BOTANICAL SURVEY

FLORA AND VEGETATION OF THE MARANDOO TO GREAT NORTHERN HIGHWAY ROAD

A report to the Main Roads Western Australia, Pilbara Region, and the Shire of Ashburton from the Science and Information Division, Department of Conservation and Land Management.

Prepared by
Stephen J. van Leeuwen and Robert N. Bromilow

September 1995

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1. INTRODUCTION

The Shire of Ashburton, in conjunction with the Main Roads Western Australia, propose to construct a new 76 km sealed road linking the Marandoo Access Road to the Great Northern Highway. The new road will traverse the Karijini National Park and a portion of the Juna Downs pastoral leases. As part of the environmental review process for this project, which has been set at a Consultative Environmental Review (CER) level, the Environmental Protection Authority (EPA) have highlighted impacts on the existing (receiving) environment as key issues to be addressed. Specific flora and vegetation themes identified as key issues include:

- drainage management and hydrological impacts, particularly on Mulga communities;
- the protection of rare flora and the timing of the surveys to determine the presence of rare flora;
- the protection of other flora species and associations having significant conservation value; and
- the impacts of construction of the road, and how these (impacts) will be minimised, including:
  - the measures to prevent the introduction and spread of weeds such as Ruby Dock.

To fulfil the EPA guidelines and associated review requirements and develop relevant Environmental Management Commitments addressing the key issues identified by the EPA, the project's proponents commissioned the Science and Information Division of the Department of Conservation and Land Management (CALM) to undertake a botanical survey of the proposed road alignment. The survey brief presented to CALM identified several significant issues which are presented in Section 2.1, Study Objectives. The survey undertaken by CALM was designed to fulfil the proponents requirements and comply with Departmental and National Parks and Nature Conservation Authority (NPNCA) guidelines for biological surveys on the CALM Estate.

This survey report principally provides baseline data on the flora and vegetation of the road alignment. Additionally, this report provides:

A) an inventory and description of;
   - the vascular plants, including rare, poorly known and species of interest.
   - the vegetation communities present along the alignment.

B) a review and assessment of the;
   - biological and conservation significance of the vascular plants, especially those considered to be rare, poorly known or of special interest.
   - conservation significance of vegetation communities encountered.

C) a synopsis of management recommendations designed to mitigate deleterious impacts of this project on the flora and vegetation present along the road alignment and associated receiving environments.

1.1 Location

The survey area is located in the Central Pilbara Region of Western Australia (Figure 1). The proposed road will cover a distance of 76 km linking the Marandoo Access Road, via the Karijini Link Road, in the west to the Great Northern Highway in the east. The alignment traverses gently undulating terrain in the Hamersley Range passing through the Karijini National Park and a portion of Juna Downs Station. The proposed alignment essentially does not follow existing infrastructure routes passing to the north of Mt Windell, south of Dignam Gorge, north of the Karijini National Park headquarters, north of Dinner Hill, south of Mt Oxer and north and west of Mt Bruce. The proposed route is south of the main gorge and tourist areas within the national park and north of the southern wilderness areas.

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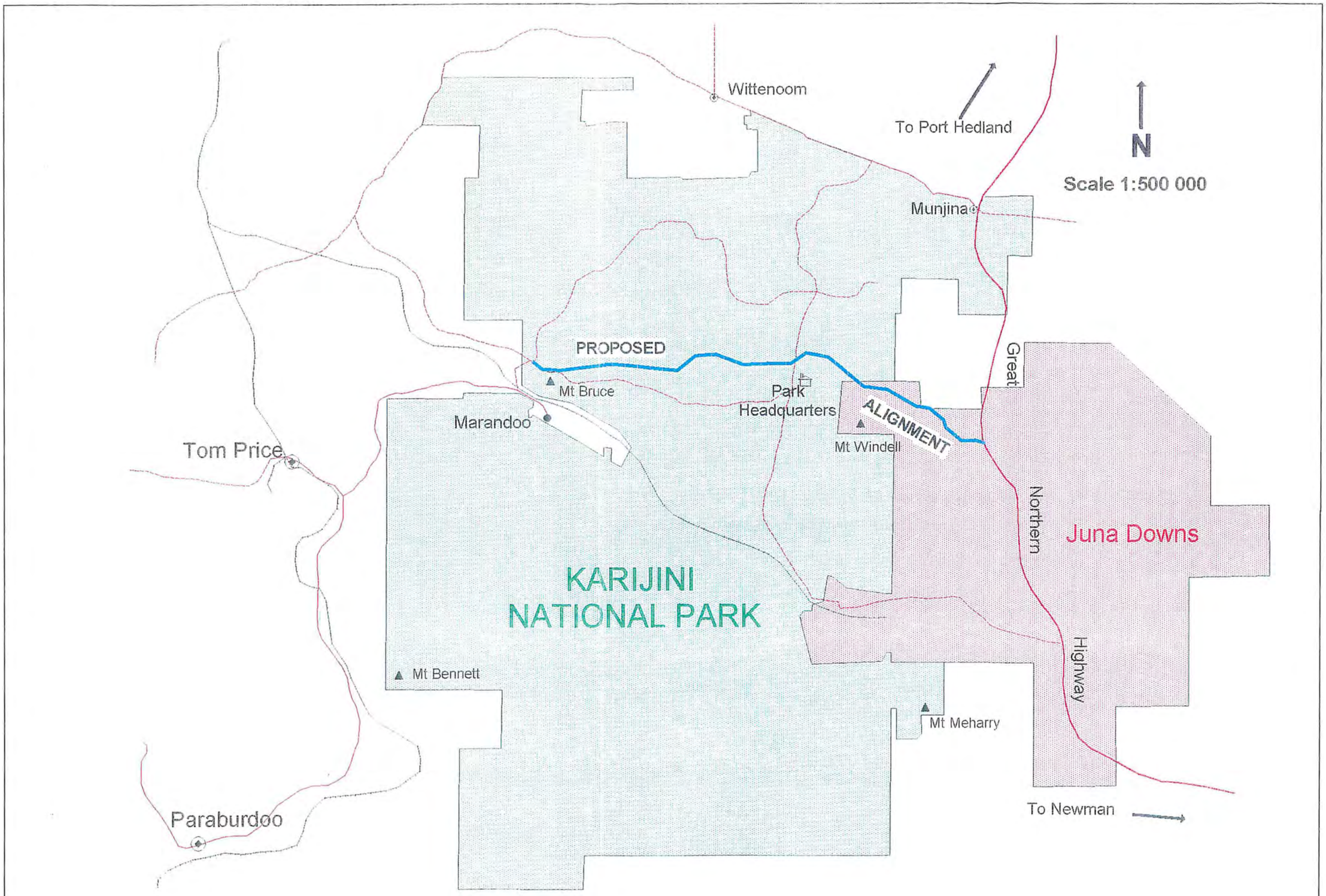


LOCALITY PLAN
MARANDOO TO GREAT NORTHERN HIGHWAY ROAD

Figure 1

Locality plan for the
Marandoo to Great Northern Highway Road

2. METHODOLOGY

No previous systematic flora and vegetation studies have been undertaken along the proposed alignment of the Marandoo to Great Northern Highway Road. Previous botanical studies in the Karijini National Park have primarily been of an opportunistic nature and at locations distant to the majority of the proposed alignment. Exceptions to this opportunistic botanical survey work have resulted from research activities undertaken by the Science and Information Division of CALM under the auspices of the Fire - Mulga Study and through the biological survey activities of various resource development companies, principally Hamersley Iron, with regards to the Marandoo Mine and Central Pilbara Railway projects.

Exceptions are also present at each end of the proposed road alignment where botanical surveys have previously been undertaken. The majority of the route for Alignment 1A has already been investigated through the Environmental Assessment and Management Plan prepared by the Shire of Ashburton (1993) for the Karijini Link Road. At the eastern end of the proposed alignment a small portion of the route for Alignment 3A, which abuts the Great Northern Highway, has also been surveyed through the auspices of the Environmental Review and Management Plan for the Newman to White Springs section of the National Highway (Dames and Moore 1984).

2.1 Study Objectives

The design of this investigation into the flora and vegetation of the Marandoo to Great Northern Highway Road was aimed at fulfilling a number of objectives. Paramount among these was the fulfilment of key issues identified in the amended guidelines for the Consultative Environmental Review of this project issued by the Environmental Protection Authority on the 20 December 1994. These guidelines identify as key issues the:

- protection of rare flora;
- the protection of other flora species and associations having significant conservation value; and
- drainage management and hydrological impacts, particularly on mulga communities.

Sympatrically, the study was also designed to comply with requirements for flora and vegetation surveys on lands vested in the National Parks and Nature Conservation Authority as outlined in guidelines issued by the Authority in March 1995.

The Shire of Ashburton, through Main Roads Western Australia, commissioned the Science and Information Division of CALM to undertake this study. The key issues outlined in the project brief, which are addressed in this report, were:

- an inventory of the vascular plant species in the survey area;
- a review of plant species considered to be rare and endangered, geographically restricted and/or representative of outlier populations;
- an inventory of the exotic plants, including Declared plants; and

- a description, including mapping, of the plant communities within the survey area.

2.2 Flora

2.2.1 *Survey Sites and Borrow Pits*

A corridor approximately 100 m wide along the proposed route of Alignments 2B, 2C and 3A was surveyed for vascular plant species and vegetation communities between July 1991 and July 1995. The survey area comprised a linear corridor of approximately 74 km by 100 m in which the flora was recorded. All flora species within approximately 50 m of the centre-line between consecutive intercept points (IP), except at locations where intercept points were positioned, were recorded during this investigation. At the various IP sites the survey area was displaced in the direction of the proposed road curvature. At the eastern (E656350 - N7501650) and western (E633740 - N750850) jump-ups on the routes of Alignment 2C, the survey area was extended to a width of approximately 150 m as the road design for these locations had not been formalised prior to commencement of the 1995 field programme.

Along the proposed alignment, 20 permanent quadrats for flora sampling and monitoring were established. Five of these quadrats were installed in July 1991 along the route of Alignment 3A, while an additional 15 were installed along the route of Alignment 2C in April 1995. No permanent quadrats were located along the route of Alignment 1A as it followed the existing Karijini Link Road and the Mt Bruce Flats Road. The Karijini Link Road has previously been subjected to a flora survey (Shire of Ashburton 1993). In July 1991, four additional permanent quadrats were also established along the route of Alignment 3A west of its junction with Alignment 2C. At the time of establishment, Alignment 2A was the favoured alignment for the proposed road. A total of 24 permanent quadrats were sampled during this study. The location of these quadrats is depicted in Figure 2, while the AMG coordinates are presented in Table 1.

The permanent quadrats were located in a representative array of the vegetation communities typical of the proposed alignment. Wherever possible, permanent quadrats were replicated in each of the dominant vegetation communities present. At each of these permanent sites a series of nested quadrats were established which varied in size from 5 m^2 to 100 m^2. These quadrats comply with details provided in the project brief and fulfil CALM's survey requirements for botanical research undertaken in the Pilbara region.

The flora species present at ten borrow pit sites identified as potential sources of material (base/sub-base and sheeting) for road construction were also documented during the field programme. The location of these borrow pits is presented in Table 2. The majority of these pits were adjacent to the proposed alignment, however, a few were located some distance away. Five of the borrow pits were existing pits used concurrently for road maintenance purposes by the Shire of Ashburton.

Table 1. AMG coordinates of the twenty four permanent quadrats investigated during the flora survey of the alignment for the Marandoo to Great Northern Highway Road.

Permanent Flora Quadrat	Year Established	AMG coordinates	
		Easting	Northing
1	1991	668054	7496414
2	1991	665206	7497060
3	1991	665207	7497183
4	1991	664385	7497715
5	1991	660035	7499545
6	1995	657751	7499610
7	1991	656209	7499708
8	1995	656228	7501492
9	1995	656143	7501616
10	1991	655239	7499841
11	1995	652225	7503993
12	1991	650012	7499739
13	1991	650558	7500072
14	1995	649604	7504756
15	1995	649286	7504360
16	1995	648826	7504026
17	1995	646308	7503619
18	1995	643761	7503152
19	1995	635258	7504183
20	1995	634165	7503238
21	1995	633733	7502873
22	1995	633957	7502388
23	1995	632928	7502357
24	1995	631499	7502154

2.2.2 *Flora Collection and Identification*

Opportunistic random flora collecting in the survey area was conducted through foot and vehicular traverses. Collecting effort was concentrated on period after good rainfall to ensure that the full suite of perennial and annual (ephemeral) species present were sampled and recorded. Systematic flora collecting concentrated on the 24 permanent quadrats where all plant species within the nested arrays were sampled. Those permanent quadrats established in July 1991 were sampled on two occasions (Table 1). Time constraints imposed by the proponents precluded a repeated sampling of the permanent quadrats established in April 1995.

Prior to the commencement of the field programme, a search of relevant literature and herbarium records was undertaken to identify plants species considered to be rare, threatened or geographically restricted which may occur in the survey area. This resultant species list was used to focus survey effort during the field programme which culminated in a disproportionate amount of effort directed to searches for such species. Similarly, at sites where rare, threatened and geographically restricted species were located, additional effort was directed towards determining the size of the population present and it's areal extent with regards to the location of the proposed road alignment.

Table 2. AMG coordinates for the ten borrow pits investigated during the flora survey of the alignment for the Marandoo to Great Northern Highway Road.

Borrow pit number	AMG coordinates	
	Easting	Northing
1	E674100	N7492600
2	E673100	N7492800
3	E670900	N7493200
4	E665300	N7496700
5	E662600	N7499500
6	E657700	N7500100
7	E650400	N7507800
8	E610700	N7503400
9	E613400	N7507700
10	E618200	N7512200

All plant specimens collected were processed and prepared for incorporation into the Pilbara Regional and Western Australian Herbariums following established curatorial procedures. Plant identification was achieved with reference to taxonomic keys and citation of vouchers housed in the Pilbara Regional and Western Australian Herbariums. When necessary, specialist plant taxonomists were consulted as to the identification of particular specimens or taxonomic groups. In many instances, this involved forwarding specimens to taxonomists at interstate institutions. Specimens collected during the field programme were incorporated into the Pilbara Regional Herbarium's collection with, wherever possible, duplicates forwarded to the Western Australian Herbarium. In some instances duplicates have also been forwarded to interstate herbaria.

Plant nomenclature adopted for this report generally follows Green (1985) and that presented in the Census of Australian Vascular Plants (Hnatiuk 1990), which is the scheme advocated by the Pilbara Regional and Western Australian Herbariums. Nomenclature

exceptions to that presented in Green (1985) and Hnatiuk (1990) have been advanced by recent taxonomic revisions.

2.3 Vegetation

The survey area lies in the Fortescue Botanical District within the Eremaean Botanical Province (Beard 1990) of Western Australia. No vegetation description or mapping has previously been conducted along the proposed road alignment at a sufficient scale to allow evaluation of the conservation significance and possible impacts of the road on receiving environments.

Numerous vegetation descriptions and summaries, at varying scales, encompass the Hamersley Range and form the basis of the current project's vegetation description and mapping. A broad summary of the vegetation in the survey area was provided by Beard (1975) who mapped the different vegetation types in the Pilbara Region at a scale of 1:1 000 000. This project's survey area is located within Beard's *op. cit.* Hamersley Plateau physiogeographic unit in which he recognised three prevailing vegetation complexes. These complexes varied from:

- Range Country covered predominantly by low scattered trees of *Eucalyptus leucophloia* over hummock grassland of *Triodia wiseana* which often supports a rich flora of small shrubs and sometimes mallee (*E. gamophylla*);
- Valley Plain carrying low woodlands of *Acacia aneura* with a rich shrub and forb understorey interspersed with cracking clay soils dominated by grassy plains (*Aristida, Astrebla, Chrysopogon, Themeda*); and
- Rolling Basaltic Hills covered by a complex mosaic of mulga (*A. aneura*) and spinifex (*Triodia* and *Plectrachne* spp.) forming low woodlands or shrub steppe which are interspersed by scattered, emergent eucalypts and a rich understorey of *Acacia, Senna* and *Eremophila* species.

Interrogation of Beards (1975) 1:1 000 000 vegetation map (Figure 3) indicates that the proposed alignment traverses three vegetation types which are typical of the Hamersley Plateaux physiogeographic units Range Country and Valley Plain vegetation complexes. These three types were defined as:

- Tree Steppe (hummock grassland) of *E. leucophloia* over *T. wiseana*;
- Low *A. aneura* woodlands with a continuous canopy; and
- Grove - intergrove *A. aneura* low woodlands.

A more detailed and informative description of the vegetation associations likely to be encountered along the proposed alignment was provided by Dawe and Dunlop (1983). Like Beard (1975), Dawe and Dunlop's (1983) classification emphasised landform (topographical setting) and edaphic characteristics (soil type) in the delineation of vegetation units culminating in the recognition of 11 landform and 21 vegetation units. Similarly, the detailed (1:10 000) vegetation mapping prepared by Mattiske and Associates (1992) for the

Marandoo Project Area, which also emphasised the role of landform and edaphic attributes in the delineation of vegetation communities, also provides an informative insight into the vegetation communities present along the proposed alignment. Within the Marandoo Project Area Mattiske and Associates (1992) identified 37 vegetation communities.

2.3.1 *Vegetation Mapping*

The preparation of the vegetation map covering the survey area was based upon the principal investigators previous experiences in the Pilbara Region, in particular the Karijini National Park and its environs. Delineation of different plant associations was based on topographical and edaphic considerations combined with an interpretation of the structural arrangement and the floristic composition of the plant assemblages present in each association. The structural arrangement and floristic composition of the vegetation was based primarily on the perennial plants present. Muir's (1977) vegetation classificatory system was used to describe the vegetation associations detected along the proposed alignment.

The mapping process utilised:

- Interrogation of 1:10 000 colour and grey scale aerial photography along the proposed alignment. This photography was supplied by Main Roads Western Australia.
- Interrogation of 1:25 000 colour aerial photography provided by Enviroscan (through Hamersley Iron).
- Foot and vehicular traverse along the proposed alignment and associated access tracks and opportunistic field observations in close proximity to the proposed alignment.
- Validation, manipulation and plotting of 1:50 000 digital topographic and cadastral data for the Mt Bruce (2552-IV), Mindi (2552-I) and Mt Windell (2652-IV) maps. The topographical digital data for these maps was provided by the Department of Land Administration.

Production of the vegetation maps was undertaken using the digital topographical and cadastral data manipulated through MapInfo® software. The vegetation map was prepared at a scale of 1:20 000. This scale was selected to comply with NPNCA guidelines for biological survey work on the CALM Estate. The scale chosen complements Beard's (1975) large scale vegetation map covering the survey area and permits local floristic variation between vegetation communities encountered along the proposed alignment to be documented.

2.4 Survey Effort and Personnel

During the 5 year period of this investigation, a total of six site visits over 33 days were undertaken as part of this field programme, which amount to 52 person days in the field. Included in this field effort were two person days investigating the flora associated with

borrow pit locations. Approximately five person days were specifically directed towards locating and documenting the extent of any rare, threatened and geographically restricted flora, especially in the vicinity of the eastern and western jump-ups.

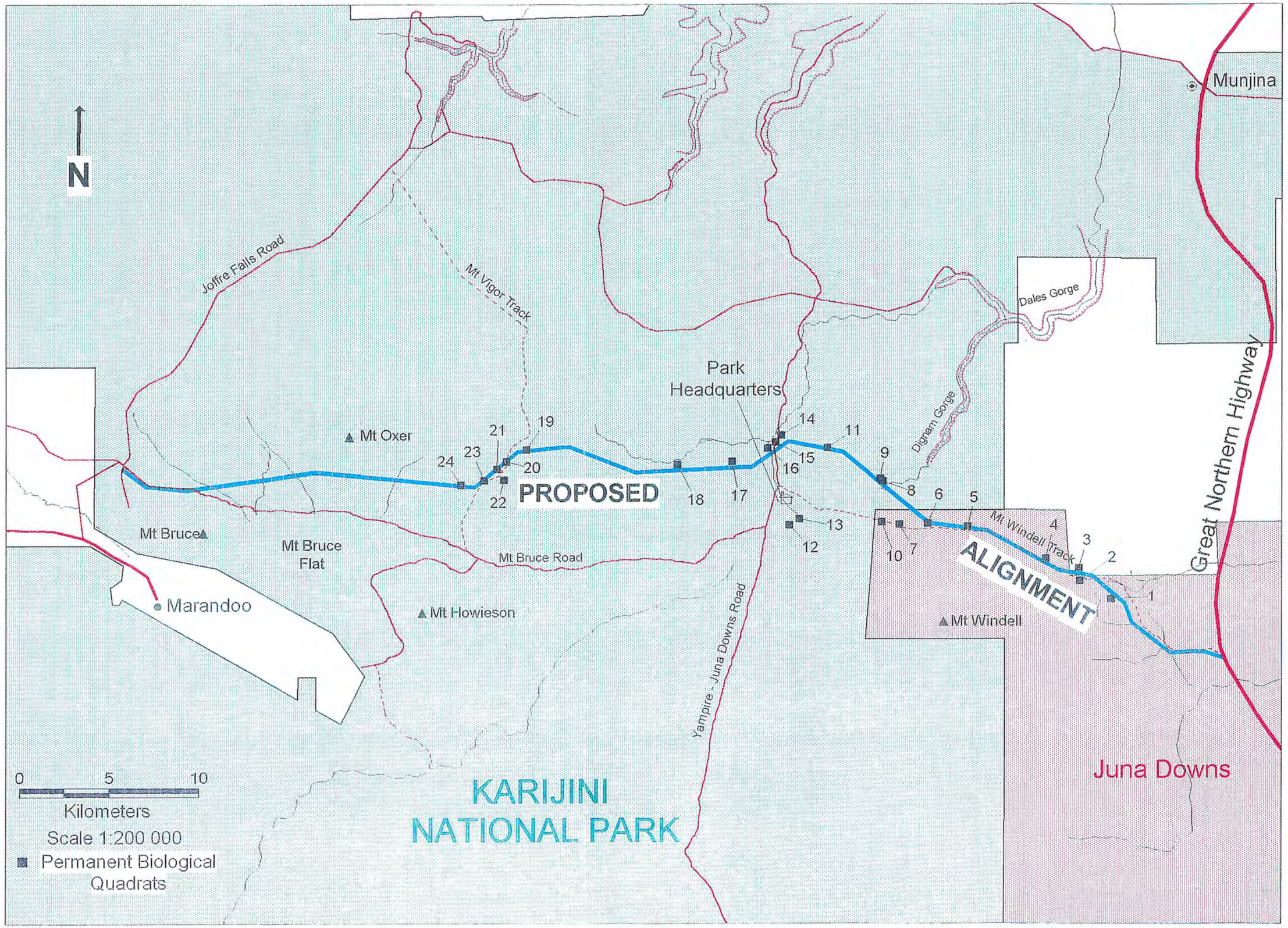
An equivalent amount of person days has been spent processing, identifying and incorporating specimens into the various herbaria. Approximately fifteen person days have been spent preparing and verifying the report for this project.

The following personnel were involved in the field programme and subsequent report preparation for this project:

Principal Investigator and Botanist	Stephen van Leeuwen (CALM).
Technical Assistance and Computer Support	Robert Bromilow (CALM).
Field Assistance	Keith Cunningham (CALM). Regina Flugge (Volunteer). Peter Kendrick (CALM). Michael Hughes (CALM). Karijini Aboriginal Corporation.

The following personnel were consulted and assisted with the identification of plant specimens:

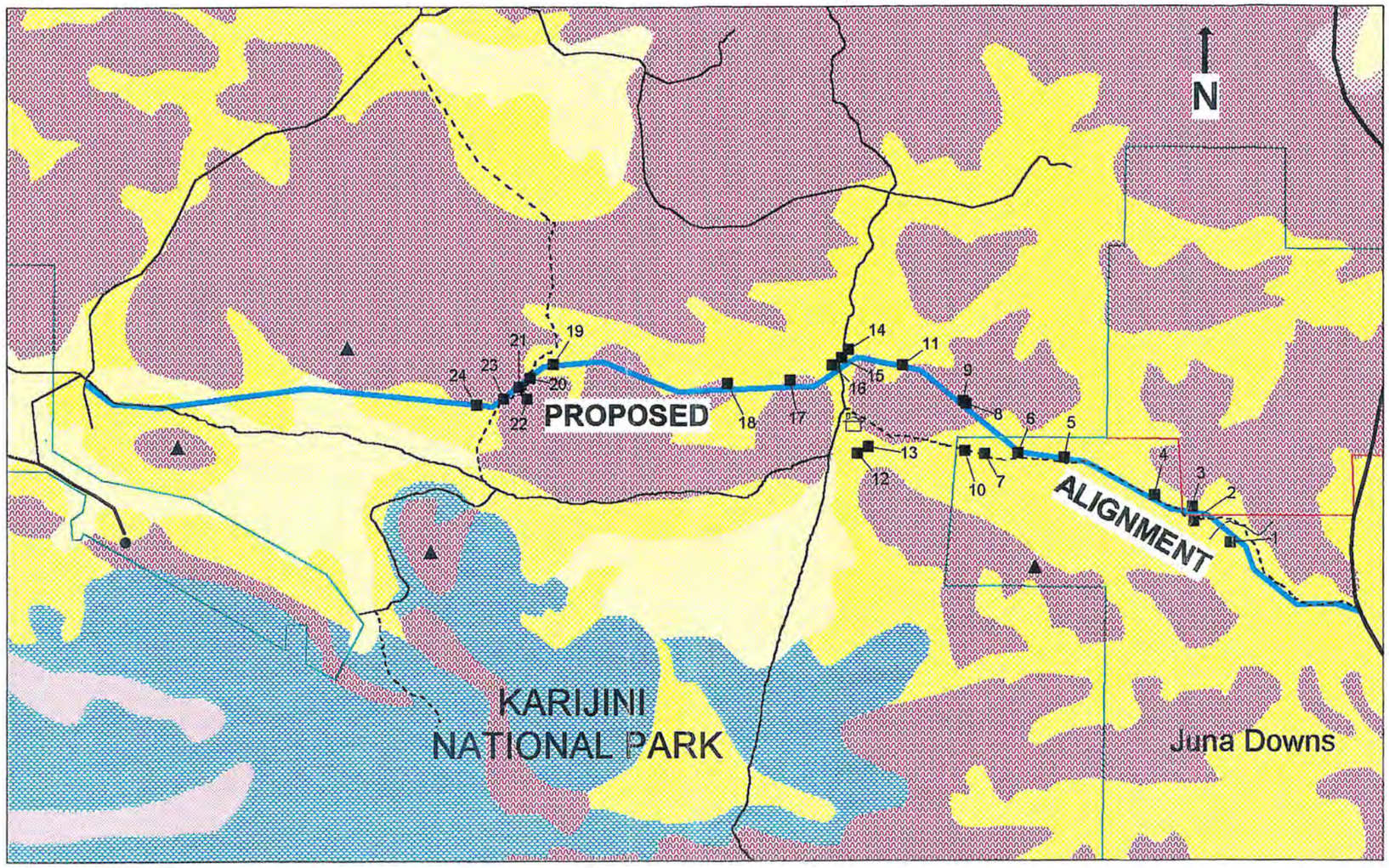
Robyn Barker, Adelaide Botanic Gardens and State Herbarium - *Abutilon* and *Sida*.
Tony Brown, Division of Plant Industry, CSIRO - -*Glycine*.
Ian Brooker, Australian National Herbarium - *Eucalyptus*.
Roger Carolyn, Royal Botanic Gardens Sydney - Goodeniaceae.
Bob Chinnock, Adelaide Botanic Gardens and State Herbarium - *Eremophila*.
Ray Cranfield, Western Australian Herbarium - general.
Laurie Johnson, Royal Botanic Gardens Sydney - *Eucalyptus*.
Mike Lazarides, Australian National Herbarium - Poaceae.
Bruce Maslin, Western Australian Herbarium - *Acacia*.
Tony Start, Wildlife Research Centre - Loranthaceae.
Malcolm Trudgen, Private consultant botanist - general.
Paul Wilson, Western Australian Herbarium - Asteraceae and Chenopodiaceae.
Peter Wilson, Royal Botanic Gardens Sydney - *Indigofera*.



Locality Plan - Permanent Biological Quadrats

Figure 2

Locality plan for Permanent Biological Quadrats established along the alignment of the Marandoo to Great Northern Highway Road



Vegetation Types

- Tree steppe (Snappy gum and spinifex)
- Mulga in valleys
- Mulga in groved patterns
- Mulga and spinifex
- Spinifex, no trees or shrubs
- *E. gamophylla* and spinifex

Symbols

- National Park boundary
- Dominant Mountains
- Permanent biological quadrats
- Great Northern Highway
- Roads
- Tracks
- Ranger headquarters
- Marandoo

Scale 1:250 000

BEARD'S (1975) VEGETATION MAP OF SURVEY AREA

Figure 3

Vegetation types within the survey area as depicted in Beard's (1975) Vegetation Survey of Western Australia: Pilbara

3. RESULTS

3.1 Flora

A total of 52 families, 149 genera and 342 vascular plant species were recorded along the proposed alignment of the Marandoo to Great Northern Highway Road (Appendix One). Five species were considered to be introduced and seven were determined to be of conservation significance.

The plant families with the greatest species representation in the survey area was the Poaceae with 53 representatives followed by the Mimosaceae with 34 (Table 3). Seventeen families were represented by only one species. The Poaceae family also had the highest representation of genera in the survey area. The most frequently encountered genus in the survey area was *Acacia* with 34 species, followed by *Senna* with 14 species (Table 4). Numerous genera were represented by only one species.

3.1.1 *Species of Interest*

3.1.1.1 *Declared Rare Flora Species*

No species declared as Rare Flora under Subsection (2) of Section 23F of the Wildlife Conservation Act 1950 were located in the survey area between July 1991 and July 1995.

The two Pilbara species currently gazetted as Declared Rare Flora, *Lepidium catapycnon* and *Thrypotmene wittweri*, have previously been recorded from the Hamersley Range, however, the absence of suitable habitats impeded their detection in the survey area. The small number of Declared Rare Flora in the Pilbara reflects deficiencies in the botanical knowledge of the region and thus some of the Priority Flora species identified as occurring in the survey area may be added to the schedule of Declared Rare Flora in the future. Indeed, the Priority Two species, *Acacia daweana*, has been recommended for addition to the schedule of Declared Rare Flora as the survey requirements have now been fulfilled for this species.

3.1.1.2 *Priority Flora Species*

Seven Priority Flora species were identified in the survey area. Two of these were categorised as Priority Two, three as Priority Three and two as Priority Four. Priority code definitions are provided in Table 5. The various priority rankings imply different levels of representation on the conservation estate, divergent levels of endangerment and contrasting knowledge on their distribution and habitat requirements. Details on the location and population size of these species are presented below:

Table 3. Vascular plant families with the greatest representation of species within the proposed alignment of the Marandoo to Great Northern Highway Road.

Family	Number of genera	Number of species
Poaceae	26	53
Mimosaceae	1	34
Papilionaceae	13	25
Malvaceae	5	22
Amaranthaceae	5	17
Asteraceae	13	16
Caesalpiniaceae	2	15
Chenopodiaceae	7	14
Goodeniaceae	4	12
Myrtaceae	2	12

Table 4. Genera of vascular plants with the greatest representation of species within the proposed alignment of the Marandoo to Great Northern Highway Road.

Genus	Number of species
Acacia	34
Senna	14
Eucalyptus	11
Ptilotus	11
Sida	9
Eremophila	8
Goodenia	8
Abutilon	6
Indigofera	6
Triodia	6

Brachychiton acuminatus

This Priority Four species was found at one location along the route of Alignment 3A where it was represented by a single individual. This individual occurs on the edge of the proposed road alignment and is unlikely to be impacted by construction activities or the road development.

Acacia daweana

This Priority Two species was found along the route of Alignment 2B at the point where the new road alignment intercepts the existing Mt Bruce Flats Road. This taxon was

represented by 43 individuals extending over approximately 900 m between AMG coordinates E615860 - N7502100 and E616580 - N7502040 (Figure 4). Most plants (40) were located on the north side of the existing road. This population is the largest of the two known, both of which occur in the national park. The majority of the population was restricted to an area within, or immediately adjacent to, the proposed alignment and associated receiving environments.

Table 5. Definition of the Priority Flora conservation codes for vascular plant species in Western Australia.

PRIORITY CONSERVATION CODES FOR WESTERN AUSTRALIAN FLORA.

Priority One - Poorly Known Taxa

Taxa which are known from one or a few (generally < 5) populations which are under threat, either due to small population size, or being on lands under immediate threat, e.g. road verges, urban areas, farmland, active mineral leases, etc., or the plants are under threat, e.g. from disease, grazing by feral animals, etc. May include taxa with threatened populations on protected lands. Such taxa are under consideration for declaration as 'rare flora', but are in urgent need of further survey.

Priority Two - Poorly Known Taxa

Taxa which are known from one or a few (generally < 5) populations, at least some of which are not believed to be under immediate threat (i. e. not currently endangered). Such taxa are under consideration for declaration as. 'rare flora', but are in need of further survey.

Priority Three - Poorly Known Taxa

Taxa which are known from several populations, at least some of which are not believed to be under immediate threat (i. e. not currently endangered). Such taxa are under consideration for declaration as 'rare flora', but are in need of further survey.

Priority Four - Rare Taxa

Taxa which are considered to have been adequately surveyed and which, whilst being rare (in Australia), are not currently threatened by any identifiable factors. These taxa require monitoring every 5 - 10 years.

Source: Conservation Codes for Western Australian Flora. ***Nuytsia***, 10(1): 141.

Acacia effusa

This Priority Two taxon was located at the same site as *A. daweana*. There are in excess of 150 plants at this location, where the population extends over approximately 1.4 km. The population spread into areas outside the proposed alignment and associated receiving environments.

Eremophila "magnifica" subsp. *"velutina"*

This Priority Three taxon was located at the western jump-up along the route of Alignment 2C. At this location the species was represented by approximately 30

individuals growing along the rim and scree slopes of a small breakaway. The population extended into breakaway areas outside the proposed road alignment.

Eucalyptus pilbarensis

This Priority Four species was represented by one population of approximately 90 plants located at the eastern jump-up along the route of Alignment 2C. The population extended over approximately 50 m of the western slopes of a steep breakaway down to the foot of a narrow, steeply incised gully. The location of this population, with respect to the proposed road alignment, was not determined because of insufficient design details for this portion of Alignment 2C. Advice from the Main Roads Western Australia and the field location of IP 11 (E656520 - N7501490) indicate that this population may be impacted.

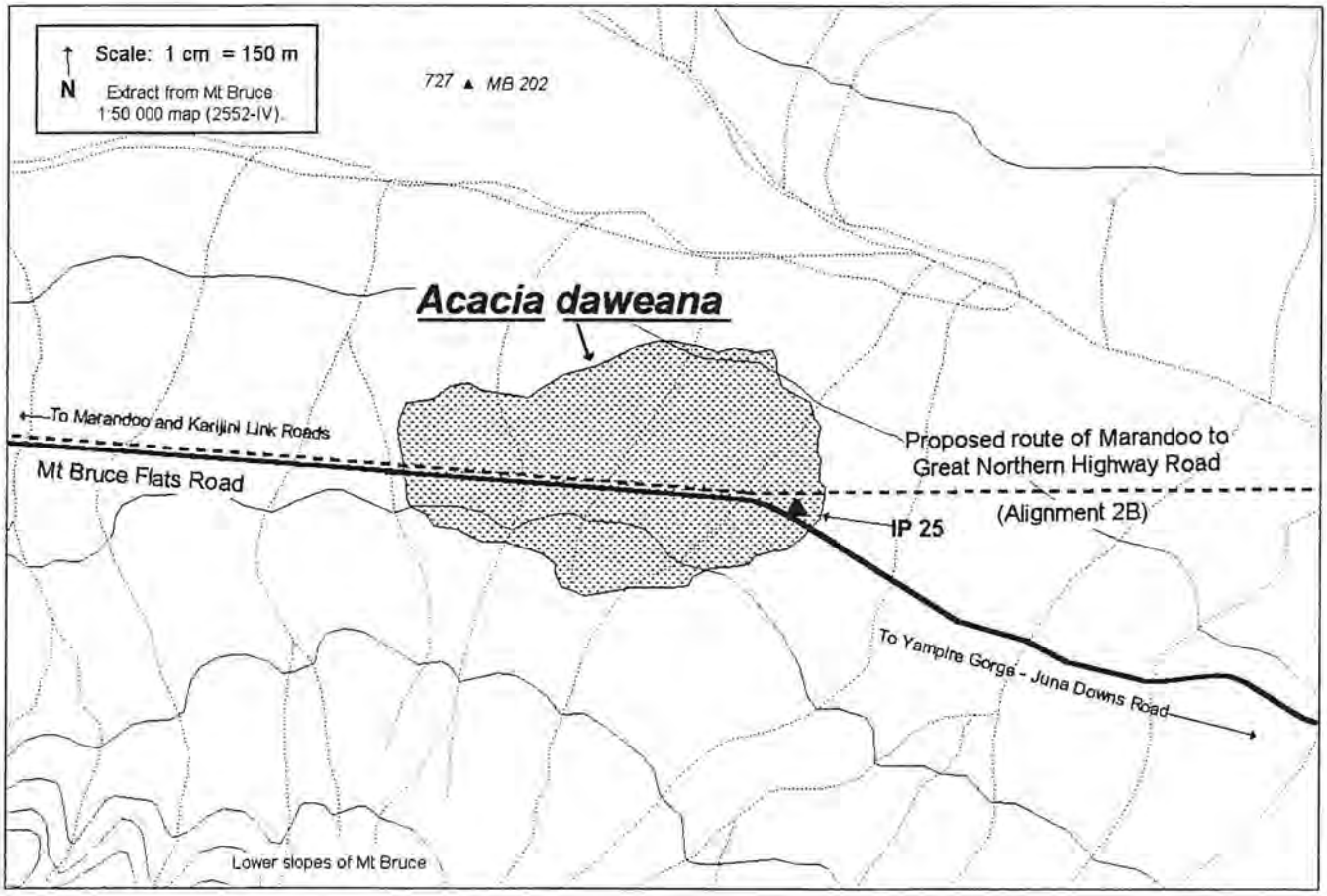


Figure 4. Location and areal extent of the *Acacia daweana* population located along the proposed alignment of the Marandoo to Great Northern Highway Road.

Indigofera "gilesii"

This taxon, represented by about 50 specimens, was located on the breakaways and scree slope at the western jump-up along the route of Alignment 2C. This taxon has been proposed for addition to the Priority Flora list with a conservation code of Priority

Two. The population located at the western jump-up extends beyond the proposed alignment of the road, although the heaviest concentration of specimens appeared to be in and immediately adjacent to a narrow gully in the centre of the proposed alignment and associated receiving environments.

Indigofera "ixocarpa"

This taxon has been ascribed a Priority Two conservation code. This taxon was also located at the western jump-up along the proposed route of Alignment 2C. It was represented by approximately 130 individuals. These plants were situated on the rim, scree and foot slopes of breakaways in the vicinity. Several plants were also located in a stony drainage line. The population was not confined to the proposed alignment, extending along the breakaway to the west for approximately 250 m.

In addition to the species mentioned above four further Priority Flora species may occur in the survey area. These species are *Spartothamnella puberula* (Priority Two), *Hibbertia glaberrima* (Priority Two), *Dampiera* sp. 'Mt Bruce' (Priority Two) and *Triumfetta leptacantha* (Priority Three). All four species occur in the vicinity of Mt Bruce and are associated with ridge habitats. The failure to detect these species during this field programme may be attributed to the location of the proposed alignment on the lower slopes of ridges and hills, as opposed to the upper slopes where these Priority Flora species have previously been recorded.

3.1.1.3 *Geographically Restricted, Disjunct Outliers and Poorly Known Species*

Due to inadequacies in our knowledge of the Pilbara flora, the taxonomic and conservation status of many plant species has still to be determined and assessed. As a consequence of these deficiencies a number of apparently geographically restricted, disjunct geographic outliers and poorly known species were identified in the survey area. These species are detailed below:

Acacia trachycarpa

A apparent geographical outlier represented by two individuals adjacent to the eastern jump-up on the route of Alignment 2C. Usually confined to alluvial and sandy soils, these specimens were located on the edge of a breakaway in skeletal stony soil under a canopy of *E. leucophloia*.

Acacia sp. (SVL 770)

This taxon superficially resembled *Acacia ancistrocarpa,* although morphological differences are evident. Further material, including flowers and fruits, are required to accurately determine the specimen's identity.

Acacia sp. (*effusa* x *ancistrocarpa*) (SVL 1848)

This apparent hybrid was represented by three specimens located in the vicinity of the *A. daweana* and *A. effusa* populations on the route of Alignment 2B. Specimens of this

taxon require monitoring to determine if they are fertile and capable of self perpetuating. Fruiting material is required to confirm the parentage of this taxon.

Amyema aff. *sanguineum* var. *pulchrum*

An undescribed mistletoe which was recorded growing on a number of *E. deserticola* plants in the survey area. The taxon appears restricted to the Pilbara region, however, further study is required to determined the relationship with a similar taxon in the Kimberley region.

Dysphania rhadinostachya subsp. "unsorted"

This taxon requires further study to delimit the taxonomic status of the two subspecies. Specimens of this taxon collected during the field programme were not positively identified as they represented taxonomic anomalies that did not adequately match established definitions delimiting the two subspecies.

Corchorus spp.

Further study is required on this genus to verify the existing taxonomy, clarify species complexes and provide determinations for numerous undescribed taxa. The Hamersley Range may have as many as four undescribed species.

Enchylaena tomentosa var "unsorted"

This taxon requires further study to delimit the taxonomic status of the two varieties. Specimens of this taxon collected during the field programme were not positively identified as they represented taxonomic anomalies that did not adequately match established definitions delimiting the two varieties.

Eremophila spp.

Continuing study of this genus is required to verify the existing taxonomy and clarify species complexes. This is especially the case with *E.* "*magnifica*" as the distinction between the two subspecies, "*magnifica*" and "*velutina*", may not be as well defined as originally conceived.

Hibiscus spp.

Further study is required on this genus to clarify the existing taxonomy and provide determinations for numerous undescribed taxa.

Maytenus sp. (SVL 846)

This species is common throughout the central Hamersley Range and may be an endemic species. Further study is required to determined the status of this taxon and verify it's distinction from an allied taxon in the Northern Territory.

Triodia spp.

This genus requires further study to clarify the taxonomic status of various species complexes. Clarification of differences between the various forms within the *T. pungens* and *T. wiseana* complex is required.

Tricoyne sp.

This species appears to be endemic to the Hamersley Range and has been recorded from a number of localities within the Karijini National Park. The taxon was recorded adjacent to the western and eastern jump-ups on the alignments of Alignment 2C.

3.1.2 *Introduced Species*

Five introduced species, belonging to four genera in three families, were identified in the survey area. All introduced species have previously been recorded in the Karijini National Park and are known from other localities in the Hamersley Range and Pilbara region. The five introduced species were:

Bidens bipinnata (Beggar's Ticks)

This species was located at numerous sites in the survey area. It was usually associated with the leaf litter and bark apron fringing large *Eucalyptus* trees and shaded sites with heavy soils in mulga woodlands. This species occurs throughout the tropics and subtropical region of the world and is considered to be naturalised in Western Australia. It extends from the southern Kimberley region to the North West Cape and eastward into the Little Sandy Desert.

Cenchrus ciliaris (Buffel grass)

This species was recorded from numerous localities along the surveyed alignment. The most prevalent occurrence was along to the drainage line adjacent to the Yampire Gorge - Juna Downs Road (E648840 - N7504070). This site is part of the route for Alignment 2C. Buffel grass is a native of Africa and India which has become naturalised in Western Australia, where it extends from the Kimberley region to the south coast.

Cenchrus setiger (Birdwood grass)

This species was recorded from two localities along the route of Alignment 2C. Both localities were along the drainage line adjacent to the Yampire Gorge - Juna Downs Road (E648840 - N7504070) where the species grew sympatrically with *C. ciliaris*. Birdwood grass is also a native of Africa and India which has become naturalised in Western Australia. The species extends from the Kimberley region to Carnarvon and is frequently found growing in alluvial and heavy soils, usually along drainage lines.

Rumex vesicarius (Ruby Dock)

This species was recorded from seven localities along the route of Alignments 2B and 2C. (Table 6). All locations were associated with drainage lines where stream flow induced ground disturbance appears to provide a suitable habitat for the species.

Populations ranged in size from ten plants to several thousand. This species is an environmental weed which is widespread through the arid zone of Western Australia. Ruby Dock is ubiquitous after rain, particularly in areas experiencing or recovering from significant ground disturbance. The species is indigenous to north Africa and west Asia. Significant site markers were erected along the proposed routes of Alignments 2B and 2C to facilitate identification of the populations.

Table 6. AMG coordinates and number of individuals in the seven populations of *Rumex vesicarius* identified along the alignment of the proposed Marandoo to Great Northern Highway Road.

AMG Coordinates	Number of plants
E640880 - N7503180	10
E630880 - N7502140	30 - 50
E627920 - N7502470	500+
E627840 - N7502480	200+
E622990 - N7502800	1 000+
E622380 - N7502890	3 000 - 5 000+
E620690 - N7502620	50 - 100

Sigesbeckia orientalis (Indian weed)

This species was located at two locations along the route of Alignment 2B. At both locations the species occurs in heavy soils associated with the down-slope edge of a mulga grove. Indian weed is a tropical Old World species that has become naturalised in Western Australia.

3.1.3 *Borrow Pit Flora*

No flora species of conservation significance were located at the ten borrow pits investigated as part of this field programme. The floral composition of all borrow pits examined was similar to that encountered along the proposed road alignment, as borrow pits were generally located immediately adjacent to the alignment and in a similar habitat and vegetation association to the majority of the proposed alignment traversed.

The introduced species, *Rumex vesicarius,* was identified as a dominant understorey species at borrow pit 9 (E613400 - N7507700).

3.2 Vegetation

A total of 23 vegetation communities were identified and mapped along the proposed alignment of the Marandoo to Great Northern Highway Road. Details of the 23 communities

identified are presented in Table 7. The structural arrangement and floristic composition of the 23 vegetation communities is summarised in Appendix Two while maps delimiting the extent of and location of each community along the proposed alignment are mapped in Appendix Three.

Table 7. Mapping codes and description of the 23 vegetation communities identified along the alignment of the proposed Marandoo to Great Northern Highway Road.

MAPPING CODE	VEGETATION COMMUNITY DESCRIPTION
Hummock Grassland	
1a	Hummock grassland with emergent eucalypts and mixed *Acacia* shrub.
Shrubland	
2a	Low *Acacia* - *Senna* shrubland over hummock grass.
2b	Mixed *Acacia* shrubland with emergent eucalypts.
2c	*Acacia aneura* - *Senna* shrubland.
Mallee	
3a	*Eucalyptus gamophylla* shrub mallee with emergent eucalypts over mixed shrubs and hummock grass.
3b	*Eucalyptus gamophylla* shrub mallee with emergent eucalypts over *Acacia* shrub.
3c	*Eucalyptus trivalvis* shrub mallee over mixed *Acacia* shrub.
3d	Mixed shrub mallee with emergent eucalypts over mixed *Acacia* shrub and hummock grass.
3e	Mixed open shrub mallee over mixed *Acacia* shrub and hummock grass.
Woodland	
4a	*Acacia aneura* woodland over mixed shrubs and open low grass.
4b	Grove - intergrove *Acacia aneura* woodland over mixed shrub.
4c	*Acacia aneura* woodland with emergent eucalypts over mixed shrubs and hummock grass.
4d	*Acacia aneura* woodland with emergent eucalypts over mixed *Acacia* shrub.
4e	*Eucalyptus leucophloia* woodland over open *Acacia* shrub.
4f	*Eucalyptus leucophloia* woodland over *Acacia hamersleyensis* shrub.
4g	*Eucalyptus leucophloia* woodland over *E. pilbarensis* shrub mallee over mixed *Acacia* shrub.
4h	*Eucalyptus leucophloia* woodland over *E. gamophylla* shrub mallee over mixed *Acacia* shrub.
4i	*Eucalyptus leucophloia* woodland over *E. gamophylla* shrub mallee over mixed shrub.
4j	*Eucalyptus leucophloia* woodland over open mixed shrub.
4k	*Eucalyptus terminalis* woodland over mixed shrub.
4l	Mixed *Eucalyptus camaldulensis* - *Acacia aneura* woodland over mixed shrub and tall grass.
4m	Mixed *Eucalyptus* woodland over mixed shrub.
4n	Mixed *Eucalyptus* woodland over open shrub and hummock grass.

To assist with the identification of the various vegetation communities the mapping units were rationalised by vegetative structure and floristic composition resulting in the identification of four dominant vegetation complexes:

- Hummock Grassland dominated by *Triodia* and *Plectrachne* species (1 association identified);
- Shrubland dominated by a variety of *Acacia* and *Senna* shrubs over scattered *Triodia* and *Plectrachne* species (3 associations identified);
- Mallee Shrub dominated by a number of *Eucalyptus* species over a mixed stratum dominated by *Acacia* species over hummock grass, predominantly *T. wiseana*, and *Plectrachne bynoei* (5 associations identified); and
- Woodland dominated by either *A. aneura* or *E. leucophloia* over a diverse *Acacia*, *Senna* and *Eremophila* shrub layer. The lower stratum in the *A. aneura* woodlands were dominated by an understorey of Chenopodiaceae and Amaranthaceae low shrubs, together with herbs and low grasses. In the *E. leucophloia* woodlands the lower vegetation stratums were dominated by *Acacia* shrubs over hummock grass, mainly *T. wiseana* and *T. basedowii*, with scattered occurrences of *T. longiceps* (14 associations identified).

The division of the 23 vegetation communities into the four complexes was resolved by subjective assessments based on the principal investigators previous experience in the Karijini National Park. No quantifiable assessment and interrogation of the structural arrangement and floristic composition of communities was attempted due to time constraints imposed by the proponents and a lack of replication in survey sites.

A direct comparison of the relationship between vegetation communities mapped during this project and those mapped by Beard (1975) was not possible because of the difference in mapping scale. From the interpretation of Beard's vegetation map for the survey area (Figure 3) it was concluded that most of the communities identified during this study are sub-units representative of the vegetation types identified as occurring on this Hamersley Plateaux Range Country and Valley Plain physiogeographic units. Similarly, comparisons with the 21 vegetation units identified by Dawe and Dunlop (1983) was not possible as mapping was not produced by these authors. It was noted, however, that the 23 vegetation communities identified during this survey can be classified into nine of Dawe and Dunlop's units.

4. DISCUSSION AND RECOMMENDATIONS

4.1 Flora

4.1.1 *Floristic Richness*

The 342 vascular plant species present in the survey area represent approximately one quarter of the 1 200 species estimated to be present in the Fortescue Botanical District. Many of the species recorded have ubiquitous distributions throughout the region and Eremaean Botanical Province of Western Australia, with only a small percentage appearing to be restricted to the Hamersley Range. Even fewer species are apparently restricted to the Karijini National Park.

The combination and distribution of species among the various families and genera encountered in the survey area (Table 2) appears to be representative of the Fortescue Botanical District. Indeed, nine of the ten families listed in Table 2 are also among the top ten families for specimens collected in the Fortescue Botanical District and vouched in the Pilbara Regional Herbarium. The top ten families match those identified by Mattiske and Associates (1992) in the Marandoo Project Area with the rank of the first four families being identical. The ranking of genera in terms of species representation also appears to be typical of the Fortescue Botanical District, with seven of the genera listed in Table 3 being also in the top ten genera for the district based on specimens housed in the Pilbara Regional Herbarium.

Table 8 compares the floristic richness between this study and results obtained for other flora surveys within the Hamersley Range. This table illustrates that the survey area has a relatively high floristic richness which is comparable to an area approximately four times its size (Marandoo Lease Area). Such a conclusion is, however, misleading as the trend depicted is probably more a reflection of the length of the surveyed alignment (76 km) and the array of habitats encountered along the route. A similar explanation was invoked to account for the apparent species richness of the Marandoo Project Area, which had 462 species in an area of approximately 200 km^2 (Mattiske and Associates 1992).

Nevertheless, comparisons with the levels of floristic richness for similar linear developments suggest that the richness of the survey area is high. In the case of results for the Tom Price North Road and Karijini Link roads, the discrepancy in results with the current survey may be attributed to the one-off field sampling programme for these projects. This is especially true in the case of floristic richness results for the Tom Price North Road, which was conducted in December when many annual (ephemeral) plant species would be unrepresented. Deficiencies in survey effort may also be invoked to explain these results and the discrepancies, as highlighted by the disparity between survey effort in the present study, with 33 field days, and the Tom Price North Road survey with a maximum of four field days.

Table 8. Comparison of floristic richness and approximate survey area size between seven Hamersley Range study areas and the Marandoo to Great Northern Highway Road survey area.

Location	Number of plant species	Approximate Area (km^2)
Marandoo Lease Area [D]	352	45
Marandoo to Great Northern Highway Road	**342**	**10**
Channar Survey Area [A]	288	120
Central Pilbara Railway - South east corridor [D]	267	30
Central Pilbara Railway - North west corridor [D]	228	125
Tom Price North Road [C]	174	11
Brockman No. 2 [B]	123	12
Karijini Link Road [E]	87	0.6

Source: A - Mattiske and Associates (1986), B - Mattiske and Associates (1989), C - *ecologia* Environmental Consultants (1992), D - Mattiske and Associates (1992), E - Shire of Ashburton (1993).

Disparity in floristic richness results with the Central Pilbara Railway corridor surveys cannot be attributed to deficiencies in sampling effort as the flora inventory lists for these projects were produced over a number of years during numerous field visits. It is postulated that the relatively high floristic richness of the survey area in this study can be attributed to the array of contrasting habitats traversed by the road alignment, many of which were not encountered on the railway corridors because of engineering design requirements and restrictions associated with railway gradings.

4.1.2 *Species of Interest*

Seven vascular plant species of conservation significance were located in the survey area. All were categorised as Priority Flora and no Declared Rare Flora species were identified. The Priority Flora species identified belonged to the Priority Two, Three and Four categories which imply contrasting levels of rarity and endangerment (Table 4). The species, their conservation significance and the importance of the population(s) located in the survey area are detailed below:

Brachychiton acuminatus

This species is known from numerous locations throughout the Pilbara region. It has been identified on the Burrup Peninsula, in the Chichester Range and throughout the Hamersley Range. It is known to occur elsewhere in the Karijini National Park and has been recorded in the Millstream Chichester National Park. Populations are usually small and it generally occurs in isolated locations where its preferred habitat is rocky scree slopes and stony outcrops. The conservation status of this species, as confirmed

by its conservation code (Priority Four) indicates it is a rare species which is not currently threatened. This species is represented by a single individual along the route of Alignment 3A.

It is unlikely that road construction activities will impinge on this species.

Acacia daweana

This species is known from only two populations in the central Hamersley Range. Both populations occur in the Karijini National Park, with the largest being the population encountered during this study. The majority of this population appears to occur along the route of Alignment 2C where the existing Mt Bruce Flats Road and the proposed alignment proceeding to the north of the Mt Bruce flats intercept. As indicated by its high conservation code (Priority Two) this species is rare and may be a candidate for addition to the schedule of Declared Rare Flora. Indeed, this species will be recommended for addition to the schedule of Declared Rare Flora during the next review as the survey requirements for gazettal have now been fulfilled.

Construction of the road will significantly impinge on this population and dramatically increase the threat to this species. Road design alterations are needed to protect this species.

Acacia effusa

This species was located at the same site as *A. daweana* along the route of Alignment 2C. This species in known from three populations in the central Hamersley Range, of which two occur in the Karijini National Park. The population identified during this survey appears to be the second largest, although further population counts are required. This species is also a candidate for addition to the Schedule of Declared Rare Flora as the survey requirements for addition have now been fulfilled.

Construction of the road will reduce the population size of this rare species. Road design alterations are recommended to protect this population.

Eremophila "magnifica" subsp.*" velutina"*

This taxon appears to be restricted to the Hamersley Range where it is known from approximately 12 populations. Within the Karijini National Park this taxon is known from four locations. If combined with the typical subspecies "*magnifica*", from which it may not differ significantly to warrant subspecific rank (R. Chinnock, personal communication), then the taxon is known from approximately 25 populations throughout the Hamersley Range. This species appears to be rare, although this may simply be a reflection of inadequate survey effort.

Construction of the road along the proposed alignment at the western jump-up will destroy several plants of this taxon, however, the species extends beyond the bounds

of the proposed alignment and the population should not be detrimentally affected. Numerous populations occur elsewhere on the Pilbara conservation estate.

Eucalyptus pilbarensis

This Priority Four species is known from ten populations throughout the Pilbara region, the majority of which occur in the Hamersley Range. Several are known from the Karijini National Park. This species generally grows in isolated roughed upland locations where there are no perceived threats. Current knowledge on the distribution of this species probably reflects a lack of adequate survey effort, especially of upland sites.

Construction of the road along the route of Alignment 2C at the eastern jump-up may significantly impinge on the *E. pilbarensis* population. Appropriate management prior to and during construction, together with remedial action upon completion of the road will be needed to mitigate deleterious impacts on this species.

Indigofera "gilesii"

This taxon is known from four populations throughout the Eremaean Botanical Province. Populations extend from the central Murchison District east to the Warburton Range and north into the Hamersley Range. No populations, apart from the one located during this study, are known to occur on conservation reserves. The population located at the western jump-up extends beyond the bounds of the proposed road alignment. This species requires further survey to adequately assess its conservation status and identify possible threats. This taxon may respond well to disturbance as many other *Indigofera* species appear to be disturbance opportunists (Peter Wilson, personal communication).

Construction of the road along the surveyed route of Alignment 2C through the western jump-up will destroy a number of plants of this taxon. Appropriate environmental management prior to and during construction, together with remedial action upon completion of the road will mitigate deleterious impacts on this species.

Indigofera "ixocarpa"

This taxon was also located at the western jump-up along the proposed route of Alignment 2C. It is known from six localities throughout the Pilbara Region, five of which are from the Hamersley Range. Two populations, including the one identified during this study, are located in the Karijini National Park. This species requires further survey to adequately assess its conservation status and identify possible threats. The species distribution at the western jump-up extends beyond the surveyed alignment. Preliminary indications suggest that this taxon responds well to disturbance.

Construction of the road along the surveyed route of Alignment 2C through the western jump-up will destroy a number of plants of this species. The impact of road

construction may be mitigated through appropriate environmental management during construction.

The following recommendations are proposed to mitigate the deleterious impacts of road construction on the Priority Flora species identified above. Implementation of these recommendations will ensure that the conservation status of these species remains unchanged. The recommendations are:

- **Prior to the commencement of road construction activities collect seed from *Eucalyptus pilbarensis*, *Indigofera "gilesii"* and *I. "ixocarpa"* for storage and subsequent sowing, once construction activities are complete, over cuttings, batters and embankments at the appropriate jump-up locations.**

  This work should commence prior to October 1995, if possible within the next two months, as all species are currently endowed with numerous fruiting structures. Seeds should be stored under sterile conditions in a constant environment to prevent any reduction in seed viability through insect predation and fluctuations in ambient temperature. Sowing of the seeds on cuttings, batters and embankments should occur prior to the first significant rainfall event after completion of the road, preferably in March or April to maximise germination and seedling establishment.

- **A similar seed collection, storage and sowing strategy to that advocated above is recommended for *Acacia daweana* and *A. effusa*. This recommendation aims to promote these species along the batters and embankments of the new road in the vicinity of the populations identified during this study.**

  The collection, storage and subsequent sowing of seed from *Acacia daweana* and *A. effusa* will assist with their conservation and minimise the deleterious impacts of this project on these species. Seed should be sown on the batters and embankments associated with the proposed road in close proximity to the populations identified during this study. It may also be appropriate to sow *A. effusa* seed onto areas of the existing Mt Bruce Flats Road, east of the proposed road alignment, once the existing road is closed, ripped and rehabilitated.

- **Re-align/reposition the proposed route of Alignment 2B at its junction with the Mt Bruce Flats Road. This new alignment should intercept the Mt Bruce Flats Road at a point 150 m east or 800 m west of IP 25 (E616550, N7502070).**

  This re-alignment should occur immediately to prevent the passage of vehicles and associated machinery through the *A. daweana* population. Such a re-alignment will also protect a significant portion of the *A. effusa* population at this locality. If the re-alignment is to the east of IP 25 then a restriction on widening the existing Mt Bruce Flats Road will need to be enforced to protect numerous individuals of

A. daweana. These restrictions will be particularly stringent on widening of the existing road in a northerly direction as most *A. daweana* plants are located on the north side of the road and are in close proximity to the existing alignment. Re-alignment to the west will negate any such widening restrictions.

- **During construction of the route for Alignment 2B through the western jump-up, collect and store topsoil material for re-application to cuttings, batters and embankments at this site upon completion of construction activities. Topsoil should be harvested from the top 200 mm of overburden material and re-applied as soon as practicable after completion of construction activities.**

  This soil management practice will enhance the re-establishment of the diverse, species-rich flora currently located at the western jump-up and may assist with the perpetuation of the two Priority Flora *Indigofera* species which are present. Establishment and persistence of these Priority Flora species will be enhanced by their bountiful response to opportunistic disturbance. This management practice may also enhance the re-establishment of *Eremophila "magnific"* subsp. *"velutina"* which is notoriously difficult to propagate. Top soil recovery and storage should be for the shortest duration possible to ensure maintenance of seed viability and vigour.

4.1.3 *Introduced Species*

Five introduced vascular plants species were located along the surveyed alignment. All have been recorded from elsewhere in the Karijini National Park and are widely distributed throughout the Pilbara region. Most species recorded were considered naturalised. One species, *Rumex vesicarius* (Ruby Dock), is a serious environmental weed that can have major impacts on nature conservation values as a consequence of it's invasive habit. The control of this species prior to construction, the initiation of environmental hygiene procedures during construction and subsequent post-construction monitoring of *R. vesicarius* will be required to mitigate any deleterious impacts of this species on the immediate survey area and receiving environments. If control and eradication of the seven populations of *R. vesicarius* identified along alignment **2A** is not undertaken prior to construction, then this environmental weed may spread throughout the road alignment and impinge on new areas of the national park. CALM would not consider this an acceptable impact. Such an impact on receiving environments would also not be favourably received by the EPA.

The following recommendations are suggested to mitigate the impacts of introduced species:

- **Initiate environmental hygiene procedures to prevent the introduction and spread of introduced (naturalised) plant species and their propagules throughout the proposed alignment, especially within the Karijini National Park.**

The development and introduction of environmental hygiene procedures is designed to prevent the further spread of introduced species identified during this study and impede the introduction of 'novel' weeds. Such procedures are proactive and preventative in operation rather than responsive, which is usually more costly and requires an ongoing long-term commitment. Nature conservation values along the route will be maintained by a proactive approach to introduced species, particularly environmental weeds.

- **Initiate control measures prior to construction which are designed to eradicate and impede the further spread of the environmental weed, *Rumex vesicarius*, throughout the proposed alignment, especially within the Karijini National Park.**

  The eradication of *R. vesicarius* from the seven locations along Alignment 2A prior to construction will diminish the weed's potential to disperse along the road corridor during construction and in the years following completion of construction activities. Eradication of *R. vesicarius* prior to construction will reduce the potential for this species to deleteriously impinge on receiving environments in the Karijini National Park.

- **Establish an introduced species monitoring programme to detect and eradicate outbreaks of introduced plant species, particularly *Rumex vesicarius*, along the proposed road alignment for a period of five (5) years after completion of the project.**

  The establishment and implementation of an introduced species monitoring programme will facilitate the identification of 'novel' introduced species within the surveyed area and will enable outbreaks of existing introduced species, particularly *R. vesicarius*, to be identified and controlled prior to becoming a serious problem. The monitoring programme should continued for a period of five years and involve at least biannual inspections. Inspections should include the road and its associated cuttings, embankments, batters and drains together with borrow pits and other sites disturbed during construction.

4.1.4 *Borrow Pit Flora*

No species of conservation significance were identified on or adjacent to any of the borrow pits surveyed during this study. One pit (number 9, E613400 - N7507700) was afflicted with *R. vesicarius*. Re-contouring, re-spreading of topsoil and supplementary seed sowing, if required, as is established Main Roads procedure for the rehabilitation of such sites, should minimise any deleterious impacts. Monitoring of borrow pits for introduced species, as previously recommended, will impede the introduction and establishment of weeds and mitigate their impacts on receiving environments.

The following recommendation is made with reference to borrow pits:

- **Material for road base/sub-base and sheeting should not be obtained from borrow pit 9 (E613400 - N7507700) as this pit is afflicted with the environmental weed *Rumex vesicarius*. This pit should be closed, rehabilitated and control measures initiated to eradicate *R. vesicarius*.**

4.2 Vegetation

4.2.1 *Representativeness of Vegetation Communities*

Twenty three vegetation communities representative of four broad vegetation types were identified along the alignment of the Marandoo to Great Northern Highway Road. These 23 vegetation communities and four broad vegetation types are representative of plant communities in the Hamersley Range and Karijini National Park. The four broad vegetation types are typical of the Hamersley Range, in particular Beard's (1975) Range Country and Valley Plain vegetation complexes. All 23 vegetation communities are compatible with nine of the 21 vegetation units identified by Dawe and Dunlop (1983) as occurring in the national park.

All vegetation communities identified along the proposed alignment of the Marandoo to Great Northern Highway Road extended into or are located elsewhere in the Karijini National Park.

4.2.2 *Vegetation Communities of Significance*

One plant community of conservation significance was identified along the proposed alignment of the Marandoo to Great Northern Highway Road. This plant community was located at the western jump-up and is of conservation significance because of its high floristic richness and the presence of three Priority Flora species (see Flora discussion). This plant community may occur elsewhere in the Hamersley Range and in particular, the Karijini National Park, as the landforms and terrain characteristics of the site are not uncommon. Further surveys are required to accurately assess the conservation status of this community.

No recommendations are made regarding strategies to mitigate the impacts of the proposed road on this community. The recommendation suggested under Flora for the Priority Flora Species present at the wester jump-up should be adequate, if implemented efficiently. This Flora recommendation emphasised the harvesting of topsoil and its re-application to batters, embankments and cuttings, upon completion of construction activities, thereby promoting the re-establishment of the floristically diverse community.

4.2.3 *Mulga Woodlands*

The proposed alignment of the road traverses several mulga woodland communities where the maintenance of overland/surface drainage will be paramount in the mitigation of deleterious impacts of this road, especially for the receiving environments. These communities have been denoted as Drainage Management Areas and their locations are presented in the Table 9.

Table 9. Location and extent of Drainage Management Area (DMA) along the proposed alignment of the Marandoo to Great Northern Highway Road.

AMG coordinates		Length of DMA (m)	Mulga community type	Comments
Easting	Northing			
E661000	N7499500	500	woodland	sluggish drainage, no defined channels
E649200	N7504150	1 000	grove - intergrove, some woodland	sluggish and well defined channels, some flat terrain
E645150	N7503350	1 000	woodland and grove - intergrove	sluggish and well defined channels
E641200	N7503000	1 000	woodland	sluggish drainage, flat terrain, no channels
E636270	N7504200	200	woodland	creekline
E623700	N7503000	800	woodland	sluggish drainage, gentle slope, some channels
E622750	N7502900	500	grove - intergrove	sluggish drainage, no channels
E621000	N7502600	1 300	grove - intergrove, some woodland	sluggish drainage, some well defined channels

The following recommendations are presented for the management of mulga woodland communities located in Drainage Management Areas:

- **At locations identified as Drainage Management Areas final road design should not impede overland/surface drainage.**

  This recommendation is paramount in the mitigation of the road's impact on the flora and vegetation of the survey area and is primarily concerned with limiting the development of drainage shadows. Reductions in the road's effect on surface drainage in Drainage Management Areas, mitigation of the impacts of any drainage shadows and thus impacts on receiving environments, may be achieved by a number of engineering designs employed by the Main Roads Western Australia. It

is recommended that the most efficient of these designs is the construction of floodways flush with the existing topography. All other designs have weaknesses which do not eliminate the effect of drainage shadows. Numerous examples of the deleterious impacts on mulga communities and other receiving environments of poor and inappropriate road and engineering design impeding overland/surface drainage are present elsewhere in the Pilbara.

- **Develop and commence a mulga woodlands monitoring programme designed to quantifiably document the health and survivorship of mulga woodland communities and their constituent species at the Drainage Management Area located along the proposed alignment of the road, upon completion of construction.**

  This recommendation is suggested to ensure that the drainage management system employed at Drainage Management Areas along the proposed alignment functions as anticipated. The monitoring programme should be designed so that changes in the health and survivorship of mulga woodland communities and their constituent species can be detected so that remedial action can be taken to mitigate such impacts. The monitoring programme will need to commence upon completion of the road and run for an number of years to document temporal change.

- **The proponent make a commitment to modify the drainage management system employed at locations along the proposed road alignment where a reduction in overland/surface drainage is promoting unacceptable change to mulga woodland communities and other receiving environments.**

  The identification of locations where the drainage management system may need modification will be facilitated through the mulga woodland monitoring programme proposed above. Modifications to the drainage management system at these sites will hopefully mitigate the deleterious impacts promoted by the existing drainage systems and reduce subsequent deterioration in the health and survivorship of adjacent woodlands and receiving environments.

5. SUMMARY

The flora and vegetation of the Marandoo to Great Northern Highway road is representative of the flora and vegetation in the Hamersley Range and in particular, the Karijini National Park.

A total of 342 vascular plant species were recorded along the proposed alignment. Seven of these species were of conservation significance being enumerated on CALM's Priority Flora schedule. No species of Declared Rare Flora were located along the alignment. As a consequence of deficiencies in our knowledge of the Pilbara flora the conservation status of numerous species of taxonomic, biological and ecological significance has still to be determined. Five introduced flora species were identified along the proposed alignment. All introduced species were known from elsewhere in the national park and appear to have ubiquitous distributions through the Pilbara. The introduced species of most concern was the environmental weed, Rumex vesicarius.

Twenty three vegetation communities were recorded and mapped along the alignment of the proposed road. All communities extended into or were present elsewhere in the national park. One community of conservation significance, due to its high floristic richness and presence of three Priority Flora species was identified at the western jump-up along the route of Alignment 2C. Several mulga woodland communities were identified where the maintenance of overland/surface drainage will be paramount in the mitigation of any deleterious impacts from the road. Localities along the proposed alignment susceptible to alterations in overland/surface drainage were demarcated as Drainage Management Areas.

Recommendations to mitigate the impacts of the road on the flora and vegetation of the survey area and associated receiving environments are presented. These recommendation emphasise:

- the re-alignment of the proposed road to avoid Priority Flora populations;
- rehabilitation of sites containing Priority Flora with seed material collected prior to road construction and through the re-application of stored overburden;
- control and eradication of environmental weeds, particularly *Rumex vesicarius*, through the adoption of environmental hygiene procedures, pre-construction eradication and post-construction monitoring;
- implementation of road designs and engineering works which do not impede overland/surface drainage in Drainage Management Areas associated with mulga woodlands; and
- monitoring the impacts of the road on Drainage Management Areas, their associated mulga woodlands and other receiving environments to identify unacceptable impacts which are remediated through appropriate design and engineering modifications.

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8. APPENDICES

8.1 APPENDIX ONE

Vascular Plant Species along the proposed Marandoo to Great Northern Highway Road.

8.2 APPENDIX TWO

Structural Arrangement and Floristic Composition of the 23 Vegetation Communities Mapped along the Alignment of the Marandoo to Great Northern Highway Road.

8.3 APPENDIX THREE

Vegetation Mapping along the Alignment of the Marandoo to Great Northern Highway Road.

8.1 APPENDIX ONE

Vascular Plant Species along the proposed

Marandoo to Great Northern Highway Road.

This list of vascular plants includes all specimens collected during field programmes between July 1991 and July 1995 and subsequently positively identified before 1 July 1995. Taxa are listed alphabetically in the order of genus and species within their respective families. The family sequence follows approximately the classification presented in Green (1985). Nomenclature generally follows Green (1985) and that employed by the Western Australian Herbarium, apart from a few exceptions where recent taxonomic revisions have suggested alternative classifications.

* - indicates an introduced species.

P2, P3, P4 - indicates conservation code (see text - Table 5).

ADIANTACEAE

Cheilanthes brownii
Cheilanthes sieberi

POACEAE

Amphipogon caricinus
Aristida contorta
Aristida holathera
Aristida obscura
Bothriochloa ewartiana
Brachyachne convergens
**Cenchrus ciliaris*
**Cenchrus setiger*
Chrysopogon fallax
Chrysopogon sp.
Cymbopogon ambiguus
Cymbopogon bombycinus
Cymbopogon sp. (SVL 851)
Dactyloctenium radulans
Dicanthium sericeum subsp. *humilius*
Dicanthium sericeum subsp. *sericeum*
Digitaria sp. (SVL 1111)
Enneapogon caerulescens
Enneapogon clelandii
Enneapogon polyphyllus
Eragrostis dielsii
Eragrostis eriopoda
Eragrostis setifolia
Eragrostis tenella
Eragrostis sp.
Eriachne aristidea
Eriachne dominii
Eriachne mucronata
Eriachne ovata
Eriachne sp. (SVL 926)
Eulalia aurea
Iseilema eremaen
Iseilema membranacea
Iseilema vaginiflorum
Iseilema sp.
Paraneurachne muelleri
Paspalidium clementii
Paspalidium rarum
Pennisetum sp. (SVL 1101)
Perotis rara
Plectrachne bynoei
Setaria dielsii
Setaria surgens
Sporobolus australasicus
Themeda triandra
Tragus australianus
Triodia basedowii
Triodia longiceps
Triodia pungens
Triodia ? *pungens* (woolly)
Triodia wiseana
Triodia aff. *wiseana*
Ulrochloa piligera

CYPERACEAE

Bulbostylis turbinata
Cyperus bulbosus
Eleocharis sp.
Fimbristylis sp.

COMMELINACEAE

Commelina ensifolia

ANTHERICACEAE

Tricoryne sp. (SVL 915)

PROTEACEAE

Grevillea stenobotrya
Grevillea striata
Grevillea wickhamii subsp. *aprica*
Hakea suberea

SANTALACEAE

Anthobolus leptomerioides
Exocarpos sparteus
Santalum lanceolatum

LORANTHACEAE

Amyema bifurcatum
Amyema fitzgeraldii
Amyema aff. *sanguineum* var. *pulchrum*
Diplatia grandibracteata
Lysiana murrayi

POLYGONACEAE

**Rumex vesicarius*

CHENOPODIACEAE

Chenopodium melanocarpum
Dysphania kalpari
Dysphania rhadinostachya
Dysphania rhadinostachya subsp. "unsorted"
Enchylaena tomentosa
Enchylaena tomentosa var. "unsorted"
Maireana melanocoma
Maireana planifolia
Maireana villosa
Rhagodia eremaea
Salsola kali
Scleroleana cornishiana
Sclerolaena tetragona
Sclerolaena sp. (SVL 880)

AMARANTHACEAE

Achyranthes aspera
Alternanthera nodiflora
Amaranthus mitchellii
Amaranthus pallidiflorus
Gomphrena affinis
Gomphrena cunninghamii
Ptilotus aervoides

Ptilotus astrolasius
Ptilotus calostachyus
Ptilotus clementii
Ptilotus exaltatus
Ptilotus gaudichaudii
Ptilotus helipteroides
Ptilotus macrocephalus
Ptilotus obovatus
Ptilotus polyphyllus
Ptilotus rotundifolius

NYCTAGINACEAE

Boerhavia coccinea
Boehavia repleta
Boerhavia sp.

GYROSTEMONACEAE

Codonocarpus cotinifolius

PORTULACACEAE

Calandrinia ptychosperma
Portulaca oleracea
Portulaca ? oleracea

CARYOPHYLLACEAE

Polycarpea longiflora

LAURACEAE

Cassytha capillaris
Cassytha ? capillaris
Cassytha ? racemosa

CAPPARACEAE

Capparis lasiantha
Capparis umbonata
Cleome viscosa

BRASSICACEAE

Lepidium echinatum
Lepidium oxytrichum
Lepidium pedicellosum
Lepidium platypetalum
Lepidium sp. (SVL 878)
Stenopetalum anfractum

SURIANACEAE

Stylobasium spathulatum

MIMOSACEAE

Acacia acradenia
Acacia adoxa
Acacia adsurgens
Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia ayersiana var. *latifolia*
Acacia bivenosa
Acacia citrinoviridis
Acacia coriacea subsp. *pendens*
Acacia coriacea subsp. *sericophylla*
Acacia cowleana
Acacia ? cowleana
Acacia daweana (P2)
Acacia dictyophleba
Acacia effusa (P2)
Acacia farnesiana
Acacia hamersleyensis
Acacia hilliana
Acacia inaequilatera
Acacia ? kempeana
Acacia maitlandii
Acacia marramamba
Acacia monticola
Acacia pachyacra
Acacia pruinocarpa
Acacia pyrifolia
Acacia rhodophloia
Acacia stowardii
Acacia tenuissima
Acacia tetragonophylla
Acacia ? trachycarpa
Acacia validinervia
Acacia sp. (SVL 770)
Acacia sp. (*effusa* x *ancistrocarpa*) (SVL 1848)

CAESALPINIACEAE

Petalostylis labicheoides
Senna artemisioides subsp. x *artemisioides*
Senna artemisioides subsp. *glaucifolia*
Senna artemisioides subsp. *hamersleyensis*
Senna artemisioides subsp. *helmsii*
Senna artemisioides subsp. *oligophylla*
Senna artemisioides subsp. *symonii*
Senna glutinosa subsp. *chateliana*
Senna glutinosa subsp. *ferraria*
Senna glutinosa subsp. *glutinosa*
Senna glutinosa subsp. x *luerssenii*
Senna glutinosa subsp. *pruinosa*
Senna notabilis
Senna pleurocarpa var. *angustifolia*
Senna venusta

PAPILIONACEAE

Cajanus aff. *cinereus*
Crotalaria medicaginea
Crotalaria ? medicaginea
Crotalaria novae-hollandiae
Gastrolobium grandiflorum
Glycine canescens
Gompholobium polyzygum
Indigofera colutea
Indigofera georgei
Indigofera "gilesii" (P3)
Indigofera "ixiocarpa" (P3)

Indigofera monophylla
Indigofera trita
Isotropis atropurpurea
Isotropis forrestii
Lotus cruentus
Mirbelia viminalis
Psoralea cinerea
Psoralea leucantha
Rhynchosia minima
Swainsona formosa
Tephrosia clementii
Tephrosia rosea var. *glabrior*
Tephrosia uniovulata
Tephrosia ? uniovulata

ZYGOPHYLLACEAE

Tribulus astrocarpus
Tribulus macrocarpus
Tribulus platypterus
Tribulus suberosus
Zygophyllum iodocarpum

POLYGALACEAE

Polygala chinensis

EUPHORBIACEAE

Euphorbia australis
Euphorbia boophthona
Euphorbia coghlanii
Euphorbia drumondii
Euphorbia sp.
Phyllanthus lacunellus
Phyllanthus maderaspatensis

CELASTRACEAE

Maytenus sp. (SVL 846)

STACKHOUSIACEAE

Stackhousia muricata

SAPINDACEAE

Diplopeltis stuartii
Dodonaea coriacea
Dodonaea lanceolata
Dodonaea petiolaris
Dodonaea viscosa subsp. *mucronata*

TILIACEAE

Corchorus tridens
Corchorus sp.

MALVACEAE

Abutilon exonemum
Abutilon aff. *exonemum*
Abutilon indicum
Abutilon lepidum
Abutilon otocarpum
Abutilon oxycarpum
Gossypium robinsonii
Hibiscus burtonii
Hibiscus coatesii
Hibiscus sturtii
Hibiscus sp. *1*
Hibiscus sp. *2*
Malvastrum americanum
Sida arenicola
Sida aff. *calyxhymenia*
Sida cardiophylla
Sida echinocarpa
Sida fibulifera
Sida platycalyx
Sida rohlenae
Sida sp.
Sida sp. "spiciform panicles"

STERCULIACEAE

Brachychiton acuminatus (P4)
Keraudrenia integrifolia
Keraudrenia ? nephrosperma
Rulingia ? kempeana
Rulingea rotundifolia
Waltheria indica

VIOLACEAE

Hybanthus aurantiacus

MYRTACEAE

Calytrix carinata
Eucalyptus camaldulensis
Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus hamersleyana
Eucalyptus kingsmillii
Eucalyptus leucophloia
Eucalyptus pilbarensis (P4)
Eucalyptus striaticalyx
Eucalyptus terminalis
Eucalyptus trivalvis
Eucalyptus victrix
Eucalyptus "xerothermica"

HALORAGACEAE

Haloragis gossei

APIACEAE

Trachymene oleracea
Trachymene ? oleracea

OLEACEAE

Jasminum didymum subsp. *lineare*

ASCLEPIADACEAE

Cynanchum floribundum
Cynanchum sp.
Rhyncharrhena linearis
Sarcostemma viminale subsp. *australe*

CONVOLVULACEAE

Bonamia rosea
Convolvulus erubescens
Evolvulus alsinoides
Ipomaea lonchophylla
Ipomaea mulleri
Porana commixta

BORAGINACEAE

Heliotropium heteranthum
Heliotropium ovalifolium
Heliotropium tenuifolium
Trichodesma zeylanicum

VERBENACEAE

Clerodendrum lanceolatum

CHLOANTHACEAE

Dicrastylis cordifolia
Dicrastylis georgei
Spartothamnella teucriiflora

LAMIACEAE

Prostanthera albiflora

SOLANACEAE

Nicotiana benthamiana
Nicotiana occidentalis subsp. *occidentalis*
Nicotiana aff. *occidentalis*
Solanum ferocissimum
Solanum horridum
Solanum lasiophyllum
Solanum phlomoides
Solanum sturtianum

SCROPHULARIACEAE

Stemodia grossa

ACANTHACEAE

Dipteracanthus australasicus

MYOPORACEAE

Eremophila forrestii
Eremophila "jucanda"
Eremophila "jucunda" subsp. *"pulcherima"*
Eremophila latrobei
Eremophila latrobei subsp.*"filiformis"*
Eremophila "lanceolata"
Eremophila longifolia
Eremophila "magnifica" subsp. *"velutina"* (P3)

RUBIACEAE

Canthium latifolium
Canthium lineare
Hedyotis crouchiana
Spermacace brachystema

CUCURBITACEAE

Cucumis melo subsp. *agrestis*
Mukia maderaspatana

CAMPANULACEAE

Wahlenbergia tumidifracta

GOODENIACEAE

Dampiera candicans
Goodenia heterochila
Goodenia microptera
Goodenia muelleriana
Goodenia prostrata
Goodenia stellata
Goodenia stobbsiana
Goodenia triodiophila
Goodenia sp. (SVL 867)
Scaevola parvifolia subsp. *pilbarae*
Scaevola spinescens
Velleia connata

BRUNONIACEAE

Brunonia australis

ASTERACEAE

**Bidens bipinnata*
Brachycome sp.
Calocephalus multiflorus
Calotis hispidula
Calotis multicaulis
Calotis plumulifera
Centipeda minima
Flaveria australasica
Helichrysum gilesii
Pterocaulon sphacelatum
Rhodanthe floribundum
Rhodanthe humboldtiona
Rutidosis helichrysoides
**Sigesbeckia orientalis*
Streptoglossa decurrens
Vittadinia eremaea

8.2 APPENDIX TWO

Structural arrangement and floristic composition of the 23 vegetation communities mapped along the proposed alignment of the Marandoo to Great Northern Highway Road.

Structural arrangement of the vegetation follows Muir's (1977) classifactory system.

HUMMOCK GRASSLAND

VEGETATION COMMUNITY 1a

Hummock grassland with emergent eucalypts and mixed Acacia shrub

Stratum : Very Open Low Woodland B

Eucalyptus deserticola

Stratum : Open Dwarf Scrub D

Abutilon lepidum
Acacia aneura
Acacia maitlandii
Canthium latifolium
Codonocarpus cotinifolius
Hakea suberea
Indigofera rugosa
Keraudrenia integrifolia
Senna venusta
Sida fibulifera
Sida sp.

Stratum : Dense Hummock Grass

Plectrachne bynoei
Triodia wiseana

Stratum : Open Low Grass

Themeda triandra

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SHRUBLAND

VEGETATION COMMUNITY 2a

Low Acacia - Senna shrubland over hummock grass

Stratum : Open Low Woodland B

Eucalyptus deserticola
Eucalyptus leucophloia

Stratum : Very Open Shrub Mallee

Eucalyptus gamophylla

Stratum : Low Heath D

Acacia adoxa
Acacia hilliana
Hakea suberea
Senna artemisioides subsp. oligophylla
Senna artemisioides subsp. pruinosa
Senna glutinosa subsp. glutinosa

Stratum : Hummock Grass

Triodia aff. wiseana
Triodia basedowii

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VEGETATION COMMUNITY 2b

Mixed Acacia shrubland with emergent eucalypts

Stratum : Open Low Woodland A

Eucalyptus deserticola
Eucalyptus patelaris

Stratum : Heath A

Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia maitlandii
Acacia monticola
Acacia pruinocarpa
Gossypium robinsonii

Stratum : Low Scrub B

Acacia ancistrocarpa
Acacia aneura
Acacia bivenosa
Acacia cowleana
Acacia hamersleyensis
Acacia maitlandii
Acacia pruinocarpa
Hakea suberea

Stratum : Dwarf Scrub C

Acacia aneura
Acacia bivenosa
Acacia dictyophleba
Acacia pruinocarpa
Bonamia rosea
Eremophila forrestii
Keraudrenia integrifolia
Senna artemisioides subsp. helmsii
Senna artemisioides subsp. oligophylla
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa
Senna venusta
Sida sp.
Solanum lasiophyllum
Solanum sturtianum

Stratum : Mid-Dense Hummock Grass

Plectrachne bynoei
Triodia pungens
Triodia wiseana

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VEGETATION COMMUNITY 2c

Acacia aneura - Senna shrubland

Stratum : Low Scrub A

Acacia ancistrocarpa
Acacia aneura
Eremophila forrestii
Grevillea stenobotrya

Stratum : Low Scrub B

Abutilon lepidum
Acacia ancistrocarpa
Acacia aneura
Acacia bivenosa
Acacia pruinocarpa
Eremophila latrobei
Senna artemisioides subsp. helmsii
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa

Stratum : Dwarf Scrub C

Dipteracanthus corynothecus
Ptilotus obovatus
Rhagodia eremaea
Senna venusta
Sida sp.

Stratum : Dense Hummock Grass

Triodia brizoides ?
Triodia pungens
Triodia wiseana

Stratum : Tall Grass

Themeda triandra

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MALLEE

VEGETATION COMMUNITY 3a

Eucalyptus gamophylla shrub mallee with emergent eucalypts over shrubs and hummock grass

Stratum : Low Woodland B

Acacia aneura
Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus patelaris
Eucalyptus terminalis

Stratum : Open Shrub Mallee

Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus leucophloia
Eucalyptus patelaris
Eucalyptus terminalis

Stratum : Dwarf Scrub C

Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia bivenosa
Acacia coelei
Acacia cowleana
Acacia dictyophleba
Grevillea wickhamii subsp. aprica
Santalum lanceolatum
Senna artemisioides subsp. oligophylla

Stratum : Open Dwarf Scrub C

Acacia maitlandii
Acacia validinervia
Bonamia rosea
Gompholobium polyzygum
Indigofera monophylla
Keraudrenia integrifolia
Maytenus sp.
Senna glutinosa subsp. pruinosa

Stratum : Dense Hummock Grass

Plectrachne bynoei
Triodia pungens
Triodia wiseana

Stratum : Tall Grass

Chrysopogon fallax
Cymbopogon sp.
Eulalia aurea
Themeda triandra

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VEGETATION COMMUNITY 3b

Eucalyptus gamophylla shrub mallee with emergent eucalypts over Acacia shrub

Stratum : Shrub Mallee

Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus leucophloia
Eucalyptus patelaris
Hakea suberea

Stratum : Heath A

Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia bivenosa
Acacia hamersleyensis
Maytenus sp.

Stratum : Low Scrub B

Acacia adsurgens
Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia bivenosa
Acacia cowleana
Acacia inaequilatera
Acacia maitlandii
Acacia marramamba
Acacia pruinocarpa
Acacia tetragonophylla
Capparis umbonata
Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus leucophloia
Eucalyptus patelaris
Gompholobium polyzygum
Hakea suberea
Keraudrenia integrifolia
Santalum lanceolatum
Senna artemisioides subsp. helmsii
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa

Stratum : Open Dwarf Scrub D

Acacia adoxa
Indigofera rugosa
Keraudrenia integrifolia
Ptilotus rotundifolius
Santalum lanceolatum
Senna artemisioides subsp. oligophylla
Senna glutinosa subsp. glutinosa
Sida sp.
Solanum lasiophyllum

Stratum : Mid-Dense Hummock Grass

Plectrachne bynoei
Triodia aff. wiseana
Triodia basedowii
Triodia longiceps
Triodia pungens
Triodia wiseana

Stratum : Tall Grass

Cymbopogon ambiguus
Themeda triandra

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VEGETATION COMMUNITY 3c

Eucalyptus trivalvis shrub mallee over mixed Acacia shrub

Stratum : Tree Mallee

Eucalyptus trivalvis

Stratum : Open Low Scrub B

Acacia ancistrocarpa
Acacia atkinsiana
Acacia tetragonophylla

Stratum : Mid-Dense Hummock Grass

Plectrachne bynoei
Triodia wiseana

* * * * * * * *

VEGETATION COMMUNITY 3d

Mixed shrub mallee with emergent eucalypts over mixed Acacia shrub and hummock grass

Stratum : Open Shrub Mallee

Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus kingsmillii
Eucalyptus leucophloia
Eucalyptus patelaris
Eucalyptus terminalis
Eucalyptus trivalvis

Stratum : Heath A

Acacia aneura
Acacia coelei
Acacia cowleana
Acacia pruinocarpa
Acacia validinervia

Stratum : Low Scrub A

Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia bivenosa
Acacia coelei
Acacia dictyophleba
Acacia inaequilatera
Acacia pruinocarpa
Acacia stowardii
Acacia validinervia
Hakea suberea
Rhagodia eremaea

Stratum : Dwarf Scrub C

Abutilon exonemum
Abutilon sp.
Acacia ancistrocarpa
Acacia bivenosa
Acacia maitlandii
Acacia tenuissima
Bonamia rosea
Capparis umbonata
Eremophila latrobei
Eremophila longifolia
Indigofera monophylla
Indigofera rugosa
Keraudrenia integrifolia
Maireana planifolia
Ptilotus rotundifolius
Senna artemisioides subsp. helmsii
Senna artemisioides subsp. oligophylla
Senna artemisioides subsp. x atemisioi
Senna glutinosa subsp. chatelainiana
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa
Sida fibulifera
Solanum lasiophyllum

Stratum : Mid-Dense Hummock Grass

Plectrachne bynoei
Triodia pungens
Triodia wiseana

Stratum : Tall Grass

Chrysopogon fallax
Eulalia fulva
Sporobolus australasicus
Themeda triandra

Stratum : Low Grass

Aristida contorta
Enneapogon polyphyllus
Paraneurachne muelleri
Setaria dielsii
Themeda triandra

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VEGETATION COMMUNITY 3e

Mixed open shrub mallee over mixed Acacia shrub and hummock grass

Stratum : Tree Mallee

Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus leucophloia
Eucalyptus terminalis
Eucalyptus trivalvis

Stratum : Open Shrub Mallee

Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus leucophloia
Eucalyptus patelaris
Eucalyptus terminalis
Eucalyptus trivalvis

Stratum : Heath A

Acacia adsurgens
Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia bivenosa
Acacia dictyophleba
Acacia hamersleyensis
Acacia maitlandii
Acacia stowardii
Acacia validinervia

Stratum : Low Heath C

Acacia atkinsiana
Acacia maitlandii
Acacia tenuissima
Acacia validinervia
Maytenus sp.

Stratum : Dwarf Scrub D

Acacia adoxa
Canthium latifolium
Keraudrenia integrifolia
Ptilotus rotundifolius
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa

Stratum : Mid-Dense Hummock Grass

Plectrachne bynoei
Triodia pungens
Triodia wiseana

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WOODLAND

VEGETATION COMMUNITY 4a

Acacia aneura woodland over mixed shrubs and open low grass

Stratum : Low Forest A

Acacia aneura
Eucalyptus patelaris

Stratum : Scrub

Acacia aneura
Eremophila forrestii
Eremophila longifolia
Santalum lanceolatum

Stratum : Dwarf Scrub C

Eremophila "lanceolata"
Ptilotus obovatus
Rhagodia eremaea

Stratum : Tall Grass

Chrysopogon fallax
Themeda triandra

Stratum : Low Grass

Enneapogon caerulescens
Enneapogon polyphyllus

Stratum : Open Hummock Grass

Plectrachne bynoei
Triodia pungens

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VEGETATION COMMUNITY 4b

Grove - intergrove Acacia aneura woodland over mixed shrub

Stratum : Low Woodland A

Acacia aneura
Acacia pruinocarpa
Eucalyptus deserticola
Grevillea stenobotrya

Stratum : Scrub

Acacia ancistrocarpa
Acacia bivenosa
Acacia maitlandii
Acacia monticola
Acacia pruinocarpa
Gossypium robinsonii
Grevillea stenobotrya
Grevillea wickhamii subsp. aprica
Hakea suberea

Stratum : Low Scrub B

Abutilon lepidum
Acacia aneura
Acacia pruinocarpa
Canthium latifolium
Eremophila forrestii
Eremophila longifolia
Grevillea stenobotrya
Rhagodia eremaea
Santalum lanceolatum
Senna artemisioides subsp. helmsii
Senna glutinosa subsp. glutinosa
Senna venusta
Sida aff. fibulifera
Sida arenicola
Solanum lasiophyllum
Solanum sturtianum

Stratum : Dwarf Scrub D

Abutilon lepidum
Acacia bivenosa
Canthium lineare
Capparis lasiantha
Dipteracanthus corynothecus
Enchylaena tomentosa
Eremophila latrobei
Hybanthus aurantiacus
Indigofera monophylla
Maireana planifolia
Ptilotus obovatus
Salsola kali
Sida fibulifera
Sida sp.
Solanum lasiophyllum

Stratum : Open Dwarf Scrub C

Acacia aneura
Enchylaena tomentosa
Eremophila forrestii
Eremophila latrobei
Rhagodia eremaea

Stratum : Tall Grass

Chrysopogon fallax
Cymbopogon obtectus
Themeda triandra

Stratum : Open Low Grass

Aristida contorta
Aristida holathera var. holathera
Aristida obscura
Enneapogon caerulescens
Enneapogon polyphyllus

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VEGETATION COMMUNITY 4c

Acacia aneura woodland with emergent eucalypts over mixed shrubs and hummock grass

Stratum : Low Forest A

Acacia aneura
Acacia pruinocarpa
Eucalyptus leucophloia

Stratum : Low Woodland A

Acacia aneura
Eucalyptus leucophloia
Eucalyptus terminalis

Stratum : Heath A

Acacia hamersleyensis
Acacia maitlandii
Acacia monticola
Gossypium robinsonii
Grevillea wickhamii subsp. aprica
Indigofera georgeii

Stratum : Open Low Scrub B

Acacia aneura
Acacia atkinsiana
Acacia hamersleyensis
Acacia tetragonophylla
Canthium latifolium
Canthium lineare
Eremophila latrobei
Senna artemisioides subsp. oligophylla
Senna glutinosa subsp. pruinosa
Senna notabilis

Stratum : Low Grass

Cymbopogon obtectus
Eriachne mucronata
Themeda triandra

Stratum : Hummock Grass

Triodia basedowii
Triodia pungens
Triodia wiseana

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VEGETATION COMMUNITY 4d

Acacia aneura woodland with emergent eucalypts over mixed Acacia shrub

Stratum : Open Low Woodland B

Acacia aneura
Eucalyptus deserticola
Eucalyptus patelaris

Stratum : Low Scrub A

Acacia aneura
Acacia bivenosa
Acacia pruinocarpa

Stratum : Dwarf Scrub C

Acacia adsurgens
Acacia ancistrocarpa
Acacia bivenosa
Acacia coelei
Acacia cowleana
Acacia dictyophleba
Acacia inaequilatera
Acacia maitlandii
Acacia monticola
Acacia pachyacra
Acacia pruinocarpa
Acacia stowardii
Acacia tenuissima
Gossypium robinsonii
Hakea suberea
Ptilotus obovatus
Senna artemisioides subsp. helmsii
Senna artemisioides subsp. oligophyll
Solanum lasiophyllum

Stratum : Open Dwarf Scrub C

Acacia ancistrocarpa
Acacia bivenosa
Acacia cowleana
Acacia pachyacra
Codonocarpus cotinifolius
Gossypium robinsonii
Keraudrenia integrifolia

Stratum : Mid-Dense Hummock Grass

Plectrachne bynoei
Triodia pungens
Triodia wiseana

Stratum : Open Tall Grass

Chrysopogon fallax
Themeda triandra

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VEGETATION COMMUNITY 4e

Eucalyptus leucophloia woodland over open Acacia shrub.

Stratum : Low Woodland B

Eucalyptus deserticola
Eucalyptus leucophloia

Stratum : Thicket

Acacia atkinsiana
Acacia bivenosa
Acacia hamersleyensis
Acacia maitlandii
Acacia monticola

Stratum : Low Scrub B

Acacia bivenosa
Acacia hamersleyensis
Acacia maitlandii
Acacia monticola
Senna glutinosa subsp. pruinosa

Stratum : Dense Hummock Grass

Triodia basedowii
Triodia longiceps
Triodia pungens
Triodia wiseana

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VEGETATION COMMUNITY 4f

Eucalyptus leucophloia woodland over Acacia hamersleyensis shrub

Stratum : Low Woodland A

Eucalyptus leucophloia
Eucalyptus terminalis
Grevillea stenobotrya
Hakea suberea

Stratum : Low Heath C

Acacia maitlandii
Indigofera ixiocarpa
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa

Stratum : Low Scrub A

Acacia hamersleyensis
Acacia monticola
Clerodendrum tomentosum
Dodonaea spathlatum
Gossypium robinsonii

Stratum : Dense Hummock Grass

Triodia basedowii
Triodia wiseana

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VEGETATION COMMUNITY 4g

Eucalyptus leucophloia woodland over E. pilbarensis shrub mallee over mixed Acacia shrub

Stratum : Very Open Low Woodland B

Eucalyptus leucophloia

Stratum : Shrub Mallee

Eucalyptus pilbarensis

Stratum : Mid-Dense Hummock Grass

Triodia basedowii
Triodia longiceps
Triodia pungens

Stratum : Tall Grass

Themeda triandra

Stratum : Low Grass

Eriachne mucronata

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VEGETATION COMMUNITY 4h

Eucalyptus leucophloia woodland over E. pilbarensis shrub mallee over mixed Acacia shrub

Stratum : Low Woodland A

Eucalyptus deserticola
Eucalyptus leucophloia
Eucalyptus terminalis

Stratum : Open Shrub Mallee

Eucalyptus gamophylla
Eucalyptus terminalis

Stratum : Heath B

Acacia atkinsiana
Acacia bivenosa
Acacia hamersleyensis
Acacia maitlandii
Acacia monticola
Senna glutinosa subsp. pruinosa
Senna glutinosa subsp. x luerssenii

Stratum : Open Scrub

Acacia adsurgens
Acacia ancistrocarpa
Acacia aneura
Acacia atkinsiana
Acacia ayersiana var. latifolia
Hakea suberea

Stratum : Open Low Scrub B

Acacia bivenosa
Acacia cowleana
Acacia tenuissima
Hakea suberea
Maytenus sp.

Stratum : Open Dwarf Scrub C

Acacia adoxa
Acacia ancistrocarpa
Acacia bivenosa
Acacia maitlandii
Acacia tetragonophylla
Corchorus sp.
Gompholobium polyzygum
Grevillea wickhamii subsp. aprica
Keraudrenia integrifolia
Ptilotus obovatus
Senna artemisioides subsp. oligophylla
Senna glutinosa subsp. glutinosa

Stratum : Mid-Dense Hummock Grass

Triodia basedowii
Triodia pungens
Triodia wiseana

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VEGETATION COMMUNITY 4i

Eucalyptus leucophloia woodland over E. gamophylla shrub mallee over mixed shrub

Stratum : Low Woodland B

Acacia aneura
Eucalyptus leucophloia
Eucalyptus terminalis

Stratum : Open Low Woodland A

Eucalyptus deserticola
Eucalyptus gamophylla
Eucalyptus leucophloia
Eucalyptus terminalis
Hakea suberea

Stratum : Open Tree Mallee

Eucalyptus gamophylla
Eucalyptus trivalvis

Stratum : Low Scrub A

Acacia ancistrocarpa
Acacia atkinsiana
Acacia bivenosa
Acacia cowleana
Acacia marramamba
Acacia stowardii
Acacia tenuissima
Acacia tetragonophylla
Capparis umbonata
Eremophila fraseri
Eremophila latrobei
Gossypium robinsonii
Hakea suberea
Maytenus sp.
Senna artemisioides subsp. helmsii
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa

Stratum : Dwarf Scrub C

Acacia atkinsiana
Acacia bivenosa
Acacia cowleana
Acacia hamersleyensis
Acacia inaequilatera
Acacia maitlandii
Acacia tenuissima
Capparis lasiantha
Dodonaea spathlatum
Grevillea wickhamii subsp. aprica
Indigofera monophylla
Maytenus sp.
Ptilotus calostachyus
Ptilotus rotundifolius
Senna artemisioides subsp. oligophylla
Senna glutinosa subsp. ferraria
Senna glutinosa subsp. glutinosa

Stratum : Hummock Grass

Triodia basedowii
Triodia wiseana

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VEGETATION COMMUNITY 4j

Eucalyptus leucophloia woodland over open mixed shrub

Stratum : Low Woodland A

Eucalyptus leucophloia

Stratum : Open Low Scrub B

Acacia ancistrocarpa
Acacia monticola
Gossypium robinsonii
Maytenus sp.

Stratum : Open Dwarf Scrub C

Acacia adoxa
Acacia bivenosa
Acacia hilliana
Capparis umbonata
Gompholobium polyzygum
Keraudrenia integrifolia
Senna glutinosa subsp. glutinosa
Senna glutinosa subsp. pruinosa
Senna glutinosa subsp. x luerssenii

Stratum : Mid-Dense Hummock Grass

Triodia basedowii
Triodia longiceps
Triodia wiseana

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VEGETATION COMMUNITY 4k

Eucalyptus terminalis woodland over mixed shrubs

Stratum : Woodland

Eucalyptus terminalis

Stratum : Open Low Woodland B

Eucalyptus leucophloia
Eucalyptus terminalis

Stratum : Very Open Shrub Mallee

Eucalyptus terminalis

Stratum : Scrub

Acacia ancistrocarpa
Acacia atkinsiana
Acacia hamersleyensis
Acacia maitlandii
Grevillea stenobotrya

Stratum : Low Scrub B

Acacia ancistrocarpa
Acacia bivenosa

Stratum : Dwarf Scrub D

Canthium latifolium
Canthium lineare
Keraudrenia integrifolia
Senna artemisioides subsp. oligophylla

Stratum : Open Dwarf Scrub D

Acacia inaequilatera
Acacia pyrifolia
Indigofera rugosa
Ptilotus obovatus
Tephrosia rosea

Stratum : Dense Hummock Grass

Triodia pungens
Triodia wiseana

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VEGETATION COMMUNITY 4I

Mixed Eucalyptus camaldulensis - Acacia aneura woodland over mixed shrub and tall grass

Stratum : Open Woodland

Acacia aneura
Acacia citrinoviridis
Acacia coriacea subsp. pendens
Eucalyptus camaldulensis
Eucalyptus patelaris
Grevillea striata

Stratum : Scrub

Acacia aneura
Acacia cowleana
Acacia inaequilatera
Acacia maitlandii
Acacia monticola
Acacia pruinocarpa
Acacia validinervia
Eremophila longifolia
Gossypium robinsonii
Senna artemisioides subsp. x atemisioides

Stratum : Open Dwarf Scrub C

Eremophila "lanceolata"
Ptilotus obovatus
Rhagodia eremaea

Stratum : Tall Grass

Chrysopogon fallax
Eragrostis sp.
Eulalia aurea
Themeda triandra

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VEGETATION COMMUNITY 4m

Mixed Eucalyptus woodland over mixed shrub

Stratum : Low Woodland A

Eucalyptus leucophloia
Eucalyptus patelaris
Eucalyptus terminalis

Stratum : Scrub

Acacia monticola
Gossypium robinsonii
Grevillea wickhamii subsp. aprica
Hakea suberea

Stratum : Low Scrub A

Acacia aneura
Acacia bivenosa
Acacia coelei
Acacia cowleana
Acacia maitlandii
Acacia monticola
Acacia validinervia
Gastrolobium grandiflorum
Hakea suberea

Stratum : Dwarf Scrub C

Acacia ancistrocarpa
Acacia maitlandii
Capparis umbonata
Indigofera rugosa
Jasminum didymum subsp. lineare
Ptilotus obovatus
Ptilotus rotundifolius
Senna artemisioides subsp. oligophylla
Senna artemisioides subsp. x atemisioides
Senna glutinosa subsp. glutinosa

Stratum : Open Dwarf Scrub D

Keraudrenia integrifolia
Scaevola spinescens
Solanum lasiophyllum

Stratum : Mid-Dense Hummock Grass

Triodia pungens
Triodia wiseana

Stratum : Tall Grass

Cymbopogon obtectus
Themeda triandra

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VEGETATION COMMUNITY 4n

Mixed Eucalyptus woodland over open shrub and hummock grass

Stratum : Low Woodland A

Eucalyptus leucophloia
Eucalyptus terminalis

Stratum : Dwarf Scrub C

Acacia adoxa
Acacia hamersleyensis
Acacia maitlandii
Acacia monticola
Acacia rhodophloia
Keraudrenia sp.
Tricoryne sp.

Stratum : Dense Hummock Grass

Triodia basedowii
Triodia wiseana

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8.3 APPENDIX THREE

Vegetation Mapping along the proposed alignment of the Marandoo to Great Northern Highway Road.

MARANDOO TO GREAT NORTHERN HIGHWAY ROAD

VEGETATION MAP LEGEND

VEGETATION TYPES	MAPPING CODE	PLANT COMMUNITY DESCRIPTION
HUMMOCK GRASSLAND		
	1a	Hummock grassland with emergent eucalypts and mixed *Acacia* shrub.
SHRUBLAND		
	2a	Low *Acacia - Senna* shrubland over hummock grass.
	2b	Mixed *Acacia* shrubland with emergent eucalypts.
	2c	*Acacia aneura - Senna* shrubland.
MALLEE		
	3a	*Eucalyptus gamophylla* shrub mallee with emergent eucalypts over mixed shrubs and hummock grass.
	3b	*Eucalyptus gamophylla* shrub mallee with emergent eucalypts over *Acacia* shrub.
	3c	*Eucalyptus trivalvis* shrub mallee over mixed *Acacia* shrub.
	3d	Mixed shrub mallee with emergent eucalypts over mixed *Acacia* shrub and hummock grass.
	3e	Mixed open shrub mallee over mixed *Acacia* shrub and hummock grass.
WOODLAND		
	4a	*Acacia aneura* woodland over mixed shrubs and open low grass.
	4b	Grove - intergrove *Acacia aneura* woodland over mixed shrub.

VEGETATION TYPES	MAPPING CODE	PLANT COMMUNITY DESCRIPTION
WOODLAND		
	4c	*Acacia aneura* woodland with emergent eucalypts over mixed shrubs with hummock grass.
	4d	*Acacia aneura* woodland with emergent eucalypts over mixed *Acacia* shrub.
	4e	*Eucalyptus leucophloia* woodland over open *Acacia* shrub.
	4f	*Eucalyptus leucophloia* woodland over *Acacia hamersleyensis* shrub.
	4g	*Eucalyptus leucophloia* woodland over *E. pilbarensis* shrub mallee over mixed *Acacia* shrub.
	4h	*Eucalyptus leucophloia* woodland over *E. gamophylla* shrub mallee over mixed *Acacia* shrub.
	4i	*Eucalyptus leucophloia* woodland over *E. gamophylla* shrub mallee over mixed shrub.
	4j	*Eucalyptus leucophloia* woodland over open mixed shrub.
	4k	*Eucalyptus terminalis* woodland over mixed shrub.
	4l	Mixed *Eucalyptus camaldulensis - Acacia aneura* woodland over mixed shrub and tall grass.
	4m	Mixed *Eucalyptus* woodland over mixed shrub.
	4n	Mixed *Eucalyptus* woodland over open shrub and hummock grass.

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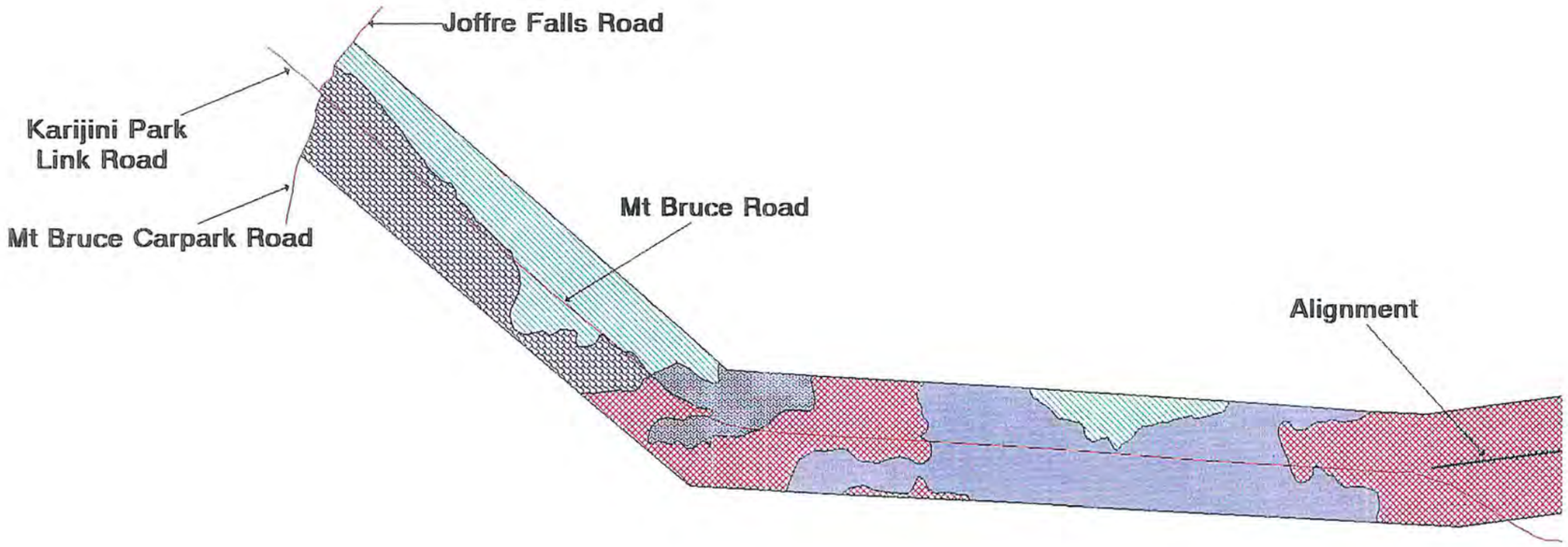
8.3 Appendix Three

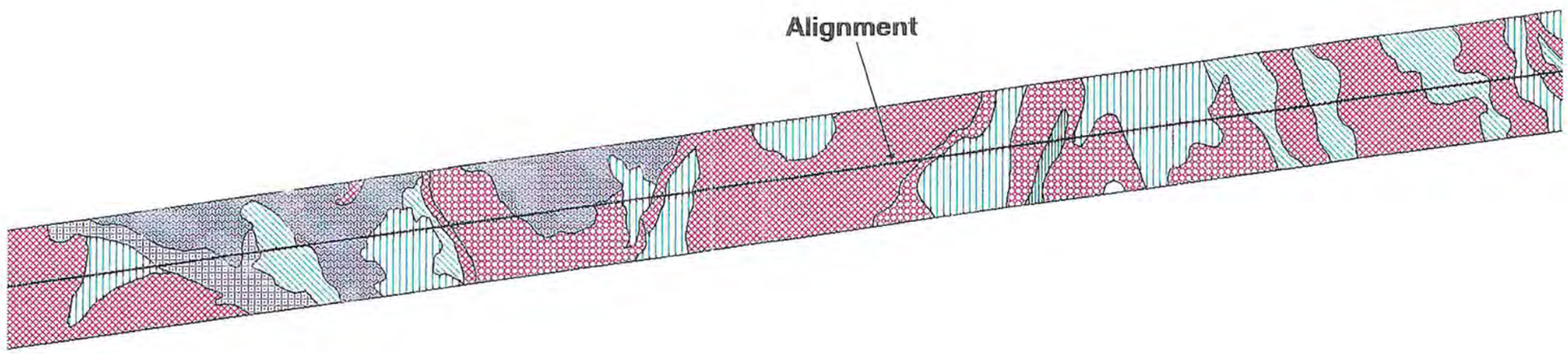
Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Legend

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP
SHEET A





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Kilometers
Scale 1:20 000

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8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

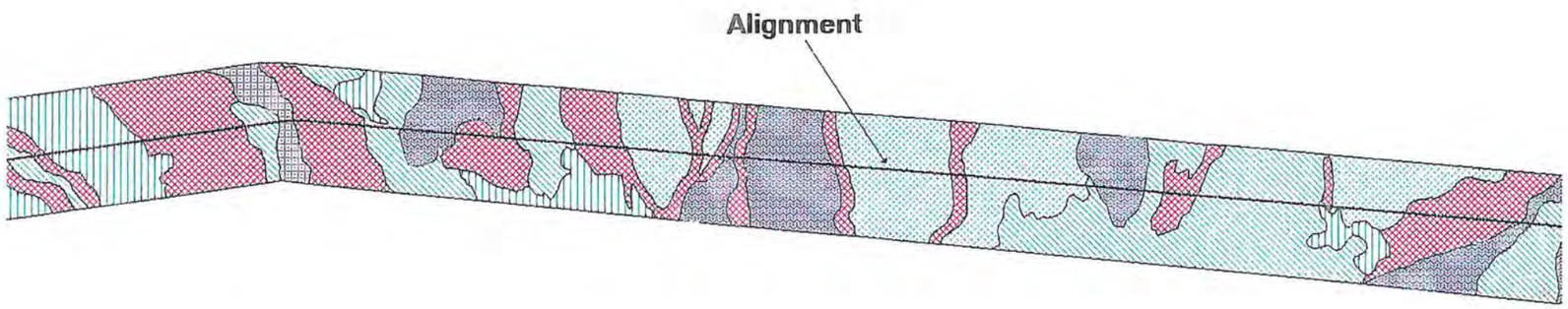
Vegetation Map - Sheet A

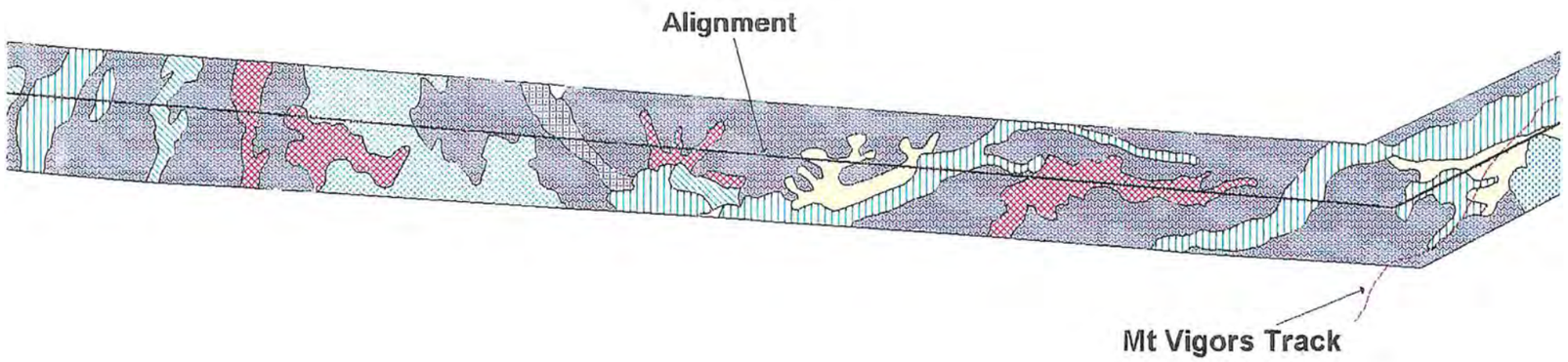
MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP

SHEET B

N





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Kilometers
Scale 1:20 000

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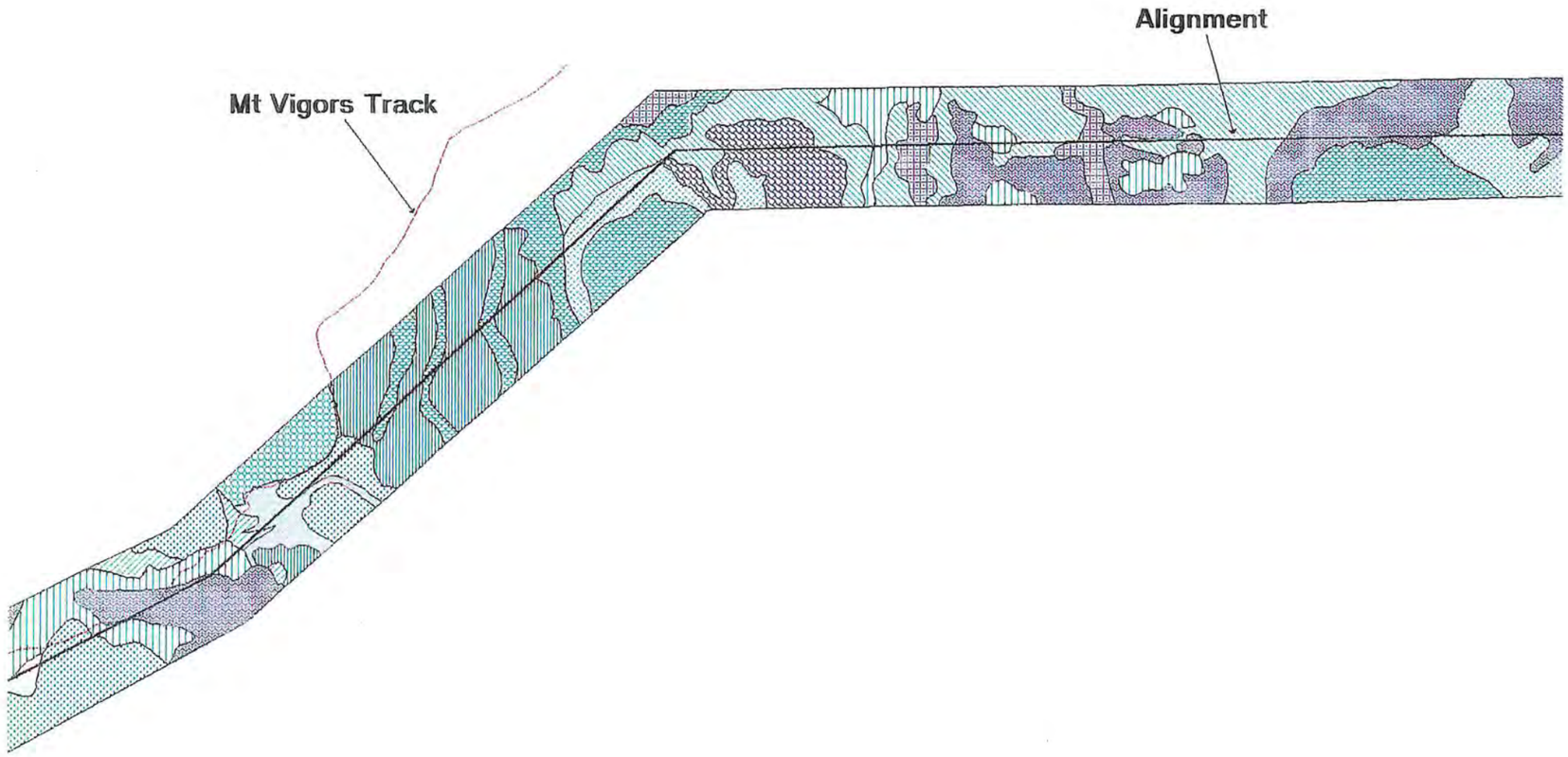
8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Sheet B

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP
SHEET C



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Scale 1:20 000

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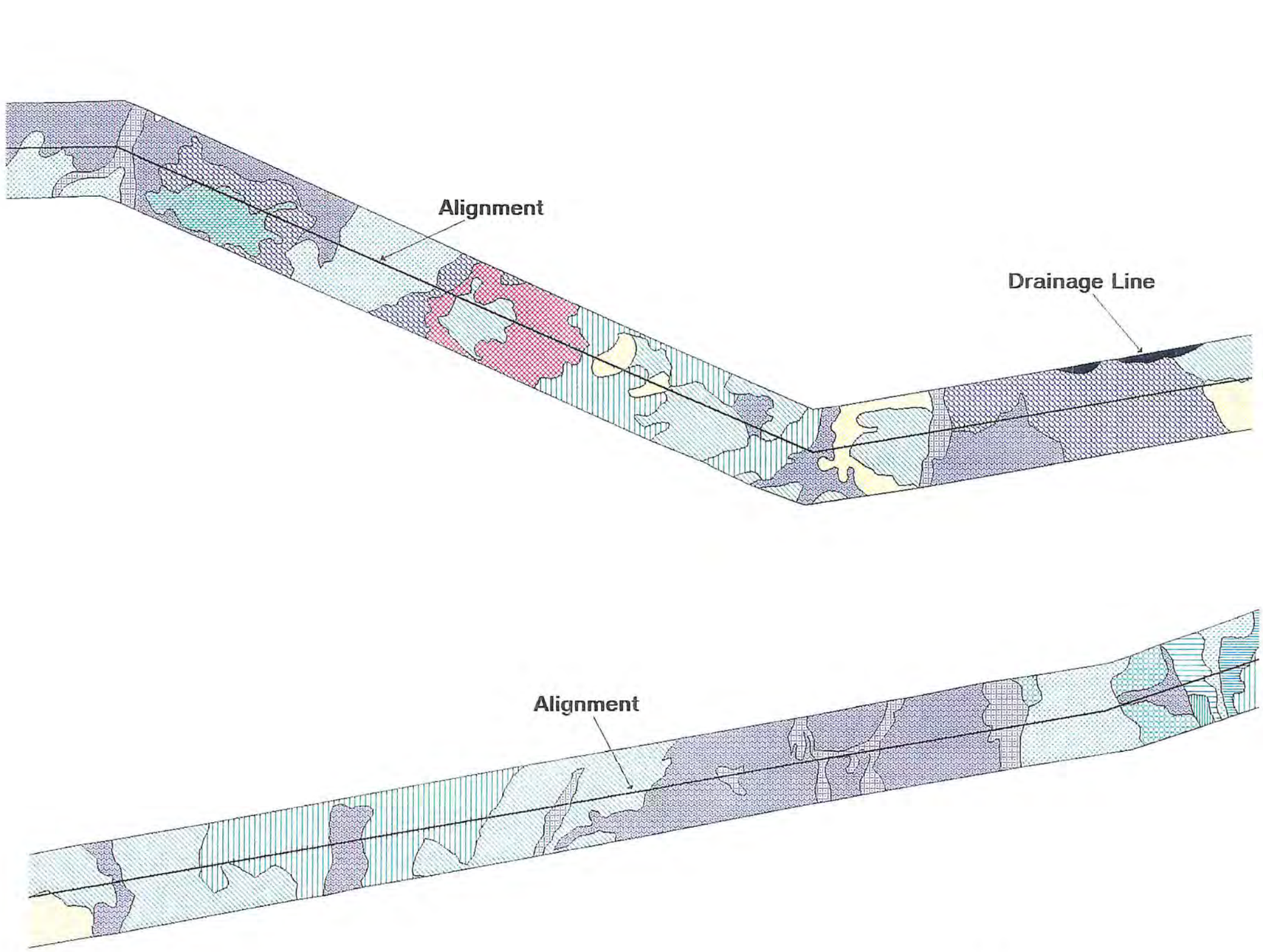
8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Sheet C

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP
SHEET D



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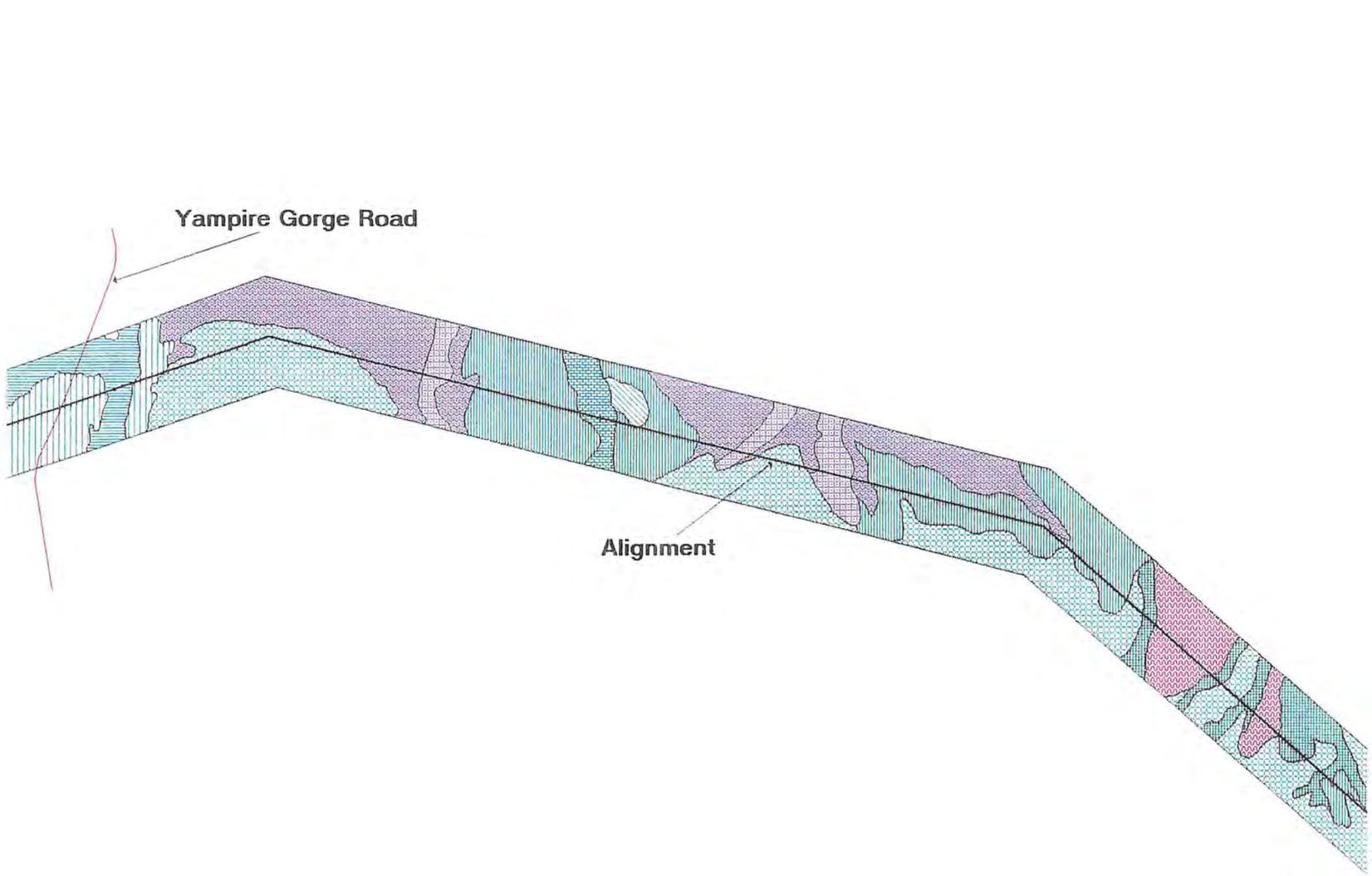
8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Sheet D

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP
SHEET E



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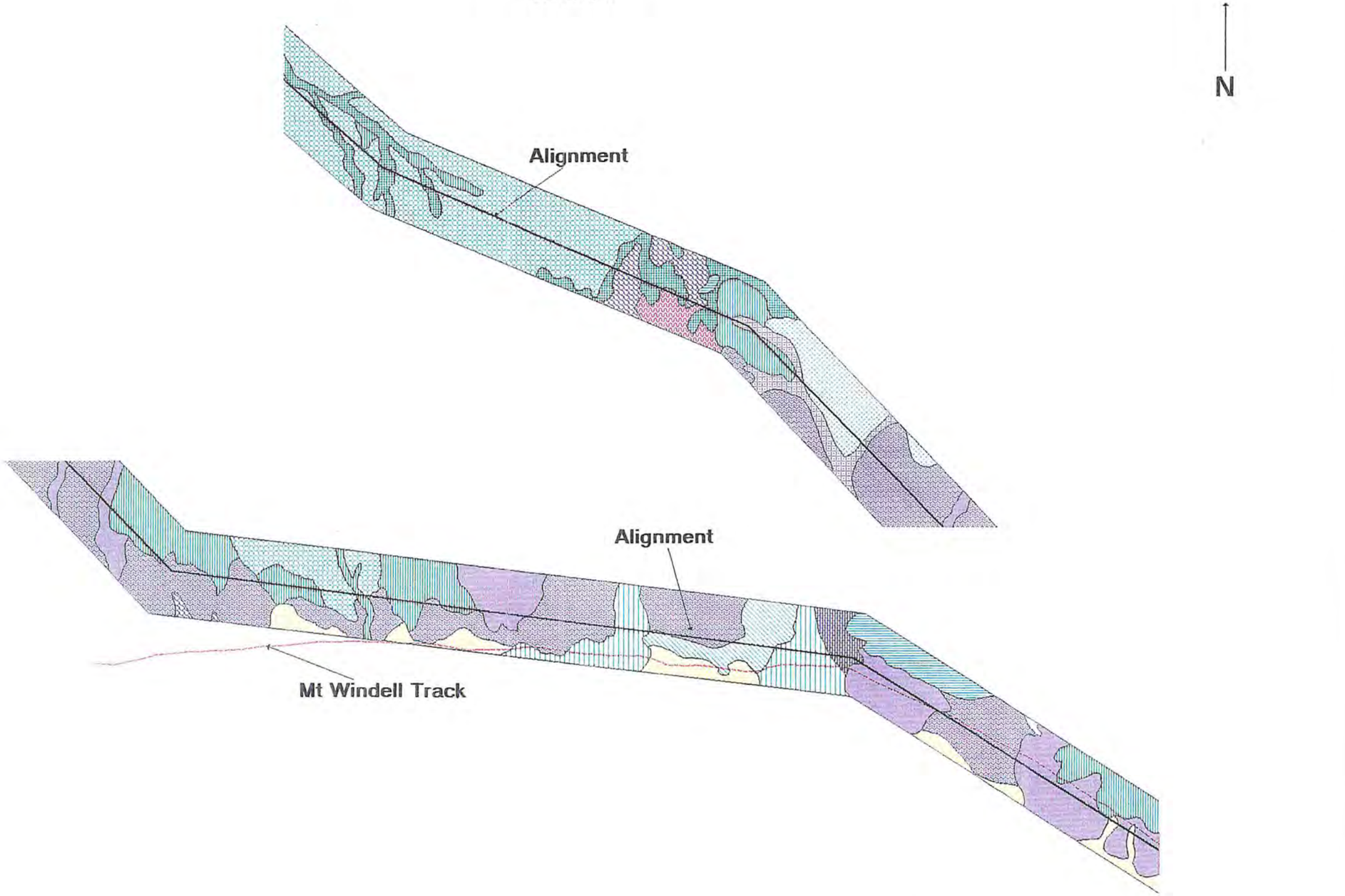
8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Sheet E

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP
SHEET F



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8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

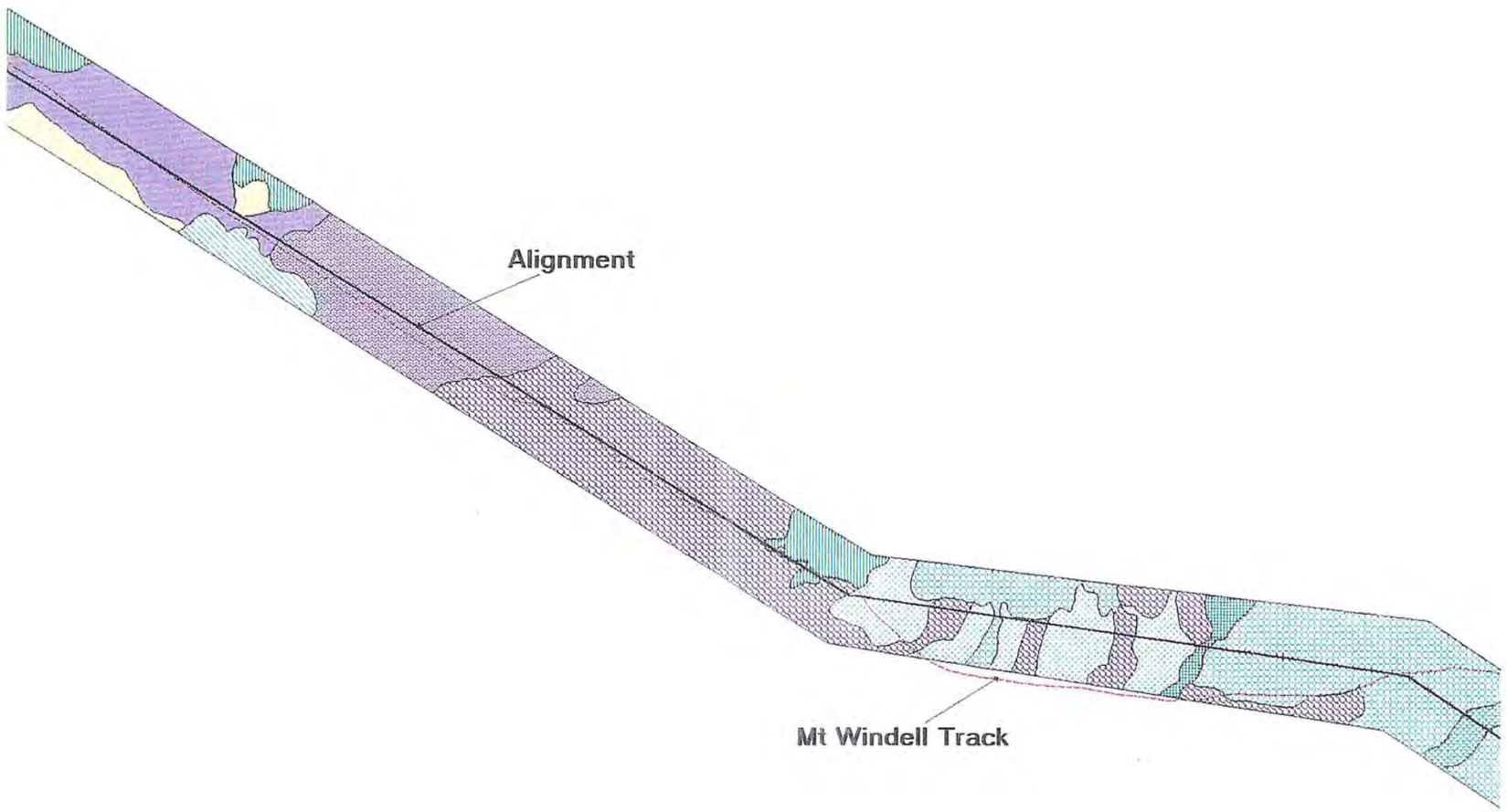
Vegetation Map - Sheet F

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP

SHEET G

N



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Kilometers
Scale 1:20 000

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8.3 Appendix Three

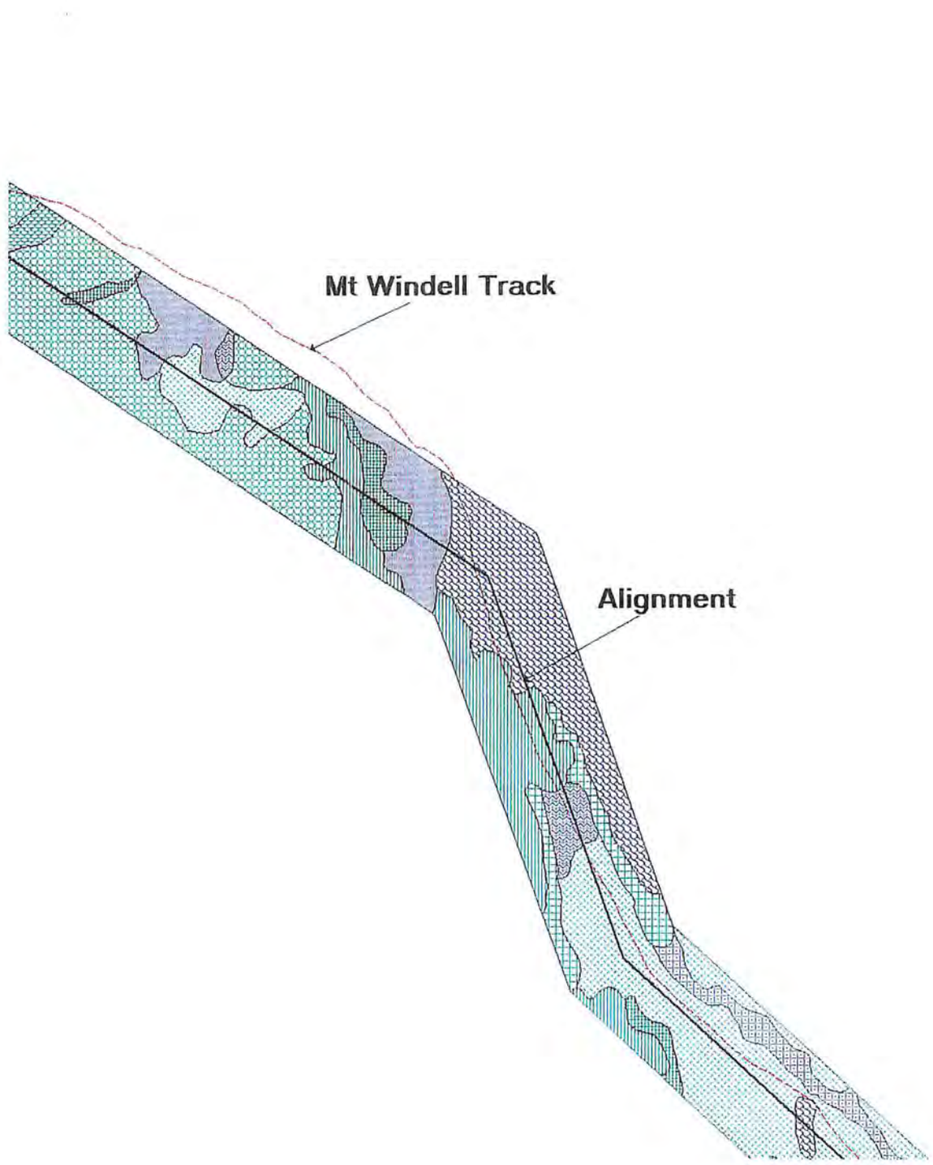
Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Sheet G

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP

SHEET H



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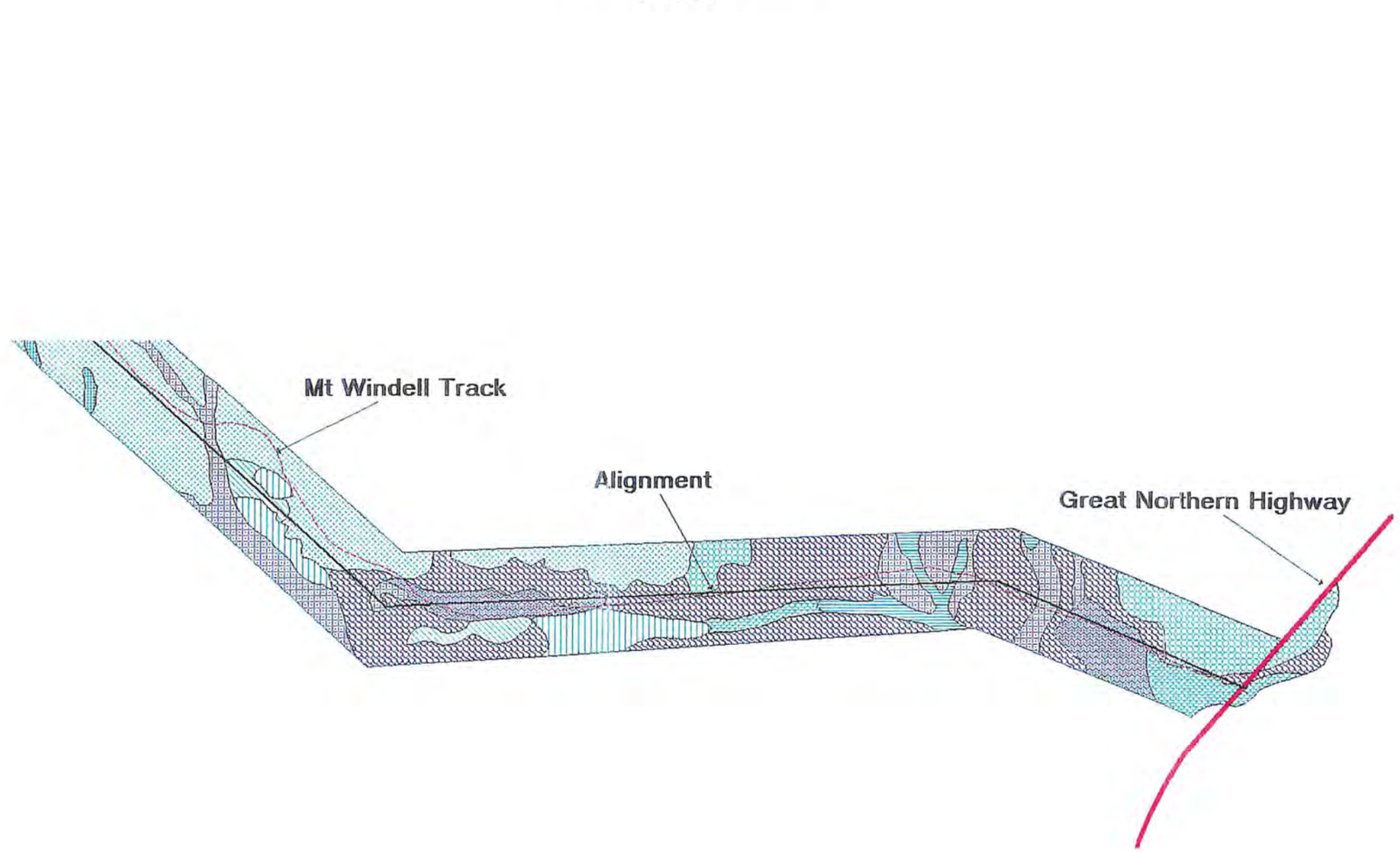
8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Sheet H

MARANDOO TO GREAT NORTHERN HIGHWAY LINK ROAD

VEGETATION MAP
SHEET I



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8.3 Appendix Three

Vegetation Mapping - Alignment of the Marandoo to Great Northern Highway Road

Vegetation Map - Sheet I