Wittenoom-Wittenoom Groundwater Source). Airlift yields measured in the Wittenoom Formation ranged from approximately 6.5 L/s to 45.7 L/s, with the maximum yield measured at bore WB18KRP0013.

Airlift yields measured in the Hamersley-Fractured Rock Groundwater Source were generally less than 5 L/s. An airlift yield of 16 L/s was recorded in bore Warp 5, which is located close to the contact between the Hamersley-Fractured Rock and the Wittenoom-Wittenoom Groundwater Source (Figure 7.2). The bore geological log for Warp 5 indicates that the bore is screened within fractured shale of the Hamersley-Fractured Rock Groundwater Source.

Gravelly clay and clayey gravel deposits within the Hamersley-Fortescue Groundwater Source had airlift yields ranging from less than 1 L/s (WB16KRP0003) to 10 L/s (WARP20). Hamersley – Millstream Groundwater Source clays, gravelly clays, cherts and shales had airlift yields ranging from 2 L/s to 7 L/s.

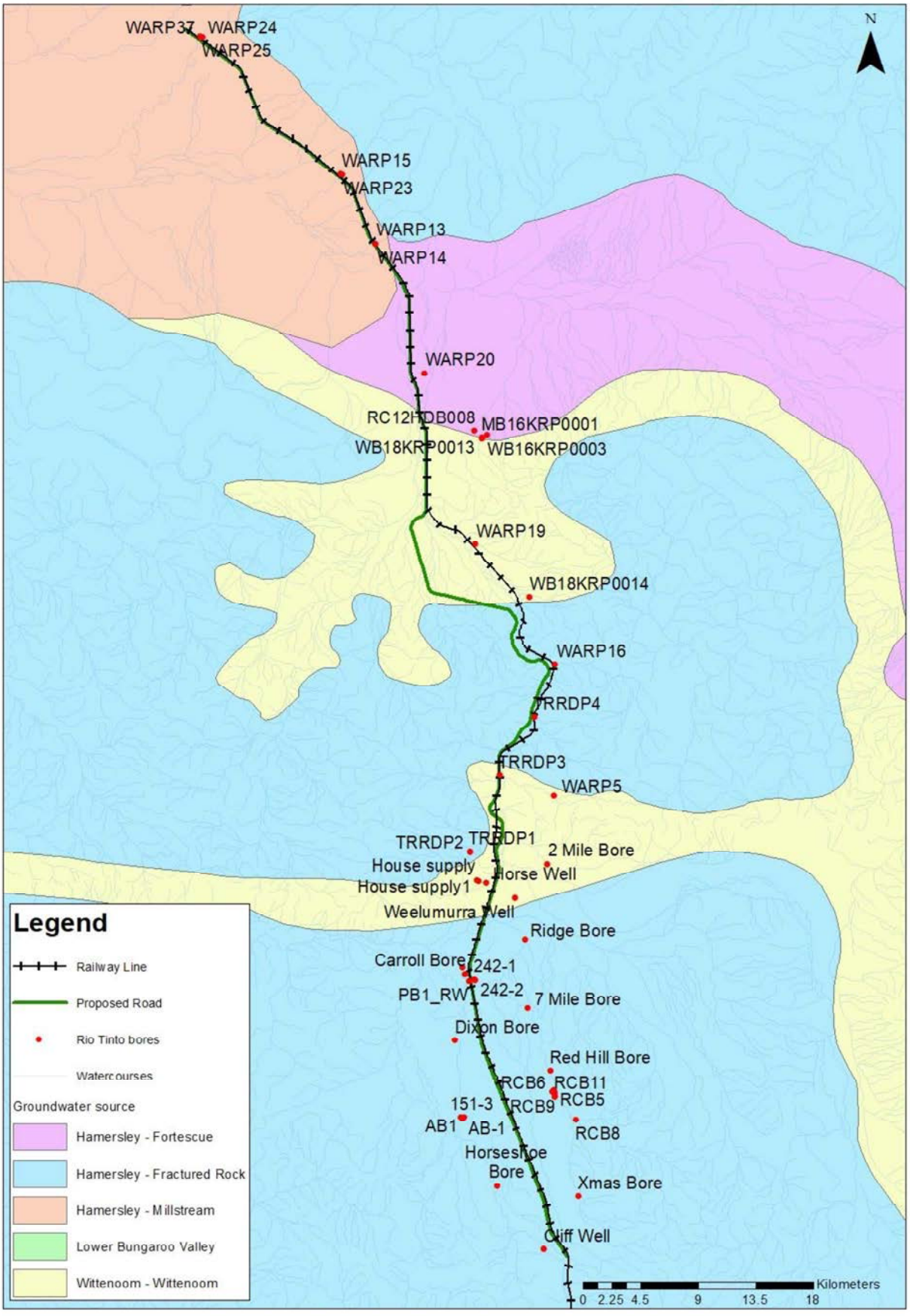

Figure 7.1: Location of Rio Tinto bores.

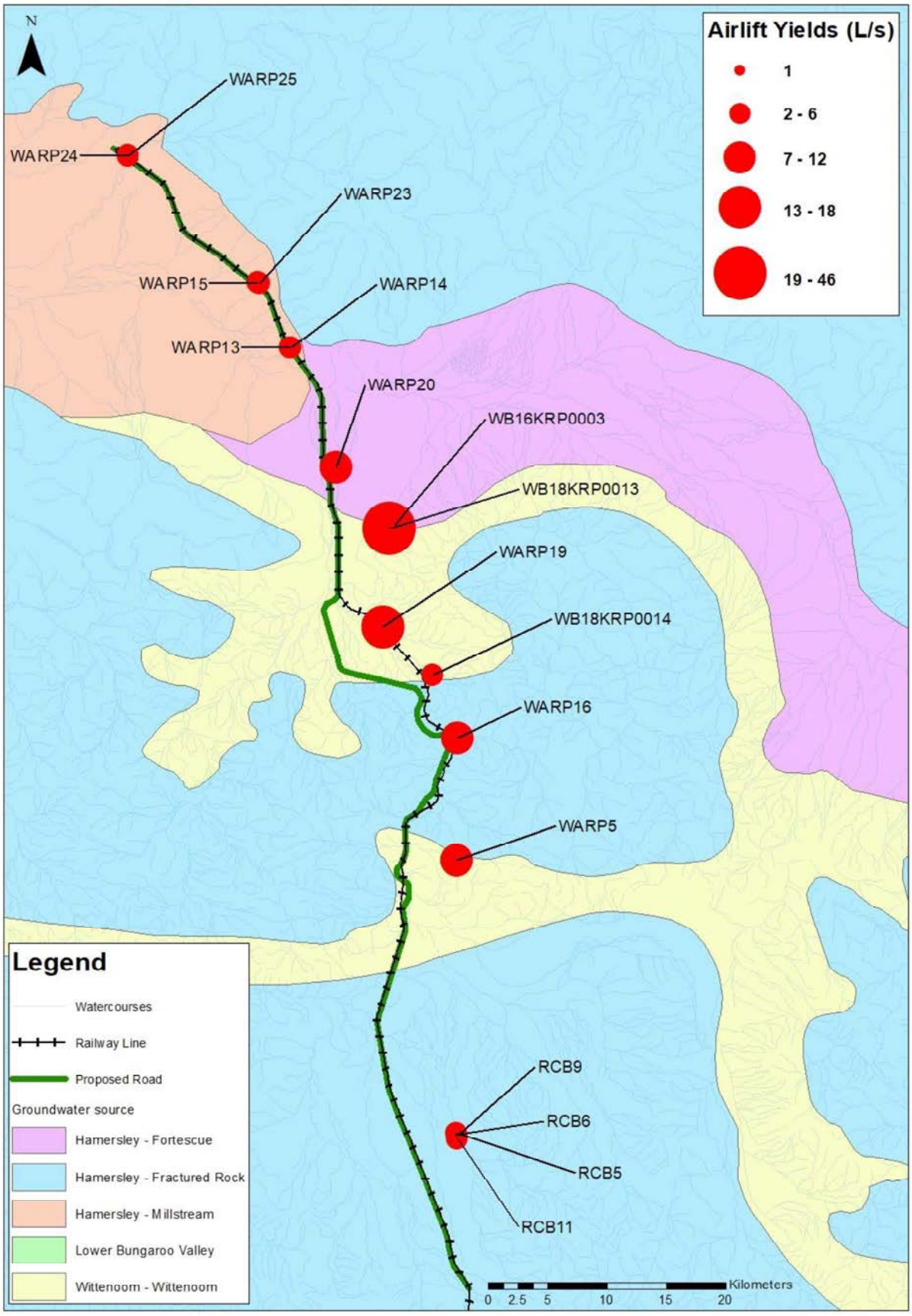

Figure 7.2: Airlift yields for Rio Tinto bores.

Table 7.1: Airlift yields and geology for Rio Tinto bores.

Bore	Depth (m)	Airlift yield (L/s)	Groundwater source	Geology of screened interval (target formations)
RCB11	83	4	Hamersley-Fractured Rock	Quartzite, sandstone and siltstone, shale (Jeerinah Formation)
RCB5	72	3.5	Hamersley-Fractured Rock	Clayey/silty gravels and silty clay
RCB6	72	1	Hamersley-Fractured Rock	Clay, gravelly clay
RCB9	86	5	Hamersley-Fractured Rock	Clay with bands of quartzite, siltstone and sandstone (Jeerinah Formation), ferricrete, dolerite
WARP13	62	5	Hamersley - Millstream	Shale (Jeerinah Formation?)
WARP14	78	5	Hamersley - Millstream	Shale (Jeerinah Formation)
WARP15	78	5	Hamersley - Millstream	Shale (Jeerinah Formation?)
WARP16	60	10	Hamersley-Fractured Rock	Gravel (Tertiary sediments)
WARP19	96	18	Wittenoom-Wittenoom	Dolomite with minor shale
WARP20	66	10	Hamersley-Fortescue	Clayey-gravel to gravel (Tertiary sediments)
WARP23	72	5	Hamersley - Millstream	Shale and chert (Jeerinah Formation?)
WARP24	96	3.8	Hamersley - Millstream	Gravelly clay, chert, shale (Jeerinah Formation)
WARP25	84	2-7	Hamersley - Millstream	Clay, chert, shale (Jeerinah Formation)
WARP5	130	16	Hamersley-Fractured Rock	Shale (fractured)
WB16KRP0003	97	<1	Hamersley-Fortescue	Gravelly clay, clayey gravel, gravel, channel in iron deposits.
WB18KRP0013	145	45.7	Wittenoom-Wittenoom	Dolomite with minor shale. Extensive fracturing with brown staining
WB18KRP0014	84	6.25	Wittenoom-Wittenoom	Dolomite with minor shale

7.2 Pumping Tests

7.2.1 Step Discharge Tests

Step discharge tests was performed in bore WB18KRP0013 and WB18KRP0014. Details of the step discharge test are presented in Appendix A. Table 7.2 and Table 7.3 show the short-term relationship between yield and drawdown for the step discharge tests.

Table 7.2: Step discharge test results for Bore WB18KRP0013.

Step	Pumping duration (minutes)	Discharge (Q)		Drawdown		s/Q [1] (day/m^2)
		L/s	m^3/d	Incremental (m)	Cumulative (m)	
1	100	25	2,160	4.48	4.48	2.07 x 10^{-3}
2	100	30	2,592	1.55	6.03	2.32 x 10^{-3}
3	100	35	3,024	1.56	7.59	2.51 x 10^{-3}
4	100	40	3,456	1.69	9.28	2.69 x 10^{-3}

[1] s = drawdown and Q = discharge

Table 7.3: Step discharge test results for Bore WB18KRP0014.

Step	Pumping duration (minutes)	Discharge (Q)		Drawdown		s/Q [1] (day/m^2)
		L/s	m^3/d	Incremental (m)	Cumulative (m)	
1	100	4	346	4.40	4.40	1.27 x 10^{-2}
2	100	6	518	3.10	7.50	1.45 x 10^{-2}
3	100	8	691	5.51	13.01	1.88 x 10^{-2}
4	100	10	864	29.75	42.76	4.95 x 10^{-2}

[1] s = drawdown and Q = discharge

A comparison of the step discharge test results for the two bores indicates there were smaller drawdowns in bore WB18KRP0013 for much larger pumping rates compared to bore WB18KRP0014. For example:

- there was an additional 1.7 m drawdown in bore WB18KRP0013 after pumping at 40 L/s for 100 minutes
- there was an additional 29.8 m drawdown in bore WB18KRP0014 after pumping at 10 L/s for 100 minutes

In summary, the results of the step drawdown tests indicate that bore WB18KRP0013 has a higher pumping capacity compared to bore WB18KRP0014.

7.2.2 Constant Rate Pumping Tests

A constant-rate pumping test was performed at bore WB18KRP0014. A summary of the pumping test and data analysis is provided in Appendix A. The following aquifer properties values were estimated from the pumping test:

- Transmissivity = 57 m^2/day
- Hydraulic conductivity = 0.88 m/day (based on an aquifer thickness of 65 m)
- Storativity = 2.5 x 10^{-5}

8. Water Strategy

8.1 Water Demand

Appendix C presents the calculations for the water demand assessment carried out by Jacobs (2020). The water demand calculation is based on water required for a 15 km long section of the proposed 107 km road. The water demand assessment was based on the following assumptions:

- Road construction would be carried out 12 hours per day, seven days a week
- Pumping bores would operate 24 hours per day, seven days a week
- It would take 45 days to complete a 15 km long section of the road

The results of the water demand assessment presented in Appendix C indicate that the water demand (excluding potable water supply for camps) for a **15 km** long section of road is between 5.3 L/s and 14.3 L/s.

8.2 Water Supply

The proposed KTP4 alignment has been divided into eight sections for the purposes of assessing the water supply options. Figure 8.1 shows the location of the road sections. All the sections are approximately 15 km long, except Section 8, which is approximately 11 km long.

A water supply assessment was carried out for each of the eight road sections to assess options for supplying the estimated upper limit of the water demand of at least 14.3 L/s for 24 hours per day, seven days a week for a construction period of 45 days (total Stage 4 construction time is estimated at 321 days). The following sections of this report provide a summary of the proposed water supply options for the road sections. The location of the bores relative to the KTP4 alignment and the Rio Tinto rail line may impact access to the bores. At this stage, the report does not consider these impacts but refers only to potentially suitable bores.

The method used to estimate in-use pumping capacities for existing and new bores is described in Section 8.2.1. The water supply options for each road section are presented in Section 8.2.2.

8.2.1 Methods Used to Estimate In-use Pumping Capacity

For fractured rocks and valley-fill deposits within the Hamersley-Fractured Rock and Hamersley-Fortescue Groundwater Sources, the in-use pumping capacity for a bore was estimated as follows:

- For existing bores where airlift-yields were estimated during drilling, the in-use pumping capacity is conservatively assumed to be the greater of 25% of the airlift yield achieved during testing or 1 L/s.
- For existing bores with no airlift yield information, the in-use pumping capacity was assumed to be 1 L/s based on the lower end of the range of typical yields for production bores drilled into these hydrogeological units.
- Groundwater exploration for the new bores will target zones of potential yields greater than 5 L/s.

For Wittenoom Formation dolomites, the in-use pumping capacity for a bore was estimated as follows:

- For existing bores where airlift-yields were estimated during drilling, the in-use pumping capacity is conservatively assumed to be the greater of 25% of the airlift yield achieved during testing or 5 L/s.
- For existing bores with no airlift yield information, the in-use pumping capacity was assumed to be 5 L/s based on the lower end of the range of typical yields for production bores drilled into the Wittenoom Formation.
- Groundwater exploration for the new bores will target zones of potential yields greater than 10 L/s.

8.2.2 Water Supply Options

The water supply options provided in this section are based on water supply from existing Rio Tinto bores and new bores to meet the water demand. Further engagements with Rio Tinto are required to get permission for MRWA to abstract the proposed amounts from the existing Rio Tinto bores. If the proposed water volumes cannot be obtained from the existing new Rio Tinto bores, additional new bores will be required to meet the water demand.

8.2.2.1 Proposed Water Supply Option for Road Section 1

The proposed water supply option for Road Section 1 is based on water supply from a bore-field comprising nine existing Rio Tinto bores and one new bore. The nine Rio Tinto bores are located both east and west of the rail line. Table 8.1 summarises information on the proposed water supply bores and Figure 8.1 shows the existing bore locations for Road Section 1.

All the proposed water supply bores for Road Section 1 are located within the Hamersley Fractured Rock Groundwater Source. The proposed combined groundwater take from the Hamersley Fractured Rock Groundwater Source is approximately 14.25 L/s which is equivalent to 55,404 kL over 45 days of continuous pumping. The Hamersley Fractured Rock Groundwater Source does not have an allocation limit and aquifers are managed solely through case-by-case licensing (Section 5.4)

Table 8.1: Road Section 1 water supply option summary.

Bore	Aquifer [1]	Depth (m)	Airlift Yield (L/s)	In-use Pumping Capacity (L/s)	Bore Status	Railway Station Water Supply
RCB11	Fractured rock	83	4	1	Abandoned	No
RCB5	Fractured rock	72	3.5	1	Abandoned	No
RCB6	Fractured rock	72	1	1	Abandoned	No
RCB9	Fractured rock	86	5	1.25	Abandoned	No
RCB8	Fractured rock	62	Unknown	1	Abandoned	No
AB1	Fractured rock	64	Unknown	1	Abandoned	No
Xmas	Fractured rock	Unknown	Unknown	1	Unknown	Yes
Horseshoe	Fractured rock	Unknown	Unknown	1	Unknown	Yes
Cliff Well	Fractured rock	Unknown	Unknown	1	Unknown	Yes
New bore	Fractured rock	90	-	5	NA	NA

[1] Aquifer type based on review of bore location on map of main aquifer types (Figure 4.1)

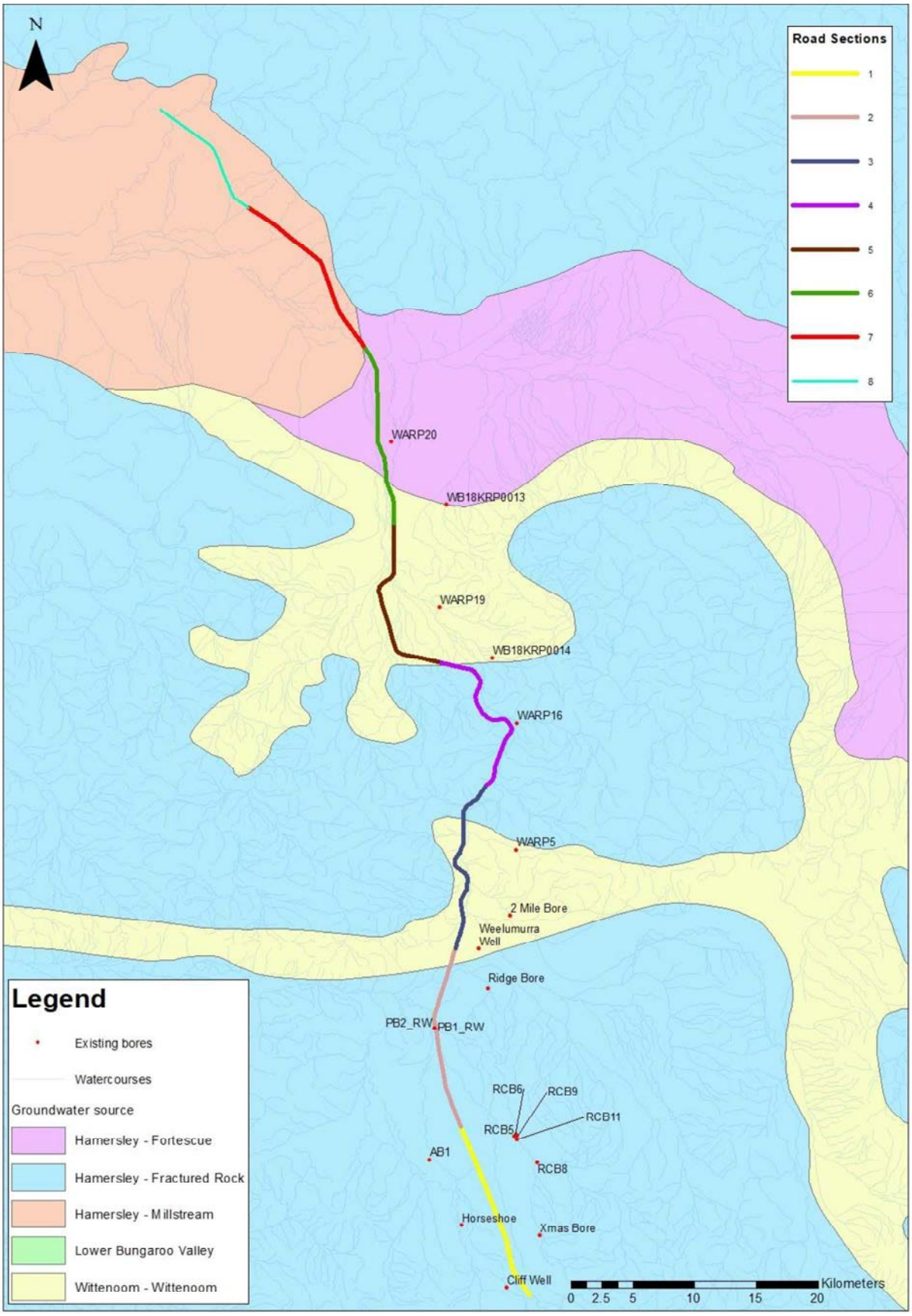

Figure 8.1: Road sections and water supply options.

8.2.2.2 Proposed Water Supply Options – Road Section 2

The proposed water supply option for Road Section 2 is based on water supply from a bore-field comprising four existing Rio Tinto bores and one new bore. The four Rio Tinto bores are located both east and west of the rail line. Table 8.2 summarises information on the proposed water supply bores and Figure 8.1 shows the bore locations for Road Section 2. The bores have an assumed combined pumping capacity of 18 L/s which is greater than the maximum assessed demand of 14.3 L/s.

The locations of the proposed water supply bores for Road Section 2 are in both the Wittenoom-Wittenoom Groundwater Source and the Hamersley Fractured Rock Groundwater Source (Figure 8.1). A summary of the potential groundwater take from the two groundwater sources is as follows:

- the proposed combined groundwater take for the bores in the Wittenoom-Wittenoom Groundwater Source (Weelumurra Well and the new bore) is 15 L/s which is equivalent to 58,320 kL over 45 days of continuous pumping. The total proposed take from the Wittenoom-Wittenoom Groundwater Source is 0.8% of the water available annually for allocation from the groundwater source (Section 6.2).
- the proposed combined groundwater take for the bores in the Hamersley Fractured Rock Groundwater Source (PB1_RW, PB_2RW and Ridge bore) is 3 L/s which is equivalent to 11,664 kL over 45 days of continuous pumping. The Hamersley Fractured Rock Groundwater Source does not have an allocation limit and aquifers are managed solely through case-by-case licensing (Section 5.4).

Table 8.2: Road Section 2 water supply option summary.

Bore	Aquifer [1]	Depth (m)	Airlift Yield (L/s)	In-use Pumping Capacity (L/s)	Bore Status	Railway Station Water Supply
Weelumurra Well	Wittenoom Formation	Unknown	Unknown	5	Unknown	Yes
PB1_RW	Fractured rock	77	Unknown	1	Abandoned	No
PB2_RW	Fractured rock	104.3	Unknown	1	Abandoned	No
Ridge Bore	Fractured rock	Unknown	Unknown	1	Unknown	No
New bore	Wittenoom Formation	90	NA	10	NA	No

[1] Aquifer type based on review of bore location on map of main aquifer types (Figure 4.1).

8.2.2.3 Proposed Water Supply Bores – Road Section 3

The proposed water supply option for Road Section 3 is based on water supply from a bore-field consisting of two existing Rio Tinto bores and one new bore. The two Rio Tinto bores are located east of the rail line. Table 8.3 summarises information on the proposed water supply bores and Figure 8.1 shows the bore locations for Road Section 3. The bores have an assumed combined pumping capacity of 19 L/s which is greater than the maximum assessed demand of 14.3 L/s.

The locations of the proposed water supply bores for Road Section 3 are in both the Wittenoom-Wittenoom Groundwater Source and the Hamersley Fractured Rock groundwater source (Figure 8.1). A summary of the potential groundwater take from the two groundwater sources is as follows:

- the proposed combined groundwater take for the bores in the Wittenoom-Wittenoom Groundwater Source (2 Mile bore and the new bore) is approximately 15 L/s, which is equivalent to 58,320 over 45 days of continuous pumping. The total proposed take from the Wittenoom-Wittenoom Groundwater Source is 0.8% of the water available annually for allocation from the groundwater source (Section 6.2).
- the proposed groundwater take for bore Warp 5 from the Hamersley Fractured Rock Groundwater Source is approximately 4 L/s, which is equivalent to 15,552 kL over 45 days of continuous pumping. The Hamersley

Fractured Rock Groundwater Source does not have an allocation limit and aquifers are managed solely through case-by-case licensing (Section 5.4).

Table 8.3: Road Section 3 water supply option summary.

Bore	Aquifer [1]	Depth (m)	Airlift Yield (L/s)	In-use Pumping Capacity (L/s)	Bore Status	Railway Station Water Supply
Warp 5	Fractured rock	130	16	4	Abandoned	No
2 Mile Bore	Wittenoom Formation	Unknown	Unknown	5	Unknown	Yes
New bore	Wittenoom Formation	90	NA	10	NA	No

[1] Aquifer type based on review of bore geological logs and bore location on map of main aquifer types (Figure 4.1).

8.2.2.4 Proposed Water Supply Bores – Road Section 4

The proposed water supply option for Road Section 4 is based on water supply from a bore-field comprising two existing Rio Tinto bores and one new bore. The two Rio Tinto bores are located east of the rail line. Table 8.4 summarises information on the proposed water supply bores and Figure 8.1 shows the bore locations for Road Section 4. The bores have an assumed combined pumping capacity of 17.5 L/s which is greater than the maximum assessed demand of 14.3 L/s

The locations of the proposed water supply bores for Road Section 4 are in both the Wittenoom-Wittenoom Groundwater Source and the Hamersley Fractured Rock groundwater source (Figure 8.1). A summary of the potential groundwater take from the two groundwater sources is as follows:

- The proposed combined groundwater take for bores in the Wittenoom-Wittenoom Groundwater Source (WB18KRP0014 and the new bore) is 15 L/s, which is equivalent to 58,320 kL over 45 days of continuous pumping. The total proposed take from the Wittenoom-Wittenoom Groundwater Source is 0.8% of the water available annually for allocation from the groundwater source.
- The proposed groundwater take for bore Warp 16 from the Hamersley Fractured Rock Groundwater Source, is approximately 2.5 L/s, which is equivalent to 9,720 kL over 45 days of continuous pumping.

Table 8.4: Road Section 4 water supply option summary.

Bore	Aquifer [1]	Depth (m)	Airlift Yield (L/s)	In-use Pumping Capacity (L/s)	Bore Status	Railway Station Water Supply
Warp 16	Fractured rock	60	10	2.5	Abandoned	No
WB18KRP0014	Wittenoom Formation	84	6.25	5	No top	No
New bore	Wittenoom Formation	90	NA	10	NA	No

[1] Aquifer type based on review of bore geological logs and bore location on map of main aquifer types (Figure 4.1).

8.2.2.5 Proposed Water Supply Option – Road Section 5

The proposed water supply option for Road Section 5 is based on water supply from the existing Rio Tinto bore Warp 19 and a new bore. The Rio Tinto bore is located east of the rail line. Table 8.5 summarises information on the proposed water supply bores and Figure 8.1 shows the bore locations for Road Section 5.

The proposed combined groundwater take from the Wittenoom-Wittenoom Groundwater Source by Warp 19 and the new bore is 14.5 L/s, which is equivalent to 56,376 kL over 45 days of continuous pumping. The total proposed take from the Wittenoom-Wittenoom Groundwater Source is 0.77% of the water available annually for allocation from the groundwater source.

Table 8.5: Road Section 5 water supply option summary.

Bore	Aquifer [1]	Depth (m)	Airlift Yield (L/s)	In-use Pumping Capacity (L/s)	Bore Status	Railway Station Water Supply
Warp 19	Wittenoom Formation	96	18	4.5	Abandoned	No
New bore	Wittenoom Formation	90	NA	10	NA	No

[1] Aquifer type based on review of bore geological logs and bore location on map of main aquifer types (Figure 4.1).

8.2.2.6 Proposed Water Supply Bores – Road Section 6

The proposed water supply option for Road Section 6 is based on water supply from two existing Rio Tinto bores (WB18KRP0013 and Warp 20). The two Rio Tinto bores are located east of the rail line. Table 8.6 summarises information on the proposed water supply bores and Figure 8.1 shows the bore locations for Road Section 6.

The locations of the proposed water supply bores for Road Section 6 are in both the Wittenoom-Wittenoom Groundwater Source and the Hamersley-Fortescue groundwater source (Figure 8.1). A summary of the potential groundwater take from the two groundwater sources is as follows:

- The proposed groundwater take from the Wittenoom-Wittenoom Groundwater Source by bore WB18KRP0013 is 11.4 L/s, which is equivalent to 44,323 kL over 45 days of continuous pumping. The total proposed take from the Wittenoom-Wittenoom Groundwater Source is 0.6% of the water available annually for allocation from the groundwater source.
- The proposed groundwater take from the gravels of the Hamersley-Fortescue Groundwater Source by bore Warp 20 is 5 L/s, which is equivalent to 19,440 kL over 45 days of continuous pumping. The Hamersley-Fortescue Groundwater Source does not have an allocation limit and aquifers are managed solely through case-by-case licensing (Section 5.4)

Table 8.6: Road Section 6 water supply option summary.

Bore	Aquifer [1]	Depth (m)	Airlift Yield (L/s)	In-use Pumping Capacity (L/s)	Bore Status	Railway Station Water Supply
WB18KRP0013	Wittenoom Formation	145	45.7	11.4	Abandoned	No
Warp 20	Valley fill alluvium/ palaoevalley deposits	66	10	5	Operational	No

[1] Aquifer type based on review of bore geological logs and bore location on map of main aquifer types (Figure 4.1).

8.2.2.7 Proposed Water Supply Bores – Road Section 7 and Section 8

Road Section 7 and Section 8 are within the Hamersley-Millstream Groundwater Source which is fully allocated. Therefore, new bores cannot be drilled and existing bores within the Hamersley-Millstream Groundwater Source in the vicinity of Road Section 7 and Section 8 cannot be used for road construction.

New bores to supply water to Road Section 7 and Section 8 can be drilled in the Hamersley-Fractured Rock Groundwater Source located approximately 750 m to the east of the proposed road.

As indicated in Section 8.2.1, groundwater exploration for the new bores in fractured rocks will target zones of potential yields greater than 5 L/s. This means that at least:

- three new bores will be required for Road Section 7 with a combined pumping capacity of 15 L/s, which is equivalent to 58,320 kL over 45 days of continuous pumping.
- three new bores will be required for Road Section 8 with a combined pumping capacity of 15 L/s, which is equivalent to 58,320 kL over 45 days of continuous pumping.

8.2.3 Water Supply - Summary

The proposed road was divided into eight sections (Figure 8.1) for the purposes of developing water supply options. The water demand assessment carried out by Jacobs (Appendix C) indicates that the required water for constructing a 15 km road section is between 5.3 L/s and 14.3 L/s assuming bores will be operating for 24 hours per day, seven days per week over a 45-day construction period (see assumptions below).

The water supply options assessment was for the supply of the estimated upper limit of the water demand of 14.3 L/s for each road section. However, the existing potential bore capacity is presented in Table 8.7 to enable a comparison to the water demand requirement of between 5.3 L/s and 14.3 L/s.

The method used to estimate in-use pumping capacities for existing and new bores is described in Section 8.2.1. The water supply options for each road section are presented in Section 8.2.2.

Table 8.7 provides a summary of the proposed water supply bores (existing and new) and the water take from each groundwater source for each road section.

Assuming the construction period for the proposed 107 km road would be one year. The total proposed groundwater take from each groundwater source are as follows:

- The proposed groundwater take from the Wittenoom-Wittenoom Groundwater Source is approximately 275,659 kL, which is approximately 3.8% of the water available annually for allocation.
- The proposed groundwater takes from the Hamersley-Fractured Rock and Hamersley-Fortescue Groundwater Sources are 208,980 and 19,440 kL/year, respectively. There are no groundwater allocation limits for both groundwater sources and the aquifers are managed solely through case-by-case licensing.
- There is no proposed groundwater take from the Hamersley-Millstream Groundwater Source which is already fully allocated.

Table 8.7: Summary of proposed water supply bores.

Road Section	Existing Bore Capacity (L/s)	No. of water supply bores		Groundwater take (kL/year)		
		Existing	New	Wittenoom-Wittenoom	Hamersley-Fractured Rock	Hamersley-Fortescue
1	9.25	9	1	0	55,404	0
2	8	4	1	58,320	11,664	0
3	9	5	2	58,320	15,552	0
4	7.5	3	2	58,320	9,720	0
5	4.5	1	2	56,376	0	0
6	16.4	2	0	44,323	0	19,440
7	0	0	3	0	58,320	0
8	0	0	3	0	58,320	0
Total Take for groundwater source (kL/year)				275,659	208,980	19,440
Available water for groundwater source (kL/year)				7,278,700	No allocation limit	No allocation limit
Proposed groundwater take as a percent of available water				3.8 %	Not Applicable	Not applicable

The water supply strategy assumes that new water bores would preferentially target the Wittenoom Formation dolomites, where the road section is located within a reasonable distance from the aquifer. The Wittenoom Formation has the potential for bores with higher yields (>10 L/s) compared to the fractured rocks of the Hamersley-Fractured Rock Groundwater Source or the alluvial deposits of the Hamersley-Fortescue groundwater source.

Table 8.1 to Table 8.6 summarise the available information on the current water use of the existing Rio Tinto bores provided by Rio Tinto. Some of the bores are currently used for train station water supply (Table 8.1 to Table 8.6). Further information is required to determine if the bores have the capacity to meet the requirements for both Rio Tinto and the road construction water supply.

Information obtained from Rio Tinto and presented in Table 8.1 to Table 8.6 classifies the bores as “abandoned”, “unknown” or “operational”. Further consultation and field audits are required to assess the condition of the existing bores to determine any rehabilitation works that may be required.

9. Summary

Main Roads Western Australia engaged Jacobs to develop a water strategy for the proposed 107 km Karratha to Tom Price Stage 4 road construction. Water is required for the dust suppression and material conditioning (substrate engineering/compaction).

The review of the available information indicated the following:

- Groundwater systems within the Pilbara region are classified into the following aquifer types:

  Channel Iron Deposits (CIDs) aquifers

  - inland alluvial systems and paleovalleys including calcrete and valley-fill aquifers
  - karstifed dolomites underlying inland valleys within the Hamersley Range
  - Permian and Cenozoic paleochannels in the northeast of the study area
  - fractured rocks comprising mineralised BIF of locally high yields and limited storage
  - fractured bedrock formations
- The study area falls under the Ashburton administrative sub-area of the Pilbara groundwater allocation plan. The plan defines four groundwater resources within Ashburton administrative sub-area covering the study area:
  - The Ashburton – Hamersley-Millstream resource includes aquifers within Millstream Dolomite (Millstream Aquifer), shales, gravelly-clay and chert. The allocation limit for the Ashburton – Hamersley-Millstream Groundwater Resource is 15,682,500 kL/year and the groundwater system is fully allocated.
  - The Ashburton – Wittenoom-Wittenoom resource which consists mainly of groundwater resources within the karstic dolomite aquifers of the Wittenoom Formation. There was 12,721,300 kL/year allocated to 24 licences with 7,278,700 kL/year available for allocation from the groundwater resource.
  - The Ashburton – Hamersley-Fortescue resource covers to groundwater within the valley-fill deposits along the Fortescue River. There is no allocation limit for the Ashburton – Hamersley-Fortescue resource and licence applications are assessed on a case-by-case basis.
  - The Ashburton – Hamersley-Fractured Rock resource which also does not have an allocation limit
- The proposed road will run in a similar alignment to the existing Rio Tinto rail corridor (Figure 7.1). Rio Tinto installed water supply bores along the rail corridor for railway line construction purposes. A review of the airlift yields obtained during testing after drilling hydrogeological information provided by Rio Tinto indicated the following:
  - The highest airlift yields were obtained from bores drilled into the Wittenoom Formation, with yields ranging from approximately 6.5 L/s to 45.7 L/s.
  - Airlift yields measured in the Hamersley-Fractured Rock Groundwater Source were generally less than 5 L/s. An airlift yield of 16 L/s was recorded in bore Warp 5, which is located close the contact between the Hamersley-Fractured Rock and the Wittenoom Formation.
  - Gravelly clay and clayey gravel deposits within the Hamersley-Fortescue Groundwater Source had airlift yields ranging from less than 1 L/s to 10 L/s.
  - Hamersley-Millstream Groundwater Source clays, gravelly clays, cherts and shales had airlift yields ranging from 2 L/s to 7 L/s.
- Hydraulic parameter values for the Wittenoom Formation bore WB18KRP0014 obtained from a constant rate pumping test were as follows:
  - Transmissivity = 57 m^2/day
  - Hydraulic conductivity = 0.88 m/day (based on an aquifer thickness of 65 m)
  - Storativity = 2.5 x 10^{-5}

The water demand calculation is based on water required for a 15 km long section of the proposed road. The water demand assessment was based on the following assumptions:

- Jacobs carried out a water demand assessment to estimate the water demand for the construction of a 15 km long section of the road. The assumptions applied to the water demand assessment were as follows:
  - Road construction would be carried out 12 hours per day, seven days a week
  - Pumping bores would operate 24 hours per day, seven days a week
  - It would take 45 days to complete a 15 km long section of the road
- The results of the water demand assessment indicated that the water demand (excluding potable water supply for camps) for a 15 km stretch of road would be between 5.3 L/s and 14.3 L/s
- The proposed 107 km road was divided into eight sections of approximately 15 km length (Figure 8.1) for the purposes of the water supply options assessment. The water supply options assessment was for the supply of the estimated upper limit of the water demand (14.3 L/s) for each road section
- The total proposed groundwater takes from each groundwater source are as follows:
  - The proposed groundwater take from the Wittenoom-Wittenoom Groundwater Source is approximately 275,659 kL, which is approximately 3.8% of the water available annually for allocation
  - The proposed groundwater takes from the Hamersley-Fractured Rock and Hamersley-Fortescue Groundwater Sources are 208,980 kL/year and 19,440 kL/year, respectively. There are no groundwater allocation limits for both groundwater sources and the aquifers are managed solely through case-by-case licensing
  - There is no proposed groundwater take from the Hamersley – Millstream Groundwater Source which is already fully allocated

The water supply strategy assumes that new water bores would preferentially target the Wittenoom Formation dolomites, where the road section is located within a reasonable distance from the aquifer. The Wittenoom Formation has the potential for bores with higher yields (>10 L/s) compared to the fractured rocks of the Hamersley-Fractured Rock Groundwater Source or the alluvial deposits of the Hamersley-Fortescue Groundwater Source.

10. Water Supply Risks and Mitigation

This section summarises the risks associated with the proposed water supply strategy and provides solutions to mitigate the risks.

10.1 Insufficient Information on In-use Pumping Capacity

The water supply assessment was based on very limited information on the in-use capacity of existing bores. The in-use capacity estimates applied to existing Rio Tinto bores in the water supply options assessments were based on conservative assumptions (Section 8.2.1). There may be a potential for higher pumping rates to be achieved for existing bores. Therefore, there is a risk of drilling of new bores which may be in excess of the required demand.

The available solutions to mitigate risks associated with insufficient information on in-use pumping capacity include:

- Further engagement with Rio Tinto to obtain additional information on historical pumping rates and groundwater levels from monitoring bores.
- Performing pumping tests in both existing and new bores.

10.2 Low Yields from New Nores

The in-use pumping capacity estimates applied to new bores in the water supply options assessments are generally higher than pumping rate estimates applied for existing bores. This is based on the assumption that the groundwater exploration programme would be able to identify areas of potential moderate to high bore yields. There is a risk of the groundwater exploration programme failing to identify areas of potential moderate to high yields due to factors including unfavourable hydrogeological conditions and other constraints.

The available solutions to mitigate risks associated with low yields from new bores include:

- A robust groundwater exploration programme to increase the chances of identifying zones of high bore yields. The groundwater exploration could include a desktop assessment to identify highly permeable geological structures that could be associated with high yielding bores; field geophysical investigations to identify potential fracture zones and other features potentially associated with high bore yields; and drilling of pilot bores to improve the understanding of local hydrogeological conditions and provide information on aquifer productivity.
- Increasing the number of new bores to match the water demand
- Where viable bore site locations close to the road section cannot be identified, water transfer and storage from bores located further afield. Water pipelines can be used to transfer water from distant bores to turkey nest reservoirs/storage points, located adjacent to the road construction sites.

10.3 Insufficient Additional Capacity in Existing Bores

Some existing bores may not have additional capacity to supply water for the proposed road construction. Further information is required from Rio Tinto on the current usage of existing bores.

10.4 Excessive Groundwater Drawdown and Well Interference

Pumping from a well at high rates can result in the groundwater level dropping below major water-yielding zones. Excessive drawdown in bores can result in reduced yields from bores. Specific capacity (which is the sustainable discharge divided by drawdown) tends to be low in fractured rock aquifers.

In addition, the simultaneous pumping from bores located close to each other can result in well-interference effects resulting in excessive cumulative groundwater drawdown effects.

Groundwater drawdown impacts include:

- Reduction of bore yields resulting in a reduction in the volumes of groundwater that can be abstracted from bore-fields for road construction purposes
- Third-party impacts on other groundwater users
- Impacts on surface water flow (stream depletion) and groundwater dependent ecosystems

Groundwater drawdown impacts can be minimised by implementing the following measures:

- Performing pumping tests in proposed water supply bores and measuring drawdown and recovery in the pumping bore and surrounding observation bores
- Pumping test results can be used to determine sustainable pumping rates, specific capacity and aquifer parameters (hydraulic conductivity and storativity). Aquifer parameters can be used in bore-field design to:
  - determine minimum separation distances between bores to reduce well-interference effects
  - determine minimum separation distances between bores and water courses to minimise drawdown at water courses.

10.5 Existing Bore Access Constraints

Where the truck-fill point is at the bore site, truck access roads are required from the bores to the construction site. There is a risk that some bores site may be inaccessible by road for the water trucks.

Mitigation measures include the following:

- Undertake a physical bore infrastructure survey to assess the access to the bore sites. Where bores are inaccessible, recommend alternative bore locations that have access.
- In cases where inaccessible bores are still required for construction water supply, the following measures can be taken:
  - Construct temporary access roads from inaccessible bores to construction sites.
  - Install pipelines from the bore site to a turkey nest or other storage facility located closer to the construction site

10.6 Bore Location Relative to Railway Line

It is preferable for water supply bores and the road to be on the same side of the existing Rio Tinto railway line to avoid water being transported from one side of the railway line to the other. This is because trains pass a given point on the railway line approximately every five minutes and the train lengths can be in excess of 2,000 m.

Mitigation measures include the following:

- Undertake a physical bore infrastructure survey to assess the location of existing bores relative to the railway line. Recommend alternative water supply bore locations if water supply bores and the proposed road are not on the same side of the existing Rio Tinto railway line.
- In some areas it may be possible to use railway culverts to transfer water from one side of the railway line to the other. A field visit is required to inspect the location of the railway culverts.

11. Recommendations

The following tasks are recommended:

- Consult with Rio Tinto - consultations should be made with Rio Tinto to establish their water requirements from any bores included in the water supply options outlined in Section 8.2. For bores with no spare (or adequate) capacity to meet the additional requirements for the proposed road construction, new water supply bores are to be identified.
- Ground-truth existing bores - the locations of the existing bores, relative to the KTP4 alignment and the Rio Tinto rail line, must be ground-truthed to confirm accessibility.
- Audit borefields - a field borehole audit should be carried out to confirm the condition of existing bores not currently in use that are to be used for water supply. The borehole audit would include:
  - bore depth assessment to check bore diameters and depths against construction details
  - surface condition assessment including the condition of the sealed base and possibility of surface disturbances
  - measurement of static water level
  - airlift bores identified as being blocked or where excessive sediment build-up is suspected. If the attempt to remove the blockage using airlifting is unsuccessful, then downhole inspection should be conducted.
  - refurbishments (where required) including flushing, disinfection, scale removal, re-sleeving.
- Testing of the aquifer and bores - pumping tests should be carried out in selected bores targeting the Wittenoom Formation aquifer. The water supply option assessment conservatively assumes that the in-use pumping capacity of existing bores targeting the Wittenoom Formation is 5 L/s. However, the Wittenoom Formation aquifer has the potential to supply more than 5 L/s, where hydrogeological conditions are favourable. Pumping tests and data analysis can be used to provide more realistic estimates of the in-use pumping capacity of existing bores.
- Identify new water supply bore locations - a desktop study should carried out to identify the locations for new water supply bores. The following guidelines should be used for identifying new bores locations:
  - the process of identifying new bore locations should preferentially target the relatively high yielding Wittenoom Formation aquifer, where possible.
  - new bores in consolidated rocks should preferentially target geologically deformed zones, such as fracture zones.
  - new bores in unconsolidated sediments should target thick sequences of well-sorted gravels or coarse sands.
- Implement mitigation measures - Jacobs has recommended mitigation measures for water supply risks identified in Section 10. It is recommended that mitigation measures provided in Section 10 are implemented based on the evaluation of all the project constraints.

12. References

Department of Water, (2013). *Pilbara groundwater allocation plan*. Produced by Department of Water, Government of Australia. October 2013.

Department of Water 2009c, *Operational policy no. 5.12 – Hydrogeological reporting associated with a groundwater well licence*, Department of Water, Perth.

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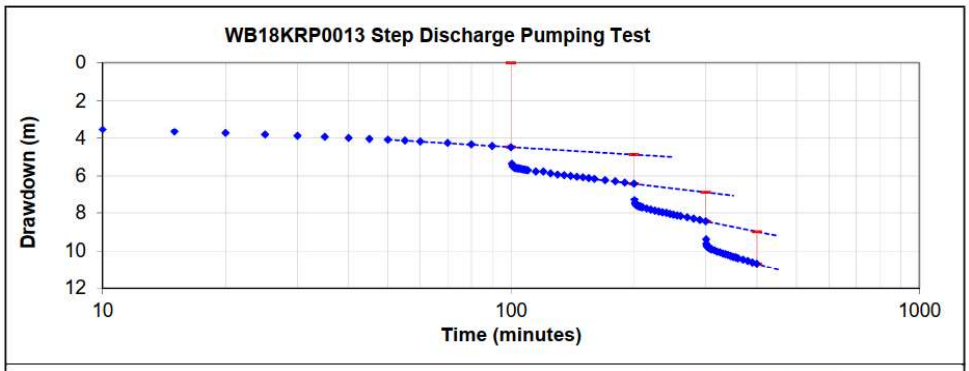
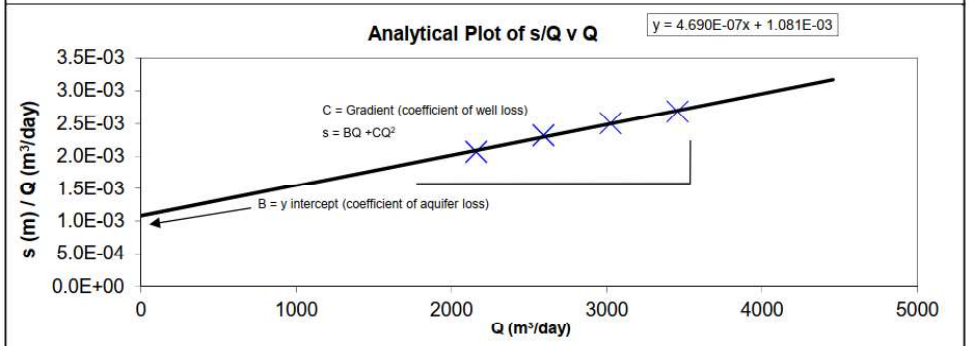
Thorne, A. M., and Trendall, A. F., 2001, *Geology of the Fortescue Group, Pilbara Craton, Western Australia*: Western Australia Geological Survey, Bulletin 144, 249p.

Johnson SL, Wright AH (2001) *Central Pilbara groundwater study*. Water and Rivers Commission, Hydrogeological Record Series, Report HG 8, p 102

Appendix A. Step Discharge Pumping Test Results





$s_{w(n)} = BQ_n + CQ_n^P$ (Rorabaugh's equation)

Where: B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

Components of Jacob's (1947) equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively. They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

Please note: 1. In thin or fissured aquifers large components of well loss are due to high flow velocities in the aquifer rather than inefficient bore design. Therefore, the term "apparent well loss" is better than well loss.
2. In aquifers where the flow horizons are vertically anisotropic, changes in bore performance often relate to changes in the rest water level with respect to the primary aquifer horizons.

$Ew = (BQ/(BQ + CQ^P)) \times 100$

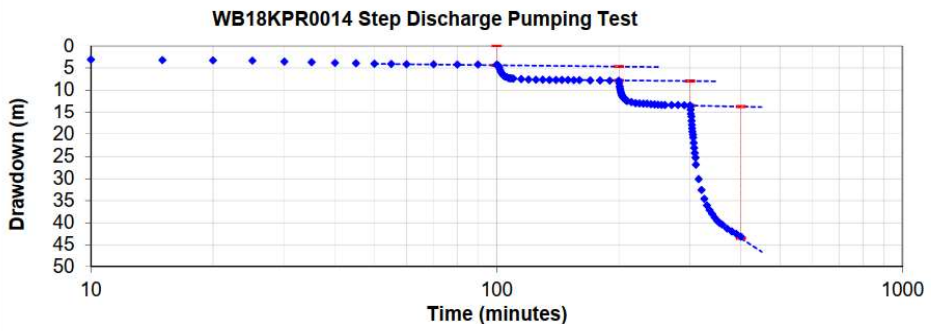
Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

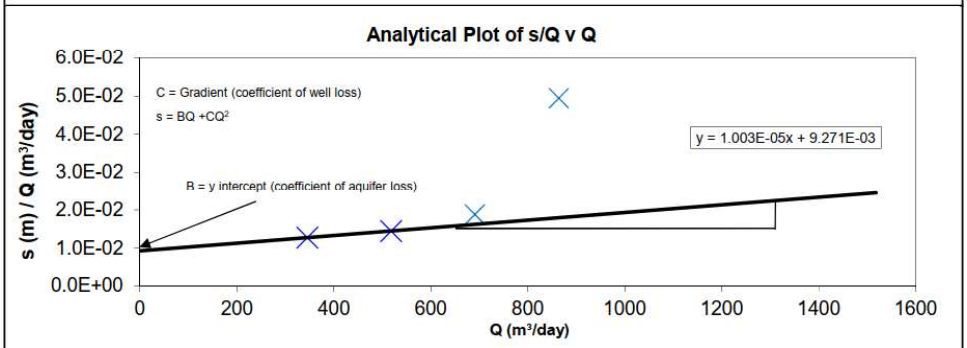
From plot of s/Q v Q (trend line equation): **Intercept (B)** 1.081E-03
Gradient (C) 4.690E-07

ANALYSIS TABLE

Calculation of well efficiency and comparison of observed and predicted drawdowns

Step (100 minute duration)	Discharge (l/s)	Discharge (Q) (m^3/d)	Measured Incremental Drawdown (metres)	Corrected Drawdown (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1	25.0	2160	4.48	4.48	4.52	2.07E-03	51.6
2	30.0	2592	1.55	6.03	5.95	2.32E-03	47.1
3	35.0	3024	1.56	7.59	7.56	2.51E-03	43.3
4	40.0	3456	1.69	9.28	9.34	2.69E 03	40.0





$s_{w(n)} = BQ_n + CQ_n^P$ (Rorabaugh's equation)

Where: B = Intercept with y axis (coefficient of aquifer loss or laminar flow)
C = Gradient (coefficient of turbulent flow loss or apparent well loss)
s = Drawdown in the borehole
P = Value determined using Rorabaugh's method of superposition

Components of Jacob's (1947) equation BQ and CQ^2 are termed the aquifer loss and apparent well loss respectively. They give an indication of the proportion of total drawdown caused by laminar and turbulent flow.

Please note: 1. In thin or fissured aquifers large components of well loss are due to high flow velocities in the aquifer rather than inefficient bore design. Therefore, the term "apparent well loss" is better than well loss.
2. In aquifers where the flow horizons are vertically anisotropic, changes in bore performance often relate to changes in the rest water level with respect to the primary aquifer horizons.

$Ew = (BQ/(BQ + CQ^P)) \times 100$

Ew or Well Efficiency represents the proportion of drawdown caused by laminar flow

From plot of s/Q v Q (trend line equation):

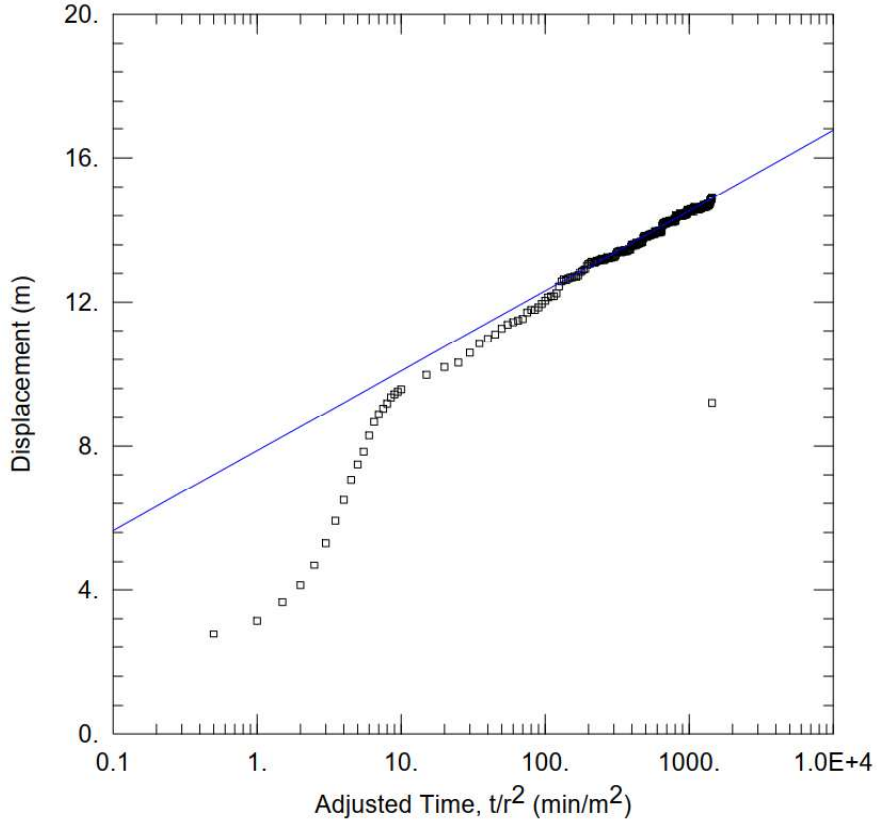
Intercept (B) 9.271E 03
Gradient (C) 1.003E-05

ANALYSIS TABLE

Calculation of well efficiency and comparison of observed and predicted drawdowns

Step (100 minute duration)	Discharge (l/s)	Discharge (Q) (m³/d)	Measured Incremental Drawdown (metres)	Corrected Drawdown (metres)	Predicted Drawdown (metres)	s/Q	Apparent Efficiency (Ew) %
1	4.0	346	4.40	4.40	4.40	1.27E-02	72.8
2	6.0	518	3.10	7.50	7.50	1.45E-02	64.1
3	8.0	691	5.51	13.01	11.20	1.88E-02	57.2
4	10.0	864	29.75	42.76	15.49	4.95E-02	51.7

Appendix B. WB18KRP0014 Constant Rate Test Results



WELL TEST ANALYSIS

Data Set: K:\...\WB18KRP0014.aqt
Date: 10/23/18 Time: 08:17:09

PROJECT INFORMATION

Company: RTIO
Location: Yandi

AQUIFER DATA

Saturated Thickness: 65. m Anisotropy Ratio (Kz/Kr): 1.

WELL DATA

Pumping Wells

Well Name	X (m)	Y (m)
WB18KRP0014	573598	7558815

Observation Wells

Well Name	X (m)	Y (m)
WB18KRP0014	573598	7558815

SOLUTION

Aquifer Model: Confined Solution Method: Cooper-Jacob
T = 57.03 m^2/day S = 2.541E-5

Appendix C. Water Demand Calculations

Assumptions	Number	Unit	Assumptions for:	
			High water use	Low water use
Materials conditoning				
Road length (m)	15,000	m		
Road width (m)	20	m		
Pavement footing/subgrade (m)	1	m		
Materials conditoning denisty (g/cc)	2	g/cc		
Fill Volume (road subgrade)	180,000	m^3		
Fill mass - road subgrade (tonnes)	360,000	tonnes		
Fill mass - ADDED moisture (%)	-	%	10	5
Concrete (in-situ/pre-cast)/cement grout	-	m3	7,000	3,500
Concrete (in-situ/pre-cast)/cement grout water content (%)	50	%		
Dust suppression				
road work area lengths (m)	3,000	m		
road work area width (m)	5	m		
road area (m2)	15,000	m2		
stockpile lengths (m)	100	m		
stockpiles base width (m)	20	m		
stockpiles height (m)	5.8	m		
stockpiles traverse length (m)	23.2	m		
stockpiles area (m2)	6,960	m2		
watering rate (L/m2)	-	L/m2	2	0.2
watering passes (passes/day)	-	passes/day	8	4
Washdown				
Pump rate (L/s)	20	L/s		
	0.0000002	m3/day		
Minutes wash per vehicle	-	minutes/vehicles	2	1
Vehicles per day		each	100	50
Camp and potable water				
Water use (L/person/day)	210	L/person/day		
Persons at camp	200	person		
Days				
Days	45.0	days		

Water requirements		
Water need	High water use	Low water use
Total water need for fixed project tasks		
Materials conditoning (m3)	36,000 m^3	18,000 m^3
Concrete/cement grout (m3)	3,500 m^3	1,750 m^3
Total water demand for per diem tasks		
Dust suppression – road work areas (m3/day)	10,800 m^3	540 m^3
Dust suppression – stockpiles - 3 x 100m stockpiles (m3/day)	5,011 m^3	251 m^3
Washdown (m3/day)	180 m^3	45 m^3
Camp and potable water	1,890 m^3	1,890 m^3
Water demand per diem		
Materials conditoning (m3)	800 m^3/day	400 m^3/day
Concrete/cement grout (m3)	78 m^3/day	39 m^3/day
Dust suppression – road work areas (m3/day)	240 m^3/day	12 m^3/day
Dust suppression – stockpiles - 3 x 100m stockpiles (m3/day)	111 m^3/day	6 m^3/day
Washdown (m3/day)	4 m^3/day	1 m^3/day
Camp and potable water	42 m^3/day	42 m^3/day
Total water need for project - 45 days (m3)		
7 days/week	57,381 m^3	22,476 m^3
Total water need for project - 45 days - minus potable water (m3)		
7 days/week	**55,491 m^3**	**20,586 m^3**
Estimated daily demand (m3/day)		
7 days/week	1,275 m^3/day	499 m^3/day
Estimated daily demand - minus potable water (m3/day)		
7 days/week	1,233 m^3/day	457 m^3/day
Estimated pump operation rate (L/sec)		
7 days/week	14.8 L/sec	5.8 L/sec
Estimated pump operation rate (L/sec) - minus potable water		
7 days/week	**14.3 L/sec**	**5.3 L/sec**

Assumptions

365.25 days/year. 250days = 52 x 5 day weeks minus 10 public holidays
600mm road footing, 107km in 1 year (15km road length in 50 days), 20 m road width incl shoulders. Additional moisture content of materials conditionsing 5 to 10% of footings mass.

50m wide, 10,000L/5 hectares(2m2/Ha) WA mines guide for high risk

QLD Guidelines - 210 litres per day. Assume 1 camp operating
Assume 50% concrete volume is water

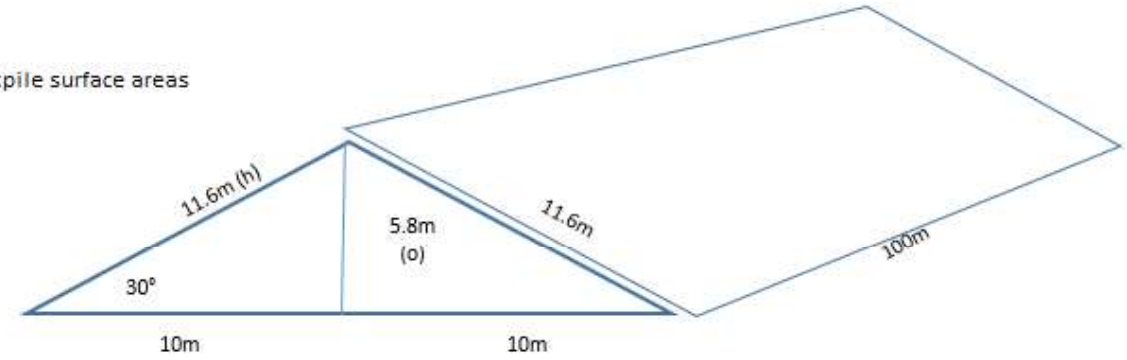
stockpile surface area (100m long, 30deg angle of repose, ~5.8m high, 11.6m hypotenuse on one side, so 23.2m traverse x 100m length = 2320m2 x 3 stockpiles = 6960m2
washdown - high 20L/min x 2 mins each for 100 vehicles/day; low - 20L/min x 1 mins each for 50 vehicles/day
damping down - high- 8 times per day (1 x 1 hour) (; low - 4 times per day (1 x 2 hours
3x1kmx5m stretch of road being watered down at 2L/m2/hr and 0.2L/m2/hr
WORK OUR IF 2L or 0.2L for dust suppression - NATIONAL POLLUTANT INVENTORY (2012) states that 2L/m2/hour is the recommended volume for dust suppression.
The WA Mining guide sugests 10kL/5 Ha (which is 0.2L/m2). We will use conservative 2L/m2
dust suppression width - 5m (per 1km stretch of road at 3 separate sites - 3km of road total)
concrete high 50k cubes of concrete vs Low of 25k cubes of concrete

denisty of compacted soil between 1800-2300/m3. we have assumed SG of compacted soil to be 2
we have assumed a working period of 12 months (365 days)…which assumes about 300m road compelted per week.

15km stretch of 107km total is 14% of project
15km will take 45 days to build

work period to completion of Stage 4 is 3days per km
107km x 3 days = 321 days to construct

Soil stockpile surface areas



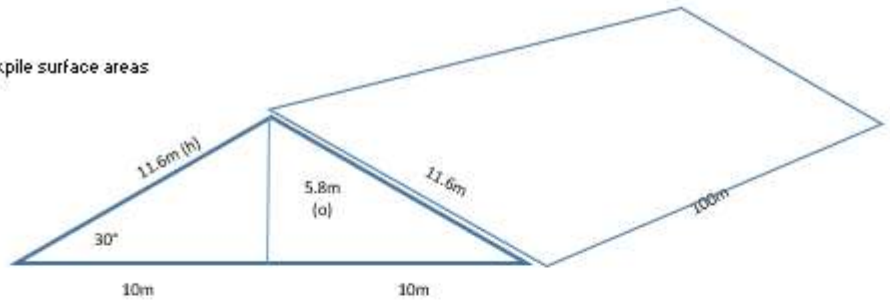
Cos30 = 10/h
0.866 = 10/h
10/0.866 = h
11.54734411
h = 11.54

tan30 = o/10
0.577350269189625 = o/10
0.577350269189625 x 10 = o
o=5.7735

Dust suppression rate calculations

Nat Pollution inventory (2012)	water in cub. m	area in m2	cub m per m2	L/m2
2L/m2	0.002	1	0.002	2
WA guideline	water in cub. m	area in m2	cub m per m2	L/m2
10000L/5Ha	10	50000	0.0002	0.2

Soil stockpile surface areas



Cos30 = 10/h
0.866 = 10/h
10/0.866 = h
11.54734411
h = 11.54

tan30 = o/10
0.577350269189625 = o/10
0.577350269189625 x 10 = o
o=5.7735

Dust suppression rate calculations

Nat Pollution inventory (2012)	water in cub. m	area in m2	cub m per m2	L/m2
2L/m2	0.002	1	0.002	2
WA guideline	water in cub. m	area in m2	cub m per m2	L/m2
10000L/5Ha	10	50000	0.0002	0.2

Appendix 3 MRWA Vegetation Placement within the Road Reserve Doc. No. 6707/022 (Main Roads, 2013).

Environmental Guidelines

Vegetation Placement within the Road Reserve

D12#157580
April 2016

Contents

Document Control

Owner	Executive Director Planning & Technical Services
Custodian	Manager Environment
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Amendments

Revision Number	Revision Date	Description of Key Changes	Section / Page No.
2	Apr 2016	Update document to new Corporate Branding	All
1	Jan 2013	Minor amendments References and Related Documents list updated Diagrams minor amendments and all references updated.	Section 1 & 2 Section 1.5 Section 3
0	Oct 2003	Initial issue	

1 INTRODUCTION

1.1 Purpose

This document provides guidance on the placement of new vegetation within road reserves managed by Main Roads Western Australia (Main Roads).

1.2 Scope

The guidance notes in this document set out the recommended setbacks and clearance requirements:

- from all driving surfaces
- at intersections and crossings
- from all directional signs
- from overhead services and paths

That apply for all revegetation (planting/seeding or transplanting) or landscaping associated with any new road works or remedial roadside works. Guidance on the control of the growth of existing vegetation is contained within other Main Roads documents.

1.3 Application

The guideline is intended for use by staff and agents involved in the placement of vegetation within road reserves for which Main Roads is responsible. All new revegetation and landscaping works within the road reserve must conform to this guideline. These requirements are summarised in the diagrams provided as Appendix A.

1.4 Definitions

Term	Definition
Vegetation Placement	Refers to the lateral clearances and height constraints applied, within the road reserve, on the placement of any vegetation (by seeding, planting or transplanting) relative to the roadway edge, signs, paths, overhead services and other roadside furniture and facilities.
Vegetation Control	Refers to the mowing, slashing of grass and shrubs, the pruning of trees, the spraying of herbicides or the physical removal of existing vegetation within the road reserve. For general guidance refer to Main Roads guideline *Vegetation Control* (Document no. D12#157574).
Roadside Maintenance Zone (refer to Figure 1)	A zone (of variable width) is maintained on both sides of the roadway to retain clear sightlines and lateral clearances from the roadway and for functional off road drainage. Refer to each regional office of Main Roads for further details requirements within the region.
Clear Zone (refer to Figure 1)	A safety 'clear zone' or 'recovery zone' adjacent to both sides of the roadway is maintained clear of non-frangible objects, to help reduce the severity of accidents if vehicles run off the road. Restrictions apply for trees and fixed objects within this band of variable width. Refer to *Main Roads Supplement to Austroads Guide to Road Design Part 6 and AUSTROADS. Guide to Road Design, Part 6, Roadside Design, Safety and Barriers.*
Conflict Points, Safe Intersection Sight Distance, Sight Triangle	Refer to Glossary of terms in AUSTROADS, *Guide to Road Design*.
Crossing Sight Distance	Refer to Main Roads Supplement to *Austroads Guide to Road Design Part 6* and *AUSTROADS. (2009) Guide to Road Design, Part 4A Unsignalised and Signalised Intersections.*

1.5 References and Related Documents

The following references are cited in the guidelines.

Document Number	Description
D11#38472	MRWA Supplement to Austroads Guide to Road Design Part 6 Roadside Design, Safety and Barriers
D12#157574	Vegetation Control Guideline
Department of Commerce, (Dec 2012), *Guidelines for the management of vegetation near power lines*	
AASHTO. (2011). *Roadside Design Guide, Chapter 6 - Median Barriers*, American Association of State Highway Transportation Officials.	
AUSTROADS, *Guide to Road Design,* Part 3: Geometric Design Part 4: Intersections and Crossings - General Part 4A: Unsignalised and Signalised Intersections Part 4B: Roundabouts Part 6: Roadside Design, Safety and Barriers Part 6A: Pedestrian and Cyclist Paths	
AUSTROADS, *Guide to Traffic Management,* Part 10: Traffic Control and Communications Devices	

2 VEGETATION MANAGEMENT WITHIN THE ROAD RESERVE

Main Roads has the responsibility to manage vegetation within the road reserve for:

- Road safety
- Protection of road formation and structures and adjacent properties
- Biodiversity values within the road reserve
- Roadside amenity values

The width of the road reserves and roadsides varies across the state network. In rural areas an open channel (table drain) designed to receive road storm water runoff, is usually present adjoining the roadway. Beyond the table drain, the roadside (from a few meters to over 100 meters) extends to the edge of the road reserve and typically contains remnant native vegetation. In urban areas the roadway may be edged with a concrete kerb and road storm water runoff is collected into an underground drainage system. Medians may be present between roadways. The roadside may contain signs and other road furniture, footpaths and other facilities, as well as vegetation.

Functional management zones for vegetation within a typical road reserve are summarised in Figure 1.

Restrictions apply on the placement of vegetation permitted close to road infrastructure to assist in road safety, to help protect the integrity of the infrastructure assets and minimise the on-going need to control vegetation growth and to achieve a suitable level of amenity.
The roadway (the portion of road for use of vehicles) is kept clear of all vegetation.
All roadsides (includes the median where it exists) contain a maintenance zone (of variable width) to retain clear sightlines and lateral clearances from the roadway and for functional off road drainage. Vegetation within the maintenance zone is limited to a height < 200mm to limit the potential for screening of hidden objects that may reduce the capacity of drains and cause damage to the underside of vehicles leaving the roadway. Restrictions apply for all roadside surface

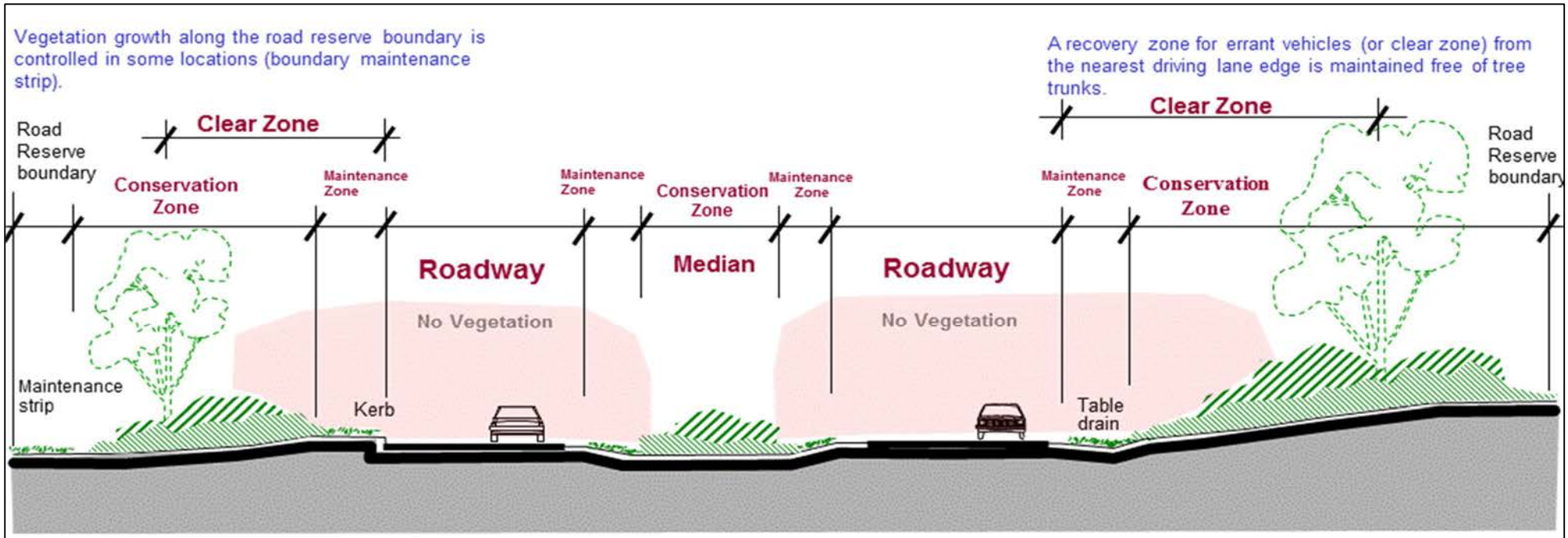
treatments. For example road intersections or entry to roundabouts are paved (in part), maintained clear of vegetation, or planted with grass or low ground covers.

A ‘recovery zone’ or safety ‘clear zone’ adjacent to the road (on both sides of the roadway) is also maintained clear of non-frangible objects, to help reduce the severity of accidents if vehicles run off the road. Restrictions apply for trees and fixed objects within this band of variable width.

2.1 Existing vegetation within the road reserve

Restrictions apply on the growth of existing vegetation within the road reserve. Refer to Main Roads guideline *Vegetation Control* (Document no. D12#157574) for general details on vegetation control practices. Also refer to Main Roads regional offices for details of the vegetation control at a specific roadside location within a region.

Figure 1 Typical cross section of a road reserve in agricultural regions



ROAD RESERVE - VEGETATION MANAGEMENT OBJECTIVES

ROADWAY
No Vegetation

Width as necessary to meet operational needs.

Pavement stability.
Off road surface drainage.
Driver visibility.
Placement of road hardware.
Maintained free of debris.
Maintain and enhance visual quality.

MAINTENANCE ZONE
Vegetation controlled

Zone width varies by location and height of vegetation is controlled to meet operational needs.

Vehicle recovery area.
Maintain clear sight distances at curves intersections and driveways.
Ensure effective surface drainage.
Prevent erosion.
Control weeds.
Control fires.
Maintain clearances to utilities.
Maintain and enhance visual quality.

CONSERVATION ZONE
Vegetation conserved

Width to road reserve boundary varies by location
Vegetation type and condition varies by location.
Vegetation is managed as necessary to:

Maintain safety clear zone (or recovery zone).
Remove hazards (overhanging branches).
Maintain clearances to utilities.
Control fires.
Control weeds.
Prevent erosion.
Maintain and enhance visual quality.
Conserve and enhance biodiversity.
Preserve heritage values.

3 NEW VEGETATION PLACEMENT WITHIN THE ROAD RESERVE

Lateral setbacks and vegetation height constraints are applied for the placement of any new vegetation (by seeding, planting or transplanting) within the road reserve, relative to the roadway edge, signs, paths, overhead services and other roadside furniture and facilities.

The width of the roadside maintenance zone and the clear zone is nominated by the specific road location within a region.

Vegetation placement requirements are dependent on a number of parameters including the road design speed, road alignment and the roadside batter slopes. An assessment of these parameters must be undertaken to determine the vegetation setbacks and clearances appropriate for a specific location.

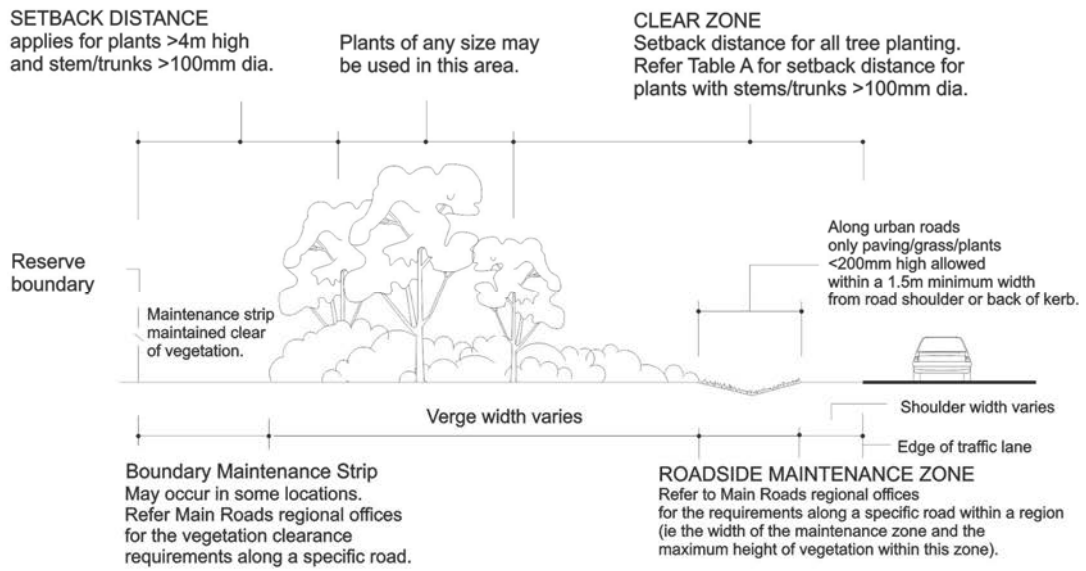
Recommended setbacks for trees (or plants with a trunk diameter>100mm) are adapted from the AASHTO, Roadside Design Guide, chapter 6 and the Main Roads Supplement to AUSTROADS Guide to Road Design Part 6 (online on Main Roads website, http://www.mainroads.wa.gov.au/Standards and Technical/Roads and Traffic Engineering/ Roadside Items/ MRWA Supplement to Austroads Guide to Road Design Part 6).

All planting/seeding or transplanting of vegetation within the road reserve must conform to the diagrams (not drawn to scale) in Appendix A.

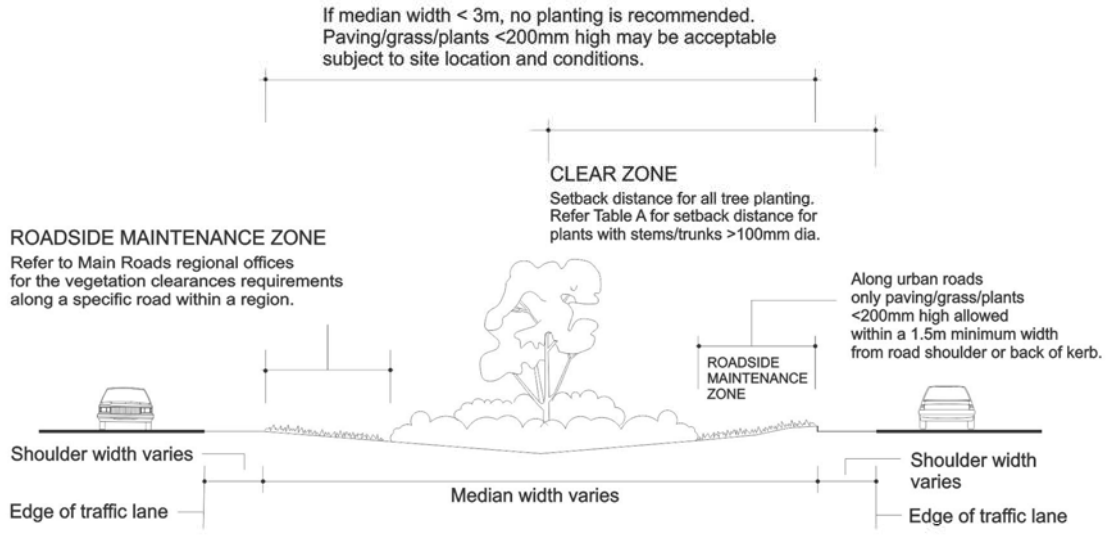
4 APPENDICES

Appendix 1: Vegetation Placement Guides

NOTE: (All diagrams not to scale)



VEGETATION PLACEMENT GUIDE FOR VERGES



VEGETATION PLACEMENT GUIDE FOR MEDIANS

TABLE A

RECOMMENDED SETBACK DISTANCES TO PLANTS WITH STEMS/TRUNKS >100mm diameter.

Design Speed Assumes ADT>6000 (km/hr)	Nearest Driving Lane Edge Assumes batter slopes 6:1 or less	
	Fill	Cut
≤ 60	5.0 m	5.0 m
70 - 80	6.5 m	6.5 m
90	7.5 m	7.5 m
≥100	10.0 m	8.5 m

Table A is adapted from AASHTO. (2006). Roadside Design Guide.- chapter 6 and the Main Roads Supplement to AUSTROADS Guide to Road Design Part 6.

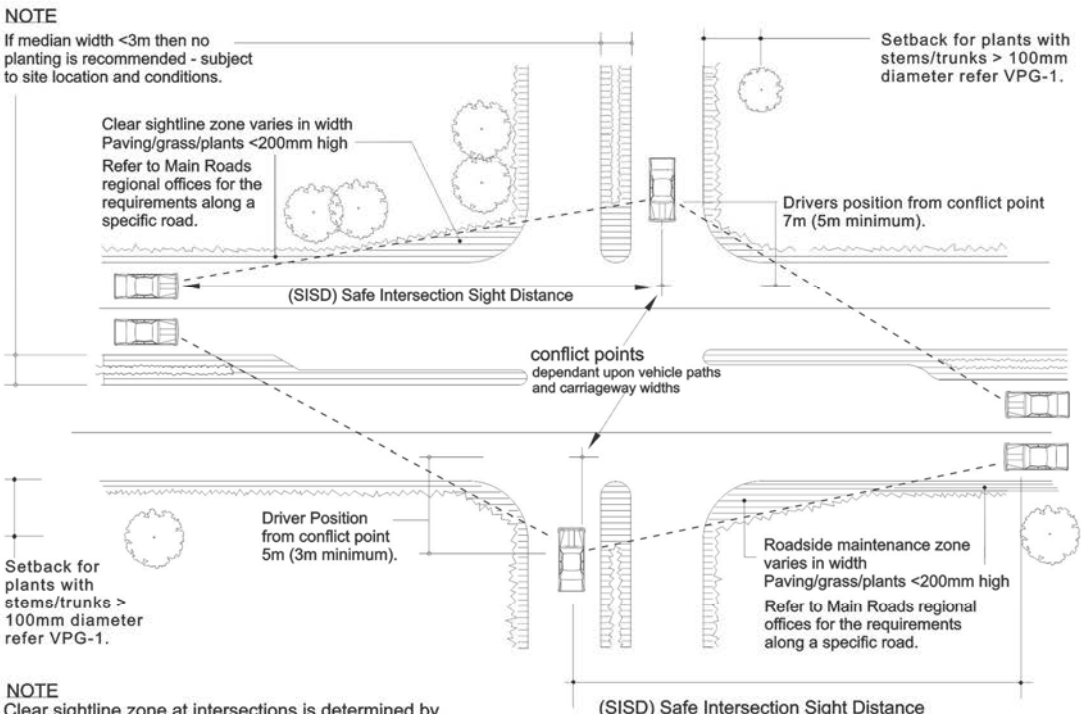
NOTE

Acceptable setback distances along a road vary with the road design speed, the average daily traffic (ADT) volumes and the adjacent roadside environment (if recoverable or non-recoverable for errand vehicle and presence of roadside hazards). Road curvature correction factors also apply.

Refer to AASHTO. (2006). Roadside Design Guide, chapter 6 and the Main Roads Supplement to AUSTROADS Guide to Road Design Part 6 and AustRoads (2009) Guide to Road Design, Part 6, section 4.2.2. for guidance on how to determine the appropriate clear zone distances.

Other factors may also need to be considered in determining the appropriate vegetation setback distance along a section of road e.g. for urban roads . In some cases, the setback distances may be varied as approved by MAIN ROADS. Any reductions to the vegetation setback distances must include details of the proposed protective measures, e.g. guardrail barriers.

Dwg. No. VPG1

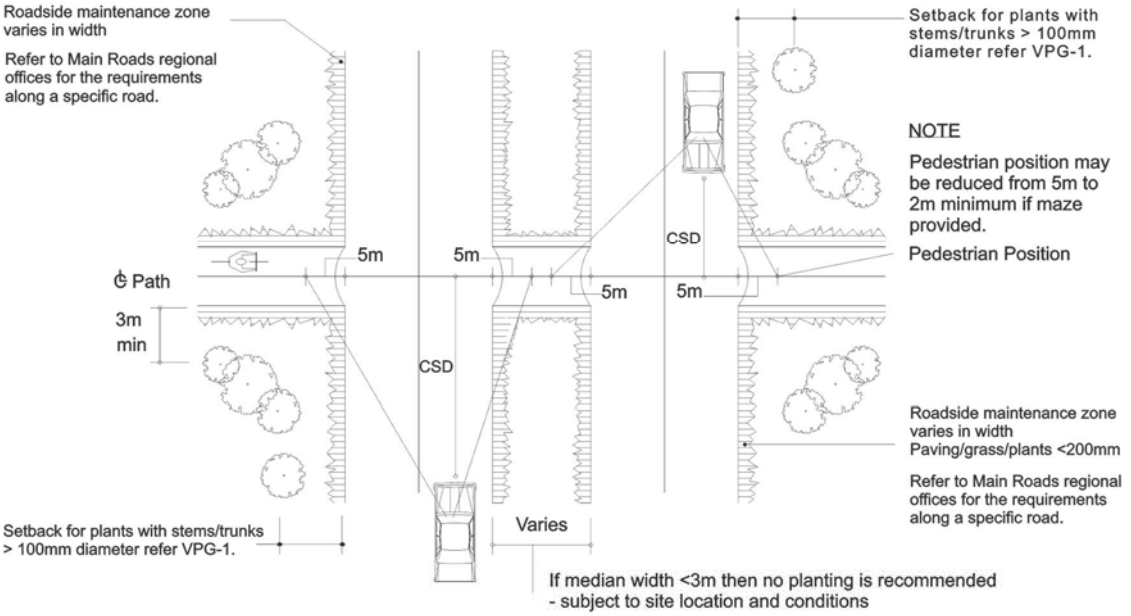


NOTE
Clear sightline zone at intersections is determined by applying SISD and the vegetation lateral clearance requirements for the specific road. Refer to Main Roads regional offices for the vegetation lateral clearance requirements along a specific road.

(SISD) Safe Intersection Sight Distance is dependent on speed and grade of road. Refer to Main Roads Supplement to AUSTROADS Guide to Road Design and AustRoads (2009) Guide to Road Design, Part 4A, Unsignalised and Signalised Intersections, section 3.2.2.

A. VEGETATION PLACEMENT GUIDE FOR INTERSECTIONS

(Applies to all intersections, staggered T and 4 way with/without medians, traffic lights or signs)
(To be read in conjunction with Dwg No VPG-1)

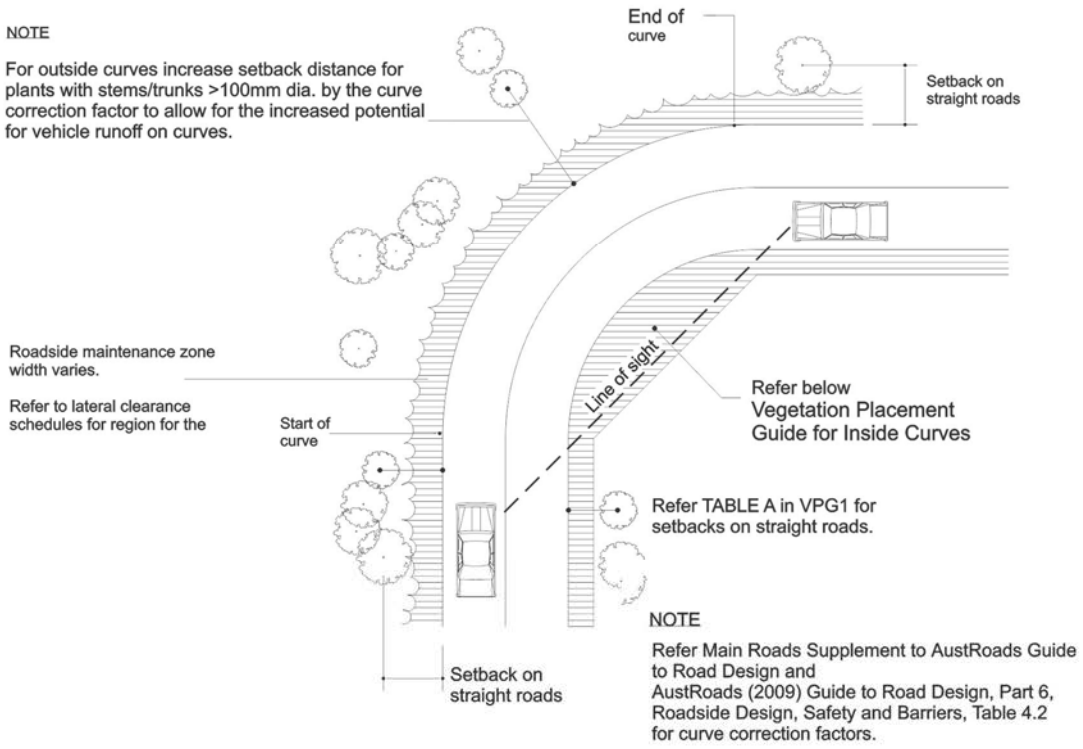


NOTE
Crossing Stopping Distance (CSD) is dependent on speed and grade of road. Refer to Main Roads Supplement to AUSTROADS Guide to Road Design and AustRoads (2009) Guide to Road Design, Part 4A, Unsignalised and Signalised Intersections, section 3.3 and Part 6A, Pedestrian and Cyclist Paths.

B. VEGETATION PLACEMENT GUIDE FOR CYCLE/PEDESTRIAN CROSSINGS

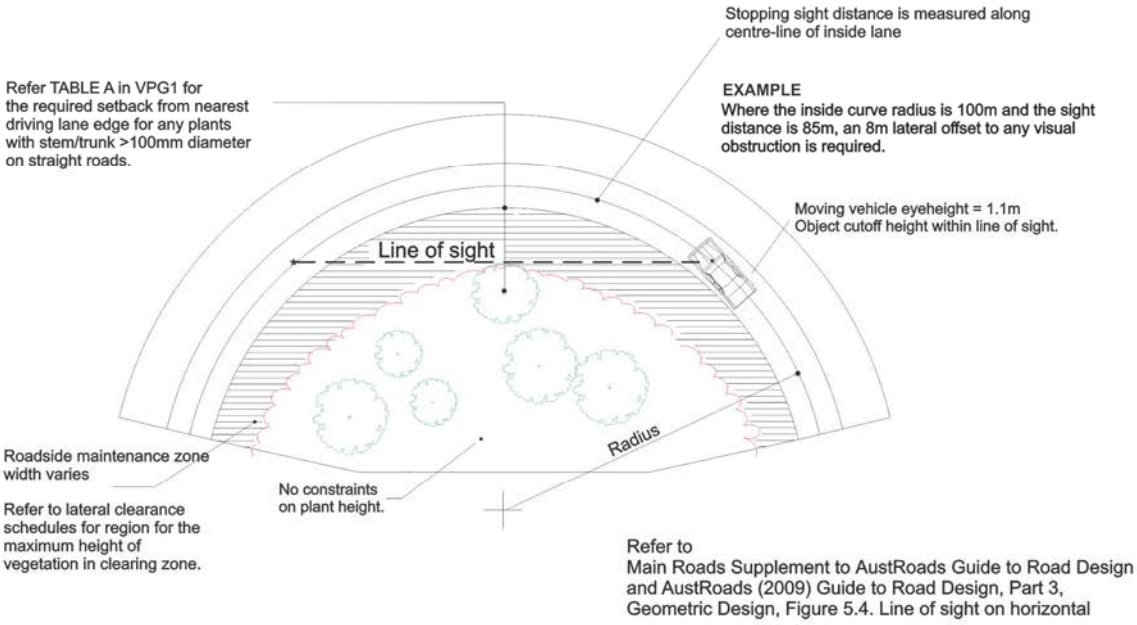
(To be read in conjunction with DWG No VPG-1)

Dwg. No. VPG2



A. VEGETATION PLACEMENT GUIDE FOR OUTSIDE CURVES

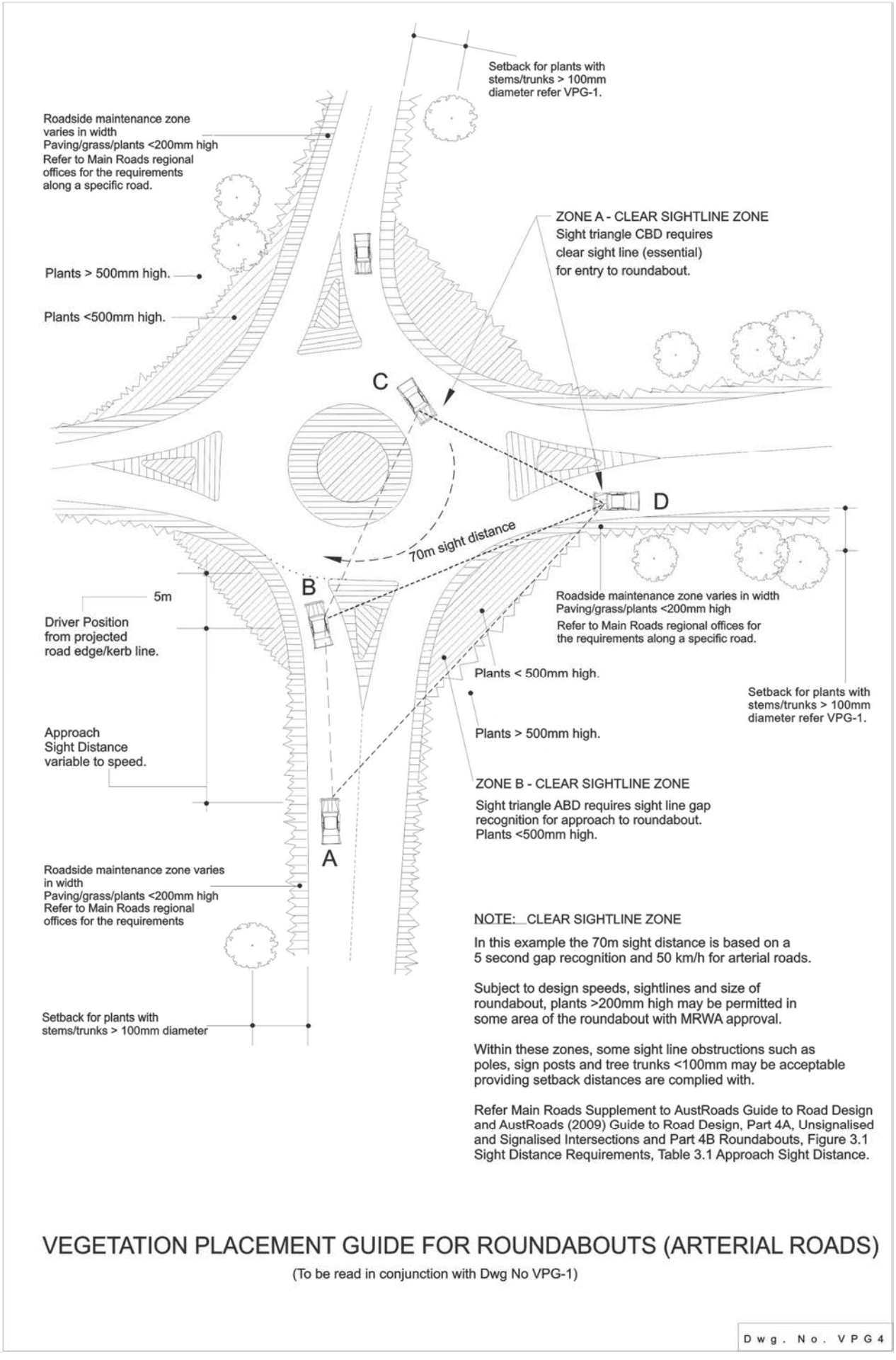
(To be read in conjunction with Dwg No VPG-1)



B. VEGETATION PLACEMENT GUIDE FOR INSIDE CURVES

(To be read in conjunction with Dwg No VPG-1)

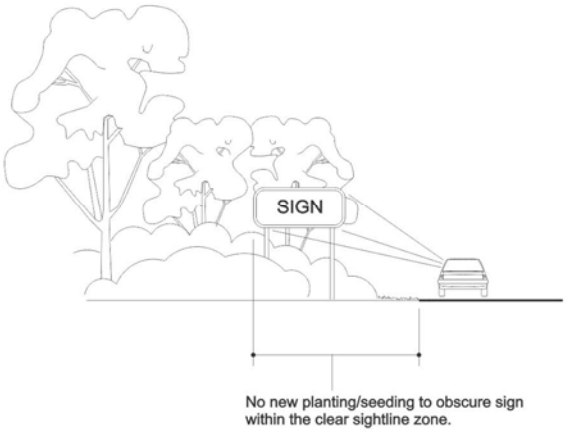
Dwg. No. VPG 3



VEGETATION PLACEMENT GUIDE FOR ROUNDABOUTS (ARTERIAL ROADS)

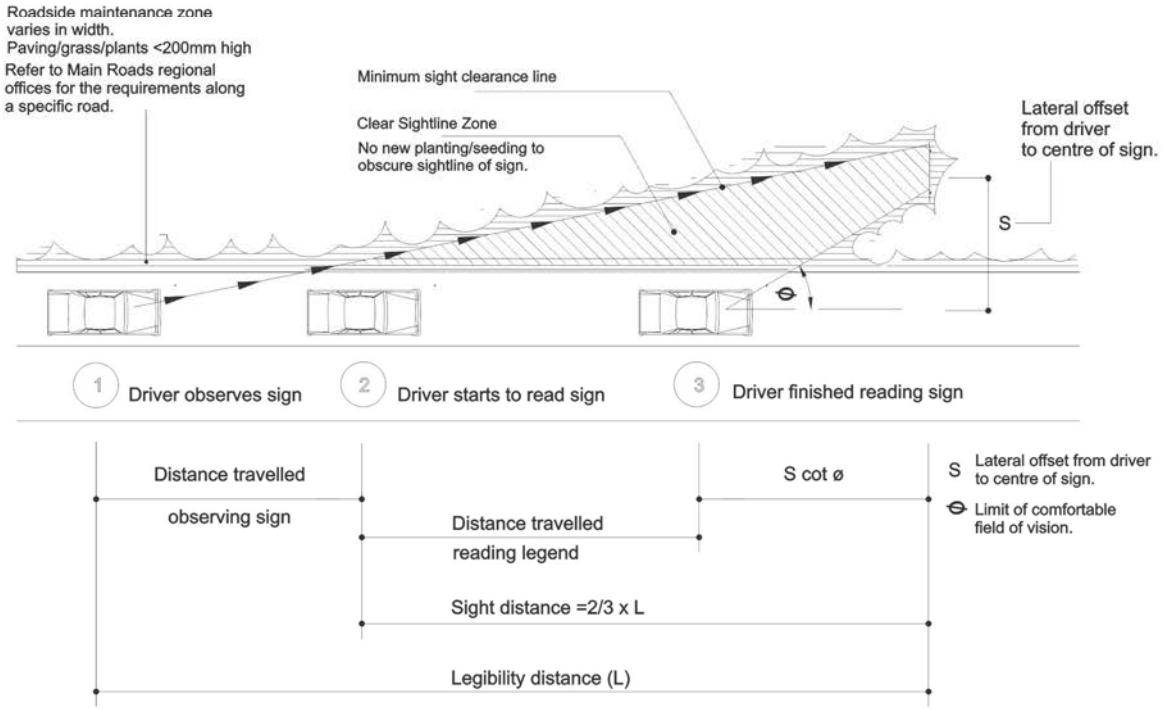
(To be read in conjunction with Dwg No VPG-1)

Dwg. No. VPG4



NOTE

Sight distance to direction and other signs is measured from where the whole sign is visible to the driver in the lane closest to the verge with the sign.



NOTE

Planting/seeding selected for use within clear sightline zones to signs shall not exceed 0.5m at maturity.

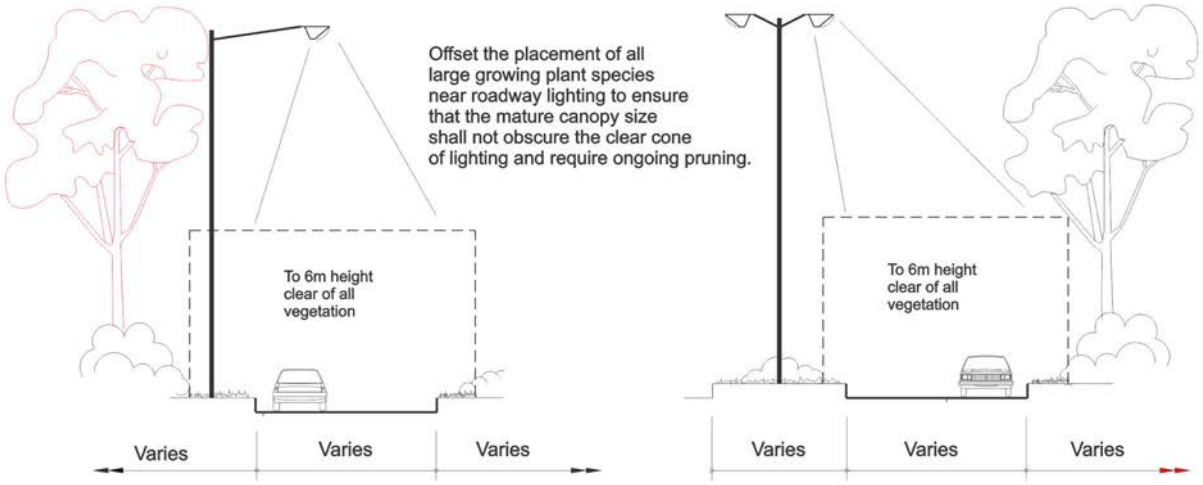
Legibility distance (L) varies with topography and speed..

Refer to AustRoads (2009). Guide to Traffic Management, Part 10, Traffic Control and Communication Devices, Figure 4.3 Sign Legibility Distance.

VEGETATION PLACEMENT GUIDE FOR SIGHT CLEARANCE TO SIGNS

(To be read in conjunction with Dwg No VPG-1)

Dwg. No. VPG5



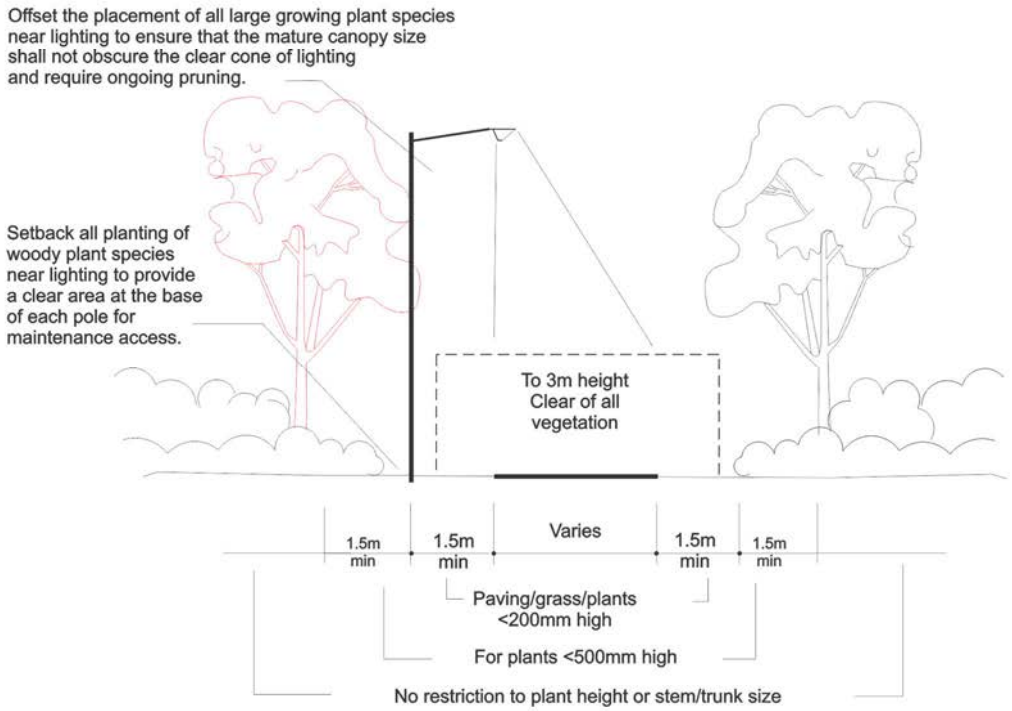
NOTE

Setback all planting of woody plant species near roadway lighting to provide a 2m clear area around the base of each pole for maintenance access.

Roadside maintenance zone varies in width. Paving/grass/plants <200mm high. Refer to Main Roads regional offices for the requirements along a specific road.

Refer to Dwg No VPG1 for setback requirements from roadway for new planting and seeding.

A. VEGETATION PLACEMENT GUIDE NEAR ROADWAY LIGHTING



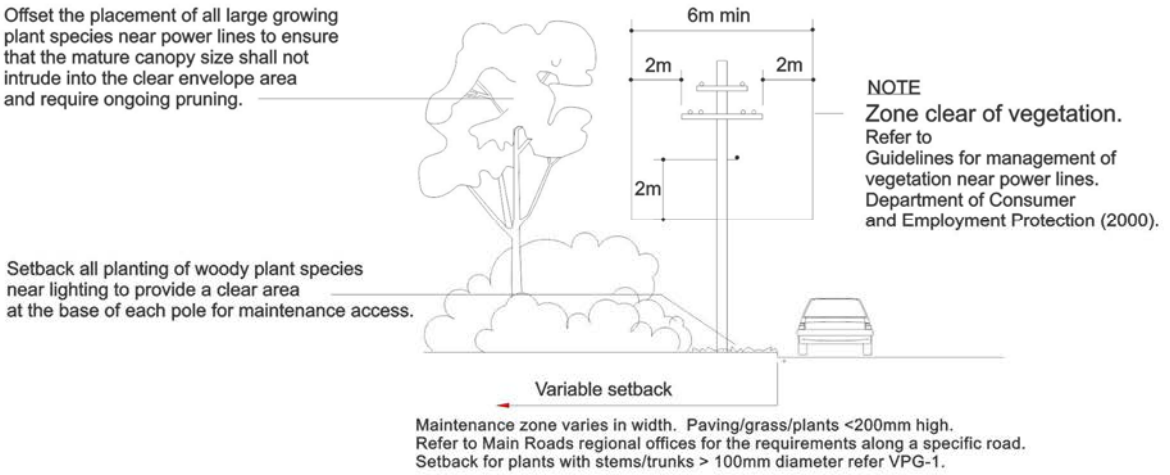
NOTE

Placement of all new planting or seeding must comply with setback distances and height restrictions as illustrated above.

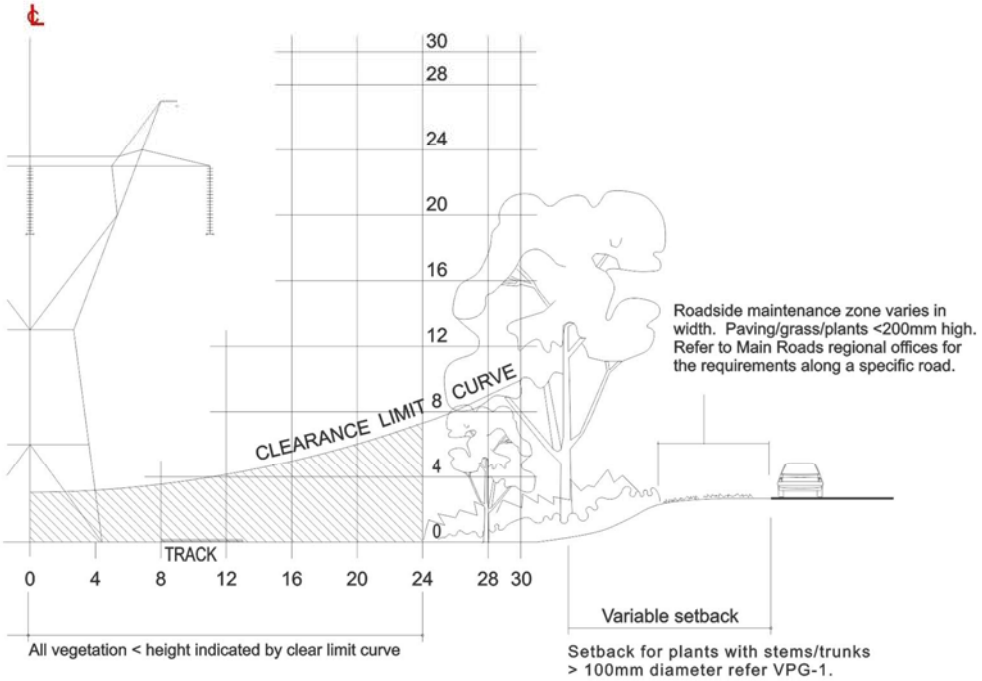
Clearance requirements derived from Main Roads Supplement to Austroads Guide to Road Design Part 6 and Austroads. (2009) Guide to Road Design, Part 6A, Pedestrian and Cyclist Paths (Refer Figure 4.7, and 5.1).

B. VEGETATION PLACEMENT GUIDE FOR SHARED PATHS

Dwg. No. VPG6



A. VEGETATION PLACEMENT GUIDE NEAR ROADSIDE POWER TRANSMISSION LINES



NOTE

Example for overlapping transmission and road corridor boundaries.

Difference in ground level between centreline and base of tree to be included in height of tree.

Within boundary of power transmission corridor heights shown by clearance limit curve shall apply for all new planting within road reserve.

Refer to Department of Consumer and Employment Protection (2000), Guidelines for management of vegetation near power lines.

B. VEGETATION PLACEMENT GUIDE FOR HIGH VOLTAGE TRANSMISSION LINES

Dwg. No. VPG7

Appendix 4 Manuwarra Red Dog Highway Stage 4 Biological Survey (Biota 2021a)

Biota Environmental Sciences

Manuwarra Red Dog Highway Stage 4 Biological Survey

Prepared for Main Roads Western Australia

April 2022

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project No.: 1511

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Document Quality Checking History

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	Rev D	Amendments	D. Kamien
		Approved for issue:	G. Humphreys

Manuwarra Red Dog Highway Stage 4 Biological Survey

Contents

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1.0 Executive Summary

Main Roads Western Australia (Main Roads) is planning to commence work on Manuwarra Red Dog Highway Stage 4 (hereafter 'the project'), located in the Pilbara region of Western Australia. Main Roads commissioned Biota Environmental Sciences (Biota) to carry out a biological survey for the project in order to identify key flora and fauna values relevant to the design and construction of the project. The survey will support the environmental impact assessment (EIA) process for the project and inform referral of the project to the State Environmental Protection Authority and the Commonwealth Department of Agriculture, Water and the Environment.

The spatial scopes for the biological survey comprised:

- the survey area (the development envelope for the project, which will accommodate all aphysical components of the proposal for the purposes of EIA);
- a contextual area (a 500 m buffer on the centreline of the survey area; mapping was extended out to the edge of the contextual area where the survey area was narrower than this overall 1 km corridor); and
- the study area (an 18 km buffer from a centreline of the survey area for broader context setting).

A desktop flora and fauna assessment was undertaken for the study area, to use existing information to identify likely fauna and flora within the survey area. This was followed by a field survey work of the survey area, which comprised a detailed and targeted flora and vegetation survey and a basic and targeted fauna field survey. The surveys were undertaken over four mobilisations in April, May and October 2020 and March 2021.

Vegetation and Flora

A total of 29 vegetation types were identified for the survey area, broadly grouped into hills, cracking clay plains, Mulga low woodland, stony to gravelly plains, drainage lines, and floodplains. Approximately 5% of the survey area was comprised of cleared and/or disturbed ground.

Three of the vegetation types (C4, C5 and P6) represented a Threatened Ecological Community (TEC), the "*Themeda* grasslands on cracking clays (Hamersley Station, Pilbara)" TEC, which is listed at State level as Vulnerable. The TEC occurred in the Tom Price section of the survey area where 115.3 ha was mapped, representing 38.8% of the extent of the TEC in the local area.

One Priority Ecological Community (PEC), the Priority 1 "Brockman Iron cracking clay communities of the Hamersley Range", was recorded in the survey area: vegetation type C3, which was present in the Tom Price section with a total of 88.1 ha mapped, representing 39.1% of the extent of this vegetation type in the local area.

A third ecological community, represented by vegetation units C2 and one site from P7, corresponds to one of the four plant assemblages described for the Wona Land System, the "Mitchell grass and Roebourne Plain grass (*Eragrostis xerophila*) plain on gilgai", which is a Priority 3 PEC. However, as these vegetation types did not occur on the Wona Land System but rather the Hooley Land System, they may be considered to be of local conservation significance rather than representing the PEC itself. In the far north of the survey area, a total of 206.8 ha was mapped for C2, representing 2.4% of the survey area, while P7 comprised 43.2 ha (0.5% of the survey area), noting that the latter figures include all P7 sites and the proportion of this vegetation type that is of local conservation significance is minor.

A total of 590 native vascular flora species from 190 genera and 56 families were recorded from the survey area, and 16 introduced flora species (weeds). One Threatened flora species, *Seringia exastia,* which is listed under State and Commonwealth legislation, was recorded from the survey area, with no other Threatened flora considered Likely to Occur. This species has recently been

incorporated into the common and widespread species, *Seringia elliptica,* and is no longer considered to be of conservation significance.

Twenty-one State-listed Priority flora species were recorded from the survey area, with no other Priority flora considered Likely to Occur. The species recorded comprised:

- three Priority 1 species: *Hibiscus* sp. Mt Brockman (E. Thoma ET 1354), *Josephinia* sp. Woodstock (A.A,. Mitchell PRP 989) and *Vittadinia* sp. Coondewanna Flats (S. van Leeuwen 4684);
- three Priority 2 species: *Aristida lazaridis, Euphorbia inappendiculata* var*. inappendiculata* and *Euphorbia inappendiculata* var*. queenslandica*;
- twelve Priority 3 species: *Aristida jerichoensis* var*. subspinulifera, Astrebla lappacea, Dolichocarpa* sp. Hamersley Station (A.A. Mitchell PRP 1479), *Euphorbia australis* var*. glabra, Glycine falcata, Gymnanthera cunninghamii, Rhagodia* sp. Hamersley (M. Trudgen 17794), *Sida* sp. Hamersley Range (K. Newbey 10692), *Swainsona thompsoniana, Themeda* sp. Hamersley Station (M.E. Trudgen 11431), *Streptoglossa* sp. Cracking Clays (S. van Leeuwen et al. PBS 7353), *Triodia basitricha*; and
- three Priority 4 species: *Eremophila magnifica* subsp*. magnifica, Goodenia berringbinensis* and *Goodenia nuda*.

Fauna

Database and literature searches of the study area identified a total of 305 vertebrate fauna species with the potential to occur in the survey area, 31 of which are listed as significant. Prior to the field survey, eight of these species were assessed as Likely to Occur within the survey area, with a further ten that May Occur.

During the field survey, a combined total of 110 species of vertebrate fauna was recorded within the survey area and contextual area, including five ground mammals, 11 bats, 75 birds, 15 reptiles and four amphibians.

Four fauna species of conservation significance, including three mammal species and one bird species, were recorded from the survey area:

- Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia* Pilbara form; State and Federal: Vulnerable);
- Ghost Bat (*Macroderma gigas;* State and Federal: Vulnerable);
- Western Pebble-mound Mouse (*Pseudomys chapmani*; State: Priority 4); and
- Grey Falcon (*Falco hypoleucos;* Vulnerable*).*

Two of the above species, the Pilbara Leaf-nosed Bat and the Grey Falcon, were recorded with certainty from the survey area through call recordings and sighting respectively. Secondary evidence of the other two species also confirmed their presence: Ghost Bat remains and scats were identified inside a cave within the survey area, and a recently active Pebble-mound Mouse mound was recorded.

Based on previous records from the study area, and field assessment of the habitats present within the survey area, seven other fauna species of conservation significance were considered Likely to Occur: Northern Quoll (*Dasyurus hallucatus*), Short-tailed Mouse (*Leggadina lakedownensis*), Pacific Swift (*Apus pacificus*), Peregrine Falcon (*Falco peregrinus*), Pilbara Olive Python (*Liasis olivaceus barroni*) and *Notoscincus butleri*.

Most of the fauna species of conservation significance recorded from the survey area, or deemed Likely to Occur, would be associated with the rocky habitats of the Hamersley Range (habitat types HS, RHS, MDE, MDM and RG), which would be considered to have the highest local conservation significance for fauna.

2.0 Introduction

2.1 Project Background

Main Roads Western Australia (Main Roads) is planning to commence work on the construction of Manuwarra Red Dog Highway Stage 4 (hereafter 'the project'), located in the Pilbara region of Western Australia (WA) (Figure 2.1). The project includes 110 km of new highway construction from the southern end of Stage 3 of the highway (at Wallyinya Pool) to its intersection with the existing Nanutarra - Munjina Road. This will complete Straight Line Kilometre (SLK) 136 to 245 of the highway, and will be the final stage of works. The 110 km of the project is planned to be constructed in three sections, from north to south:

- Coolawanyah – the initial 32.5 km of highway;
- Hamersley – the following 47.5 km; and
- Tom Price – the final 30 km.

On completion, the highway will be called Manuwarra Red Dog Highway in recognition of both the traditional owners of the area[1] and the iconic Red Dog kelpie who was often seen along parts of the original road in the 1970s. The purpose of the project is to provide a safe and efficient transport connection between Karratha and Tom Price as an alternative to the existing Rio Tinto rail access road, which is an unsealed track and unsuited to heavy freight traffic.

Main Roads commissioned Biota Environmental Sciences (Biota) to carry out a biological survey for the project in order to identify key flora and fauna values relevant to the design and construction of the project. The survey will support the environmental impact assessment (EIA) process for the project and inform referral of the project to the WA Environmental Protection Authority (EPA) and the Commonwealth Department of Agriculture, Water and the Environment (DoAWE).

2.2 Spatial Scope and Report Terminology

The primary spatial scope of the survey comprised the development envelope within which the project will be constructed. Terminology for the spatial extents referenced in this document is defined in Table 2.1 and shown in Figure 2.1.

Table 2.1: Spatial extents and terminology used in this document.

Report Terminology	Definition	Size (ha)	Flora Survey	Fauna Survey
Survey area	The development envelope for the project, which will accommodate all physical components of the proposed project for the purposes of EIA.	8,746.4	Detailed and Targeted flora and vegetation survey.	Basic and targeted fauna survey[2].
Contextual area	A 500 m buffer on the centreline of the survey area. Mapping was extended out to the edge of the contextual area where the survey area was narrower than this overall 1 km corridor.	4,841.5	Not surveyed in sections wider than the survey area, with vegetation and fauna habitat mapping was extrapolated from survey area data and aerial imagery.	
Study area	An 18 km buffer from the centreline of the survey area, within which a desktop review was carried out to determine a potential species list and identify any conservation significant species that may occur within the survey area.	505,809.4	Desktop background information gathered from database and literature sources.	

[1] Manuwarra is the Yindjibarndi word for 'heaps' or 'masses', which the people use to describe Red Dog Gorge located within the Millstream Chichester National Park.

[2] The fauna survey extended into adjacent habitats of the contextual area to inform the use or potential use of habitats within the survey area, given that fauna are mobile.

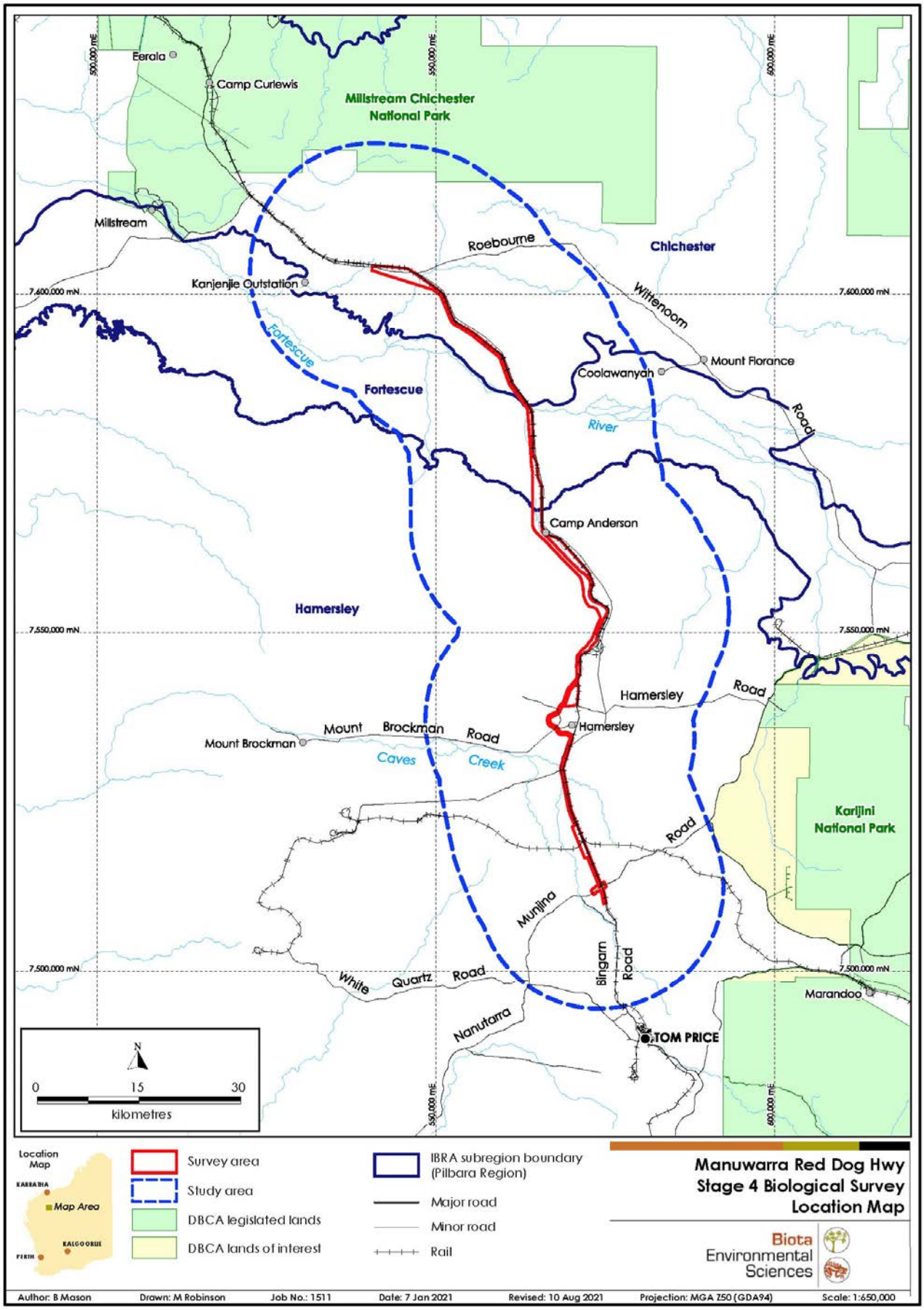

Figure 2.1 Location of survey and study areas for the project.