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# The sand extraction industry in Wollongong, N.S.W.: its development and future

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THE SAND EXTRACTION INDUSTRY IN WOLLONGONG, N.S.W.

ITS DEVELOPMENT AND FUTURE

Gillian Reffell

THESIS SUBMITTED FOR THE DEGREE OF  
MASTER OF ARTS

1980

University of Wollongong

Except where acknowledged in the text, this thesis is my own original work and does not contain material previously published or written by any other person. It has not been submitted for a higher degree at any other University.

ABSTRACT

In Wollongong, 80 km south of Sydney on the New South Wales coastline, there has been widespread speculation that local sand resources are inadequate to supply future demands for construction sand in an environmentally sound manner.

This thesis objectively appraises the many factors that influence the nature of Wollongong's local sand extraction industry. It systematically integrates these factors to produce a comprehensive and functional overview of the demands and constraints on the industry. Such an overview exposes the most pressing problems associated with continued sand extraction and gives rise to recommendations of rational guidelines for the future planning of the industry.

As the first study to attempt such an all-embracing analysis of the sand extraction industry, this thesis is valuable not only as a guide to future planning in Wollongong but also as a guide to dealing with similar problems in other areas.

ACKNOWLEDGEMENTS

The accent of this thesis is on the interaction of the many diverse areas related to sand mining in Wollongong. Coupled with a local emphasis, this fact has meant that much of the necessary information originates in personal communication with those directly involved in the various facets of the industry. Initially thanks must go to the N.S.W. Planning and Environment Commission for providing the impetus for the study and much time and assistance during its completion. Other government bodies including the N.S.W. Geological Survey, the N.S.W. Soil Conservation Service, the Metropolitan Water, Sewerage and Drainage Board and the various local governments have also given considerable time and information.

Representatives of private industry including Australian Iron and Steel Pty. Ltd., South Coast Equipment Pty. Ltd., Southern Gravel Suppliers Pty. Ltd. and Pioneer Concrete have freely provided local knowledge, field assistance and information enabling insight into local industrial matters. Individuals including Dr. K. Ausburn (President of the South Coast Conservation Society), Dr. I. Eliot (Geography Department, University of Western Australia), Mr. M. Harris (The Lake Committee), Mr. G. Mitchell (Wollongong University) and Dr. J. Roper (Civil Engineering Department, Sydney University) to name only a few, have also freely provided information. Without the co-operation of all of these people, clearly information basic to this study would not have been available.

Special thanks must go to Dr. Bob Young, my supervisor, who has provided local insight, geographical expertise and an abiding interest in this study. Thanks to Helen Mutch for typing the script and lastly, thanks to Graham Hill for his time and patience in proofreading.

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## CHAPTER ONE

### INTRODUCTION

In the last two decades the world's developed countries have been forced into an awareness of the finite nature of natural resources. This has engendered a realisation of the need to rationalise man's exploitation of, and impact on, his environment (e.g. Dalland, 1978; Eyre, 1978; Hails, 1977; and Holmes, 1976). Continued population growth, the escalating demands of modern society, and technological advances that have facilitated the rapid utilisation of resources have resulted in increasing pressure on the often highly vulnerable natural environment.

According to many authorities the time is rapidly approaching when the physical environment will be unable to accommodate the demands placed on it by modern man (e.g. Ehrlich, 1969; *The Ecologist*, 1972). The increasingly rapid transformation of the environment can hardly be denied, but the evidence for imminent "eco-catastrophy", as Ehrlich called it is by no means conclusive. Clayton (1971), has attacked what he termed a "confused mixture of quasi-scientific concern, and thorough-going sentimentality" pervading the conservation movement in the United Kingdom. Hare (1980) has more recently observed that "the environmentalist movement has captured and occasionally intoxicated a number of first class minds". Hare concludes his review, more than a decade after the first premises of doom, by a timely call for a very careful weighing of evidence to avoid the colouring of factual evidence in environmental research by emotive issues.

Apart from this pragmatism Hare's review is notable on three



other counts. Firstly, he emphasises that there are two distinct classes of environmental problems; those associated with the legitimate use of resources, and those which spring from poor industrial or domestic technology; and that we should not lose sight of the former class. Secondly, he points out that, because of the complexity of modern society, the two classes are often intertwined: environmental degradation can be caused by a faulty approach to the meeting of essential demands. Lastly, he suggests that geography, with its tradition of looking at both man and land, is well-positioned to make a major contribution to this problem.

Hare has by no means been alone in his interpretation of the current environmental problem. Rather, an awareness of the complex interrelationships between man and his environment is evident in the work of many contemporary geographers (e.g. Clayton, 1971, 1974; Conacher, 1975, 1977; Eyre and Jones, 1966; Hails, 1977; Komar, 1974; Leszczycki, 1974; O'Riordan, 1970; Robinson, 1970; Rose, 1976; White, 1965). All of these, and many more, have emphasised the central role that the discipline of geography should assume in coming to terms with the problems of re-establishing an equilibrium between man and his environment. Moreover, there has been a strong call for a refocusing of research towards applied geography, that is the solving of practical problems (Eyre, 1978; Clark, 1978).

Applied geography has a long history (Dunbar, 1978). However there is a new trend evident in the last decade that differs from the traditional view (Frazier, 1978). While it is based in the "new geography" of specialisation of the 1960's, with a particular concern for a rigorous, scientific method, it also embodies a desire to increase the relevance of geography to real world problems by

addressing environmental, socio-economic and political issues in context. To achieve these ends the new applied geography goes beyond mere data gathering of fragmented information lacking in direction. Recent exercises in applied geography attempt the integration of divergent yet relevant areas of technical expertise to enable well founded predictions of future possibilities in problem areas. Of the value of applied geography to the field of geography as a whole Frazier (1978) stated:

*To achieve and maintain academic respectability, visibility, stability and credibility in the 1980's will require that our work have demonstrable utility.*

Eyre, an enthusiastic proponent of this move toward applied geography, strongly advocates the need for, and value of, integrated studies that provide insight into the practical problems associated with environmental exploitation. He questions:

*... if one has the expertise and knowledge which might be helpful in the clarification or resolution of a vital world problem, is there not an element of immortality in devoting one's energies entirely to academic pursuits? (Eyre, 1978)*

The value of integrated studies lies in their ability to synthesise the findings of many disparate specialisms and systematically explain the nature and role of the many and diverse aspects of any man-land problem. Such studies then clarify the nature of the problem and provide what seem to be the most logical solutions to the problems involved.

While it is necessary to recognise the potential values of applied geographical study, it is also necessary to recognise the

role that environmental variation plays on the relationships that man develops with his surroundings. Variations in the physical environment, the types of community and economic hierarchies all interact to determine the requirements and consequently the pressures that communities place on their environments. As early as 1947 Dickinson (1947) proposed that:

*... a sound knowledge of the anatomy of a society must precede the treatment of its defects.*

In recent years geography's traditional concern with local or regional issues has been largely abandoned. Yet Bunge (1973) emphasised the significance of local attributes in determining the relationship that man may develop with his surroundings, and said of the decline in area-specific studies in the early 1970's:

*The decline in regional work is appalling. At a time when cities are crying out for regional consideration, regionalists and regionalism are in eclipse.*

More recently Holmes (1976) and Conacher (1977) have noted the merit of functionally defining regions on the basis of specific environmental and land use problems. Eyre (1978) encourages a new and motivated "regional geography" capable of supplying administrations with sufficient information from which to devise long term regional plans and assess their viability. Furthermore Stutz (1980) has noted the advantages of state and local governments sponsoring research into local, regional and state problems as a means of gaining insight into the nature of specific areas and valuable implications for their planning.

This thesis is based on a fundamental conviction of the value of applied geographical study to problems emanating from man's interaction with his environment. It adopts the broad integrative approach espoused by geographers such as Eyre (1978), Clark (1978) and Holmes (1976). While concentrating on one particular locale, it ranges over diverse specialisms in order to establish a comprehensive overview from which information may be drawn to contribute to solving a practical and pressing area-specific problem.

### The Problem Stated

Sand mining has been carried out on the New South Wales coast since the beginning of European settlement, and as the scale of demand has grown so has the associated impact on the environment. In recent years the environmental disruption has received considerable publicity, but this has been directed predominantly at the environmental damage accompanying the extraction of heavy minerals. The extensive and potentially disruptive extraction of sand for the building industry has received little attention.

There have been few studies of the characteristics and environmental impact of sand extraction for the building industry. In New South Wales research has been essentially concerned with the present and future availability of such sand. Predictions have been made of imminent future shortages of construction sand in the Sydney Basin (Adamson, 1974) and the New South Wales Geological Survey has initiated numerous research projects over widespread areas (Herbert, 1969; Patterson, 1974; Wallace, 1974; Stroud, 1974; Neville, 1976; Uren, 1973, 1974; Smith, 1974, 1976, 1977, 1979). Despite these purely resource orientated studies, there has been little attempt, until recently, to examine the environmental

impact of large scale sand extraction. A notable exception is the detailed research of the impact of sand extraction from the Georges River southwest of Sydney (Warner and Pickup, 1974; Warner, Pickup and McLean, 1976). In this area extensive sand dredging from the bed of the river and from off-channel ponds has considerably disrupted the river's hydrological regime, not only by increasing turbidity and pollution levels, but also by enlarging the tidal prism, which in turn increases tidal flows and results in widespread bank erosion. Even this study, however, did not consider the social and economic factors which influence and are influenced by sand extraction procedures.

Problems arising from intensive sand removal are, of course, by no means limited to New South Wales or Australia. Rather, the problem of maintaining a continuous supply of low cost sand for the building industry in an environmentally acceptable manner has been recognised throughout the world (Ketchum, 1972; Cooke and Doornkamp, 1974; Bronitsky and Wallace, 1974; Amir, 1975). As yet, however, there has been no real attempt to analyse the sand extraction industry. While it would be wrong to suggest that sand extraction has been ignored, the emphasis has been indisputably on specialist studies which, as previously mentioned, yield a highly fragmented information base.

In the journal Economic Geography, for example, research has been devoted purely to analysing the economic constraints of transport on the location of the sand extraction industry (Bronitsky and Wallace, 1974). In mining journals such as Quarry Mine and Pit and the Institute of Quarry Transactions, the few relevant articles are concerned only with methods and future prospects in sand resource

exploitation (Sargent, 1976; Cottell, 1978). Publications associated with the steel industry such as the Australian Institute of Mining and Metallurgy refer to the sand mining industry only when publicising alternatives to natural sands such as blast furnace slag sand (Eggleston, 1979; Munn, 1979). General geography texts including Thoman, Conkling and Yeates (1962), Alexander and Gibson (1972) and Robinson (1977) devote no more than a passing mention to sand extraction, while journals in which reference to the diverse problems of sand extraction could well be expected, such as the Journal of Environmental Management, and Environmental Affairs contain no reference to it whatsoever.

The sand extraction industry in any area reflects an interaction of the local resource base and the economic and social climate of the community. However, no attempt has previously been made to develop a broad understanding of how the different facets of the industry combine and interact.

As Hare (1980) emphasised, environmental problems often result from a faulty approach to meeting essential resource demands and this seems so in the case considered here. In Wollongong, 80 km south of Sydney on the New South Wales coast line, sand extraction has given rise to environmental disruption and in turn community dissension as persistent high demands for construction sand threaten to seriously overtax the limited resource base. Clearly construction sand is a necessary resource in a developing industrial city such as Wollongong but the environmental damage and community dissension that sand extraction threatens suggests that the methods adopted to date to acquire this resource may have been inappropriate. This thesis aims at a comprehensive overview of the sand extraction

industry in and surrounding Wollongong as the basis for recommending rational guidelines for the future planning of the industry.

### Methodology

An historical approach presents a logical means of analysing the complexity of the sand extraction industry. Initially, chapters two and three establish the long term evolution of the physical characteristics of the sandbodies surrounding Wollongong. Assessment of the processes involved in their formation and maintenance enables an evaluation of their susceptibility to disruption as a result of sand removal. A review of the type and the extent of the sand available in each deposit provides an indication of their commercial value. It is appropriate that the physical environment should be discussed first because the availability and nature of sand resources in Wollongong constitutes the basis of the problems evident within the sand extraction industry in this area.

Chapters four and five document the relatively recent but significant impact of European settlement on the sand deposits surrounding Wollongong. Characterised by rapid industrial urban growth, the city's development was accompanied by extensive exploitation of local sand reserves. The documentation of the growth of the industry and the related urban expansion, the increasing exploitation of sand resources, and the development of a community awareness of the importance of maintaining the natural environment, provides a background to the present controversy over the utilization of Wollongong's limited sand resources. Moreover, such documentation enables a clear idea of the social atmosphere in which future planning of sand extraction must operate.

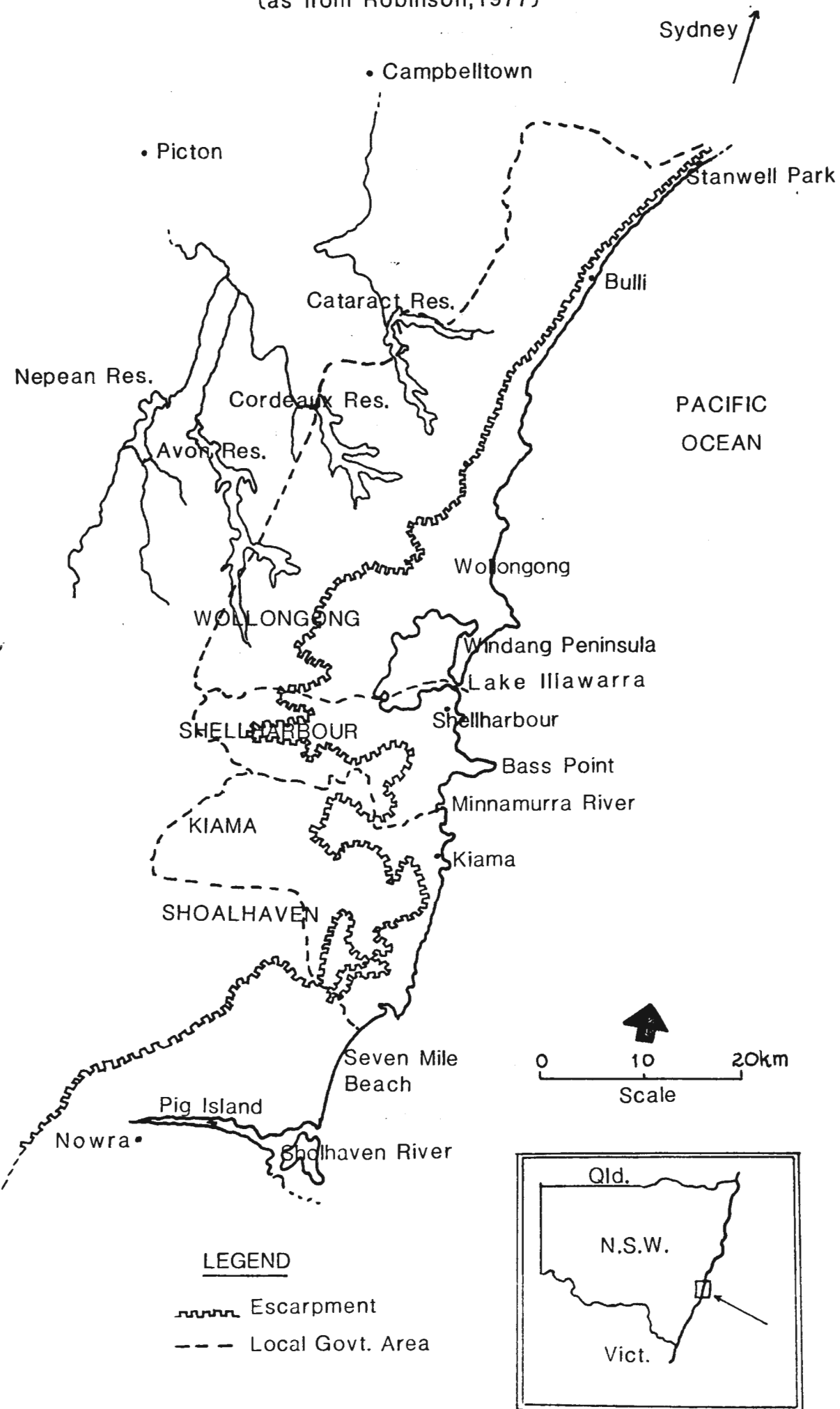
Chapter six deals with the contemporary situation in Wollongong. The study of population predictions and trends in the construction industry give rise to the prediction of the continuation of a persistent demand for sand, and that the problem of sand supply in Wollongong is likely to continue as a contentious issue. This chapter also introduces the current developments in the production of synthetic alternatives to sand. Blast furnace slag sand, a product of steel production, appears to be capable of satisfying, at least partially, the expected sand demand. If it is possible to utilise a preexisting synthetic alternative rather than continuing the extraction of natural sand, this must be a significant factor to consider.

Chapter seven draws together the disparate themes raised throughout the previous chapters and supplements this with other relevant information on the current nature of available sand reserves. Such a comprehensive body of knowledge bringing together the many and diverse facets affecting the functioning of the sand extraction industry clearly demonstrates the availability of sand resources and the origins, nature and probable future maintenance of demands for sand. At this point what becomes obvious is the need for, but lack of, systematic planning measures capable of satisfying the diverse demands of the community within the context of physical and economic constraints. Chapter seven also highlights the implications for the future planning of the sand extraction industry in the area surrounding Wollongong by utilising several principles for optimum extraction techniques.



FIG.1 The Regional Setting of Wollongong.

(as from Robinson, 1977)



The integrative approach of this thesis represents a methodological initiative in research related to the sand extraction industry. Moreover, the study, of which this thesis is a result, has practical significance in that it was originally undertaken as part of an environmental investigation commissioned by the New South Wales Department of Environment and Planning with the specific aim of contributing to a regional plan of the Illawarra Region (Young and Reffell, 1980). It is, in short, the type of study that Stutz (1980) advocates for applied geography. While the methods adopted may well establish guidelines for enquiry into sand extraction in other areas where problems arise related to sand extraction, perhaps most obvious are the implications for area specific planning of the sand extraction industry in Wollongong.

#### The Study Area

Wollongong, the third largest city in New South Wales, is the capital of the Illawarra Region. The city's development has been confined to a north-south elongated strip of coastal lowland enclosed between the Illawarra Escarpment in the west and the Pacific Ocean to the east (Fig. 1). Approximately 50 km long, the coastal plain tapers northwards from a maximum of 20 km in the south to end at the foot of seacliffs in the north (Young and Johnson, 1977). The coastal plain is composed mainly of small alluviated valleys draining the limited area east of the escarpment. Sandy coastal dune barriers lie across the mouths of these valleys and have impounded shallow lagoons, the largest of which is Lake Illawarra, at the southern end of the plain. Most of the coastline consists of rocky seacliffs while the remainder is characterised

by beaches ranging in size from small pocket beaches to long sweeping zeta form beaches.

Wollongong was initially established as an agricultural settlement on the rolling foothills of the coastal plain but the discovery of coal, in the northern areas of the plain, and the ensuing development of scattered mining centres encouraged linear development along the northern coast. In the early 1900's, to take advantage of the cheap power source provided by coal, heavy industry, the most significant of which was the steel industry, developed around Port Kembla. This represented the beginning of a period of unprecedented economic and urban growth. From a population of just over 3,000 in 1891 it had expanded to over 66,000 by the end of World War II and continued to grow rapidly until well into the 1960's. This rapid development of industry was paralleled by a growing demand for sand. Australian Iron and Steel Pty. Ltd. (A.I.S.) for example utilised huge quantities of sand (up to three million tonnes) for fill in extensive reclamation works of swamplands, in the construction of their industrial plants and, of course, developed and maintained a persistent demand (up to 500,000 tonnes per annum) for sand for use in their steel moulding processes. With the promise of employment in the heavy industries the urban sector developed rapidly and this also resulted in consistent demands for sand in the building of homes and public utilities. The rapid growth rates typical until the late 1950's and 1960's have not been sustained. Demand for sand however has been, and predictably will remain, significant. A slight shift in the centre of demand has also become evident in the last decade as the city area of

Wollongong has become fully developed. Urban growth generated by industrial Wollongong tends to be focused on suburbs slightly to the south of the city centre, especially in the Shellharbour Local Government Area (Fig. 1). Indeed Shellharbour's population has grown by four per cent per annum over the last decade while Wollongong's Local Government Area is significantly lower at .8 per cent per annum growth rate from 1971-76. The high growth rate of Shellharbour should be sustained by a large scale Housing Commission development proposed for the area. Thus in the future, although the demand for sand generated by heavy industry will persist around Port Kembla, the southern suburbs of Wollongong will generate most of the sand demand.

In short the intensive industrial and urban development of Wollongong in the past and the projected future development has and will be strictly confined by topographical boundaries. As a result the large and persistent demands for sand are concentrated in a relatively small area. In defining the scope of this study, the low intrinsic value of sand becomes an important factor. As has been the case in the past, in the future Wollongong's sand resources will need to be located close to the market centre in order to remain economically viable. Thus, taking into account the distribution of sand deposits capable of satisfying the city's demands as well as topographical and economic constraints, the area in study will extend from Stanwell Park in the north to the Shoalhaven River in the south, and from scattered swampland sand deposits west of the Illawarra Escarpment eastward to the Pacific Ocean (Fig. 1).

## CHAPTER TWO

### BACKGROUND TO SAND SUPPLY IN WOLLONGONG - GEOMORPHOLOGY OF SAND DEPOSITS

#### (i) Introduction

As noted in Chapter One, the origins and processes shaping the development of sand bodies in and surrounding Wollongong are of critical importance in later evaluation of their potential for disruption. This chapter discusses these various origins and processes.

The major (commercially viable) deposits of sand available to Wollongong appear to be predominantly of marine origin. Most of them originated when the sea reached its present level at the completion of the Holocene Transgression some 6500 to 7000 years ago (Thom and Chappell, 1975; Jones, Young and Eliot, 1980). After a period of relatively rapid deposition these deposits received no more sediment input and today are essentially relict. Similarly, offshore sand and gravel deposits appear to be a legacy from the Holocene Transgression.

Several fluvial sand bodies of contemporary origin occur in the region surrounding Wollongong. These deposits, which include scattered tableland swamp deposits and small surplus accumulations in the Shoalhaven River, are of very limited extent. Finally, the majority of coastal streams in the region offer no economically viable potential for sand extraction as they contain high proportions of clay and readily weatherable lithic material unsuitable for use in construction sand.

## (ii) Marine Sand Deposits

Contemporary or Relict

Many coastlines of the world actively receive sand nourishment from rivers. This fact is particularly well documented for areas such as the western coast of the U.S.A., where Bowen and Inman (1966) have demonstrated that the construction of dams on coastal rivers has reduced the contribution of terrestrial sand to the Californian coast and caused a deficit in the sediment budget. In the Gulf of Mexico where the Mississippi River reaches the sea, the role of river sand in nourishing Gulf beaches has also been well documented (Shepard, 1971). Moreover, massive inputs of river sand into beach systems have been clearly demonstrated on some parts of the Australian coast. For instance, Hopley (1979) recorded evidence of sediment inputs on the north Queensland coast near the Burdekin Delta where massive sediment influxes, under the influence of south-north long-shore drift, are redistributed into spits and bars and form an actively prograding coastline.

Despite evidence of sediment input to many of the world's coastlines it is equally clear that many others are receiving little or no inputs of sand into beach systems. As Russell (1967) stated:

*As long as seas were rising rapidly from their preRecent (Ice Age) low level . . . they encroached on old coastal plains, and new surfaces were being flooded. These provided sources of sand, which, together with relatively coarse material, were transported by wave action. Beaches increased in volume as they were pushed inland and gently upward across old and invaded coastal plains. Some surplus sand was blown off to*

*accumulate as dunes. But when stillstand (i.e. the present sealevel) was attained new sand supplies were no longer encountered. Beaches and the older dunes had attained maximum volume.*

Two hypotheses may thus be advanced to account for the origins of the coastal sand bodies of the southern N.S.W. coast. The first is that streams may be adding substantially to their volume. The other is that they may be relict of the shoreward push of sand by the rising level of the sea during the Holocene Transgression.

Only two decades ago it was widely believed that the rivers of N.S.W. were delivering sand to the coast and that this sand was moving in longshore currents to replenish the beaches (see comments by Davies, 1974). However, in 1963 A. R. Ford questioned this view arguing that *the prevailing movement is from the ocean into (river) entrances and not vice versa.* He used aerial photographs to demonstrate that in the lakes and rivers of N.S.W. sand from the ocean moves landward up the entrances for 3-4 km under the action of flood tides. He also noted that although large quantities of sand and silt are brought down many coastal rivers of N.S.W., sediment deposition occurs inside the river entrances due to the effect of density currents and flocculation. Only on smaller rivers on the southern coast of N.S.W. have studies (Jennings and Bird, 1967; Bird, 1967) suggested the contemporary release of sand sediment onto the coast.

Recent studies of estuarine sediments in the mouths of major N.S.W. rivers, such as the work of Albani (1974) in the lower Hawkesbury River and Broken Bay, have supported Ford's conclusions. Albani concluded that fluvial and marine currents meet approximately

5 km upstream from the entrance to Broken Bay and at that point deposition of fluvial material commences. This deposition is largely completed by the time the fluvial currents approach the entrance. The farthest upstream deposition of sediment transported by incoming marine currents is also approximately 5 km upstream. In a second study Roy (1977) showed that in the Hunter River 120 km north of Sydney, the medium to fine quartz sand which infills the lower 9.5 km of the estuary is the product of a now largely inactive landward transport of marine sand from the open coast. Upstream of this marine sand occurs lithic sand of terrestrial origin which becomes finer in the seaward direction. Roy concluded that under the present conditions the Hunter River does not contribute significant amounts of sand to the adjacent beaches or nearshore zone. The absence of a significant buildup of river sediment on Stockton Beach near the river mouth is further evidence against a significant supply of river sand to the coast in the recent past.

Thom's (1974, 1978) research on stratigraphy and chronology provides further and compelling evidence of the essentially relict nature of coastal sand deposits in N.S.W. This research has shown sand to be pushed inland as the glaciers of the Wisconsin Stage began to melt and the sealevel began to rise in the Holocene Transgression, some 17000 BP in eastern Australia (Thom, 1978). During this transgression sand masses were pushed landward by the advancing waves until, when the sea reached its present level, sand masses emerged from shallow water to form 'barriers' closing off coastal inlets.

There has been marked controversy over the estimation of the rate of sealevel rise (Davis, 1972). The majority of evidence, however, tends to support the hypothesis that the rise was relatively



Beaches & dunes build rapidly until about 5500 years B.P.

Slow growth until about 3000 B.P. Coastline then stabilizes or retreats

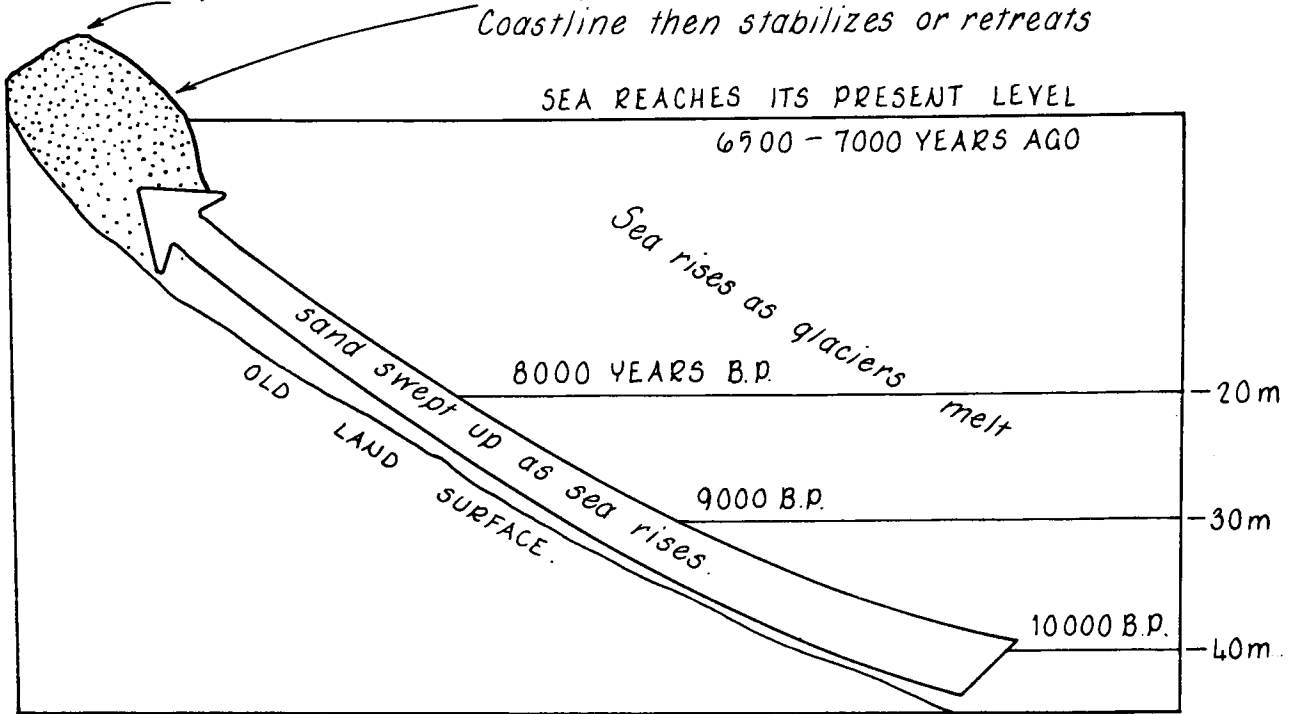
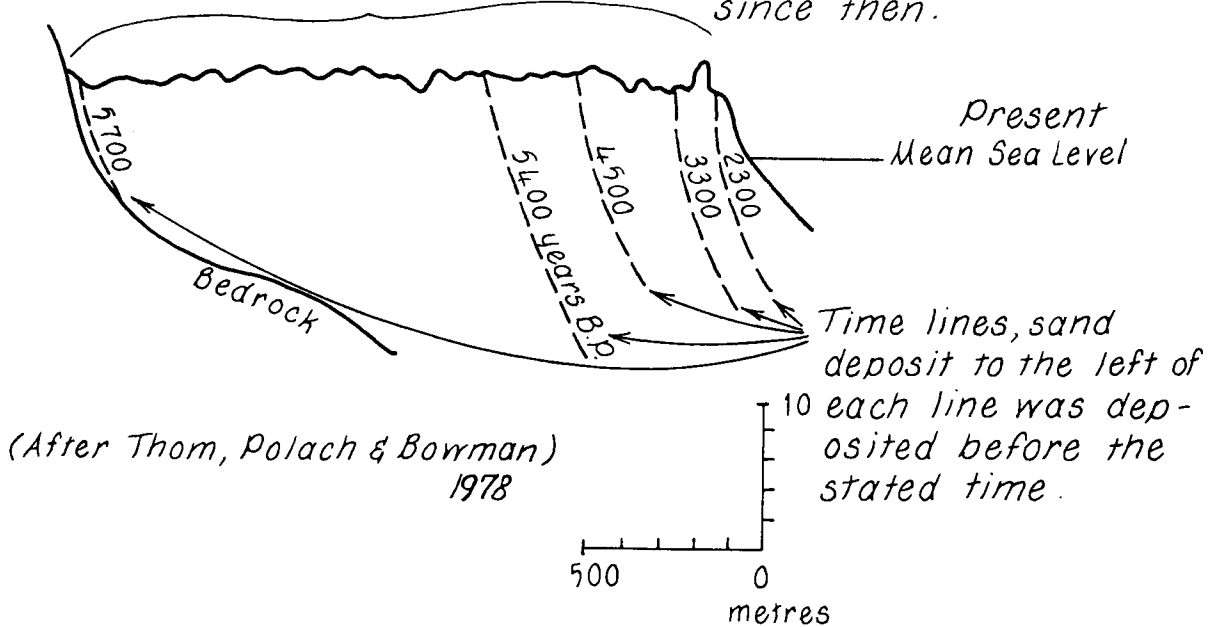


FIGURE 2 a) General relationship between sea-level change & sand barrier development. (Based on studies by B.G. Thom.)

SAND DUNES ~ N.B.  $\frac{2}{3}$  of sand accumulation deposited before 4,500 B.P., only  $\frac{1}{3}$  since then.



(After Thom, Polach & Bowman) 1978

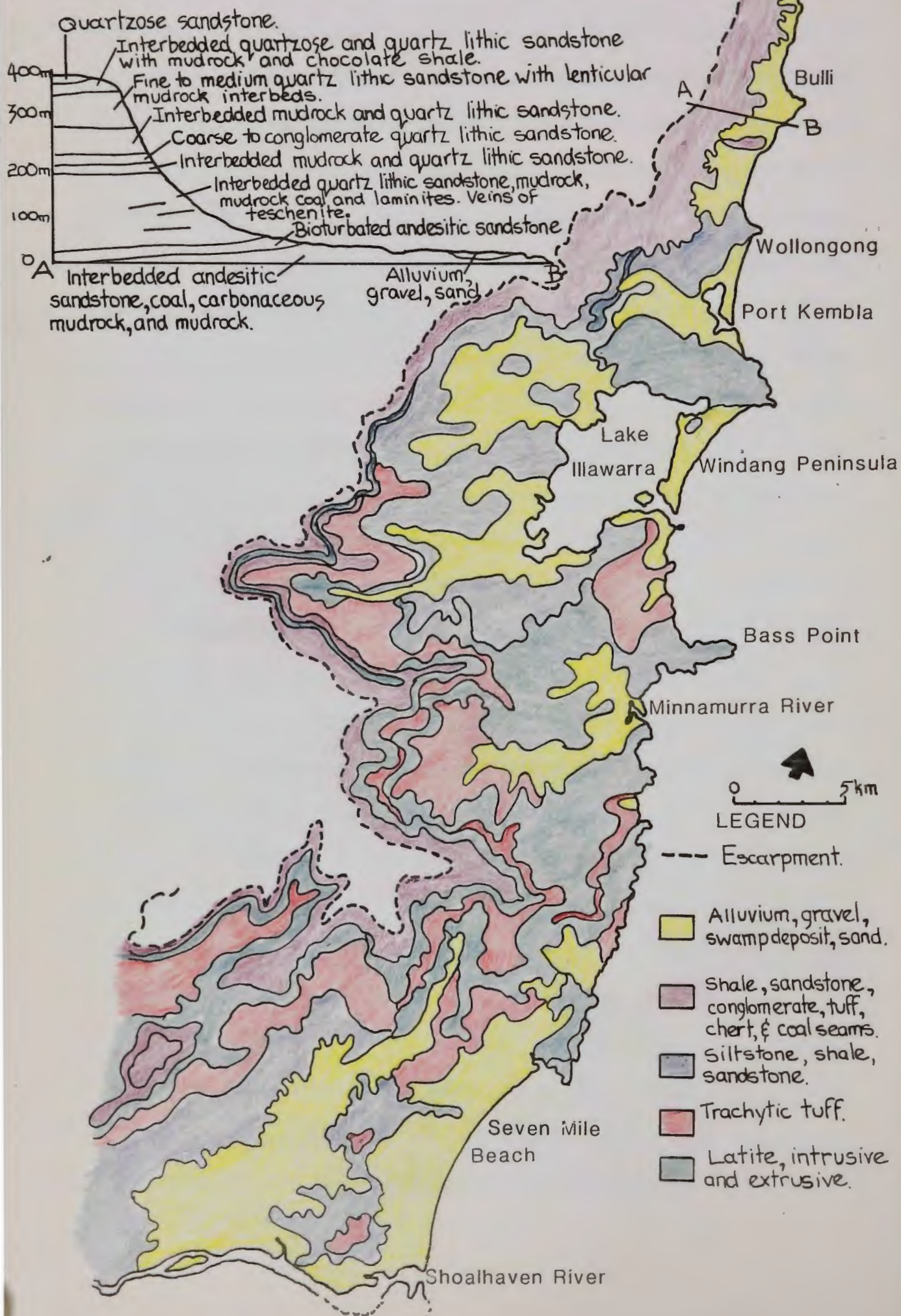
b) Growth of the Moruya barrier showing the decrease in sand supply over the last 5000 years. (W → E cross section)

rapid (in the order of 10 m/1000 years) (Fig. 2a). Thom and Chappell (1975) concluded that relative sealevel reached its present position 6500-6000 years ago along the eastern Australian coast and since then there has been a virtual stillstand ( $\pm 1$  m). Recently, research completed by Jones, Young and Eliot (1979) on the northern Illawarra coast provides evidence for considering 7500-6500 BP as the interval in which sealevel reached its present level or thereabouts and in which modern barrier building commenced. Although this disparity of ages for the completion of post-glacial marine transgression must be recognized, for the purposes of this thesis it is sufficient to note that all of the evidence supports the view that sand deposits originated approximately 7000 BP and appear to be receiving no contemporary input.

Numerous  $C^{14}$  age determinations obtained in Thom's research programme indicate that the major period of sand deposition in most of the barriers of the N.S.W. coastline was between approximately 6500-4000 BP, and that sand available for beach and foredune construction waned markedly between 4000 and 3000 BP. It also appears that over the last 3000 years there has been no significant input and in many cases considerable erosion of sand. Evidence from the Moruya sand barrier, 280 km south of Sydney (Thom et al., 1978), illustrates this trend. At Moruya dunes were built seaward from about 6000-2500 BP.  $C^{14}$  determinations of the ages of seventeen shell samples show that two thirds of the deposit had formed by 5400 BP and that only the last few ridges were built during the last 3000 years (Fig. 2b). After the initial input when the sea rose to its present level, the sand supply to the Moruya barrier declined rapidly and most certainly has not been augmented

FIG.3 Geological Map of the Wollongong Coastal Plain.

(as from Geol. Sheet Series S.I.56-9, 1:25,000)



by large inputs since that time.

Studies by Thom (1965, 1978) on the central north coast of N.S.W. in the Port Stephens-Myall Lakes area, provide additional support for the theories of Holocene development of coastal sand bodies.  $C^{14}$  age determinations from 'outer barrier' complexes in the area reflect similar ages of sediments and also suggest similar processes to those acting on the southern areas. Thom's work indicates that the N.S.W. coastline consists primarily of relict sand deposits which are receiving little, if any, contemporary replenishment and the Illawarra region seems no exception. This, however, needs to be established rather than simply assumed.

#### The Influence of Lithology on Sand Availability

There are several reasons for asserting that Illawarra beaches do not receive contemporary sediment input. These are rooted in the lithological makeup and drainage patterns of the Illawarra region. Rocky headlands seem an obvious source of sediment for nearby beaches. However, despite high powered wave attack and relatively rapid headland erosion, most local headlands contain little quartzose material and, therefore, add insignificant amounts of quartz to the beach systems. Rocks rich in quartzose fragments also occupy relatively small proportions of the catchments of coastal streams in the region, thus there is little quartz available to be transported in streams (Fig. 3). Furthermore the major drainage lines run inland away from the coast leaving only minor streams to drain to the sea. In the Illawarra region streams rising near the escarpment crest almost invariably follow the northwesterly fall of the Hawkesbury Sandstone plateau, the only

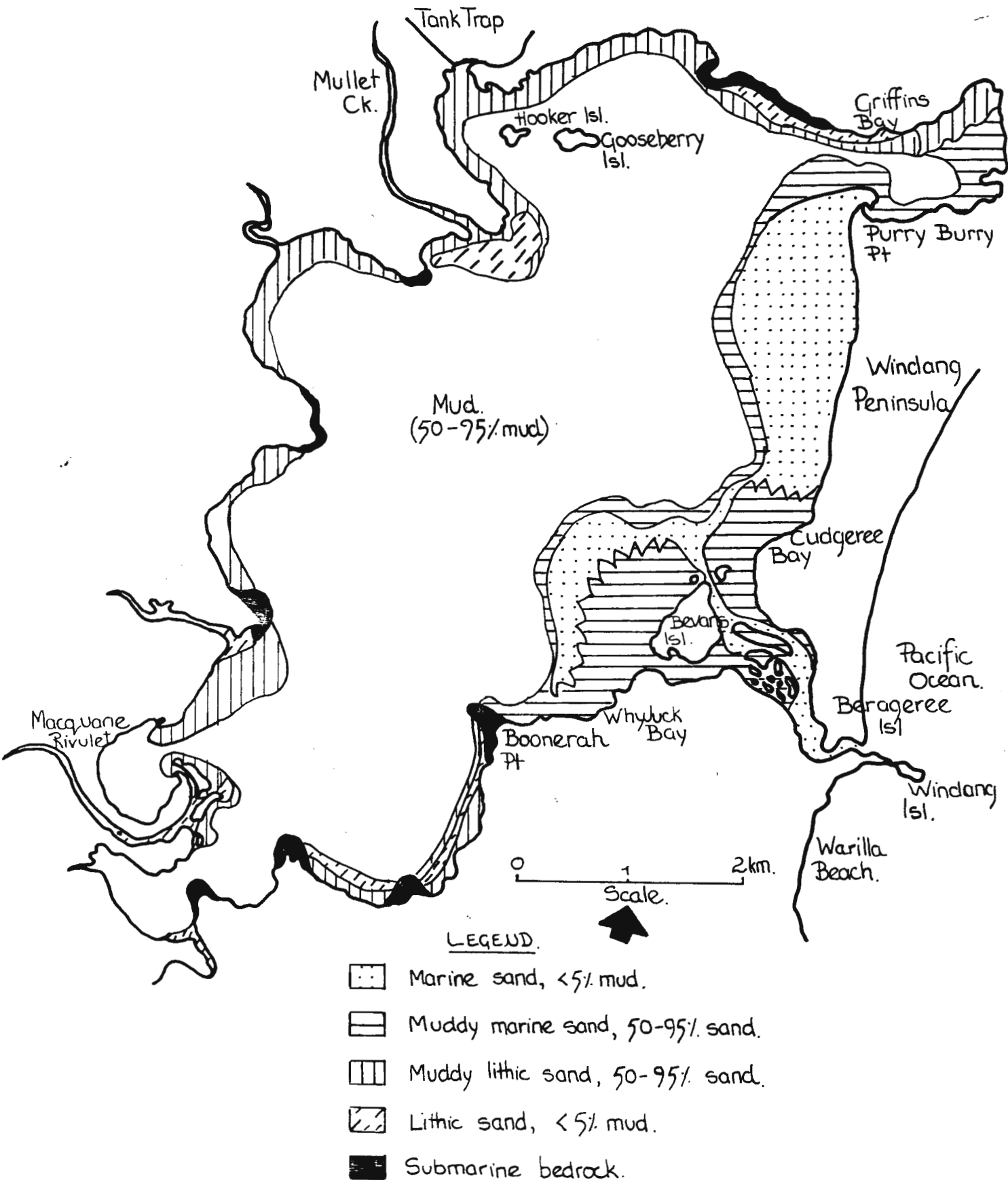
exceptions are Macquarie Rivulet and the Minnamurra River which are streams that drain to the Illawarra coastline. The significance of the concentration of erosive energy along major westward flowing streams is readily seen in the contrast between the deep valleys west of the escarpment and the much smaller valleys cut into the face of the scarp by the tiny coastal streams (Young, 1978). Farther south in the region relatively larger streams such as Macquarie Rivulet, the Minnamurra River and the Shoalhaven River have worn the escarpment well back from the shoreline.

Although there is considerable quartzose material in the Narrabeen Formation and the Hawkesbury Sandstone outcropping in the north from Stanwell Park to Austinmer (Fig. 3), this is precisely the part of the region where beaches are smallest and sand deficient. This is due to the high resistance of quartz-rich lithologies to weathering, and to the small size of stream catchments in the vicinity that are incapable of massive erosion. Southward between Austinmer and Port Kembla quartz bearing sandstones and shales occupy less of the drainage area and non-quartzose sandstones and Illawarra Coal Measures dominate the surface lithology (Fig. 3). Therefore, although stream catchments are larger and hence more competent to erode and transport sediment, sand available to renourish beaches is minimal due to the lack of quartz fragments in the weathered sediments.

South of Port Kembla latites and tuffaceous sandstones of the Gerringong volcanics dominate the lithology (Fig. 3). In this area, the escarpment occurs well away from the coast and several large streams, especially the Macquarie Rivulet and Minnamurra River, transport much eroded sediment. The lithology of the drainage basins, however, determines that the sediment yield is predominantly fine

FIG 4. Lake Illawarra Bottom Sediments.

(as from the N.S.W. Dept. of Mines)  
1975



lithic debris, not quartzose sediment capable of renourishing beaches.

### Lagoon Sediment Traps

Although the stream bedload in the region is predominantly fine material, a small amount of quartz sand is transported seaward in the stream channels. It is certain, however, that virtually none of this quartz reaches the ocean beaches. This is because many coastal streams pass through lagoons which, as a result of their placid environments are incapable of sustaining sediment in suspension or motion and act as sediment traps. Lake Illawarra, enclosed behind Windang Peninsula, is a fine example of this feature. Research conducted in the nature of lake floor sediments in Lake Illawarra (Peat and Roy, 1975; Jones and Eliot, 1976) shows that the floor of the lake consists of muds that clearly separate fluvial sands from marine sands. Lithic sandy sediments occur on the westward periphery of the lake especially in the deltas of Macquarie Rivulet and Mullet Creek and these are separated from the marine quartzose sand banks on the eastern side of the lake by extensive areas of soft black muds (Fig. 4).

The Minnamurra River does not pass through a lagoon as it approaches the ocean, but it also does not appear to deposit sediment on adjacent beaches. The sedimentological nature of the river's banks and bed suggests that the Minnamurra may be similar to the rivers of N.S.W. discussed earlier by Ford (1963), Albani (1974) and Roy (1977). That is, relict marine sand bodies penetrate up the river's course and associated with this, fluvial sediments are deposited upstream. Sampling completed in the river

channel (G. Nanson, pers. comm.) shows a profound change in sediment characteristics approximately 4 km landward of the river's mouth. Upstream of this point samples consisted of a significant proportion of lithic grains with some subangular to rounded quartz crystals (under Roy and Peat's 1975 classification they were termed 'lithic sands'). Downstream of this point, however, samples consisted of smaller, rounded quartz grains with small shell fragments ('quartzose sands' under Roy and Peat's 1975 classification) indicative of marine influences. This marked transition from 'lithic sands' to 'quartzose sands' suggests that in the Minnamurra River fluvial sediments are being deposited in the river channel rather than penetrating to the ocean to renourish beaches.

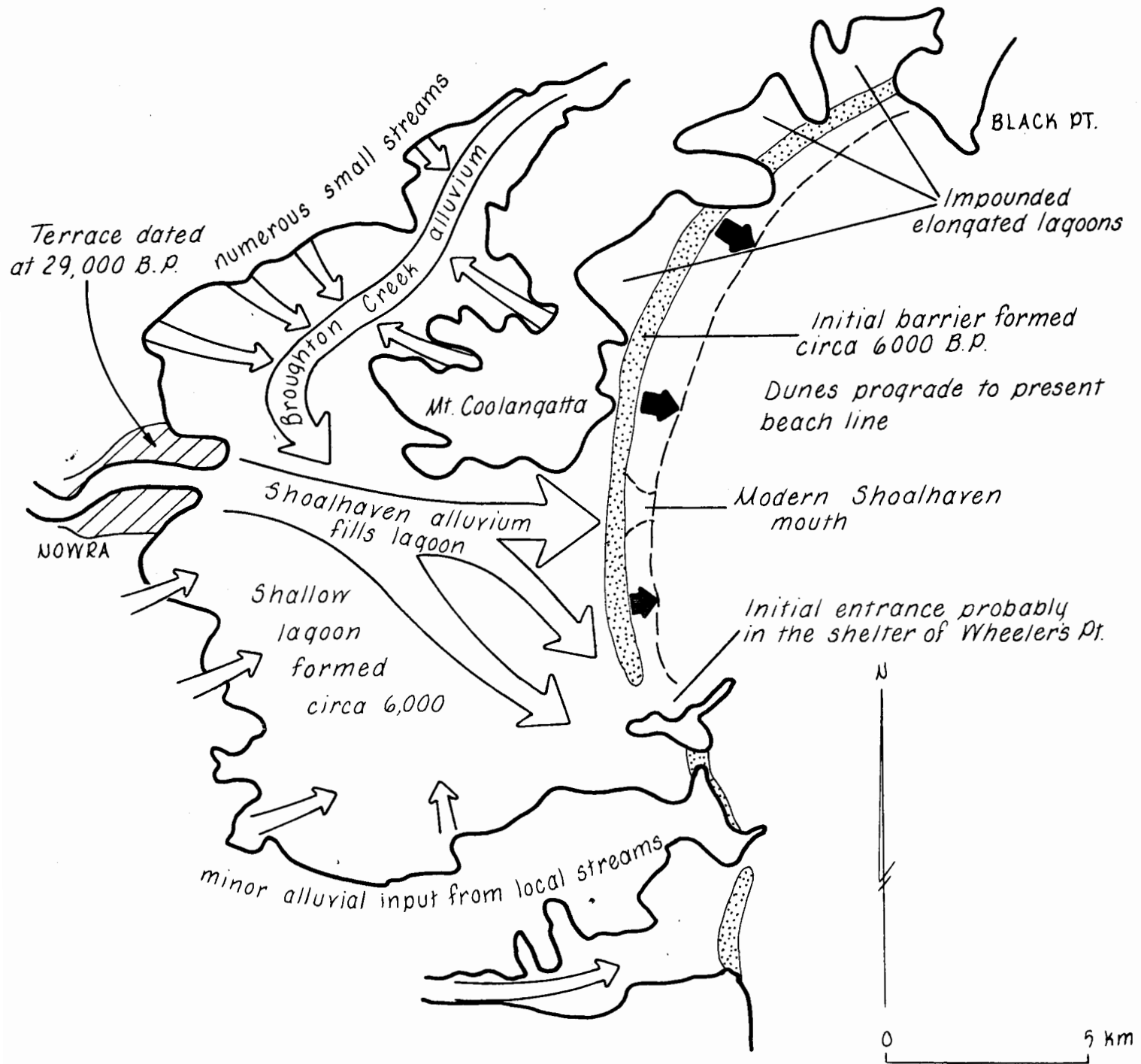
#### The Shoalhaven - a Source of Sand?

The Shoalhaven River in the south of the Illawarra region may represent the only large river in the study region, and indeed the whole of N.S.W., that is actively delivering sand onto ocean beaches (Wright, 1967). This hypothesis is by no means proved. Draining large areas of sandstone country, the bedload of the Shoalhaven contains considerable amounts of coarse quartz grains potentially valuable for renourishing the eroding coastal beaches of the Shoalhaven Bight. The lower reaches of the Shoalhaven have developed in a fashion similar to those of other streams along the coast. A sand barrier formed in shallow water about 6000 years ago, impounding a large lagoon when the valley east of Nowra was drowned by the rising sea. The portion of the old floodplain which ran down to the sea level well below the present one can be seen east of Bomaderry (Walker, 1962). The lagoon was



FIG.5 Schematic Evolution of the Lower Shoalhaven Valley

During Holocene Times



(Based on work by Walker, 1962, and Wright, 1967)

then filled with alluvium carried by the Shoalhaven River and its tributaries (Fig. 5). The critical question is whether the estuary of the Shoalhaven has still to be completely filled and is therefore still storing sediment, or whether river sand is now being transported across the deltaic deposits and is reaching the sea in significant quantities.

Evidence that the river is adding sand to Seven Mile Beach comes from a study by Wright (1967). He observed that the size of beach sand became progressively finer in a northerly direction away from the mouth of the river, and suggested that this trend was probably the result of the selective transport of river sand, with the finer grains being carried further along the beach than the coarser grains. An alternative interpretation is that the variation in grain size is simply due to wave resorting of beach sand and that the river sand is still being predominantly stored in the estuary. As Wright's work was based on a relatively small number of samples taken over a short period of time it is conceivable that during times of dominant northeast swell the size distribution of sand along the beach may well undergo a substantial shift. Such shifts in size distribution are certainly known from elsewhere along the N.S.W. coast (E. Bryant, pers. comm.). Moreover wave rider records that have become available since Wright's initial study indicate that he underestimated the significance of the northeast components in the wave regime.

A recent study by P. Roy (pers. comm.) suggests the contemporary input of fluvial sand to Seven Mile Beach. Examination of sand particles from each of the beach ridges reveals that the easternmost ridges are composed of a significantly higher proportion of

fluvial sand particles than are the more westerly ridges. Although it is difficult to draw firm conclusions from this information, it appears valid to conclude that over the period of beachridge accumulation, the easternmost ridges partially composed of fluvial sediment have received input of sand from the Shoalhaven River.

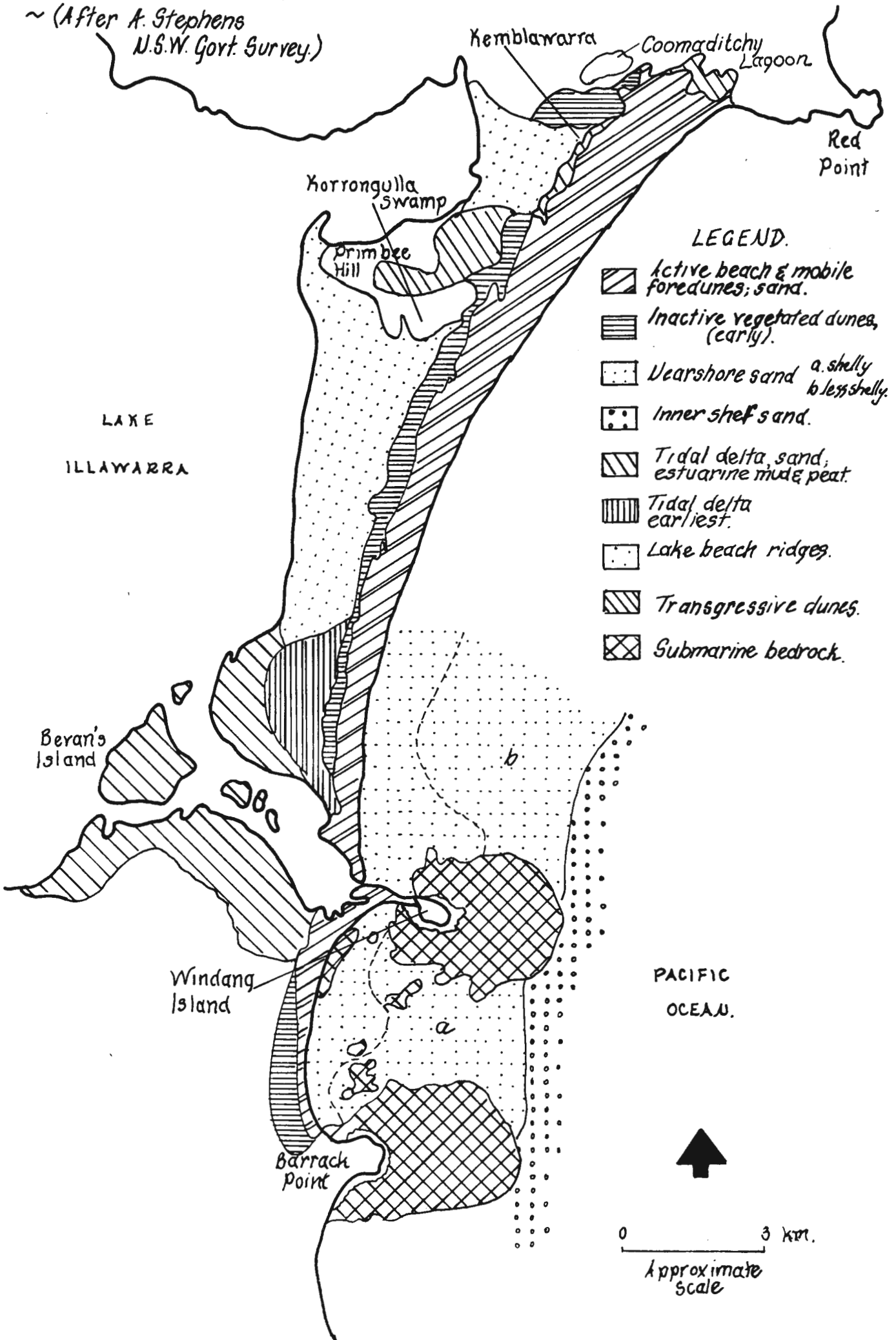
#### Obstruction to Longshore Drift

Even if sand is issuing from the Shoalhaven River, this sediment can be no more than an influx of purely local significance. The crenulate nature of the Illawarra coastline notably complicates longshore current movement and the associated longshore transport. Prominent headlands extending into deep water prevent 'leakage' of sand into adjacent embayments. If there was, for instance, any sand movement northward from the Shoalhaven Bight around Black Point (Fig. 5) in the prevalent south to north longshore drift, the embayments of Gerroa and Kiama would presumably be well supplied with sand. This strip of coastline, however, remains one of the most sand deficient in the region. Only Werri Beach, which lies at the mouth of a relatively large valley, has a substantial barrier deposit.

The major promontory of Bass Point (Fig. 3) also represents an efficient obstruction to longshore drift. An isolated pocket of Pleistocene sand (associated with Pleistocene dunes on top of Bass Point) survives in Bushranger's Bay at the apex of the point. As this pocket of older sand survives with no significant mixing of more recent Holocene sand typical of the rest of the coastline, then longshore drift cannot be transporting nearshore sand past this bay and around Bass Point (A. Stephens, pers. comm.).

FIG. 6. Windang Peninsula ~ Nature of sand Deposits.

~ (After A. Stephens  
N.S.W. Govt. Survey.)



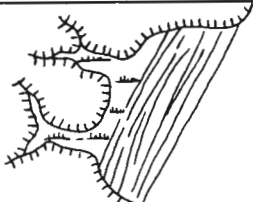
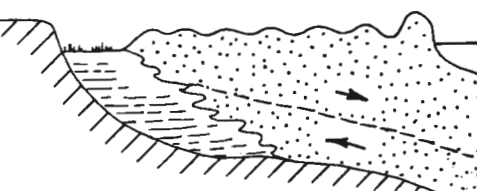
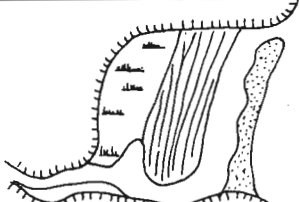
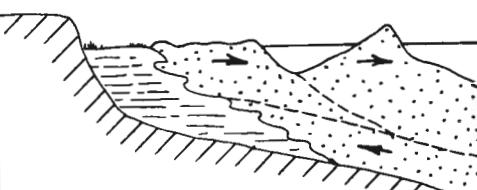
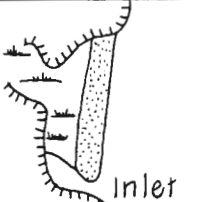
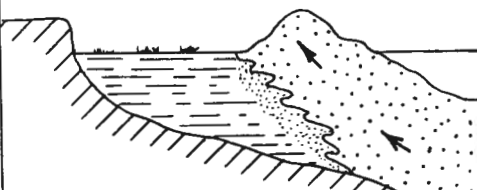
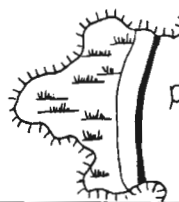
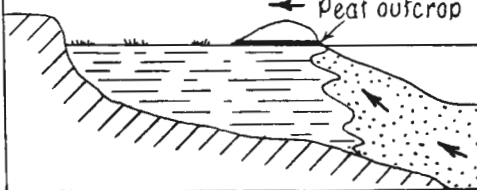
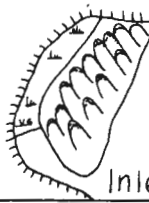
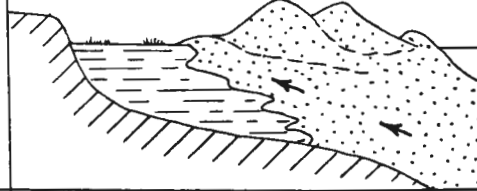
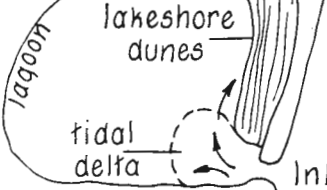

An offshore map of sediment types and their distribution (A. Stephens, pers. comm.) (Fig. 6) further illustrates how promontories interrupt south to north sand drift along the coast. Windang Island and its associated offshore reef extends beyond the limit of nearshore sediment exchange, therefore does not permit the interchange of more dynamic nearshore sand between the south and north of the rock barrier. Beyond this, sedimentological differences recorded between nearshore sands to the south and north of Windang Island further suggest that there is little or no interaction between these sand bodies. Nearshore sand north of the island contains a significantly higher shell content than sands to the north (Fig. 6).

#### Stratigraphic Evidence of Relict Sand Deposits

Probably the most convincing evidence of the relict nature of Illawarra coastal sand deposits comes from stratigraphic work in the region. Extensive research on the region's beaches and their associated dunes has revealed that many beaches either overlie or contain substantial Pleistocene deposits. The depositional history of coastal sand deposits in the Illawarra region can be readily summarised by applying the classification of barrier types developed by Thom (1974, 1978).

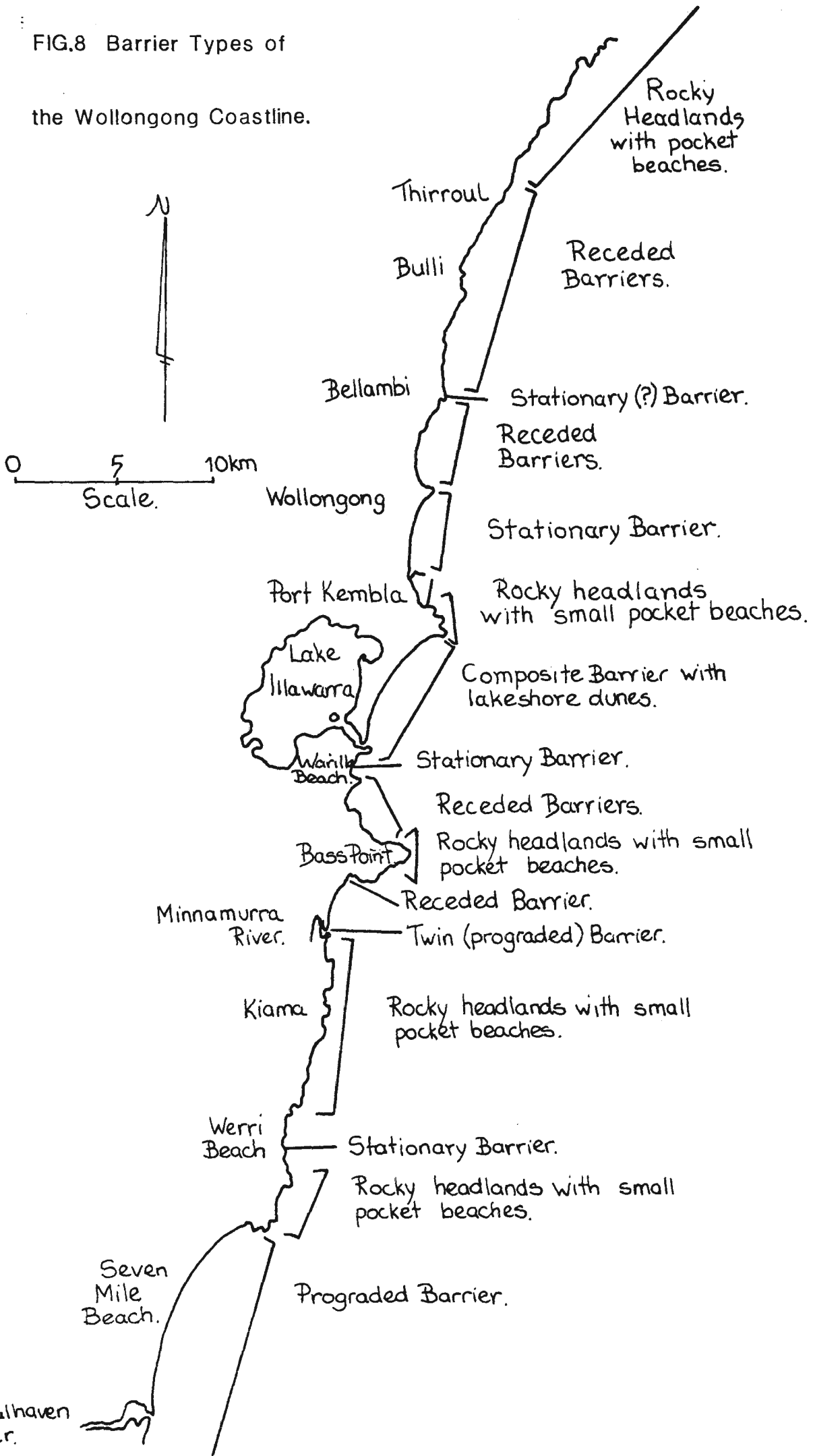
Thom has demonstrated marked variations in the manner in which coastal sand barriers have developed. In constructing a classification system for barrier types, Thom relied on the use of existing stratigraphy and  $C^{14}$  dating to reconstruct the evolutionary sequence of the sand barrier in question. Eight types of coastal barrier have been identified (Thom, Polach and Bowman, 1978) of which four are

FIG.7 Models of Sand Deposition Associated with Sealevel Change  
of the Holocene Transgression.

TYPE	MORPHOLOGY (PLAN)	STRATIGRAPHY (CROSS SECTION)
<i>PROGRADED BARRIER</i> <i>Beach ridges</i>		
<i>PROGRADED BARRIER</i> <i>Twin barriers</i>	 Inlet	
<i>STATIONARY BARRIER</i> <i>High foredune</i>	 Inlet	
<i>RECEDED BARRIER</i>	 Peat outcrop Inlet	 Peat outcrop
<i>EPISODIC TRANSGRESSIVE</i> <i>Parabolic dunes</i>	 Inlet	
<i>COMPOSITE BARRIER</i> <i>With lake-shore dunes</i>	 lagoon lakeshore dunes tidal delta Inlet	

(after Thom et al 1974,1978)

FIG.8 Barrier Types of  
the Wollongong Coastline.



directly relevant to this study. Another type of barrier not documented by Thom has been identified in the Illawarra region by Young (1976). The main characteristics of each type of barrier and their local applications are discussed below. A summary of their mode of development is illustrated in Fig. 7, while Fig. 8 illustrates the regional distribution of the various barrier types (based on Young and Eliot, 1978).

Prograded Barriers consist of sand that during the Holocene Transgression has been pushed up over basal estuarine sediments and deposited. Characterised by multiple sand ridges running parallel to the coastline, accumulations of estuarine sediments on which swamplands have subsequently developed are typically trapped behind the barrier.

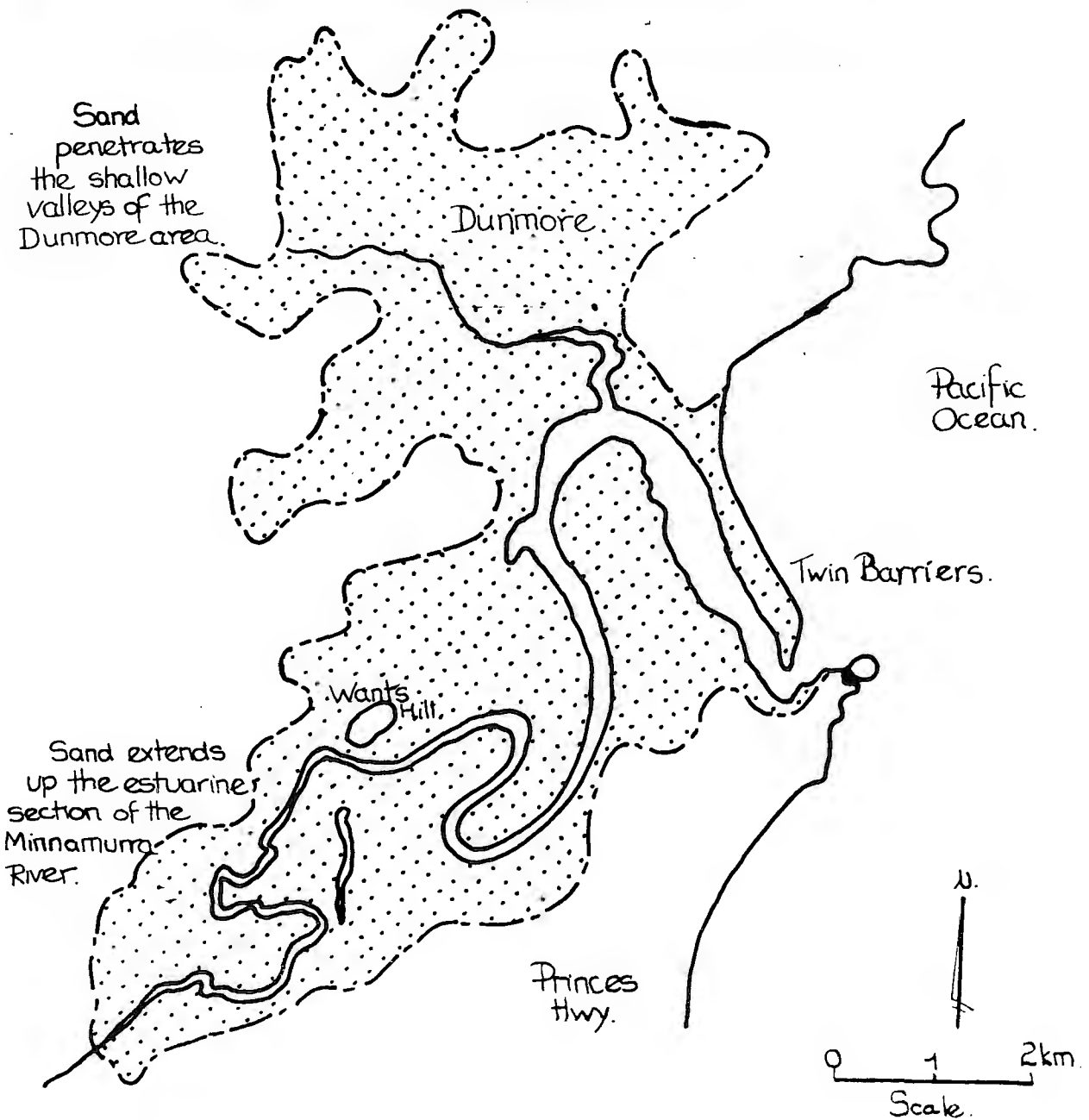
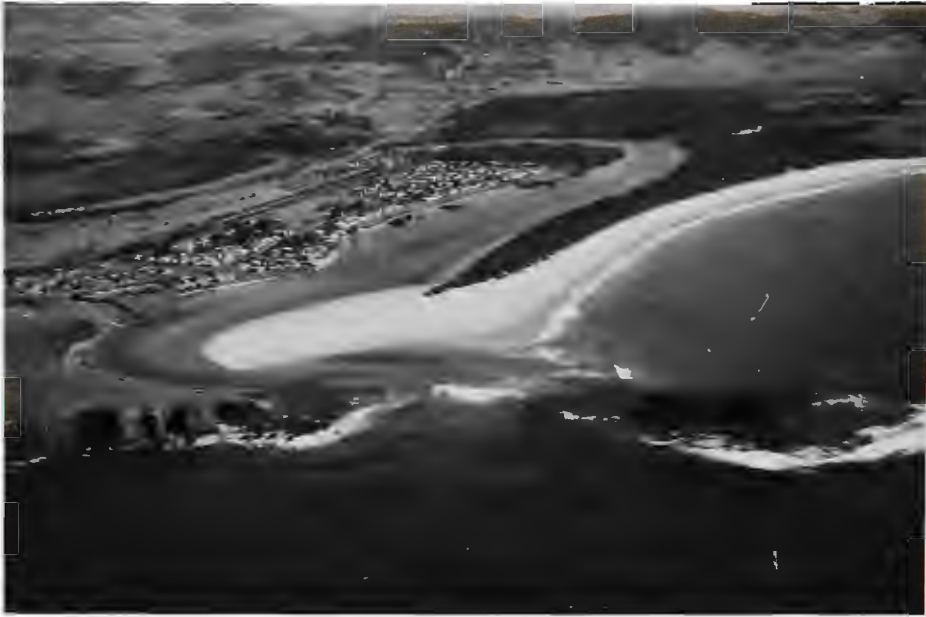
Seven Mile Beach prograded barrier (Fig. 5), consists of a series of ten vegetated dunes running parallel to the present coastline of Seven Mile Beach. The ridges range in height from 5-10 m above the present sealevel and are flanked by low vegetated dunes on the eastern margin adjacent to the beach (Smith, 1979). The width of the barrier varies from about 1.5 km in the south to .5 km in the north. There is little doubt that the original source of the barrier sand was the Shoalhaven River. However, as mentioned previously, the interrelations of the river and barrier since the beginning of the Holocene Transgression are considerably less obvious (Wright, 1970). Suffice to say, as sealevel rose offshore, sand originally derived from the Shoalhaven River catchment was pushed onshore to form a barrier. Typical of prograded barriers, a large area of swampland, Coomondery Swamp, exists behind the Seven Mile Beach barrier.



FIG.9. Distribution of Sand in the Minnamurra River Estuary.

(source N.S.W. Geol. Surv.).

plate: view from southeast of the twin barriers of Minnamurra.



Twin Barriers, like prograding barriers, are composed of sand built seaward. However, unlike prograding barriers they consist of two discrete sand masses separated by well developed tidal channels. Both sand masses in twin barriers are a legacy of the Holocene Transgression and should not be confused with the very old 'inner' barriers of Pleistocene age found on other parts of the N.S.W. coast (Thom, 1978). The mouth of the Minnamurra River forms the only twin barrier on the Illawarra coastline and the associated sand mass forms a major relict sand deposit. As Fig. 9 illustrates the surrounding embayment is inundated with relict sand extending up shallow coastal valleys for several kilometres in the northwest and southwest directions.

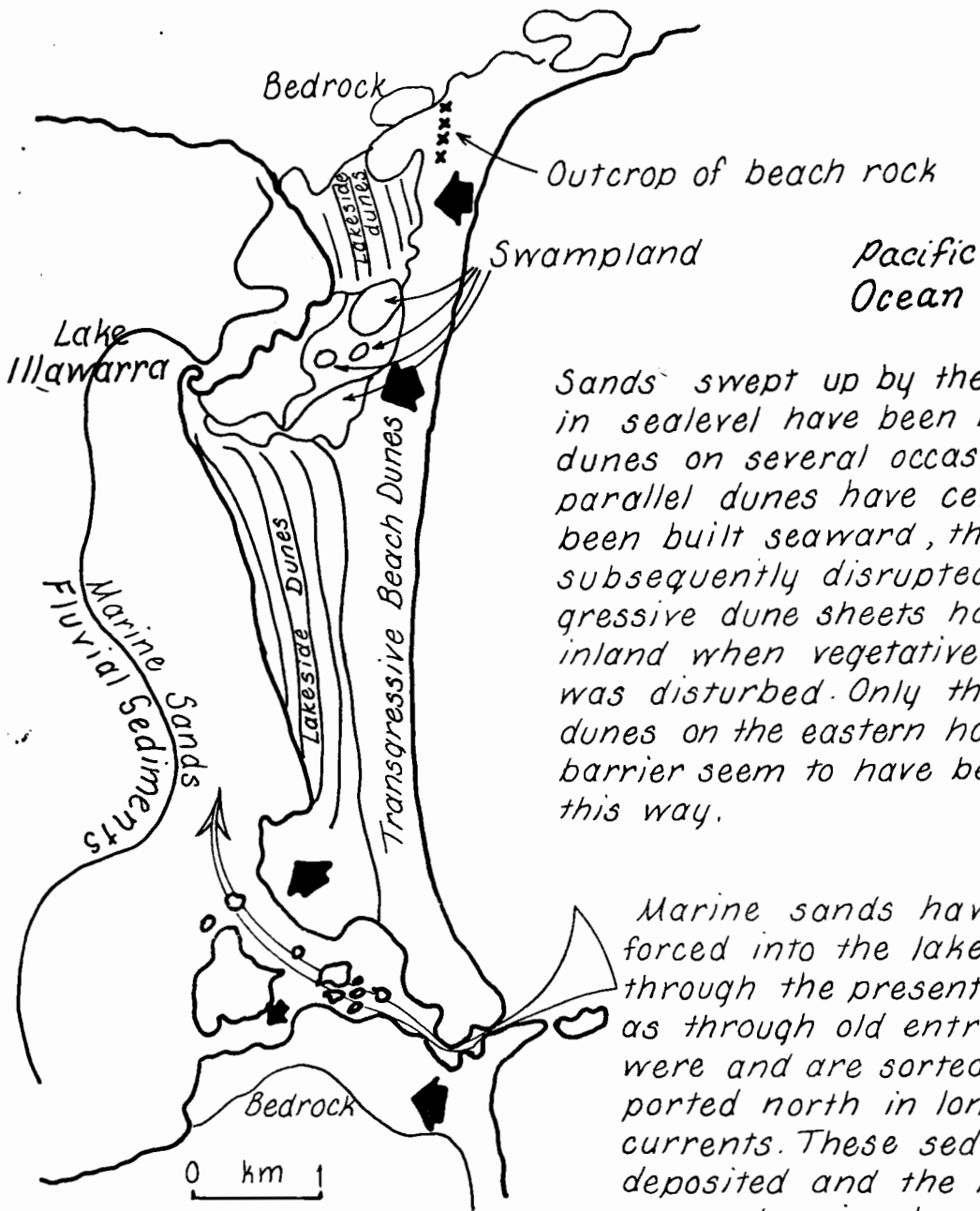
The course of the Minnamurra River has moulded the development of the main divisions in sand deposit, especially in the southerly portion. Here the sand has been reworked into large meander loops and modern spits characteristic of river floodplains. In the long term this southern area is an unstable form.

The northern portion of the sand mass in the Dunmore area represents a more stable form. Here sands with high shell content (probably of Pleistocene origin) penetrate the shallow valleys of the area and lie undisturbed by contemporary dynamic processes.

Composite Lakeshore Barriers do not appear in Thom's classification, but are present on the Illawarra coastline. Initiated by the formation of a narrow sand spit in shallow water (probably initially a stationary barrier) subsequent dune growth has occurred in a lagoon impounded behind the barrier. Fed into the lagoon via a tidal channel, sand forms a 'reverse delta' in contrast to a normal stream delta where sediment is fed into the sea. The tidal

FIG. 10. The Evolution of the Windang Barrier:

a composite barrier with lakeshore dunes.



Sands swept up by the last rise in sealevel have been built into dunes on several occasions. Sub-parallel dunes have certainly been built seaward, though subsequently disrupted as transgressive dune sheets have swept inland when vegetative cover was disturbed. Only the higher dunes on the eastern half of the barrier seem to have been formed this way.

Marine sands have been forced into the lake basin through the present as well as through old entrances, they were and are sorted and transported north in longshore currents. These sediments are deposited and the lake shore progrades in elongated lakeshore dunes.

Old entrances.

← Sand swept up by the rising sea onto eroded remnants of an older barrier. The emerging barrier was extended by waves, winds and currents both on its oceanic and lakeshore sides. Sand was swept in through several tidal channels, only one of which is still open.

Taken from  
Lake Report 1976.

delta sediment is reworked by waves and currents in the lagoon into a succession of beach ridges running along the lagoon shore.

Windang Peninsula enclosing Lake Illawarra is a composite barrier although its origin is complicated by the presence of Pleistocene deposits (Fig. 10). In Pleistocene times when sea level was close to its present level, masses of marine sand were deposited in relatively shallow water, thereby impounding the lower reaches of Macquarie Rivulet and Mullet Creek forming a lake. When sea level fell, these streams cut through this barrier and largely destroyed it. Peat and Roy (1975) have shown that the lake was formed and destroyed several times in this manner, the last phase occurring 6000 years ago. Remnants of this old Pleistocene barrier survive especially at the northern extremity of the present peninsula where the older sands have very well developed podsol soils with thick layers of organically bound sand ('coffee rock'). Indeed McElroy (1953) and Harris (1976) noted multiple layers of coffee rock at these sites. During the Holocene Transgression sand was swept up and covered these older sediments to form a single land mass. In this case, however, no clear topographic distinction can be made between Inner (older) and Outer (more recent) barrier complexes as Thom (1978) has identified on the central coast of N.S.W. Holocene sands were either transported inland from the beach as transgressive dunes or swept in through present and former mouths of the lake where they were reworked into lakeside dunes (as mentioned previously). The alignment of lakeside dunes (Young et al., 1976) and the recovery of estuarine shells from depths of about 6 m in the core of northern Windang (made available by South Coast Equipment Pty. Ltd.), indicate that sand in the lake may have

been fed in through several tidal deltas (Fig. 10).

Today, despite the general lack of sand input into the coast, a process that has been termed the 'trap door effect' (I. Eliot, pers. comm.) still allows sand to be pushed into the entrance of Lake Illawarra (Plate 1). However, considerable volumes of sand lying in the inlet throat have in the past ensured that this sand transport is not great. In periods of lower wave energy, Windang Island, immediately off the coastline, is connected to the mainland south of the lake by a sand spit. However, in periods of high southeast wave energy (the predominant high energy swell direction Wright, 1978), this spit is breached. Accompanying this high wave energy, south-north longshore drift along Warilla Beach immediately south of the lake entrance transports sand northward through the breach in the spit and either into the lake entrance or onto Perkins Beach north of the inlet. The reconstitution of the spit after the high energy period effectively debar any compensatory southward sand transport.

Receded Barriers are characterised by outcrops of peat or mud beneath the sand on the beach face. As peat and mud could not have been deposited in the high energy conditions on an open beach, they must have been originally laid down in a lagoon or estuary behind a sand barrier which was once situated farther offshore and has since migrated inland or been destroyed. Receded barriers are dominant between Thirroul and Wollongong, with the possible exception of the deposits at Bellambi Point which may form a stationary barrier. Storm erosion on Thirroul Beach together with a detailed drilling programme on north Bulli Beach (Jones, Young and Eliot, 1979) has shown that the modern sands are only

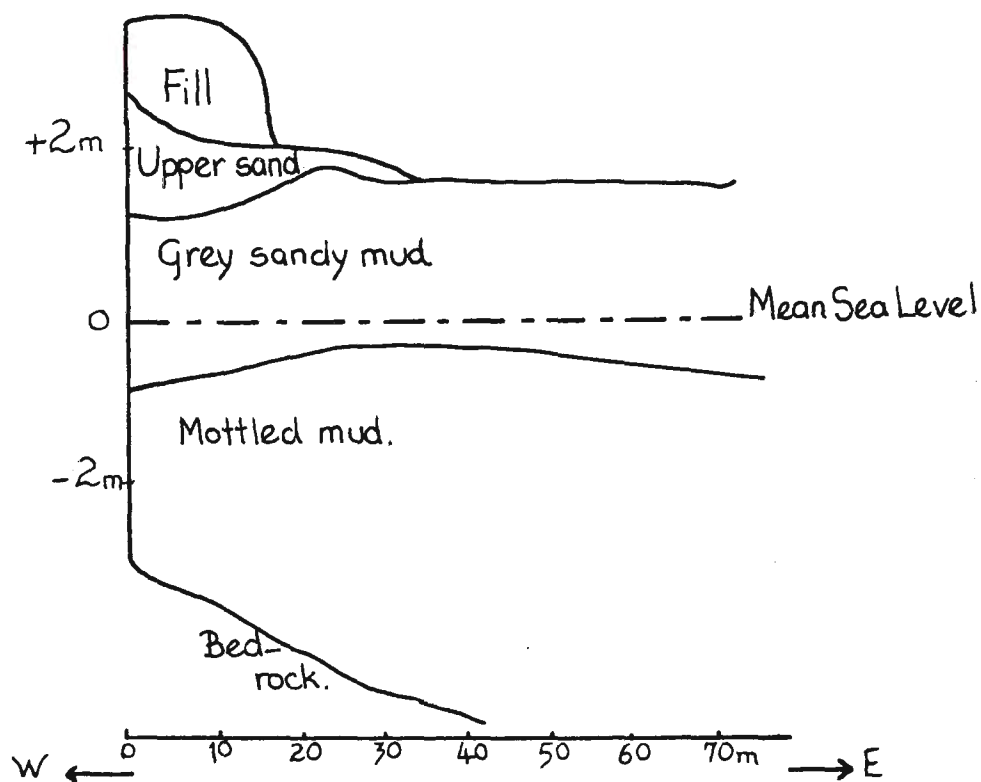


PLATE 1. Lake Illawarra entrance - The "Trap Door" Effect. Heavy seas breach the tombolo attaching Windang Island to the southern side of the lake entrance. South to north longshore drift may then transport sand from Warilla Beach into the lake entrance or onto Perkins Beach. The sand deposited in the lake entrance is gradually pushed up the tidal channel. When high seas subside, the tombolo reforms terminating the longshore drift and preventing compensatory southerly drift of sediment.



PLATE 1. Lake Illawarra entrance - The "Trap Door" Effect. Heavy seas breach the tombolo attaching Windang Island to the southern side of the lake entrance. South to north longshore drift may then transport sand from Warilla Beach into the lake entrance or onto Perkins Beach. The sand deposited in the lake entrance is gradually pushed up the tidal channel. When high seas subside, the tombolo reforms terminating the longshore drift and preventing compensatory southerly drift of sediment.

FIG.11. Features of Receded Barriers on Wollongong's Northern Beaches.



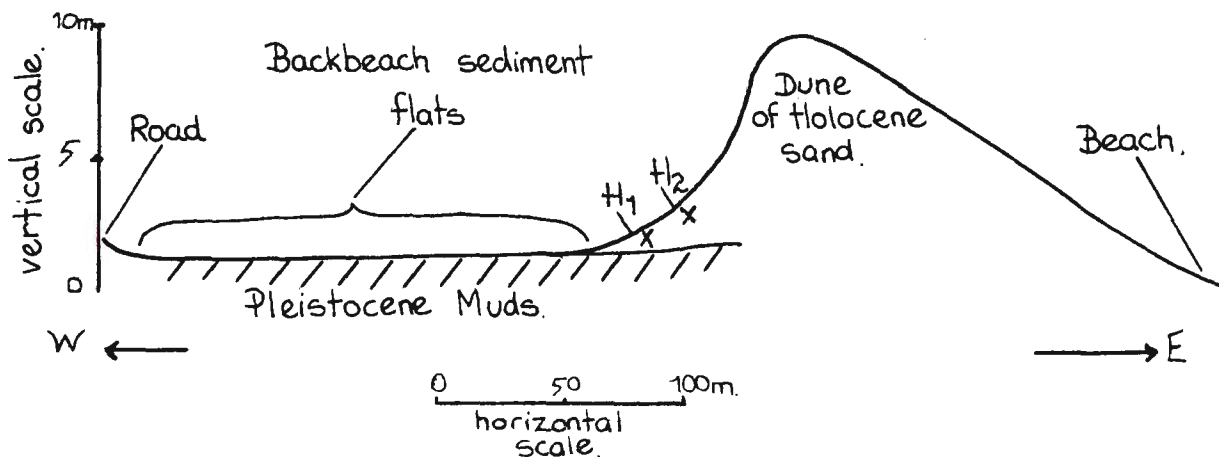
a) Stratigraphy of north Bulli Beach receded barrier

(simplified after Jones, Young and Eliot 1979)

b) Section through Fairy Meadow Beach receded barrier.

LEGEND.

- x H<sub>1</sub> — position of auger holes
- x H<sub>2</sub> — penetrating dune sands.





two metres thick and overlie both estuarine muds and old Pleistocene stream deposits (Fig. 11a). More recent drilling (Young and Reffell, 1980) has demonstrated that old stream deposits also extend seaward under the dunes at Towradgi and Fairy Meadow (Fig. 11b) while muds also seem to extend below dunes between Towradgi and Bellambi. Another group of receding barriers lie north and south of Shellharbour. Storm exposures on the beach north of Shellharbour revealed thick peat beds beneath beach face sands and drilling has revealed deep peat deposits behind this beach.

Sand deposits in this type of barrier are exceedingly small compared to the prograded, twin and composite barriers so far discussed. Indeed, most or all of their sand is directly involved in maintaining the equilibrium of the beach system. In periods of high wave energy, the beach foredunes are eroded and removed offshore where the sand is deposited in a sand bar which in turn dissipates the wave energy and protects the remaining beach from further erosion. When wave energy abates, this sand is returned onshore and eventually reforms the eroded dunes. None or very little of the sand in these barriers lies permanently inactive behind the beach system.

Stationary Barriers are composed of sands built up vertically during the Holocene Transgression. Although these barriers are generally composed of larger volumes of sand than are receded barriers they are also a product of an impoverished sand supply and show no signs of any significant seaward progradation (Fig. 7). As with receded barriers a significant proportion of sand in these barriers is directly involved in processes maintaining beach equilibrium. Examples of stationary barriers surrounding Wollongong include North Wollongong Beach, Warilla Beach and Werri

Beach (Fig. 8).

In addition to true 'barriers' which form slightly offshore in shallow water, there are mainland or 'pocket' beaches where sand has been driven onto solid rock at the head of embayments (Plate 2). On the Wollongong coastline these occur primarily north of Thirroul, from Red Point north to Port Kembla and from Minnamurra south to Seven Mile Beach, excluding Werri Beach (Fig. 8). The volume of sand on these beaches is strictly limited and, even more so than receded and stationary barriers, their sand is an integral part of the dynamic beach system. None lies permanently inactive.

#### Offshore Sands

In addition to onshore deposits surrounding Wollongong, sizeable sand deposits lie offshore. The recent interest in dredging several areas along the Sydney coast for sand suggests offshore sand to be a significant potential sand source in the future. The offshore of the Illawarra is similar to the surrounding Sydney Region offshore areas which have been termed as palimpsest and autochthonous (Swift, 1974). Palimpsest indicates that the sediment is a product of processes not active today but undergoing contemporary marine reworking and redistribution, while autochthonous indicates that the processes active on the sediment are marine based rather than of fluvial origin. As with onshore sediments, offshore sediments are relict.

The Continental Shelf off N.S.W. is very narrow in relation to many parts of the world and off the Sydney region it is approximately 32 km wide. Over this shelf area three major zones



PLATE 2. Walkers Beach, South Kiama. A pocket beach where sand has been driven onto solid rock at an embayment head.

have been distinguished from the shore to the seaward edge of the shelf (Davies, 1979; Shirley, 1974; Boshier, 1977), each of these zones is associated with characteristic sediment types and morphology:

- i) From the shore to approximately 60 m depth, sediments are largely composed of rounded quartzose grains forming gently sloping sand dunes. It has been suggested (Hails, 1965) that these deposits are the result of barrier destruction and shoreline recession during the Holocene Transgression.
- ii) From 60 m - 120 m fine terrigenous sands and extremely poorly sorted silts and clays compose a steeply dipping terraced midshelf region.
- iii) From 120 m to the edge of the shelf is a flat outer plain mantled with poorly sorted carbonates of varying sizes.

The innermost zone (to 60 m depth) contains sand sediment most suitable for dredging for construction sand, but this is also the most significant zone in terms of coastal processes and beach behaviour (Wright et al., 1980). The slope and width of this zone is determined not only by the amount of shelf sediment available for redistribution but also by the accumulated energy available from approaching waves, currents and tides. Off the narrow but high energy coast of N.S.W. the interaction between oceanographic processes and the solid boundary is highly complex. Without going into detail it suffices to say that although offshore sand may represent an extremely valuable source of sand in the future, intensive and thorough research on both the short and long term effects of dredging on the shoreline is essential before dredging

is permitted.

Therefore, the majority of evidence supports the hypothesis that the Illawarra region marine sand deposits both onshore and offshore are primarily relict. That sand is not actively re-nourishing existing sand deposits is supported by several facts:

- i) The occurrence of predominantly nonquartzose lithology
- ii) The small stream catchments coupled with mechanisms by which streams deposit their bedload prior to reaching the coast, and
- iii) The crenulate coastline which interrupts any long-shore movement of available sands.

Moreover, the relict nature of existing marine sand bodies is further reinforced by stratigraphic evidence derived from  $C^{14}$  dating of fragments embedded in barrier sediments and the logical reconstructions of processes responsible for the sand formations.

### (iii) Fluvial Sand Deposits

Fluvial sand sediments, like marine quartz sands may be of commercial value for the construction industry. As previously discussed, much of the Illawarra coastal plain yields little quartz sediment, however there are areas to the west and south of Wollongong where fluvial sand accumulations may be found.

### Swampland Deposits

The plateau west of the Illawarra escarpment is a ramp-like feature that dips generally northwest (Young and Johnson, 1977). This causes the streams to the west of the escarpment to flow landward. The major stream catchments west of the Illawarra

escarpment near Wollongong include the O'Hares, Cataract, Cordeaux, Avon and Nepean catchments. In the headwaters of each, close to the escarpment, the topographic surface is relatively flat, having an average fall over 15-20 km of less than  $1^{\circ}$  (A. Young, pers. comm.). In these areas water percolates slowly by throughflow, overland flow and in small streams down the valleys. Well jointed, porous Hawkesbury Sandstone, coupled with this slow water movement allows deep water penetration, facilitating deep *in situ* weathering. Where this occurs, the quartz-rich weathered debris is not moved away quickly due to the low competence of the streams to transport sediment. Rather, the unconsolidated sands remain choking the relatively small headwater valleys (A. Young, 1980). Thus these upland swamps represent contemporary fluvial sand deposits.

As the streams in these catchments grow, both their erosive power and their sediment carrying capacity increases. Consequently, whilst they deeply erode the Hawkesbury Sandstone plateau downstream of the headwaters the sediment is carried far from the Illawarra region to be deposited in areas such as Camden/Elderslie and in the channel of the Georges River. Here it is of no commercial value to the Wollongong market.

#### Riverbed Deposits

Another example of fluvial sand within the Wollongong area occurs in the Shoalhaven River estuary. In the Shoalhaven's catchment area there are extensive surface exposures of silicious rock which, on weathering, yield quartz fragments. These are transported downstream. Much of the river flows through a narrow incised valley in which little deposition can occur. As the river

widens in reaching the coastal plain, the river loses much of its capacity to transport sediment. As illustrated earlier (Fig. 5) an extensive deltaic plain is associated with the coastal reaches of the Shoalhaven. Much of the sediment which has infilled this basin since its formation 7000 years ago consists of fine alluvial sediment, while the sandy portions of the bedload have been confined to the river channel by the river levees (Norwood, 1975). This explains the relative abundance of sand in the river channel downstream from Nowra (Wright, 1970; P.W.D., 1977). Pig Island (Fig. 1) downstream of Nowra obstructs the river's flow. The consequent slowing of river flow results in sand being deposited in a spitlike form upstream of the island. Whilst the small volumes of sand deposited around Pig Island are available for extraction, the limited nature of this deposit renders it of low commercial significance.

In summary, while sand occurs in scattered headwater catchments west of the escarpment, streams of the region yield little sandy alluvium. Despite the limited sand accumulations in the channel of the Shoalhaven River, coastal streams of the Illawarra do not carry much sediment because their catchments contain large expanses of fine grained lithology that weathers to fine lithic sediment. Clearly, compared to marine sand deposits, the production of sand by fluvial processes is strictly limited.

#### (iv) Summary

As there has been some controversy over the nature of coastal deposits it has been deemed necessary to clarify their origin and the processes active in their construction. This is because their

sediment renourishment status will clearly be of critical importance in later evaluations of their potential for disruption.

Evidence suggests that the coast of N.S.W. as a whole is not receiving contemporary sediment input, but rather that it is composed of relict sediment, a legacy from the Holocene Transgression. Although the Illawarra coastline is typical of that of much of N.S.W., the body of this chapter has been concerned with showing that processes active on the N.S.W. coast are indeed prevalent in the Illawarra. Furthermore, it has been concerned with illustrating how the geology and distinctive structure of the Illawarra region have been of outstanding importance in influencing the existence and distribution of sand resources around Wollongong.

In essence it appears that the sand resources available to Wollongong are predominantly of marine origin. These marine deposits however are relict, undergoing no contemporary renourishment and this, once removed, are irreplaceable. Fluvial deposits are clearly of little significance to Wollongong as there are very few present and these are strictly limited.

The following chapter focuses on the sand deposits available to Wollongong in terms of their commercial resource potential.



## CHAPTER THREE

### THE COMMERCIAL VALUE OF WOLLONGONG'S SAND DEPOSITS

#### (i) Introduction

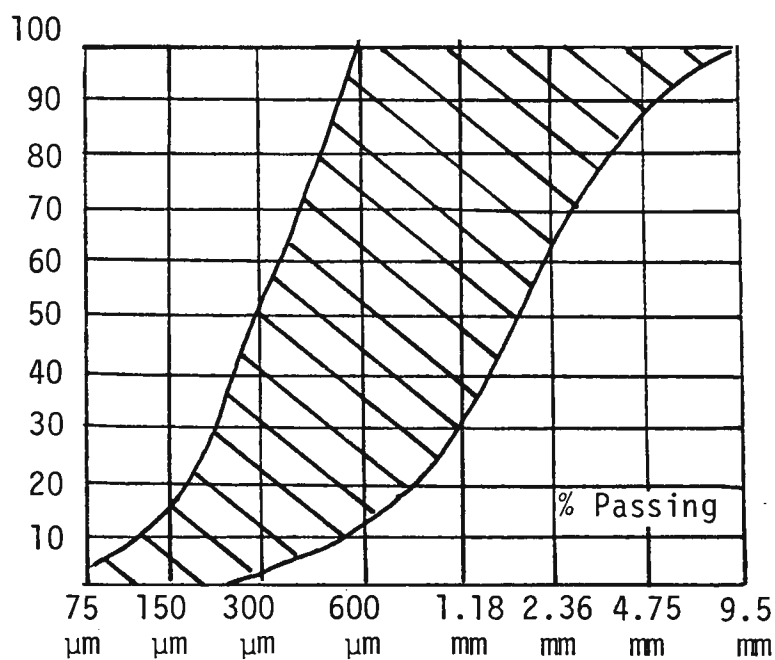
The aim of this chapter is to establish a clear picture of the nature, extent, and hence the commercial value of sand deposits surrounding Wollongong.

The marine sand deposits of the Illawarra region are of obvious commercial potential and have been the centre of research by many groups. This chapter will first draw together the fragmented information available on these sands and supplement that data with original data based on field research. Secondly this chapter presents the results of new field research carried out on extensive Quaternary alluvial deposits west of Lake Illawarra and on deltas built out from the western margins of the lake. Little was previously known about these fluvial deposits. In the past there have been suggestions that these may contain extensive sandy lithofacies (Young, et al., 1976; South Coast Equipment Pty. Ltd., pers. comm.), but as noted in the previous chapter the catchment lithologies yield little sand. Clearly the claims about the potential of these deposits need to be evaluated. Field research has also been completed on other minor fluvial sand deposits such as Iluka Creek, an upland swamp where sand weathered *in situ* rests on Hawkesbury Sandstone.

Each of the main deposits is described in terms of its areal extent and depth, the physical traits of the sand and its potential uses. Estimations of the volume of sand are included, as too are estimates of the height of the water table which is so important

FIG. 12 : SAND SUITABLE FOR CONCRETE MUST COMPLY WITH AUSTRALIAN STANDARD 1465-1974 WHICH SETS OUT THE FOLLOWING REQUIREMENTS:

Natural Fine Aggregate		
Sieve Aperture	% Passing	Max. Total Deviation
9.50 mm	100	-
4.75 mm	90-100	±5
2.36 mm	60-100	±5
1.18 mm	30-100	±10
600 μm	15-100	±15
300 μm	5-50	±15
150 μm	0-15	±5
75 μm	0-5	±2



- Other requirements:
- Water absorption  $\leq$  5%
  - Clay and silt content (75μm)  $\leq$  5%
  - Shape of grains-rounded
  - Deleterious materials including friable particles, material finer than 2 μm, organic impurities, structurally weak substances and alkali reactive material must constitute  $<$ 1%

for determining whether dry extraction or dredging will be necessary. For the less significant deposits, only a general appraisal of the amount of sand present and its quality is included.

Beyond an inventory of sand deposits available to Wollongong, this chapter also provides a basis for the most efficient use of the sand resources. By locating the sand deposits suitable for more specialised uses, it enables preservation of these quality sand deposits in the face of pressing demand for lower quality construction sands.

At this point a more precise definition of the type of sand commercially valuable for building and industrial purposes is in order. Essentially, sand suitable for concrete (commonly referred to in the building industry as fine aggregate) is composed of particles 90% of which passes a 4.75 mm test sieve. The sediment must also conform with the particle grading and other requirements summarised in Figure 12. Depending on the characteristics of the sand, however, it may be utilised for more specialised applications. Foundry sand, for example, must possess uniform chemical and physical properties that will allow it to be moulded into the desired shape, while the particles must be rounded and sufficiently well-sorted to give high permeability and allow gases to escape when the molten metal is poured. Sand suitable for glass manufacture must be consistently fine grained and contain very low proportions of metal or organic inputs. Sand used for filling in construction work, however, does not have to conform to such rigid specifications.

## (ii) Marine Sand Deposits

### Resources of Stationary and Receding Barriers and Pocket Beaches

As discussed in Chapter Two these barrier types are present along areas of coastline where sediment supply has been low. They are dominant from Stanwell Park south to Port Kembla and from Warilla Beach south to Seven Mile Beach (with the exception of the Minnamurra River Estuary and Werri Beach). The sand on these beaches and barriers has, in the case of pocket beaches, been driven on to solid rock, or, in the case of stationary and receding barriers, on to estuarine clays. Although sand volumes vary, they are generally small. The study by Jones, Young and Eliot (1979) on Thirroul and North Bulli beaches revealed that on those receded barriers sand deposits were only 1-2 m thick (Fig. 11a). Drilling into the larger stationary barrier of Fairy Meadow Beach (Young and Reffell, 1980) revealed that sand depths vary from as little as 1-2 m to 10 m deep (Fig. 11b). It suffices to say that on these beaches and barriers the sand volumes present do not make commercial extraction an economically viable proposition. What is more, extraction from these small deposits where a high proportion of the sand is frequently involved in maintaining the dynamic equilibrium of the beach face (Chapter Two), would prove environmentally disastrous.

### Resources of the Windang Peninsula/Lake Illawarra Composite Barrier

One of the largest sand deposits in the immediate vicinity of Wollongong lies in the composite barrier of Windang Peninsula situated only 5 km south of Wollongong. The main portion of the barrier is approximately 7 km long and 1 to 2 km wide and extends from Red Point south to the entrance of Lake Illawarra. A southerly extension of much smaller dimensions runs south from the lake's

entrance to Barrack Point (Fig. 6). As the barrier drapes a bedrock saucer-like embayment, the depth of the sediment varies considerably. At Red Point and Barrack Point sand depths are only approximately 1 m deep, whereas beneath Korrongulla Swamp in the centre of the barrier, sand depths are approximately 40 m deep (E.R.S. borelogs, 1969, appendix).

Windang Peninsula has been the site of much research both for scientific and commercial interests. Research has been carried out by various private companies and government bodies, including South Coast Equipment Pty. Ltd. (S.C.E.), Australian Consolidated Industries (A.C.I.), The Electrolytic Refining and Smelting Co. of Australia (E.R. and S.) and the Metropolitan Water, Sewerage and Drainage Board (M.W.S. and D.B.). Synthesis of data from these various sources enables a reliable estimate of the sediment types in the peninsula. Representative borelogs are mapped and recorded in the appendix.

Figure 6, derived from research by A. Stephens (of the Geological Survey, pers. comm.), C. Harris (1976) and Young (1976), illustrates the variation in the areal distribution of sediment types of the surface of the peninsula. Examination of available literature (McElroy, 1953; E.R.S., 1969; M.W.S.D.B., 1972-1975 - see appendix) shows that variation in sediment type is not restricted to the surface of the barrier, but also varies with depth below the surface. These variations in sediment type associated with the mode and age of deposition have marked effect on the resource potential.

Most research has been completed on the northern part of the peninsula, particularly at Kemblawarra (Fig. 6). In 1967 South Coast Equipment Pty. Ltd. completed geological investigations at Kemblawarra in which some bores penetrated to approximately 24 m.

Borelogs 12 and 13 (appendix) reveal that sand from 0-4 m is generally clean, fine grained, yellowish quartz sand with a low shell content (approximately 3%). With depth the sand becomes more grey and fragments of wood occur until at approximately 8 m depth evidence of old estuarine channels is encountered. These channels are represented by bands of finer muddy sand, coffee rock and clays. Bores terminate at 12 m because these bands of coffee rock and clays are not economically attractive. Evaluation of surface sand deposits in the vicinity of Kemblawarra by Australian Consolidated Industries in 1971 (recorded in appendix), established that over a small area of inactive vegetated dunes sand to a depth of 6 m consisted of grey-white sand of glass manufacture quality (having a very low iron content). Above and below this high quality strata, sand becomes contaminated with iron and thus unsuitable for glass.

Over the majority of the Kemblawarra area sand grains are well sorted. With washing and screening to remove shell and other fragments the sand is suitable for construction, foundry and abrasive uses. In the Kemblawarra area the average depth of the water table is approximately 2 m below the surface, thus dredging is necessary for large scale extraction.

South Coast Equipment Pty. Ltd. investigations west of Kemblawarra, near Griffins Bay (appendix), show a prevalence of clean sand suitable for construction, foundry and abrasive uses to a depth of 10 m. Below 10 m the sand becomes interdigitated with layers of silts and clays which represent old estuarine channels and is not commercially attractive.

In the vicinity of Korrongulla Swamp, in 1969, the Electrolytic Refining and Smelting Company of Australia thoroughly explored sand deposits to bedrock (appendix). The sand in this area is suitable

for construction, foundry and abrasive uses after washing and screening. Below this sand a zone of sandy clay some 6 m thick lies on tuffaceous bedrock.

Southward from Korrongulla very little exploration has been carried out on the peninsula, although clearly there are huge quantities of sand present on the lake ridges and inactive vegetated dunes. In the far south of the barrier the Metropolitan Water, Sewerage and Drainage Board (1972-1975) has sunk several bores north and south of the lake entrance and these are recorded in the appendix. The northernmost borelog (No. 6) was sunk into tidal delta sediments where medium to coarse sand with some organic material, shell and pebbles predominated to 16 m depth where sand met estuarine clays. The sand in this profile, after washing and sieving, would be suitable for construction use. Boreholes sunk adjacent to the lake entrance and in tidal delta sediments (numbers 3, 4 and 5) quickly grade from sand into silty sand or dense dark grey sand which becomes more dense with depth. The commercial viability of these sands is much less than in areas to the north.

On the western side of Windang composite barrier, a very large sand deposit extends out under the eastern section of Lake Illawarra. The deposit of quartzose sand runs from Purry Burry Point south to Boonerah Point and includes the small area occupied by the lake mouth tidal channel and "reverse" delta (Fig. 4). As noted in Chapter Two this sand body originated primarily from marine sand being pushed through former and present day estuarine channels during the Holocene Transgression. This marine sand, together with aeolian sand blown from adjacent dunes (Peat and Roy, 1975) has been, and is being, sorted by waves and currents active in the

lake. The area of the bar is approximately  $3.5 \text{ m}^2$  or 10% of the lake's area and the average depth of the sand is 7 m. Using these statistics Soros, Longworth and McKenzie (1976) estimated that well over 30 million tonnes of sand was present there. Smith (1979) of the N.S.W. Geological Survey accepts this estimate with reservation and suggests that the real amount is somewhat less.

Dense weed growth on the surface of the sand in the lake creates an environment conducive to the deposition of mud. However, this muddy sand deposit is only superficial and grades downwards into clean sand (Peat and Roy, 1975) in which the organic content is low (2-3% by weight) (Smith, 1979). The areal distribution of sand, representative borelogs and sediment size analyses are recorded in the appendix. Essentially, the sediment composing the lake shore consists of approximately 95% sand size particles of which more than 95% is quartz. The sand fraction is medium to medium fine grained, subrounded in subangular, moderately well sorted, and contains minor shell fragments (Peat and Roy, 1975). Hydrochloric acid tests established that after screening, land sands were very low in calcareous content which would indicate potential for industrial uses (Smith, 1979). Sieve analyses, however, reveal that the lake deposits have a grading more suited to construction uses (Soros, Longworth and McKenzie, 1976).

Lake Illawarra's present tidal channel passes to the north of Bevan's Island, and the tidal delta complex extends from Why Juck Bay in the south to Cudgeree Bay in the north and seaward to Berageree Island (Fig. 4). Clean quartzose sands occur on the bed of the main channel while muddy sands occur in the shallows on its sides (Peat and Roy, 1975). Sand samples from this area consist of



relatively high levels of iron ( $\text{FeO}_2$ : .4%), carbonate ( $\text{CaO}$ : 8.39%), and aluminium ( $\text{Al}_2\text{O}_3$ : 1.47%). Although these levels are too low to be of commercial value for heavy minerals, and too high to be utilised in glass manufacture, the sands are suitable for construction and industrial uses.

It is unreasonable to estimate absolute volumes of sand available for extraction from the tidal channel area. As discussed in Chapter Two, the operation of the "trap door effect" (Plate 1) creates a continuous supply of sand to this area with sand removed from Warilla Beach to the south. This means that sand removed from the seaward sector of the lake entrance merely accentuates a sink into which sand flows whenever the "trap door" operates. Thus, although sand may be continually available in this area, it is at the expense of other areas.

The available formation suggests that the northern and central portions of the Windang Peninsula represent the most commercially attractive sand deposits on the barrier, while the southern portions hold less potential for economic exploitation. Marine sediments under the eastern portion of Lake Illawarra, despite their inaccessibility appear to consist of high quality, economically attractive quartz sand.

Thus most of the sand composing Windang Barrier is suitable for use in the construction industry after screening and washing. Only limited areas consist of higher quality sands available for uses such as glass manufacture. It is clear that the barrier includes a very large volume of sand suitable for extraction, although in reality the amount of sand available for extraction is restricted by environmental, aesthetic and ecological considerations

as well as land use regulations.

### Resources of the Minnamurra Estuary Twin Barrier Complex

Detailed subsurface investigation by the N.S.W. Geological Survey (Smith, 1979) has revealed very large reserves of sand 20 km south of Wollongong in the lower reaches of the Minnamurra River valley and the adjacent Dunmore area. As illustrated in Figure 9 the deposit extends from the twin barriers of the Minnamurra River mouth southwest up the Minnamurra River valley and northwest into the low coastal valleys of the Dunmore area. In all, the area of the sand deposit covers some 40 km<sup>2</sup>. The depth of sand over the bedrock varies from 4-14 m, generally deepening toward the east. Smith (1979) estimated in excess of 35 million tonnes of sand to be present in the deposit.

Geological Survey investigation has involved extensive boring of the area. Representative borelogs together with selected sediment analyses are recorded in the appendix. The eastward deepening of sand becomes obvious in the comparison of borelogs 29 and 33. Situated close to the middle of the deposit borehole 29 penetrates well over 12 m of sand, whereas borehole 33 located in the southwest extremity of the deposit rapidly reaches clays and clayey sands typical of river floodplains on latite bedrock. The variable sedimentary stratigraphy influences the commercial value of the sands. Generally the top 7 m, composed mainly of fine to medium grained, subangular to subrounded poorly sorted quartzlithic sand (see appendix), is commercially valuable. Below 7 m, however, a marked increase in shell and clay content greatly reduces the commercial value of this lower portion of the deposit. Although latite fragments can constitute up to 20% of sand sized grains throughout the

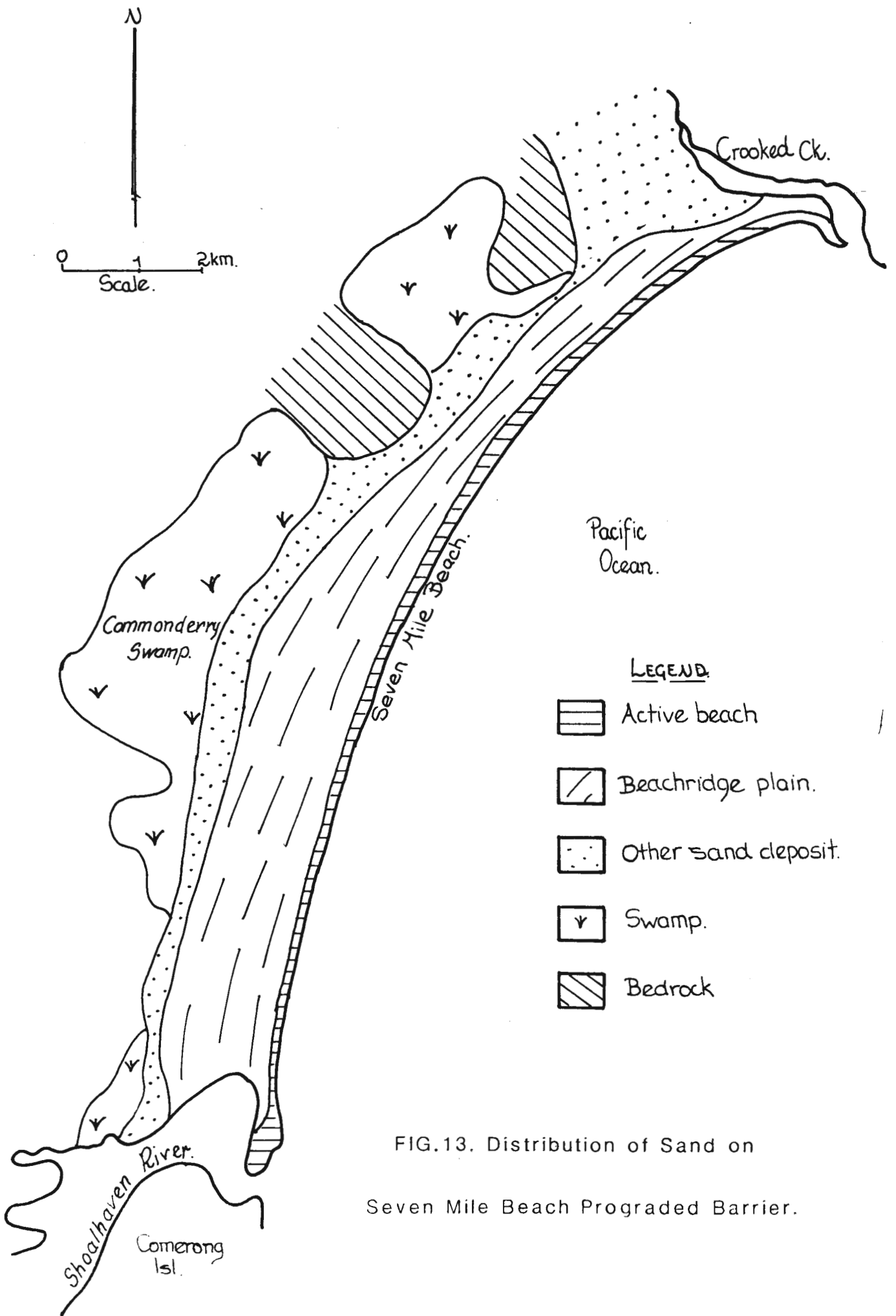


FIG.13. Distribution of Sand on  
Seven Mile Beach Prograded Barrier.

borehole profiles, they are relatively unweathered and for instance would not break down in concrete (Smith, 1979).

The removal of shell and clay by screening and washing prepares sand to be suitable for construction. In localised areas, such as in the vicinity of borehole 24 (appendix), an Australian Iron and Steel drilling programme revealed an estimated quarter of a million tonnes of sand suitable for foundry use. The high proportion of rock fragments renders sand in the Minnamurra deposit unsuitable for glass manufacture. In general, the water table varies from 1-2 m below the surface, and large scale sand extraction would require the use of a dredge.

Although an estimated 35 million tonnes of sand is present in this deposit, as will be discussed later, environmental ecological and aesthetic considerations, together with land use by-laws greatly reduce the sand available for extraction. While localised areas of high quality sand exist, the majority of the deposit is composed of high proportions of lithic grains and shell fragments which detract from the quality of the sand. Indeed, only the top 7 m appears commercially attractive.

#### Resources of the Seven Mile Beach Prograded Barrier

Situated approximately 40 km south of Wollongong the prograded barrier of Seven Mile Beach is an arcuate mass approximately 9.5 km long, from .8-1.5 km wide and covering an area of 11.5 km<sup>2</sup> (Fig. 13). In this area the N.S.W. Geological Survey (Smith, 1979) has carried out geological investigation, which has been concentrated in the central and northern end of the barrier. Much of the remaining area is National Park and is thus effectively "sterilized". Outside the National Park boundaries, an estimated 6 million tonnes of sand is

available for extraction (Smith, 1979). Recorded in the appendix are the areal distribution of sand outside park boundaries, representative borelogs and selected sediment analyses. Smith (1979) noted a northerly fining of sediment in the deposit, and sediment analyses (appendix) support this. Vertical variation in the nature of the sand is also evident. Whereas the surface sands tend to be fine with no or minor shell content, as depth increases sand becomes more coarse and shell content increases (this is especially obvious in boreholes 35, 37, 40 and 42). Sand grain shape ranges from subangular to subrounded.

Localised areas of fine, even grained sand with a low shell content exist toward the northern end of the barrier. These sands are suitable for foundry use, whereas the coarser sands further south are not. Traces of heavy minerals also occur in this deposit including iron ( $\text{FeO}_2$ : .4%) and titanium ( $\text{TiO}_2$ : 1.9%) (Herbert, 1969). While they render the sand unsuitable for glass manufacture these minerals occur in concentrations too small to be commercially viable. Most of the sand in this deposit is suitable for construction purposes. As the water table is approximately 1-2 m below the surface, large scale extraction requires a dredge.

In summary it can be said that the marine deposits of the Illawarra region are generally composed of quartz sand of commercial value especially for construction and industrial uses. The size of these deposits varies considerably along the coastline. Stationary, receded and pocket beach barriers are of little or no commercial value. However the barriers associated with Windang Peninsula, the Minnamurra Estuary and Seven Mile Beach each stand out as the most commercially valuable sand resources for Wollongong because of their considerable size coupled with good quality sand.

## (ii) Fluvial Sand Deposits

The commercial value of the region's fluvial sands has yet to be firmly established. As mentioned previously, these deposits are markedly less attractive than marine sands because of their generally small and scattered nature, lower quality sand, and remoteness from the City of Wollongong. Their comparatively low potential is reflected in the greatly reduced amount of research carried out into the extent and nature of sand in these deposits.

Field research has been conducted into the nature of deltaic sediments on the western side of Lake Illawarra and on the large alluvial plain west of the lake. In both of these areas there has been some suggestion that the sand might be of some commercial value (Young et al., 1976; South Coast Equipment, pers. comm.). As no previous work has examined these alluvial sediments, clarification of the nature of sediments was considered necessary. Areas of upland swamps immediately west of the Illawarra escarpment have also been the subjects of very little study, hence research was also conducted into the nature of these deposits. The appraisal of these lesser known deposits has required drilling and laboratory analysis of collected sediment samples.

### Fluvial Sediments In and West of Lake Illawarra

It has been speculated that sediment in the deltas of streams entering the western side of Lake Illawarra may represent a source of commercially viable sand, but field evidence has shown it not to be so. Macquarie Rivulet is the largest stream entering Lake Illawarra, it has a high sediment carrying capacity especially during floods and is competent to transport any available sand. Young et al. (1976) noted that Macquarie Rivulet has "small, active and clean

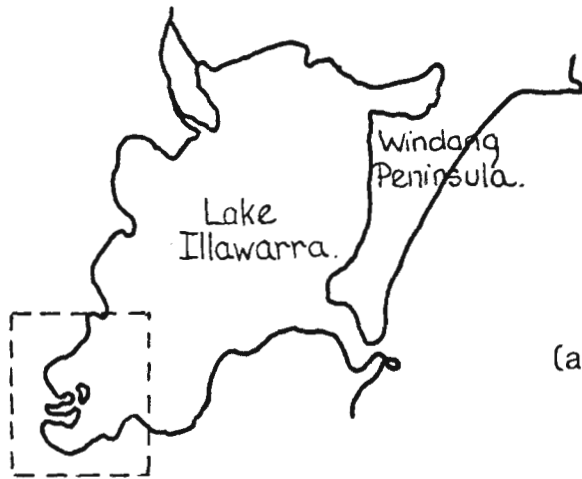
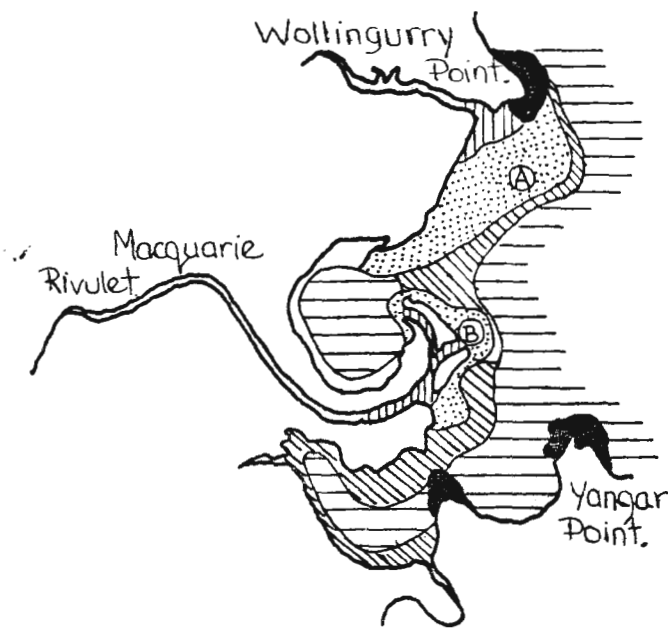





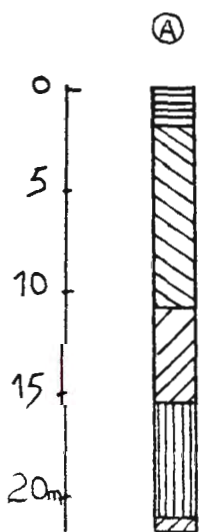
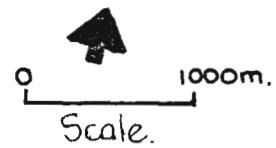
FIG. 14 Sediments Of  
Macquarie Rivulet

(as from the N.S.W. Dept. of Mines)



LEGEND.

-  Clean lithic sand, < 5% mud.
-  Muddy lithic sand, 50-95% sand.
-  Lithic sandy mud, 50-95% mud.
-  Mud, > 95% mud.
-  Rock outcrop.







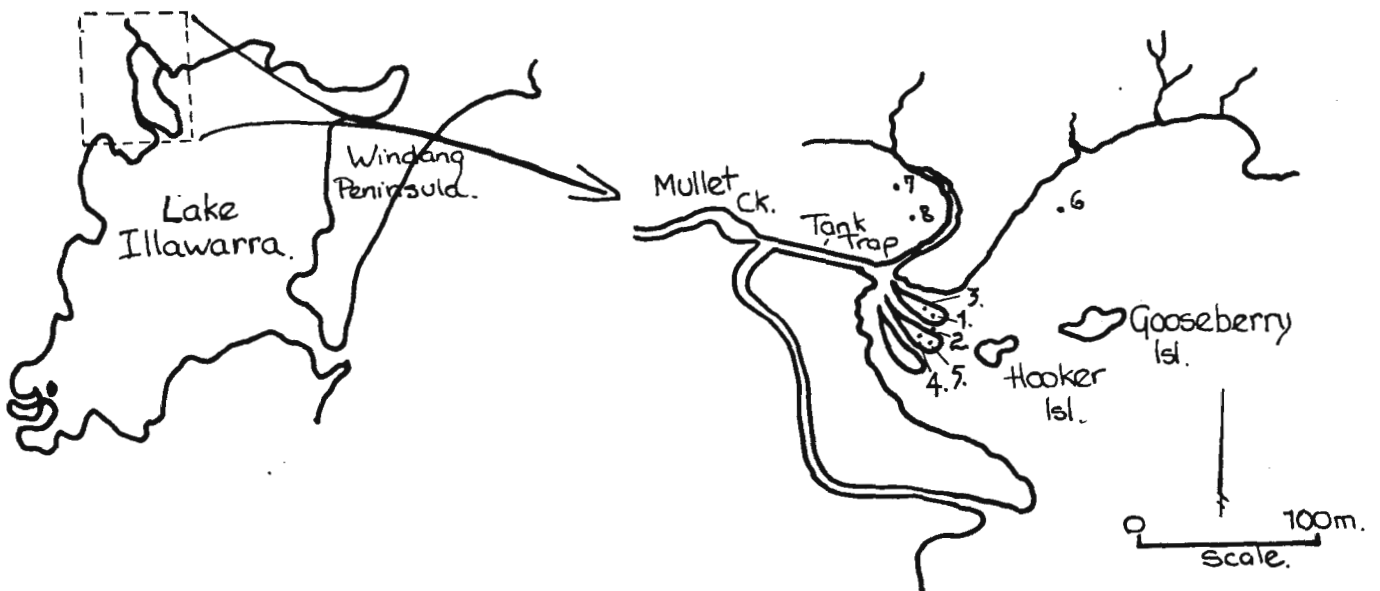
-  Water
-  Unclassified sand.
-  Mud.
-  Clay.

Fig. 15. Sediment Sample Analysis—Mullet Ck/Tank Trap Area.



Hole no. (see map).	Depth.	% Medium sand, coarser than 350 $\mu$ m	% Fine sand/silt, coarser than 63 $\mu$ m	% Finer than 63 $\mu$ m.	Comment.
1	1m	5	45	50	
	2m	5	75	20	shelly.
2	surface	10	80	10	
	1m	5	45	50	
3	1.5m	5	75	20	very shelly.
	1m	0	90	10	
	1.5m	2	65	33	
	2m	2	60	38	shell
4	2.5m	5	55	40	shell.
	surface	25	60	15	
	1m	10	80	10	
5	1.5m	5	70	25	shell
	surface	55	30	15	
	1m	10	80	10	
	1.5m	2	80	18	
6	2m	5	50	45	
	surface	2	95	3	
	.5m	5	90	5	
	1m	2	95	3	
7	1.5m	1	25	74	shell
	.5-1m	20	50	30	
8	5-6m	10	20	70	shell.
	1m.	25	70	5	

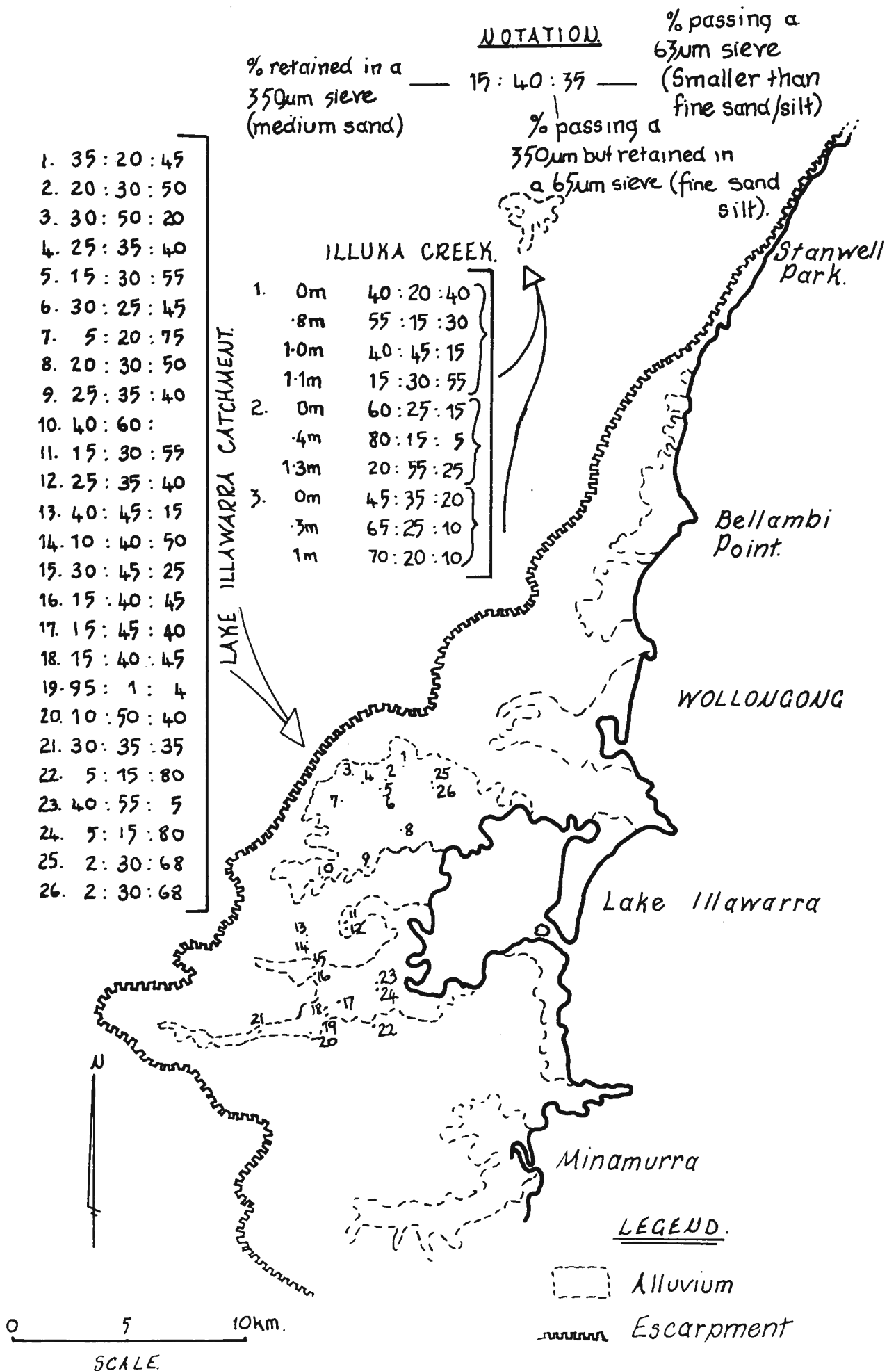


subaqueous deltas adjacent to each distributary channel". Thus it appears that sand is present at least on the surface of the delta. Borelogs recorded by Peat and Roy (1975) provide information on the nature of subsurface sediment. Borehole B (Fig. 14) penetrates a sand surface and passes quickly into muddy sand with interdigitated sand and mud layers over a clay basement. Thus, despite the fact that Macquarie Rivulet rises west of the escarpment on Hawkesbury Sandstone, little sand reaches its mouth. Half a kilometre north near Wollingurry Point, muddy sand is found on the lake floor but as Borelog A shows below this is 10 m of mud.

Sand deposits in the mouth of Mullet Creek have also been investigated. Peat and Roy (1975) and Young et al. (1976) noted the sandy nature of surface lithofacies in this locality, but did not know the thickness of the sandy layer. Field research has now been completed in the mouth of the "Tank Trap", an artificially constructed channel which diverts the flow from Mullet Creek into the northwest of Lake Illawarra (Fig. 15). It is assumed that since construction of the canal 40 years ago any sandy bedload in Mullet Creek would also be diverted and deposited in the delta actively developing at the mouth of the Tank Trap. Shallow bores were augered 2-3 m into the Mullet Creek/Tank Trap delta; the location of these bores in the delta sediments is recorded in Figure 15. Sediment samples were collected at half metre depth intervals and grain size analyses were carried out on them. Analysis of sediment samples involved deflocculation of aggregates where necessary and passing each sample through a 350  $\mu\text{m}$  sieve retaining medium sand grains or larger, and a 63  $\mu\text{m}$  sieve retaining fine sand/silt sediments or larger. Thus the proportions of sand, silt and clay could be calculated. Analysis showed that the majority of sediment in the sampled area consisted

FIG. 16. Sediment Analysis from Alluvial Deposits:

West of Lake Illawarra and Tableland Swamps.



of fine sand/silt or finer sediment, and this sediment became finer with increasing depth. The occurrence of numerous shell fragments at depths of 1.5-2 m in the Tank Trap delta indicates the predeltaic estuarine environment, and the base of delta lithofacies. Therefore, despite the considerable extent of surface sand, this deposit has no potential as a commercial sand extraction site.

Alluvial river flats immediately to the west of Lake Illawarra have also been examined in detail in order to evaluate their potential as a source of sand. Field work was conducted firstly in association with South Coast Equipment Pty. Ltd., who were interested in exploring the area as a potential commercial sand deposit. Two deep bores were augered into low lying river flats adjacent to the lake between the Tank Trap and Hooker Creek (Fig. 15, Bores 7 and 8). In both holes samples were collected and analysed by the method described above. Sediment here was predominantly finer than 63  $\mu\text{m}$  and became finer with depth. This deposit certainly has no commercial value for sand extraction. Extensive field examination of road cuttings, creek banks, and stream terraces, on the alluvial sheet west of Lake Illawarra (Fig. 3), enabled evaluation of this area as a possible sand source. Representative sediment samples were collected from over the area (Fig. 16) and sediment analysis revealed that a very high proportion of each sample passed through a 63  $\mu\text{m}$  sieve. This indicates that there are no areas of sand in this locality suitable for commercial sand extraction.

The fluvial deposits in and to the west of Lake Illawarra offer very little sand of commercial quality. Despite suggestions that sand may be present in deltaic facies because of surface layers of sandy sediment, the lithological characteristics of the associated stream catchments (discussed in Chapter Two) restrict the availability of quartzose sand grains and rather, produce fine lithic sediments. This research then, clarified not only the question of commercial sand availability in fluvial sediments west of the lake, but further reinforces arguments for the lack of contemporary sand additions to the Illawarra coast discussed in Chapter Two.

### Upland Swamps

West of the escarpment where drainage is principally north-westward over Hawkesbury Sandstone, sand deposits of probable commercial quality and size exist in the headwaters of the O'Hares, Cataract, Cordeaux, Avon and Nepean catchments. The slow percolation of water via throughflow and overland flow, and down the small streams of the gently sloping headwater slopes, penetrates the well jointed sandstone surface. This results in extensive *in situ* weathering and also a very slow shifting of weathered sands down slope. There is no massive removal of debris in the streams which seem incompetent to transport large amounts of sand.

Trial sampling was carried out on one small headwater stream, Iluka Creek in O'Hares Creek catchment, which is considered representative of the rest of the headwater catchments in the region (A Young, pers. comm.). Field work entailed augering boreholes between the small creek channel and an adjacent ridge. Sand/silt/clay analysis results are recorded in Figure 16. These results show that the sand is coarser near the creek, reflecting the downslope movement of sand. In contrast the *in situ* weathered profiles on the ridges have a high proportion of fine sediments.

Despite their fine matrix, the deep quartz-rich profiles of the ridge areas represent commercially viable sand deposits. *In situ* weathering has decomposed the sandstone so it is easily ripped up and removed with earthmoving equipment. The low water table on ridge areas allows dry extraction methods. Screening of these deposits leaves sands suitable for construction uses. Downslope, in closer proximity to the creek, sands are equally valuable but less accessible because of the higher water table and reduced access for heavy equipment.

While this very limited sampling indicates the nature of sand sediments in this type of environment, it obviously does not provide a basis for estimating the extent of sand deposits. Nonetheless, the fact that sand deposits of this type are scattered in small pockets over catchment headwaters greatly limits their potential for commercial exploitation.

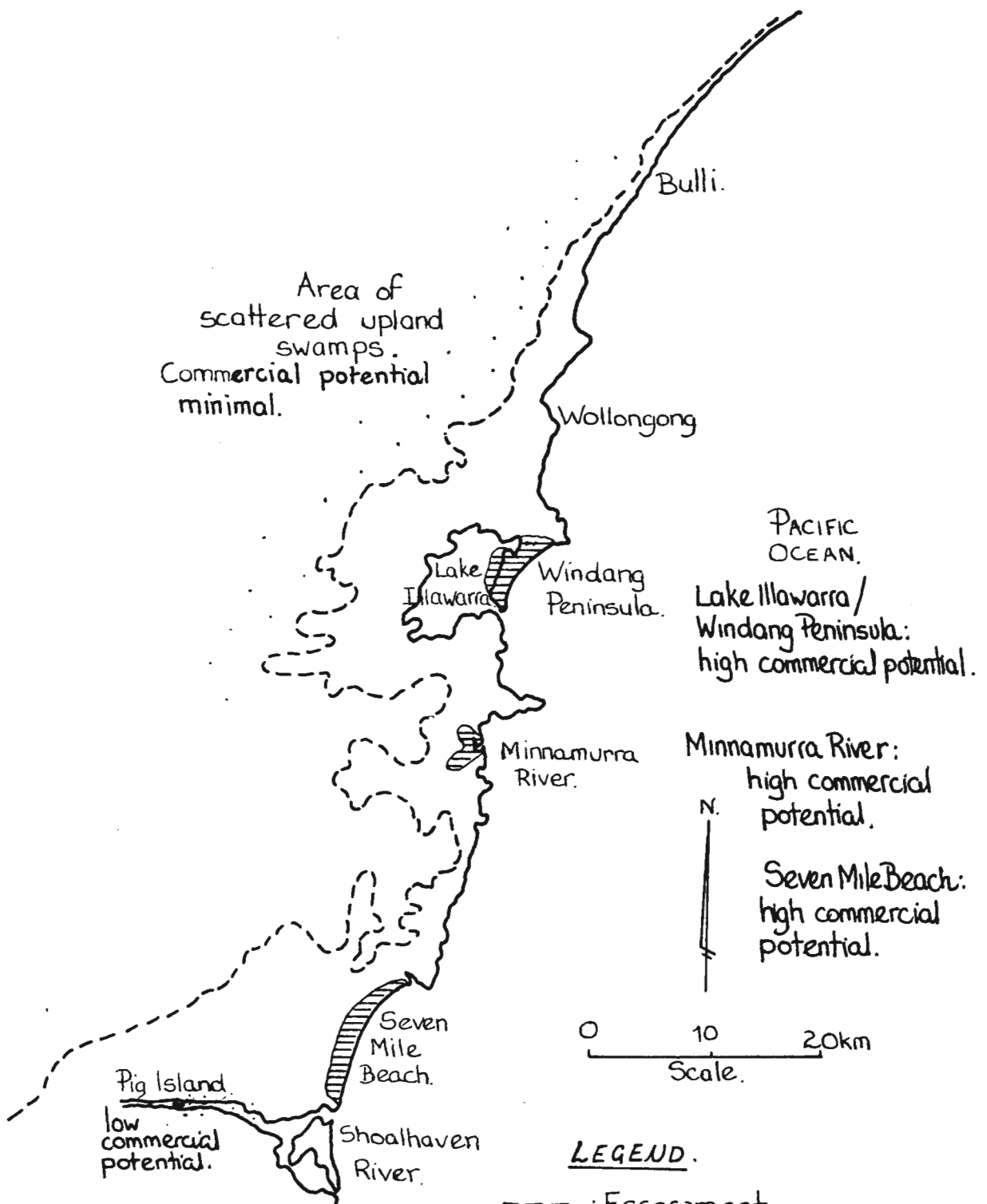
#### The Bed of the Shoalhaven River

As mentioned in Chapter Two, a fluvial sand resource of limited proportions lies in a sand bar immediately upstream of the Pig Island channel constriction of the Shoalhaven estuary (P.W.D., 1977). The precise volumes of sand present in this accumulation are impossible to estimate because they are part of a dynamic fluvial system in a state of continual flux, varying with river flow and sediment input upstream. The available sand is predominantly quartz and is suitable for concrete and other construction uses, however, the small size of this deposit renders it of low commercial significance. A dredge is necessary to remove sand from this bar in the river channel.



#### (iv) Summary

Relict marine deposits represent the most commercially attractive deposits to Wollongong. Of these the larger barriers including the Windang composite barrier, the Minnamurra River twin/prograding barrier, and the Seven Mile Beach prograding barrier are the most commercially valuable deposits. Extensive research on these deposits has revealed variation in sand quality, from medium quality construction sand, through foundry sand, to localised areas of high quality glass manufacture sand. Other marine deposits, including receded barriers, stationery barriers and pocket beaches do not represent commercially

FIG. 17. Inventory of Sand Deposits Available  
to the Wollongong Market.



LEGEND.

- : Escarpment
-  : Marine sand deposit of potential significance to Wollongong.
-  : Fluvial Sand deposits of potential significance to Wollongong.

valuable sand resources. Although their sediment is of high quality, their small size and hence their sensitivity to erosion, precludes them from consideration for large scale sand extraction.

Fluvial sand deposits surrounding Wollongong hold far less economic potential than marine deposits, as they are strictly limited in extent and are composed of lower quality sand. Field research has shown that deltaic and alluvial sediments west of Lake Illawarra are of no economic value, while in upland swamps west of the Illawarra escarpment sand deposits of limited economic value occur. These scattered deposits, however, consist of lower quality sand than the marine deposits. In the Shoalhaven River, very limited local sand surpluses in the river channel represent a sand resource of little long term economic potential to Wollongong.

Figure 17 summarises the distribution of sand resources of significance to the city of Wollongong and indicates the relative importance of each of these deposits. It must be emphasised, however, that all of the sand present in each deposit is not, and will not, be available for extraction. Varying proportions of each of these deposits is "sterilised" by statutory ruling, residential development, and also by community demands to conserve areas of particular ecological and aesthetic quality. These limitations to sand availability will be discussed in later chapters.

## CHAPTER FOUR

### SAND EXPLOITATION UNTIL THE EARLY 1970'S

#### (i) Introduction

Prior to European settlement of the Wollongong area in the early nineteenth century interruption of the natural processes active on sand deposits by the Aboriginal population was probably minimal. Middens along the seaward edge of dune systems generally show little sign of major sand movement, though at some sites such as Bass Point, middens had been buried by drifting sand prior to European settlement (Hughes, 1973). However, after European settlement extensive modification of the landscape occurred, including exploitation of the sand resources. As the city of Wollongong grew and the industry developed, interference with the natural systems escalated. Imbalances became apparent in the processes controlling the sand masses and environmental degradation became more obvious. Moreover, the development of Wollongong as a heavy industrial centre has had a pronounced effect on, among other things, the manner in which local sand deposits have been exploited. The original small scale sand removal expanded in response to the growing demand both of heavy industry and the building trade. In turn environmental disruption became increasingly obvious until the case for implementation of legislative controls could no longer be ignored.

#### (ii) The Growth of Wollongong

##### Wollongong Until World War II

The first occupation of the Illawarra region occurred during the years following 1812. The settlement was primarily agricultural



in nature, with cattle raising, dairying and cultivation being the main occupations (Perry, 1977). Coal was discovered in 1779 but not until 1849 was a small adit opened in a coal outcrop at Mt. Keira, west of Wollongong (Bolton, 1977). From this meagre start, coal mining developed along the northern coast of Wollongong from Mt. Keira north to Coalcliff. The distribution of mines had a great influence on population growth and settlement with villages developing and growing around each mine head. Through the nineteenth century the coal industry struggled through depression periods and thrived in boom periods, gradually expanding and gaining momentum. Rail arrived in 1889, linking Wollongong to Sydney and this new link provided for an upturn in demand for all Wollongong products, including coal. Prior to 1900 the coal industry dominated the development of Wollongong, but its dominance was soon to wane.

Until the early 1900's sand extraction was probably very limited in extent and consequently was not an issue that demanded governmental action. The environment was considered only as something to be conquered (White, 1967) and consequently little heed was given to any environmental degradation that did occur. In any event the small scale of sand removal ensured that damage was minimal compared to later large scale extraction. The only relatively large sand extraction operation was begun in the tidal inlet of Lake Illawarra in the 1890's as part of the Illawarra Harbour and Land Corporation's attempt to convert the Lake into a coal exporting harbour (G. Mitchell, pers. comm.). Dredging was begun in the tidal inlet, but the scheme was abandoned in 1895 and Port Kembla developed instead.

After 1905 Wollongong began the transformation from a country and mining centre into a major industrial centre. The initial form of industrial development involved the processing of local raw materials. Milk, for example, was processed into butter and cheese, and coal into coke (Cardew, 1977). Wollongong's coastal location, close proximity to power producing raw materials, and proximity to the major market of Sydney later resulted in an attempt to use local raw materials to process products from far distances. In the late 1890's a shortlived attempt to do this was the establishment of the Australian Smelting Company at Dapto, importing ores from Broken Hill, Cobar, New England, Queensland and Tasmania. The development of Port Kembla by the Public Works Department enabled the Electrolytic Refining and Smelting Co. (E.R. and S.) to be established on the shores of the new port in 1908. By 1914 Wollongong was on the verge of rapid industrialisation.

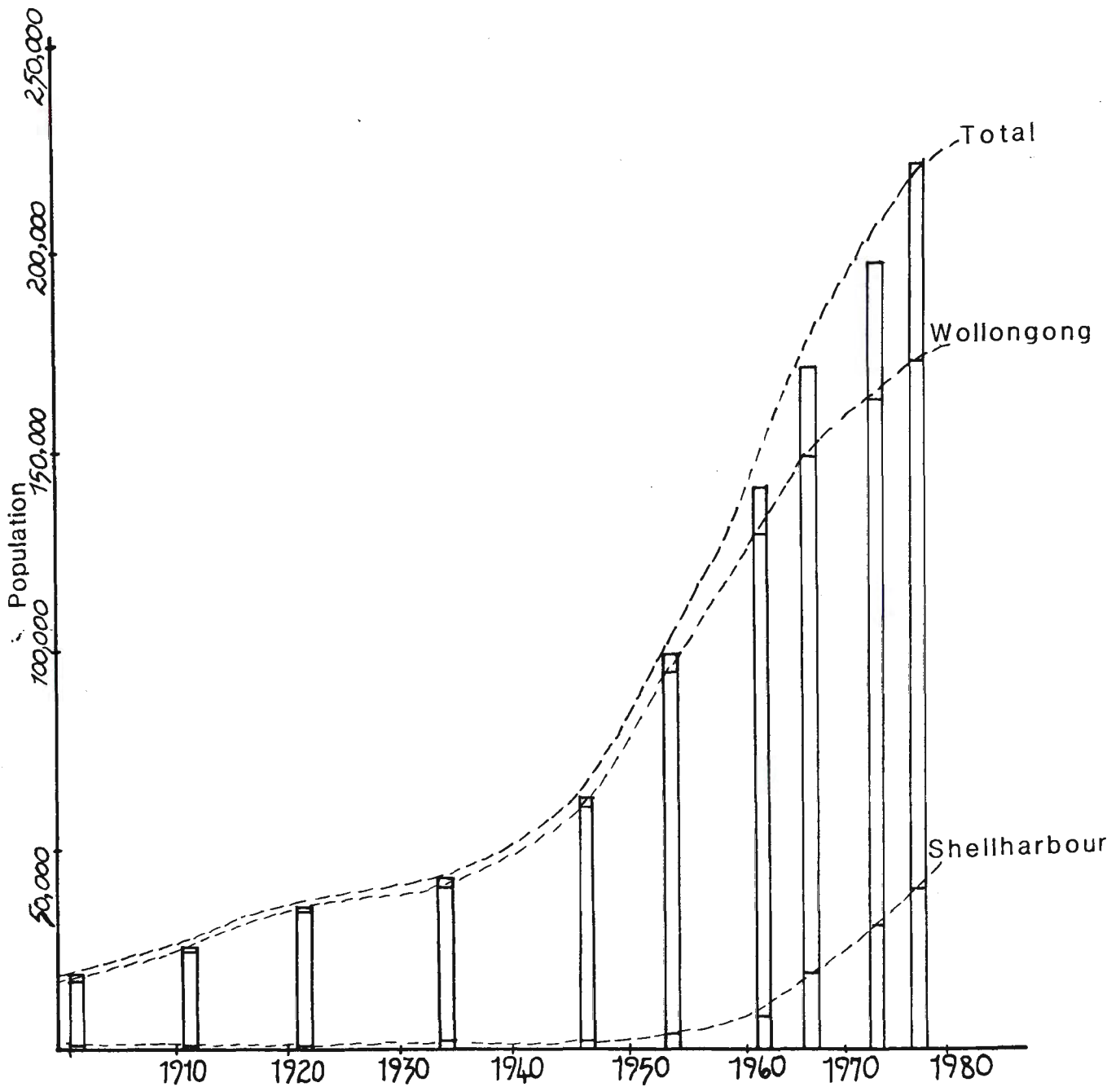
From 1908 to 1933 the rapid development of coal mining initiated population growth in the northern suburbs, from Wollongong north to Coalcliff. In the same period Port Kembla, which was the only suitable harbour, became the centre of heavy industry. Four large factories were established adjacent to the port by 1930, these included; E.R. and S in 1908, Metal Manufacturers Ltd. in 1918, Australian Fertilizers in 1921, and Hoskins Steelworks (later to become Australian Iron and Steel) in 1928.

As noted by Cardew (1977) industrial development determined the distribution of the expanding urban development; "the main thrust of the conurbation and functional integration of the urban system came from the heavy industry around Port Kembla". As early as 1936 this dominance by the heavy industry sector was firmly

FIG. 18. Demographic Statistics for the Local Government

Areas of Wollongong and Shellharbour.

(as from Cardew, 1977, and the Aust. Bureau of Statistics)



	1901	1911	1921	1933	1947	1954	1961	1966	1971	1976
Shellharbour	1,929	1,512	1,527	1,877	3,118	5,523	13,394	22,062	31,137	37,316
Wollongong	17,182	24,940	31,381	42,853	62,973	90,853	131,754	149,523	160,902	165,087
Total	19,111	26,452	32,908	44,730	66,092	96,375	145,148	171,582	192,039	202,403

established. Census figures for the city of Wollongong and Shellharbour (Fig. 18) illustrate this rapid growth. In 1891 the population was 3,041 but over the period before World War I it grew to 44,000. Following the Great Depression of the 1930's industry again progressed rapidly aided by economic revival and the demand generated by the approach of World War II (Cardew, 1977). Prior to World War II, two more major heavy industries were established at Port Kembla, these were Lysaghts (metal fabricators, a subsidiary of Australian Iron and Steel) in 1936, and the Commonwealth Rolling Mills in 1938.

#### Industrial Boom After World War II

At the close of World War II, the economy of Wollongong surged ahead under a programme that established Port Kembla as the largest steel making centre in the Southern Hemisphere. Wollongong became a "steel town" dominated by Australian Iron and Steel. Associated with this boom of A.I.S. was an unprecedented population growth, especially noticeable in the 1950's, when technological advances increased the steelmaking capacity and hence the employment capacity. Expansion by A.I.S. has consistently accounted for 10-13% of the total population growth of the city over the last four decades (Wilson, 1978). This rapid increase in population, which expanded from over 66,000 in 1947 to 202,000 in 1976 is illustrated in Figure 18.

The overwhelming domination by A.I.S. and the related rapid development of Wollongong, had a profound influence on the perceptions and policies of the decision makers. Indeed development progressed in an atmosphere of *laissez faire* and the saying "When A.I.S. sneezes, Wollongong/Port Kembla catches a cold" became a common expression.

Associated with this enormous population growth was an explosion of urban expansion, a building boom for which the physical planning was inadequate. The maintenance of an administration established for, and only adequate for, a small community resulted in these authorities being unable to control the rapid development. This resulted in uncoordinated exploitation of the surrounds of Wollongong on a massive scale in order to accommodate the demands of heavy industry and to accommodate the expanding population. Indeed, it was not until 1968 that the first integrated city plan, the Illawarra Planning Scheme, was introduced.

The nature of the development of the sand extraction industry clearly reflects the exploitive attitude that pervaded Wollongong up until 1970. The following section draws together the available data illustrating the development of sand extraction to the point when overexploitation threatened serious environmental damage of the coastline's erosional stability and aesthetic appeal.

### (iii) The Development of the Sand Extraction Industry

#### Industrial Growth Accelerates Sand Extraction

The parallel development of heavy industry and sand exploitation is particularly obvious in Wollongong since 1945. Prior to this there is little recorded information. The small scale demand associated with early manufacturing industry and the developing urban centre was apparently satisfied by indiscriminate but small scale removal of sand from the dunes in the immediate vicinity of Wollongong. Small coastal settlements associated with, but separate from, Wollongong undoubtedly haphazardly removed sand from adjacent sand reserves in order to satisfy the local demand. When Wollongong City Council records recommenced in the late 1940's after World

War II, persistent widespread and uncoordinated sand extraction is well documented.

In 1935 with the takeover by B.H.P., Australian Iron and Steel (A.I.S.) began a phase of rapid expansion (Cardew, 1977). Sand was needed in huge quantities as fill and construction material and large scale sand extraction became centred near to the industrial centre, on the north of Windang Peninsula immediately south of Coomaditchy Lagoon (Fig. 6). A.I.S. took out the first leases on the Crown Land and by 1949 had removed 56,000 tonnes of sand (Wollongong City Council file S20 Vol. 1). Over the period from 1948-1955 approaching 3 million tonnes of sand was carted from the sand leases (Plates 3 and 4) to raise the level of reclaimed land on the western foreshores of Tom Thumb Lagoon prior to the erection of steel mills (Plate 5). In addition to A.I.S. extractions from the Crown Land on northern Windang, there were also other operators, some authorised, others not. These operators extracted sand in order to supply other heavy industries, as well as the rapidly expanding building trade. By the early 1950's, the dunes of North Windang, which were quite high before large scale extraction, had undergone significant depletion (Plates 3 and 4).

In the late 1940's and early 1950's downgrading of the sand extraction area was extensive. The N.S.W. Soil Conservation Service noted the extensive sand drift in the area and the need to control the situation before it worsened, and Wollongong Council also recognised the need for "restoration and beautification" (Wollongong City Council file S20 Vol. 2). However, as the worst drift conditions existed on private land immediately north of the



PLATE 3: Windang Peninsula, May 1947. Southwesterly view from the north of the peninsula. Sand extraction operation in centre. Note localised sand dune stabilisation centre left. (N.S.W. Soil Conservation Service).

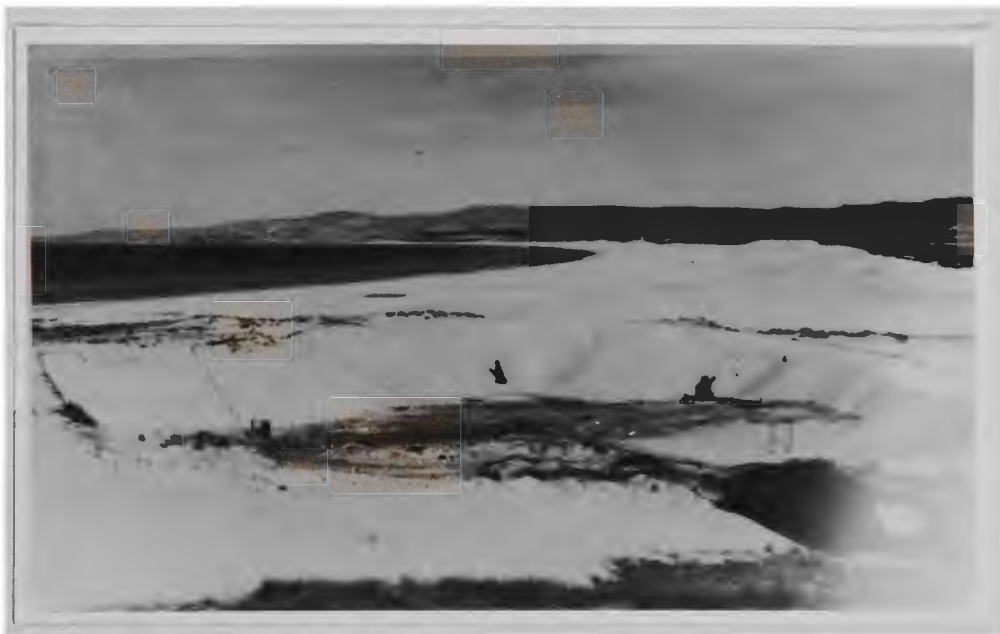
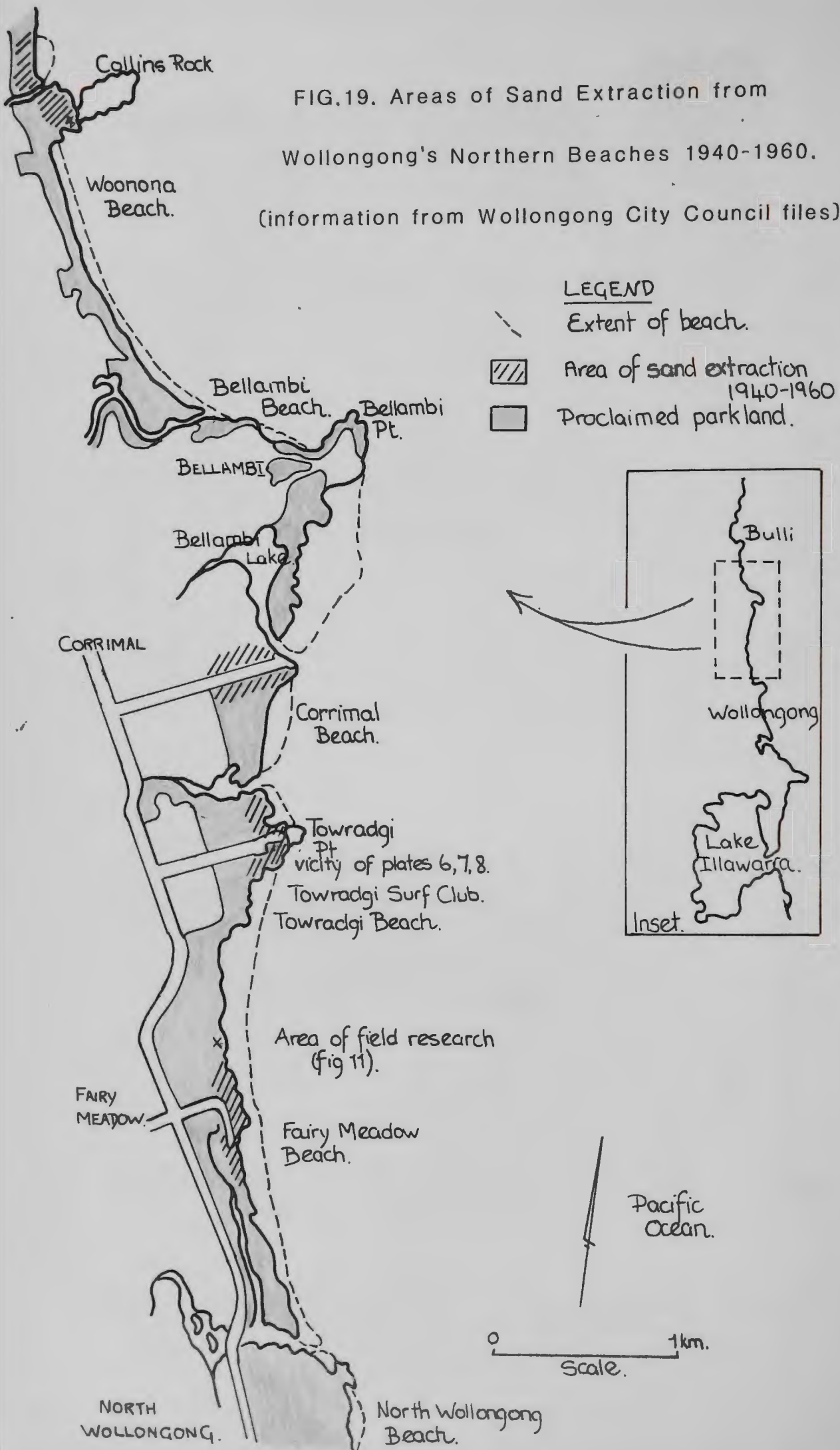


PLATE 4: Windang Peninsula, April 1954. Southeasterly view from the north of the peninsula. Sand extraction operation in centre. (N.S.W. Soil Conservation Service).

FIG.19. Areas of Sand Extraction from Wollongong's Northern Beaches 1940-1960. (information from Wollongong City Council files).





Crown Land the responsibility for restoration was perceived to be a private matter, and little was done. The stability of sand dunes on the north of Windang continued to decline and the problems grew gradually worse, compounded by continuing sand extraction.

#### Scattered Sand Removals Surrounding Wollongong

Sand extraction was by no means limited to the Coomaditchy area in these early years. Sand was also removed both officially and unofficially from the relatively small receding and stationary barriers on the northern beaches of the region. Although extraction from these areas was not of the scale characteristic of Windang Peninsula, in these small and sensitive barriers (as discussed in Chapters Two and Three) the indiscriminate removal of sand even on the relatively small scale practised, illustrates well the lack of environmental awareness characteristic of the early sand extractors. In the more populated areas from North Wollongong to Bulli these sand removals are well documented.

In the receding barrier of Corrimal Beach south of Bellambi Point (Fig. 19) the first official sand extraction commenced in 1949, although undoubtedly this was not the first removal of sand in the vicinity. The two licenced operators involved removed in the order of 10,000 tonnes of sand (Wollongong City Council file no. S.20 Vols. 1 and 2); a considerable amount when the relatively small size of the barrier is taken into account. By 1952 these legal extractors had removed the bulk of "surplus" sand, and the leases were terminated in order to reserve the remaining sand for Council purposes.

Little was done to rehabilitate these pits, and by 1953 dune

instability, aggravated by predominant southeast winds, resulted in dune transgression over roads in the vicinity. Rather than treating the cause of the problem (the extensive clearing of stabilizing vegetation, leaving bare sand surfaces open to depletion) by halting extraction and revegetating the dunes, the response was to disguise the symptoms by further removing sand from the dune tops, thereby reducing the sand available to be transported (Wollongong City Council file S.20 Vol. 2).

Throughout this period, in addition to authorised extraction at Corrimal as well as other beaches along the coast, extensive unauthorised extraction continued. Although extraction was illegal there was little active enforcement of appropriate laws and it appears that the majority of people seem to have viewed the maintenance of sand dunes as a problem of little significance. In 1958 Council files reveal that residents still regularly reported illegal extractions, Council continued to authorise the removal of sand from the dwindling sand accumulation in the vicinity of Corrimal (Fig. 19). As late as 1959 a lease was issued permitting small but continual removals of sand and this continued until the early 1960's (Wollongong City Council file S20 Vol. 2).

Immediately south of Corrimal, the receding barrier of Towradgi Beach (Fig. 19) was also subjected to relatively large scale extraction in the 1950's. In 1951 Council files record evidence of both legal and illegal sand extraction (Wollongong City Council file S.20 Vol. 2). Evidently, designated areas for sand extraction in the vicinity of Marine Parade and Towradgi Road (Fig. 19) had been set aside to satisfy the very small scale demand for sand that existed in the earlier years, and to localise the disruption to the sand dunes.

These areas, however, became either insufficient or inconvenient and residential correspondence to Council (1951) complained of widespread illegal sand extraction occurring in the vicinity of Towradgi Point. These complaints also emphasised that individuals in increasing numbers had indiscriminately hacked away vegetation allowing sand to be "blown out" (Plates 6, 7 and 8). Clearly the measures suitable for pre-boom periods in and around Wollongong were becoming entirely inadequate as the population expanded and the demand for sand grew. This inadequacy became a contentious local issue in Towradgi (as it did in many areas of the coast). However, even as late as 1958 permits continued to be granted for sand extraction from this delicate area.

Evidence of widespread illegal extraction further south on Fairy Meadow beach is also recorded in correspondence from residents in 1958 (Wollongong City Council file S.20 Vol. 3). One resident reported the extensive damage to Elliotts Road (Fig. 19) caused solely by vehicles used to carry sand. He reported . . . "sand pits have been developed and (due to) indiscriminate digging the old road resembles a rabbit warren". The impact of the widespread, sporadic and haphazard removal of sand from these dunes remains obvious today and there are numerous poorly vegetated man made depressions in the present day dune lines (Plate 9). Some of these pits have since been revegetated by the Soil Conservation Commission.

In addition to these well documented areas of continual exploitation, other areas are listed in Council files (Wollongong city Council file S.20 Vols. 1-3) in connection with illegal sand extraction. These include Woonona Beach (1958), Austinmer (1951),



PLATE 5: The western foreshores of Tom Thumb Lagoon. Sand removed from nearby Windang Peninsula (approaching 3 million tonnes) was used as fill to reclaim the western foreshores of Tom Thumb Lagoon. Today the steel mills of A.I.S. stand on this land.  
(Photograph courtesy of B.H.P. Review, Sept, 1952)

SAND REMOVAL FROM TOWRADGI TYPICAL DURING THE 1950's  
(as from Wollongong City Council file no. S.20. Vol. 2).



PLATE 6: Indiscriminate sand extraction from roadside has left bare sand exposed to wind erosion.



PLATE 7: Sand removal from adjacent dunes has precipitated wind driven sand drift. This drifting sand in many cases threatened homes and public utilities.



PLATE 8: Hacking of sand from vegetated dunes creates localised areas of bare sand predisposed to being undermined by wind erosion.



PLATE 9: Corrimal Beach (4/7/1979). Many poorly vegetated depressions remain in the dune lines of Wollongong's northern beaches from past periods of sand extraction. (N.S.W. Soil Conservation Service).

the northern shores of Lake Illawarra (1953), Tom Thumb Lagoon (1953) and Warilla Beach (1965). It is also certain that considerable quantities of sand were taken from all beaches close to populated areas.

Sand extraction is also well documented at Stanwell Park in the north of the region (Fig. 1, Plate 10). Though small in size the receding barrier of Stanwell Park represents the largest sand accumulation on the sand-deficient northern coastline (discussed in Chapter Three). Most sand extraction was carried out in the 1950's when Stanwell Park represented one of the few sand deposits where individuals could legally obtain sand in small quantities. All other legal sand pits in the district were leased to commercial contractors. The Council freely issued permits on demand (Wollongong City Council file S20 Vol. 2), and in 1955 it became possible to buy permits from the Stanwell Park Beach Kiosk. As more and more individuals removed sand, and the removal became increasingly obvious, local residents protested against the adverse visual effects (Wollongong City Council file S20 Vol. 3), while the removal of dune vegetation cover left the sand unstable and drifting, in the predominant southeast winds, toward beach dressing sheds and carpark (N.S.W. Soil Conservation Service file 15/68). However, because there was no other ready source of sand in the northern suburbs, the protests came to little, and the exploitation continued well into the 1960's. The Soil Conservation Service began re-stabilization of this area in 1972 (Plate 10).

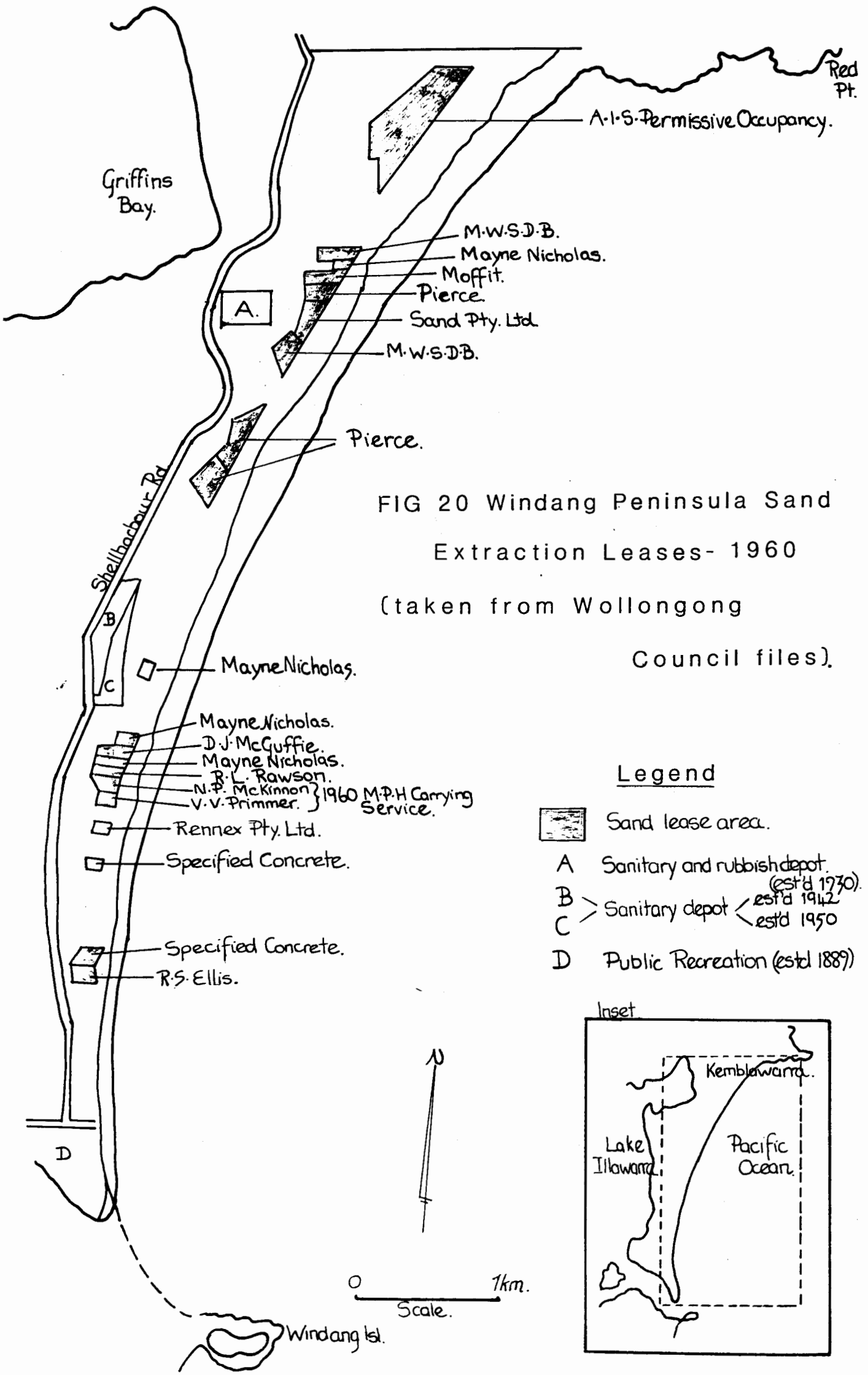
#### Exploitation on Windang Peninsula from the Late 1950's

The fact that an application to dredge the marine sand bar on the eastern fringes of Lake Illawarra (discussed in Chapters 2



PLATE 10. Stanwell Park Beach - a Receded Barrier. This barrier is the largest sand accumulation on the sediment deficient coastline north of Wollongong (note the rocky coastline in the background). Sand extraction was carried out on the northern sector of this barrier, this area has since undergone restabilisation.  
(photograph: N.S.W. Planning and Environment Commission)





and 3) gained conditional approval in 1959, illustrates well the environmentally unaware attitudes held by Wollongong local government at that time. Although the District Engineer felt that it would be more desirable to dredge the middle of the lake, away from shore areas (an area completely devoid of sand!) dredging of the bar was approved with conditions essentially restricted to preventing short term inconvenience or danger to the public, rather than the long term environmental impact associated with such a drastic interference with the natural processes of the lake. As this dredging in the lake did not eventuate, it appears that a Council condition, requiring the permission of landowners directly affected by the dredging proposal, could not be obtained.

The attitude typical of government authorities in these early years is further illustrated in a comment, recorded in a letter from a city engineer in 1959:

"On the matter of sand leases, generally I was given to understand that there was no objection to Council taking an odd load or two of sand from other than leased land".

In 1959 the area of authorised sand removal on Windang Peninsula was extended. Applications were lodged to excavate large dune areas on the southeast of the peninsula and these were accepted as well as several others in the immediate vicinity. By 1960, Windang Peninsula supported no less than 20 individually leased sand pits, not to mention unauthorised extractions (Fig. 20). Council file LB72-839 records that no objections were voiced to the extension of sand mining pits on Windang and Council conditions attached to the leases were equally complacent. It is interesting

to note that in 1959 the purpose of bond money required on all leases (£200) was "to make up deficiencies in rent, royalty payments or other charges that the Minister determines are payable". This is markedly divergent to the stated purpose of bond monies in recent years, where the emphasis is on insurance of environmental rehabilitation, rather than on monetary shortfalls. This further illustrates the marked change in attitude toward environmental deterioration that has occurred in the last decade.

Massive amounts of sand were removed from the numerous pits on Windang Peninsula (Table 1 records registered extractions from north Windang in the early 1960's). This large scale but piecemeal practice greatly increased the occurrence of dune transgression and made administrative control of extraction virtually impossible. However, the road damage created by loaded sand trucks, rather than the looming threat of dune transgression and beach erosion, was the main bone of contention between the Council and sand extractors (Wollongong City Council file 3560-60).

Sand extraction continued in the Kemblawarra area until in 1964 removal from the large dunes had reached the point where the remaining sand needed to be retained until it could be replaced by a suitable filler (Wollongong City Council file 3560-60). Coomaditchy Lagoon in this period twice overflowed during heavy rain. The overflow was channelled into the depressions created by sand extraction and broke through the foredunes to the sea. Residents also claimed that in stormy weather high seas broke through the foredunes (Wollongong City Council file S20 Vol. 3). By 1965 the necessity for widespread dune stabilisation became an unavoidable fact and increasing amounts were being spent on it.

TABLE 1

REGISTERED SAND EXTRACTIONS FROM NORTH WINDANG PENINSULA DURING  
THE EARLY 1960's (in tonnes)

Month	1961	1962	1963	1964	1965	1966
Jan.		28 280	21 099	39 414	30 236	
Feb.			32 208	51 690	38 945	33 837
Mar.	55 616	14 679	28 428	38 379	48 312	
Apr.	51 485		20 369	37 620	33 565	Council
May		12 658	41 042	50 335	39 389	
June	42 160	14 728	29 686	38 449	39 192	Records
July		20 796	54 471	52 904	44 494	
Aug.		23 402	41 414	38 280	47 769	Incomplete
Sept.	38 882		41 335	38 175	37 614	
Oct.		14 800	25 646	46 341	36 297	
Nov.	37 053	18 312	38 791	46 812	46 795	
Dec.		16 923	28 698	39 555	44 298	
			403 397	514 954	486 986	

Revision of Extraction Techniques of Windang Peninsula

It became obvious that radical revision of sand extraction methods was needed in order to satisfy the demands for sand of the developing city of Wollongong, while also avoiding the imminent environmental reprisals looming as a result of uncontrolled extraction practises. Thoughts turned toward the long term localised dredging of huge volumes of sand below the watertable and replacement of the removed sand with community waste including domestic garbage, coal-

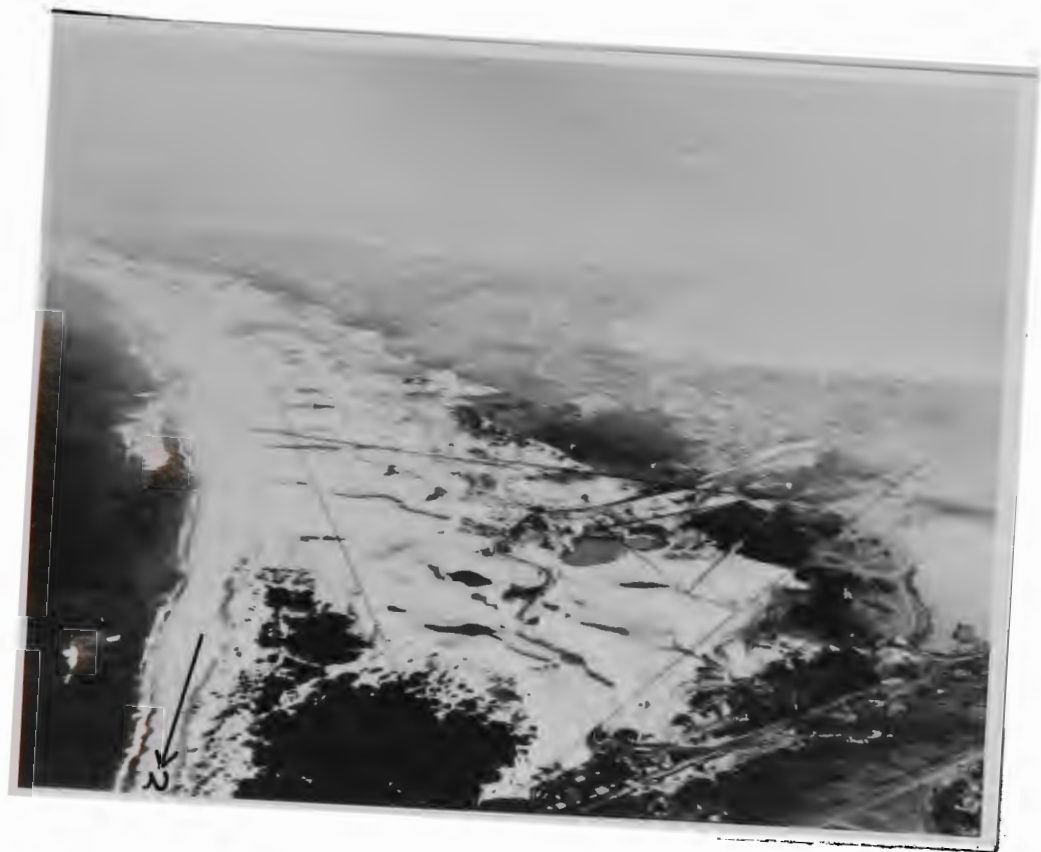
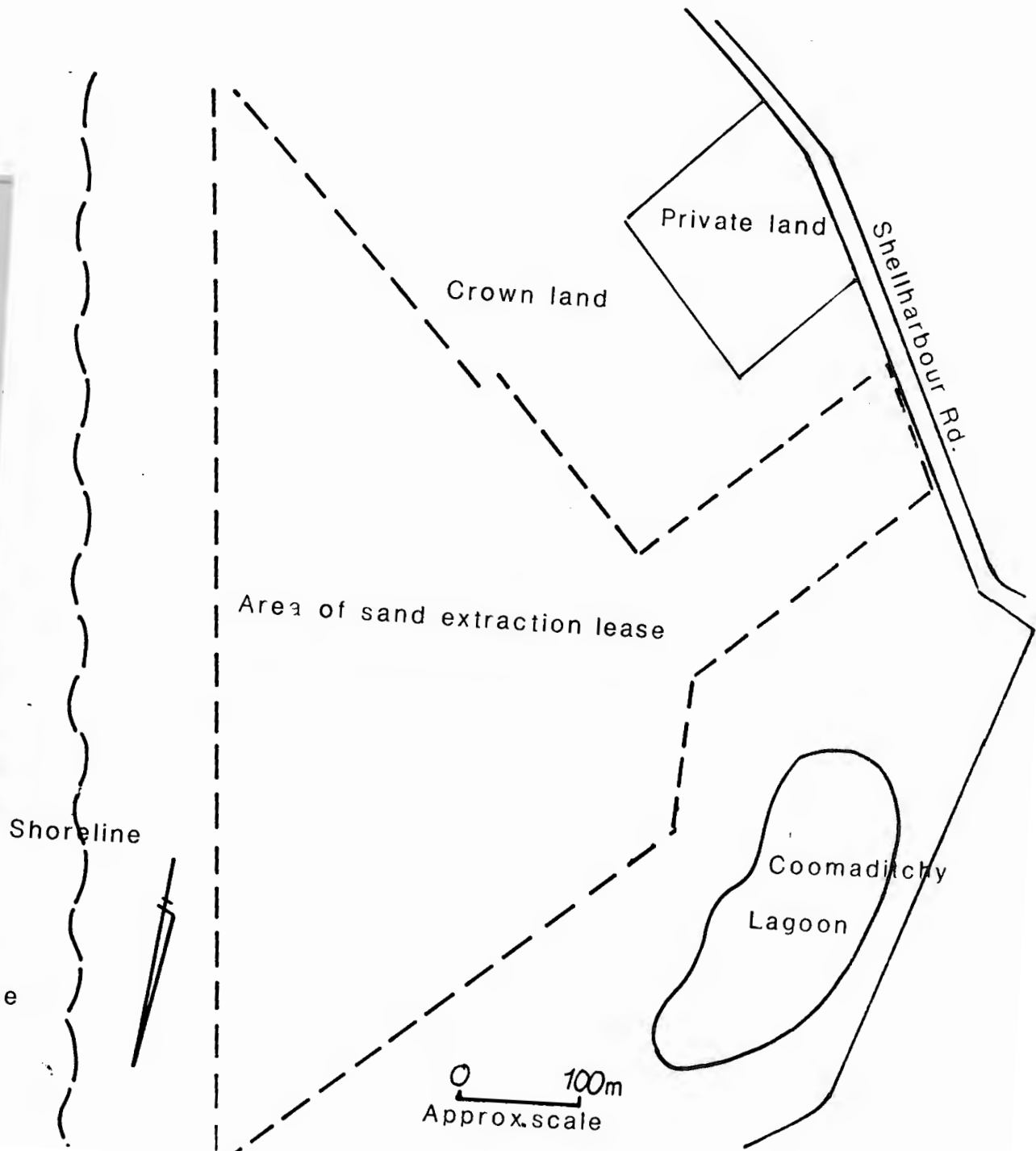


FIG 21 Plan and Aerial Photograph of  
the 1967 Kemblawarra Sand Extraction Lease  
on Windang Peninsula. (photo. 1970)



washery refuse and slag (a waste product of steel production) (Wollongong City Council file 3560-60). It was decided, in an effort to:

- 1) control the administrative tangle resulting from multiple leases over Windang;
- 2) discourage illegal sand removal; and
- 3) restrict the inevitable environmental degradation associated with sand removal,

that all sand extraction leases on Windang Peninsula would be terminated and one large extraction site be developed (Wollongong City Council file S.20 Vol. 3). On termination of the twenty scattered leases, concerted efforts to deter unauthorised sand removal included the destruction of access roads to abandoned pits and regular patrolling of the area. These efforts appear to have been effective, at least in discouraging illegal extraction on a commercial scale, but "weekender" removals continued (Wollongong City Council file LB 72/839).

In 1967 a Permissive Occupancy (P.O. 67/1) was established which extended over 53 ha. of Kemblawarra (Fig. 21). The original term of occupancy was for nine years with an added provision for twelve months for rehabilitation of the area. Conditions on the occupancy focussed predominantly on the staging and restoration of the area in a manner decided by the District Surveyor, rather than ensuring the environmental integrity of the area during and after extraction.

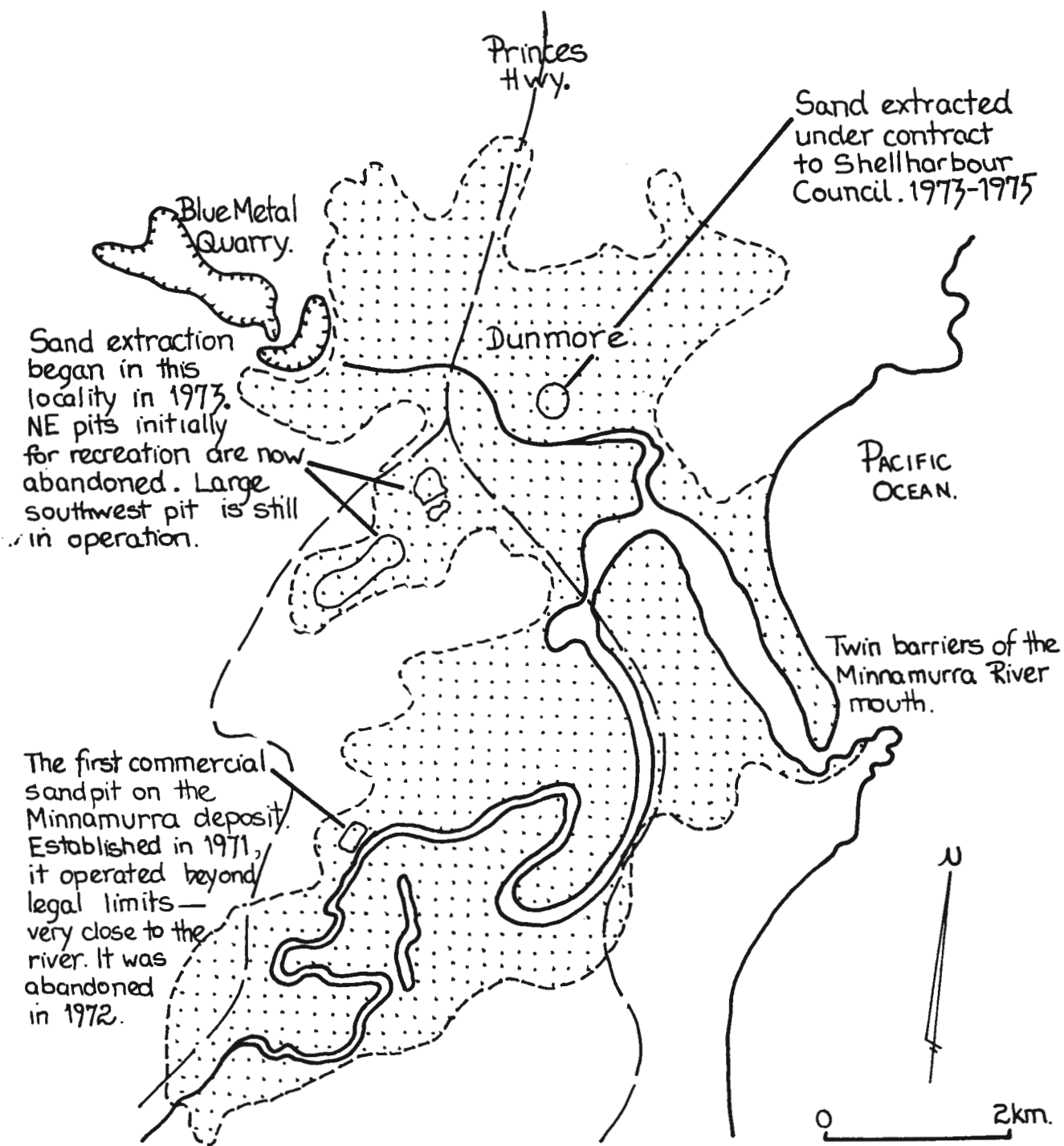
Sand from the newly created lease provided 70% of the Wollongong/Shellharbour demand both for building and industrial purposes. However the lack of awareness of Wollongong's strictly limited sand resources is illustrated in the export of 40 000 tonnes of sand from North Windang to Hawaii in 1970.

### Continuing Environmental Threats on Windang Peninsula

Although the new arrangements on North Windang were, from an administrative viewpoint, a marked improvement on earlier conditions, the dangers of serious environmental disruption were by no means eliminated. Indeed the potential for long term damage was increased by the disruptive influence of the 6 m deep dredge pond and its associated areas of garbage, coalwash and slag fill. This environmental threat became particularly obvious as, in the early 1970's, the sand extraction plant approached the foredunal area of North Windang.

Also in the 1970's, dredging operations in the seaward reaches of the entrance of Lake Illawarra threatened to cause widespread environmental damage. As outlined in chapters 2 and 3, this area represents a sediment sink into which coastal sand may be forced in periods of high wave energy. In areas where surplus sand is continually available, dredging from this type of location may be environmentally safe. However, in Wollongong, where there is no contemporary sand input and where surplus sand is minimal, the removal of sand from this type of location is complemented by the compensatory robbing of sand from other areas. In the case of Lake Illawarra, entrance dredging accentuated the sink into which sand flowed via the "trap door" effect (Plate 1) from Warilla Beach to the south of the entrance and aggravated the already deteriorating quality of Warilla Beach (Dr. I. Eliot, pers. comm.). Clearly extraction from the lake entrance promised widespread disruption on a long term basis.

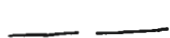
FIG.22 Distribution of Commercial Sand Extraction Pits  
on the Minnamurra River Deposit.



LEGEND.



Extent of sand deposit.



Roads.



### The Development of Sand Extraction South of Wollongong

As the narrow coastal plain immediately surrounding and north of Wollongong became fully developed, during the later years of 1950's and 1960's, the continually growing population spread southward toward Shellharbour and Kiama (Fig. 1). As population developed in these areas a growth in the demand for sand was also experienced. The first commercial sand pit opened on the Minnamurra River sand barrier in 1971, although undoubtedly small scale sand removal had occurred on this barrier and the other smaller southern beaches before this time. In 1971 the first commercial pit consisted of a dredge pond in close proximity to the main channel of the Minnamurra River (Fig. 22). Initially legal, as the pit extended beyond authorised limits and encroached very close to the river bank it became illegal (N.S.W. Planning and Environment Commission, pers. comm.). Other sand pits were developed in close succession and in 1973 sand was removed from east of the Princes Highway (Fig. 22) under contract from Shellharbour Council, and also in 1973 a sand pit was developed on the Wild Australia Animal Park on the Princes Highway at Dunmore (Fig. 22). The latter operation has since that time operated on three separate dredging ponds in that immediate vicinity. Beyond these operations there have been no other commercial pits on the deposit. The fragmentation of extraction areas, however, in the few years of development in this area suggest the need for rationalisation in order to minimise environmental damage.

The prograded barrier of Seven Mile Beach has also in recent decades become an area of growth, even though this growth, however, is more related to Nowra, the rapidly developing service

centre of the Shoalhaven Shire, than to Wollongong. The recent development in this area is reflected in the minimal disruption of the barrier due to sand extraction. Until the late 1960's only small scattered pits were established, primarily on the northern end of the beach. In more recent years a large sand extraction dredge pond has been established on the northwest part of the barrier. Although of no immediate threat, this operation is indicative of the increasing scale of sand extraction and the related possibility of causing environmental damage.

#### (iv) Summary

Since the earliest years of Wollongong's development, sand extraction has been concentrated on the relict marine sand barriers lining the Illawarra coast. Early settlements in and around Wollongong generated only limited demands for sand and these were satisfied by the removal of sand from any dune area or beach nearby. Although the dangers of environmental damage to the many small and sensitive barriers were unheeded, the small scale of exploitation ensured that the effect was negligible.

With the establishment of Wollongong as a centre of heavy industry in the early years of this century, the rapid industrial and urban development engendered an unprecedented demand for building and industrial sands. In order to satisfy this large and persistent demand, sand was removed haphazardly from any deposit available and with very few restrictions. Thus the smaller and more sensitive receded and stationary barriers, which occupy much of the Wollongong coastline were extensively exploited, as was the larger composite barrier of Windang Peninsula. As time passed, the detrimental

impact of sand extraction became particularly evident on the smaller barrier beaches, and eventually resident action resulted in the curtailment of their widespread exploitation. Despite these localised and ad hoc rationalisations there was no recognition of the basic inability of Wollongong's relatively limited marine sand resources to indefinitely continue to satisfy the city's demand for sand without causing massive environmental degradation.

As Wollongong developed, the sand extraction industry also expanded to satisfy the city's demands. In the late 1960's and early 1970's developments within the sand extraction industry threatened not only imminent widespread and long term environmental damage in close proximity to Wollongong, but also, because of Wollongong's southward expansion, a widening sphere of coastline subjected to intensive exploitation. While the north of Windang Peninsula was threatened with storm damage, and dredging in the mouth of Lake Illawarra threatened massive erosion on Warilla Beach, southern sand deposits including Minnamurra and Seven Mile Beach barriers became subject to threats of environmentally dangerous exploitation.

During this period of irrational and uncoordinated exploitation, however a new environmental awareness developed. The following chapter traces this development and describes its influence on the sand extraction industry in Wollongong.

## CHAPTER FIVE

### CHANGING ATTITUDES ABOUT EXPLOITATION

#### (i) Introduction

An awareness of the adverse impact that sand extraction may have on the environment came late to Wollongong, for it was not until the mid 1970's that widespread criticism of sand exploitation methods developed. This chapter briefly documents the development of environmental awareness in the Wollongong area and describes its influence on the sand extraction industry.

The sand extraction industry is by no means the only industry in which the impact of developing environmentalism was felt. However, because of the demand for sand in the industrial and urban centre of Wollongong and the limited and vulnerable nature of many sand resources, it rapidly became apparent that satisfaction of resource demands threatened the preservation of the natural environment.

The delayed development of an awareness of the environmental threat posed by sand extraction can probably be attributed to the importance of economic values in the industrially based Wollongong community. The environmentalist attitudes clashed strongly with the deeply rooted and long established predisposition to utilise the environment to obtain the maximum profit. Moreover Wollongong simply did not have the resources or the administrative structure available to extensively plan the city development. As the Australian Financial Review (30/7/1973) stated:

*Canberra has more planners working on a single suburb than Wollongong has on the entire conurbation.*

The development of small clubs and societies e.g. the South Coast Conservation Society, and the publications of these groups,

e.g. "Smoke Signal" - the journal of the South Coast Conservation Society, clearly illustrate a growing interest in the general public concerning the natural environment. Of this development, the Australian Financial Review (30/7/1973) stated:

*Wollongong has seen more action in terms of community consciousness than in the past decade. There is evidence of dissatisfaction, criticism of the past development and an awakening determination to inject some life into future planning and development.*

As appreciation of the natural environment grew, controversy developed within the community as exploitation of sand resources continued in the face of changing attitudes. The growing public dissatisfaction and the changing response of the government authorities is now illustrated by tracing several specific cases.

(ii) Community Action Verses Government Procrastination

Organised Local Opposition to Extraction on Windang Peninsula

The first major clash between environmentalists and the sand extraction industry occurred in 1974. Since 1967 extraction had continued on a large scale on the Kemblawarra Permissive Occupancy on the north of Windang Peninsula. Excavation first took place by dry extraction methods (Plate 11) and later by the use of a dredge to penetrate below the water table (Plate 12). Initially little concern was expressed for the operation, but as dredging commenced and became more extensive Port Kembla Surf Club and local residents became actively opposed to the aesthetic downgrading of the area. Initially action against the operation was purely an individual concern. Letters of complaint were sent to Wollongong City Council and local members of Parliament, but as the exploitation increased



PLATE 11: North Windang Peninsula, Kemblawarra, July 1967.  
Dry extraction from high dunes. (N.S.W. Soil  
Conservation Service).



PLATE 12: North Windang Peninsula (Kemblawarra), 1970.  
Aerial view of initial dredging operation.  
(R. W. Young)

residents and interested people organised themselves into an environmental action group S.O.U.L (Save Our Unspoilt Landscape).

Prior to 1974, S.O.U.L. agitated to reverse the decision to allow large scale extraction so close to residential and recreation areas. The aesthetic deterioration caused by the sand extraction and the associated replacement material (coal wash, garbage, and industrial waste), was considered to be entirely inappropriate in an area close to residential development and adjacent to recreational land valued by the whole community. Secondly, lease conditions pertaining to issues such as fencing the dredge pond and progressive rehabilitation were not adhered to and S.O.U.L. aimed to stop these breaches for the safety of the community. Thirdly, the environmental integrity of Coomaditchy Lagoon (Plate 12) had been threatened by the removal of surrounding sand dunes, and S.O.U.L. intended to ensure its continued existence.

Early activities of S.O.U.L. included meetings, representations to local members and correspondence to the appropriate authorities, stressing aesthetic deterioration of the area by sand extraction and noting the possibility of erosive damage. (They were, however, unaware of the actual erosive hazard that had already been created as the dredge approached the foredunes). These issues, although capturing local interest did not generate widespread active support and the agitation had little effect.

Sand extraction was permitted to continue on a very large scale and approached very close to the beach face (Plate 13). Sand was removed not only from the leased area but also indirectly from the surrounding foredunes as considerable volumes of sand were blown into the dredge pond. This activity left the surrounding dunes,



PLATE 13. North Windang Peninsula 1975. The Kemblawarra sand extraction operation and garbage/coalwash dump.  
(photograph: N.S.W. Planning and Environment Commission)

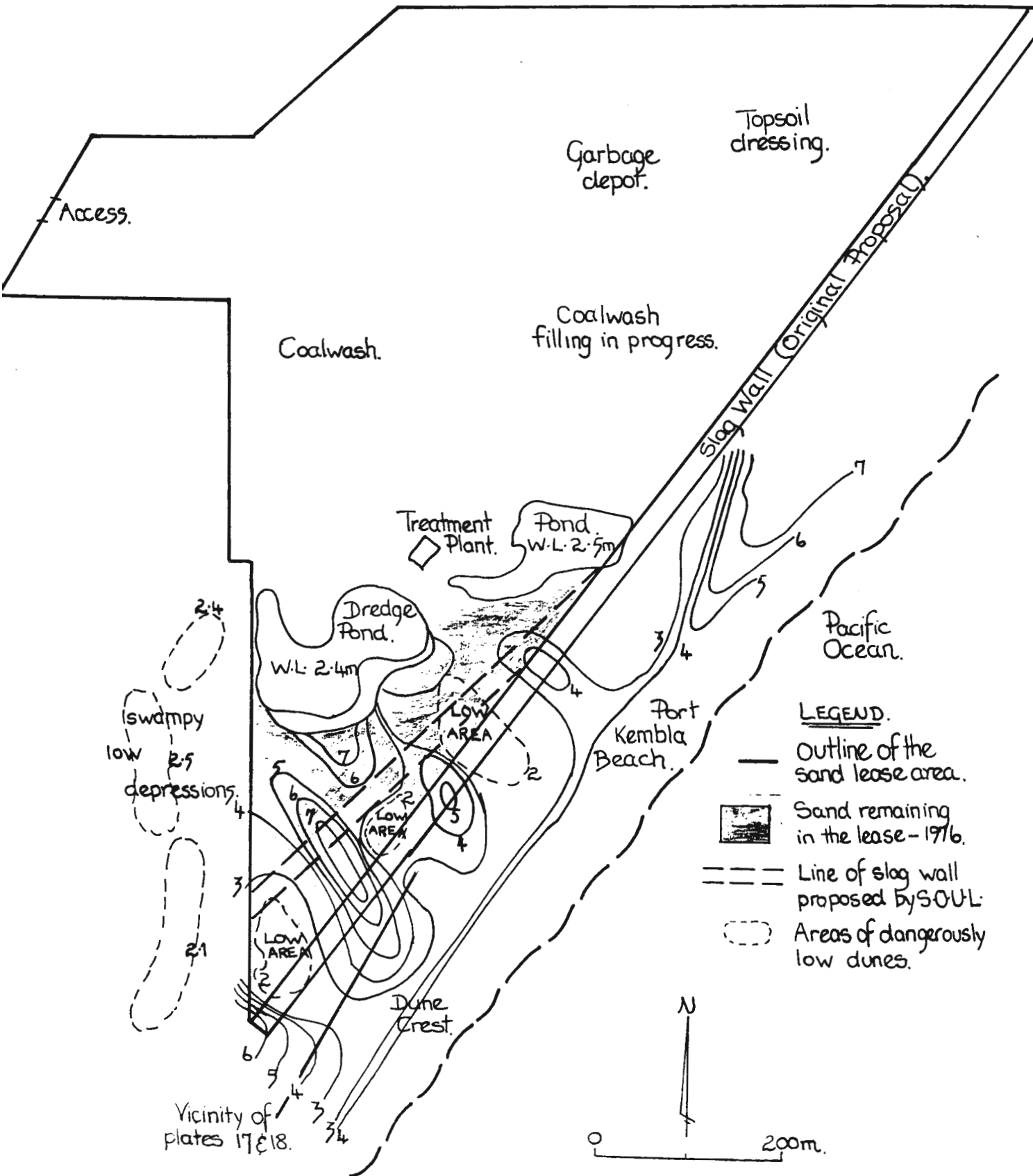




PLATE 13. North Windang Peninsula 1975. The Kemblawarra sand extraction operation and garbage/coalwash dump.  
(photograph: N.S.W. Planning and Environment Commission)

FIG.23 Plan of Kemblawarra Sand Extraction Lease in 1976,  
 also showing S.O.U.L. recommendations to realign the slag  
 retaining wall. (as from S.O.U.L. files).

Contour Interval 1m.



especially on the southeast of the leased area, precariously vulnerable to storm wave overwashing (Fig. 23). The danger inherent in the proximity of the dredge pond to the beach face became obvious in May-June 1974, when major storms ravaged the coastline bringing threats of disaster to the sand extraction operation. Storm swell and high tides coincided and waves penetrated stretches of the foredune in close proximity to the dredged area (Plate 14). Breach of the foredunes and slag wall enclosing the extraction operation gave rise to fears of erosion of the extraction ponds and associated fill areas. Had this occurred the release of pollutants would have been massive.

This threat sparked a new urgency in S.O.U.L. agitation against extraction. Their public meetings attracted good attendances but letters to public authorities gained expressions of concern rather than any action. Indeed it was evident that those authorities would benefit from the continuation of dredging. Sand extraction provided the N.S.W. Department of Lands, the body with the ultimate control of Crown Land, with a substantial revenue from royalties. Moreover, sand extraction at Kemblawarra provided the City Council with facilities for the disposal of garbage, industrial waste and coal-wash, all of which were pressing local problems and ultimately the development promised the construction of playing fields.

### Green Bans

In July 1974, what originally began as ineffectual complaint by public minority groups to government bodies developed into a fullscale confrontation between the government and trade unions. It is ironic that while industrial development in Wollongong was an initial cause of large scale extraction at Kemblawarra (as discussed



PLATE 14: North Windang Peninsula, 1974. Storm waves threaten to breach foredunes adjacent to the Kemblawarra sand extraction operation (foreground). Closeby, middle background, the foredunes were extensively breached. (R. W. Young).

in Chapter 4), the powerful trade union structure to which industrial development also gave rise, was responsible for the control of extraction.

The activities of S.O.U.L. won the support of the South Coast Trades and Labour Council and through this local organisation, the support of the powerful Australian Workers Union (A.W.U.) was gained. It was resolved that what was called "legalised vandalism" should cease. Accordingly, the Union imposed a Green Ban or "environmental strike" (Roddewigg, 1978) on the Kemblawarra dredge. This direct action by the A.W.U. achieved immediate and widespread publicity for the S.O.U.L. arguments, which had previously not occurred.

The closure of the Kemblawarra pit had a cumulative effect because it supplied 70 per cent of Wollongong's sand requirements. Such largescale disruption resulted in immediate action. The industrial threat placed direct political pressure on the state government and in turn the N.S.W. Lands Department. A public meeting was immediately called in which it was agreed to withdraw the ban and commence negotiations.

#### Expert Opposition

At the commencement of negotiations (August, 1974) S.O.U.L. sought expert advice on the potential impact of sand extraction immediately adjacent to the beach face. D.N. Foster (University of N.S.W. Water Research Laboratory) and R. W. Young (Wollongong University) prepared reports which became the basis of S.O.U.L.'s argument in negotiations. The crux both of Foster's (1974) and Young's (1974) reports stressed the inadequacy of the buffer zone between the sea and the sand extraction operations. The relict nature of the deposit and the lack of contemporary renourishment

meant that removal of sand from the mobile zone of the frontal dune would not be replaced.

Young pointed out that the proposed buffer zone of 120 m between the infilled dredged area and the high water mark was totally inadequate as two breaches had occurred within a few months (i.e. the May 1974 breach associated with storms (Plate 14) and a later breach in August 1974 when the dunes were burst by high runoff from the filled areas transporting waste into the sea (Plates 15 and 16)). He went on to note that in some areas, excavation already extended three quarters of the way across the proposed buffer to within 30 m of the high water mark.

Foster emphasised that

*the primary requirement at Port Kembla is to reestablish an adequate dune barrier in front of the proposed mining operations.*

The basic data from which sound engineering judgements could be made was not available for Port Kembla Beach thus no concrete figures could be given as to what would represent an "adequate buffer". However, by extrapolating from a knowledge of processes involved and wave tank experiments, he suggested a more substantial buffer than was allowed for was necessary. Initially, he recommended that foredunes should be reconstructed to form a smooth transition between existing dunes to the north and south and that this dune should be at least 7 m above standard datum with a minimum crest width of 6 m to prevent waves overtopping it. He went on to state that sufficient sand should be placed in the dune system to prevent erosion by normal cyclic beach changes over a long period (for this no data was available). While admitting that much of the sand



PLATE 15: North Windang Peninsula, Kemblawarra. A breach of the foredunes associated with an overflow of Coomaditchy Lagoon. (N.S.W. Soil Conservation Service).

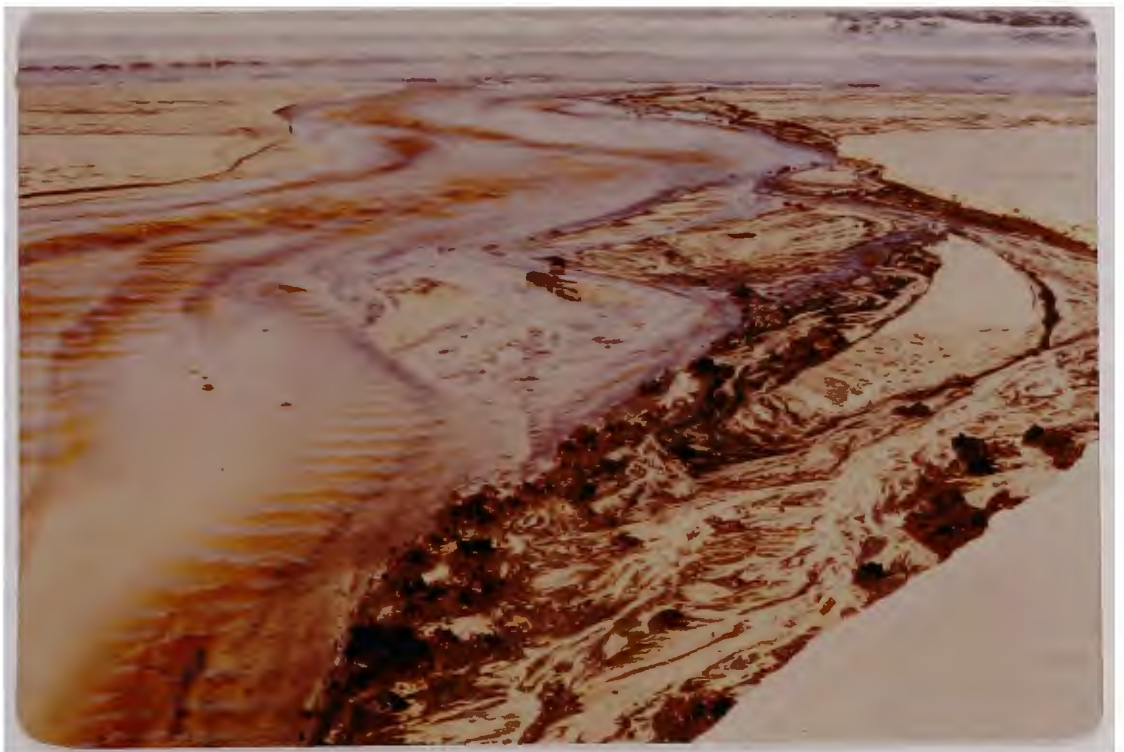


PLATE 16: North Windang Peninsula - beach adjacent to the sand extraction lease at Kemblawarra, 1974. Discharge from garbage and coalwash dump seep into the beachface. (R. W. Young).

deficit being experienced immediately after the storms would be returned from offshore bars, Foster suggested that pumping additional sand from the mining lease would be necessary to adequately renourish the dunes. These dunes should then be stabilised by the N.S.W. Soil Conservation Service.

After the stirring of industrial action subsided, government delays again prolonged necessary decisions. In opposition, the release of expert advice condemning the continuing exploitation in such an environmentally sensitive area, and the widespread and sympathetic media coverage, engendered a growing public support.

S.O.U.L. continued to reiterate demands that:

- i) dredging be prohibited close to the foredunes
- ii) the slag wall enclosing the sand extraction operation be realigned further inland as shown in Figure 23
- iii) the low dune area bordering the southeast of the lease area (Fig. 23) be rebuilt and revegetated, and
- iv) that Coomaditchy Lagoon be protected from degradation.

Throughout 1975 very little was achieved, although the S.O.U.L. argument was reemphasised in July 1975 when heavy rains filled and overflowed Coomaditchy Lagoon. The overflow, rather than infiltrating the impervious filled area flowed seaward and breached the foredunes for a second time in two years (Plate 15). In desperation, in mid 1976, a threat of reinstatement of the Green Ban on the extraction operation again pressured the Land's Department into action.

#### Government Response

Ministerial inspection ensued and, faced with the threat of industrial action, expert criticism of the operation, and the weight of community dissatisfaction, the Department of Lands finally agreed



to allow the wall to be realigned 20 m landward to allow a wider buffer zone. Following on from this decision came the move to rebuild and stabilise the area of low foredune. Eighty thousand tonnes of sand was pumped from the sand extraction operation into the area (Plate 17) and the N.S.W. Soil Conservation Service restabilised the newly created foredune area (Plate 18).

These developments initiated by S.O.U.L. by no means guarantee the future safety of Port Kembla Beach from devastation by future storms. Perhaps irreparable damage has already been done and even the realigned slag wall and reconstructed dunes may not allow an adequate buffer zone for future storm erosion. This public outcry did however, represent an emerging vital concern in the maintenance of the environment and it was capable of being sustained even in the face of government condonance of exploitation. Although the widespread opposition achieved only a minor variation in extraction policies on Windang Peninsula, it emphasised a changing public attitude.

The developing environmental concern within the community is further illustrated in the reaction to the sand extraction dredge operating in the tidal reaches of Lake Illawarra (previously mentioned in Chapter 4). Considerable community outcry, especially from residents of Warilla Beach, from where sand was rapidly disappearing, and sympathetic media coverage, formally established public opposition to the operation. Little authoritative action was achieved to terminate the dredge however, and in 1974 the sabotage of the dredge during the period of major storms, forcibly terminated extraction. The widespread public condonation of this action and the uncertain economic viability of the operation resulted

NORTH WINDANG PENINSULA, 1977. RECONSTRUCTION AND RESTABILISATION OF THE LOW FOREDUNES SOUTHEAST OF KEMBLAWARRA SAND EXTRACTION LEASE (SEE FIG. 23).

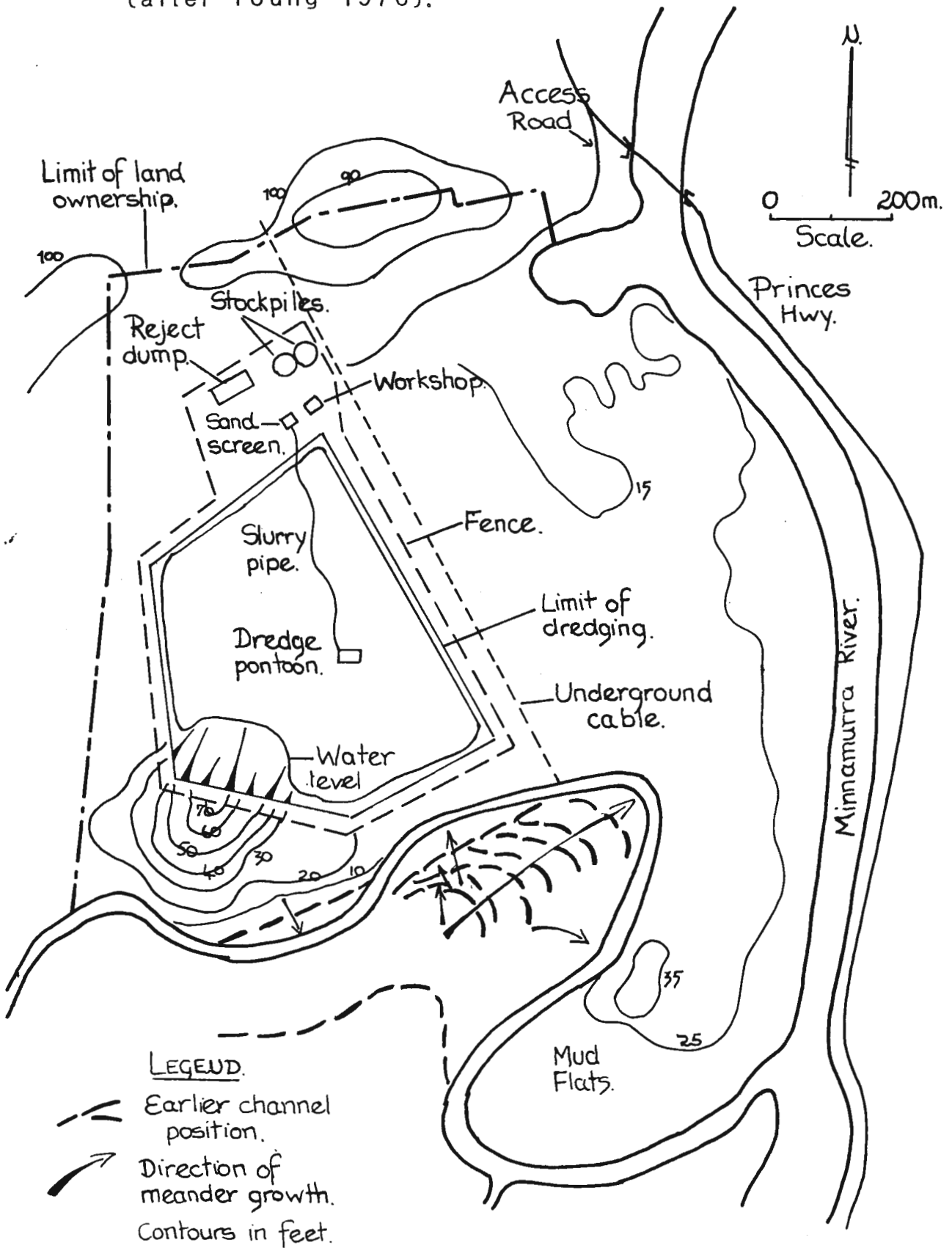


PLATE 17: Dune rebuilding by pumping dredged sand onto the dunes.



PLATE 18: Restabilisation in progress in background - foreground still undergoing rebuilding.

FIG. 24 Proposed Site Plan for Sand Extraction Adjacent to the Minnamurra River. (Pak Poy, 1976), and Meander Behaviour of a River Bend Adjacent to the Proposed Pit. (after Young 1976).



in the permanent cessation of the dredging in the lake mouth.

### (iii) Local Authorities Versus Developers

#### A Proposal to Mine the Minnamurra River

Over the period from 1975-1977 debate over a proposal to extract sand from the banks of the Minnamurra River again clearly illustrated the friction generated within the community as inappropriate sand resource exploitation continued in the face of changing attitudes. Unlike the earlier clash at Kemblawarra where public authorities effectively condoned the developer's actions, in this case public authorities assumed a prominent role in rejecting the development proposals.

Throughout 1975 developers made clear the intention to utilise a large tract of land adjacent to the Minnamurra River and in close proximity to the Princes Highway for sand extraction. It was not until 1976, however, that the final development proposal was publicised in an environmental impact statement (Pak Poy, 1976). In this document it was stated that the proposal provided for the extraction of sand from 28 ha on the northern bank of the river (Fig. 24). It was intended to utilise a dredge to remove approximately two million tonnes over a 10-12 year period and create an artificial lake 5 m deep immediately adjacent to the river bank.

To gauge public reaction to this proposal Shellharbour Council invited comment through local press advertisement. This initiative provided the basis for a "tremendous groundswell of opposition" (Kiama Independent, 27/8/1976). Local papers adopted the issue as important news, editorial columns became preoccupied with the comment of concerned residents, letters of protest poured into the Council, and public meetings devoted to stopping the intended extraction

operation became commonplace. Clearly the public were not in favour of the development.

### Expert Opinion

Beyond this purely local comment, Shellharbour Council also sought out the objective opinion of more qualified individuals. Dr. R. W. Young was approached to comment on the reliability of the environmental impact statement and to assess the physical impact of the proposed development on the Minnamurra River estuary. Initially Young (1976) criticised the conclusions of the report which favoured sand extraction as entirely suitable in the proposed area. He felt that much pertinent information had been totally ignored, including the proportion of sand to finer sediment (which determined the volume of waste sludge); the presence, extent, and proposals on the handling of overburden; and the effect of the development on groundwater throughflow. Furthermore, he felt that much of the information had been misinterpreted. While the impact statement minimised the ecological value of the area, Young observed that, although considerably damaged, the habitat was far from irreparably damaged, and that it supported numerous varieties of native flora and fauna.

Young also suggested that the long term stability of the river channel should be carefully studied in relation to the proposal. Changes in channel location are clearly recorded in the vegetative and minor topographic patterns on the river meander adjacent to the sand extraction site (Fig. 24). Evidence of a long term shift of this meander to the northeast and, more seriously, the development of a secondary growth of this bend toward the northwest (directly opposite the proposed dredge pond), prompted the conclusion that

although the river has been stable for the last 30 years, there is not sufficient evidence to predict continued stability for another 20 years. He argued that in consideration of such a long term sand extraction proposal, the emphasis must be placed on the long term effects and concluded that the developer's impact statement was inadequate and misleading.

In November 1976 Shellharbour Council held a special meeting in which, in the light of public opposition and expert criticism of the proposal, the development application was formally refused. In addition an intention to establish an environmental protection zone (prohibiting all development for purposes other than agriculture) surrounding that portion of the Minnamurra River estuary in Shellharbour municipality was reaffirmed. Dissatisfied with this decision, in 1977 the developer appealed to the Local Government Appeals Tribunal for reassessment of the proposal. This move served purely to reemphasise the widespread opposition to the development in question. In their defence Shellharbour Council presented the views of the state and local government, local organisations and individuals. The following brief summary of the criticisms clearly illustrates the unified opposition to the proposal.

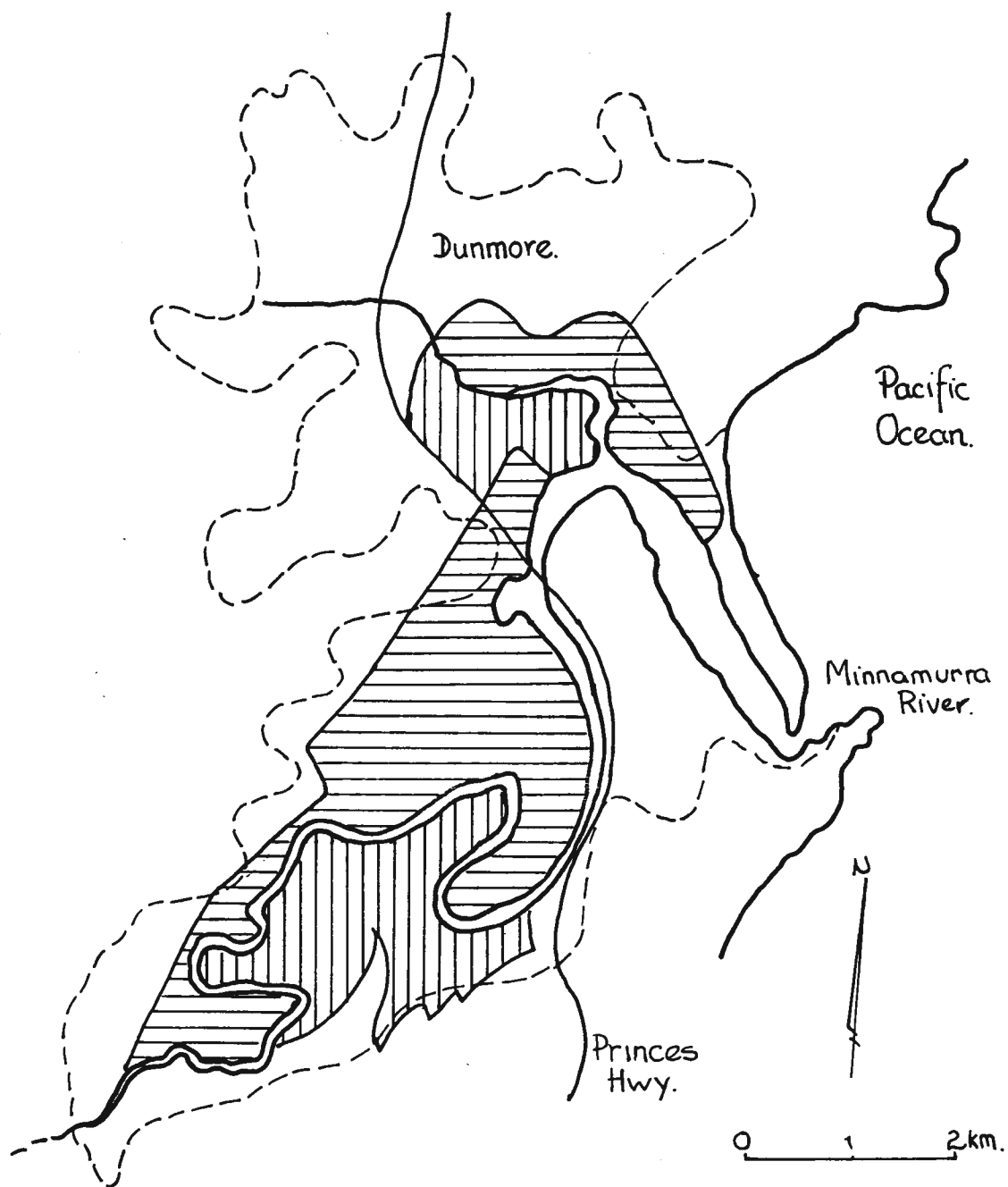
#### Unified Government Objection

The N.S.W. State Pollution Control Commission in correspondence with Shellharbour Council (8/10/1976) objected to the development as it was "not compatible with preserving the high scenic and ecological quality of the Minnamurra estuary". The N.S.W. Planning and Environment Commission in correspondence to Shellharbour Council (13/2/1976) supported rejection of the application "because of the adverse effect the proposed uses would have on the ecological

balance of this sensitive estuary system". Beyond this they endorsed the establishment of a protection zone and recommended that Kiama municipality establish a similar protection zone on the southern bank of the river. The N.S.W. Public Works Department noted the many similarities between the proposal in question and the disastrous development at Chipping Norton, where dredge ponds close to the Georges River became attached to the river and remained as stagnating bodies of water (Shellharbour Town Planner, pers. comm.). The National Parks and Wildlife Service, in correspondence with Shellharbour Council (6/10/1976), recognised the area as a highly significant estuarine area on the Illawarra coast and thus deserving of preservation. On 24/3/1976 the N.S.W. Mines Department refused the developer a prospecting licence (Shellharbour Town Planners, pers. comm.) thus showing their disapproval of the development and suggested the availability of more suitable sand elsewhere on the Minnamurra deposit. The N.S.W. Department of Main Roads and the N.S.W. Police Department did not favour the development because of the adverse effect that the road transportation of sand would have on roads and traffic congestion (Shellharbour Town Planner, pers. comm.).

The Illawarra Regional Organisation of Councils in correspondence to Shellharbour Council (18/3/1976) expressed serious concern at the development proposal and emphasised that the National Trust's inclusion of the Minnamurra River Valley in the Jamberoo-Cambewarra Scenic Protection Area (1975) reflected the regional significance of the area. Kiama Council supported by the municipality's progress association unanimously opposed the proposal and resolved to make no decisions on sand mining until more information on the regional

FIG. 25. Boundaries of the Environmental Protection Zones  
Surrounding the Minnamurra River estuary.



- Extent of sand deposit.
- Environmental Protection Zone.  
 Shellharbour Municipality - established 13-5-1977
- Environmental Protection Zone (proposed).  
 Kiama Municipality.



sand resources became available.

In addition to both the state and local government attacks, the general public presented authoritative and diverse criticism. Correspondence with Shellharbour Council from regionally authoritative groups including the South Coast Conservation Society (4/2/1976), the Illawarra Natural History Society (31/1/1976) and the Shellharbour/Barrack Heights Branch of the A.L.P. (5/4/1976), totally opposed the development. Their arguments rested primarily on the grounds of conservation and the need to maintain passive recreation space in an area in which over the next decade it is envisaged that the population will grow by some 25,000-30,000, with the development of a new Housing Commission area. Petitions and letters objecting to the aesthetic downgrading of the area were also numerous (Shellharbour Town Planner, pers. comm.). Clearly the development proposal represented a land use totally opposed by the bulk of the general public and as such was rejected by the Appeals Tribunal. In 1977 the establishment of an Environmental Protection Zone surrounding the Minnamurra River estuary in Shellharbour municipality became law and an extension of this zone into Kiama municipality is expected to become law in the near future (Fig. 25).

The proposal to develop sand extraction in the Minnamurra River estuary, an area of striking natural beauty viewed daily by thousands of passers-by, provided an impetus to government authorities, local residents and interested individuals to oppose the development in the strongest terms. Clearly, the extraction of sand, while a necessary activity, was not tolerated as a valid reason for impairing the long term aesthetic and recreational enjoyment of the general public in this area. The support of government agencies,

the enthusiasm of social groups, and the sustained interest of individuals united to establish strong disapproval to the development, which had it been suggested a decade earlier would no doubt have proceeded unhindered. This controversy illustrates not only strengthening opposition to persistent inappropriate exploitation of the local sand resources but also a developing environmental awareness within government authorities.

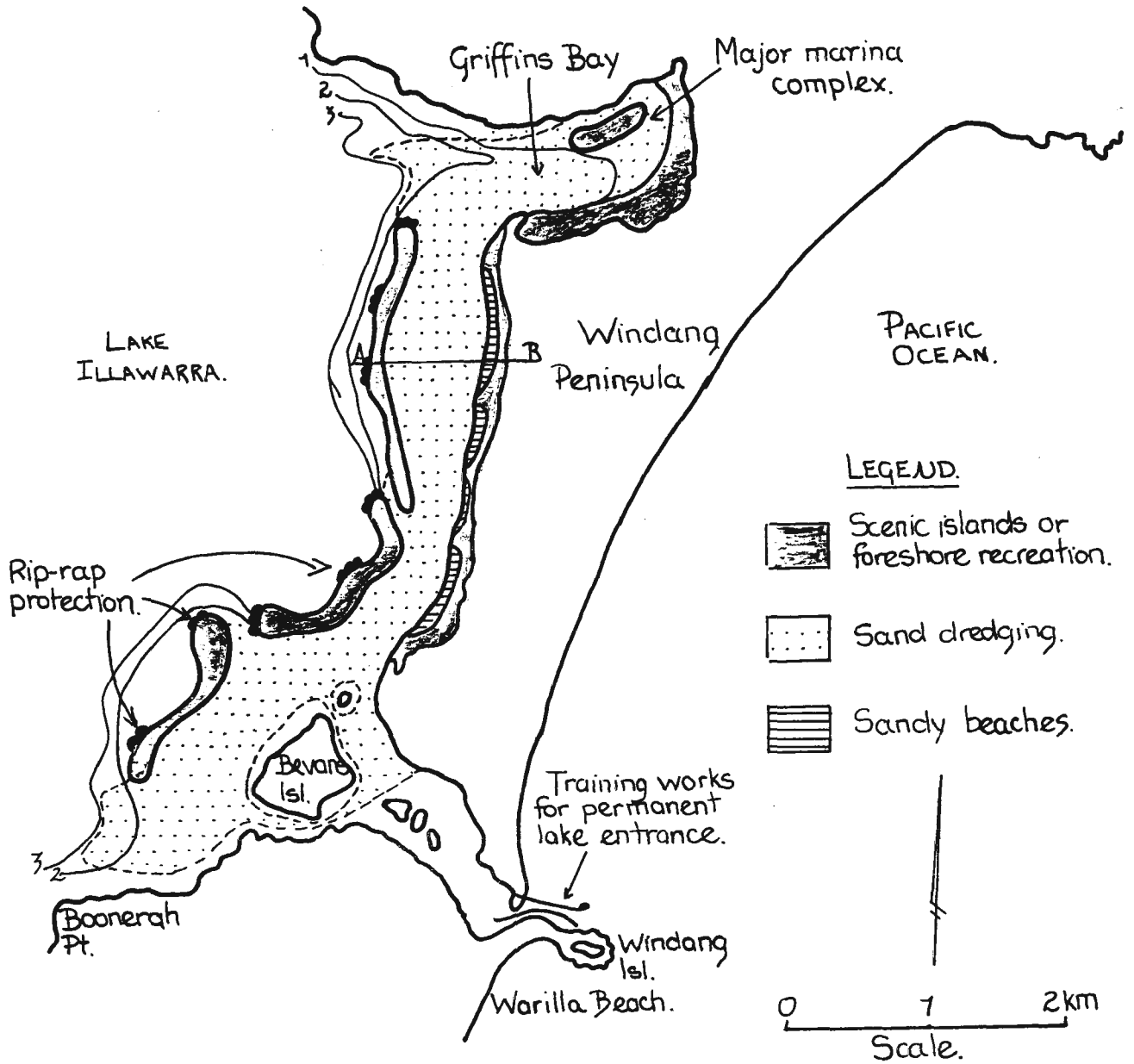
#### (iv) Conflicting Expert Advice

##### Short Term Needs Versus Long Term Environmental Considerations

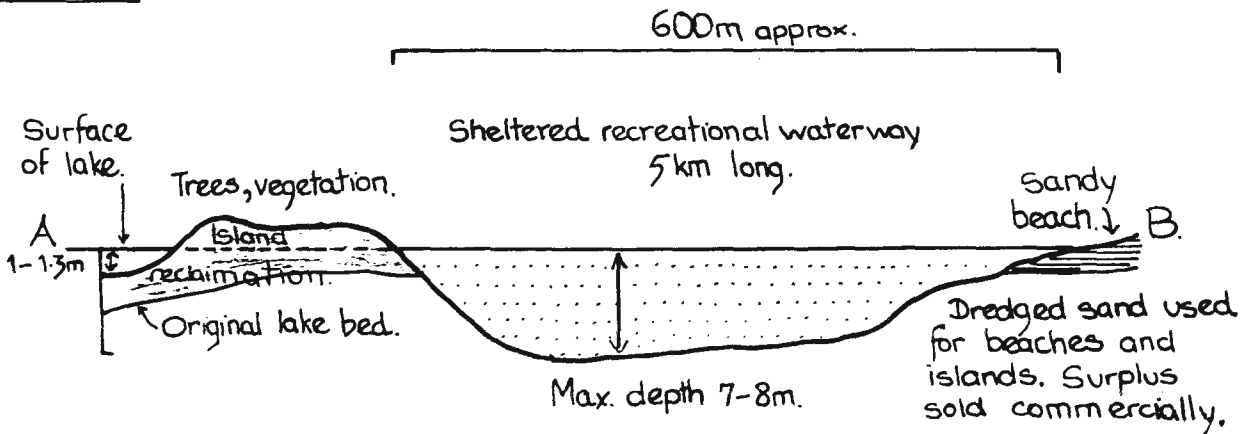
On several occasions the marine sand banks in Lake Illawarra have only narrowly escaped extensive modification threatening gross alteration or destruction of its environmental equilibrium. The lake was proposed as a port in the 1890's, dredging of the sand bar for construction sand was advocated in the 1950's and also tentatively suggested in the 1970's. Formulation of a rational plan for the lake, undertaken in association with the last of these dredging proposals, was complicated by the conflicting recommendations of two environmental assessment reports. Indeed the preparation of reports illustrates the new awareness of the need to weigh potential economic and social gains against the long term environmental constraints on any development. However, in this case the decision concerning which recommendations should be adopted, even more clearly illustrates a growing environmental concern within local authorities.

A major area of controversy was the question of whether the eastern marine sand bar (Fig. 4) should be removed by dredging. A report released by the N.S.W. Department of Public Works (1976) recommended massive restructuring of the lake including exploitation

FIG.26. Waterway Proposal for Lake Illawarra :  
plan and crosssection.



Crosssection.



(from Soros, Longworth and McKenzie, 1976).

of its sand assets. A second report, released in the same year by Wollongong City Council and Wollongong University, recommended the preservation and enhancement of the lake's natural assets.

#### Option 1: Short Term Social and Economic Benefit

The "Lake Illawarra Waterway Planning Study" completed in June 1976 for the N.S.W. Public Works Department by the consultant firm Soros Longworth and McKenzie focused primarily on hydraulic coastal engineering and waterway usage of Lake Illawarra. As well as recommending the creation of a permanent lake entrance, extensive dredging of the lake mouth, and the improvement of adjoining beaches, the report proposed a recreational waterway for the eastern side of the lake (Fig. 26). Extensive dredging of the eastern sand bar was suggested as a means of satisfying both the economic and social needs of Wollongong. Dredging to a depth of approximately 6 m would yield not only massive commercial sand resources (estimated at approximately 30 million tonnes by Soros Longworth and McKenzie, 1976) but also deepen the lake to improve boating facilities and improve the lake's appearance by reducing the turbidity associated with the weedy shallows. An integral part of this plan was to utilise the lower quality dredged material to create offshore islands (Fig. 26). These islands were intended to reduce the wave activity approaching the eastern shore and to create additional limited access foreshore parklands supporting natural flora and fauna. This report, therefore, recommends radical restructuring of the lake, endeavouring to couple resource exploitation with socially acceptable rehabilitation.

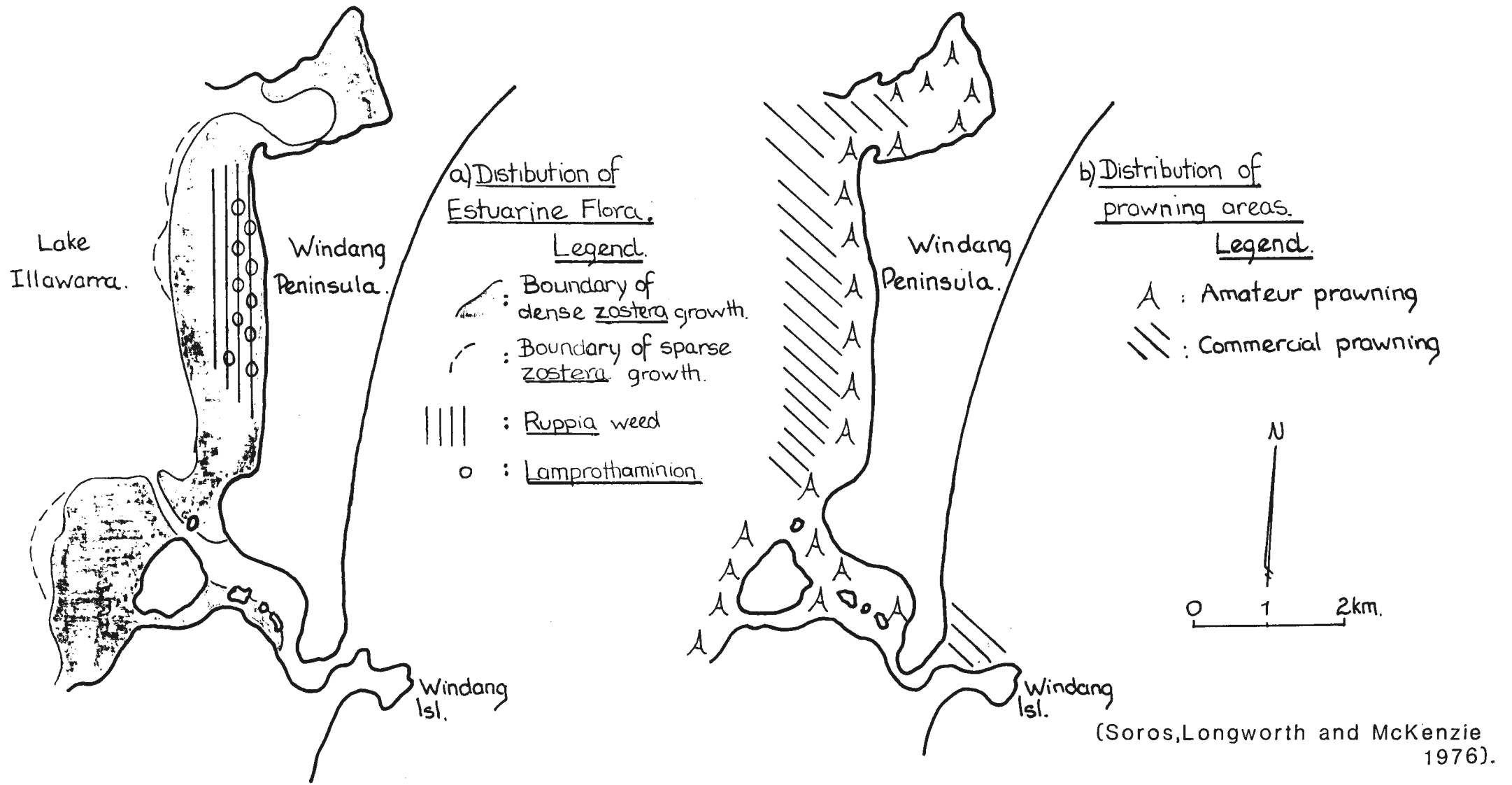


FIG.27. The Distribution of Selected Flora and Fauna on the Eastern Bar of Lake Illawarra, see also Fig.4.

## Option 2: Long Term Environmental Stability

The "Illawarra Lake Report" (1976) completed for Wollongong City Council by Wollongong University emphasised caution in planning the lake's future. Based on the recognition of contemporary ignorance about many aspects of the lake's environment, it was suggested that the soundest and cheapest policy was one avoiding initial damage and discouraging indulgence in extensive corrective works. Although the effects of many actions are readily predictable, there are some which are not, and the latter may be significant in the long term. The report concluded that the eastern marine sand bar plays an important role in maintaining geomorphological and biological equilibrium in the lake. It provides protection for the eastern lake shore. As waves generated on the lake approach the abrupt shallows of the bar, they break along its westward edge, rapidly dissipating their energy before reaching the shore. The quiet shallows of the bar also support extensive estuarine flora (Fig. 27) which forms an essential part of the food chain of many species of wading birds, fish and prawns (Fig. 27). The area of these weed beds is approximately 500 ha, or 15% of the lake's area. The report concluded that the desirability of improving the lake's amenity must be weighed against the possible destruction of the natural habitat, which, given the lack of other natural environments in such close proximity to Wollongong, assumes particular significance.

## Discussion

Both reports received widespread consideration but the passive, minimal action recommendations of the University report were adopted. Careful study of the "Lake Illawarra Waterway Planning

Study" revealed that in many cases the environmental responses to the suggested modifications were not adequately considered. M. Harris, of the Lake Management Committee (pers. comm.), expressed serious doubts about the feasibility of dredging and establishing the chain of offshore islands. He predicted that interference with the sand bar would have a drastic effect on circulation patterns in the lake which would result in massive erosion, the full implications of which are difficult to comprehend. The repercussions would almost certainly include massive cut of the eastern lake shore and extensive reworking and shifting of the lake entrance bar due to the increased tidal exchange and altered circulation patterns. The progressive removal of the bar (over 10-20 years) and the continual turbidity associated with dredging over such an extended period would inevitably have adverse effects on lake flora and fauna generally, not to mention the massive reduction of the potential for wildlife with the removal of the prime habitat that the bar creates. Furthermore, Harris doubted the feasibility of creating offshore islands as proposed by Soros, Longworth and McKenzie (1976) at the same time as dredging. The proposed protracted period of island development and the steep batter of the lakeward side of the islands would mean that windwaves, which may reach up to one metre in a south-westerly wind, and currents would destroy the structures before completion.

This debate over the lake's future illustrates well the problem of weighing conflicting expert advice, but perhaps more it illustrates a definite change in the environmental awareness of the local authorities. Rather than adopting the suggestions of the potentially economically and socially attractive but environmentally disruptive Public Works Department report, Wollongong

Council adopted the policy promising the least environmental risk but sacrificing the possibilities of short term economic and social advancement.

#### (v) Government Action

The N.S.W. Soil Conservation Service has been active in dune stabilization work in the Wollongong area since the 1940's. In recent years the increasing awareness of the general public and authorities of the value of maintaining environmental quality is reflected in the allocation of substantial amounts of revenue for sand stabilisation. In the past local authorities dealt with the problems of sand instability with piecemeal treatment of an immediate problem as it arose (Chapter Four). In recent years, however, emphasis has been placed on the prevention of dune drift and wind erosion by stabilising widespread dune areas with vegetation cover and ensuring minimal disturbance of sensitive areas (Godfrey, 1972).

Sand extraction is by no means the only cause of dune destabilisation, but wherever extraction has occurred or does occur it certainly aggravates instability. Particularly on the smaller and more sensitive receded and stationary barriers of Wollongong's northern beaches haphazard hacking of the dunes removed extensive areas of vegetation leaving bare sand prone to wind erosion (Plates 6, 7 and 8). Over time many of these disturbed areas have grown to become serious problems. Sand transported by winds threatened to bury roads and buildings, but of more long term significance the removal of sand from many small dunes has resulted in the considerable diminution of foredunal buffer areas capable of sustaining the beach systems



in periods of storm wave activity. Clearly dune instability involves both short and longer term problems.

In 1972 Wollongong City Council in association with the N.S.W. Soil Conservation Service formulated a restabilisation priority list for the Wollongong area (Soil Conservation Service, Southern District's file 15/68). Three of four areas on the high priority list were areas that in the earlier years (discussed in Chapter Four) were extensively exploited for sand. These areas included Bellambi, Towradgi, and Stanwell Park. With restabilisation costing in excess of \$5,000/ha, the cost to restabilise 36 ha of Bellambi dunes, 8 ha from Fairy Meadow north to Towradgi, and part of the small Stanwell Park barrier (Plate 10), amounted to well over \$168,000 (N.S.W. S.C.S. file 15/68). In addition to this, the restabilisation of more localised damage to dune lines resulting from sand removal (Plate 9), costs the community considerable sums every year. In 1976 the restabilisation of the rebuilt dune adjacent to the southeast boundary of the Kemblawarra sand extraction lease (Plates 17 and 18) cost approximately \$10,000 for only 5 ha of work (S.C.S. file 15/68).

Recent substantial increases in financial support of comprehensive sand dune restabilisation programs, not only once again exhibits the new found awareness of the desirability of maintaining environmental integrity, but also illustrates the lack of economic logic in sacrificing dune stability for short term economic gain.

#### (vi) Towards Coordination in Planning

The emerging community and government awareness of the need to protect the environment against inappropriate development is reflected in moves by the state government to establish environmental

planning offices in decentralised areas. The opening of a branch of the Planning and Environment Commission in Wollongong in 1977 introduced a new and authoritative interest in regional planning.

One of the main tasks of this office has been the formulation of a comprehensive plan for the Illawarra region. A main purpose of this plan is to provide a framework for coordinated action between state and local government agencies and individuals, in order to achieve the best utilisation of all available resources. In so doing it is necessary to assess the region's various resources and demands. It must be emphasised that in examining these needs and resources, while economic development and urban growth assume importance, so do "quality of life" issues such as conservation, resource management and maintenance of the quality of manmade and natural environments.

A direct consequence of the formulation of a Draft Regional Plan (1979) was the concise definition of many objectives with regard to the region's major problems. Sand extraction is one of these and the draft plan establishes an objective to "manage the extractive resources of the region in a coordinated manner, to meet community needs while ensuring that adverse impact on the community and environment is minimal" (Draft Illawarra Regional Plan, 1979).

Thus the draft plan has prompted the realisation that the problems associated with the sand extraction industry do not involve merely several localised clashes between conflicting sectors of the community which could be solved in a piecemeal and ad hoc fashion. It suggested rather that the problem is a sand shortage of regional significance which requires thorough integrated analyses

above the local level. This realisation has opened the way for a coordinated attempt to come to grips with the problem, and in 1979 the state government sponsored an objective analysis of land capability and policy options relating to sand extraction in the Illawarra Region (Young and Reffell, 1980). This thesis forms the basis of more rational region-wide management of sand resources as advocated by Stutz (1980).

The recent moves toward more rational planning of sand resources in Wollongong and the surrounding Illawarra Region have been sponsored by the state government. However without the numerous controversies that occurred throughout the 1970's, the realisation of the need to plan for Wollongong's continued sand supply may not have occurred until much later.

#### (vii) Summary

During the 1970's the sand extraction industry in Wollongong became the object of much criticism by many of the community who found the downgrading of the environment objectionable. Sequential study of the controversies between those in favour of and those opposed to sand extraction, reveals a gathering momentum in the community to halt environmentally inappropriate exploitation of sand resources.

The general public, experiencing first hand the undesirable environmental consequences of sand extraction on Windang Peninsula generated the first major outcry against the industry. Resisting the continual extraction of sand from the foredunes of Kemblawarra and the tidal entrance of Lake Illawarra, the public with the support of the trade unions challenged both developers and authorities alike who were in favour of continuing extraction.

In a subsequent disagreement local authorities followed the lead of the public and adopted more environmentally orientated policies to sand extraction. This is illustrated in Shellharbour Council's firm opposition to sand extraction on the banks of the Minnamurra River. In the footsteps of these locally based controversies the moves of the state government to repair environmental damage and establish regional planning bodies is indicative of the spread of government recognition of the need to develop a new, more balanced planning process to deal with both developmental and environmental demands.

This historical statement is of considerable interest in an area such as Wollongong where environmentalist interest emerged so rapidly and dramatically. However the true value of such a statement only becomes clear when the past development of the sand extraction industry is placed in the context of Wollongong's predicted future trends of sand demand and supply. The following chapter attempts to predict future trends of sand demand and discusses the contemporary alternatives available to meet this demand.

## CHAPTER SIX

### TRENDS IN FUTURE SAND DEMAND AND AN ALTERNATIVE TO NATURAL SAND

#### (i) Introduction

The basis of any practical planning of the sand extraction industry in Wollongong must include an estimation of the city's future sand demands, and the recognition of the alternatives available for meeting this demand.

In order to project the possible future demand for sand, population trends have been examined together with the trends evident in the construction industry. By looking at these two factors together it is possible to derive an approximate figure of sand demand for the period until the end of the century. But such a raw estimate of the amount of sand likely to be required is inadequate by itself. In the light of recent soaring costs of fuel and road transportation it is necessary also to evaluate the location of the developing demand and establish whether sand resources of suitable size and low environmental sensitivity exist in adequate proximity to the market. As sand is such a low value/high bulk commodity, clearly long distance haulage rapidly becomes a significant and uneconomic percentage of the sand's final cost.

Granulated blast furnace slag sand, a waste product of the steel industry, may with suitable processing represent a viable replacement for natural sand. After estimating the volume and location of future sand demand in and around Wollongong, consideration will be given to the possibility of developing this form of synthetic sand as an alternative to natural sand resources.

TABLE 2: POPULATION TRENDS IN AND SURROUNDING WOLLONGONG, 1971-1978

	Population				% Annual Growth Rates		
	1971	1976	1977 (est.)	1978 (est.)	Average 1971-76	1976-77	1977-78
Wollongong City	164,150	171,150	171,300	171,700	0.84	0.84	0.23
Shellharbour	31,750	38,700	39,700	40,800	4.07	2.46	2.77
Kiama	6,900	8,950	9,250	9,500	5.38	3.36	2.71
Shoalhaven	29,300	38,650	39,700	40,900	5.69	2.46	3.03
Total Region (including Wingecarribee, Bowral and Mittagong Shires)	252,250	279,600	282,100	285,350	2.16	0.89	1.15

Source: Handbook of Local Statistics, Australian Bureau of Statistics

## (ii) Trends in Demand

Population Trends

Until recently the best available estimate of projected demand for sand in the region was that by the Geological Survey of N.S.W. (Smith, 1979). However it now seems that the survey's estimate of 600,000 tonnes per annum by 2001 must be viewed as a maximum probable level of consumption. Data that have recently become available indicate that the projected populations and consumption per capita on which this estimate was based are excessive (Young and Reffell, 1980).

The growth rate of population used by the Geological Survey in estimating future demand is a simple projection of 1971-76 trends. The likelihood of that rate being sustained now seems slight. Even the "low" projected population, from the Draft Illawarra Regional Plan (1979), of 367,200 for the entire region by 2001 might be too high. Certainly the growth rates of 1971-76 are not being sustained at present.

The annual growth rate for the region has fallen from an average of just over 2% for 1971-76 to about 1% by 1978 (all population figures from Handbook of Local Statistics). For Wollongong city the annual rate fell tenfold from an average of 0.84% for 1971-76 to 0.09% for 1976-77, then rose slightly to 0.23% for 1977-78. Even centres with the highest annual growth rates during 1971-76 such as Shellharbour, Kiama and Shoalhaven, showed marked declines in 1976-77 and 1977-78 (Table 2).

Given present trends, the "low" estimate of regional population stated in the Draft Illawarra Regional Plan is more realistic than the "medium" or "high" estimates presented in the same document.

Indeed, an annual growth rate of 1% on the latest available estimate of population would fall short of the "low" projected estimate by 3,000 in 1981 and the gap would, of course, widen thereafter. The uncertainties of projecting population from current trends are obvious enough, but the likelihood of a marked recovery in growth seems slight. It is quite conceivable that development of aluminium processing at Newcastle could result in a significant loss of tradesmen and further reduction in population growth in the industrial core of the Illawarra. Again present trends indicate that such loss would not be offset by growth in the remainder of the region. Population in the region by the turn of the century might be little more than 20-25% higher than now.

#### Trends in Sand Demand

Estimating per capita consumption of sand 20 years from now is even more speculative than estimating the population. It is probably reasonable to assume, as did the Geological Survey, that the per capita rate will be constant. However, another equally, if not more probable trend needs considering. A reduced population growth coupled with a decline in economic activity could significantly reduce the per capita consumption of sand. Indeed, if current trends in the building industry are maintained (Table 3) a decline in total demand cannot be ruled out.

At first sight regional trends in the building industry, and thus demand for construction sand, seem sound enough. The Draft Illawarra Regional Plan (1979), for example, cites an annual housing growth rate of 7%, though this rate was estimated in 1975. Trends in the monetary value of completed building jobs (Table 3 below) also show a substantial increase, with a 42% rise for the whole



Illawarra region and 22% rise for the Wollongong Statistical Division between 1973-74 and 1977-78. But reference to trends in the Consumer Price Index show these gains to be illusory. When adjustments are made for the 70% increase over the same period in the Sydney Housing C.P.I. - this is the best indicator that could be obtained - it is clear that the rise has not kept pace with inflation. Even allowing for a substantial margin error in the use of the Sydney C.P.I. as an indicator of Illawarra trends, there can be little doubt that building activity has declined.

TABLE 3: CURRENT BUILDING TRENDS

		Wollongong Statistical Division	Balance of Illawarra	Total Illawarra
Value of completed Building Jobs \$,000	1973-74	48 006	22 879	70 885
	1976-77	60 816	33 022	93 838
	1977-78	58 835	42 170	101 005
Total New Dwellings	1973-74	2 483	1 288	3 771
	1976-77	1 498	1 175	2 673
	1977-78	1 460	1 098	2 558

Source: Handbook of Local Statistics

Trends in adjusted value of buildings are supported by those in the number of dwellings completed. For the total region the latter fell by over 30% between 1973-74 and 1977-78. Moreover, there is nothing to suggest that building rates will recover. Reduction in funds available to the N.S.W. Housing Commission has unquestionably lowered prospects for rapid expansion of a planned

Housing Commission Estate at Shellharbour, the only large scale residential development planned for the near future. In the longer term, electrification of the railway to Sydney may bring a population influx to Wollongong's northern suburbs, but the available space for building on areas free from land slip in those suburbs is not great.

Given recent trends both in population growth and building, it seems unlikely that consumption of sand in the Illawarra region in 2001 will rise by the 50% or so, as has been estimated by the Geological Survey, on the present-day level. Their estimate of 600,000 tonnes per annum can now be considered as a maximum estimate, with maintenance of consumption around 400,000 tonnes being more likely. Of course some Illawarra sand might go to the Sydney market, but in the foreseeable future demand on that market will be met from the Nepean River.

#### A Shift in Demand

Demand for sand in the Illawarra region, especially within the Wollongong Statistical Division, is continually becoming more widespread, thus favouring sand extraction from more widespread sites in order to minimise transport costs. Based on trends in population and building activity there seems little doubt that demand in the main urban area will be greatest in Shellharbour Municipality. For example, Shellharbour's absolute increase in population since 1971 has exceeded that of Wollongong City; the differential has increased fourfold since 1976. The electrification of the railway certainly will introduce a new element of uncertainty but the likelihood of the centre of population growth and demand moving northward seems slight.

Demand for sand in the outer parts of the Illawarra region will continue to be highest in Shoalhaven Shire. In fact between 1976-78 Shoalhaven accounted for almost 40% of the region's total increase. Perhaps the most telling fact of all is that 85% of the region's total increase in population for the same period was in the three southern local government areas of Shellharbour, Kiama and Shoalhaven.

It is possible to identify a core growth area extending from Shellharbour to Nowra. It is here that the increase in future demand for sand will probably be greatest and thus where any estimates of the cost of transporting sand should be focused (Young and Reffell, 1980).

(iii) The Role of Transport Costs in Determining the Availability of Sand

As with demand, there are great difficulties in predicting trends of transport costs. It is impossible to predict the likely outcome of the interaction of variables such as fuel costs, wages costs, road taxes, etc. In fact, it is no simple matter to estimate present transport costs because of the disparity in rates charged by major operators in the region. Table 4 summarise the charges from three major operators in the Wollongong area (the transport rates are calculated for the minimum load of 9 tonnes).

The disparity in quoted costs is quite marked. Moreover even these figures have to be adjusted for variables affecting the basic costs of sand and rates of transport. These include factors such as the size of the order (bulk order reduces price), backloading (this often reduces transport rates), long term ordering (regular large buyers obtain discounts) etc. Based on these facts it becomes obvious that figures such as those quoted below are an

FIG.28. Trends in Sand Supply. Population trends reveal the maintenance of Wollongong's population, but a southwards shift in growth rates. The major sand deposits of Windang Peninsula and Minnamurra River lie in close proximity to the developing market center of Shellharbour affording cheap transport rates.

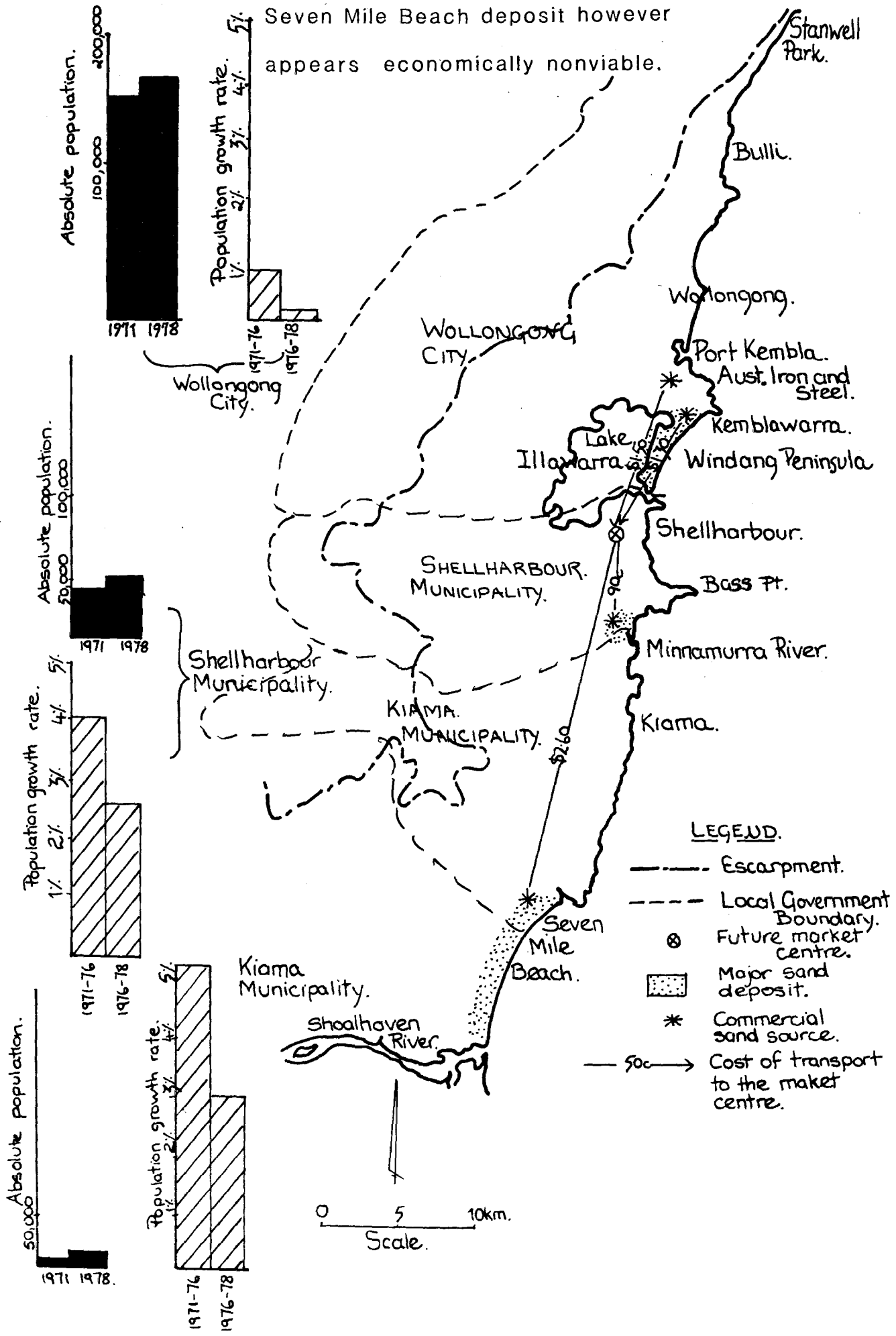


TABLE 4: COSTS OF SAND AND DELIVERY FROM THREE MAIN OPERATORS  
SURROUNDING WOLLONGONG

	Cleary Bros., Seven Mile Beach	South Coast Equipment, Kemblawarra	Southern Gravel, Dunmore
Price/tonne \$	3.30	3.30	4.00
Base Cost 9 tonnes	29.70	29.70	36.00
Cost First km.	.70	.40	.70
Additional kms.	.05	.10	.06
10 kilometres	30.85	31.00	37.24
20 kilometres	31.35	32.00	37.84
30 kilometres	31.85	33.00	38.44
40 kilometres	32.35	34.00	39.04
50 kilometres	32.85	35.00	39.64

Source: Phone prices quoted by suppliers

indication of a more complex reality. But to get a representative figure for transport rates throughout the region, the mean rates of transportation have been calculated from the three quoted cases.

These are:

Average rate for the first km = 60¢

Average rate for every km thereafter = 7¢

The average transport costs of sand are thus considerable compared to the relatively cheap cost of sand (\$3.30/tonne). Given this, it is clear that sand extraction sites close to the area of demand become more economically viable than those further removed. Figure 28 reveals that while Windang Peninsula (Kemblawarra) may continue to satisfy the industrial and construction

demands of Wollongong city, the centre of demand for sand is tending to shift southward. Thus the Minnamurra River sand deposit will become more economically attractive for the Shell-harbour and Kiama areas. However, because of increasing transport costs, the Seven Mile Beach deposit does not appear to be economically viable as a supplier to the Wollongong market.

#### (iv) Demand Reconciled with Availability

The natural sand resources available in the Illawarra region are more than adequate to meet the projected demand for sand. Even taking into account the current and predicted shift in demand, distribution trends to the south of Wollongong and the prohibitive costs associated with long distance haulage, the major coastal deposits, especially Windang Peninsula and Minnamurra River estuary are capable of satisfying these demands.

While natural resources are, therefore, capable of meeting this demand, an attractive alternative to this exploitation may be the utilisation of blast furnace slag. In recent years the notion has developed that slag, a waste product of steel production, may be processed into a form closely resembling sand and used widely as a substitute for sand. In Wollongong, slag sand is a particularly attractive alternative as it represents the use of what otherwise may be a waste product. Requiring minimal processing, it is cheap to produce and as it is produced close to the Wollongong market, haulage costs would be minimal.

The steel industry has been largely responsible, both directly and indirectly, for much of the past sand extraction in Wollongong; directly by removing huge quantities of sand for construction and the production of steel, and indirectly by being responsible for

the rapid population growth and its associated demand for huge quantities of sand (primarily for construction). Thus it would be fitting that a problem largely created by industry should be overcome with an industrially based solution.

(v) Slag - An Alternative to Natural Sand

What is Blast Furnace Slag Sand?

The gradual re-evaluation of slag and its potential for use in lieu of natural resources is evident in the changing manner of reference; it is no longer termed a "waste product" of steel production, but rather a "by-product" (R. Dunn, A.I.S., pers. comm). The current production of blast furnace slag at the Port Kembla Steel Works totals approximately 1.4 million tonnes/year (Lanigan, 1979). In 1977 approximately 10,000 tonnes was granulated for use as a replacement for medium grained natural sands in concrete. At present slag sand is produced intermittently as demand requires.

The American Society for Testing Materials defines blast furnace slag as a "nonmetallic product consisting essentially of silicates and aluminosilicates of lime and other base materials which are developed simultaneously with iron in a blast furnace". Slag is produced in various physical forms depending on the method used to cool the molten material as it emerges from the furnace. Granulated slag sand is produced in a water cooling process. Molten slag discharged during the casting operation is "cooled" rapidly by passing it through jets of cold seawater. The rapid cooling produces a coarse granular sand-like material. This particular form of slag is most suited to be an alternative to natural sand.

While the physical properties of slag are dependent on the

method of cooling, the chemical properties are largely independent of the cooling process. Slag results from the fusion of limestone and other fluxes with silica and alumina in the burden and ash from coke. Slag's main role is to remove sulphur from the iron. This results in the formation of calcium sulphide in slag. The chemical nature of slag is tabulated in Table 5.

TABLE 5: CHEMICAL NATURE OF BLAST FURNACE SLAG

Constituent	%
CaO	39
SiO <sub>2</sub>	38.2
Al <sub>2</sub> O <sub>3</sub>	17.9
MnO	1.4
MgO	1.0
FeO	.75
K <sub>2</sub> O	.6
S	.5
TiO <sub>2</sub>	.5
SO <sub>4</sub>	.05
Cl	.025

(As from A.I.S.)

The chemical properties of slag, however, vary between furnaces and even over time in one furnace. As slag is a by-product of iron production its nature varies with the quality of steel produced and the quantity of other ingredients used. This variation is illustrated in Table 6 of Port Kembla slag over the 1970/78 period.



TABLE 6: VARIATION IN CHEMICAL CONSTITUENTS OF SLAG, PORT KEMBLA 1970-78

Constituent	Port Kembla 1970	Port Kembla 1978
CaO	35-40	39-42
SiO <sub>2</sub>	32-35	34-36
Al <sub>2</sub> O <sub>3</sub>	18-23	17-19
MgO	1- 2	3- 4
Fe <sub>2</sub> O <sub>3</sub>	1- 2	.3-.4
MnO	.5- 1	.8- 1.1
S	.4-.6	.5-.7

(As from Munn R.L., 1979)

The quality of slag as a construction material has improved with decreased iron (Fe<sub>2</sub>O<sub>3</sub>) content and increased silica (SiO<sub>2</sub>) content. This is because iron staining has been minimized and chemical stability enhanced. Continued alkalinity (pH-10) has been ensured by constant lime fractions.

Granulated slag sand is a glassy, sandlike material with a size grading similar to that of medium to coarse natural sand (with a wider size range than dune sand). The particles are very sharp and needlelike. Slag sand also has a similar density and strength to natural sands when considering it as a construction material. Its physical properties are summarised in Table 7.

Continuing research into the use of slag as a replacement for sand in concrete has been carried out mainly by Australian Iron and Steel, Sydney University, Wollongong University and the Metropolitan Water, Sewerage and Drainage Board. The majority of results suggests slag is a highly satisfactory sand replacement.

TABLE 7: PHYSICAL PROPERTIES OF BLAST FURNACE SLAG SAND

Property	Granulated Slag Sand
Size Passing 19 mm	-
9.5 mm	-
4.75 mm	98%
1.18 mm	53.6%
300 $\mu\text{m}$	8.3%
75 $\mu\text{m}$	1.4%
Unit Mass	1050 kg/m <sup>3</sup>
Water Absorption	.1%
Particle Shape	elongated
Staining Index	nil
Loss on Ignition	.1%
Normal Angle of Repose	38 <sup>o</sup>

(As from Munn, R.L., 1979)

### Slag Sand in Construction

Granulated slag possesses properties that equip it very well for utilization in construction. It possesses excellent hydraulic properties which allow weak cementing bonds to form in the presence of water. Its irregular structure allows a high level of internal friction and affords excellent bonding. Its initial closed porosity gives good thermal insulation, it is impervious to moisture and is stable in widely varying climatic conditions (Dussart, 1979).

An Australian Standard for Metallurgical Furnace Slag Aggregates (AS 1466, 1974) has been in existence for several years and provides adequate regulations for ensuring the maintenance of slag aggregate

quality. More recently the Australian Standard "Concrete Structures Code (AS 1480, 1974)" was amended to include slag aggregates complying with AS 1466 as normal aggregates for construction.

Granulated slag has been used in concrete in two ways:

- i) as a replacement for natural sand in Portland Cement or bituminous concrete, or
- ii) when finely ground, as a pozzolan i.e. the cementing agent of the concrete.

At this stage it may be useful to point out the disparity between concrete and cement - cement is a finely ground product that when combined with water, sand, gravel and other materials forms concrete.

Most concrete laid in the A.I.S. since 1965 has used ground granulated slag as a partial replacement for Portland cement and sand with considerable success. The rate of strength gain of slag concrete is generally lower in early stages than that of traditional concrete, however, good ultimate strengths may be achieved. The ingredients used in most concrete at Port Kembla steelworks consist of a blend of slag sand, flyash and Portland cement. This combination has given good durability even under harsh conditions such as contact with seaspray. Concrete containing granulated slag as a total or partial sand replacement has been used in several locations subjected to heavy traffic within the Port Kembla steelworks (Munn, R.L., 1979).

When using granulated slag in cement, mix design alteration (variation in the proportions of ingredients) is necessary to allow for the angularity of the particles and its effect on workability. Total sand replacement by granulated slag results in a mix which is initially harsh and difficult to control in consistency. The

mix, however, is readily finished by conventional means. Hardened state properties are excellent. The inclusion of 20% natural dune sand in the fine fraction improves the overall grading and particle shape to a more acceptable degree.

Granulated slag sand has been used successfully as a filter medium for road drains, replacement for coarse sand in the production of hotmix for road surfacing, and as a replacement for sand in concrete block manufacture. About 20,000 tonnes of Port Kembla slag are used a year as filter medium. Of this up to 8,000 tonnes are used by the D.M.R. as filter medium around plastic subroad drainage pipes and as backfill for crib block walls (e.g. Mt. Ousley and Dapto). The D.M.R. has also used up to 10,000 tonnes/annum of granulated slag sand for the production of hotmix in road surfacing. The latter use is relatively new and requires long term performance trials. The use of granulated slag to replace sand in concrete block manufacturing is also a fairly recent application. It is under close scrutiny to determine its suitability in this role (Smith, 1979).

The characteristic that makes granulated slag such an attractive alternative to natural materials is its comparative cheapness (\$2.00/tonne compared to \$3.30/tonne for natural sand). Its accessibility to the centre of the Wollongong market also gives savings on cartage costs.

Granulated slag sand appears to be an acceptable replacement for natural sands in most instances; however, there have been reports of problems with its use. These problems relate primarily to its chemical nature (M.W.S.D.B.) and to one undesirable physical property.

Negotiations were conducted between the M.W.S.D.B. and A.I.S. in 1977 on adopting slag sand as the backfill medium for underground pipes in the Wollongong region. The rejection of A.I.S. slag was based primarily on chemical grounds. The main objection was the increased potential corrosion of metal pipes that slag would create due to its high level of soluble salts (sulphates and chlorides). As 99% of water pipes are iron or steel, this factor was unacceptable.

Sulphides in soil have always been suspected as corrosion agents of metal. Slag sand has an abundance of these sulphides. Sulphides ( $\text{SO}_4$ ) and chlorides (Cl) make up .05% and .025% of the slag sand mass respectively. The M.W.S.D.B. have compiled specifications for the chemical composition of any granular slag sands for pipe backfill (Table 8).

TABLE 8: M.W.S.D.B. SPECIFICATIONS FOR THE CHEMICAL COMPOSITION OF SLAG SANDS FOR PIPE BACKFILL

Property	Value
pH	not < 7.0
Total acidity	not > 5 meq/100g
Inorganic sulphide	not > 1 meq/100g
Magnesium as Mg.	not > .01% by mass
Chloride as Cl	not > .015% by mass
Sulphate as $\text{SO}_4$	not > .015% by mass

Because of the high  $\text{SO}_4$  and Cl levels granulated slag sand is unacceptable. These high levels result from the use of seawater in the slag cooling process.

Controlled tests conducted by the M.W.S.D.B. compared the corrosive reaction of both slag sand and clays with high salt levels on iron strips. It was found that slag gave rise to deep pitting in the iron whereas the clays gave rise to only shallow pitting. These results are contradictory to those in a five year corrosion study conducted by A.I.S. at Port Kembla. The control of the A.I.S. experiment has been questioned by the M.W.S.D.B. on the following grounds:

- a) the chemical composition of slag is highly variable, and this fact was not stated in results;
- b) the chemical reactions on buried structures depends on groundwater conditions and these appear not to have been closely monitored; and
- c) the erosive properties of natural soils vary widely and these were not recorded.

The M.W.S.D.B. hold that these considerations are of vital importance. Their pipes are often laid in low lying areas below the watertable and often the backfilled trench acts as an aquifer so that continually percolating water provides replenishment of chemical attack.

Experimental washing with distilled water was found to remove 66% of the sulphates and 89% of the chlorides and rendered it satisfactory for use according to M.W.S.D.B. standards. However, the production cost of this process was economically prohibitive.

Weathering was also tested as an alternative method of reducing the level of soluble salts. Exposing the granulated slag to the weather for some months gradually reduced the amount of salts through leaching. Although this was a cheaper process, the time

and organisation associated with it did not make it an attractive alternative. Another undesirable quality of slag sand is its physical form.

The needlelike shape of slag makes it difficult and unpleasant to work with. This property has resulted in industrial bans on its use. Several methods have been experimented with in order to correct this flaw but each beneficiation process involves a price increase that does not provide an incentive to transfer from traditional, tried-and-tested materials. One process carried out on granulated slag is that of Rod Milling, which grinds the sand with huge metal rods in a rotating cylinder. This process serves a dual purpose. It removes sharp edges from the particles and increases the percentage of fines in the slag sand rendering it more suitable for use in concrete (J. Roper, Department of Civil Engineering, Sydney University). Rod Milled slag sand, however, costs \$3.80/tonne compared to \$2.00/tonne for granulated slag sand and \$3.30/tonne for natural sands. Experimental washing of granulated slag sand with fresh water has also served not only to remove the sharp edges from the particles without increasing the percentage of fines, but also to remove a high percentage of sulphides and chlorides which render it unsuitable for use in association with metal.

#### Demand for Slag Sand

At present granulated slag sand is produced on demand, however its potential and attractive price are not well known, consequently the demand is not high. As A.I.S. does not intend to actively promote slag sand until tests on long term expansion/shrinkage,

creep, breakage, and corrosion being carried out in the Civil Engineering Department at Sydney University are completed (R. Dunn (A.I.S.), pers. comm.), the short term future for slag appears limited. While slag production is being treated on such a small scale, the costs associated with improving its quality are bound to remain high (because of the limited economies of scale).

The long term future for granulated slag sand as a replacement for natural sand appears to have high potential. D. Prosser (Blue Metal Industries, pers. comm.) estimates that up to 12% of the present annual 1,250,000 tonne slag production at Port Kembla could be turned over to granulated slag should the demand arise. This would result in approximately 150,000 tonnes of slag sand per year. Assuming an approximate sand consumption of 400,000 tonnes per annum over the next 20 years, then approximately 25% of Wollongong's future sand needs could be satisfied by slag sand. These figures, however, are highly speculative and depend on optimum marketing of slag as a sand substitute. Slag usage has the three following advantages:

- 1) the conservation of natural resources;
- 2) the disposal of what would otherwise be a waste product; and
- 3) the release of valuable land for use, both the land used to store slag on, and that from which natural products are extracted.

Presently A.I.S. is marketing its slag sands itself and does not intend to recommend it for widespread use until more information is available on its long term properties. However this does not totally explain the small utilization of slag sands. There appears to be a widespread inertia on the part of sand consumers to change



from a tried-and-tested material. This fact is more apparent with the small monetary gain involved in utilizing processed slag sand.

Additionally, J. Roper (Sydney University) pointed out, even if A.I.S. experiments prove highly favourable, each major concrete plant will need to conduct its own experiments and establish new size grading requisites etc. This means large scale transition to slag sand use could take at least several years.

While the price of upgraded slag sand remains more expensive than natural sands (\$3.80/tonne for Rod Milled sand compared to \$3.30/tonne for natural sands) there is no incentive to transfer from natural resources. In the present situation, therefore, there will probably be no "natural progression" toward the use of slag sand. Rather a situation in which there is economic gain, or natural resource depletion will be needed before a positive move is made towards alternative sources such as slag. It appears, therefore, that the problems associated with slag as an alternative to natural sands can all be overcome. The drawback with upgraded slag sand is its price. With the high price the incentive to use slag decreases rapidly in the present situation.

#### (vi) Summary

Recent demographic statistics indicate that in the Wollongong local government area the growth rates typical of the early 1970's are not being sustained. Together with the decline in the building industry, this trend suggests that demand for sand in the region will level off at approximately 400,000 tonnes per annum. In the southern local government areas of Shellharbour and Kiama population growth rates are still increasing and this holds significant implications for the distribution of demand. A consistent demand

within the Wollongong local government area will be ensured by the demands of heavy industry, but urban growth within the southern local government areas will result in a southerly movement of the centre of demand for sand for construction purposes.

The spatial redistribution of sand demand has potentially significant implications for supply. Only two of the three major sand deposits (i.e. Windang Peninsula and the Minnamurra River) are capable of economically supplying the projected demand, while the deposit at Seven Mile Beach appears to fall beyond the limits of economic transport.

There are adequate reserves of natural sand to meet this projected demand, but given the ready availability of slag and the progress already made in developing slag as a sand substitute, it would be unwise not to make every effort to utilise this potential resource. Not only would this help preserve the natural environment but it would also provide a means of disposing of what in the past was considered a waste product.

## CHAPTER SEVEN

### TOWARDS A POLICY FOR SAND EXTRACTION

#### (i) Introduction

Chapters four and five have documented the growing awareness of problems involved in utilising the sand resources surrounding Wollongong. While there is a continued and legitimate need for the exploitation of sand, there has developed a mounting outcry against damage to the coastal environment. In the past the weighing of the need for resources and the desire for environmental protection has been on a purely ad hoc basis. Decisions were made only on individual sites and generally only after divergence of interests had resulted in public controversy. No real attempt was made to plan for the future, nor was thought given to the formulation of sand extraction guidelines for the entire region. Clearly this unsatisfactory state of affairs could not continue when the consequences of defective planning threaten region-wide repercussions.

This chapter introduces a number of principles considered suitable for policy formulation. Implications for policy formulation are revealed as the disparate themes raised are drawn together, and are supplemented with additional information.

#### (ii) A Statement of Principles

Previous chapters have provided much of the basic information from which implications for policy formulation are derived. However several principles, incorporating value judgements on which policy recommendations are based, still need to be clarified:

- 1) It is assumed here that erosional damage to the beaches and foredunes of the region is undesirable. Their value as recreational resources and also as economic resources attracting tourists to the region more than offsets their value as sources of sand for construction. This seems obvious, but in the light of past policies of extraction (Chapter Four) it needs to be stated formally. It should not be forgotten that one of the region's major recreational beaches, Warilla Beach, already has been virtually destroyed by a faulty management policy in which unwise sand extraction in the mouth of Lake Illawarra played a significant role.
- 2) The sand extraction industry is particularly sensitive to the economic constraints of long distance transport (Chapter Six). The high bulk/low cost nature of construction sand dictates that in order to retain economic viability, extraction sites must be located in proximity to the place of market. Sites less favourable for extraction from other viewpoints may be the more economically desirable, resulting in increased pressure for their exploitation.
- 3) Sand extraction can lead to biological as well as erosional damage. It is assumed here that damage to the region's natural ecosystems should be avoided wherever possible. An evaluation of the ecological status of the main sand masses will be outlined.
- 4) Aesthetic despoliation, in addition to erosion and biological damage, has all too frequently been the result of sand extraction. While aesthetic qualities of landscape are notoriously difficult to define, they are undisputably significant to the wellbeing

of the community (Leopold, 1968; Goodey, 1971; Craik, 1972) and should be preserved where possible. Criteria for aesthetically rating the major sites for sand extraction is also provided later.

- 5) One of the main lessons to be learned from the review of past sand extraction in the region is that if disruption is to be minimised and if regulations controlling extraction are to be enforced, fragmentation of operations must be avoided. Far better to have a few large pits than many small ones.
- 6) Decisions regarding sand extraction need also to take into account the potential for alternate uses of a given site, both during and after mining. This by no means limits consideration to, say, present day and future recreational value. On the contrary, it requires that close attention be given to other community requirements such as garbage and industrial waste disposal, that sand extraction can make possible.
- 7) Emphasis is given here to the regional impact of recommendations. Far too frequently in the past, decisions have been made purely in the context of a given site. Clearly, decisions must also be based on the role of the site in the region as a whole.

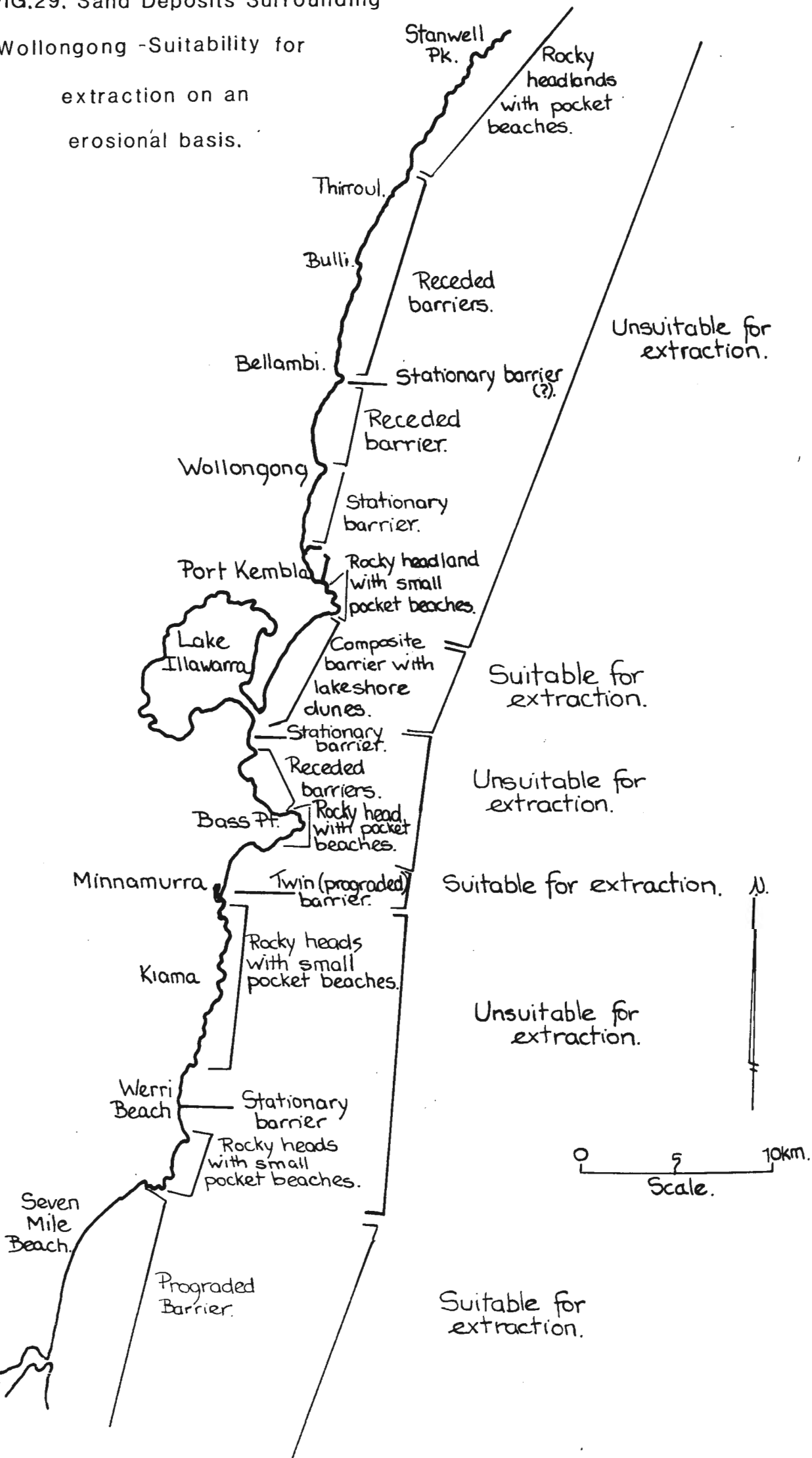
These principles are now dealt with in turn and applied to the locale in question. In conclusion an attempt will be made to create a regional synthesis by considering the sum total of the application of all principles.

### (iii) Application of Principles

#### Geomorphological Constraints

As has been discussed at length in Chapters Two and Three, Wollongong and its surrounding area is severely deficient in fluvial

FIG.29. Sand Deposits Surrounding Wollongong - Suitability for extraction on an erosional basis.



sand deposits. Fluvial deposits which are available do not yield consistently high quality sand nor do they promise long term supply. Sand resources of significance to Wollongong are concentrated in marine sand deposits which have accumulated along several areas of the coastline. Initially it must be emphasised that these marine deposits are strictly limited compared to other areas of the New South Wales coast.

Thom's (1974, 1978) classification of barrier types discussed in Chapter Two is useful for outlining the history of the deposits, thereby demonstrating that they are essentially relicts of the Holocene Transgression. This fact is of the utmost importance, for the sand must be considered as a non-renewable resource; sand removed will not be replaced by nature. Thom's classification is also useful for rating the susceptibility to erosion of particular sites. Several barriers consist of massive volumes of sand which extend a considerable distance inland and can be mined without necessarily promoting erosion. Other barriers are strictly limited in extent and overlie finer Pleistocene deposits which come close to the surface. The latter types of barriers are much more susceptible to obliteration through erosion. Moreover, some deposits show clear evidence of long term natural erosion and are thus very susceptible to disruption triggered by mining. Brief recapitulation of the major barrier types and their distribution will clarify the implications of sand extraction to various parts of the region's coastline.

Much of the coast surrounding Wollongong is composed of receded barriers, stationary barriers or pocket beaches (Fig. 29), all of which are unsuitable to support sand extraction. Reference to Chapter Two reminds that these barrier types are a product of

impoverished sand supply and consist of a small volume of sand which acts as a thin veneer over older fine consolidated sediments or rock. Much of the sand in these barriers forms part of the foredune system and performs a frequent and vital role in maintaining equilibrium in their associated beach system. As the extent of these barriers is so small and their presence so essential to continued equilibrium, the environmental impact of sand extraction would be disastrous. Extraction would not only reduce the store of sand available for maintaining equilibrium, but, by removing the vegetation cover and exposing the sands to winds, create instability which may result in sand drift. This would also effectively remove sand from the vitally important foredune area.

In the study area there are three major sand deposits (Fig. 29)

- Windang Peninsula, a Composite Barrier;
- Minnamurra River Estuary, an extensive Twin Barrier; and
- Seven Mile Beach, a Prograding Barrier.

Each of these deposits, although not receiving sand today (perhaps with the exception of Seven Mile Beach, as noted in Chapter Two), is situated at the mouth of a sizeable river, or stream system. Prior to the Holocene Transgression the rivers deposited sand at the then lower sea level on the continental shelf. As the sea level rose, this sediment was pushed up the shelf accumulating massive volumes which when the sea level rise halted were deposited in sizeable barriers on today's coastline. These voluminous barriers represent the most suitable areas for sand extraction.

The composite barrier of Windang Peninsula supports several areas suitable for extensive extraction, but also several environmentally



FIG. 30. Buffer Zones, and Erosionally Safe Sand  
Extraction Areas on Windang Peninsula.

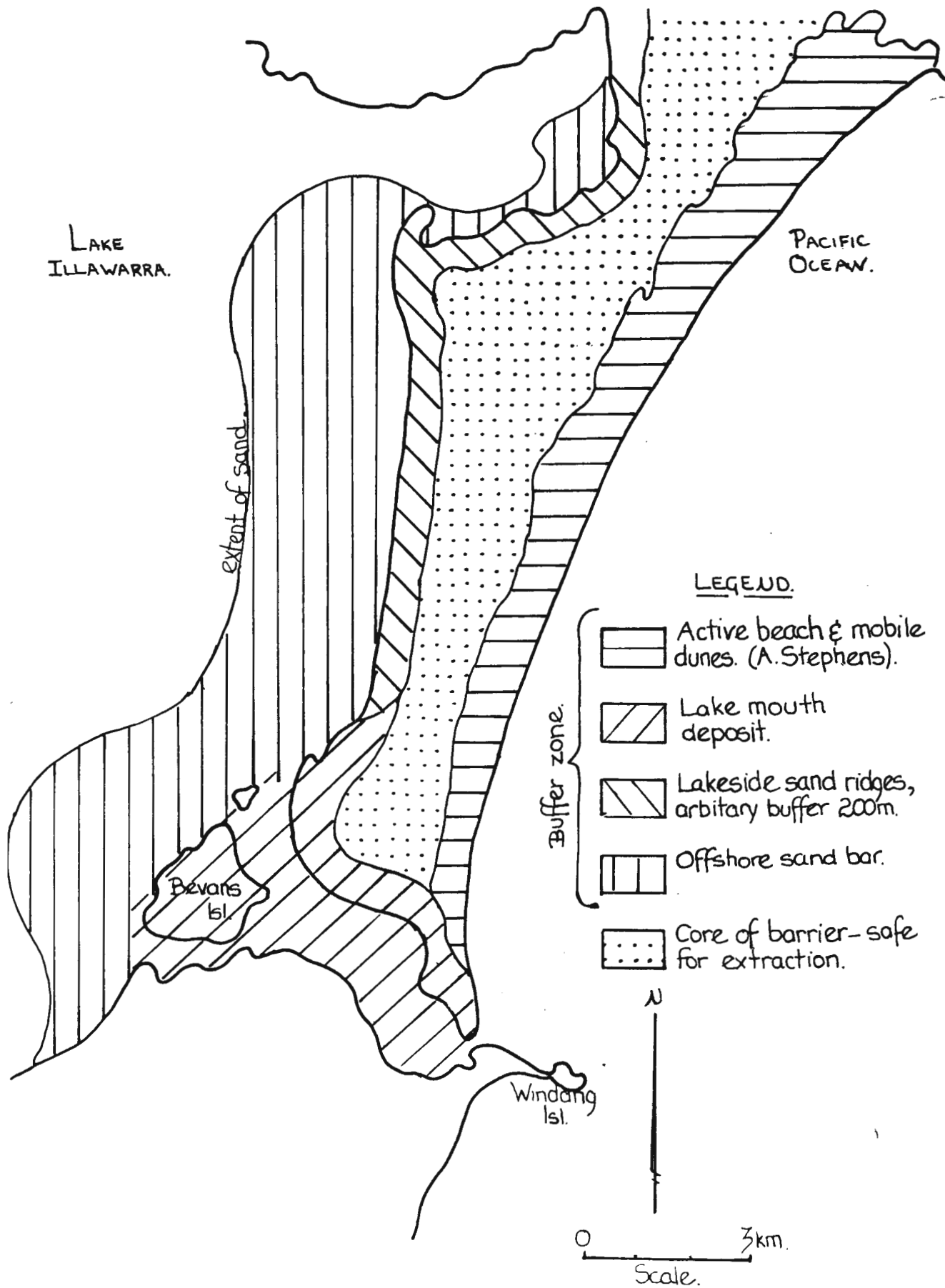
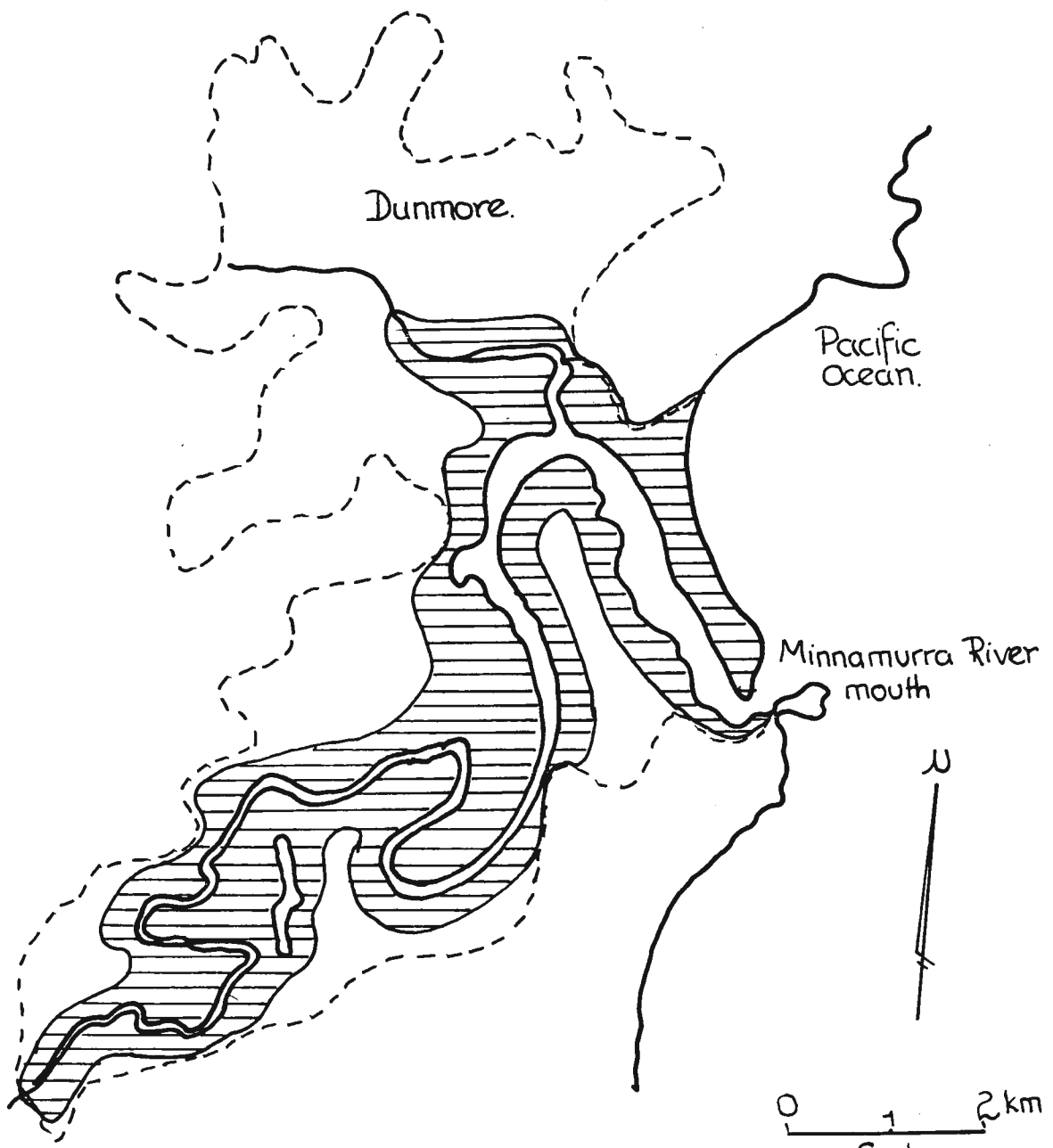



FIG.31. Buffer Zones, and Erosionally Safe Sand Extraction  
Areas Surrounding the Minnamurra River.



LEGEND.

- - - - - Distribution of sand.
-  Area recommended as a buffer zone between sand extraction and the Minnamurra River. (arbitrary 200m wide).

sensitive areas (Fig. 30). Essentially, all foreshore areas and the submerged offshore bar in Lake Illawarra, where waves and currents act on the sand body, represent the most sensitive areas. As shown in Chapters Four and Five, extraction in these areas disrupts the dynamic equilibrium of processes active in these areas and results in extensive erosion. Beyond these environmentally sensitive areas, it appears that the core of the barrier constitutes a suitable sand extraction area, at least in terms of its very low erosional potential. Furthermore, this core area appears to contain large quantities of good quality sand (Chapter Three).

The large sand body adjacent to the estuary of the Minnamurra River also represents a suitable sand extraction area. Again, however, there are several erosional sensitive zones that should be avoided (Fig. 31). Sand comprising the outer arm of the Twin Holocene barrier complex should be left intact, as should sand forming and surrounding the banks of the river. Long term mining near the channel may well trigger large scale erosion (Chapter Two). Beyond these sensitive areas, there lies extensive sand suitable for extraction. These now inactive masses were pushed up the shallow river valleys in the northern sector of the deposit, into the Dunmore area. An estimated 13 million tonnes of sand suitable for extraction lies there (Smith, 1979).

The multiple parallel beach ridges of the Seven Mile Beach prograded barrier are, apart from the foredune zones, now largely inactive as the sand lies under dense vegetation. Removal of sand not involved in the beach system (which includes the foredune areas) would have minimal impact on the erosional stability of the barrier system.

Wollongong, therefore, has three large supplies of good quality construction sand available for future use. However, the relict nature of the sand deposits and the lack of contemporary sediment input dictates that in the future the city will have no more sand than is presently available. Any removal of sand must permanently change the environment. Thus, even on the largest deposits, large scale damage could occur if basic environmental constraints on extraction were ignored.

Firstly, sand in or immediately adjacent to foredune areas should under no circumstances be extracted or degraded by sand extraction. The imperative role of foredunes in maintaining beach stability in periods of high wave energy cannot be overemphasised.

Secondly, sand adjacent to any active waterway should not be disrupted. Wherever sand occurs in such sites, whether it be part of a sand body adjacent to a river or actually within a tidal channel, the interaction of water and sand creates a dynamic equilibrium. Interruption of such a balance may have serious and far-reaching erosional consequences on the surrounding environment.

Thirdly, areas of transgressive dunes should not be further disrupted by sand extraction. This should be so regardless of whether transgression is natural, as on the eastern perimeter of Windang Peninsula where high dunes are destabilised by winds, or the result of man-made disruption, as in the case of many intensively used dunes or unrehabilitated areas of past sand removal. In each of these three particularly sensitive areas of sand deposits, an adequate buffer zone should be retained between them and any sand extraction.

### Economic Constraints

High and ever increasing costs of road transport, coupled with the high bulk/low value nature of sand, exerts an extremely powerful constraint on the location of sand extraction operations and in order to retain economic viability the place of sand extraction must be close to the main market place (Cooke and Doonkamp, 1974). Ketchum (1972) has pointed out that in America most of the nations 6,000 sand pits were within 35 km of their market place. A closely comparable limit to transport also seems to operate here. The main pits lie close to Wollongong. Indeed one Wollongong concrete company finds it uneconomical to transport sand from their own pit at Seven Mile Beach 40 km to their Wollongong concrete plant. With the steep increases in the cost of motor vehicles, petrol, and labour, it seems reasonable to assume that in the future sand pits will need to be considerably closer than 35 km from their market. Clearly then, Windang Peninsula and the Minnamurra River estuary are, and will remain, economically attractive sand deposits, whereas Seven Mile Beach will be much less so.

### Ecological Constraints

The ecological status of the three main potential sand mining areas in the region differ markedly.

Because it is situated close to the centre of Wollongong the natural landscape of the Windang Peninsula has been extensively altered since the settlement of the area. Nonetheless ecological constraints on sand extraction still do hold, though to varying degrees on the peninsula. Kemblawarra, in the north of the peninsula

(Plate 13) is extensively disrupted by dredging and waste tipping and its western margin is occupied by light industry and some dwellings. While there are areas of ecological significance, including limited areas of natural vegetation on dunes to the south and the east of the area and Coomaditchy Lagoon in the north which provides an important resting ground for birds, much of the area could well be exploited further without serious ecological disruption. The central area of Windang Peninsula has almost been completely cleared of natural vegetation except for limited areas of dunes to the east (Plate 19). Provided extraction did not encroach into these easterly dunes or interrupt the lakeside buffers, ecological disruption would be negligible.

The marine sand bar in Lake Illawarra, to the west of Windang, has to date escaped disruption and retains its natural morphology, flora and fauna. This sand bar and its related ecology represents a necessary base for the maintenance of the lake's geomorphological and biological equilibrium. The bar creates a buffer protecting the peninsula from waves generated on the lake (Chapter Five). Moreover extensive weed beds growing in the shallows of the bar produce oxygen essential for maintaining the water quality in the lake, provide a habitat and food for numerous species of estuarine fauna such as fish and prawns, and also form a refuge for a wide variety of aquatic birds (Harris, 1976). Removal of sand from this bar would disrupt an ecologically valuable wetland close to the centre of Wollongong.

The sand deposit surrounding the Minnamurra River estuary represents an area of highly variable ecological status. A low hill (Plate 20) divides the deposit into two sectors; a southern

WINDANG ISLAND.

LAKE  
ILLAWARRA.

WINDANG  
PENINSULA

PACIFIC  
OCEAN.

PLATE 19. Aerial view of central and southern Windang Peninsula, 1978.  
(photograph: N.S.W. Planning and Environment Commission).

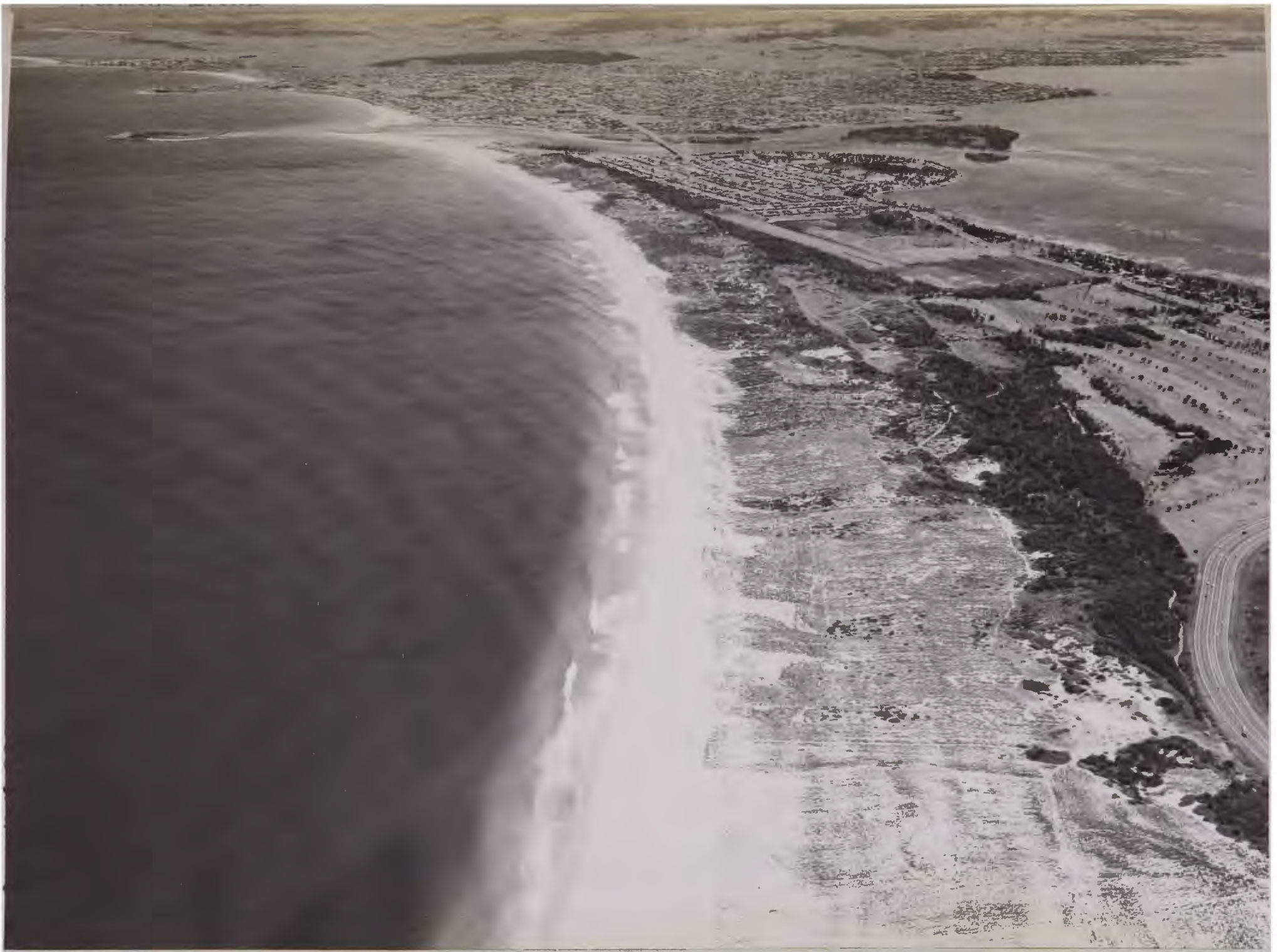


PLATE 19. Aerial view of central and southern Windang Peninsula, 1978.  
(photograph: N.S.W. Planning and Environment Commission).





PLATE 20. Aerial view of the Minnamurra River main channel and the Dunmore area. Note the low hill line separating Minnamurra from Dunmore, and a sand extraction pond in Dunmore- left background.

(photograph: N.S.W. Planning and Environment Commission)



PLATE 20. Aerial view of the Minnamurra River main channel and the Dunmore area. Note the low hill line separating Minnamurra from Dunmore, and a sand extraction pond in Dunmore- left background.

(photograph: N.S.W. Planning and Environment Commission)

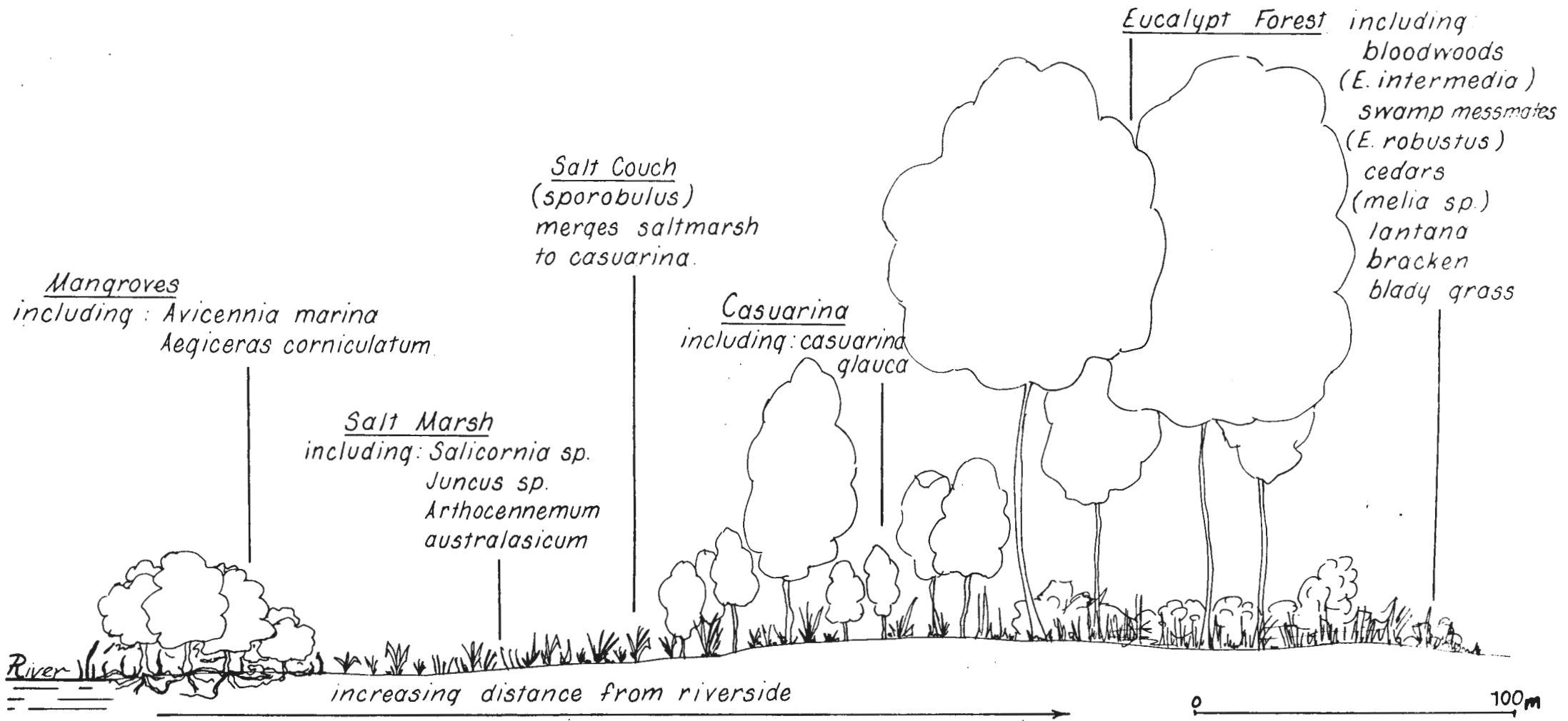


FIG. 32. Sketch of Vegetation Succession Typical of the Minnamurra River.

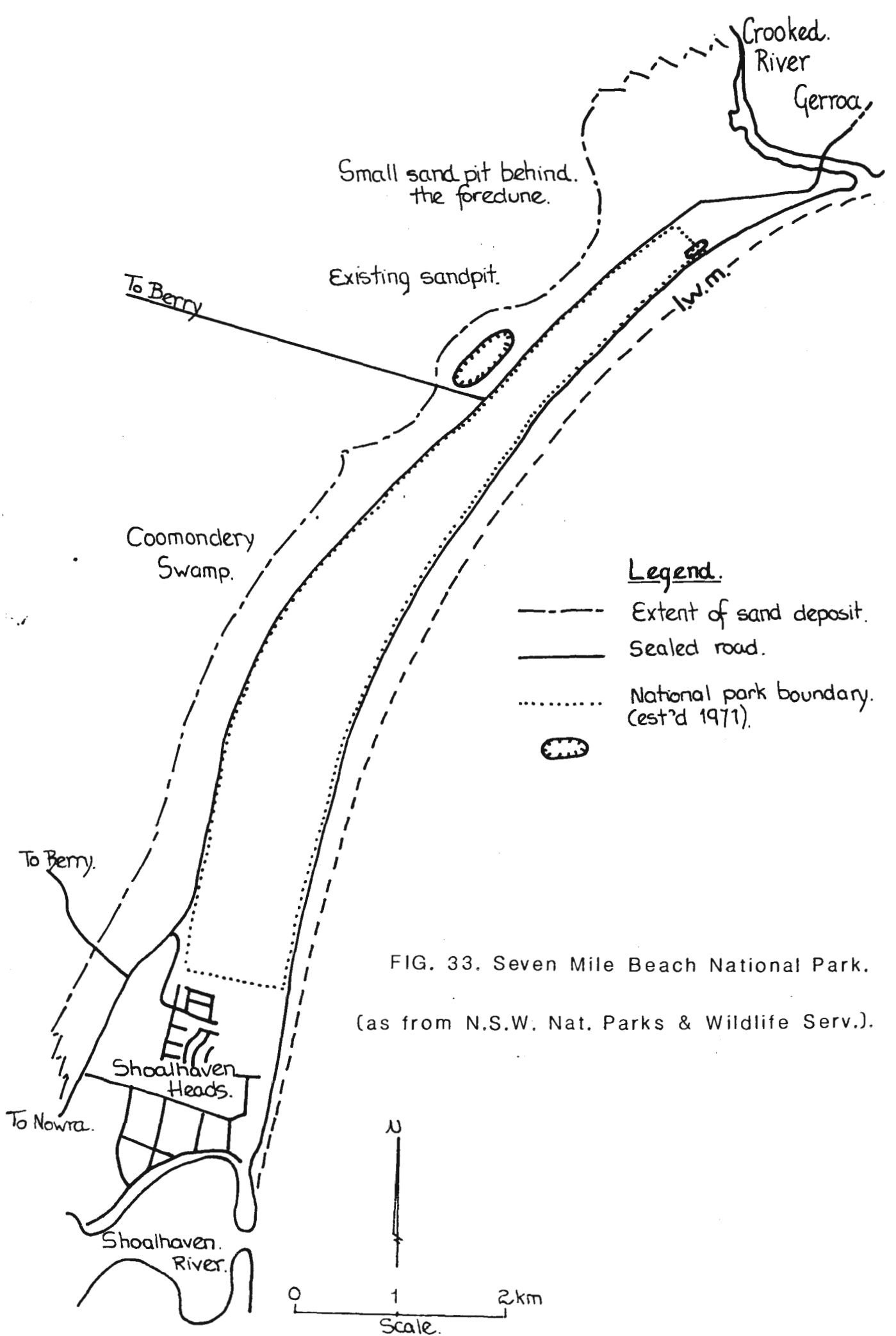
(as from the N.S.W. Pollution Control Comm.).

area along the main channel of the Minnamurra River and a northern area near Dunmore. These two areas differ not only in terms of drainage, but also in terms of their ecological status. The section traversed by the Minnamurra River represents a predominantly natural ecosystem. The large meander scrolls discussed in Chapter Two support the second largest forested area (Plate 20) on the Wollongong coastal plain (exceeded only by the stand behind Seven Mile Beach). The forest consists predominantly of eucalyptus and casuarinas and is only partially disrupted where clearing has resulted in dense *lantana* growth. The forest area is an ecologically viable habitat and supports several species of small native mammals and is rich in birdlife (Young, 1976). The Minnamurra estuary and adjacent sand flats also include extensive wetland areas which serve as a valuable nursery and feeding ground for estuarine organisms. A well developed and clearly defined plant succession from mangrove to forest is also evident to the area (Fig. 32). The main channel of the Minnamurra River represents one of the few areas in the Wollongong area with a large variety of original and still reasonably intact vegetation. The dedication of a large proportion of this area as an Environmental Protection Zone emphasises the ecological value of this area.

Dunmore, the northern sector, is an area of much lower ecological status. The area is largely cleared of natural timber except in the vicinity of a major backwater to the Minnamurra River. In this area, wildlife typical of the southern sector of the Minnamurra is found in the stand of wetland which predominantly supports mangroves, casuarinas and swamp grasses. Natural vegetation scattered along smaller water courses (Plate 21) consists of casuarinas with a



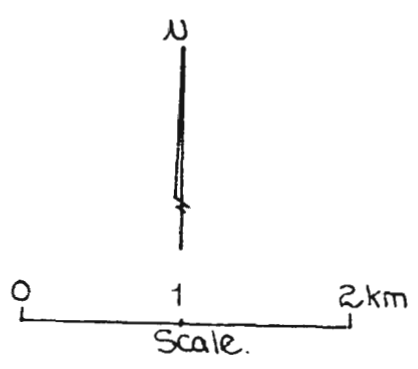
PLATE 21: Aerial view typical of the Dunmore area. The area is extensively cleared of natural vegetation and supports a wide variety of secondary development. Pictured is a sanitary depot adjacent to the forested backwater of the Minnamurra River.



Legend.

- Extent of sand deposit.
- Sealed road.
- ..... National park boundary. (est'd 1971).
- Existing sandpit.

FIG. 33. Seven Mile Beach National Park.  
 (as from N.S.W. Nat. Parks & Wildlife Serv.).



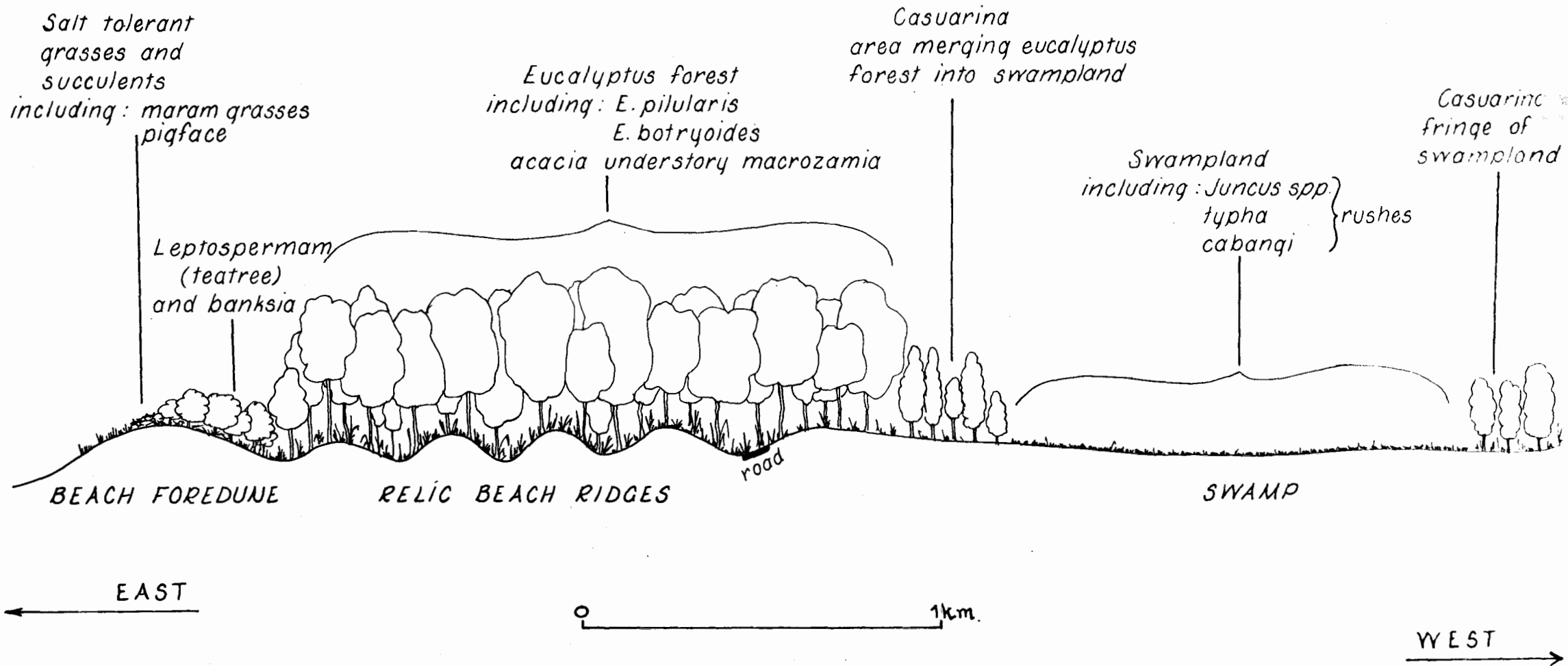


FIG.34. East/West Crossection Typical of the Integrated Beach/Beachridge/Swamp System of South Seven Mile Beach and the Coomonderry Swamp Area.

leptospermam understorey. The majority of Dunmore is not ecologically valuable and from this viewpoint more suitable for the extraction of sand.

Seven Mile Beach sand ridges support native flora and fauna of extreme ecological value (Plate 22). The widely accepted value of this area is evident in the dedication of much of the beach ridge area as national park in 1971 (Fig 33), and the probable intention of several government bodies to extend the parkland by acquiring the adjacent freshwater wetland of Coomondery Swamp. The beach/dune/wetland ecosystem typical of the southern area of the sand deposit (Fig. 34) is still essentially in its natural state and supports numerous species of native mammals, reptiles and birds. The area is of scientific value as it represents one of the only forest refuges near the coast and has an extensive adjoining fresh water swamp. Although the north of the sand deposit is of less ecological value due to sporadic clearing and development associated with a nearby village, the natural forest still predominates the sand body, especially in the east.

Thus while areas such as the submerged sandbar west of Windang Peninsula, the southern sector of the Minnamurra estuary sand deposit, and Seven Mile Beach (especially the parkland sector), stand out as biologically valuable areas where the disruption associated with sand extraction would create obvious ecological degradation, other areas of less ecological value could accommodate sand extraction with less adverse impact. These areas include Kemblawarra and the central portion of Windang Peninsula, Dunmore in the north of the Minnamurra estuary sand body, and limited areas on the northwest of the Seven Mile Beach deposit.





PLATE 22: Aerial view of Seven Mile Beach looking toward the Shoalhaven River mouth.

### Aesthetic Constraints

There is a considerable array of schemes that have been devised for "objectively" rating the aesthetic value of a landscape (e.g. Leopold, A., 1968; Leopold, L.B., 1969; Melhorn et al., 1975; Land Use Consultants, 1971). The problems involved in devising an "objective" basis for landscape aesthetics have been discussed at some length of Lowenthal (1962) and Appleton (1978). They maintain that despite claims of "objectivity" by quantitative approaches to landscape appraisal, even the most stridently "objective" rest on a subjective basis. Indeed, perception of scenic quality is clearly related to cultural background (Clark, 1949; Lowenthal, 1962; Craik, 1971). What appeals to one group, need not necessarily appeal to another. There seems no sound reason to believe that a scheme devised in England or the U.S.A. can be validly applied to eastern Australia. It would seem much more reasonable to apply a rating scheme devised here, and especially to use one which seems to reflect local values. However, even the use of a locally devised scheme which attempted to emulate the detailed rating of the foreign systems would be difficult to justify. Rather the evaluations of the National Trust of New South Wales, the official organisation for preserving outstanding localities, have been adopted.

In a report specifically on the Illawarra region, the National Trust of New South Wales (1975) sought to identify in qualitative terms those areas which, because of their outstanding beauty, deserve preservation. The report makes no pretence to objectivity, nor does it claim to be able to distinguish with a high degree of precision or reliability between areas. In order to reflect the values of contemporary society within the Illawarra region, those

involved in preparation of the report possessed varied and long standing experience in the region. The fact that the recommendations of the National Trust have been endorsed by local government bodies accentuates the representative nature of the report.

In addition to the recommendations of the National Trust (1975), the dedication of areas to be parkland by local, state, or national government bodies is accepted as indicative of the recognition of the aesthetic value of an area to the community. Finally, it must be emphasised that in any area of high aesthetic appeal, visually disruptive landuse such as sand extraction is most unsuitable.

The high scenic, recreational and environmental importance attached to the small coastal sand bodies associated with receding barriers, stationary barriers, pocket beaches, and indeed all fore-dune areas is reflected in the policy of the New South Wales Government to acquire all available sea front land in this region for dedication as parkland. A glance at a representative interval of coastline (Fig. 19), clearly illustrates the intention of the government to protect small sand bodies from development. The aesthetic and recreational importance of these deposits dictates that sand extraction apparently would no longer be tolerated by the government.

Beyond these small sand deposits, the three large sand bodies of Windang Peninsula, Minnamurra River and Seven Mile Beach, each support several environments of variable aesthetic appeal. On Windang Peninsula the extensive alteration of the area since settlement, including extensive vegetation clearing and industrial and residential development (Plates 13 and 19) has resulted in the area retaining very little aesthetic appeal. Indeed the only

parts of this area mentioned by the National Trust (1975) were the entire foreshores of Lake Illawarra, including the submerged sand bar west of Windang. These sites were proposed as reserves for public recreation. On purely aesthetic grounds, the remainder of the peninsula can be considered as suitable for extraction.

The variation between the area of the Minnamurra River main channel and the Dunmore area is as great in aesthetic terms as it is in ecological terms. The well defined topographic boundaries separating the Minnamurra River channel from Dunmore in the north and from Kiama in the south, together with the imposing escarpment in the west, create a pronounced visual unity stretching from the river's headwaters to its mouth. Essentially untouched by secondary development, this visual unit is undoubtedly one of the finest vistas not only in the Illawarra region, but of the entire coast of New South Wales. Its apparent rural isolation, but its actual proximity to the intensive industrial city of Wollongong, enhances its value to the community. The National Trust has designated the Minnamurra River estuary and its associated valley as part of the Jamberoo-Cambewarra Scenic Protection Area, for which strict planning controls are recommended to protect the scenic quality. Moreover, the dedication of much, and the intended dedication of other parts of the area surrounding the Minnamurra River channel as Environmental Protection Zone (Fig. 25) by the local councils, reinforces the high ecological and aesthetic priority emphasised in the National Trust recommendations. The Dunmore area to the north is considerably less aesthetically appealing. Most of the area surrounding Dunmore has been extensively cleared of natural vegetation and much of this area utilised for secondary industrial development including

an extensive basalt quarry, several sand extraction ponds, and a cement plant. Furthermore, several waste disposal sites are located here, while the visual quality of the area has been in no way enhanced by the opening of an animal "park". The backwater of the Minnamurra River which flows into the southeast of the area represents the only area of aesthetic quality. The majority of this vegetated area lies in the Environmental Protection Zone. But the proximity of a sanitary disposal area and garbage tip certainly detract from its aesthetic appeal. The Dunmore area was given no mention in the National Trust (1975) preservation recommendations, and there is little doubt that further sand extraction could be accommodated with little disruptive effect.

Seven Mile Beach, the largest sand body in the vicinity of Wollongong, contains extensive areas of outstanding aesthetic appeal (Plate 22). The majority of Seven Mile Beach remains under a cover of natural vegetation, and the dedication of an extensive National Park in 1971 (Fig. 33) illustrates not only the area's high aesthetic quality, but also the general acceptance of its regional value. Coomondery Swamp, adjacent to the park (Plate 22) has been recommended in the National Trust Report (1975) as an area worthy of acquisition as a Nature Reserve. Sand extraction in the park, and on the area of beach ridges between the park and the swamp, would represent development inappropriate with the perceived high aesthetic quality of the area. North of the park the nearby village of Gerroa has been responsible for localised interruption of the beach ridge area, including small sand pits, a garbage tip and car parks for the beach and park. An extensive sand extraction plant also operates northwest of the park (Fig. 33).

Although not in pristine condition as is much of the southern parkland and its associated areas, this locale retains considerable aesthetic appeal due to the limited nature, or limited visibility of developed areas. Although not in the National Park, this area retains much of the aesthetic appeal typical of the park area with which it is closely associated. Any disruptive development such as sand extraction would need to be strictly controlled in order to protect the high aesthetic quality of the close-by parkland.

Essentially, then, in localities including the small sand deposits scattered along the coastline, the eastern side of Lake Illawarra, the main channel area of the Minnamurra River, and the parkland areas of Seven Mile Beach, the aesthetic disruption associated with sand extraction would be incompatible with the high aesthetic quality of the areas. In localities that include the core of Windang Peninsula, the Dunmore area, and selected areas north of the Seven Mile Beach National Park, however, sand extraction could be accommodated with less adverse effect on their aesthetic appeal.

#### Centralising of Sand Extraction

Fragmentation of sand extraction operations should be avoided. In the past there was no real attempt at centralisation of sand extraction operations, and many small pits operated over a wide area. This resulted in a veritable rash of environmental problems and widespread aesthetic downgrading.

For example, in 1967 there were no less than twenty separate extraction leases scattered over Windang Peninsula. Of course, the persistent demand for sand will ensure that environmental

disruption must occur, but the centralisation of sand pits would facilitate more efficient control of extraction procedures. As long as extraction occurs in the areas most suitable in terms of erosional, ecological, aesthetic and economic considerations, and is conducted in an environmentally responsible manner, there must occur in the long term a reduction in the disruption which would result from unrestrained extraction. In short, it would be better to utilise the entire resources of one of two localities than to permit widespread and piecemeal disruption.

On Windang Peninsula this principle has already been realised with the termination of the many small leases available in 1967 and the development of one large permissive occupancy at Kemblawarra (Plate 13). Extensive areas of sand still exist in Kemblawarra in areas erosional, ecologically, aesthetically and economically suitable for extraction. Further centralisation of disruption to this area would be preferable to the establishment of a new operation elsewhere.

In Dunmore, at least three separate sizeable sand extraction pits have operated in the past, each creating a scar on the landscape. Several localities in Dunmore appear economically suitable for supporting sand extraction in the future without compromising the areas environmental, ecological, or aesthetic qualities. However, in order to avoid continued fragmentation in selecting any future sand extraction site, an area capable of supporting long term extraction should be sought. Similarly, should further extraction be considered on the Seven Mile Beach deposit, controlled expansion of the existing pit (northwest of the park area, Fig. 33) would be preferable to the opening of new pits.

Taking into consideration the principle of consolidation, the large scale pits currently in operation on the north of Windang Peninsula and on the northwest of Seven Mile Beach appear the most suitable areas for future extraction in these deposits. On the Minnamurra River deposit Dunmore represents the most suitable locale for extraction. No long term pit currently operates in this area, however, in delineating future extraction areas, only sites capable of supporting a long term operation should be considered.

#### Alternative Uses

A rational policy for the control of sand extraction should consider the potential for coordinating sand extraction with other activities that generate problems in the region. Waste disposal stands out as perhaps the major problem. Sand extraction on the coastal deposits surrounding Wollongong has created deep pits filled with turbid water which deteriorate into dangerous wastelands. Clearly these pits do not represent regional assets, but backfilling with soil is prohibitively expensive. One method of overcoming this problem of derelict pits is by backfilling them with domestic garbage and solid industrial waste. As with all modern cities Wollongong produces large quantities of domestic waste, and being a mining and industrial centre the city also produces large quantities of solid industrial wastes such as coalwashery refuse and blast furnace slag. Indeed the total volume of waste far exceeds that of Sydney (Draft Illawarra Regional Plan, 1979) but while Sydney's waste is mainly household refuse, the bulk of Wollongong's comes from the coal and steel



industries. The availability of acceptable sites for waste disposal is a particularly difficult problem on the narrow Illawarra Plain. The utilisation of old sand extraction ponds as garbage disposal sites would not only enable the infilling of these pits and dispose of garbage, but would also in the long term create land suitable for a range of uses including recreation.

Filling of pits with waste is already in progress at Kemblawarra on Windang Peninsula and could be extended. At Dunmore, waste disposal is currently carried out over considerable areas of sand deposit, effectively sterilising the sand below it from future extraction while close by sand extraction continues to create deep ponds which are totally superfluous in the area rich in water resources. At Seven Mile Beach extensive sand extraction continues to create a large pond totally out of character with its surroundings. Backfilling and revegetation of the area would, in the long term, create a less obvious scar on the environment than is presently the case. In the future, all proposals to extract sand should take into consideration the possibility of combining the solutions to several regional problems in one operation.

### Regional Outlook

Decisions concerning sand extraction location should be made in a regional, rather than a local, context. Not only the characteristics of a given site but also the role of that site in contributing to the character of the total region should be considered. It is not enough to demonstrate the commercial viability of an intended sand extraction site. Rather, as has become clear by considering erosional, ecological, aesthetic and community issues, some sites can be seen to be more suited to sand extraction than

others. The significance of this principle becomes clear below when all the potential sand extraction sites surrounding Wollongong are compared on the various issues previously discussed.

(iv) Summary - The Weighing of Alternatives

In order to obtain a regional rather than a purely local perspective in the future planning of sand extraction in and surrounding Wollongong the relevant environmental characteristics of each potential extraction site have been collated into a matrix (Table 9). By weighing the principles discussed, with the environmental characteristics of the sites, it becomes clear that some sites are more suited to sand extraction than others.

Reference to Table 9 reveals that the potentially commercially viable sand deposits differ in their natural environmental quality and landuse development. Areas with a higher number of crosses retain a higher quality of natural environment and are sand deposits where disruption caused by extraction would be more severe. On the other hand those areas with a greater number of circles represent deposits where considerable environmental disruption has already occurred and where the impact of new or additional sand extraction operations would be of lesser significance.

Based on these criteria, several sites stand out as areas of high environmental quality. These have minimal secondary development and sand extraction would create an obvious negative environmental impact from erosional, ecological and aesthetic viewpoints. These areas include the eastern side of Lake Illawarra, the area surrounding the main channel of the Minnamurra River and Seven Mile Beach National Park and its adjacent areas. Unnecessary exploitations of these deposits would not be advisable. This is

TABLE 9 : SUMMARY OF ENVIRONMENTAL CHARACTERISTICS OF THE MAIN SAND EXTRACTION SITES AROUND WOLLONGONG.

The environmental features isolated on the horizontal axis are derived from the principles for future sand extraction outlined earlier in this chapter. These features summarise a number of aspects of an area that are indicative of its suitability for sand extraction.

SAND DEPOSITS

Small Barriers		X	X			X				Variable
Windang Penin-sular	Kemblawarra						0	0	0	Yes
	Central Pn.					X	0			Yes
	East of Lake	X	X	X	X	X				Yes
Minna-murra River	South	X	X	X	X	X				Yes
	Dunmore						0	0	0	Yes
Seven Mile Beach	North			X		X		0	0	No
	South		X	X	X	X				No
ENVIRONMENTAL CHARACTERISTICS										
Primarily erosionally sensitive										
High aesthetic quality: National Trust classification dedicated park land or environmental protection area										
Ecological	Natural vegetation predominant									
Status	Significant faunal habitat									
Potential for recreation										
Secondary development in the area										
Centralisation of existing sand extraction industries										
Opportunity for establishing sand extraction in association with garbage dumps ie. garbage dumps in area										
Economic proximity - arbitrary 35 km distance										
Aspects of physical environment						Aspects of secondary development				

particularly true when suitable areas of lower environmental quality exist in equally close proximity to the market. More suitable areas include Kemblawarra on Windang Peninsula, Dunmore north of the Minnamurra River and, to a lesser extent, the remaining core of Windang Peninsula and the north and northwest of Seven Mile Beach sand deposit. These areas represent the least sensitive environments in terms of erosive, ecological and aesthetic characteristics. Providing that extraction was carried out in an environmentally responsible manner, further disruption in these sites could be accommodated with relatively small adverse impact.

Given the availability of commercial sand deposits for the future, however, it should not be forgotten that, as the sand masses are relict, sand taken from these sites represents a long term loss to the region's resources. A more satisfactory solution would entail the utilisation of steelplant slag sand. It would indeed be fortuitous if in the future the massive surplus of blast furnace slag could be utilised to meet Wollongong's need for construction sand. Not only would the sand deposits of the area be preserved, but what is now largely a waste product of steel production would be used profitably to produce an economic sand source in close proximity to the market. Clearly the use of slag should be encouraged in order to reduce the pressure to exploit natural resources.

## CHAPTER EIGHT

### CONCLUSION

Hare (1980) emphasised the need for and value of a rational approach to environmental problems resulting from the interactions between man and his environment. He perceived the value of establishing the nature of a problem prior to any discussion of counter-active measures. As noted previously, he differentiated two distinct classes of environmental problems; those associated with the legitimate use of resources and those which spring from a poor approach to resource utilisation, emphasising that often these two types of problems converge. Consequently, environmental damage may result from a faulty approach to the meeting of essential demands. This is certainly so in the sand extraction industry around Wollongong. The need for the mining cannot be denied, but the methods by which it has been carried out are very much open to criticism.

Many geographers (e.g. Eyre, 1978; Clark, 1978; Holmes, 1976) have advocated systematic study of the complex interactions between man and his environment as the most rational means of coming to terms with man-land problems. By integrating the many and diverse factors affecting man-land relationships and thoroughly analysing each of these factors in context, a valuable overview is achieved from which the most logical planning measures may be deduced. In order to synthesise information relevant to specific environment and landuse problems, and suggest guidelines for practical planning Bunge (1973), Conacher (1977), and Eyre (1978) have advocated regionally orientated studies. While diverging from a strong trend towards specialisation characteristic of modern geography, this

thesis follows two geographical traditions; regional study and the systematic integration of those factors affecting man's interactions with his environment.

The aim of the thesis has been to create a comprehensive overview of the sand extraction industry in and around Wollongong. It is only within such a framework that the precise nature of the problems facing the industry can be established, and rational guidelines be recommended to counteract unnecessary problems in the future planning of the industry. To obtain such an overview the following have been considered: the factors that have affected the industry to date, the factors currently exerting an effect on the functioning of the industry, and the role that the industry will be required to serve in the future.

Research has perforce been wide ranging, as is the tradition of integrated studies. However, not every aspect of the sand extraction industry in Wollongong has been dealt with in equal depth. Logistic limits have dictated that only those factors deemed most relevant to the exposition of the problems facing the industry could be dealt with in detail.

Basic to establishing the nature of problems associated with sand extraction in Wollongong is the need to understand and appreciate the nature of the physical environment of the region. Were sand resources more abundant and/or less sensitive to disruption, environmental considerations may be less significant. But in Wollongong these considerations are of foremost importance. Detailed inventory and analysis of sand reserves has revealed that available resources are predominantly marine and strictly finite. They are not being replaced and their distribution is unequal; in many areas

there is no sand at all whereas in others there are excesses. Beyond problems of distribution much of the available sand is vulnerable, constituting integral parts of dynamic systems. Disturbance of such systems is highly likely to cause widespread environmental damage and must be avoided wherever possible.

But this problem has not been approached in an ad hoc fashion. Rather it has been guided by new conceptual advances in coastal geomorphology. Indeed it cannot be too strongly emphasised that without this conceptual framework the types of conclusions reached here could not have been drawn. Thom's (1974, 1978) detailed geomorphological studies of coastal sand barriers proved invaluable in defining the physical nature of sand resources available to Wollongong as did numerous other geomorphological studies (Ford, 1963; Jones, Young and Eliot, 1979; Roy, 1977; Wright, 1978). Synthesis of this highly fragmented information yielded a body of knowledge from which it was possible to confidently predict the impact of sand extraction on available sand reserves.

Environmental damage has been caused and can be caused by the unwitting mismanagement of a misunderstood resource. It is necessary to closely examine this management (or mismanagement) in order to propose rational planning measures for the industry's future. This was the logic behind the adoption of an historical methodology in this thesis. Indeed, as Eyre (1978) has noted, any regionally based environmental problem needs to be considered as the final product of sequent occupation. The industry has, therefore, been examined against its social and economic background by documenting the relatively recent but significant impact of European settlement on Wollongong's sand deposits. By tracing this rapid

industrial and urban development up to the present it was possible to place past and contemporary sand extraction procedures and the related problems in perspective. It was not the intention to examine the reasons behind poor environment procedures prior to the 1970's, or to consider the theoretical implications of recent community controversy over sand extraction, or indeed to consider the processes of decision-making — each of which could be developed into an entire thesis. This study has had a more modest and perhaps more pragmatic aim. From documentation of past extraction practises and the community response to the industry it was possible to derive not only an indication of the type of problems facing the industry but moreover the atmosphere in which future planning of the industry must take place.

Just as it has been part of an historical methodology to consider in detail the past uses of sand, so it was necessary to pay attention to contemporary trends in resource development. Clearly these trends are significant in defining the nature and magnitude of the problems facing the industry both now and in the future. Predictions of the size and location of future demand gave indication of the pressure that will be exerted to exploit available sand, while consideration of economic constraints on the transportation of sand has provided indications of the distribution of demand. Beyond predicting the impact that future sand requirements may have on available natural sand resources, attention was also focused on a possibility of avoiding continual reliance on natural sand resources. Blast furnace slag sand, a by-product of steel production, may represent a viable replacement for natural sand in many uses. Although not a new product, little thorough consideration has been



given in the past to the potential of slag to replace sand. Integration of contemporary trends in sand demand and consideration of the supply of this demand, both with natural and synthetic sand, is clearly significant in determining both the nature of requirements on the industry and in the planning of methods to counteract unnecessary ill effects which result from supplying those requirements.

In chapter seven the disparate issues, concerns and specialisations raised in earlier chapters were drawn together within the context of several principles designed to minimise environmental, social and economic disruption. Integration of these two, when transposed into a matrix, provided an overview summarising policy recommendations in association with the many aspects of each available sand resource. Beyond indicating those instances of poor resource utilisation in the past, the matrix suggested those resources most suitable for future exploitation within the context of all the considered variables. This is clearly a step toward more rational planning of Wollongong's sand extraction industry.

By its practical approach this thesis demonstrates again that geography can, as Hare (1980) and other contemporary geographers have indicated that it should, make contributions to the solving of man-land problems. While this is the case, however, it is recognised that geography may have a wider role than study purely to solve practical problems. Indeed practical problems can not be solved without first having specialised and comprehensive information available to apply as required to the problem in hand. This thesis has relied heavily on a wide range of relevant specialist studies. This point is particularly well illustrated with regard to the analysis of physical resources. Similarly, detailed information

on demographic trends and the commercial potential of slag sand have been utilised to conclude relevant recommendations.

While specialist studies have their value, it remains that in some instances geographers do have an obligation to utilise their skills. As Eyre (1978) stated:

*... if one has the expertise and knowledge which might be helpful in the clarification or resolution of a vital world problem, is there not an element of immorality in devoting one's energies purely to academic pursuits?*

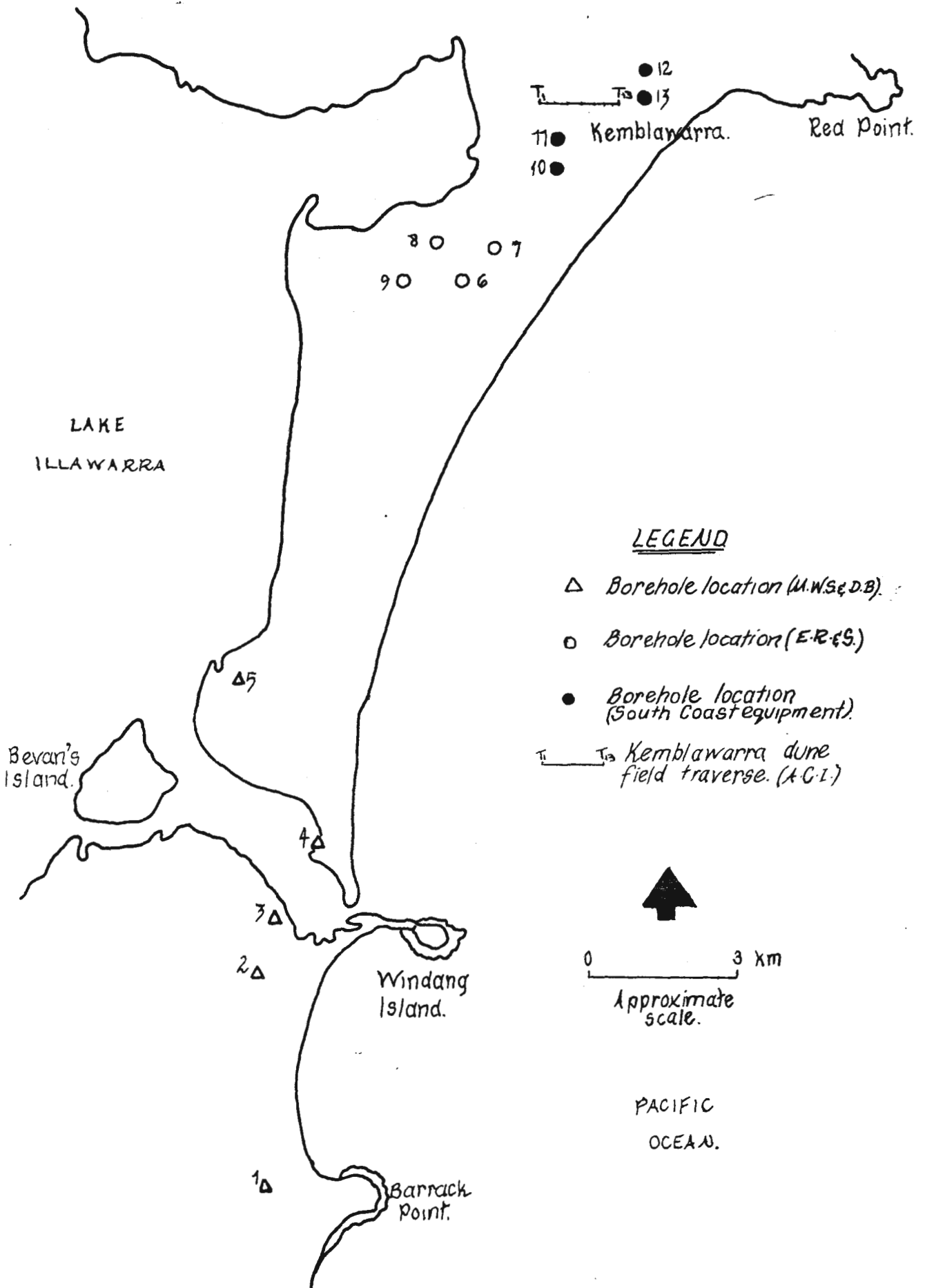
This study has tried to put Eyre's view into practice, albeit on a very modest scale.

The value then of such a study to Wollongong is demonstrated by the incorporation of its findings in regional planning. Beyond this, however, this thesis may have a wider significance. It redresses an imbalance by considering sand extraction for construction rather than heavy mineral removal: the former poses the greater environmental risk, but has been overshadowed by the latter. Moreover, it is the first attempt in either aspect of the sand mining industry to develop an all-embracing approach. In doing so, it provides guidelines for dealing with similar problems in other areas. In particular, it makes clear the need to understand the nature of the physical resources, and also the historical development of the area, the community attitude to the industry, contemporary trends determining future demand and supply and alternatives available to alleviate future demand on the natural resources. The value of such a method is that information from diverse fields is integrated, creating a comprehensive and relevant overview from which planning recommendations can be derived.

APPENDIX

BORELOG INFORMATION FROM MAJOR  
SAND DEPOSITS SURROUNDING WOLLONGONG

Windang Peninsula Borelog Information



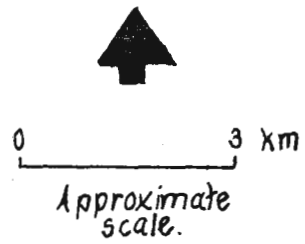
LEGEND

△ Borehole location (M.W.S.D.B.)

○ Borehole location (E.R.S.)

● Borehole location (South Coast equipment)

T<sub>1</sub> — T<sub>2</sub> Kemblawarra dune field traverse. (A.C.I.)



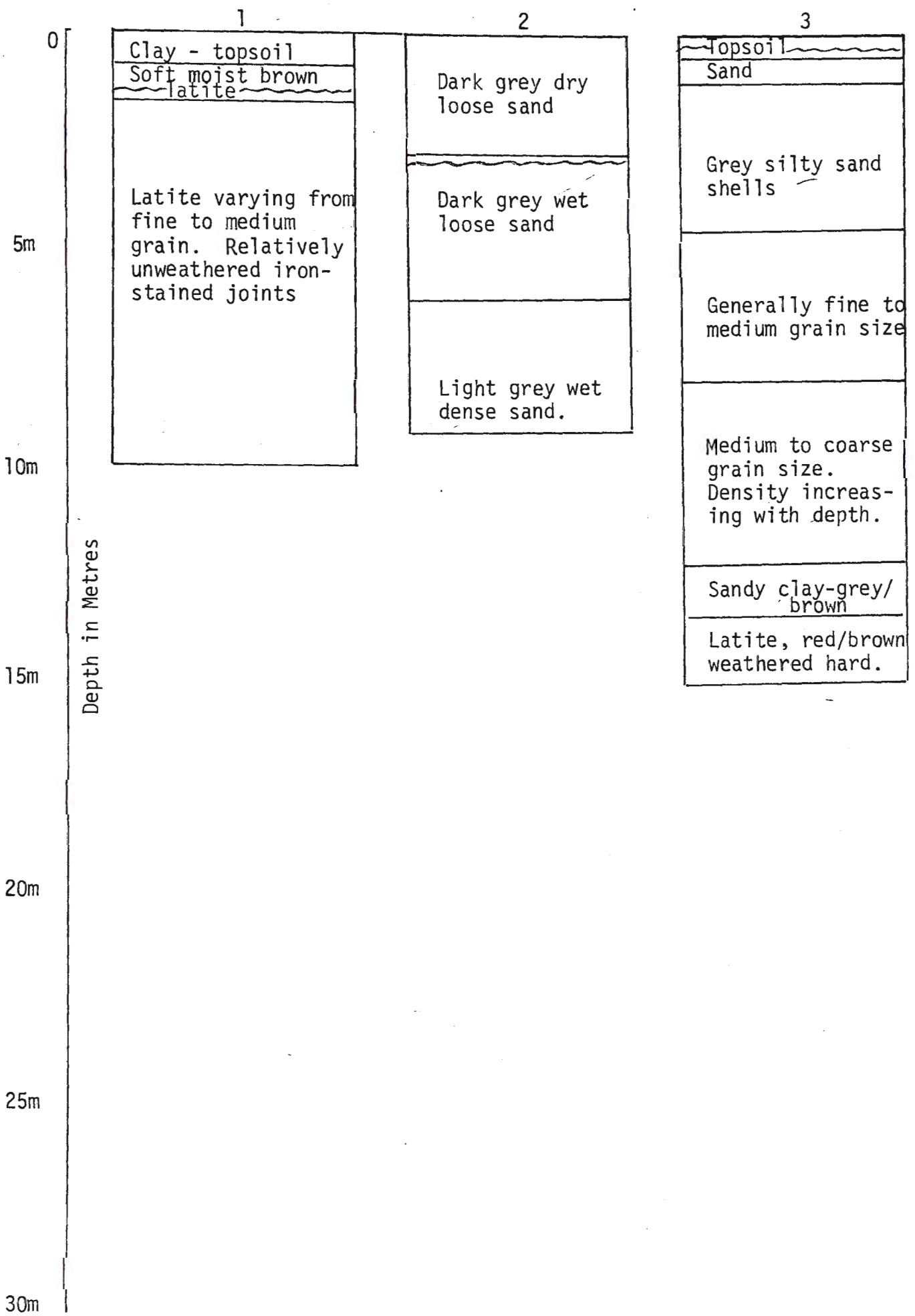
PACIFIC OCEAN.

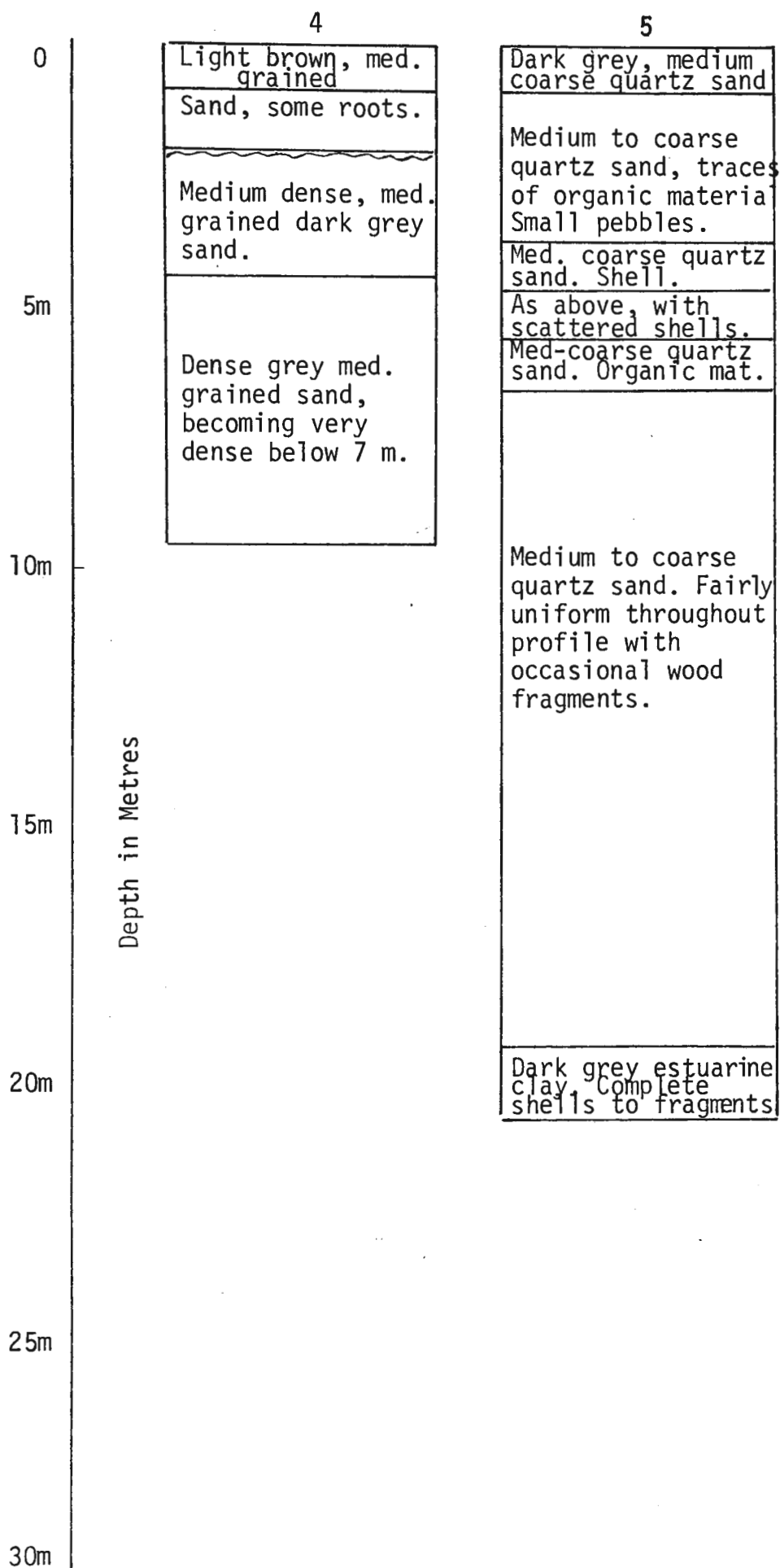
Location: South Windang Holes 1-6 (see map)

143.

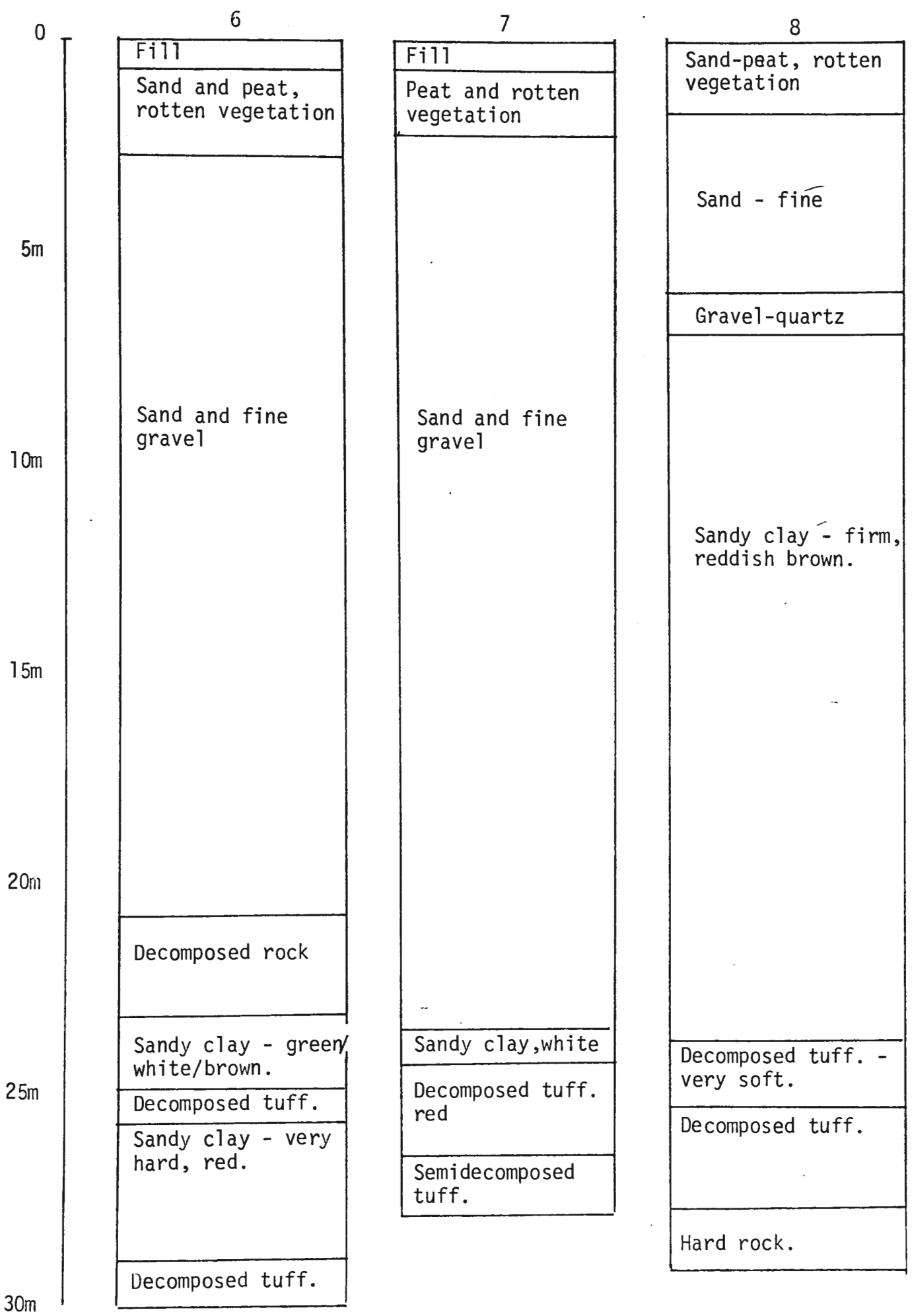
Supervisor: Metropolitan Water, Sewerage and Drainage Board

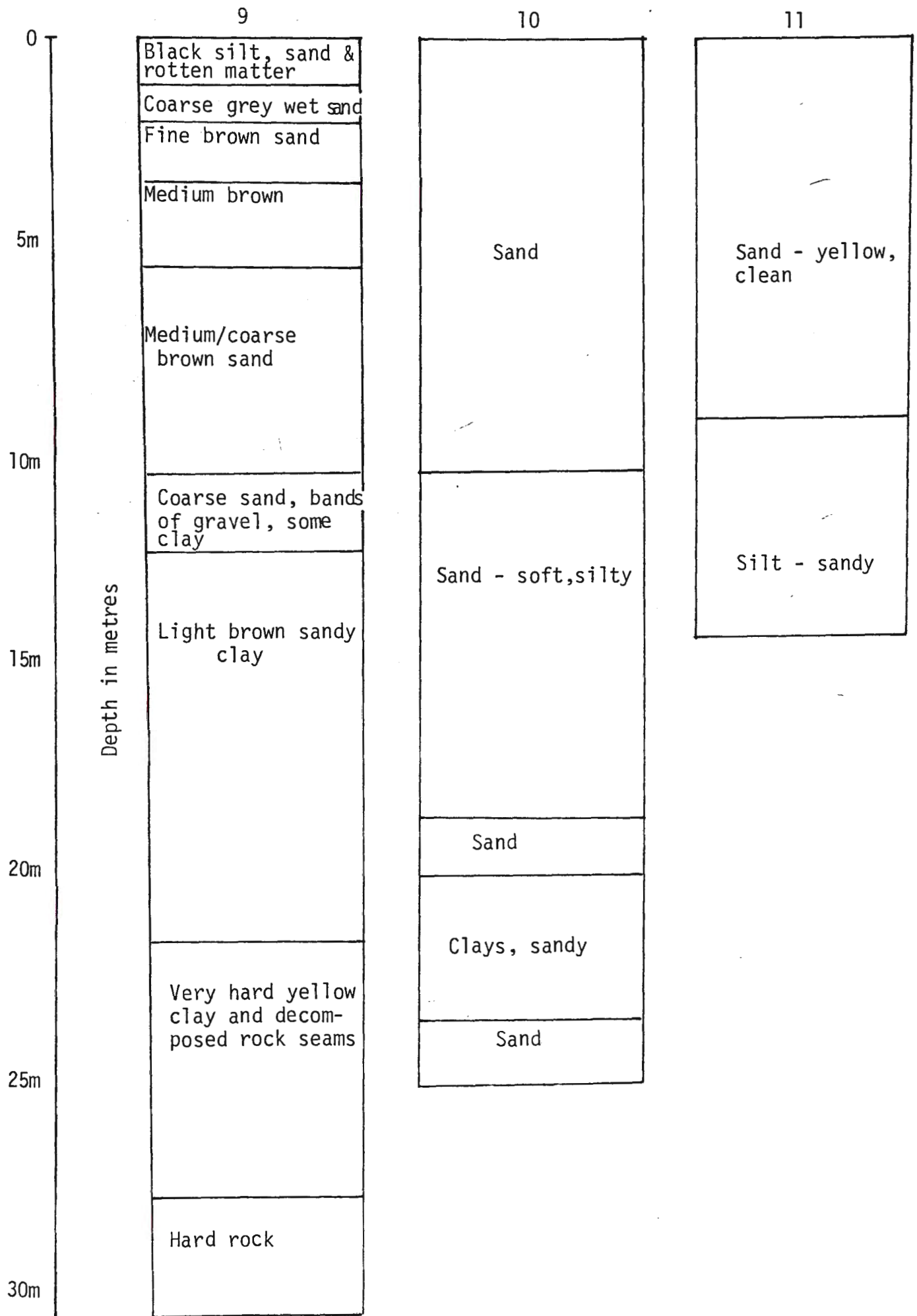
Date: 1972-1975      Legend: ~~~~~ Watertable      (Source: C. Harris, 1976)



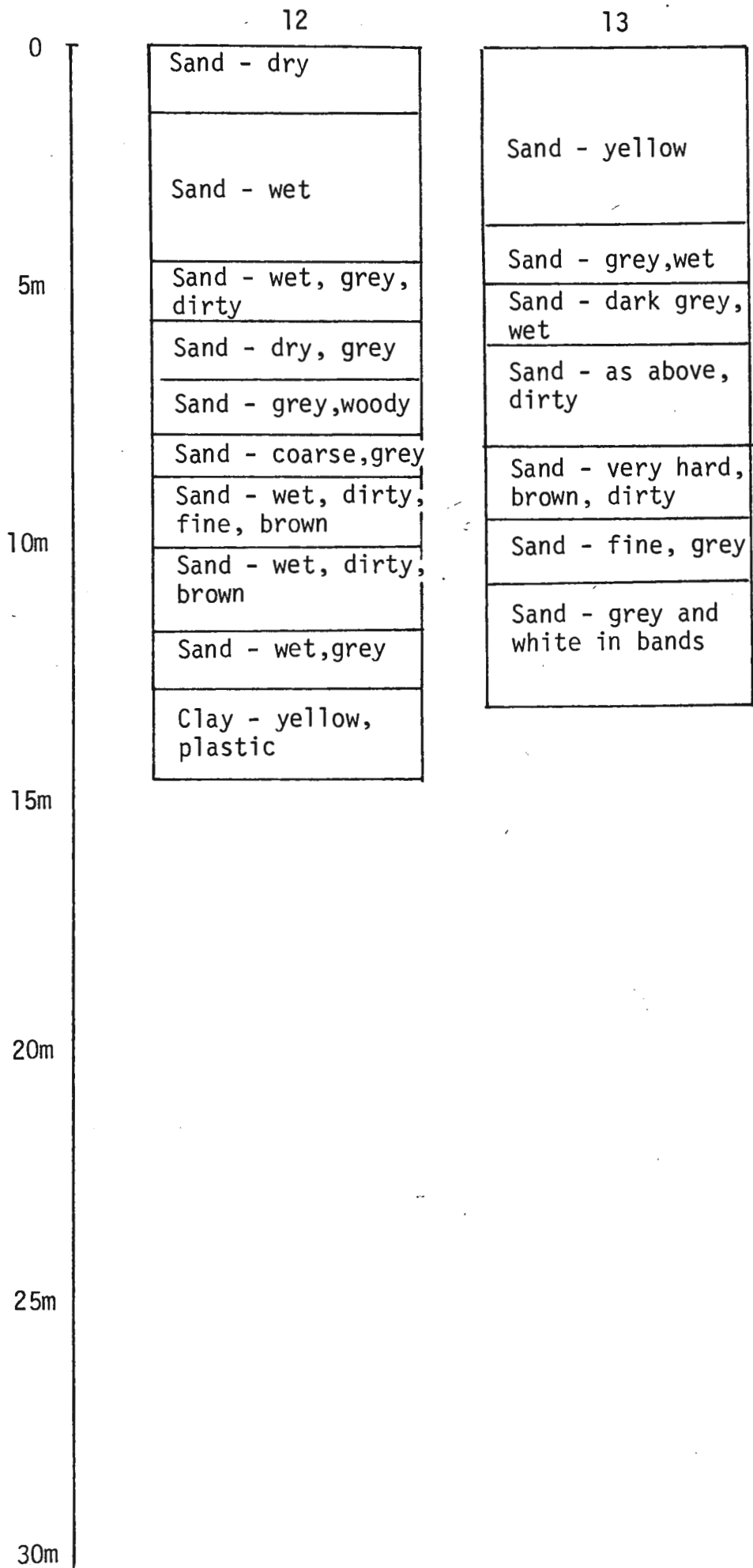


Borelogs 6-9 Location: Korrongulla Swamp - Windang Peninsula (see map)  
Supervisor: Electrolytic Refining and Smelting Co. (E.R.&S.) 145.  
Date: 4/2/1969 (Source: C. Harris, 1976)







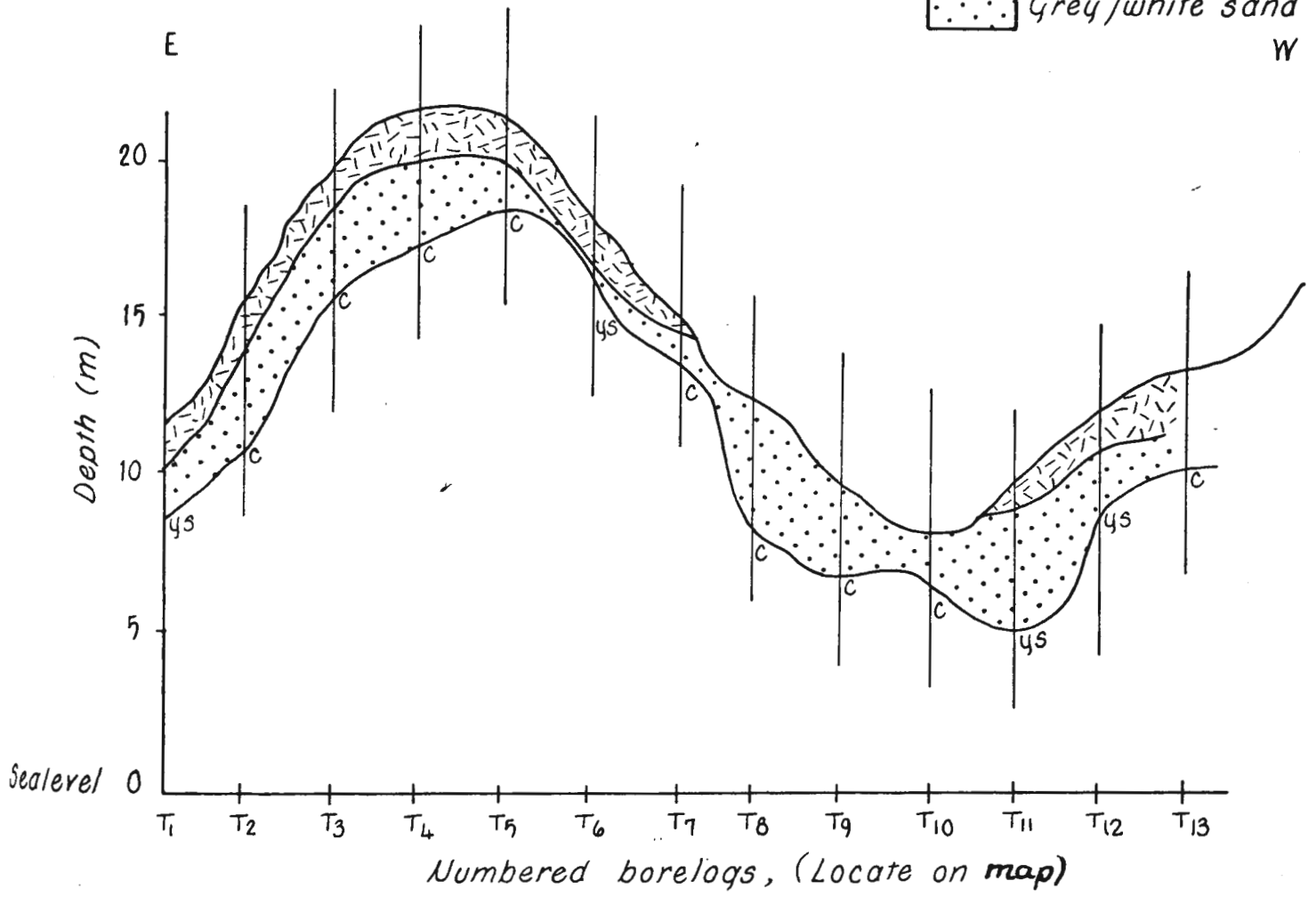




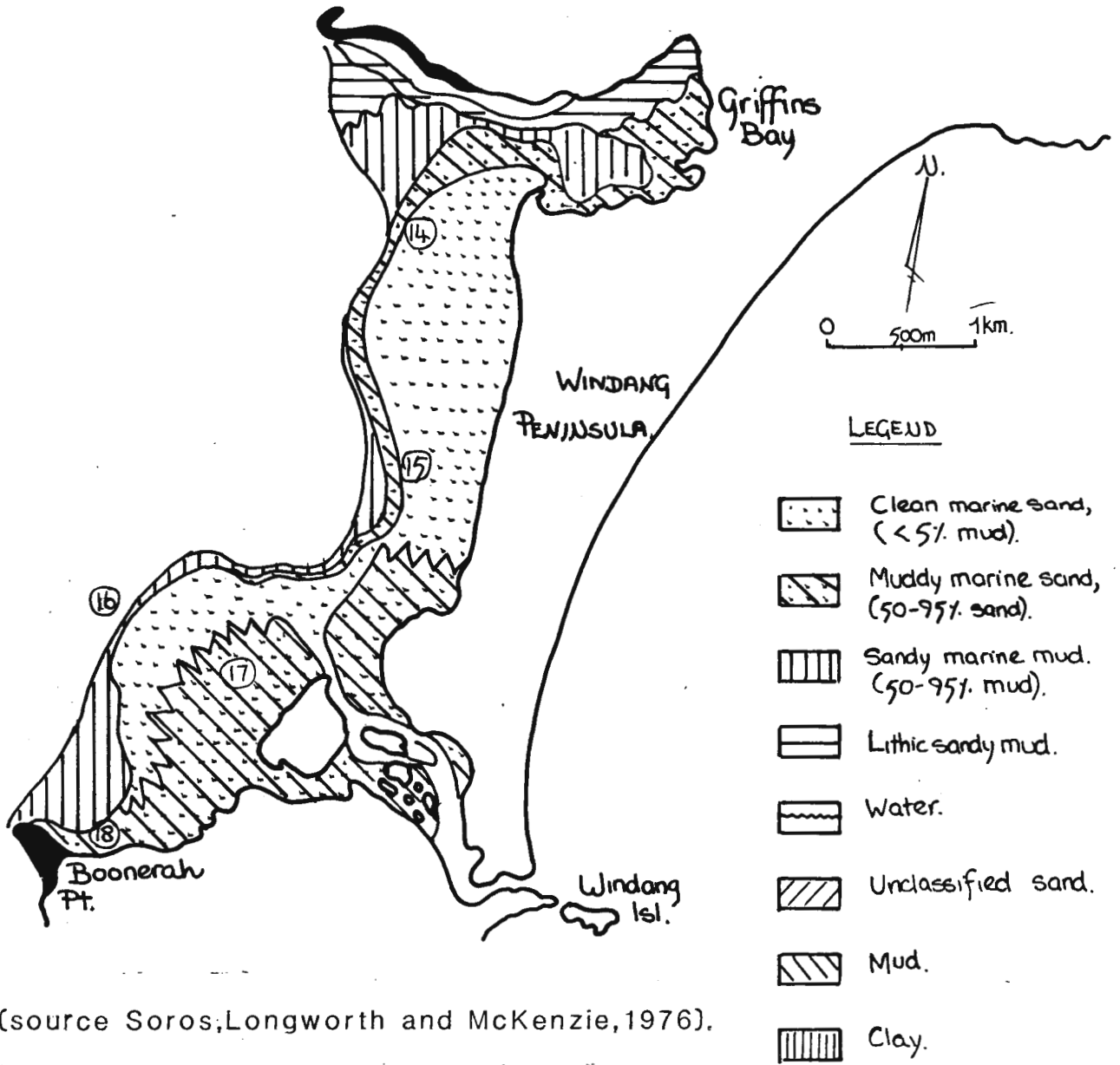
Cross-section of Eastern Kemblawarra. Supervisor: A.C.I. (1970). Three primary units are revealed. The bottom unit in the majority of cases is coffee rock (except for where yellow sands occur), overlying this is a sand band ranging in colour from grey/white to brown of varying thicknesses. The top layer, not always present, is dark organically contaminated sand.

LEGEND

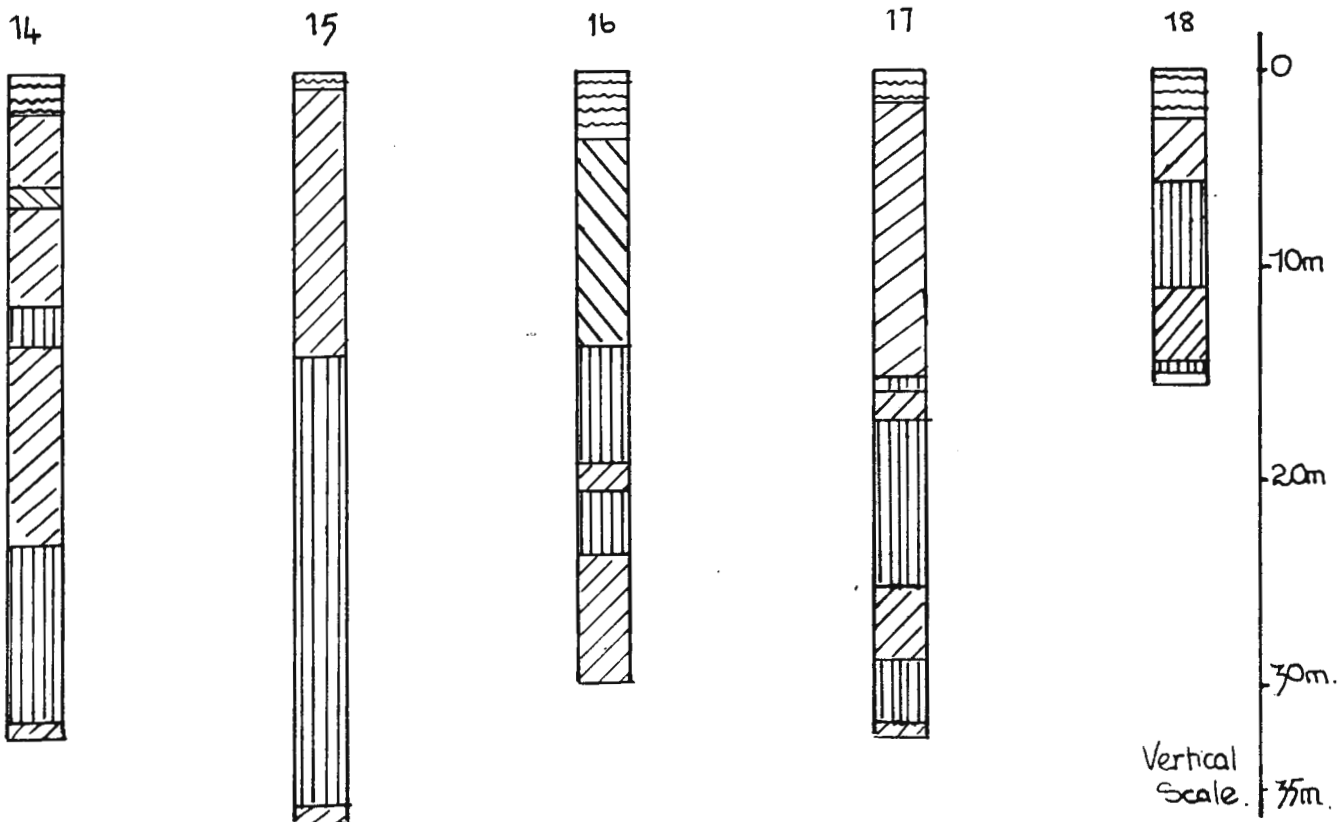
-  Dark organically contaminated sand
  -  Grey/white sand
- W



East Lake Illawarra Borelog Information.



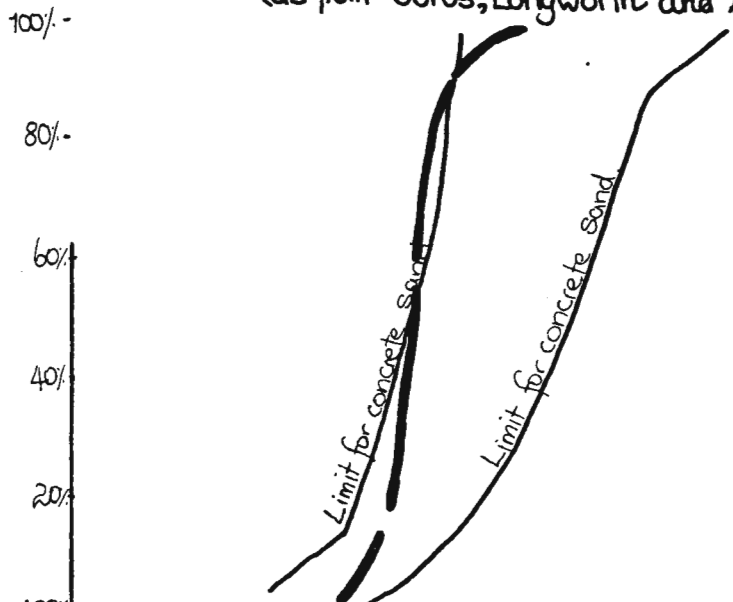
(source Soros, Longworth and McKenzie, 1976).



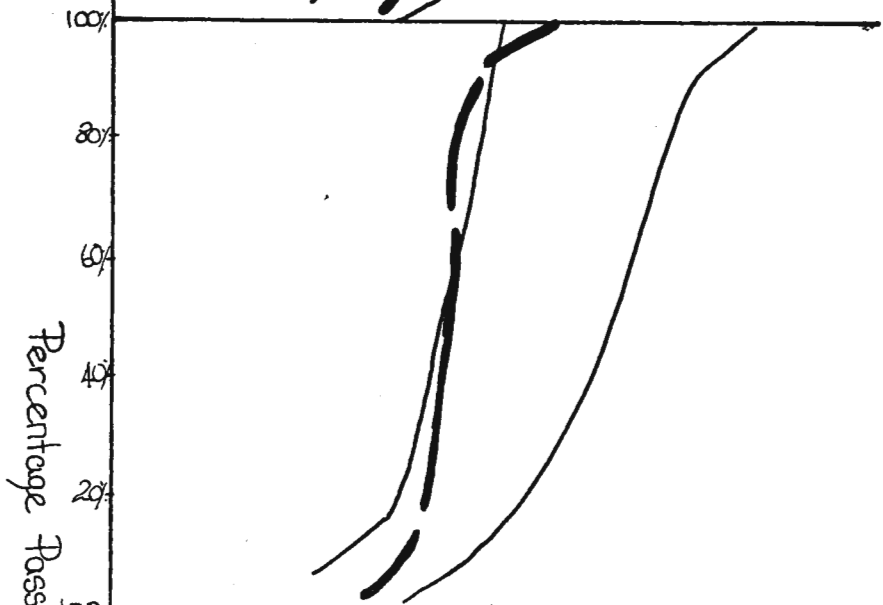
# Particle Size Distribution of Lake Sediments.

(as from Soros, Longworth and McKenzie).

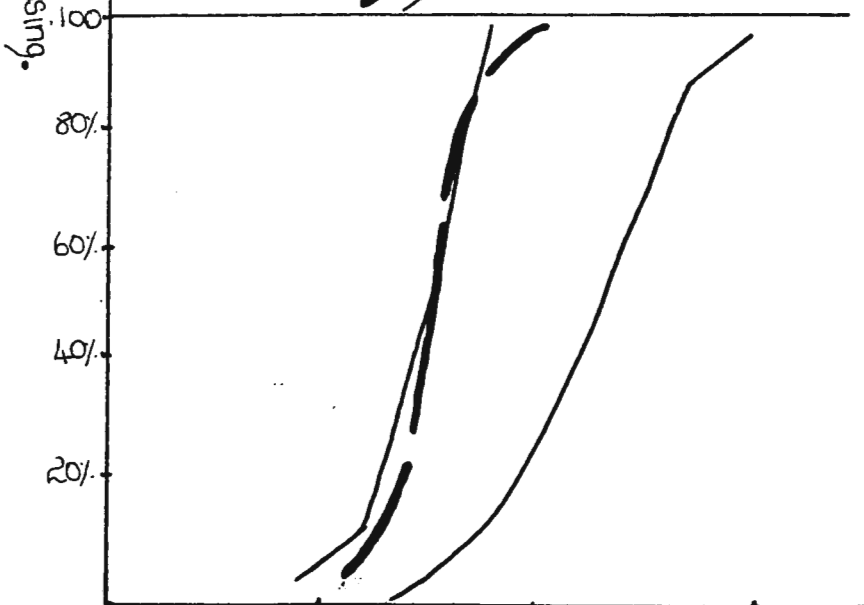
Sample 15.  
(approx. 1m  
below lake  
bed)



Sample 17.  
(approx. 1m.  
below lake  
bed).



Sample 18.  
(approx. 1m  
below lake  
bed).

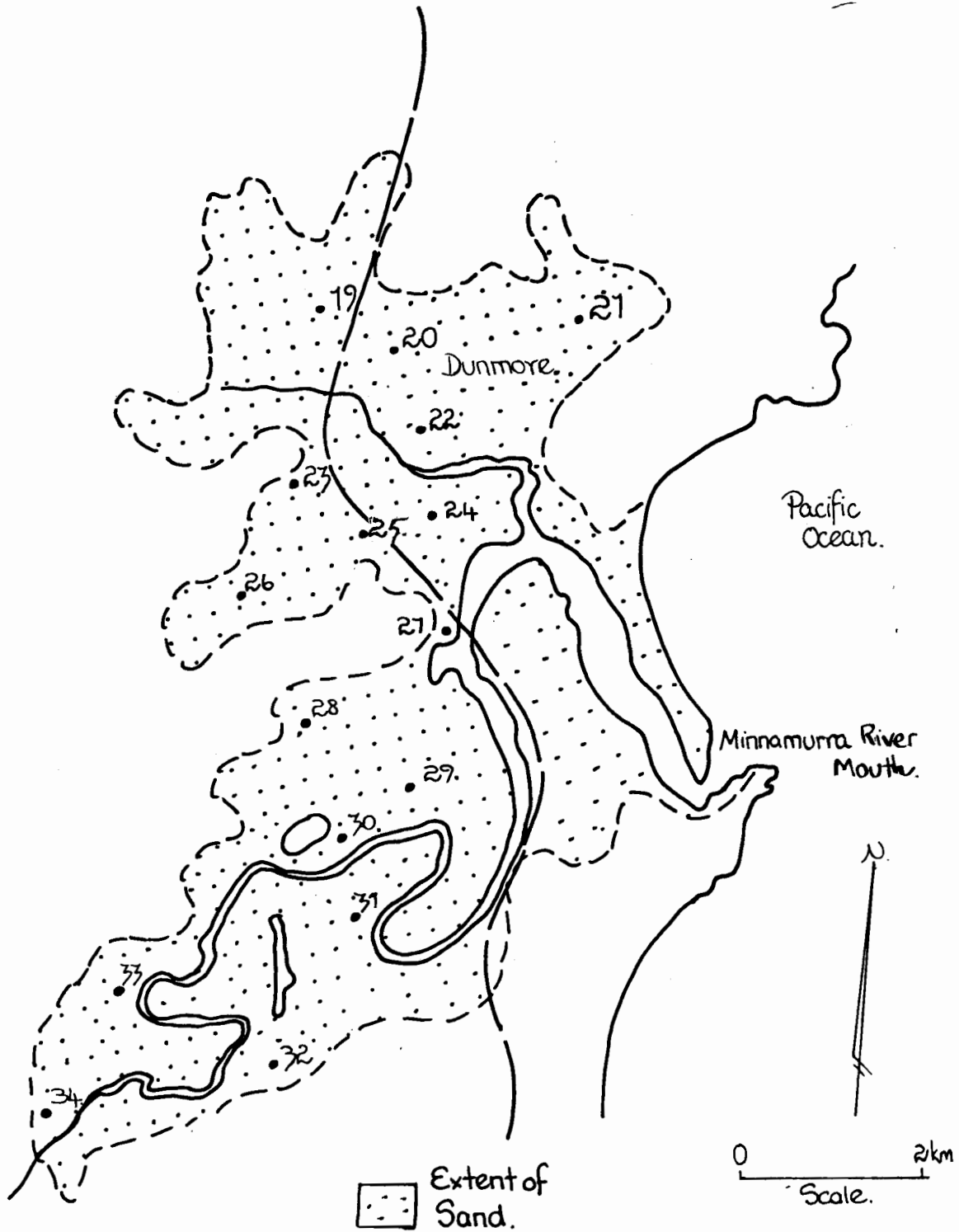


0.01      0.1      1.0      10.  
particle size (mm).

SILT		SAND		GRAVEL	
med.	coarse.	fine	med.	coarse	fine    med.

Minnamurra River Borelog Information.

(source N.S.W. Geol. Surv.).  
1979

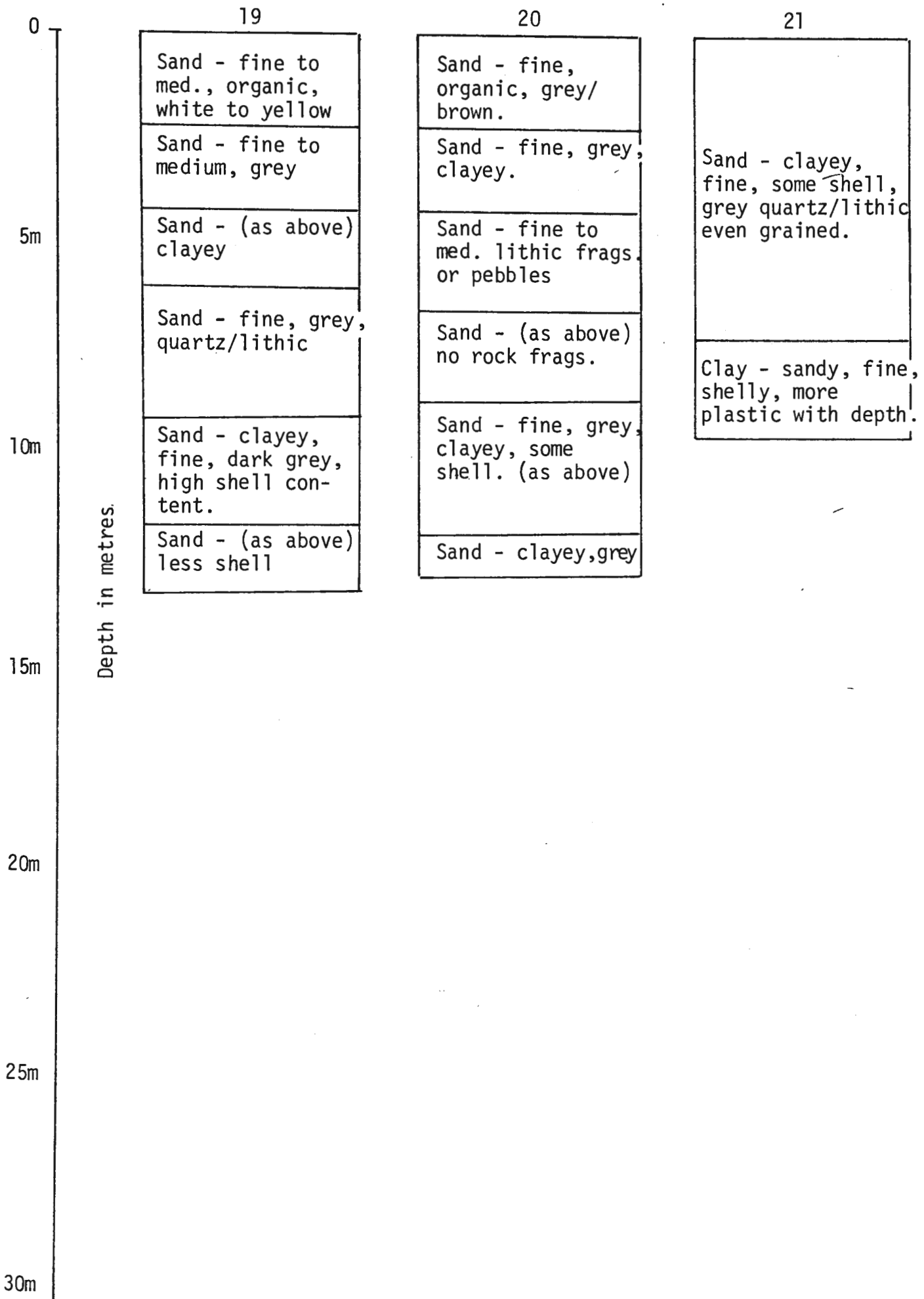


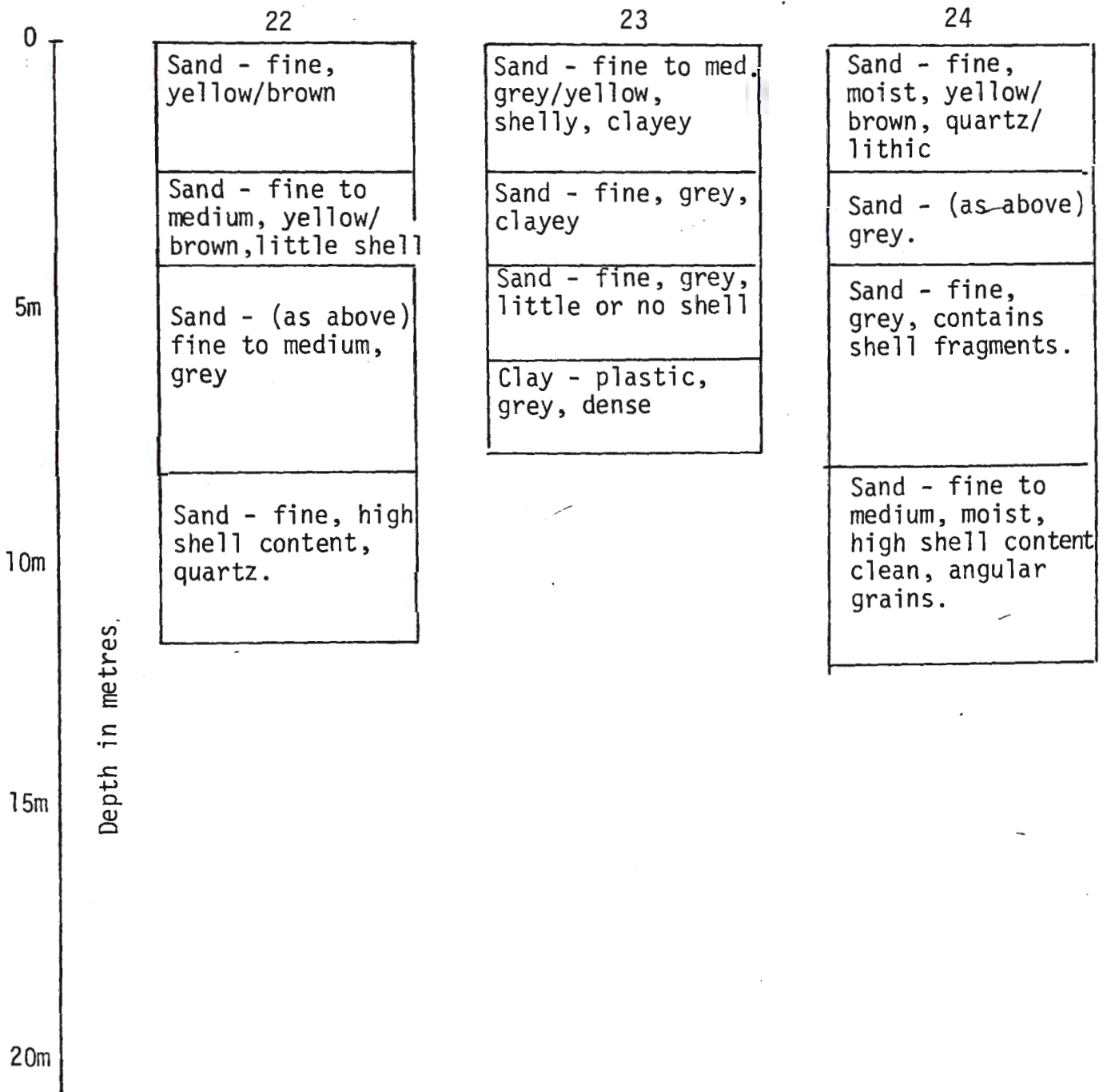
Borelogs 19-34 Location: Minnamurra River Area (see map)

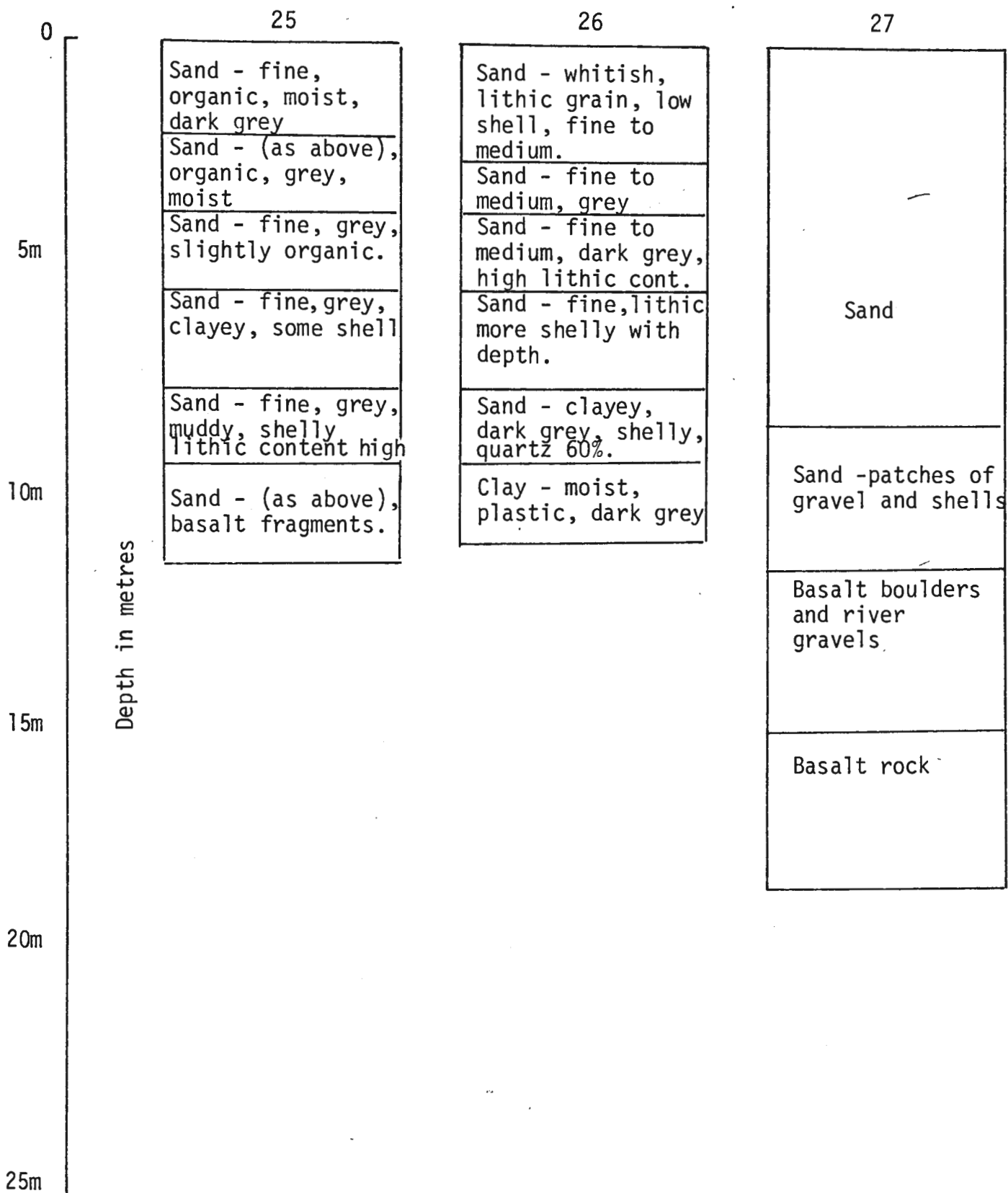
Supervisor: The Geological Survey of N.S.W.

Date: 1979

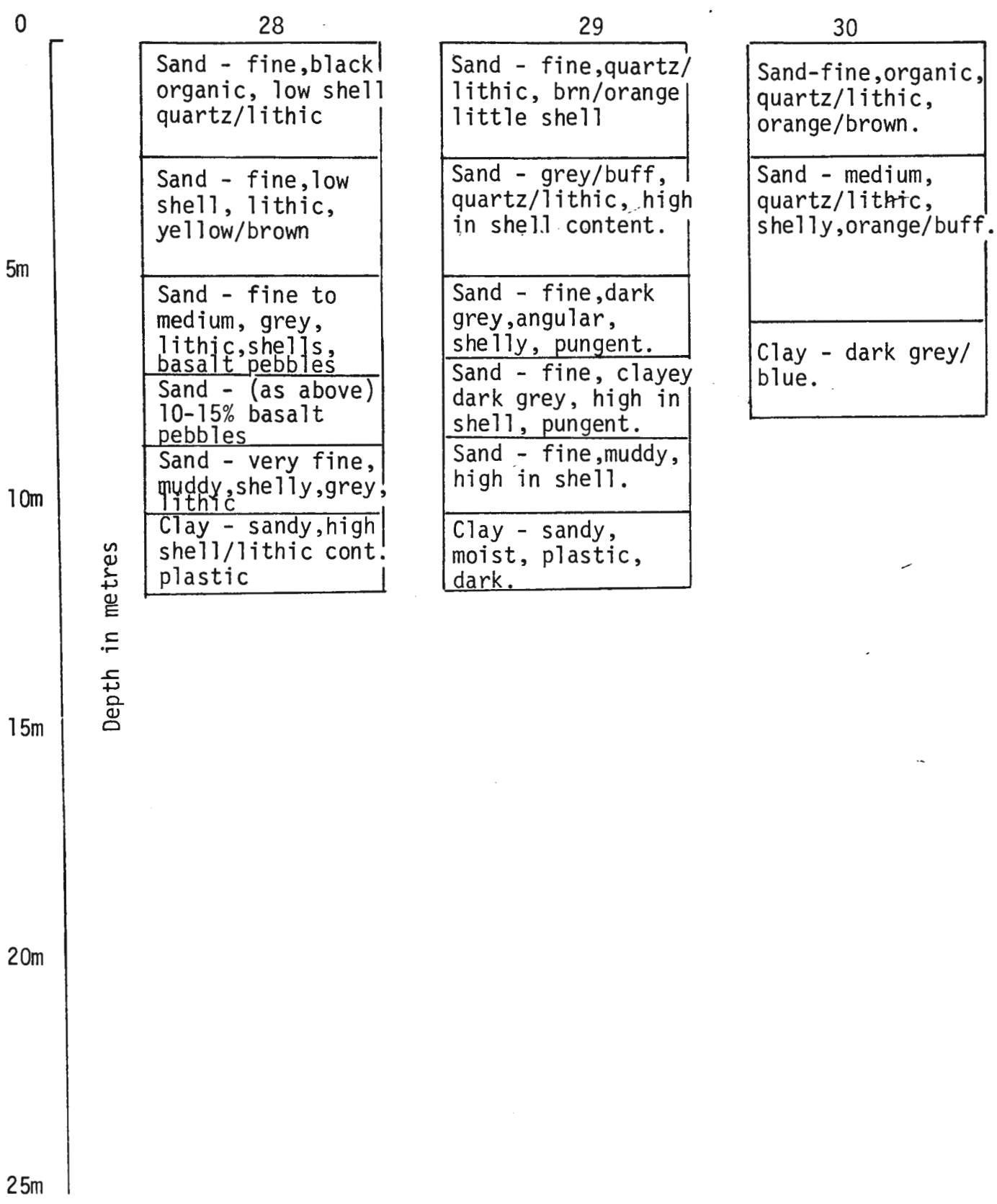
152.

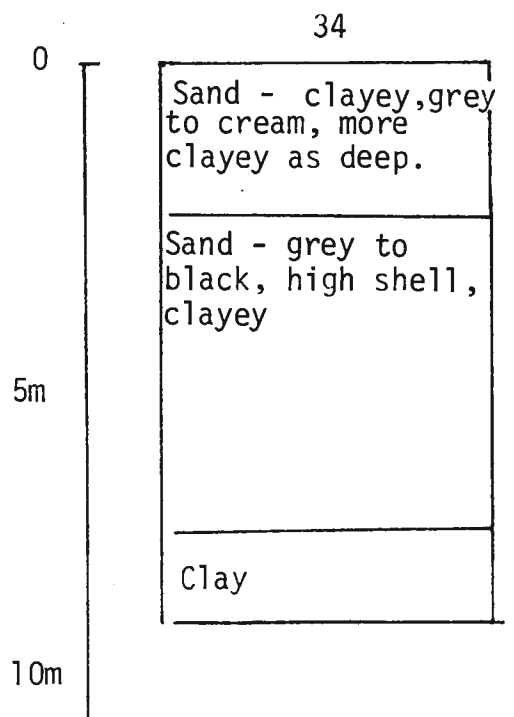
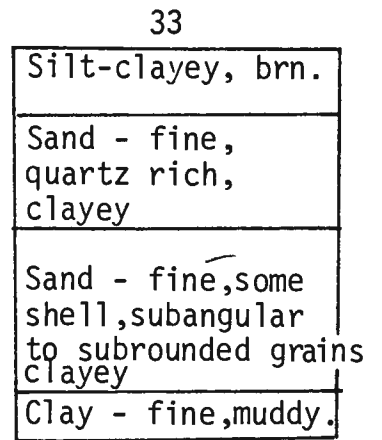
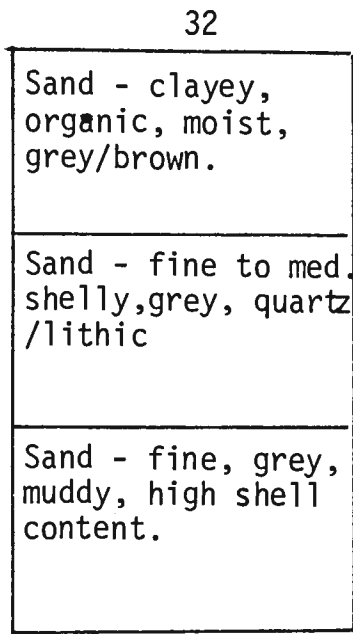
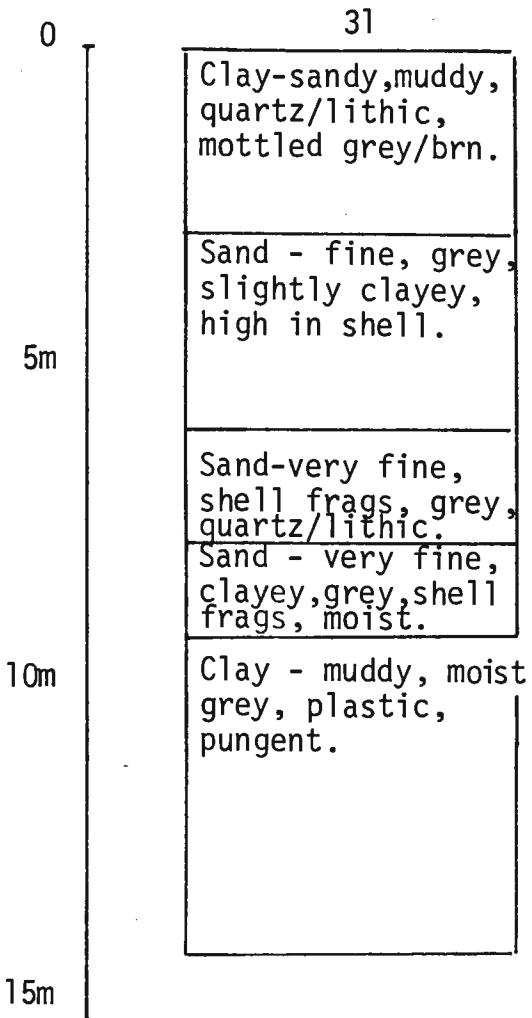






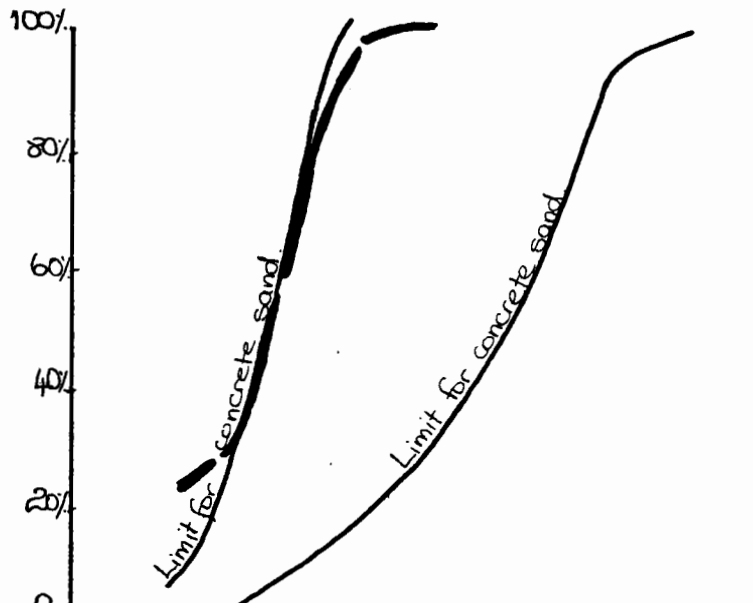




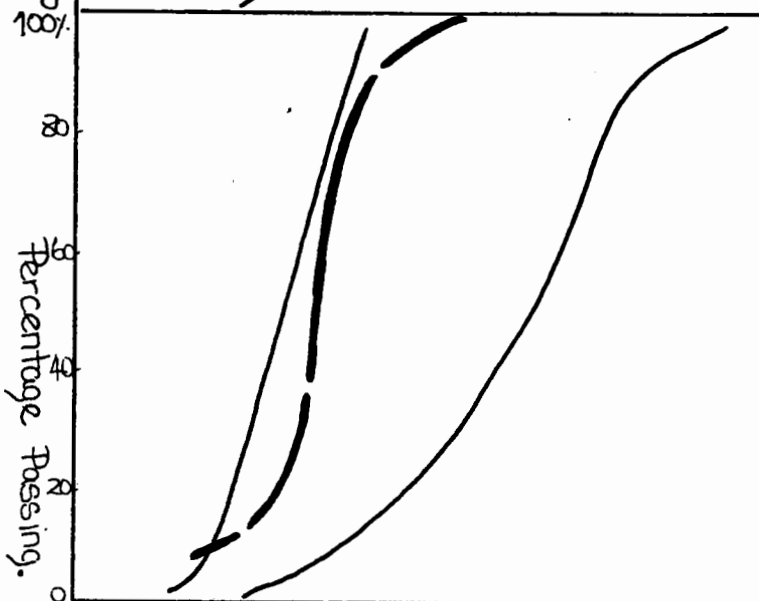


Particle Size Distribution of Selected Samples from the Minnamurra River. (source. NSW.Geol.Surv.)

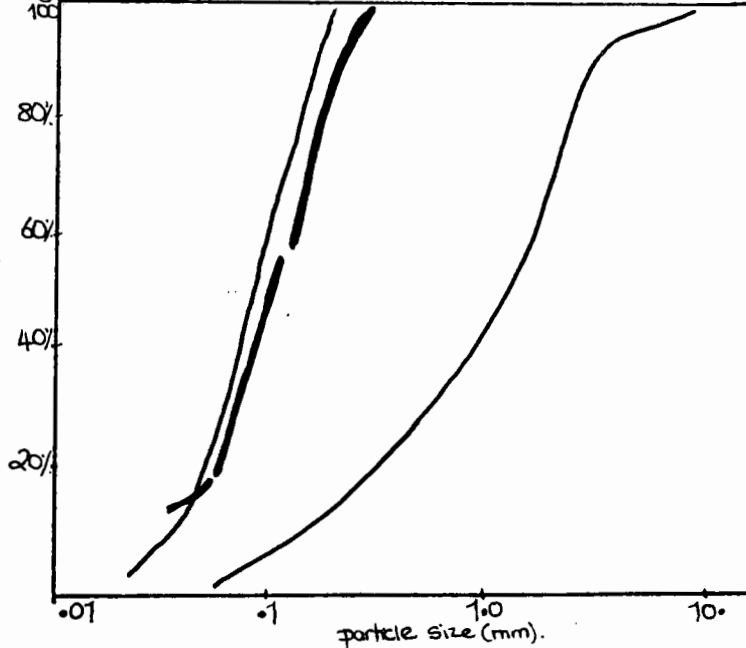
Sample 19.



Sample 22.



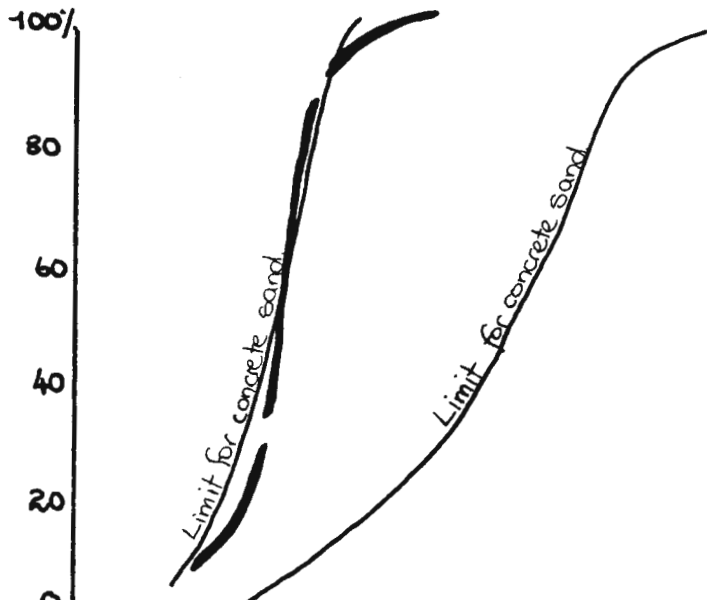
Sample 24.



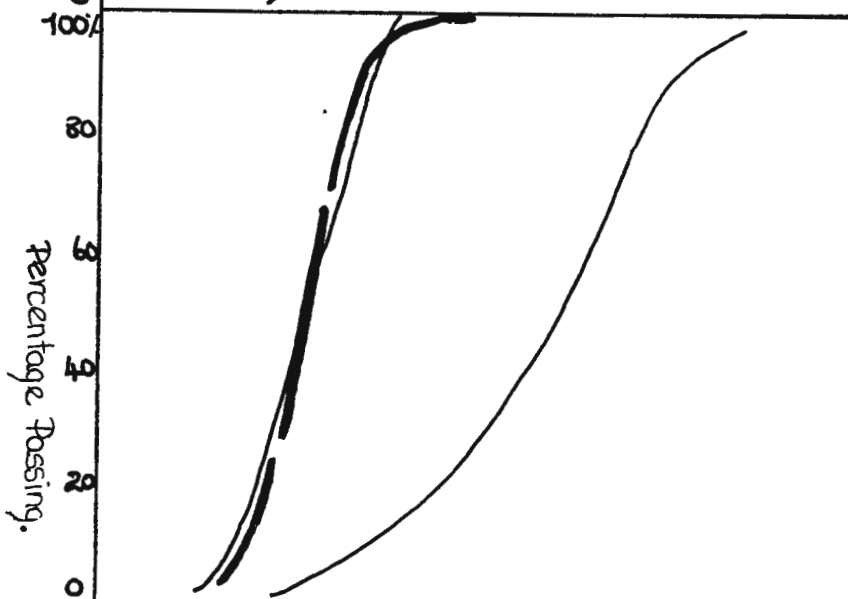
SILT		SAND		GRAVEL	
med.	coarse	fine	med.	coarse	fine med.

Particle Size Distribution of Selected Samples from the Minnamurra River (cont'd).

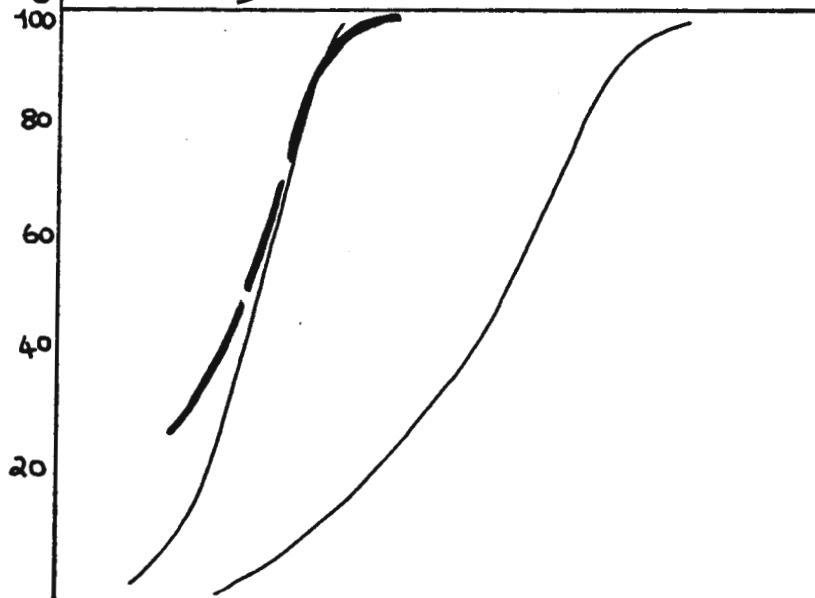
Sample 26.



Sample 29.



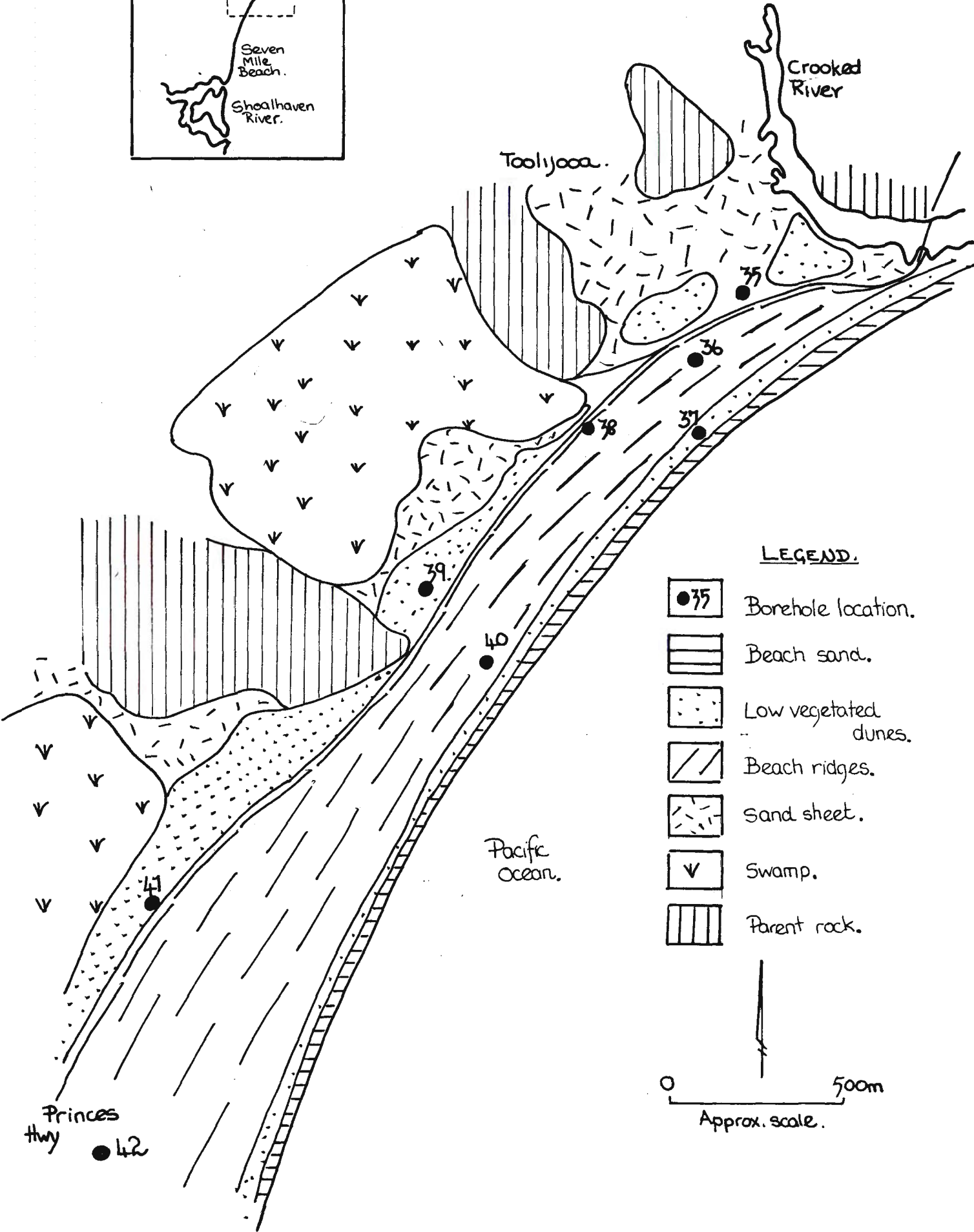
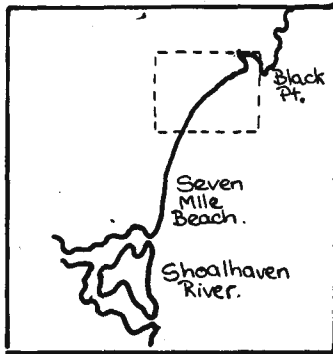
Sample 31.










SILT		SAND		GRAVEL	
med.	coarse	fine	med.	coarse	fine med.

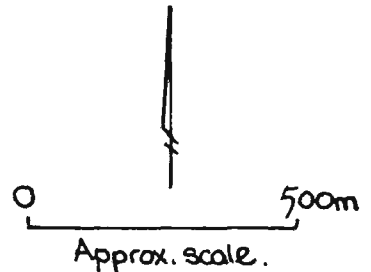
Seven Mile Beach Borelog Information.

(source N.S.W. Geol. Surv.)



LEGEND.

-  Borehole location.
-  Beach sand.
-  Low vegetated dunes.
-  Beach ridges.
-  Sand sheet.
-  Swamp.
-  Parent rock.

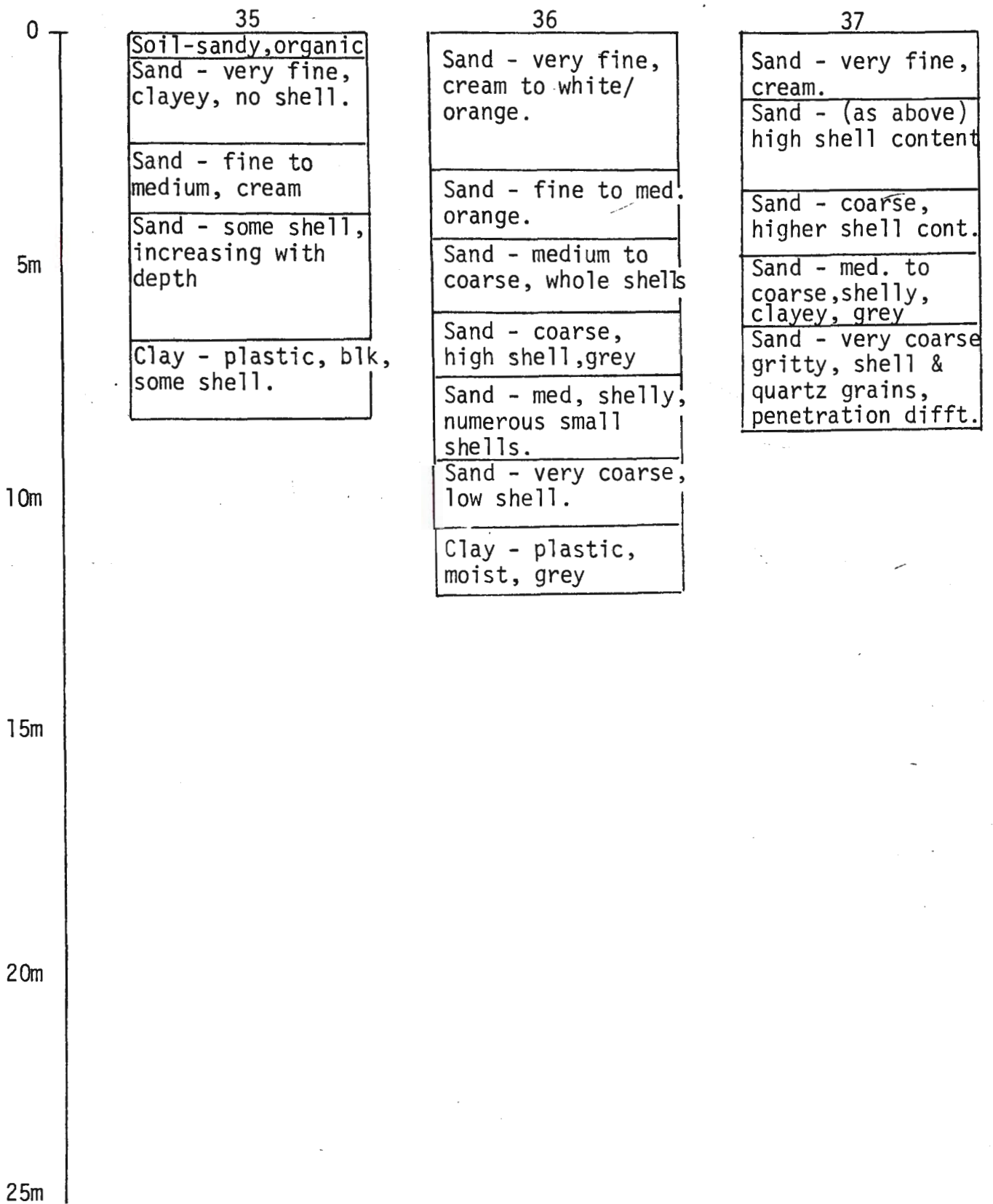


Borelogs 35 to 42. Location: Seven Mile Beach Area (see map)

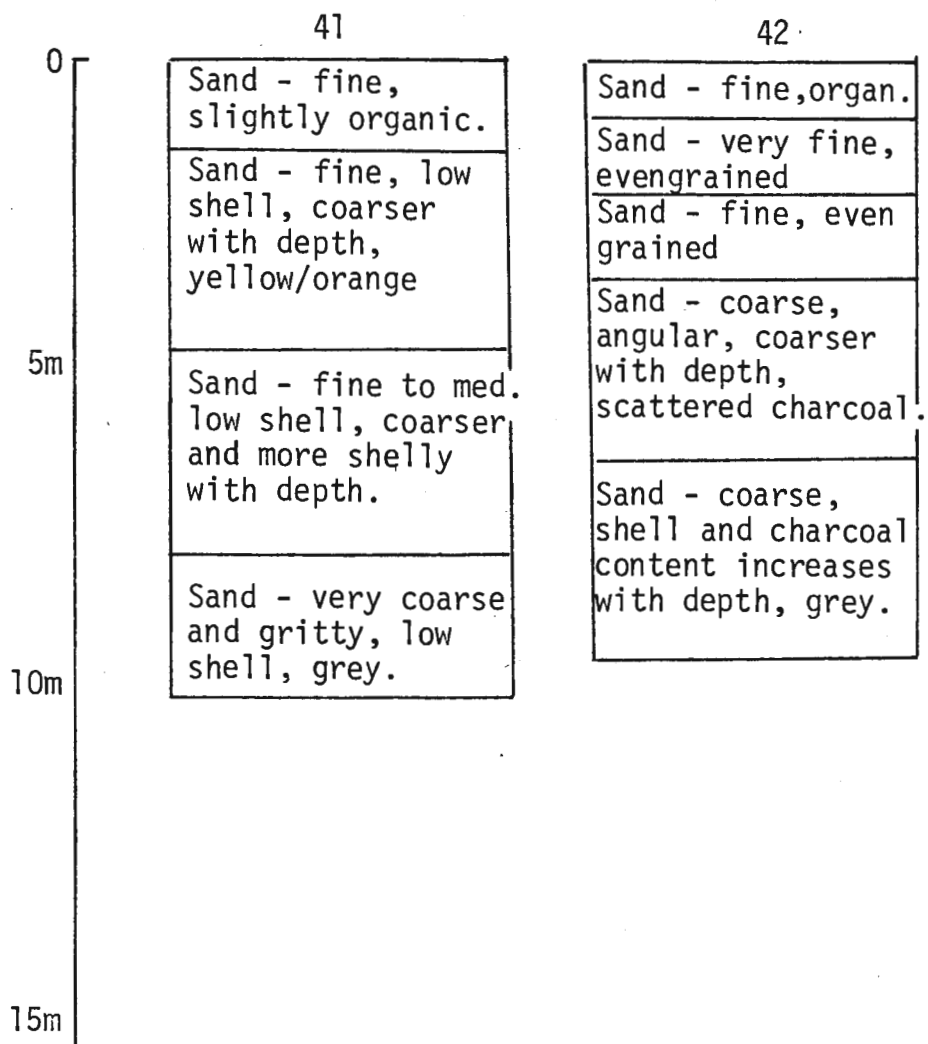
260.

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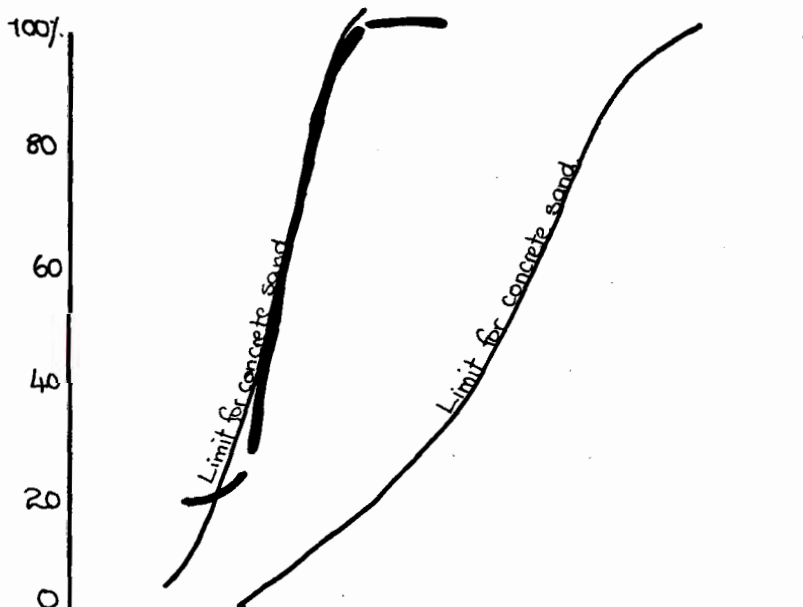
	38	39	40
0	Sand - very fine, no shell, cream to yellow.	Sand - med. to coarse, orange grading to orange/yellow	Sand - fine, no shell, cream
	Sand - cleaner with depth.		Sand - med. yellow orange
5m	Sand - fine, grey shelly with depth	Sand - coarse and gritty, clean	Sand - med. grey, minor shell.
	Sand - med. to coarse, high shell, quartz pebbles.	Sand - very coarse, high charcoal, little shell.	Sand - med. fragmented shells
	Sand - coarse, fine patches, shelly	Sand - med. to coarse	Sand - coarse, v. shelly, grey.
10m	Sand - coarse, high shell, clean, quartz pebbles.	Clay - plastic, no shell, moist, dk. slightly sandy.	Sand - coarser, shelly as above.
			Sand - very coarse, fine gravel, shelly pebbles (5 cm.)
15m			
20m			



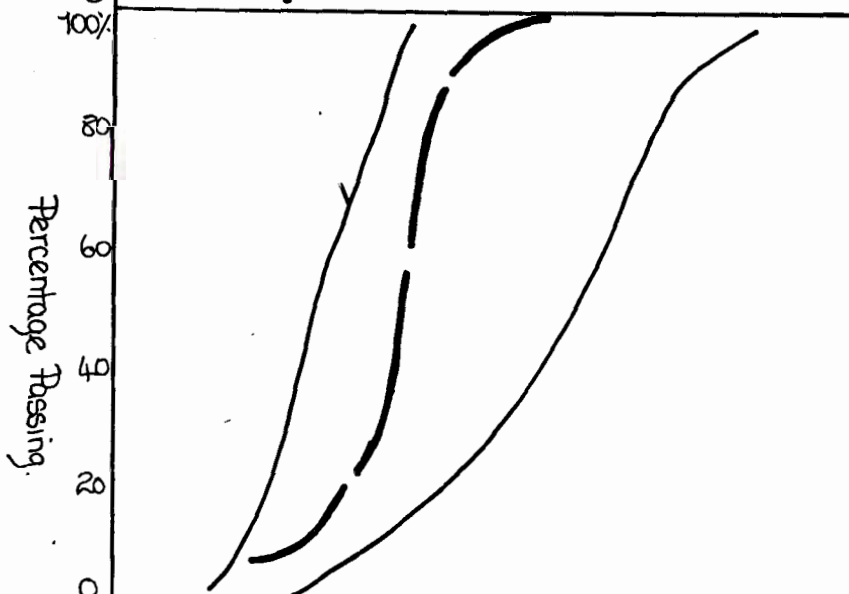


Particle Size Distribution of Selected Samples from Seven Mile Beach. (source, N.S.W. Geol. Surv.).

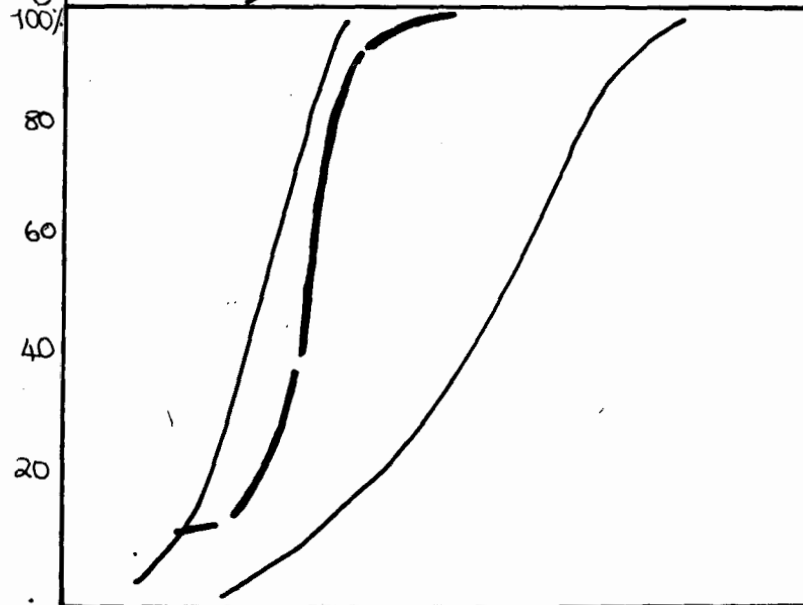
Sample 37.



Sample 39.



Sample 42.



SILT		SAND		GRAVEL	
med.	coarse	fine	med.	coarse	fine med.

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