THE CONSERVATION OF MULGA COMMUNITIES IN THE SOUTH-EAST PILBARA, WESTERN AUSTRALIA

A report to the National Parks Authority (W A)
and Department of Conservation & Environment (W A)

by

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SUMMARY: The mulga communities of the southeastern Pilbara differ from those elsewhere in Western Australia in that they occupy a semi-arid region with predominantly summer rainfall. The close association of such communities with hummock grasslands exposes the former to fire risks not shared by other mulga lands.

A variety of landscape patterns in the region gives rise to diverse mulga formations whose characteristics are described in this report; the genetic resources of the various forms of mulga may be of value to future arid zone reclamation. In this region, mulga-dominated communities include vegetation species which have not been recorded from mulga communities elsewhere, e g the Murchison district.

A detailed examination of the ant fauna in selected mulga communities suggests that faunal groups may recognise minor habitats according to site soil moisture and the dominance of hummock or bunch grasses in the ground layer. Species richness appears to be affected by disturbance to the vegetation.

Further data is presented which describes the invertebrate and vertebrate faunae of the region; in many cases, there exist close associations with particular types of mulga-dominated habitat.

In view of continuing pressures on unaliented crown land in

the region, it is important to examine the conservation requirements of the area whilst there remains the potential to acquire or otherwise manage land for its ecological values.

Conservation objectives include the reservation of stands of mulga-dominated vegetation which represent the major habitat variations, and the establishment of scientific reference areas to monitor the impact of fire, grazing and mining in the region.

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1. INTRODUCTION

In the south-eastern Pilbara (Figure I - Appendix II), those communities dominated by mulga (Acacia aneura) constitute a northern tropical outlier of similar vegetation in the Gascoyne, Murchison and the western central Deserts. Beard (1975) suggested that the northern limit of mulga distribution is determined by temperature, with hummock grass (Triodia and Plectrachne spp) replacing mulga in the hottest, dry areas of Western Australia. Mulga communities in the Pilbara differ from those elsewhere in Western Australia in that they lie in a semi-arid region (average annual rainfall 280-300 mm) with predominantly summer (November to April) rainfall.

In the south-eastern Pilbara, communities dominated by Acacia aneura occur on loamy valley floors, drainage basins elevated outwash plains, fluvial plains and on sheltered slopes of ridges and breakaways. The hot dry ridges and slopes, outcrops and sandy plains are vegetated with hummock grassland communities. No extensive areas of mulga woodland formations occur on the Hamersley plateau, a region essentially dominated by hummock grassland.

In the south-eastern Pilbara, mulga communities abut hummock grasslands, and on slopes Triodia and Plectrachne species are frequently found in the ground layer, sometimes forming a codominant stratum. The hummock grasslands are naturally subject to wildfire and the proximity of mulga communities to hummock grasslands exposes the former to fire risk. In this respect, such communities differ from other mulga lands where the typically sparse grass and forb layer greatly reduces the incidence of fire. Some leaf/phyllode variants of Acacia aneura from the south-eastern Pilbara show a limited capacity to regenerate from adventitious buds, a characteristic not found in other mulga ecosystems (Fox 1984). However, mulga in this region nevertheless appears vulnerable to increases in fire frequency.

The Hamersley Range National Park covers the central plateau of the Hamersley Ranges and the dissected northern escarpment. There are, however, no extensive areas of mulga woodland within Park boundaries. This is unfortunate in terms of the representativeness of the reserve because the Ranges exert a profound influence on the development of mulga communities in the south-eastern Pilbara. Here the plateau breaks up into a series of east-west trending ridges and parallel valleys. The associated drainage, erosion/depositional patterns and microhabitats give rise to a variety of mulga formations. The effect of the ridges and slopes in concentrating moisture in parts of the environment is an important determinant of stand location, biomass and survival (Fox & Dunlop 1983 a,b). Any regional conservation strategy based on the Hamersley Range National Park should involve adequate reservation and management of the mulga habitats on the south-eastern perimeter of the Hamersley Plateau.

Until recently the mulga communities from north and west of the Ophthalmia Range to the edge of the National Park and north to Mt Robinson were on unalienated crown land and had at no stage been used as pastoral rangeland. There is virtually no other part of Western Australia where mulga lands have escaped the ecological effects of grazing stock. In the Gascoyne grazing has led to widespread environmental degradation.

Recently (1983) large extensions to Juna Downs station were approved; these included mulga lands east of the National Park from south-west of Mt Robinson, taking in the Coondewanna Flats to Munjina. Further extensions south of the Governor are pending approval. In view of these continuing pressures it is important to examine the conservation requirements of the area whilst it is still possible for land to be acquired or otherwise managed for its ecological values.

Almost all of the area in question is included within mineral tenements held by Goldsworthy Mining, CRA, Mt Newman Mining and Cliffs International. The location of these tenements and the future infrastructure of the mining operations will be considered in relation to possible conservation strategies for the area.

This report is based on a biological examination of the region (study area shown in Figure 1) conducted in July 1984, but also draws on the findings of a number of studies conducted since 1979. It has three broad objectives:

1) to document all the available data on the biology of the mulga communities in the region,

2) to delineate a possible mulga fire management priority area within the Hamersley Range National Park (HRNP) to be used as an ecological baseline in monitoring the impact of regional changes in fire frequency.

3) to assess areas in the region in terms of their conservation values for possible inclusion in the HRNP or for incorporation in a regional conservation strategy.

This report examines the relationship between various mulga formations and the physical environment, and analyses the vegetation characteristics, the value of mulga communities as animal habitats, the nature of associated invertebrate and vertebrate faunas and possible conservation land use options involving the remaining unalienated crown land.

2. MULGA FORMATIONS AND THE PHYSICAL ENVIRONMENT

In the study area, outcrops of the Hamersley Iron Formation produce many east-west trending ridges separated by broad often elevated valleys. The major ridges, between 800 and 1200 m, include the Ophthalmia range, Pamelia Hill ridge, Rhodes ridge, Padtherung Hill ridge, Coondewanna Hill ridge, Twin Peaks ridge (West Angelas), the Governor ridge, the Mt Robinson ridge and the Mt Meharry ridge. Smaller hills which represent outcrops of Marramamba Iron Formation are found within the broad valleys, with outcrops of Wittenoom Dolomite at the foot of the major ridges. Areas of outcropping calcrete, dolerite and laterite are also found in the valleys.

Mulga communities in the region occupy a range of habitats, viz the sheltered slopes of ridges and hills including incised lateral valleys, lower slopes, elevated outwash plains, valley floors, fluvial outwash plains and drainage basins. Soil types vary widely from skeletal, scree on the slopes, to shallow sandy loams on the lower slopes, deeper colluvial sandy clay loams or clay loams on broad outwash plains and deep clay loams or clays in drainage basins. Studies on stand development of mulga in valley habitats (Fox & Dunlop 1983 a) have shown that tree size and stand biomass are related to long term moisture conditions at a site. Whilst a relationship was determined between mulga height and measured soil moisture (for trees greater and less than 5 m) a much stronger correlation existed between stand biomass (stem basal area per hectare) and an estimate of potential soil moisture storage at the site. Soil moisture storage depended on soil texture and depth. Thus the largest trees (14 m) and the highest stand biomass were found in mulga growing on deep, clay loam in a drainage basin. This relationship however does not hold for cracking clay soils subject to seasonal extremes of cracking and waterlogging. The location of a site in the landscape also affects its long term moisture status due to the influence of catchments in concentrating rainfall in particular areas.

Linked to the relationship with soil moisture storage are the patterns of dispersion observed in mulga trees. Clumped grove and intergrove dispersion is characteristic of stands on minor elevated and broad valley outwash plains. Figure 2 (Appendix II) (Fox & Dunlop 1983 b) shows the results of a micro- topographic survey through two groves on an outwash plain south-east of Pamelia Hill. The groves form on the more steeply sloping parts of the terraced outwash plain and are separated by intergroves with very little slope. The groves invariably have deeper soils than the intervening intergroves, although the actual depth varies from only 0.2 m on some elevated outwash plains to over 1.0 m on some valley floors. The intergroves are scattered with gravel which varies in size and cover. Examination of the geological map covering the Pamelia Hill area (Geological survey of W A, 1:250,000 series, Newman SF50-16) shows the deeper soils of the groves as being tertiary colluvium. At the bottom of the outwash plain is a denuded flood plain and the quaternary creek line. Thus the groves higher on the outwash plains represent former tertiary channels of the quaternary creek with the mulga trees growing in the colluvial deposits which were formerly creek banks. The intergroves with their scattering of gravel represent the former creek beds.

On outwash plains mulga height decreases down the dominant plane of slope with decreasing soil depth. At the denuded lower limits of these plains mulga is sometimes replaced by other _Acacia_ spp, and trees give way to shrubs. Along the groves, however, tree height increases downslope presumably in relation to increased soil depth due to deposition. Conspicuous mounds of trapped soil have been observed within the groves (eg. Figure 2).

Mulga trees show adaptations which conserve water both within the plant and within the soil environment of the plant roots. Clearly such adaptations are relevant to soil moisture storage. Since this storage capacity is fairly limited the survival of mulga depends more on the length of drought periods than on total rainfall. Therefore it is the relatively high frequency and rather localised rainfall events which are of greatest importance. In grove and intergrove mulga, one observes both sheet flows down the dominant plane of slope and lateral flows along the groves.

In most situations sheet flows would happen fairly regularly after heavy rainfall. Lateral flows (possibly only through the colluvium) would take place with the highest frequency, as a consequence of localised rainfall in minor catchments. In some situations lateral surface flows in the form of major cyclonic floods may occur. These are too infrequent to be of great importance in recharging the soil store.

On level plains and drainage basins receiving run-off from all sides, the mulga is not clumped but evenly distributed. Formations in these environments consist of low woodland or scrubs rather than the low forest or thicket (with intervening sparsely vegetated areas) associated with sloping outwash plains. Most water reaches such areas as surface flows.

On steep slopes mulga is best developed in sheltered positions. Thus on southern slopes, on breakaways, in incised lateral valleys or on the walls of gorges it forms low woodland. Elsewhere on the ridges or hills mulga is reduced to a scrub stratum.

3. CHARACTERISTICS OF MULGA (ACACIA ANEURA) COMMUNITIES

The Mulga Research Centre has been carrying out studies on the ecology of mulga in the study area since 1979. During this period many of the plants growing in mulga- dominated communities have been collected and identified. A list of 147 plant species is given in Appendix 1. Species are included which occur on steep slopes and in habitats where hummock grassland codominates with mulga. Also included are species recorded from mulga areas which had been recently burnt; these species may not be present in undisturbed woodland. During a survey conducted in July 1984 at eleven (11) detailed study sites (Figure 3 - Appendix II) specimens of all plants present in a 500 m^2 study plot were collected or recorded. Those observed in mulga habitats for the first time in July 1984 are indicated in Appendix I.

The only complete floral inventory for an area of mulga lands in Western Australia was compiled for Mileura station (Lat. 26°22'S, Long. 117°20'E) in the Murchison District (Davies 1970). This account probably also includes plant species which occurred in communities other than those dominated by mulga, such as Acacia scrub, Chenopod shrubland and bunch grassland. Nevertheless, the floristic composition of the area is similar to the mulga communities of the south-eastern Pilbara.

In all communities which it dominates, Acacia aneura forms the upper stratum although often in association with other species. Formations recorded in the study area include dense low forest A, low forest A, low woodland A and B and scrub (life-form density classes follow Muir 1977). Common associates on the outwash plains and valley floors were Acacia pruinocarpa, Eucalyptus setosa and Grevillea spp. Some tropical plants which were present in mulga in the south-eastern Pilbara were not recorded in the Murchison. These include Canthium latifolium and C. lineare which grow in the shade of mulga canopy and twine through the canopy of the trees. The tropical mistletoes Amyema spp are also well represented.

On drainage basins and claypans mulga codominates with coolibah Eucalyptus microtheca. Eucalypts were not recorded from mulga communities at Mileura.

Scrub or dwarf scrub strata of Eremophila spp or Cassia spp were present in most mulga communities. This is also the case in other mulga lands. Scrub of Acacia tetragonophylla and A. victoriae occurred in association with mulga on denuded floodplains, A. sclerosperma on sandy soils, A. stowardii on rocky outcrops and A. pachyacra after fire. An endemic to the Hamersley Ranges Acacia marramamba was present in mulga woodland on the slopes of low hills many of which bear economically significant iron-ore deposits.

The ground stratum of mulga communities may consist of bunch grasses, forbs including succulents, and in the south-eastern Pilbara, hummock grasses.

Important bunch grasses included Aristida spp, Eragrostis spp, Themeda australis and introduced Cenchrus ciliaris on valley floors, drainage basins and clay pans. The associated grasses on rocky hillslopes were Eriachne spp and Cymbopogon spp. The hummock grasses Trioda pungens and Plectrachne schinzii formed the understorey on lower slopes, elevated outwash plains and on broad valley outwash plains. It is not known what factor determines which of the hummock grasses is present, but differences in soil pH may be implicated. The close association of hummock grassland with mulga communities does not occur in southern parts of Western Australia. As a consequence, fire damage to mulga is more frequent and extensive in the study region. Many of the Papilionoideae recorded were from burnt-out stands of mulga. The Desert Poplar Codonocarpus cotonifolius, Cockroach Bush Cassia notabilis and the herb Corchorus walcottii were also usually recorded from regenerating areas. Fire appears to increase the abundance and widen the distribution of hummock grass particularly Triodia and concomitantly reduce the extent of mulga.

Most conspicuous among the forb species in mulga communities were representatives of the Amaranthaceae, Ptilotus spp and Gomphrena spp. A diversity of succulent herbs, particularly in intergroves, included Dysphania spp, Maireana spp and Trianthema glossostigma. Rhagodia spp were present under mulga close to creek lines and on cracking clay soils.

Throughout its range Acacia aneura has a number of leaf/ phyllode variants, the genetic control of which is not understood. All forms breed true to the parent variant when grown from seed. At least nine (9) and possibly ten (10) phyllode variants or forms have been recorded in the study area. In Table 1 these forms are described on the basis of specimens examined in July 1984. The terete leafed mulga (form C) and black mulga (form E) may be unique to the region. Table 2 shows the density of mulga trees and the forms of mulga present in relation to landform and soil type at each of the detailed study sites examined in July 1984. Forms A and B occurred widely on outwash plains in grove and intergrove mulga sometimes with form C. Where all three forms were present together on outwash plains (not in Table 2) their distribution suggested that they may constitute ecotypes. Frequently broad leafed forms (B) occupied the spine of groves on the deepest soil. Narrow leafed mulga (A) was present on the edge of the grove and terete forms (C) scattered through the intergrove. What appears to be the most xeric form with terete phyllodes also has weeping and Christmas Tree forms which show phyllode reduction. This may represent further adaptation to drought. Forms E, F, I and J were scarce and not recorded on the study sites. The

Table 1: Forms of mulga Acacia aneura recorded from the study area.

FORM	DESCRIPTION					Phyllodes			
	Life form	Maximal height (m)	Canopy	Bark	Shape	Arrangement	Colour	$\bar{x}$ width (mm) *	$\bar{x}$ length (mm) *
A. Narrow leafed mulga (typical)	Tree or shrub	5.0	open crown	grey, fissured	curved, narrow linear and flattened	ascending erect	greyish green	2.0	40.1
B. Broad leafed mulga (typical)	Tree or shrub	4.0	dense crown	dark grey or black fissured	falcate to oblanceolate and flattened	ascending erect	dark green	3.3	61.2
C. Terete leafed mulga (typical)	Tree or shrub	5.0	open crown	grey, fissured	terete	ascending erect	greyish green	0.8	35.1
D. Weeping mulga	Tree or shrub	4.0	very open crown, pendulous	grey, fissured	long, terete	declinate	greyish green	0.6	95.1
E. Broad leafed mulga 'black mulga'	Tree or shrub	7.0	dense crown	black, smooth to lightly fissured	long, falcate and flattened	ascending erect	bluish green	3.2	65.7
F. Silver mulga	Shrub	2.0	dense crown	grey, fissured	very narrow long, linear flattened	ascending erect	reflective grey-green	1.2	73.9
G. Narrow leafed mulga (short phyllodes)	Shrub	2.0	dense crown	grey, fissured	very short and narrow flattened	ascending erect	greyish green	1.2	22.7
H. Broad leafed mulga (very broad phyllodes)	Shrub	2.5	dense crown	dark grey, heavily fissured	very broad, lanceolate and flattened	ascending erect	bluish green	9.8	45.1
I. Narrow leafed mulga (long phyllodes)	Shrub or tree	3.5	clumped open canopy	grey, fissured	long, narrow linear, flattened	ascending erect	greyish green	1.3	87.1
J. Christmas tree mulga	Tree	4.5	apically dominant, open canopy	dark grey, fissured	short, narrow linear, flattened	declinate	greyish green acroscopic	1.1	52.4

* n = 100

apically- dominant Christmas Tree mulga was observed at only one locality, on a stony pavement.

The Pilbara terete phyllode mulga was the only form recorded on cracking clay soils (eg. study site 2.0) and was the common form on stony upper slopes, hills and ridges. Black mulga (form E) was restricted to well-watered groves and incised valleys or gorges.

The genetic resources of the various forms of mulga may be of some importance for future arid zone reclamation both in Australia and in other parts of the world.

4. MULGA COMMUNITIES AS FAUNA HABITATS

The plant communities dominated by _Acacia aneura_ occupy a range of landforms and a number of different soil types. This in turn leads to variation in vegetation structure which embraces low forests, woodlands, scrub formations and clumped (groved) and homogeneous patterns of dispersion. Differences also exist in the level of disturbance to which various mulga stands have been subjected, principally from fire and pastoral grazing.

4.1 Ant faunal analysis

In order to examine the ways in which these factors might influence the distribution of animals in the mulga communities a study based on analysis of the ant fauna was carried out. Ant communities have been shown to be effective indicators of land use, ecosystem development, conservation values and of animal habitats (Greenslade and Thompson 1981, Majer 1983 a,1983 b, Rossbach and Majer 1983). In the Pilbara region, ant community analysis has been used to evaluate the success of rehabilition on iron ore mines and waste dumps (Dunlop et al, in press). At West Angelas, in the study area, distinct ant assemblages occupied hummock grassland and low woodland (mulga) communities (Majer 1983 a), a pattern which was also evident from sampling at the Ophthalmia Dam area near Newman (Porter 1983). Termites (Isoptera) show a similar division in species composition

Table 2: The ant species collected at twelve (12) mulga study sites in July 1984. Numbers indicate ants collected in pitfall traps. The symbol + denotes a species collected by hand, from nests or by beating and sweeping.

ANT SPECIES		STUDY SITES 1	2	3	4	5	6	7	8	9	10	11	12
PONERINAE													
Anochetus	sp68											1	
Bothroponera	sp58						1						
Leptogenys	sp12	+	2			+	1				2	1	
Odontomachus	sp51											1	
Rhytidoponera	sp5				+		156						
Rhytidoponera	sp14		+	5		3			2	1	1	9	4
Rhytidoponera	sp17		2	2		1	3		+	1	7	7	
MYRMICINAE													
Chelaner	sp25					115	18			23	4	23	
Chelaner	sp33			7									
Chelaner	sp37	2				3					1	1	+
Chelaner	sp38	4		+					+				
Chelaner	sp69											8	
Chelaner	sp72									2			
Monomorium	sp55					19		1		1	5	4	
Pheidole	sp4	2	21		12	10	4		2	21		27	
Pheidole	sp11	7	2			2					6	1	
Pheidole	sp26					3	7					+	
Podomyrma	sp61									+			
Tetramorium	sp36	2		2		6	1	1			6	19	4
Tetramorium	sp66										1		
Crematogaster	sp15		9			5	2					16	
Crematogaster	sp24	+	+			+	1				+	+	
Crematogaster	sp44	+	+										
Meranoplus	sp3			+	1							2	
Meranoplus	sp18	2	2				1						
Meranoplus	sp46						6					+	+
DOLICHODERINAE													
Tapinoma	sp20		2			1							
Iridomyrmex	sp1	4		+	3046	+							
Iridomyrmex	sp6				+		20	+				+	
Iridomyrmex	sp7		39	109	4	59	43					19	
Iridomyrmex	sp10	7	96	138	57		+	1260	5118	589	2087	717	169
Iridomyrmex	sp16	4	5			+	1						
Iridomyrmex	sp31						+						
Iridomyrmex	sp35	2	+	18			5			+		+	+
Iridomyrmex	sp48						4						
Iridomyrmex	sp50			+		1					5		
Iridomyrmex	sp74			+									
FORMICINAE													
Paratrechina	sp45						2						
Camponotus	sp8				5	2		+	+				
Camponotus	sp19		2							1			
Camponotus	sp21		4				+					1	
Camponotus	sp22				+	1	1	+		+		1	+
Camponotus	sp23	+	+				+						
Camponotus	sp27						+				+	9	
Camponotus	sp29					+	+	+			+	+	
Camponotus	sp30					+	+	1	4	1	1	11	+
Camponotus	sp40	14	+	+		65	7	+					+
Camponotus	sp42					+							2
Camponotus	sp57				+	1							
Camponotus	sp64									+	+		
Calomyrmex	sp62								+	+		+	+
Opisthopsis	sp49					+	1				1	2	
Polyrachis	sp39	2	+			+		+	2		+		
Polyrachis	sp60			+				+	+	+			
Polyrachis	sp63									+	2		
Polyrachis	sp70											+	
Melophorus	sp2	+	+	5	1	+	1		+	2	+	2	+
Melophorus	sp34	+	+	2									
Melophorus	sp41	+	+									+	
Prolasius	sp52					1			+	2			
Prolasius	sp59							1					
Plagiolepis	sp53					1							
Stigmacros	sp54					1						+	
Formicinae indet	sp65											+	

between the two major vegetation types but other factors influenced the distribution of springtails (Collembola) (P Greenslade unpublished data).

Methods

In July 1984 ants were sampled at twelve (12) study sites in the seven areas shown in Figure 3 (Appendix II). At each site a 25 x 20 m plot was marked out within which were set 10 pitfall traps in a line with 2 m spacing. Each trap consisted of a 43 mm diameter plastic specimen jar containing preservative (alcohol/glycerol 70/30 v/v). At sites 1 to 11 traps were set for 5 days but were set for only 3 days at site 12. For approximately 30 minutes during daylight, each site in an area defined by the plot was actively searched for ants; all species found were collected. Ants active on foliage were collected by beating the branches of shrubs and trees onto a white beating tray, low vegetation was sampled using a sweep net and nests were excavated using a shovel or trowel. Some sites were also searched at night but there was little activity due to low nocturnal temperatures. Ants were sorted to species level but have not as yet been identified or referred to species codes in the W A I T collection. All ants captured in 'pitfall traps' were counted by species. Those taken by hand collection were identified and any additional species were included in the site lists.

Table 3 gives the number of ants of each species captured in pitfall traps at the twelve (12) study sites. Also shown are the species collected by hand. Pitfall trap data was used to obtain pitfall species richness, mean species per trap and dominance index (Table 4). The latter is a measure of the concentration of individuals in one or a few dominant species. This index was determined using the following relationship:

$$c = \Sigma \left(\frac{n_i}{N}\right)^2$$

where n_i is the number of individuals of the ith species captured at each site,

and N is the total number of ants captured at the site.

Data from the hand collections was used only in obtaining total species richness for each sampling site.

The presence/absence data for the 12 study sites was also used in a principal components ordination (Figure 4 - Appendix II) in which sites were grouped or separated on the basis of similarity in species composition.

Results

The vegetation and soils sampled at the 12 sites in July '84 are described in Table 5. The life form/density classes of Muir (1977) have been used to describe vegetation structure.

Table 3: The density of mulga trees (live trees/hectare) and the distribution of the forms (described in table 1) in relation to landform and soil type at each of the study sites examined in July 1984.

Study site	Landform	Soil type	Tree density (live stems per hectare)	Mulga forms present A	B	C	D	E	F	G	H
1	Elevated outwash plain grove and intergrove	Shallow, sandy clay loam	940	+							
2	"	"	920	+	+						
3	(Intergrove)										
4	Valley basin, low lying area	Deep cracking clay	120			+					
5	Lower slopes	Shallow sandy loam	620	+			+			+	+
6	Broad valley plain	Deep sandy clay loam	340	+							
7	Valley outwash plain grove and intergrove	Deep sandy clay loam	680	+							
8	Valley basin	Deep clay loam	720							+	
9	" "	" " "	260							+	
10	Broad outwash plain, grove and intergrove, proximal to quaternary creek	Shallow sandy loam and gravel	1200		+	+					
11	Broad tertiary outwash plain, grove and intergrove	Sandy clay loam	420		+	+					
12	Valley,outwash plain	Deep,clay loam	1340	+	+						

TABLE 4. Trap days, total captures, mean species per trap and dominance index for ant sampling using pitfall traps and total species richness including species collected by hand, for each of the twelve (12) mulga study sites.

	Study Sites											
	1	2	3	4	5	6	7	8	9	10	11	12
Pitfall trap/days	5	5	5	5	5	5	5	5	5	5	5	3
Total captures	52	186	288	3126	298	285	1264	5128	644	2129	882	179
Mean species per trap	1.90	2.90	2.56	1.88	4.67	4.50	1.9	2.0	3.6	3.5	6.8	1.45
± standard deviation	0.74	1.70	1.11	1.11	1.82	1.90	1.1	0.71	0.71	1.1	1.4	0.68
Dominance index	0.135	0.328	0.378	0.949	0.377	0.331	0.996	0.998	0.838	0.980	0.664	0.891
Total species richness	19	26	16	11	31	28	11	12	18	20	33	12

Table 5. Description of vegetation and soil type at each of 12 sites in which the ants were sampled in July '84. Life-form/density classes follow Muir (1977).

Sample site	Area	Habitat Description
1	1	Grove of *Acacia aneura* low forest A over open *Plechtrachne schinzii* hummock grass and open herbs and low grass on shallow sandy loam.
2	1	As for sample site 1
3	1	Intergrove between sites 1 & 2, sparse *Plectrachne* hummock grass
4	2	*Acacia aneura* scrub over low bunch grass and ephemeral herbs on deep cracking clay loam. Abutting *Cassia* dwarf scrub C on shallower soils.
5	3	Weakly defined grove of *Acacia aneura* and *Eucalyptus setosa* low forest A over *Triodia pungens* open hummock grass on shallow sandy loam and scree.
6	4	Clump of *A aneura* low woodland B over short bunch grassland on deep sandy clay loam. Scattered clumps of hummock grass *Plectrachne schinzii*.
7	4	Grove of *A aneura* low forest A over dwarf scrub C over open herbs on deep sandy loam. Abutting *Plectrachne schinzii* hummock grassland on intergroves.
8	5	*Acacia aneura* low woodland A over open herbs and grasses on deep loam. Grazed and heavily trampled.
9	5	As for site 8 but less heavily used by stock.
10	6	Clump of *Acacia aneura* low forest B over *Triodia pungens* hummock grassland on shallow loam and gravel on drainage channel.
11	6	Grove of *A aneura* low forest B over open dwarf scrub C over open herbs and grasses on shallow sandy loam.
12	7	Grove of *A aneura* low forest A over open herbs and grasses on deep cracking clay loam.

During the sampling period 64 species of ants were collected from the 12 study sites. These are shown in Table 3. Fifty-two species (81.2%) were captured in pitfall traps on at least one of the study sites. Of the remaining ants Podomyrma sp 61, Calomyrmex sp 62 and Polyrachis sp 70 did not forage on open ground, but occupied the tree trunks and deadwood. Other species including Crematogaster sp 44, Iridomyrmex sp 31874, Camponotus spp 23, 29, 64 & 62 Polyrachis sp 60 and Melophorus sp 41 were inactive and most were excavated from nests. Both Polyrachis sp 60 and Melophorus sp 41 nest on the open edges of groves and in the intergroves where there is high insolation. Polyrachis is the 'mulga ant' which arranges mulga phyllodes over the turret-like entrance of the nest; it has been collected whilst foraging in October and November. Melophorus sp 41 is a yellow 'honeypot' ant, the repletes of which were dug from nests in July '84. It has been collected in open spaces whilst active in October, November and January. In January these ants were active during daylight with air temperatures over 40°C.

Species Richness

The highest total richness was 33 species, recorded at site 11, and the lowest was 11 species at sites 4 and 7. The values for pitfall species richness and mean number of species per trap follow the same trends as total richness. Two factors appear to influence the number of species present. One of these is the density of the mulga canopy. This relationship is not clear using the canopy cover classes of Muir (1979). In table 6 the sites are grouped into classes for percentage crown cover dividing the 30-70% forest category of Muir (1977) into two classes. Table 6 shows that high ant species richness occurred on undisturbed sites with 11-30% and 31-50% canopy cover. Lower richness was associated with sites with canopy cover density less than 10% and over 50%. At those sites with over 50% canopy cover, low species richness was possibly related to low ant abundance but this was not the case with sites with less than 10% crown density. Low richness in sparse mulga stands may be related to low productivity whilst in mulga forest low insolation may reduce the number of species.

The second factor which appears to affect species richness is disturbance. Sites 8 and 9 (not included in table 6) were both on Juna Downs station and grazed by stock. The sites were on opposite sides of a fence line and site 8 was more heavily trampled than site 9. More than 20 species would have been expected from this woodland area (canopy cover 11-30%) but total richness recorded for site 8 was only 12 species and site 9 had 18 species. This loss of richness was associated with high ant abundance. Values for dominance index ranged from 0.135 (low dominance) at site 1 to 0.998 at site 8. Generally high dominance index values were

Table 6. The total ant species richness and mean number of pitfall-trapped indviduals at ungrazed sites grouped into four classes on the basis of mulga canopy cover.

	Mulga canopy cover			
	0-10%	11-30%	31-50%	51-70%
Sites	3, 4	6	1, 2, 5, 10, 11	7, 12
Total species richness	11-16	28	19-33	11-12
Mean no. of individuals	1707	285	709	747*

* numbers trapped at site 12 scaled to captures per 5 days

associated with sites with sparse or dense mulga canopy cover (ie sub-optimal habitats) and with disturbed sites. Conversely, undisturbed sites in preferred habitats were not strongly dominated by a few species. The high dominance index values recorded for dense mulga stands may be a seasonal characteristic related to low ground insolation. Increased activity in scarce species during the warmer times of year may reduce the dominance of a few winter-active species.

Figure 4 (Appendix II) shows the grouping of sites obtained by principal components analysis. Two clusters involving ten (10) sites are identified and two sites remain ungrouped. An examination of the environmental/vegetation site characteristics suggests that two (2) dominant processes control the distribution of ant species. These are the related factors of site soil moisture and soil texture and the dominance of either hummock grasses (Triodia or Plectrachne) or bunch grasses and forbs in the ground layer. Sites 1, 2, 3 and 5 occur on slopes or elevated outwash plains with shallow and sandy soils. These sites are relatively dry and hummock grasses predominate over bunch grasses and forbs.

Site 6 was unusual in that it was dominated by a species of Rhytidoponera instead of the usual Iridomyrex spp.. Although located in an area of short bunch grassland clumps of Plectrachne also occurred with the mulga. The soil was loamy but relatively dry.

Site 11 had the combination of shallow, sandy loam but with bunch grasses and forbs in the ground layer. This was not observed at other sites. The groves of low forest were narrow and the intergroves relatively broad. These conditions appear to be optimal for ants.

Thus within the mulga-dominated communities of of the study area, two (2) minor habitats were recognised on the basis of ant species composition. Broadly, these divisions also appear to be applicable to other faunal groups.

4.2 Invertebrate fauna

The only survey of invertebrates in the study area (with the exception of the ant sampling conducted in July 1984) was a survey of ants (Formicinae), termites (Isoptera) and springtails (Collembola) conducted at West Angelas in December 1979 (Integrated Environmental Services, 1980). Much of the data on ants was published in Majer (1983a, 1983b) and also in Dunlop et al, (in press). Analysis of the termite and springtail populations has not been previously presented in an open publication.

The West Angelas study was based on intensive collections in eight (8) one hectare plots, four (4) of which were in habitats with a dominant mulga stratum. The remainder were in hummock grassland habitats. In table 7 the sampled mulga habitats are described using the vegetation life-form density classes of Muir (1977).

Table 7. Description of vegetation (life form density classes) in mulga habitats sampled for invertebrates

Sample Plot	Vegetation Description
a	Mulga *Acacia aneura* low woodland B over open *Triodia pungens* hummock grassland on stoney scree slope with some outcropping rock.
b	Mulga *Acacia aneura* low forest A over *Triodia pungens* hummock grassland on shallow sandy loam.
c	Mulga *Acacia aneura* woodland A over *Triodia pungens* hummock grassland on sandy loam.
d	similar to C.

Termites were collected during searches of three (3) hours duration in daylight and one (1) at night. During the searches foragers were collected, mounds were opened, the ground surface scraped to reveal galleries, living and dead wood was inspected and leaf litter was raked. In all cases an attempt was made to collect specimens of the soldier caste of any species detected as these were necessary for reliable identification. The number of colonies of each species detected in the plot was recorded.

Three techniques were used to sample springtails. Surface-active species were collected in twenty-five pitfall traps (18 mm internal diameter tubes containing 5 ml of alcohol/glycerol, 70/30 v/v). Traps were set for 7 to 8 days.

Approximately six (6) litres of leaf litter was collected from each plot and transported in sealed polyethylene bags to the laboratory. Here the litter which was dry in the field was moistened to activate quiescent individuals. Springtails were then extracted over a one-week period in eight Berlese funnels.

Thirteen (13) soil cores were sampled from each plot and placed in sealed tins. These were sent to the laboratory and the springtails extracted using a multiple canister heat extractor. All termites were identified by Mr D H Perry of Victoria Park, (W A) and springtails by Ms P Greenslade of the South Australian Museum. Listed in Table 8 are thirty eight (38) species of Collembola collected from at least one of the four (4) mulga habitats. Many of these were also recorded from hummock grassland sampling sites with only one species, Lepidocrytoides sp 2, showing a strong association with mulga. The exotic springtail Cryptopygus thermophilus was present in the West Angelas area but was not present in the Mulga habitats. This indicates that the latter are essentially undisturbed ecosystems.

Representatives of Entomobryidae and Neanuridae were more abundant in mulga habitats than in hummock grassland. This may be due to a relationship with the relatively deep leaf litter under mulga stands. No relationship between Collembola species composition and vegetation type was found. In this respect they differ from ants (Majer 1983a, b) and termites for which distinct communities were identified with hummock grassland and mulga woodland. In table 9 twelve (12) species of termite recorded from at least one (1) of the mulga habitats sampled are listed. One species Tumulitermes tumuli appears to be restricted to mulga habitats and is known to feed on Acacia litter as does Drepanotermes columellaris. Some wood-feeding species were also more or less confined to mulga including Heterotermes occiduus, Schedorhinotermes intermedius and Nasutitermes centraliensis. Species of underground dwelling or mound building Drepanatermes were found in mulga on deeper, friable soil (plots C & D).

Table 8. List of Collembola collected from four Mulga *Acacia aneura* communities and from hummock grassland at West Angelas (P Greenslade unpublished data).

SPECIES	SITES				
SMINTHURIDAE	2	6	7	8	Hummock grassland
Sphaeridia sp	+	+	+	+	+
Sminthurinus sp		+		+	+
Aneuempodialis sp				+	
**Corynephoria* sp 1	+				+
Corynephoria sp 2		+			
**Corynephoria* sp 3			+	+	+
**Corynephoria* sp 4			+		
Corynephoria sp 6				+	
Corynephoria sp 7				+	
ENTOMOBRYIDAE					
Lepidobrya sp			+		+
Acanthurella sp		+	+	+	+
Lepidosira sp		+	+	+	+
Drepanura sp			+	+	+
Entomobrya sp				+	+
Willowsia sp		+			+
**Lepidocyrtoides* sp 1	+	+			
Lepidocyrtoides sp 2	+	+	+	+	
Lepidocyrtoides sp 3	+	+	+	+	+
Lepidocyrtoides sp 4	+				+
ISOTOMIDAE					
Acanthomorus sp	+	+	+	+	+
Proisotoma brisbanensis		+			+
Folsomides sp 1	+	+	+	+	+
**Folsomides* sp 2	+		+	+	+
Folsomides sp 3	+	+	+	+	+
**Folsomides* sp 4	+	+	+	+	+
Folsomides sp 5	+	+	+	+	+
Folsomides sp 6	+				+
Folsomides sp 7		+	+	+	+
Folsomides sp 9		+			
HYPOGASTRURIDAE					
Xenylla sp				+	
NEANURIDAE					
Odontella sp 1		+			
**Odontella* sp 2		+			
cf *Ceratrimeria* sp		+	+	+	+
Pseudachorutella sp		+			+
Pseudachorutes sp			+		+
**Probrachystomella* sp		+		+	+
**Subclavontella* sp 1		+	+		+
Brachystomella sp		+			+

* new species at time of survey

Table 9. List of Isoptera collected from four mulga *Acacia aneura* communities and from hummock grassland at West Angelas (D H Perry, unpublished data).

SPECIES	SITES				
	2	6	7	8	Hummock grassland
RHINOTERMITIDAE					
Heterotermes occiduus	+				
Schedorhinotermes intermedius		+	+	+	+
TERMITIDAE					
Tumulitermes dalbiensis	+				+
Tumulitermes tumuli	+	+	+	+	
Tumulitennes recaluus		+			+
Tumulitermes sp nov a	+			+	+
Tumulitermes sp nov c	+	+			
Nasutitermes centraliensis		+			
Drepanotermes columellaris			+		
Drepanotermes corax				+	+
Drepanotermes diversicolor				+	
Drepanotermes rubriceps				+	+

4.3 The Vertebrate Fauna

The herptile, bird and small mammal faunae of the study area are documented by Muir (ed, 1983). Mulga communities are probably the preferred habitat of about thirty (30) of the region's hundred or so herptile species. However few of them are restricted to mulga habitats, many being more closely associated with the friable substrates on which mulga stands occur eg Delma nasuta, Ctenophorus isolepis, Ctenotus helenae, Ctenotus duricola, Omolepida branchialis, Varanus brevicauda, Rhamphotyphlops spp, Pseudonaja modesta and Vermicella approximans. Other species are associated with trees (arboreal) or deadwood including Gehyra variegata, Pogona minor, Cryptoblepharus plagiocephalus and Varanus caudolineatus. Reptiles which appear to be more or less confined to mulga habitats in the area are Diplodactylus pulcher, Diplodactylus granariensis and Ctenotus schomburgkii.

Many species of birds have been observed in mulga habitats in the area, primarily because of their mobility. However as a basis for conservation it is pertinent to describe the typical assemblage of species.

The common passerine insectivores are the Thornbills Acanthiza robustirostris and A. uropygialis, Desert Flyeater Gerygone fusca mungi, Variegated Wren Maluris lamberti, Rufous Whistler Pachycephala rufiventris, Red-capped Robin

Petroica goodenovii and Hooded Robin Petroica cucullata. The Grey Shrike Thrush Colluricincla harmonica is common in the better-watered stands of mulga in incised valleys and gorges and close to creek lines. The Grey Fantail is a scarce migrant which inhabits mulga. These birds include individuals of the races alisteri of south-eastern Australia, albicauda of arid central Australia, and preissii of south-western Australia. The Western Flyeater Gerygone fusca is also a migratory visitor to the mulga lands of the south-eastern Pilbara (Johnstone 1983b).

The rare Grey Honeyeater Lacustroica whitei is not uncommon in the mulga communities around West Angelas. The Spiny-cheeked Honeyeater Acanthagenys rufogularis and Singing Honeyeater Meliphaga virescens are the most frequently observed honeyeaters.

Of the seed-feeders the Zebra Finch Poephila guttata is common and the Bourke Parrot Neophema bourkii is locally abundant eg in the vicinity of Giles Point. The Bustard Otis australis is frequently observed in mulga/bunch grassland habitats. The mulga woodlands of the study area are inhabited by the Grey Butcher-bird Cracticus torquatus with the Pied Butcher-bird Cracticus nigrogularis occupying other habitats.

Table 10 shows the distribution of small mammal species in several broadly defined mulga-dominated habitats. Three (3)

Table 10. Small ground-living or scansorial mammals recorded from mulga *Acacia aneura* dominated habitats in the study area.

	Scrub over bunch grassland	Low woodland (A or B) over bunch grassland	Low woodland (A or B) over hummock grassland	Dense low (groved) woodland (A or B)
MAMMALS				
Antechinus rosamondae			+	
Ningaui timealeyi			+	
Sminthopsis macroura	+	+	+	+
Sminthopsis ooldea			+	+
Planigale maculata			+	
Planigale cf *ingrami*	+			
Pseudomys hermannsburgensis	+	+	+	+
Mus musculus	+	+	+	+

dasyurid species Antechinus rosamondae, Ningaui timealeyi and Planigale maculata are closely associated with a ground layer of hummock grass (Dunlop & Sawle, 1983). Sminthopsis macroura is found in mulga but its preferred habitat appears to be bunch grassland. The only specimen of Planigale ingrami from the Pilbara was collected from low bunch grassland abutting mulga scrub on cracking clay. This allopatric specimen may represent a new taxon endemic to the south-eastern Pilbara. The only small mammal apparently confined to mulga-dominated vegetation in the area is the Ooldea Dunnart Sminthopsis ooldea. Of the four (4) native rodents recorded from the region only the Sandy Inland Mouse Pseudomys hermannsburgensis occurs in the mulga (Dunlop & Sawle 1983).

The Red Kangaroo Megaleia rufa is common in mulga abutting plains vegetated with bunch grassland. Euros Macropus robustus inhabit slopes vegetated with mulga. Most of the region's intermediate-sized mammals are probably extinct although there have been two recent sightings of Rabbit-eared Bandicoots Macrotis lagotis from the south-eastern Pilbara.

Bats have been netted over pools in mulga-dominated vegetation. The species captured were the smaller sized bats of the region including Eptesicus pumilis, Scotorepens greyii, Mormopterus cf beccari, Nyctophilus geoffroyii and Chalinolobus gouldii. This observation may reflect the small size of available tree hollows in mulga habitats.

5.0 CONSERVATION MANAGEMENT

In relation to the mulga communities of the south-eastern Pilbara the following conservation objectives for land-use planning have been considered.

1) Extension of the Hamersley Range National Park to:

   a) reserve stands of mulga-dominated vegetation which represent the major habitat variations,

   b) incorporate complete mulga watersheds,(where possible)

   c) include wildlife habitats not adequately represented in the HRNP,

   d) establish scientific reference areas to monitor the impact of increased fire frequency, grazing and mining in the region, and

   e) include in the reserve, where possible, any other scenic landscape features which enhance the aesthetic value of the additional area.

2. Delineation of management priority zones in areas required for other land uses. Within these zones specific design or management practices will be required to

ameliorate impact on the mulga ecosystem. Activities within management priority zones should be addressed in Environmental Review and Management Plans for proposed mineral developments and in applications for pastoral leases.

Management zones are indicated in Figure 5 (Appendix II). These include a proposed extension to the Hamersley Range National Park, a scientific reference area (fire exclusion zone) inside the present boundaries of the HRNP, and a mosaic of management priority areas within the region.

<u>Proposed Extension to the Hamersley Range National Park</u>

The extension proposed for the HRNP encompasses three east-west trending valleys vegetated with relatively undisturbed mulga communities. These valleys are contiguous with small areas of mulga and riverine habitat inside the present HRNP. The proposed boundaries take in the entire watersheds of the valleys and part of the headwater of Turee Creek East Branch. Thus the mulga drainage systems within the extension should not be affected by development activities outside the Park boundaries. The ridges, in particular the Twin Peaks Ridge, have some of the best examples in the area of mulga on slopes and in incised valleys. The Twin Peaks Ridge is also an outstanding landscape feature, and together with the inclusion of Mt Meharry (the highest point in WA) would add significantly to the scenic value of the proposed extension.

The habitats of wildlife not recorded from the Park are present in the extension. Populations of Ooldea Dunnart Sminthopsis ooldea and Lerista neander will almost certainly be added to the species conserved in the Park. Additional areas of habitat for rare species such as the Pebble-mound Mouse Pseudomys chapmani, Ghost Bat Macroderma gigas, Grey Honeyeater Lacustroica whitei and Pilbara Olive Python Liasis olivaceus barroni would also be conserved by the extension. Unfortunately it is not possible to include a representative area of tall mulga forest within the proposed boundaries, nor is the habitat of Planigale cf ingrami protected.

The proposed extension takes into account our present knowledge of future mining needs in the area. No major ore body is located within the proposed extension although the current Cliffs International Inc exploration camp lies just within the south-eastern corner. The town site proposed for future Cliffs International Inc and Goldsworthy Mining Pty Ltd operations is located just north of the Governor and is not affected. Both companies would be mining close to the proposed boundaries. At present the entire area is taken up by leases for mineral exploration.

Scientific Reference Areas

In July 1984 an extensive area in the south-eastern sector of the HRNP was traversed in search of tracts of mulga woodland and hummock grassland which had not been recently disturbed by fire. However almost the entire area showed signs of burning within the previous 4-5 years. One useful exception was an area of grove and intergrove mulga north and west of Turee Creek East Branch. This area, currently within HRNP boundaries, is representative of mulga vegetation on tertiary outwash plains; the results of the ant survey suggested that the area is rich in species and more or less undisturbed. There was however evidence of intrusion by cattle probably from Juna Downs station. The hills surrounding the outwash plain had been recently burnt but the mulga had not been affected.

It is recommended that this area be established as a scientific reference area and managed to exclude wildfire. Further, should the proposed HRNP extension be endorsed then the reference area (with a fire management priority) should be extended to include the southern half of the additional area. This zone could be used not only in monitoring the ecological impact of increasing fire frequency, but also the peripheral effects of mining and grazing.

Management Priority Areas

These include most of the major drainage basins and outwash plains in the area together with the headwaters of key catchments (eg Turee Creek East Branch). Within all priority areas steps should be taken to prevent the impediment of natural surface drainage. Design features developed for the construction of the Newman to Port Hedland National Highway (Dames & Moore 1984) should have application in the development of roads servicing new mining and townsite areas. Structures other than roads may also produce significant drainage shadows.

The Coondewanna Flats is a priority area which is now located on Juna Downs station. Stocking rates and management practices in this area should be carefully regulated to prevent further deterioration in this rangeland. Such controls should also conserve the scenic amenity of the Mt Robinson-Governor area through which the new National Highway passes.

The priority area encompassing Wanna Munna Flats and the mulga west of Giles Point has been disturbed by intense mineral exploration. However the area contains mulga formations and wildlife habitats (dense forest A, short bunch-grassland) which could not be included in the proposed extension. The possibility of establishing an Ophthalmia Range reserve which includes the scenic Mt Newman and Giles

Point peaks and some of the surrounding mulga lands should be explored. This area, and locations such as Weeli Wolli Springs, should be included in a regional system of nature reserves.

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APPENDIX I

FLORA OF MULGA ACACIA ANEURA DOMINATED COMMUNITIES IN THE STUDY AREA

PTERIDOPHYTA

ADIANTACEAE

Cheilanthes tenuifolia (Burm. f) Sw

MONOCOTYLEDONES

POACEAE

Amphipogon caricinus F. Muell

Aristida anthoxanthoides (Domin.) Henr.

Aristida contorta F. Muell.

* *Aristida obscura* Henr.

Cenchrus ciliaris L.

Chrysopogon fallax S. T. Blake

Cymbopogon bombycinus (R. Br.) Domin.

Cymbopogon procerus (R. Br.) Domin.

Dactyloctenium radulans (R. Br.) Beauv.

Digitaria brownii (Roem. & Schult.) Hughes

Enneapogon caerulescens (Gaud.) N. T. Burb.

Enneapogon pallidus (R. Br.) Beauv.

* *Enneapogon polyphyllus* (Domin.) N. T. Burb.

Eragrostis eriopoda Benth.

Eragrostis falcata (Gaud.) Benth.

Eragrostis japonica (Thunb.) Trin.

Eriachne benthamii (Domin.) Hartley

Eriachne mucronata R. Br.

Eulalia fulva (R. Br.) Kuntze

Paraneurachne muelleri (Hack.) S. T. Blake

* Paspalidium clementii (Domin.) C. E. Hubbard

Plectrachne schinzii Henr.

Themeda australis (R. Br.) Stapf.

Triodia pungens R. Br.

DICOTYLEDONES

PROTEACEAE

Grevillea berryana Ewart & White

Grevillea nematophylla F. Muell.

Grevillea striata R. Br.

Hakea rhombalis F. Muell.

Hakea suberea S. Moore

SANTALACEAE

Anthobolus leptomerioides F. Muell.

Exocarpos sparteus R. Br.

Santalum acuminatum (R. Br.) DC.

Santalum lanceolatum R. Br.

LORANTHACEAE

Amyema fitzgeraldii (Blakely) Danser

Amyema gibberulum (Tate) Danser

Amyema miquellii (Lehm. ex Miq.) Tiegh.

Amyema sanguineum (F. Muell.) Danser

Lysiana casuarinae (Miq.) Tiegh.

Lysiana spathulata (Blakely) Barlow

AIZOACEAE

* Trianthema glossostigma F. Muell.

PORTULACACEAE

Portulaca oleracea L. Purslane

CHENOPODIACEAE

Chenopodium melanocarpum (J. M. Black) J. M. Black

Dysphania myriocephala Benth.

* Dysphania kalpari (P. Wilson)

* Enchylaena tomentosa R. Br.

Maireana georgei (Diels) P. G. Wilson

Maireana sedifolia (F. Muell.) P. G. Wilson

Maireana triptera (Benth.) P. G. Wilson

Rhagodia priessii Moq.

Rhagodia spinescens R. Br.

AMARANTHACEAE

Amaranthus mitchellii Benth.

* Gomphrena brachystylis F. Muell.

Gomphrena canescens R. Br.

* Gomphrena cunninghamii (Moq.) Druce

Ptilotus aervoides (F. Muell.) F. Muell

* *Ptilotus carinatus* Benl.

Ptilotus drummondii (Moq.) F. Muell.

Ptilotus exaltatus Nees.

Ptilotus gaudichaudii (Steud.) J. M. Black

Ptilotus gomphrenoides F. Muell. ex Benth.

Ptilotus helipteroides (F. Muell.) F. Muell

Ptilotus obovatus (Gaud.) F. Muell.

Ptilotus polystachyus (Gaud.) F. Muell.

Ptilotus rotundifolius (F. Muell.) F. Muell.

NYCTAGINACEAE

Boerhavia diffusa L.

GYROSTEMONACEAE

Codonocarpus cotinifolius (Desf.) F. Muell.

CAPPARACEAE

Capparis lasiantha R. Br. ex DC

Capparis spinosa L.

Cleome viscosa L.

MIMOSOIDEAE

Acacia aneura F. Muell. ex Benth.

Acacia farnesiana (L.) Willd.

Acacia kempeana F. Muell.

Acacia marramamba Maslin

Acacia monticola J. M. Black

Acacia pachyacra Maiden & Blakely

Acacia pruinocarpa Tindale

Acacia aff. rhodophloia Maslin

Acacia sclerosperma F. Muell.

Acacia stowardii Maiden

Acacia tetragonophylla F. Muell.

Acacia victoriae Benth.

CAESALPINIOIDEAE

Cassia desolata F. Muell.

Cassia helmsii Symon.

* Cassia aff. leurssenii Domin.

Cassia nemophila A. Cunn. ex Vogel

Cassia notabilis F. Muell.

Cassia oligophylla F. Muell.

Cassia pleurocarpa F. Muell.

PAPILIONOIDEAE

Crotalaria novaehollandiae D. C.

Gastrolobium grandiflorum F. Muell.

Indigofera georgei Pritzel

Indigofera monophylla D. C.

Rhynchosia minima D. C.

Sesbania cannabina (Retz.) Poir.

Swainsona canescens (Benth.) F. Muell.

Swainsona microcalyx J. M. Black

Tephrosia bidwillii Benth.

Tephrosia sphaerospora F. Muell.

ZYGOPHYLLACEAE

Kallstroemia platyptera (Benth.) Engl.

Tribulus occidentalis R. Br.

* Tribulus terrestis L.

EUPHORBIACEAE

Adriana tomentosa Gaud.

Euphorbia atoto Forst.

Euphorbia australis Boiss.

SAPINDACEAE

* Dodonaea petiolaris F. Muell.

TILIACEAE

* Corchorus parviflorus Domin.

* Corchorus walcottii F. Muell.

MALVACEAE

* Abutilon cryptopetalum (F. Muell.) F. Muell. ex Benth.

Abutilon cunninghamii Benth.

Abutilon fraseri (Hook.) Hook. ex Walp.

Malvastrum americanum (L.) Torr.

Sida calyxhymenia Gay ex DC.

STERCULIACEAE

Keraudrenia integrifolia Steud.

VIOLACEAE

Hybanthus aurantiacus (F. Muell. ex Benth.) F. Muell.

MYRTACEAE

Eucalyptus microtheca F. Muell.

Eucalyptus setosa Schauer

HALORAGACEAE

* *Haloragis gossei* F. Muell.

OLEACEAE

Jasminium lineare R. Br.

ASCLEPIADACEAE

Cynanchum floribundum R. Br.

Sarcostemma australe R. Br.

CONVOLVULACEAE

Polymeria ambigua R. Br.

Porana sericea (Gaud.) R. Muell.

BORAGINACEAE

Heliotropium heteranthum (F. Muell.) Ewart & Davies

Trichodesma zeylanicum (Burman) R. Br.

CHLOANTHACEAE

Dicrastylis cordifolia Munir

* *Newcastelia cephalantha* F. Muell.

* *Spartothamnella teucriiflora* (F. Muell.) Mold.

SOLANACEAE

* Solanum centrale J. M. Black

Solanum lasiophyllum Dun. ex Poir

* Solanum sturtianum F. Muell.

ACANTHACEAE

* Dipteracanthus corynothecus (F. Muell. ex Benth) Bremek ex Ba

MYOPORACEAE

Eremophila exilifolia F. Muell.

Eremophila fraseri F. Muell.

Eremophila foliosissima Kraenzlin

Eremophila goodwinii F. Muell.

Eremophila latrobei F. Muell.

Eremophila leucophylla Benth.

Eremophila maculata (Ker-Gawl.) F. Muell.

Eremophila punicea S. Moore

CAMPANULACEAE

Wahlenbergia sp.

RUBIACEAE

Canthium latifolium F. Muell. ex Benth.

Canthium lineare E. Pritz.

CUCURBITACEAE

Mukia maderaspatana (L.) M. J. Roem.

GOODENIACEAE

Scaevola sp.

ASTERACEAE

Bidens bipinnata L.

Brachycome ciliaris (Labill.) Less.

Centipeda sp.

* Denotes a plant species recorded for the first time in July 1984.

APPENDIX II

FIGURES 1-5

FIGURE 1. THE SOUTH-EASTERN PILBARA REGION

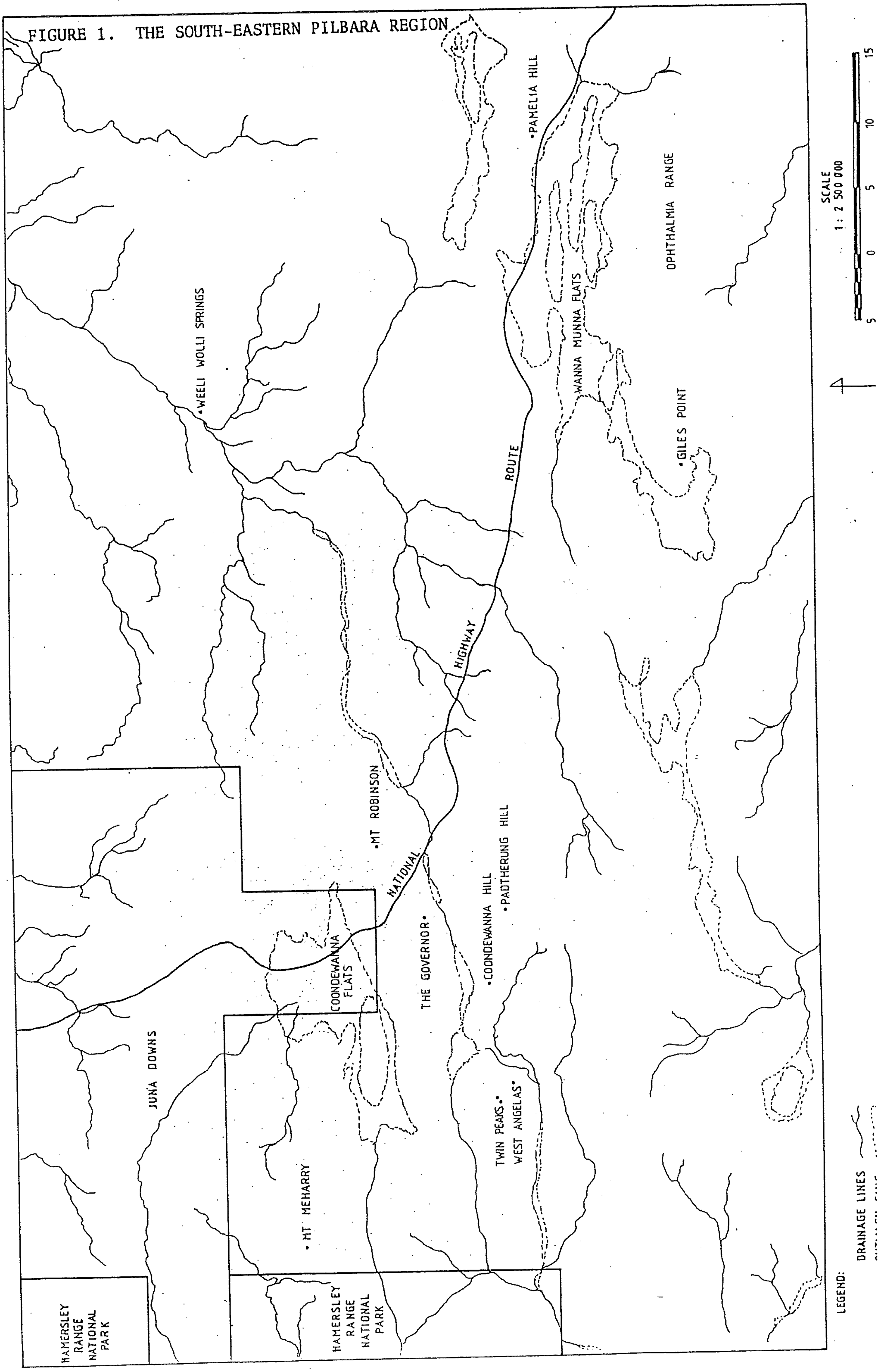


FIGURE 2. MICROTOPOGRAPHIC SURVEY THROUGH TWO GROVES ON AN OUTWASH PLAIN SOUTHEAST OF PAMELIA HILL

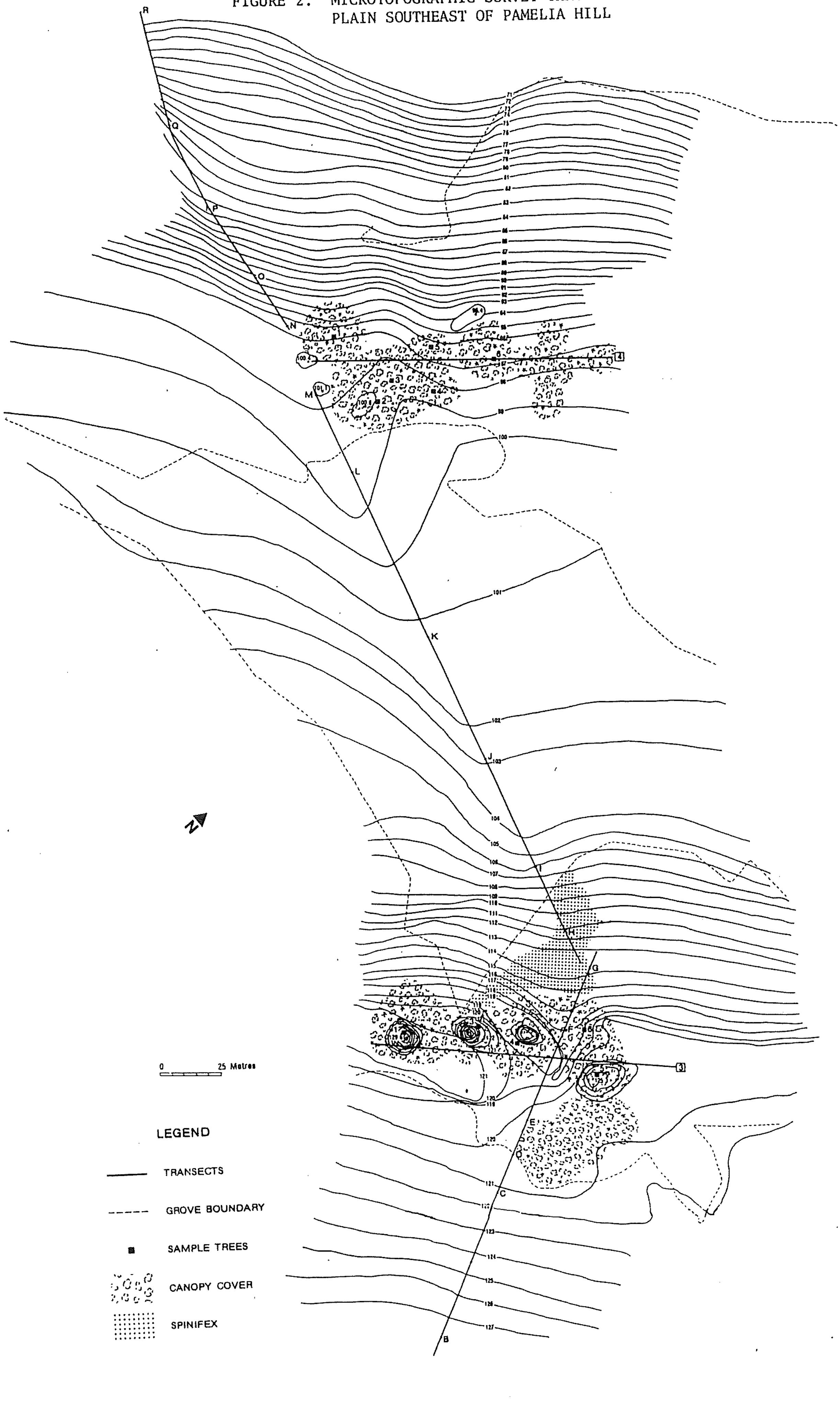


FIGURE 3. STUDY SITES
MULGA SURVEY JULY 1984

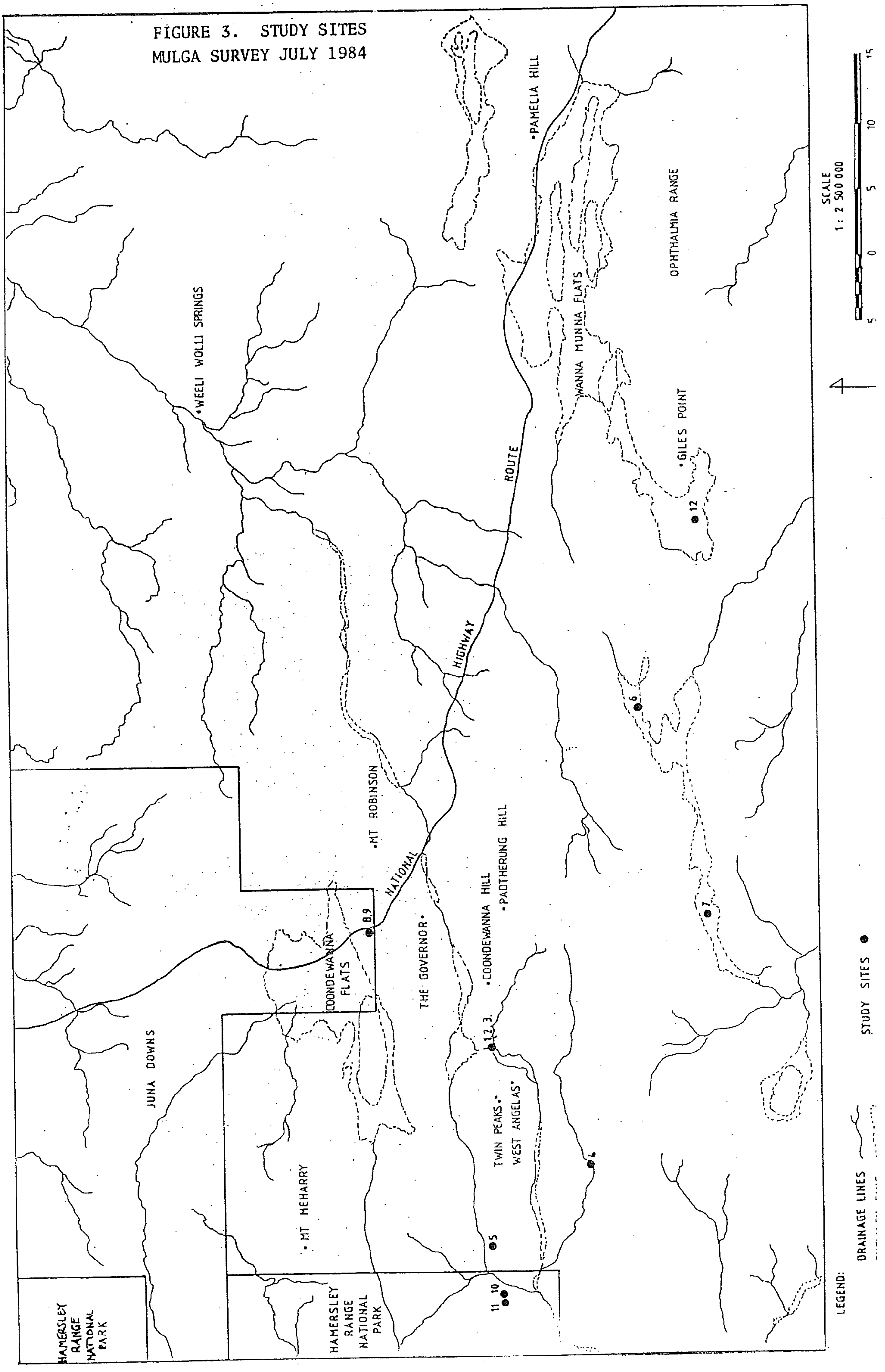


FIGURE 4. PRINCIPAL COMPONENTS ORDINATION OF ANT PRESENCE/ABSENCE DATA

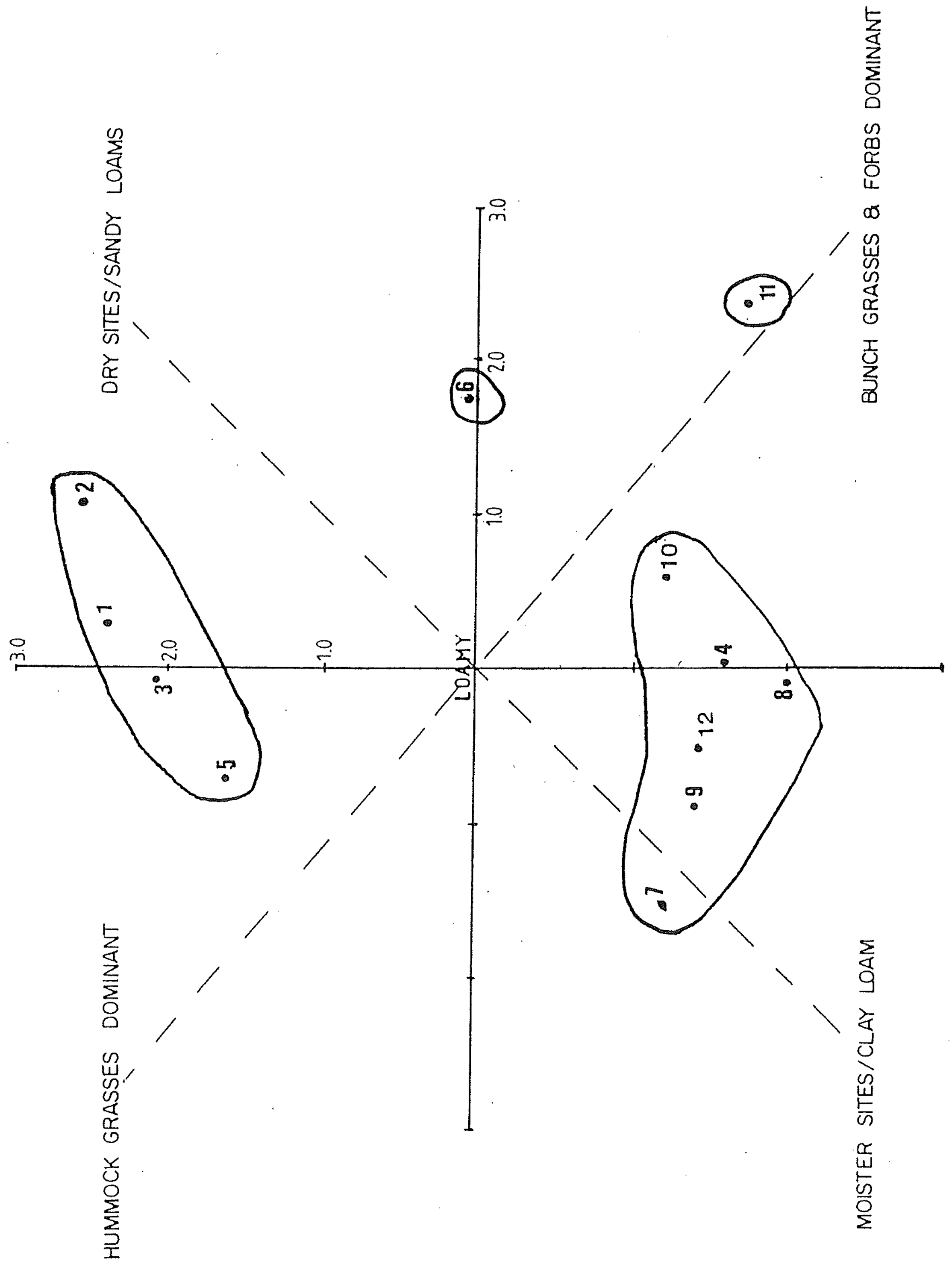
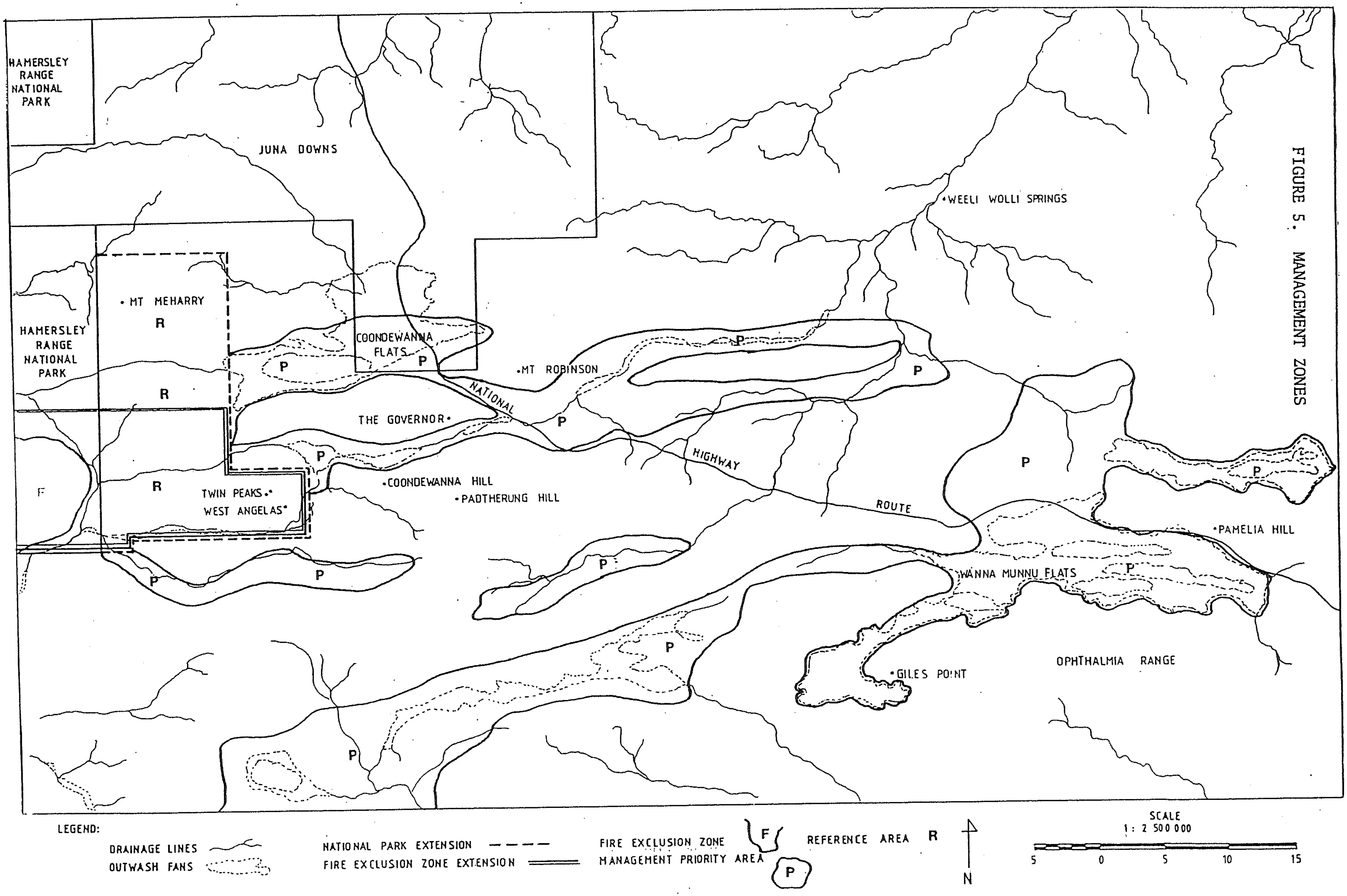
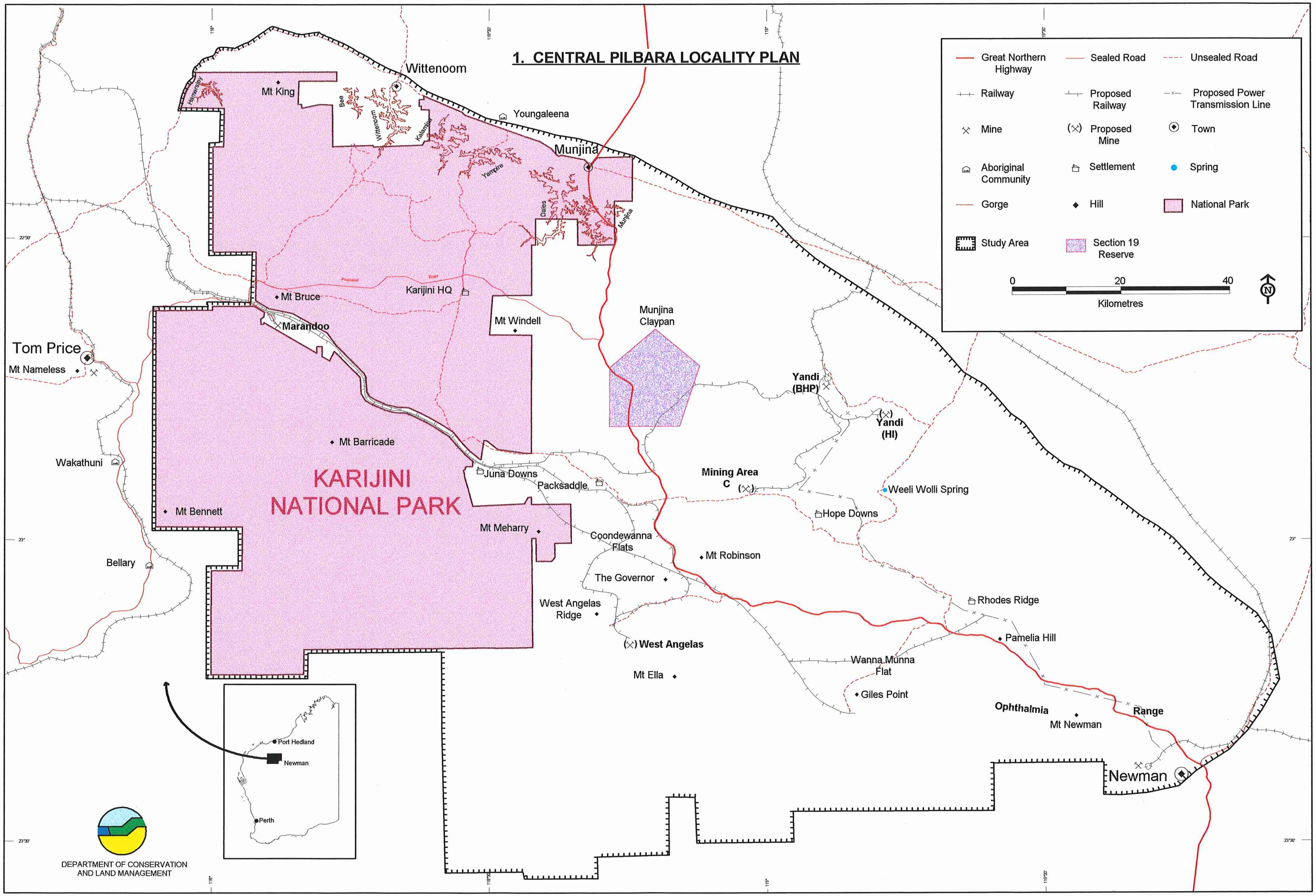
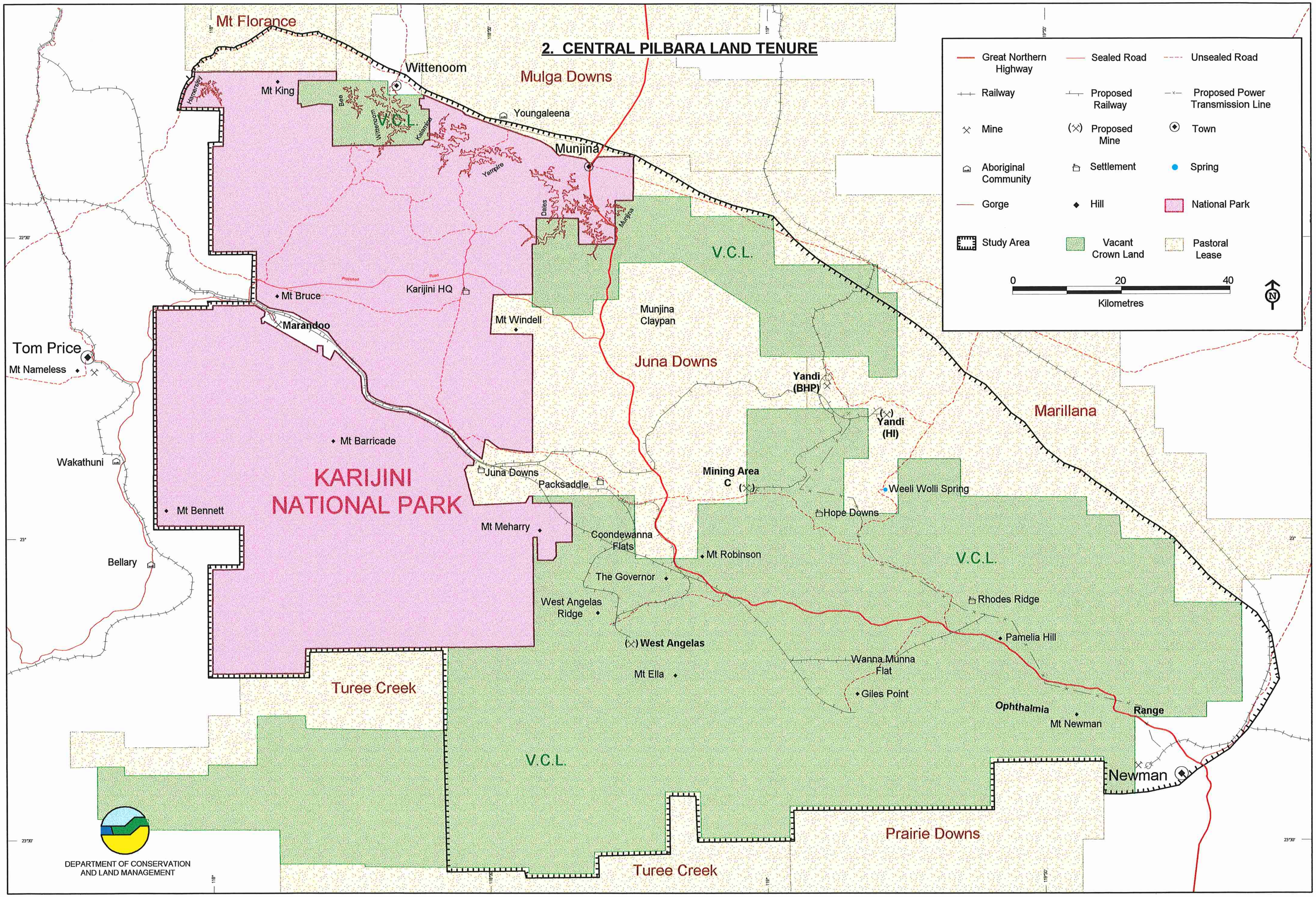


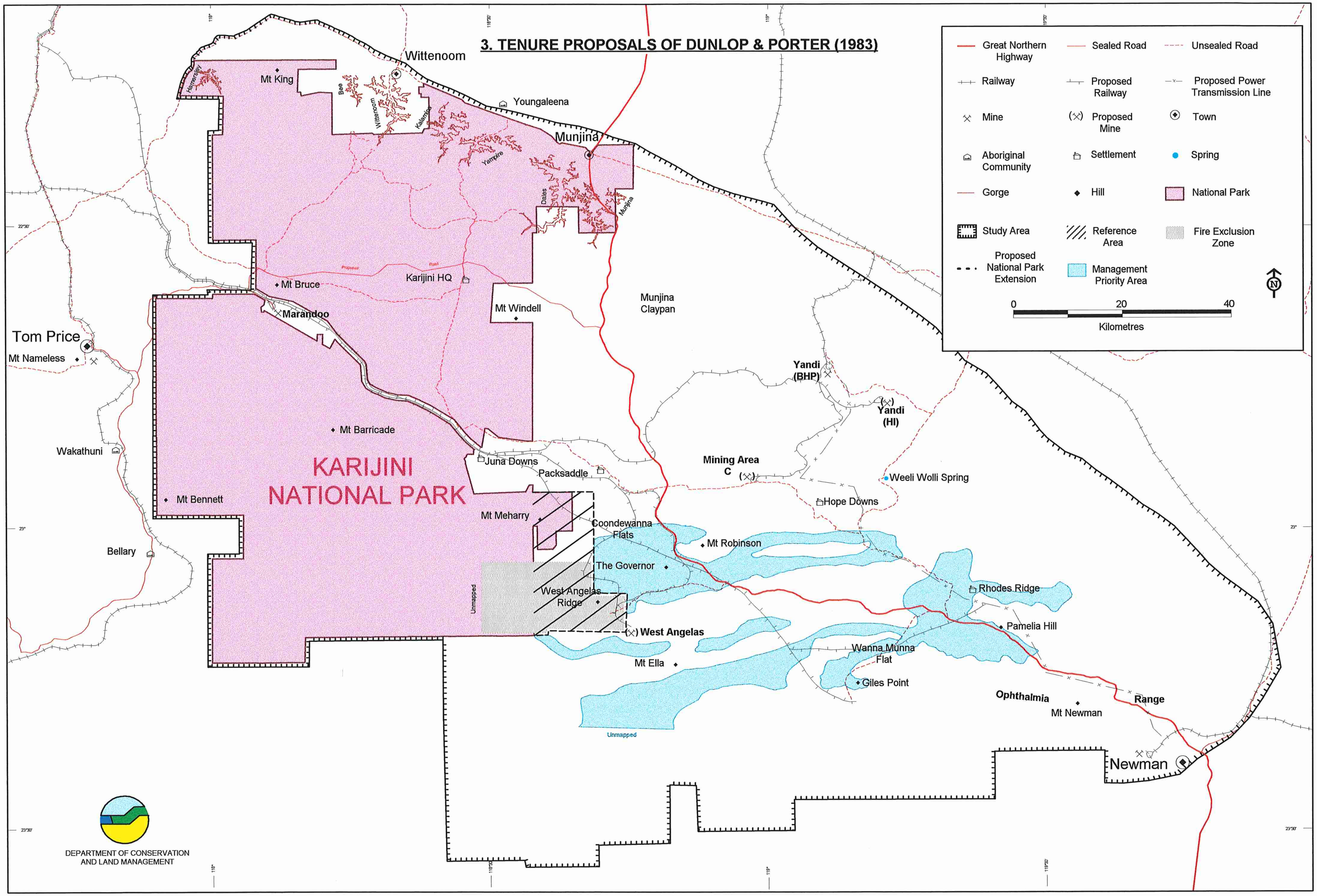
FIGURE 5. MANAGEMENT ZONES

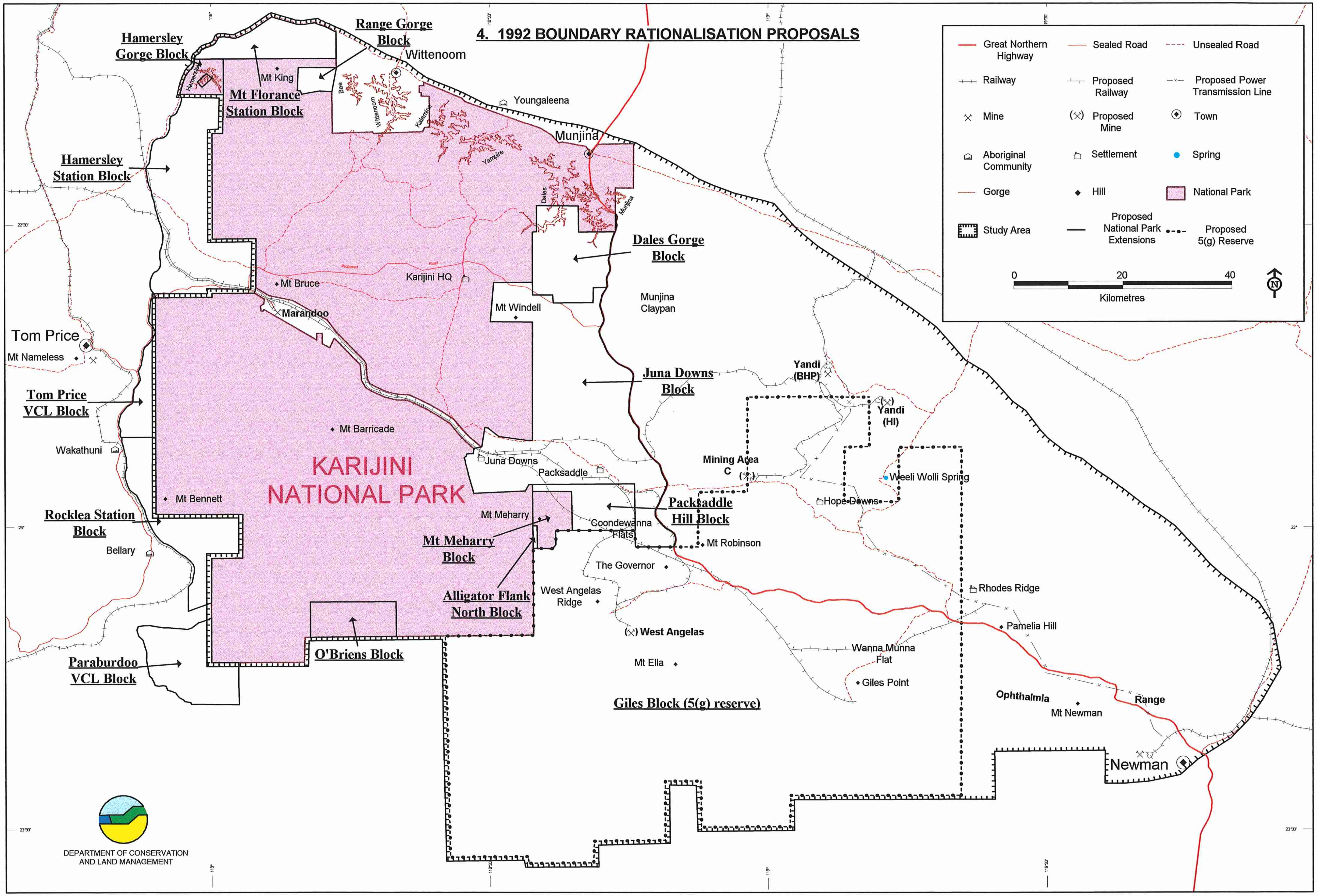


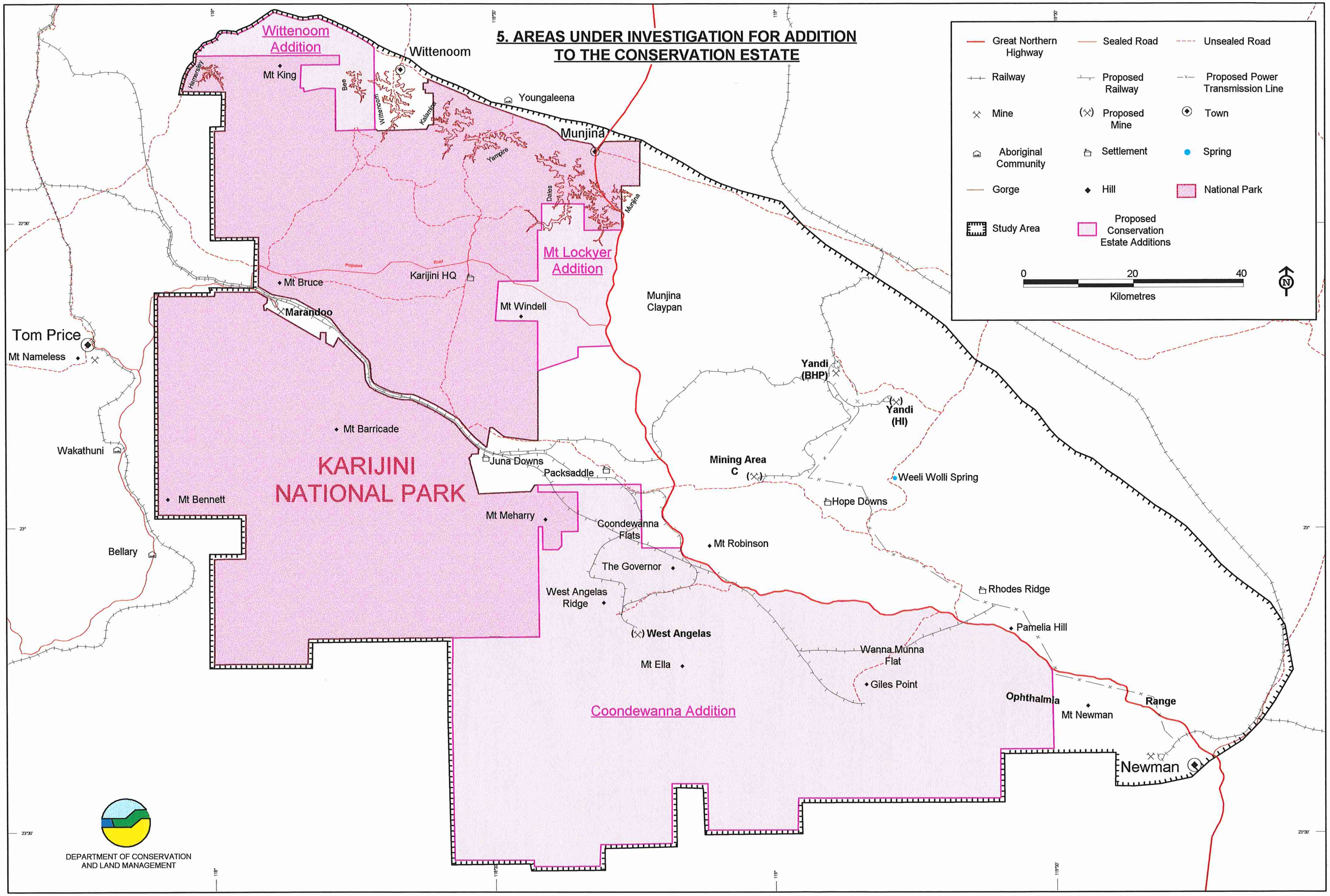


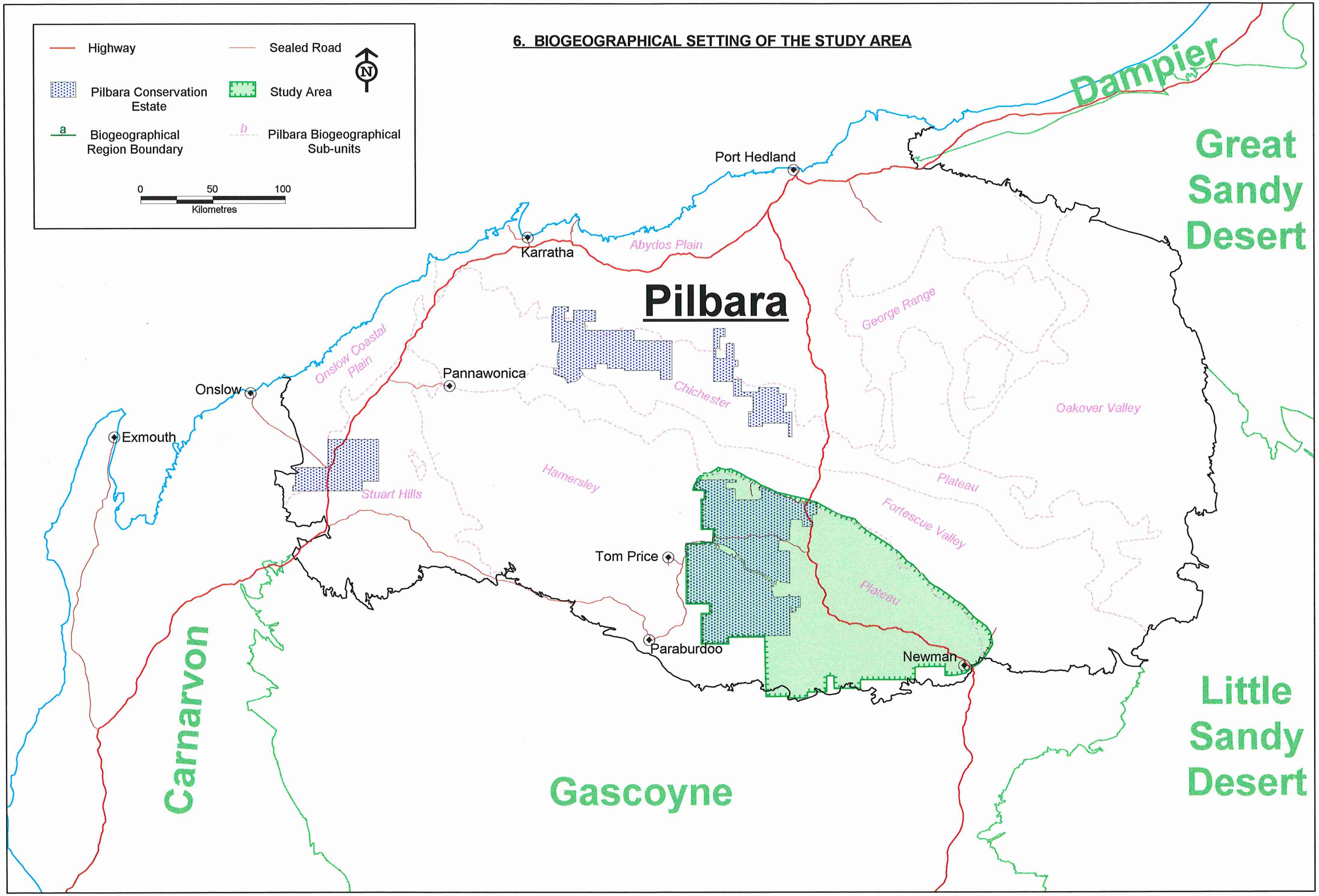
1. CENTRAL PILBARA LOCALITY PLAN

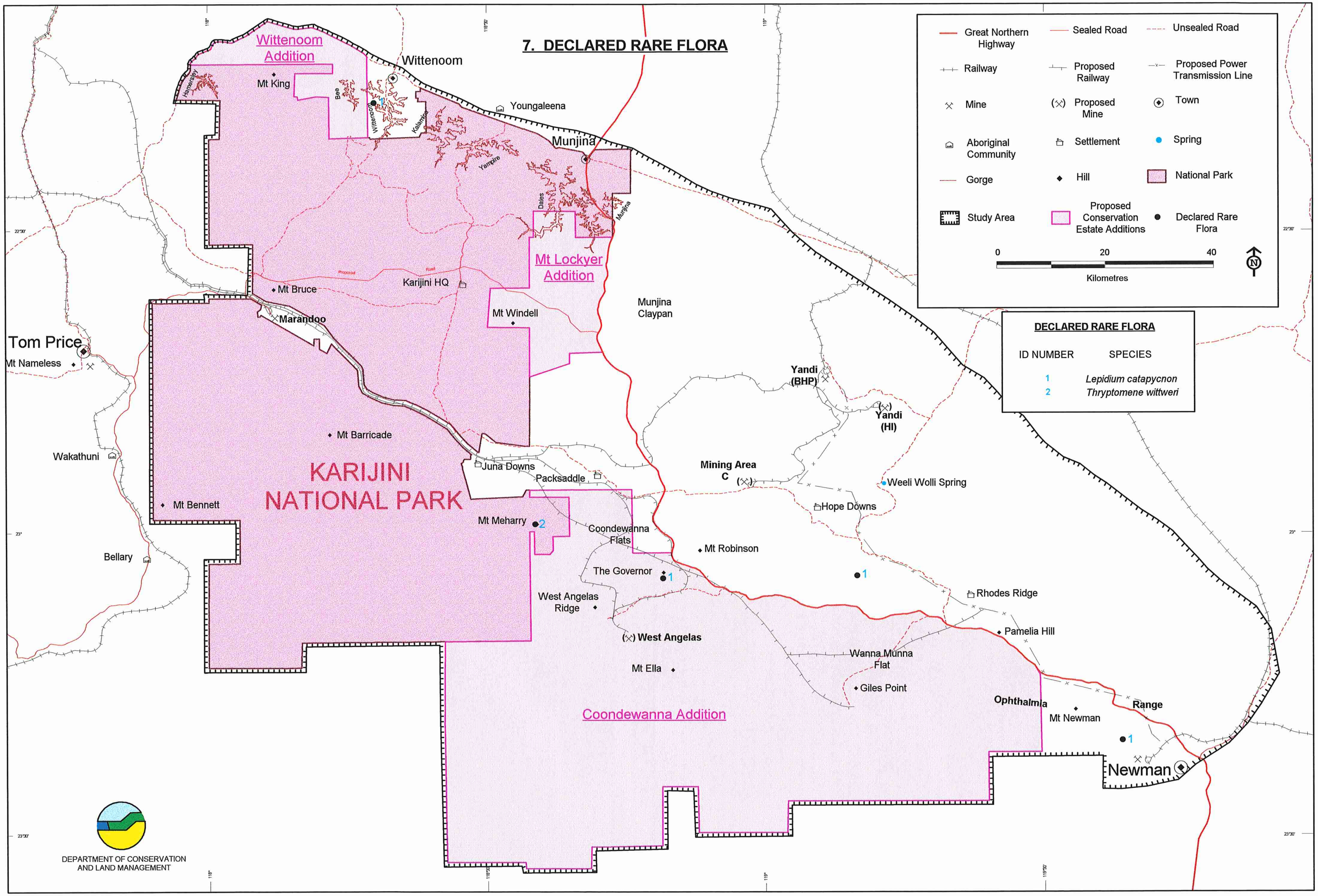

2. CENTRAL PILBARA LAND TENURE
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Vacant Crown Land
Pastoral Lease
0
20
40
Kilometres
N
Mt Florance
Wittenoom
Mulga Downs
Mt King
V.C.L.
Youngaleena
Munjina
Karijini HQ
Mt Bruce
Marandoo
Mt Windell
Munjina Claypan
Juna Downs
Tom Price
Mt Nameless
Yandi (BHP)
Yandi (HI)
Marillana
Mt Barricade
Wakathuni
KARIJINI NATIONAL PARK
Juna Downs
Packsaddle
Mining Area C
Weeli Wolli Spring
Hope Downs
Mt Bennett
Mt Meharry
Coondewanna Flats
Mt Robinson
Bellary
The Governor
Rhodes Ridge
West Angelas Ridge
Pamelia Hill
West Angelas
Wanna Munna Flat
Mt Ella
Giles Point
Turee Creek
Ophthalmia Range
Mt Newman
V.C.L.
Newman
Prairie Downs
Turee Creek
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

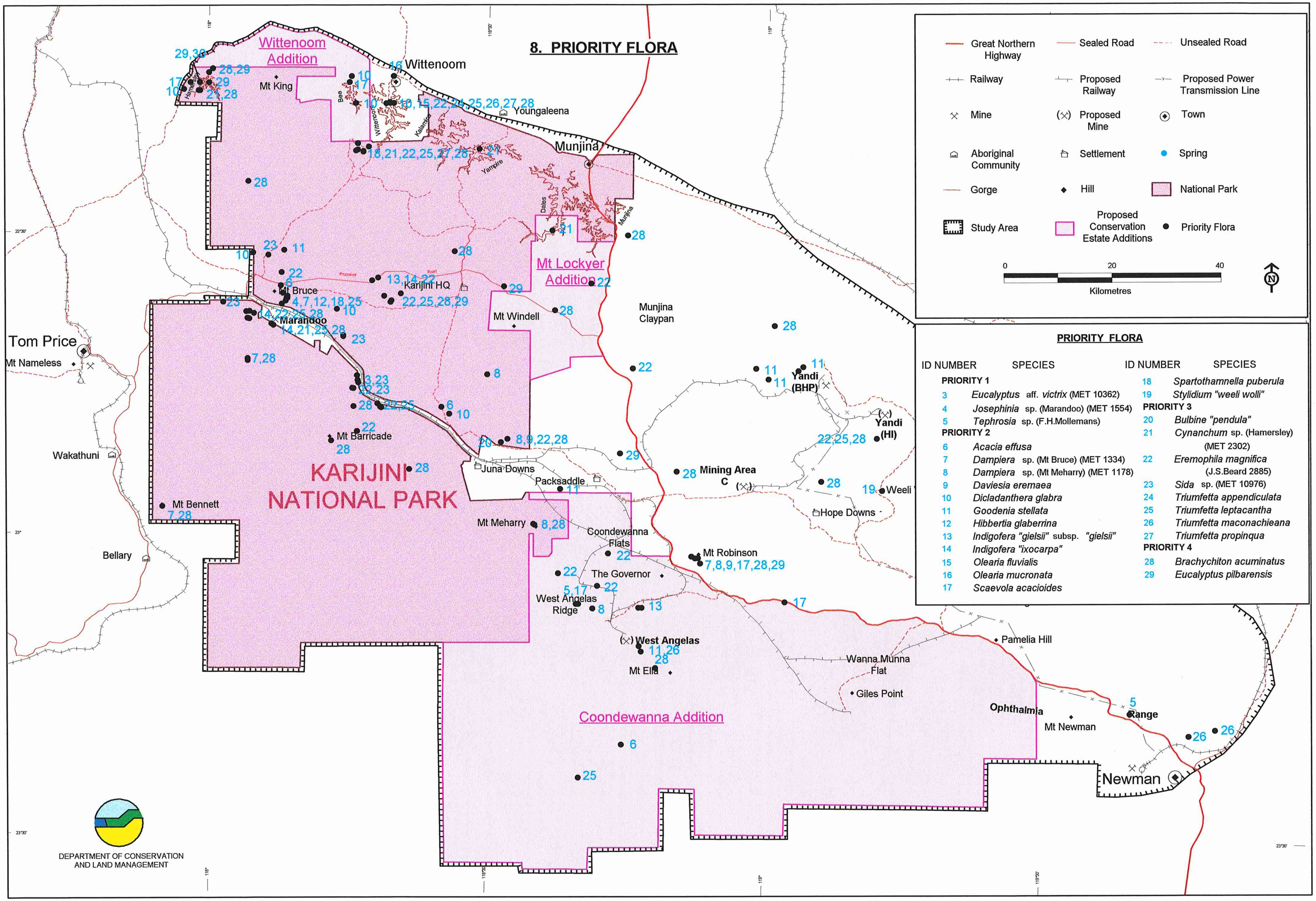

3. TENURE PROPOSALS OF DUNLOP & PORTER (1983)
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Reference Area
Fire Exclusion Zone
Proposed National Park Extension
Management Priority Area
0
20
40
Kilometres
N
Wittenoom
Mt King
Hamersley
Bee
Wittenoom
Kalamina
Yampire
Dales
Munjina
Youngaleena
Munjina
Karijini HQ
Mt Bruce
Marandoo
Mt Windell
Munjina Claypan
Tom Price
Mt Nameless
Mt Barricade
Wakathuni
KARIJINI NATIONAL PARK
Juna Downs
Packsaddle
Mt Bennett
Mt Meharry
Bellary
Yandi (BHP)
Yandi (HI)
Mining Area C
Weeli Wolli Spring
Hope Downs
Coondewanna Flats
Mt Robinson
The Governor
West Angelas Ridge
Unmapped
West Angelas
Rhodes Ridge
Pamelia Hill
Wanna Munna Flat
Mt Ella
Giles Point
Unmapped
Ophthalmia Range
Mt Newman
Newman
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT


4. 1992 BOUNDARY RATIONALISATION PROPOSALS
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Proposed National Park Extensions
Proposed 5(g) Reserve
0
20
40
Kilometres
N
KARIJINI NATIONAL PARK
Hamersley Gorge Block
Range Gorge Block
Mt Florance Station Block
Hamersley Station Block
Dales Gorge Block
Juna Downs Block
Tom Price VCL Block
Rocklea Station Block
Packsaddle Hill Block
Mt Meharry Block
Alligator Flank North Block
O'Briens Block
Paraburdoo VCL Block
Giles Block (5(g) reserve)
Wittenoom
Mt King
Youngaleena
Munjina
Karijini HQ
Mt Bruce
Marandoo
Mt Windell
Munjina Claypan
Tom Price
Mt Nameless
Yandi (BHP)
Yandi (HI)
Mt Barricade
Wakathuni
Juna Downs
Packsaddle
Mining Area C
Weeli Wolli Spring
Hope Downs
Mt Bennett
Mt Meharry
Coondewanna Flats
Mt Robinson
Bellary
The Governor
West Angelas Ridge
Rhodes Ridge
Pamelia Hill
West Angelas
Wanna Munna Flat
Mt Ella
Giles Point
Ophthalmia Range
Mt Newman
Newman
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

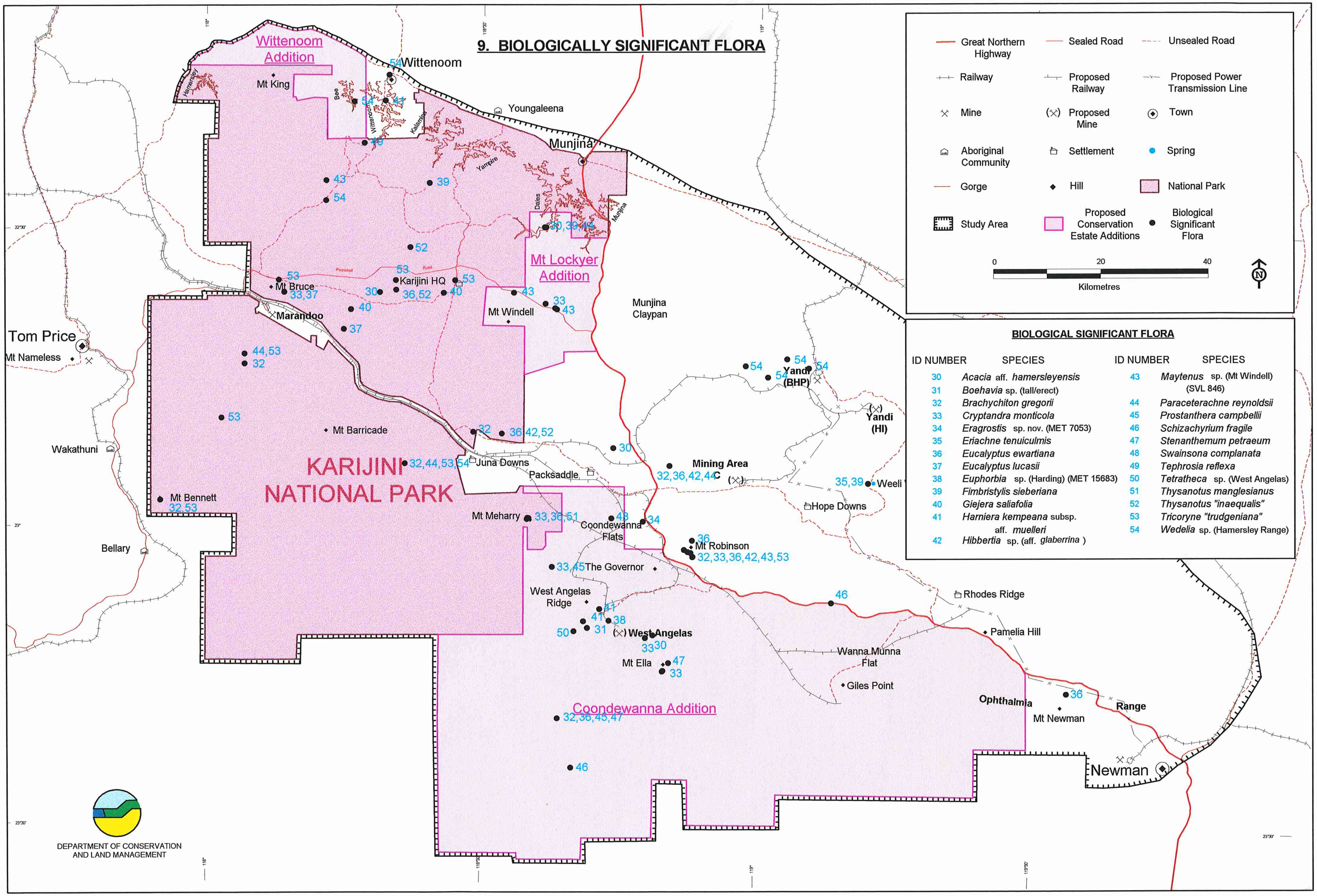

5. AREAS UNDER INVESTIGATION FOR ADDITION TO THE CONSERVATION ESTATE
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Proposed Conservation Estate Additions
0
20
40
Kilometres
N
Wittenoom Addition
Mt Lockyer Addition
Coondewanna Addition
KARIJINI NATIONAL PARK
Wittenoom
Youngaleena
Munjina
Mt King
Mt Bruce
Karijini HQ
Marandoo
Mt Windell
Munjina Claypan
Tom Price
Mt Nameless
Mt Barricade
Wakathuni
Mt Bennett
Bellary
Juna Downs
Packsaddle
Mt Meharry
Coondewanna Flats
The Governor
West Angelas Ridge
West Angelas
Mt Ella
Mt Robinson
Yandi (BHP)
Yandi (HI)
Mining Area C
Weeli Wolli Spring
Hope Downs
Rhodes Ridge
Pamelia Hill
Wanna Munna Flat
Giles Point
Ophthalmia
Range
Mt Newman
Newman
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

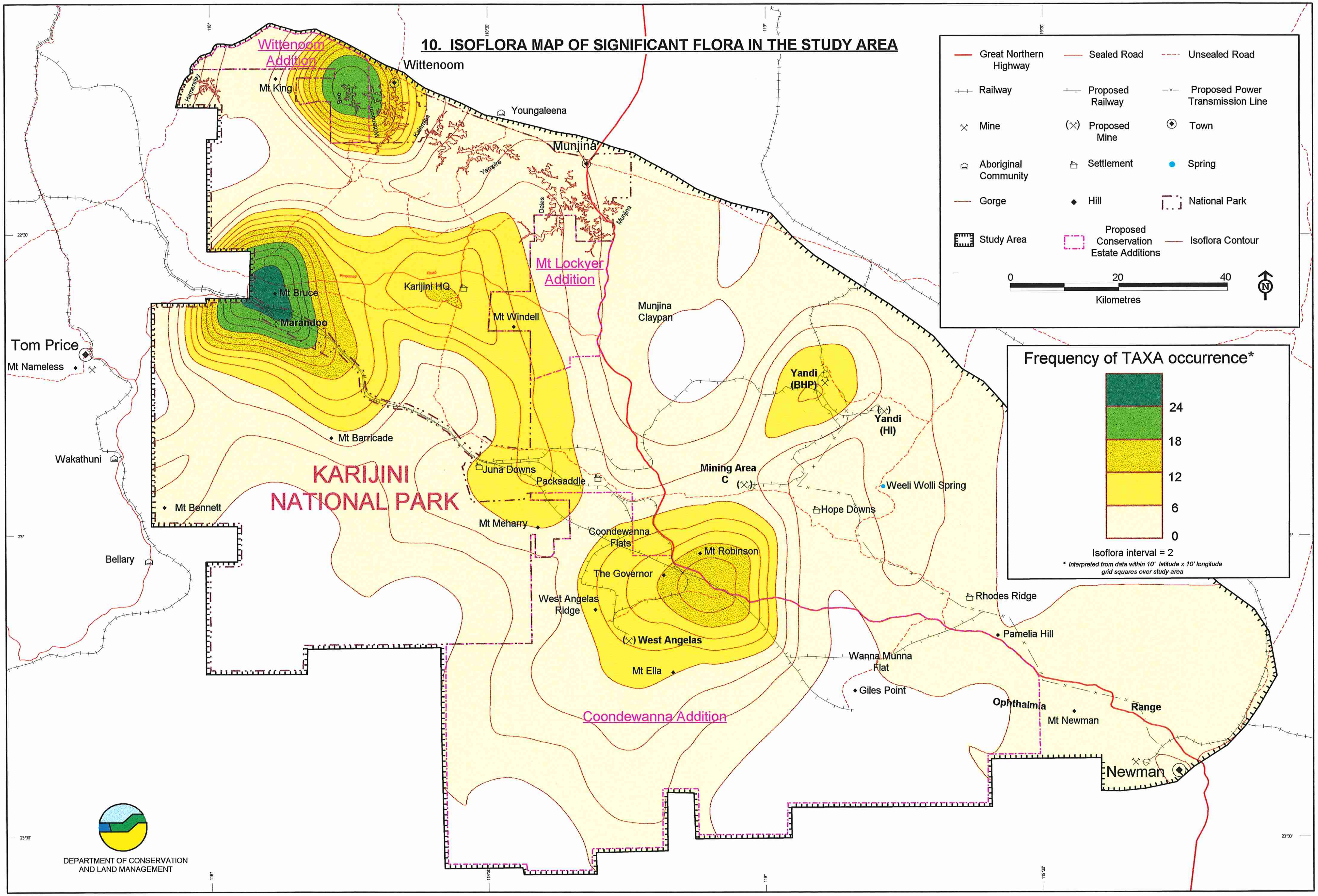

6. BIOGEOGRAPHICAL SETTING OF THE STUDY AREA
Highway
Sealed Road
N
Pilbara Conservation Estate
Study Area
a
Biogeographical Region Boundary
b
Pilbara Biogeographical Sub-units
0
50
100
Kilometres
Dampier
Great Sandy Desert
Port Hedland
Karratha
Abydos Plain
Pilbara
George Range
Onslow Coastal Plain
Pannawonica
Onslow
Chichester
Oakover Valley
Exmouth
Hamersley
Plateau
Stuart Hills
Fortescue Valley
Tom Price
Plateau
Paraburdoo
Newman
Little Sandy Desert
Carnarvon
Gascoyne


7. DECLARED RARE FLORA
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Proposed Conservation Estate Additions
Declared Rare Flora
0 20 40
Kilometres
N
DECLARED RARE FLORA
ID NUMBER SPECIES
1 Lepidium catapycnon
2 Thryptomene wittweri
Wittenoom Addition
Wittenoom
Mt King
Youngaleena
Munjina
Mt Lockyer Addition
Karijini HQ
Mt Bruce
Marandoo
Mt Windell
Munjina Claypan
Tom Price
Mt Nameless
Yandi (BHP)
Yandi (HI)
Mt Barricade
Wakathuni
KARIJINI NATIONAL PARK
Juna Downs
Packsaddle
Mining Area C
Weeli Wolli Spring
Hope Downs
Mt Bennett
Mt Meharry
Coondewanna Flats
Mt Robinson
Bellary
The Governor
West Angelas Ridge
Rhodes Ridge
Pamelia Hill
West Angelas
Wanna Munna Flat
Mt Ella
Giles Point
Ophthalmia Range
Mt Newman
Coondewanna Addition
Newman
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

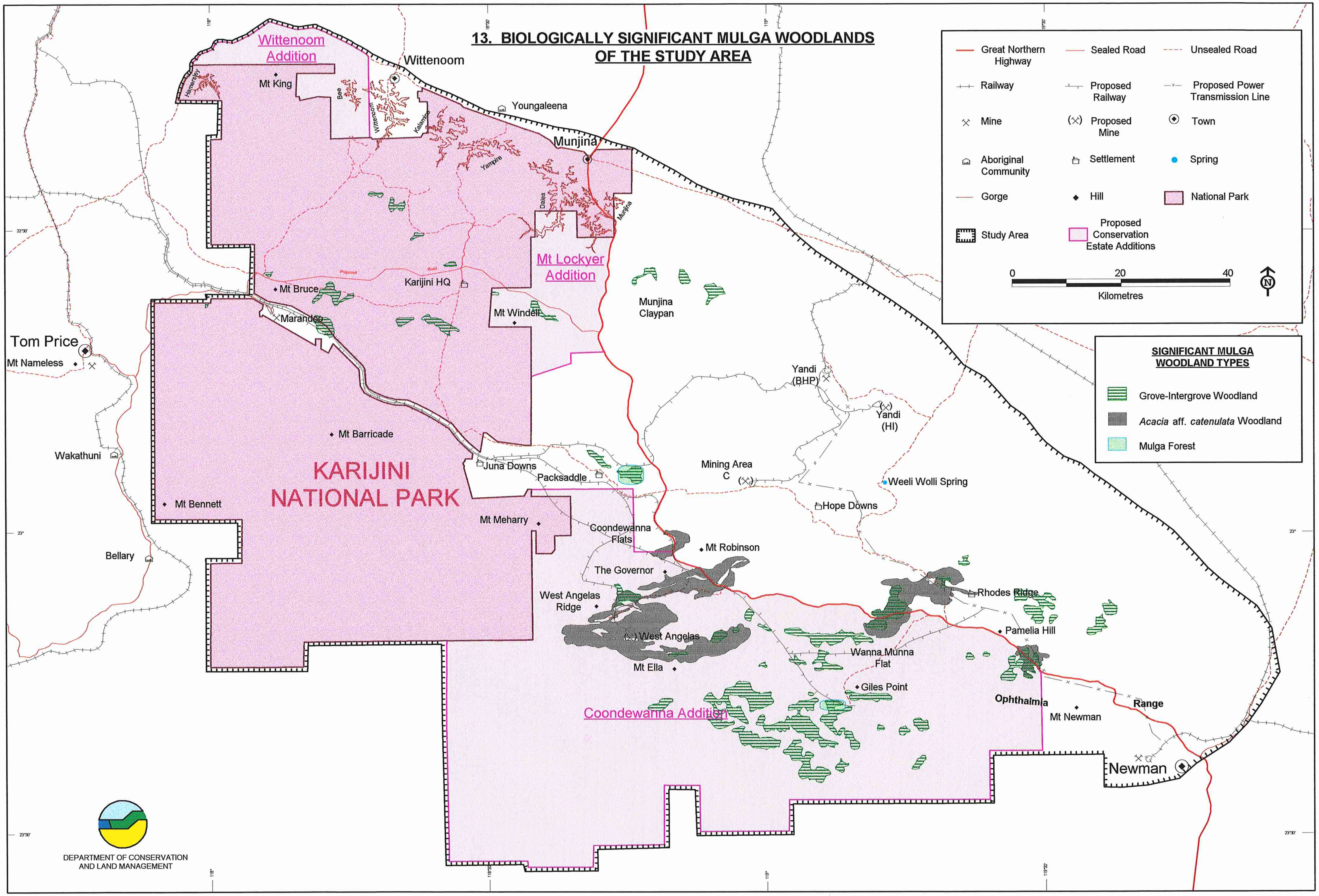


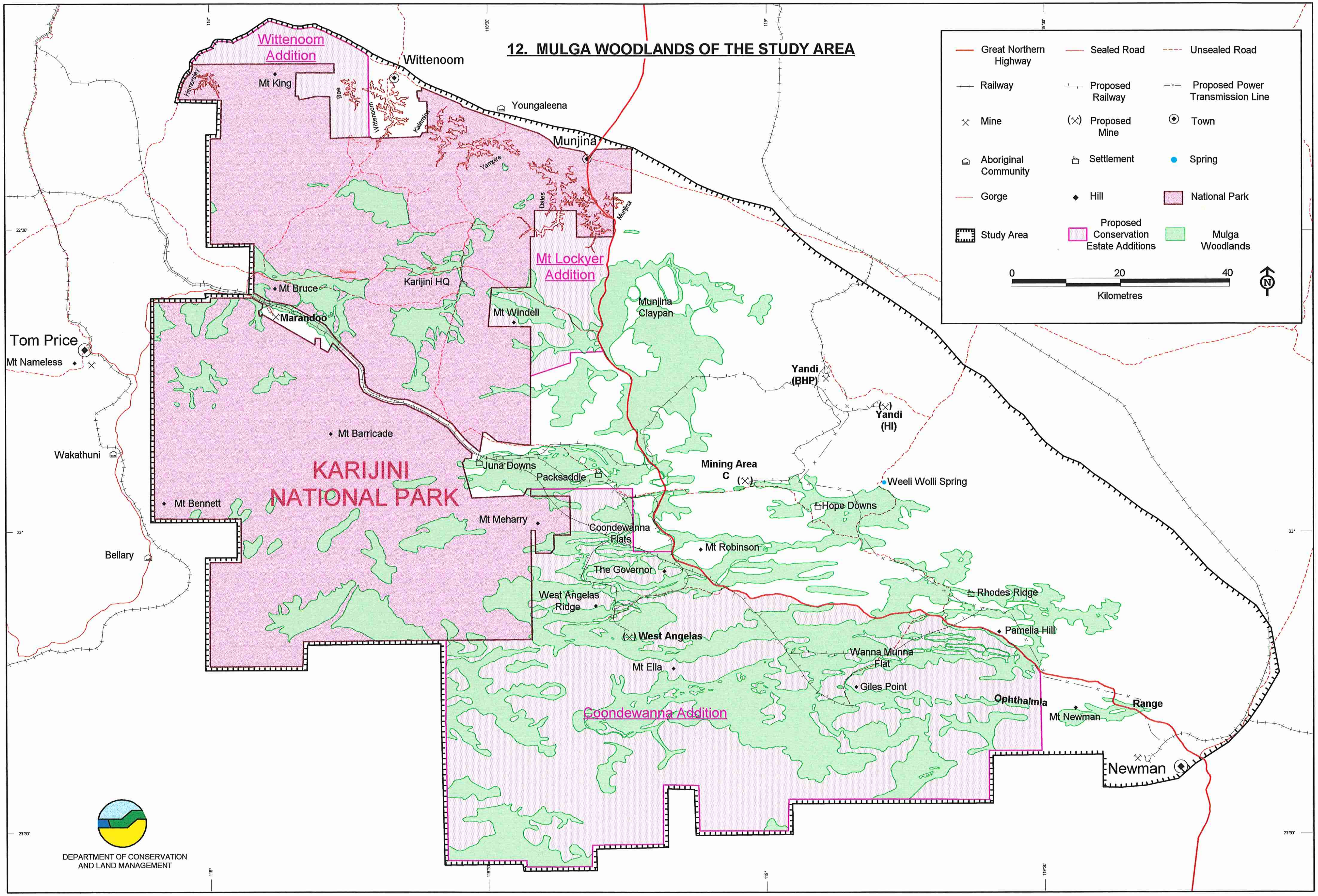
8. PRIORITY FLORA
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Proposed Conservation Estate Additions
Priority Flora
0
20
40
Kilometres
PRIORITY FLORA
ID NUMBER SPECIES
PRIORITY 1
3 Eucalyptus aff. victrix (MET 10362)
4 Josephinia sp. (Marandoo) (MET 1554)
5 Tephrosia sp. (F.H.Mollemans)
PRIORITY 2
6 Acacia effusa
7 Dampiera sp. (Mt Bruce) (MET 1334)
8 Dampiera sp. (Mt Meharry) (MET 1178)
9 Daviesia eremaea
10 Dicladanthera glabra
11 Goodenia stellata
12 Hibbertia glaberrina
13 Indigofera "gielsii" subsp. "gielsii"
14 Indigofera "ixocarpa"
15 Olearia fluvialis
16 Olearia mucronata
17 Scaevola acacioides
18 Spartothamnella puberula
19 Stylidium "weeli wolli"
PRIORITY 3
20 Bulbine "pendula"
21 Cynanchum sp. (Hamersley) (MET 2302)
22 Eremophila magnifica (J.S.Beard 2885)
23 Sida sp. (MET 10976)
24 Triumfetta appendiculata
25 Triumfetta leptacantha
26 Triumfetta maconachieana
27 Triumfetta propinqua
PRIORITY 4
28 Brachychiton acuminatus
29 Eucalyptus pilbarensis
Wittenoom Addition
Wittenoom
Mt King
Youngaleena
Munjina
Mt Lockyer Addition
Munjina Claypan
Karijini HQ
Mt Bruce
Marandoo
Mt Windell
Tom Price
Mt Nameless
Yandi (BHP)
Yandi (HI)
Mt Barricade
Wakathuni
Juna Downs
Packsaddle
Mining Area C
Weeli
Hope Downs
KARIJINI NATIONAL PARK
Mt Bennett
Mt Meharry
Coondewanna Flats
Bellary
Mt Robinson
The Governor
West Angelas Ridge
West Angelas
Mt Ella
Pamelia Hill
Wanna Munna Flat
Giles Point
Ophthalmia Range
Mt Newman
Coondewanna Addition
Newman
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT


9. BIOLOGICALLY SIGNIFICANT FLORA
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Proposed Conservation Estate Additions
Biological Significant Flora
0
20
40
Kilometres
BIOLOGICAL SIGNIFICANT FLORA
ID NUMBER SPECIES
30 Acacia aff. hamersleyensis
31 Boehavia sp. (tall/erect)
32 Brachychiton gregorii
33 Cryptandra monticola
34 Eragrostis sp. nov. (MET 7053)
35 Eriachne tenuiculmis
36 Eucalyptus ewartiana
37 Eucalyptus lucasii
38 Euphorbia sp. (Harding) (MET 15683)
39 Fimbristylis sieberiana
40 Giejera salicifolia
41 Harniera kempeana subsp. aff. muelleri
42 Hibbertia sp. (aff. glaberrina)
43 Maytenus sp. (Mt Windell) (SVL 846)
44 Paraceterachne reynoldsii
45 Prostanthera campbellii
46 Schizachyrium fragile
47 Stenanthemum petraeum
48 Swainsona complanata
49 Tephrosia reflexa
50 Tetratheca sp. (West Angelas)
51 Thysanotus manglesianus
52 Thysanotus "inaequalis"
53 Tricoryne "trudgeniana"
54 Wedelia sp. (Hamersley Range)
Wittenoom Addition
Wittenoom
Mt King
Youngaleena
Munjina
Mt Lockyer Addition
Munjina Claypan
Mt Bruce
Karijini HQ
Marandoo
Mt Windell
Tom Price
Mt Nameless
Mt Barricade
Wakathuni
KARIJINI NATIONAL PARK
Juna Downs
Packsaddle
Mt Bennett
Mt Meharry
Coondewanna Flats
Bellary
Mining Area C
Yandi (BHP)
Yandi (HI)
Weeli
Hope Downs
Mt Robinson
The Governor
West Angelas Ridge
West Angelas
Rhodes Ridge
Pamelia Hill
Wanna Munna Flat
Mt Ella
Giles Point
Coondewanna Addition
Ophthalmia Range
Mt Newman
Newman
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT


10. ISOFLORA MAP OF SIGNIFICANT FLORA IN THE STUDY AREA
Great Northern Highway
Sealed Road
Unsealed Road
Railway
Proposed Railway
Proposed Power Transmission Line
Mine
Proposed Mine
Town
Aboriginal Community
Settlement
Spring
Gorge
Hill
National Park
Study Area
Proposed Conservation Estate Additions
Isoflora Contour
0
20
40
Kilometres
Frequency of TAXA occurrence*
24
18
12
6
0
Isoflora interval = 2
* Interpreted from data within 10' latitude x 10' longitude grid squares over study area
Wittenoom Addition
Wittenoom
Mt King
Youngaleena
Munjina
Mt Lockyer Addition
Karijini HQ
Mt Bruce
Marandoo
Mt Windell
Munjina Claypan
Tom Price
Mt Nameless
Yandi (BHP)
Yandi (HI)
Mt Barricade
Wakathuni
KARIJINI NATIONAL PARK
Juna Downs
Packsaddle
Mining Area C
Weeli Wolli Spring
Hope Downs
Mt Bennett
Mt Meharry
Coondewanna Flats
Mt Robinson
Bellary
The Governor
West Angelas Ridge
Rhodes Ridge
Pamelia Hill
West Angelas
Wanna Munna Flat
Mt Ella
Giles Point
Ophthalmia
Range
Mt Newman
Coondewanna Addition
Newman
DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

13. BIOLOGICALLY SIGNIFICANT MULGA WOODLANDS OF THE STUDY AREA





12. MULGA WOODLANDS OF THE STUDY AREA