CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The first known systematic investigation of the soil resources in the Pilliga region was undertaken around the beginning of the century. Jensen (1907, 1912) and others explored the area in an effort to ascertain its pastoral and agricultural potential, though there are several earlier reports on block surveys that comment on the vegetation and soils. Various State Forestry reports (1918, 1939, 1951/52, 1986) noted vegetation associations and devised management practices aimed at maximising the potential of the forest resources in the area. Waring (1950) and Hallsworth and Waring (1964) undertook more focussed research into soil type and genesis and this was followed up by investigations conducted through Macquarie University. This latter research included; land system mapping (Mitchell *et al.* 1982) and studies on vegetation, phytoliths, soils and surface processes in the area (Norris *et al.* 1991; Hart 1992; 1995; Hart *et al.* 1996a; Eddy *et al.* 1996; Norris 1996). From this, the various sedimentary bodies were placed in a tentative stratigraphic framework and some insight into the pedogenetic processes that affect the soils of the area has been gained.

A unit recognised by Jensen (1906) and subsequently mentioned by all researchers has been the deep sand bodies that occur throughout the region. They are referred to as "Sand Monkeys" an English corruption of the Aboriginal name "Moongie". Subsequently, Waring (1950) and Hallsworth and Waring (1964), although principally assessing the pedogenesis of the texture contrast soils, provide a brief appraisal of the sand monkeys. They noted the presence of water-worn gravels and their position overlying a clay basement, ruling out aeolian deposition and *in situ* weathering respectively as sources. They proposed that the sand bodies represented channel deposits of a former aggraded stream system, an interpretation perhaps prompted by the identification of 'prior streams' by Butler (1950).

The bulk of research into prior streams in Australia has been conducted on the Riverine Plain around the Murray and Murrumbidgee Rivers. This work was initiated by Butler (1950;1958;1960;1961) and followed by others over the ensuing decades (Langford-Smith 1959;1960; Stannard 1961; Pels 1964; Schumm 1968). These researchers identified former channels up to 500 metres wide and 10.5 metres deep, which are of the same order as the larger features in the Pilliga. However, perhaps because of the different landuse in the area (or in spite of it) the prior stream channels are readily identifiable on black and white Air Photos as long, continuous ,well-defined bodies, in contrast to the more diffuse sand monkeys in the Pilliga. Large scale exposures from major road works and the excellent definition provided by the aerial photo interpretation (API) enabled researchers in the Riverina to measure characteristics such as; palaeosinuosity, meander wavelength, width and depth. Once these data were coupled with modern dating techniques available to later researchers (Bowler 1978, Page *et al.* 1991, Page 1994), accurate palaeoenvironmental reconstruction became possible.

Such information, obtainable on the Riverine Plain, was not available to previous workers in the Pilliga. A lack of resolution from air photos in delineating prior channel position, the paucity of large scale exposures and limited dating opportunities restricted the scope of this type of palaeoenvironmental reconstruction. Several factors also demand that caution is exercised in making direct comparison between the two different areas (Table 1). These factors may have their origin in the primary deposition of the sediments or in post-depositional modification.

Table 1. Summary of some fundamental differences between the Sand Monkeys of the Pilliga and Prior Streams of the Riverine Plain.

	PILLIGA	RIVERINE PLAIN *
LEVEE DEPOSITS	Not present	Fine grained levee deposits common
FLUVIAL BEDDING STRUCTURES	Not present	Cross and trough cosets, concave up foresets
GRAVEL CONTENT	up to 36 %	2 - 6 %
SILT + CLAY %	up to 20	1.6 - 3.4

* After Schumm (1968) and Page (1994)

Further studies on palaeochannels including Nanson *et al.* (1988), Pickup *et al.* (1988), Rust and Nanson (1988), Nanson *et al.* (1992) have focussed on the establishment of a Quaternary climatic framework correlating the dates of various sedimentary bodies with other global climatic indicators. Dating completed during the course of this study can be used to place the sand monkeys of the Pilliga within this existing Quaternary framework. In this context, the present study provides another case study, but in a somewhat different setting; sub-humid at the present time and marginal to the semi-arid environments of the above studies, and in a catchment some 500 kilometres north of the Riverine Plain.

It is necessary however, before considering regional palaeoenvironmental implications, to ascertain the relationships between the different units in the landscape and gain a firm understanding of the local stratigraphy, to this end the current study follows up on the work of Hart *et al.* (1996a).

Apart from palaeoenvironmental considerations, there is also the issue of the type of soil that forms or doesn't form on these sand bodies, this consideration is particularly salient if they are thousands or tens of thousands of years old. How are these sand bodies altered and what information can be obtained by considering their post depostional modification ?

1.2 AIMS

The investigation of sand monkeys and other sand bodies in the Pilliga forms the basis for this study. This study in turn, forms a link in the overall investigation of the soils and sediments of the Pilliga by focussing on one part of the "sedimentary jig-saw" *viz* the sand bodies and evaluates how they fit into existing frameworks, both local (Pilliga) and regional (e.g: Riverina, semi-arid zone). Over the course of the study three pivotal issues have been identified and it is towards resolution of these issues that the thesis is aimed.

1. Several types of sand body have been recognised in the field;

a. Yellow sand monkey

b. Red sand monkey

c. Proposed source bordering dune

d. Deposits along current ephemeral creeks

The first aim of the thesis is to characterise the different sand bodies, highlight the similarities and differences, account for the observed features and determine their origin as far as possible.

2. The sand bodies of the Pilliga form one part of a sedimentary landscape which also includes extensive clayey deposits. At present the stratigraphic relationships between the two are largely unresolved. The second aim is to advance the understanding of the palaeoenvironmental conditions that led to the depositional suite currently observed. It should be noted however, that this study does not involve a comprehensive investigation of the fine-grained deposits and as such cannot hope to entirely resolve their depositional situation. Nevertheless, a combination of stratigraphy and dating is used to more firmly establish the spatial and temporal relationships between the sand bodies and the clayey deposits, building towards a depositional history of the area.

3. Preliminary Thermoluminescence dating has obtained ages of around 45-62 ka in one of the sand bodies. Given the evidence of both climatic (Bowler 1978) and vegetation change (Dodson and Wright 1989) within that period, it is reasonable to expect that some degree of pedogenesis or post depositional modification (PDM) would affect the sand bodies in this presently sub-humid setting. Furthermore the would affect the sand bodies in this presently sub-humid setting. Furthermore the materials used in dating (quartz sand and charcoal) can be expected to be effected by bioturbation in varying ways. This mechanism has implications for PDM and the interpretation of dates. The last aim, therefore, is to undertake a preliminary assessment of pedogenesis in these sand bodies.

1.3 ORGANISATION OF THE THESIS

Due to the nature of the project and its multiple aims, the presentation does not take the form of a traditional scientific paper i.e. introduction, methods, results, discussion, conclusion. Rather, the questions outlined above will form the basis of the discrete chapters with the associated methods, results etc. adjoined. It is hoped that this format will provide greater coherence to the reader and allow more effective and focussed treatment of the material.

CHAPTER 2

THE PILLIGA REGION

2.1 INTRODUCTION

In order to fulfil the aims of the study as stated in the previous chapter, it was necessary to select a site that enabled the relevant features to be studied at various scales. These may be identified as follows:

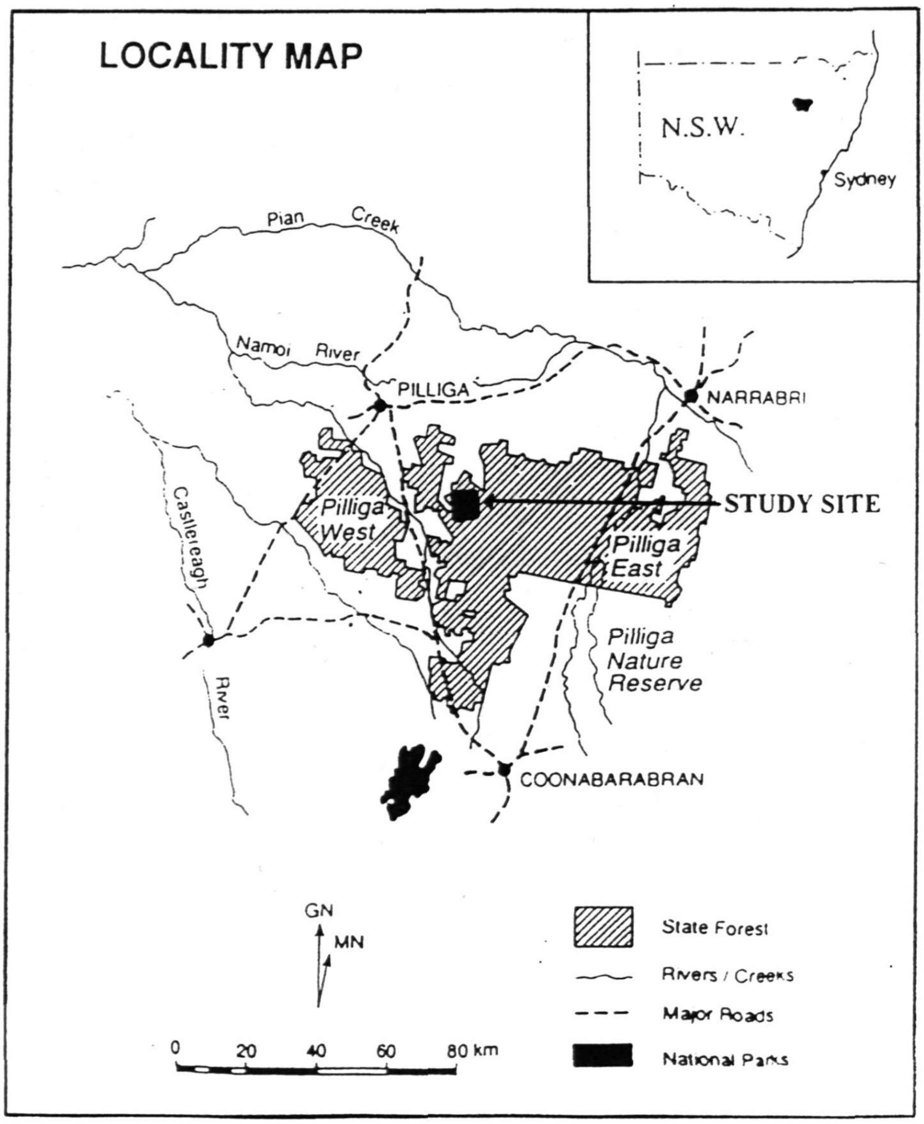
- A broad, regional scale, to assess the spatial relationships between the major depositional units over an area from the Warrumbungle's to the Namoi floodplain.
- An intermediate or geomorphic unit scale, so the different units and different examples of the same unit can be characterised and compared.
- A finer, grain scale, allowing assessment of grain size, grain to grain relationships and other detailed observations to further distinguish between various units.

Clearly, it is at these three scales that the questions raised in the previous chapter can be best addressed. It is expected that integration of data collected at these scales will provide the basis of a realistic understanding of the processes that have and are operating at the site. To put this into effect it is necessary to provide sufficient background to the Pilliga region and to place the study site into perspective. A short section outlining the relevant features of the environmental setting is presented below.

2.2 LOCATION, GEOLOGY AND GEOMORPHOLOGY

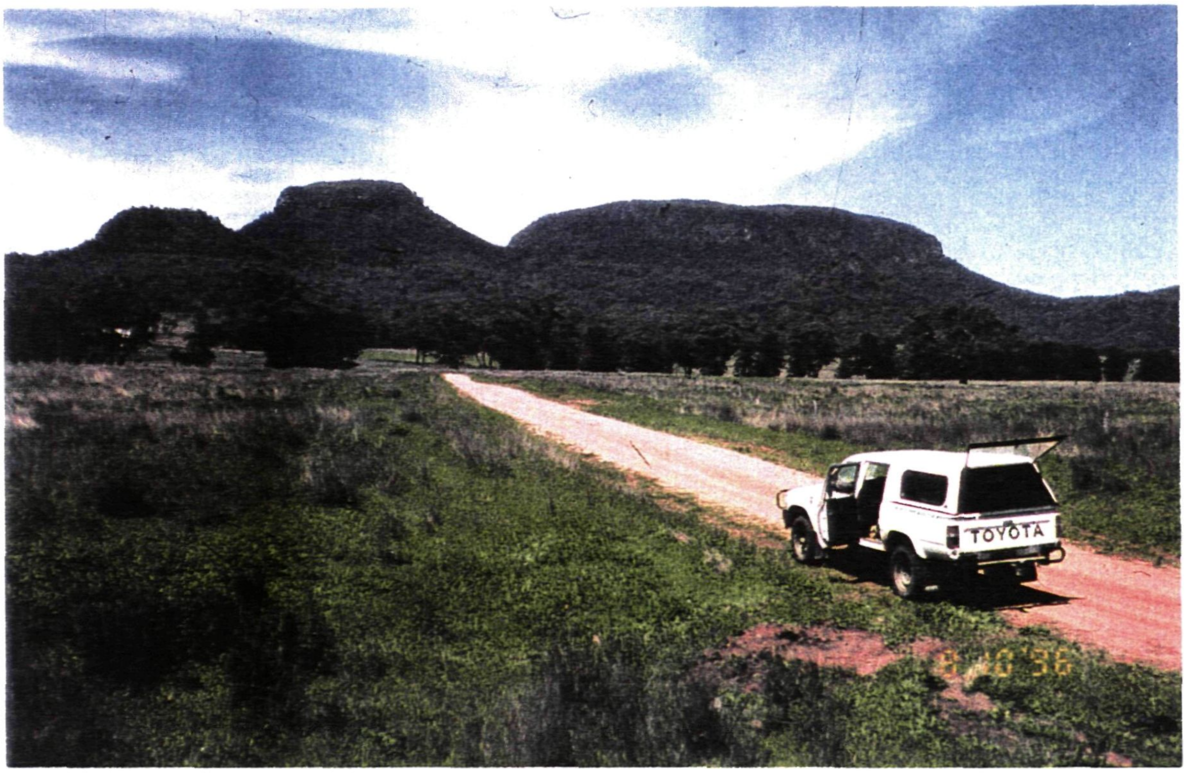
The study area lies within the Pilliga East State Forest, approximately 70 km north-north-west of Coonabarabran, (Fig. 1). The Pilliga State Forests are the largest area of dedicated native forest and relatively undisturbed soils in NSW, covering approximately 400 000 ha. They extend from the Warrumbungle Ranges in the south, west from the Nandewar Range and stretch up to the floodplain of the Namoi in the north.

Fig. 1. Map of Pilliga area



The Warrumbungle's consist of the remnants of a Jurassic sandstone plateau and Miocene volcanic structures. These volcanic structures are basaltic in composition containing alkali basalt, trachyte and pyroclastics, they form striking domes and spires in sharp contrast to the flat plain to the north (Fig. 2). Potassium/Argon dating shows volcanic activity occurred between 16.6-13.5 MyBP (Wellman and McDougall, 1974) and represents one of a chain of hot-spot volcanoes running along the eastern edge of Australia. These volcanoes show an inverse correlation of age and latitude that corresponds with the calculated northward progress of the Indo-Australian tectonic plate (Duggan and Knutson, 1993).

Fig. 2. Mount Uringery (peak on the right side of the photo), at the northern edge of the Warrumbungle's



The bedrock encompassing the study area consists of the Upper Jurassic Pilliga Sandstone, a quartzlithic sandstone of fluvial origin, with some relatively thin beds of conglomerate, minor siltstone and shale. The beds dip at 5-10 degrees to the north-west and form part of the intake beds and aquifers feeding the Surat Basin, a sub-section of the Great Artesian Basin (Arditto 1983). Outcrop, while common in the south, adjacent to the Warrumbungle's, becomes increasingly sporadic towards the north. Arditto (1982) also described the Pilliga Sandstone and investigated its source and depositional history. He suggests that the Middle-Upper Jurassic uplift in the source area (south-east of the study site) exposed Permian and Triassic sedimentary material, including parts of the Sydney Basin Hawkesbury Sandstone, to fluvial reworking. Deposition of this material was through a complex series of coalescing alluvial fans and formed the beds of the Pilliga Sandstone. A partial test of Arditto's conclusion regarding provenance was undertaken using the heavy mineral suite data of the Pilliga Sandstone and that of the Pilliga soils provided by Hallsworth and Waring (1964). The results show a strong correspondence with the Hawkesbury Sandstone (appendix 6). This suggests that Arditto's theory of a southeastern source involving the Hawkesbury Sandstone is valid.

Mitchell *et al.* (1982) mapped the contemporary sediments in the area using a land systems approach. They interpreted them as a sequence of fluvial deposits, including a series of coalescing alluvial fans derived from reworking of the Pilliga Sandstone. Taking a broader view, the sediments of the Pilliga represent the Quaternary stage of a successive sandstone consolidation and alluvial reworking system that is steadily prograding north-west and is the continuation of a sequence of events that reaches back at least 250 million years, i.e. Permo-Triassic to Jurassic to Cainozoic.

The contemporary sediments contain a complex suite of both clayey and sandy facies overlying the Pilliga Sandstone. These sediments thicken towards the north-west, reaching a depth of over 100m north of the study site (Mitchell *et al.* 1982). More detailed discussion of the character and spatial relationships of the sediments is undertaken in the following chapter. Slopes on the study site are generally very low, only 2-5 degrees and relief is minimal, commonly less than 5m.

The existing drainage network consists of sandy ephemeral streams flowing to the north and north-west. Flow is rare and requires heavy continuous rainfall. Local opinion suggests that 100 mm of rain is necessary to produce flow and this ceases soon after rainfall stops (Waring 1950). Stream channels in the area commonly show numerous sand and gravel bars, often with well-established vegetation, Fig.3.

Fig.3. Etoo Creek, looking upstream at Euligal crossing

2.3 SOILS

Hallsworth and Waring (1964) identified 10 soil classes in the Pilliga. However in the context of the present study, it is sufficient to outline only three broad morphological types; clay soils, sandy soils and texture contrast soils. Their classification is presented in Table 2 and an idealised section showing the relationship between the soil types is presented as Figure 5.

1. Clay soils; These are deep, harsh sandy clays varying in colour from grey - brown - black. The clays may contain secondary calcium carbonate concretions and some form gilgai micro-topography. The origin of the clay is as yet unresolved. It may be *in situ* altered clay from the Pilliga Sandstone or a separate, post Jurassic - possibly Quaternary - deposit (Fig 4c).

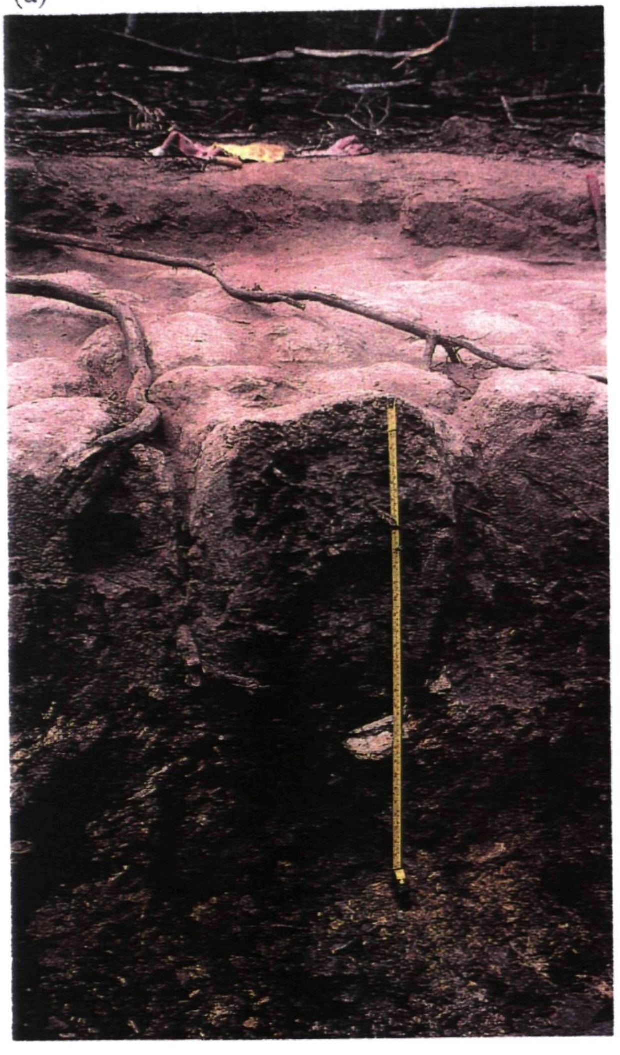
2. Sandy soils; Medium to coarse sand deposits -including the so-called "sand monkeys"- up to seven metres deep overlying a harsh clay basement. They contain varying amounts of water-worn gravel and display an earthy fabric (Fig, 4b).

3. Texture Contrast soils; The most abundant soil type in the area, these soils exhibit a sandy loam topsoil (15 to 50 cm thick) over a thin, usually bleached A_2 horizon overlying a harsh clay subsoil, often with columnar structure, (Fig. 4a).

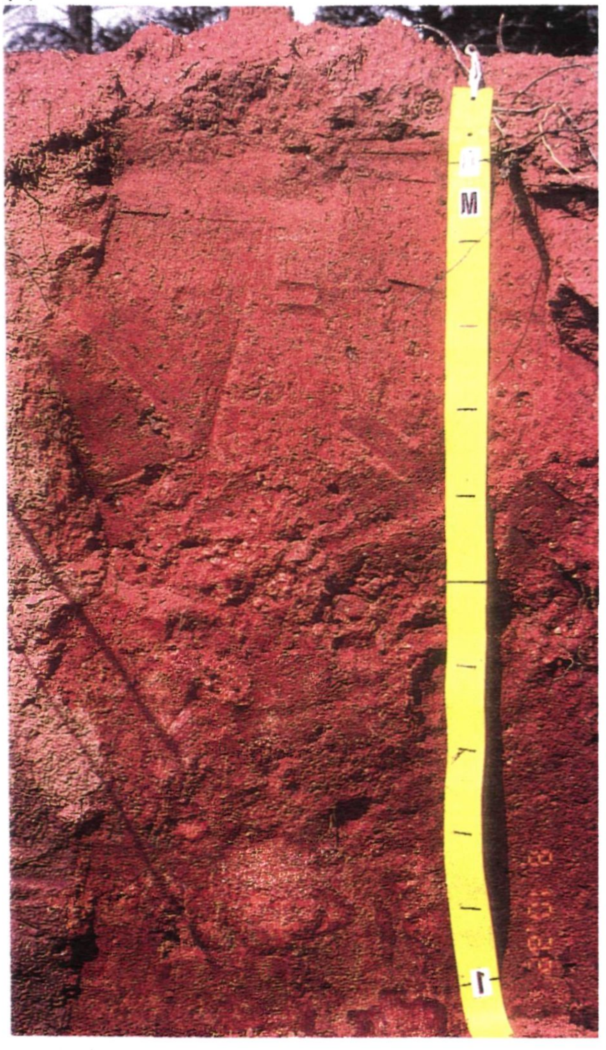
Hallsworth and Waring (1964), probably strongly influenced by Butler's (1950) Riverine Plain work, suggested that the former drainage system was largely

Fig. 4. The three principle soil types in the Pilliga. (a) Texture contrast soil showing well developed dome formation, (b) deep sandy soil, and (c) heavy clay with gilgai microrelief, note the standing water due to impeded drainage

(a)



(b)



(c)

responsible for the soil assemblage observed in the Pilliga: the sandy soils were identified as channel deposits with the texture contrast and clay soils representing floodplain deposits away from the channel. Evidence for this interpretation was provided by the decreasing modal grain size for the three soil types. They asserted that the texture contrast developed as fine overbank deposits of silt and clay was washed down through the sand to gather at the base of the profile. The implication, stratigraphically, is that the clay subsoil is approximately coeval or younger than the sandy topsoil and the sand monkey deposits.

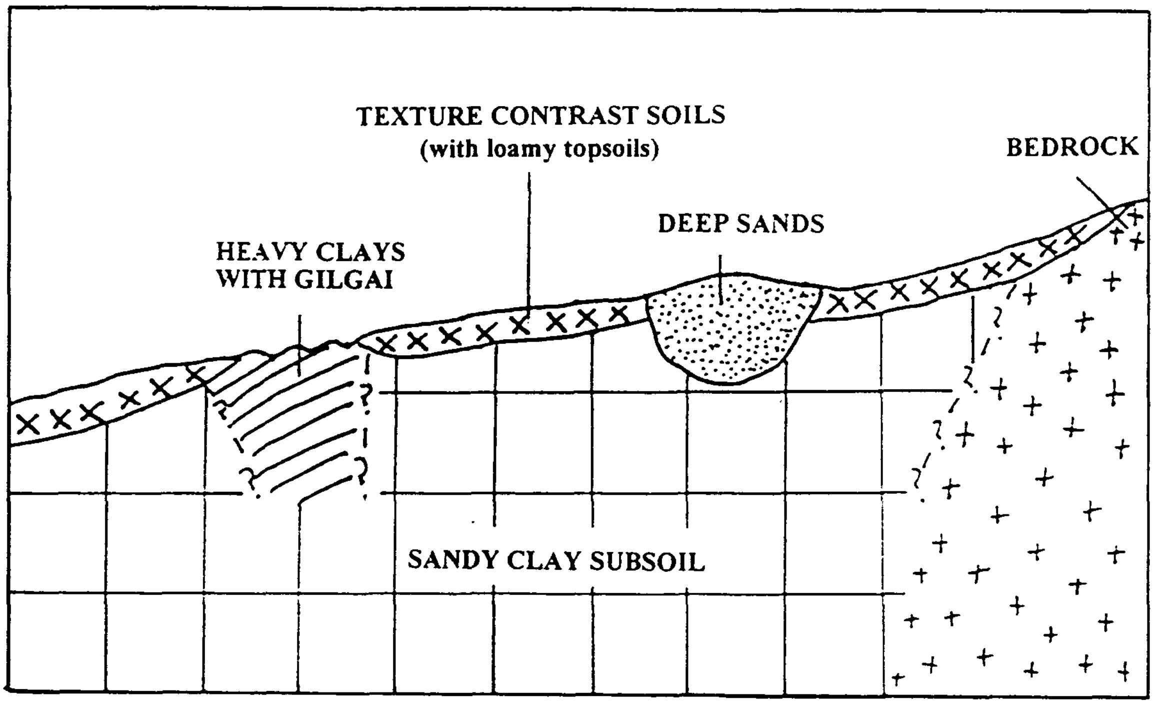
An alternative hypothesis is provided by the mobile topsoil theory applied by Hart *et al.* (1996b) and described more fully in Paton *et al.* (1995). Briefly, the sandy topsoil is a product of the combined action of bioturbation and rainwash. Bioturbation brings finer sediments to the surface, some of which is derived from subsoil and saprolite. At the surface the products of bioturbation, mounds, are reworked by rain splash and slope wash, processes which facilitate the movement of the sediment at the soil surface. Continual bioturbation and rainwash results in a mobile surface mantle that overlies the existing substrate. In the case of the texture contrast soils in the Pilliga, this existing substrate is the sandy clay subsoil. The stratigraphic implication of this hypothesis is that the sandy clay was deposited before the activity of the sand monkey streams and also predates and is independent of the sandy topsoil layer.

The sandy soils have previously been simply described as former channel deposits and very little reference has been made to any pedogenetic processes that may have altered their character since deposition. One obvious, though nevertheless presumed change is the development of an earthy fabric, caused by fine clay-sized particles coating and forming bridges between the dominant quartz grains. Such a fabric is unlikely to have developed via granular transport and deposition of typical fluvial systems. The issue of post depositional modification of the sand bodies will be considered later in the thesis.

Table 2. Simplified classification of Pilliga Soil Types

	CLAY SOILS	SANDY SOILS	TEXTURE-CONTRAST SOILS
NORTHCOTE (1979)	Ug5.1	Uc5.22, Uc1.22, Deep Duplex soils	Dy4.31, Dy4.41
STACE *ET AL.* (1968)	Grey, brown and red clays	Alluvial Soils, Earthy Sands	Solodised solonetz, Solodics
ISBELL (1996)	Vertosols	Rudosols, Tenosols	Sodosols, Kurosols

Fig. 5. Idealised sketch of soil relationships



2.4 VEGETATION

Colloquially called the "Pilliga Scrub", the vegetation is actually a sclerophyllous closed to open-forest with a heath understorey, using the terminology of Walker and Hopkins (1984). Several vegetation associations are present in the forests, but a detailed description is not relevant here. Simply, the tree layer is dominated by *Callitris* (Pine) species and various Eucalypts including; *Eucalyptus crebra* (Narrow-leafed Ironbark), *E. blakelyi* (Red Gum), *E. populifolia/pilligaensis (*Box) and *E. chloroclada* (Baradine Gum). *Casuarina christata* (Belah) occur in the gilgai areas, *Eucalyptus viridis* dominates the mallee patches and the broom plains support *Melaleuca uncinata* and *Calythrix tetragona*. Shrub species include *Dodonea viscosa, Xanthorrhoea glauca* (grass-trees), *Geigera parviflora* (wilga), *Chloris ssp.*, *Acacia ssp.* and grasses are represented by *Aristida ssp.* and *Eragrostis ssp* (Fig. 6). Lichen and moss mats are also common in different areas. Vegetation study is an important consideration and often a very useful tool in soil research in the Pilliga due to the strong association between soil type and vegetation communities.

2.5 CLIMATE AND LANDUSE

The climate in the Pilliga is characterised by hot summers, with minimums and maximums of 18-33°C in January and 2-16°C in the mild winters of July, during which regular frosts occur. Mean annual rainfall is approximately 600 mm (Baradine) but shows great variability, hence periods of drought punctuated by short wet spells are common. The dense forests and generally dry climate are conducive to bush-fires, the most recent major outbreak of which burnt parts of the broom plain along Dunwerian Rd. in 1966/7 and a wider area including the study site in 1951.

Fig. 6. Some vegetation types in the Pilliga State Forests. (a) Mallee comprising mostly *Eucalyptus viridis,* (b) typical sand monkey vegetation including *Xanthorrhea* sp. and *E.chloroclada* and (c) the broom plain dominated by *Melaleuca uncinata.*

(a)

(b)

(c)

The Pilliga region was first explored in the early to mid 1800s as graziers looked to open new agricultural and pastoral land. Despite the idealised view, espoused by Rolls (1981) which held that, before European influence the area was a mosaic of open woodland and grassy plains maintained by Aboriginal burning, evidence suggests that little impact was made by Europeans on vegetation communities in the heart of the forest (Norris *et al.* 1991). The land , described as having "wretched sandy soils" by Jensen (1907) has generally proved poorly suited to supporting anything but its native vegetation.

The Pilliga has been under Crown control since the late 1800s, with timber extraction beginning in the 1880s (Forestry Commission 1986). Since then exploitation of the forest resources has taken several forms: Ironbark and Pine removal for railway sleepers and fence-post respectively, grazing, beekeeping, charcoal production, gravel extraction, recreation and the harvesting of broom for urban fencing. In addition the Forestry Commission have built and maintained several access roads that dissect the forest.

Many species of fauna also inhabit the forests and contribute to the natural system in various ways, they comprise native species such as; echidnas, koalas, possums kangaroos, lizards, snakes, emus and other birds as well as numerous species of ants, termites and other insects. Introduced animals include; horses, goats, pigs, cats, foxes and rabbits.

In terms of the existing project the most important aspect of the fauna is their role in bioturbation. Hart (1995) measured the rates of topsoil turnover by termites in some parts of the forest and found that this activity has considerable implications for soil formation. Ants, invertebrates and other burrowing animals are also prolific and have significant effects on soil turnover. Although no studies have been conducted in the Pilliga, the Funnel ant (*Aphaenogaster* sp.) is particularly abundant in the sand monkeys. Eldridge and Pickard (1994) calculated annual rates of mounding by this species at 336 g/m^2 on aeolian soils near Cobar where annual rainfall is about 350 mm. This mounding rate is about 40% of the rate recorded by Humphreys (1981) in a humid setting. It may be reasonably be assumed that Pilliga rates fall somewhere in between. This obviously represents a considerable volume of material and has several implications which will be discussed later in the thesis.

2.6 SUMMARY

The Pilliga State Forest represents a large area that allows relatively easy access to land that has experienced minimal disturbance since European occupation. Active management and usage of the forest has been undertaken for over 100 years, but vegetative and soil associations remain largely in tact.

This allows the study of aspects, processes and conditions in the area to be carried out with some certainty of obtaining meaningful results, ie; those relatively unaffected by outside influences. In this respect, the Pilliga provides a study site with a known management history, relevant geologic/physiographic background information, and reports on previous related scientific work, to provide a sound basis for conducting the research project.

CHAPTER 3

DISTRIBUTION OF SAND BODIES

3.1 INTRODUCTION

Initial work in the study involved establishing broad spatial relationships between the sand bodies and other parts of the landscape, thus gathering information at the geographical scale mentioned in Chapter 2. Mapping the distribution of different units also allowed the individual units to be isolated so similarities and differences could be identified. With respect to the necessity of completion of the above tasks, the Pilliga study site offers several attractions.

- Previous work has shown the existence of various types of sand body and has established the position of one.
- The dense and well-maintained road network allows reasonable access and reference points.
- The original vegetation communities remain substantially in tact (Norris *et al.* 1991), which is important because of the close association between soil type and vegetation.
- Several "borrow pits" and quarries used for the extraction of road materials give good exposures that would otherwise be lacking in such flat terrain.

3.2 STRATEGY

3.2.1 Pre-Field Base Map

The aim of this exercise was to create a reference map to show the distribution of the different sand bodies and also to provide appropriate planform information. Thus it was necessary to devise a strategy that clearly defined the extent and boundaries of the different types of sand body. Initially it was expected that adequate spatial data could be attained and the sand bodies mapped from aerial photograph interpretation (API) of several air photo runs and satellite imagery (Table 3), particularly since previous field work had already established the position of one sand body. However, none of the techniques produced the required definition.

Table 3. Summary of the image types used to create the base map.

IMAGE TYPE	SCALE	COLOUR	DATE	HEIGHT	SOURCE
SATELLITE	1:100000	See text	1986	-	Landsat
PHOTO MOSAIC	~1:50000	black and white	1970	-	NSW Crown Lands
AIR PHOTO	~1:60000	black and white	1959	6705 m	NSW Crown lands
AIR PHOTO	~1:50000	black and white	1970	5944 m	NSW Crown Lands
AIR PHOTO	~1:50000	black and white	1980	4694 m	NSW Crown Lands
AIR PHOTO	~1:50000	colour	1994	8184 m	Dept. CALM

Satellite Imagery (30m pixels, Colour Bands: 5, 7 on Red - 1, 2, 3 on Green - 4 on Blue), considered to be most useful in separating vegetation communities, clearly delineated the current drainage tracts but failed to adequately resolve the other sand bodies. This may be explained in part by the variation in plant communities subsequently encountered on the sand bodies. It is possible that further manipulation of the colour bands would have yielded better results by utilising the different reflective indices of the ground cover (e.g. O'Neill 1996). However, this was not pursued as the current study did not set out to explore the potential of remote sensing/GIS in identifying different sedimentary bodies. With respect to further work, it is likely that continued refinement of this technique would provide a most fruitful method of mapping these bodies.

A black and white Photomosaic map proved very poor in delineating the sand bodies due to inconsistent tones between adjoining mosaic sections. Only those sand bodies that were very clear on the air photos were discernible at all on the photomosaic. Several sets of black and white air photos were analysed in stereo pairs. These marked clearly the boundaries between the broom and the forest vegetation communities, but not the limits of the sand bodies to the level required. Stereo analysis of recent colour air photos provided the clearest definition of the sand bodies and consequently formed the basis for mapping. However, even this did not provide the complete coverage required primarily due to the scale of the images in relation to the size of the features.

An integration of these images was used to construct a preliminary base map in which the individual sand bodies were located in relation to the following; other sand bodies, existing creeks, pastoral land (with native forest removed) and the forestry road network.

3.2.2 Ground Truthing

Early field work concentrated on confirming the veracity of the base map. Sampling, by means of auger holes (dug to at least 2m), pits and quarry faces, involved the use of simple field descriptions of; field texture, colour, pH and gravel size/concentration.

Potential sample sites were then selected from the base map and included sites adjacent to large channels, to test for source bordering dunes as well as sites along the length of known sand monkeys. Subsequently, during the course of ground survey additional sites were added. Overall, in excess of 40 separate sites were examined and sampled (Appendix 1). The field testing confirmed that all sites identified from API and satellite imagery were in fact sand bodies. Nevertheless, two principle problems emerged.

Initial field analysis discriminated four types of sand body; yellowish coloured sand monkey, red sand monkey, source bordering dune and creek sands, their basic field characteristics are outlined in Table 4. Aside from the major, current drainage lines (eg. Etoo and Talluba Creeks) it was impossible, on the basis of API, to discriminate between the different types of sand bodies.

Table 4. Field characteristics of the sand bodies

	TEXTURE	COLOUR*	pH	GRAVEL B-MAX.
RED SAND MONKEY (RSM)	Sandy Loam/ Loamy sand	2.5YR-5YR V/C 4, 5	6 - 6.5	60 mm
YELLOW SAND MONKEY (YSM)	Sandy Loam/ Loamy sand	7.5YR-10YR V/C 4, 5	6 - 6.5	30 mm
SOURCE BORDERING DUNE (SBD)	Sandy Loam	7.5YR-10YR V/C 4, 5	6	3 mm
CREEK SAND	Sand	7.5YR-10YR V/C 2	6 - 7	150 mm

* Munsell Colour Chart

The second problem involved those sand bodies, including some current sandy creek beds, that were not detected at all through API. This was particularly evident in the north of the study area where the sand monkeys become fragmented. The main reason for this is probably the scale of the sand bodies in relation to the scale of the air photos. North of Pickaxe Rd. the sand monkeys break up into small patches, commonly less than 50m across, representing less than 1 mm on the air photo (1:50000 scale) and approximately 0.3 mm on the base map. Where the sand bodies occurred as larger entities, for example near Dunwerian Rd., API established their position quite successfully.

A further reason for the incomplete success of API in delineating all the sand bodies was the fact that the vegetation communities associated with the sand monkeys are complex and variable and not as clear-cut as proposed by Waring (1950).

3.2.3 Road Traverses

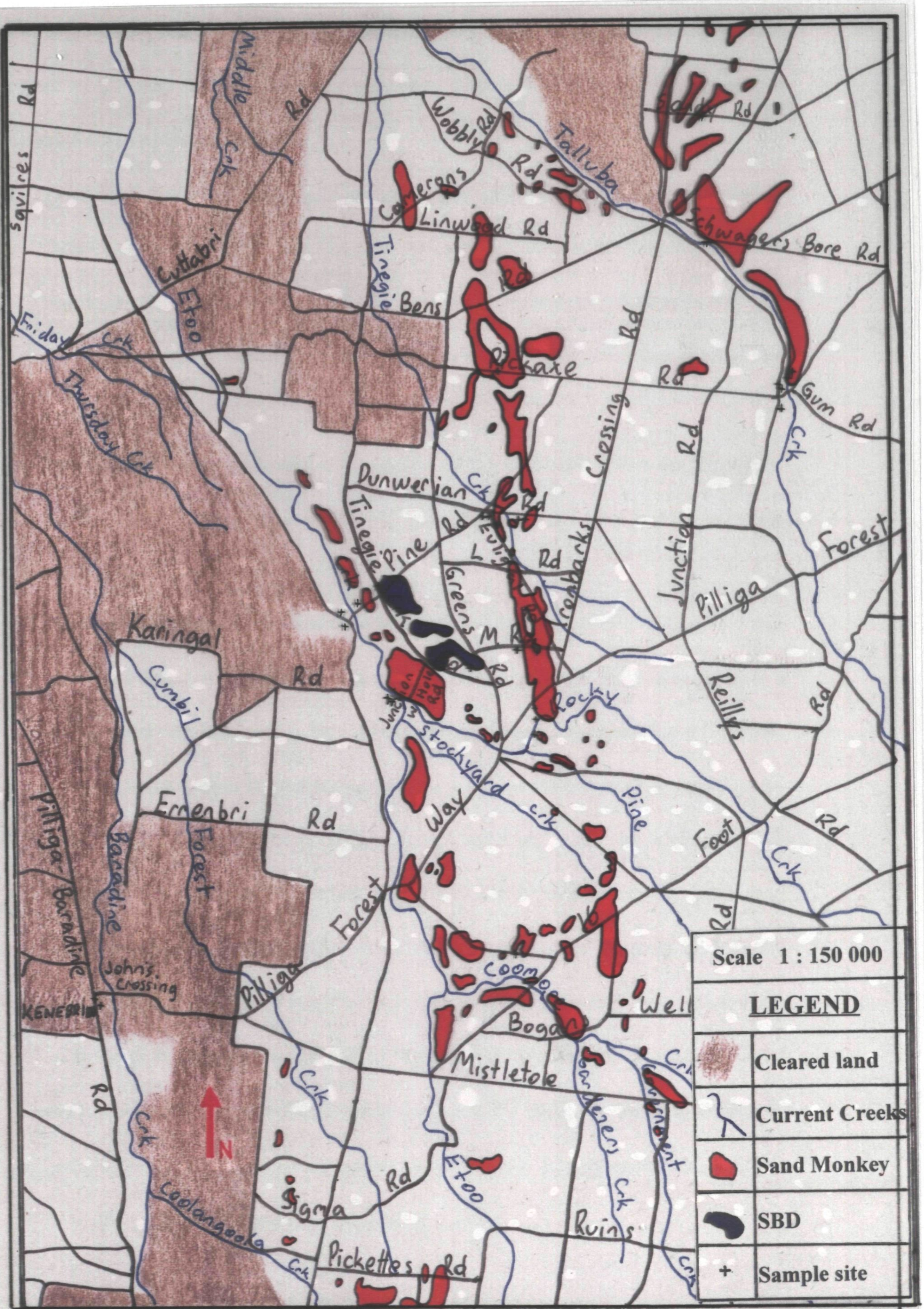
Due to the failure of remote methods in supplying a complete picture of the spatial relationships between the sand bodies a ground-based technique was devised. Initially identifying sand monkeys, even on the ground proved difficult, but became possible with experience and adjustment to the subtleties of the terrain. Several factors, in varying combinations, provide the basis for differentiating the sand bodies from the surrounding areas of texture contrast soil. These factors include, a slight and very gentle topographic rise of up to 1m though it is usually less than 0.5m, lack of vegetation along the centre of forest service roads (excluding major arterial roads), abundant *Aphaenogaster* sp. ant nests, generally more open forest, yellowish as opposed to pale pink, surface colour of sand grains, more heath-dominated shrub layer, the presence of *Xanthorrhoea ssp.* and the absence of grasses. It should be noted however, that these indicators may occur or not occur in any combination over a particular sand body.

The position of each sand body was then located in relation to the dense forestry road network using the trip-meter on a vehicle and cross-checked at road junctions. The density of the road network meant that a GPS unit was not required. This procedure enabled the production of a detailed map showing the different types of sand body in relation to drainage lines and the road network. It was hoped that this field based information could be used to fine tune an API but this was not the case.

3.2.4 Final Map

The final map is a product of the combination of information gathered through API, ground-truthing and the road traverse technique. Due to the difficulties outlined above, the result is probably not perfect and some of the large scale spatial relationships are not completely resolved, since to do so meant mapping a much larger area than was feasible. To overcome this problem the focus of the study was rationalised to more fully describe and account and for the features of the various sand bodies over the smaller area of the Etoo, Tinegie and Talluba catchments, excluding Baradine Creek (Fig. 7). The final map also shows the location and type of sample sites, soil profile sites, cross-sections and dates. The results of these other data are discussed later in the thesis.

Fig. 7. Map of the the study site



3.3 DISTRIBUTION OF THE SAND BODIES

Notwithstanding the abovementioned problems associated with mapping the precise extent of the sand bodies, it is pertinent to make some comment on the patterns of distribution as presented in Figure 7.

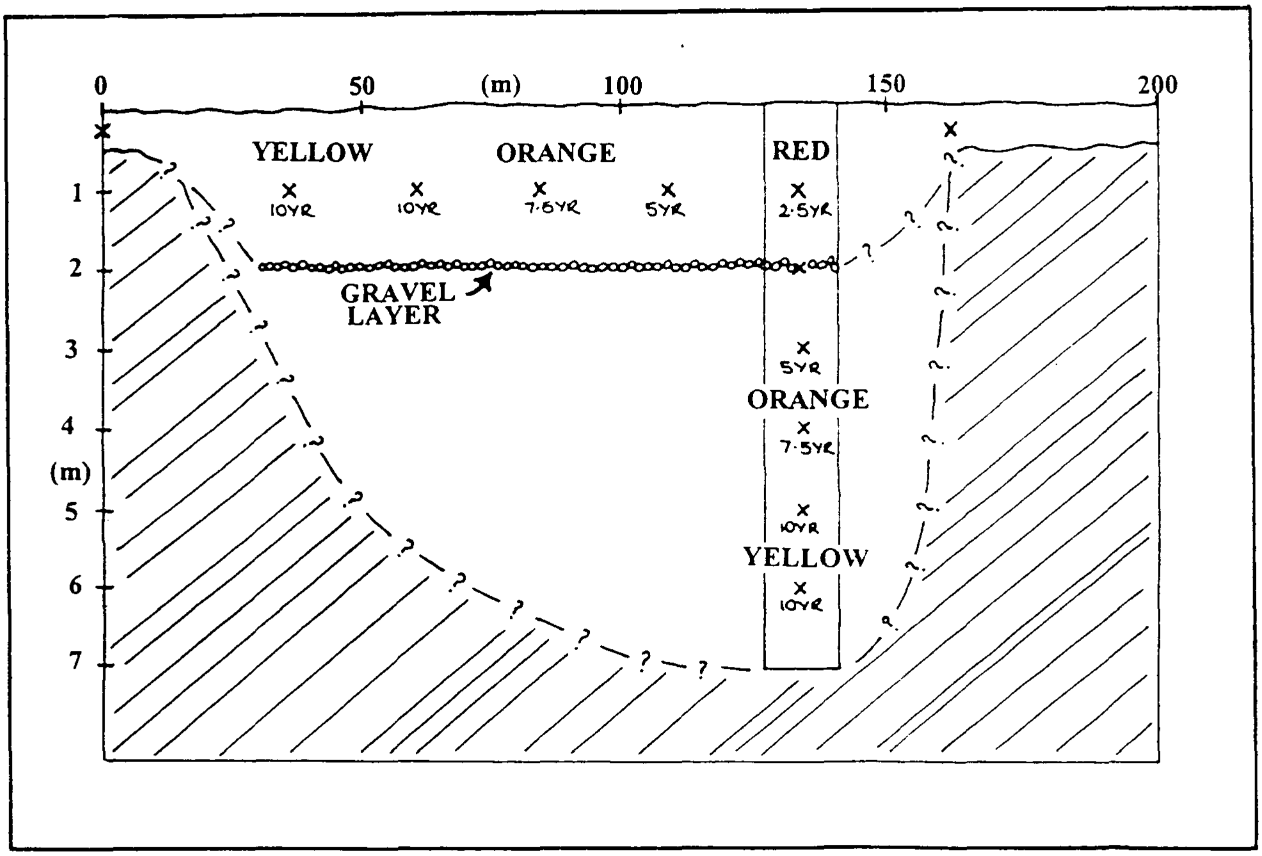
1. Three sand monkey complexes were recognised in the study area; one paralleling Etoo Creek in the west, another paralleling Talluba Creek in the east and the third positioned between these two. All three contain both red and yellow material. As the central system is larger and better defined it is sometimes referred to as the main sand monkey

2. The source bordering dunes (SBD) appear in three distinct lobes on the north-eastern side the largest creek in the study area (Etoo Creek). The prevailing winds in the area are from the south-west.

3. The main sand monkey, intersects M Rd., L Rd., Dunwerian Rd., Pickaxe Rd. and Camerons Rd. but becomes increasingly more fragmented and spreads over a wider region further north. The system paralleling the eastern side of Talluba Creek shows a similar fragmentation in the north. Here the system is described by a series of small (frequently <50m across) patches, many of which are not detectable through API. This raises the question of whether these small sand bodies represent the channels of a distributary stream system opposite in character to the current contributory system. A second possibility is that they are crevasse splay deposits, although no preserved levees have been found. Further potential explanations for this distribution pattern includes a drainage breakdown due to geomorphic factors, that are no longer active or post depositional processes that have obscured the true nature of the former stream.

4. As presented in Figure 8, it appears that the yellow and the red sand monkeys hold a close relationship. Laterally, the surface of the red sand monkey grades from red sand through orange to yellow at its edges. Vertically there is a similar trend as red sands overlie yellow. Waring (1950) noted the same lateral variation in one of his diagrams, but made no reference to it in the text. An explanation for the different colours is not clear but possibilities include; varying drainage situations affecting oxidation of iron minerals, separate depositional layers or authigenic, post-depositional processes.
5. The main sand monkey, referred to in point 1, appears to cross the catchment divides of Etoo, Tinegie and possibly Talluba Creeks. This indicates that the system operating at the time of deposition did so outside the confines of the current catchment boundaries. However, the significance of this should not be overstated due to the minimal relief in the area.

Fig 8. Pine Rd. RSM colour profile



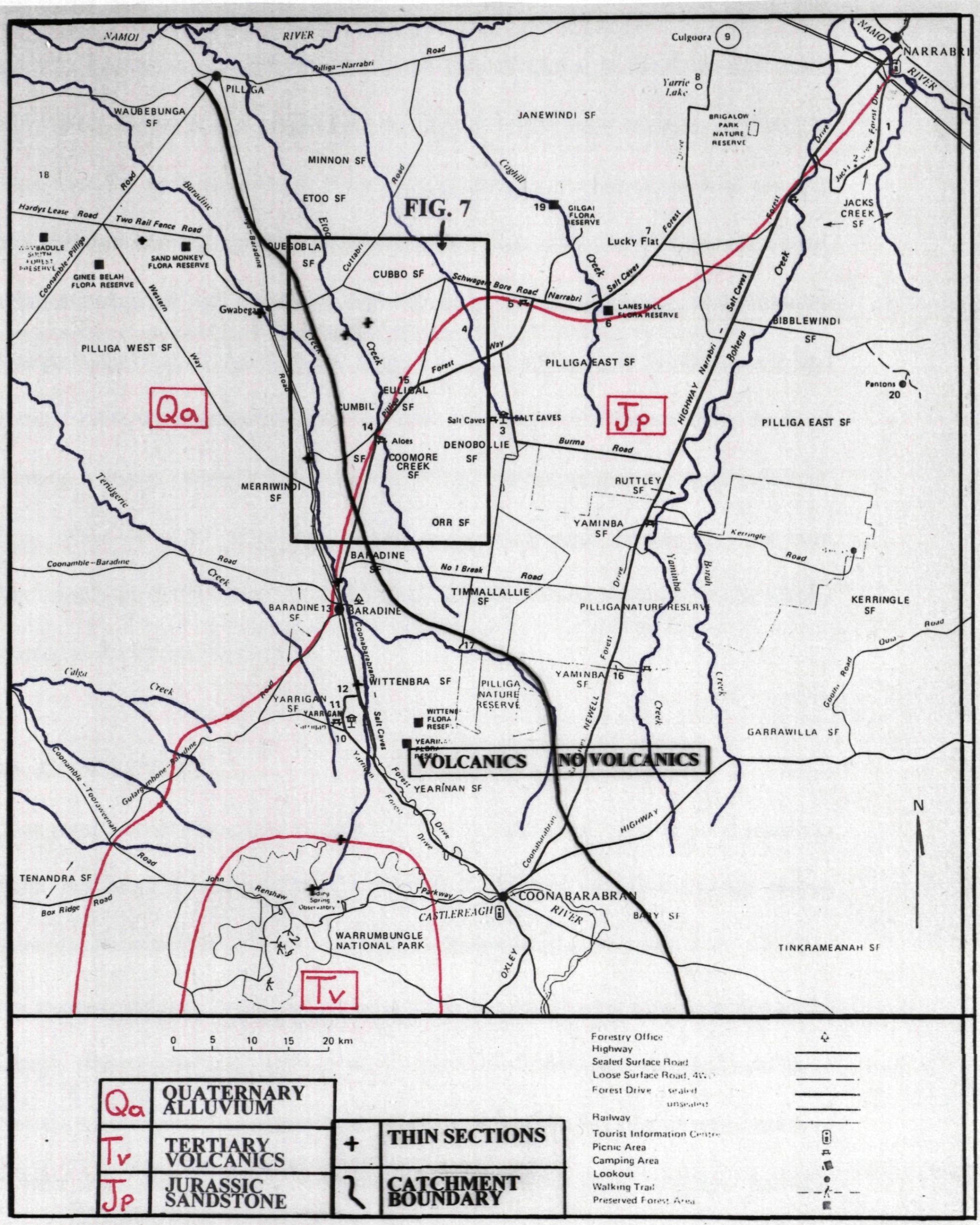
3.4 PROVENANCE

Initial observation of the main sand monkey trace on the air photos suggests that it may represent the trunk stream of a much wider, higher energy, less sinuous system than the creeks of the current drainage network, possibly comparable to the prior streams on the Riverine Plain (Butler 1950; Pels 1964; Schumm 1968; Page 1994). For reasons discussed in the following chapter, there is at present insufficient information available to recreate the palaeoenvironmental conditions at the time of deposition. However, the fact that the stream that deposited the main sand monkey appears to have operated outside the boundaries of the current catchments provides evidence for the above hypothesis.

Given the north-south orientation of the main sand monkey (as opposed to the northwest-southeast of the current streams) (Fig. 7), it is reasonable to assume that, if the above is true, some of its sediment load would be sourced from the volcanics in the south. Thus a simple test was devised to check the provenance of the sand monkey and test the above theory.

Samples from the main sand monkey and along the Baradine Creek system (located on Fig. 9) were impregnated with araldite and thin section were prepared. These were analysed under a polarising petrological microscope. Plagioclase feldspar was traced, as a marker of volcanic sediments, along Baradine Creek. This mineral was chosen for its ease of identification, abundance in the basaltic Warrumbungle suite and scarcity in the texturally mature sediments of the Pilliga Sandstone. Results showed that the marker mineral survived in the fluvial system of Baradine Creek at least as far

Fig. 9. Map showing Baradine Creek / Etoo Creek catchment divide, approximate geological boundaries and thin section sample sites



north as Gwagebar, which is roughly latitudinally equal with Dunwerian Rd., and it was found in a sand monkey adjacent to the Sand Monkey Flora Reserve (see appendix 1 for location) within the Baradine Creek catchment, to the north-west of the study site. However, no plagioclase was found in the sand monkey adjacent to Dunwerian Rd. or in Etoo Creek at Euligal Crossing. Analysis of the sand monkey thin sections showed up only minerals associated with the Pilliga Sandstone, sedimentary quartz and weathered acid volcanics, and no remnants of the basaltic Warrumbungle suite. The results of mineral analysis (Waring 1950; Hallsworth and Waring 1964; Humphreys unpublished data, Appendix 6) support these findings showing a strong correlation between the Pilliga Sandstone and the sand monkeys. Thus, while the exact geomorphic nature of the main sand monkey has not been determined, the fluvial system responsible for its deposition can be said to be wholly sourced in the Pilliga Sandstone.

3.5 CONCLUSION

Upon resolution of the spatial distribution of the sand bodies, there is good reason to retain the original assumption that the sand monkeys represent former stream channels. Relationships of the sand monkey systems to current drainage are complex; two systems maintain a close association along the eastern side of Etoo and Talluba Creeks, whereas the main sand monkey crosses the catchment boundaries of three creeks. Furthermore the apparently distributary nature of the former system north of Pickaxe Rd., also contrasts with the habit of the existing drainage network. Conversely the observed pattern of fragmentation may represent a breakdown in drainage at this point. With respect to the size of the former versus the current channels, a tentative initial hypothesis suggested that the former system was much larger. However, due to the lack of information placing the sand monkey in a larger (catchment-wide) perspective as well as the shortage of reliable channel cross-sectional and longitudinal data, it was decided that the inherent assumptions necessary in making such propositions are not sustainable. The SBD is located adjacent to and down-wind of the largest watercourse in the immediate area, this position is precisely as may be expected. However, it is unclear how the SBD relates stratigraphically to the sand monkey between it and Etoo Creek, these issues will be addressed later in the thesis.