ASSESSMENT OF SAND MINING

Impacts on Relict Dunes in Hundreds of Mudla Wirra and Port Gawler South Australia

PROJECTS SECTION
SOUTH AUSTRALIAN DEPARTMENT FOR THE ENVIRONMENT

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1. INTRODUCTION

The area immediately south of Reeves Plains, in the Hundreds of Port Gawler and Mudla Wirra, Co. Gawler is characterized by a series of north-west/south-east trending dunes some of which are being mined for sand. As these dunes and the surrounding area support a flora of considerable interest to botanists, a need was seen for an assessment of the impacts of sand-mining operations upon the area's remaining flora.* Although extensive clearing followed settlement of the area in the 1850s many of the dunes were not cleared due to early recognition of the sand-drift problems occasioned by their clearance. In comparatively recent times the sand dunes which had been excluded from earlier clearing operations have been cleared of their over-lying vegetation and either mined for the sand which constitutes them or put under crops. The aftermath of sand-mining is generally an area devoid of vegetation and offering little chance of plant establishment owing to the nature of the calcrete horizon exposed in the course of sand mining.

The area has been of interest to academic workers and naturalists for many years but there is very little published information relating to its flora and fauna. Consequently, as directed in the initiating minute, an effort has been made to collate all available information and to collect data upon which an objective assessment and any subsequent recommendations could be based. Some field-work was carried out by undergraduate students of the University of Adelaide who were directed to the area following their approach to the Department for the Environment regarding projects of an applied nature.

Following a review of previously-published information, field-studies and inspections of current and past sand-mining operations, this Report has extended its area of concern (i.e., status of native flora and recommendations for retention) to include guidelines for the operation and rehabilitation of sand-mining sites. The three principal aims of this Report are:

(i) to report upon the extent, nature and significance of the native vegetation remaining in the area.

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*See original minute, 7 July, 1977, Appendix A.

(ii) to recommend areas which should be retained for their intrinsic character.

(iii) to recommend procedures and techniques which will ameliorate the impacts of sand-mining operations and promote the restoration of these areas and previously-mined areas to a stable state.

1.1 Location of the Area

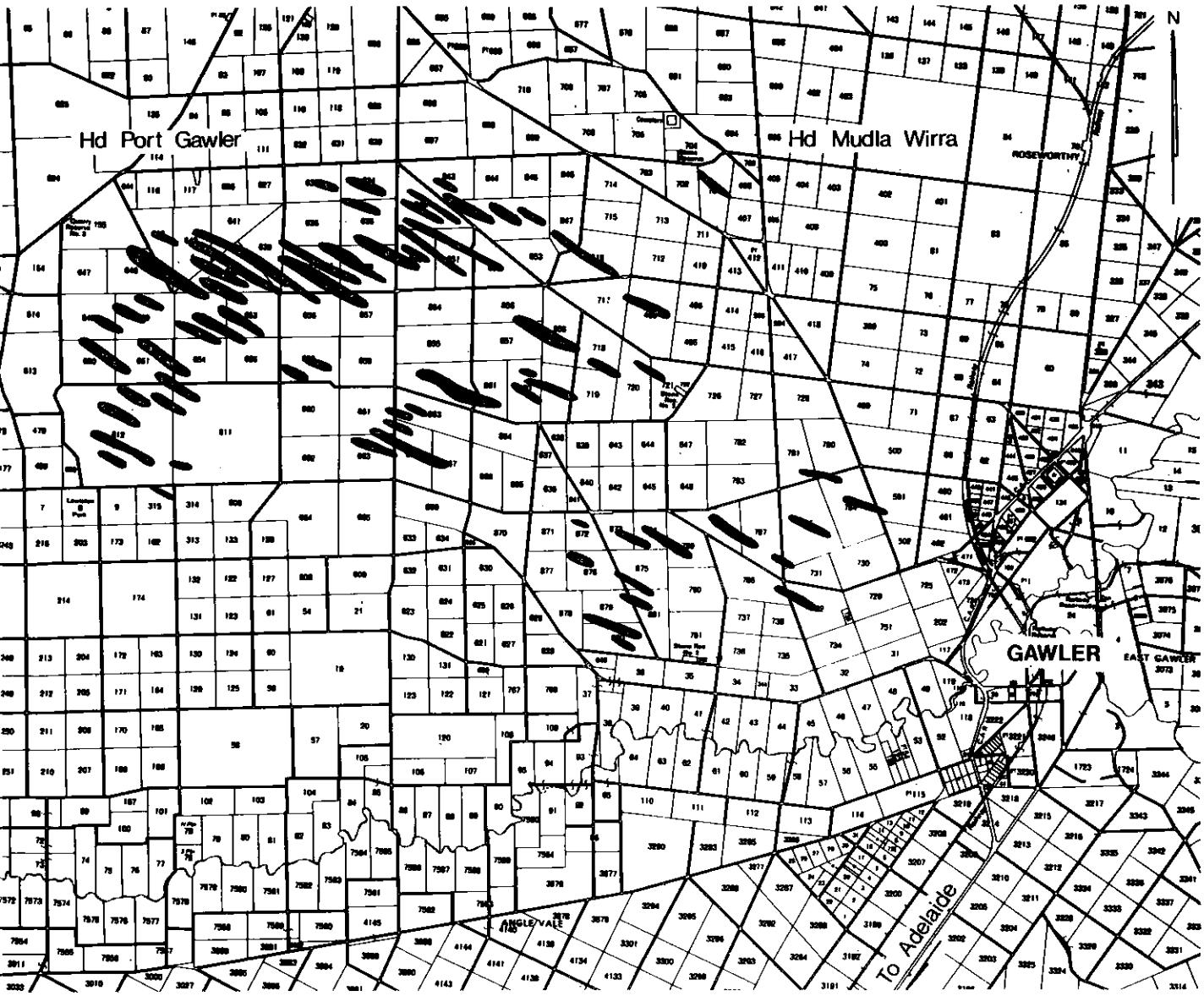
The sand dunes occur within an area of approximately 40 km^2 which straddles the Hundreds of Port Gawler and Mudla Wirra in County Gawler (Fig. 1). Located just north of the Gawler River, the area corresponds to the Quaternary Recent Sands (Qrs) shown on the Geological Sheet, Adelaide, 1:250 000. The location of individual sand dunes constituting the dune complex was mapped by the South Australian Department of Mines in the course of a survey to assess the suitability of the dune sands for foundry purposes (Hiern, 1968).

1.2 Climate

Records from Roseworthy Agricultural College provide the best meteorological data for the study area. The area is subject to a Mediterranean-type climate with characteristically hot summers and a predominantly winter rainfall. The average monthly maximum and minimum temperatures and their associated ranges over a 24-year period were 21°C (15-31°C) and 10°C (7-18°C) respectively. The average annual rainfall over 94 years is 438 mm, with the majority of it falling within the April-October period, inclusively. There is a slight decline in rainfall from east to west across the area.

1.3 Geology and Soils

The area is part of the Adelaide Plains and is underlain by Tertiary alluvial deposits (Daily *et al.*, 1976). The sand dunes are of Aeolian origin and date from the Quaternary period (Firman, 1967). They in turn overlie an horizon of Aeolian calcareous sand which was deposited during the Pleistocene Epoch. Test bores on each of six dunes found the depth of sand to vary between 1.08 m and 3.2 m (Hiern, 1968).



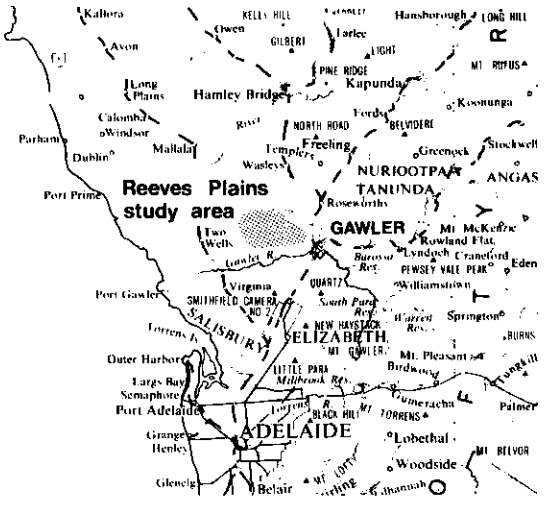


Fig. 1 Location of study area and distribution of sand dunes

After Hiern (1968)

The sand is comprised of small, rounded grains ranging in colour from off-white to orange-brown and has a clay content of between 1.8 and 7.1% by weight. A test bore in an interdunal area encountered calcrete only 75 mm below the surface; it extended to a depth of 1.9 m, after which sand prevailed to the depth of the bore (5.3 m).

The principal soil group of the area is of the Mallee type with Sandy Mallee predominating on the ridges or dunes and with a Loamy Mallee occurring on the flats.* Generalized profiles for each of these soil types, together with their principal plant associations, are given in Table 1.

1.4 Land Use

The principal land use of the area is mixed farming. The nature of the crops and stock has, however, changed dramatically since settlement (Table 2). Although wheat constituted 96.9% of the County's crops in 1903, in 1975-76 it accounted for only 43.2%. During that period (i.e., 1903 to 1975/76) barley has come to be the principal cereal crop in the area, particularly on sandy areas such as are found in the Hds of Port Gawler and Mudla Wirra. The stocking rates of both sheep and cattle have increased between 1901 and 1975. Although the number of dairy cattle has remained almost unchanged the numbers of meat cattle and sheep have risen several-fold and trebled, respectively. The rise in numbers of meat cattle in particular reflect the increased importance of meat production within the area. Comparatively, meat cattle are more important in the Hd of Port Gawler than in the Hd of Mudla Wirra, whereas the reverse is true for sheep.

Although farming is still the principal economic activity, the mining of sand dunes has increased considerably over the past ten years. Even though the total economic return may be small in relation to that from agriculture, sand mining has played, and will continue to play, a significant part in altering the landforms and general character of the area.

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*Special Bulletin 1.68, S.A. Department of Agriculture and Fisheries.

The utilization of the dune sands for other than agricultural purposes is a relatively new development. In 1964 the Department of Mines and Energy, in an attempt to find additional sources of sand for foundry use, collected surface samples from dunes within the area (Oliver and Weir, 1967). In that same year a private company involved in concrete manufacture took out a five-year lease on a Section which emcompassed some of the dunes. In 1968 the Department of Mines and Energy extended their sampling programme and drilled a number of bores to aid in the assessment of the dune sands for foundry purposes (Hiern, 1968). Only two of the nine sites drilled yielded sands which warranted further study.

In 1968 a company dealing in the sale of sand for foundry and/or garden use entered into a fifteen-year lease on three sections encompassing sand dunes. The same company currently holds licences over three Private Mines covering sections within the Hd of Port Gawler. Other companies and individuals have since become involved in mining of the sand dunes, and as of February 1979 there were two Extractive Mineral Leases, nine Private Mines and three Mineral Claims* within the area (Table 3, Fig. 2).

1.5 Vegetation

1.5.1 Original

Early references to the native vegetation of this area are very sketchy. The whole of the area occupying the coastal plain between Port Wakefield and Gawler was, very early in the colony's history, referred to as the Gawler Scrub. Goyder, Surveyor General in 1860, described the land in the Hd of Mudla Wirra as being 'of very poor character and thickly covered with mallee scrub' (Williams, 1974). He recommended that it, along with 'scrubby' land of 'inferior quality' near Port Gawler, be surveyed into large blocks.

The first surveyors traversed the area with a view to the suitability of the land for agriculture. Their comments were accordingly restricted to describing the general nature of the terrain and its associated vegetation; e.g., 'rough pasture, sandhills and dense mallee scrub'. The thoroughness of these early surveyors has left a fairly comprehensive picture of the whole area (see Appendix B). The country in

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*One mining claim was recently withdrawn.

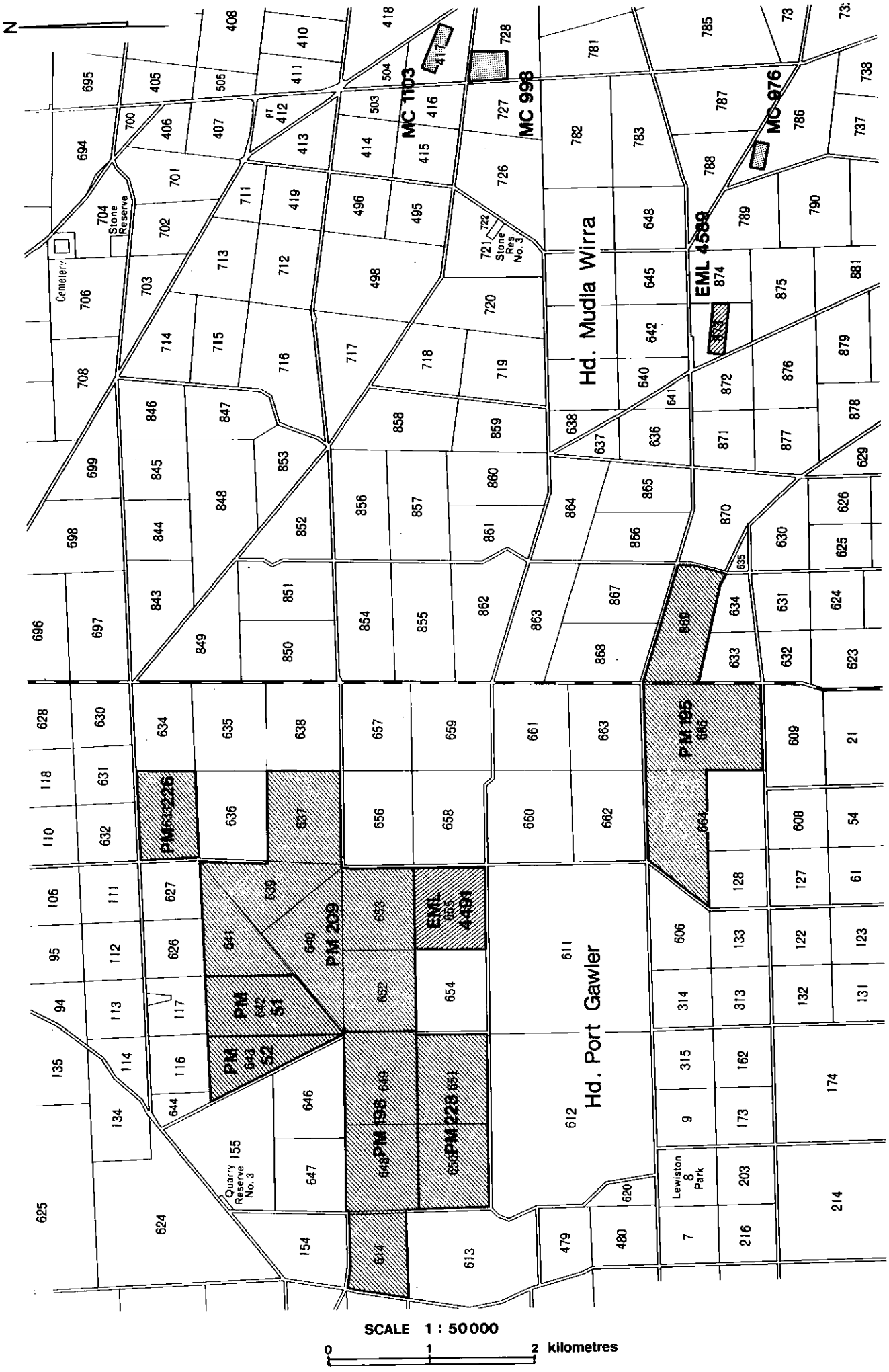

Fig. 2 **Location of Private Mines, Extractive Mineral Leases and Mining Claims in the Hundreds of Port Gawler and Mudla Wirra, January 1979**

general was covered with 'dense mallee scrub' which was occasionally interspersed with open areas of 'rough' or 'sandy pasture'. References to 'sandy soil on scrubby ridges' are undoubtedly the first relating to the sand dunes which are the focus of this study. The only specific references in these early descriptions were to 'Timber Peppermint' or 'Peppermint Gum' (*Eucalyptus odorata*) and to 'Pine' (*Callitris preissii*) which was also valued as a source of timber. In fact, the surveyor's depiction of 'timber tracks' on plans of the area suggest that timber cutting was one of the area's first industries.

1.5.2 Significance and Current Status of Vegetation

In its original state the vegetation of the area presented a sharp contrast to the more open woodland typical of the Adelaide Plains further south. Edaphic and climatic factors here combined to produce a thick mallee growth interrupted with native pasture, pines (*Callitris preissii*) and other large trees. The area's proximity to Adelaide makes it popular with Adelaide-based botanists and naturalists who visit the area to view the flora and fauna typical of this formation (Cleland, 1953; Glover, 1955).

The botanist first recorded as having visited the area was H. Behr who spent some time (1844-1847) in the Barossa district and visited the surrounding regions. His reference to the occurrence of *Eucalyptus behriana* 'in the scrubs of Sandarac - Cypresses (*Callitris*) near the Gawler River' (Behr, 1847) was probably the first botanical reference to the area. Although the term 'mallee' was not adopted until later, Behr's description of the 'scrub' as an 'endless profusion of shrubs and small trees of very different heights' leaves no doubt that he was speaking of mallee.*

Since Behr, numerous botanists have visited the area. J.G.O. Tepper, a well-known naturalist in the early life of the colony, resided at Two Wells for a period in 1869 and undoubtedly 'botanised' in the area (Kraehenbuehl, 1969). A specimen of *Calythrix involucrata* held in the State Herbarium is noted as having been collected by him at Kangaroo Flat. It was incorporated into the Herbarium in September of 1927,

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*First record of the term 'mallee' occurred in *Australia Felix* by W. Westgarth (1848). Edinburgh, Scotland.

predating a later collection by Ising in 1936 which he cited as the first record for the mainland. Unfortunately, no list of plants collected by Tepper in this area has been found.

The first published inventory of plants within the area was provided by Cleland in 1953. Subsequent lists of the flora were compiled by Kraehenbuehl (1975), Bramsey *et al.* (1977) and Picard (1977). Their collective findings are summarized in Appendix C. Of the papers cited, only that of Bramsey *et al.* (1977) attempted to describe the flora quantitatively. Unfortunately, their sampling was restricted to the sand dunes, but it was complemented to some degree by that of Picard (1977) who independently collected throughout the area. A comprehensive bibliography of references to plants of this area is given by Picard (1977).

As the sampling methods varied so markedly amongst the four sets of flora collections, it is dangerous to draw any conclusions from them. However, some general comments will be made. With regard to flora diversity, it is worth noting that collections between 1969 and 1977 failed to record 35 of the species collected by Cleland in September 1953. While it cannot be construed from this that the missing species have since become extinct within the region, it is highly probable that their incidence has declined. Their absence, in particular, from the collection by Bramsey *et al.* (1977), who visited the area at the same time of year as Cleland (September) and sampled intensively only from sand dunes, would tend to support this supposition.

The study by Bramsey *et al.* (1977) also illustrates the inadequacy of simple inventories in portraying the flora of any area. Even though 88 species of plants have been collected from the understorey within the area, Bramsey *et al.* 1977) found that on two 'disturbed' sand dunes (i.e., grazed) two introduced species (Barley grass, *Hordeum leporinum* and Cape-weed, *Arctotheca calendula* accounted for over 70% of the relative cover* within the plots examined. The flora on all of the four sand dunes sampled was impoverished. On the four sites examined, between two and four plant species accounted for between

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*Relative cover = $\frac{\text{Absolute cover species}}{\text{Total absolute cover all species}} \times \frac{100}{1}$

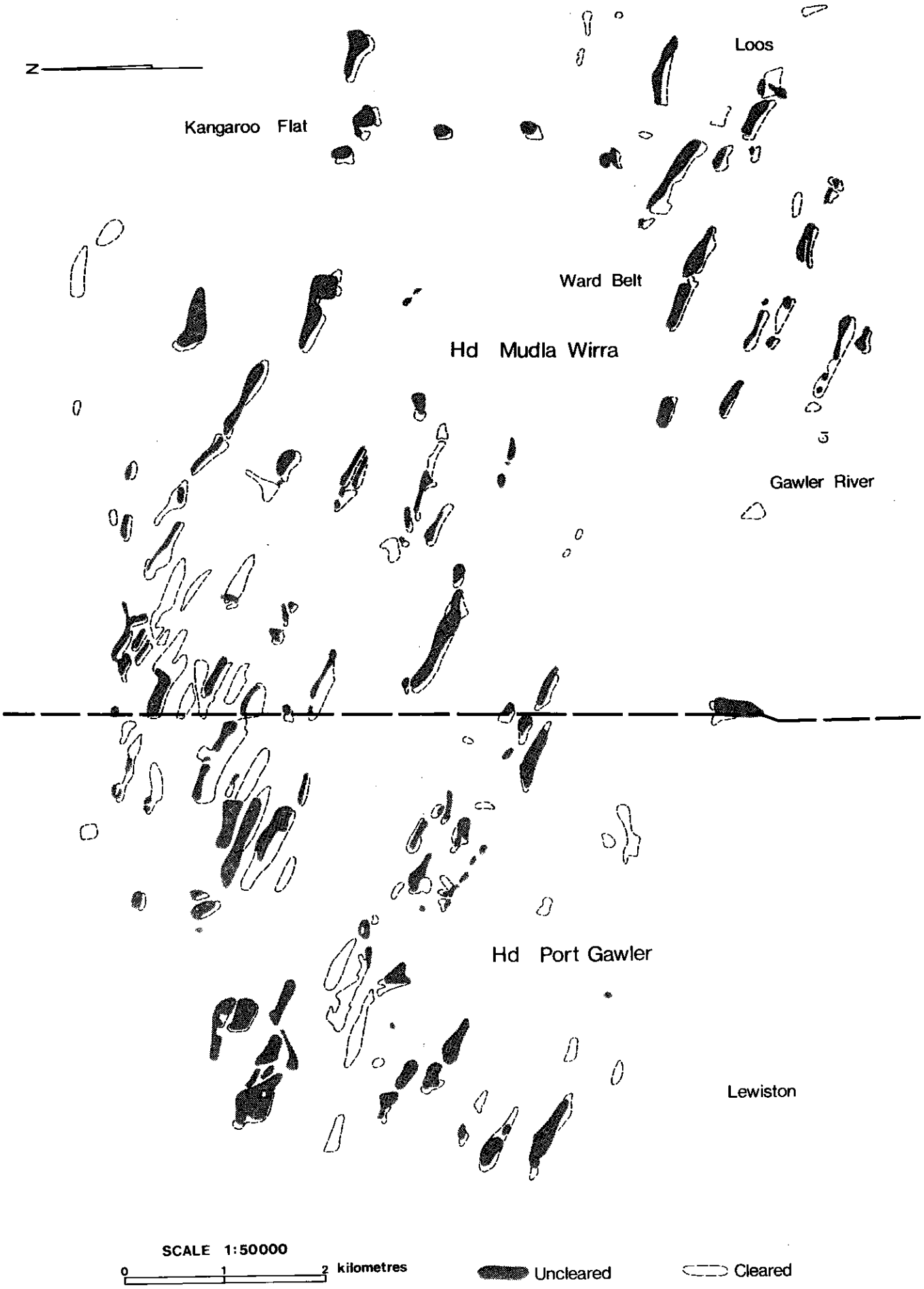

Fig. 3 **Extent of vegetation clearance in the Hundreds of Port Gawler and Mudla Wirra south between January 1949 and February 1977**

67 and 100% of the herb stratum (10 cm to 2 m) within the plots. This reduction in floral diversity probably reflects the long history of grazing on these areas.

Associated with the apparent trend towards a decrease in floral diversity has been a steady attrition of the areas occupied by native vegetation. Two important agents contributing to this have been grazing by stock and cereal growing. A Mr Horrock is reported to have grazed sheep in the area as early as 1836, three years before the township of Gawler was surveyed (Coombe, 1910). In 1845 a flour mill with a storage capacity of some 10 000 bushels was built in Gawler, which suggests that cropping with its associated clearance practices was under way even at this early date.

1.5.3 Vegetation Clearance

Initially the clearance of mallee presented great difficulties to early settlers. In 1878 the South Australian Government, in a bid to encourage land development, offered a prize of £200 for the best 'grubbing' machine adapted to clearing mallee and peppermint gum. Fourteen machines were entered in a contest which was held at Kangaroo Flat, Hd Mudla Wirra. None of the designs proved very successful and the most economical means of clearance continued to be by conventional methods; e.g., Mulleinizing, scrub rolling, stump-jump ploughing.

The rate of land development within County Gawler was initially very slow. By 1903 only 20% of the County was taken up by crops (Table 2). Since then, the increasing efficiency of land-clearance methods has made large-scale clearance both feasible and economical, with the result that mallee areas which had formerly been passed over were subsequently cleared. The rate of vegetation clearance from the turn of the century to the present day can only be surmised, but by 1973 only about 4% of the County retained significant vegetation (Vegetation Clearance Report, 1976). The majority of this 4% was made up of mangroves and samphire swamps adjoining the coastline. The native vegetation throughout the rest of the County had been reduced to sand dunes, roadside verges, cemeteries and council reserves. Aerial photographs of the area taken in 1949 and 1977 clearly show the attrition of native vegetation on the sand dunes (Fig. 3).

Notwithstanding Goyder's initial recommendation that, owing to the nature of the country, farming blocks within this area should be large, both economic factors and agricultural advances have combined to force farmers into maximizing production of their land. Areas such as the sand dunes, which were formerly regarded as being too susceptible to soil erosion, have been cleared and put under crops. Another factor mitigating against the existence of vegetation on the sand dunes is the economic value of their constituent sands.

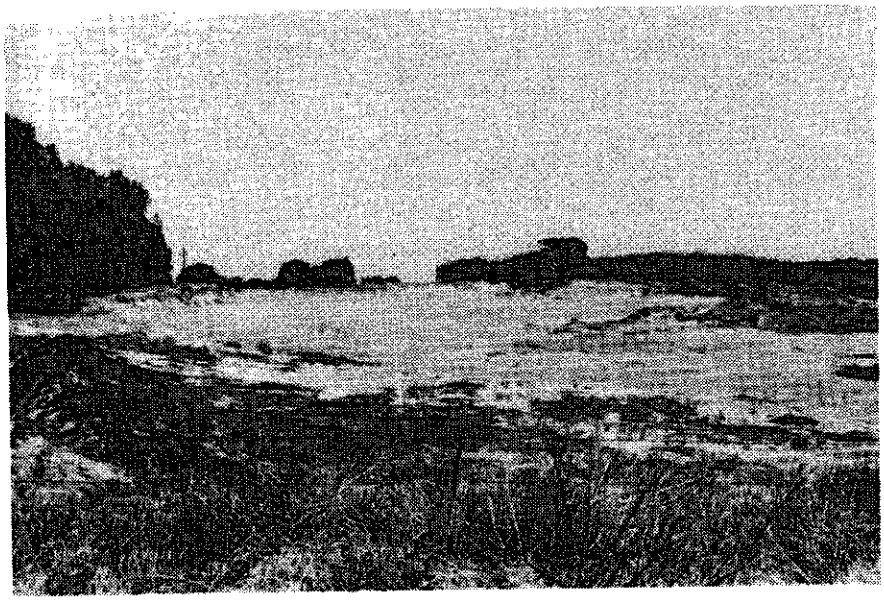

Fig. 4(a)

Former sand mining site. Note lack of basic restorative measures and susceptibility of area to wind induced soil erosion.

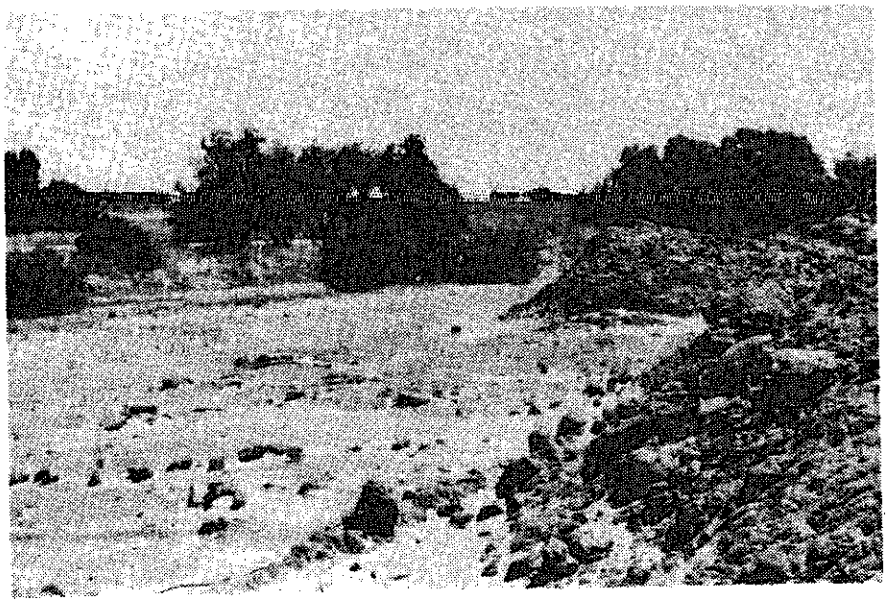

Fig. 4(b)

Illustrating lack of systematic site development

2. SAND MINING

Sand-mining operations have been underway in the district since 1964. As of 27 February 1979 nine Private Mines, two Extractive Mineral Leases and two Mining Claims were held in the area (Table 3, Fig. 2). Although the majority of the land taken up for sand-mining is currently devoid of native vegetation, the remainder encompasses some of the only remaining sand dunes with endemic flora. If the current operations follow what appears to be normal practice in this area, the dunes will be cleared, their constituent sands excavated and the area sown to pasture or cereal crops by the land-holder or alternatively left derelict.

The lack of rehabilitation measures and systematic site development of sand-mining operations in this area is common. An inspection of former and current mining sites revealed that little regard has been given to amelioration of the impacts of sand-mining activities. Worked-out sand mines are often left as derelict land with little regard for even the most basic restorative measures; e.g., battering of slopes (Fig. 4a). Where such areas abut public roads they constitute a significant detraction from the rural scene. Furthermore, such sites are centres of soil erosion and as such can create problems for adjacent lands. In general, operators of sand mines have shown no systematic approach in the development of a site (Fig. 4b). If operators can be encouraged to develop a site systematically this will lead, not only to more efficient utilization of the sands, but also to minimized restorative measures being required upon completion of mining.

The current requirements of sand-mining operators with regard to rehabilitation or amenity of sites are laid out in the Regulations under the Mines and Works Inspection Act, 1920-1970. The policing of these regulations is the responsibility of the Chief Inspector, Department of Mines and Energy. However, the large number of mines and quarries in relation to the current numbers of Inspectors precludes a stringent policing of the regulations, particularly with regard to amenity and rehabilitation of disturbed sites. The problem is, however, receiving more attention of late and it is expected that the aspect of rehabilitation measures will come to figure more prominently in the conditions associated with the granting and operation of Extractive Mineral Leases.

With regard to operations, both past and present, in the study area, an assessment of the problems and preliminary guidelines for their

resolution have been drawn up. These observations and discussion of the problem are presented in the remainder of this Report, and it is hoped that the ensuing discussion will form a basis upon which practical solutions to the problems of rehabilitation and systematic site development can be founded.

3. REHABILITATION - RESTORATION - RECLAMATION

In discussing the operation and treatment of sand-mining sites it is most important that the eventual use of the site be kept in mind. For instance, the terms 'restoration', 'rehabilitation' and 'reclamation' all imply a re-working of the site, but their respective starting points and end results may often differ depending upon their definition. In Britain the Commission on Mining and the Environment* defined the three terms as follows:

- Restoration: recreating conditions suitable for the previous use of the area.
- Rehabilitation: creating conditions for a new and substantially different use of the site.
- Reclamation: returning a derelict site to some use.

Other definitions conveying subtle differences amongst the terms can be found but the following discussion will adhere to the foregoing definitions.

The stabilization of soils within and adjacent to former sand-mining operations may prove difficult. A common practice for stabilization of sandy soils is to sow such sites with crops or pasture plants (McCord, 1975). However, the efficacy of this practice in stabilizing light sands is subject to vagaries of the climate. In years of normal rainfall this practice effectively reduces both wind- and water-induced erosion of the soils. In years of below-average rainfall the plant growth is reduced, and as the season advances the soils become increasingly susceptible to the action of strong winds. Paradoxically, the efficacy of the crops in reducing erosion is lowest when the need for them is greatest. Therefore, even though cropping may initially be judged as the most appropriate and least expensive option, it can in the long term - owing to the recurring problem of soil erosion - prove to be the most environmentally unacceptable.

In spite of these limitations, cropping of a former sand-mining site may provide an initial stabilization of these sites. Following this initial stabilization, native plants can be introduced and during their early development will undoubtedly benefit from the protection afforded by the crops used to stabilize the site.

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*Great Britain. Commission on Mining and the Environment. Report (1972) Chairman: Lord Zuckerman. London: H.M.S.O. 92 pp.

The various options open to operator/owners of sand-mining sites should be borne in mind when operating and reclamation procedures are being drawn up. Within the study area where mixed farming is the principal land use, the property owner would most probably favour sowing the former sand-mining site with cereal crops or pasture plants. As has already been stated, this practice is only partially successful in stabilizing the loose sands on these sites and it would be preferable, particularly where vegetated dunes were initially involved, to retain, supplement and encourage native trees, shrubs and ground cover.

In addition to improved long-term stabilization of the loose sands, the establishment of native plants upon former sand-mining sites has a number of other benefits over cropping. These areas will enhance the rural landscape through added diversity, provide corridors for movement of fauna, retain vestiges of the native flora and provide habitat for sedentary fauna - e.g., birds, lizards, insects. These areas will also mitigate the effects of strong winds upon adjacent crops and, if lightly stocked, will provide shelter for farm animals.

As the promotion of native flora on these sites confers many advantages, it is appropriate that some general guidelines relating to perpetuation or establishment of it be given. As soil conservation will be the primary objective of such procedures, this aspect must receive consideration in operation of the site and methods of site workings.

The single most important agent of soil erosion in this area is wind. Consequently, abatement or mitigation of winds will figure prominently in the following guidelines. As specific guidelines could be restrictive it is proposed to cite the nature of the problem and to then present general guidelines for its resolution.

3.1 Wind Erosion

The ability of wind to transport sand is a function of its velocity and the grain size of the sand subjected to it (Fig. 5a, b). The threshold velocity of average dune sands (grain size about 0.25 mm diameter) is about 6 m/sec (21.6 km/h; Fig. 5b). The average grain size of dune sands in the study area is slightly smaller than this (between 0.1-0.2 mm diameter; Hiern, 1968) consequently threshold wind velocities for sand movement would be slightly lower. However, Fig. 6a does serve to illustrate the rapid rise in sand-carrying capacity of wind as its velocity increases.

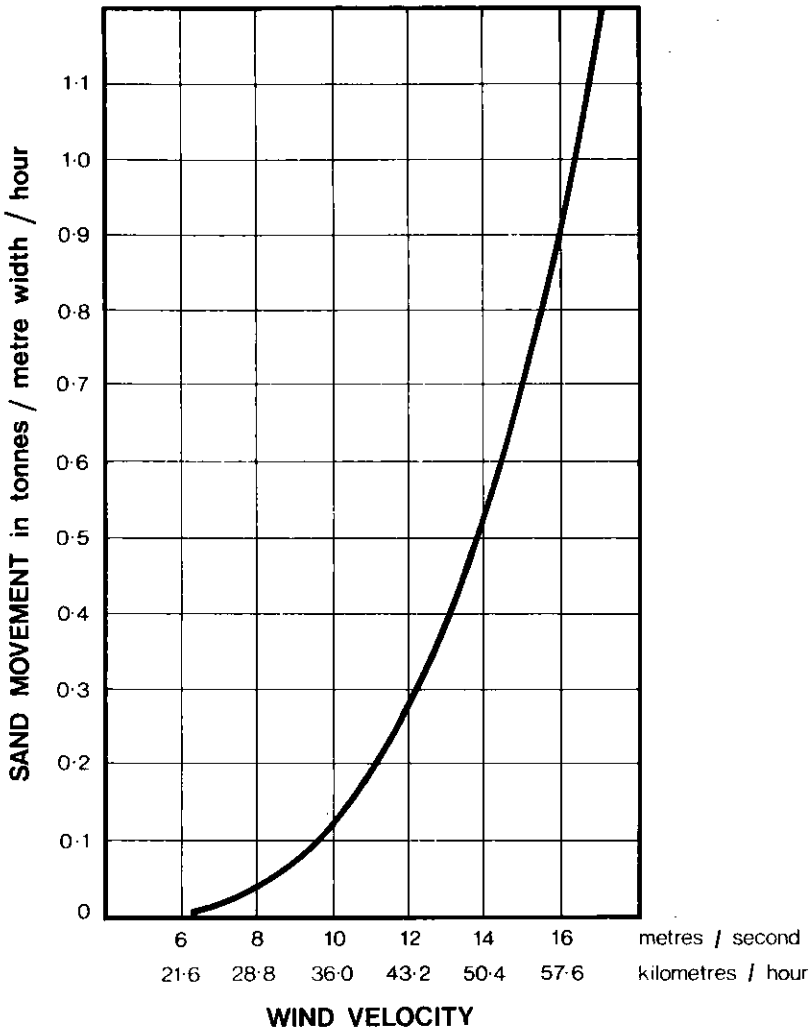

Fig 5a **Influence of wind velocity upon sand movement**

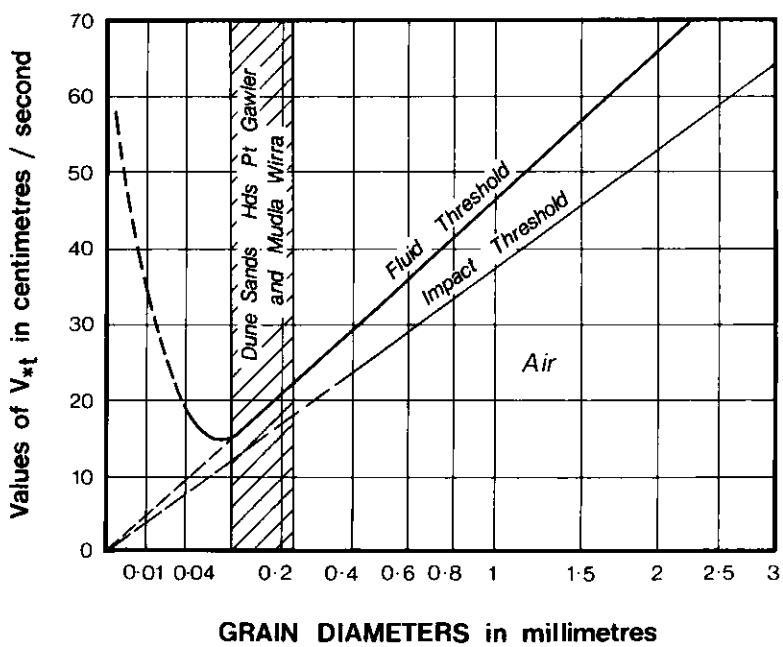

Fig 5b **Variation in threshold velocity with size of sand particles**

After Bagnold (1941)

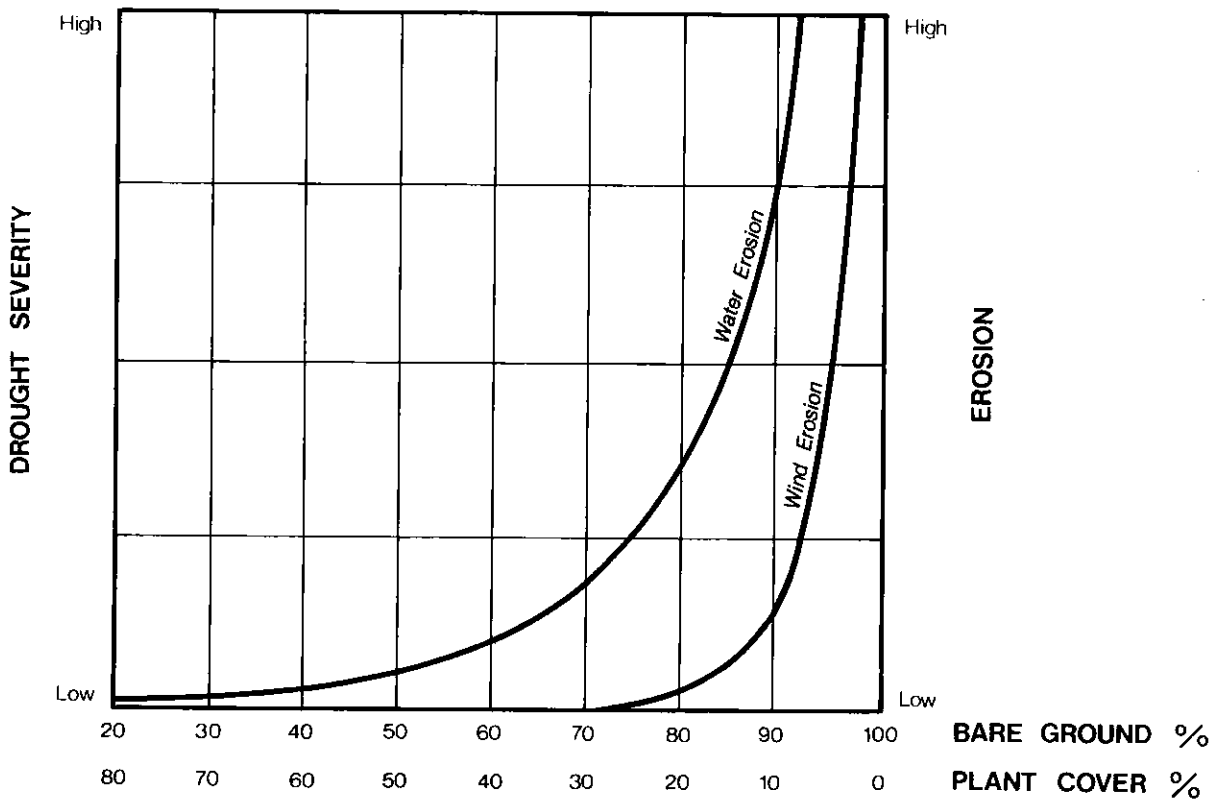

Fig. 6 **Interrelationship of plant cover and soil erosion by wind and water**

After Marshall (1972)

Figure 6a also illustrates that for any given dune the principal variable influencing movement of sand will be the velocity of the wind. The grain size of the constituent sands will be relatively stable through time. However, the exposure of the sands to wind action is almost directly proportional to the amount of plant cover on or adjoining the site (Fig. 6). The plants bind the loose sands, by means of their root systems and through their vegetative growth confer a degree of surface roughness which creates local eddies in the wind stream which abate the sand-carrying capacity of the winds. The plants which will confer the maximum protection in this regard are those having a low and sprawling habit; e.g., *Enchylaena tomentosa* (Marshall, 1970).

Another important variable influencing sand movement is the current soil moisture-content which is principally dependent upon interactions between the soil's capacity to retain water (i.e., its make-up, recent rainfall and the amount of evapotranspiration taking place). The water-holding capacity of sand is relatively very low, consequently the two most important factors in this area are rainfall and evapo-transpiration. As plants are absent from sand-mining sites, trans-piration is not a major factor. Annual variations in rainfall and evaporation are shown in Fig. 7 together with the direction and incidence of winds exceeding 20 km/h. Rainfall is lowest between November and March, when evaporation is highest. Within this period winds are mainly from the south-west, therefore any disturbances of the sand dunes during this period should have due regard for the erosional potential of these winds.

It should perhaps be mentioned that the south-western prevailing winds in the area are at right-angles to the NW/SE dune alignment, which suggests that the conditions under which the dunes where formed have most probably changed. Consequently, if the present surface stability of the dunes is upset the sands will readily drift.

3.2 Sand-Mining Procedures and Recommendations

Sand-mining operations by their nature may require the removal of some vegetation but will certainly entail some disruption of what are relatively stable soil conditions. Therefore, even though the operations

occupy a relatively small area, they may contribute to sand drift and so affect areas outside the actual sites. Because of this, it is important to operate these sites in a manner which will minimise sand drift within and from them. The three aspects of sand-mining operations to be considered in this respect are: (a) Site selection, (b) Site development and operation, (c) Site stabilization.

3.2.1 Site Selection

Before initiating any work on new sites, consideration should be given to utilisation of previously-worked sites which still have economic deposits. In this way, resource utilisation would be maximised and unwarranted disruptions to the landscape would be minimised.

The selection of new sites for sand-mining operations should be done with regard to amenity of the landscape and the reclamation requirements of the site. Amenity can generally be maintained through selection of the site with attention to neighbouring embankments, current vegetation screens and visibility from public roads.

The need for reclamation should also figure prominently in site selection. Sites totally devoid of native vegetation should be worked first. The working and reclamation of these sites would hopefully reduce their susceptibility to wind erosion. In nominating sites with vegetative cover, priority should be given to those having no native vegetation. In the study area the number of dunes which currently support native vegetation is very small while the number of cleared dunes is high. If new sand operations can be justified they should not be allowed on the remaining vegetated dunes of this area.

3.2.2 Site Operations

Prior to initiating operation on a site, consideration should be given to a systematic extraction and rehabilitation of the site as development proceeds. As the prevailing winds in this area are from the south-west, the south-western aspect of the dunes should not be disrupted either by operations on the site or traffic to and from it; operations should be restricted to the lee side of the dunes. Within this area it is suggested that, if practical, site development should begin at the south-east end of the dunes. Through doing this it is hoped that a

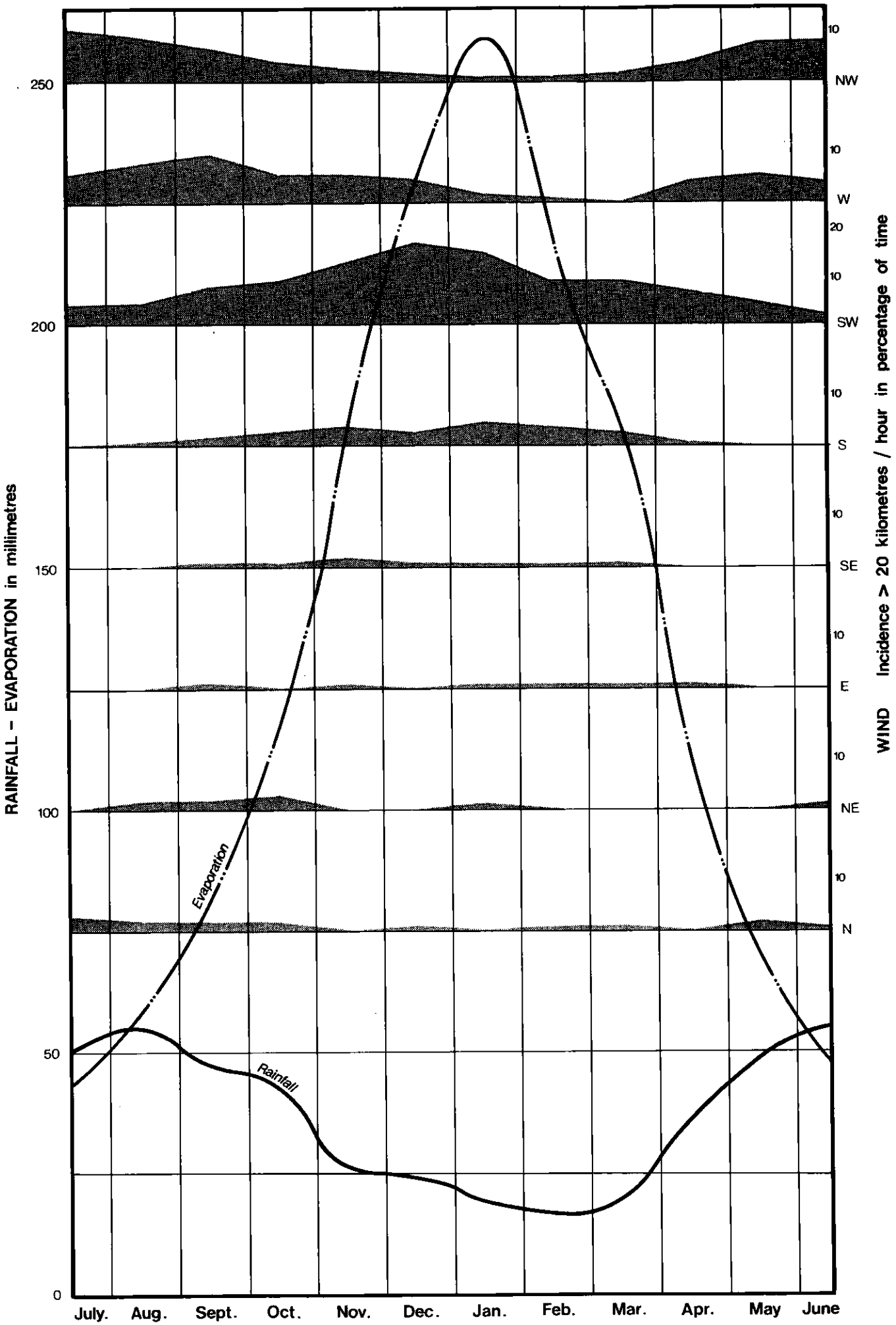

Fig. 7 Variation in average annual rainfall , evaporation and incidence of winds exceeding 20 km/hr

degree of protection from the north-west winds will be afforded by the working face of the dune as the operation moves north-west through the dune. On vegetated dunes work should not proceed past the crest. With site development, work would be in a north-west direction along the dune with the succession of sites being reclaimed as the work is extended.

The first step in site development should be the stockpiling of the overburden from the site in an area adjacent to it. The depth of overburden removed should not be less than 30 cm as this layer will contain the majority of soil nutrients, seeds, etc.

The extent of the operations should not exceed that necessary for manoeuvrability of plant and efficient operation of the site. This will minimize the effects of winds on sand movement by avoiding reaches over which wind can pass.

Any trees uprooted in the course of the overburden removal should be placed on the stockpiled overburden, and ultimately either be incorporated with it or burned prior to redistribution of it over the site. Retention of trees should be given high priority in site development.

Operations within a site should avoid stripping of the overlying sand to expose underlying calcrete or impermeable layers. A minimum of 30 cm is tentatively recommended as the thickness of sand to be left over the calcrete horizon.

3.2.3 Site Reclamation

The time and expense of reclaiming sites will be proportional to the disruption caused through the extractive procedures. If site development has been orderly the reclamation procedures should be carried out quickly. Any impervious substrate exposed in the course of the working should be ripped prior to redistribution of the overburden. Where gradients are present care must be taken to ensure that such ripping is along the contours rather than across them. The intention here is to prevent concentration of water and to reduce the likelihood of water-induced erosion which has been noted on some sites.

In respreading the overburden, a measure of surface roughness should be retained; a surface which is too smooth will increase the susceptibility of the soil to erosion by wind and/or water.

All batters should be regraded to a slope of at least 1:3 and preferably, in the case of sandy soils, 1:6. Material for this regrade should be from the working face and not consist entirely of overburden.

As development of the site proceeds there should be in its wake a series of sites which have been regraded and are in a state which will encourage natural regeneration of plant cover. In the first stages of reclamation, it is vital to promote growth of soil-binding plants which will stabilize the loose sands. Seeds of low, sprawling plants should be sown, in preference to trees or tall shrubs which could be introduced after the initial colonization has occurred (see Appendix C for appropriate plants).

If the south-west aspect of the dune is vegetated, an effort should be made to increase the density of shrubs by broadcast seeding within small areas together with the exclusion of stock from these particular areas. The resultant greater density of the scrub will improve its utility as a windbreak, while the denser understorey will favour the presence of small, sedentary species of birds. The plant species most suited for these purposes could be selected from the list of plants in Appendix C.

As with any remedial action, there is a need for monitoring of the efficiency of the procedures followed. With such information it becomes possible to modify procedures in the light of past experience and so tailor procedures to meet the specific needs of a site.

4. SUMMARY

The aims of this study were initially stated in the Introduction. These aims are reiterated here, and the principal findings and recommendations pertinent to each of them are summarized. The aims, findings and recommendations are:

Aim (i) To report upon the extent, nature and significance of the native vegetation remaining within the area.

Findings: The original flora of this region has been largely cleared. The relic sand dunes which were initially a major component of the landscape have been reduced both in numbers and character. Many dunes have been cleared of their native vegetation and the sites sown to cereal or pasture. Upon results of this current assessment, it is speculated that all of the dunes retaining vestiges of native flora have only the major vegetative components present. The incidence of shrubs and ground cover formerly characterizing these sites has been reduced through grazing by stock. The occurrence of these particular plant species is now reduced to road verges and public lands; e.g., cemeteries, stone reserves, etc.

Aim (ii) To recommend upon the basis of that assessment areas which should be retained for their intrinsic character.

Assessment and Recommendation:

While the native vegetation of this area is not unique within the State, it does constitute the closest occurrence of this association to the metropolitan area. Its proximity to Adelaide makes it convenient for excursions by educational or naturalist groups who wish to visit this type of association. The sand comprising the relic dunes is very susceptible to wind erosion and the remaining native flora serves to retain these dunes in a stable state. For these reasons it is recommended:

- that clearing of any native flora within this region be discouraged;
- that encouragement be given to the retention and reinforcement through planting of native flora present within the area;

- that approaches be made to local councils to advocate the retention of native flora on all road reserves and that management of road reserves follows a course in the best interests of the native flora and associated fauna.

Aim (iii) To recommend procedures and techniques for the amelioration of sand-mining operations and for the restoration of areas previously mined to a stable state.

Recommendation:

Although sand-mining operations occupy a relatively small area they have the potential of initiating soil movements which can affect large areas. Sand-mining operations in this area also pay little regard to efficient extraction of sands and the restoration of such sites to stable situations. For these reasons it is recommended:

- that sand-mining operators be encouraged to adopt site procedures which will maximize utilization of the resource and minimize impacts, both physical and visual, of sand mining upon the environment. Tentative guidelines are laid down in the section of the Report which deals with sand-mining operations.
- that former sand-mining sites upon which restoration procedures have not been carried out be restored to a stable state. The procedures and general guidelines for this work are presented in the section of this Report which deals with restoration.
- that the operation and restoration of sand-mining sites be monitored by the Department of Mines and Energy in association with the Department for the Environment.

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TABLE 1a: TYPE PROFILES FOR SOILS FOUND WITHIN THE STUDY AREA
(DEPT AGRICULTURE AND FISHERIES, S.A. SPECIAL BULL. No. 1.68)

Depth (cm)	Sandy Mallee Cereals and grazing; liable to drift; poor water-holding capacity.	Depth (cm)	Mallee Sand Cereals and grazing.	Depth (cm)	Loamy Mallee Cereals and grazing; large water-holding capacity.
0-76	Brown, yellow brown or pale reddish brown sand with occasionally some fine lime	0-8	Loose grey to brownish sand	0-10	Brown to reddish brown friable sandy loam to loam with traces of fine lime
		8-76	Pale brown to light grey sand.		
76-102	Brown or reddish brown loamy sand on clayey sand with slight to moderate fine lime	76-102	Reddish yellow sand with fine lime	10-23	Brownish red clay loam or sandy clay loam with slight to moderate fine lime
102+	Yellowish brown clayey sand with fine lime and/or nodular limestone			23-37	Abundant nodular limestone with a travertine capping, fine lime and clay loam
				37-90	Light clay with abundant fine lime and some nodular limestone

TABLE 1b: TYPE PROFILES FOR SOILS FOUND WITHIN THE STUDY AREA - ASSOCIATED VEGETATION

Sandy Mallee	Loamy Mallee
(1) Leached Sandhills	
Mallee Species:	**Mallee Species:**
Eucalyptus incrassatta, E. oleosa var. glauca	
Shrubs:	**Shrubs:**
Melaleuca uncinata, Lasiopetalum spp., Spyridum spp., Leptospermum coriaceum, Casuarina muelleriana	*Eucalyptus porsoa, E. odorata, E. gracillis, E. anceps, E. calycogona*
(2) Flats	
Mallee:	*Pittosporum phyllyreoides, Eremophila longifolia, Acacia retinodes, Casuarina arcuata. Alyxia buxifolia*
Eucalyptus oleosa, Eougracilus, E. brachycalyx, E. flocktianiae	
Others:	
Callitris spp., Heterodendron oleifolium, Melaleuca pubescens, Casuarina cristata	

TABLE 2: CHANGES IN LAND USE FOR COUNTY GAWLER AND PRESENT-DAY PURSUITS IN HDS OF PORT GAWLER AND MUDLA WIRRA.

	County Gawler				Hd Pt Gawler		Hd Mudla Wirra	
Area (ha)	240 356				33 929		28 360	
Under Cultivation as of 31/3/1901	234 446				-		-	
	31/3/1903		1975-76		31/3/76		31/3/76	
	Area (ha)	%	Area (ha)	%	Area (ha)	%	Area (ha)	%
Wheat	44 768	96.9	36 766	43.2	2 431	31.5	4 063	36.5
Barley	333	0.7	43 961	51.6	5 094	65.8	6 736	60.4
Oats	1 121	2.4	4 436	5.2	212	2.7	348	3.1
Stock	(1901)		(1975)					
Cattle								
Meat	2 562		17 300		3 057		1 707	
Milk	2 818		2 523		755		984	
Sheep	104 640		347 592		34 644		43 860	

TABLE 3: DETAILS OF PRIVATE MINES
EXTRACTIVE MINERAL LEASES AND MINERAL CLAIMS IN HDS
OF PORT GAWLER AND MUDLA WIRRA (SOUTH), CO. GAWLER

Licence	Held By	Hd Section	Volume Folio	Gazetted
Private Mine 51	Sloan Sands Pty Ltd	Port Gawler 642	3625/ 89	1/3/73
Private Mine 52	Sloan Sands Pty Ltd	Port Gawler 643	2197/ 70	1/3/73
Private Mine 63	Sloan Sands Pty Ltd	Port Gawler 646	1812/ 56	8/3/73
Private Mine 64	Sloan Sands Pty Ltd	Port Gawler 647	1579/ 125	8/3/73
Private Mine 195	Boundrina Pty Ltd	Mudla Wirra/869 Port Gawler/665	3377/ 90	11/10/73
Private Mine 198	H.W. Haydon & Sons	Port Gawler 614, 648/9	1636/15 3486/13	25/10/73
Private Mine 209	H.W. Haydon & Sons	Port Gawler 637, 639,640,641,652, 653	4075/799 3681/168	22/11/73
Private Mine 226	H.W. Haydon & Sons	Port Gawler 633	1616/ 11	21/2/74
Private Mine 228	M.D. Goss	Port Gawler 650, 651	1061/147 782/32	14/3/74
*E.M.L. 4491	D. Clairmont; A. East	Port Gawler 655	3625/ 117	Duration 13/1/76 - 12/1/81
E.M.L. 4589	A. Krieg	Mudla Wirra 873	3097/ 162	Duration 22/7/77 - 21/7/84
Mineral Claim 998	D.L. & D.V. Bennett, Willaston	Mudla Wirra 728	Application	25/9/78
Mineral Claim 1103	D.L. & D.V. Bennett, Willaston	Mudla Wirra 417	Application	8/1/79

* Extractive Mineral Lease.

MINUTES forming ENCLOSURE to DE *No.* 3237/77 *19*

APPENDIX A
ACTION MEMO

TO ENVIRONMENTAL OFFICER CASPERSON:

RE: Loam Extraction - Reeves Plain area

As we discussed recently, I would like you to prepare a report on the environmental significance of the relic sand dunes and their associated flora in the Reeves Plain/Roseworthy/Mallala area of the Adelaide Plains.

The dunes occupy prime farming land long-cleared for cereal growing but, because of their light erosion-prone sands, most have been left uncleared. Recently, however, the dunes and their associated vegetation have come under increasing pressure from extractive industry, for the sands (described in the trade as "Reeves Plain loams") are finding increasing acceptance as a better-textured garden soil than the once commonly-used "Gawler River loam".

Although academic workers, at Adelaide University in particular, have appreciated for some time the botanical and biogeographical significance of these dunes you will find relatively little published material and some field work will be essential.

You should concentrate, initially, on accumulating as much objective data on the dunes as possible. This data should then form the basis of a position paper or series of recommendations as to what stance this Department should adopt in relation to possible protection of the dunes. As far as possible a realistic attitude should be taken and a proposal which can reconcile or minimise the growing conflict between conservation and extractive industry needs would be desirable.

I think there is probably a more urgent need for this report than we first anticipated and you should aim to have it completed within four months.

Colin R. Harris
ACTING
SENIOR ENVIRONMENTAL OFFICER (PROJECTS)

CRH:JL
7.7.77

APPENDIX B

VEGETATION DESCRIPTION FROM ORIGINAL SURVEY, HDS - PORT GAWLER MUDLA WIRRA, CO. GAWLER, 1863, 1866

HD Port Gawler	Comments
Section	
116	Good, arable land
117	Good, arable land
115	Arable and pasture, scrubby
626	Arable and pasture, scrubby
627	Arable and pasture, scrubby
633	Rough pasture, sandhills and dense mallee scrub
634	Rough pasture, sandhills and dense mallee scrub
635	Sandy pasture, dense mallee scrub, a little timber, no surface water
636	Scrub, a little timber
642	Scrub, a little timber
643	Pasture, arable sandy soil, dense mallee scrub
644	Pasture, arable sandy soil, dense mallee scrub
646	Pasture, arable sandy soil, dense mallee scrub
647	Pasture, arable sandy soil, dense mallee scrub
648	Rough pasture, sandhills and dense mallee scrub
651	Rough pasture, sandhills and dense mallee scrub
655	Undulating country, sandy soil on scrubby ridges with red to darker soil in immediate flats
652	Sandy pasture, dense mallee scrub, a little timber, no surface water
654	Sandy pasture, dense mallee scrub, a little timber, no surface water
656	Sandy pasture, dense mallee scrub, a little timber, no surface water
657	Sandy pasture, dense mallee scrub, a little timber, no surface water
659	Sandy pasture, dense mallee scrub, a little timber, no surface water
843	Thickly wooded and scrubby
862	Thickly wooded and scrubby

Hd Mudla Wirra	Comments
419	Good land, part scrubby, timber Peppermint
495	Good land, part scrubby, timber Peppermint
496	Good land, part scrubby, timber Peppermint
498	Pasture land, little scrubby
655	Pine
666	Pine
667	Timber
711	Arable land, thickly wooded, Peppermint Gum and Mallee Scrub
721	Arable land, thickly wooded, Peppermint Gum and Mallee Scrub
729	Good pasture land, thickly timbered with Pine and Mallee, no water
738	Good pasture land, thickly timbered with Pine and Mallee, no water
786	Pasture land, dense scrub and very sandy, no water
787	Pasture land, dense scrub and very sandy, no water
789	Pasture land, dense scrub and very sandy, no water
809	Thickly timbered
826	Thickly timbered
827	Parts arable
832	Parts arable
833	Thickly timbered
839	Thickly timbered
840	Parts arable
842	Parts arable
843	Thickly wooded and sandy
848	Thickly wooded and sandy
851	Thickly wooded and sandy
858	Thickly wooded and sandy
860	Thickly wooded and sandy
862	Thickly wooded and sandy
873	Lightly timbered: Quarry D.C.M.W.
874	Lightly timbered: Quarry D.C.M.W.
879	Lightly timbered: Quarry D.C.M.W.
881	Lightly timbered: Quarry D.C.M.W.

APPENDIX C

Botanical Studies Within The Region

Species	Life Form			Sand Dunes Bramsey *et al.* (1977)				Cleland (1953)	Kraehen-buehl (1975)	Other (1977)	Picard (1977)
	Trees >5m	Shrub >2<5m	Herb >10cm <2m	1	2	3	4				
APOCYNACEAE											
Alyxia buxifolia		Φ				Δ					
BORAGINACEAE											
**Echium plantigineum*			Φ	Δ							
CAMPANULACEAE											
Wahlenbergia stricta			Φ							Δ	
CASUARINACEAE											
Casuarina muellerana	Φ				Δ			Δ	Δ		
C. stricta											Δ
CHENOPODIACEAE											
Enchylaena tomentosa			Φ					Δ		Δ	Δ
Rhagodia parabolica			Φ					Δ		Δ	Δ
R. nutans			Φ					Δ		Δ	
COMPOSITAE											
Cymbonotus lawsonianus			Φ	Δ							
Erechthites quadridentata			Φ					Δ			
Calocephalus drummondi			Φ					Δ			
Olearia pimelioides			Φ					Δ			
Helichrysum leucopsidium			Φ	Δ				Δ			Δ
H. apiculatum			Φ					Δ			
Millotia tenuifolia			Φ					Δ			
Unknown Compositae			Φ					Δ			
Senecio brachyglossus			Φ					Δ			
S. lautus			Φ					Δ			
Vittadinia triloba			Φ					Δ			
**Arctotheca calendula*			Φ	Δ	Δ	Δ	Δ				
CRUCIFERACEAE											
**Brassica tournefortii*			Φ	?	?		?	Δ			
Lepidium hyssopifolium				?	?		?	Δ			
CYPERACEAE											
Lepidosperma carphoides			Φ	Δ				Δ			
L. laterale			Φ	Δ	Δ			Δ			
L. congestum			Φ					Δ			
DILLENIACEAE											
Hibbertia virgata			Φ	Δ				Δ			

*Introduced

ΦLife Form

ΔPresent

Botanical Studies within The Region - cont.

Species	Life Form: Trees >5m	Shrub <2>5m	Herb >10cm <2m	Sand Dunes Bramsey *et al.* (1977): 1	2	3	4	Cleland (1953)	Kraehenbuehl (1975)	Other (1977)	Picard (1977)
EPACRIDACEAE											
Astroloma conostephioides			Φ					Δ		Δ	
Leucopogon cordifolius			Φ					Δ	Δ		
EUPHORBIACEAE											
Beyeria leschenaultii											Δ
GERANIACEAE											
**Erodium moschatum*			Φ							Δ	
**E. botrys*			Φ					Δ			
**E. cicutarium*			Φ					Δ			
GOODENIACEAE											
Dampiera rosmarinifolia			Φ	Δ				Δ	Δ		
Goodenia affinis			Φ					Δ			Δ
HALORAGAGEAE											
Loudonia behrii			Φ					Δ		Δ	
LEGUMINOSAE											
Acacia ligulata								Δ		Δ	Δ
A. microcarpa								Δ	Δ		
A. notablis								Δ			
A. pycnantha											Δ
A. rigens								Δ			
A. rotundifolia											Δ
A. sclerophylla								Δ	Δ		Δ
A. spinescens			Φ	Δ				Δ			Δ
Cassia sturtii								Δ			
C. nemophila								Δ			Δ
**Trifolium arvense*			Φ							Δ	
**Vicia calcarata*								Δ			
Kennedia prostrata			Φ					Δ			
Eutaxia microphylla											Δ
LABIATAE											
Westringea rigida											Δ
LAURACEAE											
Cassytha melantha										Δ	
C. pubescens								Δ			
LILIACEAE											
**Asparagus asparagoides*			Φ	Δ							
**A. medeolides*								Δ			
**Asphodelus fistulosus*								Δ			

*Introduced

ΦLife Form

ΔPresent

Botanical Studies Within The Region - cont.

Species	Life Form			Sand Dunes Bramsey *et al.* (1977)				Cleland (1953)	Kraehen-buehl (1975)	Other (1977)	Picard (1977)
	Trees >5m	Shrub <2>5m	Herb >10cm <2m	1	2	3	4				
Diannella laevis			Φ	Δ				Δ			
D. revoluta											Δ
Lomandra leucocephala			Φ					Δ	Δ		
L. micrantha			Φ					Δ			
L. effusa											Δ
Lomandra sp.			Φ					Δ			
Xanthorrhoea sp.			Φ					Δ			
Thysanotus patersonii			Φ					Δ		Δ	
MYRTACEAE											
Eucalyptus anceps	Φ							Δ	Δ		
E. brachycalyx	Φ										Δ
E. dumosa	Φ						Δ				
E. incrassata	Φ	Φ		Δ	Δ	Δ	Δ	Δ			
E. largiflorens	Φ										Δ
E. microcarpa	Φ					Δ					
E. odorata	Φ							Δ		Δ	Δ
E. oleosa	Φ							Δ		Δ	
E. porosa	Φ										Δ
E. socialis	Φ										Δ
MYOPORACEAE											
Myoporum platycarpum	Φ										Δ
Eremophila longifolia		Φ									Δ
Calytrix tetragona			Φ					Δ		Δ	
Calytrix involucrata									Δ		
Kunzea pomifera								Δ			
Melaleuca acuminata								Δ		Δ	
M. lanceolata								Δ		Δ	Δ
OXALIDACEAE											
Oxalis corniculata			Φ					Δ			
**O. cernua*			Φ					Δ			
**O. pescaprae*			Φ							Δ	
POACEAE											
Avena barbata			Φ							Δ	
Stipa falcata			Φ		Δ						
S. elegantissima			Φ		Δ			Δ			
**Hordeum leporinum*			Φ		Δ	Δ	Δ				
Triodia irritans			Φ		Δ			Δ			
**Molineria minuta*			Φ					Δ			
PITTOSPORACEAE											
Pittosporum phylliraeoides										Δ	Δ
Bursaria spinosa								Δ		Δ	Δ
PINACEAE											
Callitris preissii	Φ	Φ			Δ	Δ	Δ	Δ			Δ

*Introduced

ΦLife Form

ΔPresent

Botanical Studies Within The Region - cont.

Species	Life Form			Sand Dunes Bramsey *et al.* (1977)							
	Trees >5m	Shrub <2>5m	Herb >10cm <2m	1	2	3	4	Cleland (1953)	Kraehen-buehl (1975)	Other (1977)	Picard (1977)
PRIMULACEAE											
**Anagallis arvensis var. caerulea*			Φ		Δ	Δ					
POLYGONACEAE											
**Emex australis*			Φ							Δ	
Muehlenbeckia adpressa								Δ		Δ	
Comesperma volubile											Δ
PORTULACEAE											
Calandrinia eremaea			Φ		Δ						
C. calyptrata			Φ					Δ			
C. pygmaea			Φ					Δ			
PROTEACEAE											
Hakea muelleriana								Δ	Δ	Δ	
Grevillea ilicifolia								Δ	Δ		
G. huegelii											Δ
RANUNCULACEAE											
Clematis microphylla			Φ		Δ			Δ			Δ
RHAMNACEAE											
Cryptandra tomentosa			Φ					Δ		Δ	
Spyridium subochreatum			Φ					Δ	Δ	Δ	
SAPINDACERE											
Doedonaea viscosa											Δ
SANTALACEAE											
Exocarpous sparteus	Φ							Δ		Δ	
Santalum acuminata	Φ							Δ			
SOLONACEAE											
**Lycium ferrocissimum*								Δ		Δ	
L. australe								Δ			
Solanum aviculare or simile								Δ			
S. nigrum								Δ			
STERCULIACEAE											
Lasiopetalum behrii								Δ		Δ	
THYMELEACEAE											
Pimelea serpyllifolia											Δ
UMBELLIFERAE											
Daucus glochidiatus			Φ	Δ				Δ			

*Introduced species

ΦLife Form

ΔPresent

APPENDIX D

FIELD METHODS (BRAMSEY *et al.* (1977) REEVES PLAINS

Plot 50 x 20 m = 1000 m^2= 0.01 ha

TREES (> 5 m)	All trees in 1000 m^2 plot sampled for	a) Tree Height b) Basal Area c) No. of Stems d) Line Intercept along 100 m
SHRUBS (< 5 m >2 m)	Sampled within 3 m strip along each 50 metre tape - measurement of intercept taken	
HERBS (> 10c m <2 m)	17, 1 x m^2 plots taken along centre tape. Within each plot measurements were taken of: a) av. height of each species b) av. coverage of each species	

Computations: See Page D-2

Species Identification

- identification of Eucalypts tentative
- identification using,
  BLACKS, J.M. *Flora of South Australia* (2nd edition) and the Supplement

Robert Bramsey
Peter Sullivan
Annette Wilson
Amanda Beecroft
Violetta Hodges

BASIS OF CALCULATIONS

Trees and Shrubs

Basal Area (BA) - obtain from tables provided to convert diameter to area.

Absolute CC (Canopy cover) Dominance = total length of Intercept (m).

Absolute BA Dominance = total BA (cm^2)

Absolute Density = total No. Individuals

$$\text{Relative CC Dominance} = \frac{\text{absolute CC dominance Sp. X}}{\text{total absolute CC dominance all spp.}}$$

$$\text{Relative BA Dominance} = \frac{\text{absolute BA dominance Sp. X}}{\text{total absolute BA dominance all spp.}}$$

$$\text{Relative Density} = \frac{\text{number of individuals Sp. X}}{\text{total individuals all spp.}}$$

Herb Layer

Absolute Cover = Total cover (dm^2)

$$\text{Relative Cover} = \frac{\text{absolute cover Sp. X}}{\text{total absolute cover all spp.}}$$

HERB STRATUM SAMPLE

Date: 24 Sept. 1977 Plot No. One

SPECIES	MEAN HEIGHT (m)	ABSOLUTE COVERAGE ($cm^2/100m^2$)	RELATIVE COVERAGE (%)
Lepidosperma laterale	0.3	1612	48.0
Cymbonotus lawsonianus	0.25	986	29.0
Hibbertia virgata	0.4	235	7.0
Lepidosperma carphoides	0.2	176	5.2
*Anagallis arvensis, var. caerulea**	0.15	118	3.5
Helichrysum leucopsidium	0.2	71	2.1
Dampiera rosmarinifolia	0.15	35	1.0
Loudonia behrii	0.15	29	0.86
Dianella laevis	0.25	24	0.72
Arctotheca calendula	0.1	24	0.72
Daucus glochidiatus	0.15	18	0.53
*Asparagus asparagoides**	0.40	12	0.34
*Echium lycopsis**	0.2	12	0.34
Acacia spinescens	0.25	6	0.18
Cruiferae *	0.2	6	0.18
*Rye Grass (Lolium sp.)**	0.15	6	0.18

Date: 24 Sept.1977 Plot No. Two

SPECIES	MEAN HEIGHT (m)	ABSOLUTE COVERAGE ($cm^2/100m^2$)	RELATIVE COVERAGE (%)
Triodia irritans	0.85	206	27.9
Compositae 1.	0.15	118	16.0
Clematis microphylla	0.50	106	14.0
Helichrysum leucopsidium	0.3	76	10.3
Cruiferae	0.15	41	5.5
Dampiera rosmarinifolia	0.3	32	4.5
Arctotheca calendula *	0.1	29	3.9
Graminoid 1.	0.1	29	3.9
Compositae 2.	0.1	24	3.6
Stipa sp.	0.35	18	2.6
Lepidosperma laterale	0.35	18	2.6
Anagallis aruensis, var. caerulea *	0.1	12	1.8
Hordeum leporinum *	0.5	6	0.81
Stipa elegantissima	0.3	6	0.81
Calandrinia eremaea	0.1	6	0.81

* Introduced.

D-4

HERB STRATUM SAMPLE

Date: 25 Sept.1977 Plot No. Three

SPECIES	MEAN HEIGHT (m)	ABSOLUTE COVERAGE ($cm^2/100m^2$)	RELATIVE COVERAGE (%)
Hordeum leporinum *	0.1	-	80
Arctotheca calendula *	0.1	-	20

Date: 25 Sept. 1977 Plot No. Four

SPECIES	MEAN HEIGHT (m)	ABSOLUTE COVERAGE ($cm^2/100m^2$)	RELATIVE COVERAGE (%)
Hordeum leporinum *	0.30	435	46
Arctotheca calendula *	0.10	259	27.1
Cruciferae *	0.40	165	17.3
Compositae	0.15	94	9.9

* Introduced.

TREES

SPECIES	(S) (MS) COVER	HEIGHT (metres)	ABSOLUTE DENSITY (No./-1000m^2)	RELATIVE DENSITY %	ABSOLUTE BASAL AREA COVERAGE (cm^2/-1000m^2)	RELATIVE B.A. COVERAGE %	ABSOLUTE CANOPY COVER (m^2)	RELATIVE CANOPY COVERAGE %
PLOT 1 24.9.77								
Eucalyptus incrassata	MS	5.0	23	100	8 512.92	100	34.62	100
PLOT 2 24.9.77								
E. incrassata 89.72	MS	5.0	66	94.29	11 018.90	94.80	44.5	88.72
Callitris preissii 10.28	MS	6.2	2	2.89	430.36	3.70	5.1	10.28
Casuarina muelleriana	S	5.0	2	2.89	173.32	1.49	-	-
					11 622.58			
PLOT 3 25.9.77								
Callitris preissii	S	6.8	54	93.10	7 527.22	91.56	41.83	69.92
Eucalyptus microcarpa	MS	15	4	6.89	693.28	8.43	13.9	23.23
					8 220.50			
E. incrassata	-	-	-	-	-	-	4.1	6.85
PLOT 4 25.9.77								
Eucalyptus incrassata	MS	5.7	15	46.88	2 103.15	23.18	29.9	40.35
E. dumosa	MS	5.2	13	40.62	3 863.01	42.57	18.8	25.37
Callitris preissii	S	6.2	4	12.50	3 107.58	34.25	25.7	34.68
					9 073.74			

SHRUBS

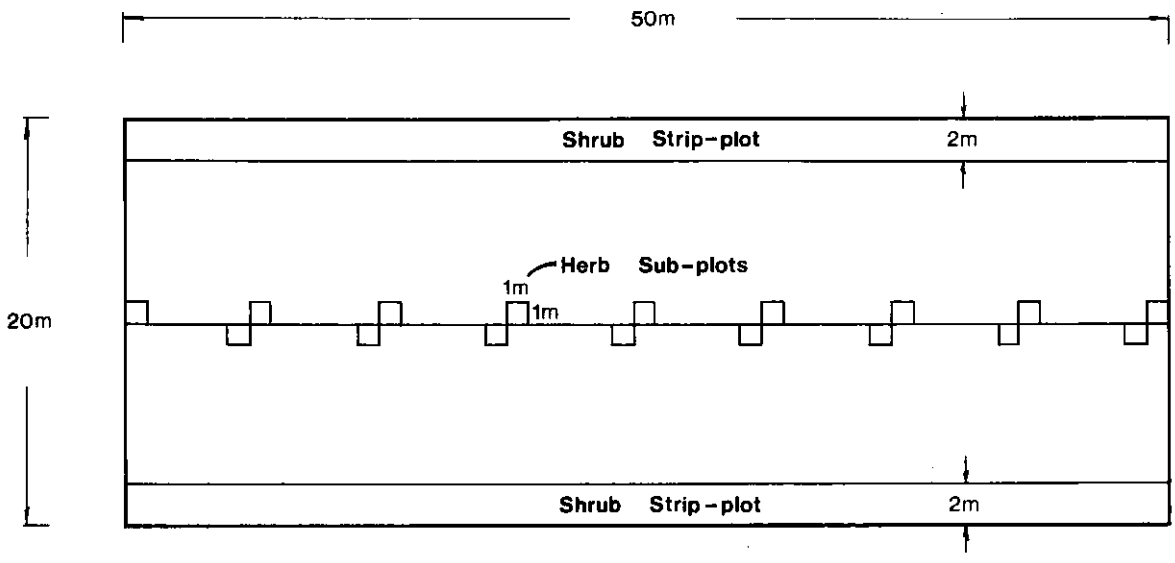
SPECIES	(S) (MS) COVER	HEIGHT (metres)	ABSOLUTE DENSITY (No./-1000m^2)	RELATIVE DENSITY %	ABSOLUTE BASAL AREA COVERAGE (cm^2/-1000m^2)	RELATIVE B.A. COVERAGE %	ABSOLUTE CANOPY COVER (m^2)	RELATIVE CANOPY COVERAGE %
PLOT 1								
E. incrassata	MS	4.5	1	100	-	-	1.9	100
PLOT 2								
E. incrassata	MS	3.38	4	100	-	-	8.44	100
PLOT 3								
Callitris preissii	S	3.75	2	66.6	-	-	3.7	59.67
Alyxia buxifolia	S	3.5	1	33.3	-	-	2.5	40.34
PLOT 4								
no shrubs intercept								

PLOT SITE DESCRIPTION

(Bramsey *et al*, 1977)

MAP SHEET 6628 - IV

PLOT NO.	ELEVATION (m) ASL	ASPECT	GRADIENT	PROFILE	PLAN	GENERAL SITE DESCRIPTION - Plot Siting - Amount & Type of Disturbance Proximity & Type of Access Road	Vegetation Described in 1860s Land Survey GAWLER COUNTY
Plot 1 G.R. 744806	35	188°	13%	Concave	Concave	Plot situated on the south-facing side of relict sand-dune. The sand-dune was situated inland of dirt track accessible by foot or bike only. The areas between the dunes were under crop and also used for grazing. The dune evidenced bike tracks and the effects of grazing. Understorey present though limited. Classified as 'relatively undisturbed'	Section, Pt Gawler Hundred 46F 636 1860 Sandy pasture, dense mallee; a little timber no surface waters.
Plot 2 G.R. 745789	30	190°	13%	Concave	Concave	South-facing side of relict sand-dune, running areas between dunes cropped and grazed. Dune evidenced effects of grazing, and rabbit burrows. Where the dune vegetation had been destroyed sand mobility had occurred. Understorey present though limited. Classified as 'relatively undisturbed'	Section 643, Pt Gawler Hundred 46F 1861 Pasture land small portions arable land, sandy soil, dense mallee scrub, no waters.
Plot 3 G.R. 695885	40	021°	13%	Convex	Linear	Plot situated on the NNE face of relict sand-dune trending in a NW/SE direction. Site adjacent to graded road and surrounded by agricultural land. Plot seriously lacked understorey, that existing consisted of grasses. Classified as 'disturbed'	Sections 786 - 732, Muddla Wirra Hundred 1866 Dense scrub and very sandy. Good pasture, thickly timbered with pine and mallee, no water.
Plot 4 G.R. 722791	40	180°	10%	Linear	Linear	South-facing plot situated on NW/SW trending relict sand-dune. Dune adjacent to graded road, and surrounded by crops and grazing land. Site actually seen to be shelter for grazing sheep. Understorey again seriously lacking. Classified as 'disturbed'	Section 611, Muddla Wirra Hundred Sandy pasture, very scrubby timbered with Peppermint Gum and Pines, portions arable.



Tree plot 50.20m = 1000 m^2

Shrub Strip-plots 2 (2.50m) = 200 m^2

Herb Sub-plots 17.1m = 17 m^2

Fig.8 Sample plots

Bramsey et al. (1977)