Northern Territory Government

DEPARTMENT OF LAND RESOURCE MANAGEMENT

Tiwi Island Economic Development

Bio-Physical Resources of North East Bathurst Island

Technical Report

May 2015

www.nt.gov.au/lrm

Department of Land Resource Management
PO Box 496
Palmerston NT 0831

ISBN-1-74350-072-6

This report is to be cited:

Department of Land Resource Management (2015)

Tiwi Island Economic Development - Bio-Physical Resources of North East Bathurst Island (Technical Report).

Technical Report Number 12/2014/D

Department of Land Resource Management, Darwin, Northern Territory.

Executive summary

This report outlines the key findings of a detailed scientific assessment of the soil and land, ground and surface water and a biodiversity resources of north east Bathurst Island.

Approximately 6 000 ha of land is considered moderately suitable for a range of crops. The availability of water will be a limiting factor in determining the extent and type of crops that will be productive and economically viable. Water source options to support potential development have been identified across the 6 000 ha area. The groundwater investigation indicated an aquifer with bore yields varying from low in the south to a maximum of 20 L/s in the north, where the potential for saline intrusion would need to be managed. The development of the groundwater resource would require the strategic location of bore fields with ongoing management, including monitoring. A surface water investigation identified creeks in the southern area where flows could also be utilised for irrigation.

The biodiversity assessment identified seventeen flora and fauna species listed as threatened under Northern Territory and Australian Government legislation. The habitat of ten of the threatened species is monsoon forests and thickets which are not located on suitable agricultural soils, but which are generally Groundwater Dependent Ecosystems. Seven threatened species occur in the Eucalypt woodland, with four species widespread in areas assessed as suitable for agriculture. The occurrence and distribution of an additional threatened mammal species requires confirmation.

If development did proceed, the potential indirect impacts from water extraction, fire, weeds and potential soil erosion would need to be carefully managed.

This report is supported by two maps;

Summary of the Bio-Physical Resources of North East Bathurst Island and *Land Resources of North East Bathurst Island*.

Acknowledgements

This Departmental project has been an extensive undertaking involving three divisions. The overall responsibility for the project was given to the Rangelands Division under the Executive Director, James Pratt. The coordination of the project involving extensive cooperation with other government agencies and the Tiwi Land Council was led by Luis Da Rocha, Director of Land Development Coordination.

The compilation of the Departmental summary and technical reports was coordinated by Jason Hill, Manager Land Assessment with formatting and editing assistance from Caroline Green, Spatial Information Officer. Other Spatial Data and Mapping Unit staff involved included Athina Pascoe Bell, Spatial Systems Development Manager who coordinated the initial collation of field and spatial data into departmental GIS, Caroline Green who undertook the necessary departmental spatial data quality controls and secured the spatial data into corporate libraries, and Lynton Fritz, Senior Cartographer who produced a series of final map products.

Stuart Smith from the Department of Primary Industry and Fisheries contributed the information required for Section 8, Crop Suitability.

Bill Cumberland, Principal Land Management Officer, coordinated the procurement required to have temporary access trails established for fieldwork. The planning required to locate these trails in the best location were identified by Bart Edmeades, Land Resource Technical Officer. Bill Cumberland and Colin Stace also undertook regular field visits to provide best practice land management advice and to monitor these works.

An extensive number of Department staff not directly involved in publishing this report such as Land Assessment Branch staff, Elizabeth Tierney and numerous Water Resources Drilling staff were critical for the success of the project. Their efforts in organising the logistics of barging field vehicles, equipment and food and water supplies including a water resource drilling rig and associated equipment to the island has to be acknowledged. Deb Bisa supported NT Herbarium field staff and assisted with specimen curation, and Michael Braby, Katerin Lowe, Tim Portas and Danielle Stockeld helped with fauna fieldwork .

Japan Aerospace Exploration Agency (JAXA) Kyoto and Carbon (K&C) Initiative provided the ALOS PALSAR FBD data used in this research. Matthew Barrett assisted with analysis of DNA samples of *Typhonium* and interpretation of results. John Wilford (GeoScience Australia) assisted with interpretation of radiometric data.

Thank you to Kate Hadden, Manager Land and Resources, Tiwi Land Council who provided on-ground support for the project and assistance with organising meetings with traditional owners, and to the Tiwi Land Rangers who provided essential logistical support for the flora and fauna assessments.

The Department would also like to thank the Northern Territory Police for allowing field vehicles to be securely stored in their compound and arranging the pick-up of vehicles from the barge landing.

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PART 1. OVERVIEW

1. Introduction

1.1 Background

In early 2014, the Northern Territory Government engaged the Department of Land Resource Management (DLRM) to undertake a land suitability assessment, water resource investigation and flora and fauna evaluation in north east Bathurst Island to develop baseline information regarding these bio-physical resources.

The Department was requested to undertake a survey of land to identify up to 10 000 ha of land suitable for agricultural purposes. A preliminary land, water and biodiversity investigation undertaken in by DLRM in late 2013 identified several areas across the Tiwi Islands which could contain potential agricultural land and require further investigation. The area targeted for detailed survey was selected in collaboration with other Northern Territory Government departments and traditional owners. The resulting study area targeted an area of 14 100 ha on North East Bathurst Island.

The Northern Territory Government is committed to further developing and providing opportunity for growth across the NT. The *Framing the Future* Strategic Plan provides policy and direction for growth of an agricultural sector in the NT for all Territorians. Priorities for development include supporting agricultural enterprises, improved access and infrastructure, facilitating Indigenous partnerships and management while maintaining environmental values for sustainable development.

The Department of Land Resource Management further implements this policy through the DLRM *Strategic Plan 2013-17* to provide best available information, assessment and interpretation of land and water resources to support development, growth and lifestyle of the Northern Territory.

1.2 Objectives

The broad objectives of the investigations were:

1. Investigate the groundwater resources to inform potential water availability.
2. Investigate the surface water resources to inform potential water availability and development options.
3. Map and describe the soil landscape and interpret this for agricultural land suitability, including assessment for crop suitability by the Department of Primary Industries and Fisheries.
4. Survey flora and fauna of conservation significance recognised under Northern Territory and Australian legislation and map significant vegetation communities.

These objectives enabled the Department to gain an understanding of the land and water resources, and biodiversity values, as well as satisfying the requirements of the *Environment Protection Authority Indicative Terms of Reference Tiwi Island Investigation* (2014).

The assessment will provide the basis for potential sustainable development of the land and water resources.

1.3 Study area

The study area comprised approximately 14 100 ha of terrestrial landscapes in north east Bathurst Island, with an additional 4 700 ha of intertidal environments broadly mapped for acid sulfate soils.

The location of the study area on the Tiwi Islands and the Northern Territory are presented in Figure 1-1 and Figure 1-2.

Figure 1-1: Location of the Study Area on the Tiwi Islands and within the Northern Territory

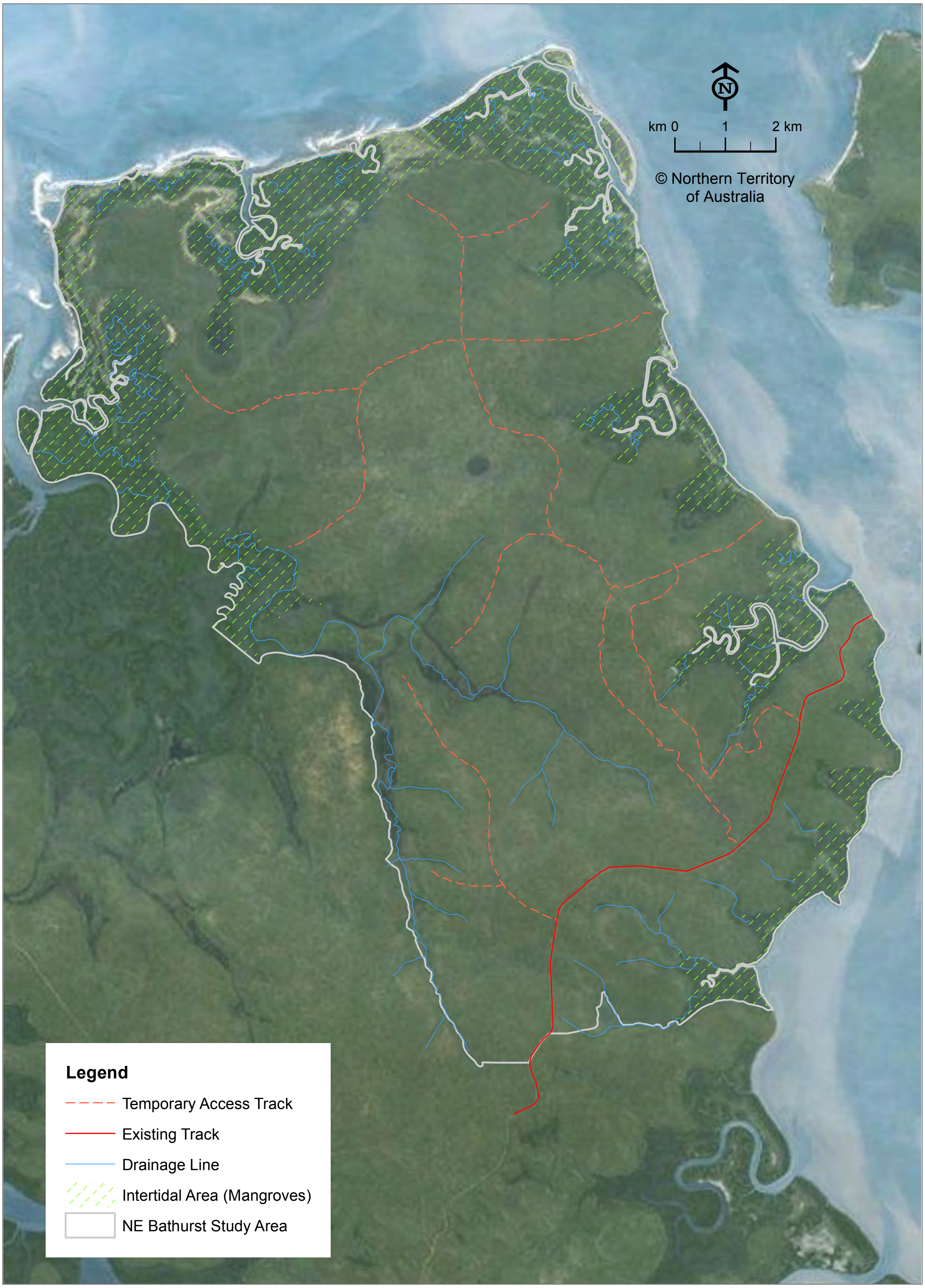

Figure 1-2: North East Bathurst study area

1.4 Climate

Dry season (May to September) temperatures range from 18-33°C and 31-33 °C during the wetter months (October to April). The climatic data from Pirlangimpi, Garden Point Airport (BOM station no. 014142) was used for the purpose of this survey. The weather station is located on Melville Island 3 km east of the survey area and has been identified as the nearest open station.

Average monthly rainfall data and average monthly maximum and minimum temperature data has been plotted in Figure 1-3. (BOM, 2014)

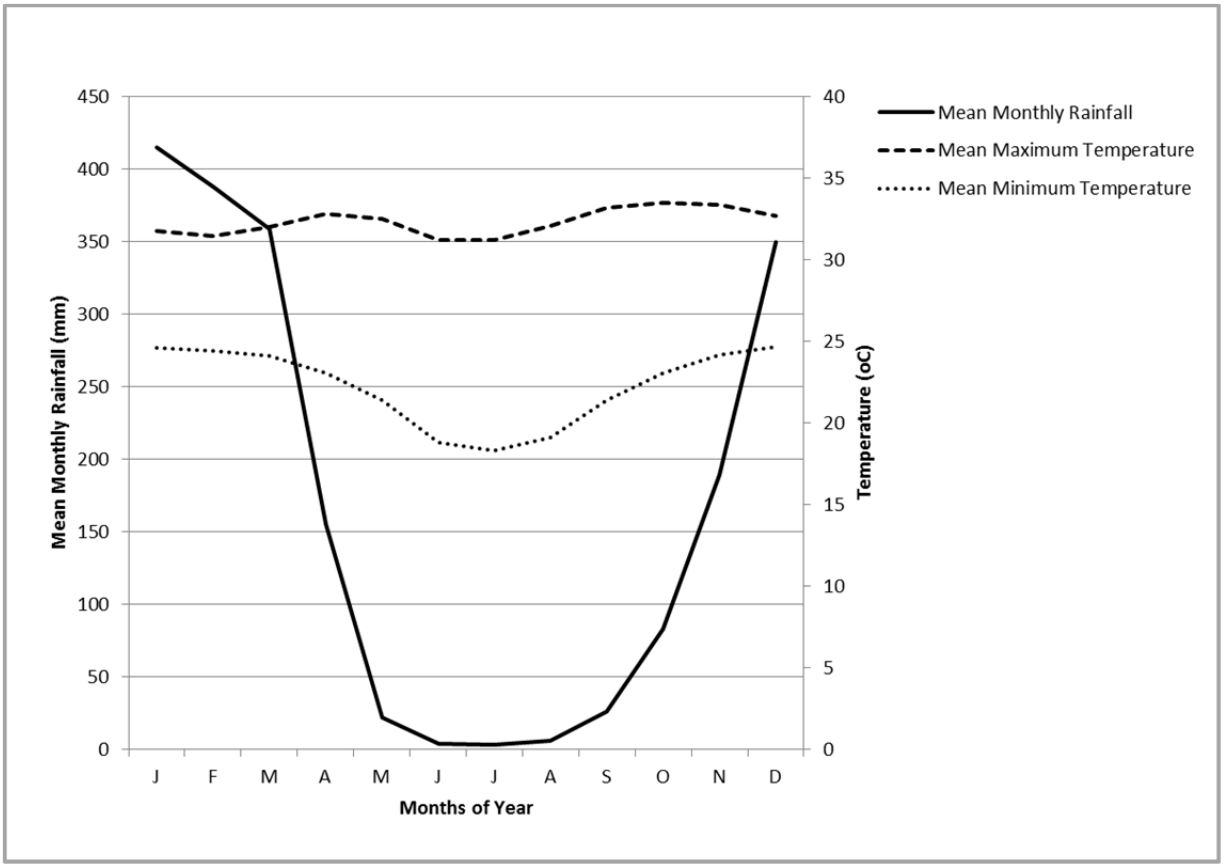

Figure 1-3: Monthly rainfall, maximum and minimum temperatures

Tropical cyclones can affect the area, generally during the wet monsoonal months from November to March where monthly rainfall is highest and falls are heaviest. Consistent high temperatures occur year round, with lower minimum temperatures during the dry season from May to September. Annual average rainfall is 2 006 mm with a majority of this occurring during the wet months from November to May, with January being the highest rainfall month (415 mm). No average daily evaporation has been recorded at this station. In comparison to Darwin's annual climatic data at Darwin Airport (BOM station no. 014015) wet months occur from November to April with annual average rainfall of 1 730 mm (BOM, 2014).

The annual average rainfall is 2 006 mm with the majority received during the wet season months from November to May. January is the highest rainfall month, averaging 415 mm (Bureau of Meteorology station, DR014142) located at Pirlangimpi Airport. These seasonal conditions represent a longer, wetter wet season than Darwin, which has an annual average rainfall of 1 730 mm.

1.5 Land use

The majority of the study area was undisturbed at the time of survey and under native vegetation. In the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) Australian Land Use and Management (ALUM) it is classified as *Traditional Indigenous Uses*.

Fires are an annual occurrence on Bathurst Island during the dry season. Feral animal's in particular wild pigs have impacted some areas of the landscape.

1.6 Legislative context

The management of water resources is regulated under the Northern Territory *Water Act* and the *Waste Management and Pollution Control Act*. Northern Territory legislation *(Territory Parks and Wildlife Conservation Act, TPWCA*) and Australian legislation *(Environment Protection and Biodiversity Conservation Act 1999, EPBCA)* both apply to the management of biodiversity. Development proposals with potential to result in environmentally significant impacts may require assessment under the *Environmental Assessment Act*.

PART 2. BIO-PHYSICAL RESOURCES

2. Geology

There are two major geological formations of project significance. These are the Van Diemen Sandstone of Tertiary age, and the Cretaceous aged Bathurst Island Formation which unconformably overlies it. The Bathurst Island Formation comprises the Wangarlu Mudstone and Moonkinu Sandstone members. A thin 3 to 5 m veneer of Quaternary age sediments overlies the Van Diemen Sandstone.

The Van Diemen Sandstone is described by Hughes (1976) as white to yellow, friable, medium to coarse grained poorly sorted quartz sandstone, with minor lenses of siltstone and granular conglomerate deposited in a fluvial environment.

Chin (1991) reporting investigations at Milikapiti, describes the Van Diemen Sandstone as an upper and lower unit in most of the bores drilled. The lower unit is a tan and white, friable fine to coarse quartz sandstone with a clayey matrix and interbedded with white and tan clay. The top of the lower unit is a hard laterised ferruginous sandstone and mottled clay. The base of the lower unit is the contact with the weathered top of the Bathurst Island Formation, which is found to be firm, white and purple mottled clay before encountering the distinct dark grey clayey mudstone. The upper unit of the Van Diemen Sandstone presents initially at 3 to 5 m below ground level as a hard laterised ferruginous sandstone, immediately followed by a medium to coarse grained tan clayey sand. With increasing depth, it grades into clayey sands, sandy clays, clay and sand. The sequential colourings with depth include tan, brown, pink, purple and white. The bottom of this upper unit grades into the hard ferruginous sandstone bands of the lower unit. The total thickness of the Van Diemen Sandstone ranges from 29 to 70 m.

Within the Bathurst Island Formation, the Moonkinu Sandstone conformably overlies and, in places, inter-finger with the Wangarlu Mudstone. It is described by Chin (1991) as a fine to very fine sub-labile sandstone inter-bedded with grey carbonaceous clay and siltstone with calcareous and limontic concretions. It was deposited in a shallow marine deltaic environment during a regressive period.

During this project, the Moonkinu sandstone was encountered at depths of around 70 to 80 m below ground level. The sand was very fine in amongst the grey mud. The grey mud had a slight green tinge and noticeably different to the stratum of the Wangarlu Mudstone.

The surface geology mapped at a scale of 1:250 000 is presented in Figure 2-1 (Geological series Bathurst Island Sheet SC 52-15 Map) with lithological descriptions in Table 2-1. The South - North sub-surface geology transect presented in Figure 2-2 has been developed from drilling data.

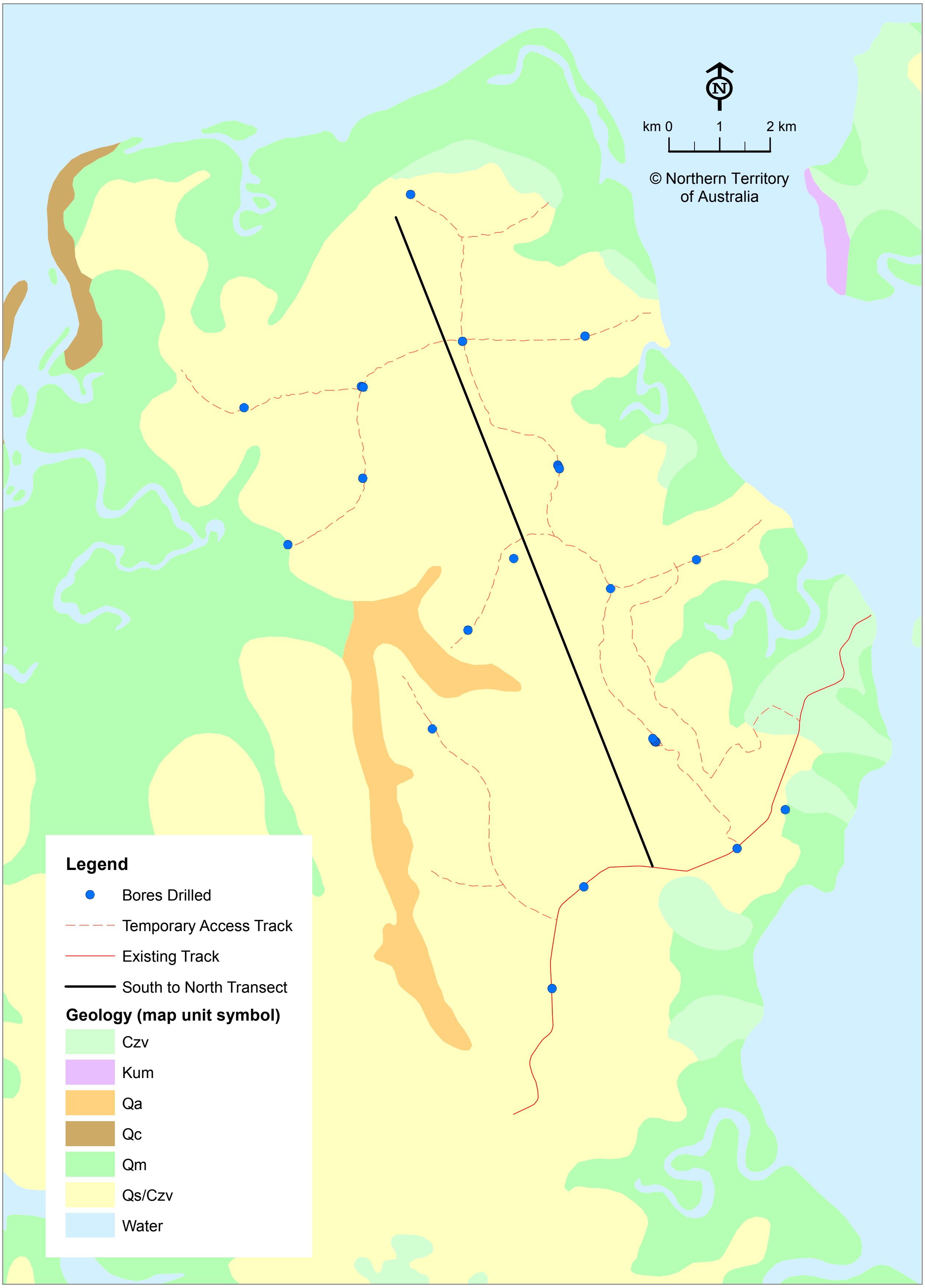

Figure 2-1: Surface Geology (refer to Table 2-1 for lithological descriptions) (Hughes 1976)

Table 2-1: Surface geology lithological descriptions (Hughes 1976)

Age	Map label	Lithological Description
Quaternary	Qa	Silt, fine sand, minor gravel, alluvium
	Qc	Quartzose sand, shell and coraline debris
	Qm	Saliferous organic mud and silt
	Qs	Poorly consolidated sand and silt, red sandy soils, mottled grey and yellow sandy soils
Tertiary (Van Diemen Sandstone)	Czv	Friable white and yellow, medium to coarse quartzose sandstone; minor siltstone and conglomerate; cross-bedded in part; strongly weathered in outcrop; fossiliferous
Bathurst Island Formation (Moonkinu Sandstone)	Kum	Sub-labile sandstone, siltstone and mudstone, glauconitic and calcareous in part

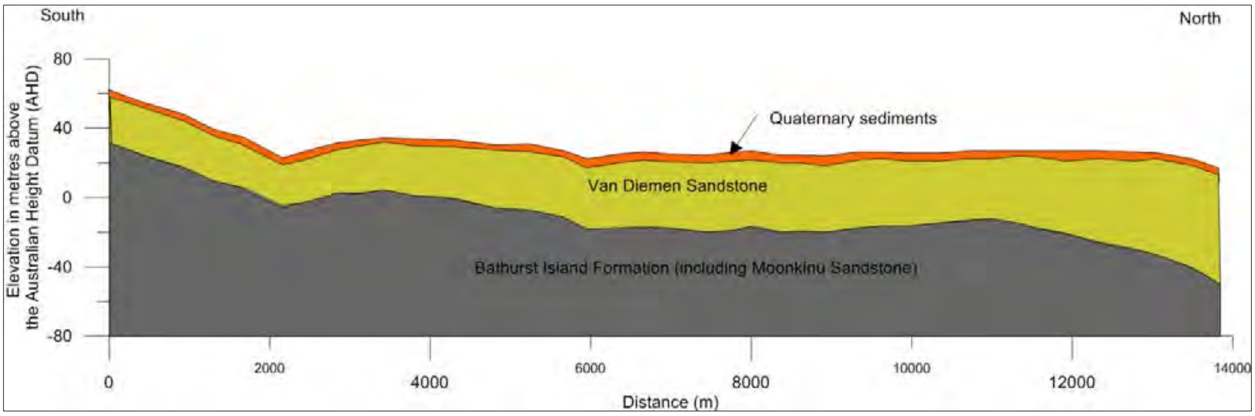

Figure 2-2: South to north cross-section of sub-surface geology (Hughes 1976)

3. Geomorphology

3.1 Tiwi Islands

The geomorphology of the Tiwi Islands is summarised in Hughes (1976). Both islands are a low relief landscape with undulating laterite rises and dissected plateaux up to 100 m above sea level (Figure 3-1). The areas of higher relief on the islands are remnants of a Tertiary land surface formed after the deposition of the Van Diemen Sandstone. The plateaux are fringed by colluvium and extensive sand plains have built up over the northern part of the islands as a result of the erosion and dissection of the Tertiary surface. Open plains characterised by poor drainage and stunted vegetation occur in the Maxwell Creek region of Melville Island, and central Bathurst Island. These are related to exposures of an earlier land surface formed in the late Cretaceous.

Alluvium has accumulated along the watercourses. On the low-lying coastal margins, mangrove-lined tidal flats extend along the river channels. Deposits of beach and littoral sand have accumulated on the western and northern coasts, and emerged former strandlines are preserved as low vegetated ridges. Sand dunes occupy a 20 km coastal strip on southern Bathurst Island. They form sets of dunes that are orientated northwest, rise to more than 20 m above sea level and extend inland up to 1.5 km.

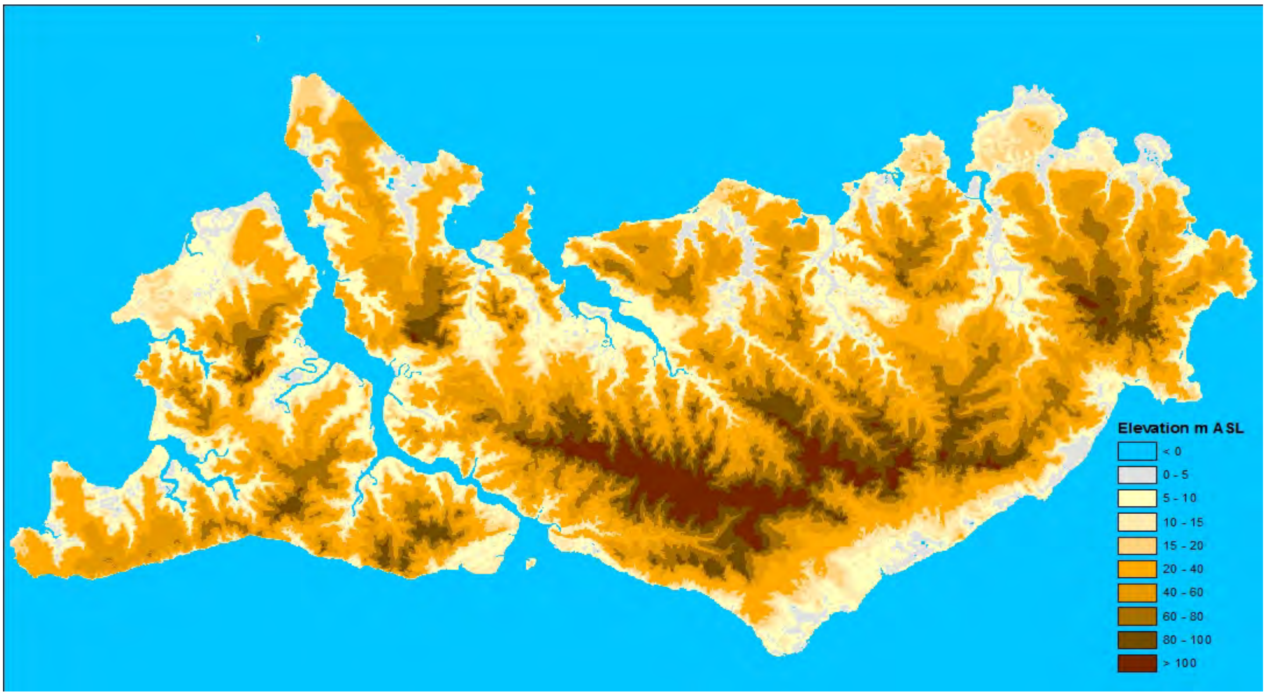

Figure 3-1: Elevation (m) ASL of the Tiwi islands

3.2 North East Bathurst Island

The North East Bathurst Island study area contains examples of most of the geomorphic features summarised by Hughes (1976) for the Tiwi Islands. These are illustrated in Figure 3-2.

The area consists largely of level to gently undulating plains formed on quaternary colluvium which has built up as a result of the erosion and dissection of the Tertiary surface further south. These plains have broad lower sloping margins and occasional short steep slopes and cliffs adjacent to the coast. The elevation of the plains increases gradually towards the south then drops away abruptly as plateau side slopes.

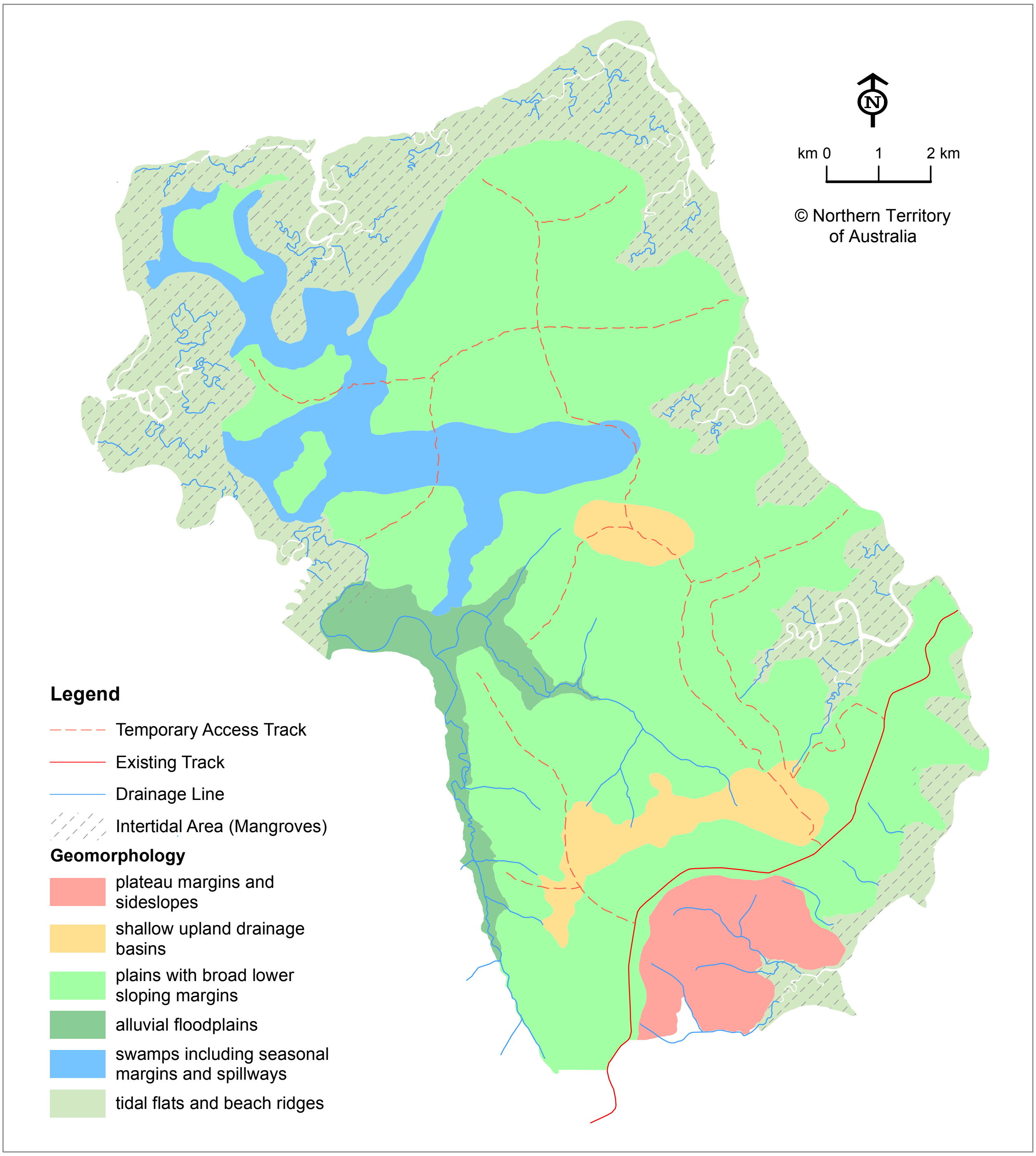

Figure 3-2: Geomorphological groupings (Hughes 1976)

The northern portion of the plain features a series of swamps which are likely to be interconnected during the wet season. The extent to which this swamp system expands during the wet season is likely to be a dynamic function with the system expanding and contracting depending on the pattern of rainfall. It is also likely that when this system is full that broad shallow spillways come into operation and directs surface flow towards the heads of drainage lines.

In the southern part of the study area is a strip of land approximately 1 km wide trending south-west to north-east. This area is distinguished by a different association of soils and vegetation which reflects a very different hydrological function to the surrounding plains. This is most likely due to the influence of the underlying Moonkinu mudstone. Although not evident during the dry season field survey these areas appear to operate as broad, shallow drainage basins which appear to retain water then direct flow to the heads of drainage channels. Smaller examples of this also occur in the north.

An elevated plateau margin with associated side slopes is located in the south-east corner of the study area. The southernmost portion of plateau margin features a small area of ferricrete capping. The steeper areas forming the side slopes of the plateau feature Van Diemen sandstone surface rock and deeply weathered variants. The plateau margin extends and becomes more prominent further south of the study area.

The plateau side slopes and the margins of the plains feature numerous seepage areas and springs. The hydrology of these features as well as the swamp system and shallow drainage basins is attributed to the interaction between the permeable Van Diemen Sandstone overlying the impermeable Moonkinu Mudstone.

The southwest boundary of the survey area is bounded by an alluvial floodplain which forms the upper reaches of Dudwell Creek. The floodplain has formed form the accumulation of sandy alluvium and varies from a few hundred metres across to approximately 1.5 km where it reaches the tidal influence. The floodplain remains wet permanently.

The coastal margin of the study area features a intertidal flat which can extend up to three kilometres in width. Within the marine and tidal zone are numerous beach ridges. The northern most margin of the coast, particularly around Brace Point has undergone some noticeable coastal erosion.

4. Groundwater

Melissa Woltmann and Des Yin Foo, Water Resources Division

The groundwater assessment focused on elucidation of an aquifer in the Van Diemen Sandstone. Investigations were also undertaken to establish the presence and potential of an aquifer at depth in the Moonkinu Sandstone Member of the Bathurst Island Formation.

The location of bore data used to undertake this assessment is presented below in Figure 4-1.

The aims of the groundwater investigation was to:

1. Identify the local hydrogeological environment and map aquifer continuity and thickness across the area to provide indicative information regarding potential bore yields and production bore viability,
2. Hydraulically characterise the aquifer to provide an analytical basis for the modelling and prediction of groundwater flow regimes and impact under potential future development scenarios,
3. Establish a strategic groundwater monitoring network to capture baseline data so as to develop an understanding of the local recharge and discharge processes and quantify the resources, and;
4. Identify potential management issues under development such as water quality and groundwater dependent ecosystems.

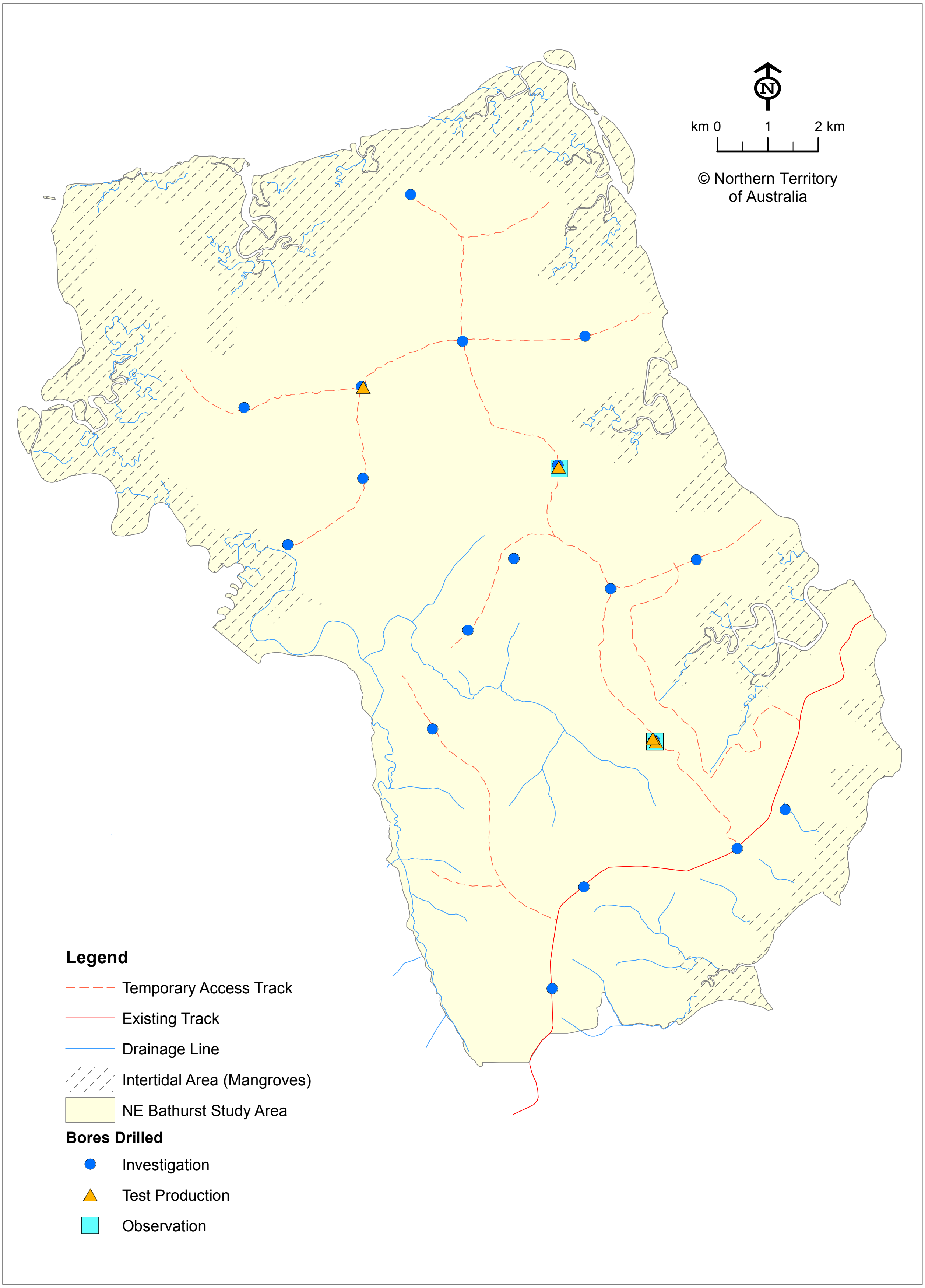

Figure 4-1: Location of bores across the study area

4.1 Methodology

The methodology undertaken consisted of the following:

- Desktop review of existing data and reports
- Investigation drilling and test bore construction
- Geological and geophysical downhole logging and interpretation
- Test pumping of bores to establish aquifer parameters
- Establishment of an ongoing groundwater monitoring program

Previous work undertaken in assessing groundwater resources on Bathurst Island and Melville Island (Yin Foo, 1992; Chin, 1993; Moser, 1994 and Haig, 2003) have largely focused on resources for community water supply and provide background detail and reference for the work undertaken during this project.

Figure 4-2:
Water Resources drilling operation on Bathurst Island

The groundwater field investigation program (Figure 4-2) was undertaken from July to November 2014. Eighteen investigation bores were strategically drilled across the study area providing information regarding spatial variability in strata as well as establishing aquifer extent and continuity. A further four test production bores and two observation bores were drilled to provide information to hydraulically characterise the aquifer. The location of these is presented in Figure 4-1. An airlift yield and field electrical conductivity and pH were obtained for each bore.

Lithology was logged from drill chips at 3 m composite sample intervals. Natural gamma downhole logs were run for most bores. These two data sets were used for lateral correlation of strata and identify optimal screening depths during bore construction. This information provided the definitive basis on which to develop a conceptual model of aquifer thickness and spatial variation of depth across the study area.

Test pumping was undertaken on three bores, RN038713, RN038714 and RN038198, all targeting the shallow aquifer. Testing at the three sites consisted of a multi-rate test of three steps and a 24 hour constant discharge rate test. Time-series drawdown data were collected in nearby observation bores during test pumping with subsequent analysis yielding indicative aquifer parameters. One bore, RN038841, was constructed to test the deep aquifer. As the airlift yield was only 0.1 L/s, it was deemed unsuitable for testing.

In addition to several rounds of manual (snapshot) standing water level readings taken during the field program, continuous monitoring of groundwater water levels is currently taking place via the installation of automated downhole water level loggers in 10 bores capturing readings twice daily. This data will be collected for analysis at the end of the wet season or when the study area is again accessible. It will be used to inform seasonal behavioural pattern as well as provide data for calculations on recharge, discharge and groundwater flow.

4.2 Assessment

4.2.1 Hydrogeological setting

There are two known aquifers within the study area. These are a shallow unconfined aquifer and a deeper confined aquifer. The shallow unconfined aquifer is hosted in the sand, quartz gravel and clays of the upper and lower units of the Van Diemen sandstone. This aquifer is extensive across the study area with a saturated thickness between 23 to 67 m, thickening to the north. The electrical conductivity of the groundwater in the shallow aquifer was generally less than 50 us/cm and slightly acidic.

The aquifer abuts the coast except to the south of the study area. Access to the coastal fringe has limited groundwater investigations in these areas. The regime of this coastal aquifer typology will have a sharp freshwater-saltwater interface directly beneath or inland of the coastal area. Past storm surge events or inundations of the low lying coastal fringe will result in the existence of a saltwater 'wedge' encroaching inland. Consequently, groundwater extraction near the coast has the potential to induce an upconing regime of saltwater movement and a groundwater management strategy would be necessary to preclude the possibility of saltwater contamination.

The deeper confined aquifer is hosted in a zone of glauconitic very fine sandy inter-beds within the dark grey mud of the Moonkinu sandstone. This aquifer has indicated to be productive in an area south of the study area however, the bores targeting this aquifer during this investigation have indicated only a low yield potential. As a result, it only warranted a limited study during this investigation. Assessment of the deeper aquifer is therefore limited to the confirmation of its extent across the study area and information regarding its potential as a low yielding aquifer. The top of the confined aquifer is subtle, presenting as very fine sand within the grey mud with a slight green tinge. The depth to the top of the deep aquifer was approximately 70 - 85 m below ground level with a 20 - 50 m thickness of grey mud and clay overlying this sand unit. The sand is clearly identified in the gamma logs by a sharp reduction of gamma radiation. However, the aquifer thickness is not well understood as tests have not been conducted over this entire interval. Due to low yields, suitably representative water samples could not be obtained for quality analysis but bores RN038718 and RN038440 will be sampled in 2015 when a monitoring team returns to retrieve logger data.

4.2.2 Hydraulic characterisation

4.2.2.1 Shallow aquifer

The lithological stratification of clay, sand and gravels create zones of varying transmissivity (a measure of permeability) within the shallow aquifer vertical profile. The zones of most water bearing potential within the saturated zone of the shallow aquifer exist within the upper medium coarse sandstone, the middle clayey fine sandy quartz gravels and the lower very fine sandy clays.

Test pumping of the shallow aquifer confirmed that the clayey to sandy stratification has significant influence on the aquifer's response to pumping, exhibiting delayed drainage effects. The sandy strata are indicated to be generally of low transmissivity. Potential bore yields across the study area are highly dependent on bore construction, aquifer thickness and the screened thickness of the aquifer. Therefore, individual bore yields potentially increase as the basement deepens towards the north and the saturated thickness of aquifer approaches 70 m. The potential yield of appropriately constructed bores in the northern deepest aquifer extent is anticipated to be a maximum of 20 L/s.

4.2.2.2 Deep aquifer

The deep aquifer was assessed as having only limited potential and therefore will not be addressed as a potential groundwater source within the context of this investigation. This is based on three bores drilled into this aquifer which produced yields in the order of 0.1 L/s.

4.2.3 Groundwater flow, recharge and discharge processes

Recharge to the unconfined shallow aquifer occurs through direct infiltration of rainfall during the wet season. Over the dry season, groundwater from the unconfined system drains laterally to perennial springs and creeks in the coastal area. Groundwater level monitoring data for at least one entire seasonal cycle (i.e. wet season and dry season) is required to quantify aquifer response in terms of recharge, and discharge processes.

A broad estimate of total annual recharge to the system provided in Gray and Paiva (2010) is 72 000 ML. The data provided by the surface water and groundwater investigation project thus far supports an estimate of recharge in this order of magnitude. The investigation awaits end of wet season groundwater data in terms of seasonal rise. It is expected though that the water table rise will be 2 to 3 m. This would equate to recharge of 50 000 to 75 000 ML.

Groundwater level data suggests the shallow aquifer flow regime mirrors topography. Water flows from high plateau areas to breaks in slope where springs have incised into the plateau draining to depressions and swamps and eventually into the intertidal zone. Diffuse discharge to the coastal fringe zone also occurs to maintain the saltwater interface within this area in equilibrium with tidal movements.

The hydraulic head potential is at its greatest in the south-west of the study area where the shallow aquifer is at its thinnest, but change in plateau surface elevation is at its greatest. This is reflected in spring discharge flows of 100 - 400 L/s in Bullabolla Creek. In the east and to the north, the change in elevation is much gentler and aquifer thickness increases to the north. Lateral flows in these areas result in spring flows less than 50 L/s.

The Groundwater Dependent Ecosystems (GDEs) are implicitly defined where perennial streams, waterholes, springs or seeps exist with thick vegetation. These landscapes are described in *Section 6. Land resources.* It would be warranted that further investigation is undertaken to determine the minimum environmental water requirements of these systems, particularly for the aquatic ecology, should developments proceed. With regard to water usage by monsoon vine forests and other vegetation communities in the spring areas, an estimate may be made based on areal coverage and applying an evapotranspiration rate of 650 mm/annum (Liddle, 2008) from such areas.

4.2.4 Groundwater monitoring

Continuous data logging systems have been installed into 10 bores to capture time series data of groundwater levels over the 2014-15 wet season and commencement of the 2015 dry season. These are also planned for height reference survey by the Groundwater Monitoring Group. The spatial distribution of the monitoring bore network provides broad detail of the groundwater regime across the study area. Additionally, a number of bores located near the coastal area have been constructed to enable groundwater sampling to be undertaken in anticipation of future development.

4.3 Potential

4.3.1 Groundwater availability

An estimate of the maximum bore yield potential from the shallow aquifer has been made using specific capacity, which relates saturated aquifer thickness and drawdown to potential discharge rate. A map of estimated maximum bore yield potential is presented in Figure 4-3. The areas excluded from the estimate of bore yield potential are low lying areas (less than 10 m above mean sea level) which are considered highly likely to have been inundated in the past by extreme tide and storm surge. Any groundwater pumping would be susceptible to saline intrusion as an interface or even a diffuse mixing zone will be present at depth in this area.

4.3.2 Production bore design

Production bore design and construction will need to incorporate measures to eliminate sand ingression problems and corrosion due to the acidic nature of the groundwater. Proven measures undertaken for bores in the Van Diemen Sandstone on the island (Yin Foo, 1992) are proposed to be adopted for similar production.

The Van Diemen Sandstone consists of highly friable sandstone, and is readily de-stabilised by any aggressive drilling actions; therefore the following is recommended.

- Use of light polymer drilling fluid adequate to transport drill cuttings to the surface. Mud invasion is not considered problematic. However, it reduces the need to break down the wall cake on the bore face which will disturb the formation.
- Use of a formation stabiliser in the construction. A maximum of 75 mm thickness is recommended as bore development will be problematic with increased thickness.
- Bore development through pumping is recommended. Aggressive bore development methods such as airlift and surging may destabilise the friable sandstone formation.
- The installation of a positive displacement pump to reduce any back-flushing effect and
- The use of inert casing material, such as stainless steel, to negate the corrosive effect of the weakly acidic environment.

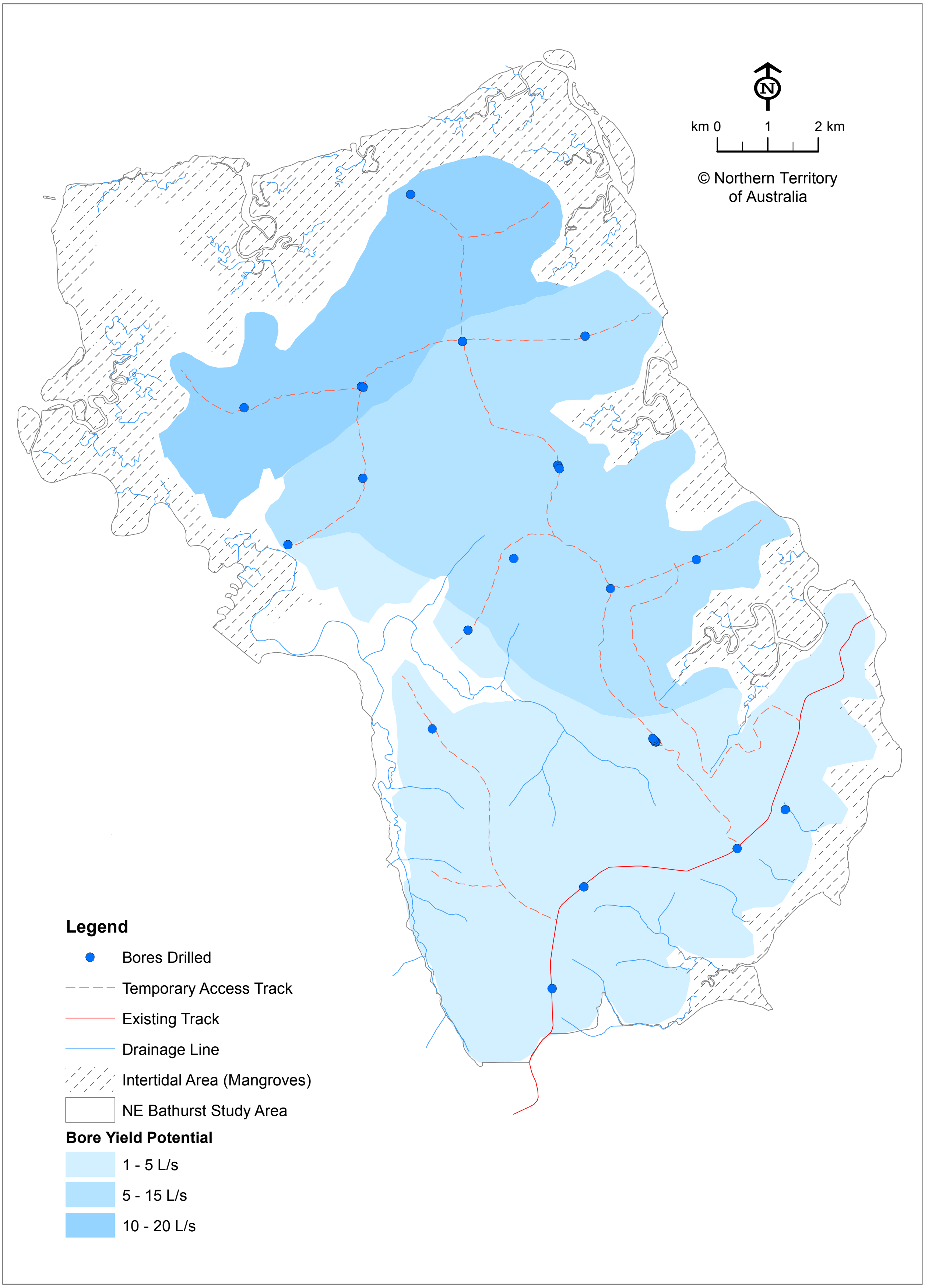

Figure 4-3: Estimated Maximum Bore Yield Potential

4.3.3 Groundwater management

Any exploitation of groundwater resources must be cognisant of the associated risks.

Low lying areas are considered to be susceptible to saline intrusion because as these areas will most likely have been inundated by storm surge or extreme high tide events in the past. A freshwater-saltwater interface will be underlying these areas and inland movement of the 'wedge' or upconing effects will occur once hydraulic equilibrium is disturbed. Therefore, any groundwater extraction regime in proximity to the coast, where the dry season standing water level is less than 5 m AHD could potentially induce saline intrusion. Appropriate monitoring and strategic management measures will need to be developed to manage this issue.

The lack of seasonal water level data precludes the groundwater recharge for the system to be calculated with any precision. However, it is estimated to be in the range of 50 000 to 75 000 ML/annum. This evaluation is essential for managing long term sustainability of the groundwater resource for all beneficial uses.

It is recognised that the aquatic and spring discharge ecosystems are dependent on perennial groundwater flow. In areas of proposed development, it is important that GDEs be identified where groundwater extraction may impact on either the quality or quantity of discharge to the springs' areas.

A groundwater monitoring network has been established to inform of the natural groundwater flow regime. Groundwater sampling are established in the proximity to the coast where saline intrusion can be detected. Specific monitoring strategies will need to be devised should any future development proceed, as well as the establishment of monitoring networks.

5. Surface water

Ursula Zaar and Lakshman Rajaratnam, Water Resources Division

The aims of the surface water investigation program were to:

1. Identify the surface water resources, and develop an understanding of the local catchments and streamflow,
2. Locate potential development sites and quantify the available resources,
3. Assess the feasibility of water harvesting methods, and;
4. Identify any ongoing strategic surface water monitoring requirements.

5.1 Methodology

Initially, all relevant information from past studies, surface water data and anecdotal evidence of flooding and water use was collated. The second step was to undertake an assessment of recorded data from similar nearby catchments.

The initial findings from the existing data indicated that there was no specific surface water data available in the study area to evaluate the surface water potential. However, recorded water data from a similar catchment was available at Bluewater Creek, within close proximity to Pirlangimpi on Melville Island.

New data was acquired through an investigation phase. Field investigations were undertaken to measure the dry season flows in streams over the 2014 dry season with an aim of identifying creeks with appreciable flows suited to development (Figure 5-1).

Using the measured flows, the minimum flows in the dry season were calculated. The historical records from Bluewater Creek were used as a surrogate to estimate flow variability, baseflow and rainfall runoff quantities by appropriate scaling at sites of interest. Average monthly flows and flow volumes were calculated (Figure 5-2).

Figure 5-1: Stream gauging

Figure 5-2: Surface water investigation areas

5.2 Assessment

5.2.1 Hydrological setting

The closest rainfall station to the study area is situated at Pirlangimpi Airport (Bureau of Meteorology site DR014142) shown in Figure 5-2. The closest historical river record is also located near Pirlangimpi at DLRM site G8160001 on Bluewater Creek also known as Lamberts River.

Figure 5-3 demostrates how recorded rainfall and river flows vary over the years. No data or recordings indicates the data for those years are incomplete.

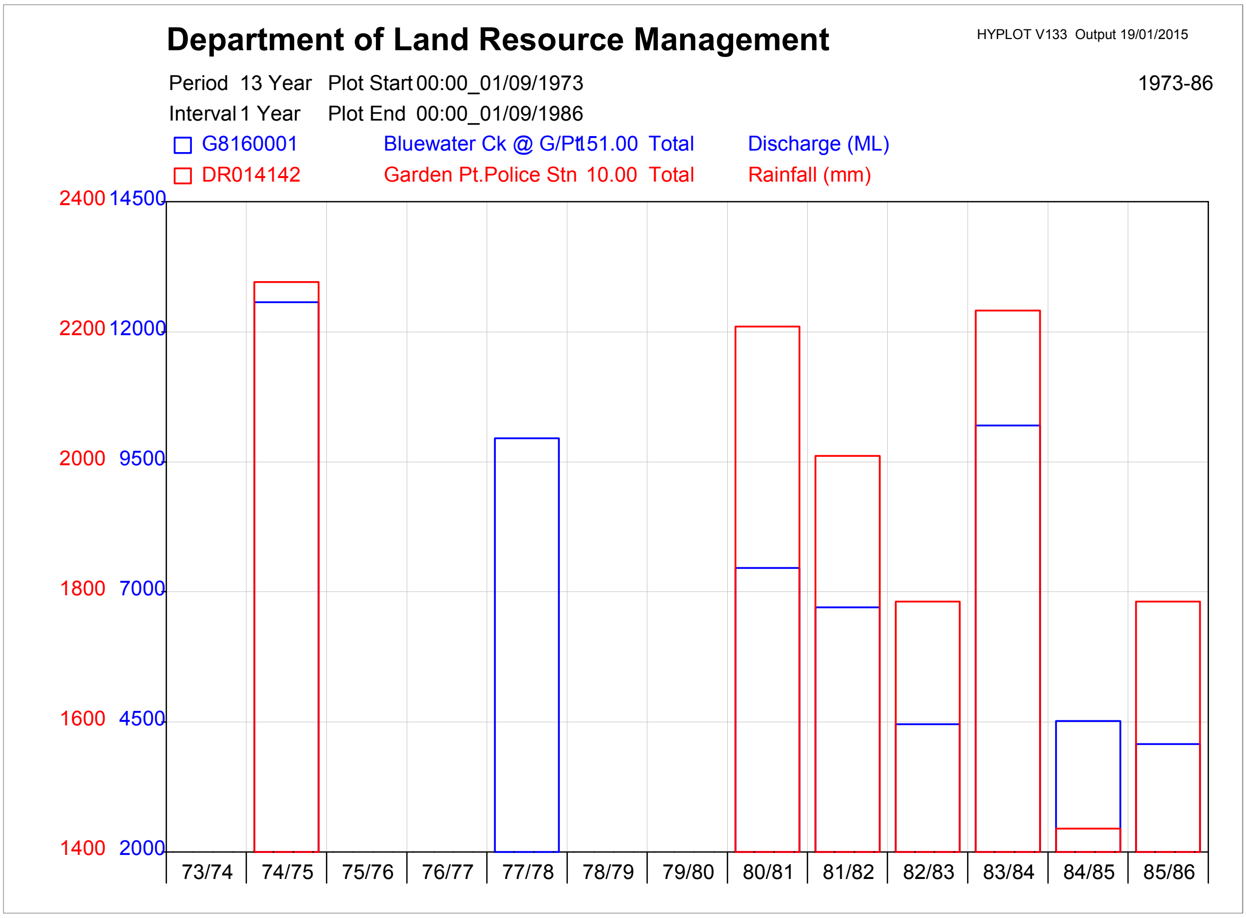

Figure 5-3: Total water year rainfall (September - August) and mean annual flow at G8160001. Unrectified data has been obtained directly from the Water Resources database.

Note: DR014142 is now situated at Pirlangimpi Airport. It was previously located at Garden Pt. Police Station

When examining surface water occurrence, it is important to distinguish between the two sources, rainfall and rainfall runoff, or groundwater discharge. The Top End has a characteristic long dry season so it is groundwater discharge which provides the baseflow to many rivers in the Top End, including those on Bathurst Island. Groundwater discharge maintains a flow throughout the year, as represented in Figure 5-4.

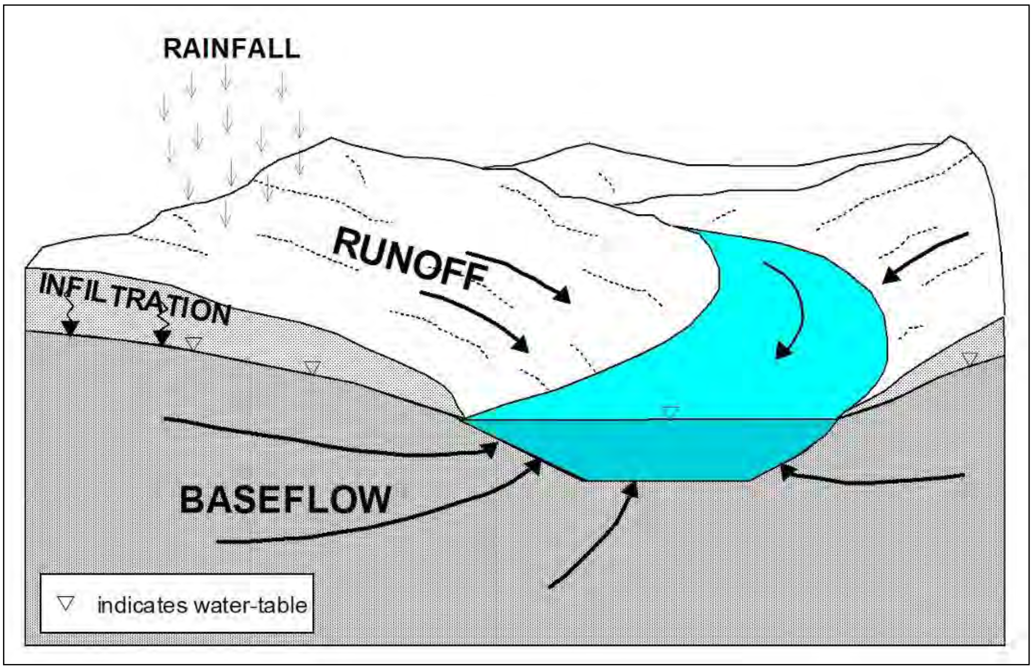

Figure 5-4: Runoff and baseflow components of surface water

Surface water derived only from wet season rainfall and runoff will only persist if storage is adequate to last through the dry season. Storage can include waterholes, lakes and dams that are deep enough to account for the high evaporation rate during an extended dry season.

Figure 5-5 depicts the hydrograph for Bluewater Creek in 1984. Discharge is represented in m^3/s as well as ML/day. The record spans approximately 15 years. The two components of baseflow and runoff are readily distinguishable. The baseflow component of flow slowly diminishes as the dry season progresses (May to October). This is because less groundwater discharges to the river as the water table declines.

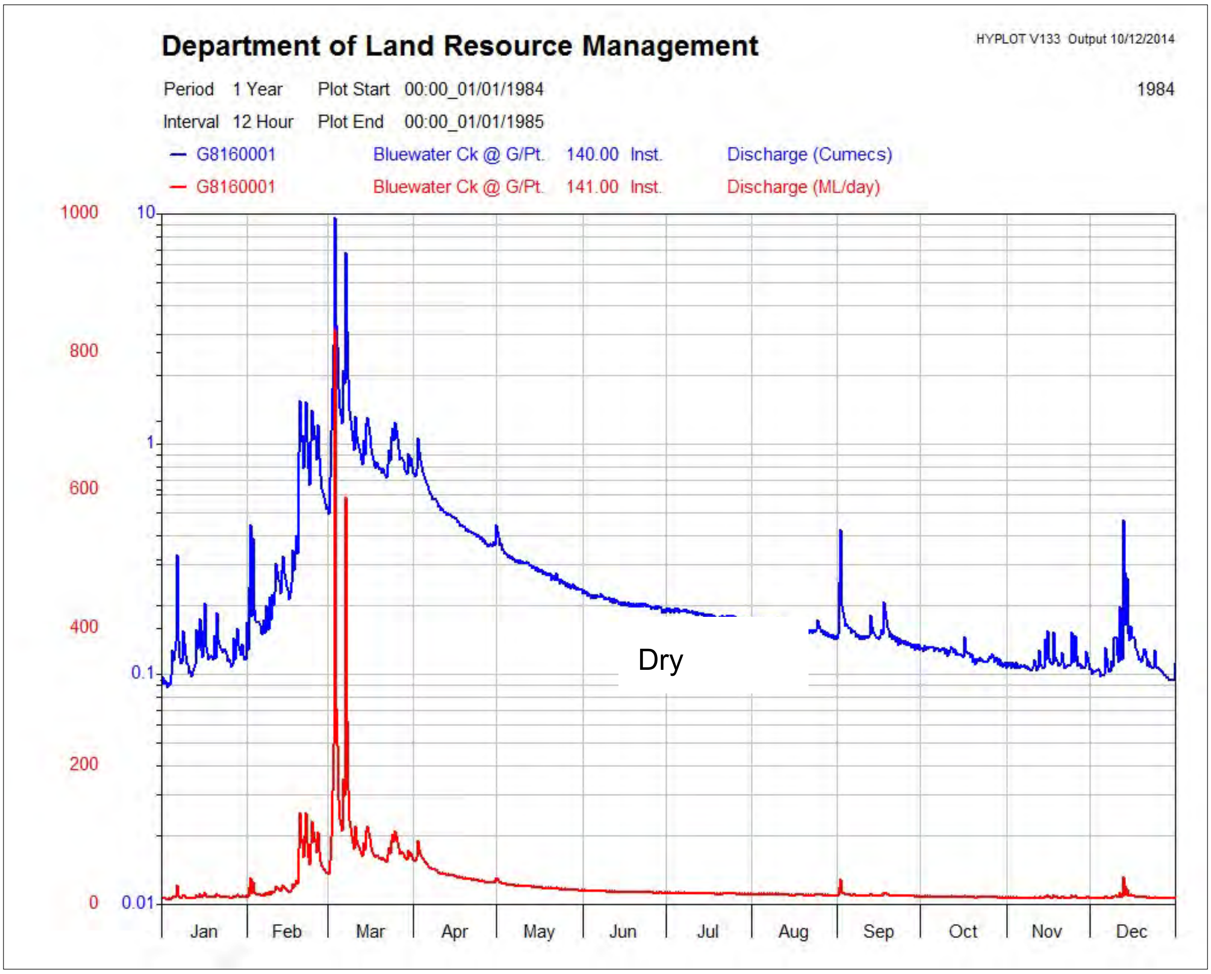

Figure 5-5: Discharge hydrograph for Bluewater Creek, Site G8160001 for 1984

5.2.1.1 Spring types

Groundwater discharges via depression and contact springs were observed in the study area (Figures 5-6 and 5-7). These springs were often associated with riparian vegetation.

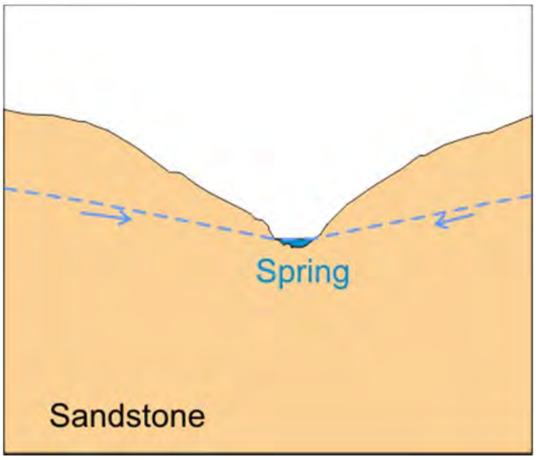

Figure 5-6: Depression spring

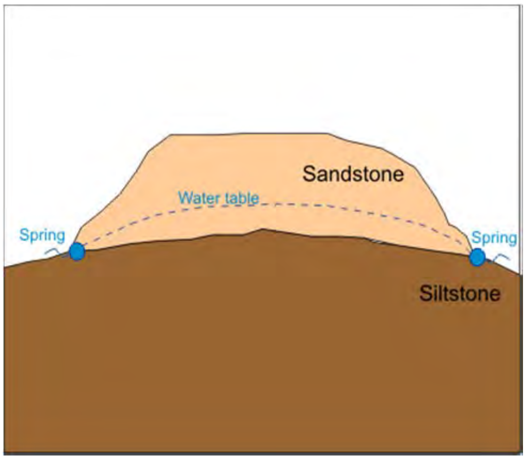

Figure 5-7: Contact spring

Depression springs result when the water table is intersected by a low point in the landscape, such as a valley or creek bed, allowing drainage to occur from the surrounding rock, such as sandstone.

Contact springs arise when a more permeable rock such as sandstone, lay above a less permeable rock such as siltstone, mudstone or clay. This is the case in the study area. Water stored in the upper layer seeps out at the contact between the two rock types because it is unable to penetrate into the lower layer. The seepage zone, as shown in Figure 5-8, is well defined, having particular landform patterns and vegetation which is obvious high resolution satellite imagery.

Figure 5-8: Satellite imagery showing seepage zones on Bullabolla Creek

5.2.2 Surface water investigations

5.2.2.1 Lakes

No perennial freshwater lakes were identified in the study area. In the north of the study area there is an intermittent lake/swamp which held water in June but by October 2014 was completely dry (Figure 5-9). Flood marks on trees in the centre of the swamp show that flood levels reached 1.7 m, with the regular flood level at about 1.6 m.

Figure 5-9: Intermittent lake

5.2.2.2 Pools in creeks - within the Dudwell Creek system

Two major tributaries of Dudwell Creek are evident. One is Bullabolla Creek (Figure 5-2), which marks the south western boundary of the study area and the other is referred to as the eastern arm of Dudwell Creek and lies centrally within the study area. Bullabolla Creek is a straight river and its tributaries are short. Table 5-2 shows how channel characteristics change with straight line distances along the river. Depth and width were determined from flow measurements made in October 2014 at the locations shown in Figure 5-2 and relate to the water depth at the time.

Table 5-2: Characteristics of Dudwell Creek and its tributaries from flow measurements in October 2014

Location	Straight line distance from head of stream (km)	Maximum depth (m)	Width (m)	Flow (L/s)
Bullabolla Creek				
G816A	0.65	0.34	1.3	31
G816B	1.35	0.5	1.85	130
G816C	2.25	0.63	2.4	257
G8160017	4.15	0.67	4.8	344
G816D	6.15	1.3	7.5	394
Eastern Arm				
G8160018	2	0.35	1.93	87

Table 5-2 indicates the depth of Bullabolla Creek increases downstream. At a distance of 6.15 km there is a notable change in depth. From field inspection it was observed that from this point onwards downstream, the depth was about 2 m, and width remained around 8 m for a distance of over 1 km. This was the largest permanent pool encountered during the field survey and would be a suitable location for pumping. Aerial imagery indicated that three pools exist in the lower reaches of Bullabolla Creek and the eastern Arm of Dudwell Creek (Figures 5-10 and 5-11).

Figure 5-10: Pool 1 on Bullabolla Creek

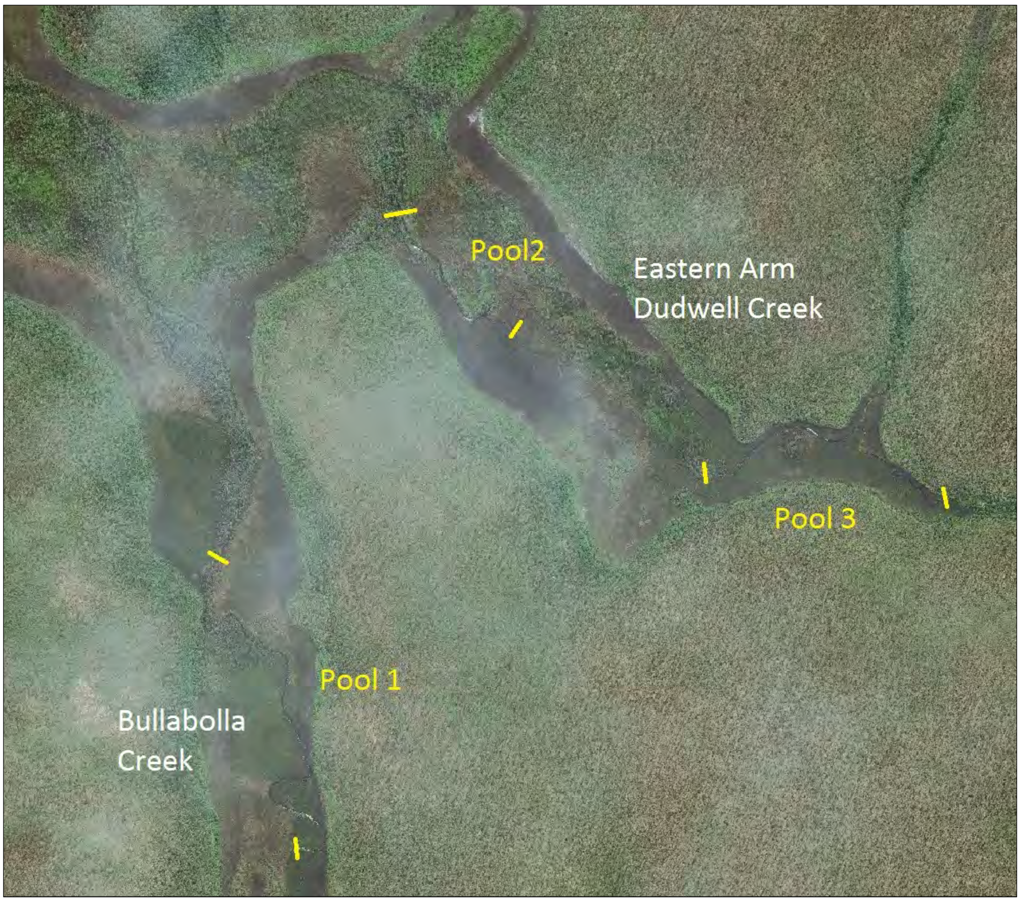

Figure 5-11: Large pools along the Dudwell Creek system

5.2.2.3 Pools in creeks - outside the Dudwell Creek system

Aside from the tributaries of Dudwell Creek no significant river pools in other creeks have been identified. These creeks have small catchments of less than 6 km^2 with late dry season baseflows generally below 100 L/s, with most below 30 L/s. The 2014 dry season flow measurements show that these creeks have a water depth up to 0.5 m and a width up to 2.5 m.

5.2.3 Surface water analysis

5.2.3.1 Baseflow in significant streams

Over the 2014 dry season, eleven surface water sites, (nine were within the study area), were established where regular field measurements could be undertaken. This data is presented in Appendix 1. The baseflows measured at these nine sites are provided in Table 5.3. The table indicates three significant dry season discharges. These were Bullabolla Creek, the eastern arm of Dudwell Creek and the Creek located near Yankilowu in the south east of the study area. The respective gauging locations (Figure 5-2) are G8160017, G8160018 and G8165051.

To obtain an estimate of total baseflow for each of these catchments, field discharge measurements were related to the catchment area.

Bullabolla Creek

Table 5-3 shows the field discharge measurements along Bullabolla Creek collected in October 2014. The approximate catchment area for each site was calculated from a 1 second SRTM DEM (Digital Elevation Model). A plot of the data is provided in Figure 5-12 and a curve fitted.

Table 5-3: Area calculations and discharge measurements on Bullabolla Creek, October 2014.

Location	Area km^2	Discharge m^3/s	Discharge L/s
G816A	2.91	0.031	31
G816B	8.72	0.13	130
G816C	10.78	0.257	257
G8160017	15.49	0.344/0.358	344/358
G816D	22.50	0.394	394

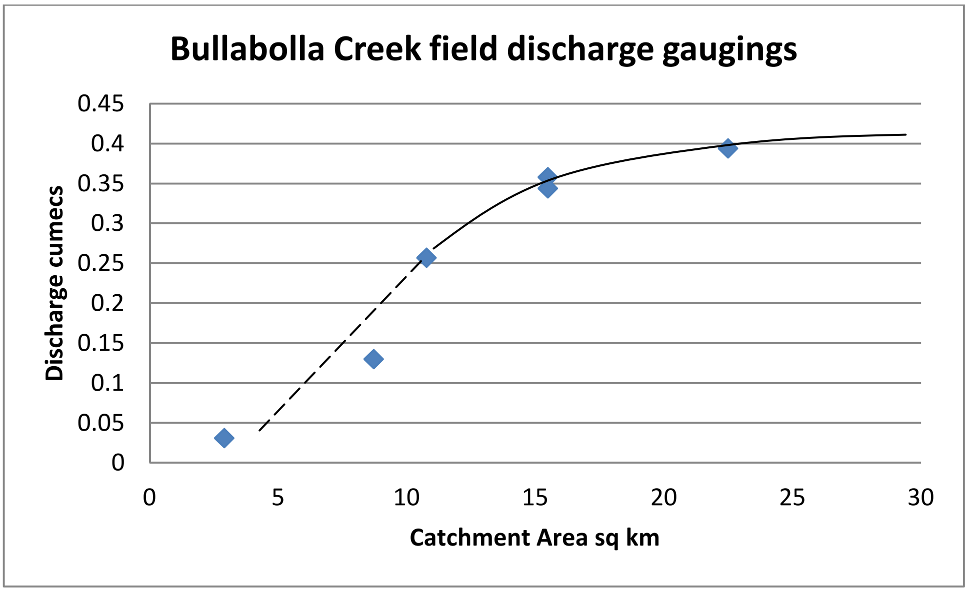

Figure 5-12: Plot of catchment area versus discharge along Bullabolla Creek, October 2014

The catchment area of Bullabolla Creek has been calculated at 25.7 km^2. The corresponding discharge in October 2014 was approximately 0.41 m^3/s.

Eastern Arm of Dudwell Creek

Table 5-4 shows the field discharge measurements on the Eastern Arm of Dudwell Creek and tributaries in October 2014. The catchment areas were calculated and a plot with line of best fit and is provided in Figure 5-13. Unlike Bullabolla Creek, which has a tapering catchment area towards the mouth, the Eastern Arm of Dudwell Creek remains quite broad along its length and it would be reasonable to estimate the relationship between discharge and area as linear. This allows calculation of the approximate discharge at the confluence with Bullabolla Creek. Here, the catchment area is 33 km^2 resulting in discharge of 0.234 m^3/s.

Table 5-4: Area calculations and discharge measurements on Eastern Arm Dudwell Creek, October 2014.

Location	Area (km^2)	Discharge (m^3/s)	Discharge (L/s)
G8160020 (Tributary)	2.42	0.0186	18.6
G8160019 (Tributary)	4.79	0.035	35
G816G (Upstream G8160018)	6.32	0.0545	54.4
G8160018	11.98	0.087	87

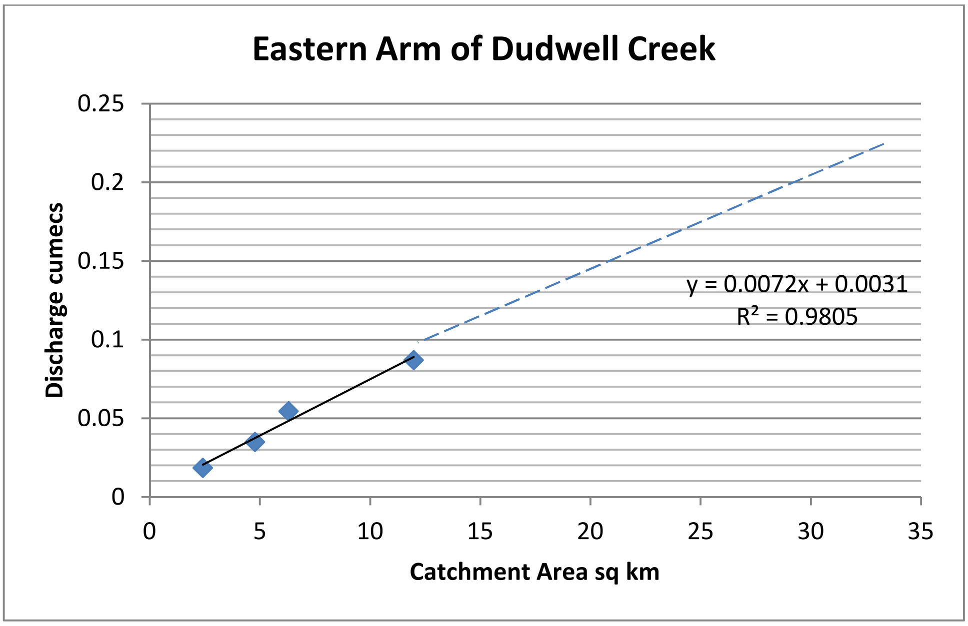

Figure 5-13: Plot of catchment area versus discharge along the Eastern Arm of Dudwell Creek, October 2014

Creek near Yankilowu

The location of this gauge site was found to be influenced by the tide. Therefore, flow measurements were taken upstream of the tidal influence. The flow gauging measured in October 2014 was 81 L/s. These provided a discharge estimate for the catchment.

Catchment discharge from significant streams

The total approximate catchment discharges from the significant streams in October 2014 is provided in Table 5-5. From flow duration analysis calculated later in this section it is estimated that river flows were somewhat below average in 2014.

Table 5-5: Total catchment discharges, October 2014

Catchment	Area (km^2)	Total Discharge, Oct 2014 (m^3/s)	Total Discharge, Oct 2014 (L/s)
Bullabolla Creek	25.7	0.41	410
Eastern Arm Dudwell Creek	33	0.234	234
Creek near Yankilowu	3.26	0.081	81

5.2.3.2 Recession analysis

A recession refers to the declining baseflow over a dry season. Flow measurements from the 11 gauge sites (Table 5-6) are plotted in Figure 5-14 on a log-linear scale. Also shown are the flow measurements undertaken in 1985 for G8160001 Bluewater Creek, located on Melville Island directly east of the study area. As there are no historical gauge sites with a continuous height record within the study area, G8160001 has been adopted to provide a point of reference.

Bluewater Creek lies in a similar geological environment to that of the study area and it possesses similar characteristics to catchments within the study area. As G8160001 has been closed since 2002, the recession gaugings from 1985 are represented in Table 5-6 and Figure 5-14.

During the October field survey a few isolated storms were experienced in the study area. Hence, the flows measured in October in a number of the gauge sites may have been influenced by these early rain events. The continuous height record at Bluewater Creek shows that early storms can affect river flow (Figure 5-15) and that runoff occurs readily after even small rainfall events. Therefore those gauge sites with three flow measurements prior to October provide a more accurate measure of recession. These are G8160023 and G8160051. An estimated line of best fit has been plotted for these sites as well as G8160017 and G8160001. It is evident that the log of baseflow against time is a linear relationship (refer Figure 5-14).

Table 5-6: Baseflow measurements and recession analysis

Date	Flow	No. Days between	log Q	log k=(log Qt - log Q1)/no. Days	k	Comments
G8160017						
2/06/2014	0.482		-0.3170			
10/09/2014	0.345	100	-0.4622	-0.001452279	0.9967	
14/10/2014	0.358		-0.4461			Likely rain influence
23/10/2014	0.344	143	-0.4634	-0.001024396	0.9976	Calculated on first and last readings
G8160018						
12/09/2014	0.099		-1.0044			
15/10/2014	0.087	33	-1.0605	-0.001700483	0.9961	
G8160019						
13/08/2014	0.047		-1.3279			
9/09/2014	0.038	27	-1.4202	-0.003419047	0.9922	
22/10/2014	0.035		-1.4559			Likely rain influence
G8160020						
12/09/2014	0.022		-1.6576			
20/10/2014	0.0186	38	-1.7305	-0.001918677	0.9956	
G8160021						
13/08/2014	0.028		-1.5528			
9/09/2014	0.0206	27	-1.6861	-0.004936697	0.9887	
18/10/2014	0.01	39	-2.0000	-0.008047877	0.9816	
18/10/2014	0.01	66	-2.0000	-0.006775122	0.9845	Calculated on first and last readings
G8160022						
8/09/2014	0.0053		-2.2757			

Date	Flow	No. Days between	log Q	log k=(log Qt - log Q1)/no. Days	k	Comments
21/10/2014	0.0026	43	-2.5850	-0.060116899	0.8707	
G8160023						
2/06/2014	0.064		-1.1938			
12/08/2014	0.033	71	-1.4815	-0.004051634	0.9907	
8/09/2014	0.0237	27	-1.6253	-0.005324652	0.9878	
8/09/2014	0.0237	98	-1.6253	-0.004402364	0.9899	Calculated on first and third readings
21/10/2014	0.0257		-1.5901			Likely rain influence
G8165050						
14/08/2014	0.028					
10/09/2014	0.023	27	-1.6383	-0.060676747	0.8696	
16/10/2014	0.0233					Likely rain influence
G8165051						(Area= 2.95 km^2)
2/06/2014	0.128		-0.8928			
14/08/2014	0.087	73	-1.0605	-0.002297133	0.9947	
11/09/2014	0.078	28	-1.1079	-0.001693737	0.9961	
11/09/2014	0.078	101	-1.1079	-0.002129855	0.9951	Calculated on first and third readings
16/10/2014	0.0815		-1.0888			Likely rain influence
G8160001						
8/05/1985	0.142		-0.8477			
4/07/1985	0.108	57	-0.9666	-0.002085344	0.9952	
4/09/1985	0.085	62	-1.0706	-0.001677497	0.9961	
1/11/1985	0.062	58	-1.2076	-0.002362539	0.9946	
1/11/1985	0.062	177	-1.2076	-0.002033314	0.9953	Calculated on first and last readings
12/11/2014	0.089					

* k values between 0.995-0.997

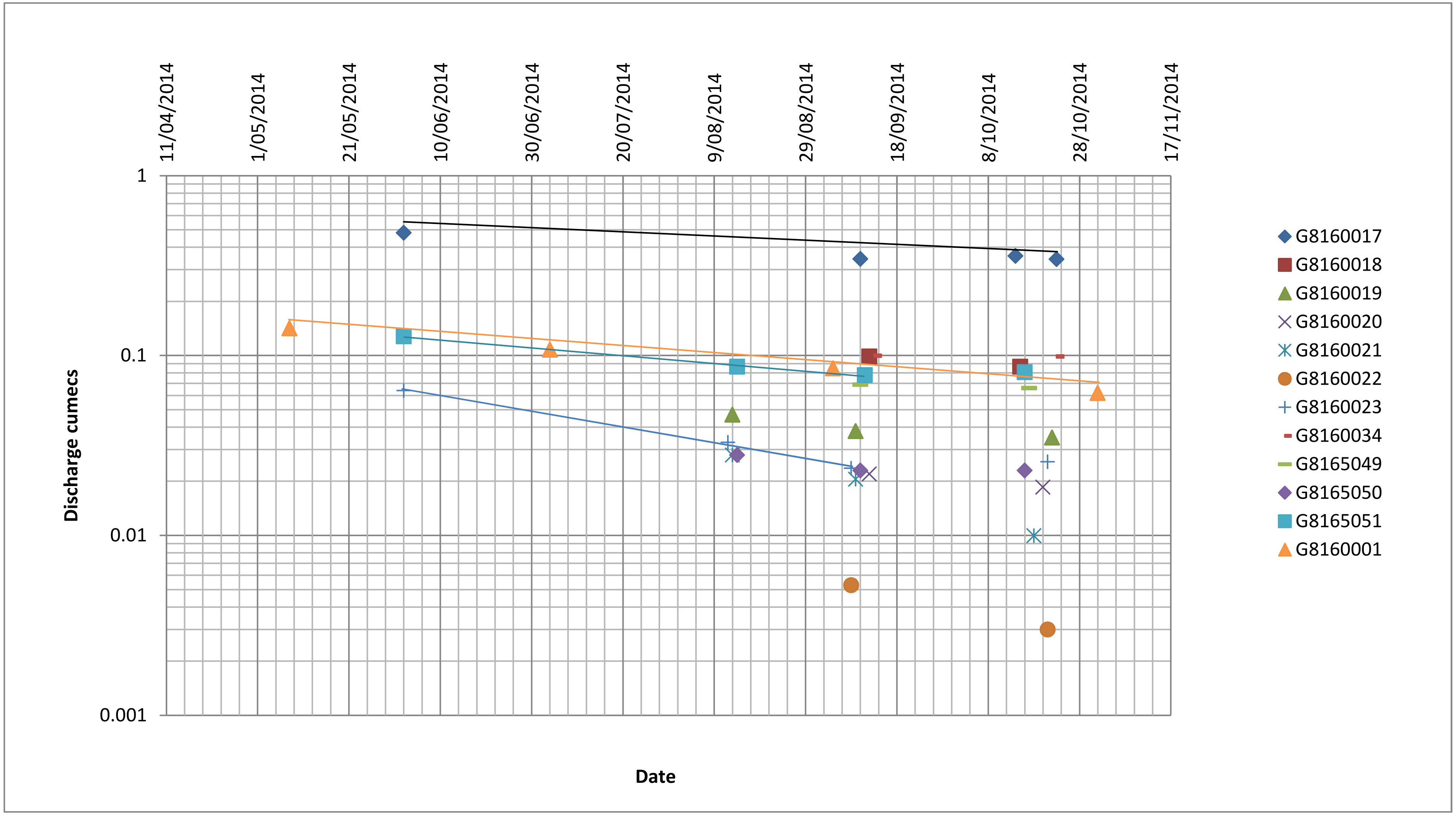

Figure 5-14: Flow gauging undertaken in 2014. 1985 flow data at G8160001is also plotted.

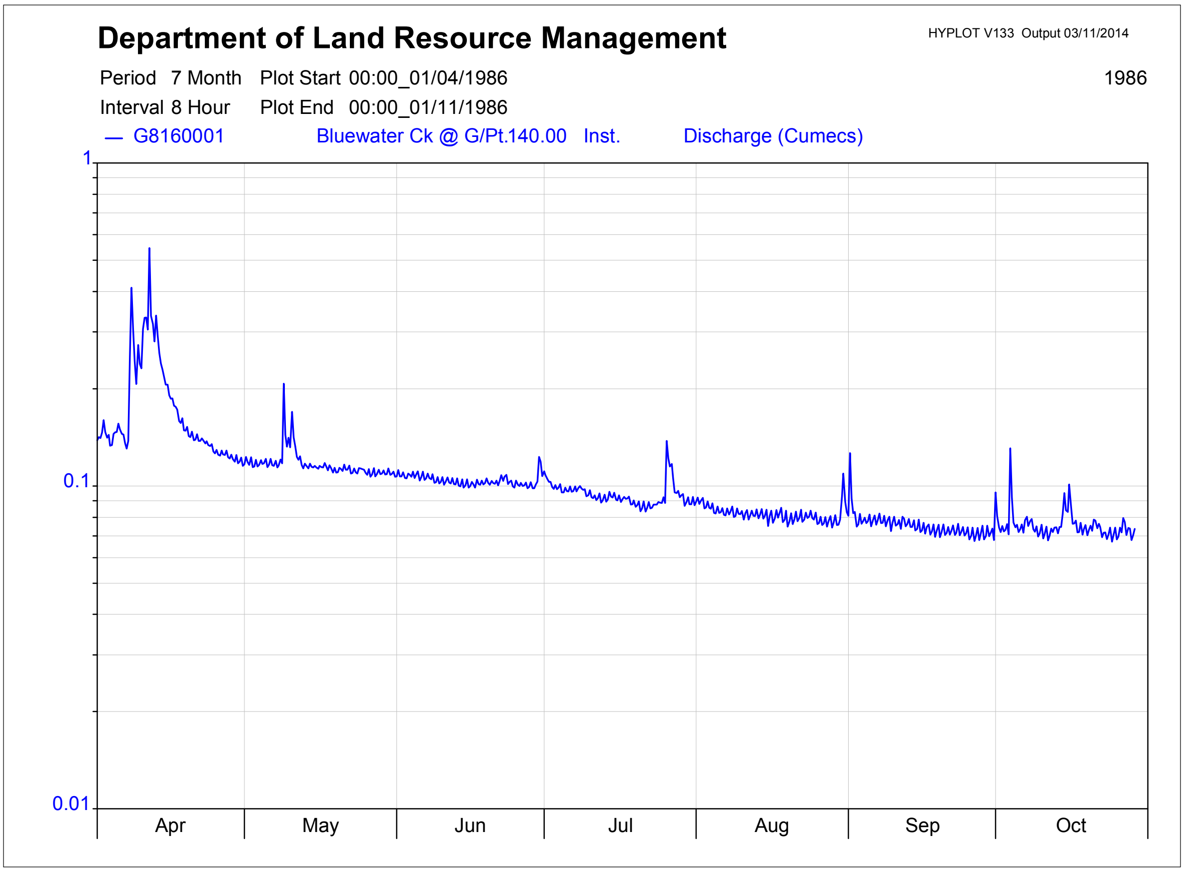

Figure 5-15: Effect of small rain events on baseflow at G8160001

The equation to the baseflow recession curve is:

$Q_t = Q_0 k^t$ where Q_t is the discharge at time t later than Q_0 and k is a recession constant.

The equation can be transposed to:

$\log k = (\log Q_t - \log Q_0)/t$ which enables k to be determined if the other parameters are known. k is the gradient of the lines shown in Figure 5.2m.

The recession constant, k, has been calculated for the catchments listed in Table 5-5. It is notable that for the catchments with higher flows, that is, for G8160017, G8160018 and G8160051, the recession constant is similar, ranging between 0.995 and 0.997 and consistent with the catchment G8160001 on Melville Island. This enables the long term record from G8160001 to be used to predict the likely flow history of the other similar catchments.

The catchment represented by G8160019 is considered as part of the above group as it has similar catchment characteristics. G8160019 is situated between the creeks of G8160020 and G8160018, has the next highest flow and its k value is close to the above range at 0.992.

The other gauge sites in the study area have lower recession flows and these all measured less than 0.025 m^3/s in October late in the dry season of 2014. Consequently, they would have limited capacity as an agricultural supply.

5.2.3.3 Minimum flows

From the site records at G8160001, the minimum measured flow of 0.062 m^3/s occurred on the 1 November 1985. On the 12 December 2014, the flow was measured at 0.089 m^3/s. Applying the recession constant k obtained in Table 5-6 and the equation to the recession curve, it is calculated that it would take a further 72 days without rain for the flow to recede to the minimum record of 0.062 m^3/s. This time frame can then be applied to other gauge sites to determine an approximation of their minimum flows (refer Table 5-7).

Table 5-7: Calculation of minimum flows

Site	Date	Q1 m3/s	k	No. Days to 12.11	Estimated discharge on 12.11	t (No. Days to min flow)	Q2 m3/s Estimated min flow
G8160001	12.11.14	0.089	0.995	0		72	0.062
G8160017	23.10.14	0.344	0.997	20	0.324	92	0.261
D/s G8160017	23.10.14	0.394	0.997	20		92	0.299
U/s G8160017 Site C	15.10.14	0.257	0.997	28		100	0.190
U/s G8160017 Site B	15.10.14	0.13	0.997	28		100	0.096
Bullabolla Ck at confluence with Dudwell Ck, Eastern Arm.	15.10.14	0.410	0.997	28	0.377	100	0.304
G8160018	15.10.14	0.087	0.996	28	0.078	100	0.058
G8165051	11.9.14	0.078	0.995	62	0.057	134	0.040
Dudwell Ck, Eastern Arm at confluence with Bullabolla Ck.	15.10.14	0.234	0.996	28		100	0.157
Example	23.10.14	0.025	0.996	20	0.023	92	0.017

The combined minimum flow from Bullabolla Creek and the Eastern Arm of Dudwell Creek at the confluence is hence estimated at 0.461 m^3/s. To provide an overview of water availability, rivers have been plotted according to their minimum flow in Figure 5-2, thereby reflecting the environment at its driest. The minimum perennial flow categories used are < 50 L/s, 50 to 100 L/s and > 100 L/s.

5.2.3.4 Catchment water balance modelling

In order to extend the streamflow record at G8160001 from 1972 to 2014, the Australian Water Balance Model (AWBM) (Boughton, 2010) was applied. This water balance model uses recorded catchment runoff obtained from G8160001, evaporation and daily rainfall (Patched point data (DSITIA *et al.)* from the BOM site at Pirlangimpi Airport 14142) to calculate runoff. There is a continuous height record for G8160001 with a number of data gaps from October 1972 to October 1986 with an additional period between June 2001 and October 2002. The model was calibrated using the most cohesive record from 1974 to 1986, filling in some gaps and excluding 1978 and 1979. A reasonable data fit of monthly runoff was obtained between the recorded and calculated values. The R-squared value was 0.814. It was noted that the calculated baseflow was lower than the recorded in a number of years (Figure 5-16).

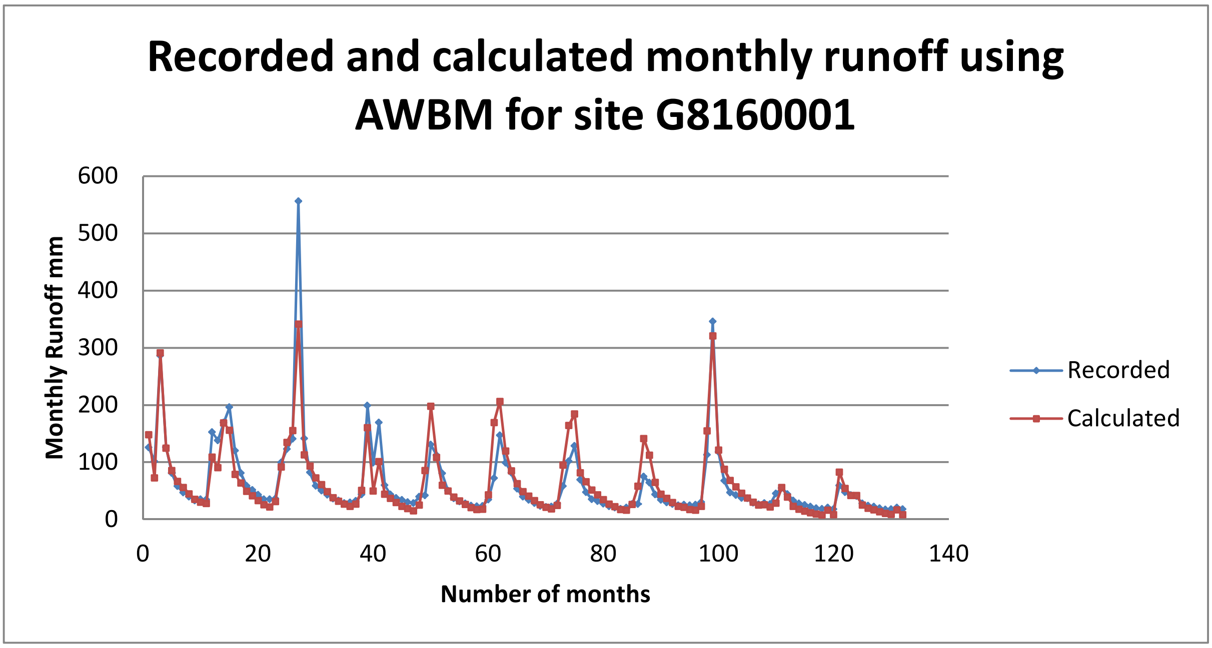

Figure 5-16: Recorded and AWBM modelled monthly runoff at G8160001

Using the calibrated parameters the model was then run for a period from 1972 to 2014. For 1978 and 1979, the two years not used in calibrating the model, the model showed to have a poor fit. In these two years, as well as 1985, 1986, 2001 and 2002, the model calculated significantly lower recession flows than recorded. These are shown in Figure 5-17. The late dry is generally the critical period for agricultural water demand due to high temperatures and time since last rainfall. It is also in the late dry that baseflow is at its lowest which limits supply. It is essential that the model has a good fit on recession flows, so it was decided that the model should not be used in this instance and the recorded data simply used as a guide for long term characteristics of the stream for the flow duration analysis. The fifteen years of records encompasses high and low rainfall periods providing a reasonable indication of the long term flow variability at the site.

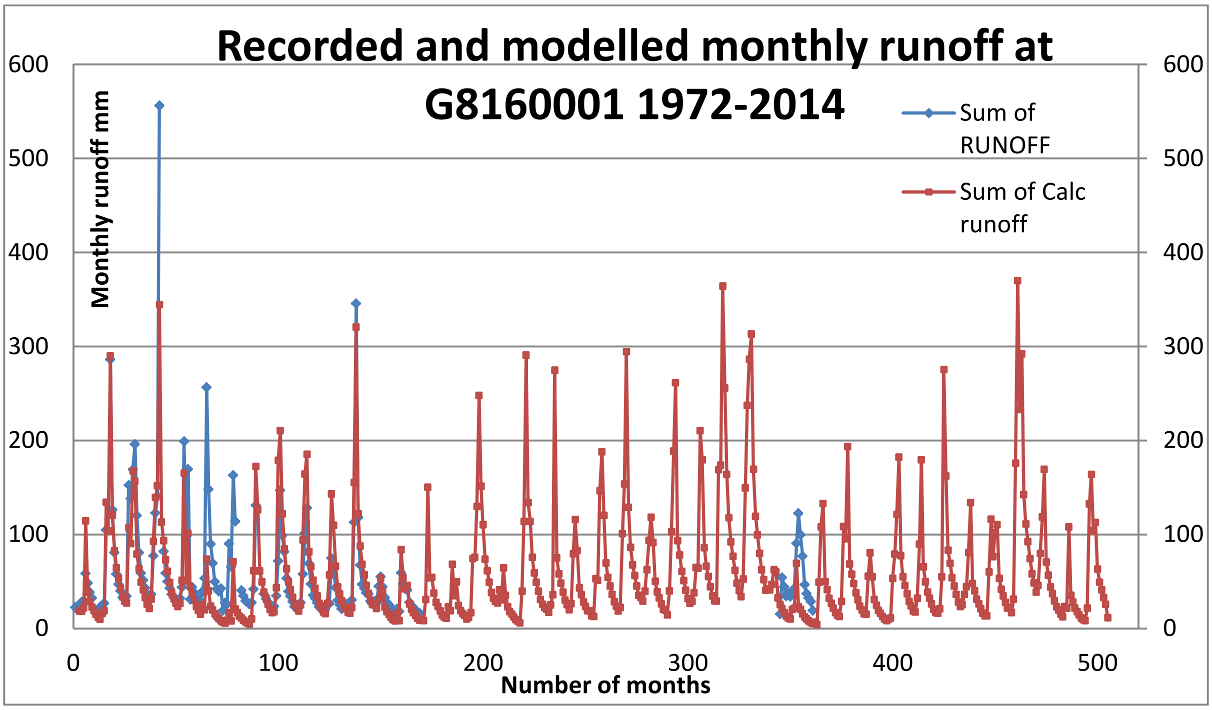

Figure 5-17: Recorded and AWBM modelled monthly runoff at G8160001

5.2.3.5 Flow duration analysis

Flow duration analysis provides information on reliability of flows. It shows the percentage of time that flow in a stream is likely to equal or exceed a specified value of interest. It can be used to show the discharge of the stream that occurs or is exceeded some percent of the time. Of particular interest is the determination of the discharge that occurs or exceeds 50% of the time, which is commonly thought of as the average. The analysis is undertaken on the record of measured streamflow. If the record is short, the record can be extended through modelling.

A flow duration analysis has been undertaken for the three catchments with dry season baseflows, Bullabolla Creek, Eastern Arm of Dudwell Creek and the catchment of G8165051. The other creeks have low baseflows in the late dry season.

To be able to apply and adapt the streamflow record from G8160001 to the North East Bathurst Island, the catchments must be hydrologically similar. The similarities are:

- Annual rainfall is similar because the study area lies only 12 km from G8160001
- Vegetation type and cover is similar
- Catchments are undeveloped and the catchment of G8160001 was largely undeveloped for the period of flow record to 1986. Since 1986 land uses in the upper catchment have changed to include forestry.
- Both areas are underlain by the Van Diemen Sandstone. The unconfined aquifer in this formation provides the baseflow to the rivers in this region
- Recession rates identified in 5.2.3.2 are similar.

G8160001 has a milder catchment slope compared with many of the catchments in northern Bathurst Island. Steeper slopes have the effect of generally increasing rainfall runoff. Average catchment elevation also varies. Catchment areas and the amount of baseflow also vary as shown in Table 5-8. Increasing catchment areas results in increasing rainfall runoff.

Table 5-8: Catchment areas and flow ratios

Site location	Catchment area km^2	Catchment area ratio to G8160001	Baseflow ratio to G8160001 on 12.11.14 (See Table 5.2f)
G8160001	11.3	1	1
G8160017	15.49	1.37	324/89=3.640
G8160018	11.98	1.06	78/89=.876
G8160019	4.79	0.42	
G8160020	2.42	0.21	
G8165051	3.26	0.29	57/89=.640

To account for the hydrological differences, the G8160001 record was applied to the three catchments in North East Bathurst Island in the following way:

I. The G8160001 streamflow record was separated into two components of baseflow and rainfall runoff through a combination of a baseflow separation program on Hydstra and recession rate extension. Two files were created of hourly instantaneous values for the available period of record.
II. Data of dubious quality was deleted.
III. For each site an hourly baseflow record was created by multiplying the new G8160001 baseflow record by the baseflow ratio in Table 5-8.
IV. For each site an hourly rainfall runoff record was created by multiplying the new G8160001 rainfall runoff record by the catchment area ratio in Table 5-8.
V. For each site an hourly instantaneous flow record was obtained by adding results from III. and IV.

For each site, now possessing a fifteen year flow record, flow duration analysis was undertaken using the Hydstra program HYFLOW. Calculations were undertaken on instantaneous hourly flow values in m^3/s. The results for the 50th percentile or average monthly flow rate in m^3/s are provided in Table 5-9. For example, for the site G8160017, the average flow rate for the month of September is 0.429 m^3/s and for the year the average is 0.523 m^3/s.

Table 5-9: Average discharge rates (m3/s). (Discharge rate which was equalled or exceeded 50% of the time).

Site location	Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
G8160001 Bluewater Ck(Lamberts R) Analysis from recorded data	0.155	0.165	0.387	0.533	0.368	0.254	0.183	0.156	0.130	0.121	0.114	0.111	0.116
G8160018 Eastern Arm Dudwell Ck Analysis from calculated data	0.139	0.152	0.366	0.516	0.344	0.227	0.163	0.137	0.115	0.107	0.101	0.100	0.106
G8165051 Creek near Yankilowu Analysis from calculated data	0.093	0.093	0.188	0.249	0.195	0.151	0.112	0.098	0.082	0.076	0.066	0.066	0.068
G8160017 Bullabolla Creek Analysis from calculated data	0.523	0.519	1.006	1.347	1.070	0.838	0.632	0.553	0.464	0.429	0.371	0.372	0.379

Table 5-10 Average total monthly volume (ML). (Total monthly volume that was equalled or exceeded 50% of the time.)

Site location	Average Monthly	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
G8160001 Analysis from recorded data	416	485	1147	1561	970	766	446	403	344	323	303	285	312
G8160018 Analysis from calculated data	374	448	1114	1521	898	679	396	357	305	284	272	258	291
G8165051 Analysis from calculated data	246	266	526	707	514	424	275	250	217	203	181	168	181
G8160017 Analysis from calculated data	1373	1479	2825	3794	2812	2307	1558	1419	1230	1155	1022	945	1015

5.3 Surface water potential

5.3.1 Surface water quantities

Given the calculated estimation of average monthly flow rates the average monthly flow volumes for the three sites have been calculated. These are presented in Table 5-10 and provide an indication of the quantity of surface water discharging through streams.

It is important to note that the information provided at sites G8160017, G8160018 and G8165051 in Tables 5-9 and 5-10 are based on correlation with G8160001 by use of one flow gauging. The results presented in these tables provide indication only. Further monitoring at these sites is required to provide further legitimacy and accuracy to the results.

Although analysis has been undertaken for the above mentioned sites, there is potentially greater surface water availability downstream of two of the sites. Downstream of site G8160017, the spot flow measured at G816D in October was 394 L/s compared with 344 L/s at G8160017. This indicates that at this site and further downstream there is a potential for a 15 % larger water supply. G816/D is located at the beginning of the pool identified in Bullabolla Creek (Section 5.2.2.2). Similarly, downstream of G8160018 there are contributions to flow from the catchment and its tributaries. From analysis undertaken in Section 5.2.3.1, these contributions could be significant and it is estimated that more than double the flow at G8160018 may be available further downstream. In the absence of such flow measurements the analysis provides an indication only.

No notable flow increases are anticipated downstream of G8165051 as the site is already located close to the river mouth.

5.3.2 Surface water usage

Sourcing irrigation supplies from surface water can be approached in various ways. Typical methods are noted below, and pending on feasibility, more than one method can be employed.

5.3.2.1 Pumping direct from Creeks

This type of sourcing is called run-of-the-river extraction. In theory, this type of surface water extraction for direct irrigation is cost effective, if the source is close to arable land. Crop water demand is likely to be highest towards the end of the dry season which is when river baseflows are at their lowest.

Three waterholes have been identified in the Dudwell Creek System. They are approximately 8 m wide and 2 m deep and would be suitable locations for pumps.

5.3.2.2 Minor weirs

If feasible, in-stream weirs, typically to a height of 0.5 m to 1.5 m depending on the depth of the creek, can be constructed to supplement the run-of river extractions. This provides storage to extract water when the flow is very low at the end of the dry season. The feasibility would need to be determined on a cost and environmental basis.

5.3.2.3 Off-stream storages

Harvesting water during the wet season is called flood harvesting. In general, this is feasible through off-stream storages. This water is then made available during the dry season. This approach is best suited for a small scale development of high value crops.

5.3.3 Surface water management

The analysis of surface water potential in this study is based on very limited streamflow measurements during the 2014 dry season and the intermittent fifteen year historical flow record (largely between 1974-1986) at Bluewater Creek near Pirlangimpi. Bluewater Creek flow analysis was used as a surrogate to understanding the flow variation in terms of probability at three selected sites on major creeks. The assumptions made in the analysis to provide some indicative surface water quantities are reasonable for the accuracy of this preliminary study.

Based on an average year, the dry season flow analysis of the three rivers indicates minimum monthly flow volumes in November of 258 ML, 168 ML and 945 ML respectively for the eastern arm of Dudwell Creek, the creek located near Yankilowu and Bullabolla Creek. In comparison, the early dry season month of June delivers 396 ML, 275 ML and 1 558 ML for the respective creeks. However in some years, the flow volumes would be less or more due to natural variability. Two of these rivers contain waterholes that would allow direct pumping. The third creek, near Yankilowu in the south-east of the study area, may have potential to meet small water supply requirements. Environmental impacts would need to be considered when determining extraction volumes.

Off-stream storages may be an option for storing water extracted during the wet season. However, these may not be cost effective. There may be potential for larger flows downstream from two of the study sites but this would need verification.

6. Land resources

Daniel Easey, Diane Napier, Brian Lynch and Amanda Trueman, Rangelands Division

The aim of the soil, land suitability and vegetation community investigation was to map and describe:

1. the soil and land resources at high resolution (1:25 000) and use the key properties mapped such as slope, rock outcrop, soil depth, and soil drainage to inform the development of an agricultural land suitability assessment,
2. the vegetation and identify sensitive and significant vegetation communities including riparian vegetation, wetlands, Melaleuca forest and monsoon forests/thickets, and;
3. the extent of acid sulfate soils.

6.1 Methodology

A land unit mapping methodology was adopted for this project because a land unit approach would address the objectives of the investigation. A land unit is described as "*a reasonably homogenous part of a land surface, distinct from surrounding terrain, with consistent properties in landform, soils or vegetation*" (Hooper 1970).

Existing land resource information collated and used to assist the project is detailed below:

- land unit survey conducted over the Seventeen Mile Plain on Melville Island in June 1973 (van-Cuylenburg and Dunlop 1973).
- In 1977, further land resource surveys were undertaken for forestry in two areas adjacent to the Tuyu and Yapilika (Wells and van-Cuylenberg 1978).
- A broad-scale land system survey of the western half of Melville Island (Wells *et al.* 1978) was also conducted to identify areas suited to forestry development.
- In 1979, a land unit survey was conducted over the south-east portion of Bathurst Island (Olsen 1980).
- In 2002, a land capability study was undertaken over the Tiwi Islands. This reconnaissance study incorporated statistical analysis and GIS technology to derive and map land units (Hollingsworth 2003).
- In 2008, interim broad-scale land system mapping was drafted for the Tiwi Islands. This was part of the Northern Territory's contribution to the Australian Soil and Land Information System (ASRIS).

The project was undertaken as a land unit survey mapped at a scale of 1:25 000.

6.1.1 Survey preparation

Aerial photo interpretation was initially used to manually delineate land unit boundaries. Two photography sets were used; black and white aerial photographs (1962) at 1:80 000 (Melville Island Run 1-6) and colour photography (1981) at 1:40 000 (NTc681 Run 1-14). Aerial photography was interpreted using a stereoscope to delineate preliminary land unit boundaries and select suitable sites for field survey and ground truthing. Satellite imagery and two digital elevation models were also used to assist the delineation of land unit boundaries. The satellite imagery used was WorldView-2 dataset with a resolution of 0.5 m pixels captured between 21/07/10 and 25/04/13.

The digital elevation models were:

1. 30 m SRTM derived DEM (Geoscience Australia 2009); and
2. 5 m pixel resolution digital elevation model over Bathurst and Melville Islands (NTT Data, Restec 2014)

6.1.2 Field survey

Field survey was undertaken over eight weeks from May to September 2014, encompassing a total of 84 sites as listed in Table 6-1. A landscape description was recorded at all sites, including landform and general soil observations. Soil profiles (morphology) and vegetation communities were described at 71 sites using national guidelines and the methods detailed below. Additionally, soil chemistry was analysed from 28 of these sites, and soil hydrology data was recorded from a subset of four sites. Landscape features were also observed along vehicle tracks and during traverses to sites only accessible by walking.

The land unit boundaries that had been initially drawn from aerial photography and satellite data were manually refined by referring to field data and observations.

Table 6-1: Data collected during field survey

Site Type	Data obtained	Number of Sites
Soil morphology sites	Landscape description, soil morphology, vegetation description	43
Soil morphology and chemistry sites	Landscape description, soil morphology, soil chemistry, vegetation description	24
Soil morphology, chemistry and hydrology sites	Landscape description, soil morphology, soil chemistry, soil hydrology, vegetation description	4
Landscape sites	Landscape description	13
Total		**84**

6.1.3 Soil descriptions

Soil morphology was described using profiles that were sampled using a hand auger to a maximum depth of 180 cm. Profile descriptions were compiled in accordance with the Australian Soil and Land Survey Field Handbook (NCST, 2009), The Australian Soil Classification (Isbell, 2002) and Munsell soil colour charts. General soil observations at landscape sites were undertaken using exposed profiles along creek banks and cliff faces. Soil hydrology was measured in pits that were hand excavated to a depth of 100 cm. Soil chemistry tests were performed on soil sampled from hand-augered profiles and soil pits.

6.1.4 Vegetation descriptions

Vegetation descriptions and communities were compiled using the Hnatiuk, Thackway and Walker (2009) classification system as outlined in the Australian Soil and Land Survey Handbook (NCST, 2009), with the exception of monsoon forests and thickets which were classified and modified in accordance with Fensham and Woinarski (1992). Vegetation floristic data were collected from a 20 m x 20 m quadrat at seventy one sites at the same location as the soil-landscape sites. Vegetation strata were identified and the average height, height ranges, predominant growth form and percentage covers recorded for each. Percentage cover was recorded for each species in each stratum, plus a basal count of dominant species in the upper stratum. Species recorded in these sites are included in the full checklist of vascular plants recorded in the study area, provided in Appendix 16.

For monsoon forest and sedgeland land units, (10a, 10b, 10c, and 8d) site data was supplemented with additional data from flora surveys. Vegetation communities in intertidal land units (12a, 12b and 12c) were described using data from the NVIS vegetation map of the NT (Department of Land Resource Management, 2012). Access to these areas was not possible at the time of the survey.

6.1.5 Data storage

Spatial information is stored in the Department of Land Resource Management (DLRM) spatial corporate library and is available upon request.

Site data for soil and landform resides in an Oracle Spatial Corporate Database, the Northern Territory Soil and Land Information System (*SALInfo*). Vegetation data is stored in the Vegetation Site Database, Northern Territory (VSDNT).

Information at http://www.lrm.nt.gov.au/nrmapsnt#digitaldata is available to assist a data request application.

6.2 Land units

6.2.1 Landform

Landform in the survey area is strongly linked to the underlying geology and geomorphological units. Landform was assessed using a combination of aerial photographs, digital elevation models (DEMs) and field observations. Seven landform classes were identified including low hills, rises, low rises, plains, drainage systems, swamps and marine areas. These are presented in Table 6-2 and Figure 6-1.

Table 6-2: Landform classes identified in the survey area

Landform Class Code	Landform Class	Land Units	Area (ha)
5	Low Hills	5a	729
6	Rises	6a	145
7	Low Rises	7a	193
8	Plains	8a, 8a1, 8b, 8c, 8c1, 8d	11 134
10	Drainage Systems	10a, 10b, 10c	1613
11	Swamps	11a, 11b	287
12	Marine	12a, 12b, 12c, 12d	4 732

6.2.1.1 Low Hills

Low Hills are landform patterns with moderate relief (30-90 m). Low Hills dominate the landscape along the southern boundary with some slopes over 20%. These areas have eroded leaving ridges and slopes exposing lateritic outcrops. They are characterised by their shallow rocky soils.

6.2.1.2 Rises

Rises are landform patterns of low relief (9-30 m). They include hillcrests, lower slopes, and drainage lines with moderately inclined slopes (10-15%). A common feature of this soil landscape is the very shallow gravelly soils.

6.2.1.3 Low Rises

Low Rises are landform patterns of very low relief (5-9 m) including some plains and lower slopes. Low Rises across the landscape consisted of gently to moderately inclined slopes (10-12%).

6.2.1.4 Plains

Plains are landform patterns of extremely low relief (<9 m). Plains are the most extensive landform class. Slopes are gently inclined (1-3%) on the upper slopes, to gently undulating on the lower side slopes. Six land units were described under this class with two distinct types being upland and lowland plains.

6.2.1.5 Drainage Systems

Drainage systems incorporate drainage depressions, alcoves, natural springs, and creek systems. Slopes ranged from 1-3%. They are characterised by their poorly drained soils. These types of landscapes are discussed in sections *4.2.3 Groundwater Flow*, *Recharge and Discharge Processes* and *5.2.1 Hydrological Settings* and *5.2.2 Surface Water Investigations*.

6.2.1.6 Swamps

Swamps are closed depressions that pond water for extensive periods. These swamps rely on water table levels and can remain wet throughout the dry season so inherently the soils range from poorly to very poorly drained. They are significant in the northern area of study area where a number of interconnected swamps are present. These swamps are described as intermittent lakes. Slope and relief are very low.

6.2.1.7 Marine

Marine environments are associated with low elevation and are generally influenced by tidal inundation or formed on Holocene sediments. They include mangroves, salt flats and beach ridges.

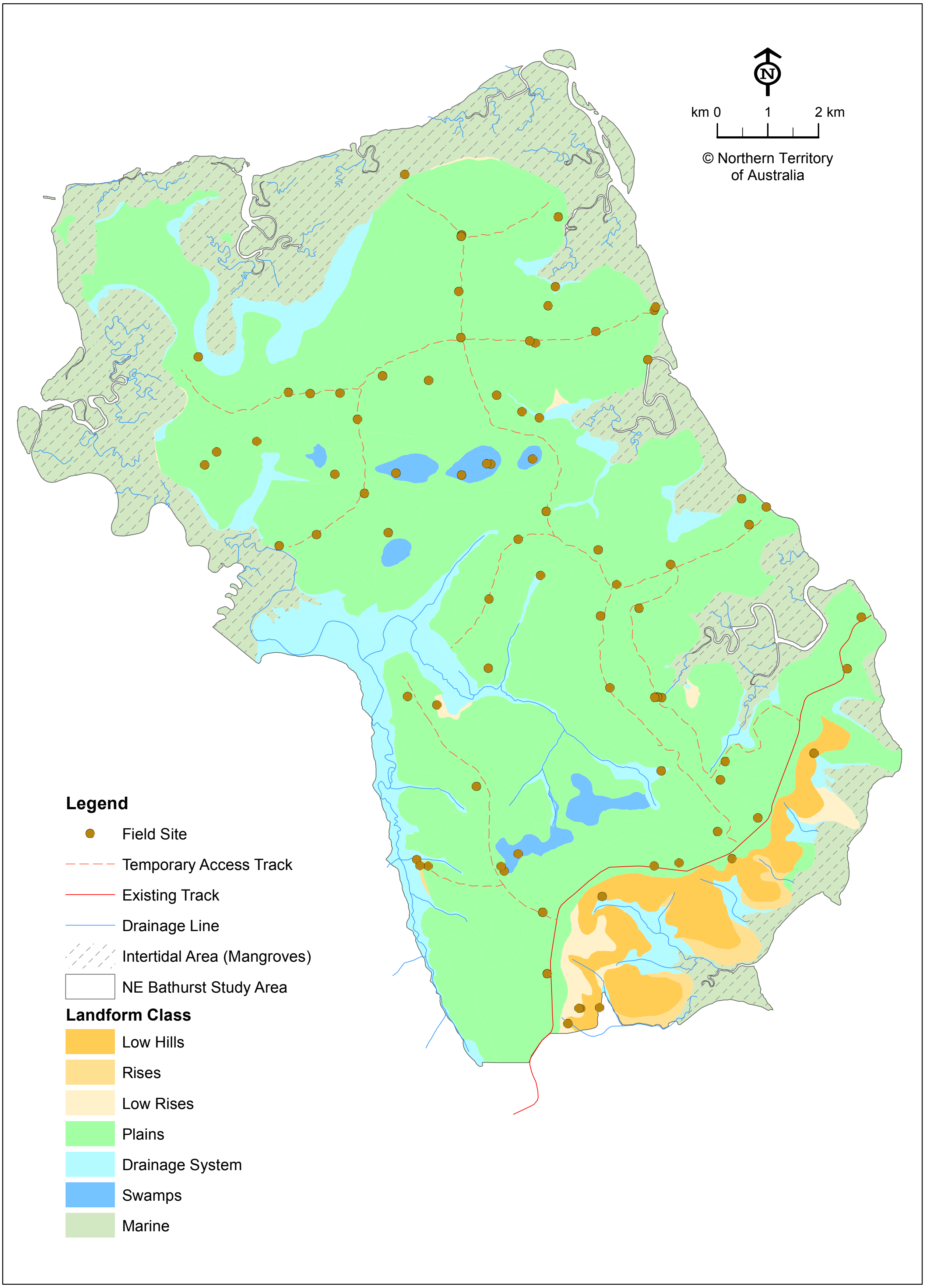

Figure 6-1: Landform classes

6.2.2 Land unit descriptions

Landform class (Section 6.2.1) was used to initially separate the landscape. Further separation was then based on soil, vegetation, and finer distinctions in landform. This allows for a simplification of land types that have a relative degree of homogeneity in often variable and complex landscapes (Napier & Hill 2012). Eighteen land units were described. These are summarised in Table 6-3. Detailed descriptions are provided in the following section. Soil characteristics and vegetation communities are described in sections 6.3 and 6.4 respectively.

Table 6-3: Summary of land units and their extent

Landform class	Land Unit	Area (ha)	Landform	Soil	Vegetation Structure	Dominant Community Species	Sites
Low Hills	5a	729	Undulating steep hillslopes	Red Kandosols	Very tall woodland	*Eucalyptus tetrodonta, Corymbia bleeseri, Eucalyptus miniata*	17
Rises	6a	145	Moderately inclined hillslopes	Brown Kandosols Red Orthic Tenosols	Tall woodland, Tall open shrubland	*Eucalyptus miniata, Eucalyptus tetrodonta, Petalostigma pubescens*	60 43
Low Rises	7a	193	Gently inclined hillslopes	Red Kandosols Red Orthic Tenosols	Tall to very tall open woodland	*Eucalyptus miniata, Eucalyptus tetrodonta*	12, 44, 62 4
Plains	8a	5908	Very gently inclined upland plains	Red Kandosols	Very tall open woodland / woodland	*Eucalyptus miniata, Corymbia nesophila, Eucalyptus tetrodonta*	1, 2, 9, 19, 23, 26, 27, 28, 29, 34, 36, 39, 40, 41, 42, 51, 52, 53, 54, 61, 63, 67, Pit 1, Pit 2, Pit 3, Pit 4
	8a1	3196	Gently inclined lower slopes	Red Kandosols	Very tall open woodland / woodland	*Eucalyptus tetrodonta, Eucalyptus miniata, Corymbia nesophila*	10, 11, 30, 38, 49, 57, 58
	8b	72	Undulating plains	Red Kandosols	Very tall open woodland	*Eucalyptus miniata, Eucalyptus tetrodonta*	5, 6, 8
	8c	1388	Seasonal wet plains	Kandosolic Redoxic Hydrosols	Very tall open woodland / tall open woodland	*Corymbia nesophila, Lophostemon lactifluus, Melaleuca leucadendra*	7, 18, 33, 46, 50, 55, 65, 66
	8c1	444	Seasonal wet plain prone to inundation and seasonal waterlogging	Kandosolic Redoxic Hydrosols Brown Kandosols	Mid high open woodland	*Melaleuca viridiflora, Lophostemon lactifluus, Acacia leptocarpa*	32, 47, 48 35
	8d	126	Lower slopes	Red Kandosols	Dry evergreen monsoon forest and dry monsoon vine thicket	*Acacia auriculiformis, Syzygium forte, Diospyros maritima*	25
Drainage Systems	10a	1091	Drainage depressions	Kandosolic Redoxic Hydrosols Oxyaquic Hydrosols Hydrosols	Tall woodland / mid high open woodland	*Lophostemon lactifluus, Melaleuca viridiflora, Melaleuca leucadendra*	56 59 13, 45
	10b	228	Drainage depressions including creeks, springs and alcoves.	Kandosolic Redoxic Hydrosols Hydrosols	Wet evergreen monsoon forest	*Calophyllum soulattri, Acacia auriculiformis, Syzygium minutuliflorum*	37 3
	10c	294	Drainage lines and depressions	Hydrosols	Sedgeland	*Schoenus* spp., *Dapsilanthus elatior, Dapsilanthus spathaceus*	
Swamps	11a	268	Closed depressions	Kandosolic Redoxic Hydrosols	Mid high open woodland	*Lophostemon lactifluus, Banksia dentata, Melaleuca viridiflora,*	20, 22, 31, 64
	11b	19	Wet closed depressions	Hydrosols, Kandosolic Redoxic Hydrosols	Tall open forest	*Melaleuca* spp.	21
Marine	12a	4117	Estuarine flats	Intertidal Hydrosols	Mid high closed forest	*Ceriops tagal, Rhizophora stylosa, Avicennia marina*	-
	12b	144	Salt flats	Oxyaquic Hydrosols	Miniature samphire shrubland	*Tecticornia indica, Tecticornia australasica*	-
	12c	415	Beach ridge	Tenosolic Oxyaquic Hydrosols	Mid high open woodland	*Melaleuca dealbata, Corymbia polycarpa*	24
	12d	56	Supratidal flat	Supratidal Hydrosols	Sedgeland	*Eleocharis* spp., *Schoenoplectus littoralis*	-

Low Hills

Land Unit: 5a **Sites: 1** **Area: 729 ha**

Landform

General Description

Undulating steep hillslopes; areas of rock outcrop; very tall woodland; shallow gravelly soils.

Slopes:	25-30%
Surface Gravel:	>60%
Rock Outcrop:	2-10%
Permeability:	Moderate
Drainage:	Well
Runoff:	Very Rapid

Soil

Common Soil Red Kandosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Loam	Soil colour:	Red
Surface soil gravels:	60-80%	Subsoils gravels:	60-80%	Soil depth:	0.25-0.5m
Field surface pH:	5.0-6.0	Field subsoil pH:	5.0-5.5		
Other soils described:	Nil				

Vegetation

Common vegetation community Very tall woodland	No sites	Av height	Av cover
Eucalyptus tetrodonta, *Eucalyptus miniata*, *Corymbia bleeseri* very tall woodland	1	30 m	crown 20%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Eucalyptus tetrodonta*, *Corymbia bleeseri* (100%)	*Eucalyptus miniata, Terminalia ferdinandiana, Buchanania obovata* (100%)
Mid stratum		*Acacia latescens, Eucalyptus tetrodonta* (100%)
Ground stratum	*Eriachne avenacea*, *Acacia latescens*, *Eriachne triseta* (100%)	*Eucalyptus tetrodonta, Coelospermum reticulatum, Acacia leptocarpa, Acacia lamprocarpa* (100%)

Land Evaluation

Excessive slopes
Rock outcrop substantial
Shallow soils
Well drained
Very high erosion risk

Agricultural Land Suitability Class - S4 Not Suitable

Comments

Elevation is highest along the southern boundary of the survey area.

Steep hillslopes with gravelly surfaces and exposed laterite outcrops.

Rises

Land Unit: 6a **Sites: 2** **Area: 145 ha**

Landform

General Description

Moderately inclined hillslopes; tall woodland /tall open shrubland; very shallow gravelly soils.

Slopes:	10-15%
Surface Gravel:	65-90%
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Well
Runoff:	Rapid

Soil

Common Soil Brown Kandosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam:	Soil colour:	Brown
Surface soil gravels:	40-65%	Subsoils gravels:	50-55%	Soil depth:	<0.25m
Field surface pH:	6.0-6.5	Field subsoil pH:	6.0-6.5		

Other soils described: Red Orthic Tenosols

Vegetation

Common vegetation community Tall woodland / Tall open shrubland	No sites	Av height	Av cover
Eucalyptus miniata, Eucalyptus tetrodonta tall woodland	1	20 m	crown 25%
Petalostigma pubescens and mixed species tall open shrubland	1	2.5 m	foliage 7%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Eucalyptus miniata*, *Eucalyptus tetrodonta* (50%)	*Corymbia bleeseri*, *Petalostigma pubescens*, *Corymbia foelscheana*, *Acacia lamprocarpa* (50%)
Mid stratum	*Acacia lamprocarpa*, *Eucalyptus tetrodonta*, *Petalostigma pubescens* (50%)	*Livistona humilis*, *Acacia oncinocarpa* (50%),
Ground stratum	*Eriachne burkitii*, *Eriachne avenacea* (50%)	*Acacia oncinocarpa* (100%), *Petalostigma pubescens*, *Calytrix exstipulata* (50%)

Land Evaluation

Excessive slopes
Very shallow soils
Well drained
High erosion risk

Agricultural Land Suitability Class - S4 Not Suitable

Comments

Very shallow gravelly lateritic and sandstone subsoils.

Low Rises

Land Unit: 7a **Sites: 4** **Area: 193 ha**

Landform

General Description

Gently inclined hillslopes; tall to very tall open woodland; very deep Red Earths.

Slopes:	10-12%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Well
Runoff:	Moderately Rapid

Soil

Common Soil: Red Kandosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Red
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	6.0-6.5	Field subsoil pH:	6.0-6.5		
Other soils described:	Red Orthic Tenosols				

Vegetation

Common vegetation community Tall to very tall open woodland	No sites	Av height	Av cover
Eucalyptus miniata, Eucalyptus tetrodonta very tall open woodland	3	26 m	crown 14%
Eucalyptus miniata and mixed species tall open woodland	1	18.5 m	crown 13%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Eucalyptus miniata* (100%), *Eucalyptus tetrodonta* (25%)	*Acacia lamprocarpa, Acacia leptocarpa, Timonius timon, Alphitonia excelsa* (50%)
Mid stratum	*Tarenna dallachiana* (25%)	*Livistona humilis* (75%), *Petalostigma pubescens, Eucalyptus miniata, Planchonia careya* (50%)
Ground stratum	*Eriachne triseta* (75%), *Cycas armstrongii, Opilia amentacea* (25%)	*Pandanus spiralis* (75%), *Pseudopogonatherum irritans, Alphitonia excels, Timonius timon* (50%)

Land Evaluation

Excessive slopes
Very deep soils
Well drained
Moderate erosion risk

Agricultural Land Suitability Class – S4 Not Suitable

Comments

Sandy veneer surface.

Red Orthic Tenosols described on the steeper slopes with loamy sand texture. Red Kandosols are the dominant soil type for this land unit.

Plains

Land Unit: 8a | **Sites: 26** | **Area: 5 908 ha**

Landform

General Description

Very gently inclined upland plains; very tall open woodland / woodland; very deep Red Earths.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	High
Drainage:	Well
Runoff:	Slow

Soil

Common Soil: Red Kandosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam:	Soil colour:	Red
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	5.5-6.5	Field subsoil pH:	5.5-6.5		
Other soils described:	Nil				

Vegetation

Common vegetation community Very tall open woodland / woodland	No sites	Av height	Av cover
Eucalyptus miniata, *Corymbia nesophila, Eucalyptus tetrodonta* very tall open woodland	17	22 m	crown 14%
Eucalyptus miniata, *Corymbia nesophila, Eucalyptus tetrodonta* very tall woodland	8	25 m	crown 27%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Eucalyptus miniata* (81%), *Corymbia nesophila* (62%), *Eucalyptus tetrodonta* (31%)	Acacia leptocarpa (31%), *Erythrophleum chlorostachys* (19%), *Eucalyptus oligantha* (15%), *Alphitonia excelsa* (12%)
Mid stratum	*Livistona humilis* (54%), *Acacia leptocarpa* (27%)	*Cycas armstrongii* (42%), *Acacia lamprocarpa* (31%), *Corymbia nesophila* (23%), *Erythrophleum chlorostachys* (23%)
Ground stratum	*Eriachne triseta* (31%), *Erythrophleum chlorostachys* (27%), *Eriachne avenacea* (15%)	*Acacia leptocarpa* (42%), *Cycas armstrongii* (31%), *Eucalyptus tetrodonta* (27%)

Land Evaluation

Gentle slopes
Very deep soils
Well drained
Moderate erosion risk

Agricultural Land Suitability Class - S2 Moderately Suitable

Comments

This land unit covers the largest area of land within the survey area. Soils are very deep and well drained with moderate limitations.

Vegetation structure is variable. Areas of this land unit contain plant species that are tolerant of poorly drained soil, suggesting a gradient towards land unit 8c.

Plains	**Land Unit: 8a1**	**Sites: 7**	**Area: 3 196 ha**

Landform

General Description

Gently inclined lower slopes; very tall open woodland / woodland; very deep Red Earths.

Slopes:	1-5%
Surface Gravel:	2-15%
Rock Outcrop:	0-2%
Permeability:	Moderate
Drainage:	Well
Runoff:	Moderately Rapid

Soil

Common Soil: Red Kandosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Red
Surface soil gravels:	5-15%	Subsoils gravels:	5-30%	Soil depth:	>1.5m
Field surface pH:	6.0-6.5	Field subsoil pH:	5.5-6.0		
Other soils described:	Nil				

Vegetation

Common vegetation community Very tall open woodland / woodland	No sites	Av height	Av cover
Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia nesophila very tall open woodland	4	23 m	crown 10%
Eucalyptus miniata, Eucalyptus tetrodonta, Corymbia nesophila very tall woodland	3	27 m	crown 23%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Eucalyptus miniata, Eucalyptus tetrodonta* (57%), *Corymbia nesophila* (29%)	*Acacia leptocarpa, Alphitonia excelsa, Cycas armstrongii* (29%)
Mid stratum	*Lophostemon lactifluus, Erythrophleum chlorostachys, Petalostigma pubescens* (14%)	*Livistona humilis, Cycas armstrongii, Eucalyptus tetrodonta* (57%), *Acacia leptocarpa, Alphitonia excelsa* (43%)
Ground stratum	*Eriachne triseta* (57%), *Acacia leptocarpa* (29%)	*Pandanus spiralis* (57%), *Erythrophleum chlorostachys, Eriachne avenacea* (43%)

Land Evaluation

Substantial slopes
Rock outcrop negligible
Very deep soils
Well drained
Moderate erosion risk

Agricultural Land Suitability Class – S3 Marginally Suitable

Comments

Ferruginous surface gravel present.

Plains	**Land Unit: 8b**	**Sites: 3**	**Area: 72 ha**

Landform

General Description

Undulating plains; very tall open woodland; very deep Red Earths.

Slopes:	4-8%
Surface Gravel:	0-60%
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Well
Runoff:	Moderately Rapid

Soil

Common Soil: Red Kandosols

Common Soil Characteristics

Surface texture class:	Loamy Sand	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Red
Surface soil gravels:	0-40%	Subsoils gravels:	0-40%	Soil depth:	>1.5m
Field surface pH:	5.5-6.0	Field subsoil pH:	5.0-6.0		
Other soils described:	Nil				

Vegetation

Common vegetation community Very tall open woodland	No sites	Av height	Av cover
Eucalyptus miniata very tall open woodland	3	26 m	crown 13%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Eucalyptus miniata* (100%)	*Eucalyptus tetrodonta* (67%)
Mid stratum	*Acacia leptocarpa* (33%)	*Livistona humilis, Eucalyptus miniata* (100%), *Cycas armstrongii* (67%)
Ground stratum	*Eriachne triseta* (100%)	*Pseudopogonatherum irritans, Cycas armstrongii, Hibbertia caudice, Spermacoce retitesta* (100%), *Acacia leptocarpa* (67%)

Land Evaluation

Substantial slopes
Very deep soils
Well drained
Moderate erosion risk

Agricultural Land Suitability Class - S3 Marginally Suitable

Comments

Surface gravels more common on the steeper slopes.

Natural springs are present on some lower slopes.

Plains	Land Unit: 8c	Sites: 8	Area: 1 388 ha

Landform

General Description

Seasonally wet plains; very tall open woodland / tall open woodland; poorly drained soils.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Imperfect
Runoff:	Slow

Soil

Common Soil: Kandosolic Redoxic Hydrosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Brown
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	5.0-6.0	Field subsoil pH:	5.0-6.0		
Other soils described:	Nil				

Vegetation

Common vegetation community Very tall open woodland / tall open woodland	No sites	Av height	Av cover
Corymbia nesophila very tall open woodland	3	23 m	crown 12%
Lophostemon lactifluus tall open woodland	3	12 m	crown 19%

Other communities: *Melaleuca leucadendra, Corymbia nesophila* tall open woodland

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Corymbia nesophila* (63%), *Lophostemon lactifluus* (38%), *Melaleuca leucadendra* (25%)	*Melaleuca viridiflora, Erythrophleum chlorostachys* (13%)
Mid stratum	*Livistona humilis* (63%), *Acacia leptocarpa* (25%)	*Banksia dentata* (38%), *Grevillea pteridifolia* (25%), *Petalostigma pubescens, Timonius timon* (13%)
Ground stratum	*Eriachne triseta* (50%)	*Acacia leptocarpa* (38%), *Pandanus spiralis, Melaleuca nervosa* (25%), *Pseudopogonatherum irritans* (13%)

Land Evaluation

Gentle slopes
Very deep soils
Imperfectly drained
Moderate erosion risk

Agricultural Land Suitability Class – S3 Marginally Suitable

Comments

Seasonally wet plains that fringe swamps. The Debil-debil microrelief suggest that these areas may remain saturated for long periods.

The vegetation of this land unit is variable and commonly has a prominent open mid stratum of trees/shrubs/palms.

Plains

Land Unit: 8c1 **Sites: 4** **Area: 444 ha**

Landform

General Description

Seasonally wet plains prone to inundation and seasonal waterlogging; mid high open woodland; poorly drained soils.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Poor
Runoff:	Slow

Soil

Common Soil: Kandosolic Redoxic Hydrosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Brown
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	7.0-7.5	Field subsoil pH:	7.0-7.5		
Other soils described:	Brown Kandosols				

Vegetation

Common vegetation community Mid high open woodland	No sites	Av height	Av cover
Melaleuca viridiflora and/or *Lophostemon lactifluus* mid high open woodland	3	9.5 m	crown 14%

Other communities: *Eucalyptus tetrodonta, Corymbia nesophila* very tall open woodland

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Melaleuca viridiflora* (50%), *Acacia leptocarpa*, *Eucalyptus tetrodonta, Corymbia nesophila, Lophostemon lactifluus* (25%)	*Grevillea pteridifolia* (75%)
Mid stratum	*Melaleuca viridiflora* (50%)	*Livistona humilis, Lophostemon lactifluus, Grevillea pteridifolia,* (50%)
Ground stratum	*Eriachne triseta* (50%)	*Acacia leptocarpa* (50%)

Land Evaluation

Gentle slopes
Very deep soils
Poorly drained
Moderate erosion risk

Agricultural Land Suitability Class – S3 Marginally Suitable

Comments

Similar to land unit to 8c. This land unit will remain wetter for longer periods during the wet season.

This land unit is more common in the north around the more defined swamp systems. Elevation in this area is very low.

Plains

Land Unit: 8d **Sites: 1** **Area: 126 ha**

Landform

General Description

Lower slopes; tall closed monsoon vine forest and thickets; very deep Red Earths.

Slopes:	3-10%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	High
Drainage:	Well
Runoff:	Moderately Rapid

Soil

Common Soil: Red Kandosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Red
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	6.0-6.5	Field subsoil pH:	6.0-6.5		
Other soils described:	Nil				

Vegetation

Common vegetation community Tall closed forest	No sites	Av height	Av Cover
Dry evergreen monsoon forest	4*	16 m	crown 71%
Dry semi-deciduous monsoon thicket	2*	22 m	crown 88%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Acacia auriculiformis, Syzygium forte* (67%), *Diospyros maritima, Buchanania arborescens* (50%), *Horsfieldia australiana, Antiaris toxicaria* (33%)	*Canarium australianum* (67%), *Litsea glutinosa, Maranthes corymbosa* (50%), *Uvaria holtzei, Terminalia microcarpa, Smilax australis, Vavaea amicorum, Zanthoxylum parviflorum* (33%)
Mid stratum	*Diospyros maritima* (33%)	*Pleomele angustifolia, Buchanania arborescens* (67%), *Cryptocarya cunninghamii, Polyalthia australis, Memecylon pauciflorum Aidia racemosa* (33%)
Ground stratum	-	*Diospyros maritima, Pleomele angustifolia* (67%), *Glycosmis trifoliata, Cryptocarya cunninghamii* (33%)

Land Evaluation

Substantial slopes
Very deep soils
Well drained
Moderate erosion risk
Significant vegetation community

Agricultural Land Suitability Class - S3 Marginally Suitable

Comments

*Vegetation information is supplemented with data from five additional flora survey sites.

Drainage Systems

Land Unit: 10a **Sites: 4** **Area: 1 091 ha**

Landform

General Description

Drainage depressions; tall woodland / mid high open woodland; very poorly drained soils.

Slopes: 1-3%

Surface Gravel: Nil

Rock Outcrop: Nil

Permeability: High

Drainage: Very Poor

Runoff: Very Slow

Soil

Common Soil: Kandosolic Redoxic Hydrosols

Common Soil Characteristics

Surface texture class:	Loam	Subsoil texture class:	Clay Loam	Soil colour:	Grey
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth	>1.5m
Field surface pH:	5.5-6.0	Field subsoil pH:	5.5-6.0		
Other soils described:	Oxyaquic Hydrosols				

Vegetation

Common vegetation community Tall woodland / mid high open woodland	No sites	Av height	Av Cover
Lophostemon lactifluus and/or *Melaleuca viridiflora* tall woodland to mid high open woodland	4*	10 m	crown 20%

Other communities: Wet evergreen monsoon forest

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Melaleuca viridiflora* (40%), *Lophostemon lactifluus*, *Acacia auriculiformis* (20%)	*Pandanus spiralis, Grevillea pteridifolia* (40%)
Mid stratum	*Livistona humilis* (20%)	*Fagraea racemosa* (60%), *Lophostemon lactifluus*, *Banksia dentata, Melastoma malabathricum* (40%)
Ground stratum	*Lycopodiella cernua* (40%), *Dicranopteris linearis*, *Eriachne burkittii*, *Rhynchospora brownii*, *Dapsilanthus* sp. (20%)	*Melastoma malabathricum* (60%), *Osbeckia australiana*, *Pandanus spiralis* (40%)

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Acid sulfate soils
Significant vegetation community

Agricultural Land Suitability Class - S4 Not Suitable

Comments

Accurate soil depth could not be measured due to water near or at the surface.

The vegetation is highly variable. *Vegetation information is supplemented with data from one additional flora survey site.

Drainage Systems

Land Unit: **10b** **Sites: 2** **Area: 228 ha**

Landform

General Description

Drainage depressions including creeks, springs and alcoves; wet evergreen monsoon forest; very poorly drained soils.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	High
Drainage:	Very Poor
Runoff:	Very Slow

Soil

Common Soil: Kandosolic Redoxic Hydrosols

Common Soil Characteristics

Surface texture class:	Loam	Subsoil texture class:	Clay Loam	Soil colour:	Grey
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	5.5-6.0	Field subsoil pH:	5.5-6.0		
Other soils described:	Nil				

Vegetation

Common vegetation community Tall closed forest	No sites	Av height	Av Cover
Wet evergreen monsoon forest	11*	19 m	crown 72%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Calophyllum soulattri* (82%) *Acacia auriculiformis, Syzygium minutuliflorum* (36%), *Syzygium forte, Syzygium nervosum* (27%)	*Stenochlaena palustris* (91%), *Horsfieldia australiana* (55%), *Syzygium hemilamprum, Gmelina australis, Dysoxylum latifolium, Smilax australis* (27%)
Mid stratum	*Calophyllum soulattri* (45%)	*Stenochlaena palustris* (72%), *Pouteria richardii* (36%), *Aglaia sapindina, Hydriastele wendlandiana, Flagellaria indica* (27%)
Ground stratum	-	*Nephrolepis hirsutula* (27%)

Land Evaluation

Gentle slopes
Moderately deep soils
Very poorly drained
Low erosion risk
Acid sulfate soils
Significant vegetation community

Agricultural Land Suitability Class - S4 Not Suitable

Comments

Accurate soil depth could not be measured due to water near or at the surface.

*Vegetation information is supplemented with data from 9 additional flora survey sites.

Drainage Systems

Land Unit: 10c | **Sites: 0** | **Area: 294 ha**

Landform

General Description

Drainage lines and depressions; medium closed sedgeland; very poorly drained soils.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Very Poor
Runoff:	Very Slow

Soil

Common Soil: Redoxic Hydrosols

Common Soil Characteristics

Surface texture class:	-	Subsoil texture class:	-	Soil colour:	-
Surface soil gravels:	-	Subsoils gravels:	-	Soil depth:	-
Field surface pH:	-	Field subsoil pH:			
Other soils described:	-				

Vegetation

Common vegetation community Medium closed sedgeland	No sites	Av height	Av Cover
Dapsilanthus spp. and/or *Schoenus* spp. medium closed sedgeland	3*	0.6 m	foliage 72%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	-	-
Mid stratum	-	-
Ground stratum	*Schoenus* spp. (67%), *Dapsilanthus elatior, Dapsilanthus spathaceus, Eriachne triseta* (33%)	*Tricostularia undulata (67%), Isachne confusa* (33%)

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Acid sulfate soils
Significant vegetation community

Agricultural Land Suitability Class - S4 Not Suitable

Comments

Limited field data from study area. Landform description from past surveys.
*Vegetation information is from 3 flora survey sites.

Swamps

Land Unit: 11a | **Sites: 4** | **Area: 268 ha**

Landform

General Description

Closed depressions; mid high open woodland; very poorly drained soils.

Slopes: 1-3%

Surface Gravel: Nil

Rock Outcrop: Nil

Permeability: Moderate

Drainage: Very Poor

Runoff: No Runoff

Soil

Common Soil: Kandosolic Redoxic Hydrosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Brown
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	5.5-6.5	Field subsoil pH:	5.0-6.0		
Other soils described:	Nil				

Vegetation

Common vegetation community Mid high open woodland	No sites	Av height	Av Cover
Lophostemon lactifluus and mixed species mid high open woodland	3	9.5 m	crown 15%

Other communities: *Acacia leptocarpa* low shrubland

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Lophostemon lactifluus* (75%), *Banksia dentata* (25%)	*Melaleuca viridiflora, Melaleuca nervosa, Corymbia nesophila, Grevillea pteridifolia*, *Corymbia polycarpa, Acacia leptocarpa* (50%)
Mid stratum	*Acacia leptocarpa* (25%)	*Livistona humilis (75%), Lophostemon lactifluus* (50%)
Ground stratum	*Asteromyrtus symphyocarpa, Eriachne triseta, Acacia leptocarpa, Melaleuca nervosa* (25%)	*Banksia dentata, Grevillea pteridifolia, Melastoma malabathricum* (25%)

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Significant vegetation community

Agricultural Land Suitability Class – S4 Not Suitable

Comments

This land unit is more prevalent in the north.

Swamps

Land Unit: 11b **Sites: 1** **Area: 19 ha**

Landform

General Description

Wet closed depressions; *Melaleuca* spp. tall open forest; very poorly drained soils.

Slopes: 1-3%

Surface Gravel: Nil

Rock Outcrop: Nil

Permeability: Moderate

Drainage: Very Poor

Runoff: No Runoff

Soil

Common Soil: Kandosolic Redoxic Hydrosols

Common Soil Characteristics

Surface texture class:	Sandy Loam	Subsoil texture class:	Sandy Clay Loam	Soil colour:	Brown
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	5.5-6.0	Field subsoil pH:	5.5-6.0		
Other soils described:	Nil				

Vegetation

Common vegetation community Tall open forest / Tall woodland	No sites	Av height	Av Cover
Melaleuca spp. tall open forest	-	16 m	crown 60%

Other communities: *Melaleuca viridiflora* and *Lophostemon lactifluus* tall woodland

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Melaleuca leucadendra*, *Melaleuca viridiflora* (100%)	*Lophostemon lactifluus*, *Grevillea pteridifolia, Corymbia polycarpa* (100%)
Mid stratum		*Melaleuca viridiflora, Lophostemon lactifluus* (100%)
Ground stratum	*Eriocaulon spectabile* (100%)	*Eriocaulon cinereum* (100%)

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Significant vegetation community

Agricultural Land Suitability Class – S4 Not Suitable

Comments

This land unit is part of the distinct swamp system that remains wet for a prolonged period of time during the dry season. The topsoil is darker in colour due to the accumulation of organic matter at the surface.

Marine

Land Unit: 12a | **Sites: 0** | **Area: 4 117 ha**

Landform

General Description

Estuarine flats; mangrove closed forest; intertidal soils.

Slopes: 1-3%

Surface Gravel: Nil

Rock Outcrop: Nil

Permeability: Moderate

Drainage: Very Poor

Runoff: Very Slow

Soil

Common Soil: Intertidal Hydrosols

Common Soil Characteristics

Surface texture class:	-	Subsoil texture class:	-	Soil colour:	-
Surface soil gravels:	-	Subsoils gravels:	-	Soil depth:	-
Field surface pH:	-	Field subsoil pH:	-		
Other soils described:	-				

Vegetation

Common vegetation community Mid high closed forest	Av height	Av Crown Cover
Ceriops tagal, Bruguiera spp. mid high closed forest	5 – 10 m	70 – 90%
Rhizophora stylosa tall closed forest	10 – 14 m	60 – 80%

Other communities: *Avicennia marina*, *Ceriops tagal, Bruguiera* spp., *Rhizophora stylosa* mid high open forest

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Ceriops tagal, Rhizophora stylosa, Avicennia marina, Bruguiera* spp., *Sonneratia alba*	*Camptostemon schultzii, Xylocarpus mekongensis, Excoecaria ovalis*
Mid stratum	*Ceriops tagal, Rhizophora stylosa, Avicennia marina*	*Aegiceras corniculatum, Scyphiphora hydrophylacea, Osbornia octodonta*
Ground stratum		*Aegialitis annulata, Acanthus ilicifolius*

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Acid sulfate soils
Significant vegetation community

Agricultural Land Suitability Class – S4 Not Suitable

Comments

Limited field data from study area. Landform and vegetation description from past surveys in the Darwin region.

Vegetation structure and species vary according to mangrove zoning.

Marine

Land Unit: 12b **Sites: 0** **Area: 144 ha**

Landform

General Description

Salt flats; samphire shrubland; intertidal soils.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Very Poor
Runoff:	Very Slow

Soil

Common Soil: Intertidal Hydrosols

Common Soil Characteristics

Surface texture class:	-	Subsoil texture class:	-	Soil colour:	-
Surface soil gravels:	-	Subsoils gravels:	-	Soil depth:	-
Field surface pH:	-	Field subsoil pH:	-		
Other soils described:	-				

Vegetation

Common vegetation community Miniature samphire shrubland	Av height	Av Foliage Cover
Tecticornia spp. miniature samphire shrubland	<0.5m	<10%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	-	-
Mid stratum	-	*Avicennia marina, Ceriops tagal*
Ground stratum	*Tecticornia indica, Tecticornia australasica, Suaeda arbusculoides*	-

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Acid sulfate soils
Significant vegetation community

Agricultural Land Suitability Class – S4 Not Suitable

Comments

Limited field data from study area. Landform and vegetation description from past surveys in the Darwin region.

Marine

Land Unit: 12c | **Sites: 1** | **Area: 415 ha**

Landform

General Description

Beach ridges; mid high open woodland; very poorly drained sandy soils.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	High
Drainage:	Very Poor
Runoff:	Very Slow

Soil

Common Soil: Tenosolic Oxyaquic Hydrosols

Common Soil Characteristics

Surface texture class:	Sand	Subsoil texture class:	Sand	Soil colour:	Brown
Surface soil gravels:	Nil	Subsoils gravels:	Nil	Soil depth:	>1.5m
Field surface pH:	6.0-6.5	Field subsoil pH:	6.0-6.5		
Other soils described:	Nil				

Vegetation

Common vegetation community Mid high open woodland	No sites	Av height	Av Cover
Melaleuca dealbata mid high open woodland	1	11 m	9%

Other communities: *Corymbia* spp. mid high to tall woodland to open woodland

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	*Melaleuca dealbata* (100%)	*Corymbia polycarpa* (100%)
Mid stratum	*Banksia dentata* (100%)	*Acacia leptocarpa* (100%)
Ground stratum	*Dapsilanthus spathaceus, Eriachne triseta* (100%)	*Verticordia cunninghamii, Banksia dentata, Xyris complanata* (100%)

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Acid sulfate soils

Agricultural Land Suitability Class - S4 Not Suitable

Comments

Vegetation structure and species composition is highly variable. The ground stratum in places is a tall sedgeland of *Dapsilanthus spathaceus*.

Marine

Land Unit: 12d **Sites: 0** **Area: 56 ha**

Landform

General Description

Supratidal flats; sedgeland; tidal soils.

Slopes:	1-3%
Surface Gravel:	Nil
Rock Outcrop:	Nil
Permeability:	Moderate
Drainage:	Very Poor
Runoff:	Very Slow

Soil

Common Soil: Supratidal Hydrosols

Common Soil Characteristics

Surface texture class:	-	Subsoil texture class:	-	Soil colour:	-
Surface soil gravels:	-	Subsoils gravels:	-	Soil depth:	-
Field surface pH:	-	Field subsoil pH:	-		
Other soils described:	-				

Vegetation

Common vegetation community Sedgeland	Av height	Av Foliage Cover
Eleocharis spp. and *Schoenoplectus littoralis* sedgeland	0.5 m	50%

Stratum	Frequency of dominant species	Frequency of other common species
Upper stratum	-	-
Mid stratum	-	-
Ground stratum	*Eleocharis* spp., *Schoenoplectus littoralis*	-

Land Evaluation

Gentle slopes
Very deep soils
Very poorly drained
Low erosion risk
Acid sulfate soils
Significant vegetation community

Agricultural Land Suitability Class – S4 Not Suitable

Comments

Limited field data from study area. Landform and vegetation description from past surveys in the Darwin region.

6.3 Soil

6.3.1 Soil morphology

The survey identified three soil orders in the study area. Kandosols and Hydrosols were dominant, as presented in Table 6-4 and Figure 6-2. Tenosols were uncommon and have been recorded as minor components in the land unit descriptions, as shown in Table 6-5. Full descriptions of soil profiles that are representative of the range of soils are provided in Appendix 2. A list of all Australian Soil Classifications (Isbell, 2002) is provided in Appendix 3.

Table 6-4: Dominant soil orders in the study area and their extent

Soil Order	Area (ha)
Kandosols	10,345
Hydrosols	8,488

Table 6-5: Occurrence of soil orders in land units. D = dominant, C = co-dominant, M = minor

Landform class	Land Unit	Hydrosols	Kandosols	Tenosols
Low Hills	5a		D	M
Rises	6a		D	C
Low Rises	7a		D	M
Plains	8a		D	
	8a1		D	
	8b		D	
	8c	D		
	8c1	D		M
	8d		D	
Drainage Systems	10a	D		
	10b	D		
	10c	D		
Swamps	11a	D		
	11b	D		
Marine	12a	D		
	12b	D		
	12c	D		
	12d	D		

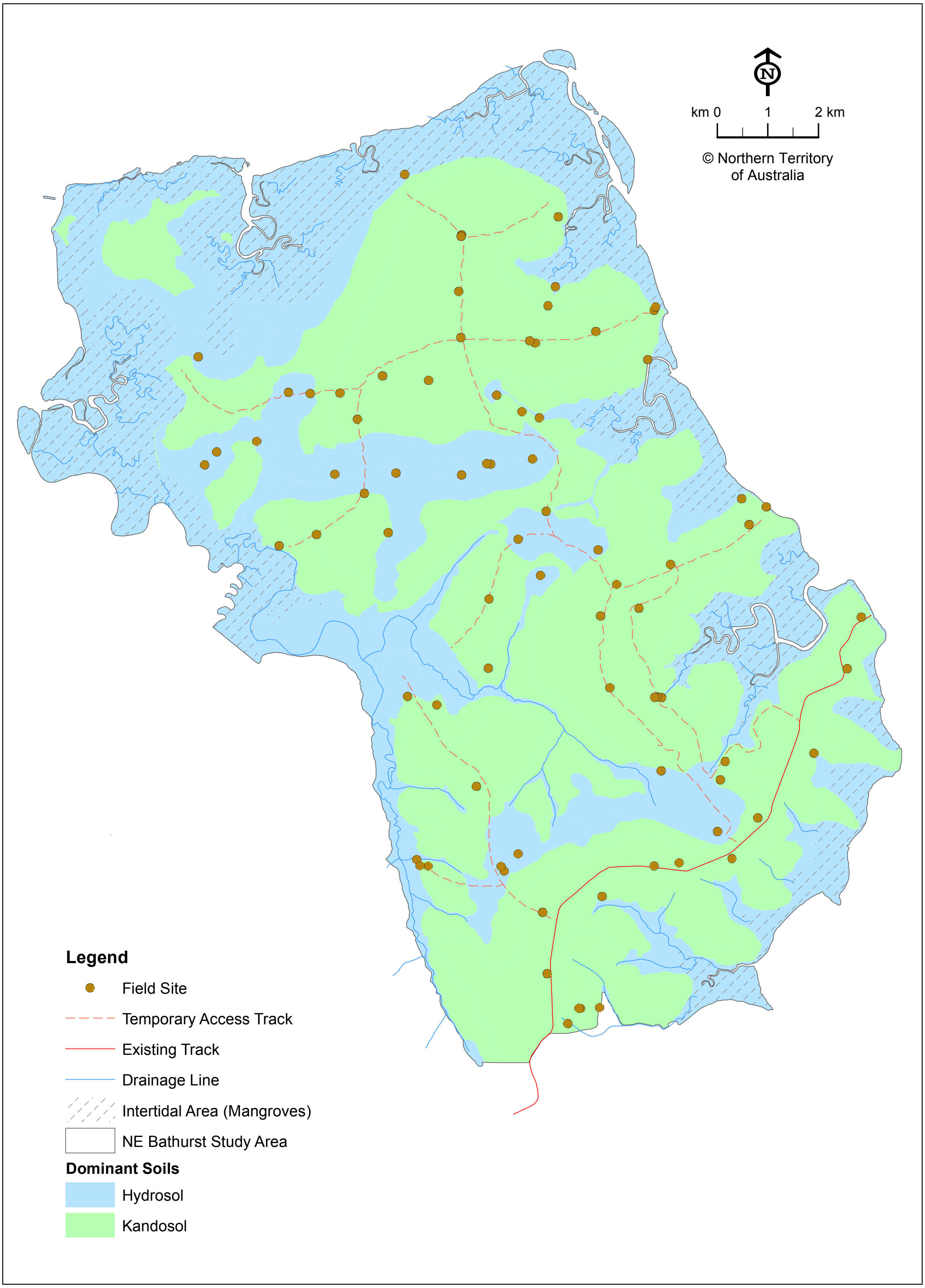

Figure 6-2: Dominant soil order

6.3.1.1 Kandosols

Kandosols lack strong texture contrast with massive or only weakly structured B horizons and are not calcareous throughout (Isbell 2002).

Red Kandosols (Figure 6-3) were widespread in the study area and associated with a variety of landforms. They were very deep, massive in structure, acidic with a texture grading from sandy loam to sandy clay loam subsoil down the profile. The soil profile displayed little colour variation, whole coloured (Haplic) between the A and B horizons, except for a darkening of the surface from organic staining.

One site was classified as Petroferric in the great group, which are soils with a B horizon either containing or directly underlain by ferricrete or cemented ferruginous nodules or concretions. Mottled and Ferric subgroups were also common in the profiles classified. Analysed soils were classified as dystrophic in the great group (Appendix 4).

The Red Kandosols located on minimal slopes were the most suitable for agriculture.

Figure 6-3: Deep sandy Red Earth (Red Kandosol) typical of soil across the gently undulating plains (land unit 8a)

6.3.1.2 Tenosols

Tenosols are soils with a weak pedological development apart from the A horizon (Isbell 2002). They have a weakly developed soil profile which is typically very sandy and without obvious horizons.

Tenosols were the least common of the three soils found in the survey area. The Red-Orthic Tenosols observed were shallow gravelly soils, with weakly developed A and B horizons, and minimal accumulation of organic matter at the surface. Of the two sites described, one site was classified as Paralithic in the great group which are soils which overlie partially weathered or decomposed rock or saprolite.

6.3.1.3 Hydrosols

Hydrosols are defined as seasonally or permanently wet soils (Isbell 2002). These poorly and very poorly drained soils typically occur in tidal areas and locations prone to flooding and seasonal waterlogging.

The most dominant Hydrosol had the major part of the solum mottled (Redoxic). The presence of mottles in these soils indicates oxidising and reducing conditions. Hydrosols not mottled were identified around the lower lying areas including tidal flats, mangroves and beach ridges. Most sites were not classified past great group because soil saturation or inundation prevented a full profile analysis. Of the twenty three Hydrosol sites, eighteen sites were Kandosolic (Redoxic) two sites were Tenosolic Oxyaquic) and three unknown in the great group. Two sites were classified as bleached in the subgroup.

6.3.2 Soil chemistry

Twenty four soil profiles were sampled at depths of 0-10, 10-20, 20-30, 50-60, 80-90, 110-120, 140-150, 170-180 cm for laboratory analysis. The sites of these samples are listed in Table 6-6 and their distribution shown in Figure 6-3. National Association of Testing Authorities (NATA) accredited testing of all soil samples was conducted by The Queensland Department of Science, Information Technology, Innovation and the Arts. Soil laboratory testing was undertaken according to Rayment and Lyons (2011) (Appendix 5). The reasons for these tests are presented in Appendix 6.

Table 6-6: Soil chemistry sampling sites

Soil Order	Site No.	Total Sites Analysed
Kandosols	Pit 1, Pit 2, Pit 3, Pit 4	4
Kandosols	001, 002, 005, 006, 008, 009, 010, 011, 012, 019, 023, 026, 028, 030, 034, 038, 063,	17
Tenosols	004	1
Hydrosols	018, 020, 021, 022, 032, 065,	6

Chemical and physical properties of each dominant soil type are summarised below with representative soil profiles summarised in Appendix 2.

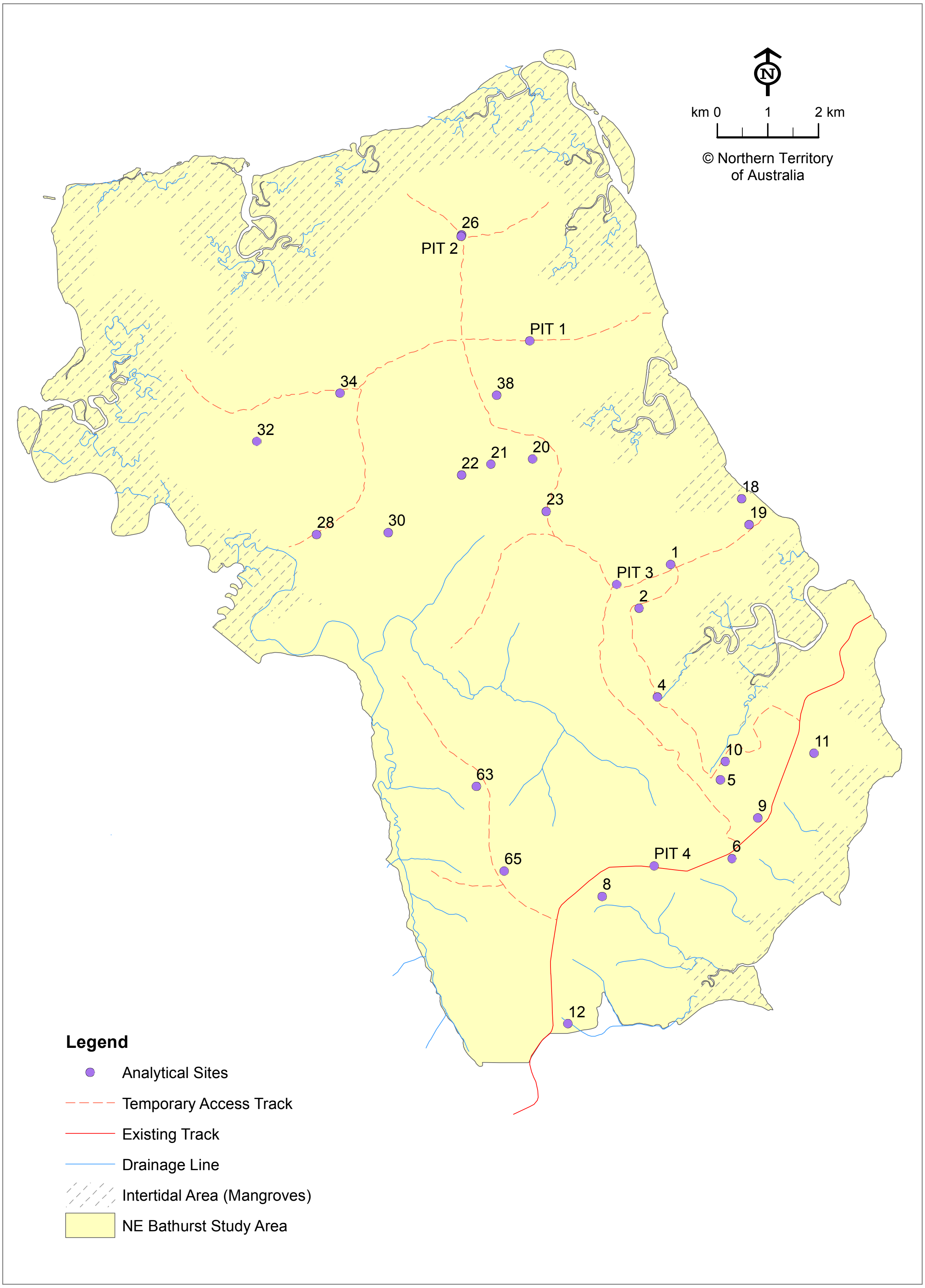

Figure 6-3: Soil chemistry sampling sites

6.3.2.1 Red Kandosols

Kandosols in the survey area had very low levels of nutrients in particular low levels of phosphorus (P) and nitrogen (N). Soils were strongly acidic (pH 4.0-5.0). Salinity (<2 ds/m) and chloride (Cl) levels were very low throughout the profile. All major cations, sodium (Na), potassium (K), calcium (Ca) and magnesium (Mg), were very low. Trace elements or micronutrients Copper (Cu), and zinc (Zn) were also very low, with manganese (Mn) present at low levels (<2 mg/kg). Iron (Fe) was present at higher levels in the upper topsoil profile then the subsoil profile. Sulfur (S) was high in the subsoil profile. The cation exchange capacity (CEC) was very low (3 cmol(+)/kg). Exchangeable sodium percentage (ESP) was not calculated because this parameter is not reliable when the CEC is below 3 cmol(+)/kg and exchangeable sodium is less than 0.3 cmol(+)/kg (Isbell 2002). Soils were calcium deficient (Ca/Mg ratio <1) and base saturation was very low (< 5 cmol (+)/kg – Dystrophic).

The fine sand fraction dominated the A and B horizons accounting for 40 - 48% of total particles with coarse sand accounting for 27 - 30%. Silt content was very low in the B horizon. Clay content increased down the profile from 10% in the upper A horizon to 40% in the lower B horizon. The C horizon was not encountered.

6.3.2.2 Red Orthic Tenosols

Tenosols in the survey area had very low overall fertility, nutrient availability and low water holding capacity. Soils were without obvious horizons, sandy, shallow, and very strongly acidic (pH 4.0-4.5), becoming more acidic down the profile. These earthy sands were more acidic than the sandy Red Kandosols. Salinity (<2 ds/m) and chloride (Cl) levels are very low throughout the profile. Major cations sodium (Na), potassium (K), calcium and magnesium (Mg) are very low. Trace elements or micronutrients Copper (Cu), and zinc (Zn) were also very low, with manganese (Mn) present at low levels (<2 mg/kg). Iron (Fe) was present at high levels in the upper topsoil profile with Sulfur (S) levels moderate in the subsoil profile. Soils were non sodic with cation exchange capacity (CEC) and exchangeable sodium very low.

Coarse sand fraction dominated the A and B horizons accounting 55 - 60% of total particles with fine sand accounting for 30 - 35% of total particles. Silt content was low throughout the profile. Clay content increased down the profile from 10% in the upper A horizon to 15% in the lower B horizon. The C horizon was not encountered.

6.3.2.3 Redoxic Hydrosols

Hydrosols in the survey area consisted of poorly drained infertile soils with the accumulation of organic matter at the surface in some areas. Soils were very strongly acidic (pH 4.5-4.7). Salinity (<2 ds/m) and chloride (Cl) levels are very low throughout the profile. Nitrogen (N) was very low (% by weight <0.05).The major cations, sodium (Na), potassium (K), calcium (Ca), and magnesium (Mg) were also very low. Colwell phosphorus (P) was very low (<5 mg P/kg soil). Trace elements copper (Cu), and zinc (Zn) were very low, with manganese (Mn) present at low levels (<2 mg/kg), and iron (Fe) present at higher levels in the upper profile. Sulfur (S) was very high in the subsoil profile. The cation exchange capacity (CEC) was very low (<3 cmol(+)/kg) throughout the profile, therefore suggesting that aluminium toxicity could occur when soil pH

($CaCl^2$) is below 4.7. Calcium was low (Ca/Mg ratio 1/4), and base saturation was very low (Dystrophic < 5 cmol(+)/kg) in the subsoil horizon.

The fine sand fraction dominated the A and B horizons accounting for 40 - 50% of total particles with coarse sand accounting for 35 - 40%. Silt content was low throughout the profile. Clay content increased down the profile from 20% in the upper A horizon to 30% in the lower B horizon. The C horizon was not encountered.

6.3.3 Soil hydrology

An additional four soil pits were located in areas most suitable for agriculture, on deep well drained Red Kandosols. The location of Pits 1 - 4 are presented in Figures 6-3. Average saturated hydraulic conductivity results are presented in Table 6-7. These were measured at pit sites at a number of levels down the profile utilising a 400 mm diameter ring and oblique ruler, with saturation results recorded at thirty second intervals. It is important to note that hydraulic properties of a soil can vary significantly so variability in the results should be expected.

Soil cores were taken at selected horizons down to a depth of 100 cm using 76 mm diameter rings and undisturbed sampling methods. Soil cores were sent to Soil Water Solutions, Adelaide for measurement of soil bulk density, water holding and hydraulic properties. The resulting report titled *Physical and water handling properties of soils on Bathurst Island in the Northern Territory* (Hignett, 2014) is provided in Appendix 7. The saturated hydraulic conductivity results in the soil water solutions report should be used with caution due to the disturbance of soil cores during transport.

The Red Kandosols had moderate to high infiltration rates in the surface soils which decreased with depth. Water holding capacity, porosity, bulk density and air filled porosity are all within the range suitable for agricultural production (Hignett, 2014). At the time of measurement the soil surface was undisturbed.

Table 6-7: Soil infiltration rates

Soil Pit	Soil Depth (cm)	Mean Saturated Hydraulic Conductivity (mm/min)
1	0 - 10	3.2
	70 - 80	0.5
2	0 - 10	2.8
	40 - 50	0.4
3	0 - 10	1.4
	50 - 60	0.9
	80 - 90	0.5
4	0 - 10	2.3
	50 - 60	0.5
	80-90	0.3

6.4 Vegetation

Fourteen main vegetation communities were described. These are summarised in Table 6-8 and are described in further detail in Section *6.4.1 Vegetation Communities*. The extent of these communities is based on the most common community/communities described in the land unit and does not account for variability or minor communities that may occur within the land units. Four other minor vegetation communities are mentioned in the land unit descriptions. They are not described in further detail here but are listed as a footnote to Table 6-8.

Most of the area consists of eucalypt woodland/open woodland and although noted as being extensive and botanically rich (Fensham and Woinarski 1992) there is little striking variation between the species composition. Structural differences occur however and as suggested by Woinarski *et al.* (2000) are due more to fire than soil preferences and characteristics. Structurally, the canopy heights and cover in both the upper and mid strata are notably taller and usually denser than on the mainland. This can be attributed to the highest rainfall in the NT and the earlier start to the wet season, usually a month before the mainland. These eucalypt communities are the tallest in the Territory with exception of Coburg Peninsula and further emphasises the distinct and unique value of the biota on these islands.

Non eucalypt communities are dispersed throughout the study area according to their landform and edaphic preferences and were found in riparian areas, swamps, coastal areas or discrete patches on the fringes and margins of plateau surfaces and plains.

Table 6-8: The main vegetation communities, distribution across land units.

Broad vegetation type	Vegetation Community*	Land unit	Approx. coverage in the land unit (%)	Extent in the land unit (ha)	Total extent (ha)
Eucalypt dominated open woodland to woodland	*Eucalyptus miniata*, *Corymbia nesophila* and *Eucalyptus tetrodonta* Tall woodland/open woodland	8a 8a1 8c1	100 100 20	5,910 3,200 90	9 200 ha
	Eucalyptus miniata and *Eucalyptus tetrodonta* Very tall open woodland	6a 7a 8b	80 100 100	120 190 70	380 ha
	Eucalyptus tetrodonta, Corymbia bleeseri and +/- *Eucalyptus miniata* Very tall open woodland/woodland	5a	100	730	730 ha
Mixed species open woodland	*Lophostemon lactifluus*, +/- *Corymbia nesophila* and +/- *Melaleuca* spp. Open woodland	8c	80	1 110	1 110 ha

Broad vegetation type	**Vegetation Community***	**Land unit**	**Approx. coverage in the land unit (%)**	**Extent in the land unit (ha)**	**Total extent (ha)**
Monsoon forest	Wet evergreen monsoon forest	10a 10b	10 100	110 230	340 ha
	Dry evergreen monsoon forest	8d	80	100	100 ha
	Dry semi-deciduous monsoon thicket	8d	20	30	30 ha
Sedgeland	Freshwater sedgeland	10c 10a	100 10	290 110	400 ha
	Saline sedgeland	12d	100	60	60 ha
Melaleuca forest and woodland	*Melaleuca viridiflora* and +/- *Melaleuca leucadendra* forest	10a 11b	30 100	330 20	350 ha
	Melaleuca viridiflora and +/- *Melaleuca nervosa* and +/- *Lophostemon lactifluus* woodland	8c1 10a 11a	80 50 90	350 550 240	1 140 ha
Mangroves and saltflats	*Rhizophora stylosa* Tall closed forest	12a	45	1 850	1 850 ha
	Ceriops tagal, *Bruguiera* spp. Mid high closed forest	12a	35	1 440	1 450 ha
	Samphire shrubland	12b	100	140	140 ha

* Other communities with small extents were:

i) Eucalypt dominated woodland to open woodland not listed above (land units 7a, 8c, 12c);

ii) *Melaleuca dealbata* open woodland (land unit 12c);

iii) Mixed species open shrubland to shrubland (land units 6a, 11a), and;

iv) *Avicennia marina* and mixed species mid high open forest (land unit 12a)

6.4.1 Vegetation communities

6.4.1.1 Eucalyptus miniata, Corymbia nesophila and Eucalyptus tetrodonta tall woodland/open woodland

This community is the most extensive in the study area and is a combination of *Eucalyptus miniata*, *Corymbia nesophila* and *Eucalyptus tetrodonta*. Generally the shrub or mid strata is reasonably dense ranging from 5 – 30% cover and the ground strata is commonly dominated by shrub and tree species rather than grasses. Common species include *Livistona humilis*, *Acacia leptocarpa*, *Cycas armstrongii*, *Erythrophleum chlorostachys* and *Alphitonia excelsa*. These communities are typically tall and can reach in excess of 25 m (some exceed 30 m) with an average crown cover of 14%. These occur on well drained plains predominately on very deep Red Kandosols.

6.4.1.2 Eucalyptus miniata and Eucalyptus tetrodonta very tall open woodland

The *Eucalyptus miniata* and *Eucalyptus tetrodonta* communities (exclusive of the Melville Island bloodwood) are found on hillslopes on well drained shallow Red and Brown Kandosols or on undulating plains on deep well drained Red Kandosols. These communities were generally tall ranging from 20 to 24 m with an average crown cover ranging from 12 to 14%.

6.4.1.3 Eucalyptus tetrodonta, Corymbia bleeseri and Eucalyptus miniata very tall open woodland/Woodland

This community was generally found on hillslopes, hill crests and rugged terrain on very gravelly, shallow Red or Brown Kandosols. The average height was 30 m with an average crown cover of 20%.

6.4.1.4 Lophostemon lactifluus, +/- Corymbia nesophila +/- Melaleuca spp. open woodland

These communities are found on seasonally wet plains, swamps, drainage depressions and along drainage lines on poorly drained deep Kandosolic Redoxic Hydrosols. Other common species included *Livistona humilis*, *Acacia leptocarpa*, *Banksia dentata* and *Pandanus spiralis*. The average height ranged from 9 to 14 m with an average crown cover of 12 to 19%.

6.4.1.5 Wet evergreen monsoon forest

These communities were mapped in discrete pockets and fragmented patches where there is persistent free surface or ground water. They are found along creek and drainage lines, seepage zones, swamps and flood plain fringes on poorly drained Kandosolic Redoxic Hydrosols. The average height was 19 m with an average crown cover of 72%. These communities are usually differentiated from 'dry' types by the presence of *Melicope elleryana*, *Fagraea racemosa*, *Planchonella xerocarpum*, *Myrsine pedicellata*, the palm *Hydriastele wendlandiana* and the fern *Dicranopteris linearis* (Russell-Smith 1991; Fensham and Woinarski 1992; and Brocklehurst 1998).

6.4.1.6 Dry evergreen monsoon forest

As the name implies, these communities are found on sites where water during much of the year is not freely available and the soil profiles are dry. They were commonly found on moderately well drained plains that exist above drainage depressions or seepage zones or on plateau surface margins before the landscape drops away to coastal habitats. Common tree species include *Diospyros calycantha*, *Litsea glutinosa*, *Polyalthia australis*, *Canarium australianum*, *Syzygium forte ssp. forte* and *Terminalia macrocarpa* (Russell-Smith 1991; Fensham and Woinarski 1992; and Brocklehurst 1998). The average canopy height was 16 m with an average crown cover of 71%.

6.4.1.7 Dry semi-deciduous monsoon thicket

These communities are found on the rocky margins and scarps of coastal foreshore habitats. The soils are generally shallow, well drained Red Kandosols. The common species are largely semi-deciduous rather than the evergreen species described in the communities above. Common species include *Croton habrophyllus*, *Drypetes lasiogyna*, *Ixora klanderana*, and *Strychnos lucida*. These communities are usually distinguished by the presence of *Diplospora australis*, *Memecylon pauciflorum*, *Pouteria sericea* and *Stenocarpus salignus* (Russell-Smith 1991; Fensham and Woinarski 1992; and Brocklehurst 1998). The average canopy height was 22 m with an average crown cover of 88%.

6.4.1.8 Freshwater sedgelands

These communities are found as small discrete components of the wetland and riparian vegetation that occur along creek lines, seepage lines, swamps and coastal environments. The soils are poorly drained and are usually inundated Kandosolic Redoxic Hydrosols. These are generally dominated by *Dapsilanthus* and *Schoenus* species and the grass *Eriachne triseta*. The average height was 0.6 m with an average ground cover of 72%.

6.4.1.9 Saline sedgeland communities

These communities fringe tidal areas on poorly drained Oxyaquic Hydrosols. They are commonly dominated by *Eleocharis* species and *Schoenoplectus littoralis*. The average height is 0.5 m with an average ground cover of 50%.

6.4.1.10 Melaleuca viridiflora and +/- Melaleuca leucadendra forest

This community was found in the centre of a large swamp in the middle of the study area however it is likely that other small discrete populations may occur elsewhere particularly in riparian zones. The soils are deep poorly drained Kandosolic Redoxic Hydrosols which are likely to remain inundated in most years. The average height was 16 m with an average crown cover of 60%.

6.4.1.11 Melaleuca viridiflora +/- Melaleuca nervosa and +/- Lophostemon lactifluus woodland

These communities are found on seasonally wet plains, drainage flats, drainage depressions, swamps and as complexes in broader riparian vegetation communities. Although they occupy areas that are poorly drained and seasonally inundated they can tolerate a moisture range from landscapes that seasonally dry out to those that remain wet for much or all of the year. Common species of these habitats include *Asteromyrtus symphomyrtus*, *Grevillea pteridifolia*, *Petalostigma pubescens* and *Banksia dentata*. In areas that remain wet or inundated for longer periods, the canopy heights are often taller and the cover more dense. Common species in these wetter habitats include *Pandanus spiralis*, *Melastoma malabathricum*, *Osbeckia australiana*, the fern *Dicranopteris linearis* and the sedges *Dapsilanthus* and *Scleria* species. Soils are poorly drained, deep Kandosolic Redoxic Hydrosols. The average height was 9.5 m with an average crown cover of 14.5%.

6.4.1.12 Mangrove and salt flat communities

Mangrove and salt flat communities are found along tidal creeks, coastal flats and foreshores. Soils are deep and saline (Intertidal Hydrosols) that are subject to tidal inundation. These communities vary and occur in zones according to tidal elevation. The two main mangrove communities in the study area are described below, along with the main salt flat community.

6.4.1.13 Rhizophora stylosa closed forest

This community is generally found on the tidal sections of creeks, creek banks and at river mouths (Brocklehurst and Edmeades 1996). The height ranges from 10 to 14 m with crown cover ranging from 60 to 80%.

6.4.1.14 Ceriops tagal closed forest

This community generally occurs on the landward side of the inner mangrove communities where the tidal influence is less frequent. These areas are usually the margins of tidal flats and creeks. The height ranges from 5 to 10 m with crown cover ranging from 70 to 90%.

6.4.1.15 Samphire shrublands

These communities exist on coastal flats on salt encrusted clays (Supratidal Hydrosols) that are generally inundated during spring tides. They are dominated by succulent species such as *Tecticornia indica*, *Tecticornia australasica* and *Suaeda arbusculoides*. The average height is < 0.5 m with an average ground cover of < 10%.

6.4.2. Significant vegetation communities

The terms significant and sensitive are somewhat interchangeable however these vegetation communities are best described as having high diversity values by containing flora or a suite of species that have conservation significance as identified by *The International Union for the Conservation of Nature* (IUCN), or support large populations of wildlife, have important wetland values, concentrations of threatened or endemic species or are considered botanical hot spots (Ward and Harrison 2009; Environment Australia DIWA 2001; Woinarski *et al.* 2000).

Five significant vegetation communities were identified, Riparian, Wetland, *Melaleuca* Forest, Monsoon forests and thickets (wet and dry) and Mangroves. All are particularly sensitive to disturbance, specifically fire, invasive plant species, feral animals or domestic stock, infrastructure and development. These are summarised in Table 6-9.

Table 6-9: Significant vegetation communities in the study area

Significant Communities	Land Unit	Landforms
Riparian	10a, 10b, 10c	Creeks, springs and watercourses
Wetlands	10a, 10b, 10c, 11a, 12a, 12d	Drainage depressions, swamps and occasionally saline marshes
Melaleuca forests	10a, 11b	Creeks and swamps
Wet Monsoon Rainforest	10a, 10b	Creeks, springs and drainage depressions
Dry Evergreen Monsoon Rainforest	8d	Lower side slopes
Dry Semi-deciduous Monsoon thickets	8d	Lower side slopes
Mangroves	12a, 12b	Tidal flats, salt flats and tidal creeks

6.4.2.1 Riparian vegetation

Riparian habitats are highly variable and often contain a complex of communities including monsoon rainforest pockets, melaleuca forests, sedgelands or grasslands and consequently contain a high level of biodiversity. These habitats occur adjacent to rivers and creeks and other drainage areas. Riparian areas protect the adjacent water body by acting as filters for sediments in overland flows moderating temperature fluctuations and oxygen levels, creating suitable breeding habitats for aquatic and other species and reducing erosion and stabilising stream banks. These areas also provide important refuge and habitats for fauna and other terrestrial species especially during the dry season or fires. The presence of water and plant growth leads to soils that are often rich in organic matter and nutrients and consequently these habitats are highly productive ecosystems particularly in northern Australia where many habitats are nutritionally poor.

6.4.2.2 Wetlands

Wetland communities in the Top End exist on seasonal and intermittent swamps, drainage depressions, lagoons, flood plains, the outer margins of some river and creek systems and also include coastal marshes, mangrove swamps and saline lakes. These communities are inundated or saturated at a frequency that supports plants/animals that are adapted to these conditions (Brocklehurst and Lynch 2001). As with the other significant communities described these have a high conservation value in the terms of plants, animals and habitat.

6.4.2.3 Melaleuca forest

Although these communities are broadly included in the Riparian and Wetland descriptions it is important to recognise that these habitats occur relatively frequently in the study area. Closed or open forests, specifically mono specific habitats, are considered significant because they provide niche habitats for a selection of species dependent upon them. For instance, *Melaleuca* forests are especially important habitats for waterbirds and aquatic fauna.

Melaleuca forests usually occur as narrow strips or small pockets of pure dense stands in riparian areas and in or around swamps. They are dominated by *Melaleuca leucadendra* and *Melaleuca viridiflora* and are typically inundated for long periods. As indicated in *5.2.2 Surface Water Investigations*, most have floodmarks on tree trunks recorded in excess of 1 m.

6.4.2.4 Monsoon forest

The Northern Territory has the largest area of monsoon forests and thickets in Australia totalling 2 700 km² and these contain over 600 species (13%) of all NT flora making them highly diverse and significant (DLRM fact sheet). The monsoon forests and thickets on Tiwi Islands are particularly diverse and highly significant, approximately 17 000 ha in area and have more than three hundred individual plant species equating to greater than 50% of all monsoon flora in the NT. To emphasise the diversity in these patches, the greatest number of species recorded in a wet monsoon forest site during this survey was 100 species and the greatest number of species recorded in a dry monsoon forest/thicket was 74 species. Monsoon forests are also significant because they usually contain a high diversity of tree and vine species and many bearing fruit that are vital to a number of territorial, birds and insect species. They also provide shelter and food resources in times of stress, such as the late dry season.

Monsoon forests exist as fragmented populations and usually occur in small discrete patches. Monsoon forests on the Tiwi Islands are distributed across more of the landscape than anywhere else in the Top End of the Northern Territory (Woinarski *et al.* 2000).

6.4.2.5 Wet evergreen monsoon forest

These communities exist on sites where free water is present either from drainage channels or spring fed. They occur along creek lines in discrete pockets, tops of drainage lines and gullies or margins of swamps.

6.4.2.6 Dry evergreen monsoon forest

These communities occur on 'dry' habitats where surface or spring water is scarce. They are generally found on margins above 'wetter' sites or coastal habitats on well drained deep Red Kandosols.

6.4.2.7 Dry semi-deciduous monsoon thickets

These communities usually exist on margins of remnant plateau surfaces and scarps before these drop away to mangrove or coastal habitats. They are associated with rocky ferruginous substrates and shallow soils.

6.4.2.8 Mangroves

Mangrove communities can be found on tropical and subtropical coast lines, tidal rivers and creeks and they can be highly variable and include trees, palms, shrubs, vines, samphires, grasses and ferns. They include a mosaic of vegetation types from tall closed forests to low open woodland plus integral components such as samphire (Woinarski *et al.* 2000). The mangrove communities in the Top End are among the most diverse in Australia making them a significant resource locally and globally (Brocklehurst and Edmeades 1996). They support highly specialised animals, provide spawning and nursery areas for many species and protect the coastline from erosion during storm surges including cyclones. They are also highly valued by Traditional owners.

6.5 Land evaluation

Land evaluation identifies the key biophysical characteristics of each land unit that could influence a number of general land uses (Napier & Hill, 2012).

The key factors considered important for land evaluation in the survey area are;

- Slope;
- Rock outcrop;
- Soil depth;
- Soil drainage;
- Erosion risk, and;
- Acid sulfate soils.

These six factors were used to evaluate the land characteristics of each land unit and determine a limitation class. Limitation classes are numbered one to four. The lower the limitation the more suitable the land is to a range of land uses. The limitations for each land unit are summarised in Table 6-10 and described below, with 1 being defined as the least limited and 4 being defined as most limited.

Table 6-10: Limitations of each land unit for a range of land uses according to multiple criteria

Land Unit	Slope	Rock Outcrop	Soil Depth	Soil Drainage	Erosion Risk	Acid Sulfate Soils	Agricultural Land Suitability	Significant Vegetation Communities*
5a	4	3	3	1	4		4	
6a	4	1	4	1	3		4	
7a	4	1	1	1	2		4	
8a	2	1	1	1	2		2	
8a1	3	2	1	1	2		3	
8b	3	1	1	1	2		3	
8c	2	1	1	3	2		3	
8c1	2	1	1	3	2		3	
8d	3	1	1	1	2		3	Present
10a	2	1	1	4	1	Present	4	Present
10b	2	1	2	4	1	Present	4	Present
10c	2	1	1	4	1	Present	4	Present
11a	2	1	1	4	1		4	Present
11b	2	1	1	4	1		4	Present
12a	2	1	1	4	1	Present	4	Present
12b	2	1	1	4	1	Present	4	Present
12c	2	1	1	4	1	Present	4	
12d	2	1	1	4	1	Present	4	Present

*From Table 6-9

6.5.1 Slope

Slope is a critical element that influences runoff and soil erosion. The risk of soil loss from water erosion increases with slope, particularly in the survey area where rainfall intensities are high. Use of any land with a slope greater than 0.5% in the survey area could pose a threat to long term productivity of the land. Table 6-11 provides limitation classes for slope and Figure 6-4 displays an overview of the slope limitations for the survey area.

Table 6-11: Limitation classes according to slope

Limitation	Slope Class (%)	Slope	Land Units	Area (ha)
1	0-1	Level	*	-
2	1-3	Gentle	8a, 8c, 8c1 10a, 10b, 10c 11a, 11b, 12a, 12b, 12c, 12d	14 374
3	3-10	Substantial	8a1, 8b, 8d	3 393
4	>10	Excessive	5a, 6a, 7a	1 066

*Not found in the survey area

6.5.2 Rock outcrop

The presence of rock outcrop reduces the area and volume of soil and creates unfavourable conditions for agricultural practices and other land uses. Most rock outcrop in the survey area was exposed on steep rises and there were small isolated patches on the lower slopes. There was no evidence of rock outcrop on the upland plains, lowland plains, drainage systems, and swamps. Table 6-12 shows the limitation classes for rock outcrop and Figure 6-5 displays an overview of the rock outcrop limitations for the survey area.

Table 6-12: Limitation classes according to rock outcrop

Limitation	Rock Outcrop (%)	Rock	Land Units	Area (ha)
1	0	None	6a, 7a, 8a, 8b, 8c, 8c1, 8d, 10a, 10b, 10c, 11a, 11b, 12a, 12b, 12c, 12d	14 908
2	0-2	Negligible	8a1	3 196
3	2-10	Rock	5a	729
4	>10	Abundant	-	-

6.5.3. Soil depth

Soil depth can restrict root penetration and the effective volume of soil that can be utilised by plants. Soil depth is a crucial element in most agricultural activities, and can play a key role in the determination of vegetation communities and species composition (Napier & Hill, 2012). Table 6-

13 provides limitation classes for soil depth and Figure 6-6 displays an overview of the soil depth limitations for the survey area.

Table 6-13: Limitation classes according to soil depth

Limitation	Soil Depth (m)	Soil Depth Class	Land Units	Area (ha)
1	>1.5	Very Deep	7a, 8a, 8a1, 8b, 8c, 8c1, 8d, 10a, 10c, 11a, 11b, 12a, 12b, 12c, 12d	17 731
2	0.5-1.5	Moderate	10b	228
3	0.25-0.5	Shallow	5a	729
4	<0.25	Very Shallow	6a	145

6.5.4. Soil drainage

Drainage is used to summarise local soil wetness conditions using the six classes defined by NCST (2009). For the purposes of this project these were condensed into four limitation classes (Table 6-14). The subsoil horizons within the survey area contained more clay than the topsoil horizons and hence were intrinsically less permeable than the topsoil. When rainfall rates exceed the permeability of the subsoil water will perch in the soil. This was evident in the poorly drained areas. Table 6-14 shows the limitation classes for soil drainage and Figure 6-7 displays an overview of the soil drainage limitations for the survey area.

Table 6-14: Limitation classes according to soil drainage

Limitation	Drainage Class	Soil Drainage	Land Units	Area (ha)
1	Rapid	No horizon is normally wet for more than several hours after water addition	-	-
1	Well	Soil may remain wet for several days after water addition	5a, 6a, 7a, 8a, 8a1, 8b, 8d	10 369
2	Moderate	Soil remains wet for up to a week after water addition	-	-
3	Imperfect	Soil saturation for several weeks after water addition	8c	1 388
3	Poor	Ponding and soil saturation for several months after	8c1	444
4	Very Poor	Water table remains at or near the surface for most of the year	10a, 10b, 10c, 11a, 11b, 12a, 12b, 12c, 12d	6 632

6.5.5. Erosion risk

Soil erosion is caused by the loss of soil due to the surface being exposed to wind and/or water. It reduces the productivity of agricultural land with rainfall driving the erosion process during the wet season. In areas of high rainfall intensity such as the survey area it is common for land units with gentle slopes (1 - 3%) to be considered as moderate to high erosion risk. Some minor rill and gully erosion was evident on the lower slopes around creeks and drainage lines where the landscape was devoid of vegetation, but generally it was absent. Areas subject to trafficking, such as temporary access tracks cleared of vegetation are prone to compaction and concentration of runoff along wheel ruts which are subsequently susceptible to rill and gully erosion. Any changes to the landscape can significantly accelerate erosion. Table 6-15 shows the limitation classes for erosion risk and Figure 6-8 displays an overview of the erosion risk for the survey area.

Table 6-15: Limitation classes according to erosion risk

Limitation	Erosion Risk	Runoff	Land Units	Area (ha)
1	Soils at low risk with minimal slopes	No Runoff	11a, 11b	6 632
1		Very Slow	10a, 10b, 10c, 12a, 12b, 12c, 12d	
2	Soils at risk due to gentle slopes	Slow	8a, 8c, 8c1	11 327
2		Moderately Rapid	7a, 8a1, 8b, 8d	
3	Soils at high risk due to substantial slopes	Rapid	6a	145
4	Soils at very high risk due to excessive slopes	Very Rapid	5a	729

6.5.6. Acid sulfate soils

Acid sulfate soils (ASS) in the Top End are largely restricted to intertidal environments and coastal plains where elevation is less than 5 m Australian Height Datum (AHD) and drainage is very poor (Hill & Edmeades, 2008). When disturbed the soils become highly acidic and can release significant acidity and heavy metals into the environment. Soil laboratory testing of Darwin Harbour intertidal soils identified extremely high potential acidity levels. Acid sulfate soils in the study area have been mapped and include tidal areas and landscapes formed on marine sediments, and drainage systems located immediately adjacent to the tidal zone. There was no evidence of ASS on upland plains or the wetter inland swamps. Table 6-16 summarises the ASS limitations in the land units of the study area. Figure 6-9 displays the location of ASS in the survey area. Although Table 6-16 and Figure 6-9 indicates that acid sulfate soils are present in land units 10a, 10b and 10c, the risk would be high immediately adjacent to the marine environment and significantly reduced or minimal further inland.

Table 6-16: Limitation classes according to acid sulfate soils

Limitation	Land Units	Area (ha)
Not Present	5a, 6a, 7a, 8a, 8a1, 8b, 8c, 8c1, 8d, 11a, 11b	12 488
Present	10a, 10b, 10c, 12a, 12b, 12c, 12d	6 345

6.6 Agricultural land suitability

The land suitability classification was determined from the types and severity of limiting factors for agricultural land use in each of the land units and summarised in Table 6-3. A land suitability class was determined by the highest ranking limiting attribute in Table 6-3. Table 6-10, which has been modified from FAO (1976 in Van Gool *et al.* 2008), summarises the agricultural land suitability class for each land unit and the areas of these classes. Agricultural land suitability classes have been mapped in Figure 6-10.

Table 6-16: Agricultural land suitability classes of land units

Class	Suitability	Description	Land Units	Area (ha)
1	Highly Suitable	Suitable land with minimal limitations. Highly productive requiring only low management practices. (Slope 0-1%; rock outcrop - nil; soil depth >1.5 m; soil drainage - rapid to well; erosion risk - low)	Not Identified	0
2	Moderately Suitable	Suitable land with only moderate limitations. Will require minor management practices. (Slope 1-3%; rock outcrop - 0-2%; soil depth 0.5 - 1.5 m; soil drainage - moderate; erosion risk - moderate)	8a	5 908
3	Marginally Suitable	Land having severe limitations. Will require major management practices. (Slope 3-10%; rock outcrop - 2-10%; soil depth 0.25-0.5 m; soil drainage - imperfect to poor; erosion risk - substantial)	8a1, 8b, 8c, 8c1, 8d	5 226
4	Not Suitable	Land not suitable for Agriculture, having extreme limitations. This includes undisturbed land with significant habitats, erosion risk due to steep slopes, soil depth, rocky outcrops, and poor drainage. (Slope >10%; rock outcrop - >10%; soil depth <0.25 m; soil drainage - very poor; erosion risk - high)	5a, 6a, 7a, 10a, 10b, 10c, 11a, 11b, 12a, 12b, 12c, 12d	7 699

There was no land considered highly suitable in the study area due to slope limitations. Land mapped as Class 2 (Land unit 8a) is considered moderately suitable for agricultural production. Class 3 (marginally suitable) is not considered suitable for agricultural production because high rainfall in the region combined with the substantial long slopes presents a high risk of erosion. The above agricultural land suitability classes do not take into account limitations of soil fertility. This would be a limiting factor for agriculture, especially on Kandosols which comprise 10 345 ha of the survey area (Table 6-4).

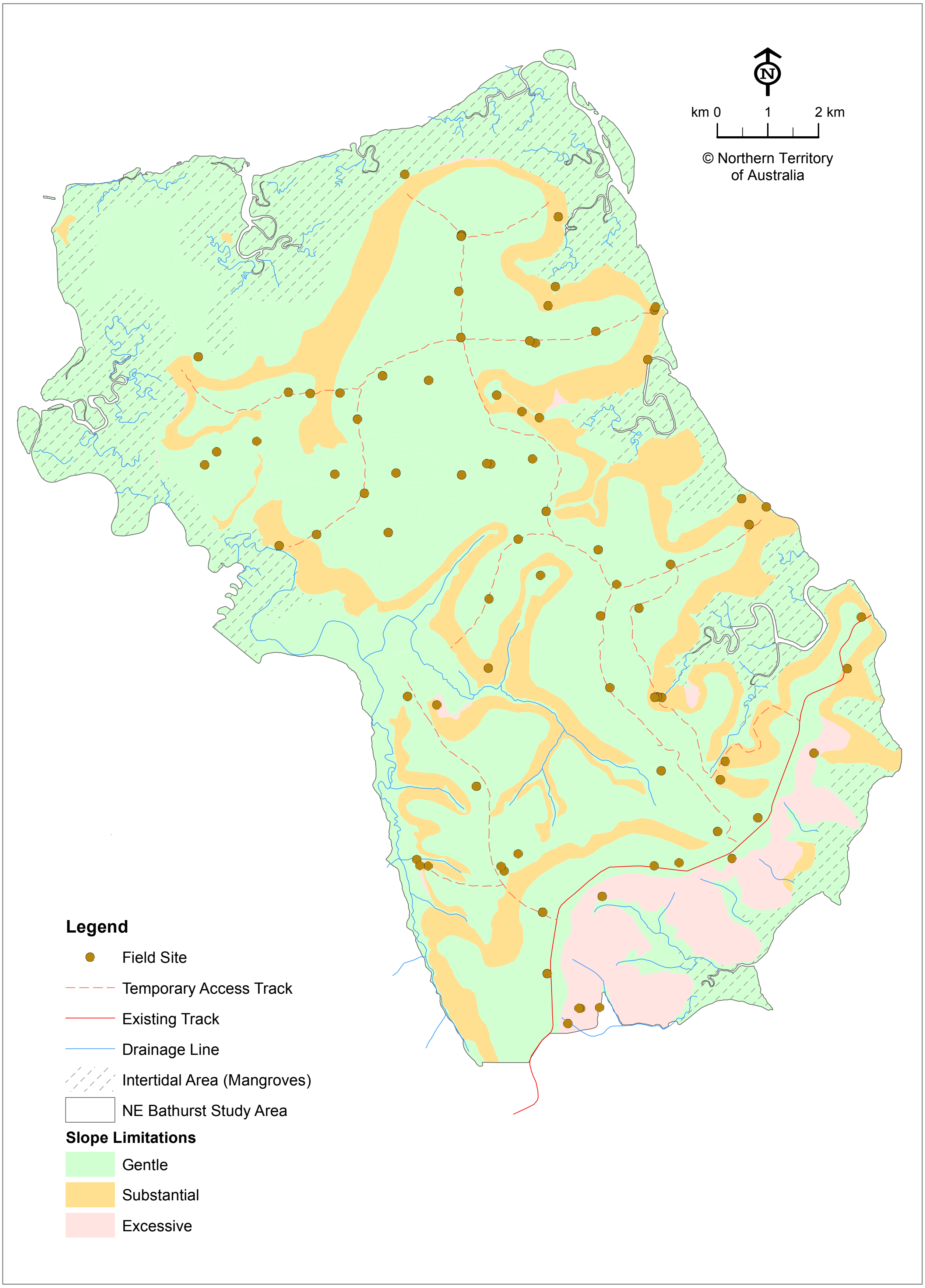

Figure 6-4: Slope classes

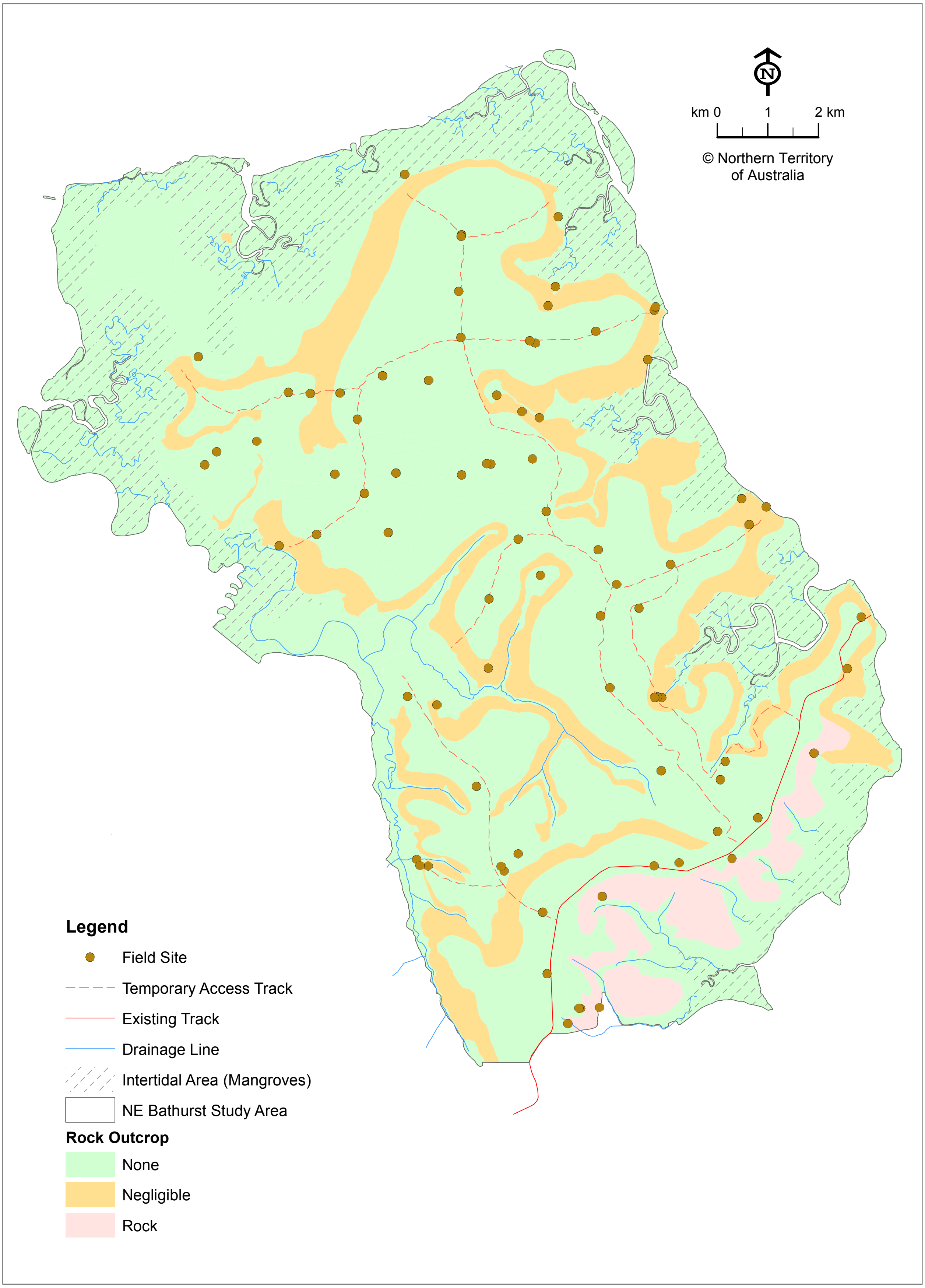

Figure 6-5: Rock outcrop classes

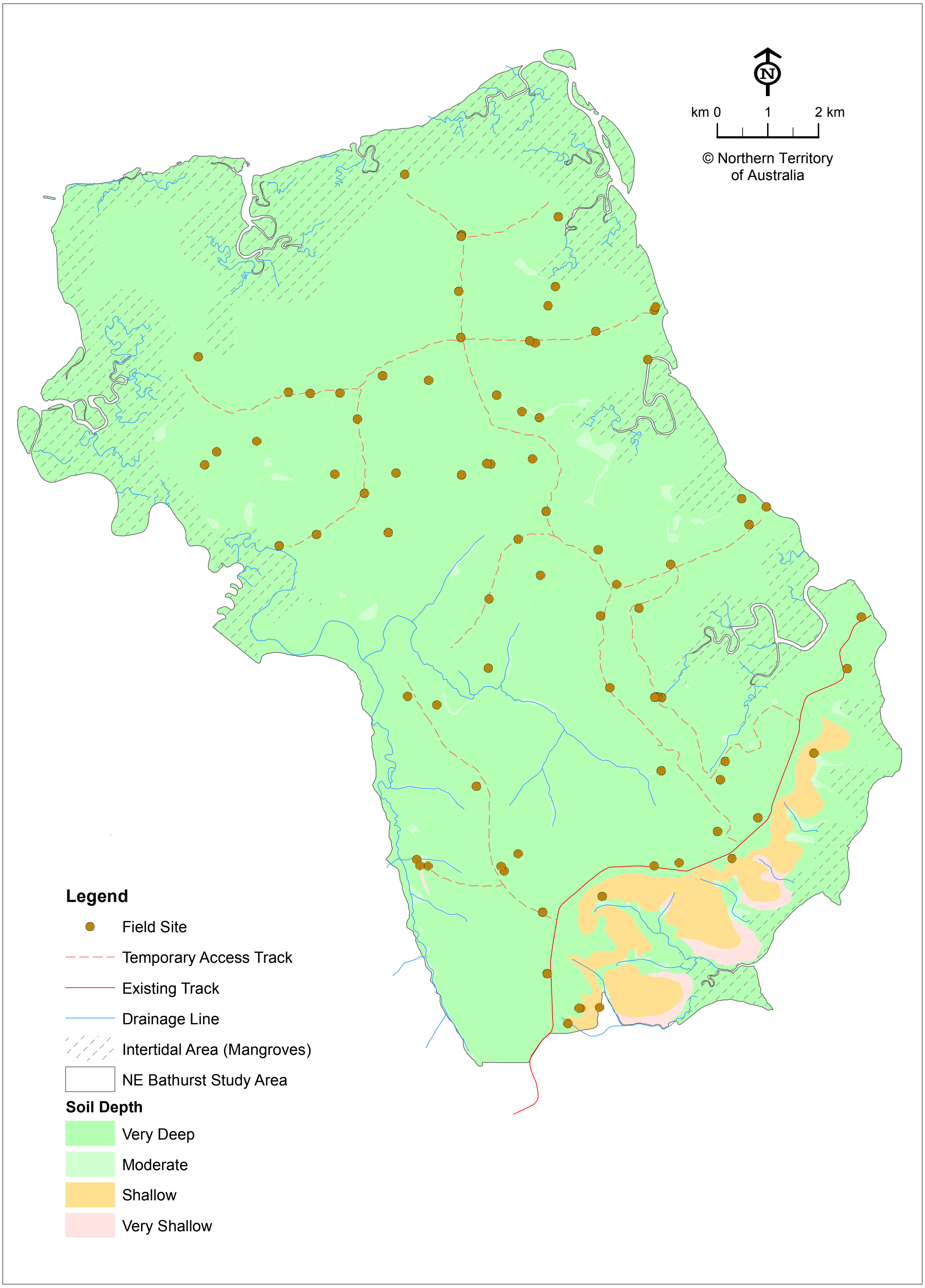

Figure 6-6: Soil depth classes

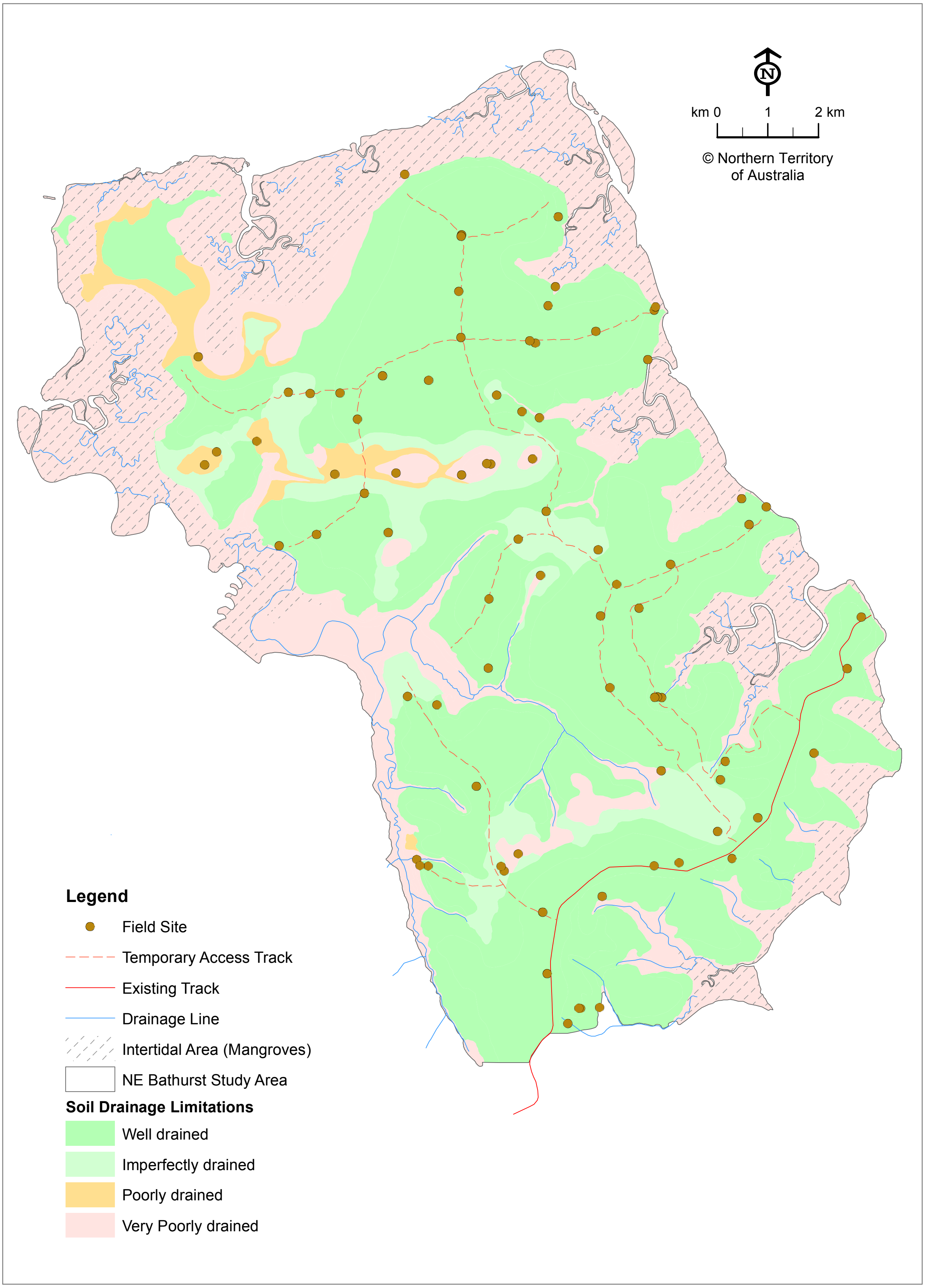

Figure 6-7: Soil drainage limitation classes

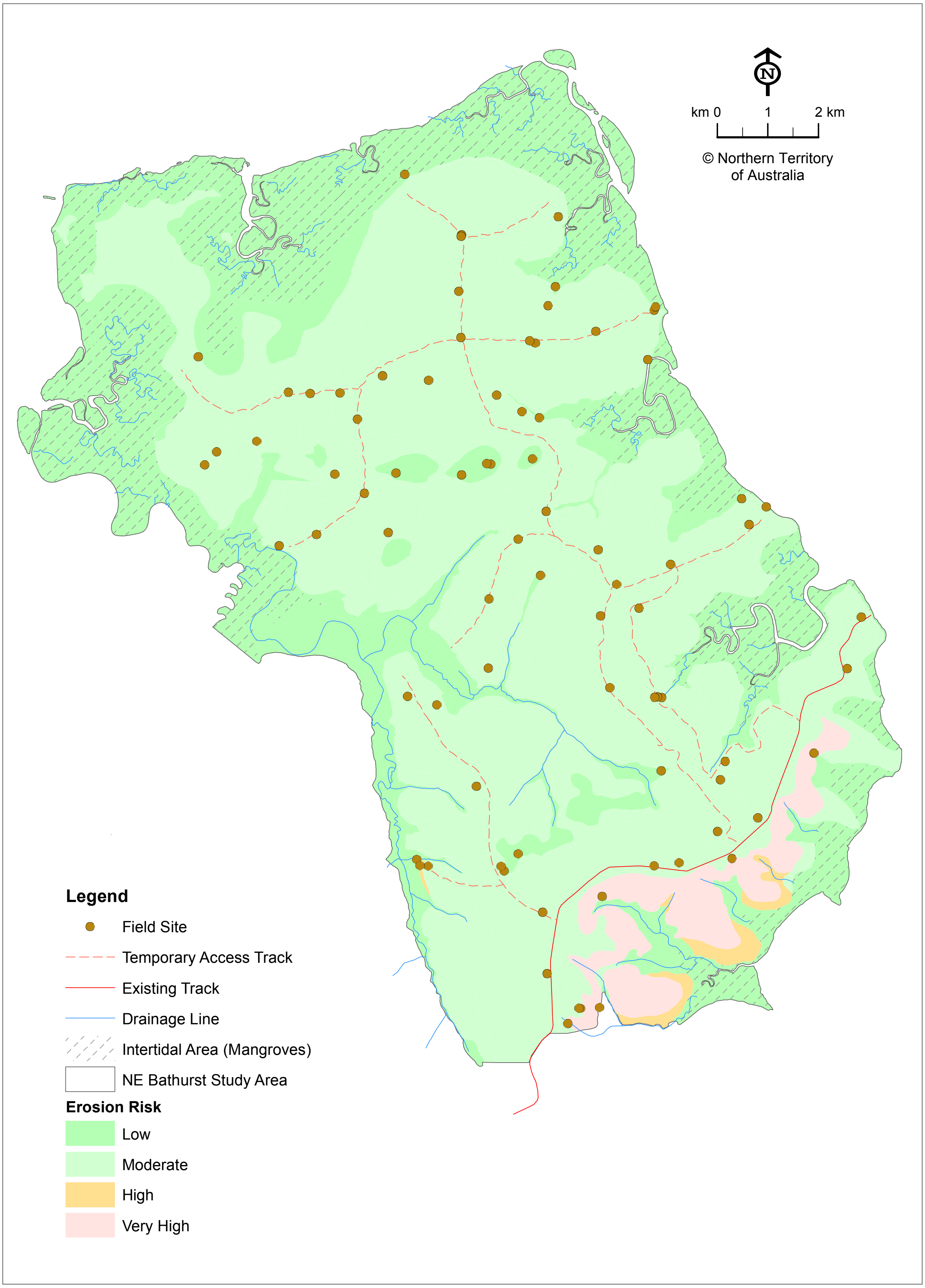

Figure 6-8: Erosion risk classes

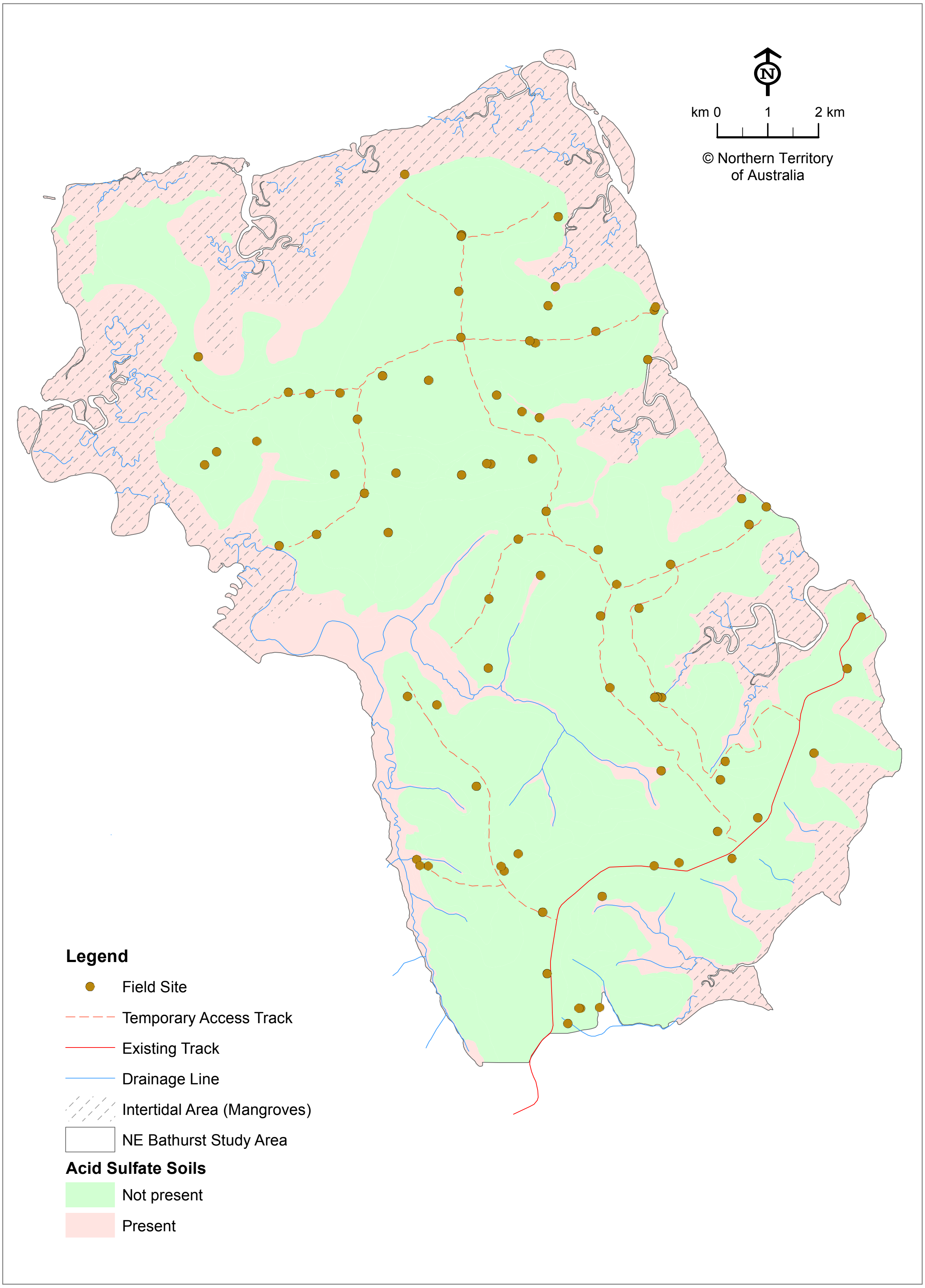

Figure 6-9: Presence and absence of acid sulfate soils

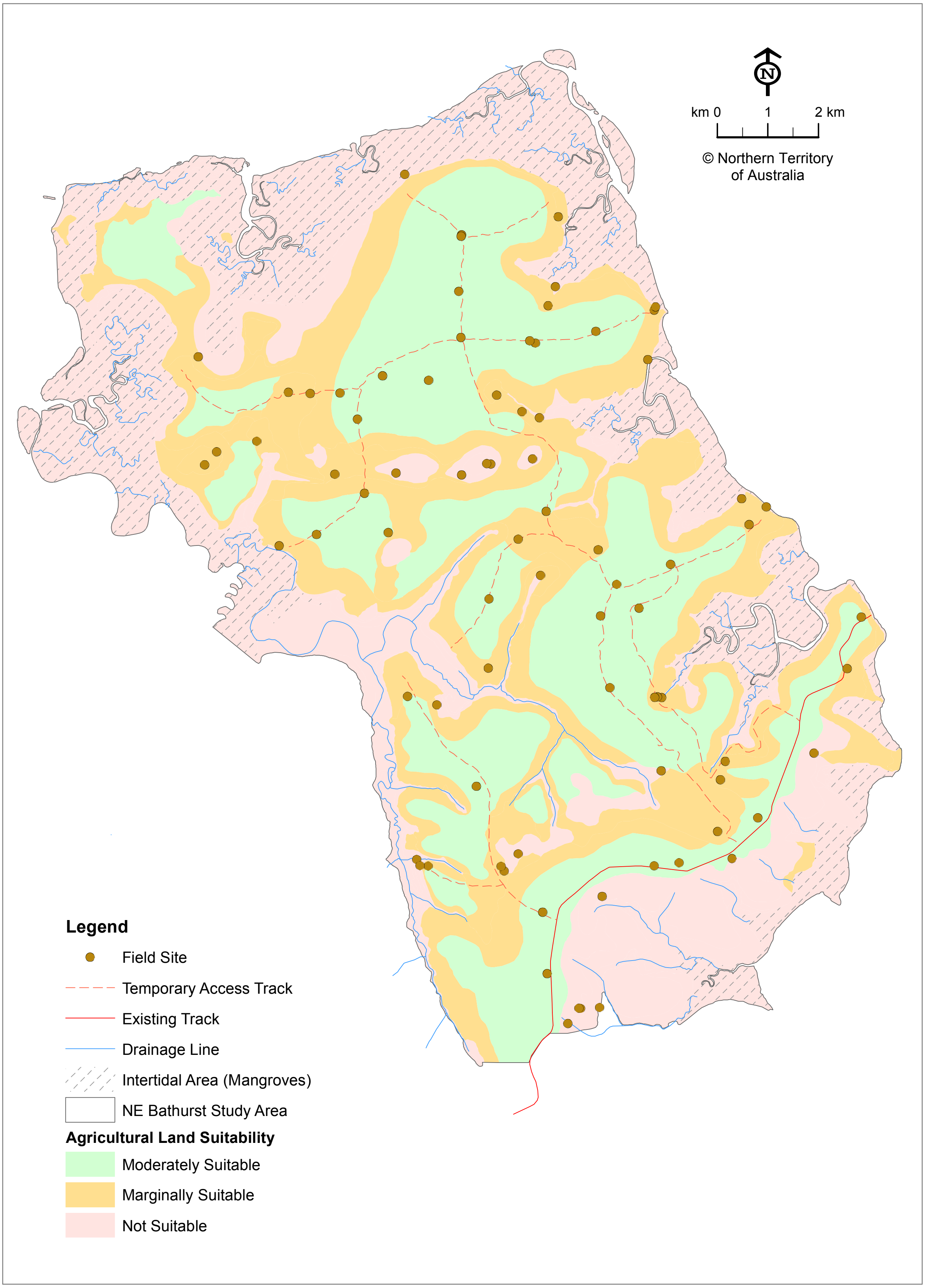

Figure 6-10: Agricultural land suitability

6.7 Management of soil erosion

The need for soil conservation in agricultural landscapes in the wet dry tropics of the NT is well documented. Key research undertaken in the 1990s in the Douglas Daly region (Dilshad, Motha and Peel, 1996) quantified the loss of soil on a number of agricultural plots under different management systems. A 2011 Department of Resources report on sustainable agriculture in the NT identified soil loss by erosion to be a major threat (Smith and Hill, 2011). Soil erosion can disrupt progress of development works, delay completion dates and create additional costs. Soil erosion is likely to result in damage to infrastructure and cropping areas, reduced agricultural productivity, extra maintenance costs and discharge of sediment to waterways and wetlands. Accepted practice recognises erosion control as an essential management component for sustainable agriculture in the semi-arid tropics (O'Gara, 2010).

Key factors for managing soil erosion include:

- timing and staging of development works
- appropriate vegetation clearing methods
- careful selection and placement of surface runoff and drainage controls
- minimising surface disturbance or modification that concentrates surface flow
- stabilisation and re-vegetation of disturbed soils
- controlling sediment to prevent discharge to sensitive environments
- use of monitoring and maintenance programs to ensure erosion controls remain effective

Timing and staging of works for erosion control generally focuses on lower risk periods such as the dry season. Installation of key erosion controls prior to major site disturbance and a progressive work schedule to limit the extent and duration of soil exposure is essential. Vegetation clearing should focus on minimum disturbance and retention of vegetation in key areas, especially adjacent to drainage lines. Areas not to be cleared should be clearly marked and clearing methods should avoid or minimise formation of flow paths in slash piles or wheel ruts that can accelerate concentrated runoff and create potential erosion.

Surface water and drainage control should aim at preventing the build-up of volume and velocity of surface water flows on disturbed and/or cleared areas and avoid or minimise the formation of concentrated flows. In broad acre situations this involves interception and control of surface flows with graded banks or diversion banks.

Suitable erosion control should be implemented to protect exposed soil surfaces and prevent or reduce erosion caused by raindrop impact and storm water flows. Loss of topsoil hampers revegetation and adversely affects the productive value of the site. Methods can include establishment of cover crops and pasture species or use of mulch. Infrastructure development such as tracks, trench back-fill and building pads or laydown areas should also be suitably stabilised.

Effective erosion control programs require planning and controlled implementation. The use of Erosion and Sediment Control Plans (ESCPs) is recommended to set out erosion and sediment control works appropriate to specific land developments. An ESCP is a schematic plan based on the development site, showing the location and technical specifications for all proposed erosion or sediment controls. The ESCP often includes notes and drawings to assist correct implementation. Further information on ESCP layout and content can be found on DLRM website at http://www.lrm.nt.gov.au/soil/management

7. Biodiversity

Kym Brennan, Ian Cowie, Nick Cuff, Matthew Fegan, Alaric Fisher, Graeme Gillespie, Tony Griffiths and David Liddle, Flora and Fauna Division

The vegetation assemblages, flora and vertebrate fauna of the Tiwi Islands are moderately well known due to a number of broad-scale vegetation, plant and fauna surveys; studies targeting particular environments, notably jungle patches; targeted surveys for and monitoring of threatened species; and environmental assessment associated with development, including forestry and sand mining projects. These data clearly demonstrate that Melville and Bathurst Islands (the second and fifth largest islands in Australia) have very high biodiversity values, which have been reviewed in detail by Woinarski *et al.* (2003) and summarised by Harrison *et al.* (2009, for the *Tiwi Islands* Site of Conservation Significance).

These biodiversity values include high plant species diversity; the presence of 51 listed threatened species (17 of which are listed as nationally threatened under the *Environment Protection and Biodiversity Conservation Act*); a large number of endemic and range-restricted species and subspecies; internationally significant aggregations of marine turtles, seabirds and shorebirds; a high density and extent of monsoon rainforest patches; and extensive areas of the tallest eucalypt open forest in the Northern Territory. Recent data suggests that the Tiwi Islands also appear to retain substantial populations of native mammal species that have undergone dramatic recent decline on the Northern Territory mainland.

Due to remoteness and limited vehicle access, detailed data for the flora and fauna of the upland areas of northern Bathurst Island is sparse and patchy. Field surveys in 2014 aimed to clarify the distribution and abundance of significant flora and vertebrate fauna species, particularly targeting listed threatened species for which the study area is likely to contain important habitat. Approaches to surveys and assessment differed for flora and fauna species, and these are described separately below. Data collected in 2014 and relevant existing data was used to assess the potential risks to biodiversity (and especially threatened species) from potential development of land suitable for agriculture within the study area, as well as to place northern Bathurst Islands with a regional (Tiwi Islands) context.

7.1 Flora

The flora of the Tiwi Islands is moderately well known from a combination of general and targeted survey and opportunistic sampling (Woinarski *et al.* 2003), with at least 1 200 native plant taxa recorded from Bathurst and Melville Island. The large size, prolonged isolation from the mainland and unique climatic regime of the Tiwi Islands has facilitated the development of a distinct flora associated with the diverse range of vegetation types present on the Islands. High degrees of endemism, particularly within rainforest, and the occurrence of a number of species restricted in their Australian distributions to the Islands has resulted in the recognition of the Tiwi's as a site of National and International significance with respect to significant and threatened plant species (Woinarski *el al.* 2003; Harrison *et al*. 2009; Liddle & Elliott 2008). The distribution of many of the significant plant species is not completely known, including within north-eastern Bathurst Island, where there has not previously been systematic and comprehensive survey of the flora.

The objectives of this study were to:

1. Review and assess the likelihood that threatened plant species (listed under the *Environment Protection and Biodiversity Conservation Act* and/or *Territory Parks and Wildlife Conservation Acts*) occur within the study area.
2. Using existing data, provide an assessment of the current status of these species within the study area and the Tiwi Islands more broadly.
3. Conduct targeted field assessment to supplement existing data for more comprehensive assessments of priority threatened species.
4. Where data allows, develop predictive tools for priority taxa to inform a biodiversity risk assessment within the study area.

7.1.1 Methods

7.1.1.1 Selection of target species

Data from Herbarium databases, previous floristic surveys and threatened plant studies on Bathurst Island were used in conjunction with expert opinion to develop a sub-set of significant plant taxa considered likely to occur within the study area. From the taxa listed in Appendix 8, an initial shortlist of 17 threatened and 37 significant species were assessed as having a reasonable likelihood of occurring on north-eastern Bathurst Island (Table 7-1).

All of the shortlisted threatened taxa (those listed as Vulnerable, Endangered or Critically Endangered under NT *Parks and Wildlife Conservation Act* or Commonwealth *Environment Protection and Biodiversity Conservation Act*) have a reasonable expectation of being encountered within the survey area. These threatened species are highlighted in bold in Table 7-1 and include one species from *Melaleuca* wetland habitats, three species from eucalypt woodland and open forest associations and fourteen species from the various monsoon forest associations present within the survey area. These species were the **priority taxa** for assessment as part of this study.

Table 7-1: Threatened or significant plant species considered likely to occur on northern Bathurst Island, listed by the broad habitat in which they occur. Priority taxa for assessment (listed as threatened under the *Parks and Wildlife Conservation Act* or *Environment Protection and Biodiversity Conservation Act,* see Table 7-3 for status) are highlighted in **bold.** Other significant species are listed as Near Threatened or Data Deficient under the TPWCA.

Habitat type	Threatened plant species	Other significant plant species
Dry monsoon forest, Coastal rainforest	***Hoya australis* subsp. *oramicola***, ***Tarennoidea wallichii***	*Clerodendrum longiflorum* var. *glabrum*, *Habenaria hymenophylla, Pittosporum moluccanum, Turraea pubescens*
Eucalypt open forest	***Cycas armstrongii***, ***Typhonium jonesii***, ***Typhonium mirabile***	*Calochilus holtzei, Desmodium tiwiense*
Eucalypt woodland		*Empusa habenarina*, *Habenaria elongata*, *Mitrasacme inornata*
Wet Monsoon forest, Ever-wet rainforest	***Burmannia* sp. Bathurst Island (R.J.Fensham 1021)**, ***Dendromyza reinwardtiana***, ***Elaeocarpus miegei***, ***Endiandra limnophila***, ***Freycinetia excelsa***, ***Freycinetia percostata***, ***Luisia corrugata* (syn. *L. teretifolia*)**, ***Mapania macrocephala***, ***Mitrella tiwiensis***, ***Tarennoidea wallichii***, ***Thrixspermum congestum***, ***Xylopia monosperma***	*Actinostachys wagneri*, *Adiantum atroviride, Clerodendrum longiflorum*, var. *glabrum*, *Crepidium fontinale, Embelia tiwiensis, Endospermum myrmecophilum, Habenaria hymenophylla*, *Hypolytrum nemorum*, *Hypserpa decumbens*, *Hypserpa polyandra*, *Lindsaea walkerae, Melodinus australis*,, *Parsonsia* sp. Melville Island, *Psychotria coelosperma*, *Strychnos minor*, *Syzygium claviflorum*, *Syzygium forte* subsp. *forte, Syzygium hemilamprum* subsp. *hemilamprum*, *Turraea pubescens*, *Vittaria ensiformis*,
Monsoon forest margins, Monsoon forest/open forest ecotone	***Dendromyza reinwardtiana***	*Pavetta tenella*, *Thismia* sp. Melville Is
Margins of creek flats		*Sophora longipes*
Melaleuca forest		*Dendrobium johannis*
Melaleuca woodland, sedgelands, swamps	***Calochilus caeruleus***	*Byblis aquatic Drosera fulva*, *Empusa habenarina*, *Habenaria ferdinandi*, *Ischaemum barbatum, Lindsaea walkerae, Scleria carphiformis*, *Stylidium tenerrimum*

7.1.1.2 Taxonomic uncertainties

Priority taxa with uncertain taxonomic status and/or particular problems for identification include *Typhonium*, *Cycas* and *Freycinetia*. Of most importance to this study are the challenges presented by the Endangered herbs *Typhonium jonesii* and *Typhonium mirabile*. Previous studies (Liddle & Elliott 2008) have noted the significant morphological variability that exists within and between populations of both *Typhonium* species on the Tiwi Islands so that, in the absence of fertile material, there are significant problems with positive identification of specimens to species level in the field. In this study therefore numerous leaf samples were collected to allow genetic testing to confirm the field identification of sampled populations.

Two cycad species have been recorded from eucalypt open-forest and woodland habitats on Bathurst Island. Existing circumscriptions of *Cycas armstrongii* and *Cycas machonochiei* readily separate these taxa at the extremes of their morphological characteristics on a combination of characters including the relative prominence of the pinnae midrib on the upper and lower surfaces and the degree of thickening and shape of the pinnae margins (Hill 1996, Dixon 2004). However, field observations suggest significant morphological variation exists within these taxa, including intermediate character states and substantial overlap in the ranges of character states used to discriminate them. The open pollination systems of *Cycas* species are well known to facilitate the production of hybrid taxa in the Northern Territory (Dixon, 2004) and the potential exists for significant uncertainty regarding the identity of the *Cycas* entities present. Specimens were therefore collected during the field survey to assist in clarifying which species is present in the study area.

The Vulnerable (TPWCA) woody climbing palms *Freycinettia excelsa* and *Freycinetia percostata* have both been recorded from within the study area, but the application of the names to this data has resulted in some uncertainty over the distribution of the species in the monsoon forests within the area. Infrequent encounter of fertile material has contributed to this uncertainty and, while no flowering or fruiting individuals were encountered during the field survey, leaf samples were collected to assist in clarifying which species were present in the rainforests visited.

All nomenclature follows Short *et al.* (2011) with the exception of taxa subject to more recent taxonomic revision where currently accepted names are those contained in the Northern Territory Herbarium specimen database (HOLTZE).

7.1.1.3 Field survey

The variability in lifeform, distribution, abundance, habitat and detectability amongst the priority taxa required a more flexible and targeted approach to survey design than the standard plot based method (Brocklehurst *et al*. 2007). The differing phenological patterns also necessitated timing field surveys to coincide with the optimal times for detection and identification of the target taxa. Similar assessment methods were appropriate for multiple species within broad habitat types and thus habitat was used as the primary basis for structuring the survey design and species-specific methods outlined below.

7.1.1.3.1 Eucalypt woodland and open forests

Initial evaluation of the study area suggested that land and water resources suitable for agriculture or horticulture were most likely to be within the extensive woodland and open forest of the gently undulating plains and plateau margins associated with the eroding Tertiary land surface. Consequently, threatened plant species associated with this habitat - *Typhonium jonesii, T. mirabile* and *Cycas armstrongii* - were the focus for assessment.

Targeted presence-absence surveys were used in the assessment of *Typhonium* species populations as the most efficient means of detecting these cryptic, ephemeral and widely dispersed taxa (Joseph *et al.* 2006). While this does not provide an estimate of total abundance, it allows a much larger number of sites to be visited within the available survey period.

Typhonium spp.

Ecological data and expert knowledge (Kerrigan & Cowie 2006; Kerrigan *et al.* 2007h, 2007g; Liddle & Elliott 2008) suggest that *Typhonium* species occur in association with specific vegetation communities and landscape positions (elevation, topography and regolith/soil combinations) on both Bathurst and Melville Islands. Known populations of *Typhonium* on the Tiwi Islands occur on well drained lateritic soils in *Eucalyptus miniata*, *Eucalyptus tetrodonta* and *Corymbia nesophila* woodland and open-forest at elevations greater than 60m AHD.

Habitat within the study area was stratified at two levels based on mapping of Broad Floristic Formations at approximately 1:25 000 scale undertaken in the planning phase of this project and elevation envelopes greater than or less than 40 m AHD (Figure 7-1). Potential habitat areas above and below 40 m AHD were divided into one hectare (100 x 100 m) grid-cells using the GENREGIONSAMPPLEPLOTS routine in the Geospatial Modelling Environment (Beyer, 2012). The sampling grid was established in a north-south and east-west orientation. Sixty grid-cells were randomly selected as target sampling units with a 60/40 bias (36 vs 24) toward the >40 m AHD elevation. Grid-cells which did not fall completely within either a habitat or elevation strata were manually reassigned to the closest adjoining grid-cell completely contained within a stratum.

A presence-absence sampling design suitable for analysis using occupancy modelling was employed. 'Surveys' (i.e. opportunities to observe the target taxa) were replicated spatially across a site (grid-cell) as the repeat measure required assessing occupancy. Six 100 m x 2 m belt transects orientated along the north-south axis of the sampling grid were sampled by three observers (2 surveys per observer per site), so that approximately 12 percent of each grid cell was searched (Figure 7-2).

Each survey involved a thorough search of the belt transect for the target *Typhonium* species with the transect start and end, and location of any individuals (or closely associated groups of individuals) recorded on handheld GPS (Garmin GPS60 of GPS62) units. The morphological details of any individual or discreet group of *Typhonium* species encountered during a survey were recorded along with a digital photograph. At each site and within each survey, additional data were collected to characterise the biophysical and meteorological conditions at the time of the sampling. These measures and the field survey proforma are described in Appendix 9).

Field sampling was conducted in two seven day blocks between 19 March 2014 and 2 April 2014. Most sites were accessed on foot, with field support provided by the Tiwi Land Rangers.

Cycas spp.

The abundance and distribution of cycads was assessed on each of the sites sampled for *Typhonium*. A larger 100 x 10 m belt transect was superimposed over each of the *Typhonium* transects and the abundance and location of Cycads was recorded within this area (Figure 7-2).

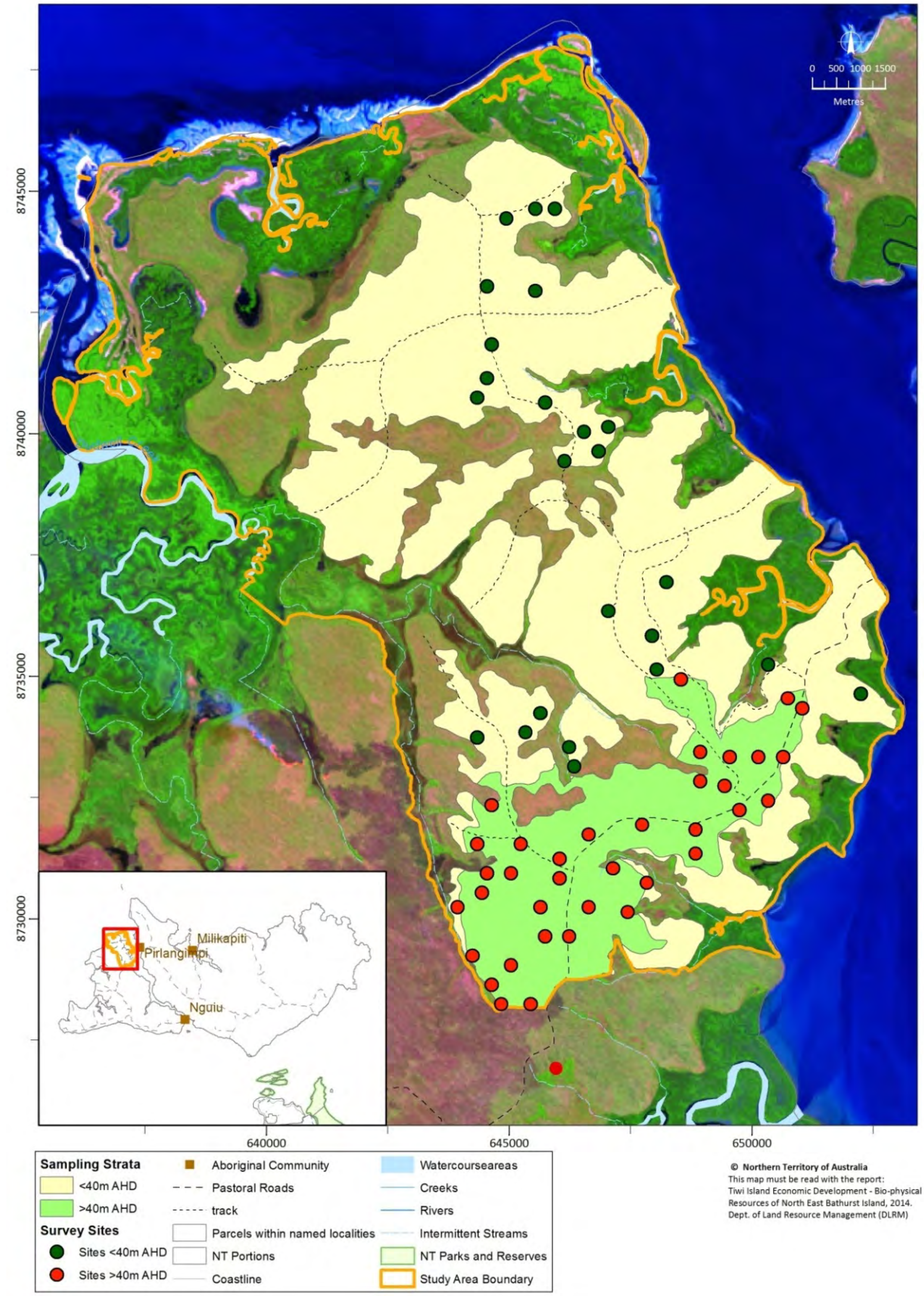

Figure 7-1: Habitat stratification and sampling sites for *Typhonium* species within the study area. Solid colours on map represent potential habitat (Eucalypt woodland and open forest) in two elevation strata (< 40 m and > 40 m AHD). Coloured points are the randomly selected sites in each of the elevation strata.

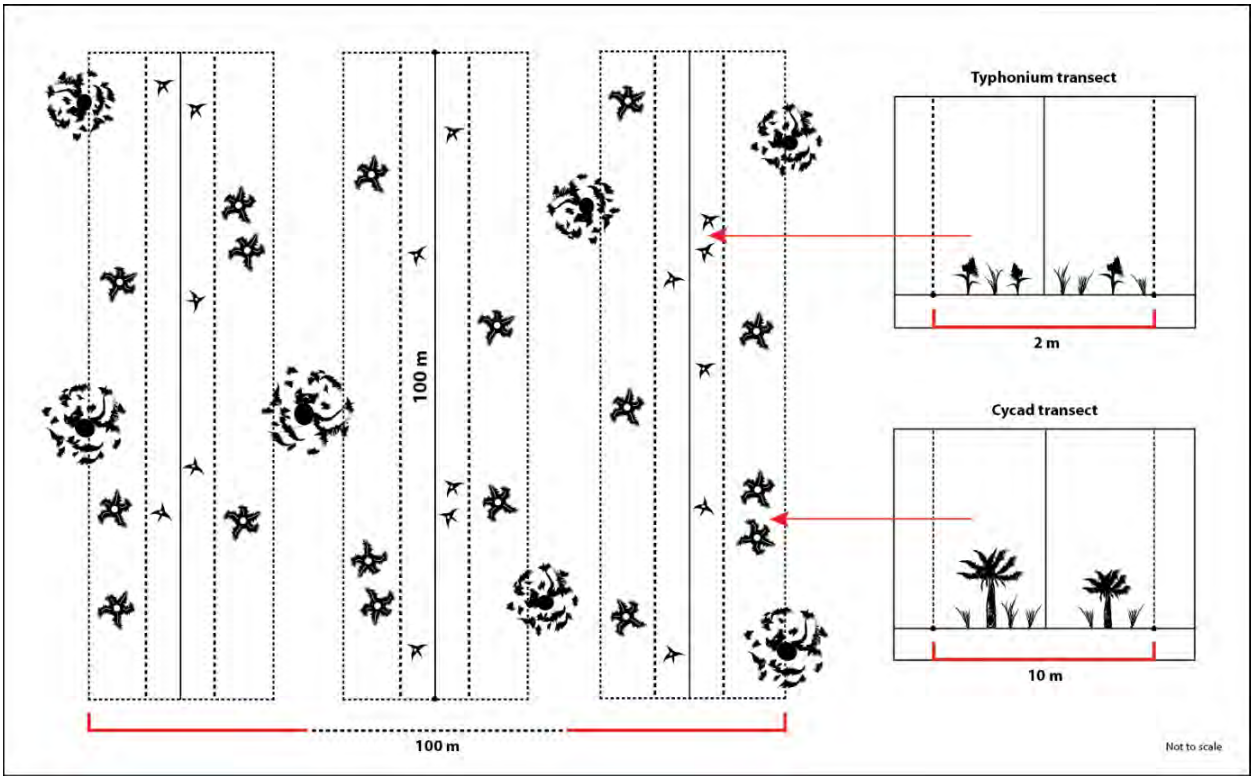

Figure 7-2: Nested arrangement of *Typhonium* and *Cycas* survey transects within a 100 m x 100 m site. Solid black lines indicate transect centrelines with coarse-dashed and dotted lines representing 2 m and 10 m belt transects for *Typhonium* and *Cycas* respectively. Transects were uniformly spaced and aligned north-south.

Incidental observations

The largely foot-based travel during field surveys in March/April 2014 provided the opportunity for incidental observations of all species of conservation significance to be documented during traverses between survey sites. Field traverses used continuous belt-transects during transit between sites in a similar manner to the surveys themselves to record species occurrence. Each observer traversed between sites on separate tracks recording the location of any individuals/populations of priority or significant species encountered. Digital photographs and vegetative samples were collected from locations where *Typhonium* species were encountered as per the methodology employed on the assessment sites, with data collection for other taxa following standard specimen data collection protocols (e.g. Brocklehurst *et al.* 2007; Queensland Herbarium 2013).

7.1.1.3.2 Monsoon forests

A large number of monsoon rainforest patches occur within the study area and are habitat for the majority of threatened plant species likely to occur in this area, so these were also targeted for assessment. A hybrid quadrat-based methodology to sample the floristic variation within monsoon forest patches, supplemented by systematic, plotless searching outside of the quadrats was employed as the best means of improving knowledge of priority species and species of conservation significance within these habitats. This also allows compatibility with previous survey data from the Tiwi Islands, providing a regional context for the monsoon forest vegetation associations.

Survey design

Existing mapping of monsoon forest vegetation in the NT (Russell-Smith 1991) was used in conjunction with preliminary mapping of broad floristic formations and land-units in the study area as the basis for identifying target areas for intensive survey. Monsoon forest patches were prioritised for survey based firstly on type (spring-fed, riparian or dry-monsoon) and size, with patches greater than 5 hectares initially selected for survey, as larger patches are likely to have higher species richness. However, field investigation showed patch area estimates based on older mapping were poor, and greater weight was given to selecting patches within each type that gave good spatial dispersion of sites across the survey area. Initial site selection discounted any monsoon forest patch for detailed survey where inventory information had previously been collected (Russell-Smith 1991, Liddle & Elliot, 2008), although supplementary survey of these sites was conducted for species of conservation significance where logistically feasible. A total of 31 rainforest sites were assessed in the field (Figure 7-3).

Field data collection

The floristic and structural attributes of monsoon forests within the survey area were characterised using standard 20 m x 20 m vegetation survey plots (Brocklehurst *et al*. 2007) replicated at multiple locations within monsoon forest patch, and these data were used in the mapping of vegetation and land resources described in Chapter 6. Searches were also conducted for additional taxa within a patch but not recorded in the plots. The extent of these searches varied with the size and complexity of the patch but was generally for approximately one hour, and searches were terminated when additional search effort did not yield additional species. Population estimates were made for species of conservation significance within each surveyed monsoon forest patch, with the estimated number of adult and juvenile individuals recorded. Representative specimens of species of conservation significance were collected for previously undocumented locations or for investigation of taxonomic issues

Floristic inventories were also compiled for monsoon forest patches within the survey area not subject to plot-based sampling, including some patches that had been visited as part of previous surveys (e.g. Russell-Smith, 1991) and where there were previous population estimates for species of conservation significance. Site inventories involved independent meander searches within the patch by multiple observers and the compilation of a species inventory, including recording population estimates for species of conservation significance.

7.1.1.3.3 Other habitats

The initial evaluation of significant plant species on the Tiwi Islands showed that a number of species potentially occurred in swampy or wetland habitats (including *Melaleuca* communities) in the study area (Table 7-1). Survey of these areas used similar methods to those for monsoon forest - a combination of plot-based sampling and searches. However, given that only one threatened species and relatively few significant species were expected in this habitat, sampling effort in wetland habitats was small.

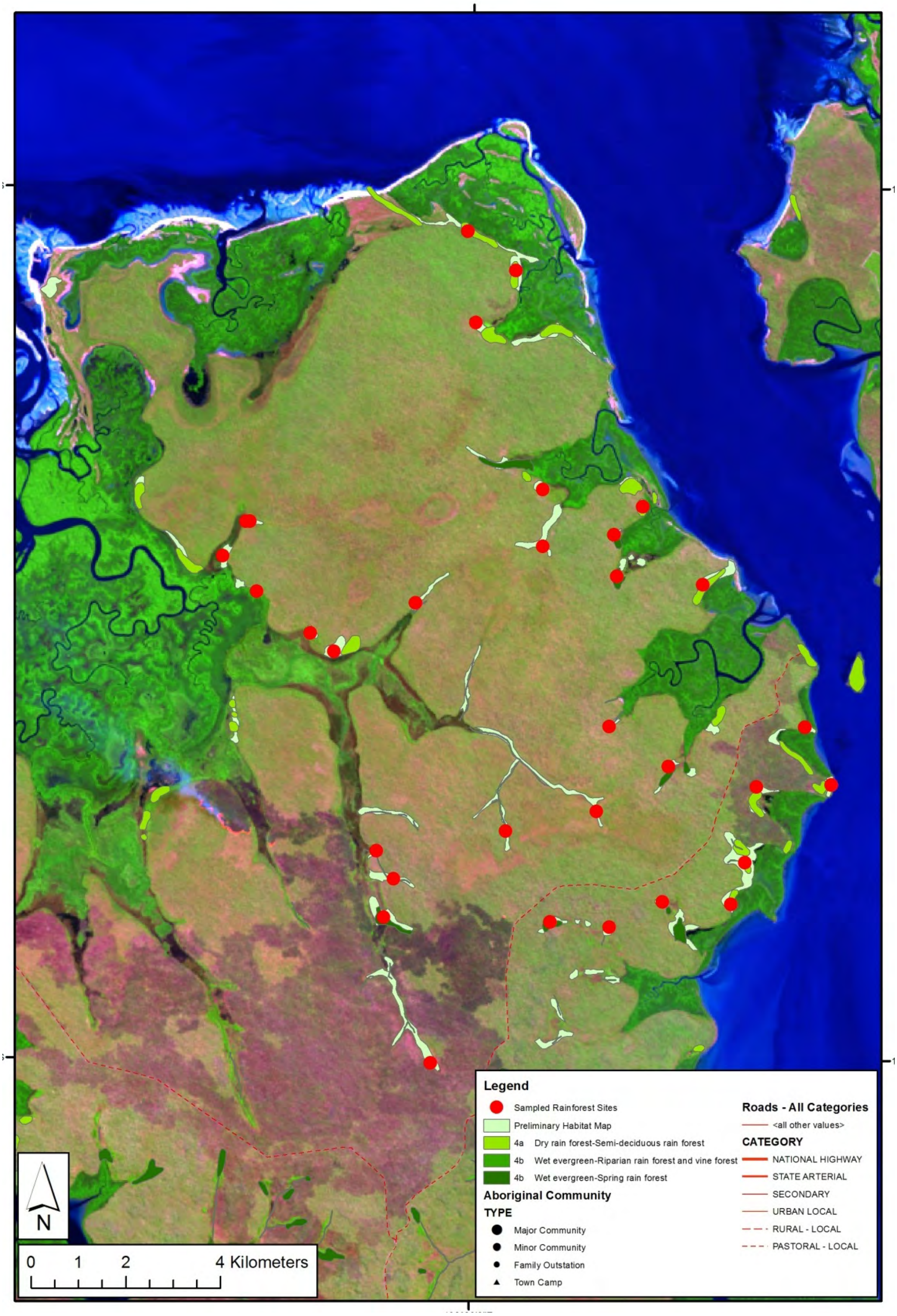

Figure 7-3: Location of rainforest sites on northern Bathurst Island sampled in October 2014. An additional five sites were sampled during previous surveys of NT rainforests (Russell-Smith 1991).

7.1.1.4 Occupancy modelling for Typhonium spp.

The effects of environmental variables and observer-specific parameters on the probabilities of occurrence and detection of *Typhonium* species within grid-cells in the study area were modelled in PRESENCE v6.2 (Hines, 2006), using single season occupancy models. The analysis was based on a modified closed-population, mark-recapture approach where 'survey' events by each observer at a 'site' represent repeat measures of the population within a sample area, fulfilling the requirement for repeat, independent 'surveys' to form the basis of the sampling regime (MacKenzie *et al.* 2002). Presence-absence data from the surveys was used to estimate the proportion of sites (grid-cells) occupied by the target species while taking imperfect detection into account.

As the aim was to spatially map the probability of *Typhonium* species occupancy within the study area, the predictive covariates had to be drawn from uniformly available environmental data, and the available processed and derived remotely sensed data is summarised in Appendix 10. Spatial covariates were extracted for each 100 m x 100 m grid cells within the stratified study area, with measures averaged if required. From the field data, an average ground cover estimate for the sample cell at the time of survey was calculated, and vegetation floristics in each stratum was summarised to produce a categorical habitat classification for the sampling site. Data for all continuous covariates were standardized.

Initial appraisal of environmental covariates suggested that a number of covariates had very low correlation with the occurrence of *Typhonium* species. A final set of 5 occupancy and 2 detection covariates was selected to form the candidate model-set for analyses. An *a priori* set of 21 models with additive linear covariates of detection and occupancy for *Typhonium* species were derived using expert opinion and existing understanding of factors affecting the species distribution (Appendix 10). Goodness of fit tests in PRESENCE (Hines 2006) were used to test assess the adequacy of the global model (the model containing all covariates) based on 10 000 bootstrap simulations. The Akiaike Information Criterion (AIC) was used to assess the relative weight of evidence to support individual models, and the relative values (AIC differences or Δ_i AIC) of each model over the other candidate models was taken as the relative level of empirical support for each model.

To examine the effects of covariates on the probability of occupancy and detection for individual species, fitted relationships for the top-ranked model were plotted with 95% confidence intervals using the delta method (Ver Hoef 2012). If the 95% confidence interval for the slope of the logit covariates did not include zero, the relationship was considered statistically significant (Williams *et al.* 2002)

Assessment of the adequacy of the survey methodology was also undertaken through the calculation of the number of repeat surveys required to ascertain absence of the target species at a confidence level greater than 0.90, using a modification of the formula of McArdle (1990):

$$N = \frac{\log_{10}(1-\alpha)}{\log_{10}(1-p)} \Rightarrow \alpha = 1 - (1-p)^N$$

Where N = Number of Surveys, p = detection probability and α = confidence level.

7.1.1.5 Review of species of conservation significance

Threatened (EPBCA and TPWCA), Near Threatened and Data Deficient (TPWCA) species with 20% or more of their estimated NT population in north-eastern Bathurst Island were assessed in detail to evaluate the significance of subpopulations in the study area (Appendix 11). For each species, new data from the 2014 field survey was combined with existing species records held in DLRM corporate databases, and the data were verified, reviewed and analysed to assess the number of known locations, extent of occurrence (EoO), area of occupancy (AoO), habitat preference, abundance and potential threats (Table 7-2). These were used in the development of species dossiers for priority and significant species recorded within the study area.

Table 7-2: Definition and calculation methods for terms used in the assessment of conservation status

Location	IUCN guidelines define a location as "a geographically or ecologically distinct area in which a single threatening event can rapidly affect all individuals of the taxon present." (IUCN Standards and Petitions Subcommittee 2014). Based on the scale of typical intensive development projects in the NT, we considered a location to be an area of 5 x 5 km^2 or 2 500 ha.
Extent of Occurrence (EoO)	Defined by IUCN as *"the area contained within the shortest continuous imaginary boundary which can be drawn to encompass all the known, inferred or projected sites of present occurrence of a taxon, excluding cases of vagrancy"* (IUCN 2012). Extent of occurrence was estimated by calculating the area of a minimum convex polygon around the known localities (IUCN 2012). Note that this is usually larger than the amount of occupied or potential habitat.
Area of occupancy (AoO).	Defined by IUCN as the *"area within its 'extent of occurrence', which is occupied by a taxon, excluding cases of vagrancy",* and *"a parameter that represents the area of suitable habitat currently occupied by the taxon"* (IUCN Standards and Petitions Subcommittee 2014). The 'grid' method recommended by IUCN (2012) was used: the number of occupied cells in a uniform grid that covers the entire range of a taxon was tallied, and total area of all occupied cells calculated. The grid size was determined by the size of habitat patches and was 400 ha (2 x 2 km) for woodland taxa, which is recommended as applicable in most cases (IUCN Standards and Petitions Subcommittee 2014). Rainforest patches in NT are small and localised, and on northern Bathurst Island average 5.9 ha in area. The rare and threatened rainforest species considered here are also typically restricted to either just the very wet core of these patches and absent from the drier margins or in one case (*Dendromyza*) found only on the margins. It was estimated that around 50 % of each rainforest patch was effectively available habitat for these species. Therefore, a 170 x 170 m (3 ha) grid was applied for rainforest species.
Subpopulation	Defined by IUCN as *"geographically or otherwise distinct groups in the populations between which there is little demographic or genetic exchange (typically one successful migrant individual or gamete per year or less)."* (IUCN 2012). For rainforest species, individuals in a rainforest patch may constitute a 'subpopulation', although may vary depending on distances between patches and the taxa involved.

7.1.2 Results

A total of 13 threatened and 20 other significant (Near Threatened and Data Deficient) plant species have been confirmed as occurring in the study area, based on previous and 2014 survey data (Tables 7-3 and 7-4). Seven threatened species and eleven other significant species have 20% or more of their known NT population within the study area. Most of these species (five threatened and ten Near Threatened and Data Deficient species) occur in monsoon rainforests, with two threatened species in Eucalypt open forest and woodland and one Near Threatened species in wetland habitats. Further details of individual species are provided in Appendix 11.

A number of species of conservation significance that have been previously recorded in the study area were not relocated during the 2014 surveys. Reassessment of historical records confirms that at least one threatened (*Thrixspermum congestum*) and four significant (*Ischaemum barbatum*, *Mitrasacme inornata*, *Scleria carphiformis* and *Xylocarpus granatum*) species records are almost certainly from within the study area. However, the reassessment suggests that the historical records of the remaining species in Tables 7-3 and 7-4 were not from the study area and have inaccurate geocoding associated with pre-GPS data. For example, a record of the Vulnerable species *Mapania macrocephala* supposedly from the study area was determined to be from Big Pig Jungle south of the study area boundary.

7.1.2.1 Eucalypt woodlands and open forests

Three threatened (*Cycas armstrongii*, *Typhonium mirabile* and *T. jonesii*) and two other significant species (*Calochilus holtzei* and *Desmodium tiwiense*) were recorded in eucalypt woodland and open forests within the study area during the 2014 field survey (Figure 7-4). Results for the threatened species are discussed further below.

7.1.2.1.1 *Typhonium* spp.

Typhonium species were recorded at 22 of the 60 sampled grid-cells, with *T. mirabile* recorded in 18 cells and *T. jonesii* in 6 cells (Fig. 7-5). The species co-occurred in only 2 of the 60 sampled grid-cells. Naive occupancy (not accounting for detection) was estimated at 0.3 and 0.1 for *T. mirabile* and *T. jonesii* respectively. Nineteen (86%) of *Typhonium* species plot records were in *Eucalyptus miniata*, *Corymbia nesophila* and *Eucalyptus tetrodonta* woodland to open forest formations on deep, superficially well-drained, red sandy clay-loam soils (Kandosols) (Table 7-5).

Table 7-3: Threatened plant species recorded from northern Bathurst Island, indicating numbers of known locations, range (Extent of Occurrence) and estimated area occupied by the species (Area of Occupancy). Species having 20% or more of their known NT population within the study area are in bold. Species where reassessment showed that the geocode for the original record was in error and there is no sound evidence of occurrence in the study area are in brackets. An (e) under 'Restricted Range' denotes endemic to the Tiwi Islands; (d) denotes a disjunct distribution species with the entire NT population restricted to the Tiwi Islands; (NT) indicates endemic to the NT. Legislative status: TPWCA = *Territory Parks and Wildlife Conservation Act*; EPBCA = *Environment Protection and Biodiversity Conservation Act*; CR=critically endangered; EN=endangered; V=vulnerable. * after the taxon name indicates the species was not recorded in 2014 surveys. EoO in the study area can only be calculated when there are more than two records.

Taxon	TPWCA	EPBCA	Restricted Range	Locations			Extent of Occurrence			Area of Occupancy		
				NT	Study area	%	NT (km^2)	Study area (km^2)	%	NT (ha)	Study area (ha)	%
[*Burmannia* sp. Bathurst Island]	EN	EN	Y (e)	1	-	-	8.8	-	-	12	-	-
Cycas armstrongii	V		N	197	5	2.5	37377	40.5	0.1	364	9	2.5
Dendromyza reinwardtiana	**V**		**N (d)**	**22**	**4**	**18.2**	**1434**	**29.4**	**2.0**	**201**	**51**	**25.4**
Elaeocarpus miegei	**CR**		**N (d)**	**8**	**5**	**62.5**	**288.3**	**36.2**	**12.5**	**66**	**33**	**50.0**
Endiandra limnophila	V		N	28	7	25.0	5502	75.7	1.4	231	72	31.2
Freycinetia excelsa	V		N	12	2	17	51668	na	na	84	6	7
[*Freycinetia percostata*]	V		N	7	-	-	2971	-	-	33	-	-
Hoya australis subsp. *oramicola*	V	V	Y (e)	8	1	12.5	2438	na	na	45	3	6.7
Luisia corrugate	V		-	15	1	6.7	5884	na	na	60	3	5.0
[*Mapania macrocephala*]	V		N	7	-	-	8386	-	-	57	-	-
Mitrella tiwiensis	**V**	**V**	**Y (e)**	**19**	**5**	**26.3**	**1148**	**41.6**	**3.6**	**135**	**21**	**15.5**
Tarennoidea wallichii	EN		N	7	3	42.9	225.3	16.8	7.5	33	12	36.4

Taxon	TPWCA	EPBCA	Restricted Range	Locations			Extent of Occurrence			Area of Occupancy		
				NT	Study area	%	NT (km^2)	Study area (km^2)	%	NT (ha)	Study area (ha)	%
			(NT)									
Thrixspermum congestum *	**V**		**Y**	**9**	**2**	**22.2**	**314.9**	**na**	**na**	**33**	**6**	**18.1**
Typhonium jonesii	**EN**	**EN**	**Y (e)**	**14**	**6**	**35.7**	**1148**	**52.0**	**4.5**	**15**	**7**	**46.7**
Typhonium mirabile	**EN**	**EN**	**Y (e)**	**13**	**6**	**46.2**	**823.0**	**64.1**	**7.8**	**21**	**16**	**76.2**
Xylopia monosperma	**EN**	**EN**	**Y**	**6**	**2**	**33.3**	**522.0**	**1.1**	**0.2**	**63**	**15**	**23.8**

Table 7-4: Near Threatened and Data Deficient (*Territory Parks and Wildlife Conservation Act*) plant species recorded from northern Bathurst Island, indicating numbers of known locations, range (Extent of Occurrence) and estimated area occupied by the species (Area of Occupancy). Species having 20% or more of their known NT population within the study area are in bold. An (e) under 'Restricted Range' denotes endemic to the Tiwi Islands; (d) denotes a disjunct distribution species with the entire NT population restricted to the Tiwi Islands; (NT) indicates endemic to the NT. Legislative status: TPWCA = *Territory Parks and Wildlife Conservation Act*; DD = Data Deficient; NT=Near Threatened; Habitat: WL= eucalypt woodland/open forest; RF=monsoon rainforest; SW=swamp. * indicates the species was not recorded in 2014 surveys; ** denotes species tentatively recorded from sterile material in 2014 surveys and requiring confirmation and further assessment.

Taxon	Habitat	TPWCA	Restricted Range	Locations			Extent of Occurrence			Area of Occupancy		
				NT	Study area	%	NT (km^2)	Study area (km^2)	%	NT (ha)	Study area (ha)	%
Calochilus holtzei	WL	DD	N	19	3	15.8	114614	5.9	0.0	20	3	15.0
Desmodium tiwiense	WL	NT	N (NT)	16	2	12.5	17964	0.0	0.0	20	3	15.0
Embelia tiwiensis	**RF**	**NT**	**Y (NT)**	**10**	**7**	**70.0**	**1477**	**55.7**	**3.8**	**51**	**39**	**76.5**
Endospermum myrmecophilum	**RF**	**NT**	**N**	**42**	**7**	**16.7**	**20806**	**73.1**	**0.4**	**201**	**42**	**21**
Hypolytrum nemorum	RF	NT	N	15	1	6.7	20219	0.1	0.0	114	9	7.9
Hypserpa decumbens **	RF	NT	-	na	na	na	na	na	na	na	na	na
Ischaemum barbatum *	SW	NT	N	13	1	7.7	15621	na	na	42	3	7.1
Lindsaea walkerae	**SW**	**NT**	**N**	**11**	**3**	**27.3**	**37738**	**3.7**	**0.0**	**36**	**12**	**33.3**
Melodinus australis	**RF**	**NT**	**N**	**23**	**10**	**43.5**	**11393**	**91.2**	**0.8**	**111**	**51**	**45.9**
Mitrasacme inornata *		DD	N	8	1	12.5	71161	na	na	9	1	11.1
Parsonsia sp. *Melville Island*	**RF**	**NT**	**Y (NT)**	**23**	**5**	**21.7**	**1645**	**34.3**	**2.1**	**114**	**21**	**18.4**
Psychotria coelosperma	**RF**	**NT**	**N**	**26**	**7**	**26.9**	**28763**	**61.0**	**0.2**	**138**	**48**	**34.5**
Scleria carphiformis *	SW	DD	N	9	1	11.1	5079	na	na	30	3	10.0

Taxon	Habitat	TPWCA	Restricted Range	Locations			Extent of Occurrence			Area of Occupancy		
				NT	Study area	%	NT (km^2)	Study area (km^2)	%	NT (ha)	Study area (ha)	%
Sophora longipes*		NT	N	19	1	5.3	41219	na	na	57	5	5.3
Strychnos minor	**RF**	**NT**	**N**	**34**	**10**	**29.4**	**2156**	**98.9**	**4.6**	**261**	**81**	**31.0**
Syzygium claviflorum	**RF**	**NT**	**N**	**58**	**9**	**15.5**	**5481**	**114.8**	**2.1**	**315**	**93**	**29.5**
Syzygium forte subsp. *forte*	**RF**	**DD**	**N**	**9**	**1**	**11.1**	**12331**	**na**	**na**	**27**	**3**	**11.1**
Syzygium hemilamprum subsp. *hemilamprum*	**RF**	**NT**	**N**	**43**	**7**	**16.3**	**9461.9**	**75.1**	**0.8**	**228**	**51**	**22.4**
Vittaria ensiformis	**RF**	**NT**	**N**	**25**	**3**	**12.0**	**36039.3**	**47.5**	**0.1**	**144**	**21**	**22.4**
Xylocarpus granatum*		NT	N	21	1	4.8	59317.3	-	-	69	3	4.3

Table 7-5: Occurrence of *Typhonium* species plot records across three Broad Floristic Formations and soil landscapes within the study area.

Habitat	Land Unit(s)	Records
Eucalyptus miniata, *Corymbia nesophila* and *Eucalyptus tetrodonta* woodland and open forest on gently undulating lateritic plains, deeper red/brown kandosols	8a, 8a1, part 5a	19
Eucalyptus miniata, *Corymbia bleeseri* and *Corymbia nesophila* woodland on lateritic plateaux margins with gravelly –surfaced shallow kandosols and some rock outcrop	5a	1
Corymbia nesophila, *Eucalyptus tetrodonta* and *Eucalyptus miniata* a with *Lophostemon lactifluus* woodlands on shallow undulations in gently undulating lateritic plains (drainage areas) with brown hydrosols	8c, 8c1	2

Typhonium mirabile was recorded at an additional 34 incidental locations and *T. jonesii* at two additional incidental locations (Figure 7-5).

Preliminary appraisal of all records supports the hypothesised preference of *Typhonium* species for the margins of elevated gently undulating plains and plateaus. The effect of elevation was not clear, with 27% of plot and 28% of incidental records in the < 40 m elevation stratum. There is some evidence of a negative relationship between *Typhonium* occurrence and 'grassiness', with 77% of plot records at sites with shrub dominated ground strata. Field observations suggest sites with mixed ground layers have lower cover of perennial tussock grasses (such as *Eriachne triseta*) that may influence the amount of available microhabitat for *Typhonium* species.

Naive detection probability was too low to adequately model the occupancy of *Typhonium jonesii* within the study area. This may be because sampling intensity (number of surveys or samples) was too low or the species was not sufficiently evident (emergence of leaves had not yet occurred or senescence had already occurred). However, the species was evident and detectable in significant numbers at known populations of *T. jonesii* elsewhere on Bathurst Island that were visited during the 2014 sampling period.

Surveys yielded sufficient data to allow the effects of environmental and observer covariates on both occupancy and detection probabilities for *T. mirabile* to be modelled. Detection rates for each observer varied from 0.22 and 0.42 between observers with the average detection probability of (0.35) having a confidence level approaching 0.95 (Table 7-6). This suggests that the number of surveys (transects) employed in the design was sufficient to confidently assess the presence/absence of the species; Figure 7-6 indicates that the confidence levels for detection drops away rapidly below four surveys.

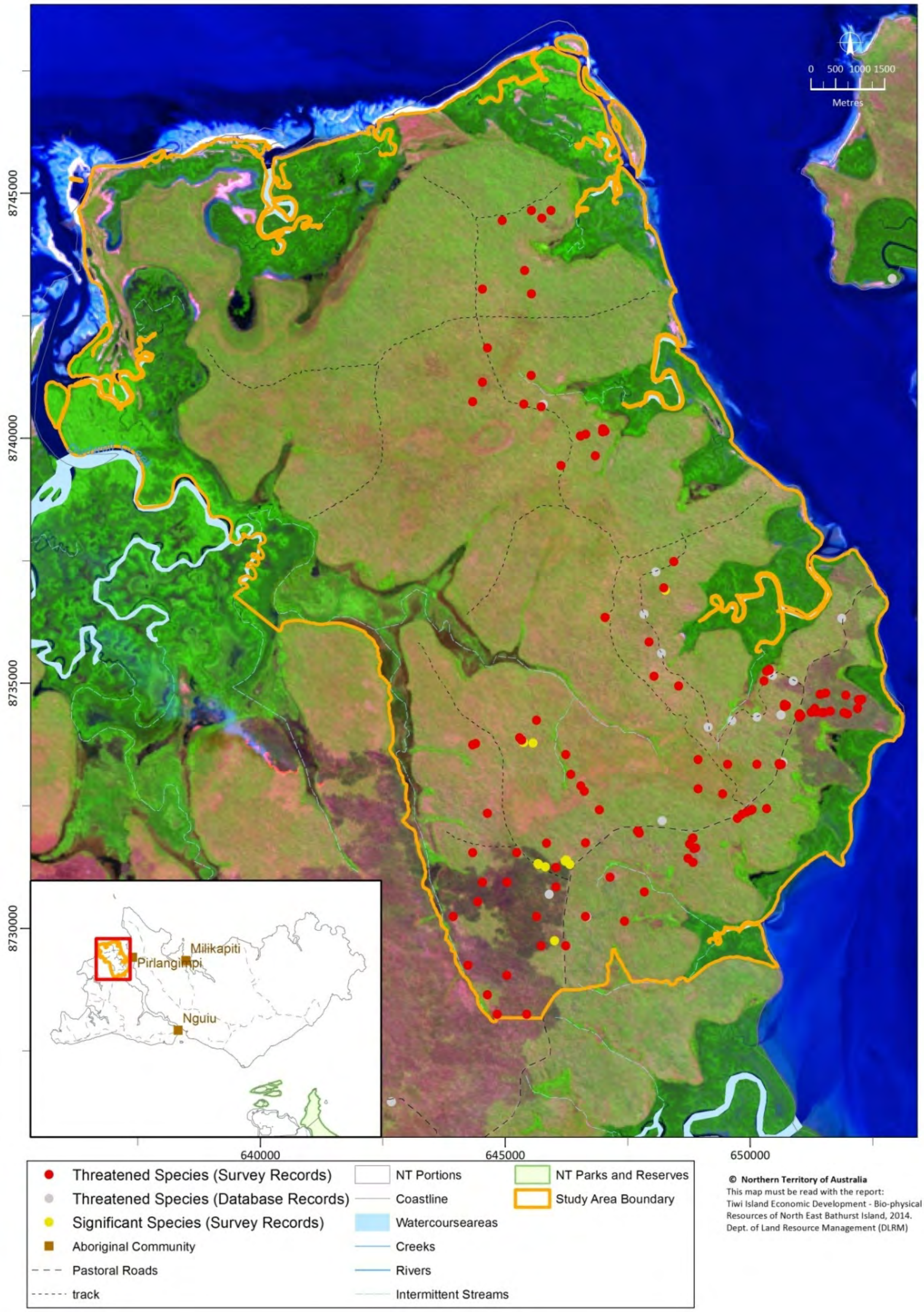

Figure 7-4: Location of all records of threatened and other significant plant species in eucalypt woodland and open forest vegetation within the study area.

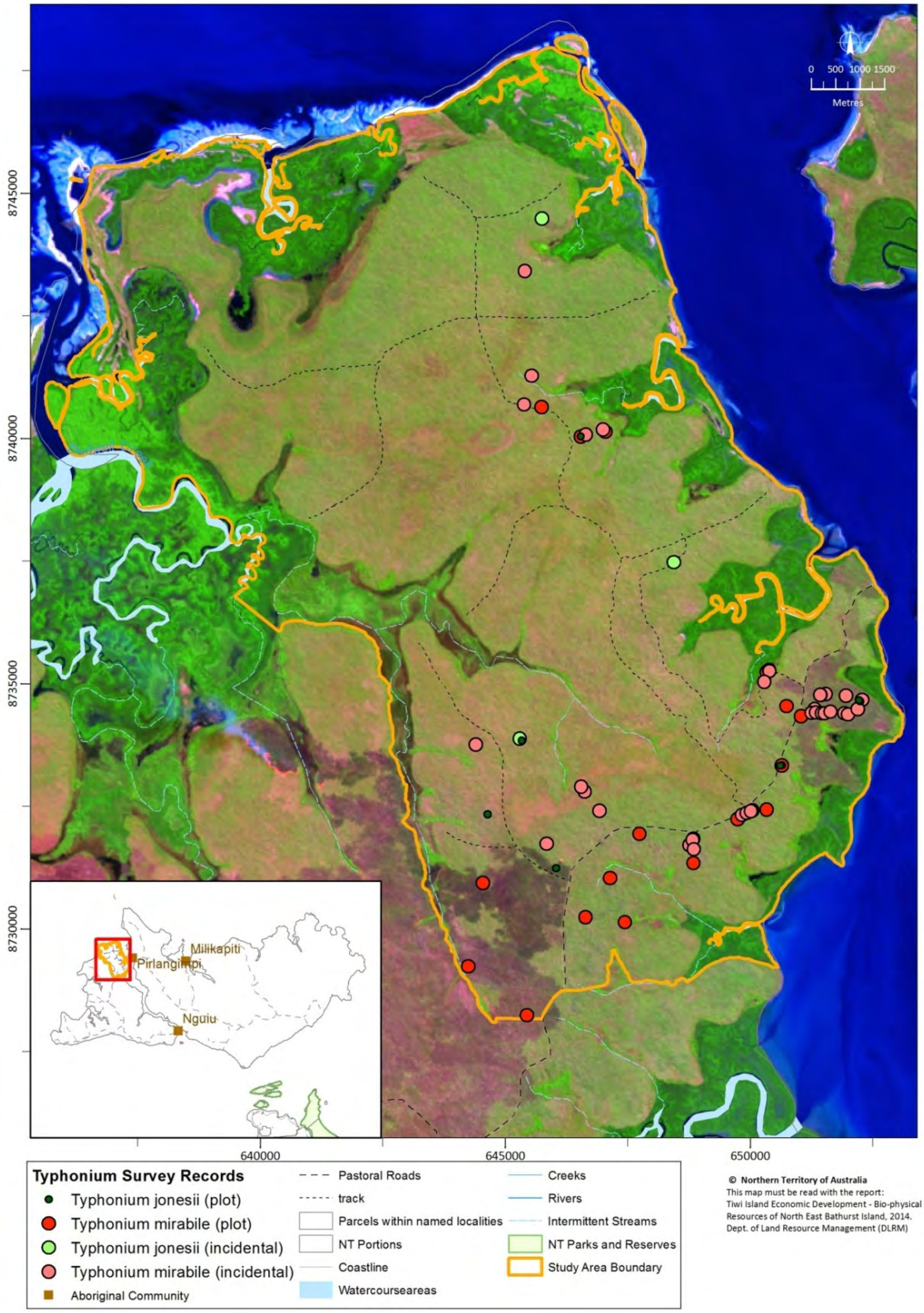

Figure 7-5: Location of *Typhonium* species recorded in the study area in March/April 2014. Plot records may represent multiple individuals.

Table 7-6: Summary detection probabilities (*p*) for *Typhonium mirabile* and individual observer estimates of detection within sites for 60 sample cells in the study area. (α) is a measure of averaged detection confidence level across observers for the survey.

Observer	Detection Probability (*p*)	Standard Error	95% Confidence Interval
A	0.421	0.082	0.273-0.584
B	0.398	0.081	0.255-0.562
C	0.223	0.067	0.118-0.380
Average	0.347		
α (Confidence Level)	0.923		

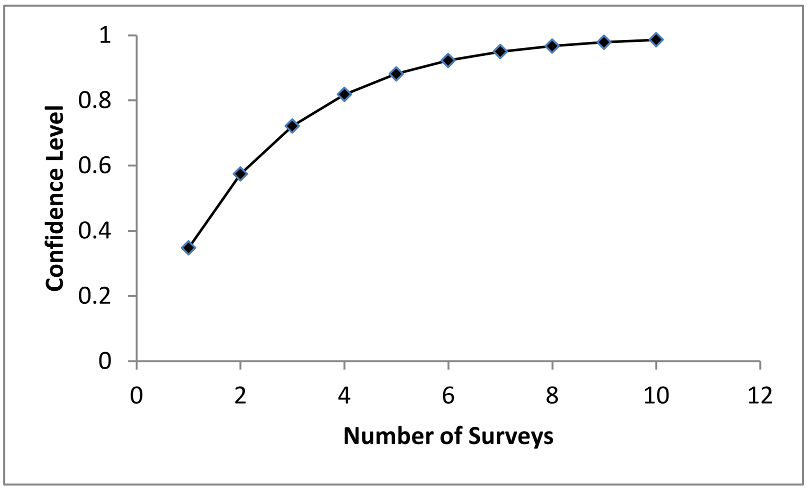

Figure 7-6: Relationship between detection confidence level and number of repeat surveys for *Typhonium mirabile* on 1ha plots with the average detection probability.

The results of goodness of fit tests based on the global model [ψ(all occupancy covariates), p(all detection covariates)] are summarised in Table 7-7. Simulations using parametric bootstrapping for *T. mirabile* were non-significant (p = 0.17) with reasonable model fit (ĉ estimate = 1.168). The non-significance of the bootstrapped global model allows the use of the AIC approach in assessing model selection and a ĉ estimate approaching but greater-than 1.0 suggests that the data is more variable than expected by the global model.

Table 7-7: Results of goodness of fit test using global model and 10 000 bootstrap simulations and observed detection histories for *Typhonium mirabile*. Ĉ is an estimate of model over dispersion derived by dividing model deviance of the observed model by the mean simulated model deviance.

From Observed Detection History	
Test Statistic (data)	83.84
From 10 000 Parametric Bootstrap Simulations	
Probability of Test Statistic >= observed	0.174
Lowest simulated Test Statistic	6.166
Mean simulated Test Statistic	71.79
Median simulated Test Statistic	62.29
Highest simulated Test Statistic	6899
Estimate of ĉ	1.168

The performance of the candidate models for *Typhonium mirabile* occupancy assessed in PRESENCE are summarised in Table 7-8. Relatively small changes in log-likelihood values (-2*Log Likelihood) between candidate models and the null model (range = 21.8) suggest that observed variability in the data is only partly accounted for by the explanatory variables. The top-ranked models for occupancy included various combinations of all the environmental covariates, with slope the most frequently included. Detection was not significantly influenced by environmental or observer covariates, although there was a marginal improvement in model performance with the inclusion of observer (O).

The top-ranked model for *T. mirabile* occupancy incorporated covariates for slope (S), Th:U radiometric ratio (R) and woody foliage projective cover (F), and these three covariates were included in four of the five top-ranked models combinations. Confidence intervals for the coefficient estimates for slope (ψ(S)) and FPC (ψ(F)) did not overlap with zero, suggesting significant effects on occupancy (Fig 7-7). Although not statistically significant, models incorporating the Th:U radiometric ratio did improve model performance (Δ-AIC = 0.58).

A model-averaging approach was used to develop the final spatial model showing the predicted variation in *T. mirabile* occupancy with environmental covariates (Figure 7-8). This involved calculating the occupancy probabilities for each grid cell within the study area for each candidate model, with the contribution of that model to the final averaged model weighted according to the AIC_w values shown in Table 7-8.

The margins of the elevated land surface are modelled as having the highest probabilities of *T. mirabile* occupancy within the study area. These areas are associated with the eastern, coastal margin of the study area and in association with Dudwell Creek, the largest northerly flowing drainage system of the southern portion of the study area.

Table 7-8: Summary of ranking and weighting of candidate models used to estimate occupancy (ψ) and detection (p) probabilities for *Typhonium mirabile* during the 2014 wet season survey. O=observer, G=ground cover, S=focal median slope, R=radiometric ratio (Th:U), F= foliage projective cover, C=% clay, A=ALOS Band1, '.' = additive covariate.

Rank	Model	AIC	Δ-AIC	AIC wt	Model Likelihood	Par.	(-2*LogLike)
1	ψ(S.R.F),p(O)	211.33	0	0.2224	1	7	197.33
2	ψ(S.R.F),p(.)	211.69	0.36	0.1858	0.8353	5	201.69
3	ψ(S.F),p(O)	212.27	0.94	0.139	0.625	6	200.27
4	ψ(S.R.C.F.A),p(O)	213.23	1.9	0.086	0.3867	9	195.23
5	ψ(ALL),p(ALL)	213.58	2.25	0.0722	0.3247	10	193.58
6	ψ(S.F.A),p(O)	213.82	2.49	0.064	0.2879	7	199.82
7	ψ(S.R.C),p(O)	214.7	3.37	0.0412	0.1854	7	200.7
8	ψ(S),p(O)	214.74	3.41	0.0404	0.1818	5	204.74
9	ψ(S.R),p(O)	214.77	3.44	0.0398	0.1791	6	202.77
10	ψ(S.C),p(O)	215.05	3.72	0.0346	0.1557	6	203.05
11	ψ(A),p(O)	216.08	4.75	0.0207	0.093	5	206.08
12	ψ(F.A),p(O)	216.61	5.28	0.0159	0.0714	6	204.61
13	ψ(R),p(O)	218.16	6.83	0.0073	0.0329	5	208.16
14	ψ(F),p(O)	218.62	7.29	0.0058	0.0261	5	208.62
15	ψ(.),p(O)	218.93	7.6	0.005	0.0224	4	210.93
16	ψ(S.A),p(O)	219.38	8.05	0.004	0.0179	2	215.38
17	1 group, Constant P	219.38	8.05	0.004	0.0179	2	215.38
18	ψ(R.C),p(O)	219.46	8.13	0.0038	0.0172	6	207.46
19	ψ(.),p(O.G)	219.81	8.48	0.0032	0.0144	5	209.81
20	ψ(C),p(O)	220.21	8.88	0.0026	0.0118	5	210.21
21	ψ(S.R.C.F.A),p(G)	220.57	9.24	0.0022	0.0099	7	206.57

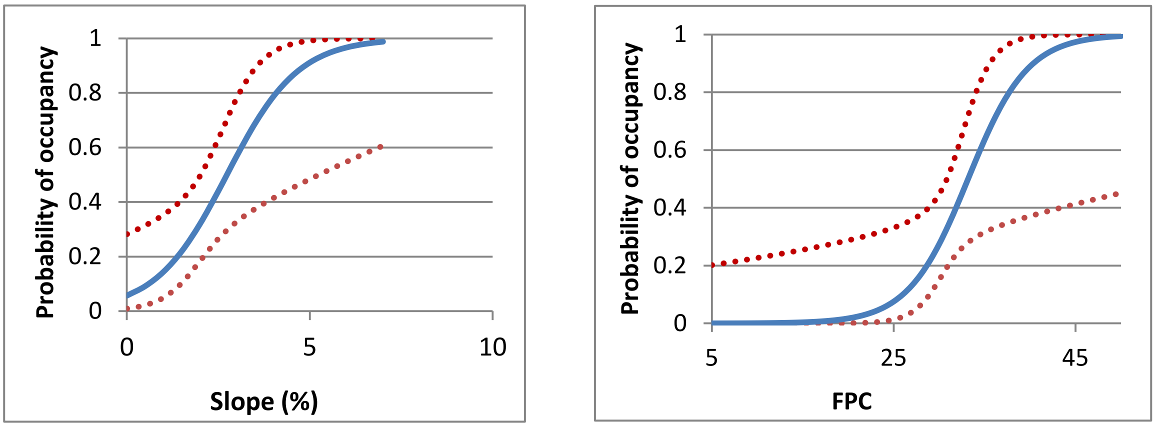

Figure 7-7: Relationship between estimated probability of occupancy for *T. mirabile* and (a) slope; (b) foliage projective cover, with 95% confidence intervals (dotted lines).

7.1.2.1.2 *Cycas armstrongii*

Cycas armstrongii was present and abundant throughout the survey area, recorded at 56 of the 60 (93%) survey sites. Numbers of individuals recorded at sites ranged from 0 to > 250 with an average of approximately 110 individuals per plot (Figure 7-9). The distribution of *C. armstrongii* in the study area was not modelled, but was extrapolated on the basis of Land Units (Chapter 6) in which it was observed to be abundant (Figure 7-10). *C. armstrongii* primarily inhabits the well to poorly drained earths (kandosols) of the elevated plains, plateaus and slopes (Land Units 5a, 6a, 7a and 8a-d) that occur extensively in the study area. The highest densities of individuals were observed in the southern parts of the study area associated with the margins of the elevated plains and plateaus.

7.1.2.1.3 Other significant species

Searches for *Calochilus* and *Desmodium tiwiense* were made incidentally during the *Typhonium* survey. The Data Deficient species *Calochilus holtzei* was recorded at three locations in the study area. The species has a wide but scattered distribution in northern NT, with 19 subpopulations on Bathurst Island, Melville Island, Cobourg Peninsula, Kapalga, near Darwin, Gove and Groote Eylandt. It appears to occurs in small subpopulations and be nowhere common. It favours soils which are deeper, very well drained and often gravelly, and some populations are on ridge tops or plateau surfaces. The study area subpopulations represent 15% of the NT total, calculated on both number of locations and area of occupancy.

Desmodium tiwiense (Near Threatened) was recorded only in two small subpopulations in the very south of the study area, near the Interview point road. Many subpopulations are known elsewhere in Bathurst and Melville Islands, with additional populations on Cobourg Peninsula, at Gunn Pt and near the Charlotte River. The study area subpopulations represent 13 - 15% of the NT total, calculated on the number of locations and area of occupancy respectively.

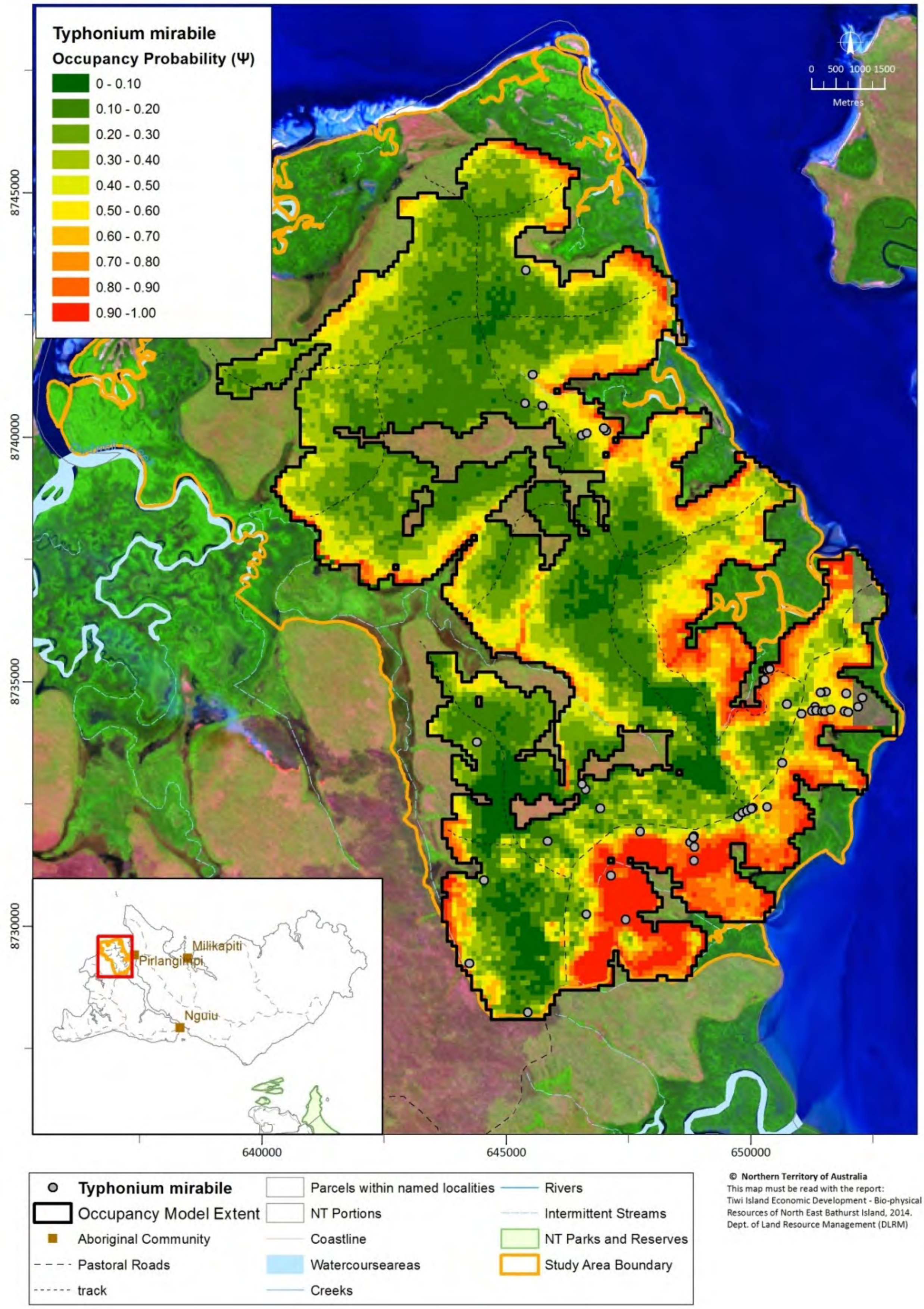

Figure 7-8: Probability of *Typhonium mirabile* occupancy (Ψ) within the study area based on the weighted average of 21 candidate models.

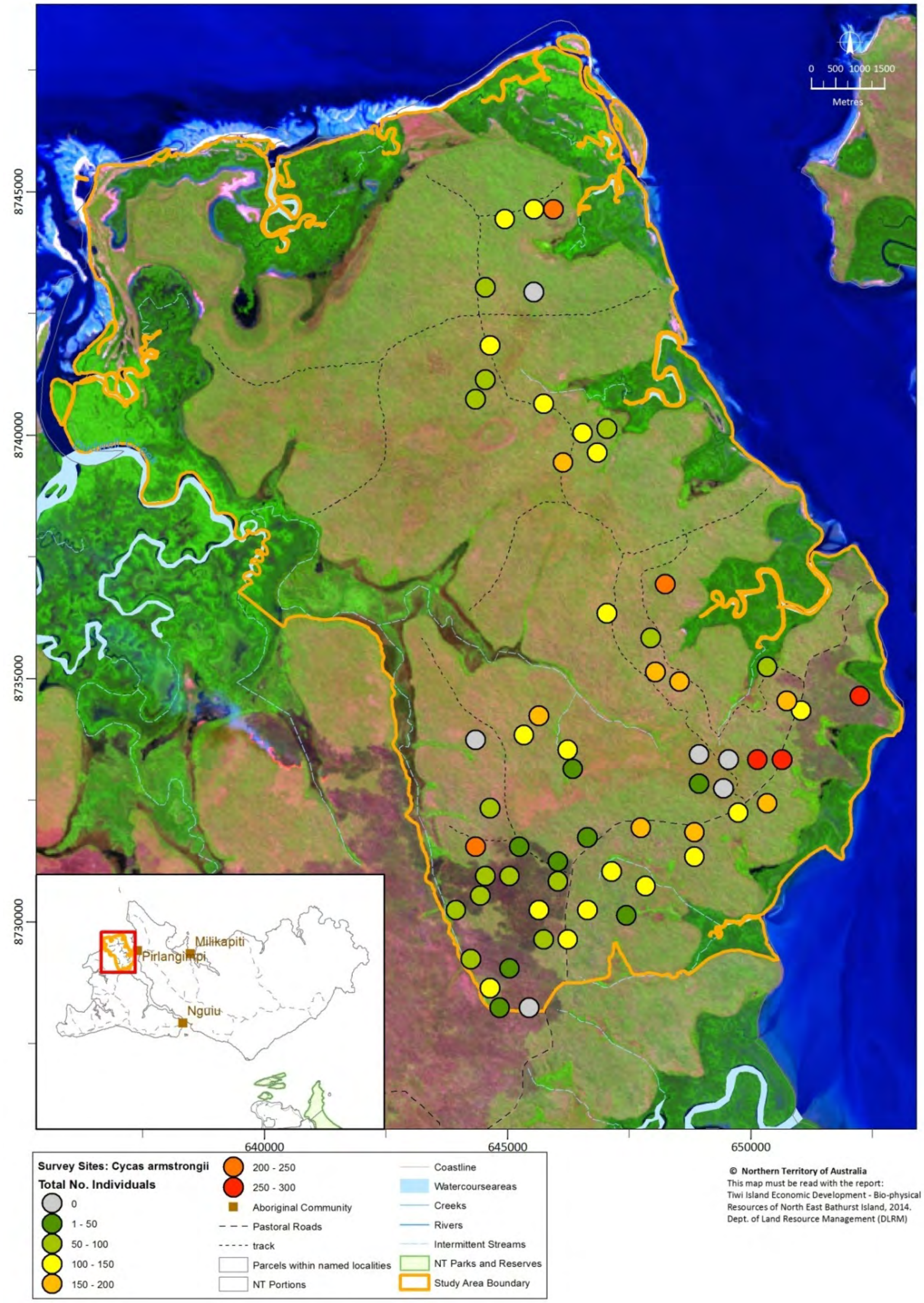

Figure 7-9: Number of individuals of *Cycas armstrongii* in 1ha survey sites sampled in March-April 2014.

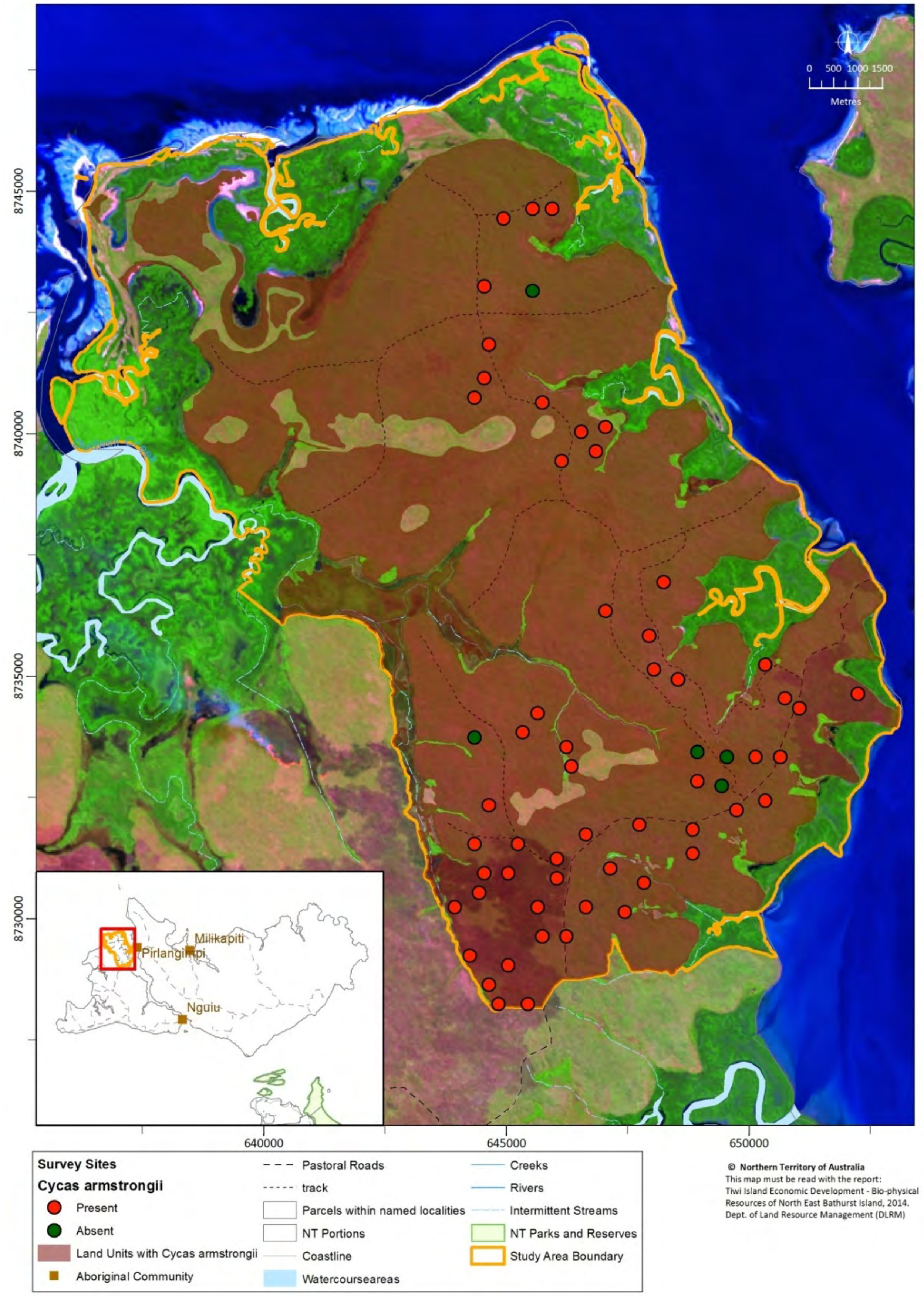

Figure 7-10: Land units (described in Chapter 6) and survey sites where *Cycas armstrongii* was recorded during 2014 surveys.

7.1.2.2 Monsoon rainforest

Within the study area, counts of the number of monsoon forest patches (irrespective of type) range between 54 and 62 depending on mapping scale, representing between 10.8% and 20.5% of the total number of monsoon forest patches on Bathurst Island. A total of 31 patches were sampled, representing between 50 - 57% and 6% of the total number of monsoon forest patches in the study area and on Bathurst Island, respectively (Figure 7-11).

Threatened plant species and other significant plant species recorded in monsoon forest surveys within the study area in October 2014 and minimum population estimates for these species are summarised in Tables 7-9 and 7-10. The proportion of patches in which each significant plant species occur is generally low - no threatened species occurred in more than 50% of all patches sampled, and seven of the nine threatened plants occurred in fewer than 5 patches.

For most significant species ten or fewer adult plants were recorded for patches where they were present (165 of 180 populations). For more than half of the populations (105 of 180) the combined count of adults and juveniles was 10 or fewer individuals. Many of the patches supported only juvenile plants with no adults recorded (48 of 105 records). The small total population size and paucity of adult plants suggests that in isolation, individual patches typically do not support populations of these significant species that are viable in the long-term. There was also a noteworthy prominence of juvenile plants for many species, often around ten times larger than the number of adults and in most cases effectively formed a ‘seedling-bank’. Such seedling banks are a common feature in rainforest plants which have short-lived seed, and serve as a pool of plants to colonise rainforest canopy gaps created by fallen tree. For some species such as *Tarennoidea wallichii* and *Xylopia monosperma*, only juveniles were recorded from within the study area (although very rare adults may have been missed).

The number of threatened plant species recorded in each rainforest patch varied from 0 to 5 (Figure 7-12) and the number of other significant species from 0 to 8 (Figure 7-13).

Table 7-9: Frequency and minimum population counts for threatened plant species recorded in rainforest patches from the study area. (Ad = Adults; Juv = Juveniles)

Species	Size class	No. of patches	Total individuals	Mean individuals per patch
Dendromyza reinwardtiana	Ad	11	25	2.3
	Juv	2	4	2
Elaeocarpus miegei	Ad	4	28	7
	Juv	4	355	88.8
Endiandra limnophila	Ad	10	84	8.4
	Juv	15	1698	113.2
Freycinetia excelsa	Ad	2	7	3.5
Hoya australis subsp. *oramicola*	Ad	1	50	50
Luisia corrugata	Ad	1	1	1
Mitrella tiwiensis	Ad	3	3	1
	Juv	3	28	9.3
Tarennoidea wallichii	Ad	0	0	0
	Juv	4	16	4
Xylopia monosperma	Ad	0	0	0
	Juv	3	25	8.3

Table 7-10: Frequency and minimum population counts for Near Threatened and Data Deficient plant species recorded in rainforest patches from the study area. (Ad= Adults; Juv= Juveniles)

Species	Size class	No. of patches	Total individuals	Mean individuals per patch
Embelia tiwiensis	Ad	10	102	10.2
	Juv	11	1026	93.3
Endospermum myrmecophilum	Ad	11	27	2.5
	Juv	2	2	1
Hypolytrum nemorum	Ad	1	100	100
Parsonsia sp. *Melville Island*	Ad	4	5	1.25
	Juv	3	5	1.7
Psychotria coelosperma	Ad	0	0	0
	Juv	10	292	29.2
Strychnos minor	Ad	10	100	10
	Juv	14	1351	96.5
Syzygium claviflorum	Ad	13	75	5.8
	Juv	17	220	12.9
Syzygium hemilamprum	Ad	13	48	3.7
	Juv	6	20	3.3

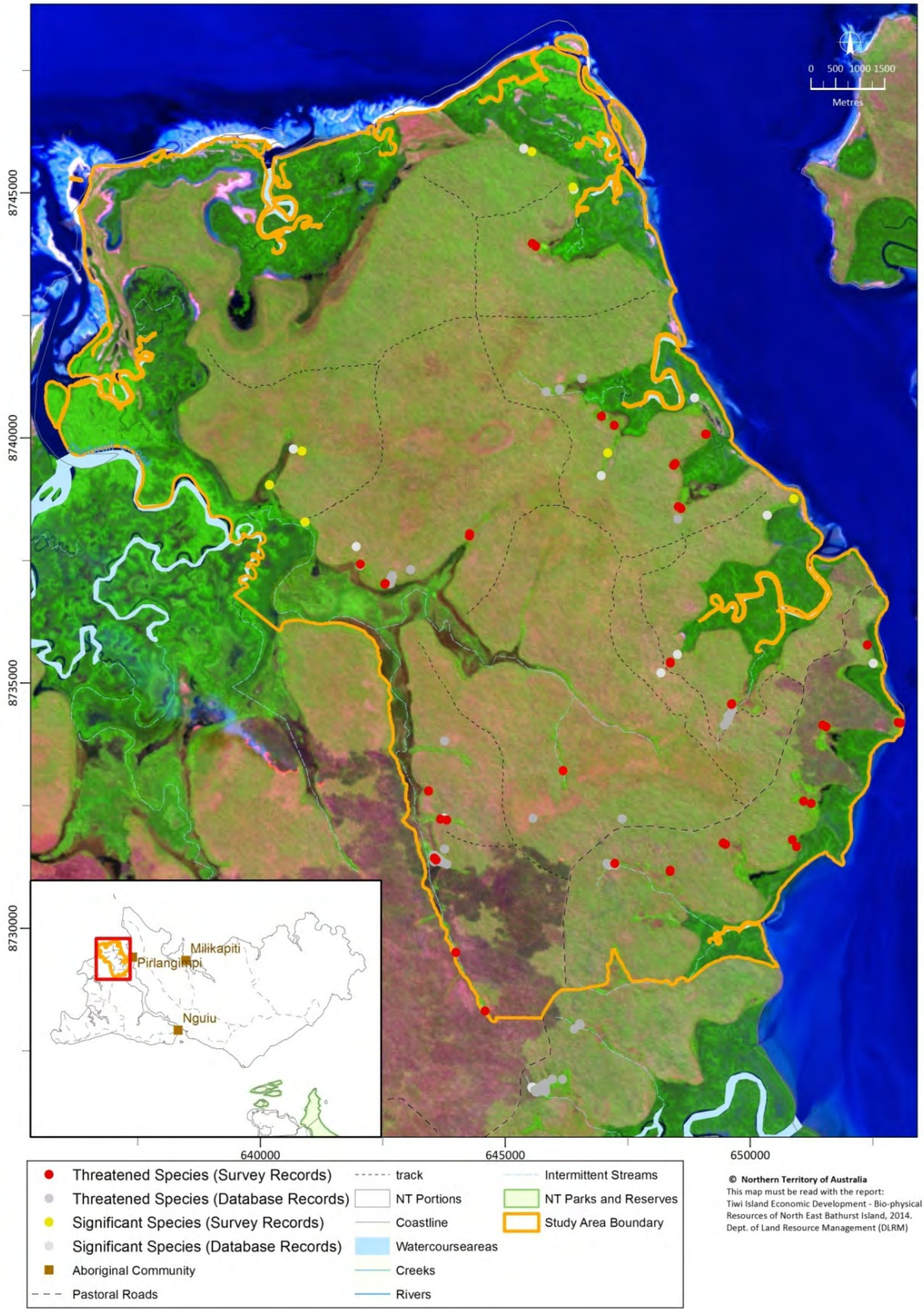

Figure 7-11: Location of all records of threatened and other significant plant species in monsoon forest patches

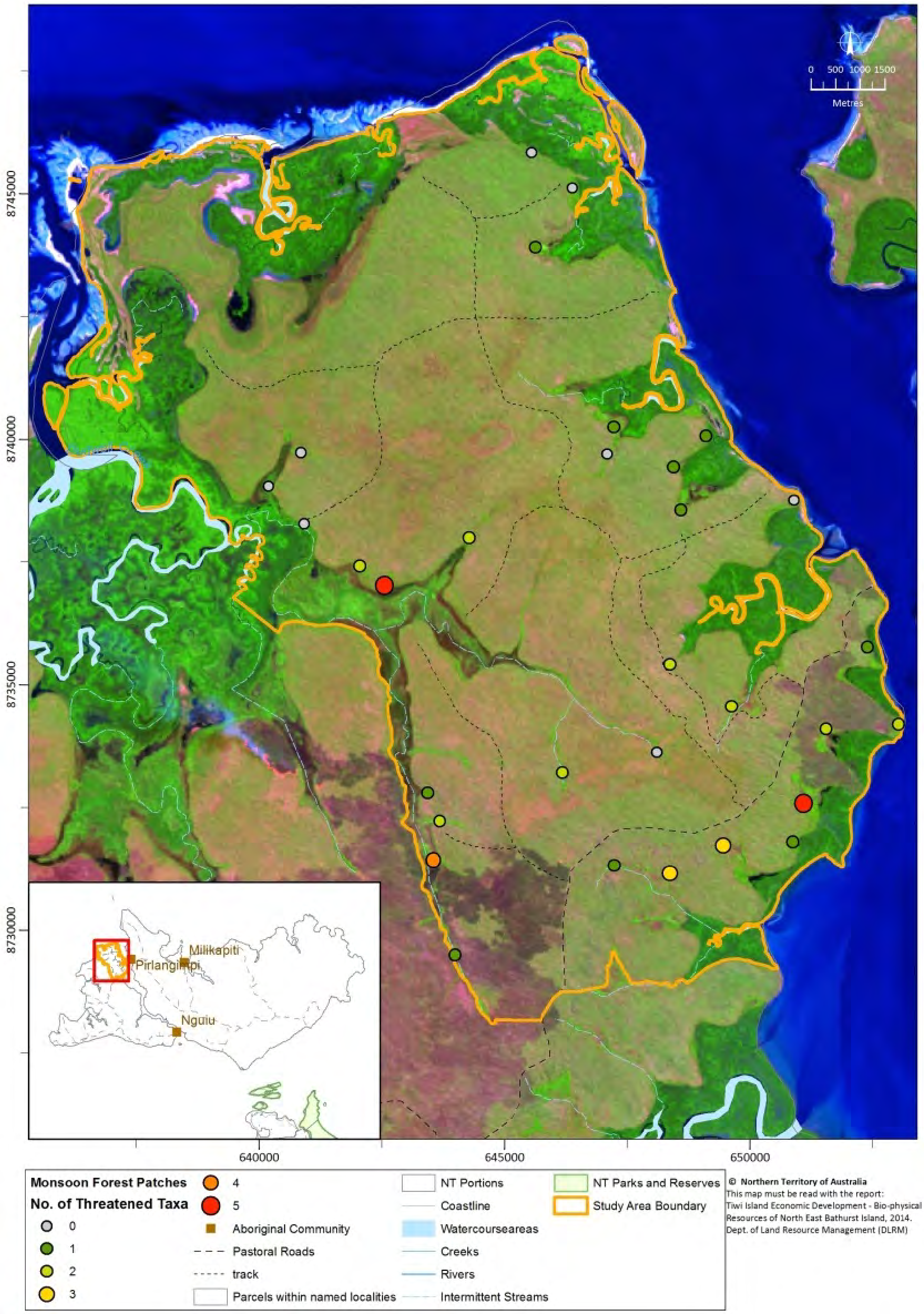

Figure 7-12: Number of threatened species recorded in each sampled monsoon forest patch

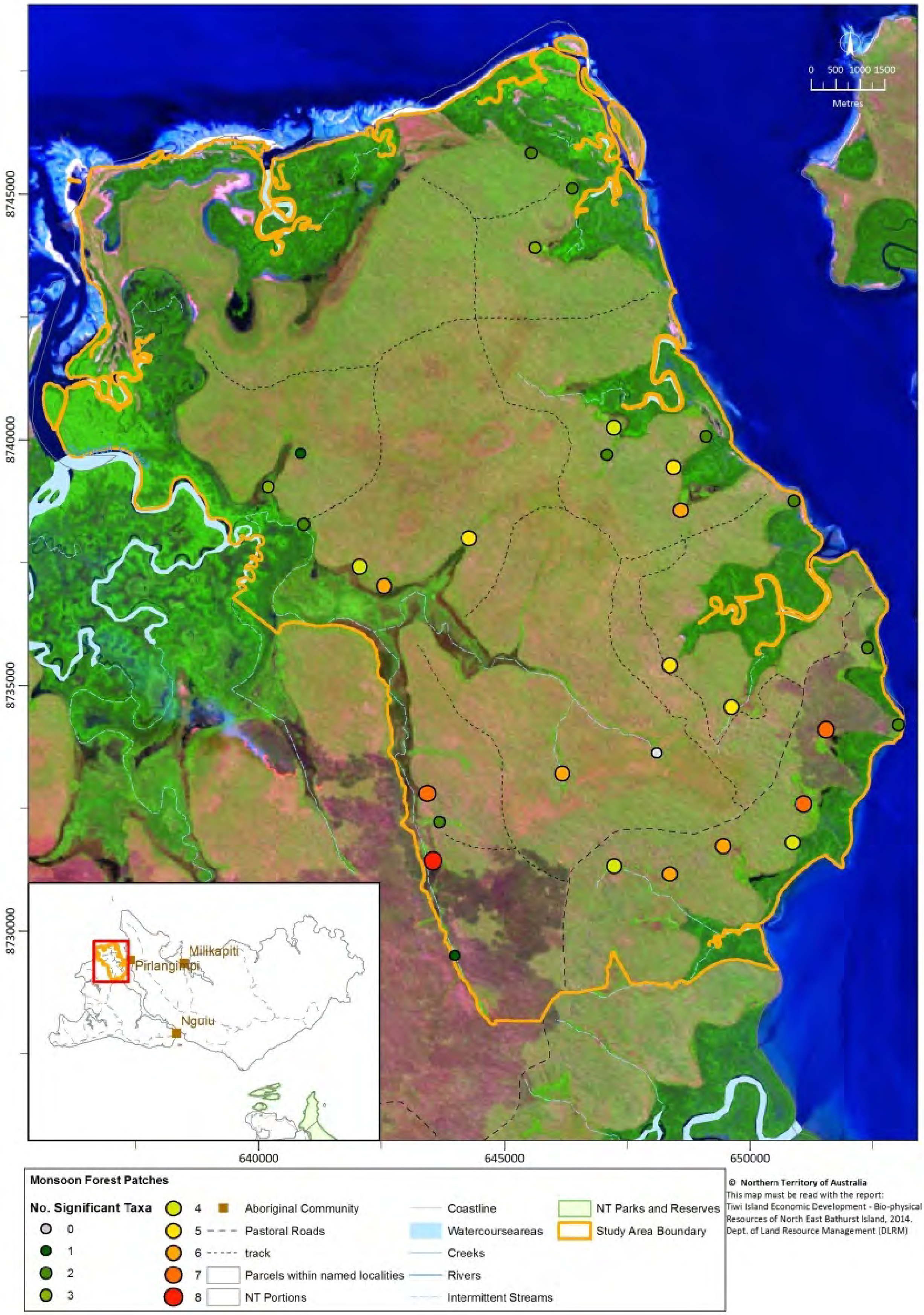

Figure 7-13: Number of other significant plant species recorded in each sampled monsoon forest patch

7.1.2.3 Swamps

The fern *LIndsaea walkerae* (Near Threatened, TPWCA) was recorded from four subpopulations in the study area, all associated with peaty permanent swamps along Dudwell Creek. Only a limited number of sites in this habitat were assessed during the survey and it is likely to be relatively common in this system (Land Unit 10c).

The grass *Ischaemum barbatum* (Near Threatened, TPWCA) was not recorded during the field survey but is known from the headwaters of Dudwell Creek. Other scattered records of the species are from other parts of Bathurst Island, Melville Island, Litchfield NP and near Port Keats.

The sedge *Scleria carphiformis* (Data Deficient, TPWCA) was recorded from a bog near Interview Point in March 2001 but was not recorded during the 2014 field survey. This species is very likely to occur at additional unsampled peaty bogs, which are often associated with rainforest patches in the study area. In the NT, the species occurs mostly on Bathurst Island with two records from Melville Island and two from Cobourg Peninsula.

Sophora longipes (Near Threatened, TPWCA) often occurs on the margins of creek flats and has previously been recorded in the north east of the study area near the estuary of Pimaroo Ck. In the NT, it occurs mostly on the Tiwi Islands but also in Western Arnhem Land and at a few locations south of Darwin.

7.2 Fauna

7.2.1 Introduction

The vertebrate fauna of Bathurst Island is considered to be moderately well known, although mostly from relatively recent fieldwork, with nearly all the vertebrate records for the Tiwi Islands prior to the 1990's from Melville Island (Fensham & Woinarski 1992). During the 1991/1992 wet season, vertebrate fauna was sampled at 29 sites (tightly clustered in three areas) on Bathurst Island as part of studies of monsoon forests across the Tiwi Islands (Fensham & Woinarski 1992). A further 115 sites were sampled on non-monsoon forest and woodland habitats in 2001 (Woinarski *et al.* 2003). Since 2001, some additional targeted vertebrate survey work has been undertaken on Bathurst Island for specific taxa or projects. After developing and refining a method to more efficiently trap Butler's Dunnarts on Melville Island, this was later used with some success at several sites in southern and central Bathurst Island (Ward *et al.* 2008). In 2012, intensive trapping for mammals were undertaken at two large grids in southern Bathurst Island as part of a project investigating the role of feral cats in mammal declines across northern NT (Stokeld *et al.* unpublished data). Other major Top End-wide surveys throughout the 1990's that contributed to the vertebrate record of Bathurst Island included those of sea birds (Chatto 2001), shore birds (Chatto 2003), waterbirds (Chatto 2000), marine turtles (Chatto 1998) and terrestrial birds (Mason & Schodde 1997). Compilation and analyses of all Tiwi biodiversity survey data up to 2003 provided comprehensive vertebrate checklists and identified the elements of the fauna for which the Tiwi Islands are important in terms of biodiversity conservation (Woinarski *et al.* 2003).

Bathurst Island is known to support 255 vertebrate species comprising 14 frogs, 55 reptiles, 157 birds and 28 mammals. The upland vertebrate fauna (i.e. excluding marine and coastal species) includes:

- nine species (2 reptile, 4 bird and 3 mammal) listed as threatened (Vulnerable, Endangered or Critically Endangered) under Australian (Environment Protection and Biodiversity Conservation Act) and/or Northern Territory (Territory Parks and Wildlife Conservation Act) legislation;
- six species (5 bird and 1 mammal) represented on the Tiwi Islands by endemic subspecies;
- two bird species listed under the BONN Convention (for the conservation of migratory species);
- 40 species (3 frog, 12 reptile, 19 bird and 6 mammal species) identified by Woinarski *et al.* 2003) as being significantly more abundant in woodland / open forest habitats on the Tiwi Islands, than in similar habitat elsewhere in northern NT (Appendix 12).

The north-eastern portion of Bathurst Island has not previously been subject to intensive fauna survey, due to remoteness and access limitations. The survey record for upland habitats in this region of Bathurst Island prior to 2014 comprises 768 terrestrial vertebrate records from 41 sites, including four species listed as threatened under Territory or Australian legislation (Table 7-11). An additional threatened vertebrate species, Butler's Dunnart, has also been recorded in similar habitats elsewhere on Bathurst Island and potentially occurs in the proposed development area.

Table 7-11: Threatened vertebrate species selected for survey in the north-east Bathurst Island study area. Brief profiles of these species are given in Appendix 13.

Common Name	Scientific Name	Status
Brush-tailed Rabbit Rat	*Conilurus penicillatus*	Vulnerable (EPBCA), Endangered (TWPCA)
Pale Field Rat	*Rattus tunneyi*	Vulnerable (TWPCA)
Tiwi Masked Owl	*Tyto novaehollandiae melvillensis*	Endangered (EPBCA, TWPCA)
Red Goshawk	*Erythrotriorchis radiatus*	Vulnerable (EPBCA, TWPCA)
Butler's Dunnart*	*Sminthopsis butleri*	Vulnerable (EPBCA, TPWCA)

The aim of this study was to assess the current status of the five threatened vertebrate species known or likely to occur in upland habitats (primarily eucalypt open forests and woodlands) in the proposed development area of north-east Bathurst Island. Sampling methods most suitable for detecting these species were employed and, while incidental data for other species were collected, this study was not intended to be a comprehensive assessment of the vertebrate fauna of the study area. There was also no attempt to sample for threatened invertebrate species that may conceivably occur in the study area (including Dodd's Azure butterfly, Atlas Moth, Cognate Land Snail).

As there is moderately good distribution data for the target threatened species across much of the Tiwi Islands, modelling was used to predict areas with a high likelihood of occurrence of each species. This allowed the significance of the project areas in containing suitable habitat for the species to be evaluated in the context of the Tiwi Islands as a whole.

7.2.2 Methods

Field surveys were conducted in two visits from May 22 to June 5, 2014 and from Oct 31 to Nov 11, 2014. Some camera traps left to record over the wet season were collected In February 2015.

7.2.2.1 Threatened mammal survey

Mammals were sampled at 40 sites, 28 sites in May/June and 12 in Oct/Nov (Figure 7-14). Each site comprised 24 live-capture traps (16 Elliott box traps and 8 Tomahawk small wire cage traps) placed equidistantly around a 50 m x 50 m square quadrat. This was consistent with the standard configuration used for mammal surveys across the Top End, except that the proportion of cage traps was increased to better target Brush-tailed Rabbit-rat. Traps were set for 4 nights and were checked, cleared and closed shortly after sunrise each morning. Traps were baited with a "standard mammal mix" of peanut butter, oats and honey with the bait replenished when traps were reset in late afternoon.

Butler's Dunnarts are rarely captured in Elliott or cage traps and readily escape from shallow pit traps. The greatest capture success has been achieved using pitfall traps 60 cm deep placed in lines of 10 along 100 m lengths of low (30 cm high) plastic fencing. This technique demands a substantial investment of time and personnel to set up and manage, which was beyond the resources available for the 2014 survey. For the survey, a trap arrangement comprising 3 deep pitfall buckets spaced 10 m apart, set along a plastic fence 25 - 30 m long, with deep pitfall lines established at 20 of the survey sites was used. At the sites without deep pitfall lines, four "standard" pitfall traps were installed at each 20 litre bucket at the centre of a 10 m length of low plastic fencing. All pitfalls were open for 4 days, and were checked early each morning, as well as periodically throughout the day to remove any captured reptiles.

In addition to live capture traps, camera trap arrays were installed at 22 sites (16 in May, 6 in November 2014). Each array consisted of 5 baited motion and heat sensitive cameras deployed in and around the trapping quadrat. Cameras set in May were collected after 26 - 29 days; those set in November were collected after 72 - 73 days. Technical information about the cameras and deployment methods are contained in Gillespie *et al.* (2015).

7.2.2.2 Threatened bird survey

Masked Owls were surveyed at night along vehicle tracks using the call-broadcast method recommended by Magrath *et al.* (2010). A pre-recorded Masked Owl call was broadcast through a portable speaker from the top of a vehicle. Any owl within earshot of the call was usually quick to respond by either replying to the call and/or flying in close to the broadcast site. Broadcasts were stopped once a response was detected or after 5 minutes if there was no response; most responses were within the first two minutes. A field test of the speaker established that the call was audible to humans at a maximum distance of around 500 m. Broadcast survey points separated by 1 km along all the tracks throughout the study area were used. This spacing was intended to ensure that the owls attracted to each broadcast site were likely to be different individuals. Wherever possible the surveys were conducted in a single session rather than spread over several nights to minimise the chance of recording the same individuals in different locations on different nights. Overall there were 63 owl broadcast sites, 30 sites sampled on 2-3 June 2014 and 33 sites on 4 Nov 2014 (Figure 7-14).

The most reliable method of locating Red Goshawk is to search for their distinctive nests (Magrath *et al.* 2010). If a nest is located then call broadcasts may be used to attract the birds to confirm their presence. Nest searches were conducted along all the vehicle tracks throughout the study area, along walking routes to the mammal survey sites (up to 1.5 km from vehicle tracks) and opportunistically along other walking routes. While this resulted in a broad spatial coverage of the study area, it was biased toward watersheds where tracks were located and habitats targeted for mammal surveys, and undersampled some areas that may be suitable for Red Goshawk, particularly denser forest along major drainage lines and margins of rainforest patches.

7.2.2.3 Species distribution modelling

Location data for each of the targeted threatened species from the 2014 surveys were pooled with previous data for Bathurst and Melville Islands from all known sources (Table 7-12). These data are from a number of systematic surveys, with some variation in methodology, as well as incidental or opportunistic sightings (particularly for the bird species) and were therefore treated as simple “presence” data for the purpose of modelling. Some spatial bias in the data is evident as there is a patchy distribution of fauna survey effort across the Tiwi Islands. The east of Melville Island is notably undersampled. While some systematic surveys deliberately sought to maximise the environmental spread of sample sites, others were more focused (e.g. on rainforests or eucalypt open forest) and there is a tendency for sites (and particularly incidental sightings) to be near access tracks.

Table 7-12: Total numbers of spatially unique records for each target species from the Tiwi Islands, used for MaxEnt modelling.

Species	Number of records
Butler’s Dunnart	56
Pale field Rat	119
Brush-tailed Rabbit Rat	129
Red Goshawk	16
Tiwi Masked Owl	81

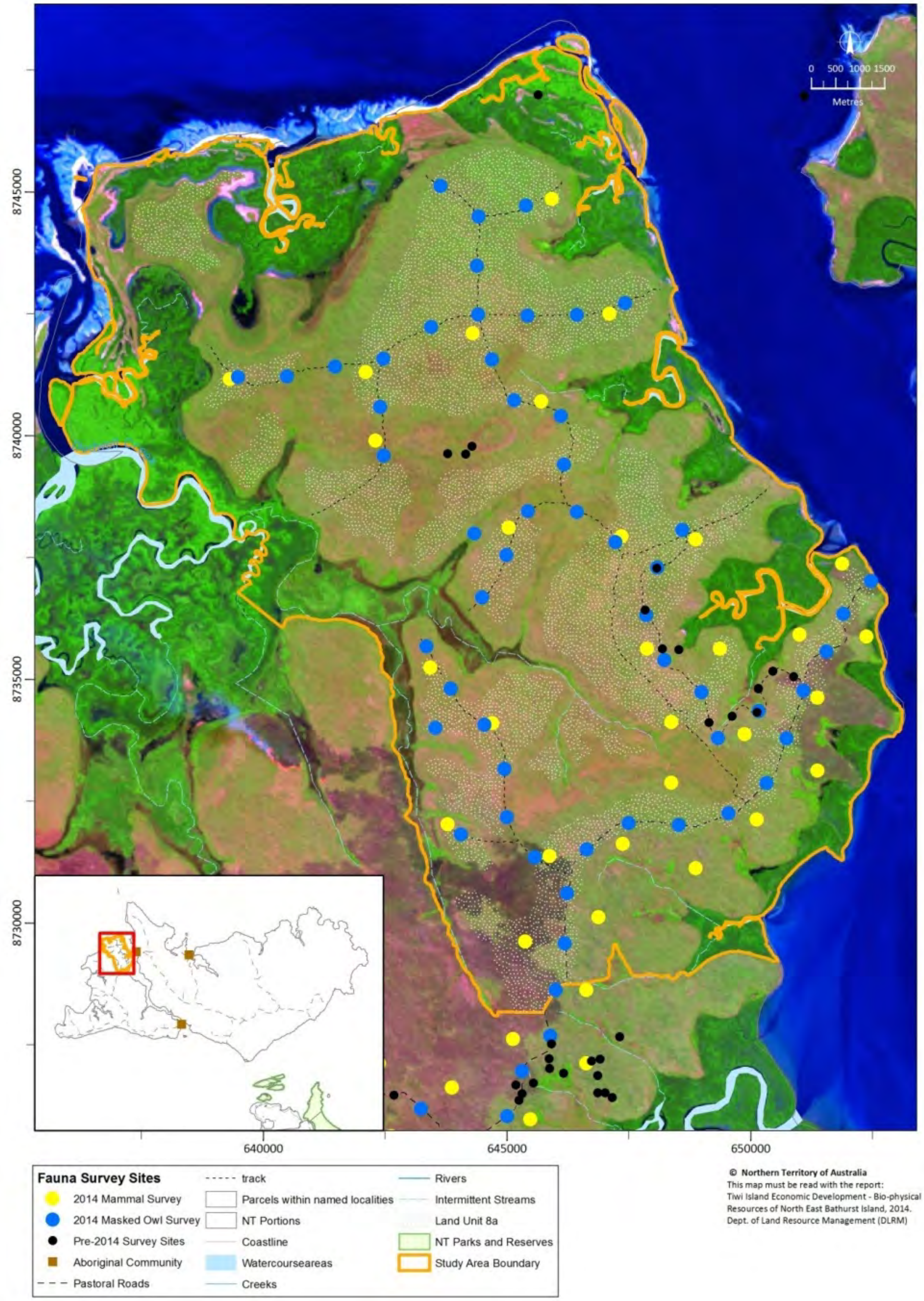

Figure 7-14: Locations of sites sampled during the 2014 fauna survey.

Species distributions were modelled using the software package MaxEnt, a widely used tool which is designed for presence-only data and has the capacity to accommodate spatial bias (Elith 2008, Elith *et al.* 2011). MaxEnt uses records of a species presence with spatial sets of relevant environmental variables (predictors) to mathematically characterise the "ecological niche" of a species in terms of these environmental variables. From this, it then calculates how closely each (unsampled) point in the rest of the landscape resembles ideal habitat for the species. MaxEnt also tests each environmental variable for its power in explaining the observed observations of that species, and through an iterative process seeks models that provide the best explanation of observed distributions with the lowest complexity. The outputs of MaxEnt include a raster map of the likelihood of occurrence for the species, and the relative contribution of each environmental variable to this model.

Environmental data layers were selected from the range available from national datasets (sourced through Atlas of Living Australia) or held within the DLRM spatial data library using the following criteria:

- Potential functional relevance to the target species
- Moderate to high spatial resolution
- Coverage of the entire Tiwi Islands
- Free from obvious artefacts
- Minimise correlation between environmental variables

Initial model runs were also used to exclude variables with very low explanatory power for any species. A final set of 14 environmental variables was selected (Table 7-13 and also Appendix 10) and expressed as 3-second grids covering the Tiwi Islands.

Table 7-13: Environmental data layers selected for use in MaxEnt modelling

Name	Detail and source
weathering	Weathering index, radiometric gamma ray aerial survey
u_th_ratio	Uranium: thorium ratio, radiometric gamma ray aerial survey
th	Equivalent thorium, radiometric gamma ray aerial survey
k	Equivalent potassium, radiometric gamma ray aerial survey
topo_wetness	Topographic wetness index, derived from Digital Elevation Model
slope_pcnt	% slope, derived from Digital Elevation Model
DEM	Elevation, Digital Elevation Model
sand100av	Mean %sand, Soil data
clay	Mean %clay, Soil data
bd100av	Bulk density, Soil data
firetslb00_12	Time since last burn, MODIS bushfire data 2000-2012
firefreq00_12	Fire frequency, MODIS bushfire data 2000-2012
1990fpc	Foliage projected cover, derived from Landsat
ann_rain	Mean annual rainfall, extrapolated surface from BoM weather data

For modelling of mammal species (where presences are mostly from systematic survey data), a bias factor of 10 was applied to all grid cells within a 1km radius of each presence location. No bias correction was made in models for bird species (where many presences are from incidental observations).

The output of the modelling runs is a grid for each species, with cell values scaled between 0 and 1. These values cannot generally be interpreted as the absolute probability of a species occurring within each cell but the values are a relative measure of the likelihood of each cell containing suitable habitat. Values greater than 0.5 were interpreted as representing a "high likelihood" of the species occurrence. Output grids were mapped back onto the extent of the study area, and of the Tiwi Islands, and the area and proportion of each occupied by high-likelihood habitat was calculated for each species. Species models were derived using data that was mostly collected before clearing of land for *Acacia mangium* plantations occurred on the Tiwi Islands. For the Tiwi Islands, the area and proportion of high-likelihood habitat subject to clearing was also calculated for each species, in order to assess what proportion of total remaining habitat was represented within the study area.

7.2.3 Results

A total of nine mammal species were positively detected in the study area during the survey (Table 7-14). The Northern Brush-tailed Possum (*Trichosurus vulpecula*) and the Northern Brown Bandicoot (*Isoodon macrourus*) were detected most frequently, being recorded at 93% and 80% of the mammal survey sites respectively. Camera traps were successful in recording most mammal species in some sites where they were not recorded by trapping (Appendix 14). Camera traps left out at six sites over the 2014/15 wet season photographed a small dasyurid at 3 sites which was provisionally identified as Butler's Dunnart *Sminthopsis butleri* (Figure 7-15). Nineteen reptiles and three frog species were also recorded from the sites, primarily from pit traps (Appendix 14). Data for targeted threatened species is described in detail below.

Table 7-14: Mammal species recorded in North East Bathurst Island in 2014, showing the number of sites from which each species was detected (n=40; *=provisional identification from camera trap photos).

Species	Status	No sites
Brush-tailed rabbit Rat *Conilurus penicillatus*	Vulnerable (EPBCA), Endangered (TWPCA)	22
Pale Field Rat *Rattus tunneyi*	Vulnerable (TWPCA)	14
Butler's Dunnart *Sminthopsis butleri*	Vulnerable (EPBCA, TPWCA)	3*
Grassland Melomys *Melomys burtoni*		9
Delicate Mouse *Pseudomys delicatulus*		1
Sugar Glider *Petaurus breviceps*		1
Northern Brush-tail Possum *Trichosurus vulpecula*		37
Northern Brown Bandicoot *Isoodon macrourus*		32
Agile Wallaby *Macropus agilis*		9
Dingo *Canis lupis*		3

Figure 7-15: Dasyurid provisionally identified as Butler's Dunnart *Sminthopsis butleri* and recorded in the study area only by camera traps (the metal post is 30 mm wide).

7.2.3.1 Brush-tailed Rabbit Rat

Brush-tailed Rabbit Rat was detected at 22 sites (55%; Figure 7-16). The species was also seen at night at several locations while driving along tracks. Records were distributed evenly in forest and woodland throughout the study area.

The MaxEnt model predicted that high likelihood habitat for this species occupies 60% of the study area (Figure 7-17).

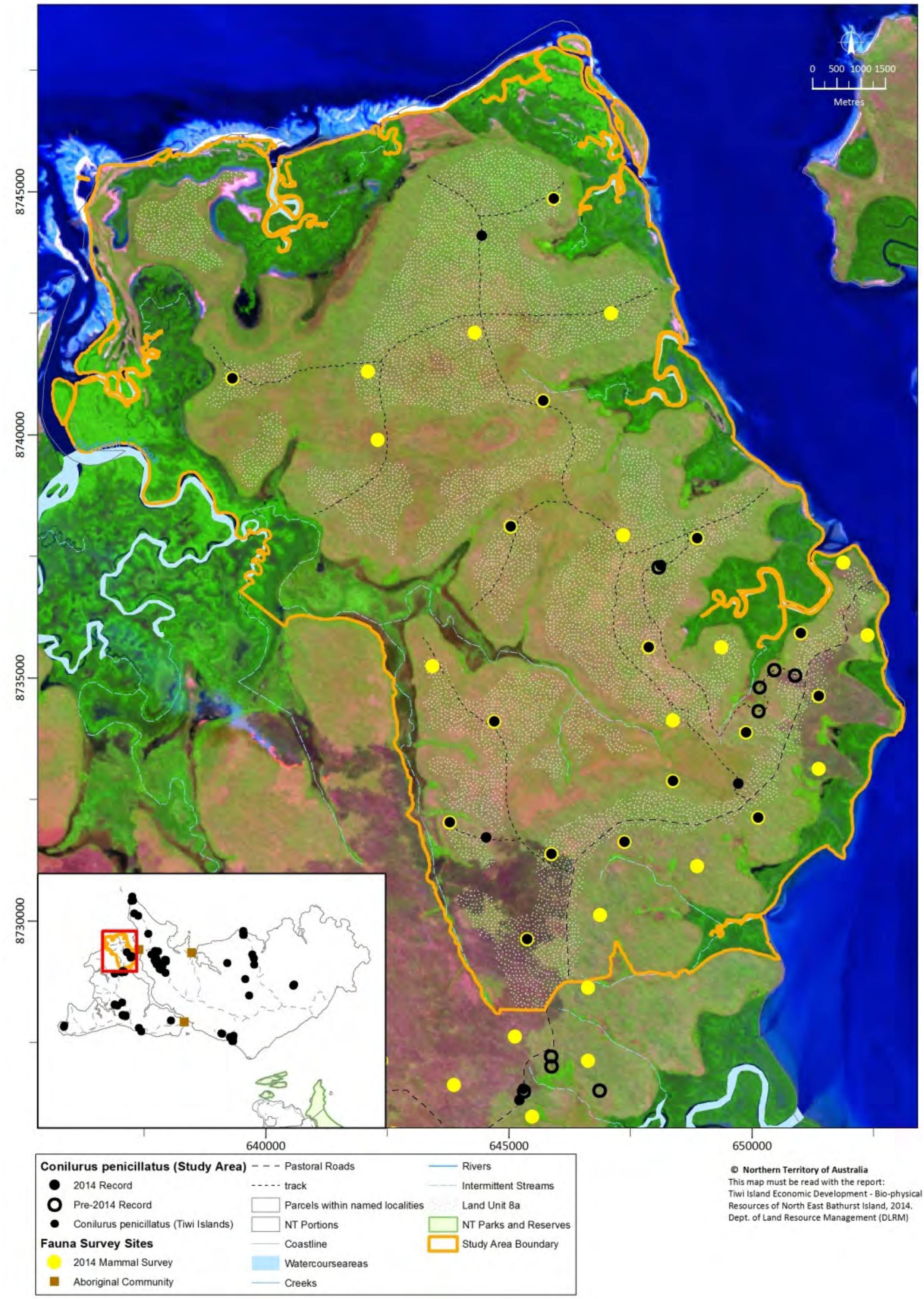

Figure 7-16: Records for Brush-tailed Rabbit Rat in the study area.

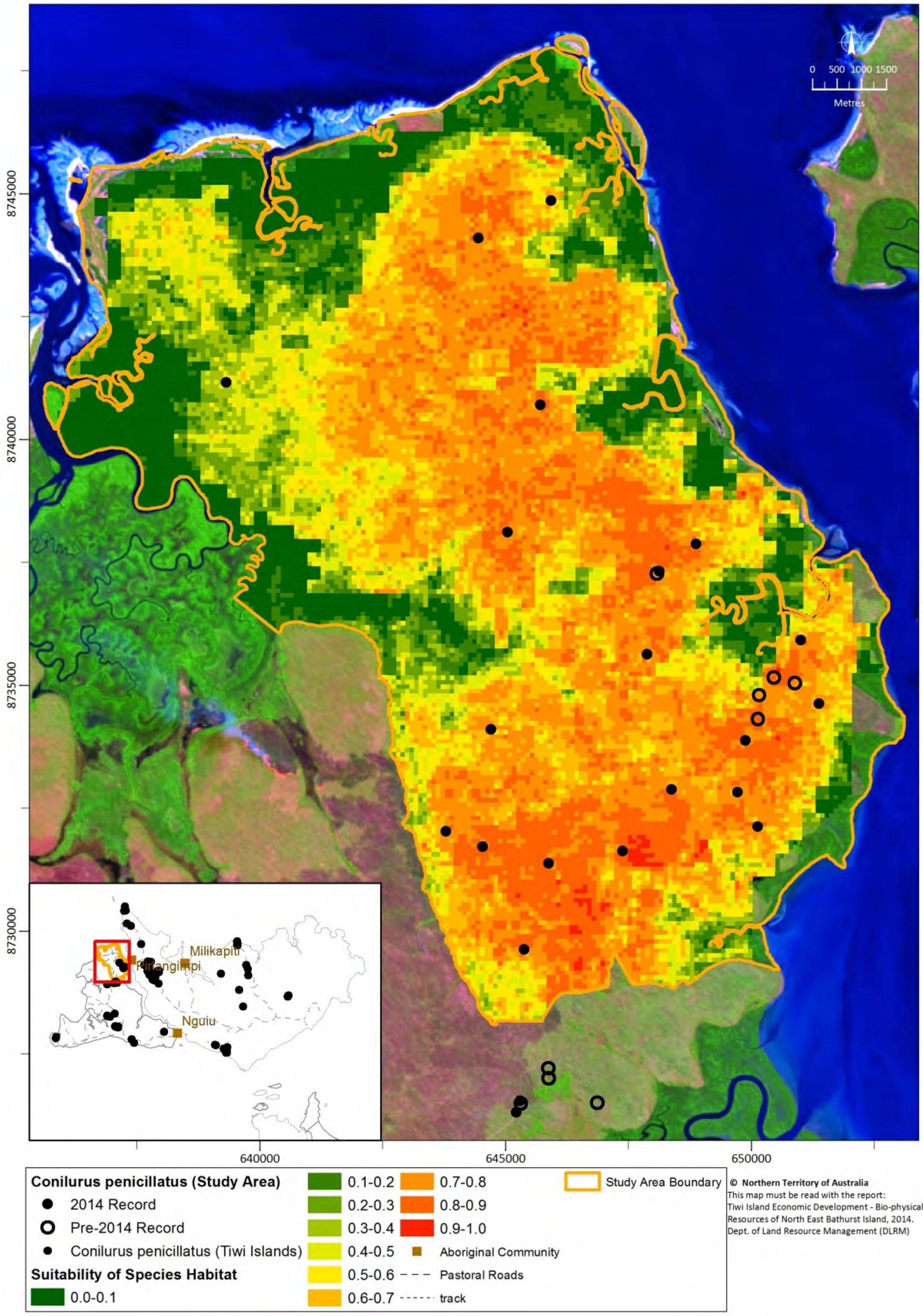

Figure 7-17: MaxEnt modelling of likelihood of suitable habitat for Brush-tailed Rabbit Rat. The model is derived for the whole Tiwi Islands (data points on inset map and see Appendix 15), however, this figure shows only the study area (with data points).

7.2.3.2 Pale Field Rat

Pale Field Rat was recorded at 14 sites (35%; Figure 7-18). The species was found throughout most of the study area, although there were no records from the most northern sites.

The MaxEnt model predicted that high likelihood habitat for this species occupies 61% of the study area (Figure 7-19).

7.2.3.3 Butler’s Dunnart

Butler’s Dunnart was not detected at any site by trapping, although this species is known to be difficult to capture. A small dasyurid provisionally identified as this species was detected at three of six sites where camera traps were left out for 10 weeks during the wet season (Figure 7-20). The photographs were attributed to Butler’s Dunnart rather than Red-cheeked Dunnart *Sminthopsis virginiae* due to cheeks not obviously flushed with rufous, and the pelage not obviously speckled with white-tipped hairs, and the preference of Red-cheeked Dunnart for more mesic habitats. Small dasyurids were not recorded by cameras established at 16 sites during the dry season, although these ran for only 4 weeks. The identity and distribution of this species in the study area therefore remains uncertain.

The MaxEnt model for Butler’s Dunnart using only confirmed records predicts that a tiny area (2 ha) of high likelihood habitat occurs within the study area (Figure 7-21). This model would likely change significantly if the provisional records form the 2014 survey were included.

7.2.3.4 Tiwi Masked Owl

Masked Owls were recorded at 14 (22%) of the broadcast sites and appear to be fairly uniformly distributed throughout open forest habitat in the study area (Figure 7-22).

The MaxEnt model predicted that high likelihood habitat for this species occupies 57% of the study area (Figure 7-23).

7.2.3.5 Red Goshawk

No Red Goshawk nests were located and there were no confirmed sighting of birds during the survey. There were two uncorroborated sightings of Red Goshawk from the same area by two different observers in different survey periods. Additional searches of the forest south-west from the back of the estuary near Sinclair Point across to the upper, north-west-flowing reaches of Dudwell Creek are required to verify these observations.

The MaxEnt model for Red Goshawk (which did not include these uncorroborated sightings) predicted that high likelihood habitat for this species occupies 7% of the study area (Figure 7-24).

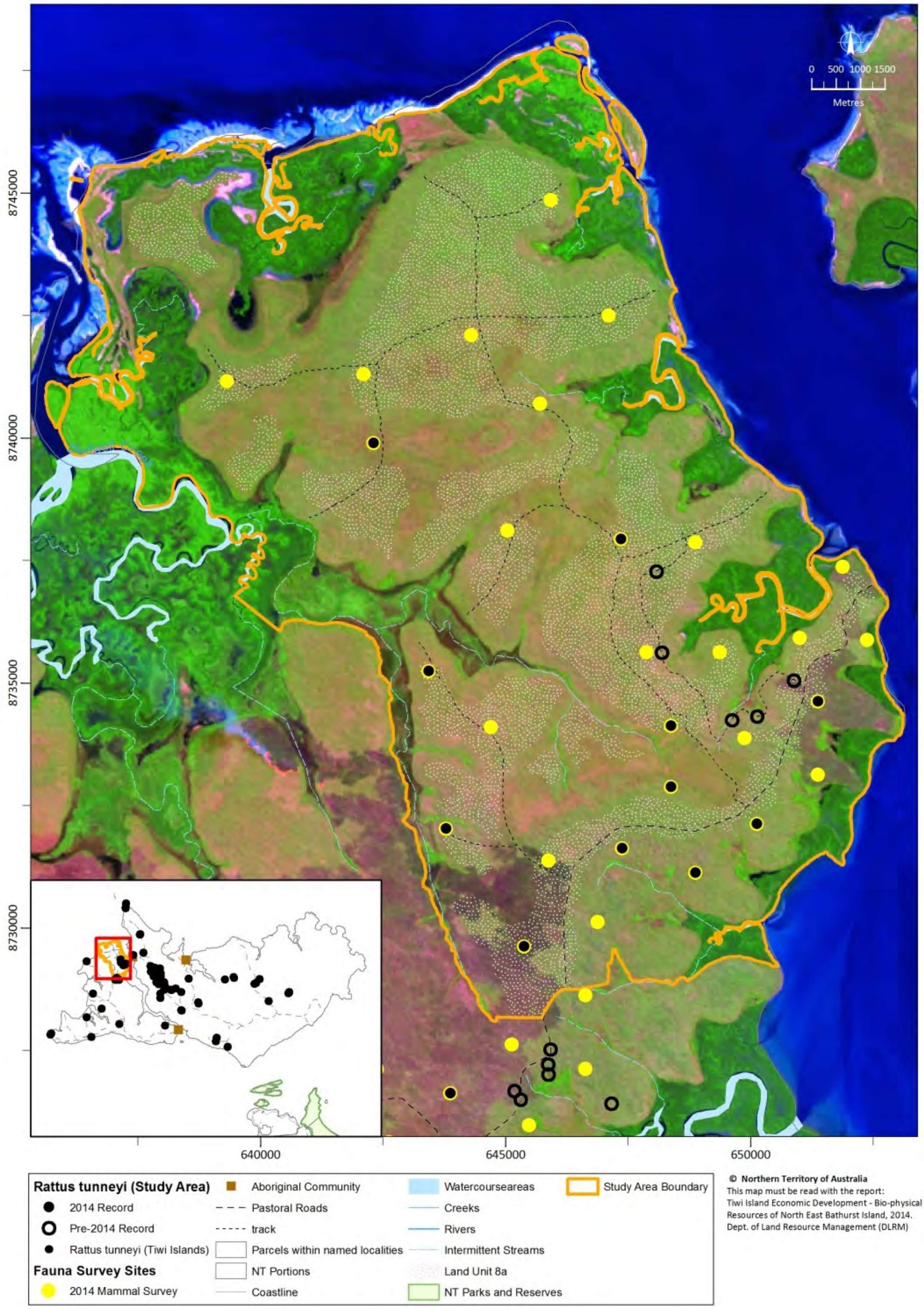

Figure 7-18: Records for Pale Field Rat in the study area.

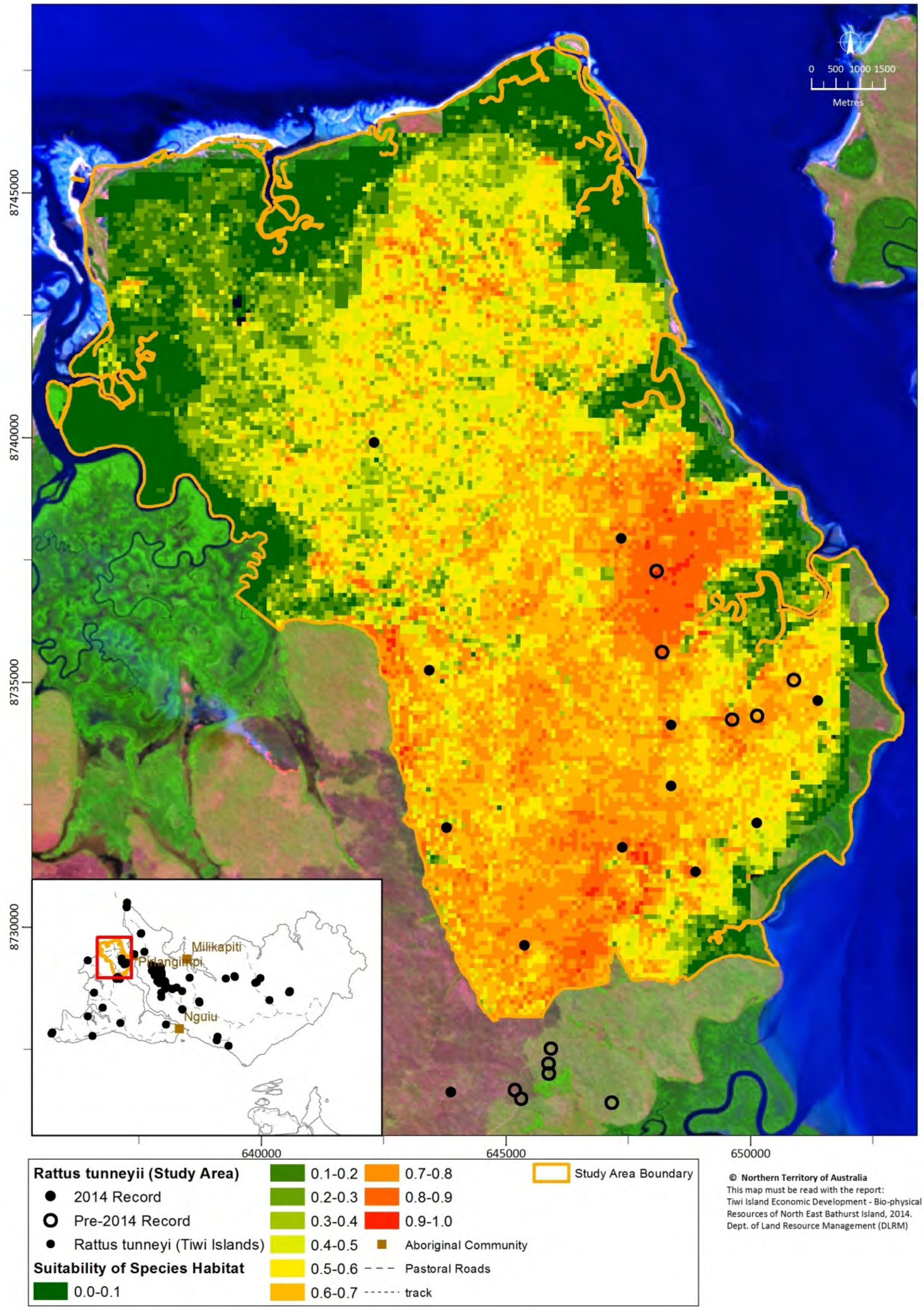

Figure 7-19: MaxEnt modelling of likelihood of suitable habitat for Pale Field Rat in the study area.

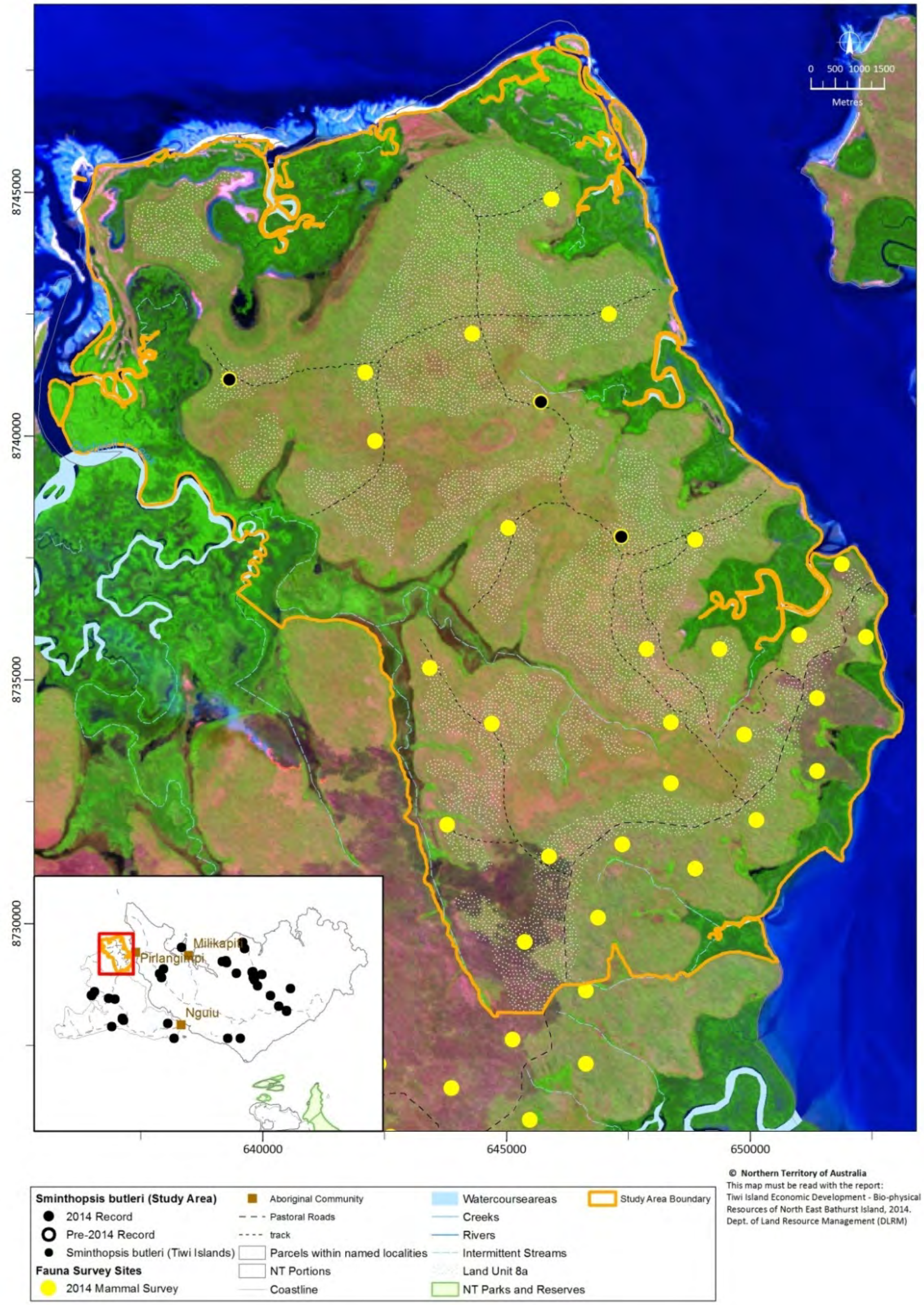

Figure 7-20: Provisional records for Butler's Dunnart in the study area.

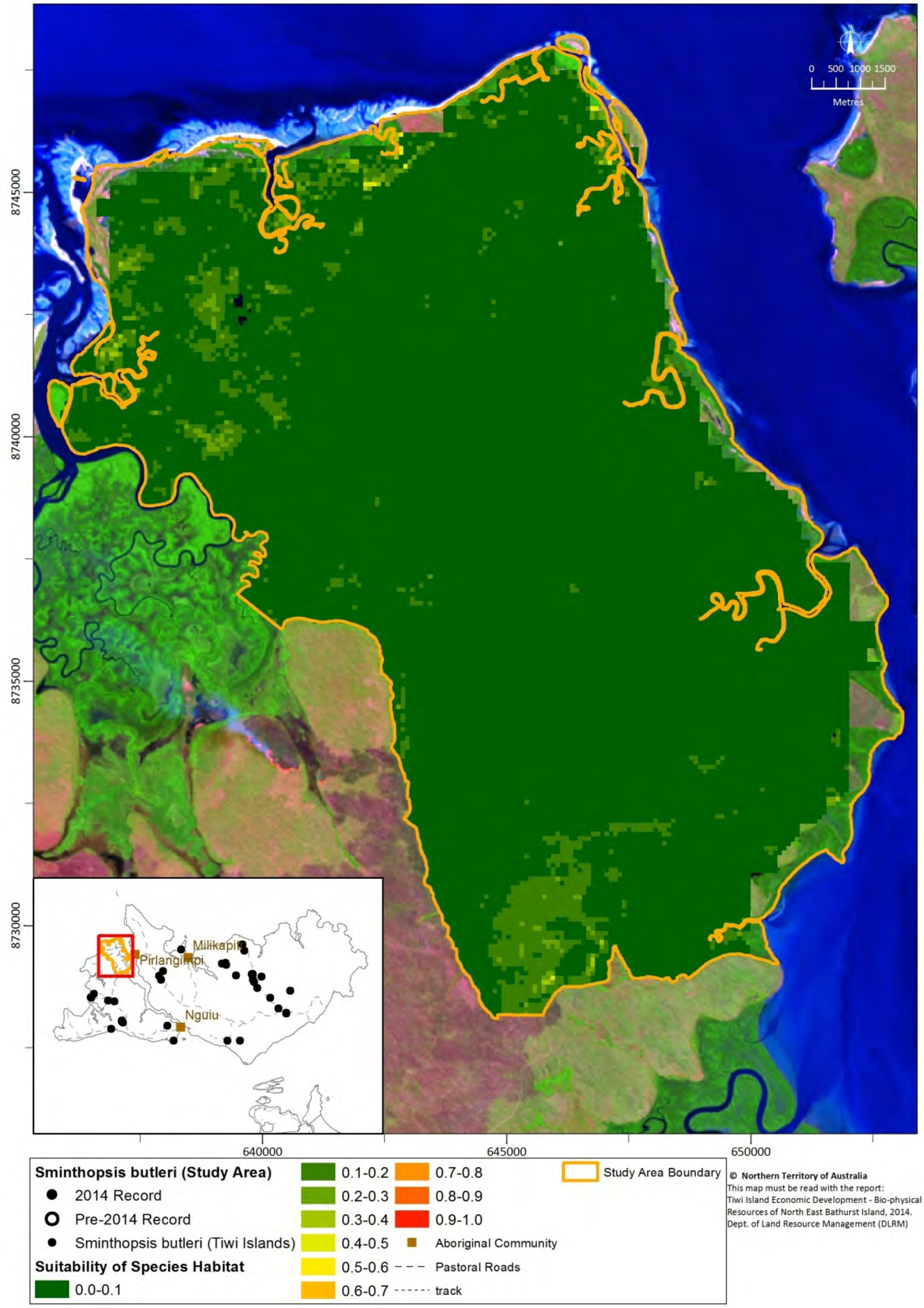

Figure 7-21: MaxEnt modelling of likelihood of suitable habitat for Butlers Dunnart in the study area, using only confirmed records (as per inset map).

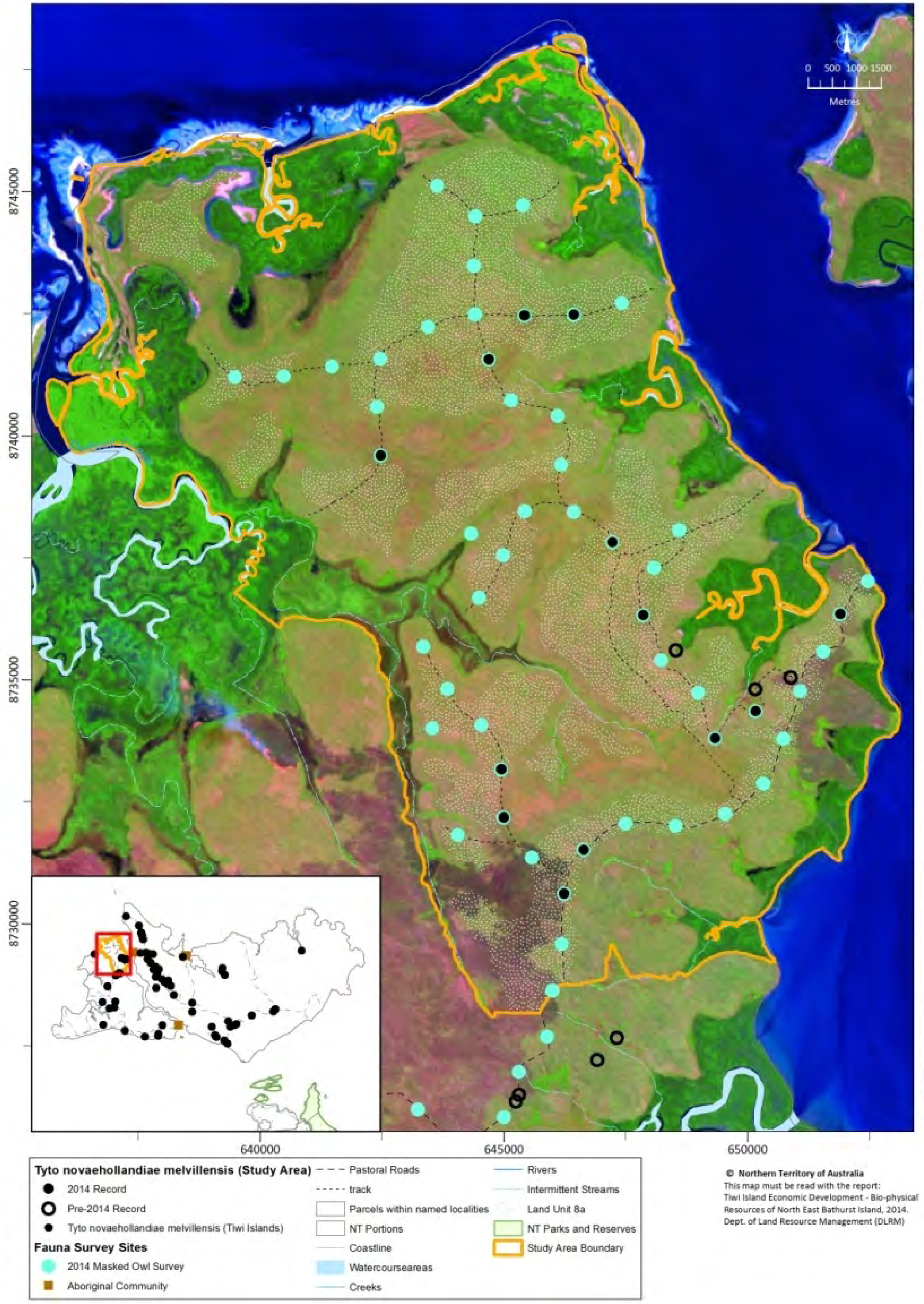

Figure 7-22: Records for Tiwi Masked Owl in the study area.

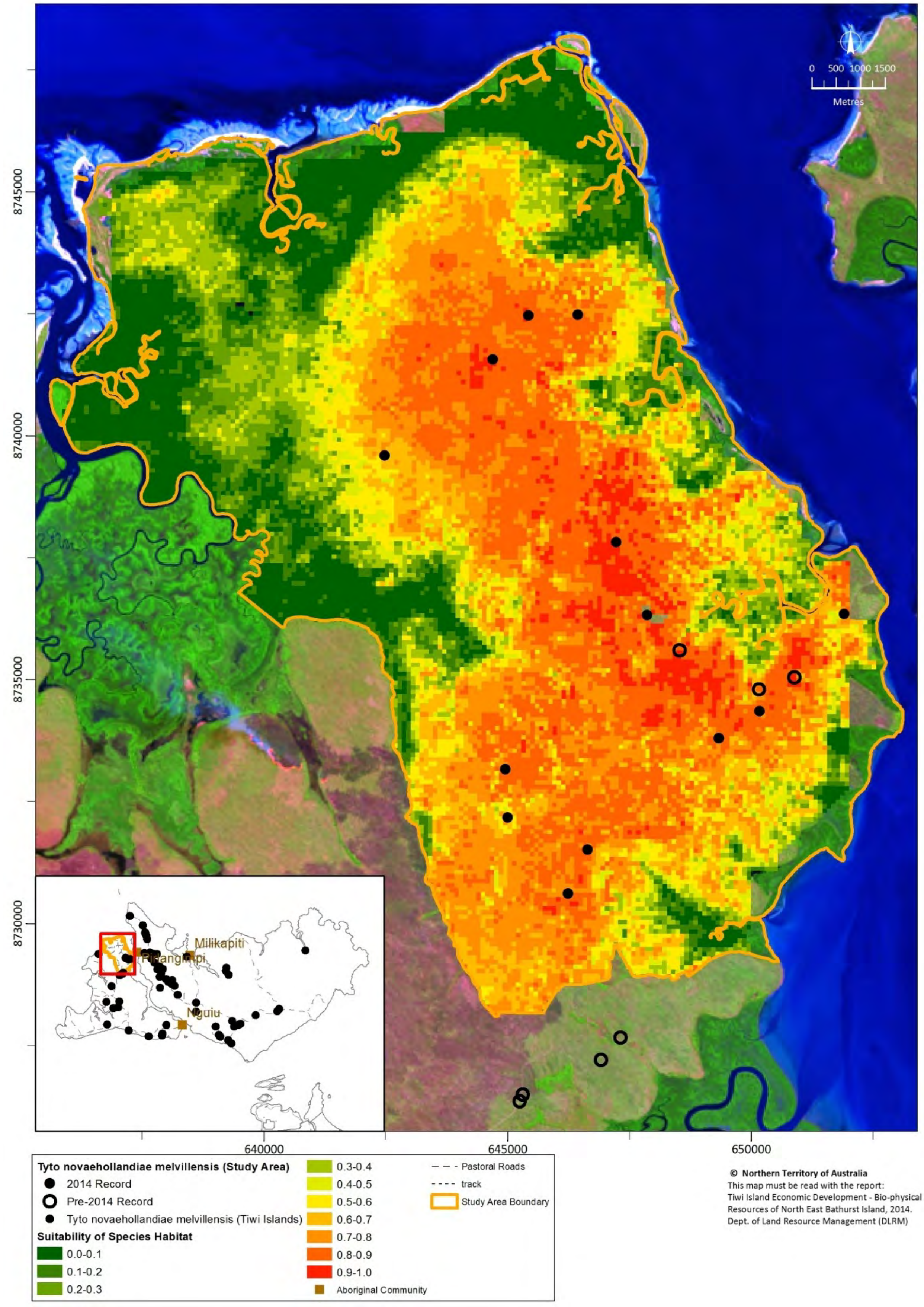

Figure 7-23: MaxEnt modelling of likelihood of suitable habitat for Masked Owl in the study area.

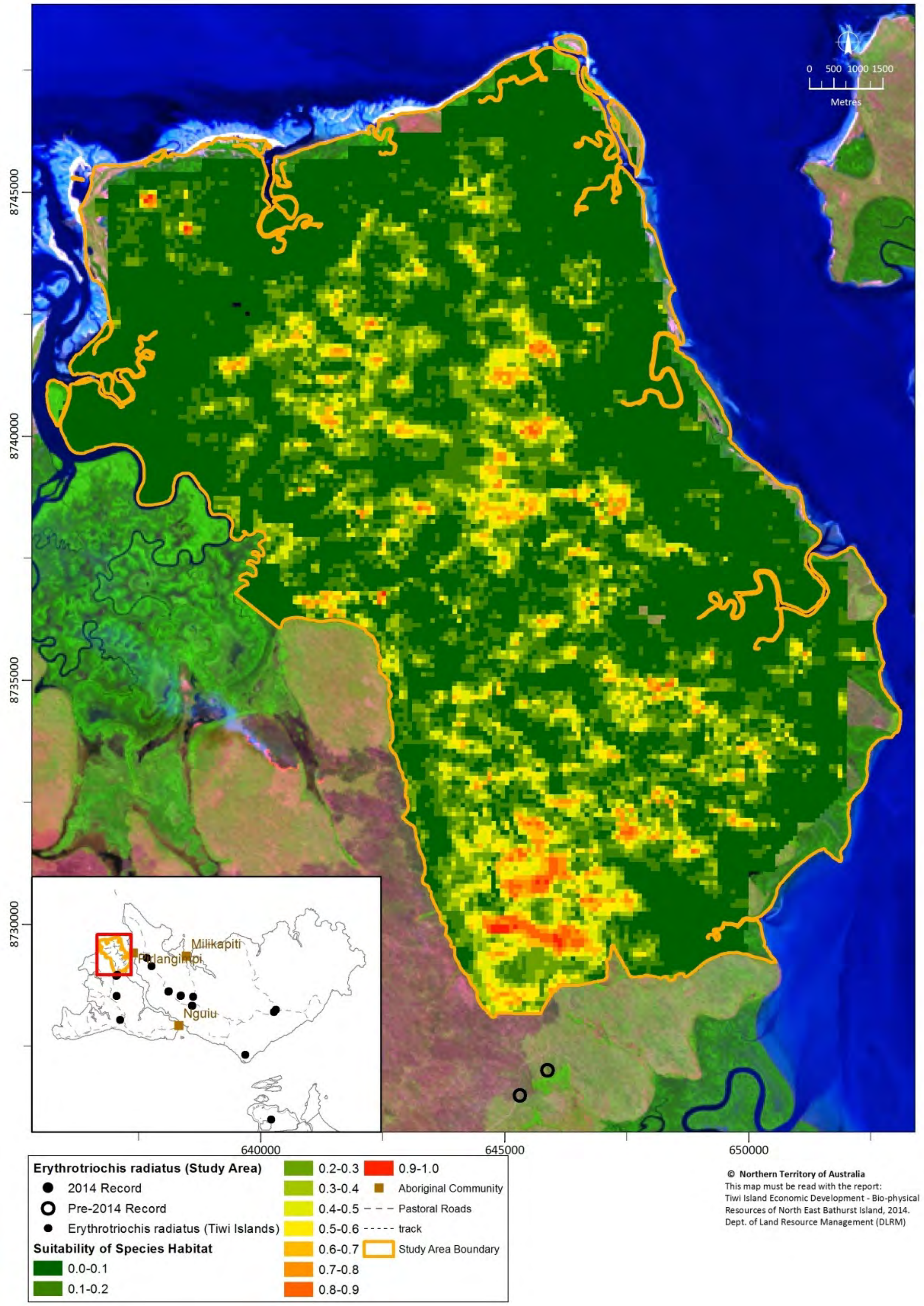

Figure 7-24: MaxEnt modelling of likelihood of suitable habitat for Red Goshawk in the study.
Note: Previous records immediately south of the study area.

7.3 Biodiversity management

Results from the 2014 surveys, combined with previous data, show that the eucalypt forests and woodlands in the study area provide habitat for four threatened vertebrate and three threatened plant species (Table 7-15), with the presence and distribution of one additional mammal species and one additional bird species requiring clarification. While some of the threatened species occurring in eucalypt woodlands occur very sparsely (e.g. *Typhonium jonesii*) or have preferred habitat with a relatively confined distribution (eg *Typhonium mirabile),* one plant (*Cycas armstrongii)*, one bird (Red Goshawk) and two mammal species (Brush-tailed Rabbit-rat, Pale Field Rat) are widespread and relatively numerous within land units assessed in Chapter 6 as moderately suitable for agriculture (Table 7-15).

Table 7-15: Threatened plant and animal species recorded or likely to occur within the study area, showing preferred habitat and status under the *Territory Parks and Wildlife Conservation Act* (TPWCA) and *Environment Protection and Biodiversity Conservation Act* (EPBCA). Eucalypt forest species that occurred widely in land units suitable for agriculture are in **bold**. Habitat: EF=eucalypt forest or woodland, MF=monsoon forest and thickets, R= riparian. Conservation status: CR=Critically Endangered, E=Endangered, V=Vulnerable. (e) Indicates the species or subspecies is endemic to the Tiwi Islands and (d) that within the NT it occurs only on the Tiwi Islands. * indicates presence and distribution in the study area requires further investigation.

Species	Habitat	TPWCA	EPBCA
Cycas armstrongii	EF	V	
Dendromyza reinwardtiana	MF	V (d)	
Elaeocarpus miegei	MF	CR (d)	
Endiandra limnophila	MF	V	
Freycinetia excelsa	MF	V	
Hoya australis oramicola	MF	V (e)	V
Luisia corrugata	MF	V	
Mitrella tiwiensis	MF	V (e)	V
Tarennoidea wallichii	MF	E	
Thrixspermum congestum	MF	V	
Typhonium jonesii	EF	E (e)	E
Typhonium mirabile	EF	E (e)	E
Xylopia monosperma	MF	E	E
Brush-tailed Rabbit Rat *Conilurus penicillatus melibius*	EF	E (e)	V
Pale Field Rat *Rattus tunneyi*	EF	V	
Tiwi Masked Owl *Tyto novaehollandiae melvillensis*	EF	E (e)	E
Red Goshawk *Erythrotriorchis radiatus* *	EF/R	V	V
Butler's Dunnart *Sminthopsis butleri* *	EF	V	V

Monsoon rainforest patches in the study area support at least ten threatened plant species (Table 7-15), which is 12% of the total number of NT plant species listed as threatened under the *Territory Parks and Wildlife Conservation Act*. These rainforest patches are on land units considered not suitable for agriculture, but are generally Groundwater Dependent Ecosystems**.**

For seven of the threatened plant species, the study area contains 20% or more of their known population within the Northern Territory. A further 20 plant species listed as Near-Threatened or Data Deficient (*Territory Parks and Wildlife Conservation Act)* occur in the study area, and for nine of these the study area contains 20% or more of their known NT population.

7.3.1 Risks to biodiversity

For species occurring in eucalypt open forest or woodland, the main direct risk from agricultural development is habitat loss through clearing or severe structural alteration. Species that have relatively large home ranges and rely on large tree hollows for roosting and nesting (Tiwi Masked Owl) or very large emergent trees for nesting (Red Goshawk) may be sensitive to the loss of relatively small areas of particularly high quality habitat. Development may also present risks of indirect impacts on habitat suitability and population viability through changes in fire regimes, spread of environmental weeds, increase in density of feral animals (including dogs, cats, cane toad and pest ants as well as pigs and large ungulates), alteration in surface water availability and soil moisture regimes, pesticide overspray or nutrient enrichment. While many native mammal species have been subject to large, recent declines across the Top End due to a variety of threats, small mammals appear to remain relatively abundant within the study area (and in at least some other localities within the Tiwi Islands), suggesting this area remains resilient to the impacts of feral cat predation and adverse fire regimes.

Monsoon rainforest patches and swamps and other wetlands are generally not within land units suitable for agricultural development. While threatened and significant species within these habitats are not directly at risk from land clearing, they may be vulnerable to indirect impacts from changes in water regimes, changed fire regimes and spread of environmental weeds. Ever-green, spring-fed rainforest in the study area are likely to be sensitive to changes in ground water hydrology resulting from excessive groundwater extraction use, or possibly excess surface water use. Lowered ground water levels and reduced discharge of springs are likely to cause a drying effect on wet rainforest and permanent swamps on drainage floors. Desiccation of the wet rainforest would likely result in loss of habitat though increased susceptibility to dry season fire, rather than simply a lack of water for plant growth.

The risk from fire to rainforest habitat will also be increased by disturbance in the landscape that facilitates the spread of exotic grasses such as perennial Mission Grass, *Cenchrus polystachios,* which increase fuel loads near rainforest boundaries. The narrow strips of riparian rainforest that occur along many drainage lines in the study area are particularly susceptible due to their large edge:area ratio. Field surveys in October 2014 revealed severe negative fire impacts on individual clumps of the threatened arboreal parasite *Dendromyza reinwardtiana.* While the permanent bogs and swamps share some potential risks with rainforest habitats (changes in moisture regimes due to ground or surface water extraction), they are reasonably fire tolerant and appear to burn regularly.

The impact of feral pigs on recruitment on most significant plant species has not been quantified but pigs in significant numbers are likely to have some effect through either disturbance or browsing. During field survey in October 2014, some rainforest patches were found to be heavily 'grubbed' by pigs, especially the moist sandy soils favoured by species such as *Endiandra* and *Mitrella*. Sites with saturated, peaty soils were apparently less targeted by pigs, although Fensham (1993) recorded grubbing by pigs as a threatening process for *Burmannia* sp. Bathurst Island, which occurs in peaty soils. *Freycinetia* plants at one site showed evidence of browsing, presumably by feral pigs.

The Tiwi Islands are periodically affected by severe tropical cyclones and the capacity of both eucalypt woodlands and rainforest patches to recover following cyclone is important. Additional stress on these systems associated with alteration in water availability, spread of invasive exotic grasses and alteration in fuel loads and fire regimes may reduce resilience to severe stochastic events such as cyclones.

Threatening processes for each significant species are described in Appendix 11 (plants) and Appendix 13 (vertebrates).

7.3.2 Spatial biodiversity risk index

A spatial "biodiversity risk" index was developed as a means of synthesising the available data on threatened species distribution within the study area into a map layer that could be readily applied in land use planning and environmental impact assessment for any proposed development. The index was constructed by scoring each cell in a raster overlain on the study area for the likely presence of threatened species associated with eucalypt forest and woodlands and proximity to known habitat for threatened species associated with monsoon rainforest, using the following approach:

- From the MaxEnt models for Tiwi Masked Owl, Red Goshawk, Brush-tailed Rabbit-rat and Pale Field Rat (see 7.2.2.3), areas with a likelihood value greater than 0.5 were given a score of one, for each species;
- From the occupancy modelling for *Typhonium mirabile*, areas with an occupancy probability greater than 0.5 (Figure 7-8) were given a score of one;
- Each mapped rainforest patch was given a score equal to the number of threatened plant species known to occur in that patch (Fig 7-11) plus one. The "plus one" ensures that all rainforest patches are considered to be of some value, based on the recognised need to manage rainforests as an interconnected network of patches.
- A 200 m buffer was applied to dry monsoon forests and thickets and a 400 m buffer to wet monsoon forests, recognising the need to insulate rainforests from indirect impacts and consistent with previous EPBCA approvals for forestry developments on Melville Island. The buffer zones were given a score equal to that of the rainforest patch they surround.

All scores were summed for each grid cell to give the biodiversity risk index (Figure 7-25), with a total possible range between zero and nine. The highest values for the biodiversity risk scores are in the south-eastern and south-western portion of the study area, which generally are not associated with the moderately suitable agricultural land. However, the majority of the study area has a score of at least three, due to some threatened species occurring widely in eucalypt open forests.

The biodiversity risk score reflects the relative value of any area as potential habitat for protection of listed threatened species. It should be noted that the score is relative, rather than absolute, as it does not include *Cycas armstrongii* (which occurs through most of the study area), and does not accounts for threatened species known to occur in the study area but with very sparse distributions (e.g. *Typhonium jonesii*), or species whose occurrence in the area is uncertain (Butler's Dunnart).

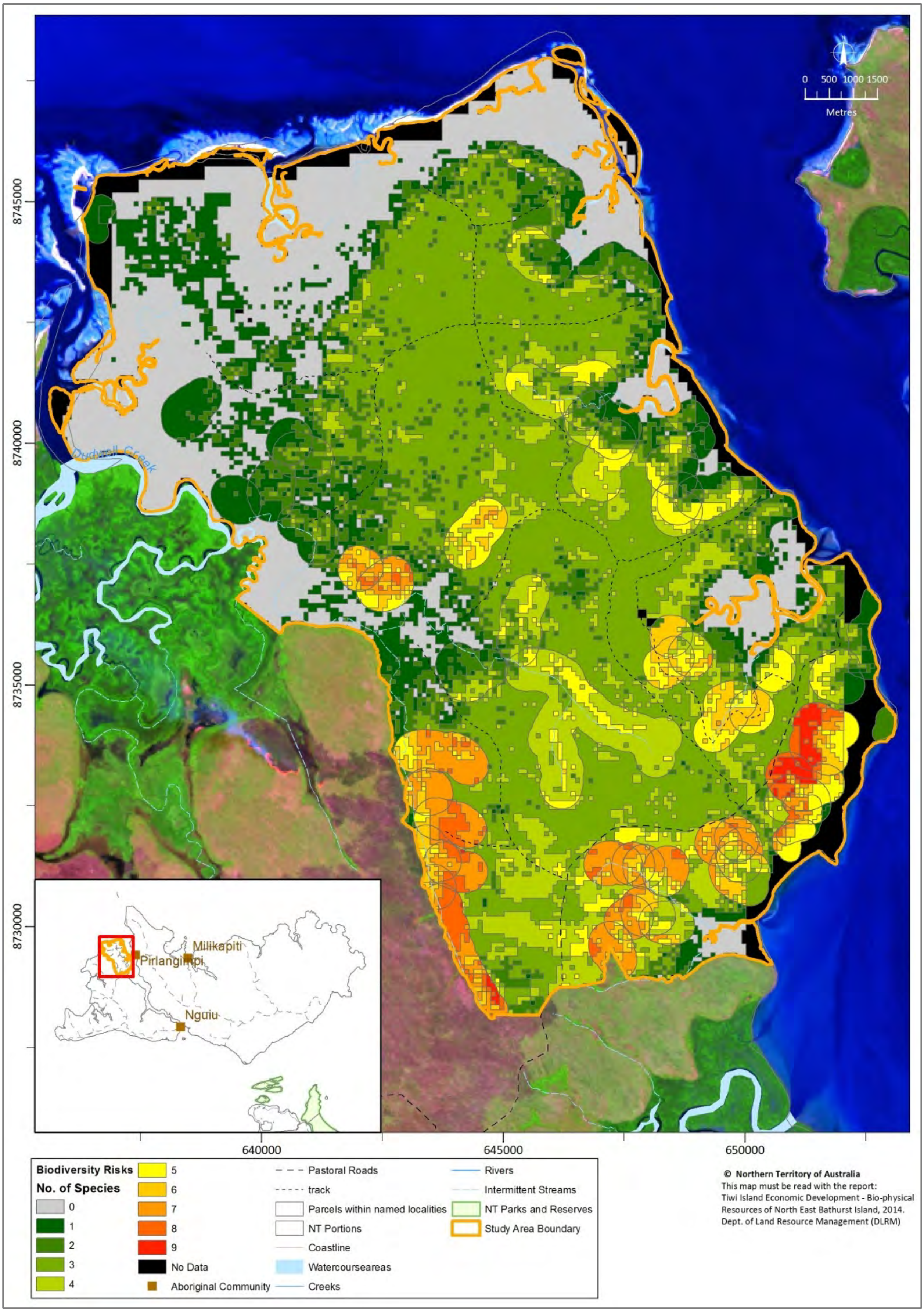

Figure 7-25: A spatial biodiversity risk index for the study area, reflecting the relative value of any area as potential habitat for protection of listed threatened species.

7.3.3 Regional context

A comprehensive biodiversity assessment should also consider the biodiversity values of the study area within a broader regional context. In this case, there is adequate data to compare the values within the study area to similar values across the Tiwi Islands as a whole.

An analysis of all current records shows that threatened and other significant plant species on the Tiwi Islands are concentrated in the northwest of Melville Island and north of Bathurst Island (Figures 7-26, 7-27). While uneven floristic sampling of the Islands may contribute to this pattern it cannot solely account for it. Rather, it is likely to reflect the greater topographic relief, presence of reliable springs and higher, more reliable rainfall in this zone and consequently the development of rainforests and taller eucalypt open forests (Woinarski *et al.* 2003). The Tiwi threatened and near threatened plant species occur primarily in ever-wet rainforests, reflecting that many rainforest plants occur in only a few, relatively small rainforest patches, and such restricted rainforests may be particularly susceptible to a range of threatening processes, both natural stochastic events and more recent anthropogenic disturbance. The distribution of Tiwi endemic and highly disjunct species also suggests that the ever-wet rainforests fringing the higher ridges of western Melville Island and Bathurst Island are refugial areas of high species diversity (see Appendix 8).

Modelling of the distribution of four vertebrate taxa for which eucalypt open forest and woodland on the Tiwi Island is important habitat – Tiwi Masked Owl, Brush-tailed Rabbit-rat, Pale Field Rat, Red Goshawk – similarly indicates that the majority of high quality habitat occurs in western Melville and Bathurst Island (Appendix 15). This is likely related to the pronounced rainfall gradient across the Tiwi Islands, and higher rainfall combined with suitable soils on elevated land surfaces allowing the development of particularly tall eucalypt open forest in the northwest of the Islands. The MaxEnt modelling for these vertebrate species suggests that the study area contains between 9 and 20% of the most suitable extant habitat for these species on the Tiwi Islands (Table 7-16), and, that the importance of the study area for these species has likely increased significantly following the clearing of large areas of suitable habitat on Melville Island as forestry plantations were developed.

Table 7-16: Based on MaxEnt modelling for four threatened vertebrate species for which eucalypt open forest and woodland on the Tiwi Island is very important habitat, the area of "high-likelihood" habitat: within the study area; on the entire Tiwi Islands prior to clearing; cleared on Melville Island for plantations; in the study area as a proportion of the uncleared extent on the Tiwi Islands. High-likelihood is taken to be a MaxEnt score > 0.5. The study area (177 km^2) is 2.5% of the area of the Tiwi Islands (7 070 km^2).

Species	Study area (km^2)	Tiwi islands, pre-clearing (km^2)	Previously cleared on Melville Island (km2)	Study area cf. Tiwi Islands uncleared (%)
Tiwi Masked Owl	101	637	126	19.8
Brush-tailed Rabbit-rat	106	739	90	16.3
Pale Field Rat	108	1200	110	9.9
Red Goshawk	12	223	86	8.8

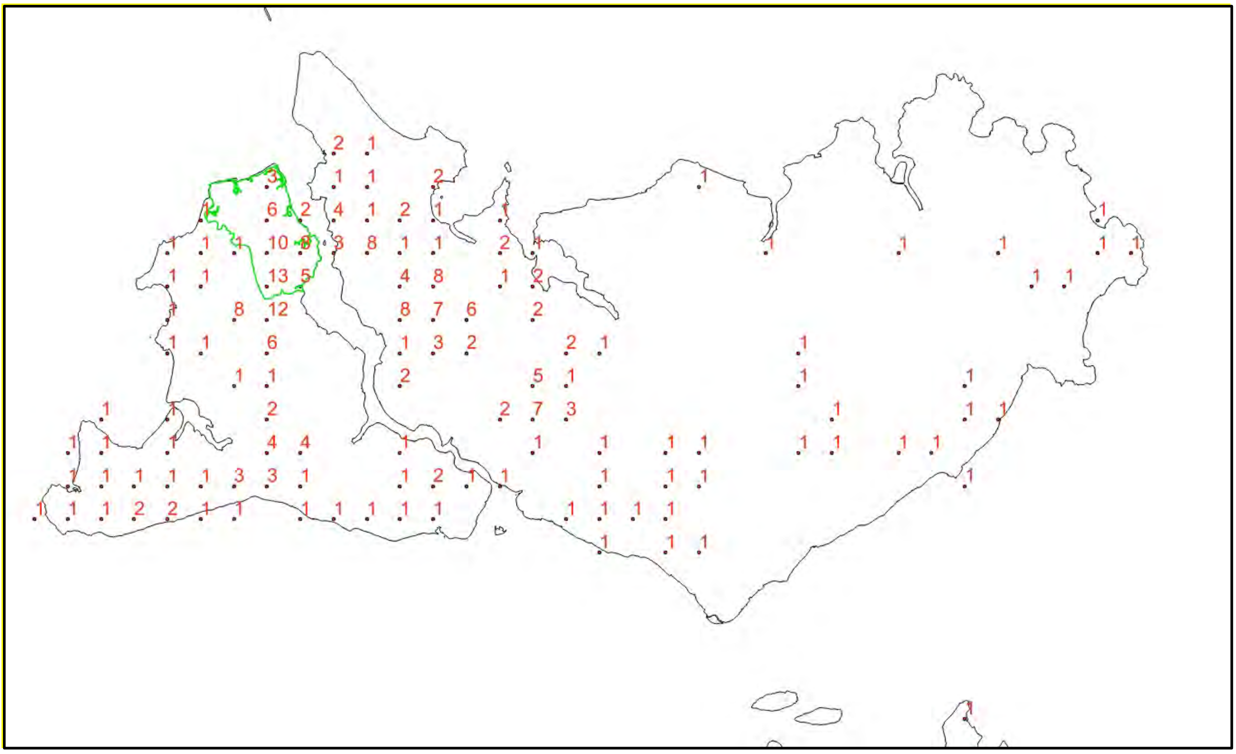

Figure 7-26: The number of threatened plant species recorded in each 5 km x 5 km grid cell on the Tiwi Islands (dots represent centroids of grid cells). The study area is outlined in green.

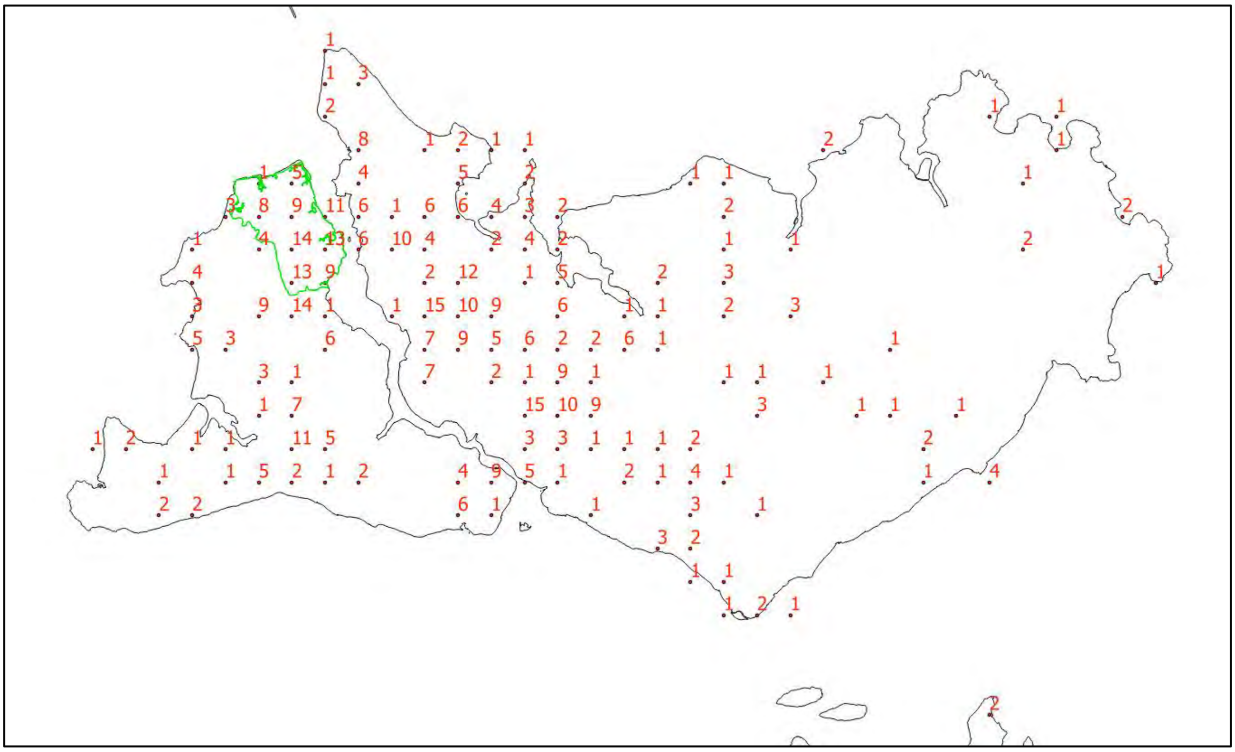

Figure 7-27: The number of near threatened or data deficient (TPWCA) plant species recorded in each 5 km x 5 km grid cell on the Tiwi Islands (dots represent centroids of grid cells).

PART 3. PLANT INDUSTRY OPPORTUNITIES

8. Crop suitability

The Department of Primary Industry and Fisheries (DPIF) has provided crop suitability information presented in Table 8-1. The commercial success of plant industries in the Northern Territory is dependent on several factors, including available markets, prevailing prices, input costs, logistics, difficulty of management and the skills and tenacity of the grower. For North East Bathurst Island, based on land suitability alone, there are a number of limiting factors. There is a significant area of well drained gently undulating land with deep soil however, this soil is sandy, has limited structure, and very low levels of available essential plant nutrients. Based on existing successful plant industries from the Top End of the Northern Territory, most enterprises would need input of grower motivation and expertise, and water and nutrients to be successful on Bathurst Island.

Most agricultural, horticultural or forestry crops that are adapted to a tropical climate would not grow and yield commercial quantities without relatively high levels of inputs such as fertiliser. In a climate such as the Top End, sustainable development requires soil conservation measures to mitigate potential soil erosion risk. Any enterprise that included cultivation of trees or crops over the wet season would also need a cyclone risk strategy and for trees growing over the dry season would need to manage fire risk.

If these requirements are fulfilled, the following crops may have potential on Bathurst Island.

Table 8-1: Description of potential crops (DPIF)

Crop group	Potential	Comments
Tropical exotic fruit trees	Wet tropic natives are at the edge of preferred conditions and include rambutan, jackfruit, durian, cocoa, coffee, pepper and mangosteen	High water requirements over the dry season; currently grown at a small scale in the Northern Territory.
Sub-tropical to semi-arid tropical fruit	Some examples of fruit with a wider climatic tolerance include banana, mango, citrus, papaya and papaw, passionfruit, pitahaya or dragonfruit and pineapple	High water requirements, however, some crops including mango, pitahaya and citrus can tolerate a dry season.
Ornamentals	Some examples include heliconias and ornamental gingers	High input of water and fertiliser required. Highly perishable and require post-harvest logistic systems to accompany cultivation.
Vegetables, herbs, annual fruits	Examples of temperate “summer” crops successfully grown around Darwin: Vegetables include pumpkin, cucumber, bitter melon, snake gourd, hairy melon, winter melon, long melon, sin qua, luffa,	Erosion from wet season rainfall, pressure from insects and diseases restricts production to dry season; All require high inputs of water and fertiliser to produce commercial yields.

Crop group	Potential	Comments
	snake bean, chili, taro, yam bean and okra. Herbs include basil, kankong, coriander and parsley. Annual fruit crops include watermelon, rockmelon, honeydew melon and hami melon	Bathurst deep sandy soils offer potential for sweet potato as this is not currently produced in the Top End, primarily because of gravelly soils.
Hay and fodder crops	Tropical introduced grasses Rhodes Grass or Sabi Grass, Aerobic (non-paddy) rice; tropical legumes such as cavalcade or fodder peanuts produce their own nitrogen.	Wet season rain fed crops or higher yield irrigated dry season crops. These are high volume, low value crops. The cost of transport can consume revenue generated by the crop.
Grains and pulses	Previous crops grown in the Top End include; rice, grain sorghum, corn and peanuts, however need appropriate inputs of water and fertiliser	The Top End has long history with limited success; some higher yields from irrigated dry season cropping Would need to overcome market and transport logistics for commercial success on Bathurst.
Fibre and industrial crops	Fibre: Kenaf, Ethanol: Cassava Biodiesel: oil palm Industrial gels/gums: Guar	Bathurst isolation is a marketing disadvantage. Some crops could be grown on wet season rainfall but others would need irrigation input.
Forestry	Cypress Pine and *Acacia mangium* are two possibilities, as are improved eucalyptus varieties.	A range of species similar to Melville are possible; however input of fertilisers is necessary for nutritionally poor soils.
Native fruit	Kakadu Plum could have potential; however it was not common during field survey.	Local species could be adapted to low fertility soil; however current markets are small.

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10. Appendices

Appendix 1. All flow measurements undertaken in 2014

Date	Flow (m^3/s)	Easting	Northing	Datum
G8160017		643274	8732061	MGA94
2/06/2014	0.482			
10/09/2014	0.345			
14/10/2014	0.358			
23/10/2014	0.344			
G8160018		646431	8734737	MGA94
12/09/2014	0.099			
15/10/2014	0.087			
G8160019		645354	8736095	MGA94
13/08/2014	0.047			
9/09/2014	0.038			
22/10/2014	0.035			
G8160020		644344	8738091	MGA94
12/09/2014	0.022			
20/10/2014	0.0186			
G8160021		647302	8739992	MGA94
13/08/2014	0.028			
9/09/2014	0.0206			
18/10/2014	0.01			
18/10/2014	0.01			
G8160022		648527	8735571	MGA94
8/09/2014	0.0053			
21/10/2014	0.0026			
G8160023		649791	8734660	MGA94
2/06/2014	0.064			
12/08/2014	0.033			
8/09/2014	0.0237			
8/09/2014	0.0237			
21/10/2014	0.0257			
G8165050		647812	8728948	AMG84
14/08/2014	0.028			
10/09/2014	0.023			
16/10/2014	0.0233			
G8165051		648400	8730702	AMG84
2/06/2014	0.128			
14/08/2014	0.087			
11/09/2014	0.078			
11/09/2014	0.078			
16/10/2014	0.0815			
G8160001				
12/11/2014	0.089			

Date	Flow (m^3/s)	Easting	Northing	Datum
Sites not in study area				
G8165034		640793	8724549	AMG84
13/09/2014	0.1			
23/10/2014	0.99			
G8165035		640743	8724285	AMG84
13/09/2014	0.053			
G8165049		646285	8724823	AMG84
12/09/2014	0.069			
17/10/2014	0.066			
Spot gauging sites				
G816A	0.031	644326	8728781	MGA94
G816B	0.13	643992	8729401	MGA94
G816C	0.257	643691	8730203	MGA94
G816D	0.394	643123	8734043	MGA94
G816E	0.017	643691	8732187	MGA94
G816F	0.029	643625	8733613	MGA94
G816G	0.0545	646475	8734647	MGA94
G816H	0.0664	641614	8725850	MGA94
G816J	0.056	646640	8725106	MGA94

Appendix 2. Representative soil profiles

Site: 004 Land Unit: 7a Australian Soil Classification (ASC): Red Orthic Tenosol (TEINYYARCEKKX)

Depth (cm)	Horizon	Description
Surface	-	Dry; soft
0-15	A11	Dark reddish brown (5.0YR 3/2); loamy sand; massive; earthy; moist; very weak; field pH 5.8
15-30	A12	Dark reddish brown (5.0YR 3/3); loamy sand; massive; earthy; moist; very weak; field pH 6.2
30-50	B1	Dark reddish brown (2.5YR 3/4); loamy sand; massive; earthy; moist; very weak; field pH 6.4
50-125	B21	Red (2.5YR 4/6); loamy sand; massive; earthy; moist; very weak; field pH 6.2
125-180	B22	Red (2.5YR 4/6); loamy sand; massive; earthy; very moist; very weak; field pH 6.4

Physical Properties

Depth (cm)	Coarse Sand %	Fine Sand %	Silt %	Clay %
0-10	56	33	1	11
10-15	59	29	3	13
15-20	58	30	3	14
20-30	56	31	3	14
50-60	59	29	3	13
80-90	54	33	4	13
110-120	58	29	3	11
140-150	55	34	3	10
170-180	57	31	1	8

Description: Low Rises with gently inclined slopes and relief up to 9m. Soils are deep to very deep, red earthy sands (Tenosols). Profiles are characterized by loamy sand texture, massive structure, earthy fabric and a moist soil water status throughout. pH trend is strongly acidic and mottling and coarse fragments are absent.

Chemical Properties

Depth (cm)	$pH_{1:5}$ H_2O	$EC_{1:5}$ H_2O	$Cl_{1:5}$ (mg/kg)	Nitrate Nitrogen (mg/kg)	Bicarb. Extract. P (mg/kg)	Organic Carbon (%)	Extract. Sulfur (mg/kg)	Air Dry Moisture Content (%)	Exchangeable Cations (Cmol/kg)				Extractable Micronutrients (mg/kg)				Base Status (Cmol/kg)	Ca/Mg Ratio
	pH	EC	Cl	NO_3-N	P	OC	SO_4-S	ADMC	Ca	Mg	Na	K	Cu	Zn	Mn	Fe		
0-10	4.4	0.01	<20	1	2	0.92	5	<1.5	0.41	0.26	<0.08	<0.03	<0.1	<0.1	<2.0	35	6.1	1.60
10-15	4.4	0.01	801	<1	<2	0.89	5	<1.5	0.20	0.24	<0.08	<0.03	<0.1	<0.1	<2.0	30	3.5	0.82
15-20	4.3	<0.01	<20	<1	<2	0.77	6	<1.5	0.14	0.09	<0.08	<0.03	<0.1	<0.1	<2.0	22	1.6	1.56
20-30	4.2	<0.01	<20	<1	<2	0.81	6	<1.5	0.14	0.07	<0.08	<0.03	<0.1	<0.1	<2.0	21	1.4	2.12
50-60	4.2	<0.01	<20	<1	2	0.19	7	<1.5	0.14	0.11	<0.08	<0.03	<0.1	<0.1	<2.0	7	2.0	1.24
80-90	4.2	0.01	<20	<1	<2	0.22	11	<1.5	0.14	0.09	<0.08	<0.03	<0.1	<0.1	<2.0	6	1.8	1.52
110-120	4.2	0.01	<20	<1	2	0.18	12	<1.5	0.14	0.13	<0.08	<0.03	<0.1	<0.1	<2.0	4	2.4	1.06
140-150	4.1	<0.01	<20	<1	4	0.08	15	<1.5	0.14	0.16	<0.08	<0.03	<0.1	<0.1	<2.0	2	3.1	0.88
170-180	4.1	<0.01	<20	<1	4	<0.05	18	<1.5	0.14	0.15	<0.08	<0.03	<0.1	<0.1	<2.0	2.2	3.7	0.92

Site: 002 Land Unit: 8a Australian Soil Classification (ASC): Red Kandosol (AAFCDAEKMX)

Depth (cm)	Horizon	Description
Surface	-	Dry; soft
0-8	A1	Dark reddish brown (5.0YR 2.5/2); loamy sand; massive; earthy; moist; very weak; field pH 5.9
8-20	A2	Dark reddish brown (5.0YR 3/3); loamy sand; massive; earthy; moist; very weak; field pH 6.5
20-28	A3	Dark reddish brown (5.0YR 3/4); sandy loam; massive; earthy; moist; very weak; field pH 6.4
28-80	B1	Red (2.5YR 4/6); light sandy clay loam; massive; earthy; moist; weak; field pH 6.2
80-110	B21	Red (10YR 4/6); sandy clay loam; massive; earthy; moist; weak; field pH 6.2
110-180	B22	Red (10YR 4/6); sandy clay loam; massive; earthy; moist; firm; field pH 6.1

Description: Very gently inclined upland plains with low relief. Soils are very deep, red gradational earths (Kandosols). Profiles are characterized by a loamy sand surface grading to a sandy clay loam subsoil, massive structure, earthy fabric and a moist soil water status throughout. pH is strongly acidic throughout the profile and mottling and coarse fragments are absent.

Physical Properties

Depth (cm)	Coarse Sand %	Fine Sand %	Silt %	Clay %
0-10	36	47	10	11
10-20	32	48	7	19
20-28	31	48	4	21
50-60	31	46	1	25
80-90	31	45	<1	25
110-120	27	39	<1	35
140-150	26	35	<1	40
170-180	28	39	<1	31

Chemical Properties

Depth (cm)	$pH_{1:5}$ H_2O	$EC_{1:5}$ H_2O	$Cl_{1:5}$ (mg/kg)	Nitrate Nitrogen (mg/kg)	Bicarb. Extract. P (mg/kg)	Organic Carbon (%)	Extract. Sulfur (mg/kg)	Air Dry Moisture Content (%)	Exchangeable Cations (Cmol/kg)				Extractable Micronutrients (mg/kg)				Base Status (Cmol/kg)	Ca/Mg Ratio
	pH	EC	Cl	NO_3-N	P	OC	SO_4-S	ADMC	Ca	Mg	Na	K	Cu	Zn	Mn	Fe		
0-10	4.7	0.01	<20	2	4	4.75	9	2.9	0.74	0.71	0.16	0.05	<0.1	<0.1	<2.0	58	15.3	1.04
10-20	4.4	0.01	<20	1	<2	0.82	10	<1.5	0.14	0.16	<0.08	<0.03	<0.1	<0.1	<2.0	23	1.6	0.89
20-28	4.5	<0.01	<20	<1	<2	0.75	10	<1.5	0.14	0.37	<0.08	<0.03	<0.1	<0.1	<2.0	12	2.4	0.38
50-60	4.6	0.01	<20	<1	<2	0.31	19	<1.5	0.23	0.53	<0.08	<0.03	<0.1	<0.1	<2.0	5	3.1	0.43
80-90	4.6	0.01	<20	<1	<2	0.19	29	<1.5	0.14	0.32	<0.08	<0.03	<0.1	<0.1	<2.0	3	1.9	0.44
110-120	4.5	<0.01	<20	<1	<2	0.08	55	<1.5	0.14	0.61	<0.08	<0.03	<0.1	<0.1	<2.0	<2	2.2	0.23
140-150	4.3	<0.01	<20	<1	<2	0.05	72	<1.5	0.14	0.64	<0.08	<0.03	<0.1	<0.1	<2.0	<2	2.0	0.22
170-180	4.2	0.01	<20	<1	<2	0.07	58	<1.5	0.14	0.51	<0.08	<0.03	<0.1	<0.1	<2.0	<2	2.1	0.27
0-10	4.7	0.01	<20	2	4	4.75	9	2.9	0.74	0.71	0.16	0.05	<0.1	<0.1	<2.0	58	15.3	1.04

Site: 010 **Land Unit: 8a1** **Australian Soil Classification (ASC): Red Kandosol (KAAAAFDQBEKOX)**

Depth (cm)	Horizon	Description
Surface	-	Dry; soft
0-12	A1	Dark brown (7.5YR 3/2); loamy sand; massive; earthy; moist; weak; field pH 6.0
12-23	A2	Reddish brown (5.0YR 4/3); sandy loam; massive; earthy; moist; weak; field pH 5.9
23-40	A3	Dark reddish brown (5.0YR 4/6); sandy loam; massive; earthy; moist; weak; field pH 5.7
40-75	B1	Red (2.5YR 4/6); sandy clay loam; massive; earthy; moist; firm; 5%, 5mm distinct pale mottles; field pH 5.5
75-130	B21	Red (2.5YR 5/6); sandy clay loam; massive; earthy; moist; firm; 20%, 5mm dominate pale mottles; field pH 5.6
130-165	B22	Red (2.5YR 5/6); light clay; massive; earthy; moist; firm; 40%, 10mm distinct pale mottles; field pH 5.5
165-180	B3	Light grey (10YR 7/1); light clay; massive; earthy; moist; firm; 20%, 10mm distinct red mottles; field pH 5.4

Description: Gently inclined lower slopes with <5 m local relief. Rock outcrop 0-2%. Soils are deep to very deep, red gradational earths (Kandosols). Profiles are characterized by a loamy sand surface grading to a light clay subsoil, massive structure, earthy fabric and a moist soil water status throughout. pH is strongly acidic throughout the profile with negligible mottling and coarse fragments in the subsoil.

Physical Properties

Depth (cm)	Coarse Sand %	Fine Sand %	Silt %	Clay %
0-10	37	36	7	20
12-20	33	38	7	25
25-30	32	39	5	26
50-60	36	37	5	27
80-90	28	38	3	33
110-120	23	33	3	42
140-150	16	33	10	43
170-180	9	33	11	45

Chemical Properties

Depth (cm)	$pH_{1:5}$ H_2O	$EC_{1:5}$ H_2O	$Cl_{1:5}$ (mg/kg)	Nitrate Nitrogen (mg/kg)	Bicarb. Extract. P (mg/kg)	Organic Carbon (%)	Extract. Sulfur (mg/kg)	Air Dry Moisture Content (%)	Exchangeable Cations (Cmol/kg)				Extractable Micronutrients (mg/kg)				Base Status (Cmol/kg)	Ca/Mg Ratio
	pH	EC	Cl	NO_3-N	P	OC	SO_4-S	ADMC	Ca	Mg	Na	K	Cu	Zn	Mn	Fe		
0-10	4.5	0.01	<20	1	<2	3.51	7	3.0	0.98	0.74	<0.08	0.07	<0.1	<0.1	<2.0	28	9.0	1.33
12-20	4.4	0.01	<20	1	2	1.54	9	2.1	0.16	0.40	<0.08	<0.03	<0.1	<0.1	<2.0	21	2.3	0.39
25-30	4.4	0.01	<20	<1	<2	1.16	9	1.7	0.20	0.38	<0.08	<0.03	<0.1	<0.1	<2.0	16	2.2	0.54
50-60	5.2	0.01	<20	<1	<2	0.26	11	<1.5	0.14	0.46	<0.08	<0.03	<0.1	<0.1	<2.0	3	2.3	0.30
80-90	4.8	<0.01	<20	1	<2	0.12	18	<1.5	0.14	0.74	<0.08	<0.03	<0.1	<0.1	<2.0	<2	2.6	0.19
110-120	4.8	<0.01	<20	<1	<2	0.10	20	<1.5	0.14	0.56	<0.08	<0.03	<0.1	<0.1	<2.0	<2	1.7	0.25
140-150	4.5	<0.01	<20	<1	<2	0.08	19	<1.5	0.14	0.43	<0.08	<0.03	<0.1	<0.1	<2.0	<2	1.3	0.32
170-180	4.3	0.01	<20	<1	<2	0.06	17	<1.5	0.14	0.51	<0.08	<0.03	<0.1	0.2	<2.0	<2	1.4	0.27

SITE: 005 **Land Unit: 8b** **Australian Soil Classification (ASC): Red Kandosol (KAAAAFCDAEKMX)**

Depth (cm)	Horizon	Description
Surface	-	Dry; soft
0-10	A1	Reddish brown (5.0YR 4/4); loamy sand; massive; earthy; moist; very weak; field pH 5.9
10-18	A2	Yellowish red (5.0YR 4/6); loamy sand; massive; earthy; moist; very weak; field pH 5.9
18-60	B1	Red (2.5YR 4/8); sandy loam; massive; earthy; moist; weak; field pH 5.5
60-110	B21	Red (2.5YR 4/8); sandy clay loam; massive; earthy; moist; weak; field pH 6.0
110-180	B22	Red (10YR 4/6); clay loam sandy; massive; earthy; moist; firm; field pH 5.4

Description: Undulating plains with <5 m local relief. Soils are deep to very deep, red gradational earths (Kandosols). Profiles are characterized by a loamy sand surface grading to a sandy clay loam subsoil, massive structure, earthy fabric and a moist soil water status throughout. pH is strongly acidic throughout the profile and mottling and coarse fragments are absent.

Physical Properties

Depth (cm)	Coarse Sand %	Fine Sand %	Silt %	Clay %
0-10	39	42	8	13
10-18	38	41	5	20
20-30	36	41	5	22
50-60	37	40	3	23
80-90	36	39	1	27
110-120	32	33	1	37
140-150	30	29	1	44
170-180	31	31	<1	38

Chemical Properties

Depth (cm)	$pH_{1:5}$ H_2O	$EC_{1:5}$ H_2O	$Cl_{1:5}$ (mg/kg)	Nitrate Nitrogen (mg/kg)	Bicarb. Extract. P (mg/kg)	Organic Carbon (%)	Extract. Sulfur (mg/kg)	Air Dry Moisture Content (%)	Exchangeable Cations (Cmol/kg)				Extractable Micronutrients (mg/kg)				Base Status (Cmol/kg)	Ca/Mg Ratio
	pH	EC	Cl	NO_3-N	P	OC	SO_4-S	ADMC	Ca	Mg	Na	K	Cu	Zn	Mn	Fe		
0-10	5.5	0.01	<20	<1	<2	1.13	6	<1.5	0.35	0.42	<0.08	<0.03	<0.1	<0.1	<2.0	19	5.9	0.84
10-18	5.0	0.01	<20	<1	<2	1.16	6	<1.5	0.14	0.54	<0.08	<0.03	<0.1	<0.1	<2.0	22	3.4	0.26
20-30	4.6	<0.01	<20	<1	<2	0.66	7	<1.5	0.14	0.54	<0.08	<0.03	<0.1	<0.1	<2.0	14	3.1	0.26
50-60	4.5	<0.01	<20	1	<2	0.25	26	<1.5	0.14	0.44	<0.08	<0.03	<0.1	<0.1	<2.0	3	2.5	0.32
80-90	4.3	<0.01	<20	<1	<2	0.10	51	<1.5	0.14	0.44	<0.08	<0.03	<0.1	<0.1	<2.0	<2	2.2	0.32
110-120	4.3	<0.01	<20	<1	<2	0.30	66	<1.5	0.14	0.71	<0.08	<0.03	<0.1	<0.1	<2.0	<2	2.3	0.20
140-150	4.2	<0.01	<20	<1	<2	0.16	83	<1.5	0.16	1.0	0.09	<0.03	<0.1	<0.1	<2.0	<2	2.9	0.16
170-180	4.2	<0.01	<20	<1	<2	0.10	76	<1.5	0.14	0.81	<0.08	<0.03	<0.1	0.2	<2.0	<2	2.5	0.17

SITE: 018 Land Unit: 8c Australian Soil Classification (ASC): Redoxic Hydrosol (HYEDFRAIBEKM)

Depth (cm)	Horizon	Description
Surface	-	Dry; soft
0-13	A11	Very Dark Grey (10YR 3/1); loamy sand; massive; earthy; moist; very weak; field pH 5.4
13-28	A12	Very Dark Grey (10YR 3/1); loamy sand; massive; earthy; moist; very weak; field pH 5.0
28-60	A2	Grey (10YR 5/1); loamy sand; massive; earthy; moist; weak; field pH 5.1
60-75	B21	Light grey (10YR 7/1); sandy clay loam - light; massive; earthy; moist; weak; field pH 4.9
75-110	B22	Light grey (10YR 7/1); sandy clay loam; massive; earthy; moist; 10% 2mm dominant yellow mottles; 3% 30mm ferruginous segregations; weak; field pH 4.7
110-147	B23	White (10YR 8/1); sandy clay loam; massive; earthy; moist; firm; field pH 4.9

Description: Seasonally wet plains with very low relief. Soils are deep to very deep, poorly drained grey mottled gradational earths (Hydrosols). Profiles are characterized by a loamy sand surface grading to a sandy clay loam subsoil, massive structure, earthy fabric and a moist soil water status throughout. pH is strongly acidic throughout the profile with yellow mottling and ferruginous segregations present in the subsoil.

Physical Properties

Depth (cm)	Coarse Sand %	Fine Sand %	Silt %	Clay %
0-10	64	27	4	9
13-20	58	33	3	13
20-28	59	30	2	13
50-60	60	26	4	16
80-90	54	25	2	23
110-120	41	29	2	26
140-147	48	22	2	31

Chemical Properties

Depth (cm)	$pH_{1:5}$ H_2O	$EC_{1:5}$ H_2O	$Cl_{1:5}$ (mg/kg)	Nitrate Nitrogen (mg/kg)	Bicarb. Extract. P (mg/kg)	Organic Carbon (%)	Extract. Sulfur (mg/kg)	Air Dry Moisture Content (%)	Exchangeable Cations (Cmol/kg)				Extractable Micronutrients (mg/kg)				Base Status (Cmol/kg)	Ca/Mg Ratio
	pH	EC	Cl	NO_3-N	P	OC	SO_4-S	ADMC	Ca	Mg	Na	K	Cu	Zn	Mn	Fe		
0-10	4.8	0.09	52	<1	<2	1.29	35	<1.5	0.58	0.75	0.30	0.05	<0.1	<0.1	<2.0	66	17.9	0.78
13-20	4.6	0.04	37	<1	<2	0.67	16	<1.5	<0.14	0.23	0.08	<0.03	<0.1	<0.1	<2.0	9	3.8	0.62
20-28	4.3	0.03	<20	<1	<2	0.55	15	<1.5	<0.14	0.10	<0.08	<0.03	<0.1	<0.1	<2.0	7	2.7	1.44
50-60	4.2	0.03	<20	<1	<2	0.15	29	<1.5	<0.14	0.21	<0.08	<0.03	<0.1	<0.1	<2.0	6	2.9	0.66
80-90	4.1	0.03	21	<1	<2	0.10	62	<1.5	<0.14	0.33	<0.08	<0.03	<0.1	<0.1	<2.0	6	2.5	0.43
110-120	4.1	0.03	24	<1	<2	0.09	67	<1.5	<0.14	0.44	<0.08	<0.03	<0.1	<0.1	<2.0	6	2.6	0.32
140-147	4.4	0.03	31	<1	<2	0.09	74	<1.5	<0.14	0.95	0.11	<0.03	<0.1	0.1	<2.0	7	3.9	0.15

SITE: 032 Land Unit: 8c1 Australian Soil Classification (ASC): Redoxic Hydrosol (HYEDFRAFAELMX)

Depth (cm)	Horizon	Description
Surface	-	Dry; soft
0-10	A1	Very dark greyish brown (10YR 3/2); sandy loam; massive; earthy; dry; very weak; field pH 7.5
10-60	A2	Yellowish brown (10YR 5/8); sandy loam; massive; earthy; moderately moist; very weak; field pH 7.3
60-90	B1	Yellowish brown (10YR 5/8); sandy clay loam - light; massive; earthy; moist; weak; 2%, 3mm prominent red mottles; field pH 7.3
90-110	B21	Strong brown (7.5YR 5/8); sandy clay loam; massive; earthy; moist; weak; 20%, 5mm distinct red mottles field pH 7.2
110-120	B22	Strong brown (7.5YR 5/8); sandy clay loam; massive; earthy; moist; weak; 50%, 10mm distinct red mottles; 10%, 5mm distinct red mottles; field pH 6.9
120-180	B23	Red (2.5YR 4/8); sandy clay loam - heavy; massive; earthy; moist; weak; 30%, 10mm distinct red mottles; 30%, 10mm distinct red mottles; field pH 7.0

Description: Seasonally wet plains prone to inundation and seasonal waterlogging. Soils are deep, poorly drained brown mottled gradational earths (Hydrosols). Profiles are characterized by a sandy loam surface grading to a sandy clay loam subsoil, massive structure, earthy fabric and a moist soil water status throughout. pH is strongly acidic throughout the profile with red mottling present in the subsoil.

Physical Properties

Depth (cm)	Coarse Sand %	Fine Sand %	Silt %	Clay %
0-10	36	45	4	19
10-20	35	45	6	21
20-28	33	50	4	19
50-60	31	48	6	19
80-90	38	43	3	21
110-120	32	39	4	27
140-150	33	39	4	27
170-180	34	40	4	28

Chemical Properties

Depth (cm)	pH$_{1:5}$ H$_2$O	EC$_{1:5}$ H$_2$O	Cl$_{1:5}$ (mg/kg)	Nitrate Nitrogen (mg/kg)	Bicarb. Extract. P (mg/kg)	Organic Carbon (%)	Extract. Sulfur (mg/kg)	Air Dry Moisture Content (%)	Exchangeable Cations (Cmol/kg)				Extractable Micronutrients (mg/kg)				Base Status (Cmol/kg)	Ca/Mg Ratio
	pH	EC	Cl	NO_3-N	P	OC	SO_4-S	ADMC	Ca	Mg	Na	K	Cu	Zn	Mn	Fe		
0-10	4.7	0.01		<20	3	<2	2	<1.5	0.14	0.03	0.08	0.03	<0.1	<0.1	<2.0	40	1.5	4.12
10-20	4.7	0.01		<20	2	<2	1	<1.5	0.14	0.04	0.08	0.03	<0.1	<0.1	<2.0	17	1.4	3.5
20-28	4.6	0.01		<20	1	<2	1	<1.5	0.14	0.06	0.08	0.03	<0.1	<0.1	<2.0	12	1.6	2.46
50-60	4.6	0.01		<20	1	<2	6	<1.5	0.14	0.12	0.08	0.03	<0.1	<0.1	<2.0	6	1.9	1.20
80-90	4.6	0.01		<20	<1	<2	8	<1.5	0.14	0.11	0.08	0.03	<0.1	<0.1	<2.0	5	1.7	1.28
110-120	4.7	0.01		<20	<1	<2	11	<1.5	0.14	0.17	0.08	0.03	<0.1	<0.1	<2.0	3	1.5	0.80
140-150	4.7	0.01		<20	<1	<2	8	<1.5	0.18	0.43	0.08	0.03	<0.1	<0.1	<2.0	2	2.6	0.41
170-180	4.6	0.01		<20	<1	<2	13	<1.5	0.14	0.28	0.08	0.03	<0.1	<0.1	<2.0	2	1.9	0.50

SITE: 022 **Land Unit: 11a** **Australian Soil Classification (ASC): Redoxic Hydrosol (HYEDFRAFBELM)**

Depth (cm)	Horizon	Description
Surface	-	Moist; soft
0-11	A1	Very dark grey (10YR 3/1); sandy loam; massive; earthy; moderately moist; very weak; field pH 5.4
11-20	A2	Brown (10YR 5/3); sandy loam; massive; earthy; moist; very weak; field pH 6.0
20-35	B1	Brown (10YR 6/4); sandy clay loam - light; massive; earthy; moist; weak; field pH 5.9
35-85	B21	Brownish yellow(10YR 6/6); sandy clay loam; massive; earthy; moist; weak; 2%, 10mm distinct red mottles field pH 5.9
85-110	B22	Light yellowish brown (10YR 6/4); sandy clay loam; massive; earthy; moist; weak; 20%, 20mm prominent red mottles; field pH 5.7
110-130	B23	Brownish yellow(10YR 6/6); sandy clay loam; massive; earthy; moist; weak; 40%, 30mm prominent red mottles; field pH 5.7
130-180	B24	Brownish yellow(10YR 6/6); sandy clay loam; massive; earthy; wet; weak; 60%, 30mm prominent red mottles; field pH 5.8

Description: Swamp systems; closed depressions with very low relief. Soils are deep, poorly drained yellow mottled gradational earths (Hydrosols). Profiles are characterized by a sandy loam surface grading to a sandy clay loam subsoil, massive structure, earthy fabric and a moist to wet soil water status. pH is strongly acidic throughout with prominent red mottling in the subsoil.

Physical Properties

Depth (cm)	Coarse Sand %	Fine Sand %	Silt %	Clay %
0-10	36	38	9	21
11-20	32	41	4	28
20-30	31	43	2	30
50-60	34	41	3	28
80-90	26	32	3	42
110-120	25	29	2	47
140-150	24	29	1	47
170-180	26	31	3	42

Chemical Properties

Depth (cm)	$pH_{1:5}$ H_2O	$EC_{1:5}$ H_2O	$Cl_{1:5}$ (mg/kg)	Nitrate Nitrogen (mg/kg)	Bicarb. Extract. P (mg/kg)	Organic Carbon (%)	Extract. Sulfur (mg/kg)	Air Dry Moisture Content (%)	Exchangeable Cations (Cmol/kg)				Extractable Micronutrients (mg/kg)				Base Status (Cmol/kg)	Ca/Mg Ratio
	pH	EC	Cl	NO_3-N	P	OC	SO_4-S	ADMC	Ca	Mg	Na	K	Cu	Zn	Mn	Fe		
0-10	4.5	0.03	22	10	<2	2.63	2	<1.5	0.34	0.30	0.08	<0.03	0.2	<0.1	<2.0	86	3.5	1.13
11-20	4.5	0.01	20	3	<2	0.52	2	<1.5	<0.14	0.27	<0.08	<0.03	<0.1	<0.1	<2.0	29	1.9	0.52
20-30	4.7	0.01	<20	2	<2	0.22	5	<1.5	<0.14	0.42	<0.08	<0.03	<0.1	<0.1	<2.0	12	2.3	0.33
50-60	4.9	0.01	25	1	<2	0.23	21	<1.5	<0.14	0.44	<0.08	<0.03	<0.1	<0.1	<2.0	7	2.4	0.32
80-90	4.6	0.01	<20	2	<2	0.15	21	<1.5	<0.14	0.45	<0.08	<0.03	<0.1	<0.1	<2.0	4	1.7	0.31
110-120	4.6	0.01	<20	<1	<2	0.11	28	<1.5	<0.14	0.47	<0.08	<0.03	<0.1	<0.1	<2.0	3	1.6	0.30
140-150	4.7	0.01	<20	<1	<2	0.08	29	<1.5	<0.14	0.58	<0.08	<0.03	<0.1	<0.1	<2.0	2	1.8	0.24
170-180	4.7	0.01	<20	<1	<2	0.09	26	<1.5	<0.14	0.51	<0.08	<0.03	<0.1	<0.1	<2.0	2	1.8	0.28

Appendix 3. Australian soil classifications

Order	Suborder	Great Group	Subgroup	Family Criteria 1	Family Criteria 2	Family Criteria 3	Family Criteria 4	Family Criteria 5
Hydrosol	ND	ND	ND	ND	ND	ND	ND	ND
Hydrosol	ND	Kandosolic	Acidic	Thin	Slightly Gravelly	Loamy	Clay Loamy	Not Recorded
Hydrosol	Redoxic	Kandosolic	ND	Thin	Non Gravelly	Loamy	Clay Loamy	Very Deep
Hydrosol	Redoxic	Kandosolic	ND	Thin	Non Gravelly	Loamy	Clay Loamy	ND
Hydrosol	Redoxic	Kandosolic	ND	Medium	Non Gravelly	Loamy	Clay Loamy	Very Deep
Hydrosol	Redoxic	Kandosolic	ND	Medium	Non Gravelly	Loamy	Clay Loamy	ND
Hydrosol	Oxyaquic	Tenosolic	ND	Thick	Non Gravelly	Sandy	Sandy	ND
Hydrosol	Oxyaquic	Tenosolic	ND	Medium	Non Gravelly	Sandy	Sandy	ND
Hydrosol	Redoxic	Kandosolic	Bleached	Thin	Non Gravelly	Loamy	Clay Loamy	Very Deep
Hydrosol	Redoxic	Kandosolic	Acidic	Thin	Non Gravelly	Loamy	Clay Loamy	Very Deep
Hydrosol	Redoxic	Kandosolic	Bleached-Acidic	Medium	Non Gravelly	Loamy	Clay Loamy	Very Deep
Hydrosol	Redoxic	Kandosolic	Acidic	Thick	Non Gravelly	Loamy	Clayey	Very Deep
Kandosol	Brown	ND	Acidic	Thin	Very Gravelly	Loamy	Clay Loamy	Very Shallow
Kandosol	Brown	ND	Mottled	Medium	Non Gravelly	Loamy	Clay Loamy	ND
Kandosol	Red	ND	ND	ND	ND	ND	ND	ND
Kandosol	Red	ND	Haplic	ND	ND	ND	ND	ND
Kandosol	Red	ND	Haplic	Medium	Moderately Gravelly	Loamy	Clay Loamy	ND
Kandosol	Red	ND	Haplic	Medium	Non Gravelly	Sandy	Clay Loamy	ND
Kandosol	Red	ND	Haplic	Thin	Non Gravelly	Sandy	Clay Loamy	ND
Kandosol	Red	ND	Haplic	Thin	Non Gravelly	Loamy	Clay Loamy	Very Deep
Kandosol	Red	ND	Haplic	Thin	Non Gravelly	Sandy	Clay Loamy	Very Deep
Kandosol	Red	ND	Haplic	Thick	Non Gravelly	Loamy	Clay Loamy	Very Deep
Kandosol	Red	ND	Haplic	Medium	Non Gravelly	Loamy	Clay Loamy	Very Deep
Kandosol	Red	ND	Haplic	Medium	Non Gravelly	Sandy	Clay Loamy	Very Deep
Kandosol	Red	ND	Haplic	Medium	Non Gravelly	Loamy	Clay Loamy	Moderate
Kandosol	Red	ND	Ferric	Thin	Very Gravelly	Loamy	Clay Loamy	ND
Kandosol	Red	Petroferric	Ferric-Acidic	Thin	Gravelly	Loamy	Loamy	Very Shallow
Kandosol	Red	ND	Ferric	Medium	Gravelly	Loamy	Clay Loamy	Very Deep
Kandosol	Red	ND	Ferric	Medium	Moderately Gravelly	Sandy	Clay Loamy	Very Deep
Kandosol	Red	ND	Mottled	Medium	Non Gravelly	Sandy	Clayey	Very Deep
Tenosol	Red Orthic	ND	Basic	Thick	Non Gravelly	Sandy	Sandy	Very Deep
Tenosol	Red Orthic	Paralithic	Basic	Thin	Very Gravelly	Sandy	Sandy	ND

Appendix 4. Base status of soil samples analysed

Soil (ASC)	Site	Land Unit	Horizon	Sample depth	Exchangeable Sodium	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	ECEC	Clay	Sum of Bases	Base Status	Base Status Classification	ASC (Isbell 2002)
				cm	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	%				
Kandosols	1	8a	A1	0.00-0.10	<0.080	1.84	0.96	0.053	3.36	14.3	2.85	19.95		
			A3	0.12-0.20	<0.080	0.15	0.391	<0.030	0.93	16.1	0.54	3.36		
			A3	0.20-0.29	<0.080	0.14	0.575	0.035	1.1	19.5	0.75	3.85		
			B1	0.50-0.60	<0.080	0.14	0.48	<0.030	0.87	22.9	0.62	2.71		
			B21	0.80-0.90	<0.080	0.14	0.64	<0.030	0.92	22.9	0.78	3.41	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.79	<0.030	1.08	29.6	0.93	3.14	Dystrophic	
			B22	1.40-1.50	<0.080	0.14	1.02	<0.030	1.33	39.8	1.16	2.91	Dystrophic	
			B22	1.70-1.80	<0.080	0.14	0.8	<0.030	1.11	36.3	0.94	2.59	Dystrophic	KAAA**AF**CDBEKMX
	2	8a	A1	0.00-0.10	0.156	0.744	0.712	0.053	3.37	10.9	1.67	15.28		
			A2	0.10-0.20	<0.080	0.14	0.158	<0.030	1.05	19.2	0.30	1.55		
			A3	0.20-0.28	<0.080	0.14	0.371	<0.030	1.1	21.1	0.51	2.42		
			B1	0.50-0.60	<0.080	0.231	0.533	<0.030	1.15	24.5	0.76	3.12		
			B21	0.80-0.90	<0.080	0.14	0.315	<0.030	0.88	24.5	0.46	1.86	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.612	<0.030	1.05	34.6	0.75	2.17	Dystrophic	
			B22	1.40-1.50	<0.080	0.14	0.641	<0.030	1.11	39.7	0.78	1.97	Dystrophic	
			B22	1.70-1.80	<0.080	0.14	0.51	<0.030	0.96	31.2	0.65	2.08	Dystrophic	KAAA**AF**CDAEKMX
	5	8b	A1	0.00-0.10	<0.080	0.352	0.42	<0.030	1.42	13	0.77	5.94		
			A2	0.10-0.18	<0.080	0.14	0.543	<0.030	1.31	19.8	0.68	3.45		
			B1	0.20-0.30	<0.080	0.14	0.537	<0.030	1.26	21.5	0.68	3.15		
			B1	0.50-0.60	<0.080	0.14	0.444	<0.030	0.97	23.2	0.58	2.52		
			B21	0.80-0.90	<0.080	0.14	0.441	<0.030	0.96	26.6	0.58	2.18	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.706	<0.030	1.2	36.7	0.85	2.31	Dystrophic	
			B22	1.40-1.50	0.089	0.16	1.01	<0.030	1.5	43.5	1.26	2.90	Dystrophic	
			B22	1.70-1.80	<0.080	0.14	0.814	<0.030	1.16	38.4	0.95	2.48	Dystrophic	KAAA**AF**CDAEKMX
	6	8b	A1	0.00-0.10	<0.080	0.904	0.858	<0.030	2.28	14.7	1.76	11.98		
			A2	0.10-0.20	<0.080	0.14	0.519	<0.030	1.26	26.4	0.66	2.50		
			B1	0.20-0.30	<0.080	0.14	0.577	<0.030	1.2	23	0.72	3.12		
			B1	0.50-0.60	<0.080	0.14	0.597	<0.030	1.02	28	0.74	2.63		
			B21	0.80-0.90	<0.080	0.14	0.811	<0.030	1.16	31.4	0.95	3.03	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	1.15	<0.030	1.46	41.6	1.29	3.10	Dystrophic	

Soil (ASC)	Site	Land Unit	Horizon	Sample depth	Exchangeable Sodium	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	ECEC	Clay	Sum of Bases	Base Status	Base Status Classification	ASC (Isbell 2002)
				cm	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	%				
			B23	1.40-1.50	<0.080	0.14	0.849	<0.030	1.17	34.8	0.99	2.84	Dystrophic	
			B23	1.70-1.80	<0.080	0.14	0.598	<0.030	1.14	34.8	0.74	2.12	Dystrophic	KAAA**AF**BUBNKMX
Kandosols	8	8b	A1	0.00-0.09	<0.080	1.08	0.478	0.037	2.35	14.6	1.6	10.92		
			A2	0.10-0.20	<0.080	0.206	0.312	<0.030	0.94	18.1	0.52	2.86		
			A3	0.20-0.30	<0.080	0.14	0.371	<0.030	0.82	19.8	0.51	2.58		
			B1	0.50-0.60	<0.080	0.14	0.485	<0.030	0.86	19.8	0.63	3.16		
			B21	0.80-0.90	<0.080	0.14	0.27	<0.030	0.77	19.8	0.41	2.07	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.274	<0.030	0.69	18.1	0.41	2.29	Dystrophic	KAAA**AF**CDAELM-
	9	8a	A1	0.00-0.08	0.112	1.86	1.38	0.054	4.43	14.7	3.41	2.07		
			A2	0.10-0.20	0.08	0.262	0.53	0.03	1.37	19.6	0.90	4.60		
			A2	0.20-0.27	0.08	0.14	0.6	0.03	1.06	21.3	0.85	3.99		
			B21	0.50-0.60	0.08	0.14	0.829	0.03	1.11	23.2	1.08	4.65	Dystrophic	
			B21	0.80-0.90	0.08	0.14	0.611	0.03	0.9	23.2	0.86	3.71	Dystrophic	
			B22	1.10-1.20	0.08	0.14	0.798	0.03	1.17	36.7	1.05	2.86	Dystrophic	
			B22	1.40-1.50	0.08	0.14	0.91	0.03	1.28	41.6	1.16	2.79	Dystrophic	
			B22	1.70-1.80	0.08	0.14	0.953	0.03	1.31	39.9	1.20	3.02	Dystrophic	KAAA**AF**CDAELMX
	10	8a1	A1	0.00-0.10	<0.080	0.978	0.736	0.068	2.88	19.8	1.78	9.0		
			A2	0.12-0.20	<0.080	0.156	0.401	<0.030	1.47	24.7	0.56	2.26		
			A3	0.25-0.30	<0.080	0.203	0.377	<0.030	1.29	26.4	0.58	9.0		
			B1	0.50-0.60	<0.080	0.14	0.461	<0.030	1.06	26.6	0.60	2.26		
			B21	0.80-0.90	<0.080	0.14	0.741	<0.030	1.19	33.3	0.88	2.65	Dystrophic	
			B21	1.10-1.20	<0.080	0.14	0.559	<0.030	1.34	41.8	0.70	1.67	Dystrophic	
			B22	1.40-1.50	<0.080	0.14	0.434	<0.030	1.72	43.2	0.57	1.33	Dystrophic	
			B3	1.70-1.80	<0.080	0.14	0.51	<0.030	1.97	45	0.65	1.44	Dystrophic	KAAA**AF**DQBEKOX
	11	8a1	A1	0.00-0.10	<0.080	3.28	1.21	0.046	4.68	14.5	4.54	31.28		
			A2	0.10-0.17	<0.080	0.807	0.852	<0.030	1.96	21.3	1.66	7.79		
			A3	0.20-0.30	<0.080	0.356	0.775	<0.030	1.43	28	1.13	4.04		
			A3	0.50-0.60	<0.080	0.14	0.521	<0.030	1.1	26.4	0.66	2.50		
			B1	0.80-0.90	<0.080	0.14	0.535	<0.030	0.9	28	0.68	2.41		
			B21	1.10-1.20	<0.080	0.14	1.06	<0.030	1.35	45.1	1.2	2.66	Dystrophic	KAAA**AF**CDAELM-
	12	7a	A11	0.00-0.05	<0.080	1.36	0.889	0.033	2.85	19.6	2.28	11.64		
			A12	0.05-0.10	<0.080	0.522	0.733	<0.030	1.83	24.7	1.26	5.08		

Soil (ASC)	Site	Land Unit	Horizon	Sample depth	Exchangeable Sodium	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	ECEC	Clay	Sum of Bases	Base Status	Base Status Classification	ASC (Isbell 2002)
				cm	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	%				
			A3	0.10-0.18	<0.080	0.199	0.5	0.030	1.31	26.5	0.70	2.64		
			B1	0.20-0.30	<0.080	0.14	0.636	<0.030	1.33	25	0.78	3.10		
			B1	0.50-0.60	<0.080	0.14	0.596	<0.030	1.13	24.9	0.74	2.96		
			B2	0.80-0.90	<0.080	0.14	0.435	<0.030	1.09	23.2	0.58	2.48	Dystrophic	
			B2	1.10-1.20	<0.080	0.14	0.782	<0.030	1.38	28.3	0.92	3.26	Dystrophic	
			B2	1.40-1.50	<0.080	0.14	0.779	<0.030	1.36	29.9	0.92	3.07	Dystrophic	
			B2	1.70-1.80	<0.080	0.14	0.916	<0.030	1.55	33.4	1.06	3.16	Dystrophic	KAAA**AF**CDAELMX
Kandosols	19	8a	A11	0.00-0.07	<0.080	1.49	0.844	<0.030	2.63	12.8	2.44	19.10		
			A12	0.10-0.17	<0.080	0.433	0.533	<0.030	1.33	14.5	1.08	7.42		
			A13	0.20-0.30	<0.080	0.198	0.516	<0.030	0.98	16.1	0.82	5.12		
			A3	0.50-0.60	<0.080	0.14	0.352	<0.030	0.85	16.1	0.60	3.74		
			B21	0.80-0.90	<0.080	0.14	0.465	<0.030	0.77	19.5	0.72	3.67	Dystrophic	
			B22	1.10-1.20	<0.080	0.157	0.765	<0.030	1.06	31.3	1.03	3.30	Dystrophic	
			B23	1.40-1.50	<0.080	0.14	0.714	<0.030	0.99	29.6	0.96	3.26	Dystrophic	
			B23	1.70-1.80	<0.080	0.14	0.576	<0.030	0.86	26.6	0.83	3.11	Dystrophic	KAAA**AF**CDCELMX
	23	8a	A1	0.00-0.10	<0.080	0.262	0.423	<0.030	1.53	21.2	0.80	3.75		
			A21	0.14-0.20	<0.080	0.14	0.46	<0.030	0.81	26.4	0.71	2.69		
			A21	0.20-0.30	<0.080	0.14	0.535	<0.030	0.81	29.8	0.79	2.63		
			A22	0.50-0.60	<0.080	0.14	0.443	<0.030	0.76	33.2	0.69	2.09		
			B2	0.80-0.90	<0.080	0.14	0.726	<0.030	1.09	39.9	0.98	2.45	Dystrophic	
			B2	.1.10-1.20	<0.080	0.14	0.46	<0.030	0.95	43.3	0.83	1.91	Dystrophic	
			B2	1.40-1.50	<0.080	0.14	0.554	<0.030	0.92	36.5	0.83	2.28	Dystrophic	
			B2	1.70-1.80	<0.080	0.14	0.344	<0.030	0.67	36.3	0.60	1.64	Dystrophic	KAAA**AF**DQBELMX
	26	8a	A1	0.00-0.09	<0.080	1.23	1.11	<0.030	3.04	19.4	2.42	12.47		
			A2	0.10-0.20	<0.080	0.511	0.851	<0.030	2.02	24.5	1.44	5.89		
			A2	0.20-0.30	<0.080	0.238	0.922	<0.030	1.66	29.3	1.24	4.23		
			B21	0.50-0.60	<0.080	0.14	0.828	<0.030	1.29	32.7	1.05	3.20	Dystrophic	
			B23	0.80-0.90	<0.080	0.14	0.785	<0.030	1.08	34.8	1.00	2.89	Dystrophic	
			B23	1.10-1.20	<0.080	0.14	0.928	<0.030	1.23	41.6	1.15	2.76	Dystrophic	
			B23	1.40-1.50	<0.080	0.14	0.98	<0.030	1.28	46.5	1.20	2.58	Dystrophic	
			B23	1.70-1.80	<0.080	0.14	0.915	<0.030	1.21	43.1	1.14	2.63	Dystrophic	KAAA**AF**CDAELMX
	28	8a	A1	0.00-0.09	<0.080	0.356	0.404	<0.030	1.72	17.7	0.84	4.75		

Soil (ASC)	Site	Land Unit	Horizon	Sample depth	Exchangeable Sodium	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	ECEC	Clay	Sum of Bases	Base Status	Base Status Classification	ASC (Isbell 2002)
				cm	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	%				
			A21	0.10-0.20	<0.080	0.14	0.193	<0.030	0.8	19.4	0.41	2.13		
			A21	0.20-0.30	<0.080	0.14	0.14	<0.030	0.53	19.4	0.36	1.86		
			A21	0.50-0.60	<0.080	0.14	0.189	<0.030	0.58	21.1	0.41	1.94		
			A22	0.80-0.90	<0.080	0.14	0.125	<0.030	0.61	22.8	0.35	1.51		
			B2	1.10-1.20	<0.080	0.14	0.153	<0.030	0.67	26.2	0.37	1.42	Dystrophic	
			B2	1.70-1.80	<0.080	0.14	0.209	<0.030	0.68	27.9	0.43	1.54	Dystrophic	KAAA**AF**CDAELMX
Kandosols	30	8a1	A1	0.00-0.10	<0.080	0.14	0.181	<0.030	1.31	19.2	0.43	2.24		
			A2	0.12-0.20	<0.080	0.14	0.096	<0.030	0.79	19.2	0.35	1.80		
			A2	0.20-0.30	<0.080	0.14	0.116	<0.030	0.6	19.2	0.37	1.91		
			A2	0.50-0.60	<0.080	0.14	0.144	<0.030	0.42	19.2	0.39	2.05		
			B21	0.80-0.90	<0.080	0.14	0.226	<0.030	0.53	22.6	0.48	2.11	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.271	<0.030	0.59	25.9	0.52	2.01	Dystrophic	
			B22	1.40-1.50	<0.080	0.14	0.266	<0.030	058	25.9	0.52	1.99	Dystrophic	
			B22	1.70-1.80	<0.080	0.14	0.309	<0.030	0.6	25.9	0.56	2.16	Dystrophic	KAAA**AF**CDBEKMX
	34	8a	A11	0.00-0.07	<0.080	0.472	0.254	<0.030	1.85	15.8	0.84	5.29		
			A12	0.10-0.19	<0.080	0.14	0.157	<0.030	0.96	19.2	0.41	2.12		
			B1	0.20-0.30	<0.080	0.14	0.515	<0.030	1.03	22.8	0.77	3.36		
			B1	0.50-0.60	<0.080	0.14	0.594	<0.030	0.88	26.2	0.84	3.22		
			B21	0.80-0.90	<0.080	0.14	0.721	<0.030	1	28.1	0.97	3.46	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.697	<0.030	1	37.8	0.95	2.51	Dystrophic	
			B22	1.40-1.50	<0.080	0.14	0.757	<0.030	1.06	41.2	1.00	2.44	Dystrophic	
			B22	1.70-1.80	<0.080	0.14	0.684	<0.030	0.96	36.8	0.93	2.54	Dystrophic	KAAA**AF**CDAEKMX
	38	8a	A1	0.00-0.10	<0.080	0.482	0.542	<0.030	1.93	24.8	1.13	4.57		
			A2	0.10-0.20	<0.080	0.14	0.45	<0.030	1.21	31.6	0.70	2.22		
			B1	0.20-0.30	<0.080	0.14	0.538	<0.030	1.03	34.8	0.79	2.26		
			B1	0.50-0.60	<0.080	0.14	0.726	<0.030	1.1	38.2	0.98	2.55		
			B21	0.80-0.90	<0.080	0.14	1.37	<0.030	1.75	55.1	1.62	2.94	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.935	<0.030	1.33	55.1	1.19	2.15	Dystrophic	
			B22	1.40-1.50	<0.080	0.14	0.807	<0.030	1.16	51.8	1.06	2.04	Dystrophic	
			B22	1.70-1.80	<0.080	0.14	1.09	<0.030	1.41	51.8	1.34	2.59	Dystrophic	KAAA**AF**CDBELMX
	63	8a	A1	0.00-0.08	<0.080	0.16	0.184	<0.030	1.35	16.2	0.45	2.80		
			A2	0.10-0.19	<0.080	0.14	0.064	<0.030	0.73	19.6	0.31	1.60		

Soil (ASC)	Site	Land Unit	Horizon	Sample depth	Exchangeable Sodium	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	ECEC	Clay	Sum of Bases	Base Status	Base Status Classification	ASC (Isbell 2002)
				cm	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	%				
			B1	0.20-0.30	<0.080	0.14	0.298	<0.030	0.87	21.3	0.55	2.57		
			B21	0.50-0.60	<0.080	0.14	0.229	<0.030	0.61	21.3	0.48	2.25	Dystrophic	
			B21	0.80-0.90	<0.080	0.14	0.329	<0.030	0.65	21.3	0.58	2.72	Dystrophic	
			B22	1.10-1.20	<0.080	0.14	0.452	<0.030	0.75	23	0.70	3.05	Dystrophic	
			B23	1.40-1.50	<0.080	0.14	0.573	<0.030	0.95	29.8	0.82	2.76	Dystrophic	
			B23	1.70-1.80	<0.080	0.14	0.46	<0.030	0.92	31.1	0.71	2.28	Dystrophic	KAAA**AF**AIAELMX
Tenosols	4	7a	A11	0.00-0.10	<0.080	0.411	0.256	<0.030	1.42	10.9	0.67	6.12		
			A11	0.10-0.15	<0.080	0.196	0.24	<0.030	1.2	12.6	0.44	3.46		
			A12	0.10-0.20	<0.080	0.14	0.09	<0.030	0.99	14.3	0.23	1.61		
			A12	0.20-0.30	<0.080	0.14	0.066	<0.030	0.87	14.3	0.21	1.44		
			B21	0.50-0.60	<0.080	0.14	0.113	<0.030	0.8	12.6	0.25	2.01		
			B21	0.80-0.90	<0.080	0.14	0.092	<0.030	0.69	13	0.23	1.78		
			B21	1.10-1.20	<0.080	0.14	0.132	<0.030	0.65	11.3	0.27	2.41		
			B22	1.40-1.50	<0.080	0.14	0.159	<0.030	0.53	9.6	0.30	3.11		
			B22	1.70-1.80	<0.080	0.14	0.152	<0.030	0.51	8	0.29	3.65		TEINYYAICEKKX
Hydrosols	18	8c	A11	0.00-0.10	0.3	0.583	0.747	0.051	2.46	9.4	1.68	17.88		
			A12	0.13-0.20	0.084	0.14	0.226	0.03	1.37	12.7	0.48	3.78		
			A12	0.20-0.28	0.08	0.14	0.097	0.03	1.28	12.7	0.35	2.73		
			A2	0.50-0.60	0.08	0.14	0.212	0.03	1.37	16.2	0.46	2.85		
			B22	0.80-0.90	0.08	0.14	0.329	0.03	1.76	23	0.58	2.52		
			B23	1.10-1.20	0.08	0.14	0.435	0.03	1.83	26.4	0.69	2.59		
			B23	1.40-1.47	0.105	0.14	0.951	0.03	1.95	31.4	1.23	3.90		HYEDFRAIBEKM-
	20	11a	A1	0.00-0.07	<0.080	0.14	0.26	<0.030	1.33	34.6	0.51	1.47		
			B1	0.14-0.20	<0.080	0.14	0.308	<0.030	0.73	38.3	0.56	1.46		
			B1	0.20-0.30	<0.080	0.14	0.431	<0.030	0.82	40	0.68	1.70		
			B1	0.50-0.60	<0.080	0.14	0.231	<0.030	0.75	38.4	0.48	1.25		
			B22	0.80-0.90	<0.080	0.14	0.344	<0.030	1.08	53.6	0.59	1.11	Dystrophic	
			B23	1.10-1.20	<0.080	0.14	0.422	<0.030	1.11	55.3	0.67	1.22	Dystrophic	
			B23	1.40-1.50	<0.080	0.14	0.354	<0.030	1	51.7	0.60	1.17	Dystrophic	
			B23	1.70-1.80	<0.080	0.14	0.303	<0.030	1.07	48.3	0.55	1.14	Dystrophic	HYEDFR**AF**AELMX
	21	11a	A1	0.00-0.07	<0.080	0.14	0.228	0.039	1.54	26.2	0.49	1.86		
			A2	0.10-0.19	<0.080	0.14	0.229	0.03	1.12	24.6	0.48	1.95		

Soil (ASC)	Site	Land Unit	Horizon	Sample depth	Exchangeable Sodium	Exchangeable Calcium	Exchangeable Magnesium	Exchangeable Potassium	ECEC	Clay	Sum of Bases	Base Status	Base Status Classification	ASC (Isbell 2002)
				cm	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	meq / 100 g	%				
			B1	0.20-0.30	<0.080	0.14	0.179	0.03	0.92	26.4	0.43	1.62		
			B21	0.50-0.60	<0.080	0.14	0.104	0.03	0.6	26.6	0.35	1.33	Dystrophic	
			B22	0.80-0.90	<0.080	0.14	0.429	<0.030	1.08	39.7	0.68	1.71	Dystrophic	
			B22	0.90-1.20	<0.080	0.14	0.445	0.03	1.21	43.5	0.70	1.60	Dystrophic	HYEDFR**AF**AELM-
	22	11a	A1	0.00-0.10	<0.080	0.337	0.298	<0.030	2.19	21.2	0.75	3.51		
			A2	0.11-0.20	<0.080	0.14	0.27	<0.030	1.11	27.9	0.52	1.86		
			B1	0.20-0.30	<0.080	0.14	0.42	<0.030	0.89	29.7	0.67	2.26		
			B21	0.50-0.60	<0.080	0.14	0.435	<0.030	0.75	28	0.69	2.45	Dystrophic	
			B22	0.80-0.90	<0.080	0.14	0.454	<0.030	0.96	41.6	0.70	1.69	Dystrophic	
			B23	1.10-1.20	<0.080	0.14	0.473	<0.030	1.01	46.5	0.72	1.55	Dystrophic	
			B24	1.40-1.50	<0.080	0.14	0.577	<0.030	1	46.5	0.83	1.78	Dystrophic	
			B24	1.70-1.80	<0.080	0.14	0.506	<0.030	0.9	41.5	0.76	1.82	Dystrophic	HYEDFR**AF**BELMX
Hydrosols	32	8c1	A1	0.00-0.10	<0.080	0.14	0.034	<0.030	0.68	19	0.28	1.49		
			A2	0.10-0.20	<0.080	0.14	0.04	<0.030	0.48	20.5	0.29	1.41		
			A2	0.20-0.28	<0.080	0.14	0.057	<0.030	0.42	18.9	0.31	1.62		
			A2	0.50-0.60	<0.080	0.14	0.117	<0.030	0.45	19	0.37	1.93		
			B1	0.80-0.90	<0.080	0.14	0.109	<0.030	0.57	21.1	0.36	1.70		
			B22	1.10-1.20	<0.080	0.14	0.174	<0.030	0.85	27.4	0.42	1.55	Dystrophic	
			B23	1.40-1.50	<0.080	0.179	0.432	<0.030	0.43	27.4	0.72	2.63	Dystrophic	
			B23	1.70-1.80	<0.080	0.14	0.281	<0.030	0.66	27.6	0.53	1.92	Dystrophic	HYEDFR**AF**AELMX

Appendix 5. Soil laboratory method and description

Method	Analyte	Name	ALHS	Uncertainty ±%	PQL	Unit	Method Description	Reporting Basis
S_ADM_105 v1	ADMC	Air dry moisture content (105ºC)	2A1	8	1.5	%	Soil: Moisture air dry	Oven dry (48 hours at 40°C)
S_AQ4_AA v2	Cl	Chloride	5A2	10	20	mg/kg	Soil: Cl NO3-N Aqueous (1:5)	Oven dry (48 hours at 40°C)
S_AQ4_AA v2	NO3-N	Nitrate nitrogen	7B1	15	1	mg/kg	Soil: Cl NO3-N Aqueous (1:5)	Oven dry (48 hours at 40°C)
S_AQ4_EL v1	EC	Electrical conductivity	3A1	10	0.01	dS/m	Soil: pH EC Aqueous (1:5)	Oven dry (48 hours at 40°C)
S_AQ4_EL v1	pH	pH	4A1	5	0.1	-	Soil: pH EC Aqueous (1:5)	Oven dry (48 hours at 40°C)
S_CAT_EQ v3	Ca	Calcium	15A1_Ca	10	0.14	cmol_c/kg	Soil: Cations extractable NH4Cl pH 7 ICP	Oven dry (48 hours at 40°C)
S_CAT_EQ v3	K	Potassium	15A1_K	10	0.03	cmol_c/kg	Soil: Cations extractable NH4Cl pH 7 ICP	Oven dry (48 hours at 40°C)
S_CAT_EQ v3	Mg	Magnesium	15A1_Mg	10	0.03	cmol_c/kg	Soil: Cations extractable NH4Cl pH 7 ICP	Oven dry (48 hours at 40°C)
S_CAT_EQ v3	Na	Sodium	15A1_Na	10	0.08	cmol_c/kg	Soil: Cations extractable NH4Cl pH 7 ICP	Oven dry (48 hours at 40°C)
S_CAT_EQ v3	Na corr	Exchangeable Sodium	15A3_Na	0	0.08	cmol_c/kg	Soil: Cations extractable NH4Cl pH 7 ICP	Oven dry (48 hours at 40°C)
S_CC2_EL v1	pH	pH	4B1	5	0.1		Soil: pH 0.01M CaCl2 1:5 electrode	Oven dry (48 hours at 40°C)
S_COLWELL v2	P	Phosphorus (Colwell)	9B2	10	2	mg/kg	Soil: P extractable 0.5M NaHCO3 AA	Oven dry (48 hours at 40°C)
S_DT1_ICP v2	Cu	Copper	12A1_Cu	10	0.1	mg/kg	Soil: Cu Fe Mn Zn (trace) 0.005M DTPA ICP	Oven dry (48 hours at 40°C)
S_DT1_ICP v2	Fe	Iron	12A1_Fe	10	2	mg/kg	Soil: Cu Fe Mn Zn (trace) 0.005M DTPA ICP	Oven dry (48 hours at 40°C)
S_DT1_ICP v2	Mn	Manganese	12A1_Mn	10	2	mg/kg	Soil: Cu Fe Mn Zn (trace) 0.005M DTPA ICP	Oven dry (48 hours at 40°C)
S_DT1_ICP v2	Zn	Zinc	12A1_Zn	10	0.1	mg/kg	Soil: Cu Fe Mn Zn (trace) 0.005M DTPA ICP	Oven dry (48 hours at 40°C)
S_DUM_TOC v3	OC	Organic carbon	6B5	10	0.05	%	Soil: Total Organic Carbon; Combustion	Oven dry (48 hours at 40°C)
* S_EX_ALAC v4	Al sat	Aluminium saturation percentage	15G2	10	0.1	%	Soil: Al Acidity exchangeable	Oven dry (48 hours at 40°C)
* S_EX_ALAC v4	ECEC	Effective cation exchange capacity	15J1	0	0.03	meq/100g	Soil: Al Acidity exchangeable	Oven dry (48 hours at 40°C)
* S_EX_ALAC v4	ESP	Exchangeable sodium percentage	15N1	10	0.01	%	Soil: Al Acidity exchangeable	Oven dry (48 hours at 40°C)
* S_EX_ALAC v4	Exch Acidity	Exchangeable acidity	15G1_H	10	0.03	meq/100g	Soil: Al Acidity exchangeable	Oven dry (48 hours at 40°C)
* S_EX_ALAC v4	Exch Al	Exchangeable aluminium	15G1_Al	10	0.03	meq/100g	Soil: Al Acidity exchangeable	Oven dry (48 hours at 40°C)
* S_EX_ALAC v4	Exch Al as read	Exch Al as read		0	0	meq/100g	Soil: Al Acidity exchangeable	Oven dry (48 hours at 40°C)
* S_K40_ICP v1	S	Sulfur		10	0.01	mg/kg	Soil: Sulfur; 0.25M KCl; ICP	Oven dry (48 hours at 40°C)
* S_PSA v1	Clay	Clay: hydrometer <2 µm	2Z2_Clay	5	1	%	Soil: Particle size analysis	Oven dry (48 hours at 105°C)
* S_PSA v1	Coarse sand	Coarse sand: Sieve 0.2 – 2.0 mm	2Z2_CS	10	1	%	Soil: Particle size analysis	Oven dry (48 hours at 105°C)
* S_PSA v1	Fine sand	Fine sand: Sieve 0.02 – 0.2 mm	2Z2_FS	8	1	%	Soil: Particle size analysis	Oven dry (48 hours at 105°C)
* S_PSA v1	Silt	Silt: hydrometer 2 – 20 µm	2Z2_Silt	8	1	%	Soil: Particle size analysis	Oven dry (48 hours at 105°C)

Appendix 6. Explanation of laboratory analyses

Laboratory analyses	Use and interpretation of data
Cation chemistry	
Cation Exchange Capacity (CEC/ECEC cmol/kg)	• CEC is a measure of a soils capacity to retain cations based on the surface area and surface charge of the clay fraction. Influences physical and chemical properties particularly in the clay subsoil
Exchangeable Calcium (cmol/kg)	• Measure of the amount of Ca on the clay exchange complex
Exchangeable Magnesium (cmol/kg)	• Measure of the amount of Mg on the clay exchange complex
Exchangeable Sodium (cmol/kg)	• Measure of the amount of Na on the clay exchange complex
Exchangeable Potassium (cmol/kg)	• Measure of the amount of K on the clay exchange complex
Base status (Isbell 2002)	• Measure of leaching status and capacity to retain nutrients; calculated as the sum of exchangeable cations (Ca, Mg, K, Na) divided by the clay fraction and expressed as a percentage
Ca/Mg ratio (Eckert 1987)	• Measure of the relative dominance of magnesium, useful in explaining soil physical behaviour
Clay Activity Ratio (CEC/clay %)	• Used to infer clay mineralogy and reactivity of the clay fraction.
Sodicity and dispersion	
Exchangeable sodium % (ESP)	• Measure of soil sodicity, which affects the physical behaviour (permeability/density/strength) and dispersive nature of soils. ESP measures the relative abundance of Na on the exchange complex
Dispersion ratio (R1)	• Measure of soil dispersion based on the amount of dispersed silt and clay during testing compared with total silt and clay levels
pH and salinity	
pH (1:5 soil/water)	• Measure of the acidity or alkalinity of soil material
Electrical Conductivity (EC)(1:5 soil/water)	• Estimate of the concentration of total soluble salts in the soil solution
Soluble Chloride (Cl) (mg/kg)	• Measure of the level of soluble Cl in the soil solution; provides a direct estimate of the soluble NaCl salt concentration in the soil solution
Particle size analysis (PSA)	
% Coarse sand (0.2 – 2 mm)	• Visible sand range, open pore spaces, friable, permeable
% Fine sand (0.02 – 0.2 mm)	• Non-visible sand, causes packing, increased density, intractable, "bulldust", hardsetting, erodible
% Silt (0.002 - 0.02 mm)	• Causes increased packing and density, highly erosive fraction, surface sealing, intractable, dilatancy, "bulldust", hardsetting
% Clay (< 0.002 mm)	• Colloidal fraction, determines CEC, moisture holding capacity, shrink-swell characteristics, soil structure and cracking behaviour
Moisture retention	
Air dry moisture content (ADMC %)	• Used for conversion of air dry data to an oven dry basis
15 bar (pressure plate/gravimetric)	• Estimate of moisture retention at approximate wilting point; calculated gravimetrically as moisture retained after 15 bar pressure plate losses

Laboratory analyses	Use and interpretation of data
Profile plant available water capacity (PAWC mm/1.0m)	• Calculated as the sum of AWC values over the effective rooting depth and provides an estimate of the field capacity of the soil within the root zone
Surface soil fertility	
Total Organic Carbon (%C)	• Provides an estimate of the total carbon store (C) in the surface soil; used to calculate to surrogate organic matter (OM%) estimates
Kjedahl nitrogen (%N)	• Provides an estimate of the total store of nitrogen (N) in the surface soil that can potentially be mineralised
Bicarbonate extractable phosphorus (mg/kg P)	• Provides a reliable and consistent estimate of plant available phosphorus (P) in the surface soil across a range of pH conditions
Acid extractable phosphorus (mg/kg P)	• Alternate measure of plant available phosphorus (P) in the surface soil; developed for fertility assessment in the Queensland cane industry
Replaceable Potassium (cmol/kg K)	• Provides an estimate of the relative abundance of potentially available potassium (K/CEC %) within the fine earth fraction in the surface soil
Extractable sulphate Sulphur (mg/kg)	• Provides a reliable and consistent estimate of plant available sulphate sulphur (S) in the surface soil
Exchangeable Calcium (cmol/kg Ca)	• Provides an estimate of the relative abundance of potentially available calcium (Ca/CEC %) within the fine earth fraction in the surface soil
Extractable trace elements -Cu, Fe, Mn, Zn (ppm)	• Provides a reliable and consistent estimate of plant available Copper, Iron, Manganese and Zinc in the surface soil

Sources: Eckert (1987), Isbell (2002); Mckenzie *et al* (2002) – soil physics and Rayment and Lyons (2011) – soil chemistry

Appendix 7. Soil - physical and water handling properties

Cliff Hignett BApp Sc

19 Lorimer Rd (PO Box 2124)

Naracoorte SA 5271

08 87624586

Physical and water handling properties of soils on Bathurst Island in the Northern Territory

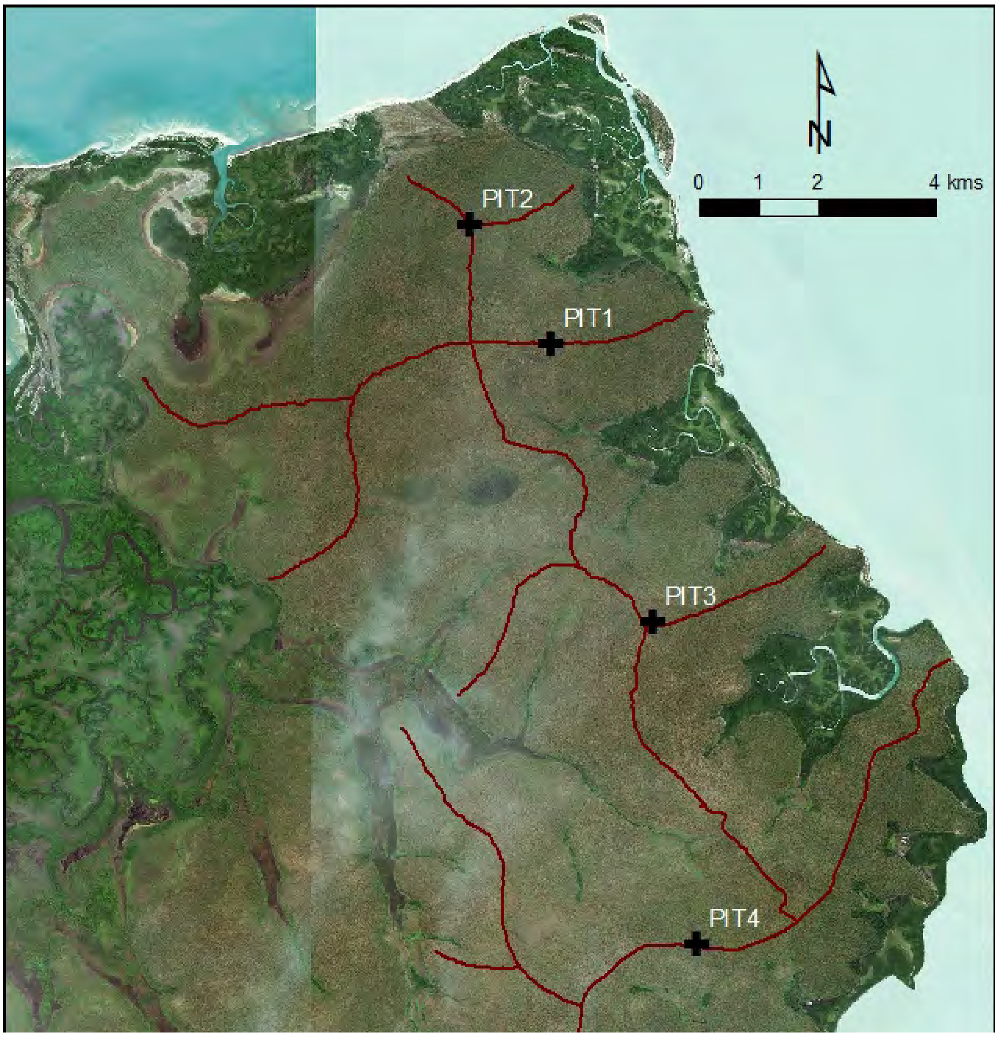
December 2014

Introduction

The Northern Territory Government has undertaken extensive investigations into the land, water and biodiversity resources of the north east portion of Bathurst Island. The investigations will assist in determining options for development, including agriculture. The soil hydrology study is part of the land resource investigation which has mapped and described the landforms, soils and vegetation. The areas most suitable for agriculture are gently undulating plains with deep well drained Red Kandosols. Four pit sites were sampled in these soils in a north-south transect through the project area.

Methods: Field

Soil pits were excavated at four locations in the catchment, marked on the air photo below.



The soil and landform were sampled and described by the Northern Territory Department of Land Resource Management's Land Assessment Unit. These results will be published elsewhere.

Soil profile information and soil chemistry, particle size and additional bulk density results will be published in the above report. The data is also stored in the Northern Territory, Soil and Land Information (SALInfo) database.

Field sampling

Soil cores were taken at selected horizons using undisturbed (tanner method) sampling with 76mm diameter rings. The soils were returned to the laboratory for measurement of water holding and hydraulic properties.

Methods: Laboratory

Soil cores were received in moist condition and cores were intact with clean cut ends.

Hydraulic Conductivity

Cores were sealed to an extension tube and the base fitted with a porous cup. They were then placed in a water bath with water depth such that the external pressure forced water up through the core into the space in the extension tube. Pressure head was maintained at unity (ie 1cm head per cm depth of soil). The cores were allowed to saturate overnight.

Then the water in the extension tube was removed, and the time flow rate as water moved to replace it was measured.

The cores were then removed from the bath, the extensions removed, and the saturated core weight measured.

The cores were then placed on a ceramic plate set to simulate a water table 10cm below the core base (1 kPa suction). They were then allowed to drain for12 hours and weighed. This provides the water content at 1 kPa tension – as near to saturation as is feasible.

The water table was then lowered to 100cm 'depth' - equivalent to a suction of 10kPa (field capacity water content) and the cores allowed to equilibrate and then weighed. This process was repeated at 300cm and 700 cm water tension (30 and 70 kPa) (70kPa may be taken as the readily available water content limit (RAW) for most crop / soil combinations.)

The cores were then oven dried to remove all water and weighed again. The volume, the dry weight of soil and the amount of water in the soil at each stage was then calculated along with such values as the density, total porosity, air filled porosity at field capacity (afp@FC).

Penetrometer

While the cores were at a tension of 70kPa, a micro penetrometer was used to measure the penetration resistance as a guide to root resistance in the field when wet. Most crops will have no difficulty penetrating soils of 3MPa or less.

Wilting point

Small sub samples of disturbed soil were collected with the cores and used to measure water holding at higher suction levels. The loose soils were slurried onto a ceramic plate and subjected to air pressure of 300kPa for 7 days, then removed and the water content measured. A similar set was set at 1500kPa for 14 days and the water again measured (wilting point).

These water content values measured as g/g were converted to a volume basis by using the density calculated from the core samples.

Results Site Locations

The location of the sites is given in Table 1. Data from these sites listed in the appendices can be identified by the pit number

Table 1. Locations : North-east Bathurst Island Pit Locations (Datum MGA94 Zone 52)

Pit No	Soil type	Easting	Northing
1	Deep Red Kandosol	645752	8742450
2	Deep Red Kandosol	644256	8744522
3	Deep Red Kandosol	647467	8737635
4	Deep Red Kandosol	648210	8732069 Hydraulic Conductivity

Saturated Hydraulic Conductivity

Detail of saturated hydraulic conductivity tests is supplied in Appendix 1. The summary results of saturated hydraulic conductivity test results are shown in Table 1. These measurements should be interpreted with caution, as they were done on 76mm diameter samples – this sample size is too small to get a good measure of average infiltration rate – particularly in surface soils. It should be used as a guide only.

Depth cm	Saturated hydraulic Conductivity mm/min				
cm	Pit 1	Pit 2	Pit 3	Pit 4	Mean
0-10	88.7	15.2	13.3	25.8	
	5.0	7.6	92.0	2.5	31.3
10-15			15.5		
			1.8		8.7
15-20	0.7	2.0	4.2	6.7	
		1.7	44.2	1.8	8.7
20-30		1.4	1.7		
	1.4	1.3	1.8	5.3	2.2
50-60	1.6	0.3	0.8	0.8	
	1.1	0.3	1.1	0.2	0.8
80-90	0.7	0.8	1.2		
	0.9	0.4	0.6	0.2	0.7

Table 1. Average saturated hydraulic conductivity (mm/min) at each depth

Note : Omitted data were extremely high values caused by major pores (probably plant roots) or cracks in soil cores – probably caused during transport.

Water retention of soils

A summary of the mean water content (cc/cc) for undisturbed soil cores subjected to a range of suctions provided in appendix 2a.   Appendix 2b reorders this information into soil depth order.

Table 2 lists the mean values of all four pits along with soil bulk density.

The same data is provided graphically in fig 1.

Table 2. Water holding at a range of suctions, and density, as a mean for all four pits

	Water Content cc/cc at indicated suction in kPa							
Depth	**0**	**1**	**10**	**30**	**70**	**300**	**1,500**	**Density**
0-10	*0.536*	*0.428*	*0.270*	*0.223*	*0.187*	*0.129*	*0.128*	***1.03***
10-15	0.485	0.429	0.340	0.199	0.185	0.119	0.128	1.16
12-20	0.474	0.394	0.235	0.212	0.185	0.133	0.131	1.23
20-30	*0.453*	*0.380*	*0.227*	*0.204*	*0.181*	*0.136*	*0.136*	***1.27***
50-60	0.435	0.375	0.275	0.219	0.200	0.137	0.138	1.43
80-90	*0.412*	*0.366*	*0.284*	*0.230*	*0.221*	*0.152*	*0.152*	1.47

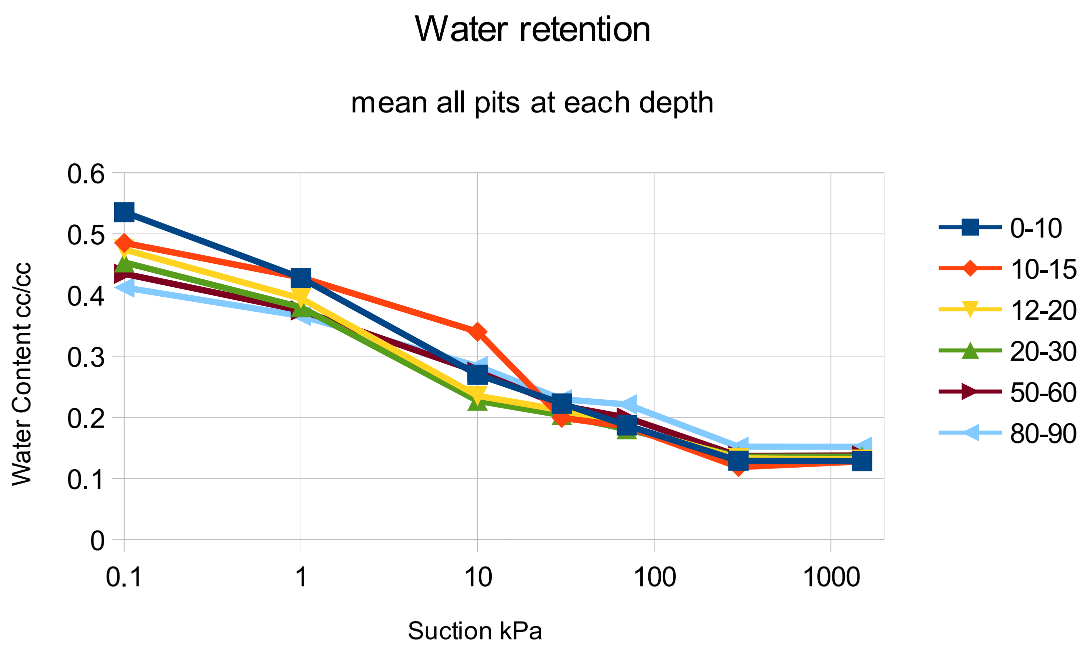


Figure 1. Water retention curves for each depth in the 4 pits.

Penetrometer resistance and derived parameters.

Table 3
Penetrometer resistance at 70kPa, with density ,total porosity, plant available water capacity (PAWC as mm water per 10cm of soil profile) and air filled porosity at field capacity (AFP@FC)– as a mean for each depth in the 4 pits.

	Penetrometer	Density	Total	PAWC	AFP@FC
pit 1	Mpa	g/cc	Porosity		
0-10	1.51	.97	.64	7	.42
12-20	1.73	1.24	.53	9	.30
20-28	1.66	1.29	.51	8	.28
50-60	1.66	1.37	.48	10	.24
80-90	1.87	1.43	.46	11	.17
Pit 2					
0-10	1.51	1.08	.59	8	.38
13-20	2.23	1.31	.50	6	.30
20-29	1.94	1.38	.48	5	.29
50-60	2.23	1.48	.44	17	.11
80-90	1.87	1.49	.44	16	.11
Pit 3					.11
0-10	1.01	1.03	.61	20	.28
10-15	.94	1.16	.56	21	.22
15-20	.94	1.18	.56	9	.35
20-30	1.08	1.27	.52	8	.32
50-60	1.15	1.42	.47	10	.24
80-90	1.66	1.46	.45	10	.22
Pit 4					
0-10	1.66	1.03	.61	21	.29
10-20	.94	1.13	.57	18	.27
20-30	.72	1.16	.56	16	.29
50-60	1.87	1.45	.45	18	.15
80-90	3.46	1.51	.43	15	.14

Conclusions

For all measured data, the four pits were very similar at corresponding depths.

Most of the soils had moderate to high infiltration rates in the surface soils – decreasing with depth and (probably) higher clay content.

Water holding, porosity, penetrometer strength, air filled porosity all fell within the range suitable for agricultural production.

Appendix 1 Detail of hydraulic conductivity testing

(cores marked A and B are replicates)

Pit 1 Depth cm		Sat. Hyd. Conductivity mm/min	Pit 2 Depth cm		Sat. Hyd. Conductivity mm/min	Pit 3 Depth cm		Sat. Hyd. Conductivity mm/min	Pit 4 Depth cm		Sat. Hyd. Conductivity mm/min
0-10	A	88.70	0-10	A	15.15	0-10	A	13.34	0-10	A	25.76
	B	5.04		B	7.64		B	92.01		B	2.47
						10-15	A	15.52			
							B	1.82			
12-20	A	0.74	13-20	A	1.99	15-20	A	4.21	10-20	A	6.70
	B			B	1.68		B	44.17		B	1.77
20-28	A		20-29	A	1.41	20-30	A	1.68	20-30	A	
	B	1.37		B	1.32		B	1.81		B	5.31
50-60	A	1.62	50-60	A	0.31	50-60	A	0.76	50-60	A	0.76
	B	1.10		B	0.29		B	1.05		B	0.24
80-90	A	0.66	80-90	A	0.77	80-90	A	1.22	80-90	A	
	B	0.89		B	0.38		B	0.63		B	0.16

Appendix 2a. Detail of moisture retention and density measurements in sampled order

Pit no	Water content cc/cc at indicated suction (kPa)							Density
Depth cm	0.1	1	10	30	70	300	1500	g/cc
pit 1								
0-10	0.570	0.373	0.190		0.154	0.134	0.134	0.83
	0.513	0.439	0.242		0.200	0.144	0.160	1.10
12-20	0.423	0.385	0.244		0.199	0.152	0.148	1.34
		0.358	0.226		0.183	0.134	0.140	1.15
20-28		0.352	0.243		0.206	0.139	0.150	1.24
	0.451	0.391	0.225		0.190	0.152	0.158	1.34
50-60	0.440	0.369	0.245		0.206	0.143	0.142	1.36
	0.432	0.359	0.236		0.193	0.146	0.138	1.38
80-90	0.435	0.388	0.297		0.243	0.176	0.182	1.49
	0.434	0.390	0.277		0.237	0.168	0.166	1.38
Pit 2								
0-10	0.546	0.439	0.231		0.192	0.113	0.127	1.08
	0.535	0.440	0.188		0.154	0.122	0.128	1.08
13-20	0.456	0.385	0.196		0.164	0.134	0.138	1.29
	0.450	0.379	0.206		0.172	0.136	0.146	1.33
20-29	0.446	0.375	0.192		0.161	0.138	0.145	1.36
	0.430	0.376	0.195		0.168	0.141	0.145	1.39
50-60	0.425	0.376	0.327	0.240	0.224	0.153	0.162	1.47
	0.425	0.369	0.330	0.240	0.223	0.150	0.165	1.50
80-90	0.439	0.366	0.326	0.233	0.230	0.158	0.153	1.48
	0.412	0.359	0.323	0.245	0.237	0.169	0.167	1.50
Pit 3								
0-10	0.542	0.421	0.337	0.221	0.216	0.128	0.141	1.10
	0.525	0.414	0.333	0.214	0.167	0.109	0.121	0.95
10-15	0.477	0.423	0.328	0.191	0.180	0.120	0.129	1.11
	0.494	0.434	0.352	0.207	0.190	0.118	0.126	1.21
15-20	0.493	0.394	0.210	0.220	0.193	0.119	0.117	1.21
	0.483	0.400	0.200	0.205	0.182	0.111	0.116	1.14
20-30	0.453	0.377	0.197	0.195	0.170	0.121	0.123	1.24
	0.446	0.381	0.211	0.214	0.187	0.126	0.129	1.30
50-60	0.460	0.392	0.227	0.206	0.175	0.118	0.126	1.42
	0.442	0.378	0.231	0.237	0.210	0.118	0.123	1.41
80-90	0.425	0.369	0.215	0.218	0.198	0.121	0.122	1.41
	0.416	0.361	0.240	0.251	0.226	0.126	0.138	1.51
Pit 4								
0-10	0.519	0.431	0.315	0.227	0.199	0.138	0.106	1.00
	0.536	0.468	0.323	0.229	0.211	0.143	0.111	1.07
10-20	0.512	0.421	0.295	0.209	0.190	0.144	0.123	1.12
	0.505	0.433	0.305	0.212	0.192		0.122	1.14
20-30	0.396	0.383	0.289	0.220	0.198	0.132	0.119	1.14
	0.552	0.404	0.265	0.185	0.164	0.136	0.117	1.18
50-60	0.413	0.360	0.284	0.200	0.190	0.138	0.127	1.45
	0.441	0.395	0.317	0.190	0.176	0.129	0.119	1.45
80-90	0.364	0.343	0.291	0.209	0.195	0.148	0.140	1.48
	0.375	0.349	0.301	0.221	0.204	0.149	0.146	1.54

Appendix 2b. Water retention measurements grouped into depth order (showing the similarity of soils at the same depth in the different pits)

Pit no	Water content cc/cc at indicated suction (kPa)							Density
Depth cm	0.1	1	10	30	70	300	1500	g/cc
0-10								
Pit 1	0.570	0.373	0.190		0.154	0.134	0.134	0.83
	0.513	0.439	0.242		0.200	0.144	0.160	1.10
Pit 2	0.546	0.439	0.231		0.192	0.113	0.127	1.08
	0.535	0.440	0.188		0.154	0.122	0.128	1.08
Pit 3	0.542	0.421	0.337	0.221	0.216	0.128	0.141	1.10
	0.525	0.414	0.333	0.214	0.167	0.109	0.121	0.95
Pit 4	0.519	0.431	0.315	0.227	0.199	0.138	0.106	1.00
	0.536	0.468	0.323	0.229	0.211	0.143	0.111	1.07
Mean	***0.536***	***0.428***	***0.270***	***0.223***	***0.187***	***0.129***	***0.128***	***1.03***
10-15cm								
Pit 3	0.477	0.423	0.328	0.191	0.180	0.120	0.129	1.11
	0.494	0.434	0.352	0.207	0.190	0.118	0.126	1.21
Mean	***0.485***	***0.429***	***0.340***	***0.199***	***0.185***	***0.119***	***0.128***	***1.16***
12-20cm								
Pit 1	0.423	0.385	0.244		0.199	0.152	0.148	1.34
		0.358	0.226		0.183	0.134	0.140	1.15
Pit 2	0.456	0.385	0.196		0.164	0.134	0.138	1.29
	0.450	0.379	0.206		0.172	0.136	0.146	1.33
Pit 3	0.493	0.394	0.210	0.220	0.193	0.119	0.117	
	0.483	0.400	0.200	0.205	0.182	0.111	0.116	
Pit 4	0.512	0.421	0.295	0.209	0.190	0.144	0.123	1.12
	0.505	0.433	0.305	0.212	0.192		0.122	1.14
Mean	***0.474***	***0.394***	***0.235***	***0.212***	***0.185***	***0.133***	***0.131***	***1.23***
20-30cm								
Pit 1		0.352	0.243		0.206	0.139	0.150	1.24
	0.451	0.391	0.225		0.190	0.152	0.158	1.34
Pit 2	0.446	0.375	0.192		0.161	0.138	0.145	1.36
	0.430	0.376	0.195		0.168	0.141	0.145	1.39
Pit 3	0.453	0.377	0.197	0.195	0.170	0.121	0.123	1.24
	0.446	0.381	0.211	0.214	0.187	0.126	0.129	1.30
Pit 4	0.396	0.383	0.289	0.220	0.198	0.132	0.119	1.14
	0.552	0.404	0.265	0.185	0.164	0.136	0.117	1.18
Mean	***0.453***	***0.380***	***0.227***	***0.204***	***0.181***	***0.136***	***0.136***	***1.27***
50-60cm								
Pit 1	0.440	0.369	0.245		0.206	0.143	0.142	1.36
	0.432	0.359	0.236		0.193	0.146	0.138	1.38
Pit 2	0.425	0.376	0.327	0.240	0.224	0.153	0.162	1.47
	0.425	0.369	0.330	0.240	0.223	0.150	0.165	1.50
Pit 3	0.460	0.392	0.227	0.206	0.175	0.118	0.126	1.42
	0.442	0.378	0.231	0.237	0.210	0.118	0.123	1.41
Pit 4	0.413	0.360	0.284	0.200	0.190	0.138	0.127	1.45
	0.441	0.395	0.317	0.190	0.176	0.129	0.119	1.45
Mean	***0.435***	***0.375***	***0.275***	***0.219***	***0.200***	***0.137***	***0.138***	***1.43***
80-90cm								
Pit 1	0.435	0.388	0.297		0.243	0.176	0.182	1.49
	0.434	0.390	0.277		0.237	0.168	0.166	1.38
Pit 2	0.439	0.366	0.326	0.233	0.230	0.158	0.153	1.48
	0.412	0.359	0.323	0.245	0.237	0.169	0.167	1.50
Pit 3	0.425	0.369	0.215	0.218	0.198	0.121	0.122	1.41
	0.416	0.361	0.240	0.251	0.226	0.126	0.138	1.51
Pit 4	0.364	0.343	0.291	0.209	0.195	0.148	0.140	1.48
	0.375	0.349	0.301	0.221	0.204	0.149	0.146	1.54
Mean	***0.412***	***0.366***	***0.284***	***0.230***	***0.221***	***0.152***	***0.152***	***1.47***

Appendix 8. Threatened and significant plant species on the Tiwi Islands

Previous studies have discussed the status and distribution of plant species of conservation significance across the Tiwi Islands (e.g. Woinarski *et.* al, 2000; Woinarski *et. al*, 2003; Liddle & Elliott, 2008). Of the approximately 1 480 plant taxa recorded from the Tiwi-Coburg Bioregion, 11 are thought to be endemic to the Islands, and a further 17 species are known in the NT only from the Islands, with 2 of these representing the only known Australian occurrence of the taxa (Table 8-3). Nineteen Tiwi plant species are listed as threatened within the Northern Territory (*Territory Parks and Wildlife Conservation Act*) and six of these are listed as nationally threatened (*Environment Protection and Biodiversity Conservation Act)* (Table 8-1).

Table 8-1. Threatened plants recorded from the Tiwi Islands, listed under the *Environment Protection and Biodiversity Conservation Act* (EPBCA) and/or *Territory Parks and Wildlife Conservation Act* (TPWCA). For TPWCA status, (e) denotes endemic to the Tiwi Islands; and (d) denotes highly disjunct species with the entire NT population restricted to the Tiwi Islands. Status codes: CR=critically endangered; EN=endangered; V=vulnerable.

Scientific Name	Family	TPWCA	EPBCA	Habitat
Burmannia sp. Bathurst Island (R.J.Fensham 1021)	BURMANNIACEAE	EN (e)	EN	ever-wet rainforest
Calochilus caeruleus	ORCHIDACEAE	V		paperbark swamp
Cephalomanes obscurum	HYMENOPHYLLACEAE	EN		ever-wet rainforest
Cycas armstrongii	CYCADACEAE	V		eucalypt open forest
Dendromyza reinwardtiana	SANTALACEAE	V (d)		ever-wet rainforest
Elaeocarpus miegei	ELAEOCARPACEAE	CR (d)		ever-wet rainforest
Endiandra limnophila	LAURACEAE	V		ever-wet rainforest
Freycinetia excelsa	PANDANACEAE	V		ever-wet rainforest
Freycinetia percostata	PANDANACEAE	V		ever-wet rainforest
Garcinia warrenii	CLUSIACEAE	EN (d)		rainforest
Hoya australis subsp. oramicola	APOCYNACEAE	V (e)	V	coastal rainforest
Luisia corrugata (syn. *L. teretifolia*)	ORCHIDACEAE	V		ever-wet rainforest
Mapania macrocephala	CYPERACEAE	V		ever-wet rainforest
Mitrella tiwiensis	ANNONACEAE	V (e)	V	ever-wet rainforest
Tarennoidea wallichii	RUBIACEAE	EN (d)		rainforest
Thrixspermum congestum	ORCHIDACEAE	V (d)		ever-wet rainforest
Typhonium jonesii	ARACEAE	EN (e)	EN	eucalypt open forest
Typhonium mirabile	ARACEAE	EN (e)	EN	eucalypt open forest
Xylopia monosperma	ANNONACEAE	EN (e)	EN	ever-wet rainforest

An additional 41 Tiwi plant species are listed as “Data Deficient” under the TPWCA. For these species there is inadequate information available to assess status. With more knowledge, some of these species may be shown to be widespread and common. Alternatively, some species now known from a few locations may actually be restricted to only those locations, and an upgrading of their conservation status may be warranted. In particular, *Crinum venosum*, *Lindernia cowiei*, and *Thismia* sp. Melville Is appear likely to qualify for threatened status in future reviews of threatened species. In many cases, the conservation status of Tiwi plant species has been assumed to be secure, largely on the basis of lack of apparent threats.

Additionally, there are also 36 “Near Threatened” species listed under the TPWCA occurring on the Tiwi Islands. These species are close to qualifying for a threatened status and relatively small changes in populations or threats may lead to a change in their status. Table 8-2 summarizes these other species of conservation significance and further details are given in Appendix 11 for those species occurring in the study area.

Woinarski *et al.* (2003) summarised the known habitats in which threatened and near threatened plant species occurred on the Tiwi Islands. The overwhelming majority of these taxa were found to occur primarily in wet monsoon forests (26% threatened and 74% significant taxa), with a smaller proportion in dry monsoon forests (5% threatened and 5% significant taxa), eucalypt open forests (4% threatened and 16% significant taxa) and wetlands including *Melaleuca* forests and woodlands (9% threatened and 5% significant taxa).

Ten plant taxa have been recorded in the world only on the Tiwi Islands (endemic species). A further 17 are known in the Northern Territory only from the Tiwi Islands but also occur beyond the Northern Territory, mostly in northern Queensland, New Guinea and/or Malesia (Table 8-3). Such distributions link areas of relatively high rainfall through Pliocene and Pleistocene land bridges. These species also include some whose distribution is now largely relictual or refugial.

Tables 8-1 and 8-3 show that the vast majority of endemic and threatened plant taxa on the Tiwi Islands are restricted to the wet evergreen rainforests associated with persistent surface water supplies. The distribution of Tiwi endemic and highly disjunct species also suggests that the ever-wet rainforests fringing the higher ridges of western Melville Island and Bathurst Island are refugial areas of high species diversity. Sea levels have been 40 m lower for more than 50% of at least the past 250 000 years (Voris 2000) and at such times or during climatically favourable periods, the area of riparian rainforest in particular is likely to have been much more extensive. During periods of higher sea level, these rainforest species would have contracted back to similar areas to the present, and during dry periods the larger, well-developed springs with more reliable ground water supplies are likely to have been key refuges.

Table 8-2. Species recorded from the Tiwi Islands that are listed under the *Territory Parks and Wildlife Conservation Act* as Near Threatened or Data Deficient. Species highlighted in **Bold** have been previously assessed as likely to transfer to a threatened category in the future.

Data Deficient (TPWCA)
Adiantum atroviride, Calandrinia sp. Berry Springs, Calochilus caesius, Calochilus holtzei, Cenchrus elymoides, Crepidium fontinale, ***Crinum venosum****, Crotalaria sessiliflora var. anthylloides, Cucumis melo, Cyanthillium patulum, Cyperus compactus, Cyperus paniceus, Cyperus pumilus, Didymoplexis pallens, Digitaria leucostachya, Drosera fulva, Empusa habenarina, Eragrostis concinna, Eriochloa fatmensis, Fimbristylis bisumbellata ,Habenaria elongata, Habenaria ferdinandi, Habenaria hymenophylla, Haemodorum sp. red flowers, Hypserpa decumbens,* ***Lindernia cowiei,*** *Mitrasacme brachystemonea, Mitrasacme inornata, Murdannia cryptantha, Najas browniana, Nervilia peltata, Pavetta tenella, Scleria biflora, Scleria carphiformis, Stylidium tenerrimum, Syzygium forte subsp. forte, Tecticornia halocnemoides subsp. tenuis,* ***Thismia sp. Melville Is,*** *Tropidia territorialis* (syn. *Tropidia curculigoides*), *Websteria confervoides, Zornia disticha.*
Near Threatened (TPWCA)
Actinostachys wagneri, *Aldrovanda vesiculosa, Barringtonia asiatica, Byblis aquatica, Canavalia cathartica, Cerbera manghas, Clerodendrum longiflorum* var. *glabrum, Cocos nucifera,* ***Dendrobium johannis,*** *Desmodium tiwiense, Embelia tiwiensis, Endospermum myrmecophilum, Entada rheedii,* ***Hedyotis auricularia*** **var.** ***melanesica,*** *Hypolytrum nemorum,* ***Hypserpa polyandra,*** *Ischaemum barbatum, Lindsaea walkerae,* ***Melodinus australis,*** *Nypa fruticans, Parsonsia* sp. Melville Island, *Peplidium maritimum, Pittosporum moluccanum, Psychotria coelosperma, Rhizophora lamarckii, Sonneratia lanceolata, Sophora longipes, Strychnos minor, Syzygium claviflorum, Syzygium hemilamprum subsp. hemilamprum, Triumfetta aquila, Triumfetta repens, Turraea pubescens, Utricularia subulata, Vittaria ensiformis, Xylocarpus granatum*

Table 8-3. List of plant species (a) endemic to the Tiwi Islands or (b) whose NT distribution is limited to the Tiwi Islands. Distribution indicates occurs on B=Bathurst Island, M=Melville Island. Status codes: CR=critically endangered; EN=endangered; V=vulnerable; NT=near threatened; DD=data deficient; LC=least concern.

Species	Family	TPWCA	EPBCA	Habitat	Distribution
(a) Endemic to the Tiwi Islands					
Burmannia sp. Bathurst Island (R.J.Fensham 1021)	BURMANNIACEAE	EN	EN	ever-wet rainforest	B
Embelia tiwiensis	PRIMULACEAE	NT		ever-wet rainforest	BM
Hoya australis subsp. oramicola	APOCYNACEAE	V	V	coastal rainforest	BM
Lindernia cowiei	LINDERNIACEAE	DD		floodplain wetlands	M
Mitrella tiwiensis	ANNONACEAE	V	V	ever-wet rainforest	BM
Parsonsia sp. Melville Island	APOCYNACEAE	NT		ever-wet rainforest	BM
Spermacoce retitesta	RUBIACEAE	LC		eucalypt open forest & woodland	BM
Thismia sp. Melville Is	THISMIACEAE	DD		ever-wet rainforest margins	M
Typhonium jonesii	ARACEAE	EN	EN	eucalypt open forest	BM
Typhonium mirabile	ARACEAE	EN	EN	eucalypt open forest	M
Xylopia monosperma	ANNONACEAE	EN	EN	ever-wet rainforest	BM
(b) NT distribution restricted to the Tiwi Islands, but also recorded beyond theNT					
Actinostachys wagneri	SCHIZAEACEAE	NT		ever-wet rainforest	M: Also occurs in northern Qld and Malesia
Clerodendrum longiflorum var. glabrum	LAMIACEAE	NT		rainforest	BM: This variety occurs also in north Qld and PNG
Crinum venosum	LILIACEAE	DD		Melaleuca	M: Also recorded from Qld

Species	Family	TPWCA	EPBCA	Habitat	Distribution
				woodland	
Dendrobium johannis	ORCHIDACEAE	NT		Melaleuca forest	M: Also NE Qld, New Guinea
Dendromyza reinwardtiana	SANTALACEAE	V		ever-wet rainforest	BM: Also recorded from north Qld, new Guinea, Philippines and Sumatra
Elaeocarpus miegei	ELAEOCARPACEAE	CR		ever-wet rainforest	BM: Also recorded in New Guinea and Malesia
Garcinia warrenii	CLUSIACEAE	EN		rainforest	M: Also recorded in north Qld
Hypolytrum nemorum	CYPERACEAE	NT		ever-wet rainforest	BM: Also NE Qld, Polynesia, to India and Taiwan
Hypserpa decumbens	MENISPERMACEAE	DD		ever-wet rainforest	BM: Also recorded from N&E Qld and NE NSW
Hypserpa polyandra	MENISPERMACEAE	NT		ever-wet rainforest	BM: Also recorded from NE Cape York Peninsula, SE Indonesia and New Guinea
Litsea breviumbellata	LAURACEAE	LC		ever-wet rainforest	BM: Also NE Qld
Scleria carphiformis	CYPERACEAE	DD		sedgelands; swamps	BM: Also recorded in north Qld
Strychnos minor	LOGANIACEAE	NT		ever-wet rainforest	BM: Also recorded from north Qld to Malesia
Syzygium claviflorum	MYRTACEAE	NT		ever-wet rainforest	BM: Also recorded in northern Qld and Malesia
Tarennoidea wallichii	RUBIACEAE	EN		rainforest	M: Also recorded from Malesia, as far north as India
Thrixspermum congestum	ORCHIDACEAE	V		ever-wet rainforest	BM: Also recorded in northern Qld and Malesia
Triumfetta repens	MALVACEAE	NT		coastal dunes	B: Also recorded from Qld, and beyond Australia

Appendix 9. Field survey proforma and site attributes

Tiwi Islands Threatened Plant Occupancy Assessment, March/April 2014

Cell: _________ Transect: ________ Observer: __________________ Date: _____________ Page: ____ of ____

Distance	**100m**	**80m**	**60m**	**40m**	**20m**	**0m**	**Bright sunny**
Veg Cover%							yes no
Comment							
Slope %		**Rock %**		**Gravel %**		**Soil Text.**	

Section	**Wpt**	**Taxon (No. of individuals)**					**Comment**
		Typh sp.	T. jonesii	T. mirabile	D. tiwiensis	C. armst	

(Section: e.g. 100/80, 80/60 or “Inc” if an incidental record in the cell or “S” = start or “E” = end)

Notes:

Table 9-1. Biophysical site attributes scored at woodland/open forest survey sites.

Attribute	Measure	Method
Vegetation Floristics	Dominant species by stratum	Recorded once for each observer at a site.
Stand Basal Area	Bitterlich count	Total live/dead count and basal area factor recorded once for each observer at a site.
Ground Cover (Vegetation)	Estimated % cover	Recorded in six 20x1m blocks of each survey transect.
Gravel Cover	Estimated % cover	Recorded once for each observer at a site.
Rock Cover	Estimated % cover	Recorded once for each observer at a site.
Slope	Degrees/percent	Measured over a minimum 20 m distance parallel to the maximum aspect of the survey transects. Recorded once for each observer at a site.
Field Surface Soil Texture	Qualitative	Categorical field-texture.
Time	Time	Recorded at start and end of both surveys on a site for each observer.
Cloudy Conditions	Yes/no indicator variable	

Appendix 10. Occupancy modelling: data sources and candidate models

Elevation data were extracted for the study area from the derived 1 arc-second (~30m) gridded Shuttle Radar Topographic Mission (SRTM) Level-2 digital elevation model (DEM) produced for Australia (Geoscience Australia, 2010).

Table 10-1. Shuttle Radar Topographic Mission (SRTM) derived terrain variables used as covariates for assessing *Typhonium* species site occupancy within the study area on northern Bathurst Island.

Covariate	Spatial Resolution	Derivation
Percent Slope	~30 m	derived from the DEM using the finite difference method (Gallant & Wilson, 2000)
Focal Median Slope	~90 m	Median slope using a 300 m window was calculated for each grid point from percent slope using a 300 m kernel (Geoscience Australia, 2009).
Slope Relief	~30 m	The slope-relief layer is an implementation of the classification of erosional landform patterns characterised by relief and modal slope as defined in Table 5 of Speight (2009).
Aspect	~30 m	Aspect was calculated from DEM-S using the finite difference method (Gallant and Wilson, 2000).
Topographic Wetness Index (Beven & Kirkby, 1979)	~90 m	TWI is a measure of site wetness calculated using the slope and partial contributing area orthogonal to flow upstream of the site. The measure indicates the degree of topographic control on hydrological processes. Calculations followed the methods described in Gallant and Wilson (2000).

Estimated percentages for sand, silt and clay sized fractions of particle size distributions (Table 10-2) have been produced for Australia at 3 arc-second (c. 90m) resolution as part of the *Soil and Landscape Grid National Soil Attribute Maps* (Viscarra-Rossel *et. al*, 2014). Surface estimates (0-5cm depth) of these parameters were used as a surrogate for soil texture within the rooting-zone.

Table 10-2. Fractional particle size distributions for surface soils mapped as part of the *Soil and Landscape Grid National Soil Attribute Maps* (Viscarra-Rossel *et. al*, 2014) at 3 arc second resolution.

Attribute	Description
Sand	20-200 um mass fraction of the < 2 mm soil material determined using the pipette method
Silt	2-20 um mass fraction of the < 2 mm soil material determined using the pipette method
Clay	< 2 um mass fraction of the < 2 mm soil material determined using the pipette method

Airborne radiometric data at 100m resolution has been captured for the Tiwi Islands as part of the Australia Wide Airborne Geophysics Survey (AWGS) (Northern Territory Geological Survey, 2006; Geoscience Australia, 2006; Clifton, 2008). These data provide raw values of gamma radiation resulting from Uranium, (U), Thorium (Th) and Potassium (K) at different energies, providing indications of soil/regolith composition, geochemistry, geomorphology and weathering (Clifton, 2009; Wilford, 2012). Radiometric ratios of Thorium (Th) to Uranium (U) derived from these raw gamma radiation values provide useful indicators of near-surface duricrust development and deep-weathering (Wilford, 2012).

Preview Landsat 8 satellite imagery for Path 106, Row 068 encompassing the whole of the Tiwi Islands was accessed via the US Geological Survey Global Visualiser (http://glovis.usgs.gov/). Captured imagery was assessed for both cloud cover and fire scars within the study area in an attempt to minimise the extent of unclassifiable or uninterpretable pixels within the scene.

Scenes from July 2013 and May 2014 were downloaded and processed to produce estimates of Foliage Projective Cover (FPC). By selecting scenes from both the wet and dry seasons, the difference in FPC between dates is assumed to represent the senescent proportion of the vegetation signal which in this instance represents annual species and graminoids, leaving the persistent woody portion of the spectral reflectance.

The Advanced Land Observation Satellite Phased Array L-band Synthetic Aperture Radar(ALOS-PALSAR) data provided to the NT Government under the Kyoto & Carbon (K&C3) agreement provided additional information on the structure and density of above-ground woody plant material across the study area (Shimada & Ohtaki, 2010).

Table 10-3. Candidate models used to estimate occupancy (ψ) and detection (p) probabilities for *Typhonium* species. O=observer, G=ground cover, S=focal median slope, R=radiometric ratio (Th:U), F=foliage projective cover, C=% clay, A=ALOS Band1

Model	Name
$\psi(.)p(.)$	(constant psi.)X(constant detection)
$\psi(.)p(O)$	(constant psi.)X(observer)
$\psi(.)p(O+G)$	(constant psi.)X(observer + ground cover)
$\psi(A)p(O)$	(ALOS band1)X(observer)
$\psi(S)p(O)$	(slope)X(observer)
$\psi(R)p(O)$	(radiometrics)X(observer)
$\psi(F)p(O)$	(FPC)X(observer)
$\psi(C)p(O)$	(percent clay)X(observer)
$\psi(R+C)p(O)$	(radiometrics + percent clay)X(observer)
$\psi(F+A)p(O)$	(FPC + ALOS band1)X(observer)
$\psi(S+F)p(O)$	(slope + FPC)X(observer)
$\psi(S+R)p(O)$	(slope + radiometrics)X(observer)
$\psi(S+C)p(O)$	(slope + percent clay)X(observer)
$\psi(S+A)p(O)$	(slope + ALOS band1)X(observer)
$\psi(S+R+F)p(.)$	(slope + radiometrics + FPC)X(constant

	detection)
$\psi(S + F + A)p(O)$	(slope + FPC + ALOS band1)X(observer)
$\psi(S + R + C)p(O)$	(slope + radiometrics + percent clay)X(observer)
$\psi(S + R + F.)p(.O)$	(slope + radiometrics + FPC)X(observer)
$\psi(S + R + C + F + A)p(G)$	(all occupancy covariates)X(ground cover)
$\psi(S + R + C + F + A)p(O)$	(all occupancy covariates)X(observer)
$\psi(S + R + C + F + A)p(O + G)$	global model

Appendix 11. Threatened and significant plant species accounts

Eucalypt Woodlands and Open Forests

Cycas armstrongii **Family: Cycadaceae**

Description

Cycas armstrongii is a medium-sized cycad up to 10 m tall with a slender trunk 6 – 12 cm in diameter. Branching occurs along with occasional offsets and basal suckers. Leaves form an obliquely erect to spreading crown. Each has 160 - 300 leaflets attached to the rachis at about 70° with a prominent midrib above. (Kerrigan *et al.* 2007)

Plants on Bathurst Island display morphological differences from mainland populations and may well represent a distinct race or taxon. In particular, new leaves are densely hairy, plants branch readily and stems tend to be stouter, sometimes in excess of 30 cm diameter at the base. The significance of these morphological differences, potential genetic differences and geographic patterns of variation are yet to be evaluated.

Ecology It occurs mainly in Eucalypt woodland on yellow and red earths, but avoids areas of poor drainage.

Distribution

This species is endemic to the northern NT. It is known from the Darwin area east to the Wildman River catchment, south to Hayes Creek and west to within 50 km of the coast. It is also common on the Tiwi Islands and has been recorded from Cobourg Peninsula.

Conservation status Vulnerable (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	197	No. Locations (NE Bathurst Island):	5 (2.5% of total)
EoE km2 (NT):	37 377	EoO km^2 (NE Bathurst Island):	40.5 (0.1% of total)
AoO ha (NT):	145 600	AoO ha (NE Bathurst Island):	3 600 (2.5% of total)

This species was abundant in the study area, and was recorded on a variety of land units, excluding swamps - 10a, 6a, 7a, 8a, 8a1, 8b, 8d, 8c, and 5a. While this species is regionally abundant, less than 1% of its population is included in conservation reserves. Applying the precautionary principle, this species qualifies as Vulnerable (under criterion A4ce) based on a predicted >30% reduction in population size over a 100 year period (=<3 generations), commencing a decade ago (Liddle 2004).

A key threatening process is land clearing due to the expansion of Darwin, as well as for rural residential living, horticulture, agriculture and forestry. In areas not subject to clearing, there is a major threat from the combined impact of introduced grasses and fire whereby increased fuel loads lead to increased mortality of adult stems and subsequent population decline (Liddle 2004).

<u>*Significance of North East Bathurst Island populations*</u> The species is widespread and very common in Eucalypt dominated communities in the study area. However, this represents a small proportion (2.5%) of the entire known population. Plants are likely to be directly affected by land clearing, and in areas left uncleared, less directly though a mixture of grassy weed invasion and increased fire intensity and frequency.

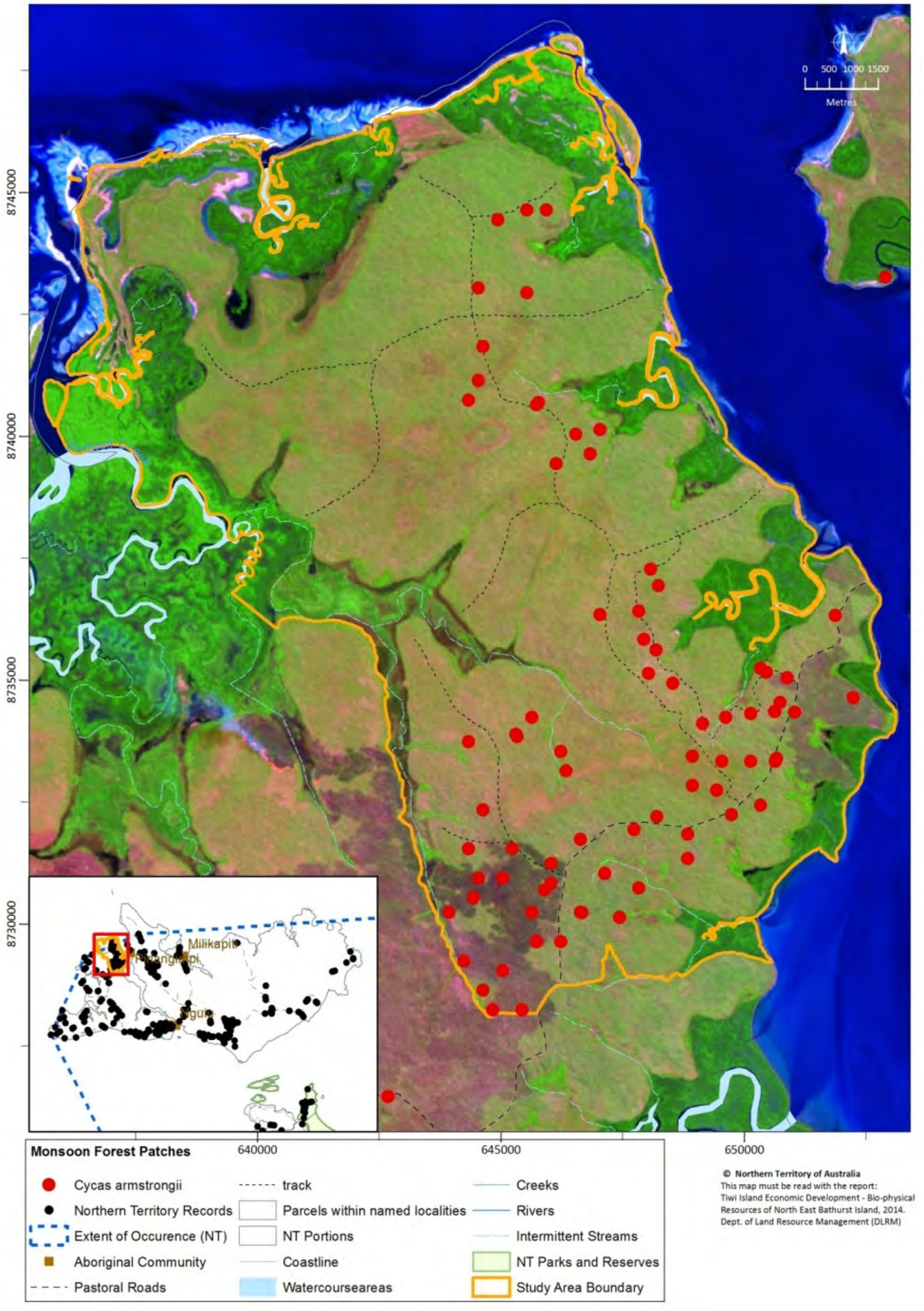


Figure 11-1: Location of *Cycas armstrongii* records in NE Bathurst Island.

Typhonium jonesii **Family: ARACEAE**

Description

A geophytic, perennial herb with annual aerial parts and a small starchy tuber. Leaf blades are deeply trilobed, hastate or auriculate at base, segments linear. The flower spathe is pale mauve-cream.

Ecology

Typhonium jonesii occurs in *Eucalyptus miniata* − Corymbia nesophila − E. *tetrodonta* dominated open forest on deep, well drained sandy soils supporting a relatively sparse grass layer.

Distribution

Endemic to Bathurst Is and the western part of Melville Island.

Conservation status Endangered (TPWCA); Endangered (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	14	No. Locations (NE Bathurst Island):	5 (36% of total)
EoE km^2 (NT):	1 148	EoO km^2 (NE Bathurst Island):	52 (5% of total)
AoO ha (NT):	6 000	AoO ha (NE Bathurst Island):	2 800 (47% of total)

It has now been recorded in 15 subpopulations, with 4 on Melville Island and 11 on Bathurst Island. Seven of the Bathurst Island subpopulations (almost 50% of the total) occur within the study area. During the field survey in March-April 2014, the species was rarely encountered despite targeted searches for *Typhonium* species and insufficient plants were recorded to be used for occupancy modeling. However, a relatively small proportion of the northern Bathurst Island area was sampled. The species was generally recorded lower in the landscape.

This species has been listed as Endangered (under criteria B1ab(iii)+2ab(iii); D) based on a small number of locations (<5), small number of mature individuals (<250), an extent of occurrence <5 000 km^2, an area of occupancy <500 km^2 and an inferred decline in the quality of habitat due to clearing for plantation forestry (Kerrigan *et al.* 2007g). Recent survey has resulted in the upward revision of some of these figures and data are scheduled to be reassessed as part of the review of threatened species scheduled for 2015.

The main threat to this species is land clearing for forestry and other purposes. On Melville Island, the preferred plantation development areas coincide with known populations and preferred habitat of this species. Although they are currently rare or absent from Bathurst Island, invasion of habitat by introduced, grassy weeds may also be a threat in the longer term.

Significance of North East Bathurst Island populations

The population in the study area represents a substantial proportion (36 - 50%) of the entire known population. However, it is likely that additional undetected populations occur both within and outside the North East Bathurst Island study area. The highest risk to the species appears to be in development of woodland areas which are lower in the landscape. Plants are likely to be directly affected by land clearing, and in areas left uncleared, less directly though a mixture of grassy weed invasion and intensified fire regimes.

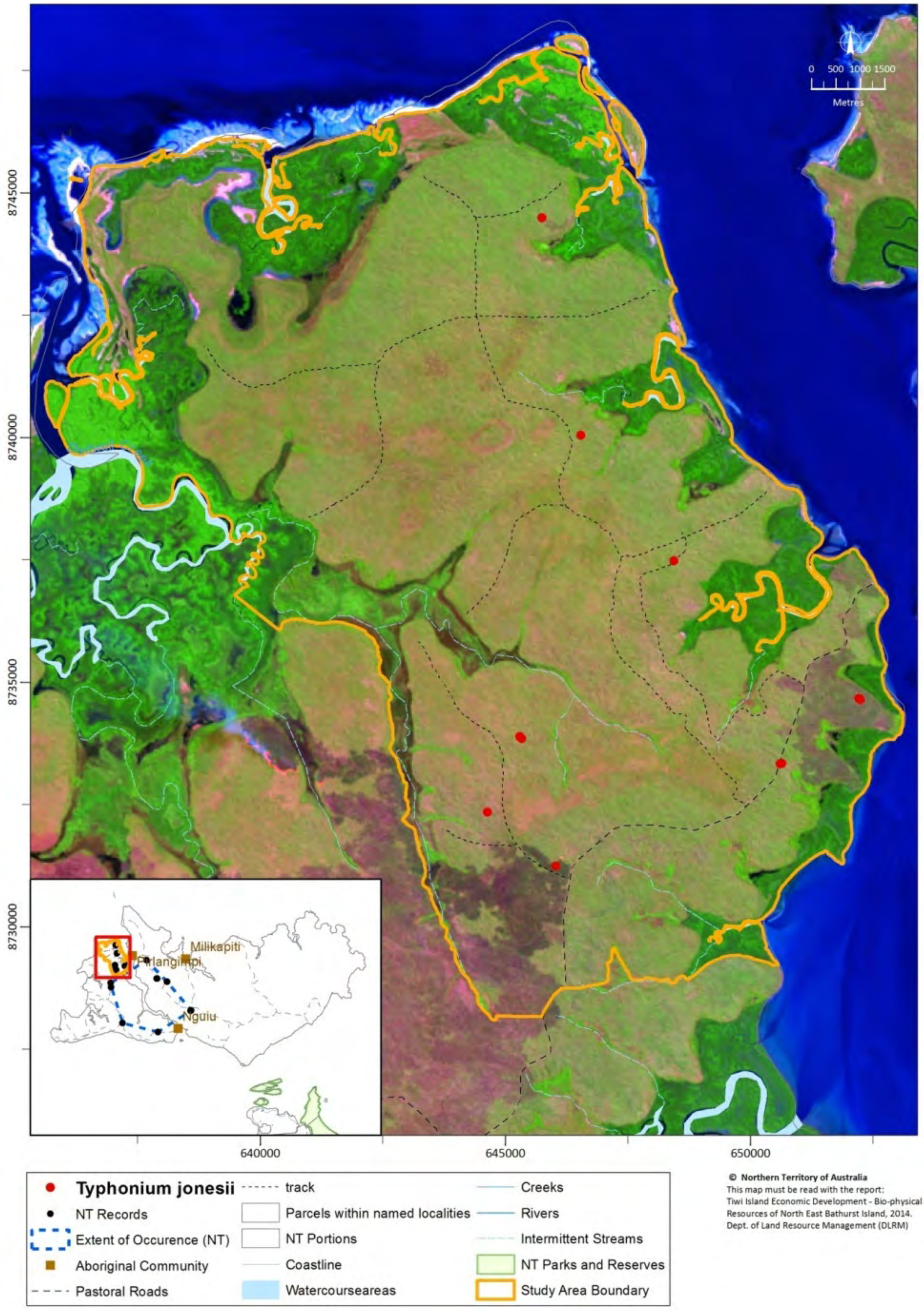


Figure 11-2: Location of *Typhonium jonesii* records in NE Bathurst Island.

Typhonium mirabile **Family: ARACEAE**

<u>Description</u>

Small tuberous herb with annual aerial parts. Leaves blue-green, cordate held on or just above the soil surface. Spathe or bract of flower partly buried in soil; part below white cream with grey mottling; aerial part mottled grey-green; spadix limb smoky grey; greenish towards the base.

<u>Ecology</u> *Typhonium mirabile* occurs in *Eucalyptus miniata* − Corymbia nesophila − E. *tetrodonta* dominated open forest on deeper well drained sandy or sometimes stoney soils supporting a relatively sparse grass layer. Soils are deeper, red-brown Kandosols (equivalent to land units 8a and in part 5a).

<u>Distribution</u> Endemic to Bathurst Is and the western part of Melville Island.

<u>Conservation Status</u> Endangered (TPWCA); Endangered (EPBC).

<u>Key Parameters</u> (see definitions in Table 7-2)

No. Locations (NT):	13	No. Locations (NE Bathurst Island):	6 (46% of total)
EoE km^2 (NT):	823	EoO km^2 (NE Bathurst Island):	64 (8% of total)
AoO ha (NT):	8 400	AoO ha (NE Bathurst Island):	6 400 (76% of total)

It has now been recorded in 4 subpopulations on Melville Island with many recorded on Bathurst Island. The species was found to be sparely occurring but common and widespread in the northern Bathurst Island area during the field survey in March-April 2014. Data were used to produce an occupancy model showing the probability of occurrence of the species across the area.

This species has been listed as Endangered (under criteria B1ab(iii)+2ab(iii); D) based on a small number of locations (<5), small number of mature individuals (<250), an extent of occurrence <5000 km^2, an area of occupancy <500 km^2 and an inferred decline in the quality of habitat due to clearing for plantation forestry (Kerrigan *et al.* 2007h).

The main threat to this species is land clearing for forestry and other purposes. The preferred plantation development areas in western Melville Island coincide with known populations and preferred habitat of this species. Although they are currently rare or absent from Bathurst Island, invasion of habitat by introduced, grassy weeds may also be a threat in the longer term.

<u>Significance of North East Bathurst Island populations</u>

Based on available data, 46 – 76% of the total known population occurs in the study area. However, this area is now by far the best surveyed part of the Tiwi Islands for *Typhonium mirabile*. It is likely that some other parts of the Tiwi Islands also support additional, undetected subpopulations of *T. mirabile*. The occupancy model indicates that the highest probability of occurrence for this species is mainly in the south and east of the study. Plants are likely to be directly affected by land clearing, and in areas left uncleared, less directly though a mixture of grassy weed invasion and intensified fire regimes.

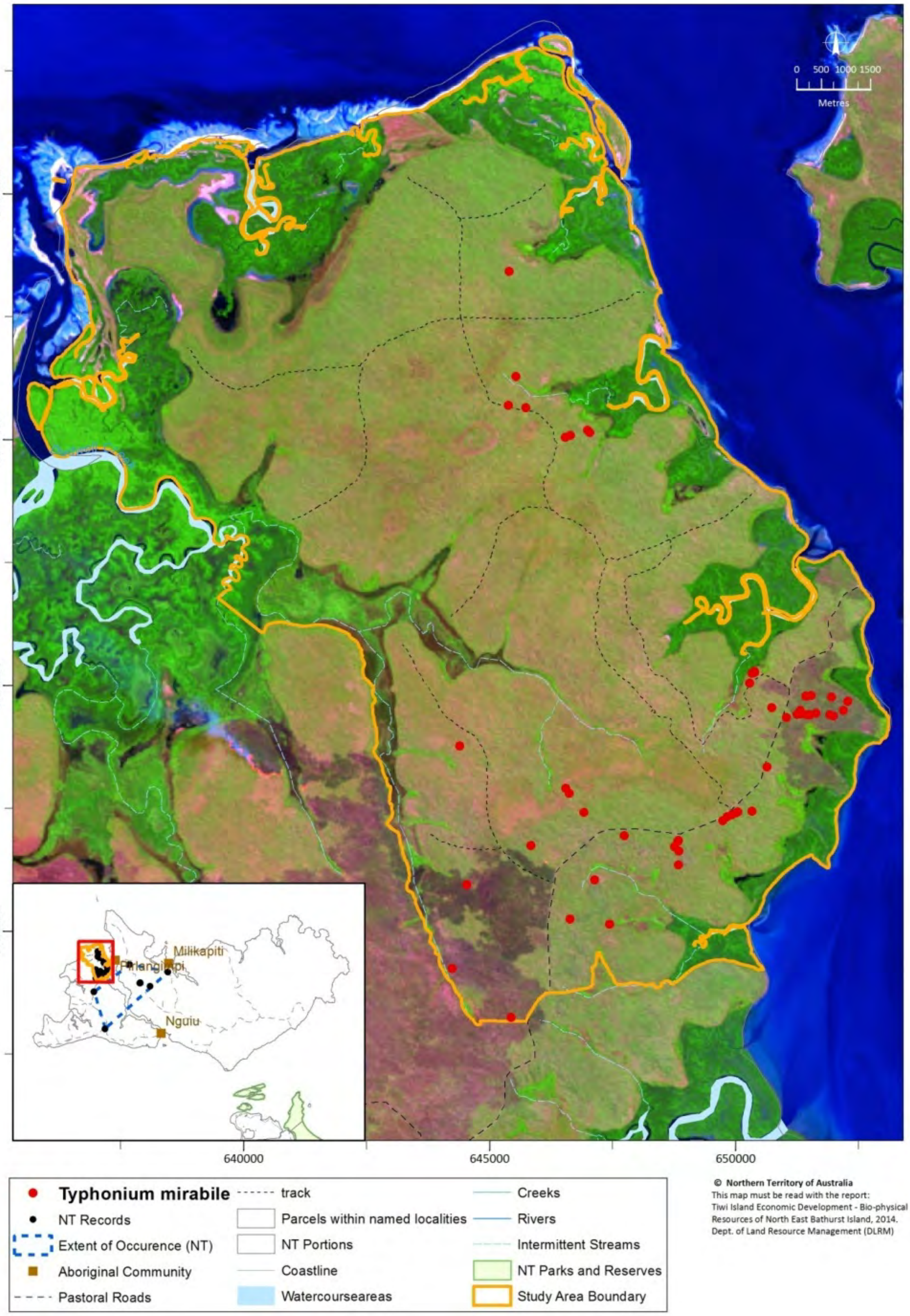
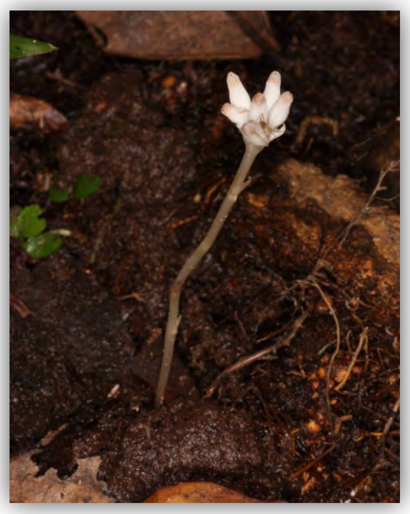


Figure 11-3: Location of *Typhonium mirabile* records in NE Bathurst Island.
Note: not all records were included in the mapped extent of occurrence but all data are included in the calculated extent of occurrence.

Monsoon Rainforest

***Burmannia* sp. Bathurst Island** **Family: Burmanniaceae**



Description This plant is an herbaceous leafless saprophytic herb to 12 cm tall, with a small tuber. Flowers are white, c. 10 mm long. All parts, including the stem, are white and translucent. (Kerrigan *et al.* 2007)

This species is thought to be undescribed, but appears closely related to the SE Asian species *B. bifaria J.J.S.* from Java and islands off SW Sumatra (Jonker 1948).

Ecology It occurs in evergreen, spring-fed rainforest on permanently wet, organic substrates beside flowing water. *Burmannia* seems to favour sites with more relief and disturbed by seasonal flooding beside small perennial streams. The saprophytic growth habit relies on the presence of an adequate supply of soil organic material and this species may be unable to establish on mineral soil (Fensham 1993).

Distribution *Burmannia* sp. Bathurst Island is entirely restricted to a small area on Bathurst Island. All of the localities are around 10 km north of Wurankuwu in spring-fed rainforest situated either side of a ridge of more elevated country which appears to act as a source of ground-water for the forests (Liddle & Elliott 2008). This ridge appears to include the highest point on the island.

Conservation Status Endangered (TPWCA); Endangered (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	1	No. Locations (NE Bathurst Island):	0 (0% of total)
EoO km^2 (NT):	8.8	EoO km^2 (NE Bathurst Island):	na
AoO ha (NT):	12	AoO ha (NE Bathurst Island):	0 (0% of total)

It is known from seven rainforest patches with none in the study area (Liddle & Elliott 2008; K. Brennan pers. comm.). However, all patches fall within one 5 km x 5 km area immediately to the south of the study area and are thus regarded as one locality. The area of occupancy has been estimated by an alternate method at approx. 40 ha, based of the sum of the size of rainforest patches at which it occurs. The population size is estimated at between 500 and 2 000 plants (Kerrigan *et al.* 2007). Big Pig Jungle, just to the south of the northern Bathurst Island area has the largest known population.

Grubbing by feral pigs is currently identified as a key threatening process. While the species may be able to persist in areas lightly disturbed by pigs, individual plants were recorded in areas of pig rooting only where the plants were protected within a network of sizeable tree roots (Fensham 1993). The threats to *Burmannia* sp. Bathurst Island are otherwise similar to those for other wet rainforest species.

Significance of North East Bathurst Island populations

While it was initially thought to occur in the area, the data point was found to be inaccurately geocoded. The plant is extremely restricted in distribution to a small area on Bathurst Island, immediately to the south of the study area. Although no additional populations were located during the survey, there is some possibility that plants may have been missed due to seasonal conditions. The nearest and largest known population is just outside the study area at Big Pig jungle. Because of its close proximity it may also be vulnerable to the effects of excessively high water extraction. Excessive ground water drawdown, grassy weed invasion, intensified fire regimes and feral pigs appear to be the most likely threats to the species and its habitat.

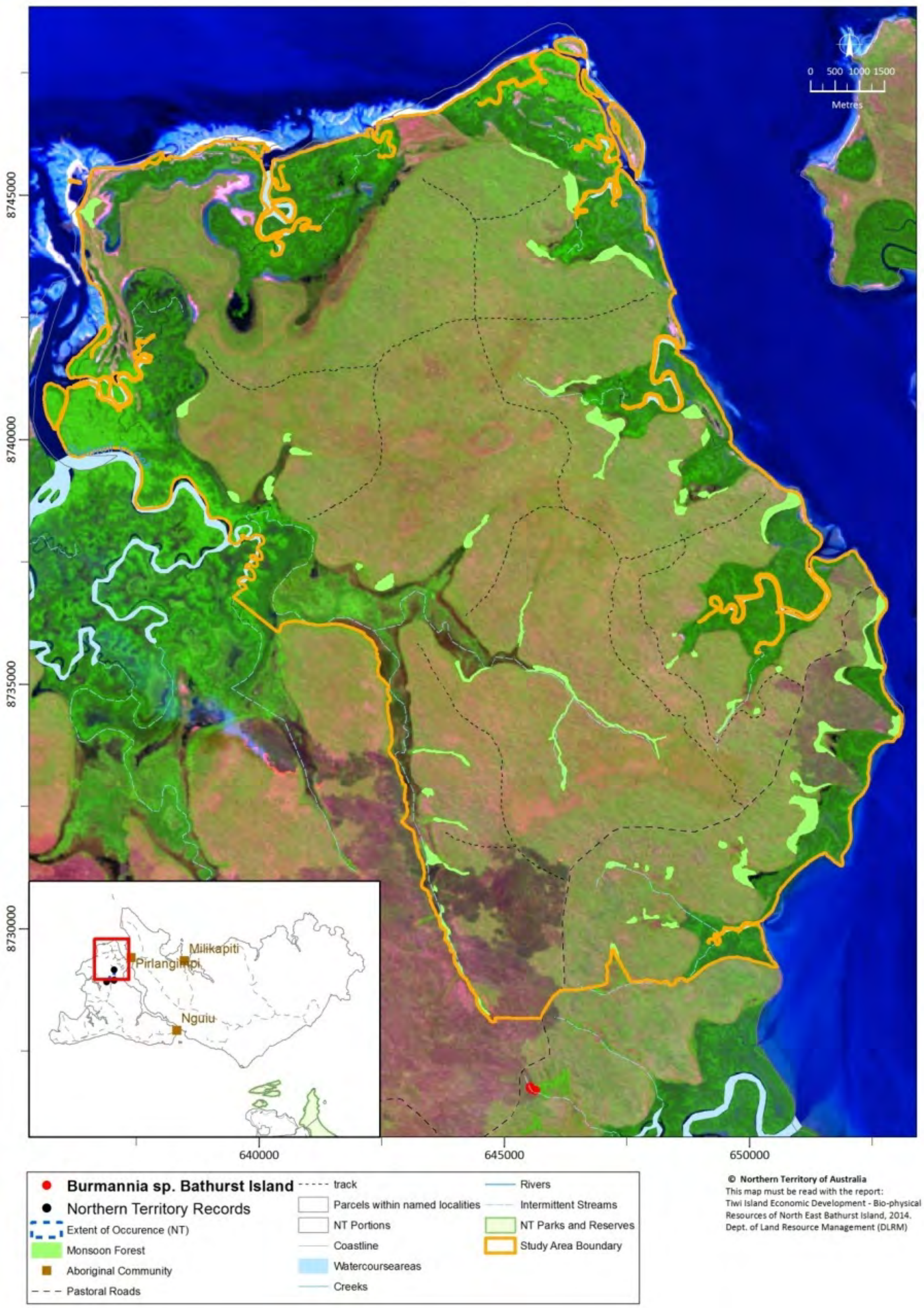


Figure 11-4: Location of *Burmannia* sp. Bathurst Is. records in NE Bathurst Island.

Dendromyza reinwardtiana **Family: SANTALACEAE**

Description

This species is a parasitic, scrambling vine. The leaves are alternate, elliptic to obovate, 20 - 100 mm long, with 3 - 9 longitudinal primary veins. It has separate male and female flowers. The fruit is pink, ovoid, 6 - 8 mm long (Dunlop *et al.* 1995).

Ecology Found on the margins of perennial wet, spring-fed rainforest, where it is usually hosted by *Calophyllum soulattri* or occasionally *Myristica insipida*, *Syzygium* species and *Melicope elleryana* (Dunlop *et al.* 1995; Liddle & Elliott 2008). The population size at each rainforest patch tends to be very small - usually only a few plants. It mostly occurs on the more exposed margins.

Distribution In Australia, it is known from Cape York Peninsula and the N.T. In the Northern Territory, the species is only found on Bathurst Island and the western parts of Melville Islands. Overseas, it occurs from Sumatra and Luzon to Papua New Guinea (Kerrigan *et al.* 2007a).

Conservation Status Vulnerable (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	22	No. Locations (NE Bathurst Island)	4 (18% of total)
EoE km^2 (NT):	1 434	EoO km^2 (NE Bathurst Island):	29 (2% of total)
AoO ha (NT):	201	AoO ha (NE Bathurst Island):	51 (25% of total)

The total population size is estimated at <1000 individuals, with individual subpopulations at each rainforest patch typically very small (<20 individuals). It has a restricted area of occupancy estimated to be much less than 20 km^2 (Kerrigan *et al.* 2007a; this study). It is now known from 36 discrete rainforest patches, with 16 (44%) of these within the study area. Many of these patches are in fairly close proximity to each other and applying a definition of 'location' according to IUCN guidelines, it is known from 22 locations, four of which are in the study area. Eight new subpopulations were recorded during the Oct 2014 survey.

It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands. With an epiphytic growth habit as well as a small population size and restricted distribution, this species is especially susceptible to the effects of cyclones (Kerrigan *et al.* 2007a). It usually occurs on the margins of rainforest patches, especially linear patches of riparian forest. The margins of these forest patches are especially susceptible to the effects of fire and more so following any reduction in water availability and invasion of margins by introduced grassy weeds.

Significance of North East Bathurst Island populations

The subpopulations in the study area represent a significant proportion of the entire known population (between 18 and 44% depending on which measure is used). The species was mostly in the south of the area, in the headwaters of Dudwell Creek and rainforest patches south and just north of the Interview Point road. Excessively high ground water drawdown, grassy weed invasion, intensified fire regimes and cyclones appear to be the most likely threats to the species and its habitat in the area.

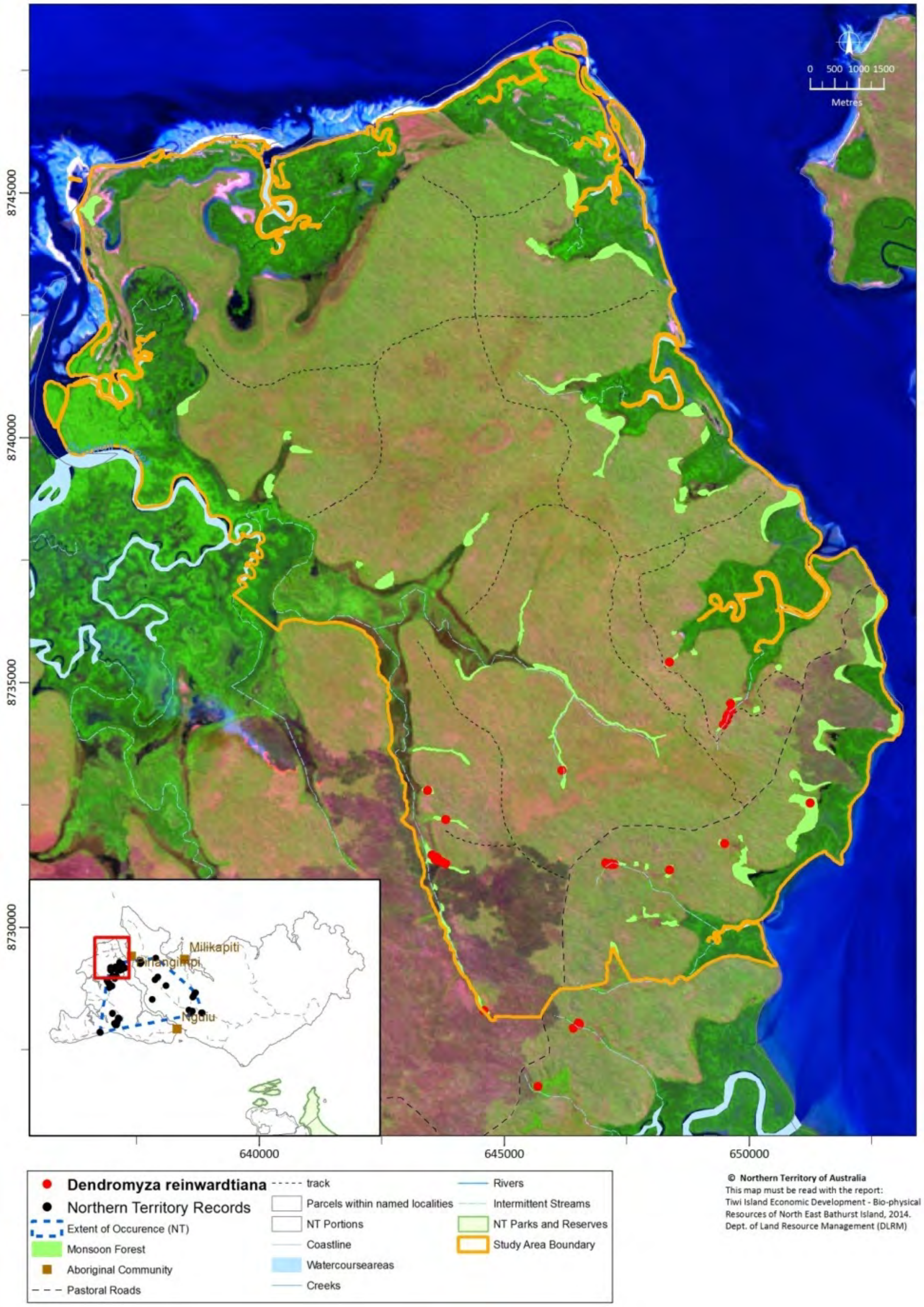


Figure 11-5: Location of *Dendromyza reinwardtiana* records in NE Bathurst Island.

Elaeocarpus miegei **Family: ELAEOCARPACEAE**

<u>Description</u>

Elaeocarpus miegei is a tall tree, to 35 m frequently with buttresses at the base. It is distinguished from *Elaeocarpus arnhemicus* by longer petioles (more than 15 mm long in *E. miegei*), and leaf shape (elliptic acute and usually acuminate in *E. arnhemicus*, obovate and obtuse in *E. miegei*) (Kerrigan & Dixon 2011a).

In Papua New Guinea, it is reported to be a variable species and a number of taxa may be involved (Coode 1981; D. Crane pers. comm.).

<u>Ecology</u>

This species grows in permanently moist soils in rainforest patches naturally supplied with water from perennial springs (Kerrigan *et al.* 2007b). Usually found on permanently wet organic substrates, in the wettest part of the forest.

<u>Distribution</u> The only Australian occurrences of this tall rainforest tree are on the Tiwi Islands where it is recorded from Bathurst Island and the western part of Melville Island. Beyond Australia, it is also known from New Guinea, Malesia and the Solomon Islands (Coode 1981).

<u>Conservation Status</u> Critically Endangered (TPWCA); not listed (EPBC).

<u>Key Parameters</u> (see definitions in Table 7-2)

No. Locations (NT):	8	No. Locations (NE Bathurst Island):	5 (63% of total)
EoE km^2 (NT):	288	EoO km^2 (NE Bathurst Island):	36 (13% of total)
AoO ha (NT):	66	AoO ha (NE Bathurst Island):	33 (50% of total)

It is now known from 15 discrete rainforest patches (perhaps subpopulations), with 7 (47%) of these in the study area. Many of these patches are close to each other and applying a definition of 'location' according to IUCN guidelines it is known from 8 locations, five of which are in the study area. The entire NT population was estimated in 2006 at <50 mature individuals (Kerrigan *et al.* 2007b). Both the present study and Liddle & Elliott (2008) confirmed this estimate, with juveniles approximately 5-10 times this number. Four new subpopulations were recorded during survey in Oct 2014.

It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands. Potential threats include cyclonic events, feral animal activity (which may affect recruitment), changes to hydrology (possibly due to more intensive land use or excessive ground water extraction near rainforest patches) and the subsequent threat from invasion by grassy weeds and fire (Kerrigan *et al.* 2007b).

<u>*Significance of North East Bathurst Island populations*</u>

The subpopulation in the North East Bathurst Island area represents a major proportion of the entire population in NT. It was located at rainforest patches on Dudwell Creek, south of Interview Pt road and in the east of the area. The largest subpopulation of the seven detected was on lower Dudwell Creek consisting of at least 20 adults and 250 juveniles. Excessively high ground water drawdown, and grassy weed invasion with intensified fire regimes appear to be the most likely threats to the species and its habitat in the area.

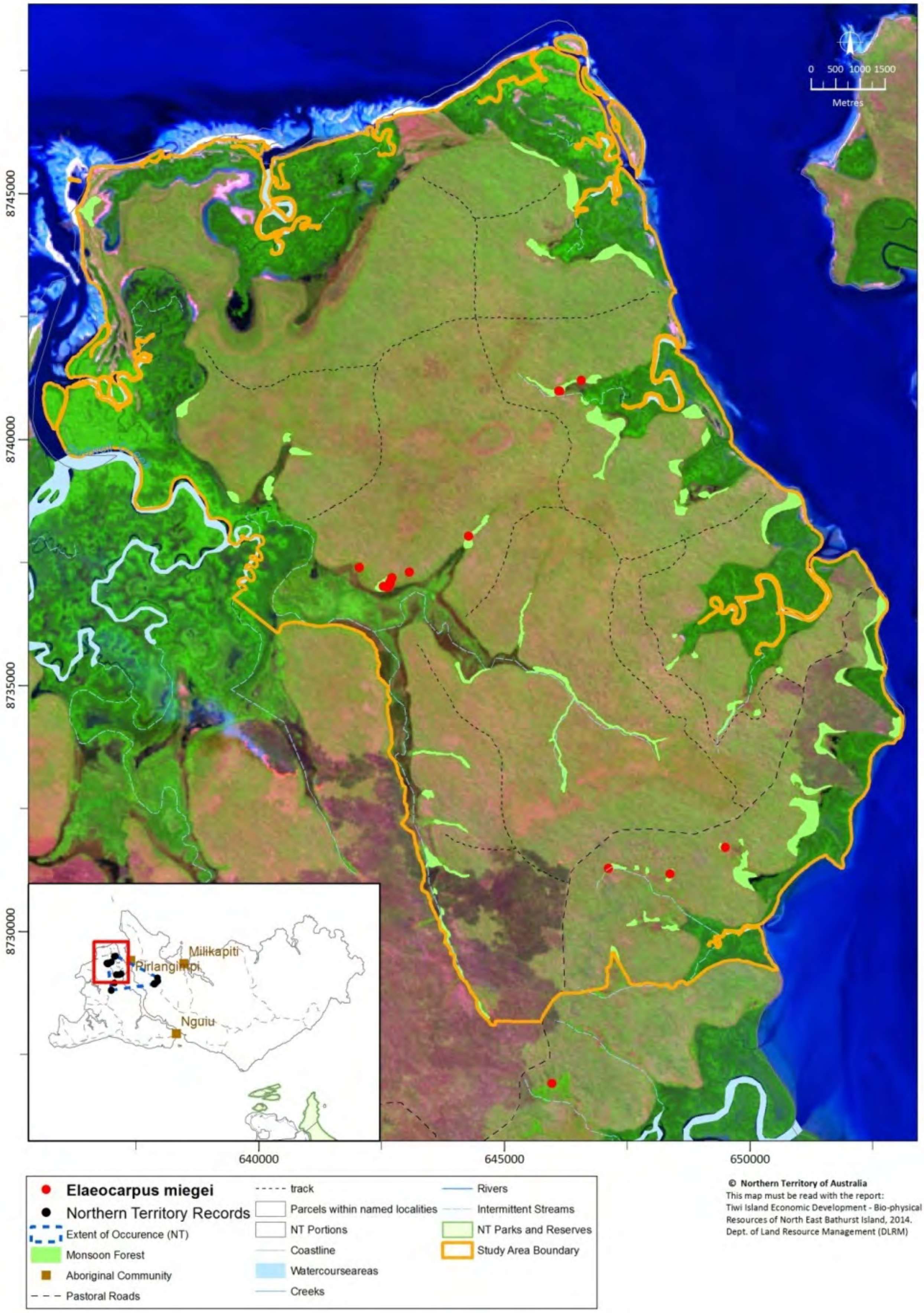
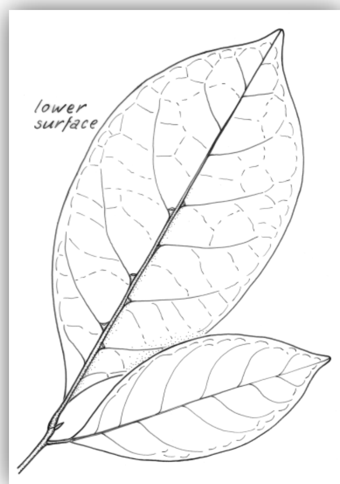


Figure 11-6: Location of *Elaeocarpus miegei* records in NE Bathurst Island.

Endiandra limnophila **Family: LAURACEAE**

Description



Endiandra limnophila is a tree to 20 m tall and 30 cm diameter at breast height, but usually smaller. Its leaves are glossy, somewhat bluish below, with domatia present. The flowers are pale green to cream, turning brown with age, perfumed or odourless. The fruits are black and glaucous, 28 - 38 mm long, 14 - 15 mm diam. (Kerrigan & Dixon 2011).

Ecology

This species grows in evergreen, spring-fed rainforest. It is normally found on permanently moist substrates and appears to prefer more sandy soils than some other species.

Distribution

An Australian endemic, it is known from the far north of Cape York Peninsula and the NT. In the NT, it is known from the Tiwi Islands (Bathurst Island and the western part of Melville Island) with an isolated population at Channel Point.

Conservation Status Vulnerable (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	28	No. Locations (NE Bathurst Island):	7 (25% of total)
EoE km^2 (NT):	5 502	EoO km^2 (NE Bathurst Island):	76 (1.4% of total)
AoO ha (NT):	231	AoO ha (NE Bathurst Island):	72 (31% of total)

It is now known from 46 discrete rainforest patches, with 23 (50%) of these in the study area. As many of these patches are close to each other, applying a definition of 'location' according to IUCN guidelines results in these estimates becoming 28 locations, seven of which are in the study area.

It has been assessed as Vulnerable on the basis of an area of occupancy estimated to be <20 km^2 and a population size estimated at <1000 mature individuals (Kerrigan & Cowie 2007a). More recent survey confirms this assessment. During the current and surveys, the vast majority of individuals observed were juveniles and trees over 5 cm DBH were relatively rare (Liddle & Elliott 2008; this study). Sixteen new subpopulations were recorded during survey work in Oct. 2014.

It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands. Known localities on Bathurst Island have high pig populations and intensive grubbing by pigs around juvenile plants was highly evident, which may affect recruitment.

Significance of North East Bathurst Island populations

The subpopulations in the study area represent a significant (25%) to high (50%) proportion of the entire Australian and NT population, depending on the parameter considered. It was present at around half of rainforest patches in the area with the largest subpopulation at a rainforest patch south of the Interview Pt Road. Excessively high ground water drawdown, grassy weed invasion, intensified fire regimes and feral pigs appear to be the most likely threats to the species and its habitat in the area.

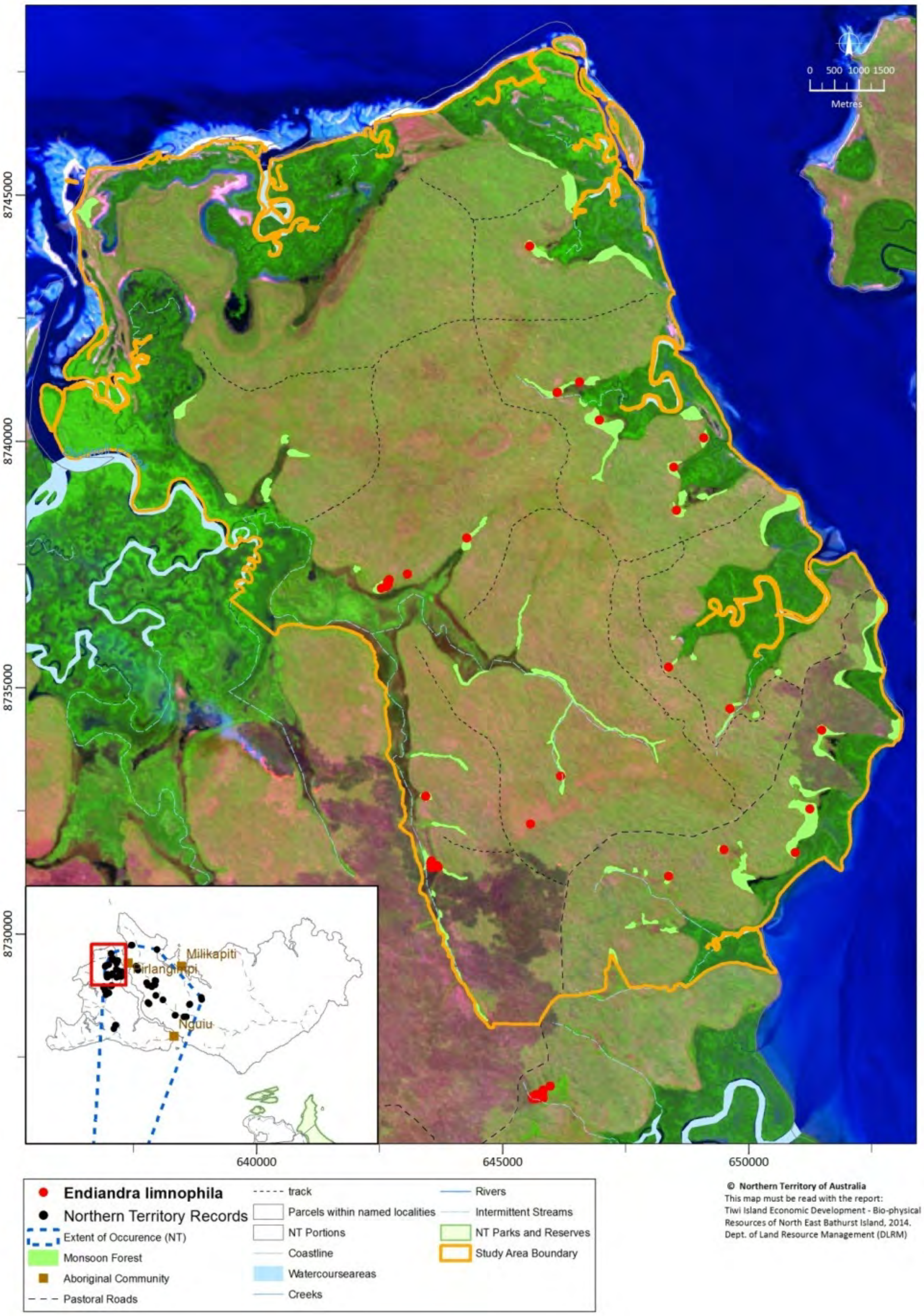


Figure 11-7: Location of *Endiandra limnophila* records in NE Bathurst Island.

Freycinetia excelsa **Family: PANDANACEAE**

<u>*Description*</u>

Freycinetia excelsa is a slender, woody climber with stems to 7-8 mm in diameter. The leaf auricles each have a rounded apex and no distinct free apical lobe. The bracts are orange to red. The male spikes are yellow to cream-brown; and fruit strawberry-red (Stone 1982).

<u>*Ecology*</u>

This plant occurs in permanently wet, evergreen rainforest fed by springs, both in the lowlands and in sandstone gorges.

<u>*Distribution*</u>

In the Northern Territory, it has been recorded from Bathurst Island, Melville Island, Gunn Pt, Kakadu and near the Arafura Swamp in central Arnhem Land. This species is also known from Cape York Peninsula and New Guinea.

<u>*Conservation Status*</u>

Vulnerable (TPWCA); not listed (EPBC).

<u>*Key Parameters*</u> (see definitions in Table 7-2)

No. Locations (NT):	11	No. Locations (NE Bathurst Island):	1 (9% of total)
EoE km^2 (NT):	51 668	EoO km^2 (NE Bathurst Island):	na
AoO ha (NT):	81	AoO ha (NE Bathurst Island):	3 (4% of total)

It is now known from 16 discrete rainforest patches, with 2 (13%) of these in the study area. In total, it occurs in seven patches on Bathurst Island, two on Melville Island, with one at Gunn Pt, one in Kakadu and 5 near Arafura swamp. Two additional subpopulations were located in the mid zone of Dudwell Creek during the survey, both very small. Using a definition of 'location' according to IUCN guidelines, it occurs at 11 locations, one of which is in the northern Bathurst Island study area.

Individual subpopulations are typically very small (one or a few plants), highly disjunct and occur in small pockets of wet rainforest. The total number of individuals is estimated to be <1000; and it has a restricted area of occupancy estimated to be <20 km^2 (Kerrigan *et al.* 2007c; this study).

It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

<u>*Significance of North East Bathurst Island populations*</u>

The subpopulation in the study area represents only a small proportion (< 10%) of the NT population. In this area, the most likely threats to the species and its habitat appear to be excessively high ground water drawdown, grassy weed invasion, and intensified fire regimes. Feral pigs are an existing threat.

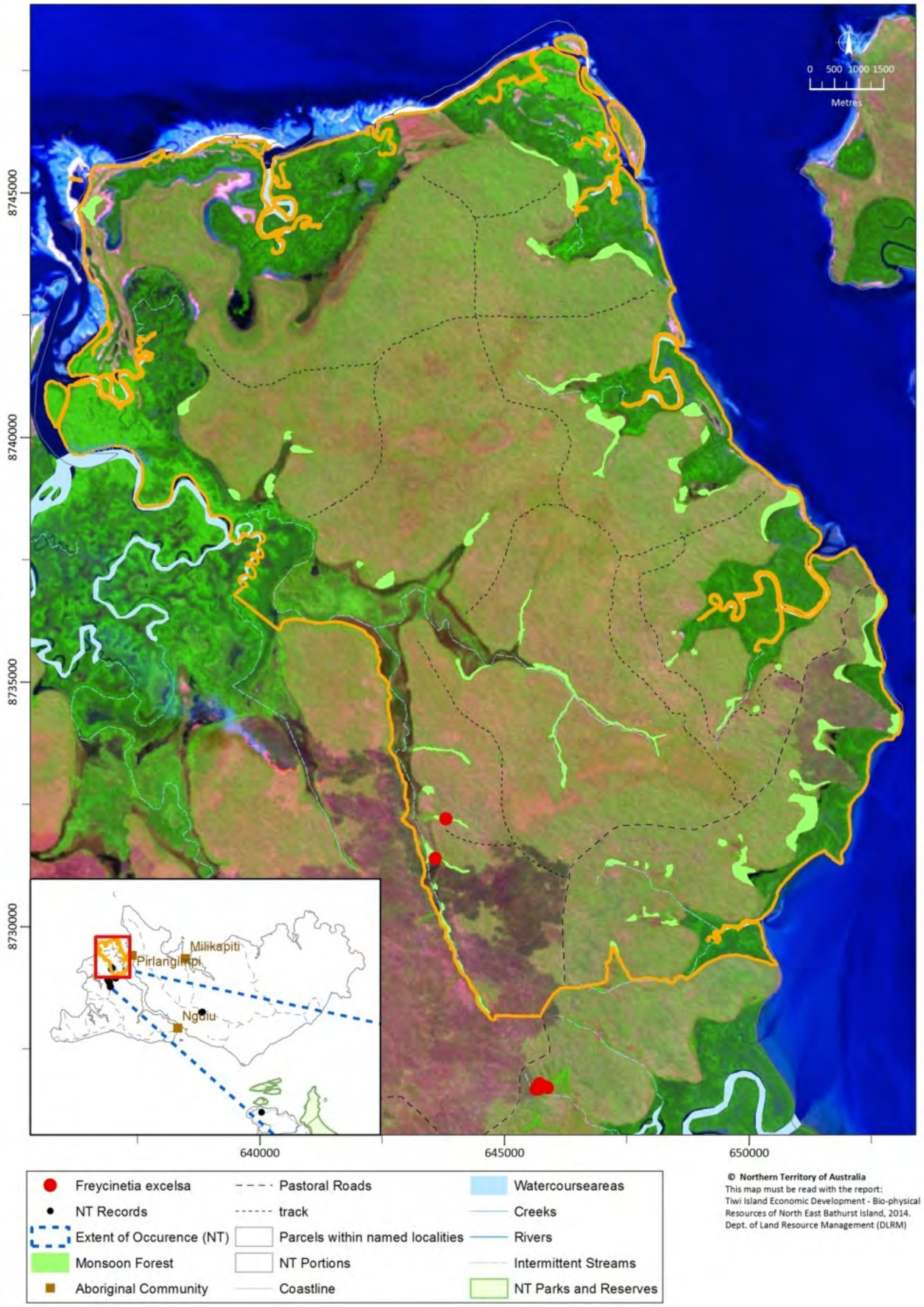


Figure 11-8: Location of *Freycinetia excelsa* records in NE Bathurst Island.

Freycinetia percostata **Family: PANDANACEAE**

Description

Freycinetia percostata is a moderately robust, woody climber, with stems to 2 cm diameter. The leaf auricles each have a distinct deltoid apical lobe, with the margins distinctly ciliate-spinulose. The spathe is yellow-orange to salmon pink. The male spikes are pale to orange-brown. The broken fruit is crimson (Stone 1982).

Ecology

This plant occurs in permanently wet, evergreen rainforest dependant on perennial springs. These patches occur in both the lowlands and in sandstone gorges.

Distribution

In the Northern Territory, it has been recorded from three rainforest patches on Bathurst Island and four near the Arafura Swamp in central Arnhem Land. This species is also known from Cape York Peninsula, New Guinea and the Solomon Islands (Stone 1982; AVH 2014).

Conservation Status

Vulnerable (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	7	No. Locations (NE Bathurst Island):	0
EoE km^2 (NT):	2 972	EoO km^2 (NE Bathurst Island):	na
AoO ha (NT):	33	AoO ha (NE Bathurst Island):	3 (9% of total)

It is now known from seven discrete rainforest patches but none are located in the northern Bathurst Island area. A data point previously thought to be from the area was found to be incorrectly geocoded. The species was not recorded from the area during surveys in October 2014.

Individual subpopulations are typically very small (one or a few plants), highly disjunct and occur in small pockets of wet rainforest. The total number of individuals is estimated to be <1000, and it has a restricted area of occupancy estimated to be <20 km^2 (Kerrigan *et al.* 2007d; this study). It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

No longer thought to occur in the study area. Occurs at Big Pig Jungle and other jungles just to the south of the area and these may also be susceptible to excessively high ground water drawdown, grassy weed invasion, and intensified fire regimes resulting from development in the area. Feral pigs are an existing threat.

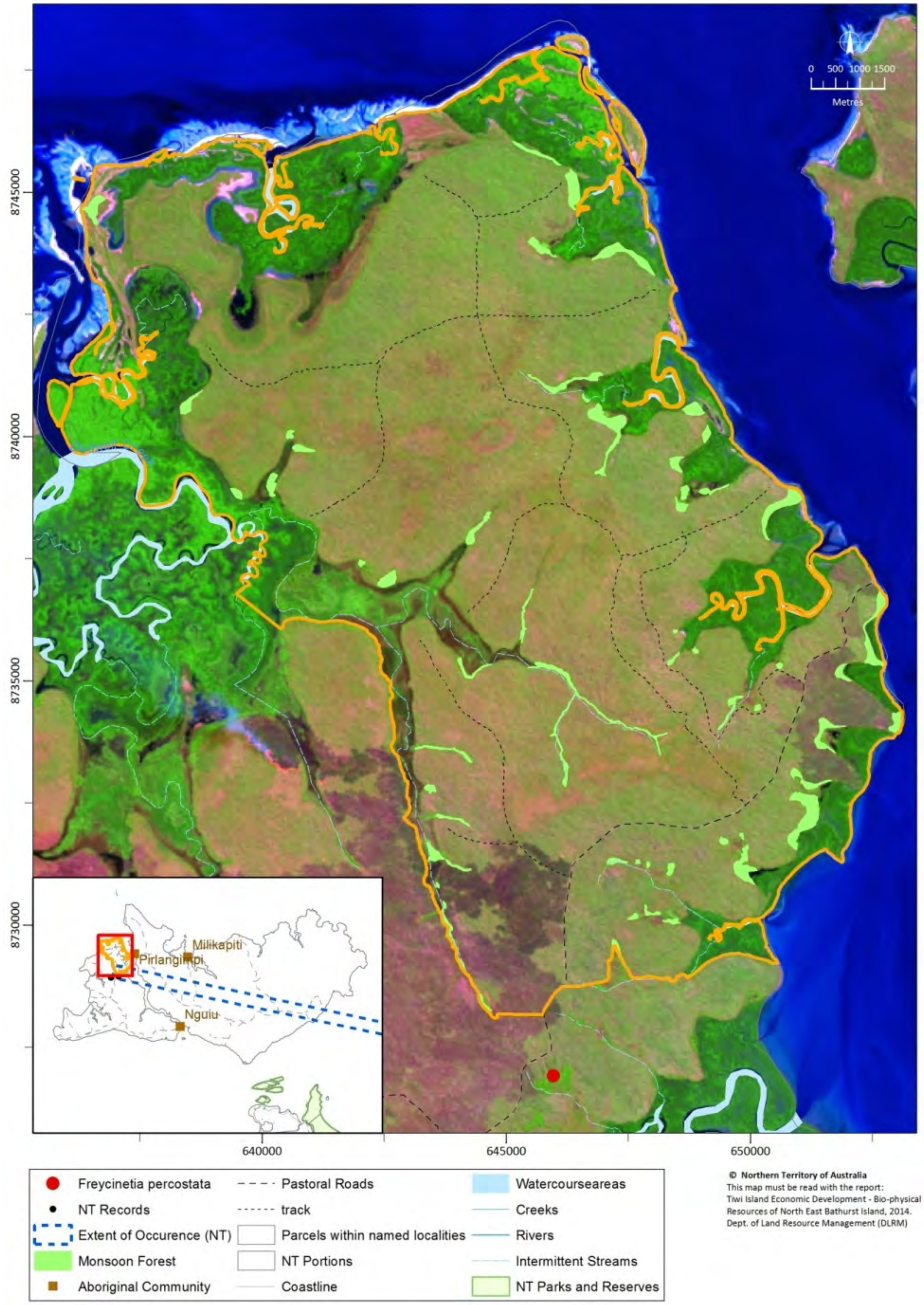


Figure 11-9: Location of *Freycinetia percostata* records in NE Bathurst Island.

Hoya australis* subsp. *oramicola **Family: APOCYNACEAE**

Description

Hoya australis subsp. *oramicola* is a scrambling vine with milky sap. Its leaves have sparse to dense covering of hairs, and the leaf blade is succulent, >10 cm long, with leaf margin strongly recurved. Glands (colleters) are absent. The flowers are cream coloured and waxy in appearance (Forster, 1996).

Ecology This subspecies usually grows on the margins of coastal monsoon rainforest on dunes or laterite outcrops (Kerrigan & Cowie 2007b). Plants were observed to be most abundant on the margin of coastal dry rainforest bordering open sand dune habitat on the south-western coastline of Bathurst Island (Liddle & Elliott 2008). The plant has sometimes been recorded in association with *Callitris intratropica* or on rocky outcrops in association with a scattering of rainforest species amid open savanna vegetation. The species appears to be display a preference for fire protected situations not just rainforest (Liddle & Elliott 2008). *Hoya* has long trailing stems and propagates vegetatively by producing roots from nodes in contact with suitable substrate.

Distribution Endemic to the Tiwi Islands, with most known populations recorded from Bathurst Island.

Conservation Status Vulnerable (TPWCA); Vulnerable (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	8	No. Locations (NE Bathurst Island):	1 (13% of total)
EoE km^2 (NT):	2 439	EoO km^2 (NE Bathurst Island):	na
AoO ha (NT):	45	AoO ha (NE Bathurst Island):	3 (7% of total)

It has been recorded at 13 discrete rainforest patches (one from Melville Island), with one in the study area. As some discrete rainforest patches are in close proximity, they are regarded as one 'location' for assessment against IUCN criteria. While the population size of this subspecies has been estimated at 350 - 700 mature individuals, this estimate is uncertain.

This species was recorded during October 2014 in one rainforest to the south of Interview Point. This represents a significant range extension for the species, which was previously known from the southern side of Bathurst and Melville islands. Additional subpopulations from the north side of Melville Island have also been recorded (D. Liddle pers. comm.). The population recorded at Interview Point extended in scattered patches in monsoon rainforest for more than 50 metres along a low laterite jump up above mangroves

It grows on a dryer substrate in relatively dry rainforest and is thus less vulnerable to immediate effects of any lowering in ground water levels and reduced discharge of springs. However, some parts of the rainforest patch it inhabits may be affected by lowered ground water levels. Also, the species may be adversely affected by grassy weed invasion of rainforest with resultant increased fire frequency and intensity. As it grows on the ground or over rocky outcrops, the species is considered less vulnerable to stochastic events such as cyclones.

Significance of North East Bathurst Island populations The Interview Point population represents a relatively small proportion of the entire population (<15%). This subpopulation represents a significant range extension for the species but was the only subpopulation recorded during the survey. Grassy weed invasion of rainforest with resultant increased fire frequency and intensity is seen as the most likely threat to the species in the area.

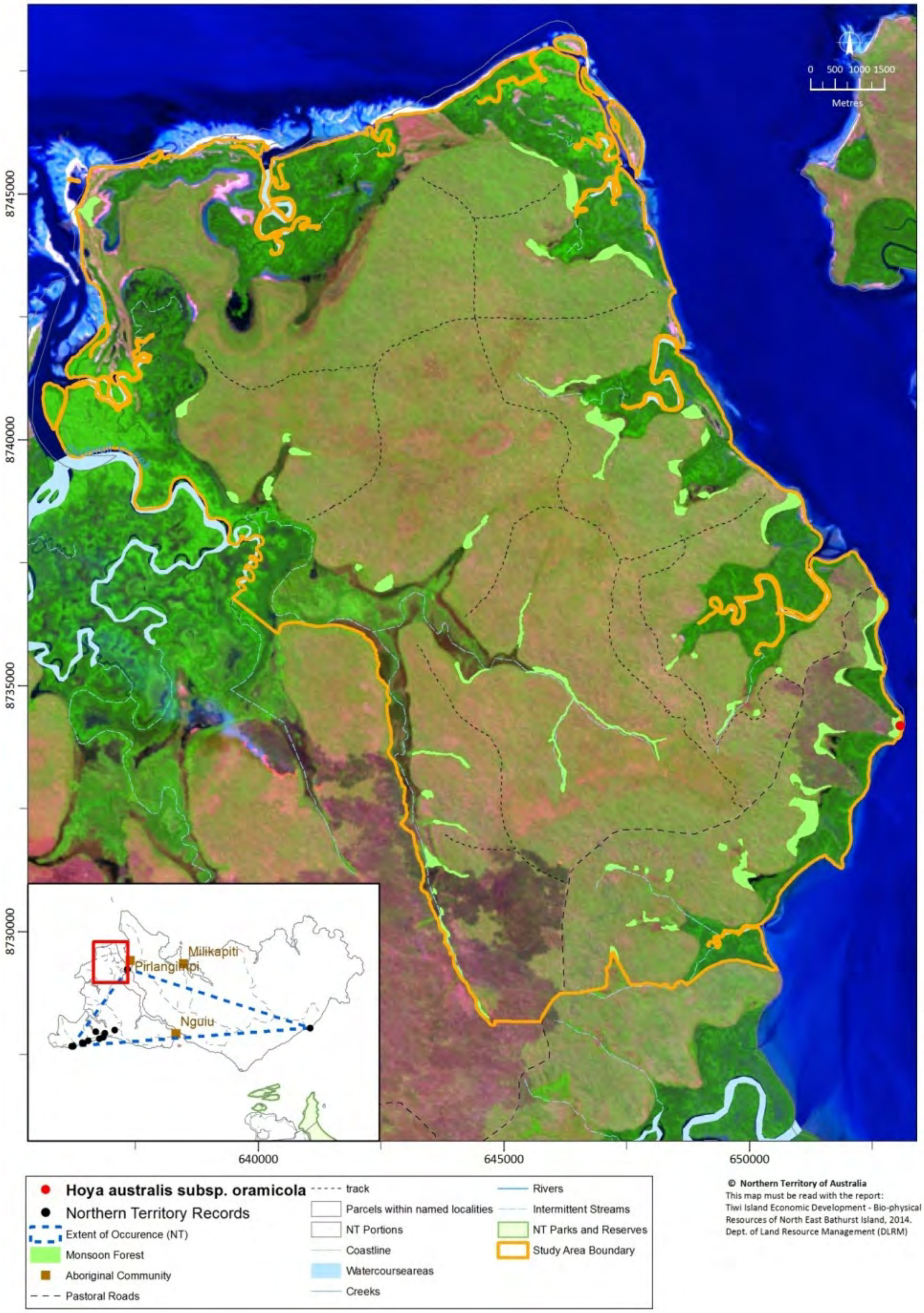


Figure 11-10: Location of *Hoya australis* subsp. *oramicola* records in NE Bathurst Island.

Luisia corrugata **Family: ORCHIDACEAE**

Description

Luisia corrugata (listed as *L. teretifolia*) is an epiphytic orchid forming straggly clumps of slender, wiry, erect or semi-pendulous stems to 30 cm long. There are two to ten leaves per stem, 15 cm x 5 mm, cylindrical in cross section. The flowers are about 10 mm across, green with a dark burgundy labellum or lip (Jones 2006).

Taxonomic investigation by Jones (2006) has determined that the Northern Territory taxon is *L. corrugata.*

Ecology

Within the NT, this species has been collected from the margins of monsoon rainforests; in other parts of its range, it is reputedly more common in coastal and near coastal habitats, including mangroves (Kerrigan & Cowie 2007c). It appears to prefer situations of relatively bright light and often occurs on trees that have rough or scaly bark. It may be associated with other epiphytic orchids and ferns (e.g. *Dendrobium affine* and *Drynaria quercifolia*). Hosts trees include *Syzygium* spp., *Sterculia quadrifida*, *Barringtonia acutangula*, *Canarium australianum* and *Vitex* spp.

Distribution

This species is regarded as endemic to the Northern Territory (Jones 2006). It is known mostly from Melville Island, but with single records from Bathurst Island, Bankers Jungle and Crocodile Creek in Black Jungle Conservation Reserve on the mainland. However the species was not relocated during surveys of both the Bankers Jungle and Crocodile Creek localities in 2003.

Conservation Status Vulnerable (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	15	No. Locations (NE Bathurst Island):	1 (7% of total)
EoE km^2 (NT):	5 884	EoO km^2 (NE Bathurst Island):	na
AoO ha (NT):	60	AoO ha (NE Bathurst Island):	3 (5% of total)

It has been recorded at 18 subpopulations at separate rainforest patches, with one in the study area. As some subpopulations are in close proximity, they are regarded as one 'location' for assessment against IUCN criteria. One new subpopulation (a number of individuals in one tree) was located in the study area during Oct 2014 surveys. As is the case with a number of rainforest species, subpopulations appear to be very small. The population size has been estimated to be <1 000 mature individuals with a restricted area of occupancy estimated to be <20 km^2 (Kerrigan & Cowie 2007c).

It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands. An epiphytic growth habit, small population and relatively restricted distribution make this species especially susceptible to effects of cyclones.

Significance of North East Bathurst Island populations

The population south of the Interview Point road represents a relatively small proportion of the entire population (<10%). It occurred in one large rainforest patch to the south of the Interview Point Rd. Habitat modification or loss through excessive ground water drawdown, grassy weed invasion, intensified fire regimes and cyclones are the most likely threats in the area.

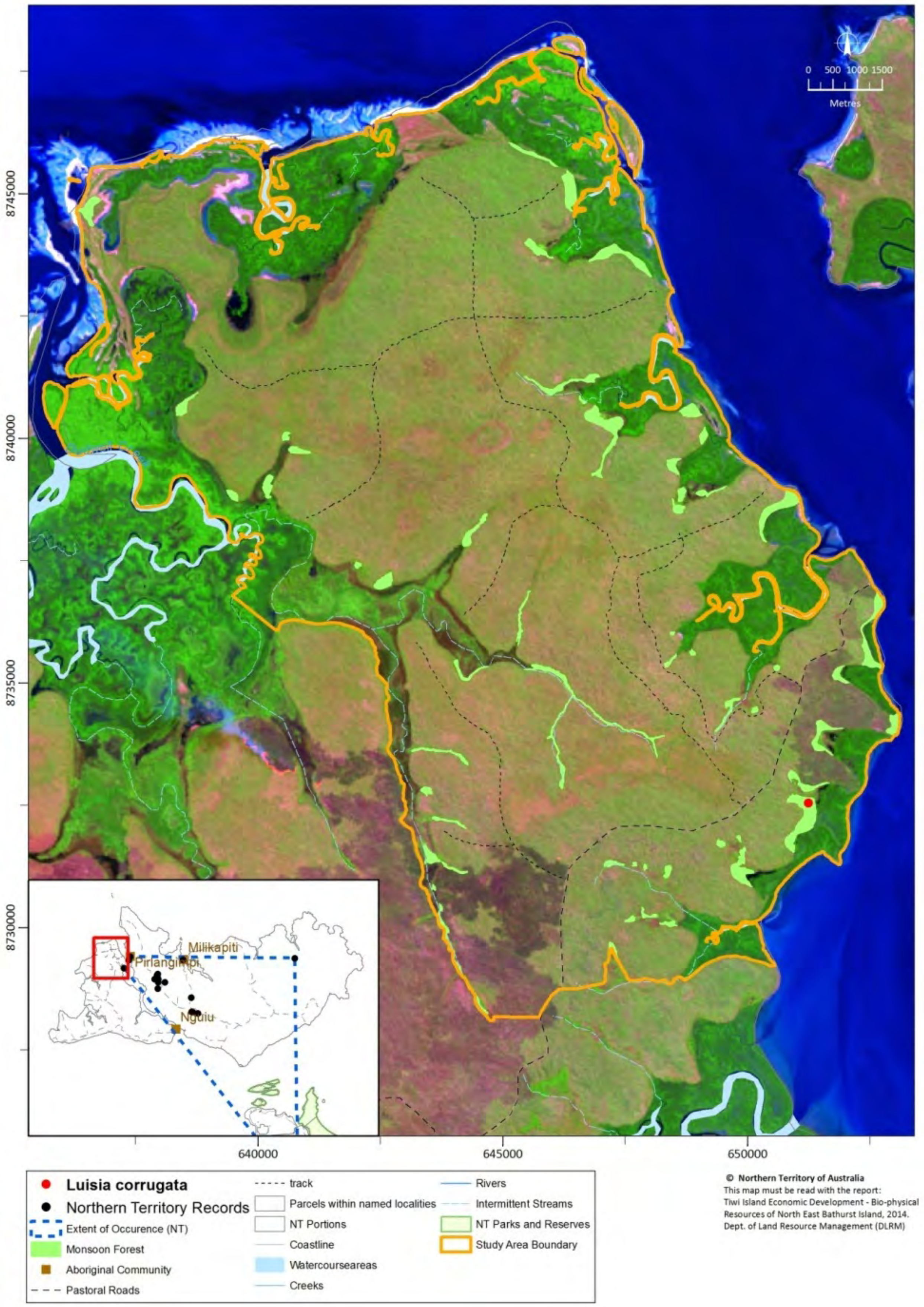


Figure 11-11: Location of *Luisia corrugata* records in NE Bathurst Island.

Mitrella tiwiensis **Family: ANNONACEAE**

Description

A twining vine to 10 m, forming a semi-weeping shrub when young. Branchlets are distinctly zig-zagged. Leaves are glossy, dark-green above, bluish (glaucous) beneath. Flowers are pinkish-orange, faintly scented. Fruit is a multi-seeded berry, pale pink-green (Kerrigan *et al.* 2011).

Ecology

Grows in permanently moist substrates in monsoon rainforest associated with perennial springs. *Mitrella* appears to prefer more sandy substrates rather than the highly organic substrates occupied by other rare species such as *Elaeocarpus miege*i.

Distribution *Mitrella tiwiensis* is found only on Bathurst and Melville islands.

Conservation Status Vulnerable (TPWCA); Vulnerable (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	19	No. Locations (NE Bathurst Island):	5 (26% of total)
EoE km^2 (NT):	1 148	EoO km^2 (NE Bathurst Island):	42 (4% of total)
AoO ha (NT):	135	AoO ha (NE Bathurst Island):	21 (16% of total)

It has been recorded in 26 rainforest patches (or subpopulations), with 16 on Melville Island and 10 on Bathurst Island. Six subpopulations (23% of the total) occur within the study area. Two new subpopulations were recorded to the south of the Interview Point Road during Oct 2014. Individual subpopulations recorded during survey work were consistently very small consisting of a few adults and some juveniles (Liddel & Elliott 2008; this study). The population size has been estimated to be <1000 mature individuals with a restricted area of occupancy estimated at <20 km^2 (Kerrigan *et al.* 2007d).

In common with a suite of co-occurring rainforest species, it is likely to be vulnerable to the effects of lowered ground water levels and reduced discharge of springs with a consequent drying out of its wet rainforest habitat. This may also result in loss of habitat though a mixture of grassy weed invasion of forest margins and increased fire.

A record apparently from open forest vegetation near the Interview Point road has the locality 'c 23 km east of Rocky Point' and the precise locality is not known. It appears most likely it is attributable to a known subpopulation at Big Pig jungle or south of the Interview Pt Rd.

Significance of North East Bathurst Island populations

The subpopulations in the North East Bathurst Island area represent up to 25% of the entire known population. Subpopulations were recorded in rainforest patches on Dudwell Ck, south of Interview Pt Rd and in two rainforest patches on the eastern side. Excessively high ground water drawdown, grassy weed invasion, intensified fire regimes and feral pigs appear to be the most likely threats to the species and its habitat in the area.

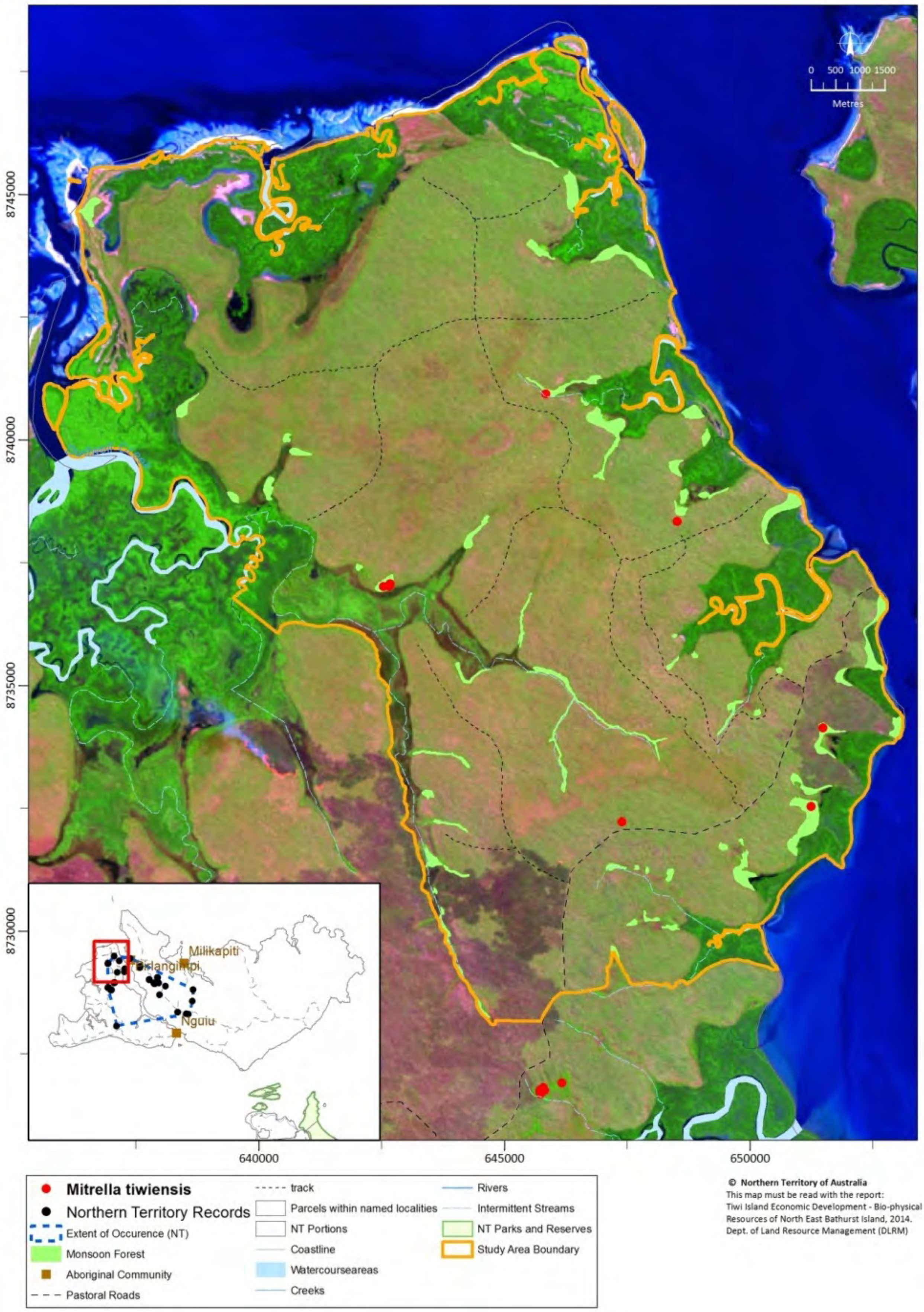


Figure 11-12: Location of *Mitrella tiwiensis* records in NE Bathurst Island.

Tarennoidea wallichii **Family: RUBIACEAE**

<u>*Description and habitat*</u>

Tarennoidea wallichii is a small tree to 5 m, with grey smooth bark. Leaves are opposite with interpetiolar stipules, dark green, glossy and relatively large. The domatia have fringing hairs. Flowers are white and relatively showy. Berry ovoid to subglobose, 7 – 18 mm diam., glabrous. (Chen & Taylor 2011).

<u>*Ecology*</u>

It occurs in the drier parts of evergreen rainforests and in semi deciduous rainforests.

<u>*Distribution*</u>

In Northern Territory, *Tarennoidea wallichii* is known only from a few monsoon rainforests on Melville and Bathurst islands. This species is widespread in SE Asia, extending from India to southern China and northern Australia (NT only) (Chen & Taylor 2011).

<u>*Conservation Status*</u> Endangered (TPWCA); not listed (EPBC).

<u>*Key Parameters*</u> (see definitions in Table 7-2)

No. Locations (NT):	7	No. Locations (NE Bathurst Island):	3 (43% of total)
EoE km^2 (NT):	225	EoO km^2 (NE Bathurst Island):	17 (8% of total)
AoO ha (NT):	33	AoO ha (NE Bathurst Island):	12 (36% of total)

It has been recorded in 8 rainforest patches (or subpopulations), with 4 on Melville Island and 4 on Bathurst Island. All four Bathurst Island subpopulations (50% of the total) occur within the study area. The species had not previously been recorded from this area. Individual subpopulations recorded during survey work were consistently very small mostly consisting of a few juveniles (Liddle & Elliott 2008; this study). It is likely that rare adults were missed as it was not possible to search all of each rainforest patch.This species qualifies as Endangered (under criteria D) based on a population size estimated to be <250 individuals (Kerrigan & Cowie 2007e).

The small population size makes this species susceptible to stochastic events such as cyclones and fire. *Tarennoidea wallichii* occurs in drier rainforest habitat than most other threatened species on Bathurst Island. However, while there were no springs evident in these rainforests, they appear likely to have ground water available at relatively shallow depth. Thus it is still likely to be vulnerable to the effects of lowered ground water levels and share similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

The maintenance of this species depends upon the retention of the Tiwi rainforest network and control of the impact of weeds, fire and feral animals in this environment. Invasion of its rainforest habitat by grassy weed weeds may result in loss of habitat though increased fire.

<u>*Significance of North East Bathurst Island populations*</u>

The subpopulations in the North East Bathurst Island area represent from 36 to 50% of the entire known population depending on the measure used. Three subpopulations were located to the south of the Interview Point Rd with one on Dudwell Creek. In this area, grassy weed invasion and intensified fire regimes are the most likely threats.

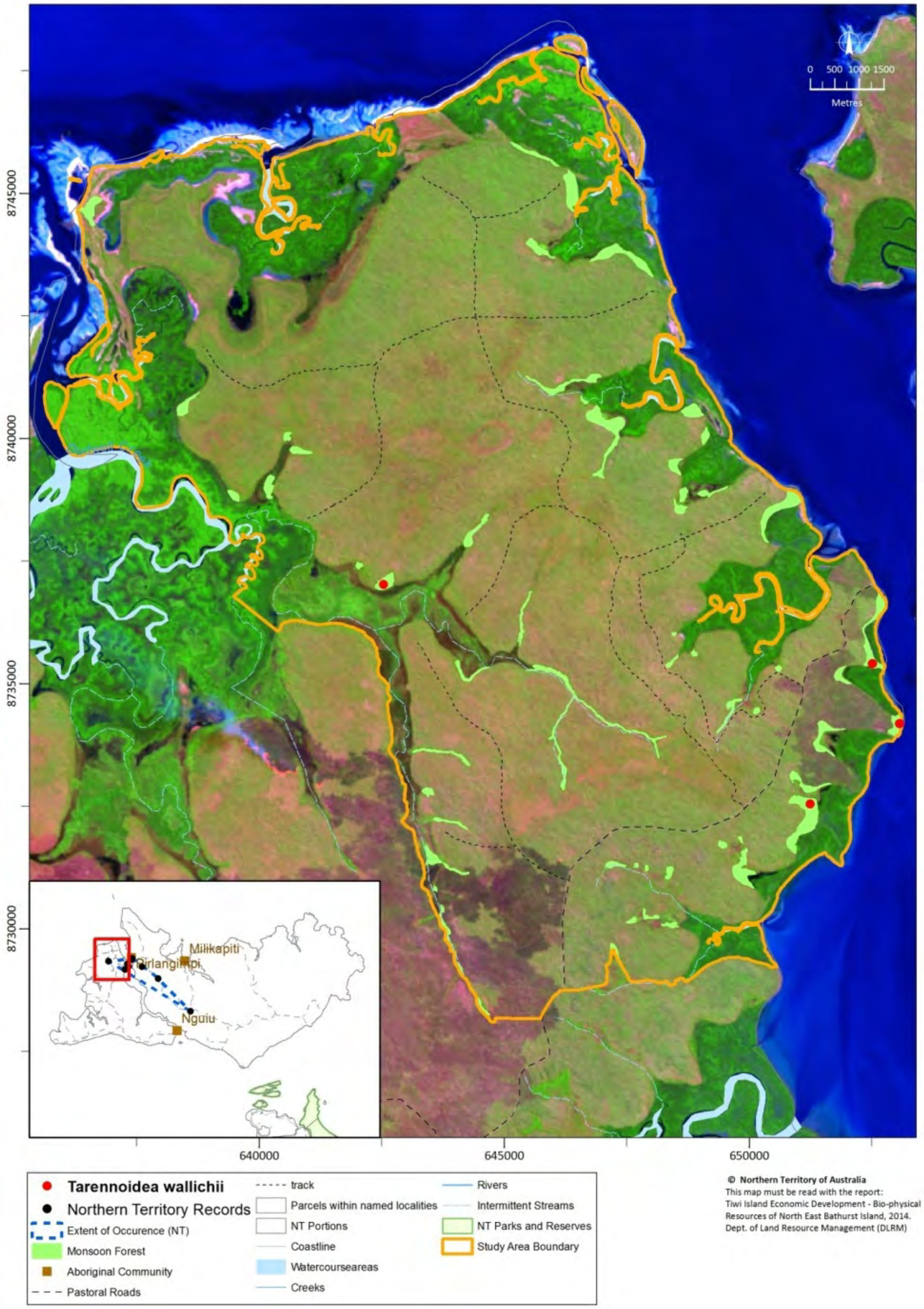


Figure 11-13: Location of *Tarennoidea wallichii* records in NE Bathurst Island.

Thrixspermum congestum **Family: ORCHIDACEAE**

Description and habitat

Thrixspermum congestum is an epiphytic orchid, forming small clumps. Stems sparsely branched, flattened to 15 cm long. Leaves 6 - 15 leaves per plant, leathery, often yellowish green. Inflorescence to 10 cm long, erect and wiry. Flowers about 15 mm across, cream or white, fragrant and open together and last about one day (Jones 2006).

Ecology

This species grows in lowland rainforests and, outside the Northern Territory, also on mangroves. It is usually found in humid but airy situations, often in exposed positions on small branches (Jones 2006).

Distribution

In the Northern Territory, it is restricted to Melville and Bathurst Island. It also occurs in far north Queensland and from the Solomon Islands west through New Guinea to Indonesia (Jones 2006).

Conservation Status

Vulnerable (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	9	No. Locations (NE Bathurst Island):	2 (22% of total)
EoE km^2 (NT):	315	EoO km^2 (NE Bathurst Island):	na
AoO ha (NT):	33	AoO ha (NE Bathurst Island):	6 (18% of total)

It has been recorded in 9 rainforest patches (or subpopulations), with 5 on Melville Island and 4 on Bathurst Island. Two Bathurst Island subpopulations (50% of the total) occur within the study area. Individual subpopulations appear to be small, although plants are cryptic and difficult to locate. It is regarded as vulnerable because the estimated population size is <1000 individuals and it has an area of occupancy estimated to be <20 EoO km^2 and plausible threats are evident (Kerrigan & Cowie 2007f).

It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands. As an epiphyte with a small population and restricted distribution, this species is susceptible to stochastic events, in particular cyclones. In common with other wet rainforest species, it is likely to be vulnerable to the effects of lowered ground water levels and reduced discharge of springs with a consequent drying out of its wet rainforest habitat. This may also result in loss of habitat though a mixture of grassy weed invasion of forest margins and increased fire.

Significance of North East Bathurst Island populations

The two subpopulations on Dudwell Creek in the North East Bathurst Island area represent around 20% of the entire known population. Habitat modification or loss through excessive ground water drawdown, grassy weed invasion, intensified fire regimes and cyclones are the most likely threats in the area.

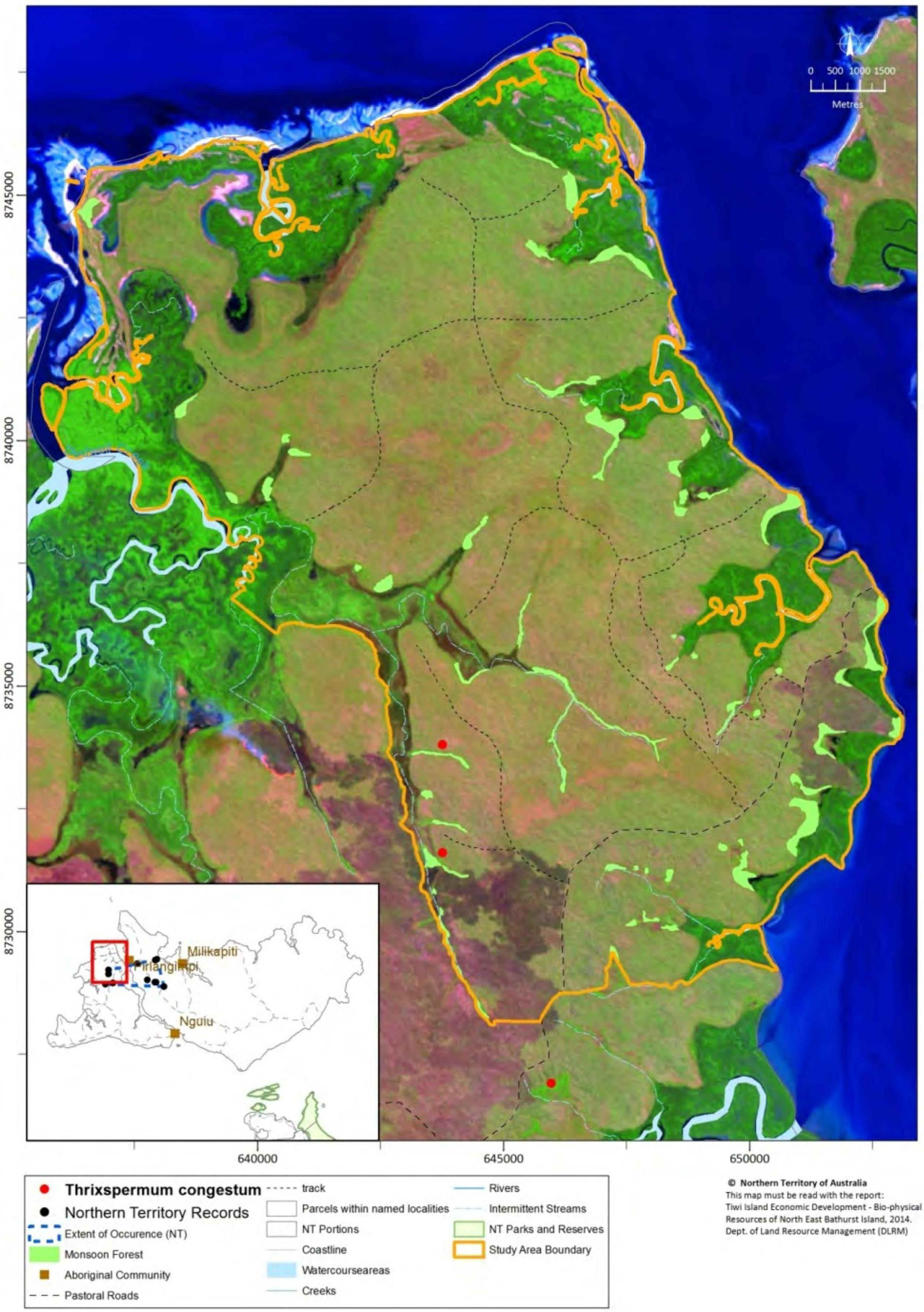


Figure 11-14: Location of *Thrixspermum congestum* records in NE Bathurst Island.

Xylopia monosperma **Family: ANNONACEAE**

Description

Tree to 20 m tall; bark in young trees reddish, peeling in thin flakes. Leaves with petioles 4–9 mm long; blade elliptic to ovate, 6–12 cm long, 2–4 cm wide, margins undulate. Inflorescence mostly solitary. Sepals depressed-ovate, 2 mm long, 2.3 mm wide, hairy. Petals 6, yellowish-green; petals of outer whorl triangular to ovate, 7.5–8.5 mm long, 4.5–5 mm wide; petals of inner whorl 3.2 mm long, 2.2 mm wide. Fruit obliquely obovoid, 20–24 mm long, 14–18 mm wide, red (Kerrigan *et al.* 2011).

It is frequently a small tree in the understorey but can reach 20 m in height (Liddle & Elliott 2008)

Ecology

This species grows in wet rainforests at springs or on spring-fed streams on permanently moist, organic substrates.

Distribution

In the NT, it is known only from Bathurst Island and the north-western part of Melville Island. It also occurs in a relatively restricted area at the northern tip of Cape York Peninsula, in Qld (AVH 2014).

Conservation Status

Endangered (TPWCA); Endangered (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	6	No. Locations (NE Bathurst Island):	2 (33% of total)
EoE km^2 (NT):	522	EoO km^2 (NE Bathurst Island):	1 (0.2% of total)
AoO ha (NT):	63	AoO ha (NE Bathurst Island):	15 (23% of total)

Xylopia monosperma has been recorded in 7 rainforest patches (or subpopulations), with 3 on Melville Island and four on Bathurst Island. Two subpopulations (28% of the total) occur within the northern Bathurst Island area. These were found to be very small, consisting of a few adults and some juveniles (Kerrigan *et al.* 2007e; Liddle & Elliott 2008; this study).

The species was listed as Endangered (under criteria B1ab(iii)+2ab(iii); D) based on: a small number of locations (<5); small number of mature individuals (<250); an extent of occurrence <5000 km2; an area of occupancy <500 km2; and a projected decline due to quality of habitat (Kerrigan *et al.* 2007e). Threats are similar to those for other wet rainforest taxa.

Significance of North East Bathurst Island populations

The subpopulations in the North East Bathurst Island area represent 23-33% of the NT population. These two supopulations both occur in wet rainforest patches on Dudwell Creek. Potential risks to the species in this area are excessive ground water extraction, weed invasion, and intensified fire regimes.

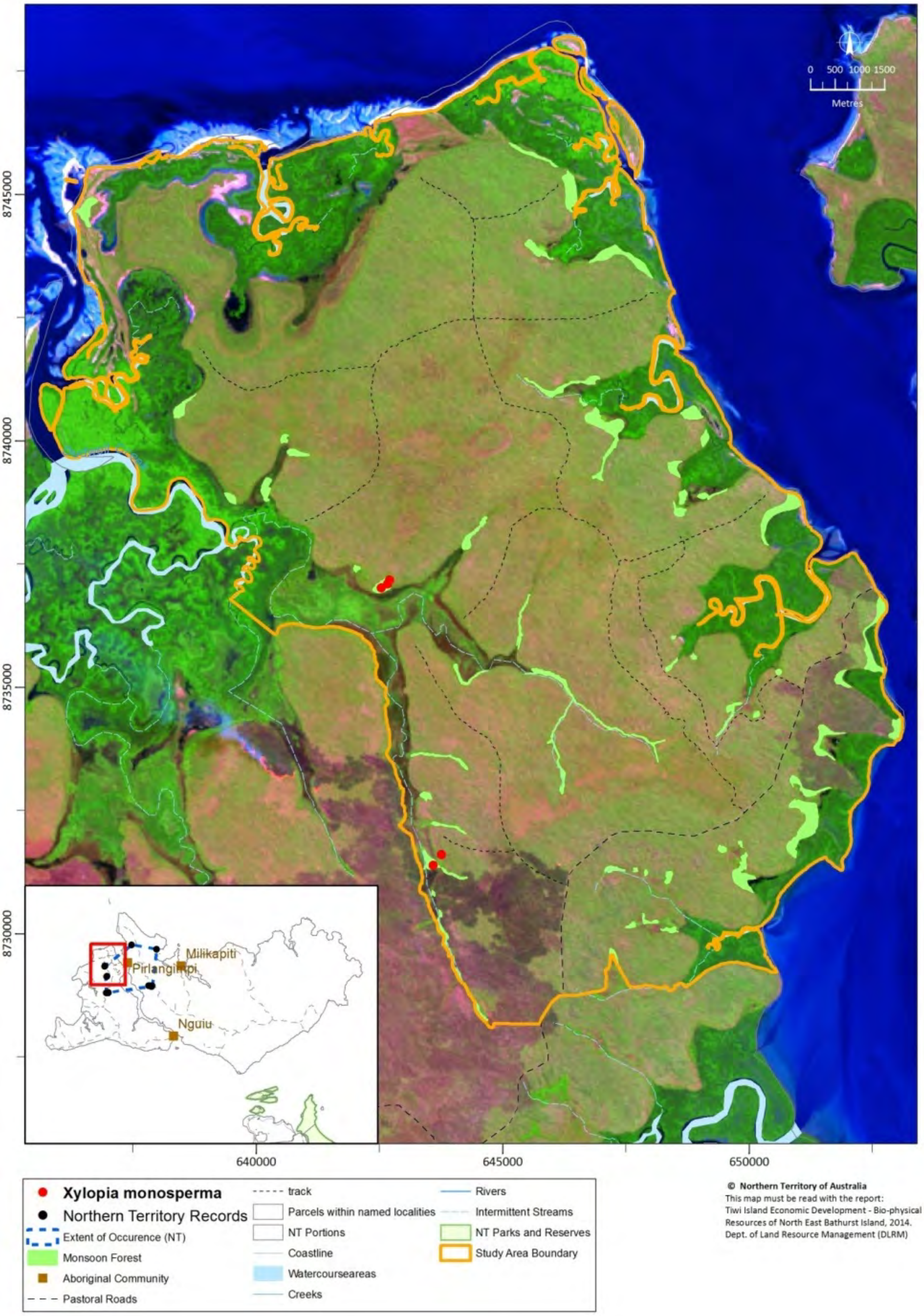


Figure 11-15: Location of *Xylopia monosperma* records in NE Bathurst Island.

Embelia tiwiensis **Family: PRIMULACEAE**

Description

A slender perennial vine. Leaves are alternate, elliptic to obovate, apex acuminate, with pale orange translucent glands evident when back-lit. Flowers and fruits are not known.

Ecology

Mostly occurs in evergreen, spring-fed rainforest but also known from the margin of a *Melaleuca* swamp abutting coastal vine thicket. It is typically found on permanently wet organic substrates, in the wettest part of the forest.

Distribution

Known mostly from Bathurst Island, with one record of a single plant from Fright Point on the Gunn Point peninsula.

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	10	No. Locations (NE Bathurst Island):	7 (70% of total)
EoE km^2 (NT):	1 477	EoO km^2 (NE Bathurst Island):	56 (4% of total)
AoO ha (NT):	51	AoO ha (NE Bathurst Island):	39 (76% of total)

It has been recorded in 16 discrete rainforest patches with 13 in the study area. The plant is relatively common where recorded.

It is likely that this taxon has been confused with *Embelia curvinervia* in previous surveys of the Tiwi Islands. No herbarium collections of the latter are known from these islands, although there are survey records from 21 discrete rainforest patches from the western half of Melville Island and Bathurst Island. While it is expected that these existing survey records actually represent *E. tiwiense*, this needs to be confirmed by field survey and collections.

It shares similar threats to other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

While the subpopulations in the study area appears to represent most of the entire known population, it is likely that this taxon has been confused with *Embelia curvinervia* in previous surveys of the Tiwi Islands. Assuming that the Melville Island records represent *Embelia tiwiense* then the study area contains around 35% of the population. In this area, the most likely threats to the species and its habitat appear to be excessively high ground water drawdown, grassy weed invasion and intensified fire regimes.

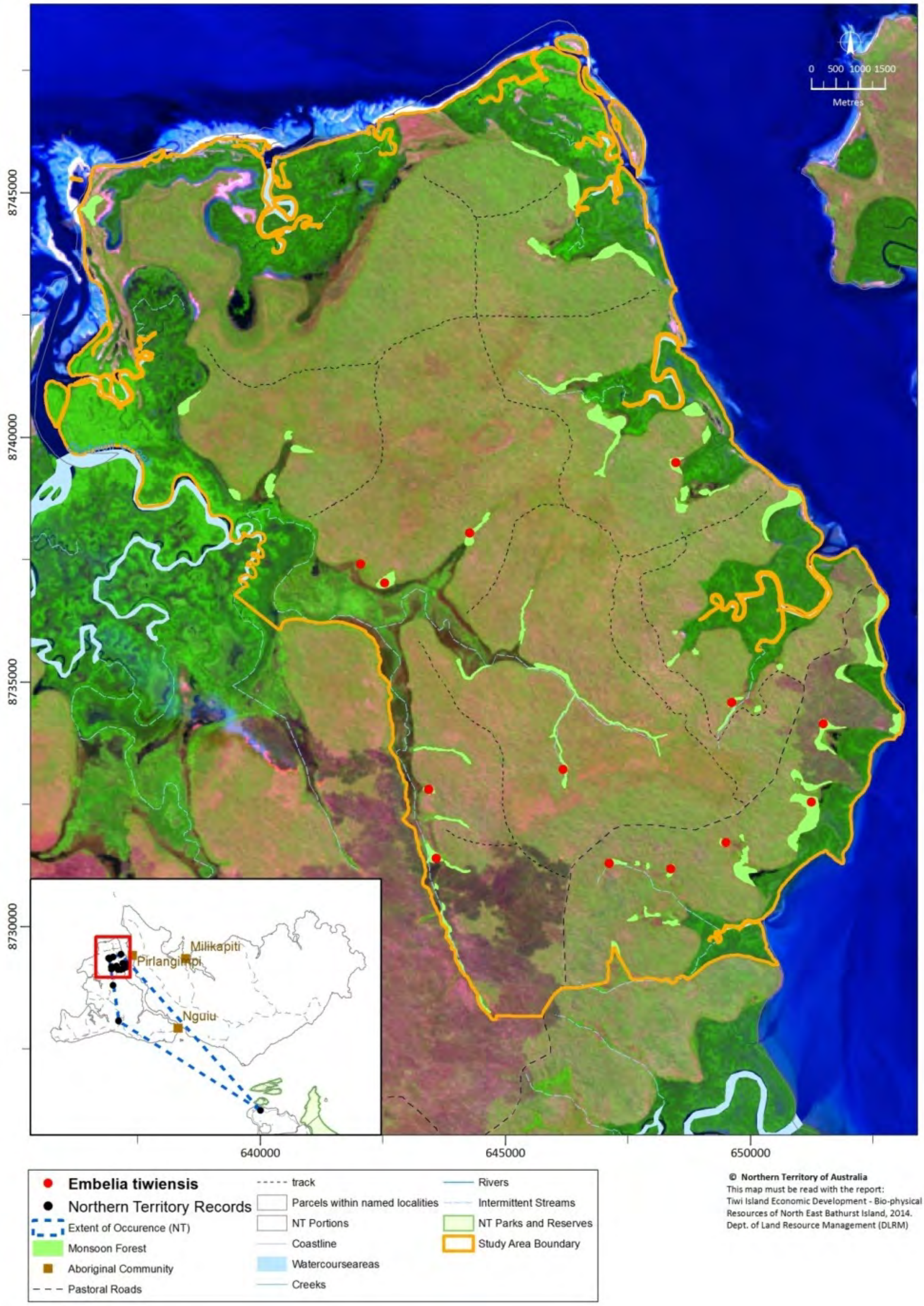
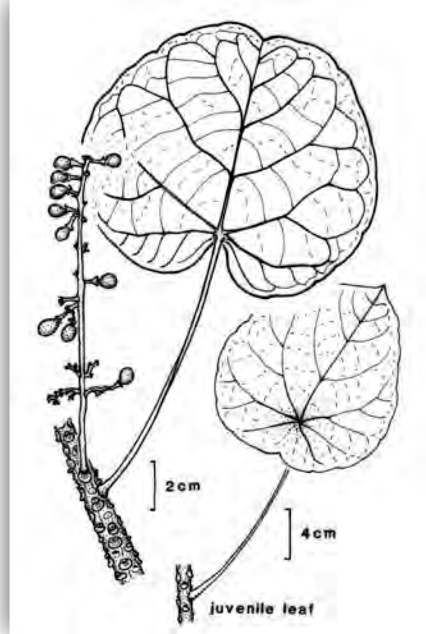


Figure 11-16: Location of *Embelia tiwiensis* records in NE Bathurst Island.

Endospermum myrmecophilum **Family: EUPHORBIACEAE**



Description

Tree to 35 m, with pale yellow to white smooth bark. Deciduous. Leaves spirally arranged. Adult leaves with petioles to 150 mm long; blades ovate to orbicular, 65-165 mm long, 60-146 mm wide, with 2 yellow-brown flattened glands at junction with petiole, margin entire with several small glands, apex rounded to shortly acuminate. Flowers are small. Fruits white, thinly fleshy, ellipsoid, c. 9 mm long, 7 mm diam. (Dunlop *et al.* 1995).

Ecology

Occurs in wet rainforests.

Distribution

In N.T., known from Bathurst Island, Melville Is., Channel Point, Reynolds River and Black Jungle; also recorded from New Guinea to the Solomon Islands, and on Cape York Peninsula.

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	42	No. Locations (NE Bathurst Island):	7 (17% of total)
EoE km^2 (NT):	2 0806	EoO km^2 (NE Bathurst Island):	73 (0.4% of total)
AoO ha (NT):	201	AoO ha (NE Bathurst Island):	42 (21% of total)

Subpopulations are known at 51 discrete rainforest patches with 14 (or 29%) in the study area. Subpopulations recorded during the survey were very small, typically less than five adults with no juveniles. This is thought to be normal for the taxon in NT.

Threats to this species are similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

The subpopulations in the North East Bathurst Island area represent up to 25% of the entire known population. Most populations were recorded in rainforest patches along the eastern and southern margins of the area and headwaters of Dudwell Creek. In this area, the most likely threats to the species and its habitat appear to be excessively high ground water drawdown, grassy weed invasion and intensified fire regimes.

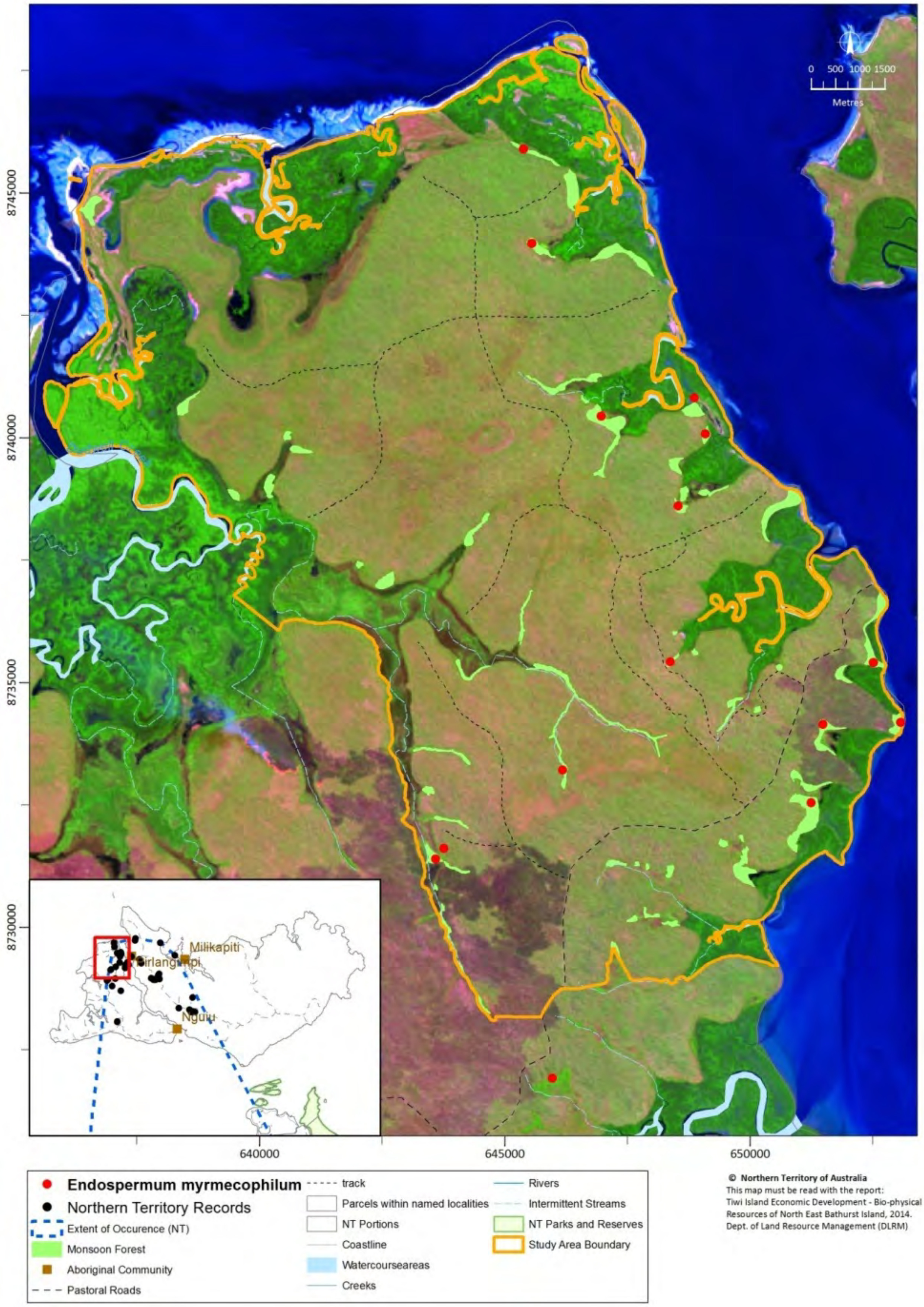


Figure 11-17: Location of *Endospermum myrmecophilum* records in NE Bathurst Island.

Melodinus australis **Family: APOCYNACEAE**

Description

A twining vine to 10m or more, with white latex. Leaves are alternate, 3-16 cm long and 0.5-6 cm wide. Flowers 4.5-7 mm long, cream-yellow. Fruit 4-15 cm long, orange-red when ripe. (Forster 1996)

Ecology

Grows in ever-wet rainforest.

Distribution

Known in N.T. from two disjunct areas – northern Bathurst Island and north-west Melville Island and near Lake Evella in Eastern Arnhem Land. It is widespread along the eastern coast of Australia from northern NSW to Cape York Peninsula.

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	23	No. Locations (NE Bathurst Island):	10 (44% of total)
EoE km^2 (NT):	11 393	EoO km^2 (NE Bathurst Island):	91 (1% of total)
AoO ha (NT):	111	AoO ha (NE Bathurst Island):	51 (46% of total)

This species has been recorded in 35 rainforest patches, with 23 from Bathurst Island, and six each from Melville Island and near Lake Evella. It was recorded at 17 rainforest patches in the study area.

Threats to the species are similar to others in this habitat, in particular changes in ground water hydrology resulting from excessively high water extraction, invasion by grassy weeds and increased vulnerability to fire.

Significance of North East Bathurst Island populations

The population in the study area represents 44 - 48% of the entire known population. In this area, the most likely threats to the species and its habitat appear to be excessively high ground water drawdown, grassy weed invasion, and intensified fire regimes.

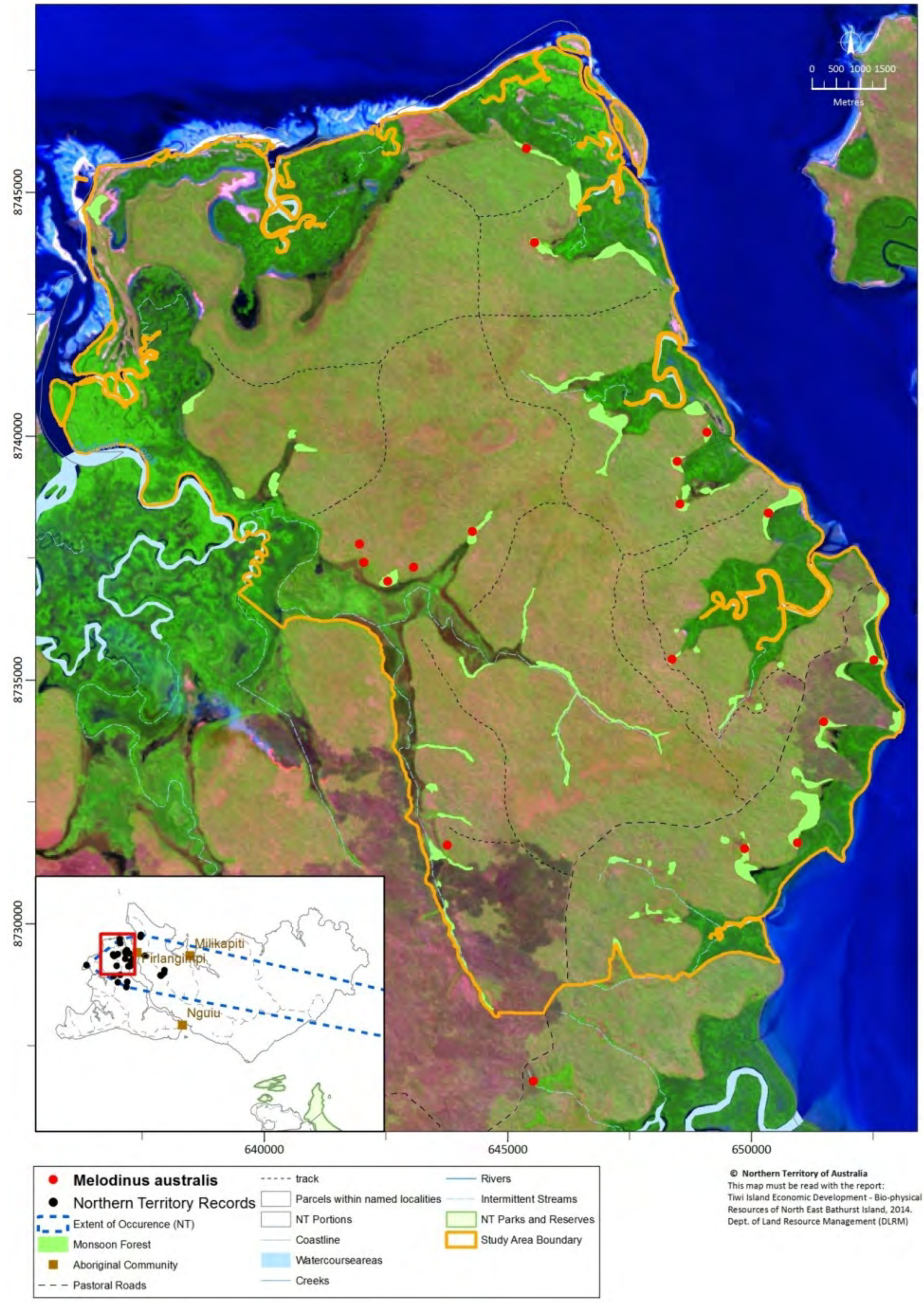


Figure 11-18: Location of *Melodinus australis* records in NE Bathurst Island.

Parsonsia **sp. Melville Island** **Family: APOCYNACEAE**

Description

This plant is a twining vine, with milky latex. Leaves are ovate, with a long leaf-stalk. Flowers are creamy white.

Insufficient collections are available to establish if it is a new species or represents a New Guinea or eastern Indonesian taxon.

Ecology

Grows in ever-wet rainforest at springs or on spring fed streams.

Distribution

It has been recorded only from the northern part of Bathurst Island and the western part of Melville Island.

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	23	No. Locations (NE Bathurst Island):	5 (22% of total)
EoE km^2 (NT):	1 645	EoO km^2 (NE Bathurst Island):	34 (2% of total)
AoO ha (NT):	114	AoO ha (NE Bathurst Island):	21 (18% of total)

Subpopulations are known at a total of 36 rainforest patches, with 9 on Bathurst Island including 7 in the study area and 20 on Melville Island. Subpopulations were small where the plant was recorded.

Threats to this species are similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands, in particular changes in ground water hydrology resulting from excessively high water extraction, invasion by grassy weeds and increased vulnerability to fire.

Significance of North East Bathurst Island populations

The North East Bathurst Island area subpopulations represent 19% of the total known. Survey records came from along Dudwell Creek and south of the Interview point Rd. The most likely threats to the species and its habitat in the study area appear to be excessively high ground water drawdown, grassy weed invasion, intensified fire regimes and feral pigs.

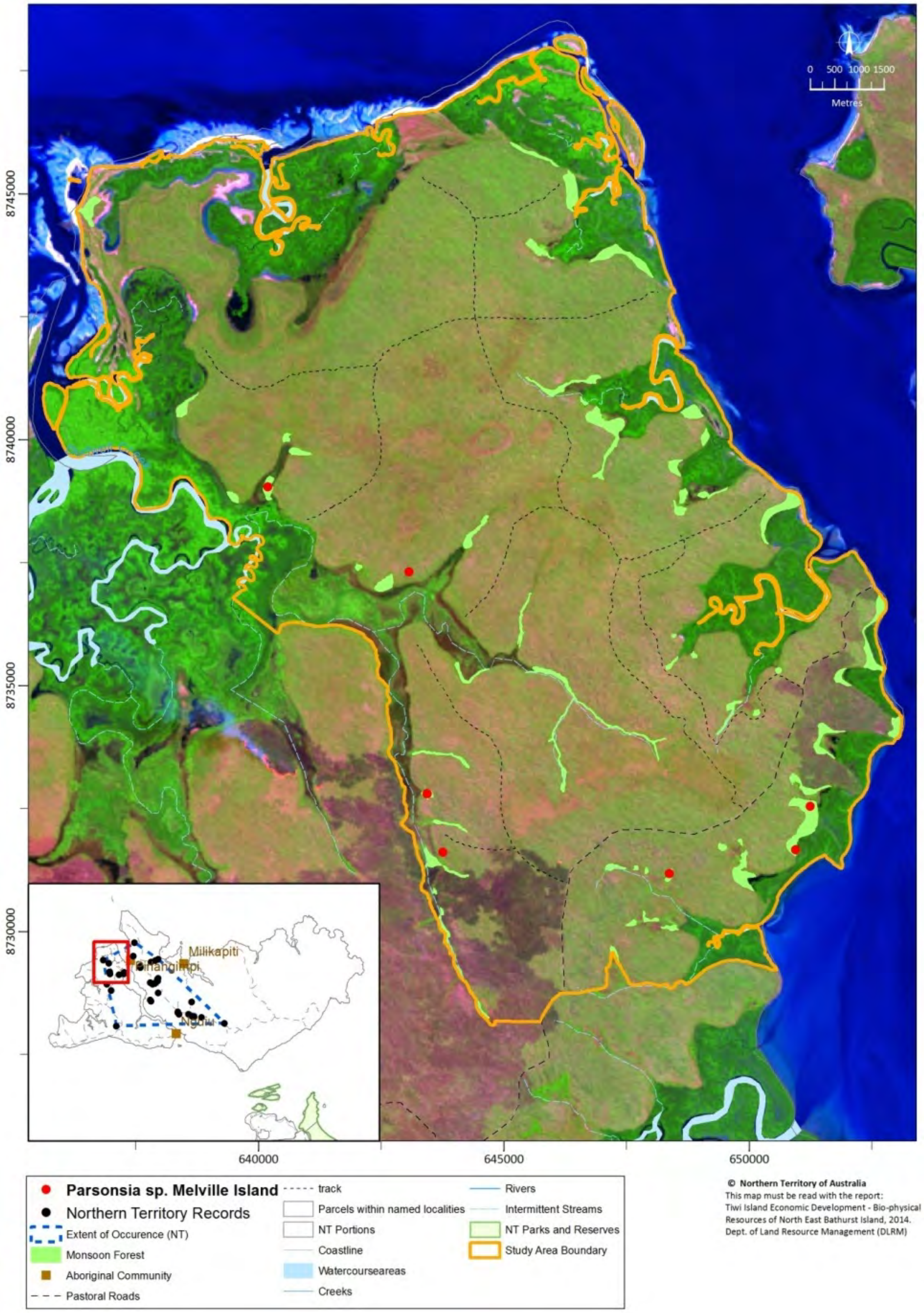


Figure 11-19: Location of *Parsonsia* sp. Melville Island records in NE Bathurst Island.

Psychotria coelosperma **Family: RUBIACEAE**

Description

This plant is a herb or slender vine climbing by roots adhering to the bark of its host. Leaves are opposite, and in juvenile plants narrowly elliptic.

Ecology

It has been recorded growing in ever-wet rainforest at springs or on spring fed streams. Usually found on permanently moist organic substrates, in the wettest part of the forest.

Distribution

Known in the NT from two distinct areas. Most records are from northern Bathurst Island and north-west Melville Island while other records are from near Lake Evella and south of Gove, in eastern Arnhem Land. It also occurs on Cape York Peninsula in Qld.

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	26	No. Locations (NE Bathurst Island):	7 (27% of total)
EoE km^2 (NT):	28 763	EoO km^2 (NE Bathurst Island):	61 (0.2% of total)
AoO ha (NT):	138	AoO ha (NE Bathurst Island):	48 (35% of total)

38 subpopulations are known with 17 at rainforest patches on Bathurst Island including 14 in the study area and 15 on Melville Island. Subpopulations were very small to several hundred individuals in size but mostly consisted of juveniles.

Threats to this species are similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

The subpopulations in the study area represent 27 - 37% of the entire known population. In this area, the most likely threats to the species and its habitat appear to be excessively high ground water drawdown, grassy weed invasion along with intensified fire regimes.

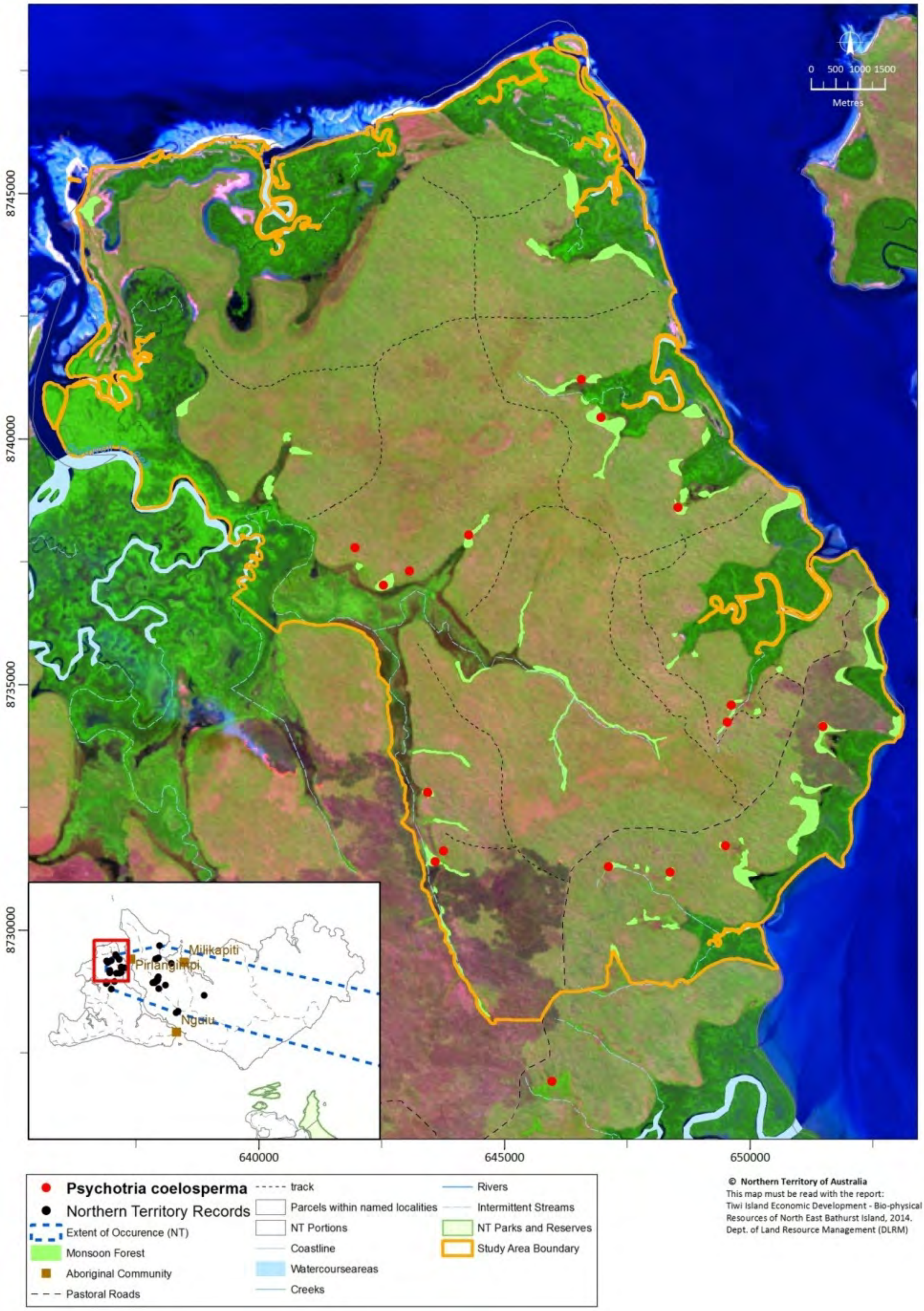


Figure 11-20: Location of *Psychotria coelosperma* records in NE Bathurst Island.

Strychnos minor **Family: LOGANIACEAE**

Description

A woody climber, with double tendrils. Leaves are opposite, lanceolate or narrowly ovate, with three longitudinal veins. Flowers are 4-5 mm long, white. Fruits are fleshy, globular, 2-4 cm diam., orange to yellow (Conn *et al.* 1996).

Ecology

Recorded as growing in evergreen, permanently wet rainforests associated with perennial springs and spring-fed streams. It appears to prefer more sandy soils that are permanently moist.

Distribution

In the NT, *Strychnos minor* is entirely restricted to the Tiwi Islands (northern Bathurst Island and western Melville Island). It also widely distributed from Sri Lanka to Papuasia and northern Australia, where it also occurs on Cape York Peninsula (Conn *et al.* 1996).

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	34	No. Locations (NE Bathurst Island):	10 (29% of total)
EoE km^2 (NT):	2 156	EoO km^2 (NE Bathurst Island):	99 (5% of total)
AoO ha (NT):	261	AoO ha (NE Bathurst Island):	81 (31% of total)

In total, 73 subpopulations are known, with 38 on Melville Island and 35 on Bathurst Island. Twenty five subpopulations are recorded in the study area.

Threats to this species are similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

The subpopulations in the North East Bathurst Island area represent around 30% of the entire known population. Excessively high ground water drawdown, grassy weed invasion with intensified fire regimes appear to be the most likely threats to the species and its habitat in this area.

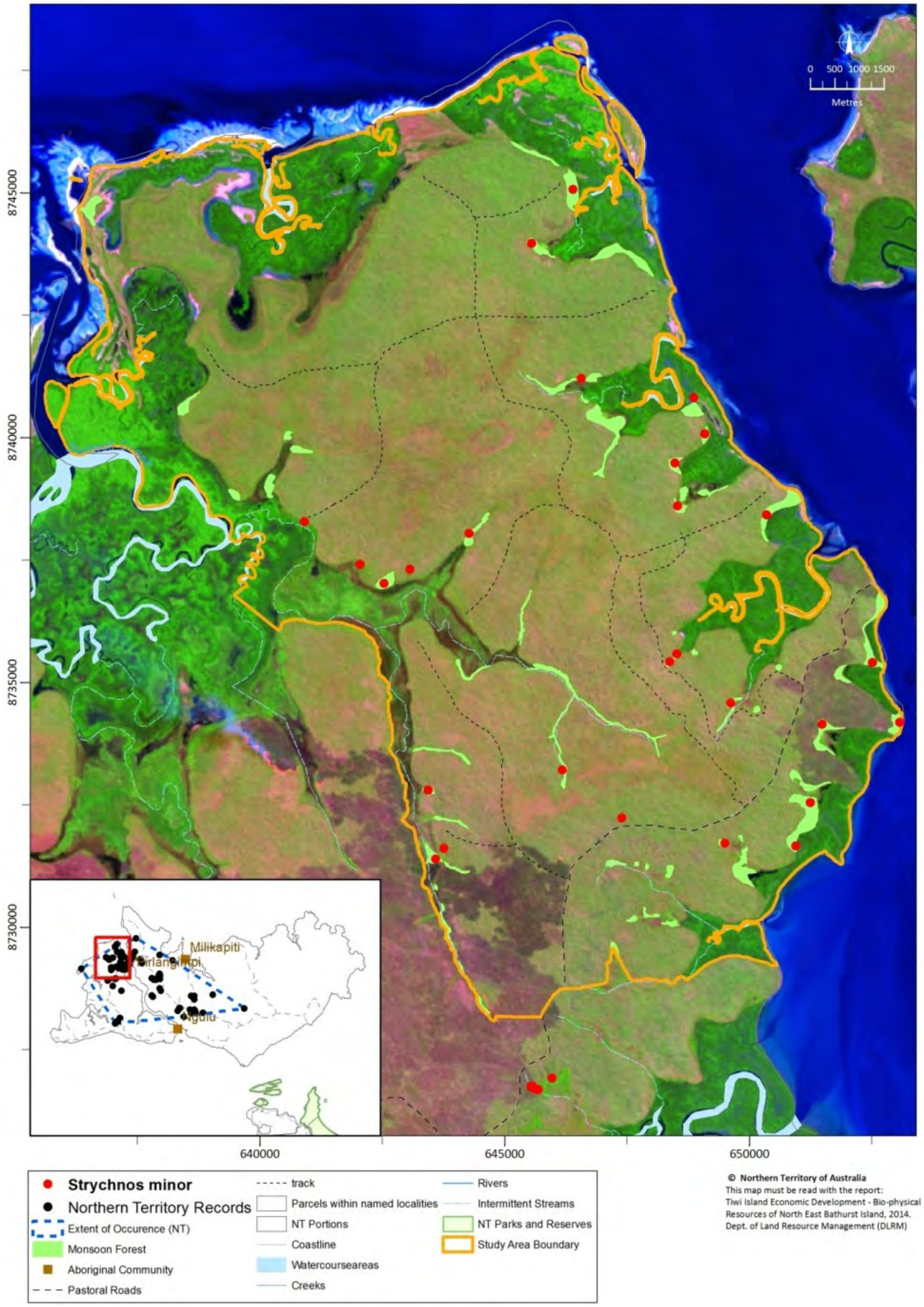


Figure 11-21: Location of *Strychnos minor* records in NE Bathurst Island.

Syzygium claviflorum **Family: MYRTACEAE**

Description

Evergreen *tree* or *shrub* to 25 m; glabrous, bark grey, lightly fissured. *Leaves* opposite; petioles c. 3 mm long; blades usually elliptic, 75-130 mm long, 27-50 mm wide, base attenuate, apex acute to acuminate. *Flower* buds clavate, 8-13 mm long. *Petals* 6-8, white, $\pm$ cohering and falling together. *Fruits* succulent, dark red to black, turbinate to ellipsoid, to 10 mm long. (Dunlop *et al.* 1995).

Ecology

Found in evergreen, permanently wet rainforests associated with perennial springs and spring-fed streams.

Distribution

In the NT, recorded only from Melville and Bathurst islands. Widely distributed from tropical Australia and New Guinea to China and India. In Qld, extending from near Mackay to Cape York Peninsula (Hyland 1983)

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	58	No. Locations (NE Bathurst Island):	9 (16% of total)
EoE km^2 (NT):	5 481	EoO km^2 (NE Bathurst Island):	115 (2% of total)
AoO ha (NT):	315	AoO ha (NE Bathurst Island):	93 (30% of total)

Widespread across Bathurst (41 subpopulations) and the western half of Melville islands (52 subpopulations).

Threats to this species are similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

Found in almost all rainforest patches surveyed in North East Bathurst Island (28 subpopulations) and one of the more common wet rainforest species restricted (in the NT) to the Tiwi Islands. The subpopulations in the study area represent around 30% of the entire known population in the NT. In this area, the most likely threats to the species and its habitat appear to be excessively high ground water drawdown, grassy weed invasion, and intensified fire regimes.

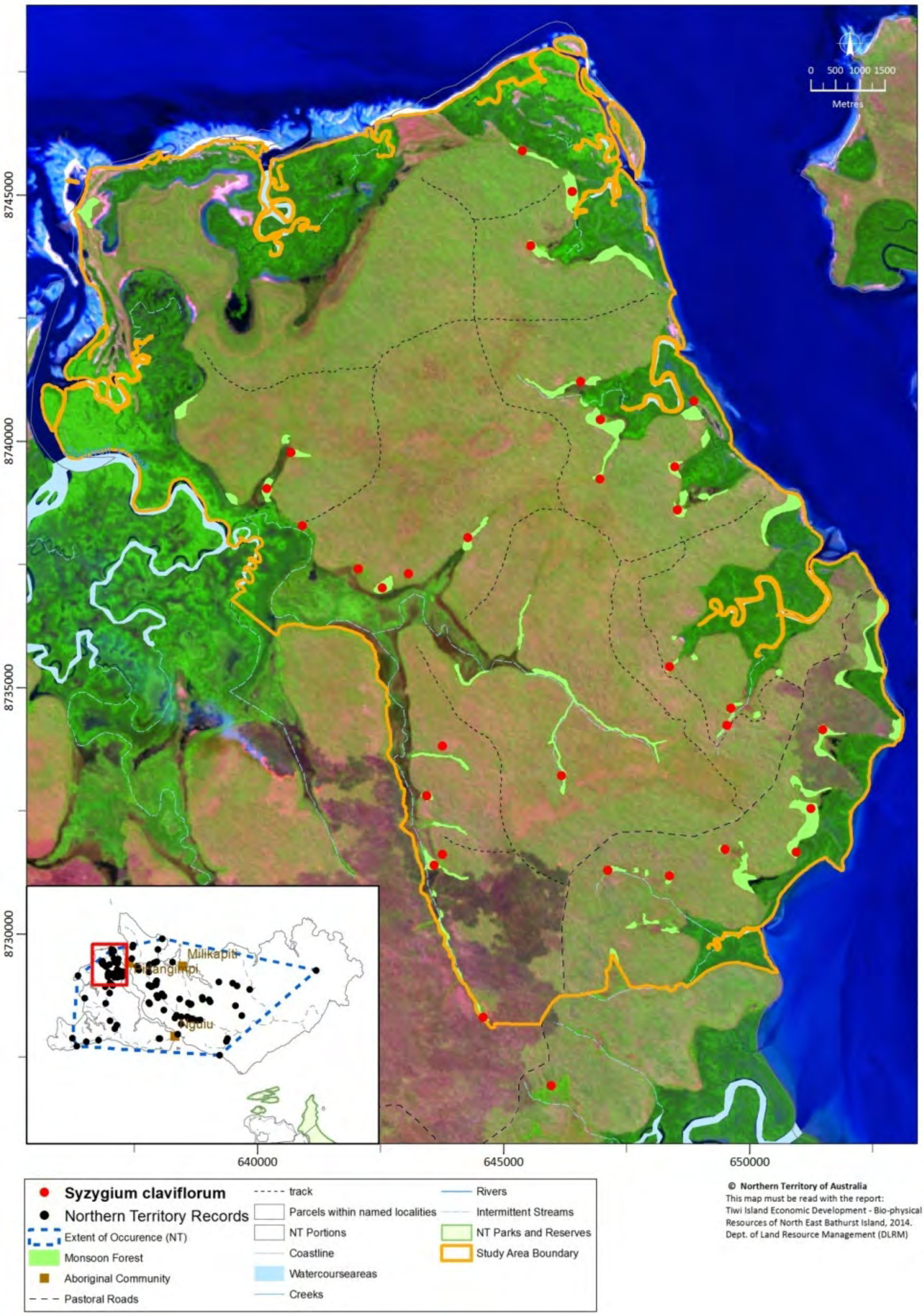


Figure 11-22: Location of *Syzygium claviflorum* records in NE Bathurst Island.

Syzygium forte **subsp. *forte*** **Family: MYRTACEAE**

Description

Tree to 25 m; bark usually flaky, reddish. Petioles 5-12 mm long. Leaf blades discolorous, subglaucous, oblanceolate, obovate or narrowly to broadly elliptic, 80-140 mm long, 32 72(80) mm wide, base attenuate, apex obtuse. Petals orbicular, c. 5 mm long. Fruit white, depressed globular, c. 25 mm long (Dunlop *et al.* 1995).

Ecology

Found in evergreen, permanently wet rainforests associated with perennial springs and spring-fed streams.

Distribution

In the NT, known mostly from Melville and Bathurst islands, with records from near Maningrida and Kakadu NP. Occurs in tropical Australia (Cape York Peninsula) and Papua New Guinea (Hyland 1983).

Conservation Status

Data Deficient (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	n.a.	No. Locations (NE Bathurst Island):	n.a.
EoE km^2 (NT):	n.a.	EoO km^2 (NE Bathurst Island):	75
AoO ha (NT):	27	AoO ha (NE Bathurst Island):	3 (30% of total)

This species is probably more common than indicated by the existing records as the two subspecies have not been distinguished in some surveys. Based on records determined to subspecies, it is known from 9 subpopulations in total, 2 rainforest patches on Bathurst Island and four on Melville Island and known. However, during the October 2014 survey 18 additional records were made. Previous rainforest survey data from the Tiwi Islands show 25 subpopulations of '*Syzygium forte'*, the majority of which probably represent this subspecies. These records are mostly from the western part of Melville Island and the northern part of Bathurst Island, a distribution pattern consistent with other wet rainforest species. Subspecies *potamophila* occurs along sandy watercourses mostly to the south and east of Darwin with very few records from the Tiwi Islands. If this argument is correct, then there are approximately 51 known subpopulations of *S. forte* subsp. *forte* in the NT with 19 from Bathurst Island and 17 (33% of total) of these from the study area.

Threats to this species are similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

While data require validation through further field survey and collecting, it is likely that around 30% of the subpopulations of this subspecies occur in the study area. It is probably one of the more common wet rainforest species in the area. In this area, the most likely threats to the species and its habitat appear to be excessively high ground water drawdown, along with grassy weed invasion and intensified fire regimes.

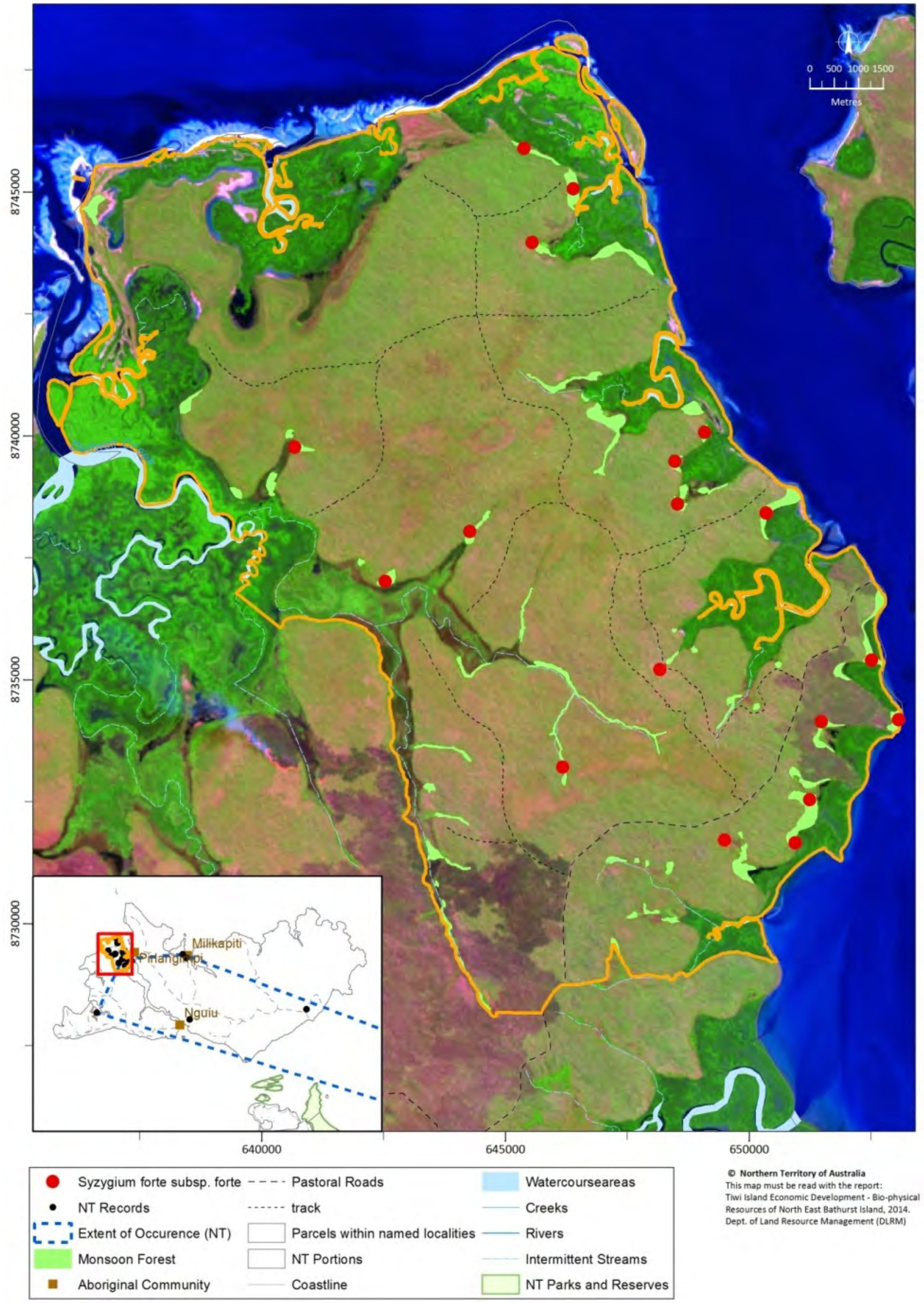


Figure 11-23: Location of *Syzygium forte* subsp. *forte* records in NE Bathurst Island.

Syzygium hemilamprum* subsp. *hemilamprum **Family: MYRTACEAE**

Description

Evergreen *tree* to 30 m; glabrous; bark reddish brown, fibrous. *Leaves* opposite; petioles 5-10 mm long; blades elliptic, lanceolate, 50-150 mm long, 27-68 mm wide, base attenuate, apex acute to acuminate. *Petals* white, c. 0.5 mm long. *Stamens* 0.5-1 mm long. *Fruit* succulent, white, depressed globular with a terminal cavity around the style base, c. 10 mm long (Dunlop *et al.* 1995).

This is the only subspecies in the NT.

Ecology

Commonly found in evergreen, permanently wet rainforests associated with perennial springs and spring-fed streams.

Distribution

Recorded from Croker, Melville and Bathurst islands in the NT. On the Australian east coast extending from Torres Strait to Port Macquarie (Hyland 1983).

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	43	No. Locations (NE Bathurst Island):	7 (16% of total)
EoE km^2 (NT):	9 462	EoO km^2 (NE Bathurst Island):	75 (1% of total)
AoO ha (NT):	228	AoO ha (NE Bathurst Island):	51 (22% of total)

Common across Bathurst Island (34 subpopulations), the western half of Melville Island (38 subpopulations) and Croker Island (6 subpopulations), with 78 recorded subpopulations in total. Seventeen subpopulations (21%) were recorded in the study area. It is a relatively common wet rainforest species within its restricted distribution.

Threats to this species are similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

Subpopulations in the study area represent around 20% of the entire known population in the NT. It was found to be reasonably widespread in rainforests in the area with the exception of northern parts of the area. The most likely threats to the species and its habitat appear to be excessively high ground water drawdown, grassy weed invasion, and intensified fire regimes in this area.

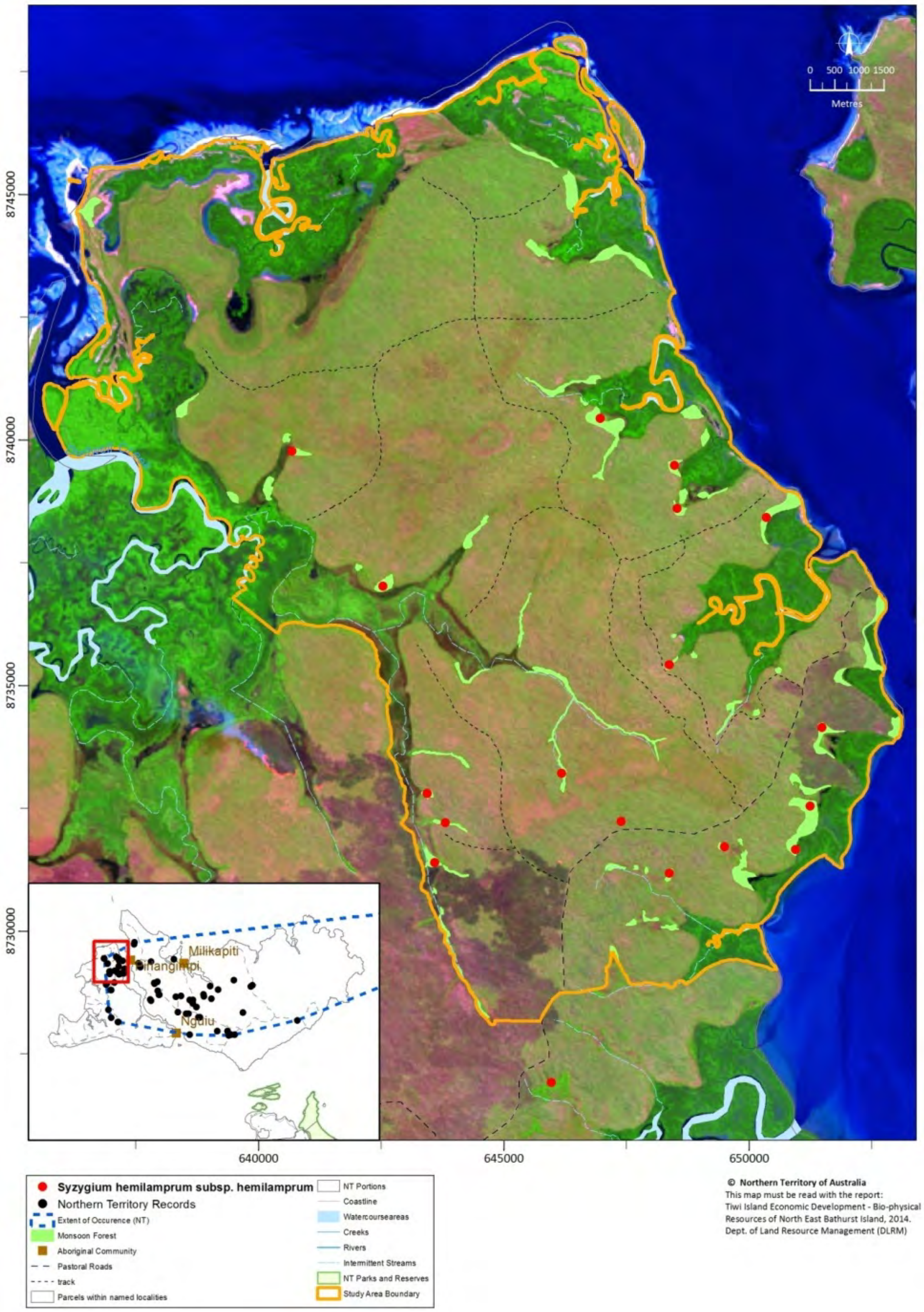
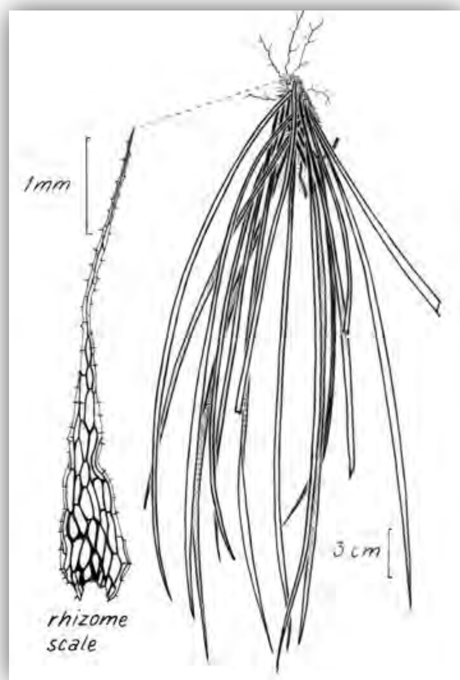


Figure 11-24: Location of *Syzygium hemilamprum* subsp. *hemilamprum* records in NE Bathurst Island.

Vittaria ensiformis **Family: PTERIDACEAE**

Description

Fronds crowded, forming a tussock, linear, 5-50 cm long, 0.25-0.6 cm wide, becoming pendulous with increasing size. Sore linear (Short & Dixon 2011).



Ecology

It commonly occurs as an epiphyte in evergreen, permanently wet rainforests favouring the rough bark of *Syzygium hemilamprum* trunks on Bathurst Island but it can also grow in sheltered rock crevices. It was seen lower down on tree trunks rather than in the canopy.

Distribution

Confined to the Top End of the N.T., with most collections from the Tiwi Islands but also recorded from Channel Point, Black Jungle and Nabarlek. In tropical and subtropical areas from southern Africa and Asia to Australia (N.T., Qld) and New Guinea.

Conservation Status

Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT):	25	No. Locations (NE Bathurst Island):	3 (12% of total)
EoE km^2 (NT):	36 039	EoO km^2 (NE Bathurst Island):	48 (0.1% of total)
AoO ha (NT):	144	AoO ha (NE Bathurst Island):	21 (22% of total)

The vast majority of subpopulations (37 of 42) of this species are from the northern parts of Bathurst and Melville islands, with 6 (14%) from the study area.

Threats to this species are broadly similar to those for other plant species restricted to evergreen, spring-fed rainforest on the Tiwi Islands.

Significance of North East Bathurst Island populations

The occurrences in the North East Bathurst Island area represent 12 - 22% of the known population. It occurs in rainforests in the east and south of the area and on Dudwell Creek.

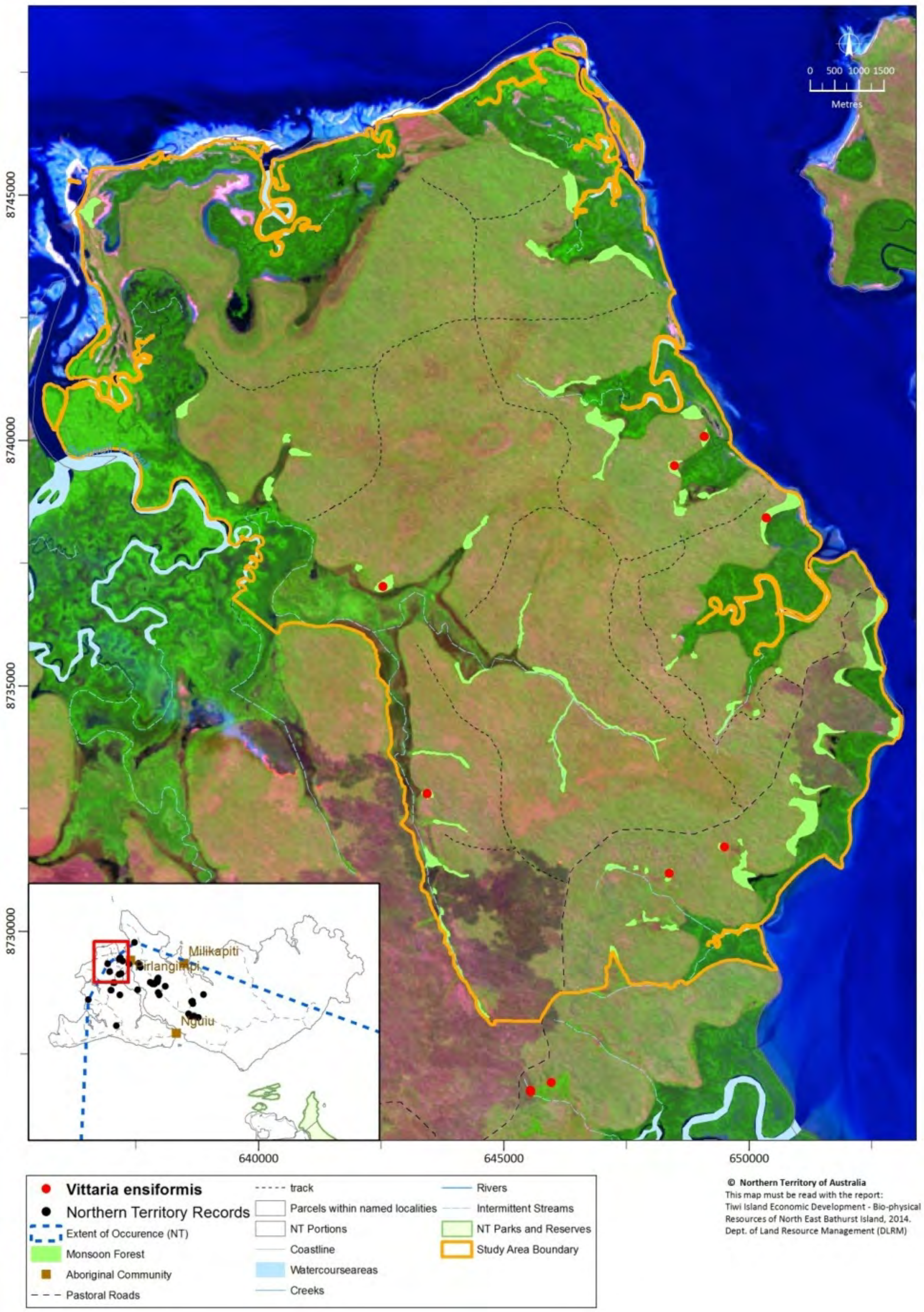
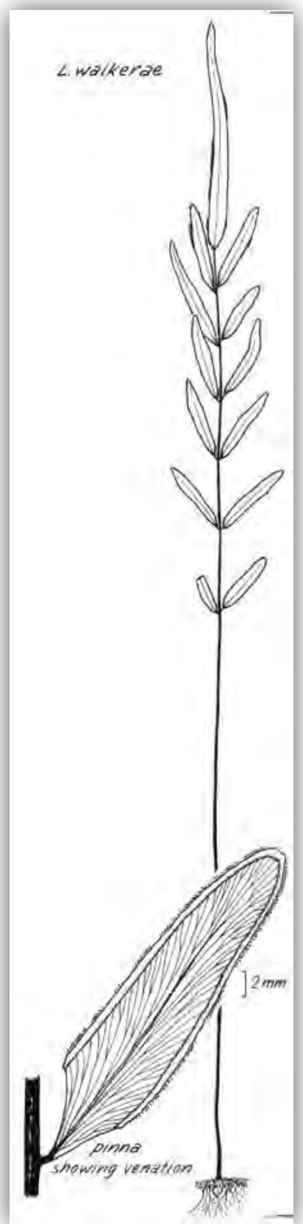


Figure 11-25: Location of *Vittaria ensiformis* records in NE Bathurst Island.

Swamps



Lindsaea walkerae **Family: LINDSAEACEAE**

Description

A terrestrial fern. Leaves pinnate, stems almost black, leaflets in 6-9 pairs, linear-lanceolate or linear-elliptic, veins free and forked 1-3 times, few joining together. Sori continuous are along the margins and mostly extending around the apices. (Short & Dixon 2011).

Ecology

Commonly occurs in peaty swamps dominated by *Dapsilanthus* on valley floors on Bathurst Island and at times recorded from the margins of spring-fed, evergreen rainforest.

Distribution

It is known in the NT from Bathurst and Melville islands as well as Cobourg Peninsula and near Lake Evella in eastern Arnhem Land. It extends from Sri Lanka to New Guinea, Micronesia and northern Australia (northern Qld and N.T.) (Kramer & McCarthy 1998).

Conservation Status Near Threatened (TPWCA); not listed (EPBC).

Key Parameters (see definitions in Table 7-2)

No. Locations (NT): 11

No. Locations (NE Bathurst Island): 3 (27% of total)

EoE km^2 (NT): 37 738

EoO km^2 (NE Bathurst Island): 4 (0% of total)

AoO ha (NT): 36

AoO ha (NE Bathurst Island): 12 (33% of total)

Four subpopulations have been recorded on North East Bathurst Island, three on Melville Island, two on Cobourg Peninsula, with one each on Croker Island and at Lake Evella.

There is a possibility that this taxon has been confused with the common species *L. ensifolia* in some surveys and some data points of the latter from the Tiwi Islands probably represent *L. walkerae.*

It is likely to be vulnerable to the effects of lowered ground water levels and reduced discharge of springs if these cause a drying out of its permanently wet swamp habitat. Regular fire is not likely to be a threat; the swampy areas it inhabits are dominated by sedge and Restionoid taxa such as *Scleria* and *Dapsilanthus* and appear to carry frequent fires even though the substrate is permanently wet.

Significance of North East Bathurst Island populations

The subpopulations in the North East Bathurst Island area represents up to a third of the entire known population. It was locally common in permanently wet, open swamp associated with

Dudwell Creek and appears to be relatively common in land unit 10c. The highest risks to the species are associated with changed hydrological regimes in that creek system.

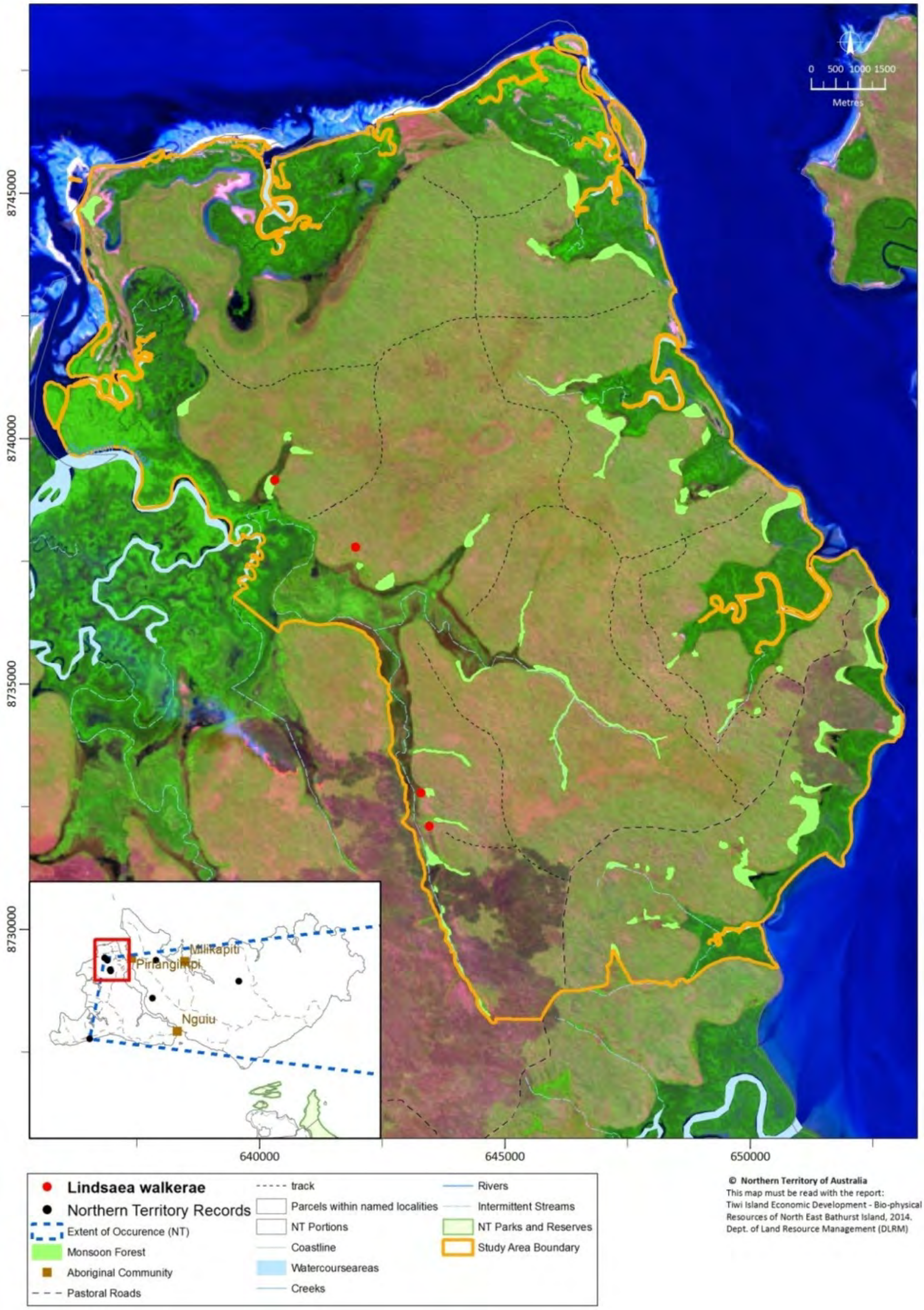


Figure 11-26: Location of *Lindsaea walkerae* records in NE Bathurst Island.

Appendix 12. Notable vertebrate species recorded from Bathurst Island

Species are considered notable because they are listed as threatened under the *Environment Protection and Biodiversity Conservation Act* (**EPBC**) or *Territory Parks and Wildlife Conservation Act* (**TPWC**) (VU=Vulnerable, EN=Endangered, CR=Critically Endangered); are a **subspecies** endemic to the Tiwi Islands; are listed under the International Convention on the Conservation of Migratory species (**BONN** Convention 1979); or are significantly more abundant within eucalypt forests on the Tiwi Islands than similar habitat on the mainland abundance (**TI>>M**). From Woinarski *et al.* (2003), with conservation status updated. Species in bold were targeted in the 2014 surveys.

Species	Common Name	Importance
Frogs		
Crinia remota	Remote Froglet	TI>>M
Uperoleia innundata	Floodplain Toadlet	TI>>M
Austrochaperina adelphe	Northern Territory Frog	TI>>M
Reptiles		
Heteronotia binoei	Bynoe's Gecko	TI>>M
Oedura rhombifer	Zig-zag Gecko	TI>>M
Lophognathus temporalis	Northern Water Dragon	TI>>M
Carlia munda	Striped Rainbow-skink	TI>>M
Cryptoblepharus cygnatus	Arboreal Snake-eyed Skink	TI>>M
Ctenotus borealis	Northern Ctenotus	TI>>M
Ctenotus essingtonii	Port Essington Ctenotus	TI>>M
Ctenotus hillii	Hill's Ctenotus	TI>>M
Eremoscincus douglasii	Douglas Skink	TI>>M
Menetia alanae	Alana's Menetia	TI>>M
Morelia spilota	Carpet Python	TI>>M
Boiga irregularis	Brown Tree Snake	TI>>M
Birds		
Accipiter fasciatus	Brown Goshawk	TI>>M
Erythrotriorchis radiatus	**Red Goshawk**	**EPBC:VU, TWPC:VU**
Turnix castanota	Chestnut-backed Button-quail	TI>>M
Psitteuteles versicolor	Varied Lorikeet	TI>>M
Aprosmictus erythropterus	Red-winged Parrot	TI>>M
Centropus phasianinus	Pheasant Coucal	TI>>M
Tyto novaehollandiae	**Masked Owl**	**TI>>M, Endemic subsp., EPBC:EN, TWPC:EN**
Podargus strigoides	Tawny Frogmouth	TI>>M
Eurostopodus argus	Spotted Nightjar	TI>>M

Species	Common Name	Importance
Aegotheles cristatus	Australian Owlet-nightjar	TI>>M
Merops ornatus	Rainbow Bee-eater	BONN
Pardalotus striatus	Striated Pardalote	Endemic subsp.
Philemon buceroides	Helmeted Friarbird	TI>>M
Lichenostomus flavescens	Yellow-tinted Honeyeater	TI>>M, Endemic subsp.
Melithreptus albogularis	White-throated Honeyeater	TI>>M
Lichmera indisticta	Brown Honeyeater	Endemic subsp.
Melanodryas cucullata	Hooded Robin	Endemic subsp., EPBC:EN, TWPC:CR
Pachycephala rufiventris	Rufous Whistler	TI>>M
Collurincincla harmonica	Grey Shrike-thrush	TI>>M
Myiagra rubecula	Leaden Flycatcher	TI>>M, BONN
Rhipidura rufiventris	Northern Fantail	TI>>M
Dicrurus bracteatus	Spangled Drongo	TI>>M
Coracina papuensis	White-bellied Cuckoo-shrike	TI>>M
Orious sagittatus	Olive-backed Oriole	TI>>M
Cracticus nigrogularis	Pied Butcherbird	TI>>M
Mammals		
Sminthopsis butleri	**Butler's Dunnart**	**EPBC:VU, TWPC:VU**
Isoodon macrourus	Northern Brown Bandcoot	TI>>M
Macropus agilis	Agile Wallaby	TI>>M
Trichosurus vulpecula	Common Brush-tailed Possum (Top End)	TI>>M
Pteropus scapulatus	Little Red Flying-fox	TI>>M
Conilurus penicillatus	**Brush-tailed Rabbit-rat**	**TI>>M, Endemic subsp., EPBC:VU, TWPC:EN**
Rattus tunneyi	**Pale Field-rat**	**TWPC:VU**

Appendix 13. Threatened fauna species profiles

Brush-tailed Rabbit Rat ***Conilurus penicillatus***

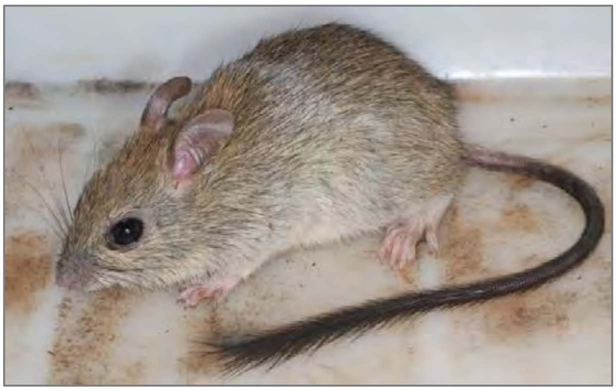
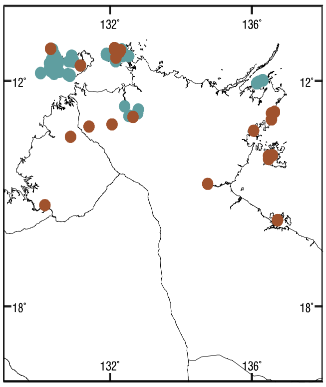



Figure 13-1: Brush-tailed Rabbit Rat and distribution map in the Northern Territory. Blue dots – recent records; brown dots – records older than 10 years.

Description

Rodent, head-body 135-227 mm, tail 102-235mm, average weight 163 g (males), 144 g (females) (Van Dyke & Strahan 2008)

Ecology

Semi-arboreal, in eucalypt open forest and woodland, diet primarily of perennial grass and their seeds (Firth et al 2005), breeding season March to October.

Distribution

Historic range comprises near-coastal woodlands and open forests around much of the Top End of the NT north of Katherine (Dahl 1897). The species is now restricted to two mainland (Cobourg Peninsula, Kakadu National Park) and four island (Bathurst Is, Melville Is, Ingliss Is, Groote Eylandt) populations. Other population also occur in Queensland (one island in the Gulf of Carpentaria), far north Kimberley, Western Australia, and southern New Guinea. The Tiwi Island populations are considered to be an endemic subspecies *Conilurus penicillatus melibius.*

Conservation Status

EPBCA – Vulnerable; TPWCA – Endangered; Woinarski *et al.* (2014) – Vulnerable

Over the past 10 years large areas of suitable habitat on Melville Island were cleared for *Acacia mangium* plantations. The mainland population in Kakadu National Park may have recently disappeared; the population on the Cobourg Peninsula has declined; the population on Ingliss Island persists but may have declined and the status on Groote Eylandt is poorly known but it appears to be rare there. Firth *et al* (2010) predicted that at current rates of decline the species could become extinct on the mainland within 10 years. Predation by feral cats, possibly enhanced by inappropriate late-season fire regimes, has been identified as one potential driver of declines (Woinarski *et al*. 2007, 2014).

North East Bathurst Island

This species had been recorded at 10 localities in North East Bathurst Island prior to 2014. It was recorded at 19 trapping sites during the 2014 survey and is predicted to occur in eucalypt forest and woodland throughout the study area.

Links

http://www.lrm.nt.gov.au/__data/assets/pdf_file/0015/10824/brush-tailed_rabbit-rat_EN_FINAL.pdf
http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=132

Pale Field Rat ***Rattus tunneyi***

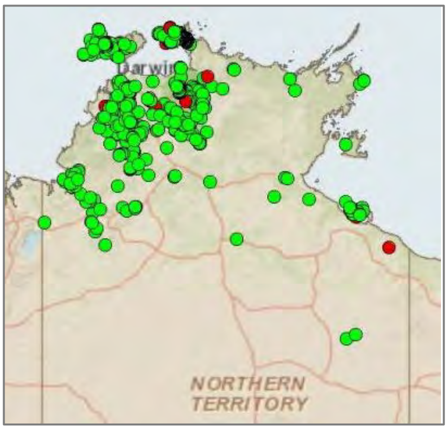


Figure 13-2: Pale Field Rat and distribution map in the Northern Territory. Green dots – post 1970, red dots – pre 1971.

Description

Rodent, head-body 100-210 mm, tail 100-162 mm, average weight 118 g (Van Dyke & Strahan 2008)

Ecology

Mostly restricted to eucalypt open forest/woodland and areas with soft sandy soils along watercourses, diet of grass stems, bases and seeds, colonial burrowing, breeding season January to August.

Distribution

Historically occurred over much of Australia but now largely confined to far northern NT, the Kimberley in WA, and parts of eastern Australia (Braithwaite & Griffiths 1996). The north-western Australian populations are regarded as a subspecies *Rattus tunneyi tunneyi.*

Conservation Status

EPBCA - not listed; TPWCA – Vulnerable; Woinarski *et al.* (2014) – Near Threatened

The species has undergone a dramatic range contraction to the north, as well as declines in these northern regions. In drier parts of its range populations typically underwent 'boom-bust' cycles in response to extreme climatic variability but across the northern Top End it is difficult to explain its current sustained decline in these terms. No single factor has been identified as a major cause for decline but contributing factors could include enhanced predation linked to adverse fire regimes, trampling of fragile burrow systems by large feral animals (cattle, horses, donkeys, and buffalo), disease, displacement by invasive *Rattus rattus* populations and low intrinsic dispersal ability (Braithwaite & Griffiths 1996, Woinarski *et al* 2010).

North East Bathurst Island

This species had been recorded at 11 localities in North East Bathurst prior to 2014. It was detected at 13 sites during the 2014 survey, throughout most of the study area but not from the most northerly sites.

Links

http://www.lrm.nt.gov.au/__data/assets/pdf_file/0010/143101/pale-field-rat_VU_FINAL.pdf

Butler's Dunnart **Sminthopsis butleri**

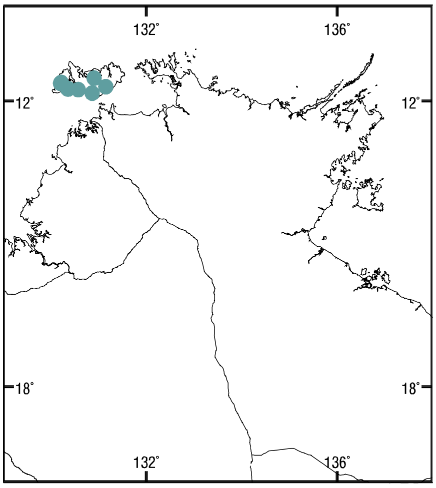


Figure 13-3: Butler's Dunnart and distribution map in the Northern Territory.

Description

Small carnivorous marsupial, head-body length 88 mm, tail 90 mm, average weight 15-30 g (Van Dyke & Strahan 2008)

Ecology

Little known, solitary, ground-dwelling, diet of invertebrates and small vertebrates, mostly recorded in tall eucalypt forest.

Distribution

Restricted to parts of the Tiwi islands and a small area of the northern Kimberley, WA (although it has not been recorded from WA since the initial three specimens were collected in 1965-6).

Conservation Status

EPBCA – Vulnerable; TPWCA – Vulnerable; Woinarski *et al.* (2014) – Near Threatened

Requires special protocols to sample or monitor effectively. Potential threats include land clearing, habitat degradation from weeds, and predation by feral cats and adverse fire regimes. On Melville Island, c 300 km^2 of potential habitat was cleared for *Acacia mangium* plantations in the past two decades (Woinarski 2004, Ward & Woinarski 2012).

North East Bathurst Island

There are no records of this species from North East Bathurst Island prior to 2014, although there had been no targeted sampling there. It was not captured in traps in the 2014 survey, but small dasyurids recorded by cameras at three sites are likely to be this species.

Links

http://www.lrm.nt.gov.au/__data/assets/pdf_file/0016/10834/Butlers_dunnart_VU_FINAL.pdf
http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=302
http://www.environment.gov.au/resource/national-multi-species-recovery-plan-carpentarian-antechinus-pseudantechinus-mimulus

Tiwi Masked Owl **Tyto novaehollandiae**

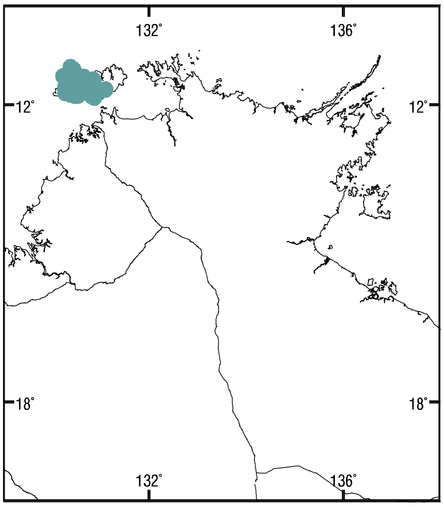


Figure 13-4: Tiwi Masked Owl and distribution map in the Northern Territory.

Description

Large owl, 33-42 cm (male), 38-57 cm (female) (del Hoyo et al (1999)

Ecology

Roosts and nests in hollows in tall eucalypt open forest, sedentary predator of small mammals, with prey mostly taken from the ground (Kavanagh & Murray 1996).

Distribution

The subspecies *melvillensis* is endemic to the Tiwi Islands, where it is reasonably widespread in tall eucalypt open forest. Subspecies *kimberli* occurs in the forest and woodland across northern Australia, and other subspecies in south-western, eastern and southern Australia.

Conservation Status

EPBCA – Endangered; TPWCA – Endangered; Garnett *et al.* (2010) - Endangered

Total population was estimated to comprise around 2 500 individuals (Garnett *et al.* 2010), but this was possibly reduced after large areas of suitable habitat were cleared on Melville Island for Ac*acia mangium* plantations between 2000 and 2009. The main direct threat is vegetation clearing, particularly removal of large trees with suitable roosting/nesting hollows, but indirect threats such as adverse fire regimes, feral animal activity, weeds and cyclones could affect habitat structure and prey availability (Woinarski & Ward 2012).

North East Bathurst Island

Masked Owls were recorded at 14 (22%) of the broadcast sites during the 2014 survey and appear to be fairly uniformly distributed throughout open forest habitat in the study area.

Links

http://www.lrm.nt.gov.au/__data/assets/pdf_file/0020/10856/Masked_owl_Tiwi_VU_FINAL.pdf
http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=26049
http://www.environment.gov.au/resource/national-multi-species-recovery-plan-partridge-pigeon-eastern-subspecies-geophaps-smithii

Red Goshawk **Erythrotriorchis radiatus**

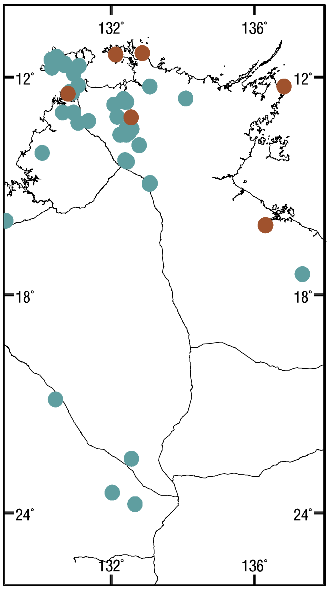


Figure 13-5:
Red Goshawk and distribution map in the Northern Territory.
Blue dots – recent records
Brown dots – records older than 10 years

Description

A relatively large raptor, 46-51 cm (males), 57-67 cm (females) (Simpson & Day 1986)

Ecology

Large territory size up to 200 km^2, sedentary, mostly a predator of birds, nests typically placed in the tops of emergent canopy trees within locally dense patches of open forest or along riparian corridors.

Distribution

Occurs sparsely in suitable habitat across northern and eastern Australia, possibly dispersive into central Australia.

Conservation Status

EPBCA – Vulnerable; TPWCA – Vulnerable; Garnett *et al.* (2010) – Near Threatened

The total population on Melville Island was estimated to be around 120 birds before large areas of suitable habitat were cleared for *Acacia mangium* plantations during the 2000's (Garnett & Crowley 2000). Land clearing and habitat fragmentation is the main threat to the species generally, but they may also be impacted by a range of factors that reduce prey abundance; their nests, which are typically placed in the tops of emergent canopy trees within locally dense patches of forest, may be periodically destroyed in violent storms and cyclones (Baker-Gabb 2012).

North East Bathurst Island

The species has been recorded at two localities in North East Bathurst Island (just south of the study area) prior to 2014. There were two possible, but no confirmed, sightings of birds during the 2014 survey and no nests were located.

Links

http://www.lrm.nt.gov.au/__data/assets/pdf_file/0004/10867/Masked_Owl_kimberli_VU_FINAL.pdf
http://www.environment.gov.au/cgi-bin/sprat/public/publicspecies.pl?taxon_id=942
http://www.environment.gov.au/resource/national-recovery-plan-red-goshawk-erythrotriorchis-radiatus

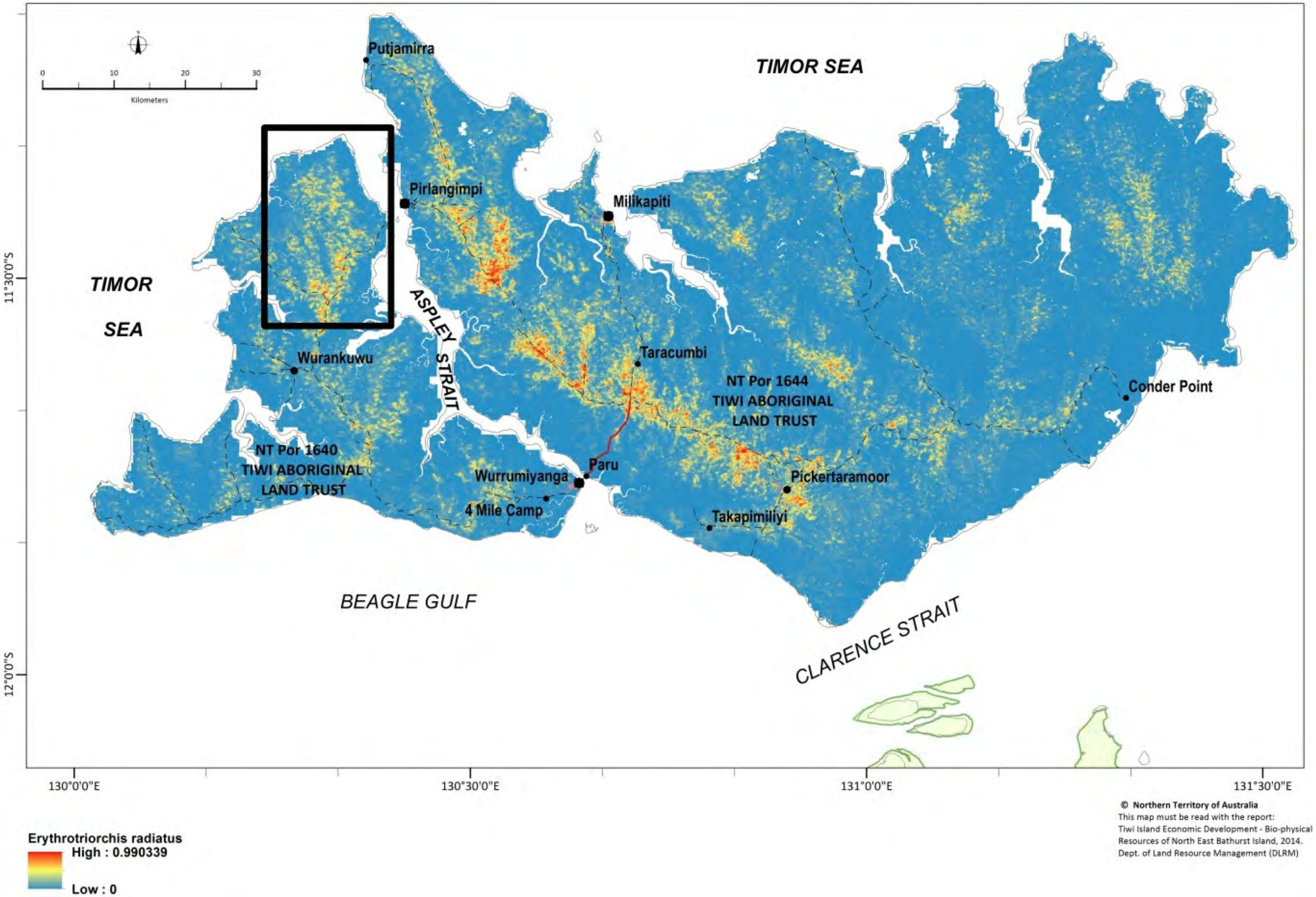
Appendix 14. Trapping data from 2014 fauna survey

For each site, the number of animals captured in box or pit traps is shown, and ‘c’ indicates species was recorded by cameras. For sites, M=sampled in May; N=sampled in November; c=cameras set at site. *=provisional identification.

SPECIES	SITES																																							
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
	M	Mc	M	M	Mc	M	Mc	Mc	M	Mc	M	M	Mc	Mc	Mc	Mc	Mc	M	M	Mc	Mc	Mc	M	M	M	Mc	M	Mc	N	Nc	N	N	Nc	Nc	N	Nc	N	Nc	N	Nc
Mammals																																								
Isoodon macrourus	1	c	2		3c	3	c	3c		1c	3	2	1c	c	1c	c	c	1	1	2c	3c	2c	1c	4	4	1c	3	c		2c			c	1c		c		c		c
Petaurus breviceps																																							2	
Trichosurus vulpecula		3c	2	3	5c		2c	1c		3c	2	2	c	1c	c	6c	4c	3	3	5c	5c	4c	6c	6	2	3c	3	2c	4	c	1	2	1c	2c	2	1c	1	1c	4	4c
Macropus agilis																													2	c	1		c	c		c		1	1	C
Conilurus penicillatus			1	1	1c		c	c		1c	3		c								1c	2c	c			c		1c	2	2c		1	c	2c		c	1	c		1c
Pseudomys delicatulus																			1																					
Melomys burtoni	1	1				1											1			1							1						c					1		1
Rattus tunneyi				1			c	1c	1	1			2					4						3	1				3	c	3		2	c					4	
Sminthopsis butleri *																																	c	c						c
Canis lupus																																						c		c
Frogs																																								
Litoria nasuta																								1																
Austrochaperina adelphe										2																														
Uperoleia				1			10		22	5	3	1					1														1								4	
Reptiles																																								
Heteronotia binoei	4			1			2				2									1				1							1					1		1		1
Oedura rhombifer																1															1									
Delma borea	1															2																								
Lialis burtonis											1																													
Carlia munda	1								2	1	2					2			3					1		1			2	2	3	5	2	1	6	6	3	2	6	
Cryptoblepharus sp.										1									4																					
Cryptoblepharus cygnatus																														3		1	2	2	2	1	2	1	1	
Cryptoblepharus	1										1	1													2			1												

SPECIES	SITES																																						
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**
	M	**Mc**	**M**	**M**	**Mc**	**M**	**Mc**	**Mc**	**M**	**Mc**	**M**	**M**	**Mc**	**Mc**	**Mc**	**Mc**	**Mc**	**M**	**M**	**Mc**	**Mc**	**Mc**	**M**	**M**	**M**	**Mc**	**M**	**Mc**	**N**	**Nc**	**N**	**N**	**Nc**	**Nc**	**N**	**Nc**	**N**	**Nc**	**N**	**Nc**
metallicus																																								
Ctenotus sp.																1																								
Ctenotus essingtonii				6			4		2	3	5	3	1	1		2	2			1				1	1	4	1	6	2	4	1	1	2	1	6		1	3	1	2
Eremiascincus douglasi	1			1																										4		1		1	3	7	7	9	10	9
Glaphyromorphus darwiniensis	2			1					1	1									1	2								1		1										
Morethia ruficauda																																		1						2
Morethia storri											2						3			1						1						1	2		1	1				
Gowidon temporalis											1									1								1							1		1			
Diporiphora bilineata	2								1			1														1		1		2										
Varanus scalaris	1																																							
Varanus tristis	1																1																1							1
Demansia olivacea																1																								1

Appendix 15. MaxEnt fauna models



Output of MaxEnt models for the distribution of five threatened vertebrate species within the Tiwi Islands, based on all known records in that area.

Predictor variables and modelling approach is described in Section 7.2.2.3.

Orange and red colours indicate higher likelihood of suitable habitat.

Figure 15-1: Red Goshawk *Erythrotriorchis radiatus.*

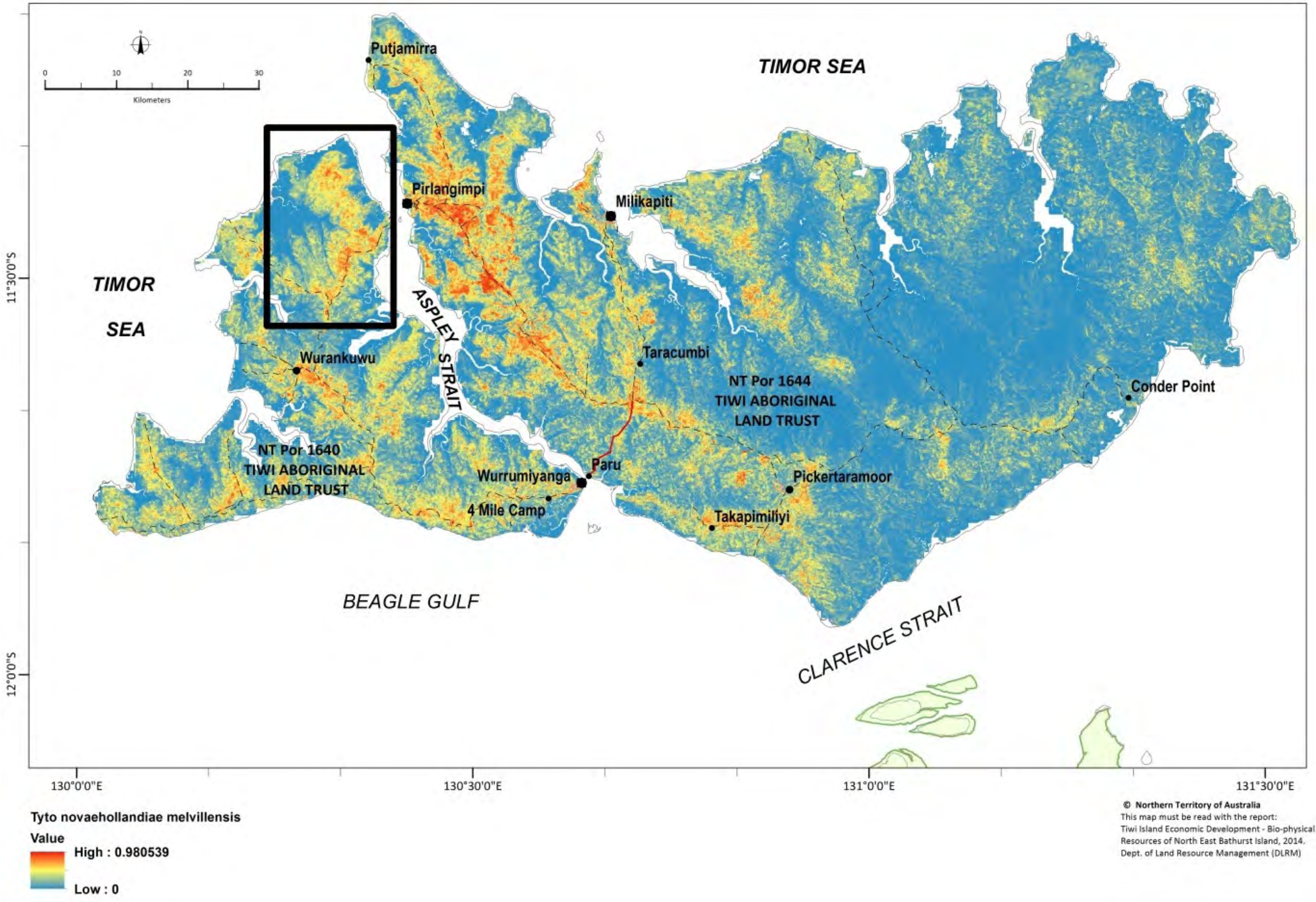


Figure 15-2: Tiwi Masked Owl *Tyto novaehollandiae melvillensis.*

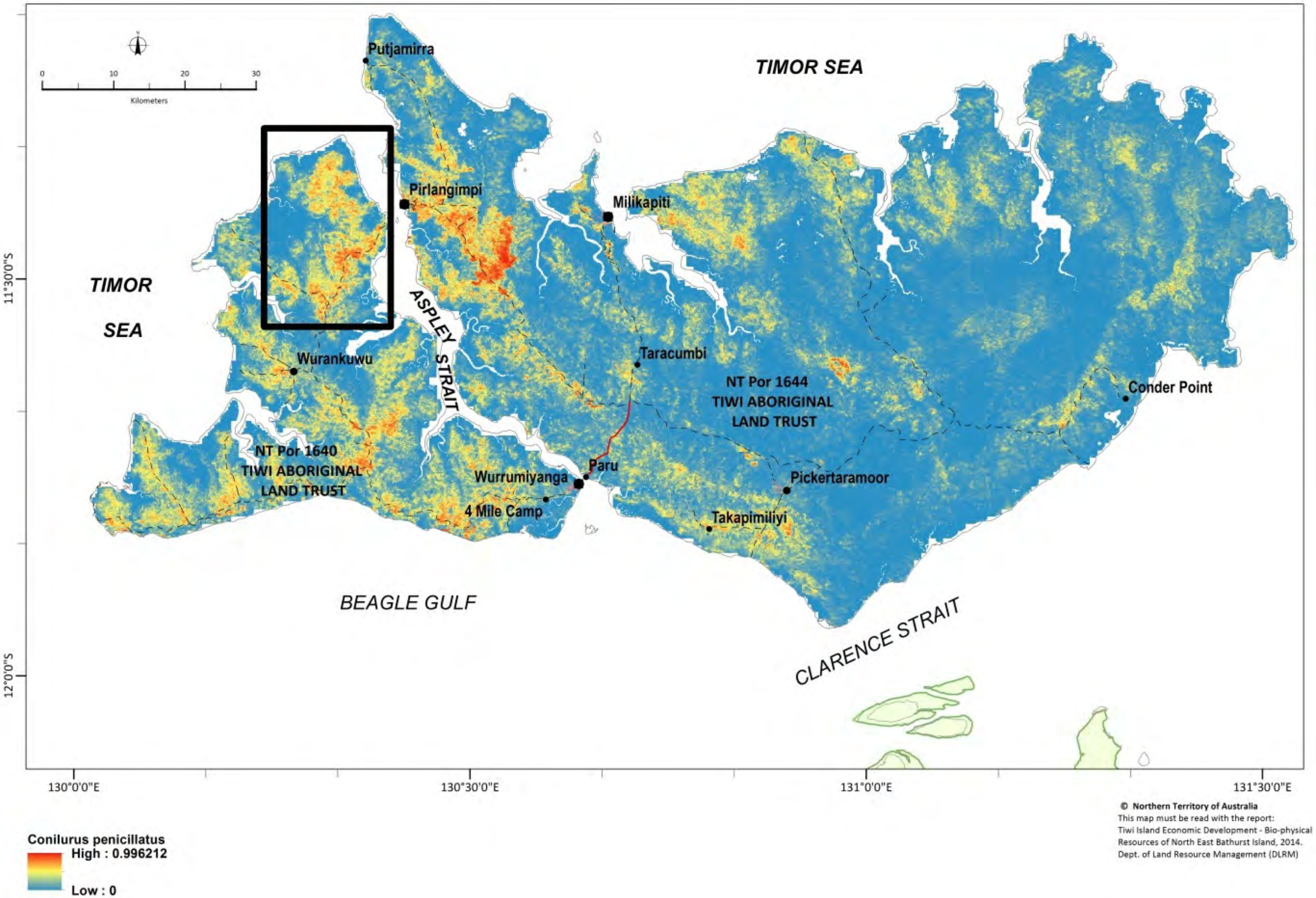


Figure 15-3: Brush-tailed Rabbit-rat *Conilurus penicillatus.*

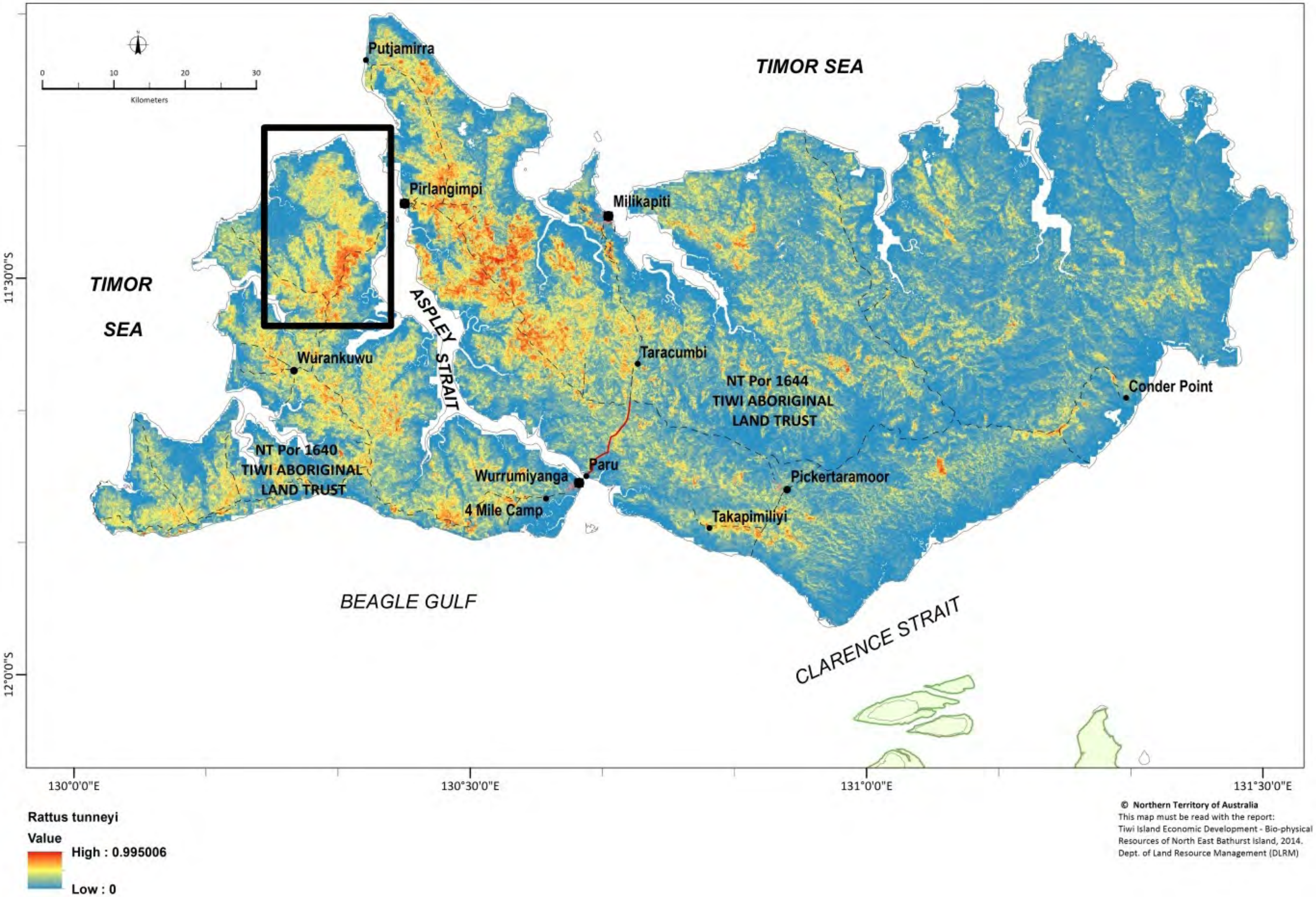


Figure 15-4: Pale Field Rat *Rattus tunneyi.*

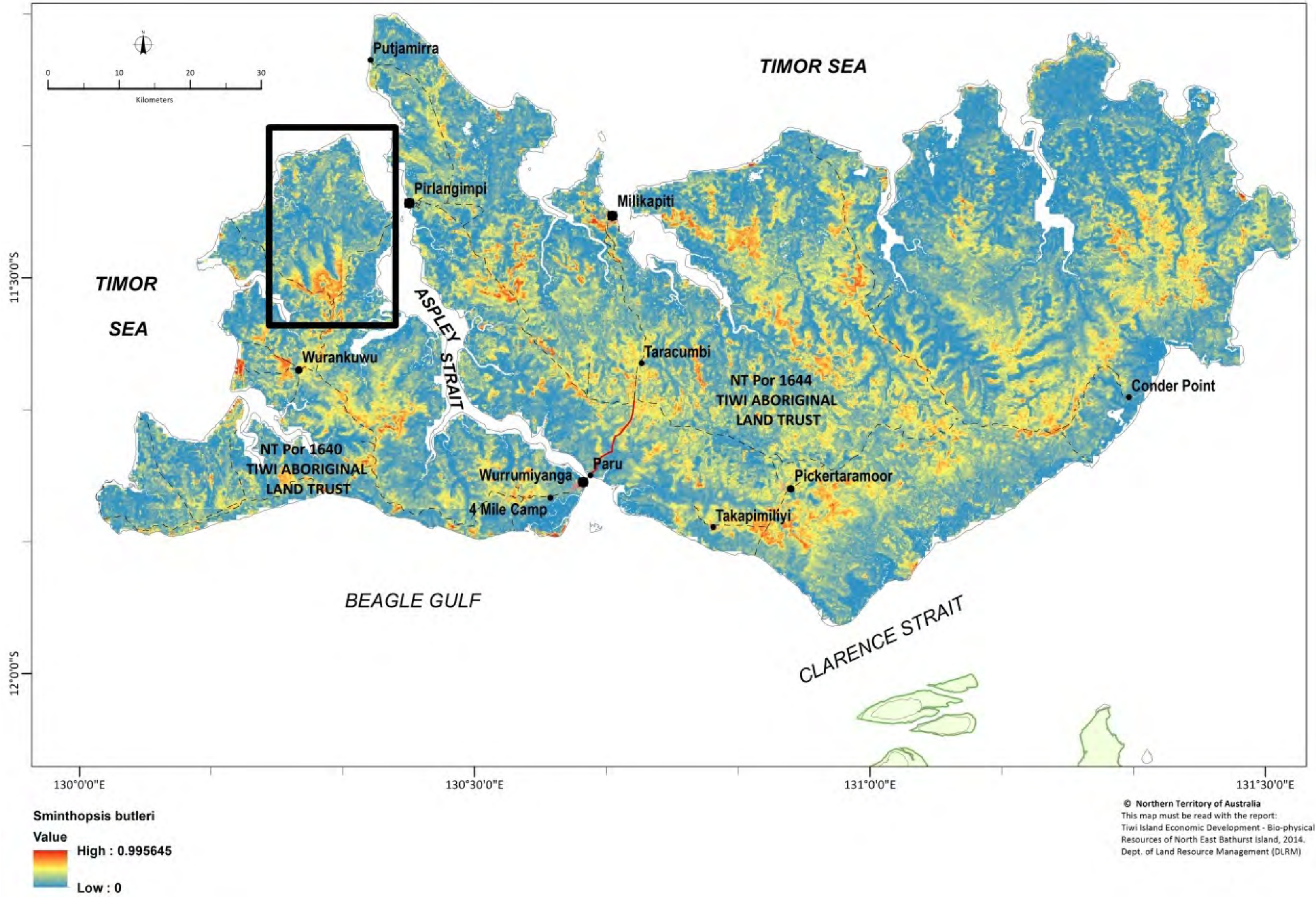


Figure 15-5: Butler's Dunnart *Sminthopsis butleri.* Note that this model does not include provisional records from camera traps at three sites in in the study area.

Appendix 16. Plant species list

Source: NT Government Vegetation Site Database (NTVSD)

FAMILY	FULL NAME
ACANTHACEAE	Brunoniella australis
ACANTHACEAE	Hypoestes floribunda var. varia
AMARANTHACEAE	Ptilotus distans
ANACARDIACEAE	Buchanania arborescens
ANACARDIACEAE	Buchanania obovata
ANACARDIACEAE	Semecarpus australiensis
ANNONACEAE	Desmos wardianus
ANNONACEAE	Miliusa brahei
ANNONACEAE	Mitrella tiwiensis
ANNONACEAE	Polyalthia australis
ANNONACEAE	Polyalthia nitidissima
ANNONACEAE	Uvaria holtzei
ANNONACEAE	Xylopia monosperma
APOCYNACEAE	Alstonia actinophylla
APOCYNACEAE	Alyxia spicata
APOCYNACEAE	Cynanchum carnosum
APOCYNACEAE	Gymnanthera oblonga
APOCYNACEAE	Hoya australis subsp. oramicola
APOCYNACEAE	Ichnocarpus frutescens
APOCYNACEAE	Marsdenia connivens
APOCYNACEAE	Marsdenia glandulifera
APOCYNACEAE	Marsdenia velutina
APOCYNACEAE	Melodinus australis
APOCYNACEAE	Parsonsia sp. Melville Island
APOCYNACEAE	Parsonsia velutina
APOCYNACEAE	Secamone elliptica
APOCYNACEAE	Tabernaemontana orientalis
APOCYNACEAE	Tylophora cinerascens
APOCYNACEAE	Tylophora flexuosa
APOCYNACEAE	Wrightia pubescens subsp. pubescens
AQUIFOLIACEAE	Ilex arnhemensis subsp. arnhemensis
ARACEAE	Amorphophallus galbra
ARACEAE	Epipremnum amplissimum
ARALIACEAE	Polyscias australiana
ARALIACEAE	Trachymene didiscoides
ARECACEAE	Carpentaria acuminata
ARECACEAE	Hydriastele wendlandiana
ARECACEAE	Livistona benthamii

FAMILY	FULL NAME
ARECACEAE	Livistona humilis
ASPARAGACEAE	Asparagus racemosus
ASPARAGACEAE	Lomandra filiformis
ASPARAGACEAE	Lomandra filiformis subsp. filiformis
ASPARAGACEAE	Lomandra tropica
ASPARAGACEAE	Lomandra tropica subsp. tropica
ASPARAGACEAE	Pleomele angustifolia
ASPARAGACEAE	Sowerbaea alliacea
ASTERACEAE	Bidens bipinnata
BLECHNACEAE	Blechnum indicum
BLECHNACEAE	Blechnum orientale
BLECHNACEAE	Stenochlaena palustris
BORAGINACEAE	Cordia subcordata
BURMANNIACEAE	Burmannia coelestis
BURMANNIACEAE	Burmannia juncea
BURSERACEAE	Canarium australianum
CANNABACEAE	Celtis philippensis
CANNABACEAE	Trema tomentosa
CAPPARACEAE	Capparis sepiaria
CELASTRACEAE	Denhamia obscura
CELASTRACEAE	Stackhousia intermedia
CHRYSOBALANACEAE	Maranthes corymbosa
CLUSIACEAE	Calophyllum sil
CLUSIACEAE	Calophyllum soulattri
COMBRETACEAE	Lumnitzera littorea
COMBRETACEAE	Terminalia ferdinandiana
COMBRETACEAE	Terminalia grandiflora
COMBRETACEAE	Terminalia microcarpa
COMBRETACEAE	Terminalia sp. Black Point
COMMELINACEAE	Murdannia gigantea
COMMELINACEAE	Murdannia graminea
CONVOLVULACEAE	Erycibe coccinea
CONVOLVULACEAE	Ipomoea abrupta
CUCURBITACEAE	Coccinia grandis
CYCADACEAE	Cycas armstrongii
CYCADACEAE	Cycas maconochiei
CYPERACEAE	Baumea rubiginosa
CYPERACEAE	Fimbristylis lanceolata
CYPERACEAE	Fimbristylis nutans
CYPERACEAE	Hypolytrum nemorum
CYPERACEAE	Lepironia articulata
CYPERACEAE	Rhynchospora brownii

FAMILY	FULL NAME
CYPERACEAE	Rhynchospora heterochaeta
CYPERACEAE	Rhynchospora rubra
CYPERACEAE	Schoenus calostachyus
CYPERACEAE	Scleria caricina
CYPERACEAE	Scleria carphiformis
CYPERACEAE	Scleria ciliaris
CYPERACEAE	Scleria laxa
CYPERACEAE	Scleria lingulata
CYPERACEAE	Scleria lithosperma var. lithosperma
CYPERACEAE	Scleria polycarpa
CYPERACEAE	Scleria rugosa
CYPERACEAE	Tricostularia undulata
DILLENIACEAE	Hibbertia brevipedunculata
DILLENIACEAE	Hibbertia caudice
DILLENIACEAE	Hibbertia cistifolia
DILLENIACEAE	Hibbertia complanata
DILLENIACEAE	Hibbertia dilatata
DIOSCOREACEAE	Dioscorea bulbifera
DIOSCOREACEAE	Dioscorea transversa
DROSERACEAE	Drosera brevicornis
DROSERACEAE	Drosera burmanni
DROSERACEAE	Drosera dilatatopetiolaris
DROSERACEAE	Drosera petiolaris
EBENACEAE	Diospyros calycantha
EBENACEAE	Diospyros compacta
EBENACEAE	Diospyros littorea
EBENACEAE	Diospyros maritima
ELAEOCARPACEAE	Elaeocarpus angustifolius
ELAEOCARPACEAE	Elaeocarpus arnhemicus
ELAEOCARPACEAE	Elaeocarpus culminicola
ELAEOCARPACEAE	Elaeocarpus miegei
ERIOCAULACEAE	Eriocaulon australe
ERIOCAULACEAE	Eriocaulon cinereum
ERIOCAULACEAE	Eriocaulon fistulosum
ERIOCAULACEAE	Eriocaulon spectabile
ERIOCAULACEAE	Eriocaulon willdenovianum
EUPHORBIACEAE	Endospermum myrmecophilum
EUPHORBIACEAE	Homalanthus novoguineensis
EUPHORBIACEAE	Macaranga involucrata
EUPHORBIACEAE	Macaranga involucrata var. mallotoides
EUPHORBIACEAE	Macaranga tanarius
EUPHORBIACEAE	Mallotus nesophilus

FAMILY	FULL NAME
EUPHORBIACEAE	Mallotus philippensis
FABACEAE	Abrus precatorius subsp. precatorius
FABACEAE	Acacia auriculiformis
FABACEAE	Acacia difficilis
FABACEAE	Acacia dimidiata
FABACEAE	Acacia lamprocarpa
FABACEAE	Acacia latescens
FABACEAE	Acacia leptocarpa
FABACEAE	Acacia mimula
FABACEAE	Acacia oncinocarpa
FABACEAE	Adenanthera pavonina
FABACEAE	Alysicarpus schomburgkii
FABACEAE	Canavalia rosea
FABACEAE	Chamaecrista nomame
FABACEAE	Crotalaria medicaginea
FABACEAE	Crotalaria montana
FABACEAE	Dalbergia candenatensis
FABACEAE	Desmodium pullenii
FABACEAE	Desmodium tiwiense
FABACEAE	Eriosema chinense
FABACEAE	Erythrina vespertilio
FABACEAE	Erythrophleum chlorostachys
FABACEAE	Flemingia lineata
FABACEAE	Flemingia parviflora
FABACEAE	Flemingia sp. sericea
FABACEAE	Galactia tenuiflora
FABACEAE	Indigofera saxicola
FABACEAE	Peltophorum pterocarpum
FABACEAE	Phyllodium pulchellum var. pulchellum
FABACEAE	Pycnospora lutescens
FABACEAE	Rhynchosia minima
FABACEAE	Sophora longipes
FABACEAE	Tephrosia lamproloboides
FABACEAE	Tephrosia remotiflora
FLAGELLARIACEAE	Flagellaria indica
GENTIANACEAE	Fagraea racemosa
GLEICHENIACEAE	Dicranopteris linearis
GLEICHENIACEAE	Dicranopteris linearis var. linearis
GOODENIACEAE	Goodenia holtzeana
GOODENIACEAE	Goodenia pilosa
GOODENIACEAE	Goodenia sp. Melville Island
HANGUANACEAE	Hanguana malayana

FAMILY	FULL NAME
HEMEROCALLIDACEAE	Dianella odorata
IRIDACEAE	Patersonia macrantha
LAMIACEAE	Clerodendrum costatum
LAMIACEAE	Clerodendrum floribundum
LAMIACEAE	Clerodendrum floribundum var. indeterminate
LAMIACEAE	Gmelina australis
LAMIACEAE	Gmelina schlechteri
LAMIACEAE	Plectranthus scutellarioides
LAMIACEAE	Premna serratifolia
LAMIACEAE	Vitex acuminata
LAMIACEAE	Vitex glabrata
LAURACEAE	Cassytha filiformis
LAURACEAE	Cryptocarya cunninghamii
LAURACEAE	Endiandra limnophila
LAURACEAE	Litsea breviumbellata
LAURACEAE	Litsea glutinosa
LAURACEAE	Neolitsea brassii
LECYTHIDACEAE	Planchonia careya
LENTIBULARIACEAE	Utricularia caerulea
LENTIBULARIACEAE	Utricularia chrysantha
LENTIBULARIACEAE	Utricularia kimberleyensis
LENTIBULARIACEAE	Utricularia leptoplectra
LENTIBULARIACEAE	Utricularia leptorhyncha
LENTIBULARIACEAE	Utricularia uliginosa
LINDERNIACEAE	Lindernia sp. Melville Island
LINDSAEACEAE	Lindsaea ensifolia
LINDSAEACEAE	Lindsaea walkerae
LOGANIACEAE	Mitrasacme aggregata
LOGANIACEAE	Mitrasacme elata
LOGANIACEAE	Mitrasacme inornata
LOGANIACEAE	Mitrasacme laevis
LOGANIACEAE	Mitrasacme multicaulis
LOGANIACEAE	Mitrasacme nudicaulis
LOGANIACEAE	Mitrasacme nummularia
LOGANIACEAE	Strychnos lucida
LOGANIACEAE	Strychnos minor
LOMARIOPSIDACEAE	Nephrolepis hirsutula
LORANTHACEAE	Decaisnina triflora
LYCOPODIACEAE	Lycopodiella cernua
LYGODIACEAE	Lygodium flexuosum
LYGODIACEAE	Lygodium microphyllum
MALVACEAE	Bombax ceiba

FAMILY	FULL NAME
MALVACEAE	Brachychiton diversifolius
MALVACEAE	Brachychiton megaphyllus
MALVACEAE	Grewia mesomischa
MALVACEAE	Sterculia holtzei
MALVACEAE	Sterculia quadrifida
MELASTOMATACEAE	Melastoma malabathricum
MELASTOMATACEAE	Melastoma malabathricum subsp. malabathricum
MELASTOMATACEAE	Memecylon pauciflorum
MELASTOMATACEAE	Osbeckia australiana
MELIACEAE	Aglaia sapindina
MELIACEAE	Dysoxylum acutangulum subsp. foveolatum
MELIACEAE	Dysoxylum latifolium
MELIACEAE	Owenia reticulata
MELIACEAE	Vavaea amicorum
MELIACEAE	Xylocarpus granatum
MENISPERMACEAE	Pachygone ovata
MENISPERMACEAE	Tinospora smilacina
MORACEAE	Antiaris toxicaria var. macrophylla
MORACEAE	Artocarpus glaucus
MORACEAE	Ficus aculeata
MORACEAE	Ficus benjamina
MORACEAE	Ficus hispida
MORACEAE	Ficus racemosa
MORACEAE	Ficus scobina
MORACEAE	Ficus virens
MORACEAE	Trophis scandens subsp. scandens
MYRISTICACEAE	Horsfieldia australiana
MYRISTICACEAE	Myristica insipida
MYRISTICACEAE	Myristica insipida var. indeterminate
MYRISTICACEAE	Myristica lancifolia
MYRISTICACEAE	Myristica lancifolia subsp. australiana
MYRTACEAE	Asteromyrtus symphyocarpa
MYRTACEAE	Calytrix exstipulata
MYRTACEAE	Corymbia bleeseri
MYRTACEAE	Corymbia confertiflora
MYRTACEAE	Corymbia disjuncta
MYRTACEAE	Corymbia foelscheana
MYRTACEAE	Corymbia latifolia
MYRTACEAE	Corymbia nesophila
MYRTACEAE	Corymbia polycarpa
MYRTACEAE	Corymbia porrecta

FAMILY	FULL NAME
MYRTACEAE	Corymbia ptychocarpa
MYRTACEAE	Eucalyptus alba var. australasica
MYRTACEAE	Eucalyptus miniata
MYRTACEAE	Eucalyptus oligantha
MYRTACEAE	Eucalyptus oligantha subsp. oligantha
MYRTACEAE	Eucalyptus tetrodonta
MYRTACEAE	Lithomyrtus retusa
MYRTACEAE	Lophostemon lactifluus
MYRTACEAE	Melaleuca dealbata
MYRTACEAE	Melaleuca leucadendra
MYRTACEAE	Melaleuca nervosa
MYRTACEAE	Melaleuca viridiflora
MYRTACEAE	Syzygium angophoroides
MYRTACEAE	Syzygium claviflorum
MYRTACEAE	Syzygium eucalyptoides subsp. bleeseri
MYRTACEAE	Syzygium fibrosum
MYRTACEAE	Syzygium forte
MYRTACEAE	Syzygium forte subsp. forte
MYRTACEAE	Syzygium forte subsp. potamophilum
MYRTACEAE	Syzygium hemilamprum subsp. hemilamprum
MYRTACEAE	Syzygium minutuliflorum
MYRTACEAE	Syzygium nervosum
MYRTACEAE	Syzygium suborbiculare
MYRTACEAE	Verticordia cunninghamii
OLACACEAE	Olax imbricata
OLEACEAE	Jasminum didymum
OLEACEAE	Jasminum didymum subsp. indeterminate
OLEACEAE	Jasminum elongata
OLEACEAE	Jasminum elongatum
OLEACEAE	Notelaea sp. Elcho Island
OPHIOGLOSSACEAE	Ophioglossum intermedium
OPHIOGLOSSACEAE	Ophioglossum lusitanicum
OPILIACEAE	Opilia amentacea
ORCHIDACEAE	Dendrobium dicuphum
ORCHIDACEAE	Luisia corrugata
ORCHIDACEAE	Thrixspermum congestum
PANDANACEAE	Pandanus spiralis
PASSIFLORACEAE	Adenia heterophylla
PHYLLANTHACEAE	Antidesma ghesaembilla
PHYLLANTHACEAE	Breynia cernua

FAMILY	FULL NAME
PHYLLANTHACEAE	Bridelia tomentosa
PHYLLANTHACEAE	Flueggea virosa subsp. melanthesoides
PHYLLANTHACEAE	Glochidion xerocarpum
PHYLLANTHACEAE	Phyllanthus reticulatus
PHYLLANTHACEAE	Sauropus glaucus
PICRODENDRACEAE	Petalostigma pubescens
PICRODENDRACEAE	Petalostigma quadriloculare
PIPERACEAE	Piper macropiper
PLUMBAGINACEAE	Aegialitis annulata
POACEAE	Aristida holathera var. holathera
POACEAE	Cenchrus pedicellatus
POACEAE	Chrysopogon fallax
POACEAE	Chrysopogon filipes
POACEAE	Chrysopogon latifolius
POACEAE	Digitaria gibbosa
POACEAE	Dimeria chloridiformis
POACEAE	Eragrostis pubescens
POACEAE	Eriachne avenacea
POACEAE	Eriachne burkittii
POACEAE	Eriachne stipacea
POACEAE	Eriachne triseta
POACEAE	Germainia grandiflora
POACEAE	Isachne confusa
POACEAE	Ischaemum australe
POACEAE	Ischaemum barbatum
POACEAE	Mnesithea formosa
POACEAE	Mnesithea rottboellioides
POACEAE	Panicum effusum
POACEAE	Panicum mindanaense
POACEAE	Pseudopogonatherum contortum
POACEAE	Pseudopogonatherum irritans
POACEAE	Schizachyrium fragile
POACEAE	Sorghum plumosum var. plumosum
POACEAE	Thaumastochloa major
POACEAE	Thaumastochloa pubescens
POACEAE	Urochloa holosericea subsp. holosericea
POLYGALACEAE	Polygala triflora
POLYPODIACEAE	Drynaria quercifolia
PRIMULACEAE	Aegiceras corniculatum
PRIMULACEAE	Embelia tiwiensis
PRIMULACEAE	Myrsine pedicellata

FAMILY	FULL NAME
PROTEACEAE	Banksia dentata
PROTEACEAE	Grevillea decurrens
PROTEACEAE	Grevillea dimidiata
PROTEACEAE	Grevillea pluricaulis
PROTEACEAE	Grevillea pteridifolia
PROTEACEAE	Hakea arborescens
PROTEACEAE	Helicia australasica
PROTEACEAE	Persoonia falcata
PROTEACEAE	Stenocarpus acacioides
PROTEACEAE	Stenocarpus verticis
PTERIDACEAE	Acrostichum speciosum
PTERIDACEAE	Adiantum hispidulum var. hispidulum
PTERIDACEAE	Cheilanthes contigua
PTERIDACEAE	Cheilanthes tenuifolia
PTERIDACEAE	Taenitis blechnoides
PTERIDACEAE	Vittaria ensiformis
PUTRANJIVACEAE	Drypetes deplanchei
RESTIONACEAE	Dapsilanthus elatior
RESTIONACEAE	Dapsilanthus spathaceus
RHAMNACEAE	Alphitonia excelsa
RHAMNACEAE	Alphitonia oblata
RHAMNACEAE	Emmenosperma cunninghamii
RHAMNACEAE	Ziziphus quadrilocularis
RHIZOPHORACEAE	Bruguiera gymnorhiza
RHIZOPHORACEAE	Carallia brachiata
RHIZOPHORACEAE	Rhizophora apiculata
RUBIACEAE	Aidia racemosa
RUBIACEAE	Coelospermum reticulatum
RUBIACEAE	Cyclophyllum schultzii
RUBIACEAE	Cyclophyllum schultzii f. angustifolium
RUBIACEAE	Gardenia schwarzii
RUBIACEAE	Gynochthodes sp. Docherty Hills
RUBIACEAE	Ixora timorensis
RUBIACEAE	Kailarsenia suffruticosa
RUBIACEAE	Morinda jasminoides
RUBIACEAE	Psychotria coelosperma
RUBIACEAE	Psychotria daphnoides
RUBIACEAE	Psychotria nesophila
RUBIACEAE	Psydrax odorata subsp. arnhemica
RUBIACEAE	Spermacoce calliantha
RUBIACEAE	Spermacoce retitesta
RUBIACEAE	Tarenna dallachiana

FAMILY	FULL NAME
RUBIACEAE	Tarenna dallachiana subsp. expandens
RUBIACEAE	Tarenna pentamera
RUBIACEAE	Tarennoidea wallichii
RUBIACEAE	Timonius timon
RUTACEAE	Glycosmis trifoliata
RUTACEAE	Melicope elleryana
RUTACEAE	Micromelum minutum
RUTACEAE	Zanthoxylum parviflorum
SANTALACEAE	Dendromyza reinwardtiana
SANTALACEAE	Exocarpos latifolius
SANTALACEAE	Viscum articulatum
SAPINDACEAE	Cupaniopsis anacardioides
SAPINDACEAE	Dodonaea hispidula
SAPINDACEAE	Ganophyllum falcatum
SAPOTACEAE	Mimusops elengi
SAPOTACEAE	Pouteria arnhemica
SAPOTACEAE	Pouteria richardii
SAPOTACEAE	Pouteria sericea
SAPOTACEAE	Sersalisia sericea
SCHIZAEACEAE	Actinostachys digitata
SCHIZAEACEAE	Schizaea dichotoma
SMILACACEAE	Smilax australis
THYMELAEACEAE	Phaleria octandra
VITACEAE	Ampelocissus acetosa
VITACEAE	Cissus adnata
VITACEAE	Cissus reniformis
VITACEAE	Leea indica
VITACEAE	Leea rubra
XYRIDACEAE	Xyris cheumatophila
XYRIDACEAE	Xyris complanata