# CHAPTER 7

# CONCLUSIONS

## 7.1 INTRODUCTION

The thesis began with a clear statement of the aims of the study and it is pertinent to comment on the degree to which they have been fulfilled as well as summarise the most important findings. With a view to further work, there is also the necessity of assessing the degree to which the structure of the study has enabled accomplishment of the aims and effective treatment of any subsidiary issues raised. Briefly, those aims were:

1. To differentiate between four sand body types, RSM, YSM, SBD and contemporary creek deposits.
2. To resolve the spatial and stratigraphic relationships between the various sedimentary bodies of the Pilliga, in order to gain some understanding of the depositional history of the area.
3. To determine the nature and degree of post depositional modification that the sand bodies have undergone.

## 7.2 DISTINCTION BETWEEN THE SAND BODIES

Four sand body types were initially identified during the course of reconnaissance work, discrimination being on the basis of a few simple field characteristics. Particle size analysis and statistical measures were then used to clarify the significance of the observed differences leading to the identification of three sedimentologically distinct types:

a. Sand monkeys

b. Source Bordering Dunes

c. Current creek deposits

The original differentiation between the YSM and RSM was made on the basis of colour, but sedimentological evidence along with resolution of the spatial relationship of the two bodies suggest that they are not separate depositional bodies. The SBD show better sorting, a marked absence of gravel and higher mud content than the other sand bodies. The current creek sediments exhibit a significantly lower mud content and a single grain fabric as opposed to the earthy fabric of the other sand bodies. Determination of this information, primarily through particle size analysis, provided the baseline data from which formulation of various hypotheses concerning the origin and history of the sand bodies could begin.

In chapter 3, the distinction was made between the main sand monkey that traverses north-south down the centre of the study site (Fig, 9) and the two other traces that parallel Etoo and Talluba creeks. During the later part of the study it has become evident that further work in pursuit of this distinction is desirable and may aid in clarification of the depositional history of the area. The two sand monkey systems associated with the contemporary creeks appear to be confined to established (if shallow) valleys and may be the result of channel abandonment. The main sand monkey is topographically higher than the others, is unrelated to the current drainage and may be older, suggesting that it could be part of a separate system, temporally and geomorphically. Clearly further investigation is required.

## 7.3 DEPOSITIONAL HISTORY

In order to establish a viable depositional history, three key issues required attention; the provenance of the material, its mode of deposition and the stratigraphic relationships of the sand bodies with respect to one another and to the finer grained sediments.

The initial hypothesis set out that the sand monkeys are fluvially derived bodies, probably channel deposits somewhat analogous to the prior streams of the Riverine Plain. Further investigation supports this theory, although several factors preclude direct comparison with the Riverine Plain (Table 1). Identification of the SBD also appears to be legitimate, supported by sedimentological and geomorphic evidence which conforms with that of previously identified examples.

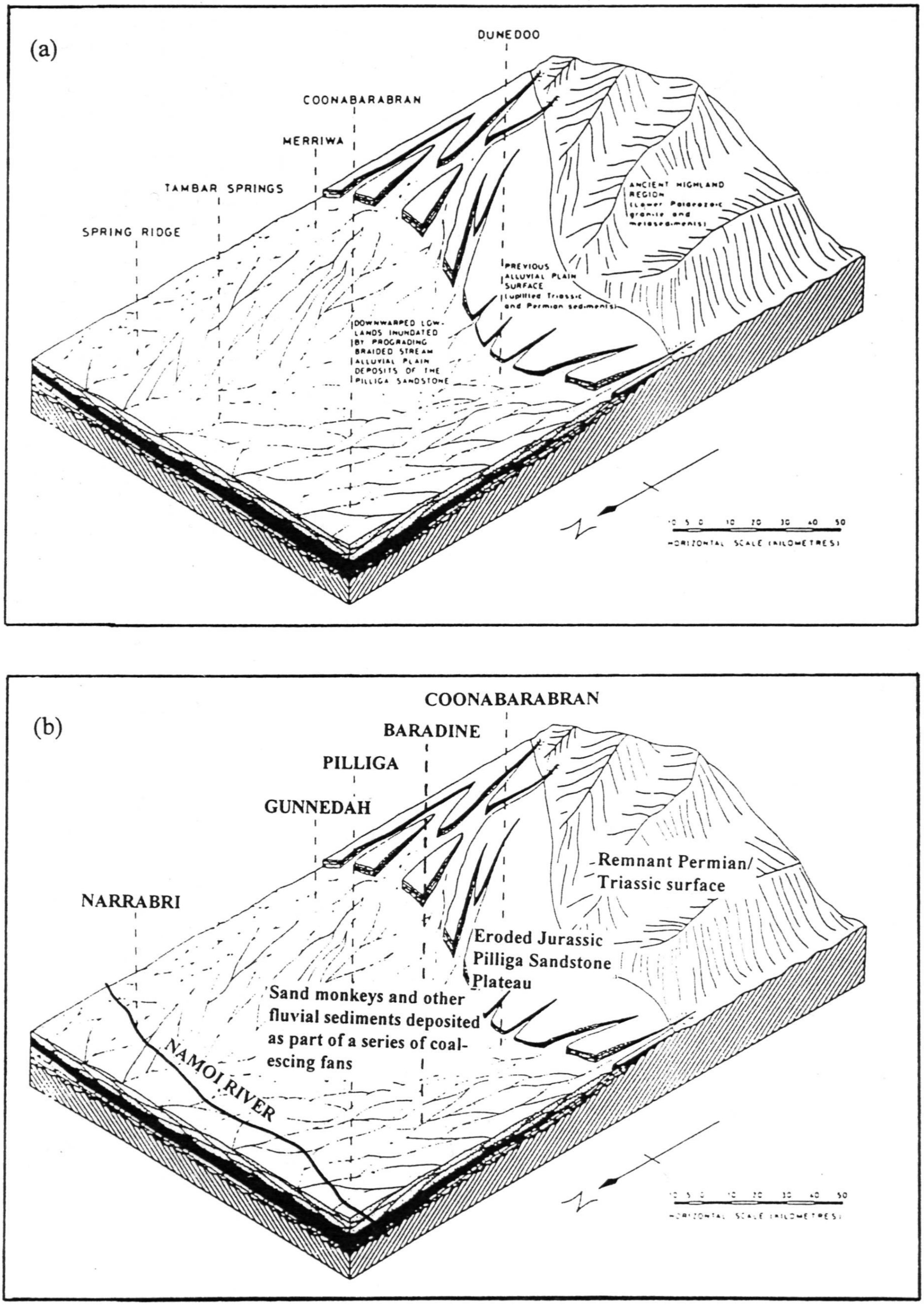
Heavy mineral analysis conducted by Hallsworth and Waring (1964) and Humphreys (unpublished data, Appendix 6) and thin section analysis shows that the sand monkey material and sediment from the existing creeks is similar to the Pilliga Sandstone. They contain mostly mature sedimentary quartz and weathered granitic material and no traces of alkali basalt derived minerals from the Warrumbungle's to the south.

Stratigraphic survey and dating results show that the sand bodies are significantly younger than the sandy clay subsoil that overlies the bedrock in most of the study area. At the time of initial deposition at least 61.5 kaBP, the stream incised its course through the existing alluvium. Net aggradation occurred up until no later than 40 kaBP, at which point the elevated position of the bed initiated channel abandonment and the position of the channel switched to an area lower in the landscape. Since abandonment however, the sand monkeys have continued to act as a conduit for sub-terranean water flow.

An alternative hypothesis is that the sand monkeys are the remnants of a much larger, subsequently eroded body. This theory bears a remarkable resemblance to Arditto's reconstruction of the deposition of the Pilliga Sandstone, which was deposited as a series of braided, sand-load streams (Fig. 21). A further consequence of the adoption of this hypothesis is the separation of the two sand monkey systems into two different regimes. Those paralleling Etoo and Talluba creek's appear to be deposited during the course of lateral migration of a meandering channel as opposed to the large braided sand sheet that has subsequently been eroded.

The sand bodies have also undergone a secondary phase of deposition in the form of an aeolian dust accession, probably sourced from the Lake Eyre Basin. Evidence for this comes from the presence of a significant mud proportion in the SBD and to a lesser extent, the sand monkeys as opposed to the current creek deposits. The latter difference is significant because evidence suggests that the sand monkeys were comparable to, or possibly higher energy streams than the contemporary creeks.

**Fig. 21.** Fig. 10 from Arditto (1982, p.201), showing a reconstruction of the deposition of the Pilliga Sandstone, above (b) the same figure transported approximately 80 km to the northwest and forward in time.



Aeolian accession is likely to have occurred during the time of the last glacial maximum in Oxygen Isotope Stage 2. Sprigg (1982) argues that these colder and drier conditions correspond to increased windiness and the entrainment of dust from the Lake Eyre Basin that was deposited over a wide area of Queensland, Victoria and NSW. McTainsh (1985, p.106) further contends that this input was of such a scale as "to have important implications for the way we view the Quaternary in Australia".

## 7.3 POST DEPOSITIONAL MODIFICATION

Within this section, the study set out to explore the fundamental differences in sediment character between the sand monkeys and the current creeks and explain any features not consistent with their original fluvial (sand monkeys) or aeolian (SBD) deposition.

The issue of increased mud content from aeolian input is addressed above, but a related factor also required consideration, the fact that the SBD has approximately double the mean mud content of the sand monkeys. It is contended that this is due to lateral transport of fines out of the sand monkeys through ground water flow along the base of the former channel. This hypothesis is sustained by a generally lower mud content in the basal samples taken from the sand monkeys.

The sediments of the sand monkeys and the SBD exhibit an earthy fabric, with fine clay and silt-sized particles forming coatings and bridges between the dominant quartz grains. It is unclear whether this fabric will form simply from mechanical inwashing of the clay from the surface or also requires a process of mixing and overturn.

Analysis of the material in thin section shows that the coatings and bridges are not preferentially thicker towards the top of the quartz grains, suggesting that the material has been mixed.

Comparison of samples taken from the near surface to those at depth displayed a significantly higher average gravel content in the lower samples (Fig. 12). This condition was found across all the sand monkeys sampled, regardless of topographic position and indicates the operation of a process causing homogenisation of the surface layer.

The primary process of bioturbation involves the removal of sand-sized material from below the surface and its redistribution above ground. This provides an efficient mechanism whereby the upper sediments are overturned, mixed and homogenised, due to the limited size range of material that ants and termites can transport. The rate of overturn has not been calculated for the sand bodies but is considered to be significant. Meso-scaled fabric analysis shows that the rate of biological activity decreases with depth below the surface, but occurs to at least two metres. This process supplies a solution to the question of the differences in gravel content with depth, and it may be responsible for the distribution of the clay and oxide coatings around the quartz grains (earthy fabric). It also provides an explanation for the lack of sedimentary structures and allows a realistic interpretation of the dates gained from the main sand monkey.

On a larger scale, the ubiquitous nature of the above processes and their enormous potential in terms of large scale modification of near surface sediments, begs serious questions as to the genetic interpretation of soils and even landscapes over very large areas. With respect to Australian landscapes, long term tectonic inactivity demands that due consideration be given to the efficacy of bioturbation as a process of pedogenesis and sedimentary modification. Probably the most serious ramification however, arises from the interpretation of dates taken from bioturbated sediments. Clearly, the operative processes of bioturbation at a particular site must be recognised and factored into any interpretation of dates attained. Consideration of this is critical in assessment of the Quaternary implications of a particular study.

## 7.4. COMPARISON WITH THE RIVERINE PLAIN

The nature of this study demands that comparison is made between it and the work done on the Riverine Plain. General consensus from research on the Riverine Plain is that the current distribution of unconsolidated sediments is the result of a former fluvial system, unlike the one operating today. More recent work has defined the character of this past system and placed it within a temporal context. The sand bodies of the Pilliga are also remnants of a former fluvial system that may well have been of a substantially different character to the contemporary drainage system. Through interpretation of the dates attained during and previous to this study the Pilliga case study can be placed in the same Quaternary framework.

While the precise geomorphic nature of the sand monkey streams is not known, there is evidence to support the view that they were larger and represented a higher energy system than the contemporary drainage tracts. This factor corresponds with the situation on the Riverine Plain, as does their calculated age, placing their activity within the subpluvial; Oxygen Isotope Stage 3. This date identifies the sand monkeys as contemporaries of the Hay Prior Streams of the Kerarbury system (Page 1994).

In the opening chapter of the thesis, the differences between the sand bodies in the two areas were highlighted, continued research however, has shown that the observed differences in the Pilliga may be largely explained by post depositional modification. Further, it is likely that ongoing research in the Pilliga will emphasise the similarities between the sand monkeys and the prior streams and reaffirm the validity of the Quaternary framework developed through work on the Riverine Plain.

## 7.5 FURTHER WORK

There remains a significant body of work necessary to be completed to unravel the complexities of the sand bodies in the Pilliga, some worthwhile avenues of research are as follows: On the large scale, mapping the distribution of the sand bodies over the whole Pilliga area, from the Castlereagh in the south to the Namoi in the north is a project that deserves attention. This information would provide a better understanding of the palaeohydrological conditions over a much larger area, placing the current study into a well-defined perspective. As mentioned in Chapter 3, the refinement of satellite imaging techniques may well prove helpful in this regard as an adjunct to air photo analysis and ground survey.

Three-dimensional mapping of the sand bodies; their geometric shape, the nature of the contacts with the surrounding sediments and the geomorphic character of the channels is generally poorly understood. This type of information is vital if detailed palaeoenvironmental reconstruction is to be accomplished. With these data, the study area can then be compared more closely with other related studies. In terms of gaining this information, geophysical survey methods such as ground penetrating radar are an area that is being increasingly used in the mapping of unconsolidated sediments and could prove instructive in this type of project.

On the small scale, there is potential for further inquiry into the nature of bioturbation processes and effects. Such issues as; overturn rates, effect on surface wash processes, variation with depth, interaction with ground water and effect on soil fabric all remain largely unresolved. The question of the colour of the various sand bodies also requires investigation, particularly in terms of the distribution of the different coloured bodies and the processes by which they came to be thus expressed.

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## APPENDIX 1

## SAMPLE LOCATIONS AND CODES

**Sand Monkey samples:**

| | |
|---|---|
| Condrens Mistake Rd., Quarry. | CQ1A: 0.25-0.5m<br>CQ1B: 1.5-2.0m |
| Camerons Rd., 2.5 km NE of Linwood Rd. junction. | CR1A: 0.25-0.5m<br>CR1B: 1.5-2.0m |
| Dunwerian Rd., 1.4 km west of Iron barks Crossing Rd. | S943: 0.5m<br>S944: 1.0m<br>S945: 1.5m<br>S946: 2.0m<br>S947: 2.5m<br>DR1A: 2.5-3.0m<br>DR1B: 3.0-3.5m<br>DR1C: 3.5-3.7m<br>DR1D: 3.7-4.0m |
| Dunwerian Rd., 200 m west of above site. | DR2A: 2.0-2.5m |
| Dunwerian Rd., 400 m east of Pine Rd. junction. | DR3A: 0.5m<br>DR3B: 1.0m<br>DR3C: 1.5m<br>DR3D: 2.0m<br>DR3E: 2.1-2.3m<br>DR3F: 2.4m |
| Junction Waterhole Rd., 50 m Nth. of Etoo Ck. | EC3A: 0.25-0.5m |
| M Rd., 600 m west of Euligal Rd. junction. | MR1A: 0.25-0.5m<br>MR1B: 1.5-2.0m |
| M Rd., 200 m west of Euligal Rd. junction. | MR2A: 1.5-2.0m |
| Pickaxe Rd., quarry 1.8 km east of Greens Rd. junction. | PQ1A: 0.25-0.5m<br>PQ1B: 1.5-2.0m |
| Pickaxe Rd., 30 m Nth of above site. | PQ2A: 0.25-0.5m<br>PQ2B: 1.5-2.0m |
| Pine Rd., RSM 450 m east of Etoo Ck. | PR3A: 0-0.3m<br>PR3B: 0.5-1.0m |

| | |
|---|---|
| | PR3C: 1.0-1.5m<br>PR3D: 1.67-1.96m<br>PR3E: 2.5-3.3m<br>PR3F: 3.3-3.7m<br>PR3G: 3.7-3.85m<br>PR3H: 3.9-4.0m<br>PR3I: 4.1-4.35m<br>PR3J: 4.5-4.9m<br>PR3K: 4.9-5.0m<br>PR3L: 5.0-5.4m<br>PR3M: 5.5-6.0m<br>PR3N: 6.0-6.3m<br>PR3O: 6.5-7.0m |
| Pickaxe Rd., burrow pit opposite Gum Rd. junction. | PXR1A: 0.25-1.5m<br>PXR1B: 1.5-2.0m |
| Pickaxe Rd., adjacent to above site. | PXP1A: 0.5m<br>PXP1B: 1.0m<br>PXP1C: 1.5m<br>PXP1D: 2.0m<br>PXP1E: 2.5m<br>PXP1F: 2.7m |
| Pickaxe Rd., 100 m NE of Gum Rd. junction. | PXR2A: 0.25-0.5m<br>PXR2B: 1.5-2.0m |
| Pickaxe Rd., adjacent to above site. | PXR3A: 0.5m<br>PXR3B: 1.0m<br>PXR3C: 1.5m<br>PXR3D: 2.0m<br>PXR3E: 2.5m |
| Rocky Creek/Pine Creek, 50 m Nth. of Rocky Ck. | RC1A: 0.25-0.5m |
| 50 m Sth. of Rocky Ck. | RC2A: 0.25-0.5m |
| 100 m Sth. of Rocky Ck. | RC3A: 0.25-0.5m |
| 10 m Wst. of RC3A. | RC4A: 0.25-0.5m |
| 50 m Sth. of Pine Ck. | RC5A: 0.25-0.5m |
| Schwagers Bore Rd., 2.2 km east of Bens Rd. | SBR1A: 0.5-1.0m<br>SBR1B: 1.0-1.5m<br>SBR1C: 1.5-2.0m<br>SBR1D: 2.0-2.3m<br>SBR1E: 2.3-2.5m<br>SBR1F: 2.5-2.8m<br>SBR1G: 2.9-2.95m. |
| Sixteen Foot Rd., quarry Nth of Coomore Ck. | SFR1A: 0.25-0.5m |

| | |
|---|---|
| Sandy Rd., 1.7 km west of Bens Rd. | SR1A: 0.25-0.5m<br>SR1B: 1.5-2.0m |
| Two Rail Fence Rd., 1.8 km east of C-Line Rd. | TRF1A: 0.25-0.5m<br>TRF1B: 1.5-2.0m |

**Source Bordering Dune samples:**

| | |
|---|---|
| Greens Rd., 0.8 km Nth. of Tinegie Ck. Rd. junction. | GR1A: 0.5m<br>GR1B; 1.0m<br>GR1C: 1.5m<br>GR1D: 1.6-1.7m |
| Pine Rd., SBD 700 m east of Tinegie Ck. Rd. | PR2A: 0-0.25m<br>PR2B: 0.25-0.5m<br>PR2C: 0.5-0.75m<br>PR2D: 0.75-1.0m<br>PR2E: 1.0-1.25m<br>PR2F: 1.25-1.5m<br>PR2G: 1.5-2.0m<br>PR2H: 2.65-2.75m |

**Creek samples:**

| | |
|---|---|
| Yearinan/Baradine Creeks, Nth. of Morrisseys Rd. | BC1A: Surface |
| upstream of Odells Crossing. | BC2A: Surface |
| upstream of John's Crossing. | BC3A: Surface |
| terrace, at John's Crossing (not Ck sand). | BC4A: 0.5-1.0m |
| | BC4B: 1.5-2.0m |
| upstream of Forest Way, nr. Kenebri. | BC5A: Surface |
| upstream of road, west of Gwagebar. | BC6A: Surface |
| Etoo Creek, Junction Waterhole, bank material. | EC1A: Surface |
| mid-channel. | EC2A: Surface |
| | EC3B: 1.5-2.0m |
| upstream of Euligal Crossing, mid-channel. | EC4A: Surface |

| | |
|---|---|
| McCullaghs/Bugaldie Creeks, NE of Mt. Uringery. | MC1A: Surface |
| upstream of road NE of Square-Top. Mt. | MC2A: Surface |
| upstream of Butlers lane. | MC3A: Surface |
| Sidings Spring Mountain, upper catchment. | SS1A: Surface |
| Talluba Creek, upstream of Pickaxe Rd. | TAL1A: Surface |
| Tinegie Creek, upstream of Dunwerian Rd. | TIN1A: Surface |

**Not sand monkey samples:**

| | |
|---|---|
| Dunwerian Rd., 350 m east of Pine Rd. junction. | DR4A: 0.25-0.5m<br>DR4B: 1.0m<br>DR4C: 1.5m<br>DR4D: 1.9m |
| Pine Rd., terrace adjacent to right bank of Etoo Ck. (not SM). | EC5A: 0.25m<br>EC5B: 0.5m<br>EC5C: 0.75m<br>EC5D: 0.85m |

# APPENDIX 2

# MUD / SAND / GRAVEL PERCENTAGES

| CODE | MUD | SAND | GRAVEL |
|---|---|---|---|
| CQ1A | 14.87 | 83.41 | 1.85 |
| CQ1B | 9.63 | 81.2 | 9.08 |
| CR1A | 11.03 | 88.63 | 0.4 |
| CR1B | 11.15 | 86.32 | 2.59 |
| SM943 | 19.6 | 80 | 0.43 |
| SM944 | 20 | 79.5 | 0.59 |
| SM945 | 21.2 | 78.4 | 0.52 |
| SM946 | 21.5 | 76.7 | 2.25 |
| SM947 | 11.6 | 82.3 | 6.99 |
| DR1A | 3.47 | 92.33 | 4.24 |
| DR1B | 1.19 | 93.62 | 5.22 |
| DRIC | 1.21 | 95.57 | 3.26 |
| DR1D | 19.47 | 77.13 | 3.43 |
| DR2A | 5.81 | 83.18 | 11.05 |
| DR3A | 17 | 81.79 | 0.29 |
| DR3B | 17.89 | 80.22 | 0.64 |
| DR3C | 17.28 | 80.83 | 1.21 |
| DR3D | 16.75 | 77.73 | 5.13 |
| DR3E | 25.8 | 72.47 | 1.15 |
| DR3F | 23.77 | 70.6 | 5.1 |
| EC3A | 13.44 | 86.4 | 0.27 |
| EC3B | 17.22 | 82.41 | 0.36 |
| MR1A | 10.66 | 89.23 | 0.17 |
| MR1B | 5.88 | 89.65 | 4.52 |
| MR2A | 12.36 | 79.74 | 7.89 |
| PQ1A | 12.04 | 87.93 | 0.09 |
| PQ1B | 14.07 | 85.6 | 0.48 |
| PQ1C | 15.65 | 82.84 | 0.19 |
| PQ2A | 17.74 | 82.12 | 0.21 |
| PQ2B | 19.01 | 78.78 | 1.33 |
| PR3A | 16.44 | 82.89 | 0.84 |
| PR3B | 17.28 | 81.92 | 0.89 |
| PR3C | 17.65 | 78.39 | 4.11 |

| CODE | MUD | SAND | GRAVEL |
|---|---|---|---|
| PR3D | 9.08 | 54.46 | 36.72 |
| PR3E | 3.66 | 89.81 | 6.62 |
| PR3F | 1.79 | 90.74 | 7.52 |
| PR3G | 2.01 | 91.72 | 7.11 |
| PR3H | 3.94 | 94.04 | 2.09 |
| PR3I | 2.58 | 89.68 | 7.97 |
| PR3J | 1.1 | 95.29 | 3.67 |
| PR3K | 0.75 | 96.63 | 2.63 |
| PR3L | 0.96 | 91.06 | 8.02 |
| PR3M | 14.37 | 85.14 | 0.53 |
| PR3N | 26.62 | 73.3 | 0.16 |
| PR3O | 39.62 | 59.8 | 0.45 |
| PXR1A | 11.92 | 86.64 | 1.44 |
| PXR1B | 1.51 | 79.42 | 19.07 |
| PXP1C | 5.02 | 44.76 | 50.04 |
| PXP1D | 1.92 | 78.78 | 19.24 |
| PXP1E | 9.31 | 81.26 | 11.39 |
| PXP1F | 34.95 | 63.46 | 0.98 |
| PXP1A | 13.49 | 84.13 | 2.02 |
| PXP1B | 11.69 | 73.63 | 14.28 |
| PXR2A | 15.24 | 84.2 | 0.56 |
| PXR2B | 16.84 | 80.53 | 2.63 |
| PXR3A | 13.19 | 85.61 | 0.25 |
| PXR3B | 14.6 | 83.66 | 0.53 |
| PXR3C | 14.76 | 83.12 | 1.14 |
| PXR3D | 15.51 | 82.37 | 1.41 |
| PXR3E | 7.4 | 86.32 | 6.02 |
| RC1A | 17.83 | 83.02 | 0.28 |
| RC2A | 8.41 | 91.65 | 0.07 |
| RC3A | 10.83 | 88.88 | 0.36 |
| RC4A | 15.83 | 83.96 | 0.31 |
| RC5A | 9.82 | 59.22 | 31.17 |
| SBR1A | 11.94 | 85.63 | 0.53 |
| SBR1B | 10.64 | 85.11 | 4.31 |
| SBR1C | 4.44 | 90.63 | 4.99 |
| SBR1D | 2.65 | 94.78 | 2.6 |
| SBR1E | 1.88 | 86.8 | 11.38 |
| SBR1F | 1.15 | 95.79 | 3.1 |
| SBR1G | 16.57 | 81.08 | 2.4 |

| CODE | MUD | SAND | GRAVEL |
|---|---|---|---|
| SFR1A | 14.27 | 85.32 | 0.42 |
| SR1A | 15.49 | 83.94 | 0.62 |
| SR1B | 9.42 | 78.75 | 11.82 |
| TRF1A | 9.43 | 90.41 | 0.14 |
| TRF1B | 11.9 | 87.62 | 0.27 |
| | | | |
| BC1A | 2.07 | 37.66 | 60.19 |
| BC2A | 2.11 | 95.8 | 1.6 |
| BC3A | 0.22 | 95.07 | 4.76 |
| BC4A | 13.12 | 86.96 | 0 |
| BC4B | 9.02 | 90.48 | 0.2 |
| BC5A | 0.15 | 99.26 | 0.58 |
| BC6A | 0.25 | 98.3 | 1.45 |
| EC1A | 4.3 | 95.72 | 0.07 |
| EC2A | 2.65 | 96.98 | 0.5 |
| EC4A | 0.33 | 74.32 | 25.43 |
| MC1A | 29.82 | 70.22 | 0.01 |
| MC2A | 0.67 | 82.88 | 16.56 |
| MC3A | 1.36 | 97.75 | 0.94 |
| SS1A | 4.42 | 51.51 | 44.9 |
| TAL1A | 2.08 | 97.52 | 0.4 |
| TIN1A | 3.18 | 90.75 | 6.08 |
| | | | |
| GR1A | 19.47 | 75.54 | 0.05 |
| GR1B | 23.4 | 72.17 | 3.49 |
| GR1C | 20.17 | 48.95 | 29.82 |
| GR1D | 57.36 | 40.66 | 1.76 |
| PR1A | 18.27 | 75.18 | 6.56 |
| PR2A | 19.9 | 80.1 | 0 |
| PR2B | 20.62 | 79.38 | 0 |
| PR2C | 22.49 | 77.51 | 0 |
| PR2D | 24.13 | 75.87 | 0 |
| PR2E | 25.9 | 74.1 | 0 |
| PR2F | 25.9 | 73.91 | 0.19 |
| PR2G | 26.27 | 73.73 | 0 |
| PR2H | 30.6 | 69.35 | 0.06 |
| | | | |
| DR4A | 25.05 | 72.62 | 0.29 |
| DR4B | 56.09 | 41.8 | 0.04 |

| CODE | MUD | SAND | GRAVEL |
|---|---|---|---|
| DR4C | 48.01 | 48.54 | 0.09 |
| DR4D | 55.39 | 43.22 | 0.74 |
| EC5A | 11.79 | 85.93 | 0.72 |
| EC5B | 13.99 | 82.71 | 1.52 |
| EC5C | 3.31 | 35.3 | 60.93 |
| EC5D | 17.33 | 62.59 | 20.05 |

# APPENDIX 3

# MEAN, STANDARD DEVIATION, SKEWNESS AND KURTOSIS

| CODE | MEAN | S.D. | SKEWNESS | KURTOSIS |
|---|---|---|---|---|
| CR1A | 1.5052 | 0.9814 | -0.0204 | 0.9117 |
| CR1B | 1.4753 | 1.0963 | -0.0861 | 0.9129 |
| S943 | 1.1906 | 0.8883 | 0.0593 | 0.9756 |
| S944 | 1.2634 | 0.9094 | -0.1039 | 0.9508 |
| S945 | 1.2928 | 0.9224 | 0.0133 | 0.957 |
| S946 | 1.2476 | 0.9692 | 0.0144 | 0.9581 |
| S947 | 0.7224 | 1.0444 | 0.1055 | 0.8175 |
| DR1A | 0.5576 | 0.7906 | 0.0347 | 1.0057 |
| DR1B | 0.4324 | 0.7553 | 0.0663 | 1.0232 |
| DR1C | 0.5408 | 0.7658 | 0.0127 | 1.0137 |
| DR1D | 0.5141 | 0.7699 | 0.0634 | 1.1027 |
| DR3A | 1.4876 | 0.9984 | -0.0731 | 1.0518 |
| DR3B | 1.5505 | 0.9629 | -0.0769 | 1.0463 |
| DR3C | 1.5473 | 0.9461 | -0.0956 | 1.0504 |
| DR3D | 1.3324 | 1.0849 | -0.1061 | 1.0377 |
| DR3E | 1.3924 | 1.0813 | 0.0487 | 1.0373 |
| DR3F | 1.3829 | 1.1309 | 0.057 | 1.05 |
| MR1A | 1.2411 | 0.8806 | 0.0892 | 1.0056 |
| MR1B | 0.9297 | 0.9996 | -0.0129 | 0.8949 |
| MR2A | 1.0424 | 1.0005 | -0.0268 | 0.9087 |
| PQ1A | 1.3303 | 0.7576 | -0.002 | 1.058 |
| PQ1B | 1.429 | 0.7736 | -0.075 | 1.0883 |
| PQ2A | 1.2863 | 0.8608 | 0.0319 | 1.0261 |
| PQ2B | 1.1992 | 0.8908 | -0.0142 | 1.0136 |
| PR3A | 1.0083 | 0.9327 | 0.1252 | 1.074 |
| PR3B | 0.9719 | 0.9448 | 0.1467 | 1.0238 |
| PR3C | 1.011 | 0.9491 | 0.1233 | 1.0711 |
| PR3D | 0.7043 | 1.0292 | 0.0178 | 0.9029 |
| PR3E | 0.8679 | 0.8784 | -0.0657 | 0.9214 |
| PR3F | 0.8157 | 0.8192 | -0.073 | 0.9488 |
| PR3G | 1.2559 | 0.8841 | -0.2936 | 1.052 |
| PR3H | 1.7109 | 0.8417 | -0.1159 | 1.1819 |

| CODE | MEAN | S.D. | SKEWNESS | KURTOSIS |
|---|---|---|---|---|
| PR3I | 1.229 | 0.9204 | -0.1855 | 0.9719 |
| PR3J | 0.9253 | 0.7712 | -0.0426 | 1.0169 |
| PR3K | 0.7602 | 0.7029 | 0.106 | 1.0193 |
| PR3L | 0.5658 | 0.7977 | 0.0412 | 1.0657 |
| PR3M | 1.3959 | 0.737 | -0.1 | 0.9477 |
| PR3N | 2.3552 | 0.701 | 0.0236 | 1.0939 |
| PR3O | 2.3567 | 0.6938 | 0.0766 | 1.0417 |
| PXP1A | 1.0228 | 1.0558 | 0.0198 | 0.9269 |
| PXP1B | 1.1118 | 1.0685 | -0.0285 | 0.9481 |
| PXP1C | 0.8257 | 0.9641 | 0.0227 | 0.9045 |
| PXP1D | 0.6327 | 0.889 | -0.023 | 0.8811 |
| PXP1E | 0.9216 | 1.0164 | 0.0258 | 0.9416 |
| PXP1F | 1.8105 | 0.9919 | 0.0519 | 1.1305 |
| SBR1A | 1.2412 | 0.9248 | 0.0501 | 0.9766 |
| SBR1B | 1.2628 | 0.9612 | 0.0124 | 0.9946 |
| SBR1C | 1.1424 | 0.784 | -0.0627 | 0.9773 |
| SBR1D | 1.0897 | 0.7617 | -0.0769 | 0.9497 |
| SBR1E | 0.7469 | 0.9221 | -0.0457 | 0.9046 |
| SBR1F | 0.7366 | 0.7125 | -0.012 | 1.0503 |
| SBR1G | 0.939 | 0.8263 | 0.102 | 1.1158 |
| TRF1A | 1.1138 | 0.7534 | 0.0297 | 1.0277 |
| TRF1B | 1.1728 | 0.7815 | -0.0459 | 1.0141 |
| | | | | |
| BC1A | 0.7308 | 0.984 | 0.0306 | 0.9271 |
| BC2A | 0.4696 | 0.5412 | -0.0113 | 0.975 |
| BC3A | 0.634 | 0.8363 | 0.0835 | 0.9915 |
| BC5A | 0.5408 | 0.5016 | -0.0943 | 1.0362 |
| BC6A | 0.7302 | 0.7205 | 0.0182 | 1.0505 |
| EC2A | 1.3363 | 0.5822 | -0.1742 | 1.0117 |
| MC2A | 0.5754 | 0.8728 | 0.0085 | 0.864 |
| MC3A | 0.605 | 0.6427 | -0.0343 | 1.0098 |
| SS1A | -0.3422 | 0.6194 | 0.3415 | 1.095 |
| TAL1A | 1.0604 | 0.704 | -0.1119 | 0.9331 |
| TIN1A | 0.3398 | 0.7233 | 0.0399 | 0.9661 |
| | | | | |
| GR1A | 1.7341 | 0.74 | 0.0525 | 1.185 |
| GR1B | 1.7378 | 0.7341 | 0.0529 | 1.1841 |
| GR1C | 1.7287 | 0.8083 | 0.081 | 1.2146 |
| GR1D | 1.6377 | 1.0041 | -0.0102 | 1.2359 |
| PR2A | 1.3216 | 0.7487 | 0.0839 | 0.9967 |
| PR2B | 1.3606 | 0.7557 | 0.0587 | 1.0244 |

| CODE | MEAN | S.D. | SKEWNESS | KURTOSIS |
|---|---|---|---|---|
| PR2C | 1.398 | 0.783 | 0.032 | 1.0325 |
| PR2D | 1.3985 | 0.7828 | 0.0296 | 1.0238 |
| PR2E | 1.4394 | 0.8228 | 0.0374 | 1.0515 |
| PR2F | 1.4246 | 0.8107 | 0.0554 | 1.0483 |
| PR2G | 1.3871 | 0.813 | 0.0721 | 1.0426 |
| PR2H | 1.3284 | 0.8024 | 0.0254 | 0.9918 |
| DR4A | 1.6664 | 0.8927 | 0.0143 | 1.0238 |
| DR4B | 1.9085 | 0.8997 | 0.083 | 0.999 |
| DR4C | 1.8248 | 0.9311 | 0.1074 | 1.0791 |
| DR4D | 1.8704 | 0.9453 | 0.0864 | 1.0915 |
| EC5A | 2.1912 | 0.7651 | -0.0523 | 1.1953 |
| EC5B | 2.1608 | 0.8963 | -0.1573 | 1.2784 |
| EC5C | 1.3716 | 1.2404 | -0.2037 | 0.8429 |
| EC5D | 0.3354 | 0.9368 | 0.0913 | 0.8366 |

# APPENDIX 4

# BULK DENSITY MEASUREMENTS *

Results of bulk density measuremants taken from two pits on the main sand monkey adjacent to Dunwerian Rd.

| **PIT 1** | |
|---|---|
| DEPTH (cm) | DENSITY ($g/cm^3$) |
| 17 | 1.594 |
| 29 | 1.515 |
| 40 | 1.546 |
| 52 | 1.502 |
| 60 | 1.576 |
| 70 | 1.586 |
| 78 | 1.558 |
| 99 | 1.619 |
| **PIT 2** | |
| 10 | 1.519 |
| 12 | 1.391 |
| 19 | 1.516 |
| 25 | 1.502 |
| 40 | 1.512 |
| 60 | 1.612 |
| 69 | 1.574 |
| 80 | 1.617 |
| 93 | 1.615 |
| 100 | 1.528 |
| 105 | 1.615 |

* Data collected by Barlow, Kelly and Lambert (1996 unpublished)

# APPENDIX 5

## ANT MOUND VOLUMES *

Measurement of the approximate volume of 30 *Aphaenogaster* mounds in a 20m x 20m quadrat.

| BASE DIAMETER (cm) | BASE AREA ($m^2$) | HEIGHT (cm) | VOLUME ($cm^3$) |
|---|---|---|---|
| 8.0 | 50.265 | 1.0 | 16.755 |
| 12.0 | 113.097 | 1.5 | 56.549 |
| 15.0 | 176.715 | 2.5 | 147.262 |
| 20.0 | 314.159 | 5.0 | 523.599 |
| 7.5 | 44.179 | 1.0 | 14.726 |
| 9.5 | 70.889 | 1.0 | 23.627 |
| 17.0 | 226.980 | 4.0 | 302.640 |
| 10.0 | 78.540 | 1.5 | 39.270 |
| 7.0 | 38.485 | 0.5 | 6.414 |
| 11.0 | 95.033 | 1.5 | 47.517 |
| 21.0 | 346.361 | 4.0 | 461.814 |
| 8.5 | 56.745 | 1.0 | 18.915 |
| 13.0 | 132.732 | 2.5 | 110.610 |
| 10.0 | 78.540 | 1.5 | 39.270 |
| 5.0 | 19.635 | 0.5 | 3.272 |
| 19.0 | 283.529 | 5.0 | 472.548 |
| 8.0 | 50.265 | 0.5 | 8.378 |
| 10.5 | 86.590 | 1.5 | 43.295 |

| | | | |
|---|---|---|---|
| 10.0 | 78.540 | 1.5 | 39.270 |
| 16.0 | 201.062 | 2.5 | 167.552 |
| 17.0 | 226.980 | 3.5 | 264.810 |
| 12.0 | 113.097 | 1.5 | 56.549 |
| 9.0 | 63.617 | 1.0 | 21.206 |
| 11.5 | 103.869 | 2.0 | 69.246 |
| 12.0 | 113.097 | 1.5 | 56.549 |
| 16.0 | 201.062 | 2.5 | 167.552 |
| 16.0 | 201.062 | 2.5 | 167.552 |
| 15.0 | 176.715 | 2.5 | 147.262 |
| 12.0 | 113.097 | 1.5 | 56.549 |
| 14.0 | 153.938 | 2.0 | 102.625 |

Total mound volume: 48 600 $cm^3$

Average mound density: 1.1 mounds per $m^2$

Average mound volume: 121.773 $cm^3$

Average density of mound material **121.5 cm/$m^2$**

* Data collected by Kelly, Barlow and Lambert (1996 unpublished)

# APPENDIX 6

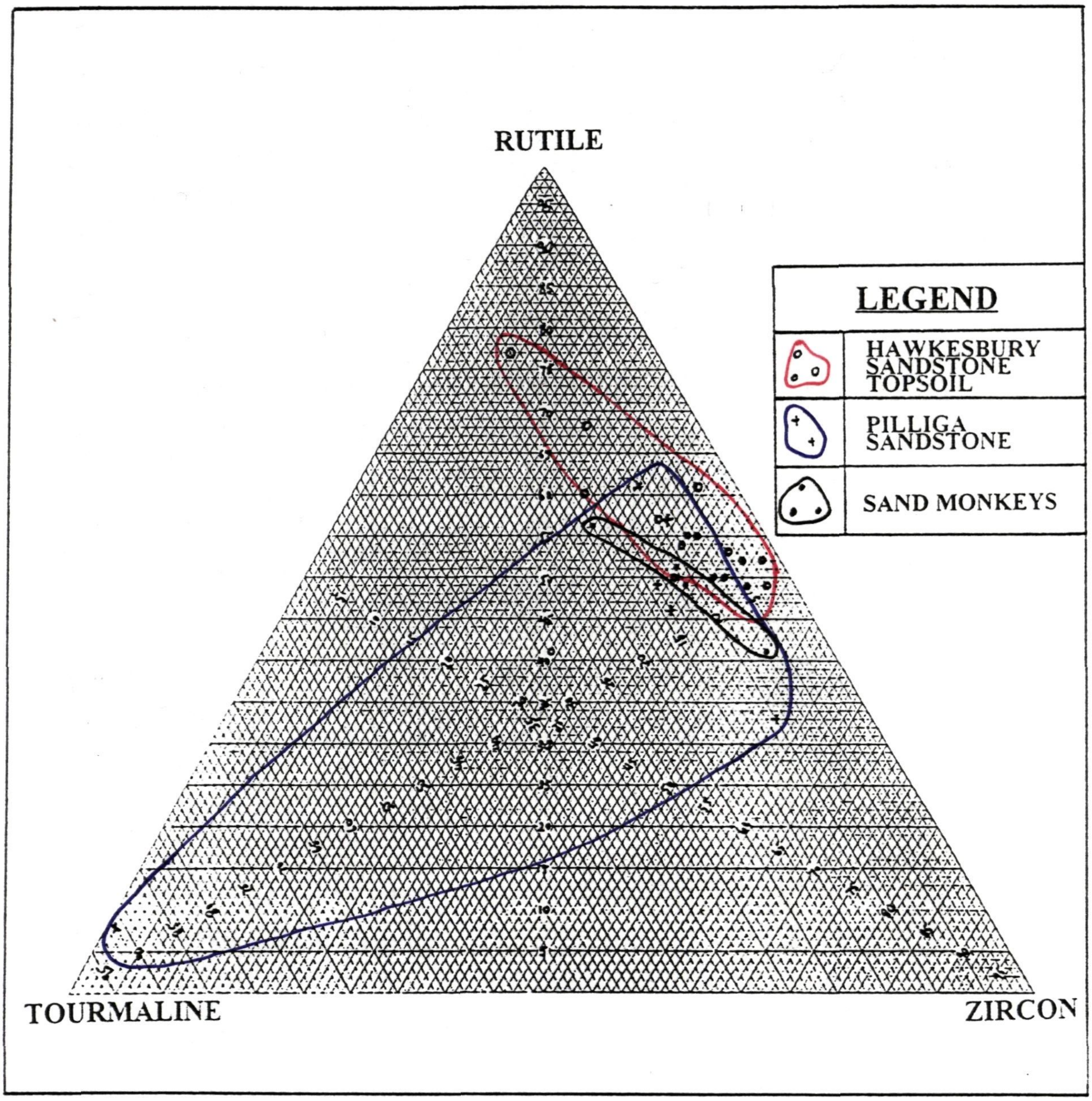
# HEAVY MINERAL ANALYSIS *

| AUTHOR | FORMATION | LOCATION | ZIRCON | RUTILE | TOUR- | TOTAL |
|---|---|---|---|---|---|---|
| | | | | | MALINE | |
| | | | (%) | (%) | (%) | -100 |
| Galloway 1972 | Hawkesbury | Culoul Ra. Howes Mt | 19 | 52 | 29 | 100 |
| " | " | " | 42 | 48 | 18 | 108 |
| " | " | " | 31 | 32 | 37 | 100 |
| " | " | " | 33 | 43 | 24 | 100 |
| " | " | " | 34 | 34 | 32 | 100 |
| Crook 1956 | " | Grose River | 19 | 44 | 37 | 100 |
| McElroy 1956 | " | Wollombi | 60 | 37 | 3 | 100 |
| " | " | " | 60 | 38 | 2 | 100 |
| " | " | " | 59 | 41 | 2 | 102 |
| " | " | " | 70 | 29 | 1 | 100 |
| " | " | " | 74 | 22 | 4 | 100 |
| " | " | " | 75 | 23 | 2 | 100 |
| " | " | " | 72 | 26 | 1 | 99 |
| " | " | " | 65 | 32 | 3 | 100 |
| " | " | " | 37 | 32 | 1 | 70 |
| McElroy 1954 | " | South Coast | 48 | 41 | 11 | 100 |
| " | " | " | 73 | 7 | 22 | 102 |
| " | " | " | 35 | 32 | 33 | 100 |
| " | " | " | 56 | 24 | 20 | 100 |
| " | " | " | 59 | 31 | 10 | 100 |
| " | " | " | 55 | 35 | 10 | 100 |
| " | " | " | 26 | 33 | 41 | 100 |
| " | " | " | 46 | 37 | 17 | 100 |
| " | " | " | 35 | 44 | 21 | 100 |
| " | " | " | 50 | 40 | 10 | 100 |
| " | " | " | 49 | 35 | 16 | 100 |
| " | " | Mt Murray Bore | 51 | 38 | 11 | 100 |
| " | " | " | 48 | 40 | 12 | 100 |
| " | " | " | 53 | 30 | 17 | 100 |
| " | " | " | 53 | 39 | 8 | 100 |
| " | " | " | 61 | 2 | 37 | 100 |
| " | " | " | 72 | 3 | 25 | 100 |
| " | " | " | 55 | 0 | 45 | 100 |
| Hallsworth & Waring | Pilliga Sst | sandstone | 34 | 57 | 9 | 100 |
| " | Pilliga Sst | sandstone | 1 | 8 | 91 | 100 |
| " | Pilliga soil | pallid zone | 29 | 61 | 10 | 100 |
| " | " | laterite | 53 | 33 | 14 | 100 |
| " | " | sand monkey | 28 | 56 | 17 | 101 |
| " | " | " | 37 | 53 | 10 | 100 |
| " | " | " | 40 | 49 | 11 | 100 |
| " | " | " | 52 | 41 | 7 | 100 |

| | | | | | | |
|---|---|---|---|---|---|---|
| " | " | Red sand | 56 | 33 | 10 | 99 |
| " | " | " | 52 | 38 | 10 | 100 |
| " | " | " | 48 | 40 | 12 | 100 |
| " | " | sand splay | 40 | 46 | 15 | 101 |
| " | " | creek bank sand | 41 | 47 | 12 | 100 |
| " | " | " | 45 | 45 | 1 | 91 |
| " | " | " | 23 | 71 | 6 | 100 |
| " | " | " | 45 | 37 | 18 | 100 |
| " | " | solodized-solonetz | 25 | 56 | 19 | 100 |
| " | " | " | 43 | 41 | 16 | 100 |
| " | " | " | 26 | 65 | 9 | 100 |
| " | " | " | 42 | 48 | 10 | 100 |
| " | " | " | 33 | 58 | 9 | 100 |
| " | " | " | 37 | 57 | 6 | 100 |
| " | " | black gilgai | 37 | 49 | 14 | 100 |
| " | " | red gilgai | 56 | 40 | 4 | 100 |
| " | " | deep sand | 46 | 45 | 9 | 100 |
| Humphreys 1985 | Hawkesbury | Cattai SP03/A1 | 45.8 | 52.5 | 1.7 | 100 |
| " | " | Cattai SP03/A2 | 37.1 | 53.8 | 9.1 | 100 |
| " | " | Cattai SP03/B2 | 53.1 | 34.5 | 12.4 | 100 |
| " | " | Cattai SP32/A1 | 38.2 | 55.2 | 6.7 | 100.1 |
| " | " | Cattai SP32/A2 | 35.4 | 60.7 | 3.9 | 100 |
| " | " | Cattai SP32/B2 | 34 | 58.7 | 7.3 | 100 |
| " | " | Cattai SP35/A1 | 37.5 | 54.8 | 7.7 | 100 |
| " | " | Cattai SP35/A2 | 46.2 | 48.7 | 5.1 | 100 |
| " | " | Cattai SP35/B2 | 31.8 | 59.1 | 9.1 | 100 |
| " | " | Cattai SP35/B3 | 50 | 23.1 | 26.9 | 100 |
| " | " | Cattai SP49/A11 | 7.7 | 77.2 | 15.1 | 100 |
| " | " | Cattai SP49/A12 | 29.7 | 41.1 | 28.9 | 99.7 |
| " | " | Cattai SP49/A2 | 23.7 | 60 | 16.3 | 100 |
| " | " | Cattai SP49/A3 | 20.4 | 68 | 11.6 | 100 |
| " | " | Cordeaux SP90/01 | 41.7 | 50 | 8.3 | 100 |
| " | " | Cordeaux SP90/A1 | 41.8 | 53 | 5.2 | 100 |
| " | " | Cordeaux SP90/A2 | 43.5 | 52.2 | 4.3 | 100 |
| " | " | Cordeaux SP90/B2 | 39.3 | 54.8 | 5.9 | 100 |
| " | " | mound | 43.1 | 49.6 | 7.3 | 100 |
| " | " | mound | 47.6 | 49 | 3.4 | 100 |
| " | " | mound | 38.1 | 50.4 | 11.5 | 100 |
| " | " | cast | 33.9 | 56.8 | 9.3 | 100 |

* Data from Humphreys (1985)

**Fig. A1.** Plot showing the relative abundance of heavy minerals in Pilliga Sandstone, Pilliga sand monkeys and topsoil derived from Hawkesbury Sandstone.



# APPENDIX 7

# SAMPLE PARTICLE SIZE ANALYSIS PROFORMA

Sample No. ________

Operator. ________

1. Moisture Factor. (determined from 10g sub-sample)

(a). Weight of drying dish (g) ______

(b). Weight of moist sediment and dish (g) ______

(c). Weight of dry sediment and dish (g) ______

(d). Moisture Factor = 1 - [((b) - (a)) / [(c) - (a)] ______

2. Proportion coarser/finer than 63µm. (determined from 100g sample)

(e). Weight of drying dish (g) ______

after wet sieving,

(f). Weight of moist sediment and dish (g) ______

(g). Weight of dry >63µm portion and dish (g) ______

(h). Dry weight equivalent of moist sample (g) = [(f) - (e)] x d. ______

(i). Dry weight of mud (g) = (h) - [(g) - (e)]. ______

(j). Percentage < 63µm. [(i) / (h)] x 100. ______

(k). Percentage > 63µm. [(g) - (e)] / 100 ______

# APPENDIX 8

# RESULTS OF T-TESTS

Table A1. Means and Standard Deviations of mud populations for the different sand body types

| | RSM | YSM | SM (total) | SBD | CK. |
|---|---|---|---|---|---|
| MEAN (%) | 12.38 | 12.66 | 12.61 | 26.35 | 1.83 |
| STD. DEV. | 4.73 | 8.48 | 7.65 | 10.31 | 1.51 |
| NUMBER OF SAMPLES | 21 | 60 | 81 | 12 | 13 |

Table A2. Means and Standard Deviation of gravel populations for the different sand body types

| | RSM | RSM* | YSM | SM (total) | SBD | CK. | CK.* | 0.25 - 0.5m | 1.5 - 2.0m |
|---|---|---|---|---|---|---|---|---|---|
| MEAN (%) | 8.90 | 3.83 | 3.39 | 6.62 | 0.03 | 12.57 | 5.31 | 0.58 | 7.27 |
| STD. DEV. | 14.01 | 5.43 | 3.84 | 9.09 | 0.06 | 19.52 | 8.23 | 0.57 | 9.29 |
| NUMBER | 21 | 18 | 60 | 81 | 12 | 13 | 11 | 23 | 18 |

* outliers removed

Table A3. T-test results from mud populations

| | YSM/ RSM | CK/ SM | CK/ YSM | CK/ RSM | CK/ SBD | SBD/ SM | SBD/ YSM | SBD/ RSM |
|---|---|---|---|---|---|---|---|---|
| ν | 79 | 91 | 71 | 32 | 23 | 91 | 80 | 31 |
| α | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| ρ | 1.992 | 1.990 | 1.994 | 2.030 | 2.069 | 1.992 | 1.992 | 2.030 |
| T | 0.598 | 4.265 | 4.055 | 3.125 | 2.986 | 4.727 | 4.322 | 3.774 |

ν degrees of freedom

α significance level

ρ critical value

T t statistic

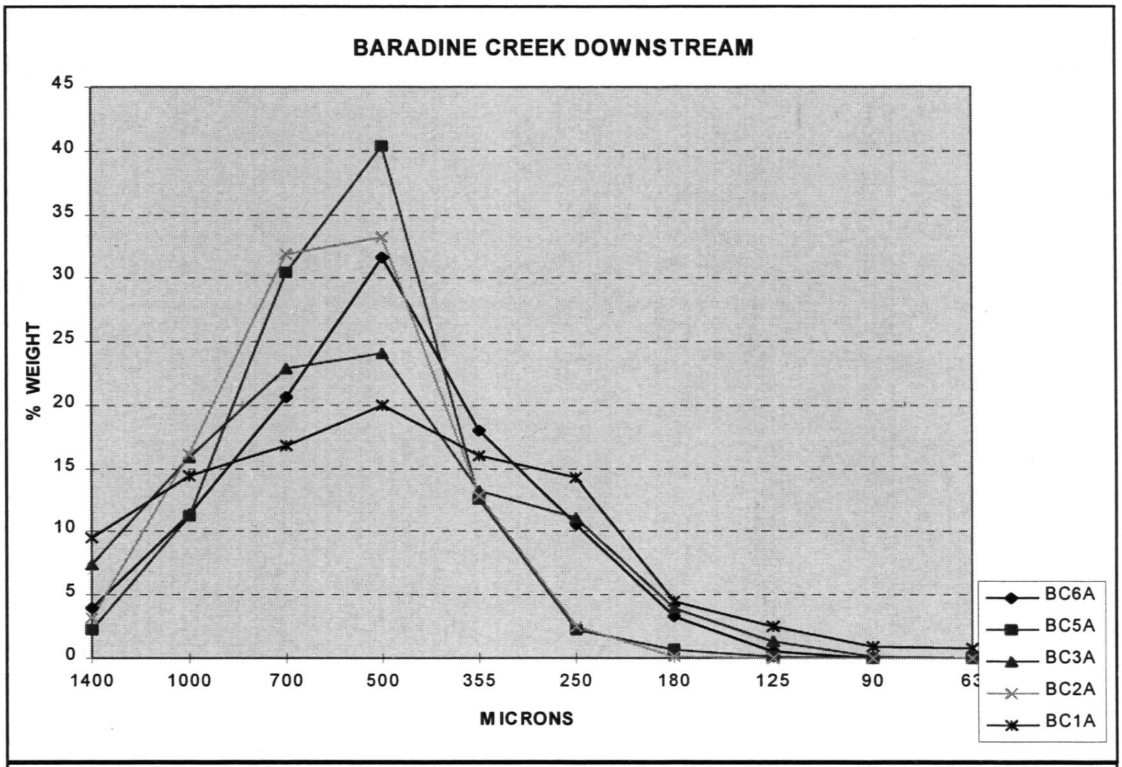
Table A4. T-test results from gravel populations

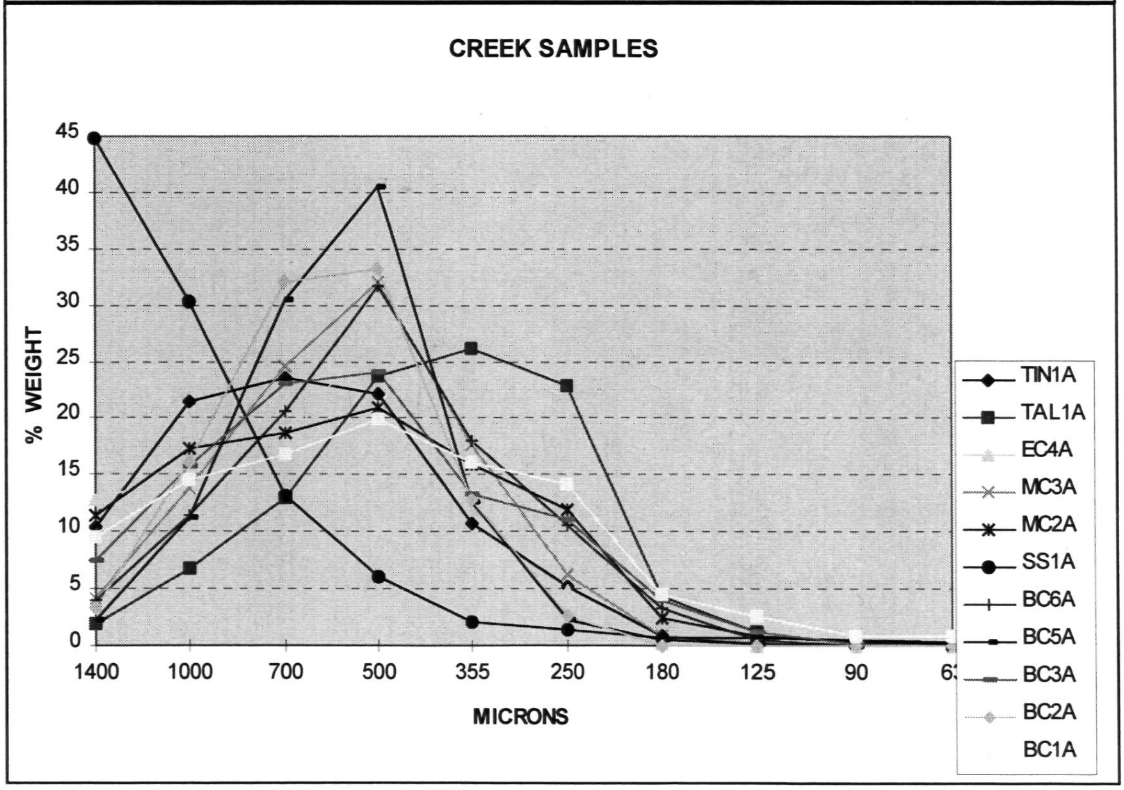
| | YSM/ RSM | YSM/ RSM * | CK / SM | CK / YSM | CK / YSM * | CK / RSM | CK / SBD | SBD / SM | SBD / YSM | SBD / RSM | 0.5 / 2.0m |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ν | 79 | 75 | 91 | 71 | 69 | 32 | 23 | 91 | 69 | 31 | 41 |
| α | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| ρ | 1.992 | 1.992 | 1.990 | 1.994 | 1.994 | 2.030 | 2.069 | 1.992 | 1.992 | 2.030 | 2.021 |
| T | 2.631 | 0.394 | 1.816 | 3.458 | 1.230 | 0.638 | 2.21 | 2.581 | 2.992 | 4.799 | 10.04 |

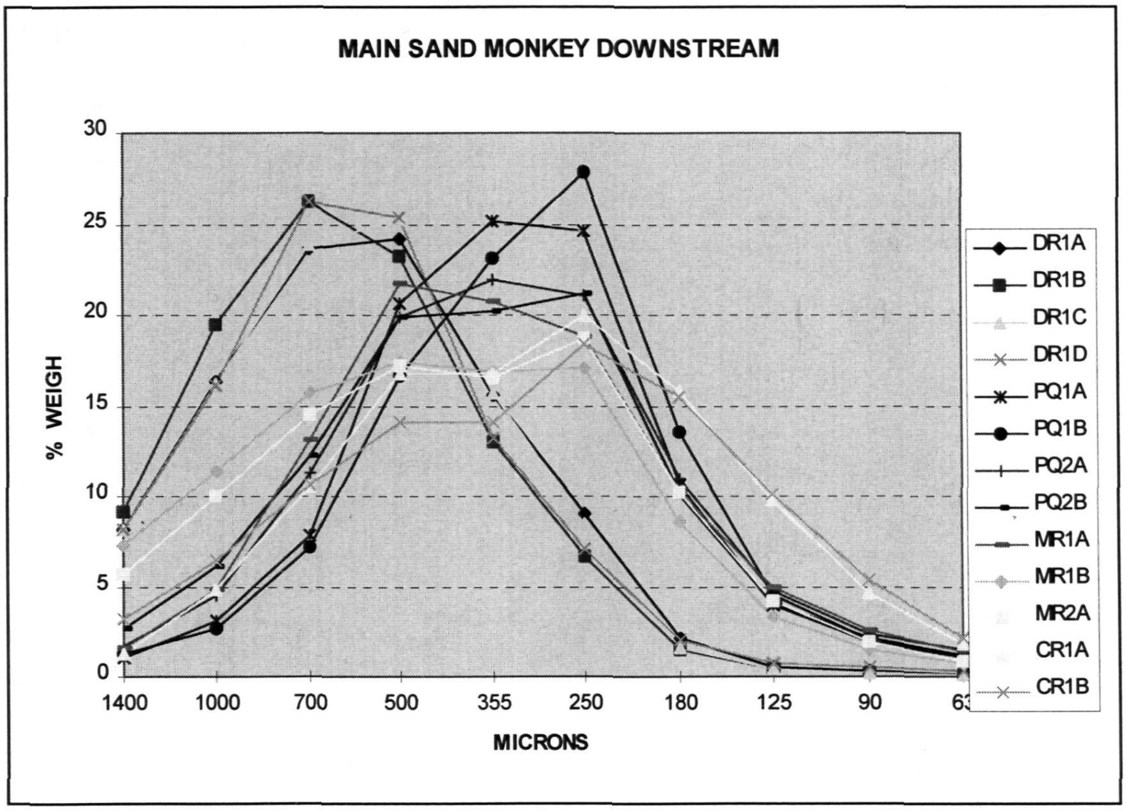
ν degrees of freedom
α significance level
ρ critical value
T t statistic
* outliers removed

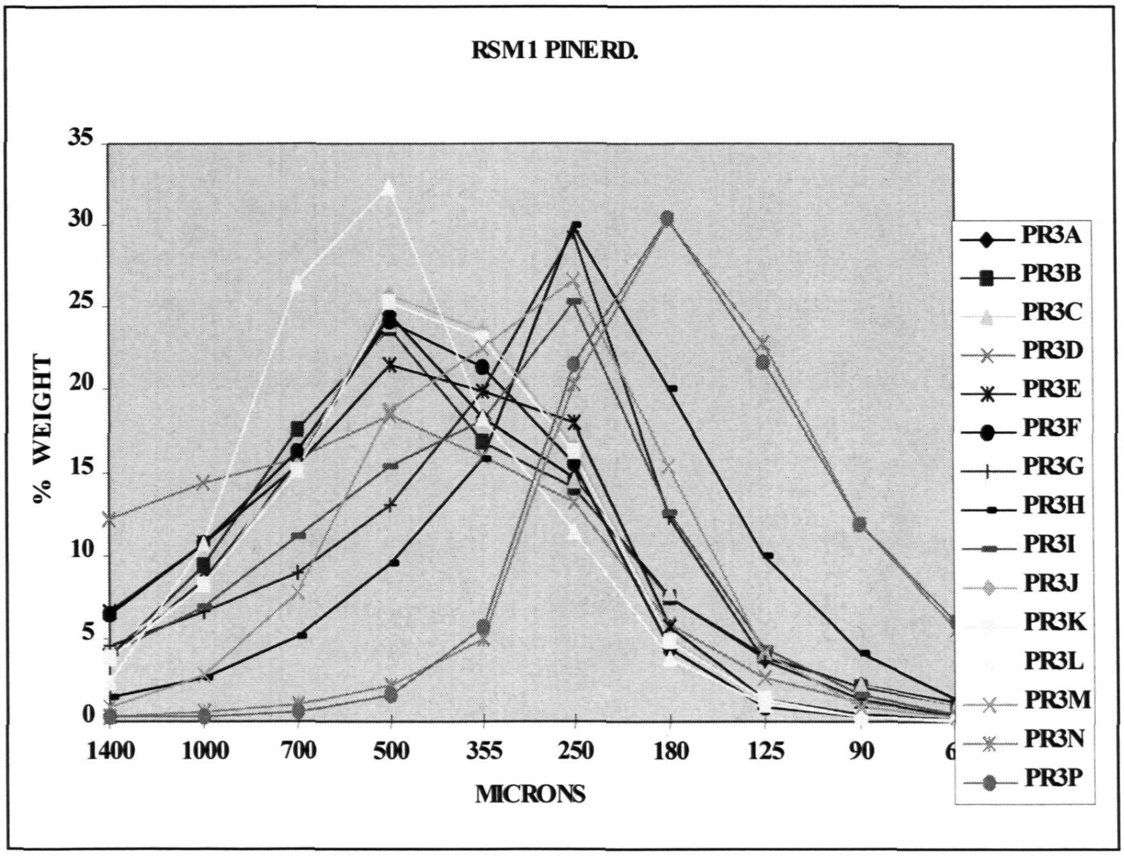
# APPENDIX 9

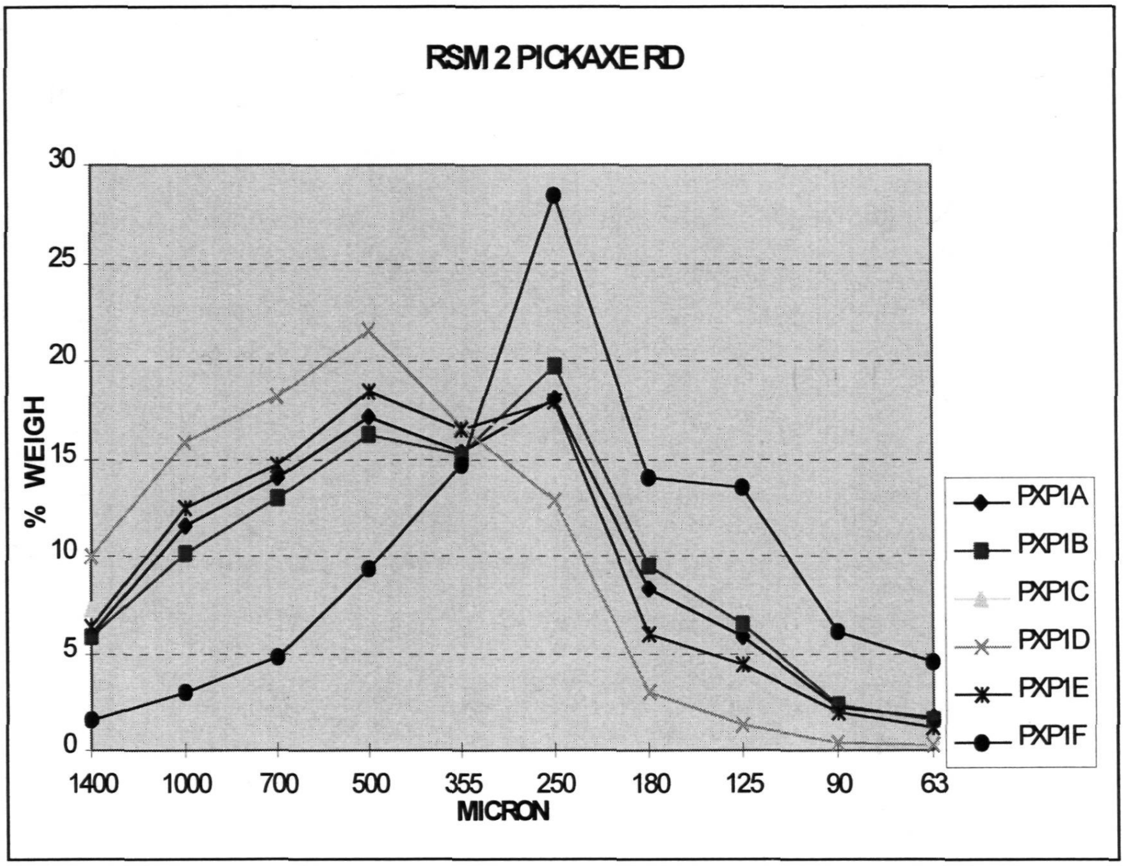
# PARTICLE SIZE DISTRIBUTIONS

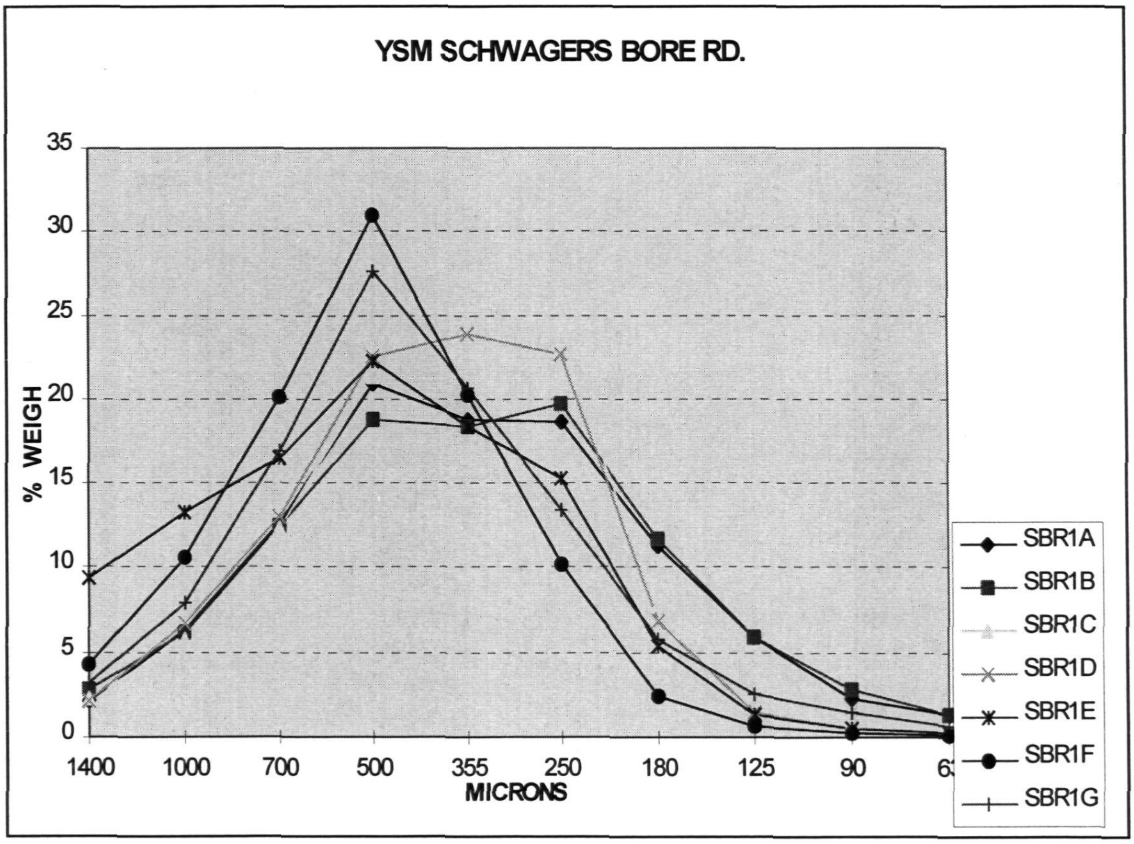


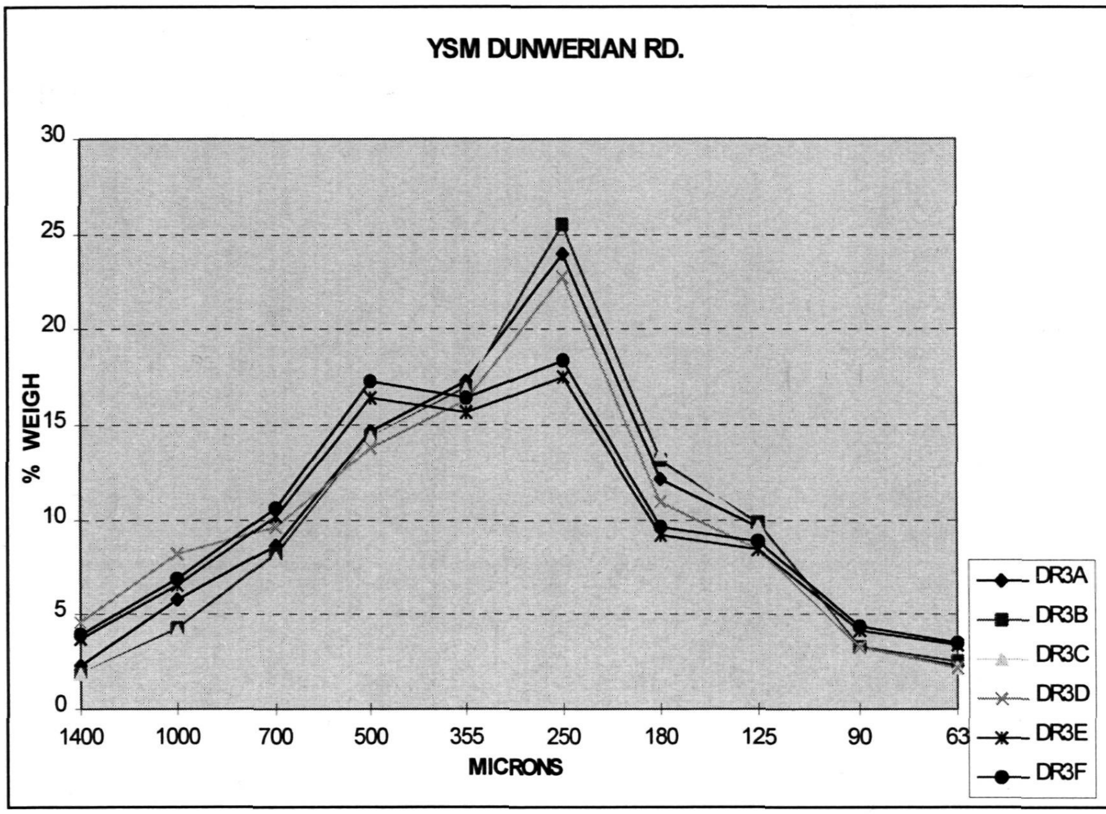




MAIN SAND MONKEY DOWNSTREAM
% WEIGH
MICRONS
DR1A
DR1B
DR1C
DR1D
PQ1A
PQ1B
PQ2A
PQ2B
MR1A
MR1B
MR2A
CR1A
CR1B


RSM1 PINE RD.
% WEIGHT
MICRONS
PR3A
PR3B
PR3C
PR3D
PR3E
PR3F
PR3G
PR3H
PR3I
PR3J
PR3K
PR3L
PR3M
PR3N
PR3P


RSM 2 PICKAXE RD
% WEIGH
MICRON
30
25
20
15
10
5
0
1400
1000
700
500
355
250
180
125
90
63
PXP1A
PXP1B
PXP1C
PXP1D
PXP1E
PXP1F


YSM SCHWAGERS BORE RD.
% WEIGH
MICRONS
35
30
25
20
15
10
5
0
1400
1000
700
500
355
250
180
125
90
SBR1A
SBR1B
SBR1C
SBR1D
SBR1E
SBR1F
SBR1G


YSM DUNWERIAN RD.
% WEIGH
MICRONS
30
25
20
15
10
5
0
1400
1000
700
500
355
250
180
125
90
63
DR3A
DR3B
DR3C
DR3D
DR3E
DR3F