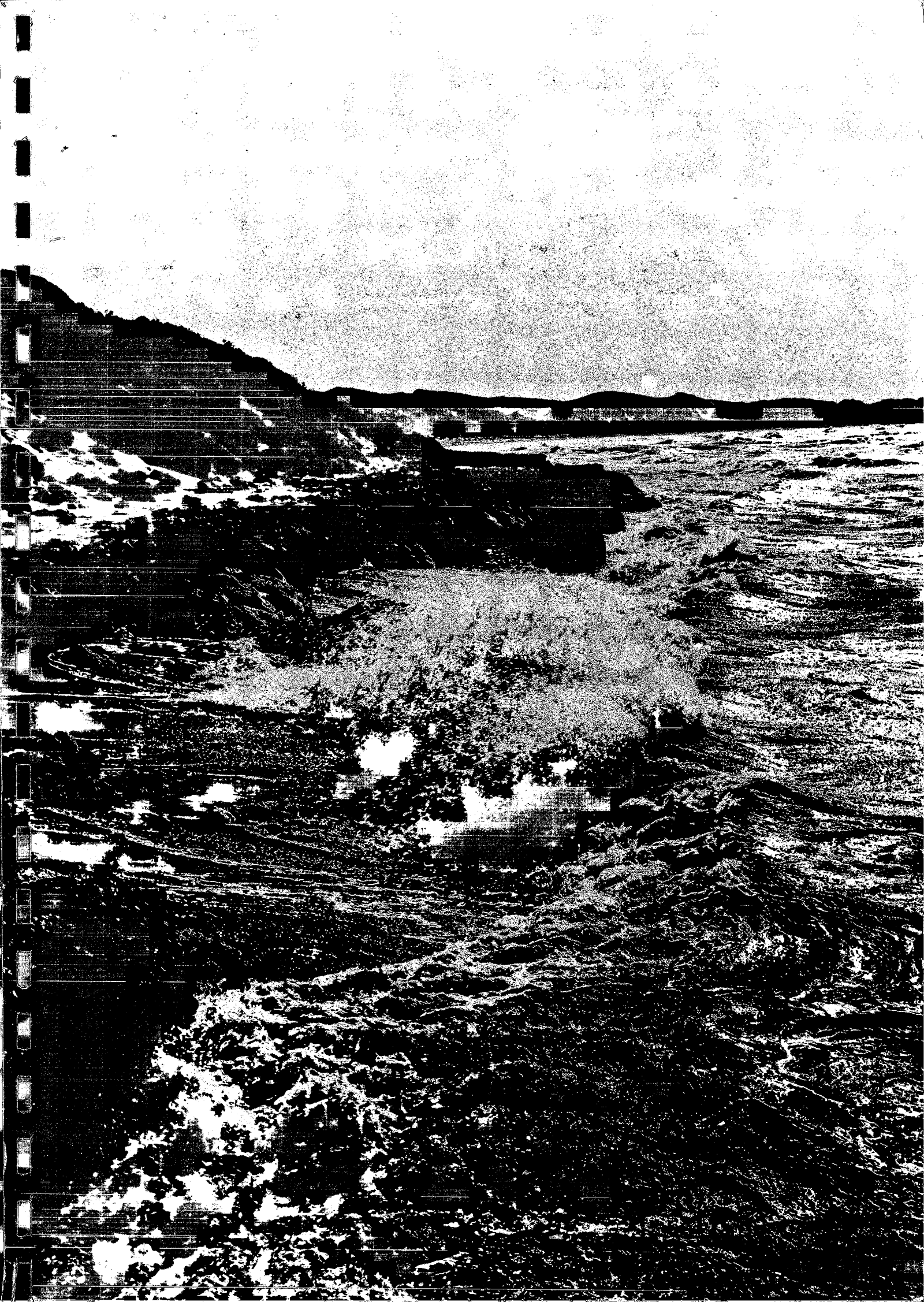


MINDARIE ENVIRONMENTAL CITY



Donald Gozzard

①

MINDARIE ENVIRONMENTAL CITY QUINNS ROCKS

**A Report Prepared for
DEVELOPMENT UNDERWRITING LIMITED**

**by
URBAN SYSTEMS CORPORATION PTY LTD
56 KINGS PARK ROAD
WEST PERTH 6005**



JUNE 1973

MAIN REPORT

TABLE OF CONTENTS

	Page No.
FOREWORD	1
1. INTRODUCTION	2
1.1 Location of Mindarie	2
1.2 Potential of Mindarie for Development	2
1.3 A New Approach	2
2. METHODOLOGY	4
2.1 General Concept	4
2.2 Physical Evaluation System	4
2.3 Planning Principles & Structure Plan	4
2.4 Marketing Factors	4
3. APPLICATION OF PHYSICAL EVALUATION	5
3.1 Physical Examination	5
3.2 General Description of Area	5
3.3 Base Data	5
3.3.1 Climate	5
3.3.2 Geomorphology	6
3.3.3 Vegetation	6
3.3.4 Visual Analysis	6
3.4 Criteria Chosen	7
3.4.1 Physical Factors	7
3.4.2 Examination of Factors	7
4. PLANNING PRINCIPLES AND CONSTRAINTS	10
4.1 The Corridor Plan	10
4.1.1 General Concept	10
4.1.2 Population Projections	10
4.1.3 Development Constraints	11
4.2 Open Space	12
4.2.1 Location	12
4.2.2 Access	12
4.2.3 Variety and Use	12
4.3 Provision of Services	12
4.3.1 Social, Health & Welfare Services	12
4.3.2 Educational Facilities	13
4.3.3 Commercial Services	13
4.3.4 Public Utilities	13
4.4 Major Road Network	13
4.4.1 Interdependence	13
4.4.2 Design Parameters	14
5. SYNTHESIS	15
5.1 Application of Planning Principles to Land Evaluation	15
5.2 Selection of National Park Links and Open Space	15
5.2.1 The Coastal Area	15
5.2.2 National Parks Links	16
5.2.3 The National Park and Possible Land Exchange	16
5.2.4 Open Space	17
5.3 Selection of Major Road Network	17
5.3.1 Improvements to Existing Roads	17
5.3.2 West Coast Highway	17
5.3.3 Stephenson Freeway	18

	Page No.
5.3.4 Marmion Avenue	18
5.3.5 East-West Arterial	18
5.3.6 Traffic Movements	18
5.3.7 Minor Subdivisional Roads	19
5.3.8 Other Forms of Access	19
5.4 Selection of Urbanization Areas	19
5.4.1 Residential Development Areas	19
5.4.2 Commercial Centres	19
5.4.3 Policy for Industrial Location	20
5.4.4 Water Supply & Wastewater Disposal	21
5.4.5 Other Land Requirements	21
5.4.6 Existing Townsite	21
6. STRUCTURE PLAN, DEVELOPMENT RATING AND STAGING	22
6.1 Structure Plan	22
6.1.1 Golf Course	22
6.1.2 Marina	22
6.1.3 Mediterranean Village	23
6.1.4 Features of Particular Interest	23
6.2 Development Rating	24
6.3 Staging	25

APPENDICES

APPENDIX A	Mindarie Environmental Study
APPENDIX B	Mapping of Natural Systems
APPENDIX C	Design Parameters for Major Road Network

LIST OF TABLES	Page No.
TABLE I Summary of Factors and Ranking Procedure (preceded by explanatory diagram)	9
TABLE II Population Distribution: Metropolitan Region 1966 and 1989	11

LIST OF FIGURES	Following Page
FIG. 1 Location of Mindarie	2
FIG. 2 Visual Area Analysis	6
FIG. 3A Suitability for Use — Conservation	9
FIG. 3B Suitability for Use — Recreation	11
FIG. 3C Suitability for Use — Urbanization	13
FIG. 3D Composite Land Value Map	14
FIG. 4 Land Use Areas	16
FIG. 5 Major Road Network	17
FIG. 6 Structure Plan	21
FIG. 7 Golf Course Design	22

		Page No.
FIG. 8	Mediterranean Village	23
FIG. 9	Land Market Value	24
FIG. 10	Development Rating	24
FIG. 11	Staging	25

ATLAS (accompanying the Report)

FIG. 1	Vegetation and Wildlife Habitats — Conservation
FIG. 2	Unique Physiographic Features
FIG. 3	Wind and Wave Erosion — Conservation
FIG. 4	Unique Scenic Features
FIG. 5	Slope Analysis
FIG. 6	Vegetation and Wildlife Habitats — Urbanization/Recreation
FIG. 7	Wind and Wave Erosion — Urbanization
FIG. 8	Sea Views
FIG. 9	Land Views
FIG. 10	Soil Drainage and Water Storage
FIG. 11	Foundation and Building Conditions

FOREWORD

The concept of an "environmental city" is based on the desire to plan for urban settlement within the environmental constraints existing in the land. It stems from the recognition that the attainment of environmental quality in suburban areas depends on prior understanding of the natural as well as the human forces and values impinging on the land.

The Mindarie Environmental City has evolved from a comprehensive examination of all aspects of the area. Its physical and social attributes have been carefully studied and documented and it is believed that the area has extremely good potential for the future development of a self-contained residential community which could eventually house some 70,000-80,000 people at currently accepted residential densities.

Proper planning for the area as a whole, if undertaken at an early stage, will enable this land to be sensitively developed with the least disruption to the natural environment. It can also ensure that community facilities are provided in conjunction with residential growth and a little ahead of the demand for them.

The present report differs from the normally accepted form of feasibility study. It is an environmental study of the land itself which divides the land into graded precincts for which specific plans can then be drawn up. It provides a firm base on which detailed precinct plans can rest and is the starting point for the establishment of a definite development program.

The approach adopted is unique in that it uses a technique described by Ian L. McHarg in a study of Staten Island New York, and adapts it to the specific problems of Mindarie. A comprehensive evaluation system has been evolved to determine the suitability of the land, in part and as a whole, for urbanization, after considering the needs of recreation and the inherent requirements for conservation.

In view of Mindarie's location within the proposed northern corridor and in view of the high quality of much of the land, it is believed that this area is imminently suited to early development.

MINDARIE ENVIRONMENTAL CITY

1. INTRODUCTION

1.1 LOCATION OF MINDARIE

Mindarie comprises 7440 acres of coastal land controlled by Development Underwriting Limited. This land is situated about 20 miles north of the Perth Central Business District, with the Indian Ocean forming its western, and the Neerabup National Park representing its eastern boundary.

The site lies in the northern growth corridor proposed by the M.R.P.A. in their Corridor Plan for Perth (1970). The future population of this corridor is estimated to reach about 185,000 by 1989, an increase of 180,000 over the 1966 Census figures.

The major road at this time connecting Mindarie to the Perth Central Business District is Wanneroo Road. A single access road connects the existing coastal settlement of Quinns' Rocks to Wanneroo Road.

1.2 POTENTIAL OF MINDARIE FOR DEVELOPMENT

The acceptance of the Corridor Plan as a statutory document is an indication of the Government's recognition of likely future development in areas such as Mindarie. The rate of population growth in the northern corridor is forecast to be one of the highest in the metropolitan area, making Mindarie a favourable location for future urban development. The high quality of much of the land emphasises this view.

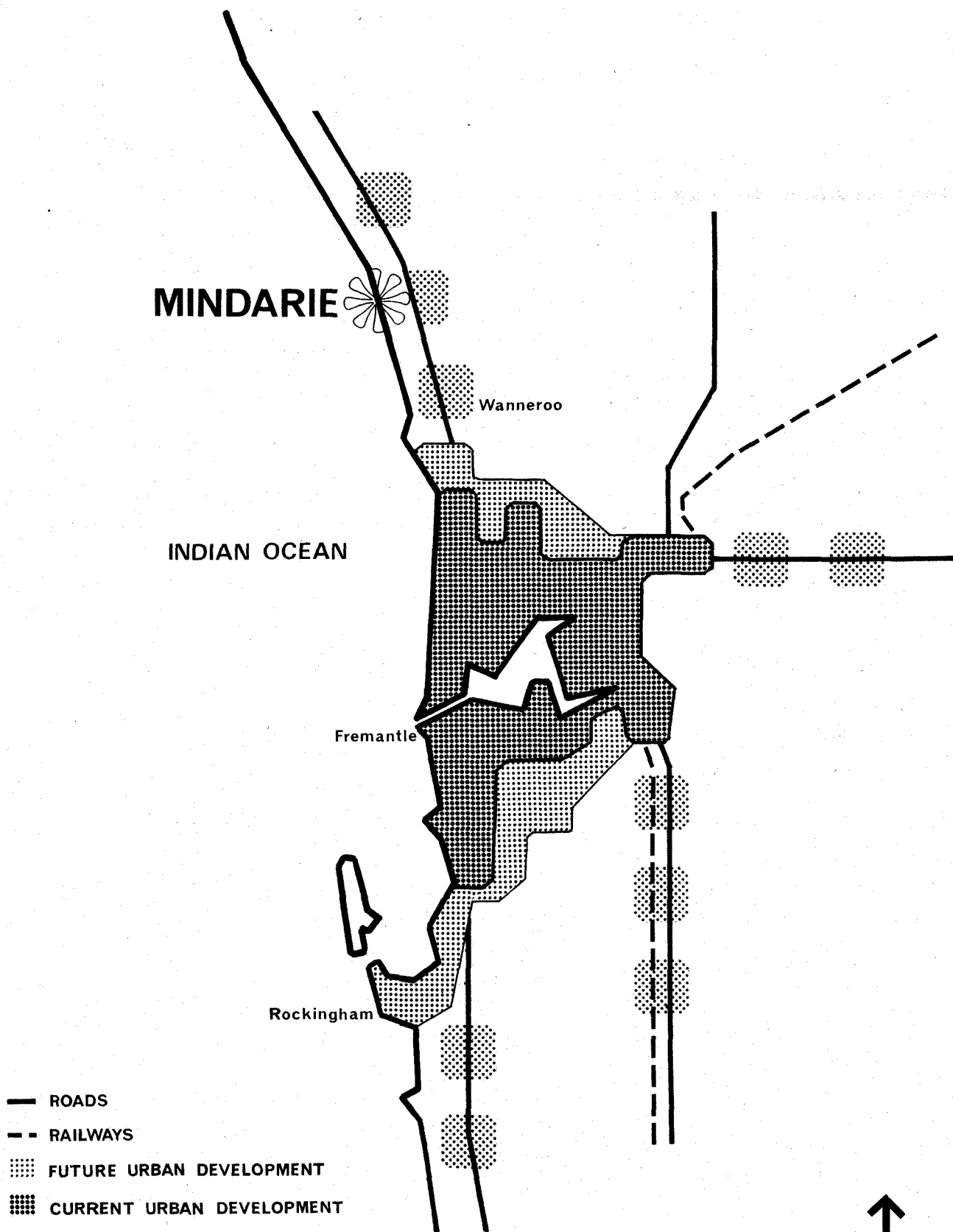
The current pace of development north of Perth can be illustrated by the number of existing and proposed development areas. The Whitfords/Mulhalloo area has expanded rapidly in recent years making Wanneroo Shire the fastest growing municipality in the entire Metropolitan Region. Beyond Mindarie, Yanchep Sun City is developing into a thriving tourist and residential community. This, together with the possible development of a port and industrial estates on the coast north of Mindarie, emphasizes the attraction of the coast and the demand for continued residential and tourist development. Mindarie is situated in an excellent position to become an integral part of this rapid expansion of coastal development.

1.3 A NEW APPROACH

The basic character and identity of our cities and suburbs stems not only from the evolution of man made structures, but also, and perhaps even more importantly, from the pre-existing natural environment into which they are introduced. To achieve development which is in sympathy with its environment, the natural forces at work in the area must be understood.

The approach adopted in this study endeavours to define the intrinsic suitability of the land for human use by combining a study of the major features of the land and the factors that affect its development. To do this, a single, comprehensive evaluation system has been evolved, which takes account of existing environmental conditions, and the suitability of the land for urbanization or recreation use. This provides the basis from which the land can be allocated into specific physical areas. Alignment of the major road pattern, having regard to these areas, results in their modification to form convenient units for precinct planning. A structure plan is produced at this stage. Consideration of marketing factors further grades the precincts according to their development potential.

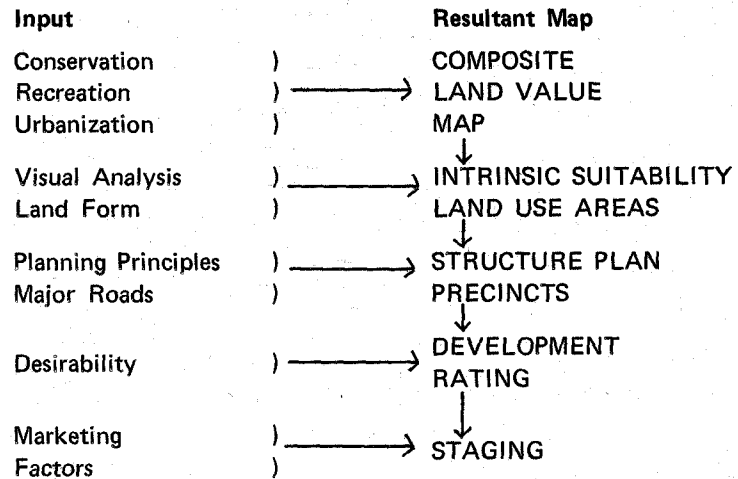
This approach recognises the inherent social, economic and natural values in the development process and attempts to bring them together in a logical manner. A diagrammatic representation of the system follows:



LOCATION OF MINDARIE

Fig. 1

THE LAND EVALUATION AND DEVELOPMENT ASSESSMENT SYSTEM



2. METHODOLOGY

2.1 GENERAL CONCEPT

A major problem facing any developer is to assess the intrinsic qualities of the land to be developed in order to draw conclusions about the desired uses and their disposition on the land.

This study draws on and expands the techniques used by Ian L. McHarg in his evaluation of Staten Island, New York.* Examination of the area is undertaken with respect to the physical and biological processes which act on the environment of the area. Such processes as water percolation, wind and wave erosion, sand dune stabilization and various fluvial processes have a dynamic influence on the nature of the area. By identifying and acting in sympathy with these processes maximum benefits may be gained from development.

2.2 PHYSICAL EVALUATION SYSTEM

The study of intrinsic suitability commences with an investigation of the natural processes. Base data are gathered, compiled and mapped. The data includes information on physiography¹ pedology², climate, vegetation, land use and view potential. Factors are then selected to reveal the most suitable land for conservation, recreation and urbanization. Three values are used to grade each factor on a high-low basis and if necessary, some information is reversed in assessment value. For example, soils most susceptible to erosion may be most suitable for conservation but least suitable for urbanization. An outline of the factors used in the evaluation system and the method of ranking these factors is found in Table 1, page 9. Appendix B may be consulted for a detailed description of the mapping process involved in the evaluation system.

Maps showing conservation, recreation and urbanization factors are produced using the chosen criteria. Each of these maps is printed in a different basic colour (Figs. 3A, 3B, 3C) and the three are then combined to give a Composite Land Value Map (Fig. 3D) which shows the relative suitability of all land for the three uses. The visual area analysis of Mindarie, which defines the cohesive "land form" areas, is applied to the land value map. The resulting map (Fig. 4) shows land use areas for proposed uses defined within natural boundaries and is a basis for the overall planning design of the area. In the case of Mindarie most areas are intrinsically suitable for a number of uses and, where this is the case, the choice of an appropriate use must be made according to economic and social principles, external to the physical evaluation.

2.3 PLANNING PRINCIPLES AND STRUCTURE PLAN

Planning principles have been applied to appraise the development proposals with reference to Mindarie. Open space planning is guided by the identification of areas intrinsically suitable for conservation while the policies adopted for defining recreation and urbanization areas follow similar guidelines.

The final structure plan was evolved from the combination of the following:

1. The Visual Area Analysis (Fig. 2)
2. The Composite Land Value Map (Fig. 3D)
3. The Major Road Network (Fig. 5)
4. The Application of Planning Principles

This structure plan, which defines the precincts/use areas, represents the optimum mode of development for Mindarie Environmental City.

2.4 MARKETING FACTORS

The attractiveness of the land from a market viewpoint — i.e. its likely popularity and the subsequent demand for urban settlement — was considered with reference to the structure plan and as a separate entity. This has been incorporated into the system, providing the basis for grading precincts according to their development potential.

* Ian L. McHarg "Processes as Values", from *Design with Nature*, New York 1969, pp. 103–115.

1 Physiography — the study of the physical shape of the land.

2 Pedology — the study of soil types and characteristics.



3. APPLICATION OF PHYSICAL EVALUATION

3.1 PHYSICAL EXAMINATION

Base data concerning climate, pedology, geomorphology³ and vegetation was gathered by Environmental Resources of Australia. Maps of this data were prepared and appear in Appendix A (Figs. A2, A3 and A10).

All other studies of the area were conducted by Urban Systems including a visual analysis which revealed a system of self contained, cohesive areas defined in the terms first used by Kevin Lynch* viz. "edges", "paths", "nodes", "links" and "landmarks".

3.2 GENERAL DESCRIPTION OF AREA

The Mindarie site is approximately six miles in length and two miles in width within a scenic, coastal setting. The coast is characterised by a sand dune topography with increasing stabilization of the dunes inland from the coast. Directly along the coast the land maintains excellent potential for residential development because of its sea views and its proximity to attractive beaches.

The entire area is part of a sandy, limestone coastal formation. Interspersed throughout the area, capstone outcrops are visible on the landscape. Large sectors of woodland and natural bushland are to be found especially on the eastern side, which is contiguous with the National Park. A large portion of the terrain is at present under pasture.

3.3 BASE DATA

3.3.1 Climate

The climate of Mindarie is characterised by warm, dry summers and cool, mild winters.

* Kevin Lynch, "Site Planning" MIT PRESS, 1961 and 1972.

3 Geomorphology — the study of landforms and land processes.

Rainfall occurs predominantly in the winter months. (Fig.A1, Appendix A). During summer, a reliable south-westerly sea breeze brings relief to hot afternoons.

The coastal location causes a moderating effect on temperatures and creates a pleasant environment. The local sand dune topography forms natural barriers protecting many areas from severe winds and retards the inland penetration of corrosive salt and sand. Exposed areas may experience high gale winds in winter but are highly desirable for residential use because of their sea views and cooling summer breezes.

3.3.2 Pedology and Geomorphology

Mindarie is situated on the Swan Coastal Plain and is dominated by rolling sand dunes which provide excellent views overlooking both the sea and inland valleys.

Unconsolidated calcareous sands are present along the coastline and form blowouts and poorly vegetated dunes. These areas of unstabilized sand may be environmentally detrimental for development and may best be left in their natural state where they can act as a wind barrier to inland development. The presence of better stabilized calcareous sand formations further inland gives rise to ideal foundation conditions for residential development and good drainage for gardening.

The outcrops of capstone (limestone) found in several scattered locations throughout the estate may present problems for development because of the hardness of the capstone which results in high costs for blasting, services and construction. Negotiations could be made with major cement manufacturing companies for its excavation. This would benefit the development in two ways:

1. by the cash income from the land lease and
2. by removal of the capstone to predetermined elevations allowing the land to be pre-formed to achieve a most attractive recreational and residential contouring.

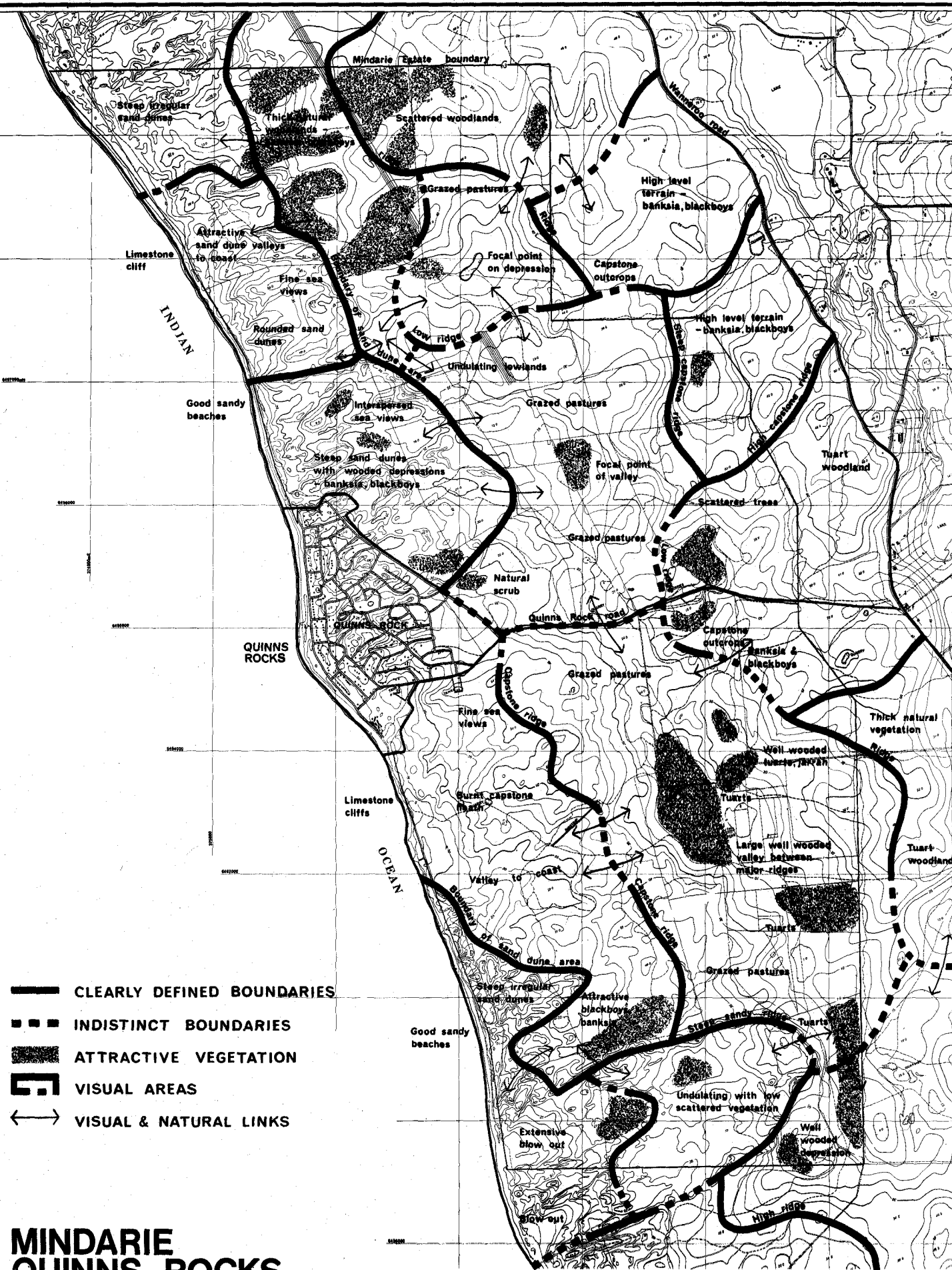
3.3.3 Vegetation

Vegetation distribution is governed by the immediate environment. This includes the soil type, degree of insolation, exposure to wind and salt spray, as well as the presence of other plant species in the area. The distribution of vegetation is mapped in Fig.A10, Appendix A.

Vegetation becomes sparse towards the coastline due to decreasing tolerance of plants to airborne salt and sand. Various types of shrubs tend to locate in the sheltered areas behind the coastal dunes, while further inland, low trees, such as blackboys and banksia, are present in dune valleys. Tuart and jarrah woodlands, some with trees from 6-12 metres in height, are found in the deep yellow sands of the inland pastures. A large area of banksia woodlands provides a unique feature at the southern end of Mindarie. Elsewhere, pockets of bushland within pasture areas provide a natural habitat for small animals and birds. Such areas can be preserved and integrated with urban development as open space or park areas. Preservation of as many trees as possible is recommended to maintain the natural character of all development areas.

3.3.4 Visual Analysis

Visual analysis of Mindarie reveals cohesive land form areas with respect to natural features such as hollows, valleys, ridges, plateaux, hills and other recognisable formations. The areas were outlined by field analysis and mapped to expose the visual "edges", "links," and "landmarks" which determine and locate their visual boundaries. Figure 2 displays these visual areas and indicates the major characteristics of each.



MINDARIE QUINNS ROCKS

VISUAL AREA ANALYSIS

SCALE 1:40,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 2



Ridges represent the boundaries of most visual areas, but in some cases, a sharp change in the nature of the landscape defines the boundary. Such instances can be observed in the north of Mindarie (Fig. 2). Another of the visual boundaries is the result of a change from grazed land to thick natural woodland. Yet another boundary ensues from a change in gradient from steep, irregular sand dunes to low, rounded sand dunes. Along most boundaries, one or more natural links to the adjacent visual area exist in the form of a shallow valley or gap. Where no clearly defined visual boundary exists, a choice has been made in order to facilitate the selection of development areas.

Good land and sea views tend to be related to the higher ridges throughout Mindarie, and can be utilized in the detailed planning of the area.

3.4 CRITERIA CHOSEN

3.4.1 Physical Factors

The various factors derived from the major categories of physiography, pedology, climate, vegetation and view potential and the factors considered to be of greatest importance to prospective land uses have been selected. However, to avoid undue bias in weighting, not all factors are used as overlays.

On inspection of the factor maps, some are discovered to exert similar effects on an area. Two such factors, in the category of pedology, are soil drainage and water storage for vegetation growth and foundation conditions for ease of building and servicing. In both cases, the capstone areas are ranked the lowest while medium sand areas are ranked highest. To avoid exaggerating the effect of pedology on land use, only soil drainage and water storage is used in the mapped overlay analysis.

A list of the major physical factors considered fundamental to conservation, recreation and urbanization is given below. Of the factors mapped, the following were selected because of their particular relevance to Mindarie.

Conservation:

- features of unique physiographic value
- features of unique scenic value
- susceptibility to wind and wave erosion
- vegetation and wildlife habitats

Recreation:

- features of unique scenic value
- degree of slope
- vegetation and wildlife habitats

Urbanization (Residential, Commercial and other uses):

- sea view potential
- land view potential
- susceptibility to wind and wave erosion
- vegetation and wildlife habitats
- soil drainage and water storage for vegetation growth.

3.4.2 Examination of Factors

Each factor is mapped for reference. These maps appear in the Atlas (Figs 1 to 11).

Physiography:

- (a) Features of unique value and features of scenic value:

These are factors deemed important enough to be preserved. In the former category are the limestone cliffs in the north-west area which may represent an early coastline and the large active blowout in the south-west corner of Mindarie. Such features are indicative of the geological history of the area. Figure 4 (Atlas) shows features of scenic value, which, while less geologically significant, form attractive areas and readily distinguishable land marks which can be utilized in the planning process. Steep ridges, disused quarries – which may be suitable for parks or picnic sites – and areas adjacent to the National Park, valuable for their undisturbed natural vegetation and wildlife, are amongst the important scenic features in the area.

(b) Slope:

Generally, extreme slopes are not a problem, apart from the ridges and blowout in the south and some isolated sand dunes with steep lee slopes. The majority of the land has gentle ridges and valleys, and has been used as uniform pastures.

Pedology:

The soils of the area were analysed and their permeability in relation to water storage for vegetation regrowth was mapped (Fig. 10, Atlas). The capstone has the least amount of water capacity and has thus been ranked third. The medium sand, found over a large portion of Mindarie, has the highest water storage capacity and is the most suitable soil for the establishment of gardens. This is an important factor when recommending areas for residential subdivision, since a high value is placed on attractive gardens. In capstone areas, importation of topsoil may be necessary.

Exposure to wind and wave erosion:

Local variation in wind speeds is recorded in Appendix A, (page A6). The major areas affected by wind and wave erosion are situated mainly on or near the coast on unstable or partially vegetated sand dunes. Removal of vegetation in these areas would result in higher erosion rates as loose sand is blown inland by the wind. Extra precautions must be taken when considering coastal dune areas for residential development and this aspect must be further investigated prior to subdivision. A new method has already been pioneered at Quinns Rocks with the use of crushed limestone for dune stabilization, allowing easier regrowth of grass and other vegetation than is usual for previously common methods.

Vegetation:

Preservation of high quality natural bush should receive the highest priority. These areas are often coincidental with wildlife habitats, providing ideal coverage for larger animals, such as kangaroos. Grazed areas have only sparse undercover and, although large trees are present, are not particularly suitable as natural wildlife habitats. Figures 1 and 6 (Atlas) show the ranking of the land for vegetation and wildlife of different kinds.

Conflicts arise when considering the usage of vegetated land. Ideally the natural bush-land should be preserved completely in its present state, but in order to cope with the increasing pressures for human settlement a compromise must be reached which will promote the maximum retention of natural vegetation, possibly by means of reserves within residential areas.

View Potential:

This is an important category because an area of land has potential not only for its physical characteristics but also for its ability to attract settlement. Views are divided into sea and land views as shown in Figs. 8 and 9 (Atlas). Areas of high land, ridges and the tops of sand dunes give the most outstanding views and are graded accordingly. Sea views are obtained only from the western slopes and the tops of hills and dunes.

From a residential point of view, much may be sacrificed, in terms of building conditions, for the privilege of a sea view. Building and maintenance costs may rise in higher locations, which, by definition, are exposed to winter gales and sea-borne salt. However, the attraction of the sea view and proximity to the ocean tend to offset other disadvantages.

STEPS INVOLVED IN READING TABLE 1

STEP 1

FACTOR : WIND AND WAVE EROSION



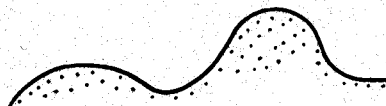
STEP 2

RANKING CRITERIA : EXPOSURE TO WIND AND WAVE EROSION

Most ————— Least



(A) Beach



(B) Secondary Dunes



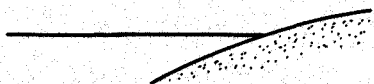
(C) Inland Areas

STEP 3

RANKING OF PHENOMENA FOR MAJOR LAND USES

Most Suited ————— Least Suited

CONSERVATION



(A) Beach



(B) Secondary Dunes

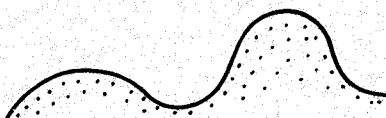


(C) Inland Areas

URBANIZATION



(C) Inland Areas



(B) Secondary Dunes



(A) Beach

TABLE 1 – SUMMARY OF FACTORS AND RANKING PROCEDURE

FACTORS	RANKING CRITERIA			PHENOMENA			RANKING OF PHENOMENA FOR MAJOR LAND USES (Most to Least)			
				A	B	C	Conservation	Recreation	Urbanization	
PHYSIOGRAPHY	Features of unique physiographic value.	Scientific Interest	Max to Min	Limestone cliffs	Blowout	—	A, B, C			
		Distinctive	Most to Least	Quarries High land Nat. Park	Sand-dunes Ridges	—	A, B, C	A, B, C		
	Degree of Slope	Gradient	High to Low	Over 1 in 8	Between 1 in 8 1 in 50	Less than 1 in 50		C, B, A		
PEDOLOGY	Soil Drainage and water storage	Relation to Vegetation growth	Best to Worst	Medium Sand	Unconsolidated sand	Capstone (Kankar)				A, B, C
CLIMATE	Wind and wave erosion	Exposure	Most to Least	Beach and dunes	Secondary dunes	Inland Areas	A, B, C			C, B, A
VEGETATION	Vegetation and wildlife habitats	Quality	Best to Worst	Banksia Woodland and Heathland	Recently stabilized dunes and heathland	Burnt capstone, grazed land	A, B, C	A, C, B		A, C, B
VIEW POTENTIAL	Sea Views	Quality	Best to Worst	Panoramic Views	Localised View	No View				A, B, C
	Land Views	Quality	Best to Worst	Panoramic Views	Localised View	No View				A, B, C

4. PLANNING PRINCIPLES AND CONSTRAINTS

4.1 CORRIDOR PLAN

4.1.1 General Concept

The existence of the Corridor Plan for Perth as a document guiding public policy provides a framework for future development projects. The general concept of the plan is that development should be concentrated within four corridors or growth lines which radiate outwards from the present urban core, the north-western and south-western corridors being along the coast. Already, development has occurred in this form, partly due to the nature of the land and partly in anticipation of the plan's acceptance. Historically, Australian cities have developed along the coast, and settlement north of Perth conforms to this pattern.

The Corridor concept visualises city growth in the form of partially self-contained districts providing residential, commercial and industrial land. It is believed by the planning authority that this form of development will aid in stabilising the central area activity and workforce and make the provision of good transport and public facilities feasible. Sub-regional and service centres are expected to develop within the corridors and the major sub-regional centre for the northern corridor is planned to be located west of Lake Joondalup.

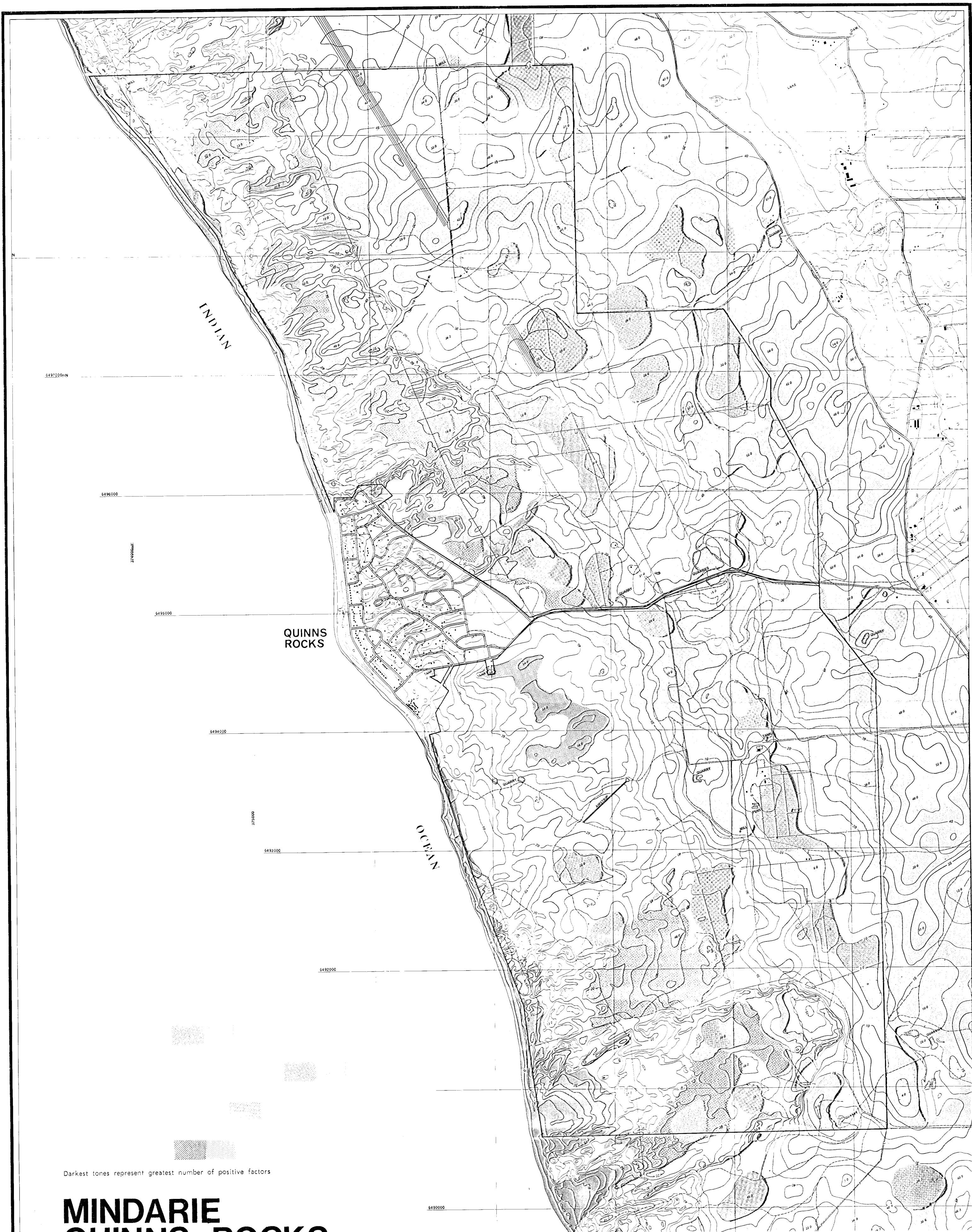
The Corridor Plan depends on established trends and assumes these will continue in the future. These include a continuing demand for low density, single family housing, a steady population growth rate, a growing proportion of the workforce employed in the service sector and a high level of car ownership.

4.1.2 Population Projections – Metropolitan Area

The Corridor Plan and the Perth Regional Transport Study (1971) offer projections for the population of the Metropolitan Area both as a whole and by sectors.

The M.R.P.A. have predicted a population of 1,437,000 in 1989 for the Metropolitan area based on projected rates of population growth. Although a slight discrepancy occurs when comparing the M.R.P.A.'s 1971 population figure to the actual 1971 Census figures (692,000 and 703,199 respectively), this is unlikely to have a major effect on the projected 1989 population.

The "Northern Sector" of the PERTS study can be taken as being synonymous with Northern Corridor of the M.R.P.A. Plan. Combining the results of these two studies, the proposed population distribution for the Metropolitan Area appears below in Table II.



Darkest tones represent greatest number of positive factors

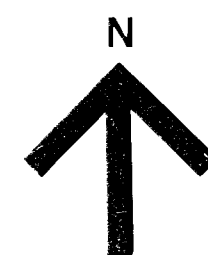
MINDARIE QUINNS ROCKS

SUITABILITY FOR USE —
RECREATION

SCALE 1:20,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 3B





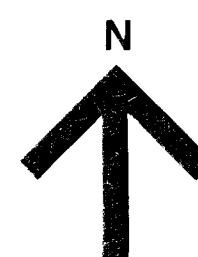
MINDARIE QUINNS ROCKS

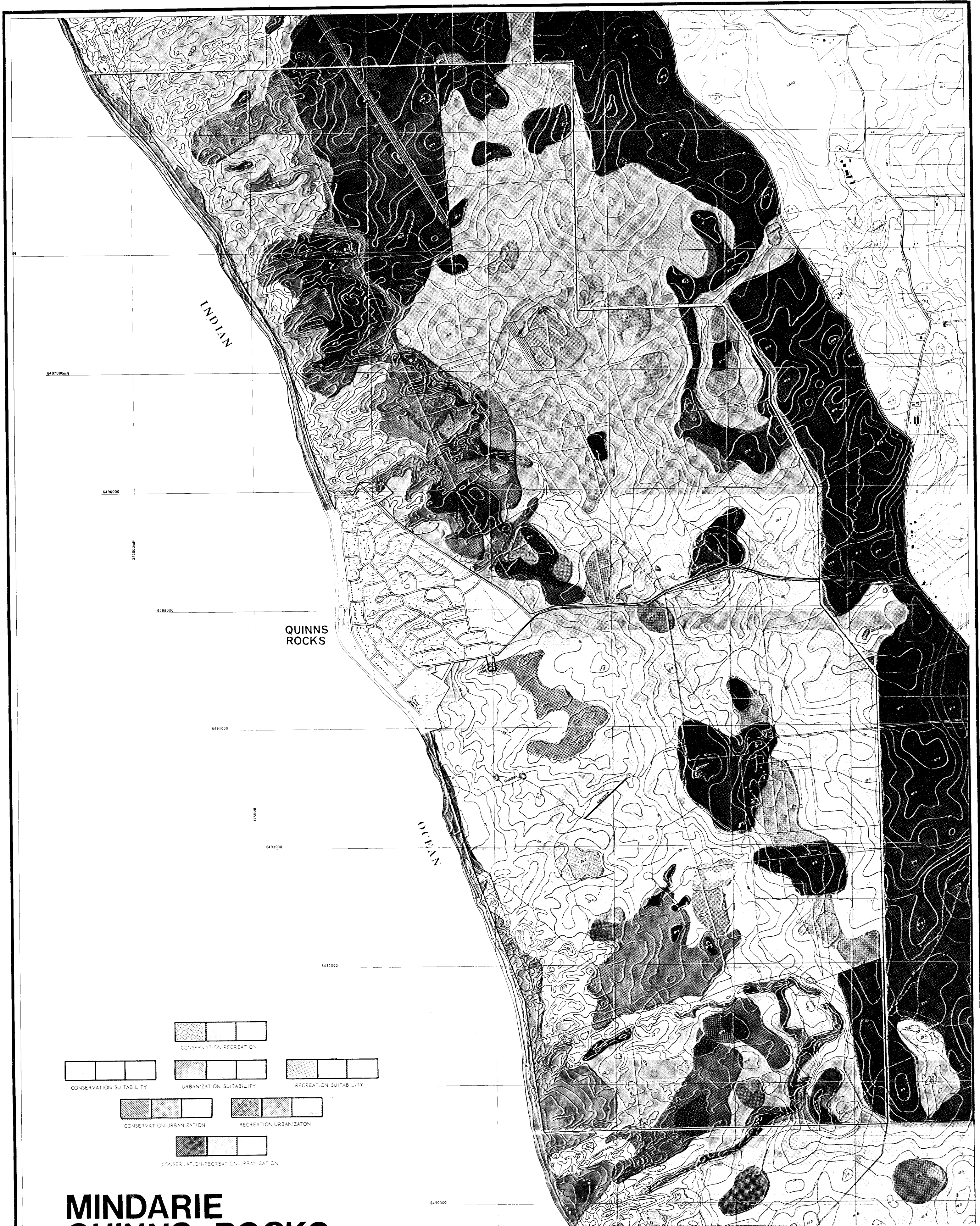
SUITABILITY FOR USE — URBANISATION

SCALE 1:20,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 3C





MINDARIE QUINNS ROCKS

COMPOSITE LAND VALUE MAP

SCALE 1: 20,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 3D

N
↑

TABLE II – POPULATION DISTRIBUTION: METROPOLITAN REGION 1966 AND 1989

AREA	1966	1989
Urban Core		
Developed	275,000	396,000
Intermediate	184,000	371,000
Outer Areas (by sectors):		
North	6,000	185,000
East	38,000	105,000
South-East	26,000	131,000
South-West	30,000	249,000
Total	559,000	1,437,000

Source: (1) M.R.P.A. "The Corridor Plan For Perth" Perth, 1970.

The table suggests a reversal of the 1966 situation when 50% of the population lived in the developed area and only 18% in the outer areas. By 1989 it is predicted that 50% of the population will live in the outer areas and only 28% in the presently developed areas.

It is expected that a trend towards living and working in the outer areas as they become increasingly "self sufficient" will be more firmly established and the M.R.P.A. predicts that by 1989, 36.2% of the population will be working in the outer areas compared with 12.3% in 1966. PERTS predicts that the most substantial concentration of working workforce (as distinct from residing workforce) will be in the northern sector, located in the coastal area between Hammersley and Wanneroo.

4.1.3 Development Constraints

The Corridor Plan provides a framework for future expansion in the Metropolitan Region by presenting a general outline in which development can progress. The relevant aspects of this framework affecting future development at Mindarie are:

1. growth in the northern corridor will follow a linear pattern along the coast, generally about four to six miles in width.
2. a rapid population increase can be expected in this area which will give rise to a demand for serviced residential lots.
3. urban growth will develop in units which can acquire individual identity but which are linked by communications networks.
4. future development in the northern corridor will be facilitated by an adjacent freeway system connecting the area to the Perth CBD.
5. the freeway will be located on the eastern boundary of the Corridor, generally between Wanneroo Road and the coast.
6. East of Wanneroo Road, the land will have non-urban uses such as forestry reserves and market gardening.

4.2 OPEN SPACE

4.2.1 Location

Allocation of open space in Mindarie can be accomplished in accordance with the concept of "intrinsic suitability" of the land. The general principles adopted for the location of open space are:

- (a) protect and conserve areas of natural flora and fauna as regional parks;
- (b) protect and conserve major physical and topographical features of special interest, rarity or scenic value;
- (c) provide a logical open space pattern by retaining physical features which define urban areas (e.g. ridges, woodlands);
- (d) protect and conserve beachfront areas;
- (e) provide both local and regional open space to meet the required demand.

4.2.2 Access

Quick and easy access to most open space areas is essential to the enjoyment and use of the area for residential settlement. The basic principles governing access to open space areas are:

- (a) provide permanent public access to usable beaches;
- (b) provide safe pedestrian routes for people residing or holidaying in the area;
- (c) link open space areas by pedestrian routes (e.g. walking paths) where practicable;
- (d) restrict or control public access where this is warranted for the preservation of open space, (e.g. natural vegetation and wildlife areas);
- (e) link parts of the beachfront with the National Park where circumstances allow.

4.2.3 Variety and Use

Open space should consist of several, separate units which vary in size and shape and are designed to provide for a multitude of different purposes. The principles governing the usage of open space are:

- (a) provide areas for private recreational uses (e.g. golf courses);
- (b) provide areas for public recreational uses (e.g. picnic sites);
- (c) provide areas for active and passive recreational use;
- (d) protect the frontal dune areas from the threat of over use.

4.3 PROVISION OF SERVICES

Social, health and welfare services, educational facilities, commercial facilities and public utilities are required to satisfy the spectrum of demands which arise as new sites are developed. The provision of these services should maintain a balance with the rate of development within the area to ensure proper growth. The principles concerning their establishment in Mindarie are outlined below.

4.3.1 Social, Health and Welfare Services

It is estimated that approximately 100 acres of land will be needed to provide these services. Facilities such as youth clubs, libraries, recreation and arts centres, community and medical centres should be strategically located to serve the needs of the community.

The majority of the facilities should be located at the neighbourhood level (e.g. serving a community of 20-30,000), within easy access of homes and to provide a stimulus for community activity.

4.3.2 Educational Facilities

In accordance with the requirements of the Education Department, fifteen primary schools and five secondary schools will be needed to satisfy the predicted population of Mindarie. Schools should be located adjacent to open space systems and both primary and secondary schools should be easily accessible to residential areas. Primary schools should be provided with safe pedestrian routes whereas secondary schools should be located on bus routes with convenient access by car or bicycle from residential areas. All schools within the area should be linked in an educational and social system, where school buildings may be used after hours for community activities. Careful site planning will ensure that schools are located to provide the maximum benefit to the community.

4.3.3 Commercial Services

A hierarchy of shopping centres will be provided in stages as the demand arises to satisfy the requirements of Mindarie's residents. All shopping centres will be sited for easy access to all sectors of the area.

At least one large shopping centre will be required. On present trends, it is estimated that the population of Mindarie by 1989 will be sufficient to support a shopping centre of at least 300,000 square feet floor space, occupying approximately 100 acres of land. A fairly level, compact site would be the most suitable for development. This shopping centre should have good visibility and access from the major lines of travel.

4.3.4 Public Utilities

The provision of utility services should be co-ordinated to satisfy the needs of the population in accordance with the envisaged sequence and rate of development of the area.

4.4 MAJOR ROAD NETWORK

4.4.1 Interdependence

Four main road types are to be developed within Mindarie:

- (a) Stephenson Freeway — a high speed through route with only one point of intersection and interchange with Mindarie.
- (b) Marmion Avenue — a main feeder artery collecting and distributing traffic generating from the suburbs on either side.
- (c) The East-West Arterial Road — to provide a link with the Freeway for traffic collected and distributed by Marmion Avenue and Wanneroo Road.
- (d) The West Coast Highway — the major route for access to the coast.

While the purpose of each road and the speed and intensity of traffic for which it must be designed is of overall importance in selecting its route, the actual route chosen contributes to and is dependent on the character of Mindarie.

The effect of the design of the roads on people using them should be as pleasant and as attractive as possible, without danger or waste of travelling time.

The three major arterial routes cover 166 hectares, as much land as would be required for 1,600 building blocks. The embankments and cuttings, 6m or 7m deep, must be sympathetically sited if they are not to overwhelm local features.

4.4.2 Design Parameters

The ideal road should:

- (i) compliment the countryside through which it passes and present an attractive appearance to its users.
- (ii) function safely for those who use it and those having to cross it.
- (iii) allow drivers to sustain the speed for which the road was designed, without fear of contact with intersecting traffic.
- (iv) permit reasonably free flow of people and, where necessary, animals and vehicles, between one side and the other.
- (v) cost an economical sum to build and maintain.

Individual road design parameters and detailed design criteria are set out in Appendix C.

5. SYNTHESIS

5.1 APPLICATION OF PLANNING PRINCIPLES TO LAND EVALUATION

The combined synthesis of planning principles and land evaluation methods results in an overall structure plan (Fig. 6). This was compiled by overlaying the visual area analysis on to the Composite Land Value Map. On the basis of the visual results of this method and an assessment of market potentials of the different areas, decisions were made regarding the extent of urbanization areas, their value for development and their visual identity. Similarly, areas for conservation are related to visual areas so that they form distinct features. Recreation areas are less defined by visual areas; they are generally incorporated within residential areas or form boundaries between them.

Choice of road locations has been made to conform to sound environmental principles and engineering considerations. The major road pattern obtained was then overlaid on the combined land evaluation/visual area map and this resulted in further modification to the boundaries of the development areas. This is the basis for the structure plan which is a combination of the results of all the physical analyses carried out within the project area. The mode of development of any piece of land can, in consequence, be directly related to its physical and visual qualities in a logical way.

5.2 SELECTION OF NATIONAL PARK LINKS AND OPEN SPACE

The land evaluation map reveals those areas of Mindarie which are intrinsically suitable for conservation.

5.2.1 The Coastal Area:

One of the major attractions of Mindarie is its extensive ocean frontage, most of which comprises excellent sandy beaches. Every effort must be made to preserve those areas in their natural state for the permanent amenity of all residents and visitors to the area.

As progressive development takes place there may be a demand for development close to the foreshore reserve. Special care must be taken to preserve the primary sand-dune system from being denuded of the stabilising effect of natural vegetation by indiscriminate

inate use and building too close to the beach. Further safeguards are provided in this respect by the Shire of Wanneroo Town Planning Scheme.

The areas of major importance are those indicated in green on the Composite Land Value Map (Fig 3D). These generally correspond to the land systems of the coastline, fore-dunes and partly stabilised dunes described in Section 6 of Appendix A.

Preservation of these areas will result in an enhanced natural environment for the residents of the area. The major areas which should be preserved are in the north and south of Mindarie where the dunes are generally less stable than in the intermediate area. Detailed studies of these areas will be needed to locate the best forms of access to the beach, and suitable areas for car parks, etc.

5.2.2 National Park Links

The generally accepted view of the Corridor Plan promotes the concept that areas of urbanization should be separated by wedges of open space extending across the Corridor from east to west. This policy is supported by the Metropolitan Region Planning Authority in their draft proposals for the development of the northern Corridor and is fundamental to the strategy adopted in this study. It is considered desirable that Mindarie be enclosed on the three landward sides by open space areas to the north and south, and by Neerabup National Park to the east. Along the northern and southern boundaries of the property, these open space links would provide extensions to the National Park.

This plan will ensure that Mindarie develops an individual identity and character of its own. Care will be taken so that overall development is related to the natural environment in an harmonious manner, so that open space and natural bush will be integrated with residential development wherever practicable.

The proposed National Park link to the north is larger than that envisaged to the south of Mindarie. It extends into Mindarie through an area of natural Banksia woodland which is recommended as a flora and fauna preservation area because of its high aesthetic and environmental quality. The link includes an area of unstable sand dunes which should not be developed.

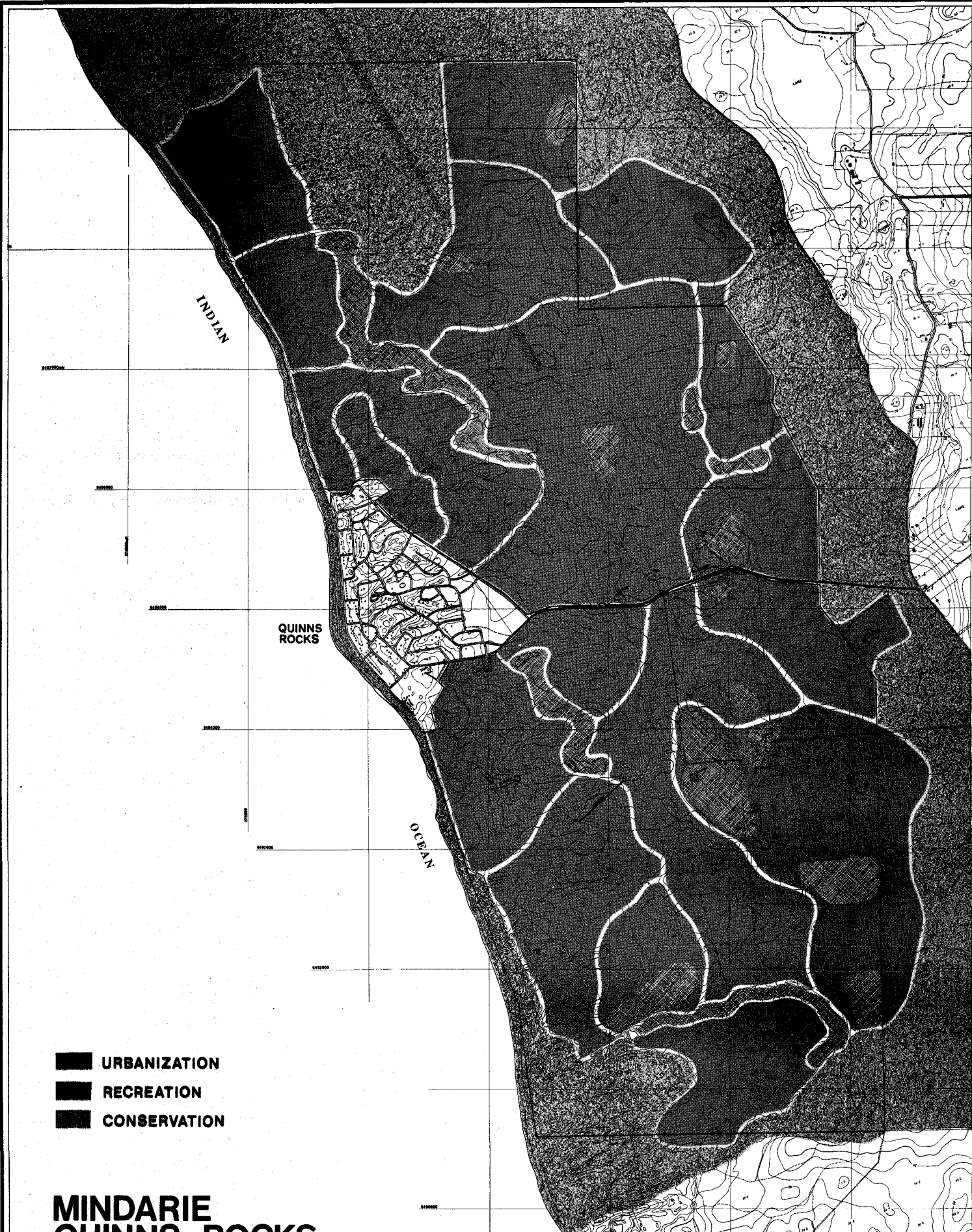
The link proposed to the south includes the large blow-out and sand hills terrain. It narrows inland to follow the steep ridge which runs towards the National Park. Analysis of the area indicates it could be quite narrow and still be effective, owing to its visual prominence. This ridge will also provide a suitable visual boundary between Mindarie and development to the south.

5.2.3 The National Park and Possible Land Exchange

The Neerabup National Park adjoins the whole eastern boundary of Mindarie and extends eastwards to Wanneroo Road. This area should undoubtedly be retained substantially in its present natural state. It is however proposed that the parts of this land that are more suitable for development should be exchanged for areas presently located within Mindarie but which are natural extensions to the National Park.

The structure plan shows complete precinct areas which in some cases encroach upon the National Park. It is evident from the studies carried out that these areas are most suitable for urbanization and it is considered that their annexation from the National Park would not be detrimental to the rest of the parkland.

The results obtained from the studies and the broad principles adopted, have been shown to the National Parks Board of Western Australia and they were most interested in the analyses carried out. The Board will wish to be satisfied of the merit of individual proposals set out in this plan, before official sanction can be obtained. Owing to the time



- URBANIZATION
- RECREATION
- CONSERVATION

MINDARIE QUINNS ROCKS

LAND USE AREAS

SCALE 1:40,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 4



available, official approaches on matters of detail have not been made at this stage of planning and negotiation of the exact areas involved in the exchange will take place once definite plans are drawn up.

5.2.4 Open Space

Within Mindarie, areas of open space have been located according to the same principles and will be designed to link and define residential neighbourhoods. At this stage it is only possible to provide recommendations on broad areas that will be suitable for both active and passive recreation purposes and these appear as blue tones on the 'Composite' Land Value Map (Fig 3D). From these, smaller areas of open space can be chosen when detailed subdivisional design occurs. Some of the high, narrow ridges should be preserved as open space for passive recreation as they serve as necessary focal points and are essential in order to retain position identity. They could provide ideal lookout points offering extensive views over the settlement, ocean and adjoining National Park to the east.

Throughout Mindarie small, densely wooded depressions form ideal locations for parks, children's play areas and Bar-b-que areas. In some cases these can be developed as the focal points of residential precincts.

Larger, more level open areas are suitable for the development of sports ovals, swimming pools and playing fields, thus catering for active recreation demands.

5.3. SELECTION OF MAJOR ROAD NETWORK

Selection of the major road routes has been made after close investigations of the areas revealed in the Composite Land Value Map and visual assessment on the site. The method of selecting the routes and their detailed design criteria are outlined below, but in principle they stem from a basic network and specific standards laid down by the Metropolitan Region Planning Authority and the Main Roads Department. Primary consideration has been given to their location from an engineering point of view, modified to conform with environmental considerations already described.

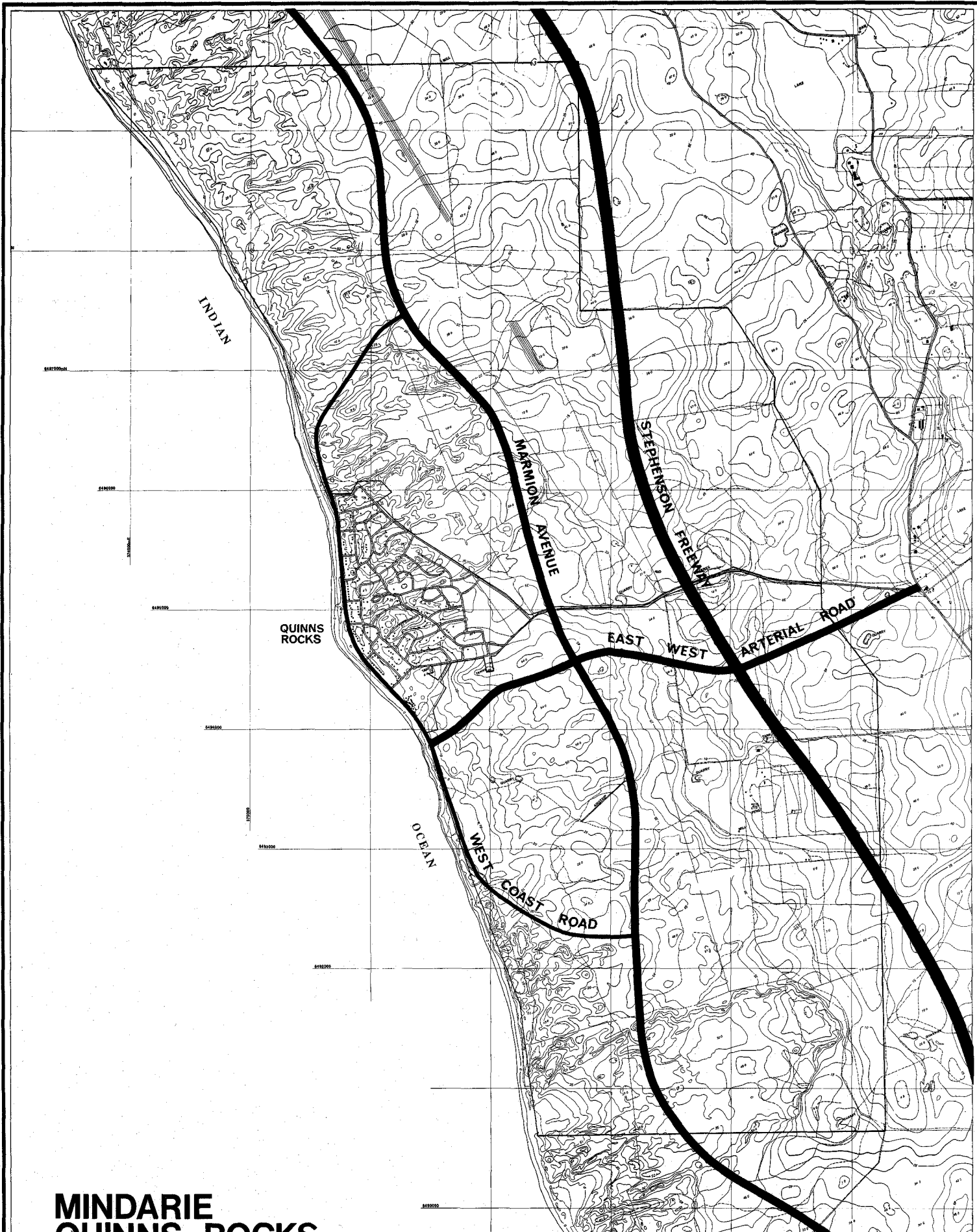
5.3.1 Improvements to Existing Roads

The road from Perth to Lancelin, through Wanneroo, is expected to be improved to a dual carriageway, urban highway at least as far as Wanneroo, within five years and the existing Quinns Rocks road could be improved relatively cheaply. The capacity of this single route and its position will however not be adequate for the full development of the whole Mindarie area.

5.3.2. West Coast Highway

The West Coast Highway at present extends as far north as Mullaloo and a route has been selected for its extension for the next three or four kilometres northwards. This is essentially the road which people who want to visit selected parts of the coast will take. Although the road is known as the West Coast Highway within the Perth Metropolitan Area, it is believed that it will not be developed for high speed, high density traffic and will therefore not be a major traffic route northwards from Perth.

Thus, while the West Coast Highway will attract people to the area because of its scenic nature it will do little to improve communications between Mindarie and Perth or between Mindarie and the land to the north. For this reason the plan has opted for a non-continuous section of this road in the Mindarie area. This is also a desirable approach from the environmental point of view, since the route will avoid the sensitive blowout areas, discouraging access and assisting dune preservation.



MINDARIE QUINNS ROCKS

MAJOR ROAD NETWORK

SCALE 1:40,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 5



The proposed route will loop off Marmion Avenue, along the limestone cliffs to the ocean side of the Quinns Rocks townsite, and rejoin Marmion Avenue some distance to the north. The provision of suitable crossings would enable people living or parking their cars on the east side of the road to walk safely to the beach.

5.3.3 Stephenson Freeway

The map following page 17 shows two continuous highways running northwards from the Metropolitan Area through Mindarie; the most easterly of these is the Stephenson Freeway.

The Stephenson Freeway will become a Primary National Route to major freeway standard, able to carry traffic at a sustained high speed with limited provision for the transfer of local traffic. It is not yet known when work on this Freeway will start, but it is intended that it will one day be the main route in and out of Mindarie through the intersection with the east-west road, at a point due east of Quinns Rocks.

Because of its high speed characteristics, engineering considerations are prominent in the choice of the route for this road. However, as a result of detailed consideration in the early stages of planning, it has been possible to locate the road in such a position that it will have the least possible visual impact and destructive effect on the natural vegetation and environment. Provision will be made within the Mindarie area to take traffic over or under the Stephenson Freeway.

5.3.4 Marmion Avenue

Marmion Avenue has been built from Warwick Road to Mullaloo to Main Roads Department Standards as a main collector for the developing areas within 4 km of the west coast. Until the completion of the Freeway and substantial upgrading of Wanneroo Road takes place, it is likely that in function, this route will serve some of the purpose for which the Freeway is to be constructed, i.e. through traffic.

It is desirable to put Marmion Avenue in a position which lies approximately midway between the coast and the Freeway. Because the design speed of this road is lower than that of the Freeway, it has been possible to permit environmental considerations to take a paramount role in the choice of the road's location. Provision should be made for pedestrian ways to go over or under this road.

5.3.5 East-West Arterial

At intervals of 6 to 8 km along the Stephenson Freeway, interchange systems are required to provide for the distribution of traffic to the areas on either side of the Freeway. One such interchange is proposed midway through the Mindarie development. A main east-west arterial route will be constructed to link the freeway with Marmion Avenue, the West Coast Highway and with Wanneroo Road. This road, like Marmion Avenue, will have two carriageways with limited intersections, and will be designed for moderate speeds. Pedestrian overpasses or underpasses should be constructed.

5.3.6 Traffic Movements

Traffic from north of Quinns Rocks will travel via Marmion Avenue and the east-west arterial road to the Freeway, or to its local destination. It is believed that Marmion Avenue will also collect a small proportion of the north bound traffic from areas south of Quinns Rocks, but the major part of this traffic generated to the south of the east-west arterial road will travel southwards along Marmion Avenue to reach the Freeway to continue their journey.

5.3.7 Minor Subdivisional Roads

Within the residential development approximately one quarter of the area will be taken up by local access roads. Design and location of these roads is beyond the scope of this study and will be undertaken when detailed planning commences. The alignment of the major roads is suited to the adaptation of a grid system. Through roads will be designed to skirt residential areas, access to homes being provided by non-continuous loop roads or culs-de-sac.

Roads feeding into the through road system will provide access to the major shopping centre, high schools and other centres.

5.3.8 Other Forms of Access

There is an airstrip suitable for single engined light planes within the property.

5.4 SELECTION OF URBANIZATION AREAS

The Composite Land Value Map (Fig 3D) is the basis for the selection of urbanization areas at Mindarie. The various land uses are indicated by colours on the map. (Refer to the colour key). Land most suited to conservation appears in yellow while land suited to recreation is in blue and urbanization in red. Where two uses are compatible in one area, a mixture of the two colours occurs. Land suited to the three uses appears as a green-brown colour on the map. The various land use alternatives shown on the map do not represent fixed land use locations but are indications of the areas most suitable for particular land uses. In the case of Mindarie, very few of the land areas are exclusively suitable for a particular land use. Where a number of land uses suit an area, a decision must be made concerning the land use most suitable for each specific case.

5.4.1 Residential Development Areas

Land suitable for residential development is represented on the Composite Land Value Map by the pink range of colour scales in the urbanization portion of the colour key. The darkest colour on each scale represents areas where most positive factors for residential development prevail. Such aspects as scenic views and extensive stands of trees are characteristic of these areas. The middle colour on each scale refers to areas of moderate attraction due to less vegetation cover and scenic views. The lightest colour on the colour scales are areas least attractive for residential development due to the lack of positive factors. For example, areas of capstone outcrop may appear in this colour tone.

This classification is generally in accordance with the recommendations of Environmental Resources of Australia for the land systems described in Section 6 of Appendix A.

The initial division into areas of visual coherence has been made (Fig 4). The urbanization areas so defined form distinct visual areas which are modified slightly by the superimposition of the major road network. This serves a two-fold purpose:

- (a) to divide larger visual areas into precincts with individual identities suitable for residential development and
- (b) to re-mould the boundaries of the visual areas into more appropriate dimensions.

The final pattern of residential precincts as shown on the structure plan, is described in more detail in Section 6.

5.4.2 Commercial Centres

The major commercial centre within Mindarie will require about 100 acres to accomm-

odate a shopping complex providing adequate retail floor space to cater for the estimated population, together with related developments such as a hotel, service stations, associated parking space, access areas and social facilities. Optimum location of this centre within the likely catchment area is essential. Having regard to the proposed programme of development and the somewhat uncertain time scale involved in the Freeway construction programme it is considered that the most suitable location would be where access can be gained primarily from the proposed East West road and from Marmion Avenue. Since this is to be a major shopping complex, care was taken to ensure that it would also be accessible from the Freeway and the existing Quinns Rocks Road.

Engineering design parameters for a unified project of this size require that a predominantly flat site be utilized. However, from an architectural viewpoint, a gently sloping site provides opportunities for some variety in horizontal levels, thus enabling a natural segregation of some of the pedestrian and vehicular traffic flow, whilst simultaneously offering a more interesting visual effect.

Furthermore, it would be socially unacceptable if a commercial centre were to occupy and thus destroy an area of high intrinsic visual and environmental quality that ought properly to be used for some social, public or residential use.

Alternative sites possessing some of these characteristics were examined and a site was chosen which incorporated most of the above factors. This site will serve as the future town centre for Mindarie and is shown on the Structure Plan (Fig 6).

It is anticipated that further sites of about ten acres will be required as the population increases to cater for specialist retail/commercial/tourist associated activities. The first of these is to be located at the intersection of the East West road and West Coast Highway, in a potentially exciting position overlooking the ocean and possible Marina development.

Additional land will be required throughout the Estate to cater for purely local shopping needs. In an area the size of Mindarie there will obviously be a demand for numerous small commercial centres. These will need to be located so as to be accessible to pedestrian and local traffic but without conflicting with the major traffic movements within the area. Detailed land requirements and location decisions will be resolved at the time of detailed planning.

5.4.3 Policy for Industrial Location

The provision of industry within Mindarie is largely dependent upon the development of the 3,000 acres of land immediately to the north of Mindarie already selected by the Government for the location of a major power station. Subsidiary industries can be expected to develop and these, together with the proposed new port further north would provide employment opportunities for the residents of Mindarie to rival those in the Metropolitan Area. This will provide a stimulus to the settlement of the area and ensure that the transport networks will be fully utilised.

Consideration has been given to the provision of additional industrial land within Mindarie but it is thought that this would conflict with environmental constraints and prejudice the basic residential character that will evolve in the area.

The creation of some small industrial estates (5-10 acres) to cater for light industrial processes which would create local employment for residents, particularly housewives, can be examined in detail at a later stage. Several suitable sites exist, and it is envisaged that if established, they would be designed to blend in with the residential neighbourhood in which they were situated.

5.4.4 Water Supply and Wastewater Disposal

Some land throughout the area will be required for the location of utility headworks and reticulation services.

The water supply for Mindarie cannot be obtained from surface streams and will be drawn from underground aquifers. The supply for the present settlement at Quinns Rocks is pumped from three bores nearby and is treated to reduce the iron content. It would be possible to augment these works to provide for moderate expansion of the existing village.

Major development would, however, require large storage reservoirs and water treatment facilities, which would have to be situated where they could command large areas. A likely source of water for these supplies would be the Gnangara Mound system of unconfined aquifers and its northward extension. Even if the aquifers underlying Mindarie are not used for public water supply purposes, major development cannot depend on septic tanks with effluent disposal to the subsoil. Wastewater will be collected by sewers and pump stations for delivery to treatment works within the area.

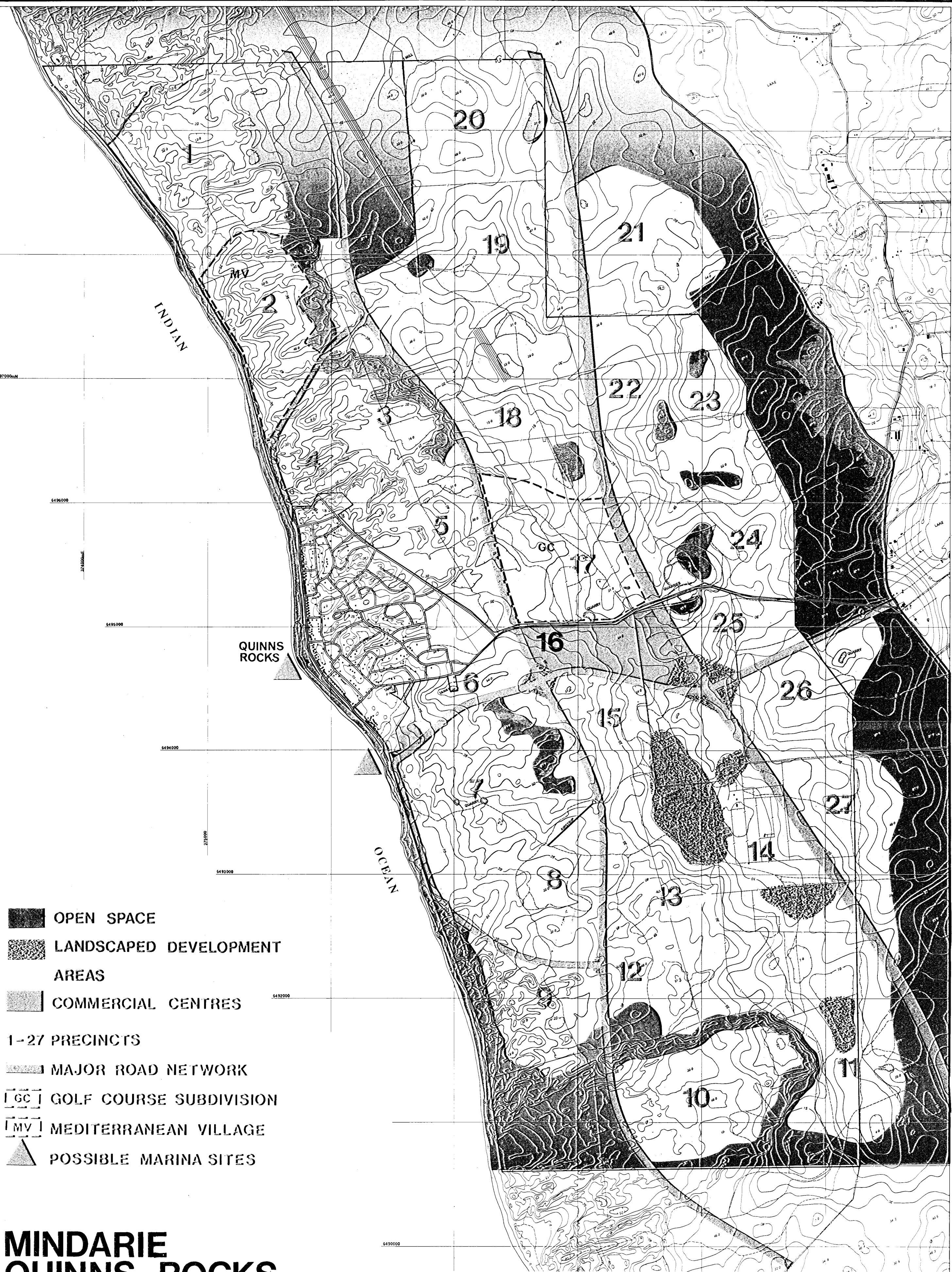
5.4.5 Other Land Requirements



A considerable amount of the land suitable for urbanization will be required for a variety of other community services. The allocation of this land will result from detailed planning and engineering considerations and will be in conformity with the environmental principles established by this study. Educational establishments will be prominent in this category. The location of schools will be of importance at a later stage of planning and will ultimately be decided after consultation with the Education Department, Public Works Department and the Metropolitan Transport Trust.

Social and community services will need to be provided for and should be located within easy access of residential areas.

5.4.6 The Existing Town Site

The existing settlement at Quinns Rocks has exerted little influence on the overall planning of Mindarie. It is of a holiday resort nature, consisting largely of older houses, several small shops and a caravan park. Recently, better quality homes have been built in the area and it is anticipated that the trend will continue. Ultimately, it is likely that all of the older dwellings will be redeveloped and the area integrated into the general concept for the area. Already, the latest subdivision areas are being developed under covenants allowing only brickwork as the external wall cladding for any dwelling.



-  OPEN SPACE
-  LANDSCAPED DEVELOPMENT AREAS
-  COMMERCIAL CENTRES
- 1-27 PRECINCTS
-  MAJOR ROAD NETWORK
-  GOLF COURSE SUBDIVISION
-  MEDITERRANEAN VILLAGE
-  POSSIBLE MARINA SITES

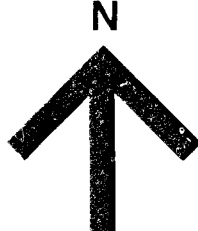
MINDARIE QUINNS ROCKS

STRUCTURE PLAN

SCALE 1:20,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 6



6. STRUCTURE PLAN, DEVELOPMENT RATING AND STAGING

6.1 STRUCTURE PLAN

The structure plan for Mindarie has been presented in Fig. 6. The general outline of the urban precincts as well as the land allotted for open space are shown on this plan. While the boundaries of the open space areas have been chosen because of their intrinsic suitability for these uses, it is not suggested that the whole of the areas be used for these purposes. Many of the areas are desirable for other land uses and may be used in a way which is most socially desirable.

The open space system, the major road system and the selection of residential areas which make up the structure plan have been explained in the previous section. However, certain precincts have unique characteristics highlighting them for specific development.

Precinct 14 is one such precinct. The half-toned green land on Fig. 6 represents landscaped development areas or areas to be developed in a careful and sympathetic way such that settlement is in harmony with the existing natural vegetation. These areas contain large stands of tuart and jarrah. On the Composite Land Value Map (Fig. 3D), this precinct is shown as an ideal inland residential area which suggests the possibility of a high quality residential subdivision being integrated into the stands of trees.

The large shopping centre proposed for Mindarie will be located in Precinct 16. It will be situated on the level-to-gently sloping terrain in the middle of the precinct. Other opportunities to highlight precinct development are discussed separately below.

6.1.1 Golf Course

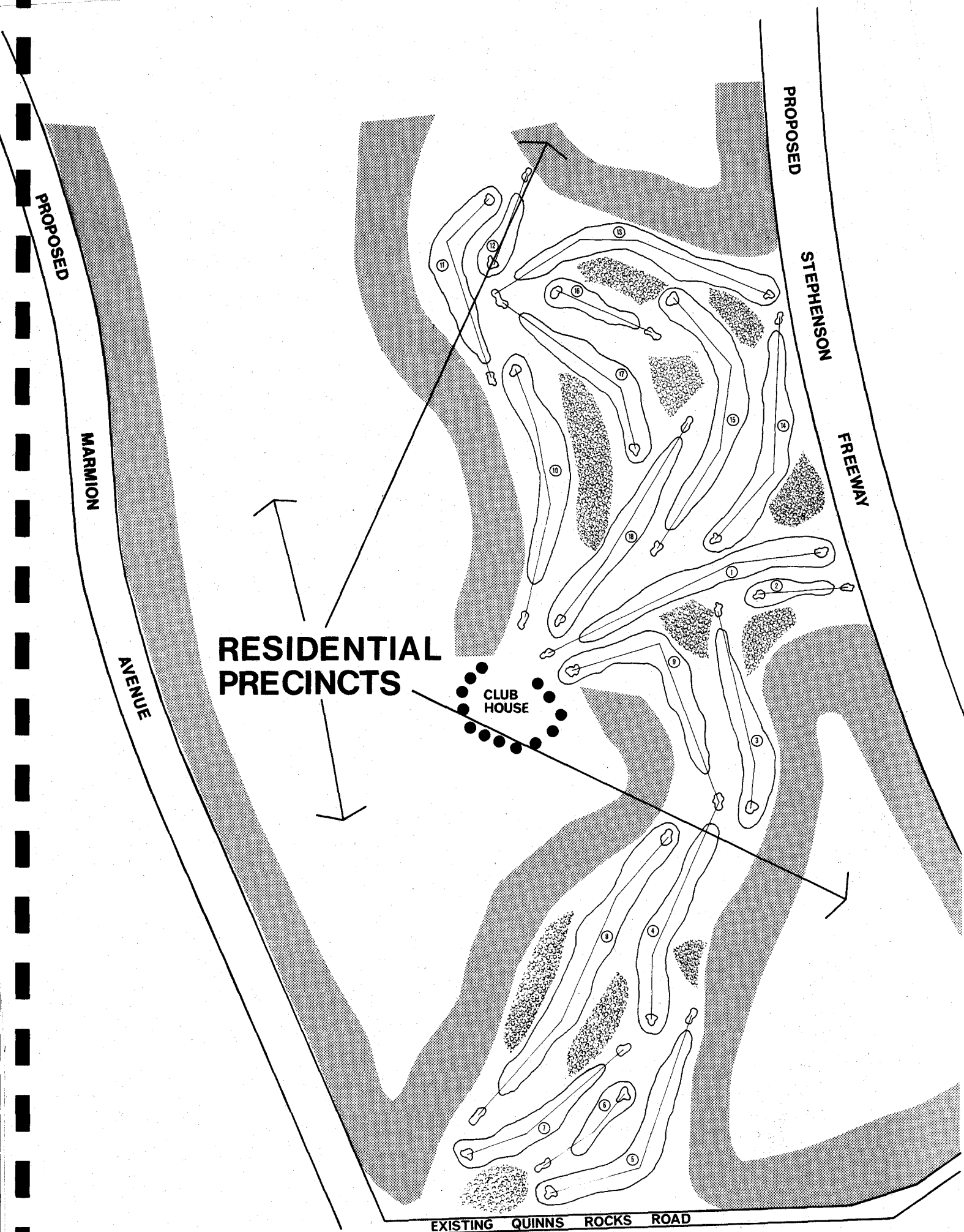
A championship golf course is proposed for Mindarie to cater for both local and regional recreation needs and to act as an incentive for settlement in the area. A feature of the golf course development is the proposed incorporation of residential land into the overall design. This subdivision will overlook the golf course resulting a high amenity value and attractive landscape. Higher demand for this land would be likely.

The location of the golf course will be within Precincts 17 and 18 on an area of approximately 500 acres adjacent to the proposed Stephenson Freeway and north of the existing Quinns Rocks Road. (Fig. 6). Its valley location offers protection from sea breezes and airborne salt and spray. Both precincts have been assigned "B" development ratings (Fig. 10), and the presence of the golf course will upgrade the appearance of this land and surrounding areas. The soils in the area (medium sands) allow good drainage and with proper management will support the vegetation growth (grass and trees) required for golf course development. The course will be visible from three major roads (Stephenson Freeway, Marmion Avenue, East-West Arterial Road) allowing it to be a landmark for visitors to the area and people passing through Mindarie. A proposed design for the golf course is shown in Figure 7.

6.1.2 Marina

A growing demand for marina sites within the Metropolitan area has ensued from an increase in the number of boats during the last ten years coupled with a deficiency of boat facilities. The coastal situation of Mindarie presents an excellent opportunity to provide facilities which could eventually assist in the relief of current and future shortfall of Marina facilities.

Two possible future locations for a marina have been tentatively selected (Fig. 6). Both sites are along the proposed West Coast Highway and in close proximity to the East-West arterial route for easy access. The Marina site should provide servicing, storage and launching facilities. A shopping centre, a tavern, as well as sales and administrative office may be built on the site to complement the Marina development. The exact location and design of the complex will be subject to detailed environmental, engineering,



PROPOSED PUBLIC GOLF COURSE SUBDIVISION
 MINDARIE ENVIRONMENTAL CITY
 URBAN SYSTEMS CORPORATION PTY. LTD.
 AUSTRALIAN GOLF SERVICES PTY. LTD.
 JUNE 1973

Fig. 7

architectural, town planning and economic considerations. However, the provision of well planned facilities would be a worthwhile and necessary addition to the amenities of the area and would benefit both local inhabitants and the city as a whole.

6.1.3 Mediterranean Village

A one and two storey Mediterranean "village" scheme is proposed for Precinct 2. The "village" style housing project should be in three separate development areas occupying small, scenic valleys which front on to the ocean. Each area would be separated by sandhills and have its own individual entrance point.

Permanent tenancies and rental housing are suggested for the "village" with house locations situated to conform to the pattern of contours within the valley. The house design with their close proximity to one another would resemble Mediterranean village architecture but be in harmony with the Western Australian coastal location. One or more of the development areas could be designed as a townhouse complex. Fig. 8 gives an impression of the "village concept.

6.1.4 Features of Particular Interest

Scattered throughout Mindarie are various features such as disused limestone quarries or old lime kilns. These could be developed for a variety of community and recreational uses. The quarries may be used as local parks and picnic sites or be developed as tiered gardens. The lime kilns could provide a focal point and perhaps be the basis for a local museum, an art gallery, or a public kiosk. Serious consideration of the potential use of these features will be undertaken in future planning design.

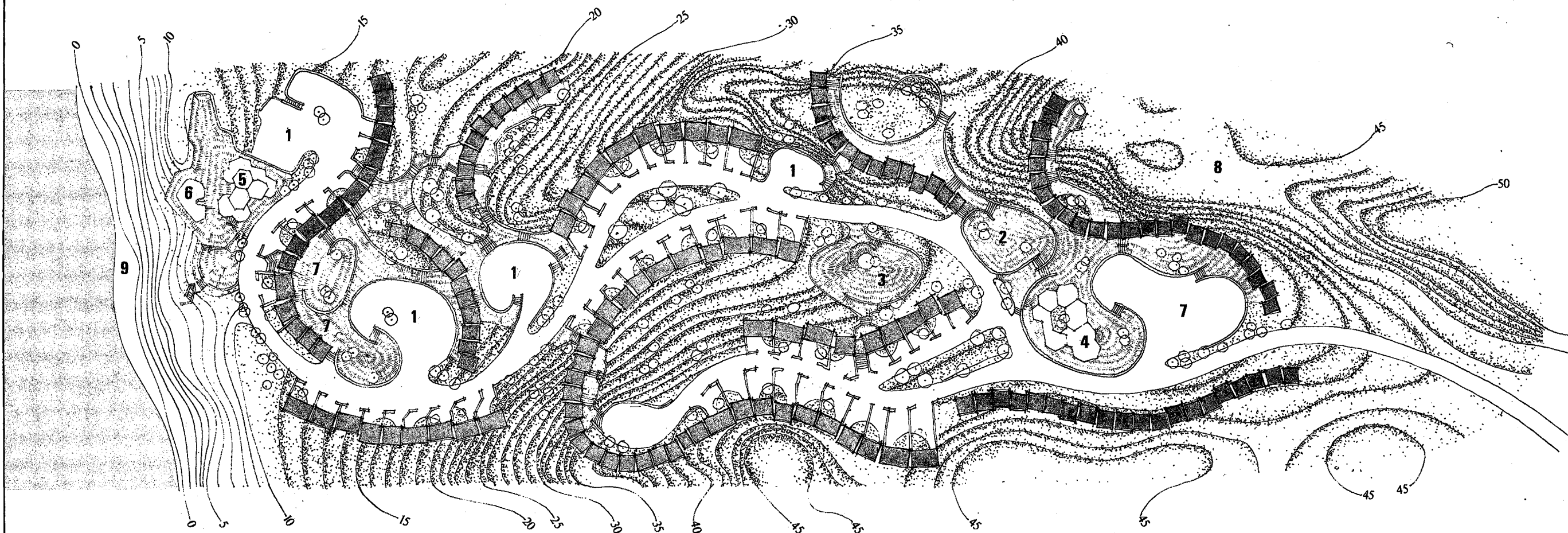
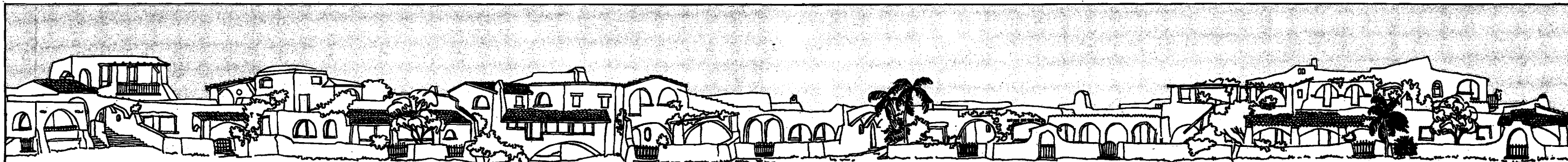


Fig. 8

LEGEND;

- 1 Parking
- 2 Look Out
- 3 Playground
- 4 Community & Shopping Centre
- 5 Restaurant & Night Club
- 6 Swimming Pool
- 7 Cafe-Bar & Shops
- 8 Tennis Courts Area
- 9 Beach

0m 50m 100m 150m 200m

MINDARIE DEVELOPMENT
1&2 STOREY TOWNHOUSES SCHEME

URBAN SYSTEMS CORPORATION PTY LTD
May 1973

One storey dw/unit number 60 = 240 people
Two storey dw/unit number 100 = 400 people
total 160 = 640 people

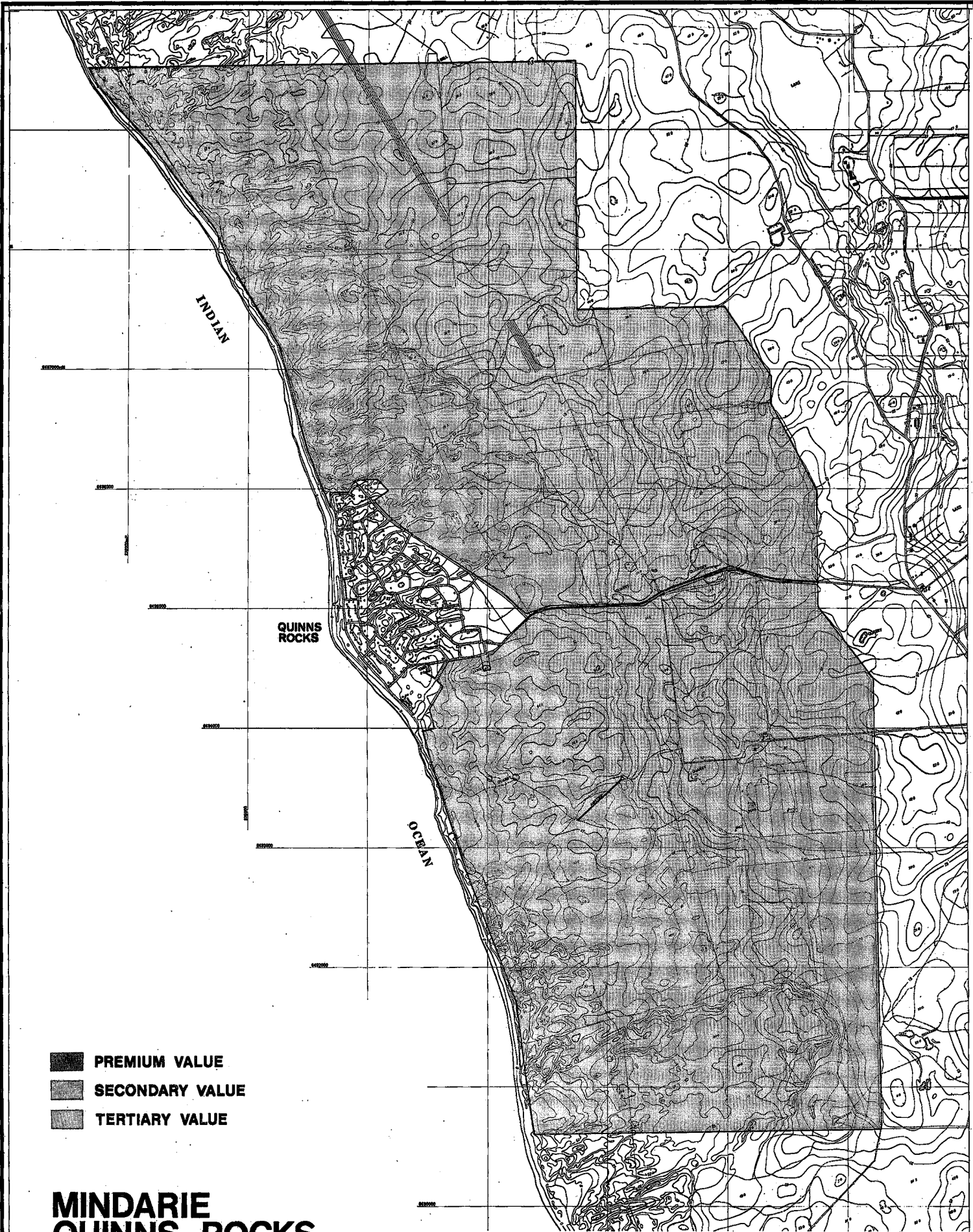
6.2 DEVELOPMENT RATING

A development rating has been derived to allocate a land quality value to the residential precincts. It was arrived at by value judgements based on the scientific factors employed in the urbanization composite, (Fig. 3C) combined with an assessment of the value of the land in relation to likely public demand for coastal sites. Historically, coastal land has always been in high demand, with the result that it is quickly developed and more valuable for housing development.

The relative market potentials of the coastal and inland areas are presented in Fig. 9. Land value generally tends to decrease in proportion to distance from the coast, unless this is offset by other attractions. The premium land in Mindarie tends to be that nearest the coast with consequent scenic views. A secondary value has been given to land further away from the coast but with isolated sea views or attractive woodland areas, while a tertiary value is allotted to all other land.

Using the potential market value and the urbanization composite factor, a scale ranging from "A" to "D" has been selected. A rating of "A" refers to the highest quality land, having good market potential, while land rated "D", although generally suitable for development, is less attractive from a physical and market point of view.

The development rating of the precincts is shown in Fig. 10 and represents the final ranking of precincts for development. This rating will serve as a consideration in the staging proposals for the area.



- PREMIUM VALUE
- SECONDARY VALUE
- TERTIARY VALUE

MINDARIE QUINNS ROCKS

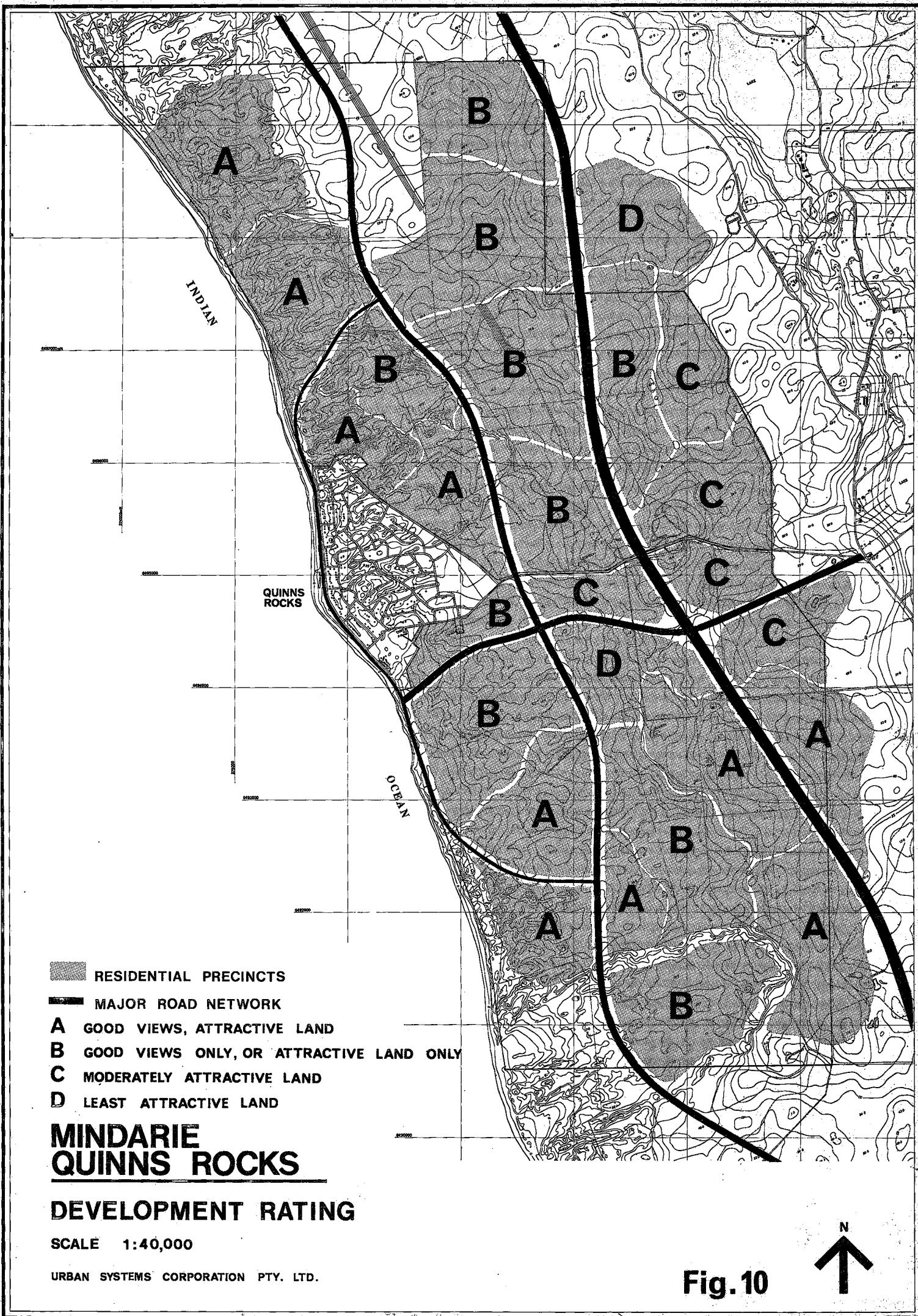
LAND MARKET VALUE

SCALE 1:40,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 9





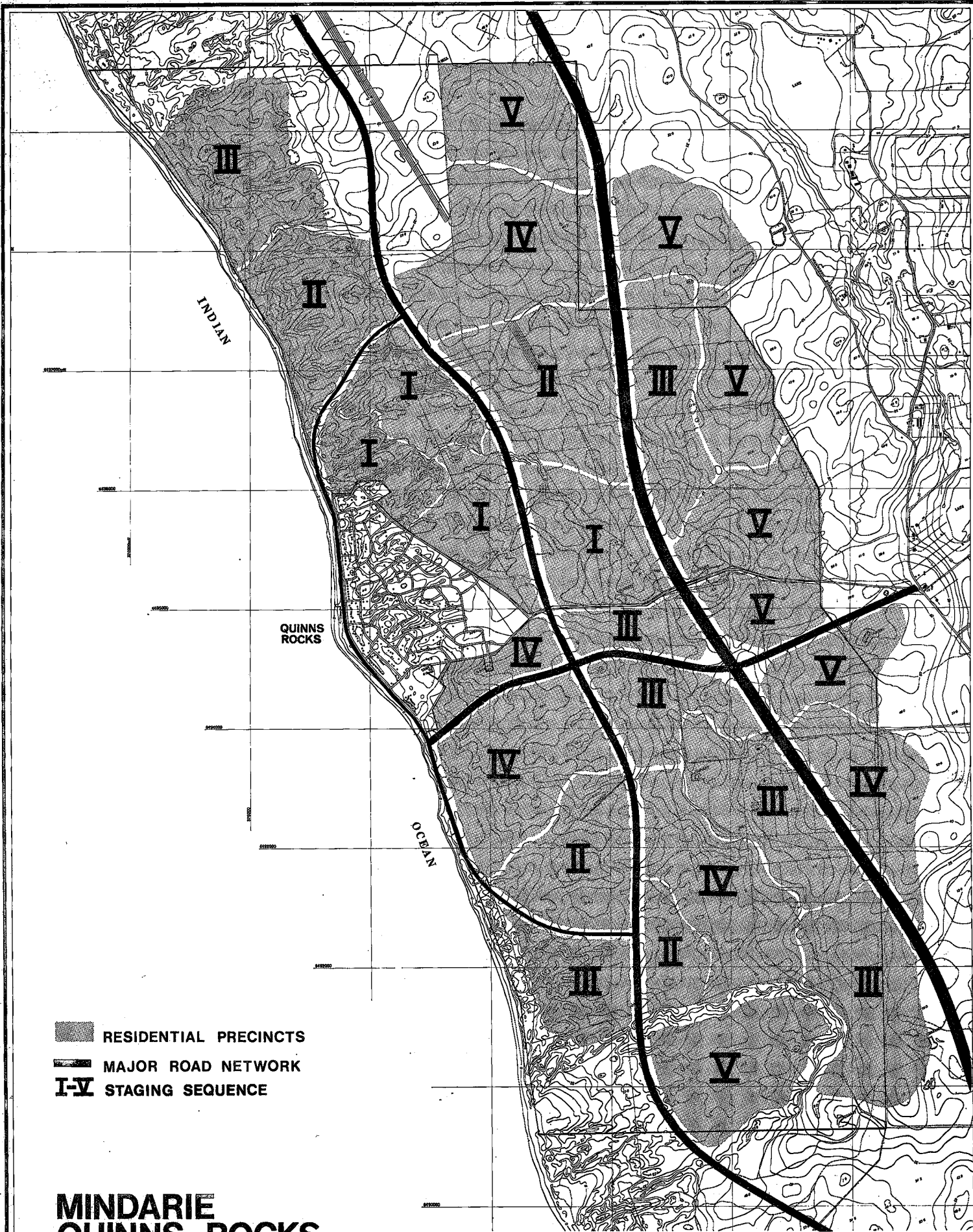
6.3 STAGING



A sequence of development for Mindarie has been proposed in response to the expected demand for coastal, residential land. A balanced programme of development is advocated for the provision of residential land both directly on the coast and further inland. This can be achieved through the development of precincts of different character proceeding independently and simultaneously.

Five stages of development are proposed for Mindarie (Fig.11). The first stage of development will occur as an extension of present settlement, where road access is already established. Thus, the first areas for development would be Precincts 3, 4, 5 and 17, north of the existing Quinns Rocks Road. Precincts 4 and 5 having "A" development ratings provide scenic ocean views whereas Precinct 3, with a "B" development rating has only limited ocean views due to its easterly slopes. Precinct 17 will be the first stage of the residential/golf course subdivision. This stage will promote the building of Marmion Avenue to the north and south of Quinns Rocks for ease of servicing the subsequent stages of development.

Stage II is a logical extension of settlement to achieve balanced development of coastal and inland areas, and includes Precincts 2, 8, 12 and 18. The remaining stages of development are shown in Fig. 11 but are more tentative in sequence and will be subject to later re-appraisal as development requirements are modified with time.

Following the growth of residential settlement, commercial and social facilities will be established at appropriate stages of development. Open space will be progressively dedicated as the areas are subdivided and will help to define the development of visual identifiable precincts.



 RESIDENTIAL PRECINCTS
 MAJOR ROAD NETWORK
I-V STAGING SEQUENCE

MINDARIE QUINNS ROCKS

STAGING PLAN

SCALE 1:40,000

URBAN SYSTEMS CORPORATION PTY. LTD.

Fig. 11



**MINDARIE
ENVIRONMENTAL CITY**

APPENDIX A

**PRESENTED TO
CLARKE GAZZARD PLANNERS
AS PART OF A STUDY FOR
DEVELOPMENT UNDERWRITING LIMITED**

**ENVIRONMENTAL RESOURCES OF AUSTRALIA
MAY 1973**

APPENDIX A

TABLE OF CONTENTS

	Page No.
1. INTRODUCTION	A1
2. CLIMATE	A1
2.1 General Controlling Factors	A1
2.2 Precipitation	A2
2.3 Temperature	A2
2.3.1 Yearly Temperature Regime	A2
2.3.2 Topographic Effects on Temperature	A2
2.4 Wind	A4
2.4.1 Yearly Wind Pattern	A4
2.4.2 Effect of Topography on Local Winds	A4
2.5 Incidence of Sea Breeze and Salt	A6
3. GEOMORPHOLOGY AND SOILS	A6
3.1 Regional Setting	A6
3.2 Pedo-geomorphic Classification	A7
3.3 Environmental Assessment of Physiographic Factors	A9
3.3.1 Features of Unique Value	A9
3.3.2 Ease of Servicing	A9
3.3.3 Wind and Wave Erosion	A9
3.3.4 Soil Drainage	A9
4. VEGETATION	A10
4.1 Vegetation Formations of Mindarie	A10
4.1.1 Primary Colonising Plants	A10
4.1.2 Sand Heath (Open)	A10
4.1.3 Capstone Heath (Closed)	A10
4.1.4 Low Open Woodland	A11
4.1.5 Woodland and Parkland	A11
4.2 The Flora of Mindarie	A11
4.2.1 Primary Colonisers	A11
4.2.2 Sand Dunes	A12
4.2.3 Sand Dune Heath	A12
4.2.4 Capstone Heath	A13
4.2.5 Banksia Association	A13
4.2.6 Tuart Association on Yellow-Brown Sand	A14
5. WILDLIFE HABITATS	A14
5.1 Areas Most Suitable for Fauna Reserves	A15
5.2 Small Fauna and Wildflower Reserves	A16
5.3 Areas Unsuitable for Fauna or Flora Reserves	A18
6. PLANNING AND ENGINEERING IMPLICATIONS	A19
6.1 Coastline	A19
6.2 Foredunes	A19
6.3 Poorly Stabilized Dunes	A19
6.4 Inter-Dunal Swales	A20
6.5 Capstone	A20
6.6 Sandy Hollows	A20
6.7 Sandy Undulating Terrain	A20
6.8 Minor Features	A21
BIBLIOGRAPHY	A21
SPECIES LIST	A22

LIST OF FIGURES

FIGURE		Following Page
A1	Average monthly (A) and effective (E) rainfall at Yanchep	A2
A2	Location of temperature and wind recording stations, Mindarie	A4
A3	Pedo-geomorphic classification, Mindarie	A7
A4	Unconsolidated calcareous sand — Profile 1.	A8
A5	Partly consolidated calcareous sands — Profiles 2, 3 & 4.	A8
A6	Calcareous sands — Profiles 5, 6 & 7.	A8
A7	Sandy Hollows — Profiles 8, 9 & 10.	A9
A8	Yellow-Brown leached sands — Profiles 11, 12 & 13.	A9
A9	Yellow-Brown leached sands — Profiles 14, 15 & 16.	A9
A10	Vegetation distribution, Mindarie.	A10
A11	Landsystems , Mindarie.	A19

LIST OF TABLES

TABLE		Page
1.	Average and extreme monthly rainfall (in points), Fremantle.	A3
2.	Monthly mean and extreme maximum and minimum temperatures, Fremantle.	A3
3.	Overnight temperature records at Mindarie, 29th to 30th March, 1973.	A5
4.	Wind Speed and direction in the sand dunes at Mindarie.	A6
5.	The relationship between geological formations, geomorphic elements and soil associations of Mindarie.	A7

LIST OF PLATES

PLATE		Page
1.	Banksia woodland on calcareous sand, with the blackboy line around the woodland formation.	A13
2.	A band of banksia woodland in a valley between sandhills in the northern sector of Mindarie.	A15
3.	Groupings of Nuytsia floribunda (Xmas tree), Banksia and blackboys in pasture adjacent to coral in northern sector of Mindarie.	A17
4.	Group of Eucalyptus tottiana, Banksia mensiesii and blackboy in pasture on a low sandy ridge.	A17

INTRODUCTION

This report has been prepared for Clarke Gazzard Planners to assist them in their planning of the Mindarie Environmental City for Development Underwriting Limited. It was commissioned to give the planners a description and an assessment of the environmental parameters at Mindarie.

Mindarie has a coastal frontage and as such is situated in a politically and environmentally contentious location. Therefore, a thorough documentation and understanding of the environment was required before planning and development could proceed.

The climate, pedo-geomorphic terrain, vegetation and wildlife habitats of Mindarie are discussed and evaluated in separated chapters.

The final section classifies Mindarie into landsystems which are areas categorised on the basis of inter-relationship between climate, geomorphology, pedology and vegetation. This allows examination of the landscape in terms of distinct units, instead of separate physical and biotic features. These landsystems are discussed with reference to planning and engineering implications.

The report therefore provides the planners not only with a documentation and evaluation of the environment at Mindarie, but in the final section it sets out guidelines for planning policy.

CLIMATE*

2.1 GENERAL CONTROLLING FACTORS

The climate of Mindarie is mainly governed by the movement of the anti-cyclonic belt which migrates west to east off the south coast of Australia.

In summer, the centre of this belt is off the south coast, and easterly winds prevail. As cells within the anti-cyclonic belt move eastward, a low pressure trough extends southward from the tropics between them, causing winds to back north and bring air from central and northern Australia. When these troughs move inland, the hot northerlies preceding them are replaced by cool southwesterlies from the new anti-cyclone moving eastwards from the Indian Ocean. Over the next few days, the southwesterly winds back through south to east, and the cycle recommences as the anti-cyclone centre moves further eastward.

A reliable southwesterly sea breeze brings relief from high temperatures on most summer afternoons. It is most effective near the coast, but usually extends over the metropolitan area. Largely because of this, the average wind speed is higher in summer than at any other time of the year.

As the year progresses, the anti-cyclonic belt moves northward, and by mid-March the change towards autumn conditions becomes apparent.

In the winter months of June, July and August, depressions originating in the Indian or Southern Ocean pass close to Cape Leeuwin and sometimes bring westerly gales to Mindarie. During these months the anti-cyclonic belt lies over the southern half of Western Australia, so that Mindarie is often in the area of light pressure gradients. Despite the occurrence of occasional winter gales, the average wind speed is lower than at any other time of the year.

Further on in the year, the anti-cyclonic system gradually moves southward again, and the southern depressions affect the area less and less. In consequence rainfall decreases, and by December, dry summer conditions and the easterly wind pattern are established again.

Unusual weather is experienced occasionally in summer due to the influence of tropical cyclones. When they are some considerable distance away, they may still dominate the weather pattern, causing calm winds associated with high temperature and humidity. At times, these cyclones may travel southward close to Mindarie, accompanied by rain, strong winds, and a drop in temperature.

* Bureau of Meteorology (1969)

2.2 PRECIPITATION

The mean annual rainfall of Mindarie is 31 inches (Bureau of Meteorology, 1969. p 81). Although rainfall is reasonably reliable, there are quite large differences between the highest and lowest annual totals. At Fremantle the extremes range from 1630 to 4638 points.

There is a marked variation in average monthly rainfall during the year (Table 1). The wettest six monthly period is from May to October inclusive. This corresponds roughly to the growing period during which plants will grow without artificial watering and amounts to about 85% of the annual rainfall total. Figure A1 shows the effective rainfall for Yanchep (12 miles north of Mindarie), where 'A' is mean monthly rainfall and 'E' is mean monthly evaporation.

As the soil is very porous, flooding will not occur in Mindarie.

No snow has been officially recorded in the Perth metropolitan area and it is highly unlikely that it ever will fall at Mindarie. Hail is only recorded at the Perth Weather Bureau. Recordings from this centre show that on the average, hail occurs less than once per month in winter. It is often small and soft and usually causes no damage.

Fog and smog are of rare occurrence at Mindarie.

2.3 TEMPERATURE

The yearly temperature regime is firstly discussed in this section. This is followed by an examination of the local topographic effects on temperature.

2.3.1 Yearly Temperature Regime

Mean maximum temperature at Perth ranges from 29.4°C (85.5°F) in February to 16.9°C (62.8°F) in July, and has been recorded over a range of 17.8°C (64.4°F), from 44.1°C (112.2°F) in February to 8.7°C (47.8°F) in June. Average minimum temperature at Perth varies between 17.5°C (63.8°F) in February to 8.7°C (47.9°F) in July, extending over extremes of 29.0°C (84.8°F) in February to 1.2°C (34.2°F) in July.

As Mindarie is closer to moderating oceanic temperature effects than Perth, the extremes in temperature range would not be as great. However, the mean maximum and minimum temperatures would only vary by one or two degrees. This is demonstrated by the mean maximum temperatures recorded at Fremantle and Perth, which are 21.7°C (71.4°F) and 22.9°C (73.6°F) respectively. The mean minimum temperatures are 13.8°C (57.1°F) and 12.9°C (55.4°F) respectively.

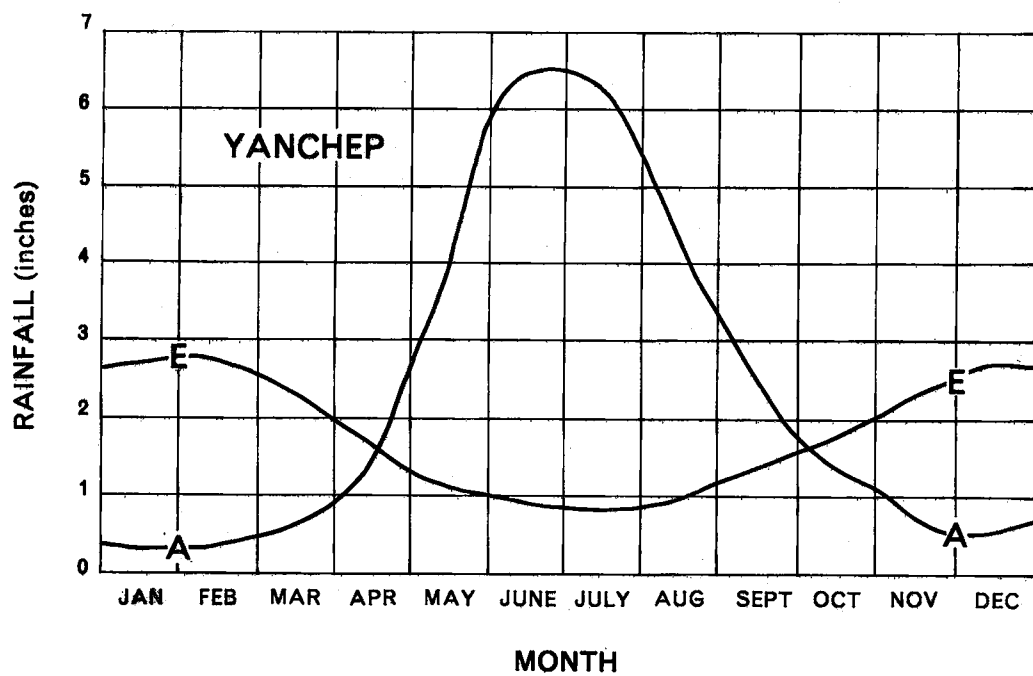
The mean and extreme maximum and minimum temperatures for each month recorded at Fremantle are listed in Table 2.

2.3.2 Topographic Effects on Temperature

There is an increase in maximum temperature and a decrease in minimum temperature with distance from the coast. This effect is evident even over the short width of Mindarie.

A study showed that at 1600 hours on 29th March, 1973, the temperature two metres above the first dune line at Quinns Rocks beach was 29.0°C. Meanwhile, at the eastern boundary of the Estate, along Quinns Beach Road, the temperature two metres above the soil was 31.1°C. *made*

A further study was done overnight at Mindarie on the 29th and 30th March, 1973, to investigate temperature variations with topography and exposure. In this study, four thermisters were set up one metre above the ground and linked so the temperature could be recorded simultaneously. Figure A2 shows the location and height above sea-level of these thermisters.



AVERAGE MONTHLY (A) AND EFFECTIVE (E) RAINFALL AT YANCIEP

FIG A1

TABLE 1

AVERAGE AND EXTREME MONTHLY RAINFALL (IN POINTS), FREMANTLE

Fremantle	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YEAR
Mean	27	38	65	139	446	659	611	477	273	172	70	48	3025
Highest	123	386	419	609	1331	1358	1325	994	655	693	258	308	4638
Lowest	0	0	0	0	0	150	212	63	0	0	0	0	1630

Source: Bureau of Meteorology, 1969, p 83.

TABLE 2

MONTHLY MEAN AND EXTREME MAXIMUM AND MINIMUM TEMPERATURES, FREMANTLE

Fremantle	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	YEAR
Mean Max°C	27.0	27.4	25.9	23.6	20.2	18.0	17.0	17.2	18.3	20.0	22.9	25.2	21.9
Highest Max°C	42.7	42.8	41.7	36.1	29.3	28.0	25.1	26.5	33.5	34.1	39.5	40.0	42.8
Mean Min°C	17.9	18.1	16.9	15.1	12.8	11.2	10.2	10.4	11.3	12.5	14.7	16.6	14.0
Lowest Min°C	8.3	8.3	6.8	5.6	3.1	2.8	2.8	3.1	4.2	3.8	5.8	4.7	2.8

Source: Bureau of Meteorology, 1969.

The results of this study are listed in Table 3. From this table it can be seen that during late afternoon and early evening, the air above the land surface has little temperature variation. However, on calm nights, differential cooling takes place so that air in lower areas is significantly cooler than that above the dune ridges. This is clearly seen when the temperatures at midnight are examined, for air in the valley was 10°C, while above the highest ridge it was 15°C.

During early morning, the temperature variation was not as significant, as wind mixed the various local air masses. The moderating influence of the ocean was seen immediately after dawn, for thermister 2 (closest to the ocean) recorded a slightly higher temperature than did the other thermisters.

From this study it can be seen that in the dunes at Mindarie during the day, variation in temperature over the land-surface is insignificant. However, during calm nights, a significant temperature inversion does occur.

2.4 WIND

2.4.1 Yearly Wind Pattern

Inadequate

Throughout the year in the mornings, winds with an easterly component prevail, and again after 2100 hours at night in the May to September period. In the afternoons, winds with a southerly component prevail during the year, but there is a westerly tendency during winter (June — August).

This situation is largely due to the development of the land breeze during the night in the colder months and the afternoon sea breeze during the warmer part of the year. However, even without the south-westerly sea breeze of summer, a southerly component would prevail, as the average pressure gradient at this time of the year produces southeasterly winds. In winter, the northeasterly land breeze is often very shallow, and the main wind flow above it is from the west. Because of this, afternoon winds following the fade out of the land breeze most frequently occur from between northwest and southwest at this time of the year.

*See
earlier
comment*

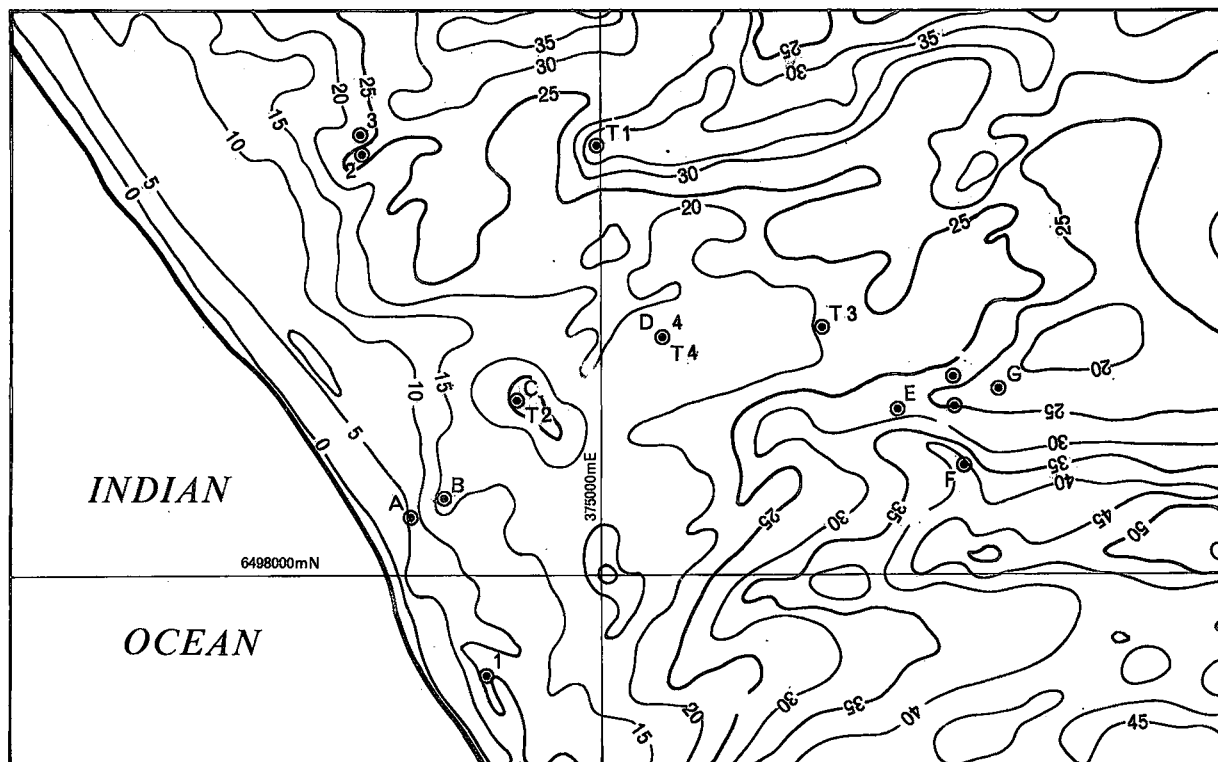
This pattern is varied by the development of a very reliable sea breeze in the afternoons of the warmer part of the year. The breeze often sets in before midday in summer at Mindarie, but arrives later in the cooler months and does not develop at all during most of winter.

2.4.2 Effect of Topography on Local Winds

The effect of topography on local wind speed was clearly demonstrated in two studies. The prevailing wind direction was different during each study.

These investigations were conducted using a four-wheel drive vehicle to convey an anemometer between recording stations. Another anemometer was established as a base station and observations recorded here were used to calibrate those recorded by the mobile anemometer. Figure A2 shows the location of the wind recording stations, and the wind speed and direction are listed in Table 4.

This study determined that wind speed is drastically reduced behind the shelter of high dunes, and with distance away from the coast.



SCALE 1:10,000

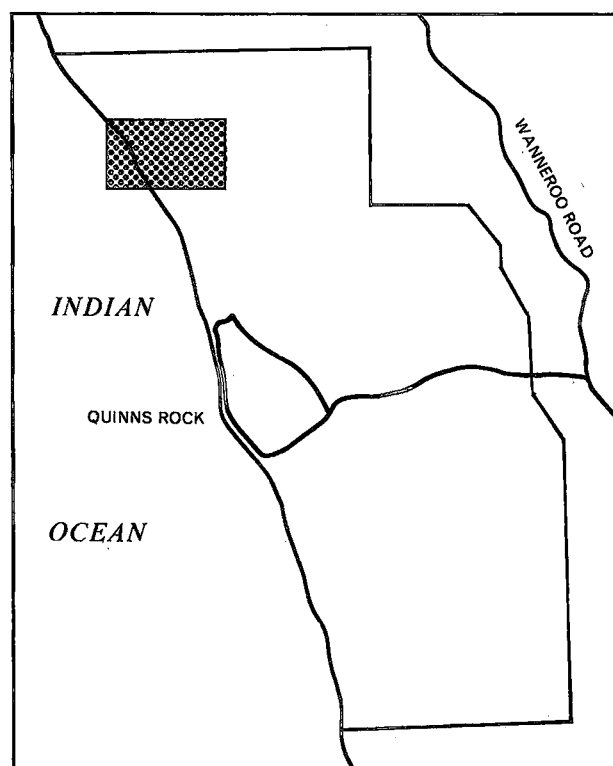
TEMPERATURE STATIONS 29-30th MARCH 1973

Thermistors Height (metres) Distance from Coast (metres)

T 1	46	550
T 2	33	260
T 3	19	620
T 4	16	440

WIND RECORDING STATIONS

Station	Date
1	26/3/73
2	26/3/73
3	26/3/73
4	26/3/73
5	26/3/73
6	26/3/73
A	29/3/73
B	29/3/73
C	29/3/73
D	29/3/73
E	29/3/73
F	29/3/73
G	29/3/73



LOCALITY DIAGRAM

SCALE 1:100,000

LOCATION OF TEMPERATURE AND WIND RECORDING STATIONS AT MINDARIE

TABLE 3
OVERNIGHT TEMPERATURE RECORDINGS AT MINDARIE
29th TO 30th MARCH, 1973

Time	T 1°C	T 2°C	T 3°C	T 4°C	Wind Direction	Wind Speed (m.p.h.)
1830	21.0	21.7	21.0	21.0	—	00
1900	20.0	20.6	20.5	20.3	—	00
1930	19.7	19.5	19.7	19.7	—	00
2000	18.5	19.0	19.0	17.0	E	0 — 5
2030	18.0	17.7	18.2	17.5	SE	0 — 5
2100	17.3	17.0	17.0	14.3	—	00
2130	17.0	15.5	17.2	13.3	—	00
2200	16.1	14.5	15.0	12.0	E	0 — 3
2300	16.1	14.0	14.0	11.1	E	0 — 3
0000	15.0	13.6	14.0	10.0	—	00
0100	15.3	14.7	14.0	11.2	—	00
0200	15.3	15.5	14.0	12.5	E	0 — 5
0500	14.2	15.5	13.5	14.5	E	5 — 8
0530	14.2	15.2	13.5	14.5	E	5 — 10
^{Dawn} 0600	14.3	15.5	13.0	14.5	E	5 — 12
0700	15.3	16.6	14.0	15.7	ENE	5 — 15
0800	17.5	18.7	15.5	17.5	ENE	5 — 10

26th MARCH, 1973

Station	Position	(metres/min.)	Direction
1.	Exposed, near beach.	349	SW
2.	Exposed, high dune.	402	SW
3.	In swale, immediately behind (2).	215	SW
4.	Sheltered swale.	241	Variable
5.	Sheltered narrow valley.	107	SW
6.	On low dune, inland.	349	SW

29th MARCH, 1973

Station	Position	(metres/min.)	Direction
A.	Sheltered low, near beach.	241	S
B.	High, near beach.	375	SSE
C.	Exposed ridge.	536	SSE
D.	Sheltered swale.	241	E
E.	Higher ground, but sheltered behind dune.	241	E
F.	On high dune, inland from coast.	402	ESE
G.	Sheltered narrow valley.	215	E

TABLE 4

WIND SPEED AND DIRECTION IN
THE SAND DUNES AT MINDARIE.

2.5 INCIDENCE OF SEA BREEZE AND SALT

An evaluation was made of the incidence of sea breeze speed and airborne salt content as these factors affect living conditions, building materials and re-vegetation projects. This evaluation was based on topographic exposure and observation of vegetation features such as species distribution, height and form.

Any evaluation must be extremely general, for great differences, depending on exposure, occur in salt deposition and salt intake by plants. Further and more detailed studies may be required in localised areas before any re-vegetation programmes are undertaken.

3 GEOMORPHOLOGY AND SOILS

3.1 REGIONAL SETTING

Mindarie is situated on part of a homogeneous landscape termed by Gentilli and Fairbridge (1951), as the Swan Coastal Plain. The section of the plain occupied by Mindarie is built up from aeolian (wind) sediments of marine origin. No fluvial or lacustrine sediments are found as water flow is all sub-surface.

Geologically, Mindarie consists of Safety Bay Sands and Coastal Limestone (Seddon, 1972). The Safety Bay Sand has been termed the Quindalup Dune System while the Coastal Limestone has been termed the Spearwood Dune System by geomorphologists (McArthur and Bettenay, 1960). Pedologically, the Quindalup Dune System has been discussed as the Quindalup Soil Association, while the Spearwood Dune System has been sub-divided into the Cottesloe and Karrakatta Soil

Associations (Bettenay, McArthur and Hingston, 1960). Table 5 lists the relationship between geological formations, geomorphic elements and soil associations of Mindarie.

Geological Formation	Geomorphic Element	Soil Association
Safety Bay Sand Coastal Limestone	Quindalup Dune System Spearwood Dune System	Quindalup Cottesloe Karrakatta

TABLE 5
THE RELATIONSHIP BETWEEN GEOLOGICAL FORMATIONS,
GEOMORPHIC ELEMENTS AND SOIL ASSOCIATIONS OF MINDARIE

Seddon (1972) groups these categories and terms them landforms in his introductory discussion. These landforms are known as the Quindalup Dune System and the Spearwood Dune System. Broadly, these dune systems are as follows:

(1) Quindalup Dune System

This system consists of the calcareous sands forming along the coastline at present. These unconsolidated sands are low in soluble salts and high in lime content. The extent of leaching is usually only slight, although there may be some cementing of the lower layers as dissolved lime from surface layers is redeposited at depth. Very little soil profile development has taken place, apart from a weakly developed A₁ (humus) horizon. In Mindarie, these sands generally occur as parabolic dunes, extending to a height of 30-40 metres. The interdunal soils show some evidence of organic matter accumulation due to the burying of vegetation by blowing sands.

(2) Spearwood Dune System

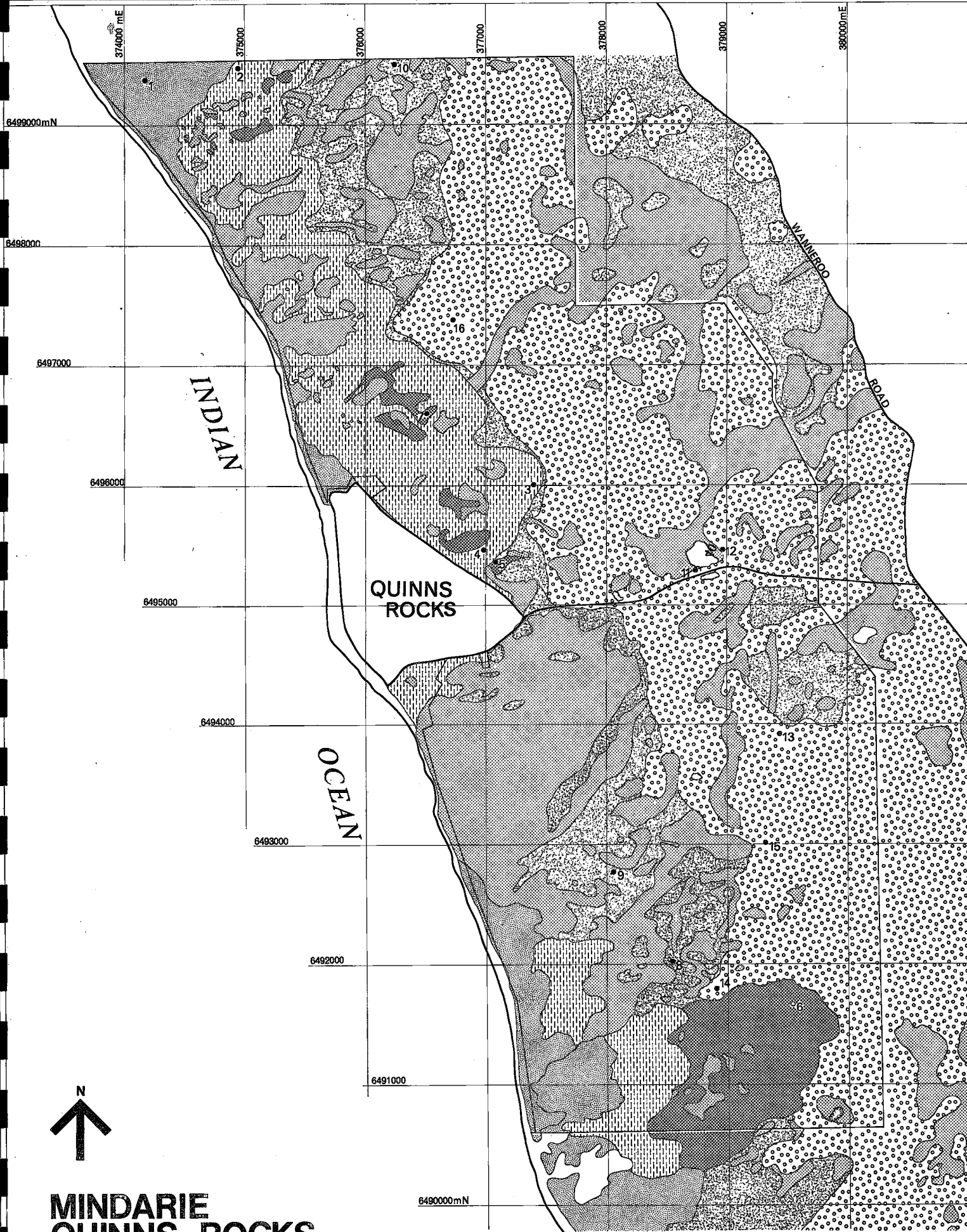
This system has higher topography than the Quindalup Dune System and the soils are weakly leached, with less lime content. Carbonate has been reprecipitated below to form layers and columns of hard compact material. The yellow and brown soil colour shows that these sands have an appreciable iron content.

Two soil types are distinguished, the shallow Cottesloe, which is closer to the coast, and the deep Karrakatta. The depth of the Karrakatta soils can partly be accounted for by leaching of the older dunes and partly by accessions of wind-blown sand from the Cottesloe Association. This deflation of the Cottesloe soils sometimes exposes hard capstone and the aeolianite core to the surface. Further west in the Karrakatta Association, the limestone may be close to the surface on higher ground or it may penetrate the surface as pinnacles, while in the lower areas it is buried at depth.

3.2 PEDO-GEOMORPHIC CLASSIFICATION

Agree

The landform classifications by Seddon (1972) of Quindalup and Spearwood are too broad to allow detailed planning and engineering considerations, or re-vegetation studies. The Quindalup Dune System can be sub-divided into several categories, depending on consolidation, topography and the development of the humus (A₁) soil horizon. The Cottesloe and Karrakatta Soil Associations are difficult to distinguish from aerial photography or by ground survey, for the general east to west trend discussed by McArthur and Bettenay (1960) and Bettenay, et. al. (1960) was not recognised in Mindarie. Instead, these soil associations varied more according to topography than distance inland.



MINDARIE QUINNS ROCKS

PEDO-GEOMORPHIC
CLASSIFICATION FIG A3

SCALE 1: 40,000

URBAN SYSTEMS CORPORATION PTY. LTD.
ENVIRONMENTAL RESOURCES OF AUSTRALIA



UNCONSOLIDATED
CALCAREOUS SANDS

KANKAR

PARTLY CONSOLIDATED
CALCAREOUS SANDS



CONSOLIDATED SANDS

SANDY HOLLOW

YELLOW-BROWN SANDS

The classification presented here is based on pedo-geomorphic features, including topography, soil pH, amount of observable free calcium, degree of lithification (hardening of material into aeolianite or kankar), the development of the humus soil horizon, and the soil colour (from Standard Soil Colour Charts) which gives an indication as to the amount of leaching. The classification is shown in Figure A3. Sixteen pits were dug to examine the soil and their locations are also shown in Figure A3.

The classification is as follows:—

- | | | | |
|-----|--------|---|--|
| (1) | U.C.S. | — | Unconsolidated Calcareous sands |
| (2) | P.C.S. | — | Partly - consolidated calcareous sands |
| (3) | C.S. | — | Calcareous sands |
| (4) | K | — | Kankar |
| (5) | S.H. | — | Sandy Hollows |
| (6) | Y.B.S. | — | Yellow/brown leached sands. |

(1) Unconsolidated Calcareous Sands

These are found along the coastline and may take the form of blowouts or poorly vegetated sand dunes. The sands have little or no soil profile development, are alkaline, and light grey or yellow in colour with no sign of leaching. Profile 1 is representative of this group (Figure A4).

(2) Partly Consolidated Calcareous Sands

These dunes are immediately inland of the unconsolidated calcareous sands and are still alkaline. A poorly developed, grey A₁ horizon exists without any structure and the vegetation cover is thicker. Profiles 2, 3, and 4 (Figure A5) are typical of soils found in this group.

(3) Calcareous Sands

These occur in swales between the dune ridges, or inland from the P.C.S. group. The A₁ horizon is better developed, showing a brownish grey/black soil down to 60 centimetres, with a poor blocky structure. The soil pH is neutral to weakly acidic, and some leaching of iron has occurred down the profile, indicated by the dull reddish brown soil colour.

Profile 5 (Figure A6) was dug in a small swale surrounded by partly consolidated calcareous dunes. Vegetation has been buried and decomposed to form a deep brownish black A₁ horizon. The humic acid has removed most of the calcareous material further down the profile, accounting for the absence of observable free calcium in the top 120 centimetres of soil.

Profiles 6 and 7 (Figure A6) also illustrate soils that occur within this classification.

The above three categories were all grouped previously into the Quindalup Dune System.

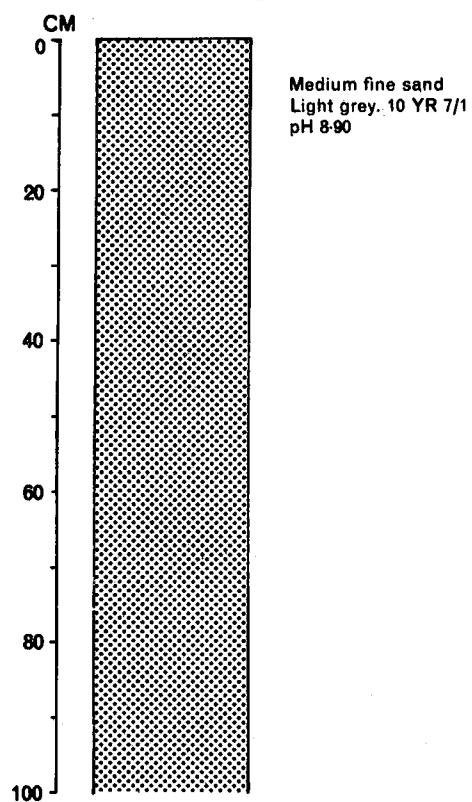
(4) Kankar

Surface outcrops of capstone (Kankar), limestone just below the surface, or lime pinnacles attached to capstone or aeolianite below the surface, fall into this category. In the areas of calcareous sands, the capstone generally is found in the lower topography, as it has been exposed by deflation (aeolian removal of sand). Beyond the calcareous sands, this capstone normally is found in higher areas, as the sands around it have been removed or consolidated.

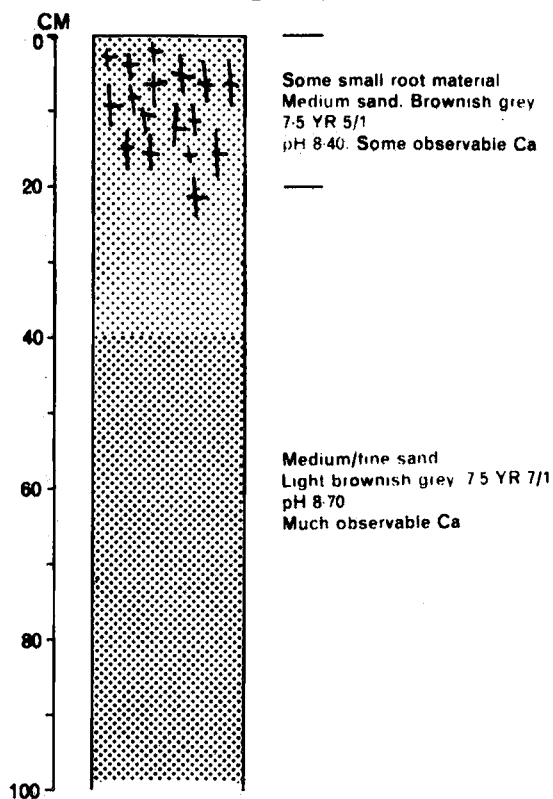
(5) Sandy Hollows

These are partly leached sands, with little or no observable free calcium in the top soil, and occur in small swales. They bury the surrounding kankar, which retains the infiltrated

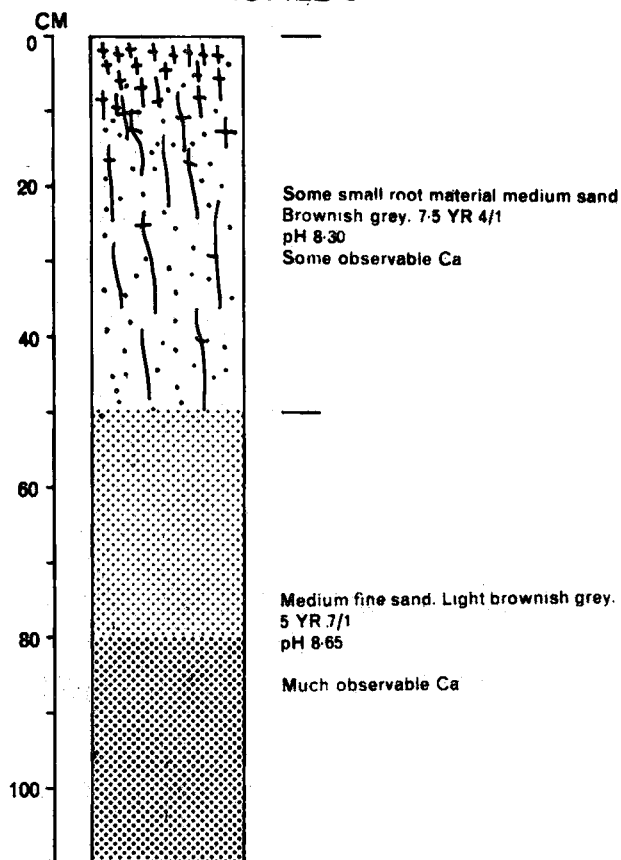
PROFILE 1



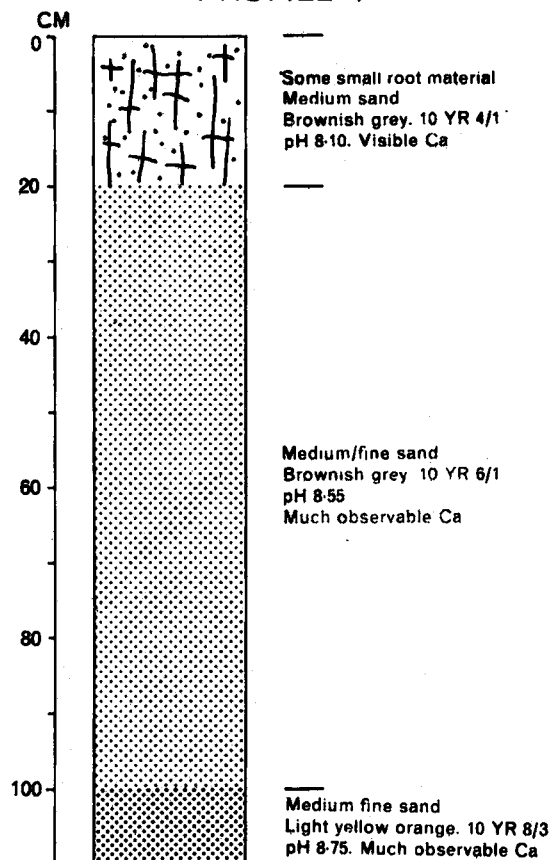
PROFILE 2



PROFILE 3



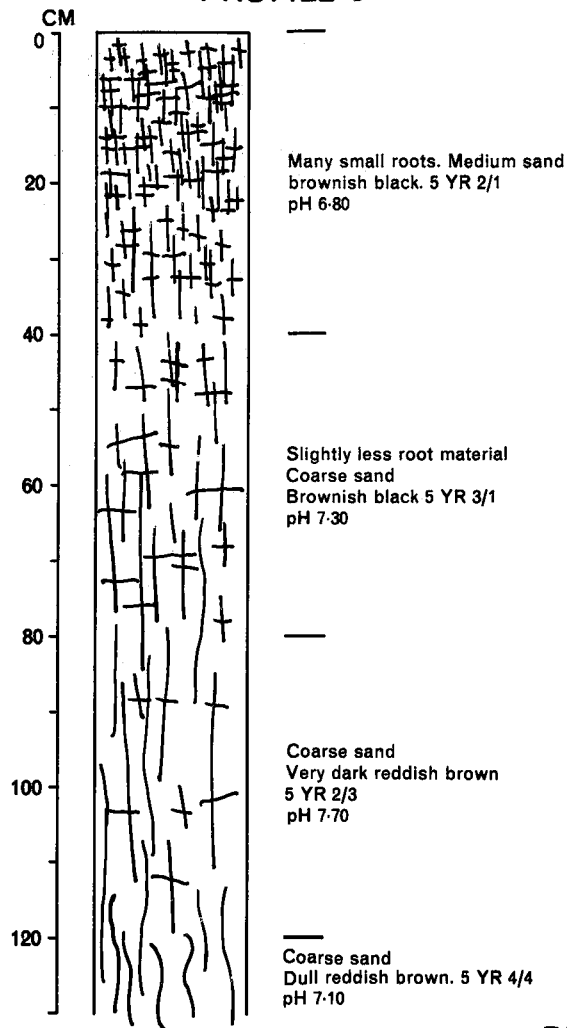
PROFILE 4



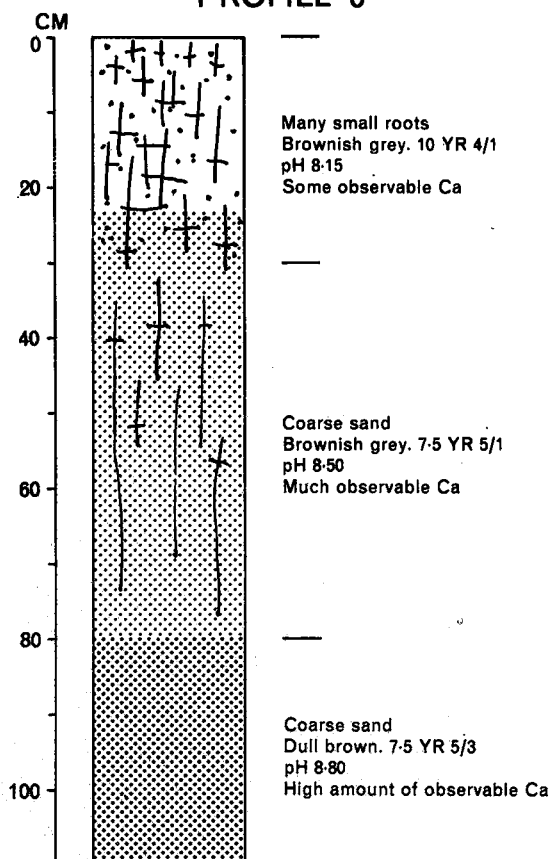
PARTLY CONSOLIDATED CALCREOUS SANDS

FIG A5

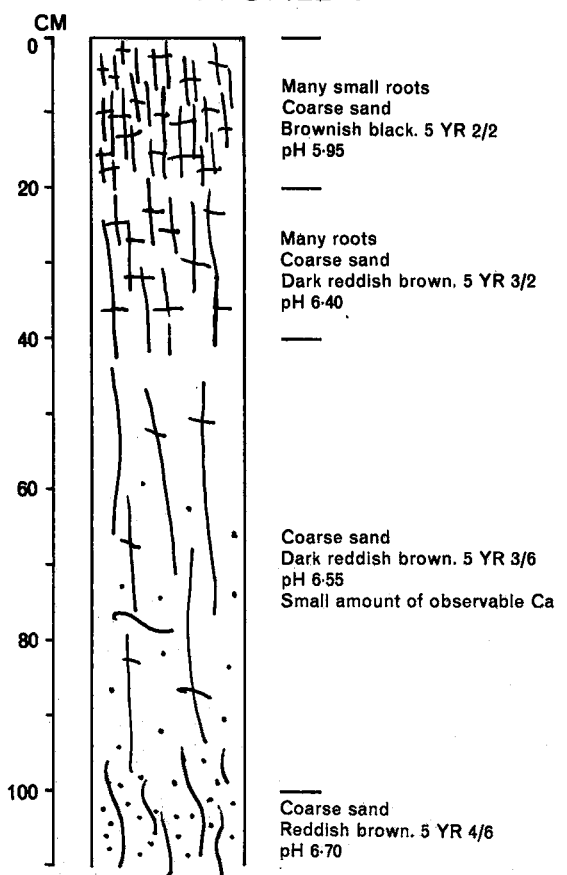
PROFILE 5



PROFILE 6



PROFILE 7



water, causing the soil to remain moist. The soil pH is neutral to slightly acidic. Soil development has occurred with a brownish grey A₁ horizon extending to 20 centimetres, followed by a bright reddish brown soil, indicating leaching of iron down the profile. This classification is represented by Profiles 8, 9 and 10 (Figure A7).

(6) **Yellow/Brown Leached Sands**

This group combines the Cottesloe and Karrakatta Soil Associations. A brownish grey A₁ horizon, sometimes weakly structured, extends to a depth of 20 to 40 centimetres. Below this, a bright reddish brown to light yellow orange sand, neutral to weakly acid is found. This overlies aeolianite or capstone one to ten metres below the surface, depending on topography.

Profile 11 (Figure A8) was dug on higher ground, and a lime pillar was struck one metre below the surface. Further down the slope, another pit was dug, (Profile 12, Figure A8), which has a deeper A₁ horizon and a greater depth of soil.

Another pit, dug part way down a slope, also struck limestone at a shallow depth, (Profile 13, Figure A8). This profile showed a layer of hard loamy sand, the cause of which is unknown.

Profiles 14 and 15 (Figure A9) are both similar, and are representative of this classification. However, in some areas, the soils appear to be leached to a greater extent, giving the appearance of a true siliceous soil. This feature is shown by Profile 16 (Figure A9).

3.3 ENVIRONMENTAL ASSESSMENT OF PHYSIOGRAPHIC FACTORS

In this section, different physiographic factors were ranked to suit various types of land use. This was done to enable the planners to make an assessment of the area, taking into consideration the various physiographic factors. Maps were then prepared showing each of the phenomenon ranking and are included in the Atlas to this report.

3.3.1 Features of Unique Value

✓ This factor was ranked according to scientific interest. The only phenomenon of moderate interest is the area of coastal limestone cliffs that are found inland of the present day shoreline. This feature is approximately half way between the Quinns Rocks township and the northern property boundary.

✓ Of minor interest is the large blowout at the southern end of the property and the various quarries. Otherwise, few important physiographic features occur.

3.3.2 Ease of Servicing

Mindarie was divided into three units of development potential and ease of connecting services, ranging from having most to least potential. The divisions correspond to the areas of sands, unconsolidated sands and kankar (capstone).

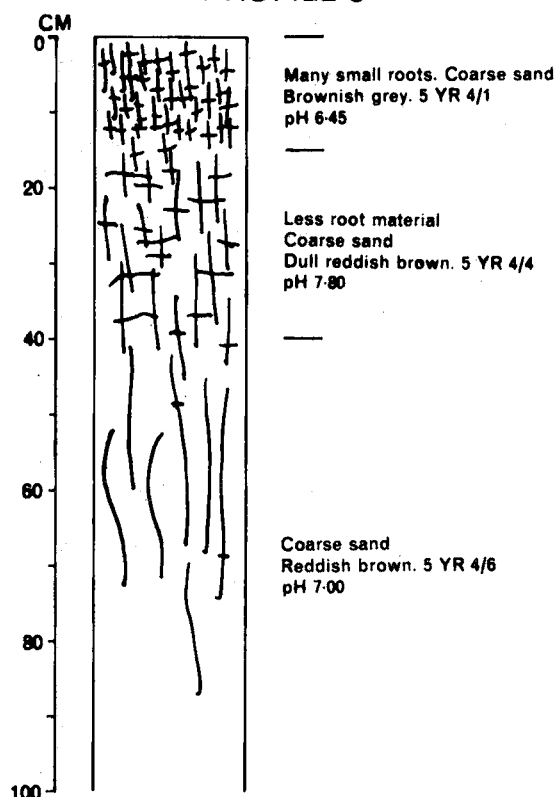
3.3.3 Wind and Wave Erosion

For conservation purposes, this factor was ranked from most to least exposure. The areas most suited for recreation, residential and commercial/industrial utilization had rankings opposed to those of conservation. Hence, those areas that need conserving as they are most susceptible to erosion, are the sections least suitable for development.

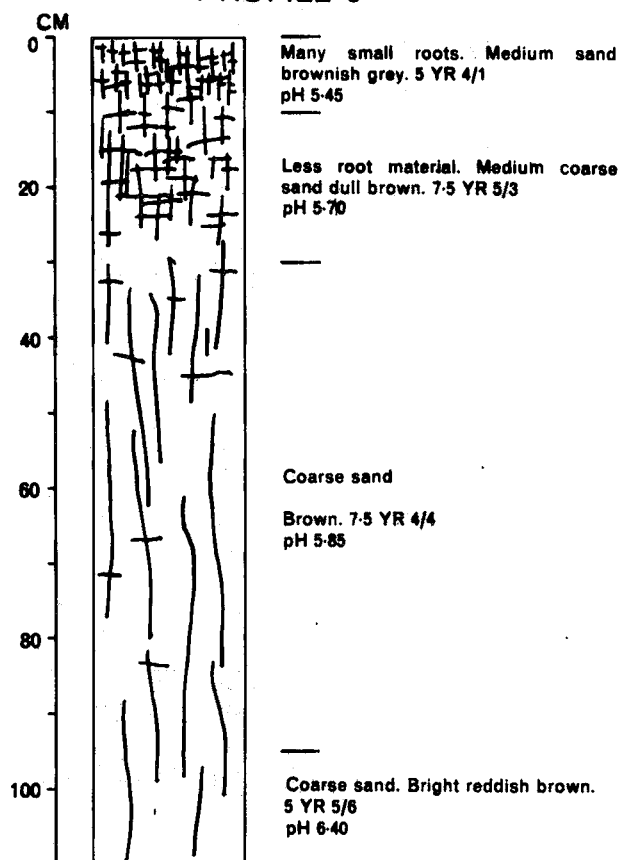
3.3.4 Soil Drainage

The soils which retained some water and are most suitable for gardening were ranked highest. Next came the highly porous soils of the unconsolidated sands. The least suitable areas are those of kankar.

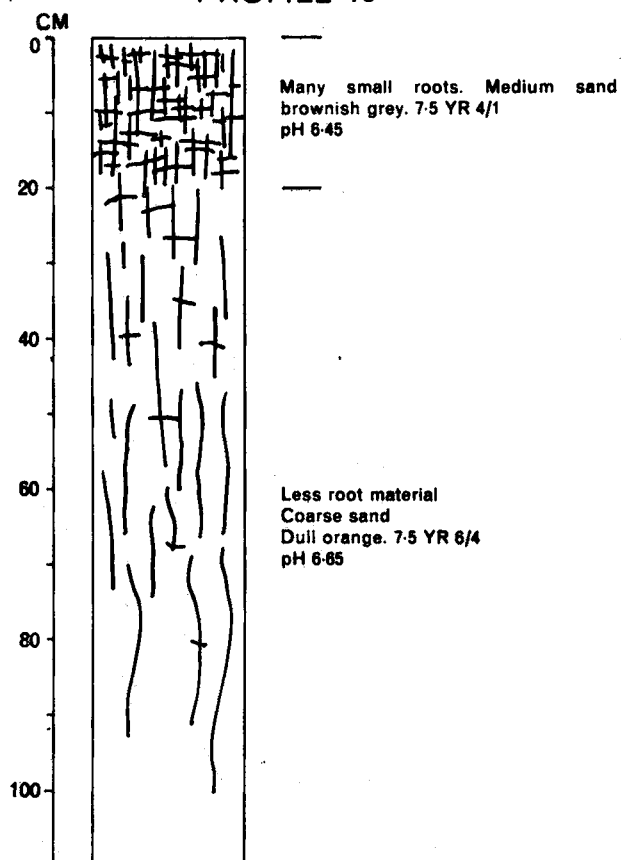
PROFILE 8



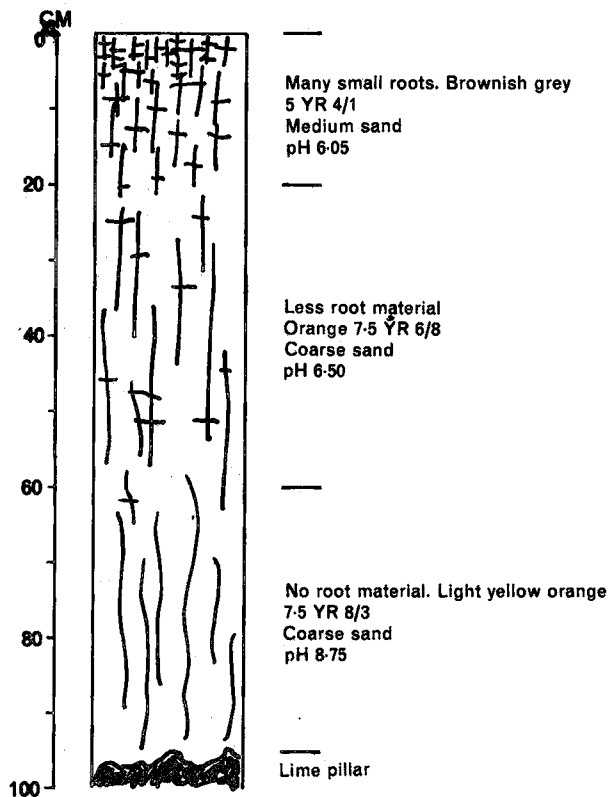
PROFILE 9



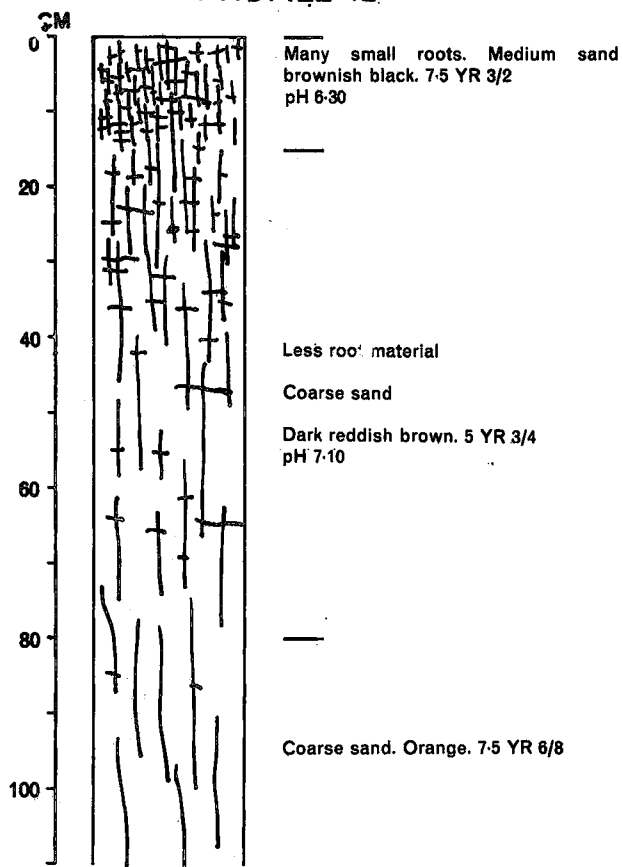
PROFILE 10



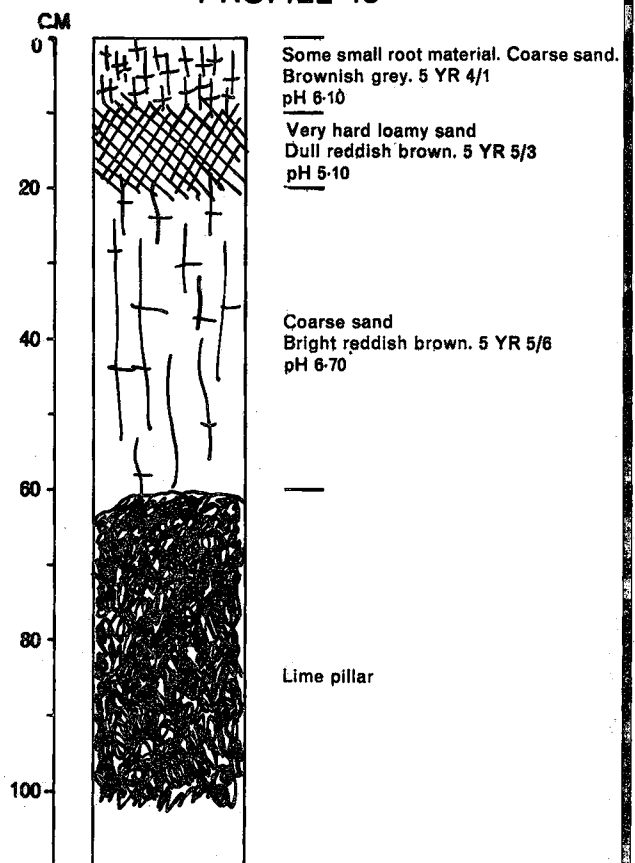
PROFILE 11



PROFILE 12

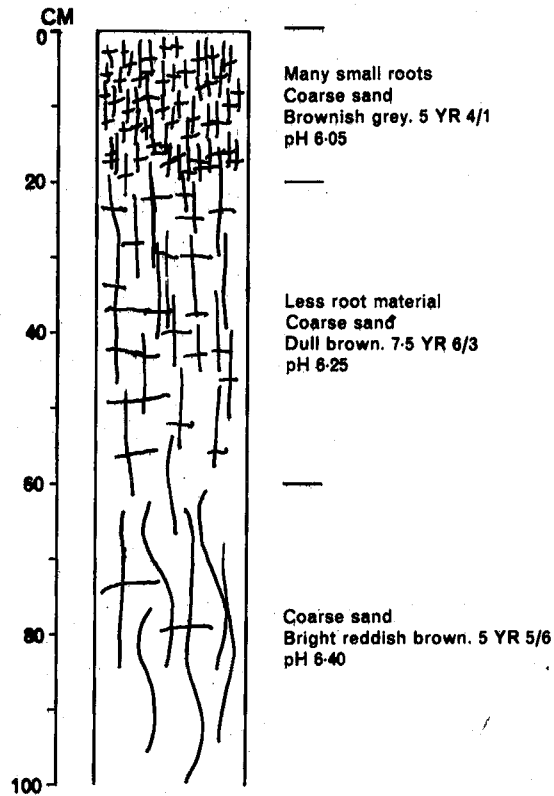


PROFILE 13

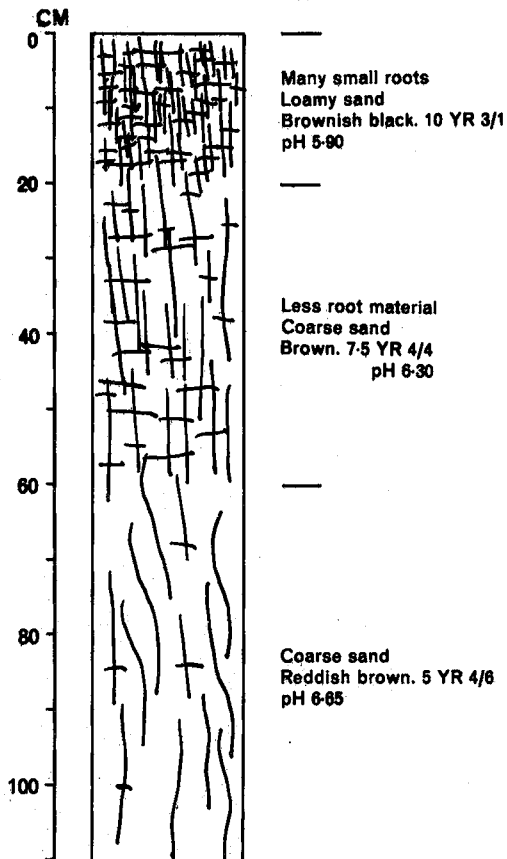


YELLOW/BROWN LEACHED SANDS
FIG A8

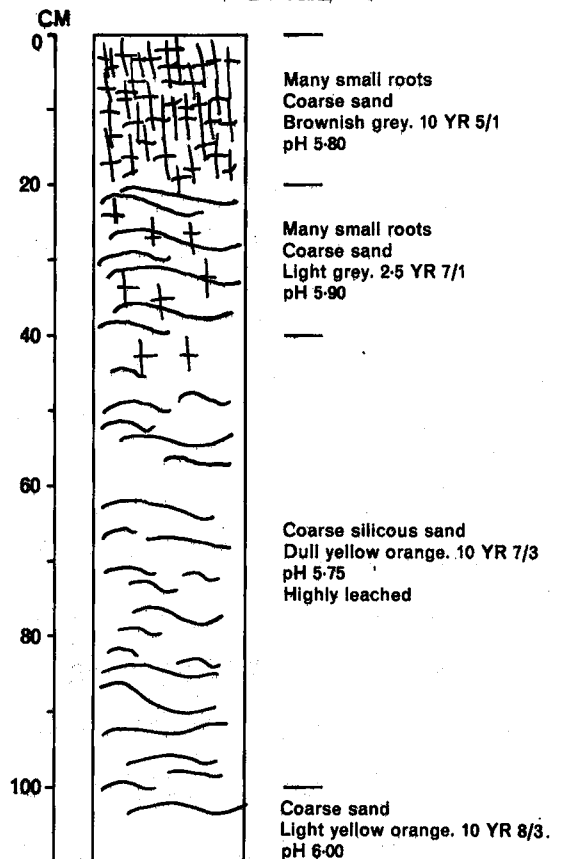
PROFILE 14



PROFILE 15



PROFILE 16



4. VEGETATION

Ecological factors producing the vegetation formations of Mindarie are discussed in Section 4.1. The species present in these formations are discussed in general terms in Section 4.2 and all species recorded during a vegetation survey are documented in the Species List at the end of this Appendix.

4.1 VEGETATION FORMATIONS OF MINDARIE

The occurrence of species and the shapes they assume are governed by the immediate environment, which includes soil type, aspect with respect to insolation, exposure to wind and salt and the presence of other plant and animal species.

Figure A10 shows the distribution of vegetation formations at Mindarie.

4.1.1 Primary Colonising Plants

Close to the sea, on the low foredunes, primary colonising plants trap and bind the sand. Seeds of these plants are often carried by water to their point of establishment.

Primary colonisers must be able to withstand the effects of high winds (including interception of salt-water droplets in colloidal form and thus small enough to pass directly into the plant tissues through the leaf (or stomata), and sand blasting), extremely high levels of radiant energy often damaging to the biological tissue, and sands low in nutrients and water, frequently shifting beneath the plant. Primary colonising plants generally have combinations of the following characteristics; deep, extensive root systems, fleshy or thin spiky leaves, white hairs on the leaves, sticky leaves which trap sand, tolerance to high salt content in the leaves, creeping underground stems and a low rounded habit. Much bare sand is presented between clumps of plants.

4.1.2 Sand Heath (Open)

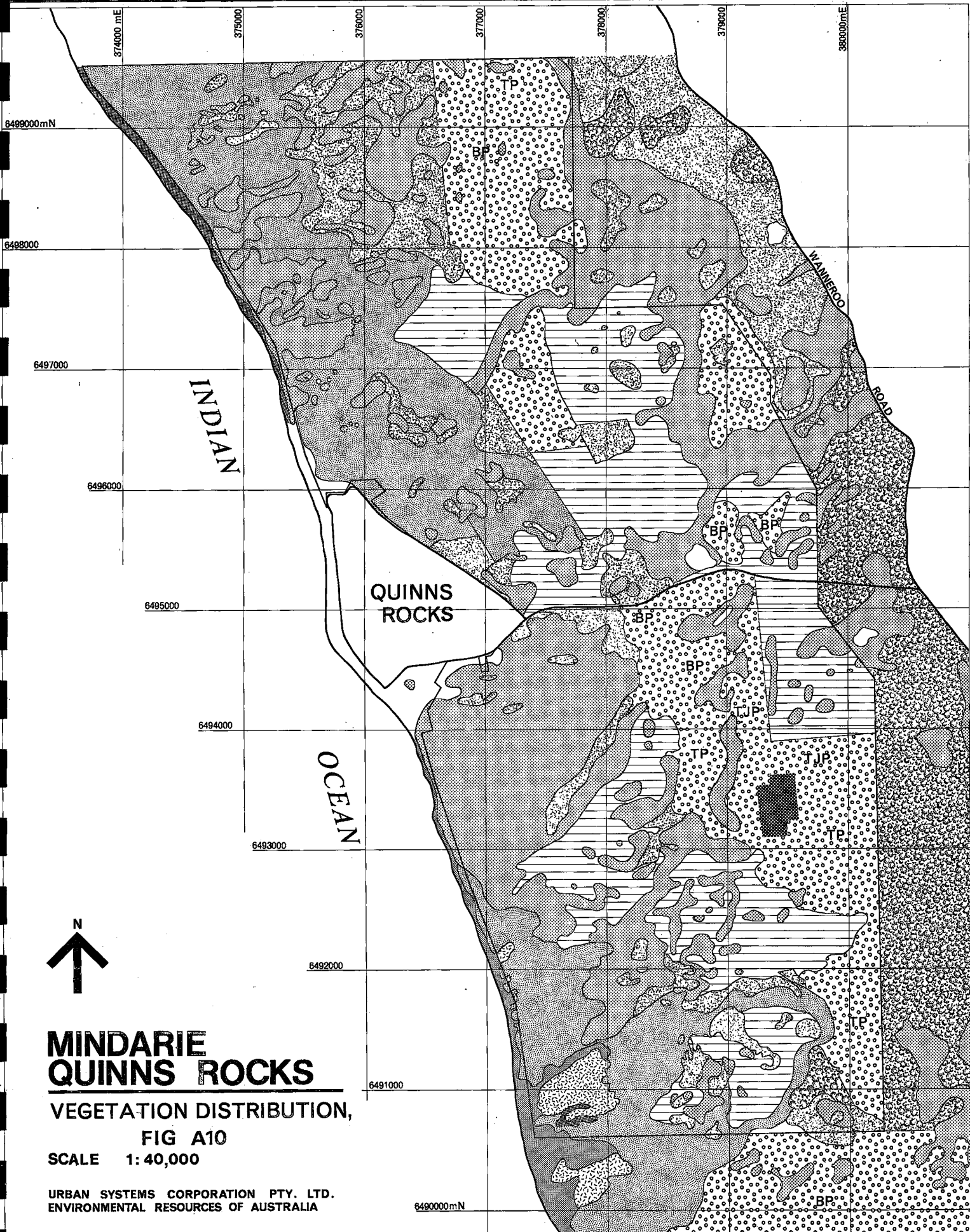
Similar problems are experienced by plants on the first partly consolidated sand dune. However, airborne salt is often less as the zone is out of reach of salt spray and sand blasting is not so great.

At the back of the first dune, wind speeds, sand blasting and airborne salt are considerably decreased, although high insolation and low soil nutrients and moisture are still a problem. There is a greater diversity of plants, less bare sand and greater size of shrubs. Most shrubs still show a rounded habit and have succulent leaves. In the dune hollows, the shrubs may reach 1.5 metres in height, forming thickets rather than an open heath. This may be attributed to more moisture, a higher humus content, derived from organic matter previously buried by sand, and shelter from wind and salt.

The true sand dune heath is present on the second dune and contains a wide range of small, woody shrubs forming an open heath, with increasing quantities of bare sand as one proceeds up the slope. Species of fleshy salt and drought tolerant plants are still present but form a less prominent part of the flora. Drought and fire tolerance are maintained by small, needle-like leaves, extensive root systems, seeds which are released after burning and the ability to produce new shoots from thick woody stems (ligno-tubers) lying at the soil surface.

4.1.3 Capstone Heath (Closed)

Species present on capstone form a more closed heath than that of the sand dunes. Close to the sea, on cliff tops for example, fleshy-leaved salt tolerant species are intermingled with the shrub species also found further from the sea. The closed heath has a very characteristic appearance, being pruned off by wind to approximately one level so that small irregularities in the contours of the land tend to be smoothed off. Wind pruning also causes a very dense canopy of leaves to form, contributing to the "smooth"



MINDARIE QUINNS ROCKS

VEGETATION DISTRIBUTION,
FIG A10
SCALE 1: 40,000

URBAN SYSTEMS CORPORATION PTY. LTD.
ENVIRONMENTAL RESOURCES OF AUSTRALIA

- | | | | | | |
|--|------------------|--|-------------------------|--|------------------|
| | SAND DUNE HEATH | | PRIMARY COLONISING DUNE | | BANKSIA WOODLAND |
| | BANKSIA PARKLAND | | PASTURE | | BLOWOUT-ACTIVE |
| | TUART JARRAH | | TUART WOODLAND | | CAPSTONE HEATH |
| | TUART PARKLAND | | | | |
| | CULTIVATED | | | | |

rossa
appearance of the closed heath. Shallow, alkaline soils, wind and fire are the main problems experienced by capstone heath. Although pockets of deep "terra rosa" soil occur in solution pipes, the roots are generally able to subsist in a few inches of soil or penetrate cracks in the rock. Rainfall would tend to be held on the stoney ground in pockets rather than soaking in rapidly as occurs on sand dunes. Differences in soil characteristics and the increase in the level of effective rainfall are attributed as the main factors producing a flora of different composition to that of adjacent sand dunes.

4.1.4 Low Open Woodland

from
Deeper soils with more humus in the valleys between and behind the second dune allow the development of a two layered, low woodland formation, with small trees and shrubs, and a herb layer. The soils are leached and dry in summer but the valleys are sheltered from wind and salt and receive water enriched by humic acids and nutrients from the rainfall percolating through the adjacent dune. The form of the woodland is open but trees and shrubs still have a low, compact appearance.

An interesting example of the influence of geomorphology on the flora is the band of blackboys which surround the dune valley woodland. This band corresponds approximately to the band of shallow sand over a core of limestone in the centre of the sandhill.

4.1.5 Woodland and Parkland

Beyond the mosaic of calcareous sand ridges and wooded valleys, the tuart woodland and the derived tuart parkland are found on yellow-brown soil that buries limestone ridges beneath. Jarrah woodland, with trees from 6-12 metres high, is found on the deep yellow sands. On low sandy ridges a low woodland similar to that of the valleys between sand dunes, was present before clearing for pasture. Scattered small trees in patches now form parkland.

These species are fairly tolerant to salt winds — for example tuarts are planted in coastal areas but the soil characteristics closer to coast are apparently not suitable for development of large trees in a woodland formation.

The main problems of persisting are those associated with survival of the summer drought and bush fires. Features such as thick rough bark, vertically hanging shiny leaves or white hairs on the undersides of the leaves help to overcome these problems of survival.

4.2 THE FLORA OF MINDARIE

only when cleared, quite high in nitrogen under native vegetation
The vegetation of Mindarie reflects the series of sand dune systems which give rise to the soils and topography of the area.

The Quindalup dune system comprising the unconsolidated and partly consolidated sands of the pedogeomorphic classification is composed of the most recent sands along the coast. The soils are high in lime and very low in nutrients. The system consists of a number of elongated dunes parallel to the shore. Their shape is modified from a strictly north-south longitudinal form by the prevailing south-west winds and blowouts are very common where vegetation has been destroyed. The calcareous dunes also encroach as blowouts on the exposed limestone or yellow-brown sands.

The typical succession along this coast shows a line of low "foredunes" nearest the sea, a line of higher and frequently broken "white dunes" succeeded by a line of stabilized dunes vegetated by shrubs.

4.2.1 Primary Colonisers (Foredunes of unconsolidated calcareous sands)

The first colonisers of the beach sand above tide marks, (e.g. Arctotheca nivea, Cakile

all plant names should
be in italics

maritima, and *Spinifex hirsutus*), are able to bind the sand with their extensive root systems and blown sand accumulates around their shoots to form the "foredunes". These pioneer plants are able to keep pace in their growth with the rising sand in the dune.

4.2.2 Sand Dune (White dunes of partly consolidated calcareous sand)

This line of dunes is relatively stable but is susceptible to "blowouts". Lime-tolerant, deep rooted shrubs and herbs form a more dense cover but with sand often exposed in patches. These plants are characterised by either fleshy bright green leaves or leaves and stems covered by a dense white layer of fine hairs. These plants grow quite tall in sheltered areas but are reduced to low rounded bushes in very exposed areas.

- (1) On the exposed seaward slopes of the white dunes the following plants are found forming open communities on the white sand:—

Olearia axillaris, *Tetragonia zeyheri*, *Calocephalus brownii*, *Scirpus nodosus*, *Pelargonium drummondii*, *Spinifex longifolius*, *Lepidosperma gladiatum*, *Carpobrotus aequilaterus*, *Senecio laetus*.

The larger shrubs *Myoporum insulare* and *Scaevola crassifolia* may occur here also and form a dense cover on the crest and sheltered sides of the white dunes.

- (2) On the sheltered slopes and in the hollows behind the main lines of white dunes a greater number of species is found and the cover is denser. The soil contains more organic matter as is shown by its greyish colour.

In addition to *Myoporum*, *Scaevola* and *Olearia*, the following shrubs and herbaceous plants occur:—

Pelargonium drummondii, *Rhagodia baccata*, *Hemiandra pungens*, *Helichrysum cordatum*, *Hardenbergia comptoniana*, *Acanthocarpus preissii*, *Lepidosperma gladiatum*, *Conostylis candicans* and *Suaeda australis*.

The vegetation in the hollow between the first and second dune is often never retained as a functional part of the landscape. Instead it is flattened into foreshore reserves and planted with couch grass. This is an expensive policy as the area is sensitive to erosion and large areas of grass require continuous summer maintenance.

The vegetation provides good shelter from the persistent sea breezes and is very aromatic. It becomes unsightly if trampled but regenerates quickly during the winter growth season. Grassed areas behind the first dune (that is in the interdunal swale) with controlled access routes — either board walks or board and chain paths to the beach — are a much cheaper and more attractive solution to providing foreshore reserves than for example, the present Quinns Rocks foreshore reserve, where small blowouts have developed in the vegetation through uncontrolled access to the beach.

4.2.3 Sand Dune Heath (Stable shrub dune but sands still only partly consolidated)

The communities of the white dunes pass into those of the stable shrub dunes often dominated by *Acacia cyclops* and *Acacia rostellifera* along with some of the plants of the white dune communities. Other species typical of the coastal heath on limestone are found here, e.g. *Santalum acuminatum*, *Exocarpus spartea*, *Leucopogon australis*, *Spyridium globulosum*, *Hibbertia racemosa*, *Templetonia retusa*, *Acacia pulchella* and *Oxylobium reticulatum*.

From the crest of the first line of stable shrub dunes, the coastal heath composed of a rich community of low growing shrubs, can be seen covering old stabilized dunes, gradually merging inland with the banksia and tuart. The vegetation is generally dominated by *Melaleuca acerosa* and *Acacia cyclops* with some *Olearia axillaris*.

4.2.4 Capstone Heath (On kankar)

A more complex heath in terms of the number of species present occurs on areas of shallow limestone with pockets of soil in solution pipes and rock depressions. *Templetonia retusa* tends to be the most common species with other small colourful shrubs and perennials forming the low (1m) closed heath. This flowers between the spring months of August and October. If the limestone grades into sand then the heath continues but is more open with bare white sand showing through the shrubs.

The dense *Dryandra* thickets characterising most of the capstone areas may be a product of repeated burning followed by grazing of rabbits, which reduce the species diversity of the area.

4.2.5 Banksia Association

This vegetation formation is one of the most widespread at Mindarie.

Two banksias form the dominant species of the banksia association; *Banksia menziesii* and *Banksia prionotes*.

Banksias are found on the sandy valleys, between sandhills and capstone ridges. The pedo-geomorphic classification are calcareous sands and sandy hollows.

Banksias also occur on the yellow-brown soils where drainage is greater than that preferred by the tuart association and on ridges of more leached soil occurring as grey sand ridges.

The natural formation of banksia is a low, open woodland; that is, the trees are 5–7 metres high, and their leaf canopies occupy between 10 – 30% of the total area. As roughly half of Mindarie has been converted to pasture, many of the areas of banksia woodland now form parkland, with small, scattered trees underlain by pasture grasses and pigface and not by the natural undergrowth.



PLATE 1

Banksia woodland on calcareous sand, with the blackboy line around the woodland formation.

Zamia

Banksias on the calcareous sands appear to follow the line of deeper sand between ridges. Blackboys are the most common understorey plant with mature specimens up to 4 metres high and thus passing to tree status. Wattles, hakeas, purple sarsaparilla creeper and small brightly flowered shrubs, herbs and bulbs form the understorey. Zamia palms become prominent as understorey plants where limestone is present below the soil ("Sandy hollows"), for example, along the edge of the large southern blowout.

The banksia woodland grades into a scrub formation and is indicative of soils becoming shallower up the slope, over the limestone core of the sand dune. Plate 1 shows the nature of this soil and topography dependent zonation of vegetation formations. A heath formation is present beyond the blackboy line, further up the slope.

4.2.6 Tuart Association on Yellow-Brown Sand

Tuart parkland is the predominant vegetation association on the limestone areas covered with shallow yellow-brown sand. *like most eucalypts*

Tuart trees are characterised by dark green vertically hanging leaves and rough grey bark. The trees may reach from 12 — 25 metres in mature specimens and are generally well spaced so that the leaf canopies do not overlap. Banksias and blackboys form the small tree-shrub layer to 5 metres and the yellow sand is covered by a number of small, brightly flowered shrubs, perennials and herbs. The shrub flora is not nearly as rich as that of the heath formations or banksia woodlands.

Jarrah and marri are also found on the deeper yellow-brown soils. For example, close to the Mindarie farmhouse site a mixed association of small tuart — jarrah — marri changes to pure stands of tuart or jarrah — marri according to soil depth over the limestone.

✓ The bulk of the woodland has had the understorey of shrubs removed to enable growth of pasture, converting the woodland formation to parkland. Much of this parkland appears very suitable for residential development, with large, well-established trees and a gently undulating landscape.

Retention of the existing tuarts in every possible case and planting of more tuarts in public open space and on private properties would maintain the harmony of the landscape.

It may be found that some of the tuarts have a considerable amount of dead wood which may be considered dangerous to adjacent houses or public open space. The species can tolerate quite severe lopping and this may improve their form after the initial vigorous flush of growth has matured into well formed branches. This treatment is preferable to removing an apparently dangerous tree and then having to wait for a newly planted tree to mature with the associated expense of care during the early stages. However, it is a fairly drastic process and looks unsightly for the first year or two.

✓ The native peppermint (*Agonis flexuosa*) and banksias are the natural understorey trees on the same soil formation south of Mandurah in slightly higher rainfall areas and so would make very suitable associates for tuarts in areas to be planted. No problem should arise with lower rainfall in this more northern area, even without reticulation, as the establishment of roads and houses in an area increases the effective rainfall by increasing run-off.

*better to
remove
dead wood
& shape rain
than lop*

5. WILDLIFE HABITATS

A figure was prepared and is presented in the Atlas by Clarke Gazzard Planners which ranks areas of Mindarie on the basis of the biological quality of the environment plus its visual attractiveness. The suitability of various areas for different types of native fauna is closely related to the vegetation type and the degree of disturbance it has undergone. The figure takes the form of a map of Mindarie divided into the following areas;

- (I) The most suitable areas for a fauna reserve and bush corridor to the national park.
- (II) Pockets of bushland to be maintained in their natural state with retention of understorey shrubs which are important for small marsupials, lizards and birds and which contain many attractive wildflowers.
- (III) Parkland areas of large trees which are important for some bird species but are of more aesthetic than ecological value.

5.1 AREAS MOST SUITABLE FOR FAUNA RESERVES

The areas likely to support most fauna are those vegetated by the low banksia woodland, occurring in valleys between ridges of sand and limestone, as seen in Plate 2.

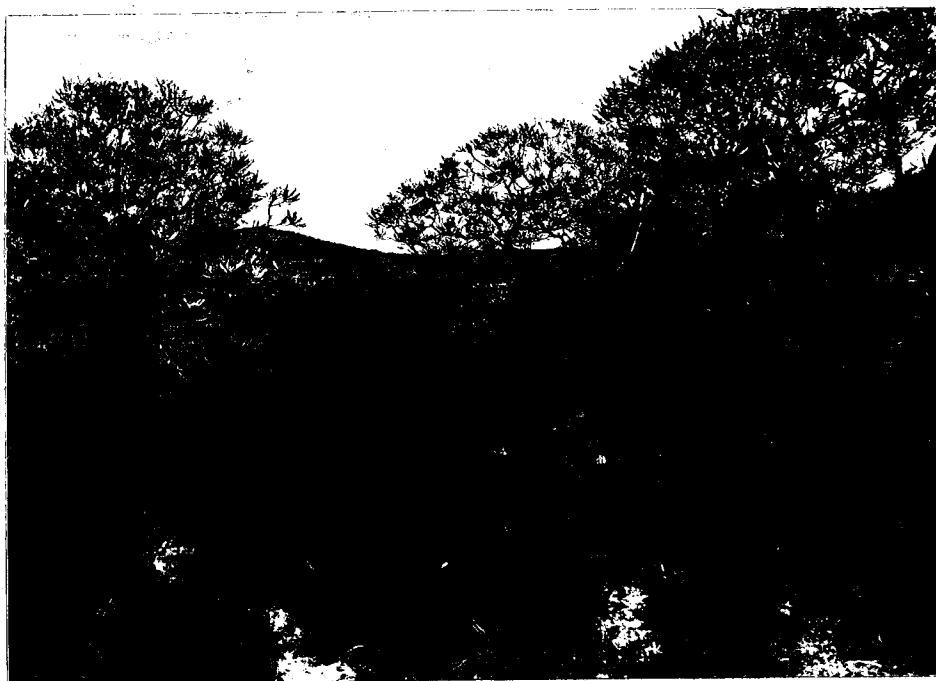


PLATE 2

A band of banksia woodland in a valley between sandhills in the northern sector of Mindarie.

Grey kangaroos were observed during the vegetation survey using the bush for shelter. Honey possums and pigmy possums (small marsupials a few inches in length which feed on banksia blossoms and insects) and short nosed bandicoots would almost certainly occur in the banksia woodland. The rarer *Sminthopsis cristicaudatus* and *Antechinus*, small carnivorous and insect-eating marsupials, may also occur. No faunal surveys have been carried out as a faunal checklist generally necessitates the collection of specimens by a trapping and shooting programme by an authorised government instrumentality.

Many birds, especially insectivorous and nectar-eating species were observed in the banksia woodland. Burrowing and perching lizards form a less well known part of the fauna. Quail and wrens were observed in the heath on capstone ridges.

The more obvious species of fauna such as kangaroos and birds could be expected to persist in these areas of banksia and capstone heath if the undergrowth of the banksia woodland was retained. It should be emphasised that fauna will persist in an area only as long as they have adequate shelter. Feeding however may be carried out in woodland, heath or pasture. Parkland (trees with underlying grass) does not provide adequate shelter for the full complement of native fauna and the extensive areas of pasture encourage the invasion of rabbits.

✓ The provision of a corridor from Neerabup National Park along a limestone ridge to banksia ✓ woodland areas in the northern sector would enable wildlife to cross from the national park to the coastal reserves. The corridor would need adequate maintenance with restricted access or observation points. Fire, cats and rabbits should be controlled and provision of food and water would increase the number of kangaroos and bandicoots visiting the area. Feeding of the kangaroos at a set location would encourage animals to cross to the reserve via the corridor from the National Park. This would enable the native animals to be viewed as they are normally shy and flee from noise.

✓ The various forms of vegetation in this area, with a range from banksia woodland, through scrub to capstone heath ensure that a wide variation in food is available for animals and birds. Staggered flowering times, for example, mean that nectar and pollen eaters are supplied with food all year round, and insect eaters such as small mammals and birds have a ready source of food in the insects attracted by flowers.

Some form of policing the area may be necessary to avoid shooting the animals or destruction of vegetation by wood collecting activities, lighting of bushfire or rubbish dumping.

Wildflowers in this highest ranked area must also be acknowledged to contribute to the high ecological and aesthetic quality. The unique forms of the native flora need no introduction and their potential as a tourist attraction is slowly leading to some form of control over their destruction.

5.2 SMALL FAUNA AND WILDFLOWER RESERVES

The areas ranked as (II) have the native vegetation intact, but do not have extensive tracts of woodland vegetation and the associated area of shelter (I). Their main attributes lie as a habitat for small animals and birds, with feeding incursions made by larger animals, and as a source of extremely colourful and varied wildflowers from early spring to early summer. These areas would be ideal for zones of open bushland not connected to the national park. They would serve to break up suburban sprawl and would be more suitable for general access (for example, paths for pedestrians, or in the larger areas overlooking the ocean, scenic drives) than the areas reserved for large fauna.

These areas are either:—

- (1) Capstone or sand dune heaths, forming a low fairly continuous cover and inhabited mainly by small mammals, birds and reptiles.
- (2) Islands of good quality banksia woodland and blackboy scrub in valleys amongst stabilised sand dunes at present used for grazing (Plate 3). The undergrowth is fairly disturbed and the areas are surrounded by pasture so that they cannot be regarded as a first class habitat, but more as a retreat for birds and small areas of wildflowers.

These areas are ideal for serving as a bushland backdrop for residential areas, nature study areas or bushland playgrounds and as a reservoir of birds which will gradually naturalise themselves into the residential areas once trees in gardens become established.

Recently stabilised blowouts such as those occurring at the extreme northern and southern ends of the property have also been added as these areas are not well suited to conventional suburban development and stabilization of the sand and its conversion into gardens is costly and unnecessary. These areas have sparse but attractively flowered vegetation and serve as food reservoirs for birds and mammals from the other, more thickly vegetated areas.



PLATE 3

Groupings of *Nuytsia floribunda* (Xmas tree) *Banksia* and blackboys in pasture adjacent to coral in northern sector of Mindarie.



PLATE 4

Group of *Eucalyptus tottiana*, *Banksia menslesii* and blackboy in pasture on a low sandy ridge.

5.3 AREAS UNSUITABLE FOR FAUNA OR FLORA RESERVES

Area (III) consists of pasture areas with a proportion of the natural trees remaining and poor quality areas such as blowouts, badly burnt heath and pigface pastures.

The pasture areas are relatively sterile with respect to wildlife, however there are a number of bird species present which will live around residential areas providing there are plenty of trees, especially the original trees or native trees from other parts of Australia.

Possums could be expected to occur in the tuart parkland, and possums, bandicoots and kangaroos in tuart woodlands where the undergrowth has been retained.

Retention of isolated patches of banksia woodland would enable many of the birds and possibly some of the smaller marsupials to remain, depending on the amount and size of intrusions and proximity to built up areas. As the areas became more built up, the species which are not disturbed by the presence of man, such as honey-eaters, willie wagtails, kookaburras and magpies would become dominant.

This area is very suitable for residential development as "garden suburbs" with retention of as many of the native trees as possible. These trees include large tuart and jarrah trees and the smaller prickly bark and banksia. A number of "islands" of vegetation occur throughout this area and should be retained as small parks, playgrounds or centres of cul-de-sacs.

The orange-flowered native Christmas Tree is present in these islands in the northern sector. The object of retaining these small islands would be purely aesthetic, serving to provide well established natural vegetation in the suburbs. The heavy flowering of prickly barks, banksias and Christmas Trees would also attract birds to the area.

These small areas of natural vegetation should not have the existing undergrowth removed for grass planting as the reticulation and fertilizer required for lawns appear to drastically shorten the life span of a number of the trees, especially the banksias. If weeds encroach or the vegetation is considered "scruffy" then attractive native shrubs may be planted. If the correct species are planted they will not require further care in the way of summer watering, extensive weeding or pruning. Lawns are often required for playgrounds and natural vegetation should be separated from the lawns as the islands are often only the size of large garden beds in a park. Natural vegetation would then persist and also look attractive and well kept. Plate 4 shows the nature of the alternating pasture and islands of vegetation.

6. PLANNING AND ENGINEERING IMPLICATIONS

This section integrates the geomorphology, pedology and vegetation of Mindarie into landsystems. These landsystems are then discussed with reference to planning and engineering considerations. Figure A11 shows each of the landsystems, which are classified as:—

1. Coastline.
2. Foredunes.
3. Poorly stabilized dunes.
4. Interdunal swales.
5. Capstone.
6. Sandy hollows.
7. Sandy undulating terrain.
8. Minor features.

6.1 COASTLINE

This unit can be sub-divided into:—

- (a) Sand beaches.
- (b) Limestone cliffs.

The beaches are generally safe for swimming, but surfing conditions are poor. Dead seagrass accumulation is only a minor seasonal problem, but can be aggravated by construction of marine installations. The normal seasonal pattern of summer accumulation and winter erosion of the beach is expected to occur. However, persistent erosion of the beach and foredunes is occurring immediately north of the limestone cliffs, adjacent to the caravan park.

The limestone cliffs are resistant to erosion and are suitable for fishing spots and the establishment of commercial activities. On calm days, underwater diving on the reefs below these cliffs would be possible. The rocky nature of these cliffs and their associated nearshore platforms forms a trap for dead seagrass which is later released and washed onto the beaches.

6.2 FOREDUNES

This landsystem is comprised of the unconsolidated calcareous sands and vegetated by primary colonising dune plants. It often has high recreational demands placed upon it, but is unable to withstand heavy utilization as the delicate ecological balance will be upset. Once the vegetation has been disturbed, wind is able to mobilise the sand, creating the problem of sand stabilisation. Therefore, access to the beach should be controlled through the foredunes. This area is also subject to wave attacks during severe storms.

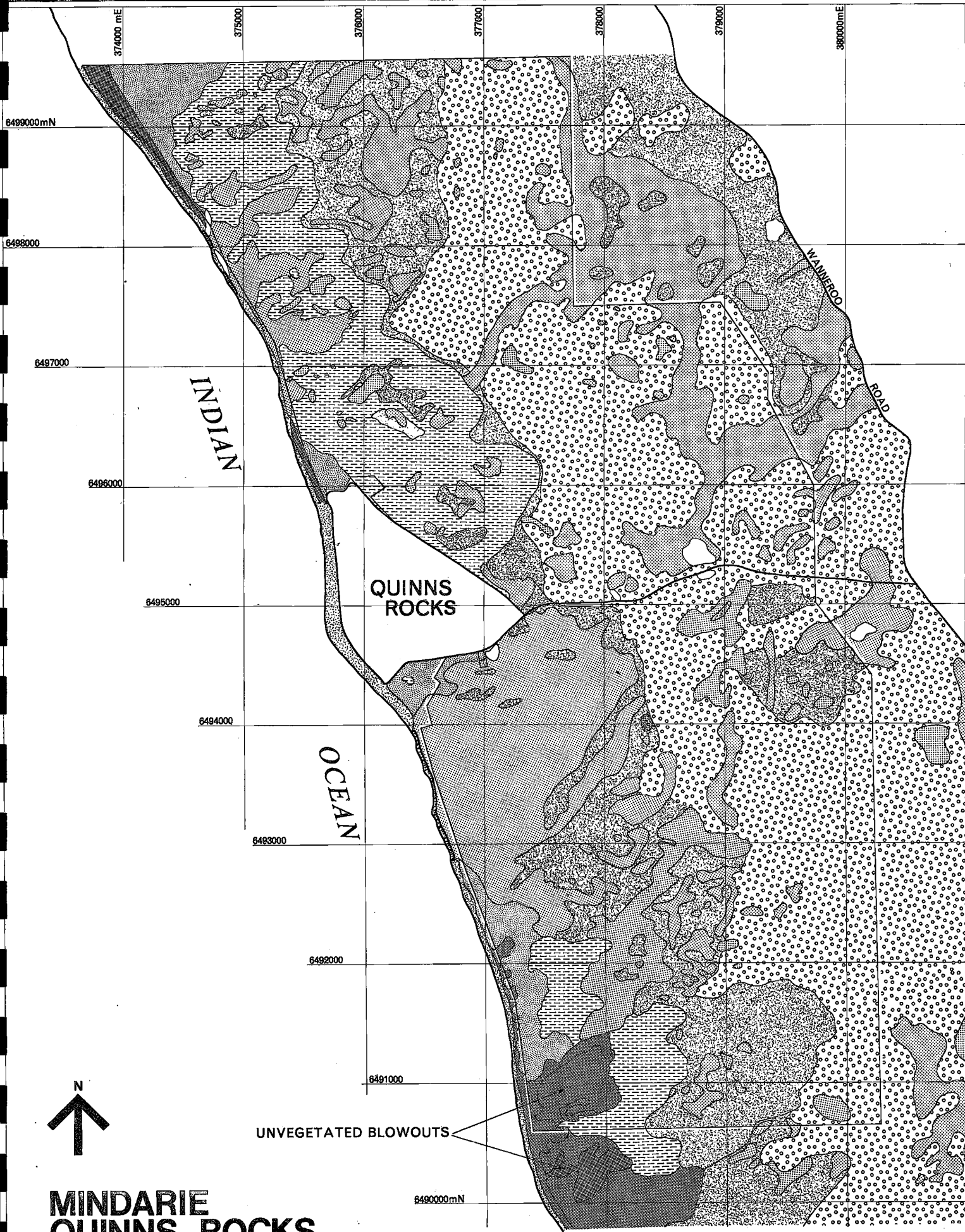
6.3 POORLY STABILIZED DUNES

These dunes are also composed of unconsolidated calcareous sand, but have a better variety of sand binding shrubs. This means that this area is relatively stable if undisturbed. However, the dunes are susceptible to blowout formation once the vegetation is disturbed because of the funnel nature of the interdunal valleys.

It is recommended that if development in this unit is desired, it should take the form of catering for passive recreation — i.e., the beach user. Access to the beach needs to be controlled and should follow the valleys between the dunes. Car parks could be placed in swales behind the first line of high dunes, as this will save bulldozing the dunes and will afford protection to cars from salt spray.

As this area presents many problems for residential development, it could be utilised by industries that desire a coastal location. Much of any industrial site is covered by buildings or bitumen, therefore the problem of drifting sand would not occur. Cooling water or treated sewage could be reticulated to water grass or plants that are stabilising unutilized land.

Roads will need to be well founded with gentle batters stabilised in some manner to prevent sand accumulation on the roads.



MINDARIE QUINNS ROCKS

LANDSYSTEMS

FIG A11

SCALE 1: 40,000

URBAN SYSTEMS CORPORATION PTY. LTD.
ENVIRONMENTAL RESOURCES OF AUSTRALIA

- | | | | |
|--|-------------------|--|--------------------------|
| | SANDY BEACHES | | POORLY STABILISED DUNES |
| | INTERDUNAL SWALES | | SANDY UNDULATING TERRAIN |
| | CAPSTONE | | SANDY HOLLOWES |
| | FOREDUNES | | LIMESTONE CLIFFS |

6.4 INTER-DUNAL SWALES

The swales in this unit have better soil development, being found in the partly consolidated calcareous sand group. The height and density of the vegetation is greater than that of the dunes due to the better soils and shelter from winds and is composed of plants such as sword-edge and wattle.

This unit is suited to development as it is better stabilised by vegetation and is not so exposed to wind. It is suggested that development take place in the swale areas, leaving the dune ridges as these are susceptible to aeolian removal. By doing this, the ridges break any monotony created in the landscape, and can be left as public open space.

6.5 CAPSTONE

*this view
might be
debated*

Capstone may present a problem to development as the rock may not be amenable to removal by bulldozer, and road construction by filling would be necessary. Sewage and water connections become more expensive because of the higher cost of drilling and blasting. Similarly, before gardens can be established the surface should be covered with a layer of sand.

Capstone and limestone may be present under sands in some areas, especially where sand-covered gaps occur in linear outcrops. This may also present problems in the connection of services such as telephones, sewage and water.

It, therefore, appears that this unit will be comparatively less suitable for residential development. However, one activity that could improve this area and eventually make it suitable for residential development is the mining of capstone and the limestone underneath to the sand layer. The mining should be conducted in such a manner as to produce quarries that can be utilised for development. An interesting relief can be created so that houses are set with a cliff backdrop, or behind a cliff to provide shelter for lawn and garden establishment. In this way, a unique and prestigious residential subdivision is created from barren, windswept land.

sq 7

6.6 SANDY HOLLOWES

Calcareous sands and shallow sands, vegetated by banksia woodland, banksia parkland and pasture combine to form this landsystem. These valleys are characterised by better soils, having a deeper and more pronounced A1 horizon. The vegetation cover is somewhat larger than on the other landsystems previously mentioned — consisting of banksia, zamia and blackboy, which have a pleasing form and flower.

This unit is sheltered from high speed winds, although some sections have limited ocean views. Re-forestation projects conducted elsewhere have indicated that various types of native and exotic trees will grow quite readily if they are sheltered from the wind.

Add to these attractions the close proximity to the ocean and the fact that capstone is not a problem, and it appears that this landsystem is highly suitable for residential development. However, it must be kept in mind that the character of this area can easily be destroyed by indiscriminate residential development. Therefore, careful planning is required to integrate the housing with the landscape.

6.7 SANDY UNDULATING TERRAIN

This landsystem includes the pasture, tuart parkland, tuart woodland and tuart-jarrah parkland on the yellow/brown sands. The terrain is relatively flat and therefore would not require extensive earthworks for development. However, it must be stressed that limestone sometimes lies close to the surface and this may present problems when connecting services.

This area is ideally suited to residential development, as much of it is already cleared for pasture. Islands of trees exist that are worth retaining for parks or open spaces, and consist of banksia, prickly bark and Christmas tree. The large tuart and jarrah trees could be incorporated into garden suburbs. These trees also aid to attract and keep bird fauna close to houses. As the area is set back

behind the dunes, and in better soil, a wide range of native and exotic vegetation will grow. However, the area is not particularly suited for fauna and conservation reserves. This is because much of it is already cleared, leaving only birds and grazing kangaroos as the main fauna.

6.8 MINOR FEATURES

Coastal hollows and existing quarries are minor landscape features that can be utilized for passive recreational purposes.

The coastal hollows have ready access to the beach but are partly sheltered from the wind, and are a natural unit suitable for a foreshore reserve. Small shrubs and Norfolk or Rottnest Island pines can be established to provide shade and increase the attractiveness of small parks. Couch grass could be planted to provide rest and picnic areas, but must be irrigated during summer. The approximate cost to establish reticulation of the grass is \$1,000 per acre.

The existing quarries are sheltered and often vegetated by large tuart trees. These areas could be landscaped to provide attractive picnic grounds.

BIBLIOGRAPHY

- Bettenay, E., McArthur, W.M., and Hingston, F.J. (1960)
The Soils Associations of the Swan Coastal Plain, Western Australia.
Soils and Land Use Series, No. 35, Div. of Soils.
C.S.I.R.O., Melbourne.
- Bureau of Meteorology, (1966)
Climatic Survey, Region 15 — Metropolitan Western Australia.
Bureau of Meteorology, Commonwealth of Australia, Melbourne.
- Bureau of Meteorology, (1969)
The Climate of Perth, Western Australia.
Bureau of Meteorology, Commonwealth of Australia, Melbourne.
- Gentilli, J. and Fairbridge, R.W., (1951)
Physiographic Diagram of Australia.
Geographical Press, Columbia University, New York.
- McArthur, W.M. and Bettenay, E. (1960)
The Development and Distribution of Soils on the Swan Coastal Plain,
Aust. Soil Pub., No. 16, C.S.I.R.O., Melbourne.
- Seddon, G. (1972)
Sense of Place,
University of Western Australia Press, Nedlands.

SPECIES LIST

Species recorded in the various vegetation zones on the vegetation map.

1. Active Blowouts (BA)

Spinifex longifolia
Scaevola crassifolia
Acacia rostellifera
Myoporum insulare
Casuarina lehmannii
Arctotheca nivea

2. Primary Colonising Plants (PC) (first dune line and blowout edges)

Cakile maritima
Spinifex hirsutus
Tetragonia zeheri *zeyheri*
Arctotheca nivea

3. Sand Dune Heath (SH)

Large areas of sand dune heath occur on Mindarie. The composition differs according to the distance from the sea and the soil type. However, this species composition is not visible from aerial photographs so that boundaries could not be validly drawn. The species in various areas differing in exposure and soil type are documented as follows:—

- (a) First stable dune.
- (b) Hollow behind the first dune.
- (c) Dune ridges (beyond the first large dune and generally overlooking valleys of banksia woodland.

3 (a) First Stable Dune (Partly consolidated sand).

- (i) sea — side
 - Scaevola crassifolia*
 - Spinifex longifolia*
 - Pelargonium drummondii*
 - Lepidosperma gladiata* *um*
 - Tetragonia zeheri* *zey*
 - Calocephalus brownii*
 - Scirpus nodosus*
 - Olearia axillaris*
 - Carpobrotus aequilaterus*

(ii) leeseide

Species as in (i) with the addition of:—

Anthocercus littoralis *cis ?*
Hardenbergia comptoniana
Rhagodia baccata
Myoporum insulare
Acacia cyclops
Exocarpus sparteus
Hibbertia racemosa

3 (b) Hollow Between Dunes

Lepidosperma gladiata
Acacia cyclops
Myoporum insulare
Syridium globulosum
Pelargonium drummondii

3 (c) Dune Ridges

Melaleuca acerosa
Olearia axillaris
Hibbertia hypericoides
Anthocercus littoralis
Conostylis candicans
Stipa sp
Acacia cyclops
Acacia cyanophylla
Acacia cuneata
Hakea prostrata

In some areas of dune ridge, limestone is just below the surface, so that a number of species placed in the "Capstone heath" classification appear in conjunction with the above species.

4.(a) Capstone Heath

Dryandra sessilis
Templetonia retusa
Grevillea thelemanniana
Acacia cuneata
Oxylobium reticulatum
Leucopogon sp
Jacksonia sternbergiana
Leucopogon verticillata
Casuarina humilis
Sphaerolobium medium
Hovea elliptica

In areas which had possibly been repeatedly burnt the predominant species was *Dryandra sessilis* forming thickets, or closer to the sea, *Melaleuca heuglii*. On slightly sandier soil *Acacia cyclops* formed a dense, low heath similar in appearance on aerial photographs to the *Dryandra* or *Melaleuca*.

4.(b) Capstone Heath on Cliff Tops (overlooking the sea north and south of present Quinns Rocks settlement.)

Grevillea thelemanniana
Rhagodia baccata
Olearia axillaris
Hardenbergia comptoniana
Melaleuca heuglii
Carpobrotus aculeatus
Beyeria viscosa
Acanthocarpus preissii
Tetragonia zeyheri
Syridium globulosum
Templetonia retusa

5. Banksia Woodland

Banksia menziesii
Banksia prionotes
Xanthorrhoea preissii
Dryandra nivea
Melaleuca acerosa
Hardenbergia comptoniana
Petrophile linearis
Hibbertia hypericoides
Hakea glabella
Dayesia brevifolia
Conostylis candicans
Acacia cyanophylla

Burch

Also bulbous plants not present at the time of the survey, such as orchids, burchardia South African gladiolus and native iris (Patersonia).

Banksia menziesii
Banksia prionotes and Xanthorrhoea preissii

Associated with either:

Casuarina fraseri

and/or

Nuytsia floribunda

or

Eucalyptus tottiana

Isolated trees were surrounded by pigface (*Carpobrotus* ^{ae} *aquilaterus*) and pasture grasses.

Islands of the above tree species, which had been retained as shelter in the pasture were associated with a few species often predominating in disturbed areas (for example recently burnt natural bush).

Stirlingia latifolia
Hibbertia hypericoides

6. Tuart Parkland

Eucalyptus gomphocephala
Xanthorrhoea preissii

Tuarts often grade into banksias or prickly bark as the soil over limestone becomes deeper and the soil becomes more acid.

Banksia prionotes
Banksia menziesii
Eucalyptus tottiana

7. Tuart — jarrah Parkland

Eucalyptus gomphocephala
Eucalyptus marginata and Eucalyptus calophylla

with a herb layer of grasses and pigface, occasional blackboys or jacksonia (*Jacksonia furcellata*).

8. Cultivated Land

Medicago sativa (Lucerne)
Olea europaea (Olive)

APPENDIX B

MAPPING OF NATURAL SYSTEMS

This appendix presents a more detailed description of the method involved in the land evaluation system. After the base data has been compiled various factors related to conservation, recreation and urbanization are drawn and identified. Each factor is evaluated in a gradient of three values, ranging from high to low. The factors are mapped in tones of grey from most dense to least dense. If necessary the same information is reversed on a further map to be employed in an inverted order.

For example, the land most susceptible to erosion is often most suitable for conservation, whereas, land least susceptible to erosion is least in need of conservation. Conversely, land most susceptible to erosion is least suitable for urbanization and the land least susceptible to erosion is most suitable for urbanization, so this factor has been mapped twice according to its use in either conservation or urbanization assessment.

All factors are mapped on transparent overlays and the group of relevant factors for each prospective land use is superimposed and photographed. The results are value gradients that incorporate the appropriate factors. They show the maximum concurrence of all positive factors (darkest tone) and the areas where fewest of these factors are relevant.

The final stage of the process is the transformation of the three maps into basic colours. The map for conservation suitability is reconstituted in tones of yellow. Recreation is mapped in grades of blue and urbanization in red. Transparencies are produced and overlayed to produce a Composite Land Value Map which indicates the intrinsic suitability of the land. A new pattern of colours results. Different scales of colour intensity appear for various combinations of land use, according to the value of their intrinsic suitability for a specified area. Thus, land rated high in value for both urbanization and conservation appears orange on the map.

This method has some real advantages. Firstly, it is rational, since much of the evidence is derived from exact science, i.e. geology, climatology, pedology. This increases the objectivity of the evaluation. Of equal importance is the fact that the method is explicit, while incorporation of community values is a crucial point in its favour.

Technically, parity of the factors requires care in selection and illustration — if one factor assumes disproportionate distinction then the results will be qualified accordingly. The mechanical problem of transforming tones of grey into colour of equal value is a difficult one and requires much careful work.

The Composite Land Value Map (Fig 3D) shows the relative concurrence of positive factors and their relative absence. The information so compiled and interpreted constitutes the basic required to subject any planning proposal to the test of least cost—maximum benefit. Once the values for the major land uses have been identified it is possible to demonstrate the degree to which any proposal will enhance or destroy the area.

This points immediately to those areas that should be conserved and highlights those areas most suitable for development. It also shows where uses may co-exist, offering an opportunity to combine uses in a socially desirable way. The Composite Land Value Map is a mosaic and, thus illustrates more accurately the complexities of the environment and the potentiality of the land for development.

APPENDIX C

DESIGN PARAMETERS FOR MAJOR ROAD NETWORK

C.1 Development Programme

Even after Wanneroo Road and Quinns Rocks Road have been developed to their optimum capacity, they will not be capable of carrying all the traffic generated by the region.

Initial construction of Marmion Avenue, as a single carriageway, will allow development of Mindarie to proceed at a natural pace without traffic congestion and if Mindarie were the only generator of traffic within the region, the dual carriageways of Marmion Avenue would probably be sufficient for more than half of the development period. Further settlement at Yanchep and the probable growth of a large industrial complex between Yanchep and Mindarie will require a high speed freeway. The proposed positions for the roads are shown on Figure C.2.

Development in Mindarie itself, and the increased use of the beaches north of Mullaloo, will demand the construction of parts of the West Coast road, although this road will contribute little to the movement of traffic through the region as a whole.

The conditions for which each type of road will be designed are described in this section. Detailed specifications and cross sections are provided at the end of this Appendix.

C.2 Stephenson Freeway

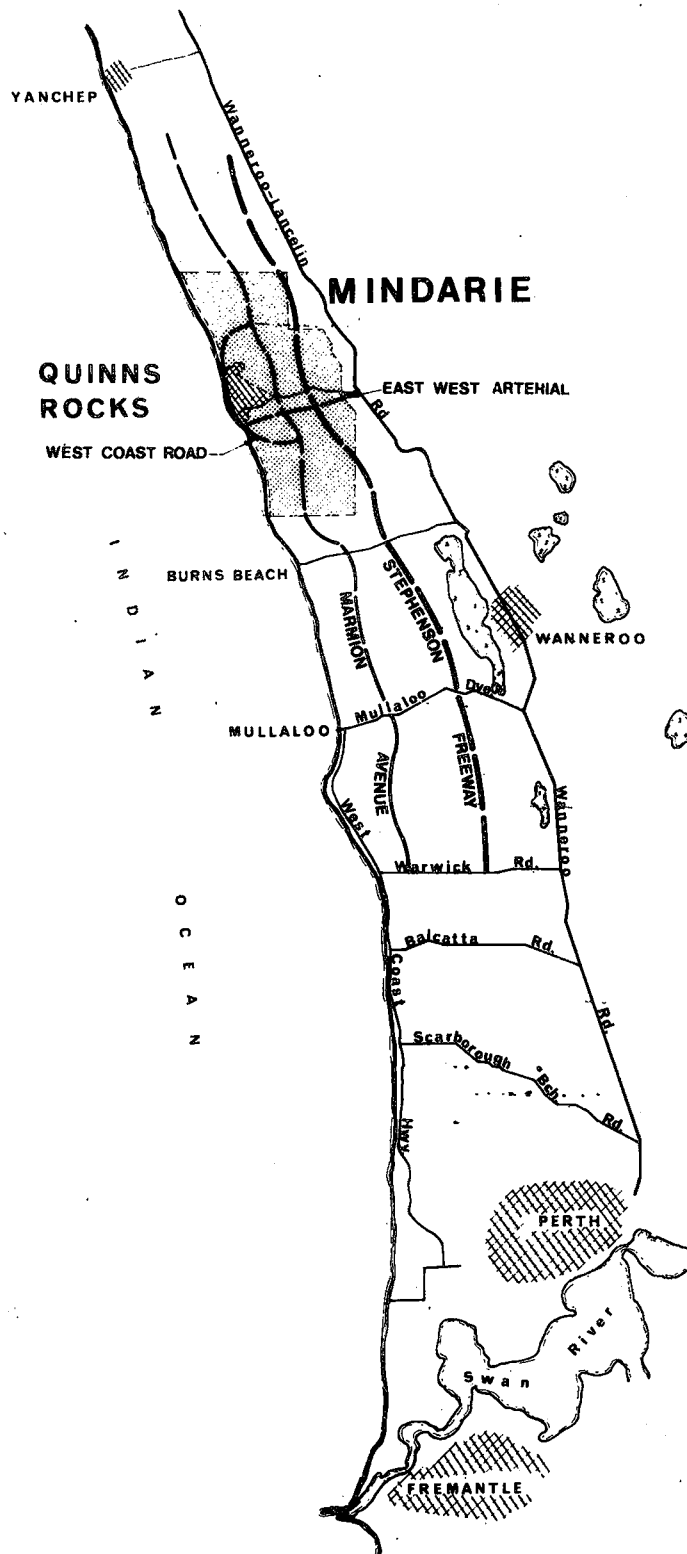
This route is of such great importance, that if necessary, other considerations might have to be subjugated to satisfy the criteria for which a major freeway must be designed. It has, fortunately, been possible, through the co-operation of the Main Roads Department, to select an alignment which will permit the economical construction of a primary traffic highway without destroying the quality of the Mindarie environment.

Stephenson Freeway is to be designed so that, as traffic leaves Perth, the safe travel speed may be increased to the present legal limit, and if all other considerations permit, to 120 km per hour. For traffic on the Freeway to safely maintain this speed, there will be no intersections at grade, and interchanges will be 6 km to 8 km apart. These interchanges will be of the flyover half clover leaf pattern with adequate lanes for weaving, deceleration and acceleration. Only one interchange will be required within the Mindarie development and this will be at the point at which the east-west road meets the Freeway. This intersection will occupy more than 20 hectares.

No access from adjoining property will be permitted, and footpaths will not be provided. For aesthetic reasons, long roads which are straight in plan and section are to be avoided, and to maintain high speeds, curves of large radii are required both vertically and horizontally. The road will be planned in three dimensions and the tangent points of vertical and horizontal curves will be related so that they become, in fact, tangents in space and not in individual planes.

The design radius selected for horizontal curves on the Stephenson Freeway is 3,300 m and vertical curves have been chosen so that full passing sight distance can be provided even when only one carriageway is in use in the earlier stages of development. It is intended that Stephenson Freeway should have two carriageways, each with four traffic lanes, and that the two carriageways should be separated by a planted median strip 20 m wide. The topography and alignment provide that, except in short sections, the height of the embankment or the depth of cut will not exceed 6m.

It is desirable that the embankments and cuttings for the Freeway should, at frequent intervals, be sufficiently deep to permit the construction of subdivisional roads through it. The Mindarie plan provides for two arms of natural bushland to connect the existing National Park with the coast, and in these two areas underpasses for animals and horses, bicycles and pedestrian traffic will be provided.



MINDARIE QUINNS ROCKS

LOCATION AND COMMUNICATIONS

Scale in kilometres
0 1 2 3 4 5 6 7 8 9 10

LEGEND
Existing Roads ———
Future Roads - - - - -



Six possible routes for the Stephenson Freeway were considered in detail. The route shown on Figure C2 was selected as the best after discussion with the Main Roads Department. The route lies conveniently close to the National Park reserve and thus provides an adequate width of country between the Freeway and the coast in which to allow freedom of choice in the selection of route for Marmion Avenue. The alignment chosen avoids destruction of valuable stands of trees and because it is sympathetic to the countryside, the cost of earthworks will be reduced.

Due east of Quinns Rocks, a section of the Mindarie development lies between the Freeway and the National Park reserve, but this section of land is divided by the east-west link into precincts which are themselves of individual geographic character and are of sufficient size to form satisfactory neighbourhood units. Access to each of these precincts will be provided off the east-west link and they will be joined to the land west of the Freeway by roads passing over or under the Freeway. The crossings themselves will enhance the visual character of the Freeway.

C.3 Marmion Avenue

Marmion Avenue will be essentially an urban highway designed for a speed of 80 km per hour. It will have two carriageways each with two lanes and a median strip 14m wide.

Because Marmion Avenue is mainly for domestic traffic, intersections must be provided at intervals of about 400 m. These intersections will not involve grade separation, but they must be situated so that the sight distances are adequate and so that sufficient length of acceleration and deceleration lanes can be provided. Intersections will be staggered as Tee junctions.

The nature of the traffic and the reduced speed of travel, permit and require environmental standards which might not be possible to attain on the Freeway.

The route of Marmion Avenue will run north and south and it will preferably lie halfway between the coast and the Freeway, but once these requirements are met, the alignment can be adjusted so that the road presents alternating vistas of coastal scenery and of the hinterland.

For the most satisfactory attainment of this goal, the route shown on Figure C2 was selected to allow Marmion Avenue to follow the upper slopes of a ridge which lies between the Freeway and the foredune. The attainment of satisfactory standards of traffic safety, combined with a realistic balance of earthworks, will require that the road should be incut up to 6m deep on some of the higher points of the route, but consideration is being given to additional earthmoving to provide scenic vistas even at these higher points.

On this road, as on the other major highways in Mindarie, horizontal and vertical curvature will be combined for the most pleasing visual effect as is reasonably possible.

The position of Marmion Avenue at the north and south boundaries of Mindarie is subject to planning requirements for the overall region. Direct access from property adjoining Marmion Avenue will not be permitted. Footpaths will not be provided in the Marmion Avenue reserve, except where they form part of a regional pedestrian network. Pedestrian underpasses or overbridges will be required.

The design criteria for Marmion Avenue are very much the same as those for Stephenson Freeway but the order of importance is changed. The selected route must provide:

- a) the most convenient distribution of traffic in Mindarie
- b) pleasant driving conditions at the selected maximum speed
- c) many opportunities for drivers and passengers to get an overall picture of the coast and the Mindarie countryside
- d) connection with desirable routes for Marmion Avenue north and south of the land within Mindarie
- e) a position approximately midway between the Freeway and the coast

MINDARIE QUINNS ROCKS

MAJOR ROAD NETWORK

SCALE 1:40,000

URBAN SYSTEMS CORPORATION PTY. LTD.
HALPERN GLICK & LEWIS PTY. LTD.

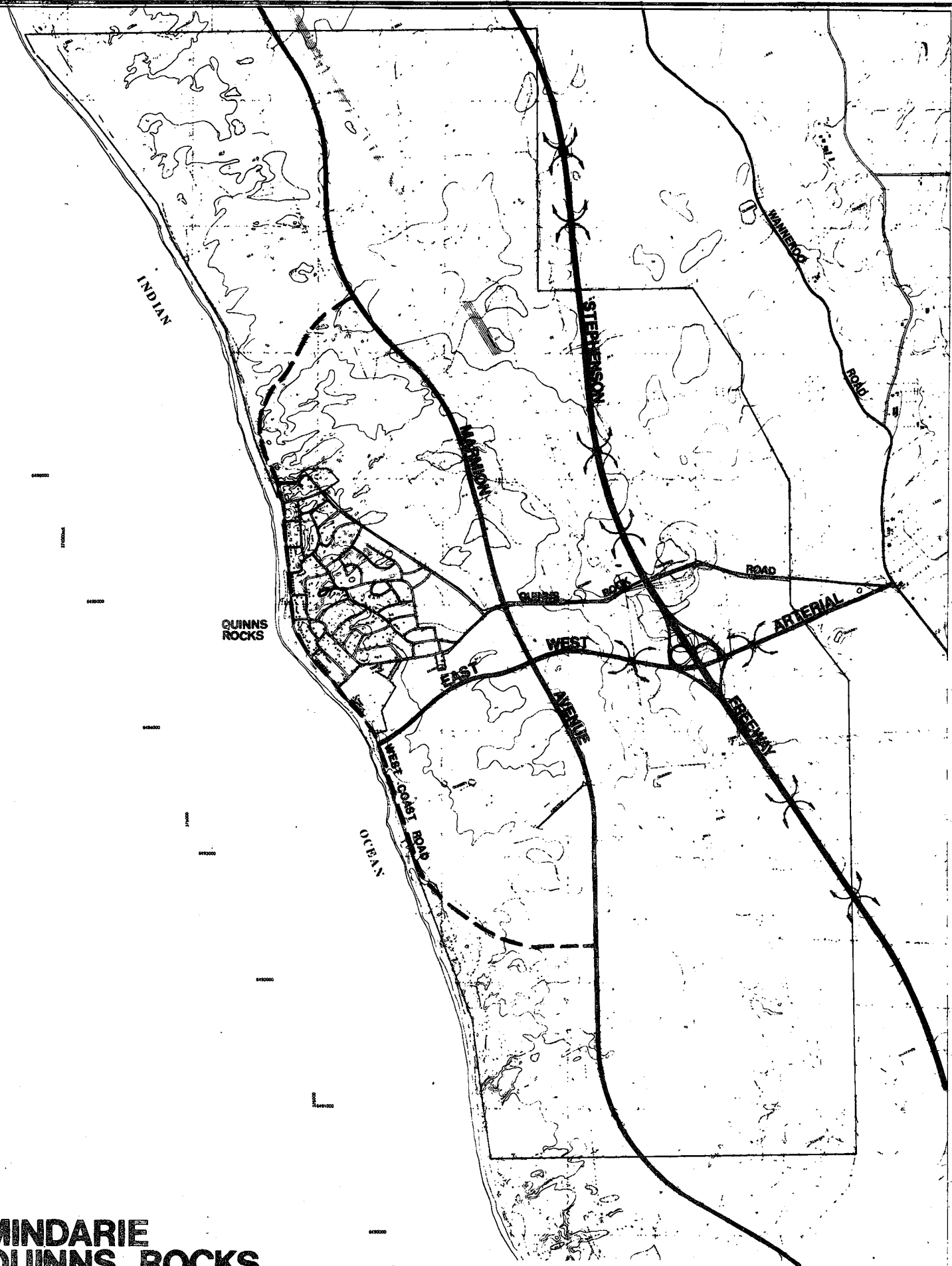


Fig. C2



- f) a flowing alignment integrated with the countryside but providing fairly flat sites for intersections at reasonable intervals
- g) acceptable cost with optimum use of local resources
- h) suitable sites for pedestrian crossings

C.4 East-West Arterial Road

The prime purposes of the east-west arterial is the connection between the Freeway and Mindarie, but the position of the intersection had to be selected after consideration of the whole area between Mullaloo and Yanchep.

This study indicated that a link would be needed near Burns Beach and another near the northern boundary of Mindarie where it would provide reasonable connection with the possible future road to the Pacminex Refinery. The best geographical position for the intermediate east-west road was then somewhere close to a line running eastwards from Quinns Rocks. The exact position was selected after determination of a suitable position on the profile of the Stephenson Freeway for the overpass and interchange. Traffic moving east and west will pass over the Freeway and the selected position is one in which the east-west road is on fill and the Freeway itself is in cut with reasonably level ground close by for the construction of the necessary interchange ramps and acceleration and deceleration bays.

The position of the eastern part of this route is determined by the position of the interchange and the necessity for approximately 90° junctions with Wanneroo Road and Marmion Avenue with acceptable sight distance.

From Marmion Avenue westwards, there is more freedom of choice but it was decided that the arterial should avoid the existing development and curve through the caprock country to the south of Quinns Rocks where excellent views of the sea and the coastline can be obtained for the westward bound traffic.

This will be a dual carriageway with intersections at intervals not closer than 200m to provide access to those parts of Mindarie which cannot conveniently be connected to Marmion Avenue. The road would, in particular, provide connections for the two precincts east of the Freeway. The design speed for the road will be 80 km per hour; direct access from adjoining properties will not be permitted.

Footpaths will be provided where they fit in with the regional network and pedestrian underpasses will be necessary.

C.5 West Coast Road

It is necessary to provide in the overall plan for a road which will permit people to drive down to the coast and drive along it with a view of the beach and the sea, and with convenient access to the beach. It is not essential that this should be a high speed road or that it should run continuously along the coast throughout the area. Frequent intersections will be required on this road to parking areas, shopping facilities and sub-divisional roads. The coastal road, therefore, need not be designed for a speed higher than 60 km per hour.

The road will only have a single carriageway and will require a maximum reserve width of 30m with a pavement width of about 10m, and it is not difficult from the engineering viewpoint to locate such a road within the topography of the country in Mindarie.

The alignment of the road will be dictated much more by planning considerations except in detail while special provision may have to be made for unusual topographical features or junctions at which traffic is concentrated.

C.6 Sub-Arterial Routes

In addition to the four roads described in this section, there will be sub-arterial routes which will distribute the traffic to local sub-divisional roads. The sub-arterial routes will mainly be east-west collectors linked by tee junctions with Marmion Avenue. Some of these will extend beneath the Freeway or over it to connect with the National Park and with the precincts to the east of the Stephenson Freeway. These roads will be designed for 60 km per hour and will have a single carriageway 10m wide, with footpaths on either side. They will be the main bus routes within Mindarie.

C.7 Reserve Widths

The subdivisional roads will be in standard road reserves 18m wide and the sub-arterial roads and the West Coast Highway will have a constant road reserve width of 30m.

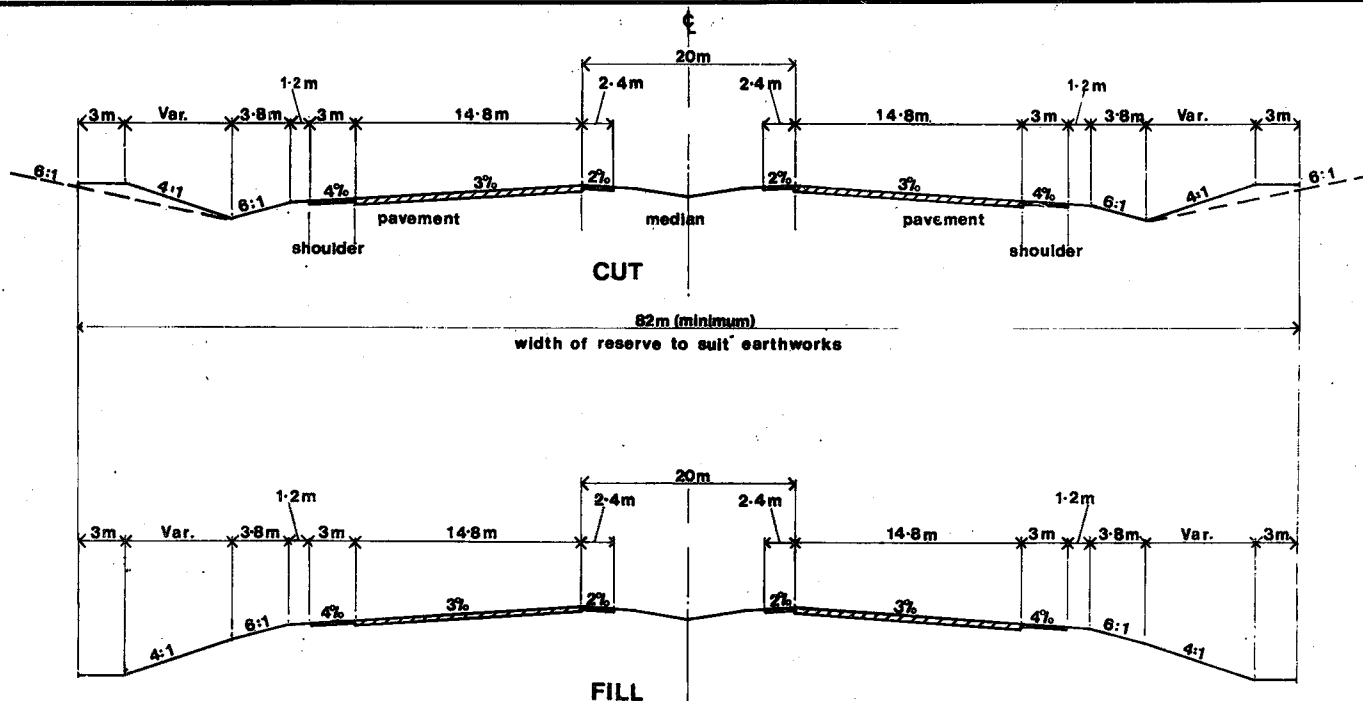
Arterial routes, however, will require wider reserves to allow for the additional width of two carriageways and the median strips, to provide for adequate shoulders and drainage swales and to provide space for the slopes of cuttings and of embankments.

The typical cross sections on Figure C3 show that the minimum width in which all the facilities required for the Stephenson Freeway can be provided is 82m where the cut does not exceed 1.5m or the fill 3.5m. This width may allow for a busway or alternative rapid transit system to operate within the median in the future. For Marmion Avenue and the east-west arterial, the minimum width will be 60m.

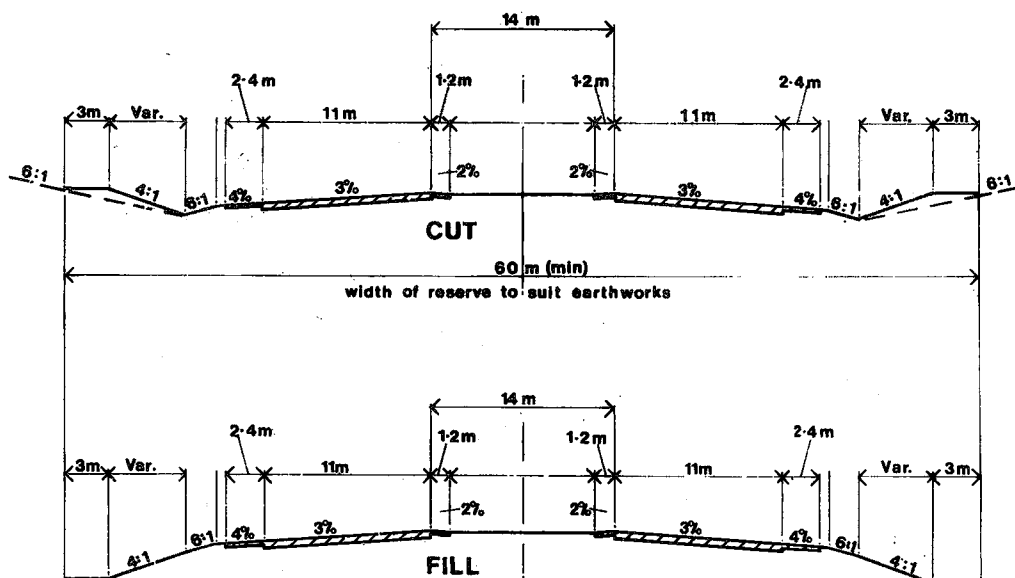
These widths will be increased to provide for the slopes of cut and of embankments, and it is intended that the road reserves should vary in width to add interest to the prospect. Where the ground slopes across the road, the road centreline may not be in the centre of the reserve.

Road reserve widths of 110m may be necessary for the maximum depth of cut or excavation in sand, but in these areas consideration will be given to providing a more gentle side slope which can be continued through into the land outside the road reserve. Part of the earthworks for the road will actually be outside the road reserve.

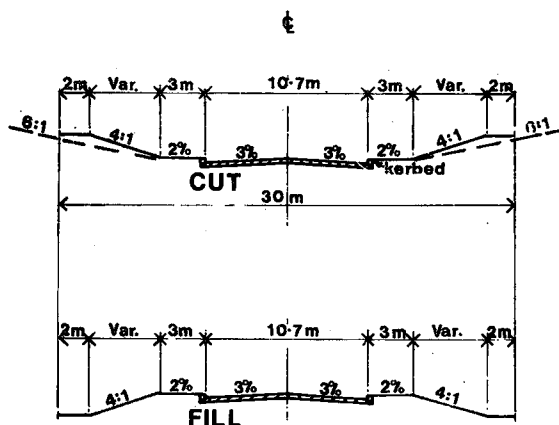
Where the roads pass through limestone country, it will be possible to reduce the width of the road excavation because much steeper side slopes will be feasible, but it may be necessary in these areas to avoid a feeling of enclosure by high limestone walls on either side of the road.



STEPHENSON FREEWAY



MARMION AVENUE AND EAST WEST ARTERIAL



SUB-ARTERIAL ROAD (West Coast Road)

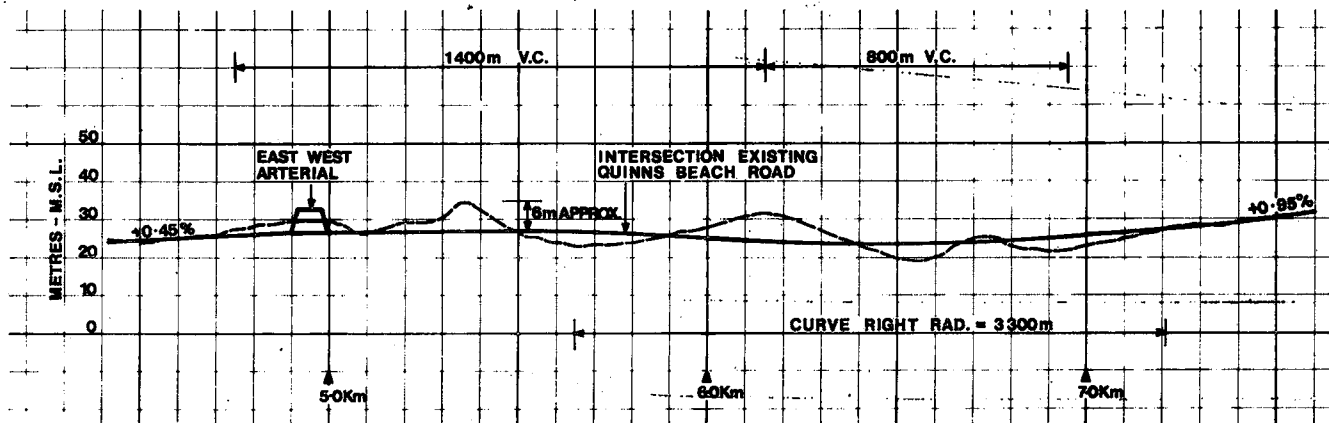
**MINDARIE
QUINNS ROCKS**

TYPICAL ROAD CROSS-SECTIONS

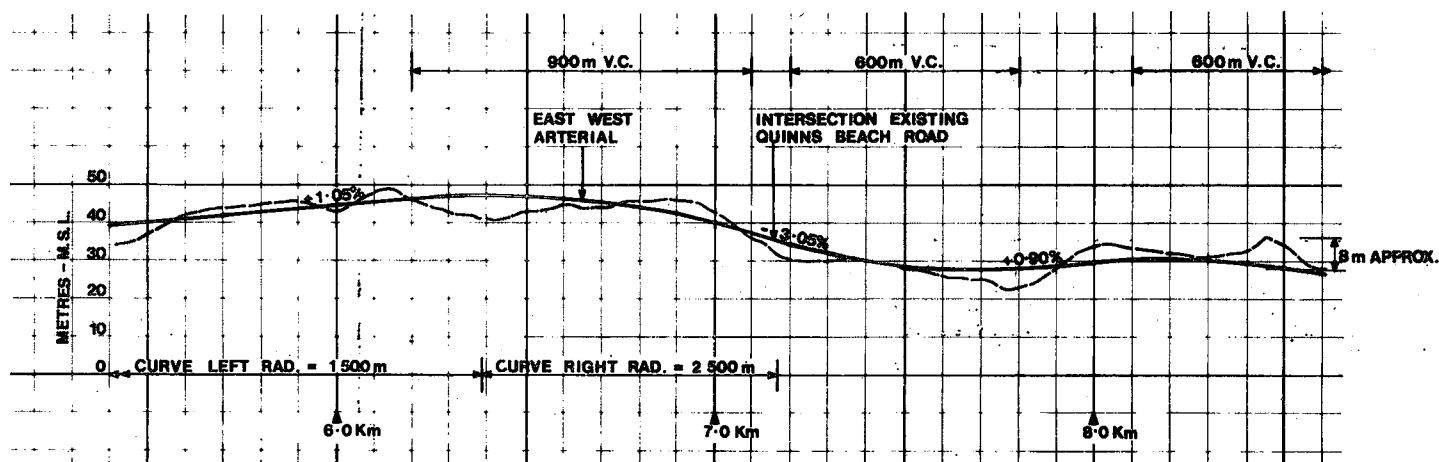
SCALE 1:500

URBAN SYSTEMS CORPORATION PTY. LTD.
HALPERN GLICK & LEWIS PTY. LTD.

Fig. C3



STEPHENSON FREEWAY



MARMION AVENUE

MINDARIE QUINNS ROCKS

TYPICAL ROAD PROFILES

SCALE HORIZONTAL 1 : 20,000
VERTICAL 1 : 2,000

URBAN SYSTEMS CORPORATION PTY. LTD.
HALPERN GLICK & LEWIS PTY. LTD.

Fig. C4

MINDARIE ESTATE ROAD DESIGN CRITERIA

STEPHENSON FREEWAY

Design speed	120 km per hour
Reserve width	82m (minimum)
Median width	20m
Carriageways	Two x 14.8m Eight lanes
Intersections	None at grade Grade separated interchanges 6 km to 8 km apart Vehicle underpasses and over- bridges required through residential areas Underpasses at regional open spaces
Maximum Grade	3%
Access to adjacent lots	Not permitted
Footpaths	None

MARMION AVENUE

Design speed	80 km per hour
Reserve width	60m (minimum)
Median width	14m
Carriageways	Two x 11m Six lanes
Intersections	Tee form, minimum spacing 400m Pedestrian underpasses and overbridges in residential areas. Underpasses in regional open spaces
Maximum grade	6%
Access to adjacent lots	Indirect access permitted through frontage service road
Footpaths	Where residential areas adjoin

EAST—WEST ARTERIAL

Design speed	80 km per hour
Reserve width	60m (minimum)
Median width	14m
Carriageways	Two x 11m
Intersections	Tee form, minimum spacing 200m, Pedestrian underpasses and overbridges

Maximum grade	6%
Access to adjacent lots	Indirect access permitted through frontage service road
Footpaths	Where residential areas adjoin

WEST COAST ROAD

Design speed	55 km per hour
Reserve width	30m
Median width	None
Carriageways	One x 10.7m
Intersections	Tee form. Underpasses to provide access to beach.

Wind — emphasis
major factor