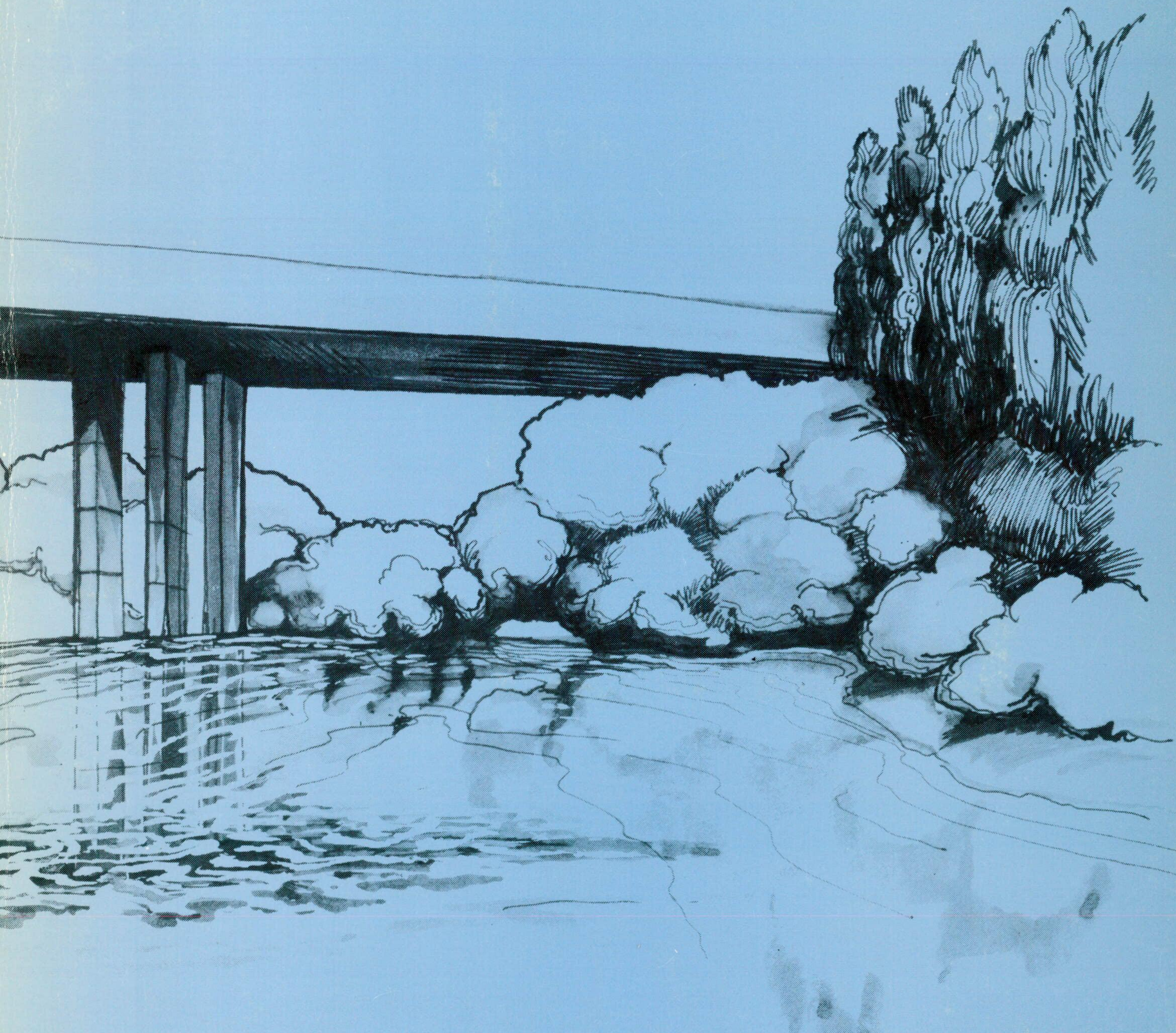
Parramatta River Regional Environmental Study

Open Space and Recreation

Issue Paper 2 Natural Systems



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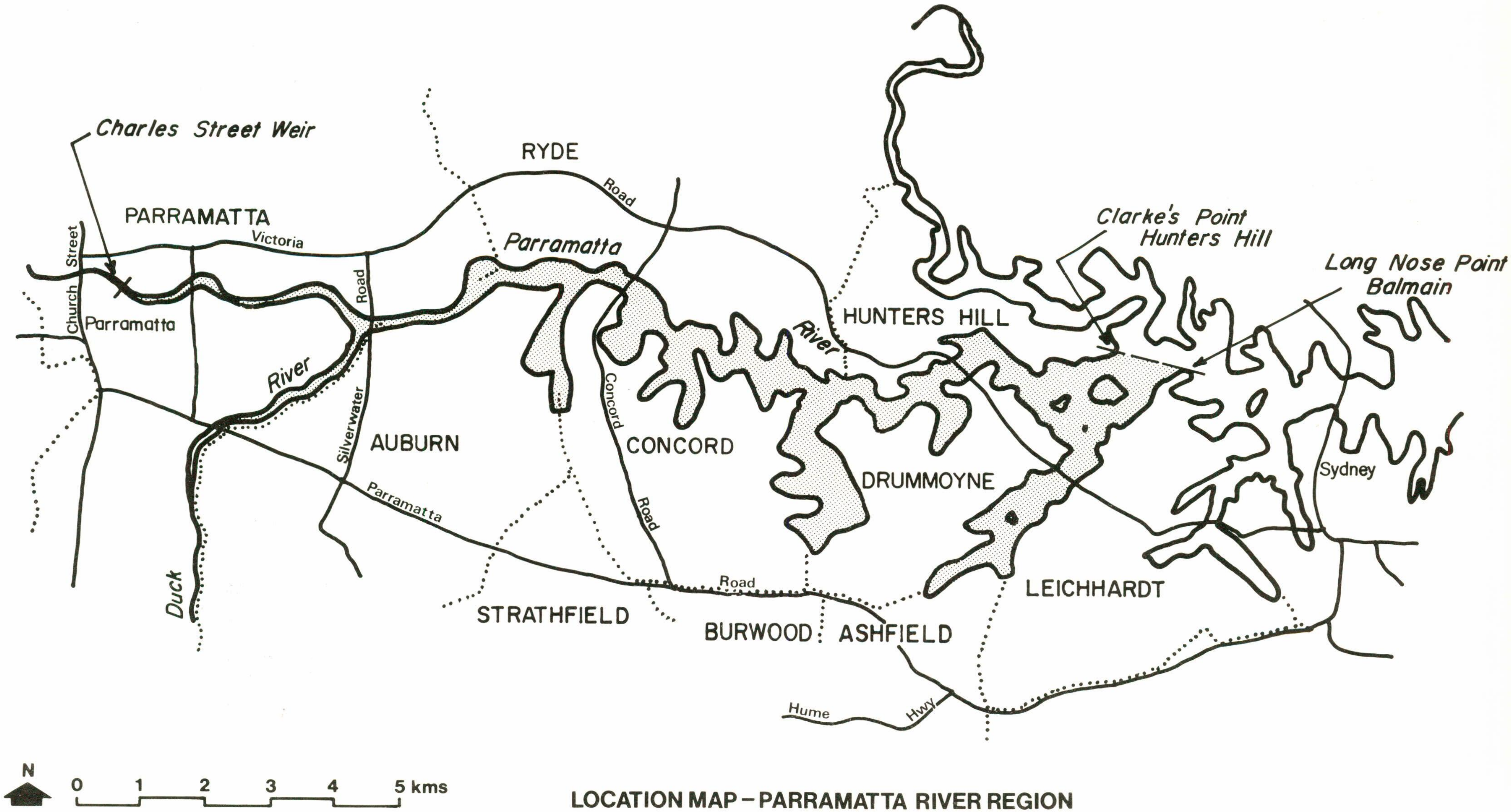

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Parramatta River regional environmental study
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Parramatta River
Regional Environmental Study

Open Space and Recreation

Issue Paper 2
Natural Systems

Department of Environment and Planning
Sydney 1986

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ISBN 0 7305 1616 4 0730547701 (corrected)
85/86

PREFACE

A regional environmental study of open space and recreation potential within the Parramatta River Region (as declared by the Minister for Planning and Environment) was undertaken in order to identify the major issues, and to provide a basis for future planning for the area.

The study, together with an atlas of mapped information, has been published as a two volume set. This paper is one of three supplementary publications giving more detailed and technical information about the visual elements, natural systems, recreational activities and open space resources of the region.

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INTRODUCTION

This paper contains detailed and technical information collected for the "natural systems" aspect of the Parramatta River Open Space and Recreation Study (Department of Environment and Planning, 1986).

The paper comprises sections on geology; soils; vegetation; fauna; and the water, air and acoustical environments.

NATURAL ENVIRONMENT

Geology

The study area is located almost at the centre of the Permo-Triassic Sydney Basin. Only the youngest Triassic rocks are exposed. The underlying strata of the Basin were laid down during the early Permian and Late Carboniferous periods under marine and marsh conditions, producing the sandstone and siltstone formations and the intervening coal measures lying beneath Sydney. The geological formations occurring in the study area are predominantly Triassic strata which were formed from sediments deposited in the estuarine environments. The strata were subsequently tilted and affected by minor folding and faulting.

Hawkesbury Sandstone dominates the eastern section of the study area. It comprises quartz sandstone with minor shale lenses. Ashfield Shale of the Wianamatta Group is found in the middle and western sections of the study area on the higher ground, removed from the Parramatta River foreshores. Because of its dominantly shaly composition it has produced moderately fertile soil and low undulating topography which has attracted a considerable portion of the urban development in the study area.

Sea level fluctuations during the Quaternary Period had an important influence on the distribution of sediments. The level of the sea during these times fluctuated through a height of 120 metres. Quaternary coastal sediments vary from muds through sands to gravelly sands. Sediment thicknesses range from 25 to 35 metres upstream of the Sydney Harbour Bridge. In the study area mud overlies sand: it is thought to be fluvial in character and was deposited as the rising sea level drowned the fluvial valley system. The mud tends to be less sandy in those bays which drain from areas of Wianamatta Group Shale than in those bays with Hawkesbury Sandstone catchments. Fossil shell beds one metre thick have been reported to exist in Hen and Chicken Bay and the Duck River at Silverwater.

Before reclamation, the embayments within the study area were bordered by extensive wetlands and, in certain areas, sandy beaches. During the early settlement of Sydney, the ready access to and the availability of, a wide range of low-cost extractive material enhanced development. Quality dimension stone from the Hawkesbury Sandstone and characteristic dark-red bricks from the

Ashfield Shale were used in many historic buildings. Urban development has prevented the further exploitation of the various resources underlying the study area; however, the State Brickworks is continuing to extract clay material from its site at Homebush Bay.

Extensive reclamation operations have been carried out in the Homebush Bay and Silverwater areas, with minor reclamation having been carried out in the majority of the other embayments along the river. It has been estimated that the total area of reclaimed river, mangrove and saltmarsh is approximately 600 hectares or 25 per cent of the Parramatta River study area before European settlement. Figure 1 shows the extent of reclamation carried out in the study area. The geological characteristics of the study area are shown on Figure 2.

Soils

The distribution of soil types throughout the study area is closely related to the lithology of the underlying strata and is also influenced by its geomorphic position. In 1960, P.H. Walker of the Soil Survey Unit, Department of Agriculture surveyed the soils of the County of Cumberland and used these relationships of soil geology and geomorphology to map soil associations.

It was observed that within each mapping unit (association) is a number of soil series whose distribution is determined by topography and parent material differences. The predominant soil associations found in the study area are the Hammondville, Cumberland and Villawood units.

The Hammondville association is complex because it is an association of mixed parent material of sandstone and shales of the Wianamatta Group. The yellow podsolics are the predominant soil group found in this association. The Cumberland association is most common on the undulating sections of the study area. The red podsolic soils of the Cumberland series are developed on siliceous fine-textured shales of the Wianamatta Group. At the south-western section of the study area the Villawood Association is the predominant series and comprises a ferruginous soil which has developed under poorly drained conditions overlying the shales of the Wianamatta Group. The swamp soils are found adjacent to the silted bays and the low-lying areas, particularly in the vicinity of Homebush Bay and Silverwater. The various soil associations to be found in the study area are shown in Figure 3.

Vegetation (Terrestrial)

Native trees principally comprise species regenerated from the original forest and to some extent those resulting from recent planting programs. The Blackbutt (*E. pilularis*) and Sydney Blue Gum (*E. saligna*) association once occupied much of the study area. This was the high forest having an average height of 26 to 32 metres. It covered much of the North Shore and areas extending south-west of the Central Business District of Sydney. Other species which occurred in this association include Grey

Ironbarks (E. paniculata), Turpentine (Syncarpia glomulifera), Smooth-barked Apple (Angophora costata), and Red Bloodwood (E. gummifera).

On shale soils on the southern side of the Parramatta River, where rainfall is lower, the forest would have included Turpentine (Syncarpia glomulifera), Forest Red Gum (E. tereticornis), White Stringybark (E. globoidea), Red Mahogany (E. resinifera) and Rough-barked Apples (Angophora floribunda).

Where natural understorey now exists it consists mainly of Pittosporum spp., Dodonaea spp., and a number of Fabaceae and Proteaceae. Small stands of these sclerophyll-leaved species still survive in Concord (Coupe, 1983) and on Department of Defence land at Silverwater.

Headlands of Hawkesbury Sandstone on the northern side of the Parramatta River would have had woodland with Blackbutt (E. pilularis), Red Bloodwood (E. gummifera), Smooth-barked Apple (Angophora costata), with shrubs of Banksia integrifolia, Casuarina littoralis and Kunzea ambigua.

The Blackbutt timber in the study area was extensively logged. Kartzoff (1969) states that approximately 90 per cent of the timber cut at one sawmill located in the West Pennant Hills area was Blackbutt. The logged areas were subsequently cleared for farming and settlement and are now largely occupied by suburbs.

It is likely that small clumps of Swamp Oak (Casuarina glauca) or Swamp Mahogany (E. robusta) occurred behind the tidal mud flat sections of the Homebush Bay area (Coupe, 1983).

Fauna

The Parramatta River valley prior to European settlement supported a diverse base of terrestrial animals including koalas, grey kangaroos, swamp wallabies, echidnas, wombats and native cats. Bandicoots, once prevalent, have declined significantly, possibly due to predation by dogs. Only the possums have adapted to living alongside urban development and are found in some areas even as suburban roof dwellers. Adamson (1980), reported that the growth of privet and balloon vine may have favoured ringtail possums, despite these weeds preventing other native plants from growing. The introduced vegetation, in particular privet, has also favoured the spread of exotic mammals such as the black rat (Rattus rattus) and house mouse (mus musculus). The water rat (Hydromys chrysogaster) one of the several native species found in the study area has also adapted to the urban and industrial devleopment adjacent to the river.

H.F. Recher (1972) reported that 89 species of birds had been observed in a section of the nearby Lane Cove River between 1968 and 1971, while 91 species were observed for the same period in a small section of the Brisbane Water National Park.

The study area is an important habitat for migratory waders, being consistently used by between six and nine hundred sandpipers, which is about 20 per cent of the N.S.W. total. The N.P. & W.S. further advises that the White Fronted Chat inhabits the saltmarsh and mangrove areas in the vicinity of Homebush Bay while the Pied Stilt uses the marsh areas for nesting sites.

Other species which are important are Eastern Golden Plover, Bar-tailed Godwit and Red-necked Stint.

The same bays are used as feeding areas for the Little Terns and Eastern Common Terns, both non-breeding visitors from the northern hemisphere, and Crested Terns, which are local non-breeding residents. All these terns take fish in the shallow tidal areas.

The areas of mangroves, particularly Yaralla Bay, Horseshoe Bay, Majors Bay, Homebush Bay and the mangrove belt on the north side of the river from Ryde Bridge to Silverwater Bridge support Grey Teal, Black Duck and Chestnut Teal (one of the largest populations in the coastal areas of New South Wales). Chestnut Teal ducks feed primarily on algae and invertebrates associated with those plants exposed at low tide. The N.P.& W.S. has reported that winter populations of Hoary-headed Grebe utilise two areas of Iron Cove, near Rodd Point, and sites at Canada Bay and Exile Bay within Hen and Chicken Bay. In addition, three species of cormorants feed on fish on the river predominantly upstream of Mortlake Point. The most common species found is the Little Black Cormorant. Silver Gulls are perhaps the most common species of all the water birds present in the study area. Hoskin (1984) has recorded that because of a population explosion of Silver Gulls, nesting sites on offshore islands have become overcrowded, forcing some birds to seek alternative nesting sites. In January 1984, breeding was confirmed when nests were observed on piles in Homebush Bay. Areas inhabited by water birds other than waders are shown in Figure 4.

WATER ENVIRONMENT

Waterway characteristics

The Parramatta River forms at the confluence of two small creeks, Darling Mills Creek and Toongabbie Creek, one kilometre west of the City of Parramatta. The river meanders through undulating terrain, passing through a succession of small weirs impounding ornamental fresh water lakes, and through the City of Parramatta before reaching the Charles Street Weir, which marks the tidal limit. It joins a tributary, the Duck River, four kilometres downstream of the tidal limit. The river flows east for a further 13 kilometres, past heavily populated suburbs which line its banks or surround its many large embayments. Several minor tributaries including Haslams Creek, Tarban Creek, Iron Creek and Hawthorne Canal flow to the Parramatta River via such embayments. It meets its main tributary, the Lane Cove River at Woolwich, two kilometres before it enters Port Jackson at Long Nose Point, which forms the eastern boundary to the study area.

A conspicuous feature of the river east of Ryde Bridge is the numerous embayments on either side formed in the ancient gullies cut from the parent sandstone rock by the tributaries of the original river. The silted bed of the drowned valley of the Parramatta River has an irregular profile. The river is between two to five metres deep west of Ryde Bridge, 25 metres deep east of Gladesville Bridge, reaching a maximum of 50 metres west of the Sydney Harbour Bridge. This is the deepest part of Sydney Harbour, far exceeding the average harbour depth of 20 metres. The variation in depth is caused by irregular siltation influenced by opposing tide currents and the occasional flood flow. The main channel of the Parramatta River has reached a stable condition and the deeps and shallows are now fairly permanent in shape and location.

The study area includes the tidal reaches of the Duck River. The tidal reach is short, being limited by a weir which divides the river near Parramatta Road at Auburn. The river drains a catchment of 45 square kilometres of flat land containing extensive residential, commercial and industrial areas. The tidal reach is almost exclusively occupied by industrial sites, including one of the largest, Sydney's first oil refinery.

The tidal range in the study area is the same as at Fort Denison. The range between the highest and lowest astronomical tide is 2.1 metres, between the mean high and low water spring tides, 1.3 metres and between the mean high and low water neap tides 0.9 metres.

Flooding

Records of flooding in the Parramatta River indicate that large floods upstream of the study area occurred in 1889 and 1914 and smaller floods occurred again in 1956, 1961 and 1967. Property damage was not widespread. The extensive urbanisation of the catchment which has occurred over the last 25 years has resulted in a change in storm flow parameters. As a result of these changes heavy rainfalls produce greater volumes of runoff, which concentrate more rapidly increasing the potential for flooding.

The Public Works Department has not found it necessary or appropriate to carry out flood mitigation works in the tidal section of the Parramatta River. However, it has in the past constructed many stormwater channels which were subsequently transferred to the control of the M.W.S. & D.B.

Waste disposal

In common with all other river systems, one of the primary functions of the Parramatta River is to direct rainfall run-off to the ocean. Under intensive wet weather conditions the waters of the Parramatta River carry large volumes of urban stormwater as well as surcharges from the sewerage system. Surcharges from emergency overflow structures in the sewerage system and urban run-off are the prime sources of pollution of the river during or immediately after periods of wet weather. Surcharges are caused by the entry of stormwater into the sewers by infiltration and from unauthorised connections. The surcharge passes into the nearest available receiving waters either directly by pipeline or indirectly by stormwater channels and surface flow.

- **Urban run-off and stormwater drainage**

As the catchment of the study area is extensively cleared and contains a significant ground coverage of impervious materials, a large proportion of rainfall enters the Parramatta River either directly or via tributary creeks, canals and stormwater drains.

Urban stormwater run-off contains large quantities of suspended material including silt, nutrients and oxygen - demanding substances, particularly garden and domestic refuse, which at times place a considerable pollution loading on the river, resulting in a deterioration of water quality. High oxygen demand exerted by stormflows is manifest, especially in the upper reaches by low concentrations of dissolved oxygen persisting for many days after storm flows have ceased. Bacterial counts are usually high. In addition, the first flush contains a considerable quantity of floating rubbish, invariably of a domestic rather than an industrial nature, as well as clumps of floating vegetation, including water hyacinth and alligator weed. Floating rubbish, as well as being visually unattractive may also be a hazard to small water craft.

Figure 5 details the network of channels within the study area designed to direct stormwater to the Parramatta River. The largest volume of inflows is derived from recent rainfall: most of the tributary creeks and streams of the river are perennial, so the base flows are low. Stream flow in tributaries following periods of rainfall is supplied by interflow and by groundwater seepage.

Councils are generally responsible for other drainage systems, and also control minor stormwater reticulation, street drainage and development within their respective areas of responsibility.

Many of the M.W.S. & D.B.'s channels do not appear to meet modern hydraulic standards and will require amplification in the future. Because of the prior demands of water and sewerage works, funds available for drainage works are very restricted and therefore are generally made available only for urgent flood relief works, mostly outside the study area. Extension of outlets into tidal areas is undesirable as tidal affected outlets are subject to siltation and are very difficult to maintain free of silt. The P.W.D. has recognised that the removal of material which has built up in the estuary over the last 100 years could make some areas more useable and pleasant.

Where dredging of bays, which receive discharges from M.W.S. & D.B.'s stormwater channels has become necessary, the M.W.S. & D.B. has in the past contributed a proportion of the cost of dredging that portion of a bay where silt from the stormwater channel is deposited. The dredging work in such instances has been carried out by the M.S.B.

A preliminary feasibility study of dredging of certain embayments of the river has been undertaken by the P.W.D. Its aim was to ascertain likely behaviour of sediments during dredging, to evaluate tidal flushing in natural conditions before and after dredging, to establish the likely distribution of dredge induced turbidity and to determine likely effects of the operations on wave climate and foreshore stability. Dredging is being given consideration as a means of maximising waterway space available for recreational boating.

The P.W.D., in its report Parramatta River Regional Study on Recreational Boating (January 1985), has set out various strategies to improve recreational boating. Action is considered desirable at the earliest possible date on some dredging to be carried out in Iron Cove, Middle Parramatta River, Five Dock Bay and Hen and Chicken Bay subject to favourable economic and environmental considerations and the availability of suitable locations to place the dredge spoil.

It is reported that after dredging the tidal flushing of the then deeper embayments would be decreased, but would still provide complete exchange with river water every few days. In addition wind waves generated would lead to increased wave energy being expended against forshore structures under high velocity winds. As such, account would need to be taken of these aspects in the dredging program, and preventative or remedial measures incorporated into the dredging plans.

It was further advised by the P.W.D. that the increased depths would place the bed below the scouring ability of most wind waves. This decreased shearing of the bed by waves, combined with lower tidal current throughout the water column has implications for behaviour of chemical and organic pollutants, which may show an increased tendency to settle. Before implementing any dredging program the desirability of this effect may warrant further consideration.

The rate at which the river water quality recovers from storm run-off stress depends to a large extent on the intensity and duration of storms and the time interval between storms, the upper reaches of the river and the long embayments being the slowest to recover. Following the successful implementation of control of point source discharges, pollution from storm run-off has emerged as a significant influence on water quality in the Parramatta River.

. **Sewerage**

The M.W.S. & D.B. is responsible for the operation of the sewerage system which is separate from the stormwater drainage system. The system accepts domestic sewage as well as industrial wastes. Since the introduction of the Clean Waters Act in 1972, trade wastes from over 6000 factories in the Sydney metropolitan area have been connected to the sewer: however, the M.W.S. & D.B. restricts the type of wastes which may be accepted. Certain types of industrial effluent require pretreatment before discharge to the sewer. Wherever possible, sewage is conveyed by gravity, but in some areas of low topography it is raised by pumping stations to the major gravitational lines.

Some sewers and sewer pumping stations are located along the foreshores of the Parramatta and Duck Rivers. Emergency sewer overflow structures are installed on all sewers and at all sewer pumping stations. Such structures are essential to provide relief to the sewerage system in the event of failures and to protect property from sewer surcharges by directing surcharges away from private property to areas considered to be less offensive. The location of major sewer overflow structures within the study area are shown in Figure 6.

During periods of wet weather, infiltration of stormwater into the sewerage system occurs because of illegal connections from premises and from infiltration of sewers via pipes and joints in poor condition. Under such conditions, the flow of the combined stormwater/sewerage can sometimes exceed average dry weather flows by a factor of ten or more. Sewerage reticulation systems are designed to handle approximately four times the peak dry weather flow. As such, surcharges into the river from certain emergency sewer overflow structures are inevitable during periods of prolonged rainfall.

- **Licenced discharges**

A very large number of industrial and other discharges to the waters of the Parramatta and Duck Rivers within the study area existed prior to the implementation of the Clean Waters Act (1970). There are currently only twelve and these consist of municipal swimming pool filter backwash wastes, ballast water and cooling water. The swimming pool filter backwash wastes have a high non-filterable residue (suspended solids) and chloride component.

Discharges licenced under the Clean Waters Act, (1970)
Parramatta and Duck Rivers

Licensee	Location	Nature of Wastes	Max Flow (kL/day)
DISCHARGES TO PARRAMATTA RIVER			
. James Hardie & Co Pty Ltd	Camellia	Treated asbestos cement wastes	650
. Mobil Oil Aust Ltd	Hunters Hill	Treated factory drainage	80
. Tanner Middleton Pty Ltd	Concord	Cooling water	930
. Goodyear Tyre & Rubber Co (Aust) Pty Ltd	Camellia	Cooling water - factory drainage	500
. Ashfield Municipal Council	Ashfield	Municipal pool	200
. Auburn Municipal Council	Lidcombe	Municipal pool	90
. Concord Municipal Council	Cabarita	Municipal pool	32

Licensee	Location	Nature of Wastes	Max Flow (kL/day)
. Drummoyne Municipal Council	Drummoyne	Municipal pool	90
. Leichhardt Municipal Council	Leichhardt	Municipal pool	140
. Ryde Municipal Council	Ryde	Municipal pool	120
DISCHARGES TO DUCK RIVER			
. James Hardie & Co Pty Ltd	Rosehill	Treated wastes after ponding	3,100
. Shell Refining (Aust) Pty Ltd	Granville	Treated excess from cooling system	1,500

Source: S.P.C.C. (October 1983).

Water quality

The water quality of the Parramatta River has been monitored by the S.P.C.C. since 1971. The principal water quality parameters monitored over this time have been dissolved oxygen, salinity, temperature, pH, and on an irregular basis such parameters as faecal coliform density, nutrients, turbidity, non-filtrable residue, biochemical oxygen demand and heavy metals have also been monitored. The water quality data has been generally sorted by the S.P.C.C. into two groups, "dry weather data" and "wet weather data" (wet weather being defined at the time of the early surveys as more than two millimetres of rainfall in the previous 48 hours, and more than ten millimetres in the previous 96 hours).

The data reflects the obvious improvements in the appearance of the river and the return of fish in large numbers. The improvements are the results of intensive efforts by the S.P.C.C.to divert polluting effluents from the river. It is S.P.C.C. policy that industrial wastes from factories be connected to the sewerage system. In the early 1970s prior to the implementation of the Clean Waters Act, the organic load imposed on the river was equivalent to the discharge of sewerage from 85,000 persons.

The S.P.C.C. has reported that under extended dry weather conditions the tidal waters of the Parramatta River are reasonably well mixed and have small salinity gradients, ranging from near oceanic salinity at the eastern end of the study area to about two-thirds of this at the tidal limit. Water quality is homogeneous over long lengths although changing gradually, as could be expected, from the narrow and shallower upper reaches to the deep waters of Sydney Harbour. The water is well oxygenated at all depths, even in the shallower upstream sector.

Under these dry weather conditions concentrations of nutrients (nitrogen and phosphorus) diminish with dilution and flushing. Phytoplankton algal activity, reflecting the low nutrient concentrations, is at no more than "natural" levels except after wet weather when phytoplankton algal blooms may occur. Faecal coliform counts are generally low. A significant characteristic in the upstream reaches is the high, but variable, concentrations of solids in suspension, composed largely of inorganic matter, indicating the continual movement of sediments by tidal translation.

Under intense wet weather conditions, the Parramatta River and its tributaries carry large volumes of urban storm water run-off, as well as surcharges from emergency sewer overflow structures. The most obvious effect of storm water run-off is the large component of silt carried into the river, which becomes very turbid for much of its length. In addition, storm flows contribute large quantities of domestic rubbish. The high oxygen demand exerted by storm flows is manifested in the upper sector, especially by low concentations of dissolved oxygen persisting for many days after streamflow has ceased. Bacteriological counts are high in certain areas under these conditions.

The S.P.C.C. has stated that its pollution control strategies to control turbidity, suspended solids and urban rubbish transported to the Parramatta River by urban stormwater run-off will require:

- introduction of a trash and rubbish cleanup program along river and tributary foreshores on a regular basis and after major storms;

- installation of detention basins and trash racks in selected urban drains and the maintenance and control of these structures to be vested in local councils;

- retention of any remaining natural features of the river and its tributaries and resistance to any pressure to canalise tributaries of the river;

- adoption by relevant authorities of procedures recommended by the Soil Conservation Service for urban erosion and sediment control in urban and developing areas;

- instigation of additional public education campaigns concerning garden refuse and litter control in order to avert transporation to the river by stormwater;

- minimisation, as far as practicable of the development of additional impervious surface areas, adoption of regular sweeping of gutters and diversion of house or factory roof water away from street drainage systems to infiltration beds within the individual properties;

- retention and maintenance of natural vegetation areas (including mangrove areas) between developments and waterways in order to maximise infiltration and minimise erosion and scouring of foreshore areas.

The installation of urban stormwater run-off controls should be carried out in conjunction with proposed developments and reflected in the overall development cost. The S.P.C.C. is currently considering whether additional legislation requiring the installation and maintenance of the abovementioned structures to control sources of diffuse water pollution should be proposed.

- **Water quality characteristics**

Dissolved oxygen

Dissolved oxygen concentration is one of the most important indicators of water quality because it is the quality factor which is most readily impaired by biodegradable organics and because an adequate level of oxygen is essential for the maintenance of the diverse life forms which normally exist in natural waters. To allow comparison of oxygen levels in waters of different salinities and different temperatures it is common practice to express dissolved oxygen as percentage of saturation rather than as a weight concentration. A dissolved oxygen saturation of 60 to 70 per cent is considered to be acceptable for the maintenance of a good marine habitat.

During the period 1971 to 1974, dry weather dissolved oxygen levels in the study area were characterised by very low levels, with minimum levels occurring upstream of Ryde Bridge, gradually increasing with downstream distance. In the same period phytoplankton algal blooms occurred infrequently upstream of Silverwater Bridge, resulting in high recordings of maximum dissolved oxygen. When many of the industrial discharges to the river had ceased during the summer of 1975-76 a noticeable improvement in water quality was achieved. The minimum dissolved oxygen levels had increased and were generally above 60 per cent of saturation. Phytoplankton algal blooms were also encountered during this period and these events resulted in mean dissolved oxygen levels frequently above 100 per cent of saturation being recorded. A maximum dissolved oxygen level of 160 per cent of saturation was recorded in the vicinity of Silverwater Bridge during this period. Where high dissolved oxygen concentrations result from photosynthesis it would be expected that the concentration during the night could be reduced to low levels due to respiration. Low dissolved oxygen levels have in the past been responsible for fish kills, particularly in the upper reaches of the river where tidal flushing is poor.

The S.P.C.C.'s 1981 to 1982 dry weather surveys recorded a substantial reduction of oxygen stress situations in the upper tidal reaches (including Duck River). This situation was also reflected in greater stability in downstream reaches. The minimum levels of dissolved oxygen reported by the S.P.C.C., were always above 60 per cent of saturation with maximum levels being generally less than 120 per cent of saturation, indicating that phytoplankton algal blooms, although still occurring, were not as significant as in earlier surveys.

The variability in oxygen saturation in the lower reaches is now no more than can be expected under natural conditions. Under prolonged dry weather conditions the dissolved oxygen levels at 0.5 metres depth may be representative of the whole water column, however, during and after wet weather stratification occurs.

The dry weather dissolved oxygen levels measured by the S.P.C.C. at 0.5 metres depth during the period 1971 to 1982 at selected stations on the Parramatta River from Gladesville Bridge upstream to the tidal limit including Duck River, are shown in Figure 7.

During wet weather, large amounts of organic matter are transported into the tidal section of the Parramatta River. Initially, the freshwater has a high level of dissolved oxygen: however, biological oxygen demands of the organic matter consumes this and both the fresh and underlying saline waters are subject to large variations in dissolved oxygen and may at times become depleted of oxygen, particularly upstream of Silverwater Bridge. This occurs because the upper section is not as well flushed by tidal exchange processes.

Salinity

During periods of extended dry weather, salinity at the Charles Street Weir at Parramatta approaches that of seawater (36 parts per thousand), although, the maximum level recorded by the S.P.C.C. has been 28 parts per thousand. Dry weather salinities show a gradual increase with distance downstream (Figure 8). Upstream of Silverwater Bridge, there is also a small vertical salinity gradient (thorough the water column) varying from 2 to 7 parts per thousand; this gradient becomes less towards Ryde Bridge and in the lower estuary to the Gladesville Bridge the water column is well mixed with very little salinity change with depth.

Wet weather salinities were only measured by the S.P.C.C. on three to four occasions for each two year period. The S.P.C.C. reports indicate that the degree of change in the salinities depended on the amount of rain, the catchment distribution of the rain and the period between antecedent rainfall. The wet weather data collected shows an incremental decrease in surface salinities with distance upstream, with salinity values decreasing to zero at the Charles Street Weir during prolonged rainfall (Figure 8). Freshwater inflows spread across the water surface forming a buoyant layer, the depth of which depends on the amount of rain. Tidal water movement results in the gradual mixing of the overlying freshwater with underlying saline waters.

Nutrients

Concentrations of nutrients (compounds of nitrogen and phosphorous) in the river reach maximum concentrations in the upper tidal sections and gradually decrease downstream due to dilution and tidal flushing. Upstream of the Ryde Bridge, the mean concentrations of total phosphorous and total nitrogen are approximately 100 and 600 micrograms per litre, respectively. These values are approximately twice the levels monitored by the S.P.C.C. for the respective values in waters between the Ryde Bridge and the Sydney Harbour Bridge and are about five times those concentrations monitored in Sydney Harbour.

The concentrations of nutrients generally reach a maximum during and immediately after wet weather, reflecting the impact of urban stormwater and sewer overflows. In the upper reaches of the Parramatta River, the peak concentrations observed for total phosphorus and total nitrogen are about 300 and 1,500 micrograms per litre, respectively. Nutrient concentrations after wet weather have resulted in phytoplankton algal blooms.

Excessive macroalgae such as Ulva and Enteromorpha occur periodically in Iron Cove, Majors Bay, Yaralla Bay, Hen and Chicken Bay and sections of Homebush Bay in response to increased nutrient levels in water which arise from run-off stormwater and the release of nutrients from bottom sediments.

Turbidity

Turbidity in water is caused by the presence of suspended matter and is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines.

S.P.C.C. reports show that turbidity levels in the Parramatta River during the period 1971 to 1983 have decreased. Compared to turbidity recorded in the estuary during 1971 to 1974, turbidity values obtained during 1975 were significantly lower, particularly upstream of Silverwater Bridge where, in the early 1970s, levels were very high (refer to Figure 9) with maximum values of 120 nephelometric turbidity units (NTU) being measured. During dry weather surveys carried out by the S.P.C.C. in 1981 and 1982, turbidity levels were observed to be low, however, small peaks due to the influence of phytoplankton algae were observed in the vicinity of Ryde Bridge. During wet weather, turbidities increase and are variable. Very high turbidities were recorded in the early 1970s ranging from 16 up to 900 NTU. During 1975 to 1976 and 1981 to 1982, maximum levels recorded were 470 NTU and 100 NTU, respectively.

Water clarity and the absence of rubbish are also important features for recreational waters because of aesthetic appeal and safety. Turbidity levels increase after periods of rain, particularly upstream of the Silverwater Bridge and turbidity remains high for longer periods of time in contrast to sections further downstream. Recovery after rain of the upper tidal section to dry weather turbidity levels (less than 10 NTU) is slow, sometimes taking up to several weeks. In its publication entitled Turbidity of Botany Bay and Georges River (1979), the S.P.C.C. has reported that for Australian bathing and swimming areas the clarity of water should be such that a Secchi disc is visible at a minimum depth of 1.2 metres. Waters having high turbidity levels and carrying large quantities of floating rubbish are known to act as a strong disincentive to swimmers.

Faecal coliforms

Faecal coliforms are a sub-group of coliform bacteria that have a high positive correlation with faecal contamination associated with all warm-blooded animals. Of the many groups of coliform bacteria only *Escherichia coli* (*E. coli*) appears to be specifically of faecal origin. Because *E. coli* can be readily detected and does not normally multiply outside the intestines of warm-blooded animals, it has been used most commonly by water microbiologists as an indicator of the possible presence of intestinal pathogens.

The mean faecal coliform densities monitored by the S.P.C.C. in the Parramatta River and the Duck River, over the period 1974 to 1976 are shown in Figure 10. Under dry weather conditions, the mean faecal coliform density of waters for the various monitoring stations within the study area is less than 200 organisms per 100 millilitres, although the variability of organism density is significantly greater in reaches upstream of the Ryde Bridge.

Under wet weather conditions the mean faecal coliform density of waters in areas upstream of the Ryde Bridge exceeds 200 and upstream of the Silverwater Bridge is as high as 1000 organisms per 100 millilitres. These figures obviously reflect discharges of urban stormwater run-off and surcharges from emergency sewer overflows which are an essential part of all sewerage systems, including those of the M.W.S. & D.B.

Other potential sources of faecal coliform are industrial effluents, tip leachates and septic tank effluents. In the study area there are no known discharges of industrial effluents containing faecal coliforms - such effluents would require a licence under the Clean Waters Act. All waste disposal depots within the study area currently receive only non-putrescible waste. It is considered highly unlikely for faecal coliforms to be encountered in any leachate should it be present. Seepage from septic tanks are not considered to be a source because all urbanised areas of the study area are sewered.

Although not specifically identified as a problem in the study area, it is possible that the practice of discharging raw sewage from moored vessels is being carried out and thus contributing to pollution during dry weather. The incorporation of holding tanks on boats and the provision of pump-out facilities at marinas may alleviate this situation should it occur.

The levels of faecal contamination which may be found in these waterways are thus influenced by the intensity of storms and location of sewer overflow structures. Tidal flushing and natural purification processes ensure that levels decrease after periods of rainfall.

Under certain conditions E. coli may die off more slowly than some pathogens and it is not uncommon for pathogens, when they occur, to survive longer than E. coli in the natural environment. Reported survival times of enteric viruses in estuary water vary from two to 130 days. Some pathogens may survive for weeks in bottom muds if there are high concentations of nutrients present. On the other hand, it can be expected that the number of faceal coliform can decrease by 90 per cent within several hours, depending on conditions such as dilution (due to rain and tide), osmotic effects, solar radiation, turbidity and predation by other organisms.

Fuhs (1975) states that bacteriological standards for bathing beaches have for some time been the subject of controversy. Most critics contend that the standards are overly restrictive, citing the extremely favourable epidemiological record of beaches considered of marginal bacteriological quality and even of areas used by bathers despite poor bacteriological quality. Other critics point out that bacteriological standards are arbitrary, since there is no proved relationship between the numbers of indicator bacteria and the transmission of waterborne illness, and urge that bacteriological tests be abandoned in favour of sanitary inspections or purely aesthetic criteria. It was not until 1972, that an attempt was made to define mathematically the risk of contracting a waterborne disease as a function of two probabilities, that of ingestion a certain dose of an infectious agent and that of contracting the disease as a result of such a dose.

In its publication entitled Health Aspects of Faecal Contamination - Environmental Control Study of Botany Bay (1979), the S.P.C.C. in referring to Shuval (1975), indicated that the probability of contracting an infection after the unavoidable ingestion of polluted ocean water while bathing was low. It was estimated that bathing adjacent to an ocean sewer outfall where the faecal coliform level was 1000 organisms per 100 ml (and using variable assumptions) the chance of becoming sick from ingestion of an associated pathogen was calculated to be one in 100,000 per bathing experience. This was considered by the S.P.C.C. to be a low risk situation. However, during epidemics, when pathogen numbers would be greater, the risk of infection would be higher for similar coliform levels.

One standard commonly used for recreational waters has been that faecal coliform levels should not exceed a geometric mean of 200 faecal coliforms per 100 ml. Many studies and authorities have used this limit as the dividing level between "acceptable" and "unacceptable" conditions for primary contact recreational activities. In using this standard, it would appear that certain areas downstream of the Ryde Bridge would be suitable for recreational purposes such as swimming in dry weather conditions during the summer months.

There appears to be no environmental reason why tidal swimming enclosures should not be repaired and once again be a valuable recreational asset as there has been a noticeable improvement in the quality of water in the study area. Consideration should now be given by the relevant authorities to examining the potential for reopening those enclosures which have been closed and/or fallen into a state of disrepair and to the establishment of new enclosures where suitable access and parking facilities can be made available. In addition, the feasibility of establishing beach areas in specific locations could also be considered, subject to the results of hydrodynamic studies.

The variability of organism density is significantly greater in the sections of the river upstream of Ryde Bridge. During wet weather conditions the mean faecal coliform density exceeds 200 F.C./100 ml and is often in excess of 1000 F.C./100 ml. Faecal coliform densities can vary according to the location of sewer overflows, character of catchment and degree of urbanisation and ability of the recieving waters to recover particularly as a result of tidal flushing. Studies carried out by the S.P.C.C. show that 10 mm rainfall would appear to be sufficient to cause marked elevations of faecal coliform levels at certain locations in the study area.

The S.P.C.C. is of the view that a minimum of two days would be required before a location could be considered safe for direct water contact recreation. Even in unusual situations a period of not greater than four days would suffice.

Sediment composition

During 1976 and 1977 the S.P.C.C. carried out a study of sediments in the Parramatta River and found that concentrations of the heavy metals, copper and cadmium were low and followed no recognisable trend along the length of the watercourse.

The highest metal concentration is of iron, with maximum levels occurring downstream of Silverwater Bridge. Silver contamination is negligible throughout the river. Chromium, lead and zinc concentrations peak in areas such as Duck River and Homebush Bay, which in the past received significant levels of uncontrolled industrial discharge. The levels of metal concentrations found in Parramatta River sediments are shown in Figure 11.

In respect of organic compounds, the investigation revealed that some of the lighter oil fractions introduced to the sediments before the implementation of the S.P.C.C.'s control policies will have been lost from the sediments by now. The expected future loss of oils will be slight but steady, since oil contamintion levels are considered to be generally low (generally less than one per cent of dry weight). Results of the investigation show that heavier oil fractions tended to predominate. Even though they discolour the muds in areas in and around Duck River, they will not act as a significant source of oil in the waters.

The only possible sediments that could contribute a measurable level of oils to the waters in low flow (dry weather) conditions would be in Duck River. The S.P.C.C. is of the view that even this would be difficult to detect and would not act as a significant source of biochemical oxygen demand. The investigation also revealed that no measurable contribution of biochemical oxygen demand would result from the low-level release of organic carbon into overlying waters. Figure 12 shows the levels of organic compounds in sediments.

The S.P.C.C. reports that, in general, levels of sediment contamination in the Parramatta River are not high enough to affect water quality. The sediments will probably release contaminants slowly, the rate depending more on natural overturning and redistribution than on direct leaching to overlying waters. This investigation conducted by the S.P.C.C. has shown that little benefit would be obtained from dredging of the sediments as a means of reducing pollution potential.

Fisheries resources

The Sydney estuary (including the waters of Port Jackson, Middle Harbour, Lane Cove River and the Parramatta River) is an important fishing ground. Commercial fishing activities in the area began with the commencement of European settlement and have persisted to the present day. Commercial prawn fishing began in the first or second decade of the 19th century. Recreational fishing increased with continued urbanisation. Complaints regarding fish stocks were made by anglers as early as 1820. In recent times the Division of Fisheries has received many complaints and allegations of impropriety concerning both commercial and recreational fishermen. Many theories of fish population dynamics show that fish stock adapted to a high natural mortality can withstand the removal of a large number of juvenile fish. The Division of Fisheries (Department of Agriculture) support the view that this theory is correct in respect of fish populations in the Sydney estuary. The Sydney estuary fish populations have been exploited for longer than any other Australian stock due to heavy, perennial recreational/commercial fishing.

Commercial fishing does not occur throughout the Sydney estuary but is restricted to about 2,500 hectares of the estuary (approximately 50 per cent). In the study area certain areas are closed to professional fishing due to heavy commercial water traffic. Other areas, such as Duck River, are closed to fishing because of pollution that occurred in the 1970s. Areas upstream of Silverwater Bridge are closed to commercial fishing and the area between Gladesville Bridge and Silverwater Bridge is closed for four months of the year. Physical obstructions such as marinas, wharves, moorings and submerged obstacles exclude commercial fishing from certain areas. No commercial fishing is permitted on weekends or public holidays.

It is estimated by the Division of Fisheries that 33 commercial fishermen (other than prawn fishermen) operate in Sydney estuary. No decline has been apparent in the commercial fish catch from 1955 to 1980. The 1980-81 commercial fish catch from the estuary was about 108,000 kg representing 22 kg fish/ha/annum, which ranked the Sydney estuary tenth of the State's sixty-five most prominent estuaries. The average fish catch for the last 10 years has included 33 fish species. The most common species were anchovy, yellowtail, trevally and silver biddy. Trevally, tailor and bream have formed the basis of commercial fishery for the last 25 years. Annual catches of these species show seasonal fluctuations considered characteristic of most fish populations. According to the Division of Fisheries, there are no long-term downward trends, and in recent years the trevally, tailor and bream catches were higher than average.

Of the 1,300 hectares of waterways in the study area only 640 hectares are available to commercial prawn trawlers. The Division of Fisheries reports that during the 1981-82 season, about 44 commercial prawn fishermen worked the Sydney estuary. The total Sydney estuary prawn catch was approximately 48,000 kilograms (kg) for the November-March 1981-82 season. Records from 1955 to 1980 show no long-term downward trend but large annual flucuations have occurred. The king prawn Penaeus plebeyus (60 per cent) and the school prawn Metapenaeus macleay (40 per cent) are the most common species caught. Prawn fishing is restricted to a six month season from 1 November to 30 April of each year.

The waterways of the study area also provide vital recreational fishing and the pressure from this activity is heavy in comparison to other Australian estuaries. The Division of Fisheries estimates the annual pressure on the Sydney estuary at about 836,900 fishermen hours or 167 hours/ha/year. The estimated number of anglers on Sydney estuary ranged from 1,700 per month in August 1980, to about 9,000 per month in January 1981.

According to the Division of Fisheries, the annual recreational fish catch from the estuary, including the study area was estimated at one million fish, having an estimated weight of 165,000 kg, which is considerably greater than the weight of fish taken by commercial fishermen. This represented a recreational fish catch of 1.26 fish per fisherman hour. The predominant species caught were yellowtail, bream and tailor.

The greatest fish catch of the individual Sydney estuary areas studied by the Division of Fisheries was recorded from an area east of the study area and the Harbour Bridge where an estimated 283,000 fish were taken. It is further reported that the recreational fisherman took 46 fish species from the Sydney estuary during the 1980-81 survey period. The species diversity was high in the areas close to the estuary mouth, but declined with distance from the mouth due to such factors as variations in salinity levels, pollution and depth. The Australian Museum has recorded in the order of 160 species of bottom fish from the Sydney Harbour estuary. However, a total of 581 fish species from all habitats in the Sydney Harbour estuary and associated watersheds have been recorded by the Museum. A majority of the fish species are unwanted by recreational anglers because of their small size, poor eating quality or are unavailable because of low abundance and unsuitable angling techniques.

Water quality is considered to be the greatest single threat to the Sydney estuary fish stock. It is generally agreed that the destruction of fish habitat and poor water quality are more responsible for a decline in estuary fish stocks than is recreation or commercial fishing.

The value of an unpolluted, high quality aquatic environment to the condition of fish stocks is well documented. Environmental damage to the river is considered to be the greatest single threat to the fish stock and the industry. The Division of Fisheries has recommended that the New South Wales Government continue to provide for the preservation of existing high quality aquatic habitats. Existing mangrove areas should generally continue to be protected from destruction by reclamation and foreshore development.

Any significant and prolonged reduction in the concentration of dissolved oxygen may have a detrimental affect on fish populations in the Parramatta River. For estuarine waters it is considered that 6.0 mg/litre (approximately 60 to 70 per cent of saturation) is the recommended level for dissolved oxygen, except when temporary natural variations cause the value to decrease. It is thought that many of the fish kills observed in the Duck River and various embayments at the western end of the study area have been due to anaerobic conditions in the water, usually following periods of run-off. The discharge of certain toxic agents to the river may also have been responsible for fish kills at various times.

The threat of an oil spill at port facilities, or from a vessel in transit is also a cause for concern. The S.P.C.C. states that because the river is long, narrow, convoluted and busy, spills may occur at any point and affect sensitive areas within an hour. Commercial and recreational fisheries are considered to be moderately sensitive to oil spills. The last major spill in August 1982, resulted when an oil barge ran aground. Approximately ten kilometres of the river were affected by the spill, resulting in the destruction of a considerable amount of marine life, disrupted bird life and destruction of a significant number of juvenile mangrove trees.

Oil dispersants particularly the older types used to clean up oil spills are toxic, sometimes more toxic when combined with the oil than when alone. The S.P.C.C. reports that particular attention should be paid to water depth because dispersants should not be used in less than five metres of water unless there are strong reasons to the contrary. The S.P.C.C. recommends that defensive deployment of booms should be standard practice around any oil spill.

The Division of Fisheries report that the Duck River and Parramatta River near Silverwater appear to have been the most highly polluted areas of the Sydney estuary. However, despite the upstream environmental damage, the fish catch per effort is equivalent to that from the unpolluted estuary mouth. It was concluded that the quality of the water at the western end of the study area has improved, or that certain species of fish are not greatly influenced by the pollution or have developed a tolerance to the conditions in the upper reaches of the river. A joint study carried out by the Australian Museum and the Division of Fisheries during the period 1972 to 1979 has found that the bottom fish diversity in the upper Parramatta River has increased in that time.

AIR ENVIRONMENT

Climate

The climate of Sydney, at latitude 34 degrees south on the east coast of Australia, is largely determined by the subtropical high-pressure belt, the continental landmass to the west and oceans to the east and south. Mean trajectories of anticyclones over Australia vary seasonally from 40 degrees south in summer to 25 degrees south in winter. Consequently, Sydney mainly experiences moist onshore winds in summer and dry continental winds or moist subpolar winds in winter. This results in an overall warm, humid climate in which rain occurs throughout the year.

A survey of the variation in climatic conditions across the Sydney region including the study area has been undertaken by the Bureau of Meteorology (1979). Climate characteristics within the Parramatta River region including the study area, which extends between 10 km and 25 km from the coastline, are outlined below.

- **Wind**

Topography and distance from the sea cause local variations in wind speed and direction. There are three distinct air drainage units within the Sydney region, namely the Hawkesbury Basin to the west and north-west; the Liverpool Basin, which generally equates with the Georges River catchment; and the Parramatta River Valley.

The direction and strength of winds are influenced by the large-scale pressure pattern and are predominantly westerly from May to September and easterly from November to March. The strongest gradient winds tend to occur in September and the weakest in April. The pattern of surface winds at Goat Island near the eastern boundary of the study area is shown in Figure 13.

During the night drainage flows tend to channel weak winds (sometimes referred to as katabatic drift) down slopes and along valleys. The characteristics of nocturnal winds in the Sydney region have been described by Hyde et al, (1983). These may be summarised as small-scale drainage flows caused by local topography that may occur beneath deeper westerly or south-westerly regional drainage flows that extend to heights of 250-500 metres. The speeds of drainage flows are usually below 10 km/hr. After cold air fills the Hawkesbury Basin during the night it tends to spill over the small ridge (in the Blacktown/ Prospect Region) to the east and flow into the Parramatta River Valley and the Liverpool Basin. Consequently, the Parramatta River Valley experiences a surface westerly drainage flow, typically 50-150 metres deep, which may be locally generated or a result of spillover from the Hawkesbury Basin.

These drainage flows can persist during most of the night until mid-morning. They are more frequent and have a longer duration in winter than in summer.

Onshore seabreezes which develop near the coast and move inland are the other major local winds affecting the study area. These usually have speeds of less than 30 km/hr and depths of less than 1,000 metres and are most prevalent during the afternoon and evening of the warmer months.

. **Rainfall**

Rainfall decreases with distance from the coast along the Parramatta River with annual averages of 1,210mm at Observatory Hill, 1,120mm at Riverview and 910mm at Parramatta. Most of this rain is associated with onshore airstreams with south-easterlies being dominant. Sydney has an average of 11 to 14 raindays per month and 148 raindays per year. Rainfall occurs throughout the year with spring being the driest season and autumn the wettest.

. **Temperature**

Maximum temperatures tend to increase and minimum temperatures tend to decrease with distance along the Parramatta River Valley from the coast. Therefore, Parramatta experiences the greatest extremes in temperature in the study area, having mean daily maximum temperatures of 17 degrees celsius in July and 28 degrees celsius in January and mean daily minimum temperatures of 5 degrees celsius in July and 17 degrees celsius in January.

. **Relative humidity**

The average relative humidity at Observatory Hill at 9 a.m. ranges from 60 per cent in November to 75 per cent in June and at 3 p.m. from 50 per cent in August to 65 per cent in February. on average, 9 a.m. relative humidities do not vary appreciably across the region while those at 3 p.m. typically decrease with increased distance from the coastline. Observatory Hill experiences fog on an average of 18 days per year. Most of these occur during the early morning in the months April to August.

Air quality

. Meteorology

The metropolitan area of Sydney has a population of approximately 3.1 million people in an area of approximately 5000 square kilometres. Sydney supports a wide industrial base including oil refineries, metallurgical and chemical industries and has approximately two million motor vehicles. Air pollution concentrations are determined by both the rate that pollutants are emitted from their many sources and the rate they are diluted by the atmosphere.

Meteorological variables such as wind velocity and atmospheric turbulence largely determine the transport and dispersion of air pollutants. Atmospheric dilution is least during the night and early morning when low-level temperature inversions restrict turbulent mixing. Surface temperature inversions occur on an average of 80 per cent of winter mornings and 35 per cent of summer mornings at Mascot. Most of these inversions are associated with drainage flows. The frequency of temperature inversions would be slightly greater in the Parramatta Valley than at Mascot because of lower night time temperatures, weaker winds and a greater incidence of drainage flows further inland.

Temperature inversions within the lower few hundred metres of the atmosphere typically restrict the dilution of pollutants above the Parramatta Valley during most of the night. These conditions can also prevail until ground heating weakens the inversion usually between one and five hours after sunrise. Because of the significant emission of air pollution by industries and motor vehicles within and near the Parramatta River and its location in a shallow valley, this region experiences high concentrations of primary air pollutants. These pollutants are usually transported inland by afternoon seabreezes and towards the coast by nocturnal and morning drainage flows. Highest concentrations of primary pollutants occur overnight and during the early morning, with the fine-particle component being visible as a grey-brown haze that is most evident on autumn and winter mornings with strong temperature inversions.

Sydney also experiences photochemical smog which is composed of ozone and other secondary pollutants that are produced after emissions are exposed to solar radiation for at least three hours. Consequently, the highest concentrations of ozone tend to occur 10-50 km downwind of the major pollutant sources. In Sydney the major direction for pollutant transport in summer is towards the south-west due to the effect of seabreezes. The other directions to which airmasses containing high concentrations of ozone are transported is the south and west. Some instances of high concentrations of ozone have been recorded at Westmead near the western boundary of the study area, but as noted above these are more frequent in the Liverpool Basin.

. Monitoring and trends

Monitoring of air quality in Sydney, including the study area, has been undertaken by the S.P.C.C. since 1971; while monitoring before this time was carried out by the then Department of Public Health. Data collected since the 1950s show a general decrease in the so-called "traditional pollutants" such as dust and sulphur dioxide. However, "emerging pollutants" including ozone, lead, oxides of nitrogen and hydrocarbons are now a cause for concern. The reduction in traditional pollutants can be attributed to less use of coal as a fuel, improved combustion technology and the implementation of pollution control legislation namely the Clean Air Act (1961) and accompanying Regulations. The rapid increase in use of the motor vehicle during the past 20 years has resulted in a significant increase in the levels of ozone, lead, hydrocarbons and oxides of nitrogen. The trend in emerging pollutants over the last few years has tapered off, possibly due to meteorological effects and/or legislative controls applied to the emission sources.

Amendments to the Clean Air Act and its Regulations have progressively required more stringent emission limits, extended the application of the Act to a wider range of sources, and allocated more pecisely, responsibility for the control of odours. The S.P.C.C. has reported that as a result of all these factors the atmosphere is now much cleaner than it would otherwise have been.

Technical advances have made available monitors for measuring specific pollutants. There has also been an increased understanding of the dispersion of pollutants in the atmosphere. The S.P.C.C. states that much has also been achieved in controlling motor vehicle emissions over the last decade. The new program of motor vehicle controls based on lead free petrol, to commence in 1985-86, will produce further improvements in these areas. Motor vehicle emissions are the main source of atmospheric lead in the study area because alkyl lead compounds are currently added to petrol to boost its octane rating. Approximately 1000 tonnes of lead are emitted from the combustion of petrol each year in the Sydney region.

To a considerable extent air-pollution trends are proceeding in the right direction. The S.P.C.C. expects reductions in the total mass emissions of particles, hydrocarbons, lead and sulphur dioxide, however there is little opportunity to relax. Greater populations and greater industrial activity will bring increasing numbers of pollution sources, particularly motor vehicles.

It is expected that the S.P.C.C. will need to continue intensifying its operations if a deterioration in air quality is not to occur after existing programs have been fully implemented. In particular, problems remain in at least two major areas. The first is the control of photochemical smog and its precusor pollutants, hydrocarbons and oxides of nitrogen. These pollutants are now a cause for concern in their own right as primary pollutants, because they contribute to the formation of photochemical smog. Ozone which is not a primary pollutant is the major constituent of photochemical smog and is formed in the atmosphere as a result of the action of sunlight catalysing a reaction with the abovementioned precursor pollutants. The majority of these precursors come from the motor vehicle, but there are concentrated soures of hydrocarbons at Clyde and the petroleum terminals at Silverwater, Auburn, Pulpit Point, Gore Bay and Berrys Bay. The level of ozone is dependent on the meteorological conditions and the concentration of precursors. It is a phenomenon that occurs in the warmer months.

The second high-priority area for increased control is open burning and incineration. The incineration equipment that is practical in domestic circumstances is primitive in design and inevitably produces undesirably high emissions of smoke, fume, ash and odours. Incineration is a major source of the "brown haze" so noticeable in Sydney on still, cool mornings. Other major contributors to brown haze have been estimated to include emissions from industrial processes, motor vehicles, vegetative burning and also soil dust and sea mist. Within the study area suspended matter may have a potential affect on health and is known to have a major impact on visibility.

Odours from industrial and commercial premises continue to be a significant cause of air pollution complaints. The most significant sources of odours occur in the Rhodes, Concord and Homebush areas. A control program had been developed by the S.P.C.C. to protect the health and amenity of the community from unpleasantness and nauseating odours. In view of the complexity of odours, the variation in perception levels and the large number of odour sources involved, this program is limited to selected problem industries, with the more specific objective of generating and applying uniform control guidelines. Significant progress has been made in reducing odours from oil refineries where a control strategy has now been partly implemented by the S.P.C.C.

Work on the control of odours from chemical industries along the Rhodes Peninsula has progressed to a stage where agreements have been made to control the odour sources identified during earlier surveys carried out by the S.P.C.C.

. **Visual effects**

Studies carried out by the S.P.C.C. indicate that all open space and recreation would be affected to some degree from backyard burning but not to such a degree as to impair the use of that open space. The Silverwater, Ermington, Meadowbank and Concord open space areas would be affected by emissions from State Brickworks, Shell refinery, the hot mix plants and Silverwater Prison. Mortlake Point would be affected by the Repatriation and General Hospital at Concord, and sites at Looking Glass Point and around Hen and Chicken Bay would be affected by Tanner Middleton. Sites at Kelly's Bush, Simmons Point, Elkington Point and King Georges Park would most likely be affected by smoke from ferries and shipping.

Health aspects and air pollution

A study conducted by the Australian National University for the S.P.C.C. has examined the relationships between respiratory health and air pollutant levels in the Sydney Metropolitan area. This was the first study of its kind ever carried out in the Sydney area and included an examination of the S.P.C.C.'s monitoring data for the period 1971 to 1979, covering acid gases, suspended matter and ozone levels in Sydney's air.

The S.P.C.C. advises that studies of this kind are always subject to practical limitations, and this particular study was limited by a lack of comprehensive air-pollution data, a lack of occupational addresses for the subject tested, inadequate information on the socio-economic status of some subjects and the self-selection (non-random sample) of subjects.

Despite these and other limitations, the following major findings were made:

- Reduction in lung function is positively related to the proportion of land used for industrial purposes.
- There are significant differences in lung-function reduction between areas in Sydney with differing levels of acid gases, suspended matter and ozone.
- The monitored levels of suspended matter and acid gases reduced between 1971 and 1979 and, with the exception of suspended matter levels in the Sydney business district, the levels are now below the W.H.O. recommended long-term goals for these pollutants.

ACOUSTICAL ENVIRONMENT

The acoustical environment in the study area is influenced in varying degrees by industrial and transport noise and, to some extent, noise generated by recreational activities.

The S.P.C.C. has primary responsibility for controlling noise from larger industrial premises and major potential sources of noise as defined in a schedule of the Noise Control Act (1975). It also controls noise from local and State government premises and most sporting events. Local government authorities have primary responsibility for controlling noise from non-scheduled premises and from public places, except those reserved for S.P.C.C. action. The M.S.B. has primary responsibiliy for controlling noise from navigable waters and this responsibility has been extended to include lawful sporting activities on navigable waters. The police have primary responsibility for premises licenced under the Liquor Act. In addition to the control of noise from public places, local government authorities are now responsible for the control of noise from particular lawful sporting activities such as trail bike riding, and their authority has been extended to all hours of the day and night.

Recommended noise levels

In passive recreation areas throughout the study area, the S.P.C.C. recommends 40 dB(A) be considered as an acceptable background noise level, with 50dB(A) as a maximum noise level. The S.P.C.C. does not have a recommended criteria for active recreation areas. For residential areas affected by noise from recreation, or other activities the S.P.C.C.'s general criterion is that the noise level from the noise source (L10) when measured at the residence not exceed the existing background level (L90) by more than 5 dB(A).

Noise sources

. **Industrial noise**

The types of premises and industries that are most likely to cause noise pollution are scheduled under the Noise Control Act, and special control provisions apply to these premises. Prior approval of the S.P.C.C. is required for any construction that would cause premises to become scheduled under the Act or for any change in operations or installation of new equipment at scheduled premises that would increase or cause noise emissions from the premises.

The S.P.C.C. has handled noise problems from a range of activities in the study area, including engineering works, chemical factories, petroleum refineries, boat building facilities and various industrial estates. Noise controls have been applied to various premises.

. **Transportation noise**

Transportation noise sources in the study area are on-river transport by barges and tugs (particularly during weekdays), motor vehicles, rail and aircraft movements. The S.P.C.C. advises that peak noise levels readings (Lm's) of 40 to 45 dB(A) are found along the shoreline of the Parramatta River in areas affected by traffic noise and general background noise. Power boat operation raised noise levels to between 51 to 54 dB(A). Recreational use of pleasure craft and power boats contribute to noise levels along the foreshores particularly at weekends.

Vessels

Although not of major concern in the study area, the recent amendments to the Noise Control Act and the introduction of a regulation controlling engine noise from vessels now provide the M.S.B. and local councils with adequate authority and means to effectively control noise from vessels. In addition, the S.P.C.C. and M.S.B. are preparing a training program to improve surveillance and enforcement activities controlling noise from vessels.

Motor Vehicles

Many people consider noise from motor vehicles to be a major problem. The motor-vehicle noise problems experienced by the community in the study area may be divided into two types:

- **Noise due to bulk traffic flow.** This noise is related to the number of vehicles using the road and particularly to the proportion of heavy vehicles. In many locations noise levels would remain above those desired despite implementation of ameliorative measures. In some cases recreational activities can be adversely affected, particularly where major arterial roads are located adjacent to foreshore areas (such as Dobroyd Parade, Ashfield) or cross over the Parramatta River.

- **Noise due to individual vehicles.** Such noise is both annoying and disturbing particularly in those areas where the background noise levels are quite low.

The S.P.C.C. has recently introduced environmental goals for road traffic noise in respect of new developments. The planning goal relating to new residences or new roads is a maximum L 10, 18 hours noise level of 60 dB(A) when measured at one metre from a residential facade or other noise-sensitive location. In situations where the growth in traffic volumes, particularly including bus and truck transport, exceeds the planning goals provided in respect of new developments, then the traffic management goal is a maximum L 10, 18 hours of 65 dB(A) at one metre from the residential facade. Whenever the measured L 10, 18 hour level exceeds 65 dB(A), the S.P.C.C. has suggested that ameliorative measures be implemented by the appropriate authority.

Some reduction in traffic noise has been achieved by legal requirements placed on individual vehicles identified as exceeding regulated levels. Although small improvements in design have been made as a result of the existing Australian Design Rules and the noise limits imposed under the Noise Control Regulation, noise levels achieved so far are well above those which could be achieved by a general adoption of existing practicable technologies. The Noise Control Regulation limits for motor cars and motor car derivatives are 96 dB(A) for vehicles manufactured before 1 January 1983, and 90 dB(A) for those manufactured on or after that date.

The S.P.C.C. reports that design standards under the Motor Vehicle Regulations of the Noise Control Act will soon be put into effect in order to achieve lower motor vehicle noise standards for individual vehicles.

Rail Traffic

The railway lines from North Strathfield to West Ryde and from Granville to Dundas traverse the Parramatta River at Rhodes and Camellia respectively. For normal trains passing by residences the S.P.C.C. has a two part criterion. The S.P.C.C. prefers the peak noise level (L MAX) to be below 80 dB(A) and the Leq 24 hour level to be below 55 dB(A). The maximum acceptable levels are considered to be 85 dB(A) and 60 dB(A) respectively.

For stationary sources, such as public address systems, stabling yards, marshalling yards and all other fixed plant and non-locomotive machines, the general criterion adopted by the S.P.C.C. is that the noise level from the noise source (L10 when measured at any residence not exceed the existing background level (L90) by more than 5 dB(A). It is unlikely that noise from track maintenance operations would meet either of the above criteria. Since the maintenance noise is expected to affect a given resident for only a couple of days per year, the S.P.C.C. allows greater noise levels.

Aircraft

A number of open space and recreational areas are located under the northern flight path for Sydney's Kingsford Smith Airport.

During 1983, a total of 39,008 aircraft made their entry flight across the study area in the vicinity of Hunters Hill and Drummoyne. A further 1,626 aircraft departed via the same route. These figures comprised 46.3 per cent and 1.9 per cent of all arrivals and departures at Kingsford Smith Airport for that year. The Commonwealth Government exercises control over the aircraft and State authorities have no power to control aircraft noise from this location.

Figure 14 shows the Australian noise exposure index (A.N.E.I.) for 1980, at Kingsford Smith Airport and indicates the extent of impact within the study area. The various A.N.E.I. contours define land areas around the airport which are affected by aircraft noise and provides a means of assessing average community response to such noise. In the areas outside the 20 A.N.E.I. contour, it is generally accepted that noise exposure is not of significant concern. Within the 20 to 25 A.N.E.I. contour, aircraft noise exposure starts to emerge as an environmental problem, while above 25 A.N.E.I. the noise exposure becomes progressively more severe. Outdoor recreation (non-spectator) within the study area is one form of land use which would not be adversely affected by noise from aircraft passing overhead.

The Department of Aviation reports that an evening curfew (11 p.m. to 6 a.m.) applies to jet aircraft movements at Kingsford Smith Airport. Piston-engined or propellor driven aircraft are exempt from this curfew. Exemptions to the evening curfew may be allowed for emergency or passenger hardship situations. The S.P.C.C. recognises that any expansion of aircraft activities could increase noise exposure within the study area.

Helicopters

The S.P.C.C. has prepared guidelines on the siting of heliports. The criteria selected were designed to ensure minimal speech interference and annoyance from take-offs and landings. There are three components to the criteria: a recommended limit on the time of operation from 7 a.m. to 10 p.m. a maximum noise limit in respect of residential premises of 82 dB(A) and a maximum Leq noise exposure limit of 55 dB(A).

The Department of Aviation has advised that as from July 1985, helicopters will operate below specified altitudes along the Parramatta River flight path. From the Sydney Harbour Bridge to the Ryde Bridge a ceiling height of 500 feet (152 metres) is proposed, while a ceiling height of 700 feet (213 metres) has been set from Ryde Bridge to the Silverwater Bridge. Elsewhere across the study area the ceiling height for helicopers has been set at 1000 feet (304 metres) in accordance with the Regulations to the Air Navigation Act (1920). The aim is to provide greater flexibility for helicopter operations in the northern part of Sydney and allow better access to helipads in the area. It could be expected that enjoyment of open space areas by some individuals will be impaired by the operation of helicopters along the Parramatta River. The level of impairment will depend to a large extent on the number of helicopter movements and the routes chosen.

WETLANDS

Aerial photographs of the study area (Sydney 1982 1:16000 Colour, Misc 1474. N.S.W. 3240) were examined to locate wetlands. Each site thus located was inspected on-site to determine the general vigour of wetlands, the dominant vegetation types, and to verify the existing situation with that interpreted from the aerial photographs.

Following verification or adjustment to information obtained from the aerial photographs the wetland community boundaries were transferred to the base maps.

Earlier aerial photographs (County of Cumberland 1946, 1953) were examined to determine the previous extent and distribution of wetlands. These photographs could not be interpreted with certainty, but give a useful indication. It should be noted that doubtful areas have been included in the majority category and so the figures for these areas may be slightly exaggerated.

A general categorisation scheme has been adopted. Wetlands have been categorised as "mangrove", "saltmarsh" and "other". The indeterminate third category was adopted primarily to deal with the older aerial photographs whose poor quality did not enable a confident interpretation. Therefore, many areas adjacent to identified wetlands which could not positively be identified as such, were included in the general wetland category, on the basis of their location and their juxtaposition with other wetlands. This category also includes ponds, brackish fringes etc. which occur in the study area. It was considered that rather than introduce several more categories and therefore complications in the mapping process, these could be grouped together and described further in the text.

Extent and Distribution

To facilitate investigation and discussion, the study area has been further divided into sections as follows:

- Charles Street Parramatta - Silverwater Bridge
- Duck River (to Parramatta Road)
- Silverwater Bridge - Meadowbank Rail Bridge
- Newington Arms, Haslams Creek, Homebush Bay and Powells Creek
- Meadowbank Rail Bridge - Putney Point and Breakfast Point (includes Brays Bay, Yaralla Bay and Majors Bay)
- Putney Point/Breakfast Point - Blackwall Point
- Hen and Chicken Bay
- Blackwall Point - Pulpit Point
- Pulpit Point - Clarkes Point, Long Nose Point - Iron Cove Bridge
- Iron Cove

Descriptions

- **Charles Street Weir - Silverwater Road Bridge**
  (Area 1)

In the 1950s mangroves formed a continuous fringe from the weir to the Silverwater Bridge and there were also extensive areas of saltmarsh. None of the saltmarsh remains.

The best stands of mangroves occur along the northern bank, where they form a continuous, and often dense, fringe from the weir to Subiaco Creek. They then form a discontinuous fringe to Thackeray Street. A seawall has been constructed between Thackeray Street and Silverwater Road Bridge. Along this stretch of the river there are mangrove seedlings and immature trees, and mangroves appear to regenerate successfully in this area.

The southern bank supports stands of mangroves rather than a continuous fringe although in some parts the stands are dense.

Two tributaries, Vineyard Creek and Subiaco Creek enter the river from the north, to the east of Rydalmere Hospital; Bishops Creek flows from the south. To the west of Aston Street Vineyard Creek and Subiaco Creek are fringed with mangroves as is Bishops Creek. The mangroves vary in height and vigour along this stretch of the river, reaching a maximum estimated height of 6-8 metres, but elsewhere the trees only reach a maximum estimated height of 2-3 metres. In some areas, the shorter trees may be immature or younger trees, the result of regeneration following previous clearing.

In some locations mangroves have been cut down, and are not vigorous, particularly on the southern bank, between Thackeray Street and the junction with Duck River. Along this stretch mangroves are characteristically stunted, sparse and have yellowing leaves or are leafless.

Despite the changes in this part the wetlands are still a significant feature of the river.

. **Duck River**
(Area 2)

Duck Creek enters Duck River just north of the Great Western Highway bridge. Both drain a large intensively industrialised catchment to the south-west and south. Duck River is the major tributary to the Parramatta River, and joins it just west of Silverwater Road Bridge.

This section of the river previously supported extensive wetland complexes, the largest being on the western side of the confluence of Duck River and the Parramatta River, and along Parramatta River. Only remnants of these wetlands remain.

Mangroves occur along the length of Duck River although their condition is extremely varied. Large areas of mangroves have died or been cut down, rubbish accumulates amongst the mangroves and generally the appearance is most unpleasant. Nevertheless there are stands of mangroves which appear mature and healthy, though not as dense as in other sections of the river. Seedlings occur, but are sparse and at the time of inspection were browning.

The most extensive mangrove stands occur near the mouth of Duck River on the western side, and upstream on the eastern side. Further upstream, mangroves form an almost continuous fringe as far as the tidal limit. Saltmarshes occur in this section, associated primarily with the large mangrove stands described above. There appears from the aerial photographs to be a wetland complex within the property of the Shell refinery, although this has not been confirmed by site inspections.

. **Silverwater Road Bridge - Meadowbank Rail Bridge**
(Area 3)

This section of the river is characterised by seawalls for retention of the river foreshore. The total area of mangroves has increased slightly, but there has been a loss of virtually all of the saltmarsh.

Mangroves now occur along approximately 50 per cent of the northern bank while there are virtually none on the southern bank. Good stands of mangroves occur along George Kendall Reserve, east of the Naval Stores, and continue in an almost unbroken fringe to the western edge of Meadowbank Park. This is one of the best areas of mangroves along the river, the trees being tall (6-8 metres estimated maximum height) mature, dense and vigorous, with abundant juveniles and seedlings.

In the bay in front of the Meadowbank Park seawall mangroves appear to be regenerating vigorously, and there are numerous juveniles and seedlings. Meadowbank Park appears to have been formed by the filling of saltmarsh and other wetland areas.

A small patch of saltmarsh occurs at the bottom of Lancaster Avenue, Ryde.

On the southern side of the river, adjoining Jamison Street Park there is a stand of Juncus (of approximately 1 hectare). This is the only such stand in the study area.

- **Newington Arms, Homebush Bay, Haslams Creek and Powells Creek**
  (Area 4)

This section of the study area contains the most extensive and the most highly modified areas of wetlands along the river. In the 1950s there were extensive areas of wetlands, comprising some 145 hectares of mangrove and saltmarsh on the western side of Homebush Bay and associated with Haslams Creek. A further 76 hectares of mangrove and saltmarsh occurred to the south of Homebush Bay and associated with Powells Creek.

The early attitude of the Maritime Services Board was that the wetlands were wastelands to be converted to more useful purposes.

> "The shortage of waterfront industrial sites for industries associated with shipping led the (Maritime Services) Board to commence, during 1948, reclamation of large areas of mangrove swamp on the upper reaches of the Parramatta River at Homebush Bay ... The reclamation of this area has ... completely changed the appearance of the western side of Homebush Bay from a thick mosquito ridden mangrove swamp to large areas of flat industrial sites" (Wallace, 1959).

Although the seawall fronting the Parramatta River and Homebush Bay had been constructed before 1920, the work of the Board from the late 1940s dramatically changed the bay. The reclamation was carried out in stages, to meet the increasing demands of industry for sites on the waterfront.

During the initial reclamation period dredging material was dumped into entraining embankments. In 1953 a road link was made across Wentworth Bay by dumping shale over the mangrove swamps. Haslams Creek was canalised and at the same time the channel was deepened by removing silt and mangroves. Further road development was necessary and work was commenced at the south-western end of the bay to form access roadways through the dense mangrove swamps. Following the reclamation works by the Board, and establishment of industry on the north-western side of the bay, the estuarine wetland area deteriorated. In the period 1951-61 the tip at the southern end of the bay was extended well into the wetlands.

While this section of the river still supports the largest wetland area, it is less than half the original extent, and greatly fragmented. The once extensive mangrove stands to the north of Haslams Creek have been reduced to fringing the edges of the ash ponds.

The Board's attitude has changed greatly since the 1950s as, along with the general public, they have become more aware of the value of these wetlands. The Board has no plans for any further reclamation in the area and has a draft Waterside Zoning Plan which recognises the importance of the mangrove fringes along the river.

Despite the alterations which have occurred, the wetlands are the largest remnant mangrove community on the Sydney Harbour waterways and are an ecologically important natural environment. Sydney Region Environmental Plan No. 4 aims to conserve the wetlands.

The R.E.P., which covers land in three municipalities, rezoned the subject land to Special Uses - 5(a) State Sports Centre, 6(a) Open Space (Recreation) and 7(b) Environment Protection (Estuarine Wetlands). It provided for the establishment of a park of 88 hectares, comprising both wetland and parkland. The plan provided for preservation of the extensive wetland and mangroves at the head of Homebush Bay and along Powells Creek. It was proposed that development of the area would include improved tidal flushing, provision of access paths and raised timber boardwalks to allow enjoyment of the area and its wildlife.

The area adjacent to the estuarine wetland has been developed to include a lake. Access to the reed swamp areas on the lake's edge is being provided by timber walkways. The rest of the area is being landscaped and facilities for visitors are being provided.

While the construction of bund walls within mangroves and Homebush Bay have had a deleterious effect on the mangroves they have in turn created a brackish pond, which has become a valuable waterbird area (Eskell, 1981).

There is a large area of wetland on the Commonwealth land fronting the river at Newington. There have been changes probably largely due to the construction of drainage channels through it, but a large area of saltmarsh remains and it is arguably one of the most important wetland areas in the study area.

This area was described (Lynch, Spence, et al, 1976) as the single remaining example of "the mangrove, saltmarsh, forest association that once comprised a large part of the river foreshores.... The scale of the component plant communities is impressive and could be an extremely valuable educational tool, if managed correctly".

- **Ryde Bridge - Putney Point/Breakfast Point** (Area 5)

On the northern side there are several stands of mangroves, together comprising approximately 1.6 hectares. The trees vary, with an estimated maximum height of 3-4 metres. They appear vigorous.

Brays Bay, Yaralla Bay and Majors Bay contain the most impressive stands of mangroves in the river. Although all three bays have been extensively modified, as can be seen from the maps comparing wetland extent in the 1950s and 1980s, the mangroves which remain are vigorous. Mature trees reach an estimated imated maximum height of 6-8 metres and there are juveniles and seedlings. They form wide bands around parts of the bays, particularly in Brays Bay and Yaralla Bay. Small patches of saltmarsh occur landward of the mangroves in Brays Bay and Yaralla Bay.

- **Hen and Chicken Bay** (Area 6)

Hen and Chicken Bay is one of the two largest embayments on the river. It has been extensively modified and the foreshore is now virtually all contained within a seawall.

In the 1950s there were extensive mangrove stands approximating 16 hectares, mostly in Exile and Canada Bays. In the older photographs filled areas adjacent to the shore are evident and these may have originally supported either saltmarsh or mangrove communities. Isolated mangroves still occur, and there is also a small group of trees at Quarantine Park on the north-eastern entrance to the bay.

- **Putney Point/Breakfast Point - Blackwall Point** (excluding Hen and Chicken Bay) (Area 7)

This section of the river is characterised by steep, rocky foreshores and conditions are not generally suitable for wetlands. Small stands of mangroves (usually only a few trees) occur in Morrisons Bay, Glades Bay and Looking Glass Bay, generally with an estimated maximum height of 4 metres.

The only significant wetland change in this section has been the loss of approximately four hectares at Morrisons Bay, now filled to form Morrisons Bay Park.

. **Henley/Blackwall Point - Pulpit Point/Drummoyne Wharf** (including Five Dock Bay and Tarban Creek) (Area 8)

The western end of Five Dock Bay in the 1950s supported a small stand of mangroves. This area is now filled, and only isolated mangrove trees now occur. A tall, dense stand of mangroves occurs in the narrow section of Tarban Creek adjacent to Gladesville Hospital grounds.

. **Iron Cove**
(Area 9)

Iron Cove, like Hen and Chicken Bay, is a large, open embayment which has a greatly modified shoreline. A small stand of mangroves occurs at Sisters Bay, and there are isolated mangroves around the northern shore of the bay.

. **Pulpit Point/Drummoyne Wharf - Charles Point/Long Nose Point - Iron Cove Bridge**
(Area 10)

There are no wetlands in this section of the river.

FIGURE 15: Comparative table showing areas of estuarine wetlands in the 1950s and 1983. (Areas are expressed in hectares and rounded to nearest 1000m2)

	1950s				1983			
Area	Man-groves	Salt-marsh	Other	TOTAL	Man-groves	Salt-marsh	Other	TOTAL
1	16.1	6.0		22.1	9.0			9.0
2	36.9	26.5	25.9	89.3	18.0	8.2	1.0	27.2
3	11.1	8.2	1.0	20.3	10.2	0.4	0.6	11.2
4	113.0	108.7	31.7	253.4	55.2	32.3	26.9	114.4
5	18.5	5.7	2.2	26.4	14.5	1.5		16.0
6	16.0			16.0	0.3			0.3
7	3.2		1.8	5.0	0.5			0.5
8	2.1			2.1	0.7			0.7
9	1.8			1.8	0.3			0.3
TOTAL	218.7	155.1	62.6	436.4	108.7	42.4	28.5	179.6

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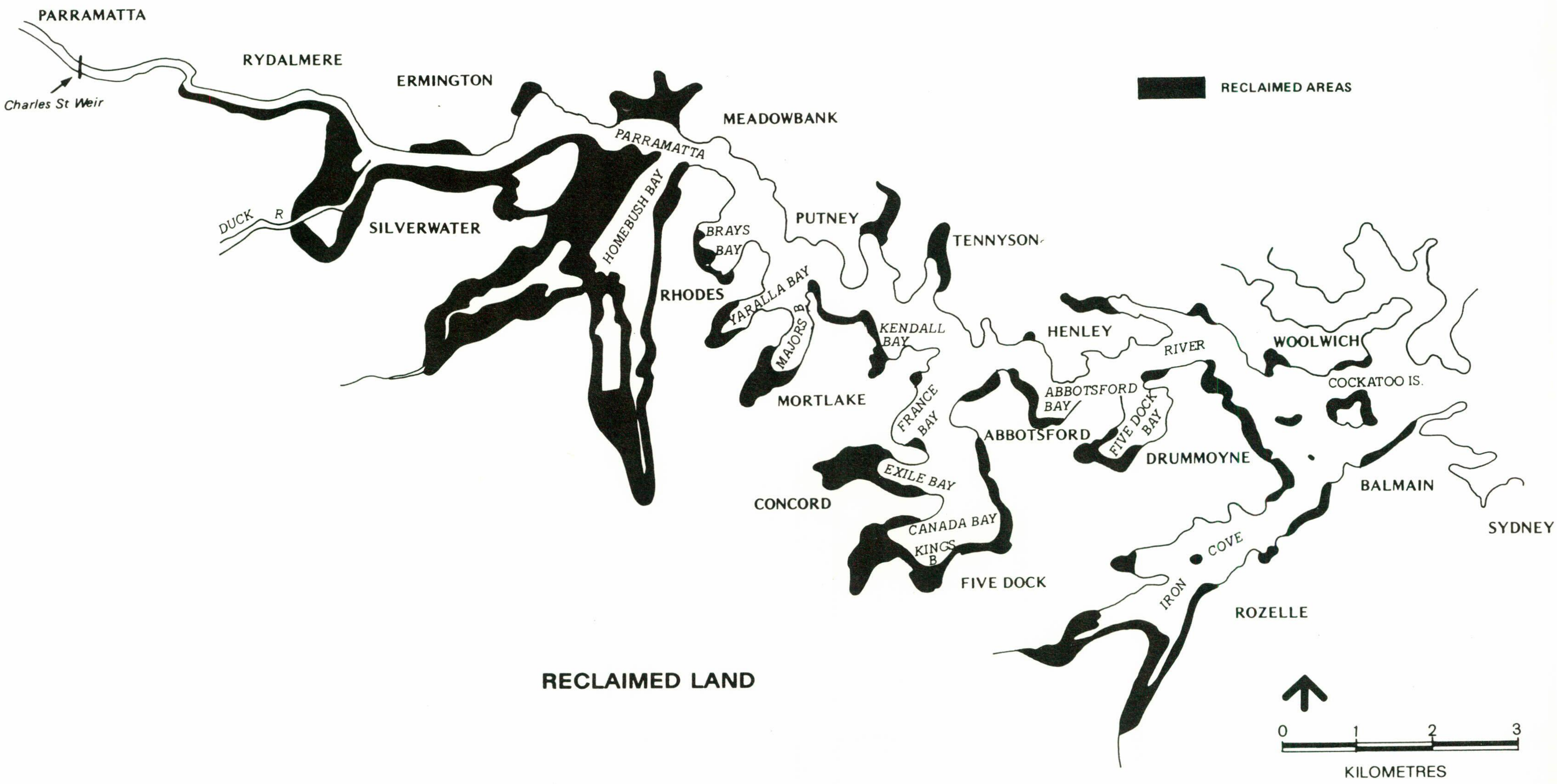
FIGURE 1

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

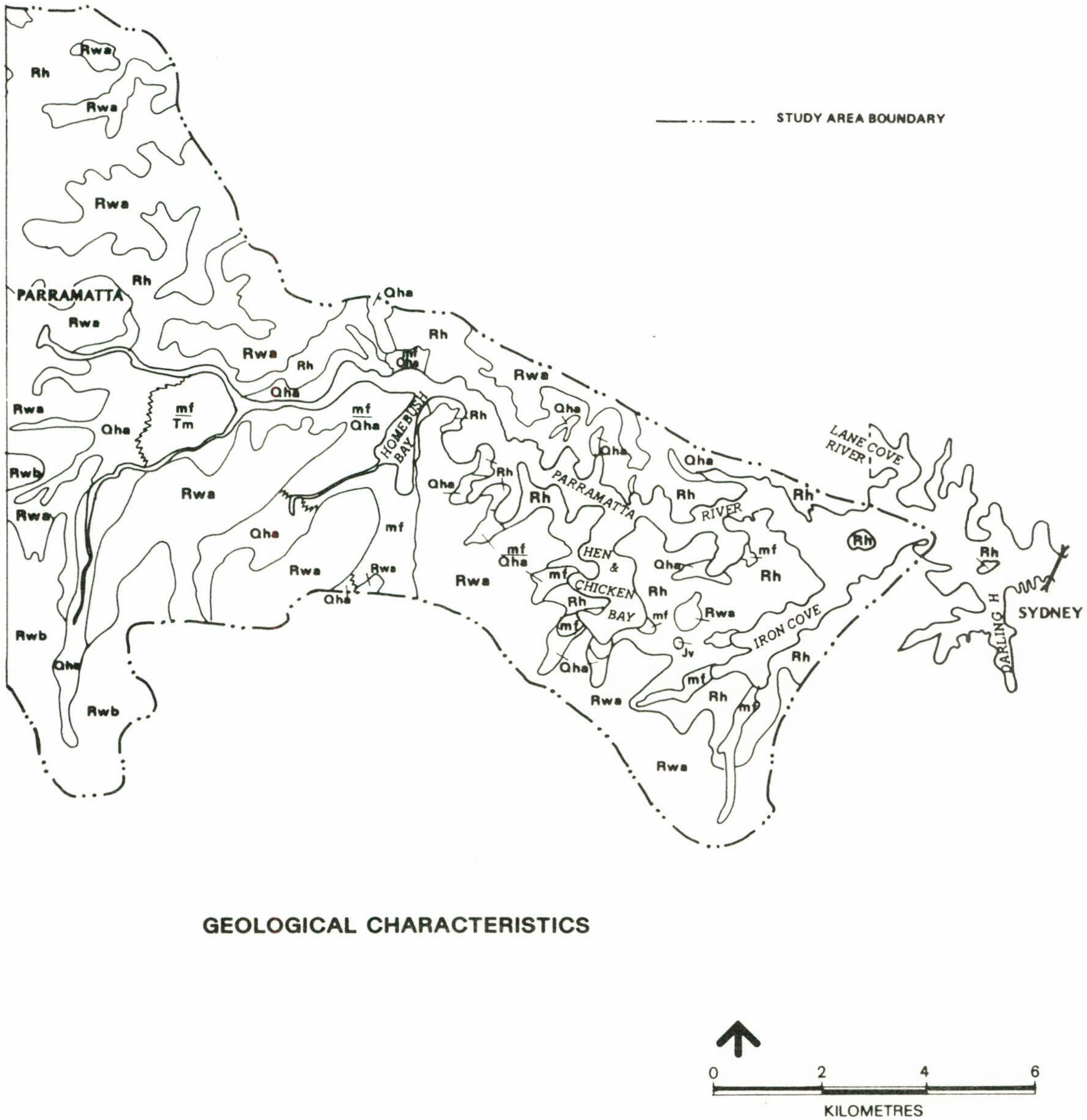


RECLAIMED LAND

Source: Lynch. L.M. et al (1976) – Parameters for Parramatta River Study, National Trust of Australia

FIGURE 2

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY



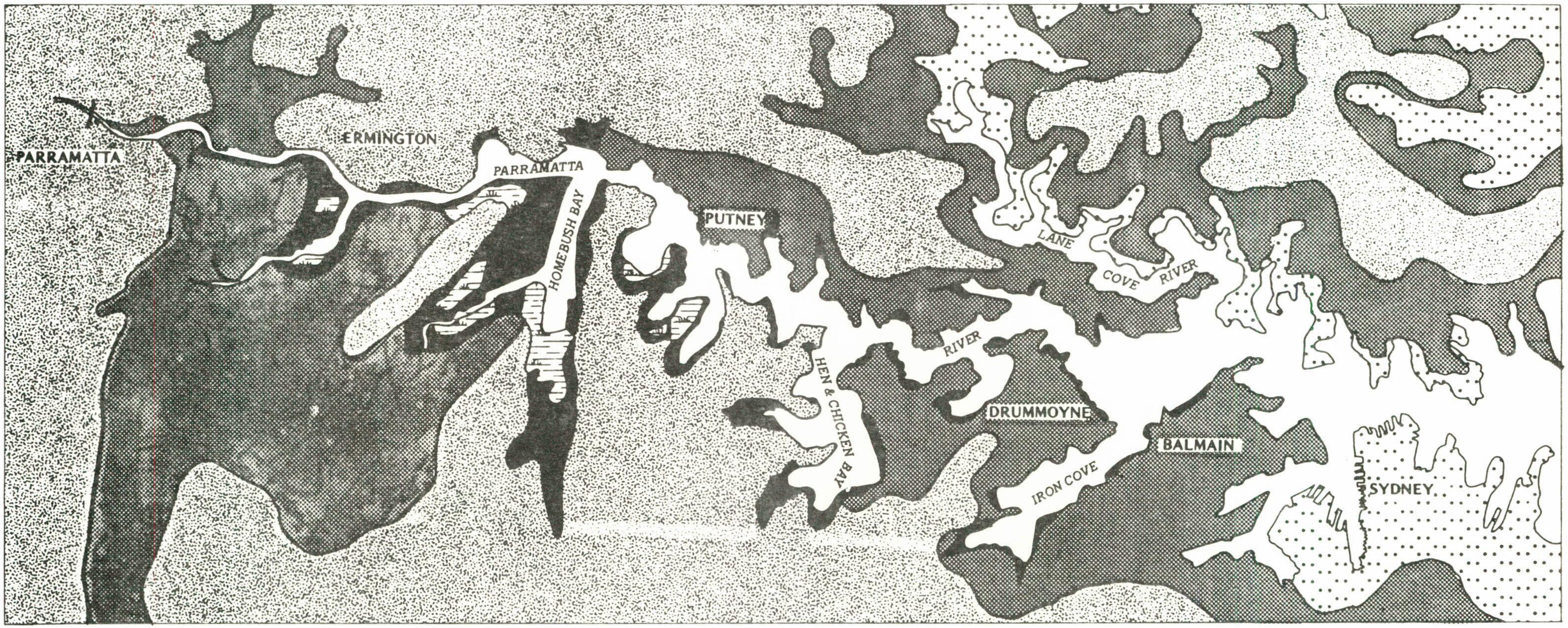
GEOLOGICAL CHARACTERISTICS

ERA	PERIOD	EPOCH		LITHOLOGY
CAINOZOIC	QUATERNARY	HOLOCENE	mf	Man-made fill. Dredged estuarine sand and mud, demolition rubble, industrial and household waste.
			Qha	Silty to peaty quartz sand, silt, and clay. Ferruginous and humic cementation in places. Common shell layers.
		PLEISTOCENE		
	TERTIARY	MIOCENE	Tm	Sand, clay, and peat, variably ferruginous.
MESOZOIC	JURASSIC		Jv	Volcanic breccia, varying amounts of sedimentary breccia and basalt.
	TRIASSIC	MIDDLE TRIASSIC		**WIANAMATTA GROUP**
			Rwb	Shale, carbonaceous claystone, laminite, fine to medium-grained lithic sandstone, rare coal. (Bringelly Shale)
			Rwa	Black to dark-grey shale and laminite. (Ashfield Shale)
			Rh	Medium to coarse-grained quartz sandstone, very minor shale and laminite lenses. (Hawkesbury Sandstone)
				NARRABEEN GROUP (Rn, undifferentiated)

Source: Geological Survey of N.S.W. – Geological Series Sheet 9130

FIGURE 3

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY



Source: P.H. Walker – A Soil Survey of the County of Cumberland (1960)

SOIL ASSOCIATIONS AND SOIL TYPES

FIGURE 4

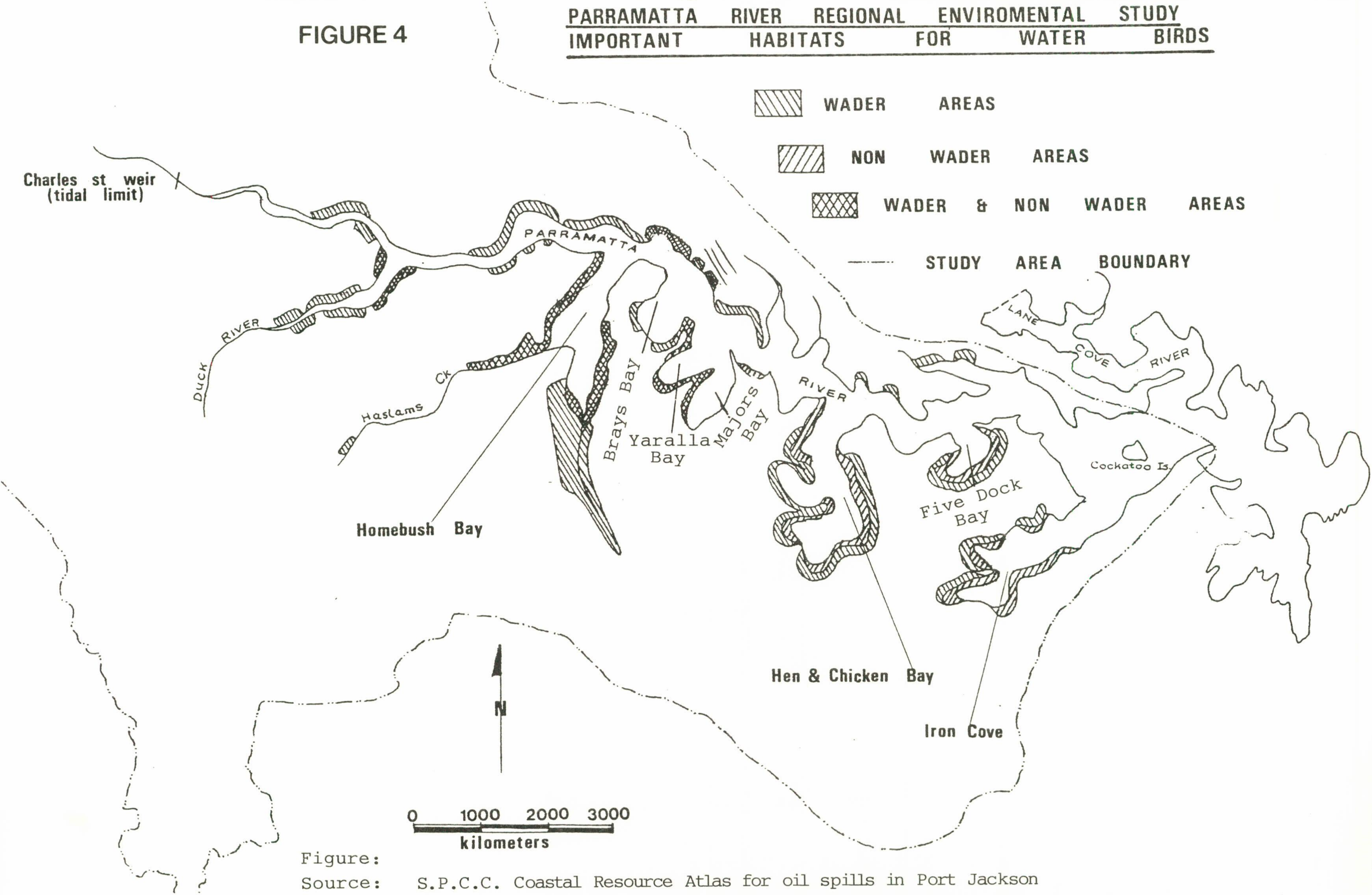
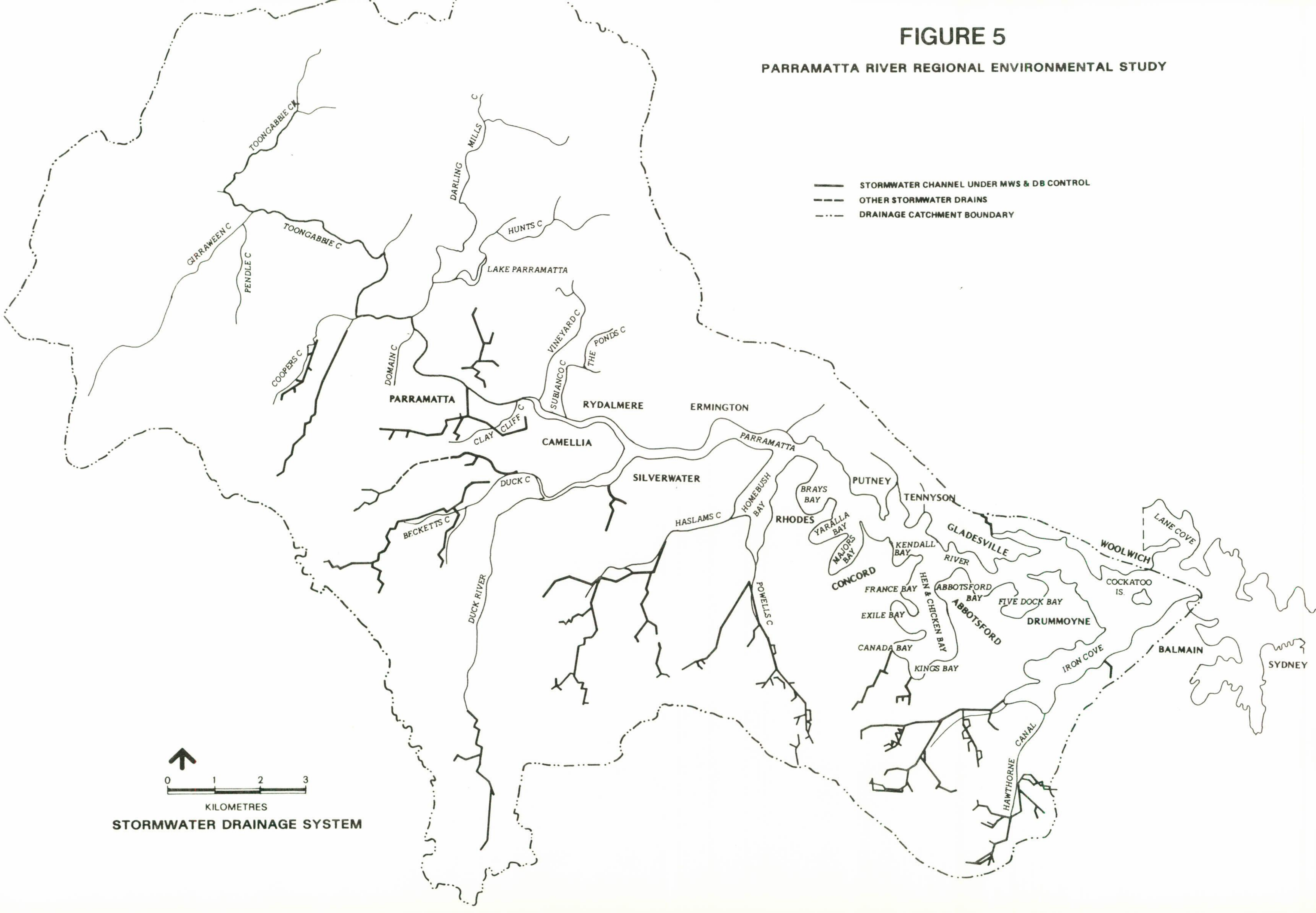


Figure:

Source: S.P.C.C. Coastal Resource Atlas for oil spills in Port Jackson

FIGURE 5

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY



STORMWATER DRAINAGE SYSTEM

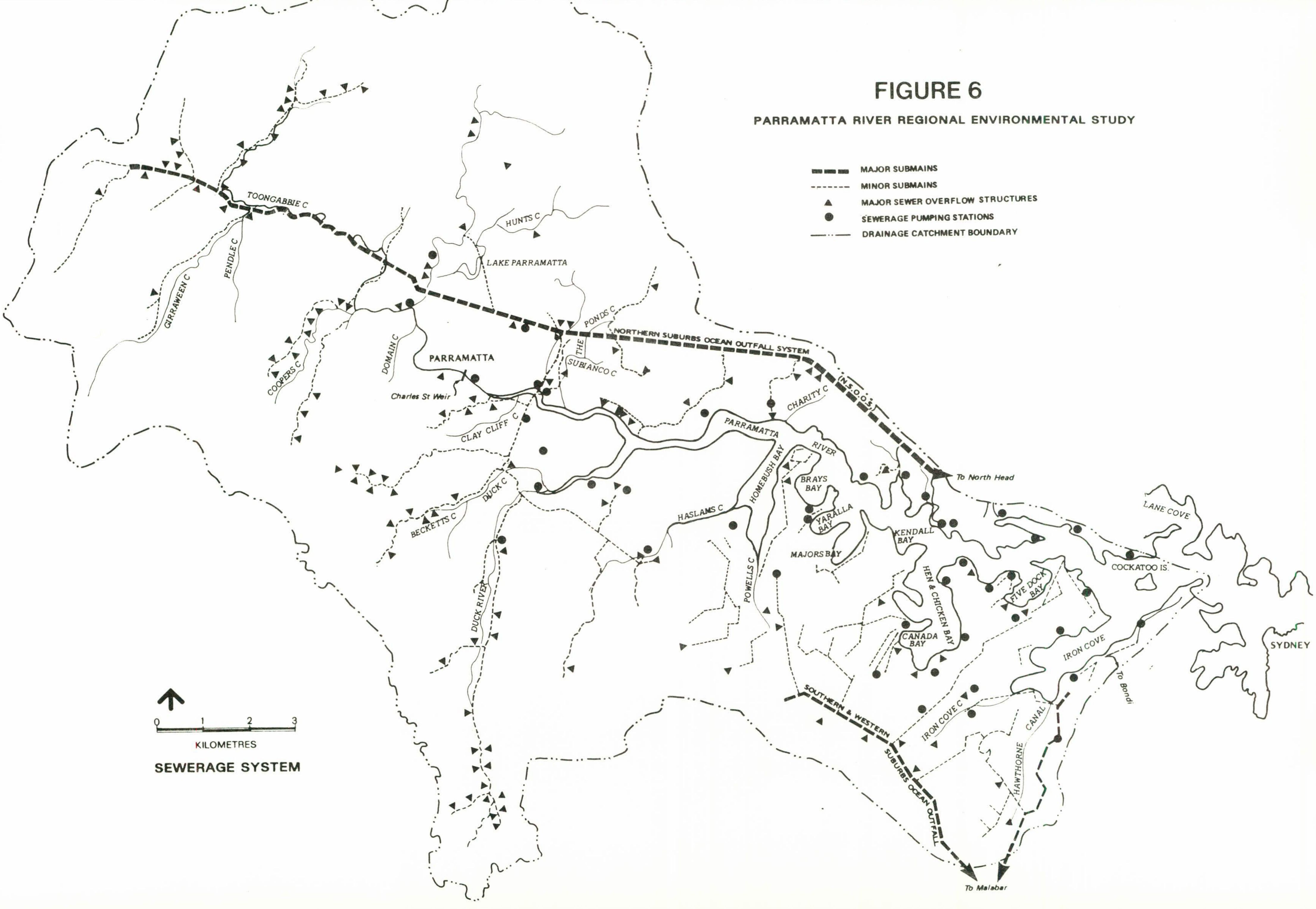
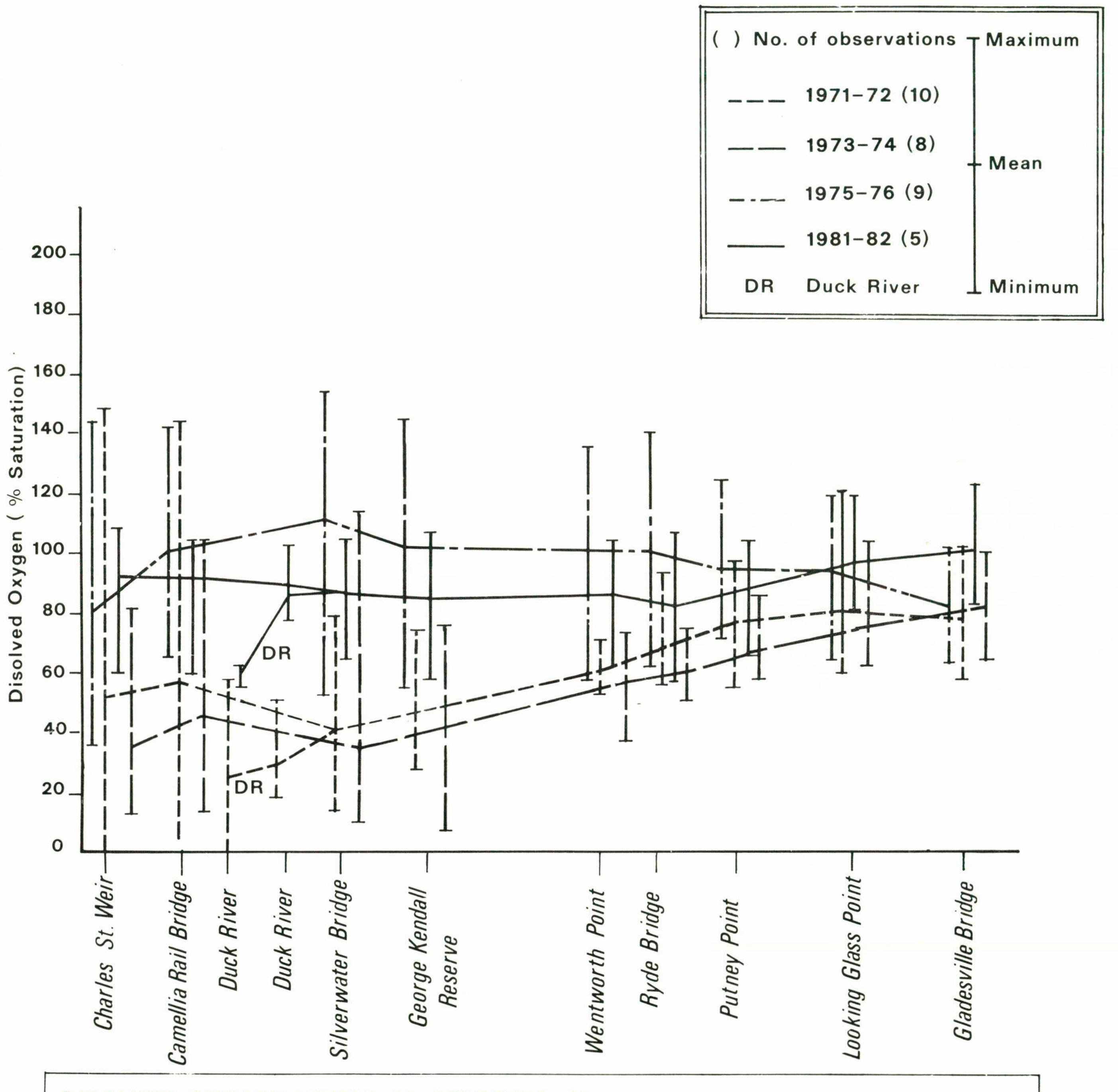


FIGURE 6

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

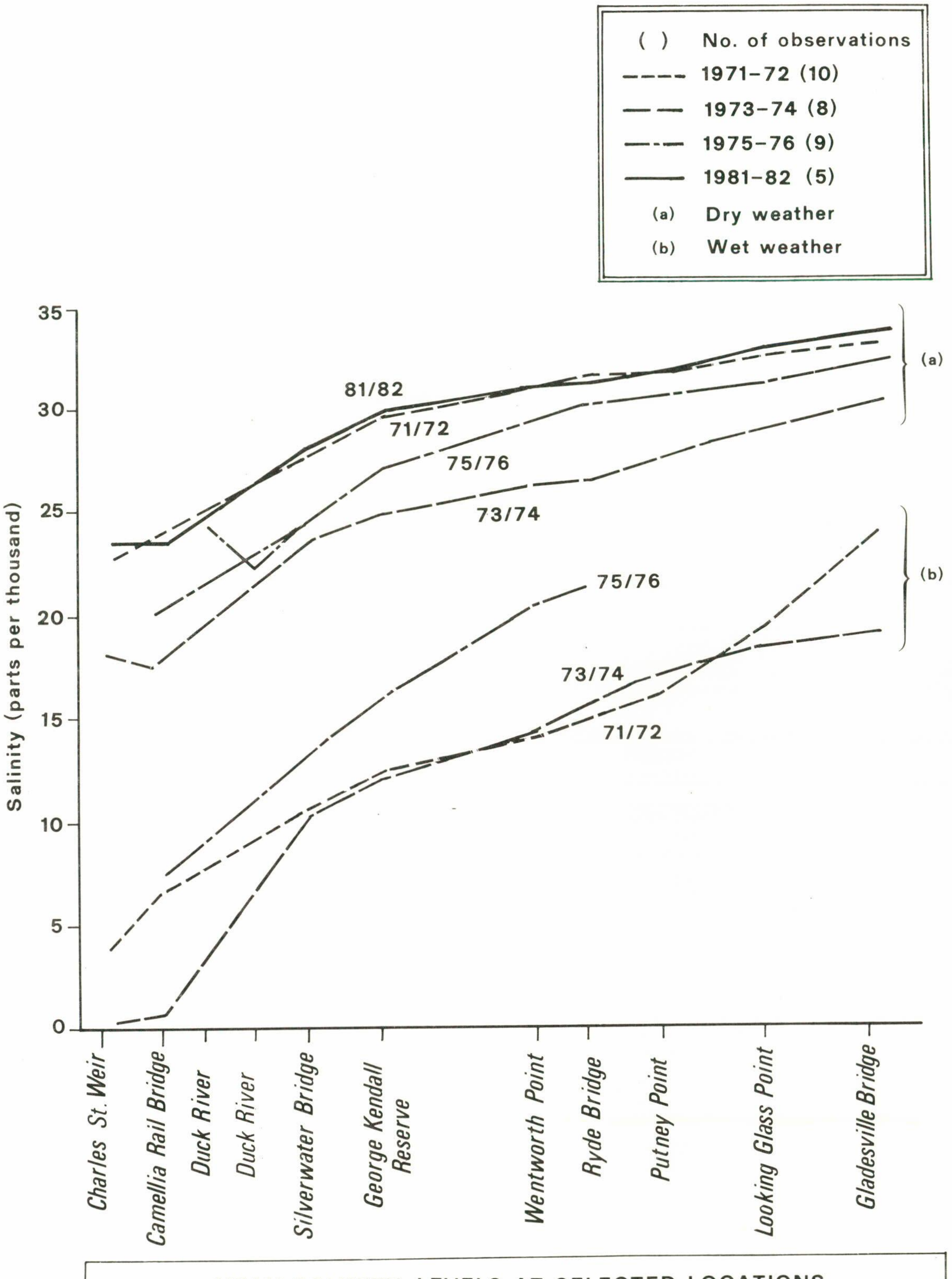


DISOLVED OXYGEN LEVELS AT SELECTED STATIONS IN THE PARRAMATTA RIVER AND DUCK RIVER 1971-74, 1975-76 AND 1981-82- DRY WEATHER

SOURCE: S.P.C.C.(1983) A COMPARISON OF THE WATER QUALITY IN THE PARRAMATTA RIVER

FIGURE 7

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

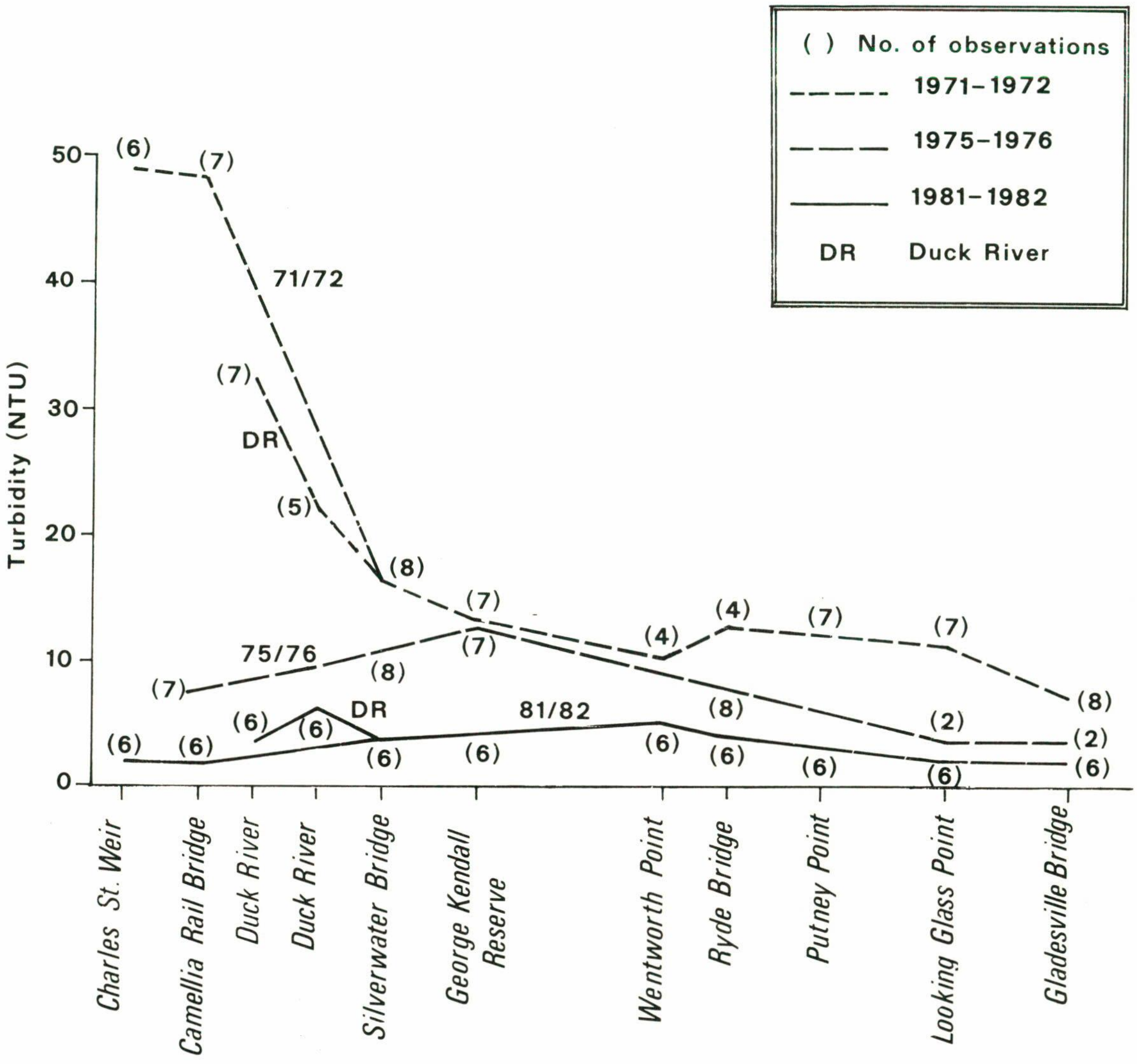


MEAN SALINITY LEVELS AT SELECTED LOCATIONS ON THE PARRAMATTA RIVER

SOURCE: S.P.C.C.(1983) A COMPARISON OF WATER QUALITY IN THE PARRAMATTA RIVER

FIGURE 8

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

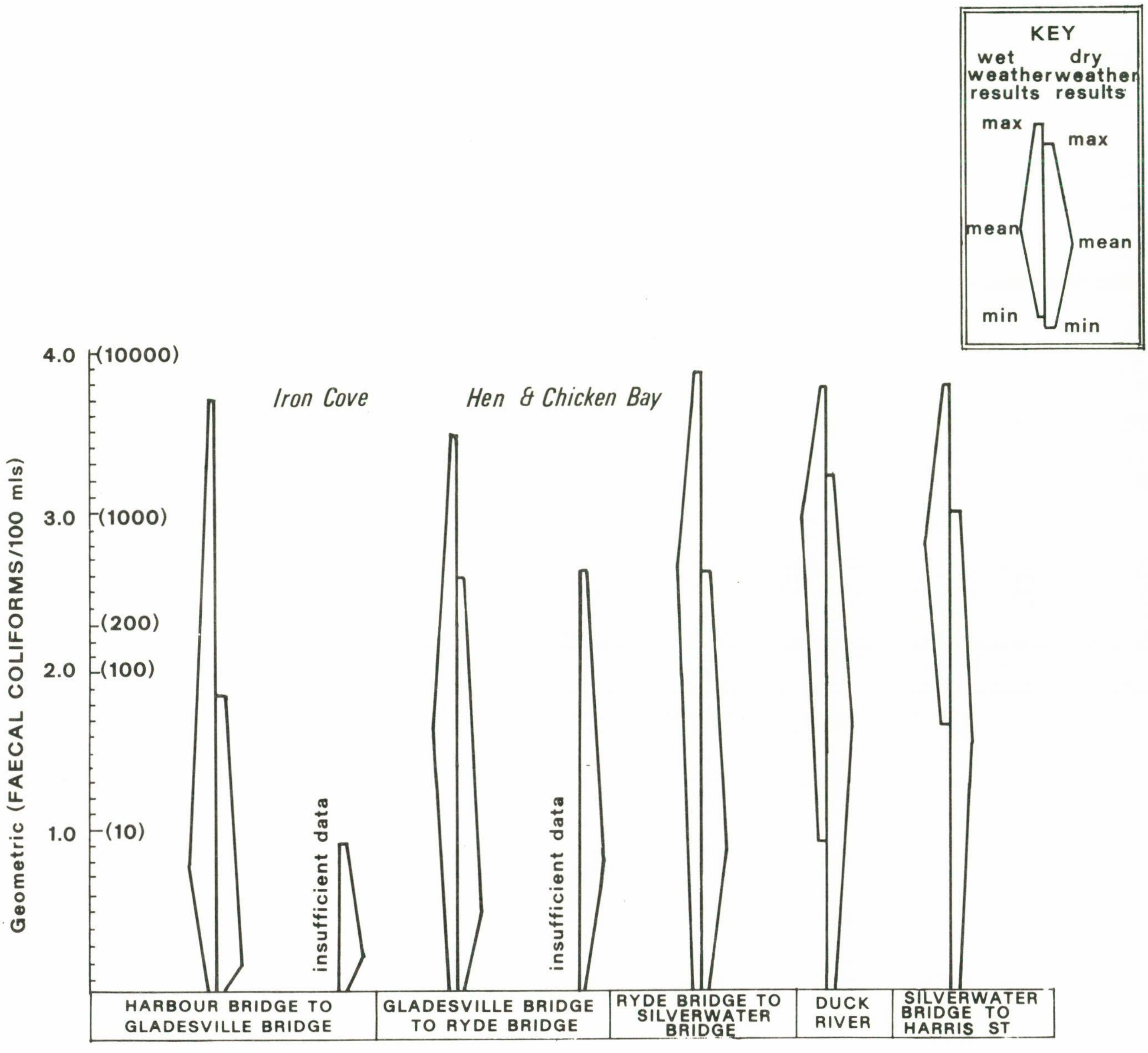


MEAN TURBIDITIES AT SELECTED LOCATIONS ON THE PARRAMATTA RIVER AND DUCK RIVER-DRY WEATHER

SOURCE: S.P.C.C.(1983) A COMPARISON OF WATER QUALITY IN THE PARRAMATTA RIVER FOR THE YEARS 1971-1976 AND 1981 TO 1982

FIGURE 9

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

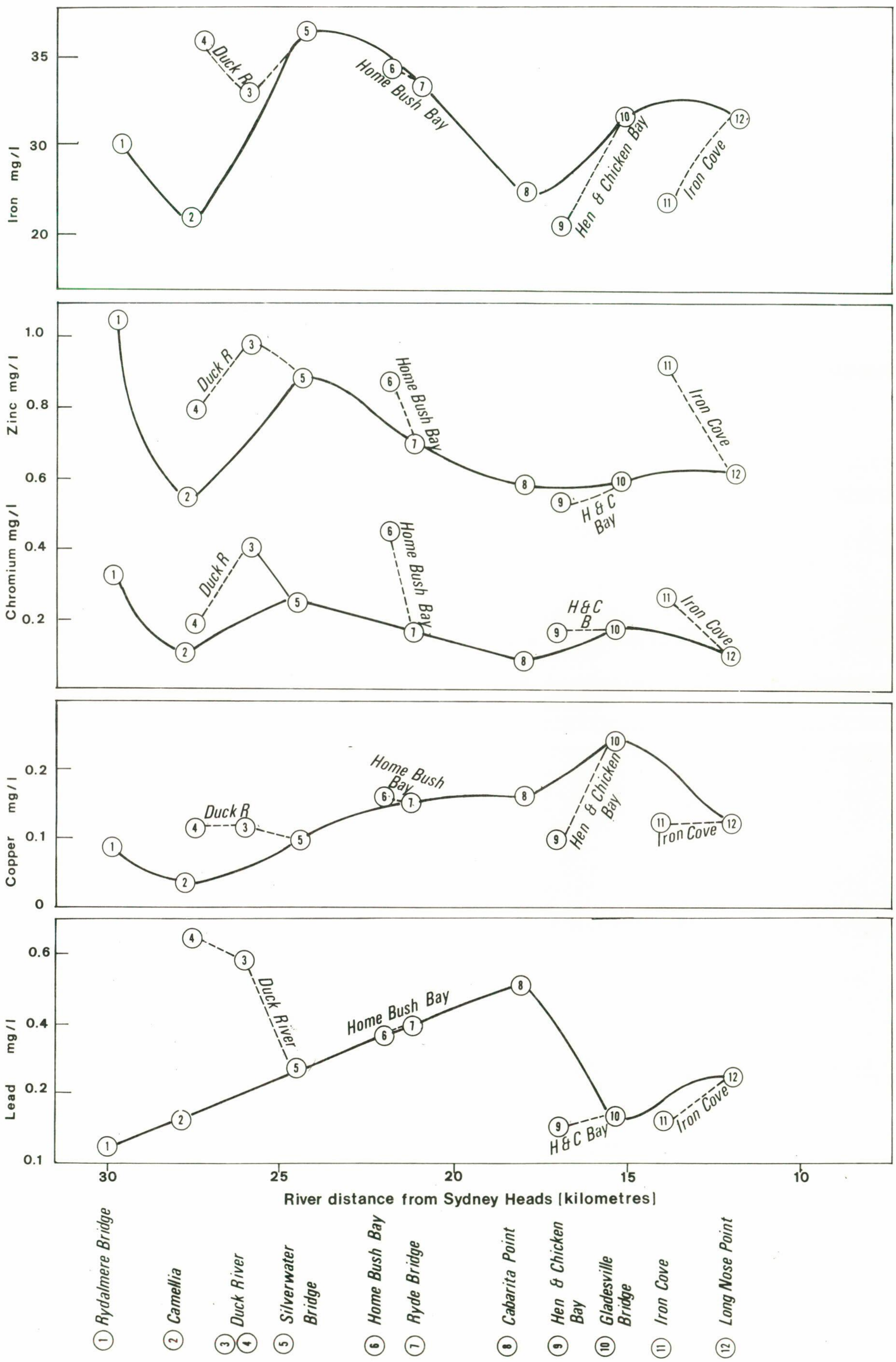


FAECAL COLIFORM DENSITIES (0.5 METRES) — PARRAMATTA RIVER & DUCK RIVER (JAN 1974–DEC 1976)

SOURCE: S.P.C.C. (1978)

FIGURE 10

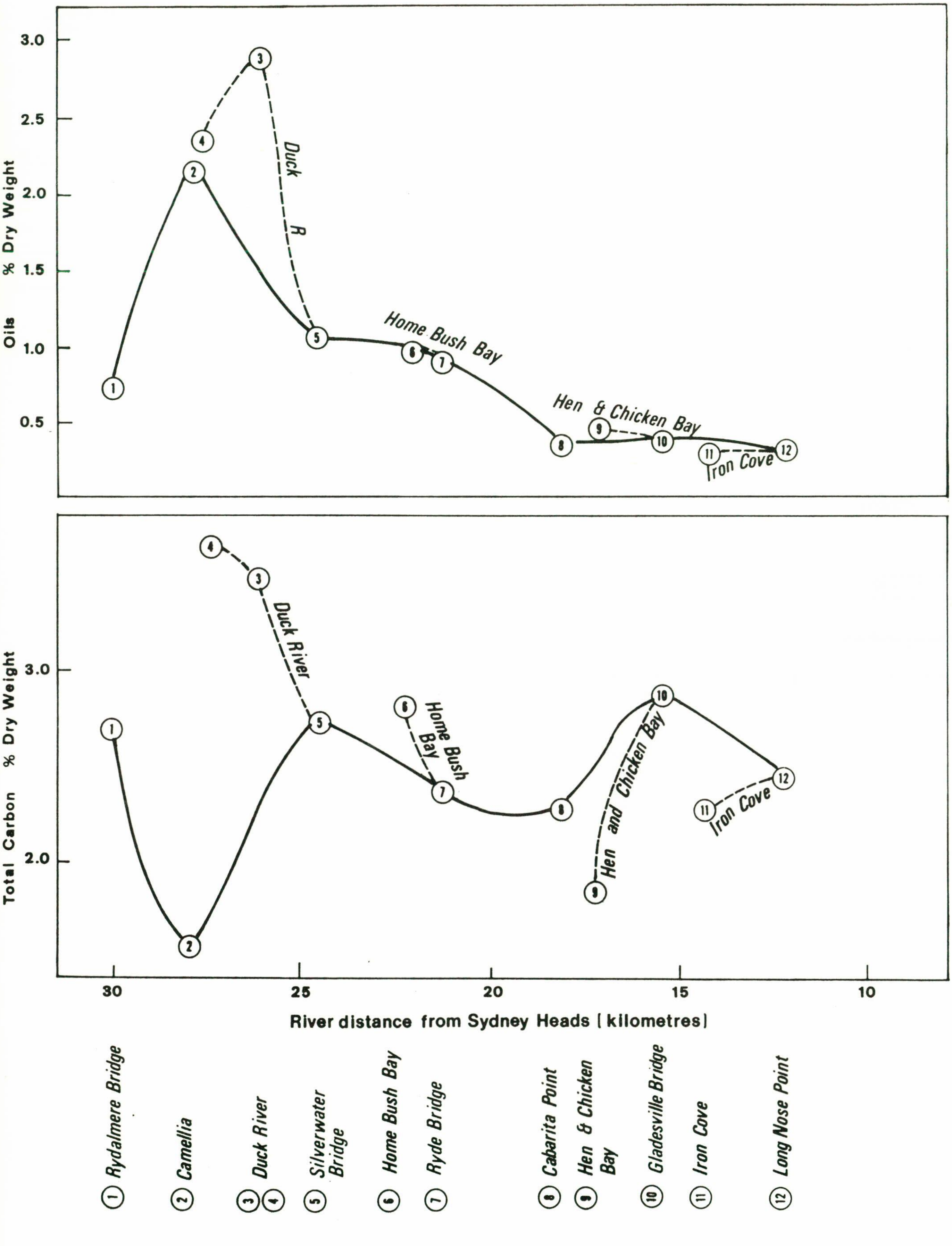
PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY



PARRAMATTA RIVER–METAL CONCENTRATION IN SEDIMENTS 30.9.76

SOURCE: S.P.C.C. (1977) COMPOSITION OF SEDIMENTS IN THE PARRAMATTA RIVER

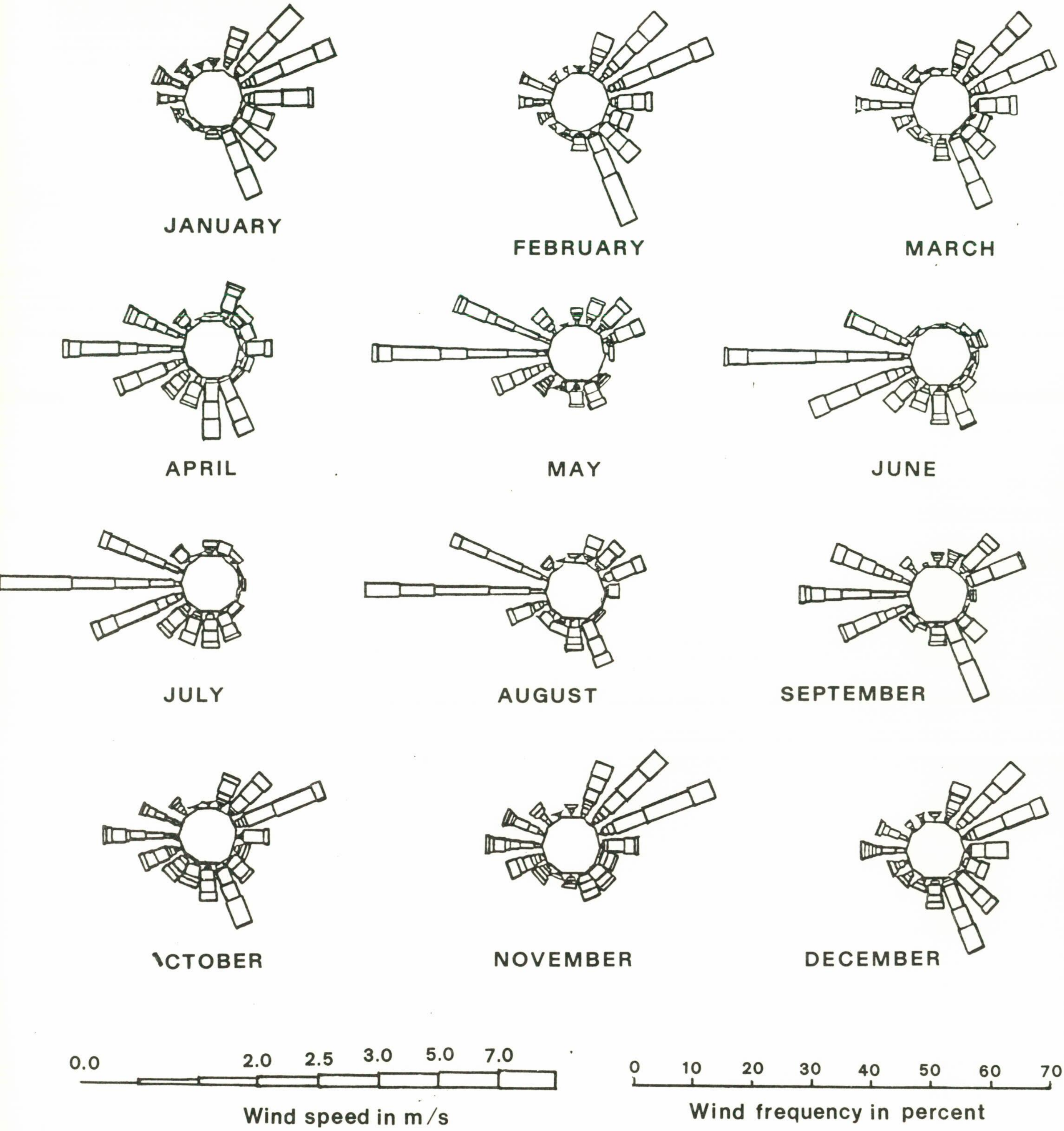
FIGURE 11



PARRAMATTA RIVER–ORGANIC COMPOUNDS IN SEDIMENTS 30.9.76

SOURCE: S.P.C.C. (1977) COMPOSITION OF SEDIMENTS IN THE PARRAMATTA RIVER

FIGURE 12
PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

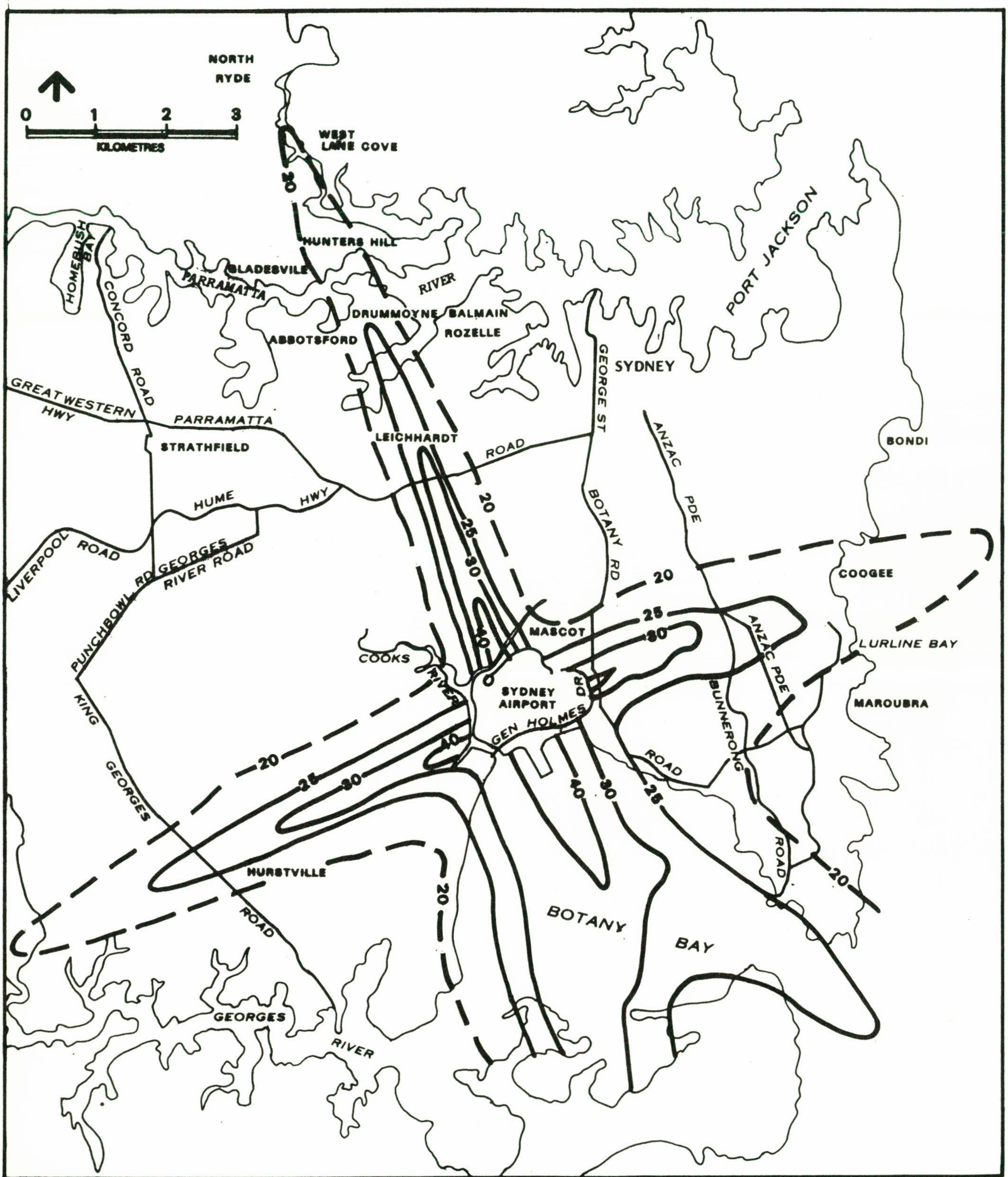


MONTHLY DISTRIBUTION OF WIND VELOCITY AT GOAT ISLAND [1982-1983]

FIGURE 13

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

SYDNEY (KINGSFORD SMITH) AIRPORT



SOURCE: COMMONWEALTH DEPARTMENT OF AVIATION

AUSTRALIAN NOISE EXPOSURE INDEX (1983 A.N.E.I.)

NOTE: THE ACTUAL LOCATION OF THE 20 ANE CONTOUR IS DIFFICULT TO DEFINE ACCURATELY MAINLY BECAUSE OF VARIATIONS IN AIRCRAFT FLIGHT PATHS

PARRAMATTA RIVER REGIONAL ENVIRONMENTAL STUDY

FIGURE 14

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