NRA Southern 103

The River Ouse, Barcombe Mills

Guardians of the Water Environment

NRA

National Rivers Authority
Southern Region

NRA Southern Region
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An Investigation of the Bacteriological Quality of Bathing Water around the Kent Coast since 1985.

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1.1 HISTORY OF THE FORMATION OF THE N.R.A.

1.1.1 May 1988
Enactment of Public Utility Transfers and Water Charges Bill
Establishment of National Rivers Authority Advisory Committee.

1.1.2 June-September 1988
Water authorities submit to Secretary of State for the Environment for approval by September 1988, schemes of organisation to separate utility from NRA functions.

1.1.3 October 1988-July 1989
Main privatisation Bill in Parliament in summer 1989
Water authorities complete restructuring and establish from 1 April 1989 at the latest NRA and utility functions as separate operational units-but still under water authority management. Appointments of NRA senior staff is completed, and the majority of staff transfers are made.

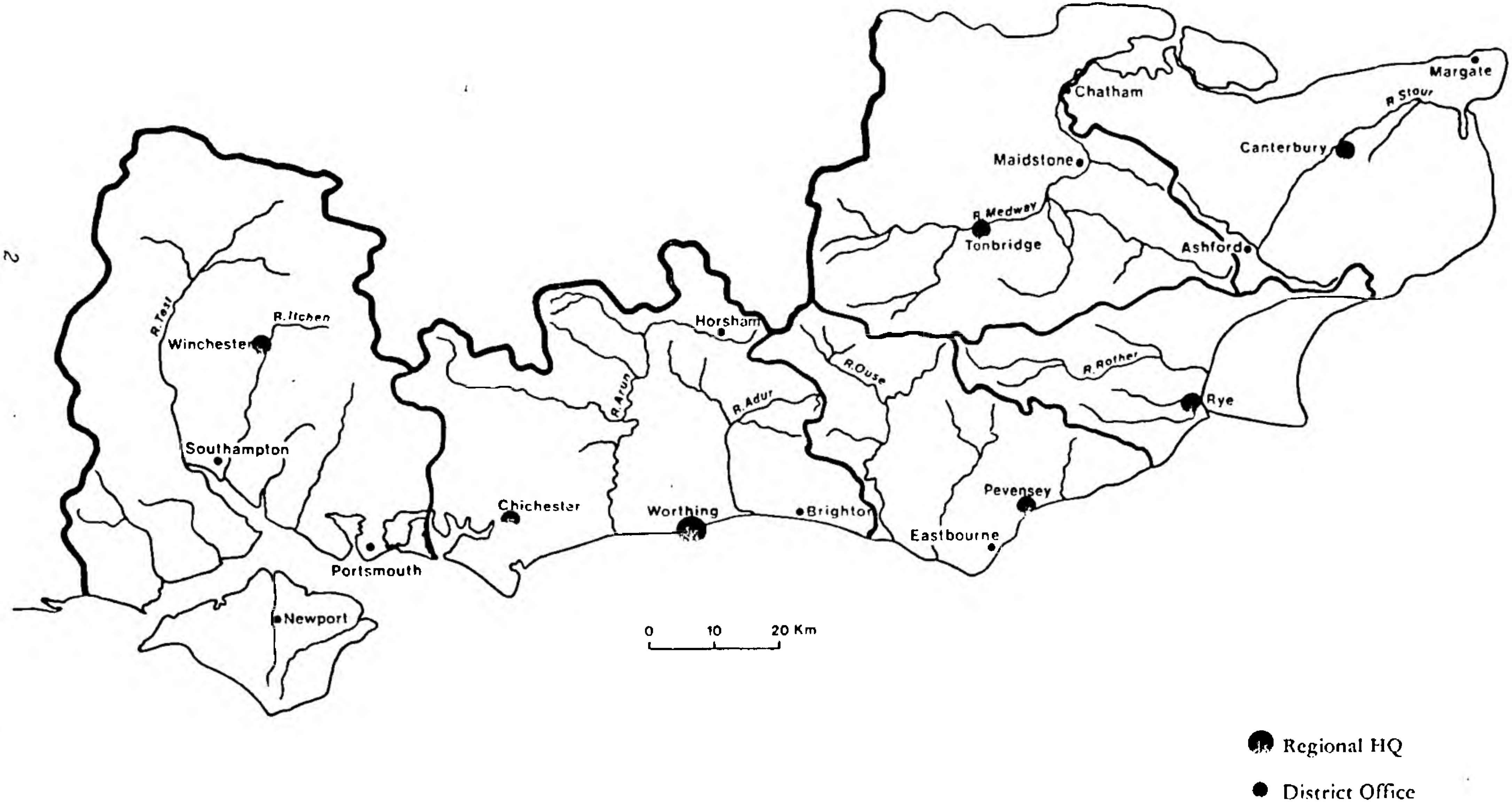
6 July
Water Bill received Royal Assent.

10 July
NRA headquarters created.

1.1.4 September 1989
Vesting of water service PLC's
Establishment of NRA
Establishment of Director General of Water Services
New regulatory framework begins to operate

1.1.5 November 1989
Flotation

Southern Region Area and District Boundaries



1.2 RESPONSIBILITIES OF THE NRA (SUMMARY)

1.2.1 The monitoring of water quality, the control of pollution and the strict regulation of discharges into streams, lakes, rivers and the sea.

1.2.2 The management and safeguarding of water resources for public supply by regulating those who take water out of rivers, lakes and from under the ground.

1.2.3 The provision of effective flood defences for people and property.

1.2.4 The maintenance, improvement and development of fisheries in inland water.

1.2.5 The continuing conservation of the water environment and its protection as an amenity.

1.2.6 The promotion of recreational activities such as boating, fishing and walking by rivers.

1.3 General Information

1.3.1 The NRA is an independent body with the resources to inspect, the right to direct and the legal powers to compel users, such as industry, business and farming whose pursuit of profits conflicts with environmental interest, to act in the most responsible fashion. The NRA seeks to balance the legitimate needs of all water users against the need to protect and improve the environment.

1.3.2 The NRA is largely self-financing, and employs around 6500 people and operates through 10 regions based on the river catchment areas of England and Wales.(fig.2). The NRA recovers much of its costs from local authorities for flood defence works and through charges for water abstraction licences and discharge consents. Any deficit is met by Government grant.

1.3.3 The NRA is answerable to Parliament through the Secretary of State for the Environment, and the Secretary of State for Wales and the Minister of Agriculture, Fisheries and Food also have policy responsibilities for the Authorities functions.

1.3.4 Its Board is appointed by the Government, and oversees and directs NRA policy across the regions. Each board is served by three specialist committees: a Regional Rivers Advisory Committee, a Regional Fisheries Committee and a Regional Flood Defence Committee.(fig.1)

1.4 Environmental Protection and Pollution Control

1.4.1 The Aquatic Environment. By the terms of the 1989 Water Act, rivers, lakes, estuaries, coastal waters and water stored naturally beneath the ground became "controlled waters," and it is now an offence to cause "any poisonous, noxious or polluting matter or any solid waste matter to enter any controlled waters." To ensure increasing quality of these controlled waters, sampling and analysis takes place all around the country every year by the NRA to give a picture of changes in quality and the cause of such changes. The Authority is empowered to decide if water quality is up to prescribed standards, and if not, can determine the most immediate, and practical way in which an improvement can be made to ensure the water is brought back to a satisfactory standard.

1.4.2 **Discharges.** The NRA is authorised to monitor and regulate materials flowing into controlled waters. All acceptable discharges require a "consent" from the Authority, each of which are subject to constant scrutiny by regular sampling and laboratory analysis to ensure compliance with set standards. Discharges which are potential sources of pollution are now subject to the tightest control by the NRA to guarantee the continuing health of our water environment.

1.4.3 **Water Quality Survey.** The NRA will conduct five-yearly quality surveys to monitor the controlled waters. Each survey will examine chemical quality and biological indices of our rivers in great depth to establish their basic health. This makes it possible to monitor the effectiveness of pollution control measures and to determine the ability of the receiving waters to accept waste discharge.

1.5 Water Resources

1.5.1 **Resource Activities.** Assessments of available resources, including their variations by time and place, must be made on an ongoing basis. This entails measurement of river flows, groundwater levels, rainfall and evaporation and the licensing of abstraction by water users. The NRA also lays down minimum requirements for river flows, particularly in view of the uses to which they are put. The NRA's policy is to encourage the interaction of man and the water environment-so long as that interaction is of benefit to both.

1.5.2 **Resource Activities.** As well as protecting the water resources of England and Wales, the Authority also committed to developing them. As well as augmenting its own facilities, it can require water users to develop their own; for example, by building enlarged reservoirs, or by readjusting the balance between abstraction and use. The NRA's water resource function is financed by charges levied by the Authority on abstractions licence holders.

1.6 Flood Defence

1.6.1 **Flood Defence.** To protect land at risk from flooding, and to keep out tide surges, the NRA maintains over 1 000 km of complex sea defences and many thousands of kilometres of river embankments. These defences are under constant threat by changing geographical and climatic factors and often they must be modified or even replaced to ensure their integrity. However flood defence activities can have their own effects on the environment, and the NRA supervises these activities so the environment is not only protected but enhanced-engaging in extensive consultation before implementing new projects. The Authority has a capital works programme to reconstruct inadequate or obsolete defences.

1.6.2 **Land Drainage.** The NRA reduces the risk of flooding by rivers, by programmes of main river maintenance and river improvement. The NRA removes weeds, dredges silt banks, mows flood banks and inspects them for damage from vermin, unauthorised excavation or any problems that could impair efficiency. The scale of these projects can be massive, such as the River Thames Flood Barrier, which will reduce the problems caused by flooding in an urban area. The NRA tests and operates many flood excluding structures on a regular basis to ensure they will be ready in the event of emergency

1.6.3 **Flood Watch.** The NRA is responsible for forecasting flood risk. The latest equipment is used by experienced engineers and hydrologists to predict and monitor areas at risk. The NRA is in constant contact with Meteorological Office and liaises closely with the Police, Local Authorities, Emergency Services, the Armed Services and Government Departments to coordinate the activities of the Regional Flood Defence Committees.

1.7 Fisheries, Recreation, Conservation and Navigation

1.7.1 **Fisheries.** The NRA's job is to assess the status of stocks of recreational and commercial fisheries, and to assess the well-being of salmon, trout, fresh-water and eel fisheries throughout England and Wales. The Authority is strongly committed to improving and developing these fisheries by the collection and collation of catch statistics, fish populations surveys, rearing of appropriate fish stocks and restocking, fish pass construction, and habitat improvement.

Fisheries are regulated by a system of NRA licences that help conserve and maintain stocks, backed up by strong measures against poaching.

1.7.2 **Recreation.** The NRA actively encourages all the recreational possibilities within the nation's aquatic environment. Wherever their is public access, the NRA aims to produce leaflets and booklets that introduce the amenities of specific river sites, from coarse fishing to water-skiing to windsurfing.

1.7.3 **Conservation.** All aspects of the NRA and its activities are designed to assist in the valuable task of conservation. Many SSSI's are located close to rivers or in the river and the NRA assesses the likely impact of any development that takes place nearby to ensure they remain in a natural and unspoiled condition. The NRA recognises its responsibility is not only the service and supply of its consumers but also the protection of the environment in which we all live.

1.7.4 **Navigation.** On some main rivers navigation is an important operational function of the NRA. As well as maintaining these navigations in good order and enforcing the navigation bylaws to ensure safe and enjoyable use by all, the NRA ensures that the close connection between navigation and other functions such as water resources and land drainage/flood protection are preserved.

2 THE NRA IN THE SOUTHERN REGION

2.1 Introduction

2.1.1 Southern Region of the NRA encompasses the counties of Kent, Sussex, the Isle of Wight, most of Hampshire and part of Surrey. It extends from the industrial low-lying Thames Estuary in the north east to the largely rural New Forest in the south and east of London.

2.1.2 There are 2 746 km of main river and 281 km of sea defences for which the Southern Region of the NRA takes responsibility.

2.1.3 The Regional Headquarters are located at Worthing and accommodates a core staff of approximately 100. This is where the functional managers responsible for environmental protection, water resources and flood defence operate.

2.1.4 These managers and their support staff provide the focus for the operational work carried out in the six mainland District Offices and the Isle of Wight. All policy and planning functions, as well as the licensing and consultative roles are carried out from Headquarters. It is also the point of contact for external organisations and for statutory committees concerned with river functions.

2.1.5 Operational activities and field work are carried out primarily by District staff, from offices appropriately located across Kent, Sussex and Hampshire. On the Isle of Wight Southern Water plc will provide a contract flood defence and hydrometric service, with the NRA directly responsible for environmental issues including sampling, licensing and planning liaison.

2.1.6 The six mainland District Offices are to be located at Winchester, Chichester, Pevensey, Rye, Tonbridge and Canterbury. The District Offices provide a strong local presence and are staffed by specialist officers in the fields of environmental protection, flood defence, and resource management.

2.1.7 Water quality, resource and flood defence activities are carried out at all District Offices. Fisheries functions are carried out on a county basis with the Fisheries Officers situated at Winchester, Pevensey and Tonbridge. The Biologist for the western part of the region is currently based at Falmer and the Biologist for the eastern part is based at Chatham, (to be moved in 1990 to Canterbury.)

2.1.8 Navigational responsibilities associated with Rye Harbour and the non-tidal Medway are controlled from the Rye and Tonbridge Offices.

2.2 Environmental Protection

2.2.1 Water Quality

The Southern Region has a total population of 3.9 million which is increasing by 18 000 per year. Populations increases in urban areas in the headwaters of small rivers in Sussex and Kent have increased the need for stringent effluent standards. Rivers depending on surface run-off, are particularly difficult to protect in periods of warm weather and low rainfall.

The risk from pollution from agricultural activity is a significant factor in all parts of the region. Farm pollution and agricultural run-off affect 70 km of river in the region and arrangements for slurry and silage disposal need constant monitoring.

Quality objectives for over 2 160 km of main rivers in the region are reviewed annually. The objective for 67 % of the rivers is either Class 1A or 1B, the objective for all but 0.1 % of the remaining stretches is Class 2.

Chalk aquifers are of extreme importance in the Southern Region and so there protection is essential. Areas of activity which pose any threat to groundwater quality require to be carefully vetted and closely monitored. These include industrial and agricultural activities as well as waste disposal by landfill.

Responsibilities for water quality protection also extend to controlled tidal waters such as those of the Solent, the Medway and Swale estuaries and beyond to 12 miles from the coast.

The Division takes bacteriological samples from 65 bathing beaches during the summer as part of a DoE programme to monitor compliance with EC standards.

At Regional Headquarters, water quality functions are the responsibility of a Principle Water Quality Officer who co-ordinates information from a water quality planning team, a Principal Pollution Prevention Officer and from the District Environmental Officers. Enquiries in respect of Control of Pollution Act Registers are answered by Water Quality staff in the Districts and at headquarters a member of the Water Quality team deals with all technical queries regarding Register entries.

2.2.2 Scientific Functions

The Environmental Protection function is carried out by a scientific section which includes a Principle Chemist, a Principle Biologist and a team of scientists at Headquarters. On a local basis the Biologist at Falmer deals with the western part of the region with a similar arrangement for the eastern area being dealt with from Chatham.

Within the Biology section of Environmental Protection, at Chatham (moving to Canterbury, September 1990) the work involves a wide variety of techniques, some of which are given below: The majority of work entails collecting, sorting and identifying the benthic macroinvertebrates from river samples both for the DoE survey (226 sites on rivers in Kent and East Sussex), and for other surveys, and pollution incidents; the performing of routine and non-routine bacteriology on bathing waters; analysing the fauna and flora around the coast for evidence of pollution; the collection and preparation of sediments and whelks for heavy metal and bacterial analysis from around the Hythe Long Sea Outfall (LSO) to assess the impact of the outfall - part of a on-running survey; the assessment of the Redox potential at sites around the Swale - as an indicator of long term pollution; analysing water from lakes and reservoirs for evidence of blue-green algae; fish parasitology; and river corridor surveys on sites prior to their dredging

2.2.3 Fisheries

The waters of the Southern Region support the whole range of freshwater fish species-ranging from trout and salmon in the rivers to a wide variety of coarse fish species inland.

The fisheries function is to "maintain, improve and develop" the fisheries of the region. This includes enforcement of the Fisheries Acts and bylaws, the provision of fish passes to ensure that migratory species are not obstructed, and helping angling clubs and riparian owners with the scientific management of their fisheries. An important function is the collection of survey data on fish stocks, which are a sensitive indicator of river water quality. The NRA fish farm in Kent produces coarse fish and trout to enhance still water and river fisheries in the region

The integration of river functions enables the fisheries department to liaise closely on land drainage, resource and water quality issues to ensure that, despite increasing pressures, fisheries in the region benefit from improved management of the aquatic environment.

The fisheries activities are organised on a regional basis under the direction of the Environmental Protection Manager at Headquarters. The work is co-ordinated by a Regional Fisheries Officer, with day to day operations being organised in the three mainland counties by Fisheries Officers based at the Winchester, Pevensey and Tonbridge District Offices. Fisheries Officers are supported by a Senior Water Bailiff and four Water Bailiffs. The day to day running of the Kent fish farm is carried out by a Hatchery Manager.

2.2.4 Conservation

Conservation has a high profile throughout Southern Region. There are many SSSI's including the whole of the Test Valley in Hampshire, whilst Sussex and Kent have a large proportion of the Country's wetlands. The north Kent grazing marshes are the most important site in Britain for breeding waders, and are recognised by International Convention.

The NRA's Conservation Guidelines are drawn up and continually revised to ensure a consistent policy to further its duty in the conservation of wildlife, landscape and historic features whilst carrying out its operational activities.

At Headquarters, a Regional Conservation Officer, working in the Environmental Protection team, co-ordinates internal conservation activities and liaises with outside bodies having an interest in conservation, such as the Nature Conservancy Council and the local Wildlife Trusts. In addition, there is a widespread emphasis on conservation at a local level by all district staff who bring to the function the benefits of uniting river activities in the National Rivers Authority.

2.3 Water Resources

In the region, rainfall averages 790 mm per year, and therefore the region is considerably drier than England and Wales as a whole, and it also lacks the upland gathering grounds of most western and northern regions. As a result nearly three quarters of public water supplies are derived from groundwater-a greater proportion than any other Water Authority area. Chalk, which outcrops in all counties from Thanet to the Isle of Wight, is the principle groundwater source, and with such a reliance on groundwater it is essential to protect it from pollution. The aquifer Protection Policy has been developed and is applied for this reason.

Most of the remaining drinking water supplies are drawn from the lower reaches of rivers, such as the Test, Ouse, Stour and Medway where careful planning and good management are needed to maximise resources.

Precipitation decreases across the region from west to east, so that eastern Kent, with only 600 mm of rain per year, is considerably drier than Hampshire. As it is also the most intensively cultivated area, it experiences greatest pressure on water resources for irrigation.

Within Southern Region resource planning, aquifer protection, abstraction licensing, hydrometric schemes, co-ordination of data needs and processing methods and modelling are all dealt with from Regional Headquarters. The collection, processing and archiving at hydrometric data from rain gauges, climate stations, observation boreholes and river flow gauges is carried out from the District Offices. Licence investigations, policing of abstractions and local liaison on resource, matters are also District functions.

2.4 Flood Defence

2.4.1 Responsibilities

Southern Region has a coastline totalling 900 km, of which nearly 300 km are the direct responsibility of the NRA for sea defence. Since the great tidal surge of 1953, extensive sea defence walls have been constructed along the southern bank of the Thames Estuary, at a cost of £70 m, and at Sheerness on the Isle of Sheppey at a cost of £10 m.

The NRA's commitment to sea defence maintenance is also very large in such areas as the Swale, Sandwich and Romney Marshes, Shoreham, Littlehampton and Selsey in Sussex and the Solent in Hampshire.

The run of the tide up-channel from the Western Atlantic, and prevailing westerly winds erode and deposit beach material along the southern coast from west to east.

A timber groyne system is used to trap sand and shingle, and each year costly replacement and maintenance is undertaken to preserve it, as a cushion of shingle must be preserved, and in some cases reinstated, to dissipate the energy of the storm waves.

West of Dungeness and in other vulnerable areas, this has been achieved by reseeding the beach with transported shingle-a continuous picking up of shingle on the east of the seawall and transporting it to the west to continue its function as part of the littoral drift along the foreshore.

A recently completed operation was at Seaford, where an artificial beach nourishment and groyne scheme created at a cost of £13 m. The majority of the flood defence expenditure in recent years has been on tidal or sea defence schemes, and with a continuing need to maintain or renew these defences this will continue to dominate over inland works.

However, there remains a considerable land drainage interest. Flooding in the Medway valley has been alleviated by the Leigh flood regulating reservoir and a similar flood storage scheme to alleviate flooding from the R. Stour in the Ashford area is currently under construction

Over the past 20 years, many schemes for drainage improvement of settlements and agricultural land have been carried out in the Region. In low-lying internal drainage districts where gravity flow can give limited improvement, pumped drainage schemes have been implemented.

A flood warning system for the collation and dissemination of flood risk information is also operated by the NRA, for times when defences are at risk of over-topping or channels are unable to contain flows.

The navigations in the region are on watercourses which have an important land drainage function and these are administered as part of the Flood Defence function. In particular, the NRA administers the Medway Navigation between Allington Lock and Tonbridge.

The Southern Region also has a Harbour Authority. It is also unique in carrying out an annual survey of the coastline for the benefit or all maritime agencies in the region.

2.4.2 Flood defence functions at Headquarters

The Flood Defence Manager is supported by a Regional Planning Engineer-responsible for the compilation and monitoring of the NRA capital programme, maintaining the land drainage asset data system, minor capital designs, flood investigations and analysis, beach monitoring, preparation of design briefs and design contracts, negotiations with MAFF, supervision of contracts and monitoring of NRA levels of service and a Regional Operations Engineer. Design and project management of capital works is put out to contract.

Also on the planning side is planning liaison, including commenting on planning applications, negotiating with applicants, liaising and commenting on local and county plans, maintaining flood records and issuing Consents as appropriate.

Also supporting the Flood Defence Manager is a Regional Operations Engineer who is responsible for operational support services such as health and safety, purchase of plant and transport, supplies and work study.

2.4.3 Flood Defence functions in the Districts

The District Engineer, in each of the six districts is responsible for the land drainage and flood defence operations and is supported in each catchment by teams headed by a superintendent. District Engineers are also responsible for those Internal Drainage Boards which are either administered by, or receive engineering advice from, the Division. They also control the Medway Navigation and Rye Harbour as appropriate.

There is a Planning Liaison Officer in each District who is responsible for land drainage consent and for some local negotiation with applicants. He is also responsible for the policing of land drainage and sea defence bye-laws.

2.5 Finance Department

2.5.1 The estimated annual turnover for Southern Region NRA is approximately £22 million at present. Water Resources and Flood Defence are self financing services with income from charges to abstracters and precepts on County and London Borough Councils. The balance of income (24%) comes from those who benefit from the other services provided. Income from the public is derived principally from the Environmental Services Charges (19%), whereas income from specific users is levied through sale of fishing licences and by way of navigation fees.

2.5.2 The Southern Region Finance Group is based at Headquarters and comprises an Accountancy Section, an Exchequer Section, an Income Section, an audit Section and a Computer Systems Section. The Accountancy Section is responsible for the preparation of the revenue budget, monitoring, preparation of accounts and the financial work relating to the capital programme. Exchequer functions include the processing of payrolls and the payment of invoices. The Income Section prepares income budgets, invoices and collects all sources of income including Flood Defence precepts. The Audit Section is responsible for reviewing, checking and reporting on all aspects or the Division's financial transactions. The Computer Systems Section monitors performance and charges of all IT contracts. It reviews systems and recommends changes to meet new requirements.

2.6 Secretary's Department

The Secretary's Department at Regional Headquarters provides the legal, estates and administrative support for the operational activities. The Personnel and Public Relations Officers are also within the department.

2.6.1 Legal services

A Principal Solicitor and staff provide a comprehensive legal service, including day to day legal advice, conveyancing, prosecution, conduct of litigation and arbitrations, debt recovery, preparation and sealing of Contracts, representation at Public Inquiries in relation to planning and development control, promotion of Bye-laws and Orders, processing and issue of abstraction licences and pollution consents, maintenance of statutory registers and main river maps.

2.6.2 Administrative Services

The Principal Administrative Officer is responsible for the provision of secretariat services to Committees and Members as well as word processing services, printing facilities and the day to day management of the offices at headquarters.

2.6.3 Estates Department

The Estates Officer deals with the acquisition of land and easements required by NRA in the region. In addition, it deals with the settlement of compensation claims arising from NRA operational works.

2.6.4 Personnel

The Personnel Manager and Personnel Officer have played a key role in establishing Southern Region of the NRA and its consultation procedures. Industrial relations are an important part of the section's activities and consultation procedures are being established.
The development of staff is seen as an important role and the Personnel Section is active in formulating training plans and programmes to further career development.

2.6.5 Public Relations

A Public Relations Officer and Assistant provide a focus for liaison between the NRA and the public, the media and specialist groups with an interest in the water environment.
The section produces promotional literature and provides an information service for the public.

2.7 The National Rivers Authority and the Advisory Committees

2.7.1 The Board of the NRA

The Water Act (1989) provides that the National Rivers Authority shall have a Board which has overall responsibility for determining the national policy of the Authority.

The Chairman of the Board is Lord Crickhowell. The Chief Executive, Dr. John Bowman is also a member. Two members are appointed by the Ministry of Agriculture, Fisheries and Food, one with a particular interest in flood defence matters and the other with a particular interest in fisheries.

The remaining members are appointed by the Secretary of State for the Environment.

Ten of the Board members gave responsibility for each of the NRA regions and act as chairmen of their respective Regional Advisory Boards. The member for Southern Region is Mrs Karen Morgan.

2.7.2 Regional Advisory Boards have been set up in each NRA region to provide advice to the Regional General Manager and to enhance links between the central NRA board and the regions.

Chairman of the Southern Region Advisory Board is Mrs Karen Morgan

The Regional General Manager and the Chairmen of the Regional Committees complete the membership of the RAB

2.7.3 Regional Rivers Advisory Committee advises the NRA on all aspects of river basin management. It is made up of representatives of local authorities, leisure groups, conservation interests, industry, agriculture and other interested parties.

2.7.4 Other committees include: Regional Flood Defence Committee; Isle of Wight Flood Defence Committee; Hampshire Flood Defence Committee; Sussex Flood Defence Committee; Kent Flood Defence Committee; Regional Fisheries Advisory Committee; Hampshire Fisheries Advisory Committee; Sussex Fisheries Advisory Committee; Kent Fisheries Advisory Committee and the Harbour of Rye Advisory Committee.

Daily Mail, Thursday, August 2, 1990

mac

'Well? Speak up man! Is it safe?'

AN INVESTIGATION INTO THE BACTERIOLOGICAL QUALITY OF BATHING WATER AROUND THE KENT COAST

3. Introduction

3.1 Responsibility of the NRA

The National Rivers Authority has a responsibility to monitor the quality, and the regulation of discharges into controlled waters. The extension of water-quality control into coastal waters, required by the EEC Directive of 1975, involves routine monitoring of existing sources of pollution, and the NRA has a responsibility to measure and control the effect of discharges and the capacity of the receiving waters to cope with them.

The disposal of sewage and sewage effluents to marine waters is one such form of pollution, and the Water Authorities responsible are coming under increasingly informed pressure to clean up their operations. The NRA is responsible for monitoring the 380 UK bathing waters which should comply with the EEC directive.

3.2 History, and the Long Sea Outfall Programme

The practice of disposing sewage to the sea is not new, but problems are caused by the increasing demands that are being made on existing sea outfalls. Many of the outfalls date back to the Victorian days when there was a drive to provide the coastal towns with a sewerage system.

A classic network was established with collector sewers running down to the foreshore where they were met by an interceptor sewer. The interceptor sewer ran parallel to the shoreline to terminate with a short outfall, often discharging directly onto the beach.

The problem of sewage on the beaches has only become apparent in recent years, due in part to: the increase in population; the continued development of land along the shoreline; and the greater mobility of people.

The building boom of the Victorians means that the UK has a legacy of short sea outfalls. Southern Water has over 80 such outfalls.

A Government survey in 1973 (Discharges of Foul Sewage to the Coastal Waters of England and Wales) disclosed that 85% of principle sewage outfalls did not extend far enough out to sea to discharge effectively, i.e. into a dilution of sea water deep enough to prevent contamination of coastal waters and bathing beaches.

In order to bring the bathing beaches in line with the EC directive, Southern Water is committed to a programme of south coast long sea outfalls (L.S.O.'s). These were considered to be the best method of treatment, as conventional sewage treatment achieves only a marginal reduction in bacterial concentration, and a treated effluent cannot be discharged directly to the sea adjacent to a bathing water.Additional treatment would be required additional treatment such as chlorination (not acceptable to fishery interests due to the organochlorine compounds formed), or discharging the effluent through a L.S.O.

The L.S.O.'s need to be situated in 15-20m depth of water with a fast tidal current to ensure a dilution of around 100 times, and a dispersion over a large area. Diffuser pipes are situated along the final part of the pipe to facilitate this. However the discharges will still receive little treatment other than screening through 5mm mesh drum screens, and with macerated screenings being returned to the flow upstream of the screens.[11]

The outfalls have been designed to operate on the "plug flow" system as advocated by Snook (1979), where sewage will accumulate in the station's wet well until sufficient volume is present for it to be pumped out to sea at high velocity.

The L.S.O.'s at Hythe and Margate were both officially opened in April 1989, and were running properly some time after this. The Broadstairs short sea outfall (North Foreland), is due to be finished in the next few years.

A list of all the outfalls around the Kent coast, from Sheppey to Dungeness is given on Table 1.

Table 1. **OUTFALLS TO COASTAL WATERS**

Outfall	Dry Weather Flow m^3/d	Outfall Discharge Point	Depth over top of pipe	Date of Construction	Pretreatment of Sewage
Swalecliffe TR 133 675	9 600	1 500m beyond LW	7m	1972	Pista Grit trap, Drum, Screen, Macerator
King's Hall, Herne Bay TR 185 684	5 600	at LW	Covered at LW	Early 1900's	None
Birchington TR 273 693	Decommissioned				
Foreness outfall (Margate) TR 384 716	14 600 (Decommissioned 1989, now = Margate LSO storm outfall)	at LW	covered at LW	1948	Screening and Maceration
Margate Long Sea Outfall TR 384 716	Not known (capacity= 8161/sec)	1.9km from headworks	Covered at LW	1989	Screening, Grit removal
North Foreland (Broadstairs) TR 402 698	7 600	350m beyond LW	7m	1923	Screening, Maceration
Ramsgate TR 377 641	13 200	350m beyond LW	2m	1887	Screening, Maceration
Deal TR 376 543	6 400	280m beyond LW	2m	1958	Screening, Maceration
Dover TR 319 402	19 900	310m beyond LW	6m	1963	Comminution
Copt Point (Folkestone) TR 242 364	16 600	at LW	Exposed at LW	Prior 1900	None
Hythe TR 156 338	5 600 (Decommissioned 1989, now = Hythe LSO storm outfall)	Between HW and LW	Covered only at HW	Prior 1900	None
Hythe Long Sea Outfall TR 156 338	Not known (capacity= 3151/sec)	2.5km from headworks	Covered at LW	1989	Screening, Grit removal
West Hythe TR 135 325	300 (Decommissioned 1990, discharge to Hythe LSO)	Direct to beach	Covered only at HW	1936	Screening, Primary sedi -mentation

3.3 <u>The EEC Directive</u>

On 8 December 1975, the Council of the European Communities introduced a directive concerning the quality of bathing waters.(76/160/EEC)[1]

The directive applies to waters in which "bathing" is "explicitly authorized" or is "not prohibited and is traditionally practised by a large number of bathers." It applies to both fresh water and sea water. "Bathing area" means any "place" where bathing water is "found" and the "bathing season" means the period during which a "large number of bathers can be expected, in the like of local custom, and any local rules which may exist concerning bathing and weather conditions."

The directive requires member states to ensure that "bathing water" is brought up to, and then maintained at certain specific standards. The mandatory guidelines are maximum levels which must not be exceeded by more than 5% of samples.

Britain at first nominated only 27 sites or 'Euro Beaches', but in 1987 this was increased to 397 'Designated Bathing Beaches' (including Scotland and Northern Ireland.)

The quality requirements for bathing water are set down in the Annex 1 of the directive. This uses coliform bacteria, and more specifically *Escherichia coli* to indicate the level of sewage contamination. The standards are:

10 000 coliforms/100 ml bathing water, and
2 000 *E.coli*/100ml bathing water.

3.4 Indicator Bacteria and Health Hazards Associated with Sewage

Indicator organisms need to have ease and accuracy of identification, as well as maximum recovery, reproducibility and comparability. Indicator organisms can only be defined in terms of what they are intended to indicate. The presence of pathogens in sea water indicates a health risk, however seeking their presence is usually impractical for monitoring purposes, and so other bacteria are used to indicate their presence and degree of pollution. Ideally, such indicator bacteria should cover the possible presence of all pathogenic organisms. They should be absent, or very few in number from all sources other than sewage; capable of easy isolation and numerical estimation; unable to grow in the aquatic environment; and preferably more resistant than pathogens to disinfectants.

In the UK, these criteria are virtually fulfilled by the use of *Escherichia coli*.[13] *E.coli* is present in the faecal material of man and warm blooded animals in such abundance that its presence in water may be used to detect recent faecal or sewage pollution. Its numbers indicate the degree of pollution, but its presence, however, denotes no more than the potential presence of pathogenic organisms.

3.5 The Bathing Beach Programme

The criteria for the sampling of bathing water are laid down in a 1979 Department of the Environment interpretation of the EEC Directive, revised in 1988.

The criteria used by the N.R.A. are those adopted, with subsequent revisions, from Southern Water, which were decided following a meeting between the Water Authority Association, Environmental and Technical Committee and the DoE on 12 May 1987. They are:-

- 20 samples to be collected and analysed from the designated bathing waters between May and the end of September.

- Samples should be taken at regular intervals during the bathing beach season.

- Only one sample per visit should be taken.

- Samples should be taken at a depth of 30cm below the surface in water between 60cm and 100cm deep.

- Recording of field data (Table 2.)

- Faecal coliforms and total coliforms must be determined on all samples.

- Salmonella, faecal streptococci and enteroviruses must be determined twice during the season.

- pH must be determined on each bathing water once per season.

The sites at which the sampling is carried consist of 19 designated bathing beaches in the eastern area of southern region. There are an additional 23 non-designated sites which are or have also been sampled to provide additional information on the state of Kent's bathing water. A full list of all the sites is given on Table 3, and are also shown on fig.1.

Table 2. **BATHING BEACH FIELD MEASUREMENTS**

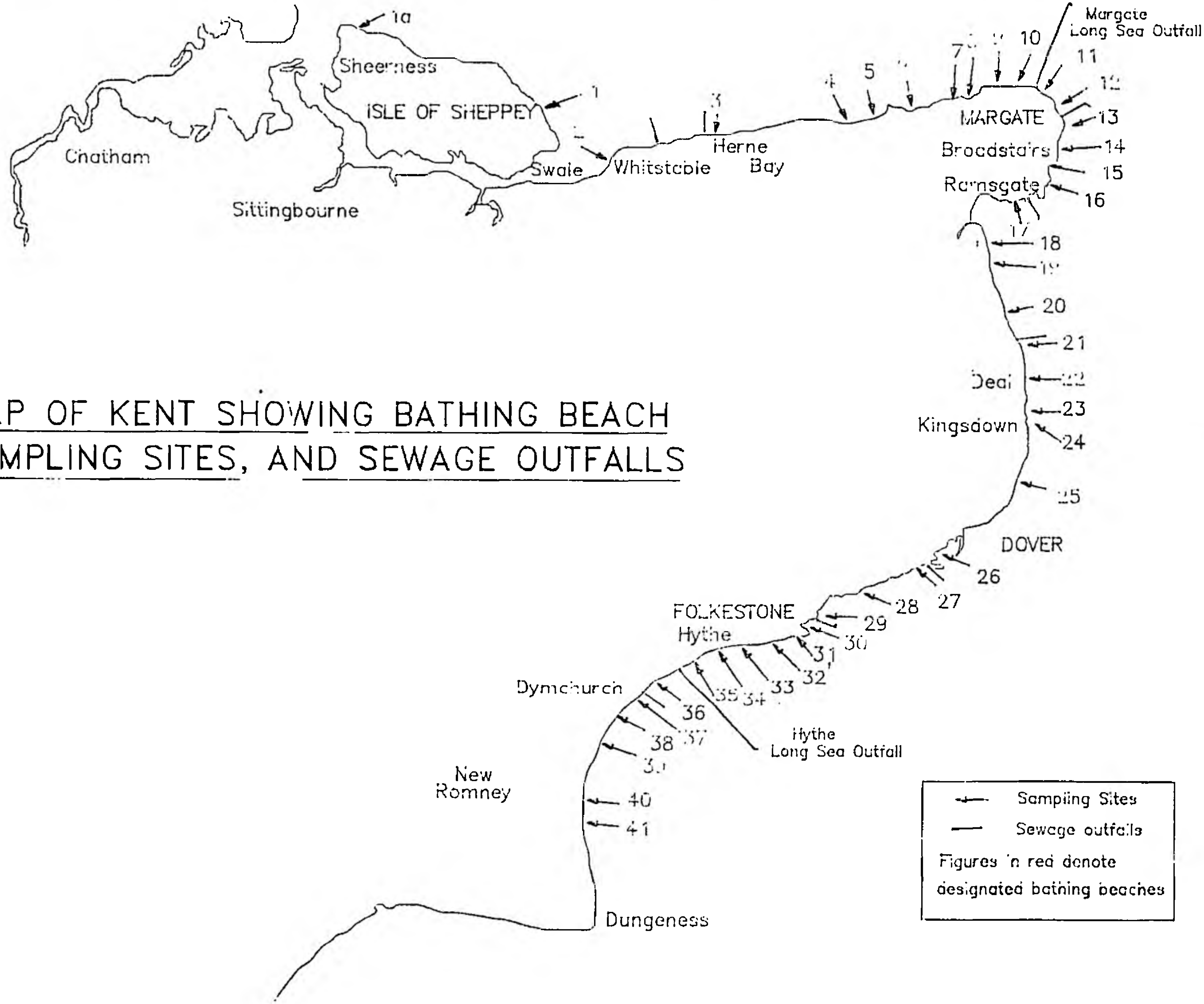
PARAMETER	UNIT OR CLASS OF MEASUREMENT
Sea Temperature	Centigrade
Sea State	0 - Calm, glassy 1 - Calm, rippled 2 - Smooth wavelets, 15 - 30cm 3 - Slight waves, scattered white horses, 30 - 60cm 4 - Moderate waves, frequent white horses 0.6 - 1.2m 5 - Rough waves, many white horses, 1.2 - 2.4m 6 - Very rough waves, greater than 2.4m
Sunshine Conditions	0 - No sun 1 - Weak sun, no shadows 2 - Weak sun, shadows 3 - Sun momentarily obscured by cloud 4 - Bright sunshine
Rainfall	0 - No rain 1 - Mist 2 - Drizzle 3 - Light rain 4 - Moderate rain 5 - Heavy rain 6 - Cloudburst
Cloud Cover	0 to 8 Oktas (eighths of sky covered)
Wind Direction Wind Speed Wind Force	Degrees 0 - 360. 999 - no wind detected Metres per second Beaufort scale
Bathers	Number in contact with the water per km
Transparency	Whether sampler can clearly see his feet in 60cm water

Table 3. BATHING BEACH SAMPLING SITES

SITE NUMBER	LOCATION	GRID REFERENCE
1a	Sheerness	TR 925 750
1	*Leysdown	TR 025 717
2	*West Beach	TR 098 660
3	*Herne Bay	TR 186 660
4	*Minnis Bay	TR 286 697
5	Westgate Bay	TR 320 702
6	*St. Mildred's Bay	TR 328 705
7	Westbrook Bay	TR 341 706
8	*The Bay, Margate	TR 347 708
9	*Margate, Fulsam Rock	TR 355 715
10	Palm Bay	TR 369 715
11	Botany Bay	TR 391 712
12	*Joss Bay	TR 399 702
13	Broadstairs, East Cliff	TR 401 688
14	*Broadstairs, Viking Bay	TR 398 677
15	Dumpton Gap	TR 397 667
16	Ramsgate Sands	TR 387 649
17	*Ramsgate, Western Undercliff	TR 372 640
18	Sandwich Bay, Golf Links	TR 355 606
19	*Sandwich Bay, Car Park	TR 358 590
20	Sandwich Bay, Princes Road	TR 366 571
21	Sandown Castle	TR 376 544
22	*Deal Castle	TR 378 520
23	Walmer Castle	TR 381 505
24	Kingsdown	TR 371 485
25	*St. Margaret's Bay	TR 368 444
26	Dover Harbour	TR 321 412
27	Shakespeare Cliff	TR 309 399
28	East Wear Bay East	TR 271 385
29	East Wear Bay West	TR 247 376
30	*Folkestone, East Pier	TR 237 363
31	Folkestone, Marine Parade	TR 230 355
32	Sandgate, Toll Road	TR 215 354
33	Sandgate, Town Centre	TR 203 351
34	*Sandgate, Princes Parade	TR 188 348
35	*Hythe, West Parade	TR 160 340
36	Dymchurch, Hythe Road	TR 128 319
37	*Dymchurch, Martello Tower	TR 113 304
38	Dymchurch, Car Park	TR 101 290
39	*St. Mary's Bay	TR 093 277
40	*Littlestone	TR 084 239
41	Greatstone	TR 081 229

* Designated Bathing Beach

Figure 1



MAP OF KENT SHOWING BATHING BEACH SAMPLING SITES, AND SEWAGE OUTFALLS

3.6 Aims of the Project

The Long Sea Outfalls at Margate and Hythe came on line in the early summer of 1989. With the collation of data since 1985 on the quality of the bathing beaches around the proposed outfalls, it is now possible, for the first time, to analyse the information to see whether or not the outfalls are having the desired effect - in improving the quality of the bathing beaches, which were previously affected by the inefficient short sea outfalls in the area.

The field sheets and bacteriological results since 1985 have been put into a computer database, where the information can be more easily manipulated. Any trends that appear to be apparent can be tested to see whether or not they are not they are statistically relevant.

With all of the back data available being put onto computer, including that of sites that are not of relevance to the L.S.O. programme, an additional aim is to see what connections there are, if any, between the field information that is taken at the time the sample is collected, and the *E.coli* count that is obtained from the sample. Again, this can be statistically analysed to see how relevant the information is. It would also perhaps be possible to create a model, based on the field data, to predict the coliform count given measured environmental variables. A model based on values taken from 'clean' sites would be a useful tool in establishing if any particular beach is polluted at the time the sample was taken.

4. Method

4.1 Sampling Sites and Frequency

The designated bathing beaches are sampled to conform with the EC directive, the frequency and duration having been discussed in section 3.5.

As part of the study on the long sea outfall programme, additional sites around the outfalls are also sampled so that a better picture of what is happening can be achieved.
A list of all the sites, that are, or have been sampled are shown in Table 3.

The additional sites vary from year to year and over the two bathing beach seasons (Summer) 1989 and 1990, the additional sites were:

Summer 1989 10,11,13,33,36,38
Non-Summer 1989-90 6,8,9,10,11,12,13,14,17,19
33,34,35,36,37,38

Sites were sampled monthly during the non-bathing beach season

Summer 1990 5,10,11,13,16,26,33,36,38,41,42.

(Figures in bold denote sites sampled by the student, those underlined were used as part of the Long Sea Outfall project. All the additional sites were sampled according to the guidelines outlined in section 3.5.)

N.B.
It should be noted that due to tradition passed down from previous students, site no.10 - Palm Bay is actually sampled from Walpole Rocks, approximately 400m west of Palm Bay. In order to prevent too much confusion over this in future years, in the list of Bathing Beach Sampling Sites (Table 3) the grid reference given for the site named Palm Bay is TR 369 715 (the grid reference of Walpole Rocks), not the grid reference of Palm Bay (TR 373 714). It is hoped that in doing this some consistency in the sample sites will be maintained.

4.2 Collection of Samples

The objective of sampling is to obtain sufficient volume of a representative portion of the water at an appropriate time and place, and to convey it to the laboratory for analysis before significant changes in the bacteriological condition have occurred. The recording of the meteorological and sea conditions when the samples were taken may be helpful when subsequently comparing results from a number of surveys over a long period.[4]

The collection of samples was done in accordance with the DoE's instructions.

Samples were collected, from the required depth, in 250ml sterile plastic bottles, which were clamped to a metal rod. The samples were then stored in a light proof cool box, until analysis could be carried out in the laboratory. It was aimed to carry out analysis within six hours of the sample being taken.

At the time of sampling, the field data was recorded, as required (Table 2.)

4.3 Laboratory Analysis of Samples

Analysis of samples was by membrane filtration, using Gelman filtration apparatus. The diluted samples were filtered under vacuum, through a membrane of cellulose esters with a pore size of 0.45 nm. Bacteria present in the sample were retained on or near the surface of the membrane.

For sample dilutions, recent results were consulted, and note taken of weather conditions, to decide on appropriate volumes; for unknown samples 0.1ml, 1ml, 10ml dilutions are recommended for Total Coliforms, and 1ml, 10ml, 100ml dilutions for Faecal coliforms.

4.3.1 General Method

Membranes were placed on filter units using sterile forceps, a funnel placed on top and approximately 10ml Maximum Recovery Diluent poured onto each filter unit.

The sample was shaken well, to dislodge bacteria that may have adhered to the bottle surface or sediments in the sample, and the appropriate volumes required were pipetted into the diluent. For 10ml and 1ml volumes, automatic pipettes with sterile tips were used. For 100ml and 50ml, the volume markers in the filter units were used. For volumes less than 1ml, 1ml aliquots of serial dilutions (1ml seawater : 9ml diluent) were used as appropriate. For the 100ml volumes, the diluent was run through afterwards to rinse any salt from the membrane.

The sample was filtered, then the membranes removed from the filter and placed on absorbent pads in appropriately labelled petri dishes. (Site number, volume of seawater to be sampled and incubation temperature.) The absorbent pads were soaked in approximately 2ml of media (1989 the media used was Membrane Enriched Teepol Broth; 1990 the media was Membrane Lauryl Sulphate Broth.)[7]

When all dilutions from one sample had been filtered, starting with the greatest dilution first, the filter units were sterilized by passing through a bunsen burner flame.

Plates were separated and inverted in brass canisters to be incubated in water baths at 37'C for presumptive total coliforms, and 44'C for presumptive thermotolerent coliforms. Initial incubation was at 30'C for four hours to resuscitate the bacteria, followed by 14 hours at the appropriate temperature.

After incubation the plates were removed and the number of yellow colonies on each plate counted and recorded. (The media contains lactose which the coliforms ferment to produce gas and lactic acid, the latter which turns the phenol red present in the media to yellow.) Plates containing between 20 - 80 yellow colonies were chosen. Plates containing more than 200 colonies (including non-coliforms) are disregarded.

The number of colony forming units per 100ml were calculated as follows;

$$\text{TOTAL/FAECAL COLIFORMS} = \frac{\text{Colony count at 37'C/44'C}}{\text{Volume filtered}} \times 100$$

If more than one dilution gave a count within the 20 - 80 range, the result was determined as a weighted average;

$$\frac{((\text{Count Diln.1})+(\text{Count Diln.2})+\ldots\ldots)}{((\text{Volume Diln.1})+(\text{Volume Diln.2})+\ldots\ldots)} \times 100$$

Media

Media for pads	- Membrane Enriched Teepol Broth (no longer used)	Oxoid MM369
	- Membrane Lauryl Sulphate Broth	Oxoid MM615
Diluent	- Maximum Recovery Diluent	Oxoid CM733

4.4 Data Handling

4.4.1 Data Entry

The information obtained had to be put into the computer in a such a way that the statistical package could manipulate it, thus it was necessary to alter some of the raw data so that the information was in a form that the computer could use.

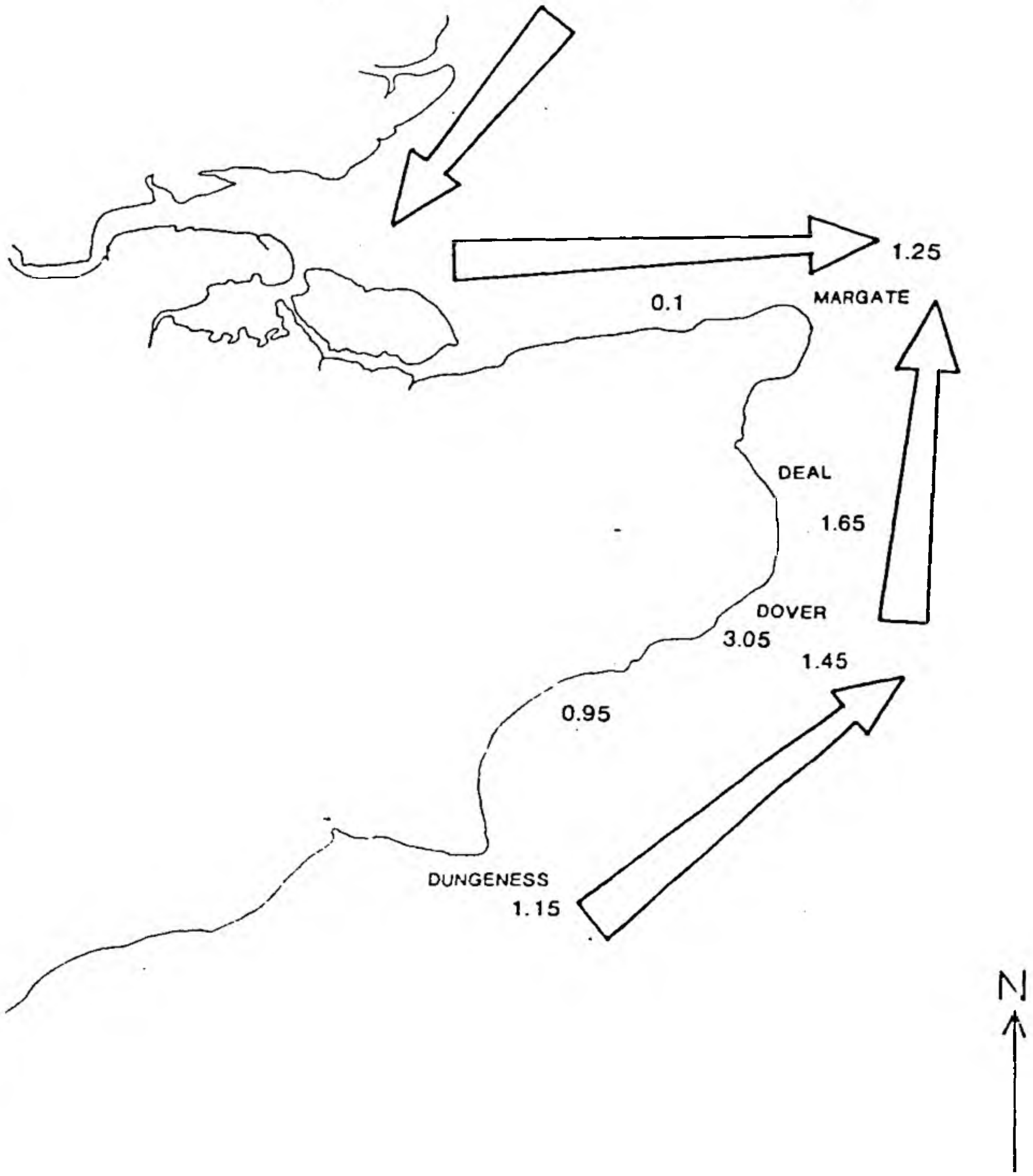
The results from the Total Coliforms, *E.coli*, Temperature, Sunshine Conditions and Seastate were already in a form that could be entered into the computer, (the data from these was entered straight off the results and field sheets.) However, the tidal information could not be entered as it was, and so changes were made to it before the data was entered into the computer:-

The information from the field sheets regarding the tidal state was a combination of the time of high water and the time that the sample was taken. For entry into the computer, this information was combined into a positive or negative integer to indicate, in hours, when the sample was taken in respect of high tide. Negative numbers indicated that the sample was taken before high tide, and positive numbers after high tide. Zero indicated that the sample was taken up to half an hour either side of high tide.

In order to account for differences in the times of high tide around the coast, and also for how the tide varied on a daily basis at different ports, the bathing beaches were grouped together according to their nearest, or most appropriate secondary port (taking prevailing tide into account - fig. 2), which the tide tables (from the Medway Ports Authority) provided adjustments for. A summary of the Standard and Secondary ports that were used for each site are shown on table 4. The appropriate adjustments were then made using the tide tables.

Figure 2

Estimated tidal direction and speed at high tide.



Speed measured in knots.

Average of spring and neap tides.

Table 4. **BATHING BEACH TIDAL INFORMATION**

BATHING BEACH		SECONDARY PORT	STANDARD PORT
NUMBER	SITE		
1a	Sheerness	-	Sheerness
1 2	Leysdown West Beach	Whitstable Approaches	Margate
3	Herne Bay	Herne Bay	
4 5	Minnis Bay St. Mildred's Bay	(Herne Bay difference/2)	
6 7 8 9 10	Westgate Bay Westbrook Bay The Bay Margate Margate, Fulsam R Palm Bay	-	
11 12 13 14 15	Botany Bay Joss Bay Broadstairs East C Broadstairs Viking Dumpton Gap	Broadstairs	
16 17 18 19	Ramsgate Sands Ramsgate West Sandwich Golf Link Sandwich Car Park	Ramsgate	Dover
20 21 22 23 24	Sandwich Princes R Sandown Deal Walmer Kingsdown	Deal	
25 26 27 28 29	St. Margaret's Bay Dover Shakespeare Cliff East Wear Bay East East Wear Bay West	-	
30 31 32 33 34	Folkestone E. Pier Folkestone Marine Sandgate Toll Road Sandgate Town Sandgate Princes P	Folkestone	
35 36 37 38 39 40 41	Hythe Dymchurch Hythe Rd Dymchurch Martello Dymchurch Car Park St. Mary's Bay Littlestone Greatstone	Dungeness	

4.4.2 Data Analysis

The data was entered onto spreadsheets in SUPERCALC 5 where it was possible to statistically look at different aspects of the data relatively easily, and where it was possible to plot graphs.
The data was also analysed using STATGRAPHICS.
(Other packages used were FREELANCE PLUS - used to produce graphical information and maps; FRAMEWORK 3 and FORMTOOL.)

a) Analysis on the Effect of the Long Sea Outfalls

The *E.coli* results for the sites used in the L.S.O. project were analysed using STATGRAPHICS. The end of May 1989 was taken as the point when the L.S.O.'s began discharging.

b) Relationship Between *E.coli* results and Field Sheet Data

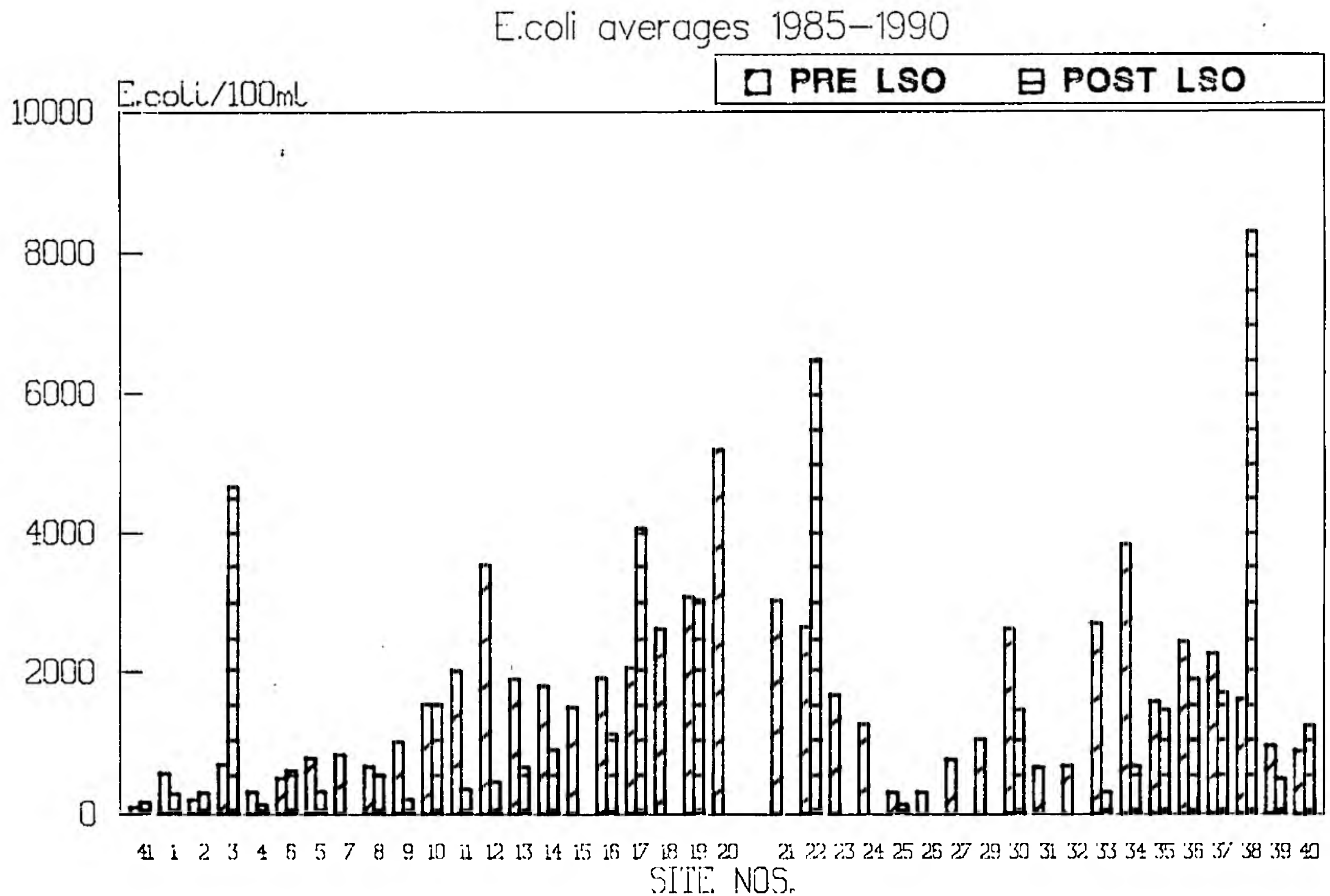
The averages of the *E.coli* results for all the sites, since 1985, both before and after the outfalls were commissioned, were calculated , and the sites whose average *E.coli* values fell well below 2000 per ml over that period, were chosen. The sites were;

1a	Sheerness
2	West Beach
4	Minnis Bay
5	Westgate Bay
6	St.Mildred's Bay
8	The Bay, Margate
10	Palm Bay
25	St.Margaret's Bay
26	Dover Harbour
27	Shakespeare Cliff
29	East Wear Bay West
31	Folkestone, Marine Parade
32	Sandgate Toll Road
39	St.Mary's Bay

The data for these sites was combined so that the increased data would make the results more meaningful statistically. Care was taken to ensure that each value for *E.coli* remained with it's corresponding field sheet values.
Graph 1 shows the averages of the *E.coli* results since 1985, both before and after the outfalls were commissioned. As there is little data since the outfalls were commissioned, any single abnormal high values can greatly affect the average (as has happened at sites 3, 17, 22 and 38). Therefore averages since the outfalls were commissioned should not have too much read in to them at this stage.

Graph 1

BATHING BEACH SURVEY



5. Results

5.1 Long Sea Outfall Project

The results obtained (field values and coliform numbers), during the industrial year by the student are given in appendix 1.

5.1.1 MARGATE LONG SEA OUTFALL

Graphs and Statistical Analysis

Graph 2 shows the percentage failures (using the *E.coli* values) that occurred at the sites around the Margate Long Sea Outfall (sites 8 to 14 inclusive) before and after it was commissioned. It can be seen that all of the seven sites studied appear to show a reduction in the percentage failures since the outfall was commissioned. The sites east of the outfall (11 to 14), which had significantly higher failure fates than those west of the outfall (sites 8, 9 and 10) appear to show the greatest degree of improvement.

Graphs 3 to 9 show the *E.coli* values from sites 8 to 14 inclusive, from 1985 to the beginning of the 1990 bathing beach season (May).

The statistical analyses (Tables 5 and 6) compare the *E.coli* numbers before the outfall was commissioned, with those obtained after the commissioning date. The null hypothesis is that it can be 95% sure that no difference has been observed. The tables show the number of values, mean, variance and standard deviation of each site studied both before and after commissioning. The t-statistic is then calculated from the equation:

The value obtained from the equation, with the degrees of freedom is then used to see whether the null hypothesis can be accepted, using t-tables (appendix 2). The significance level is also an indication of the validity of the results. (The smaller the number indicating a higher significance.)

Table 5 shows the results of the statistical analysis on the *E.coli* results from sites 8 to 14, during the bathing beach seasons since 1985.

Table 6 shows the results of the statistical analysis on all the *E.coli* results (includes non-bathing beach season data) from sites 8 to 14 since 1985.

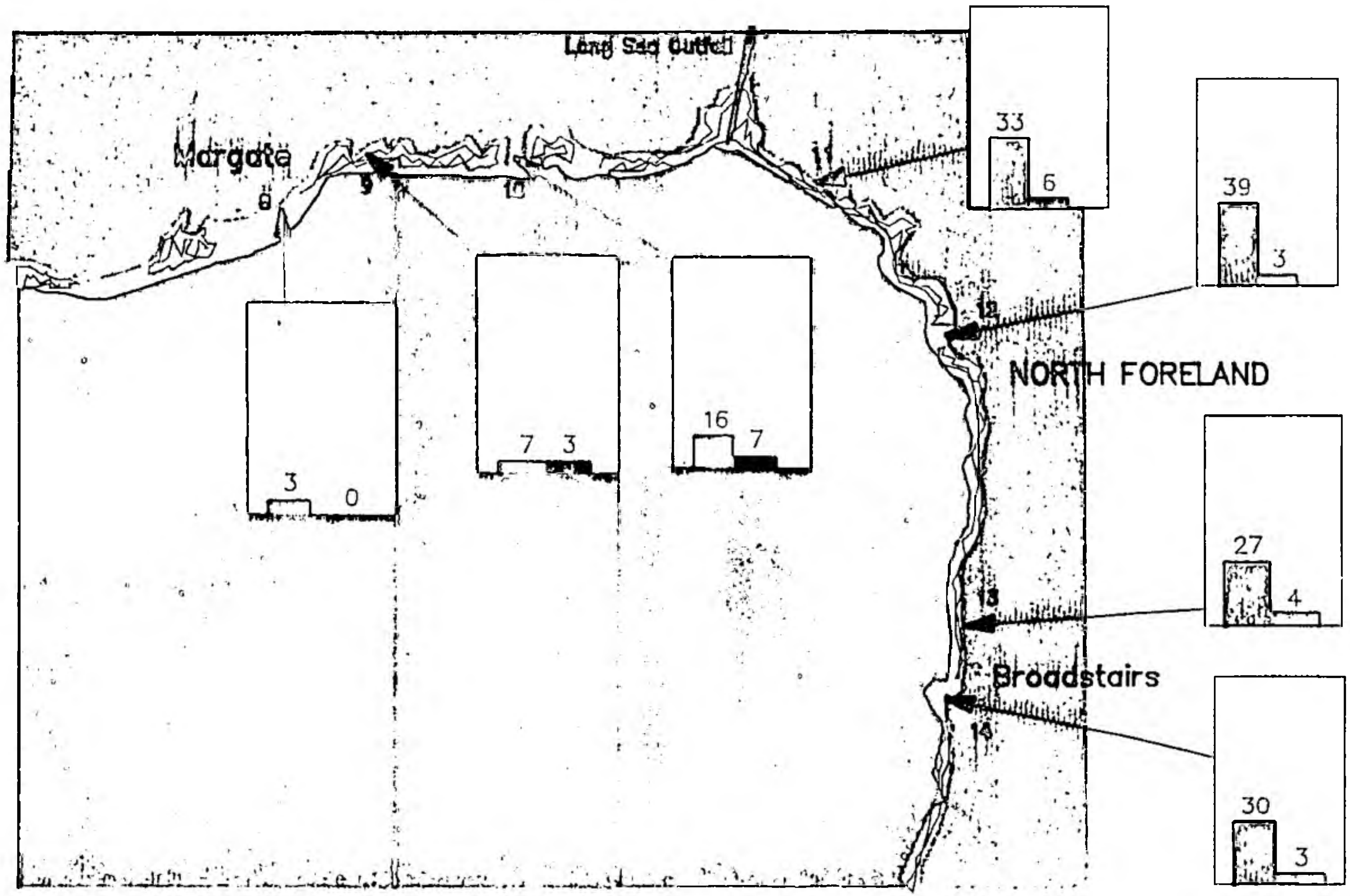
Significant differences were not observed in the statistical analyses between the data that included all samples taken, and those that only included samples taken during the bathing beach season - tables 5 and 6.

With reference to graphs 3 to 9, and the statistical analyses, tables 5 and 6, for the *E.coli* numbers at the sites around the outfall since 1985:-

Botany Bay, Joss Bay, Broadstairs East Cliff and Broadstairs Viking Bay (graphs 6 to 9), all failed the EC limit for *E.coli* numbers on a regular basis prior to the outfall being commissioned. This can clearly be seen on the graphs. However, since the commissioning of the new outfall, dramatic improvements have been seen in the quality of all these bathing beaches, with the majority of the samples being well within 2 000 *E.coli*/100 ml seawater. The statistical analysis on the data from these sites also shows that significant improvements have been made. (Note should be made of the standard deviations and the significance levels in the statistical analyses).

Graph 2

GRAPH OF PERCENTAGE FAILURES AROUND MARGATE LONG SEA OUTFALL



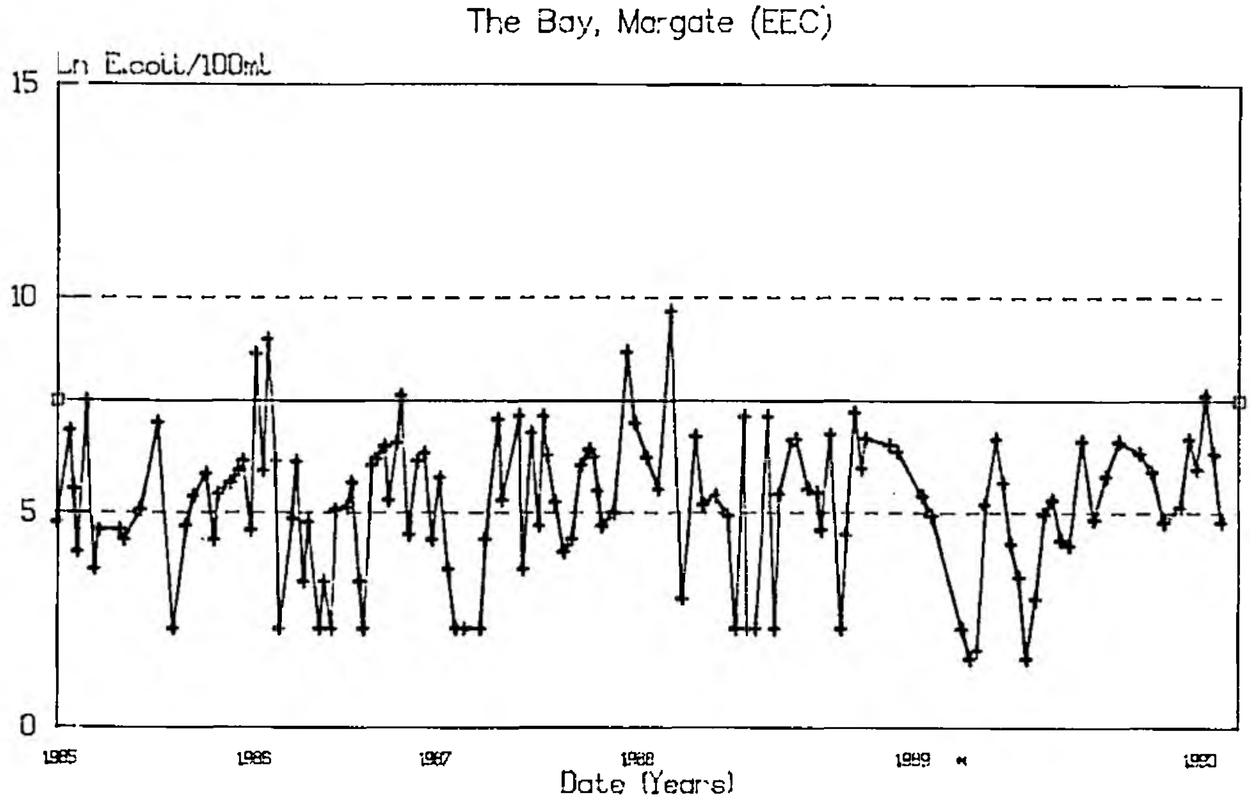
% Failure Before Commissioning

% Failure After Commissioning

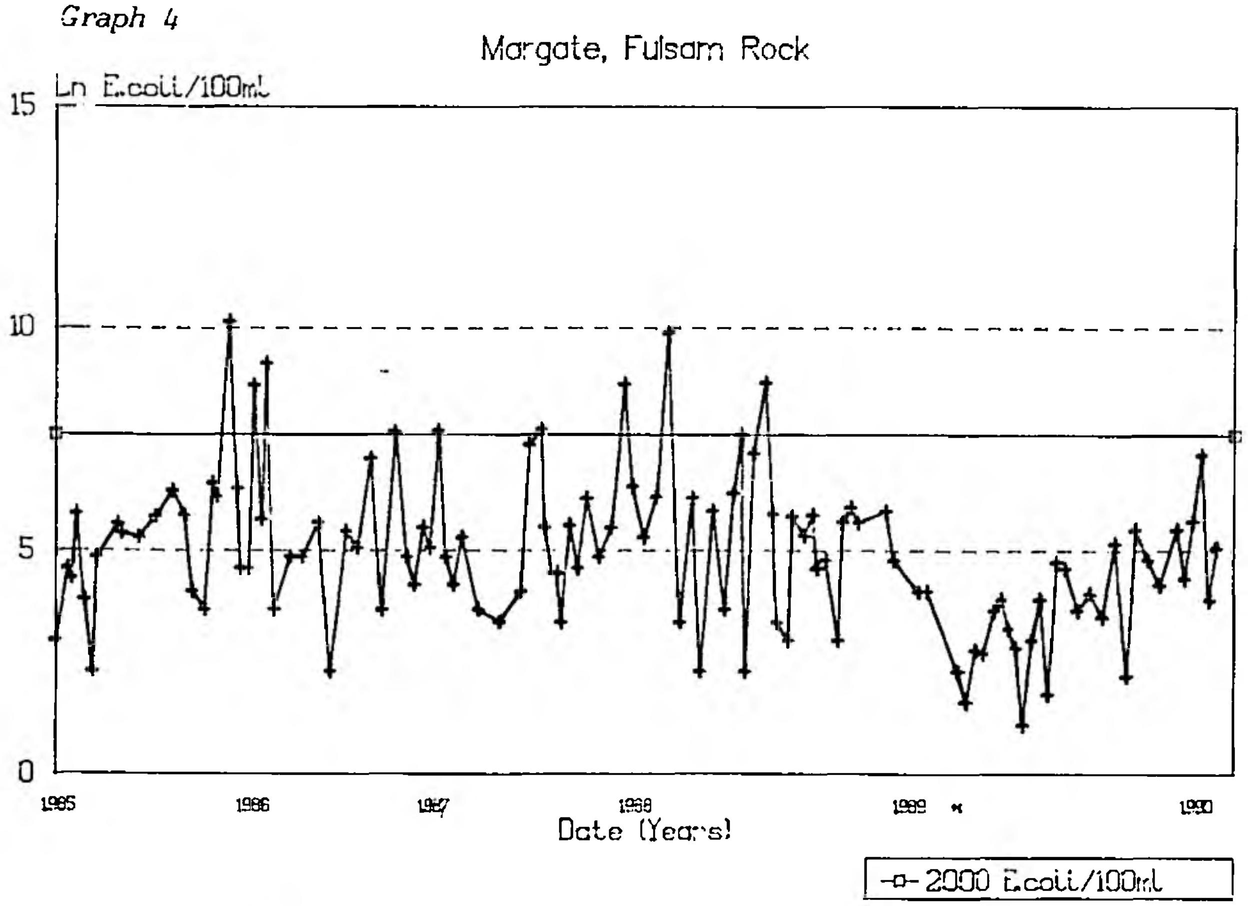
8 – The Bay, Margate (EEC)
9 – Margate, Fulsam Rock
10 – Palm Bay
11 – Botany Bay
12 – Joss Bay
13 – Broadstairs, East Cliff
14 – Broadstairs, Viking Bay

Graph 3

BATHING BEACH SURVEY
E.coli Numbers 1985 – 1990



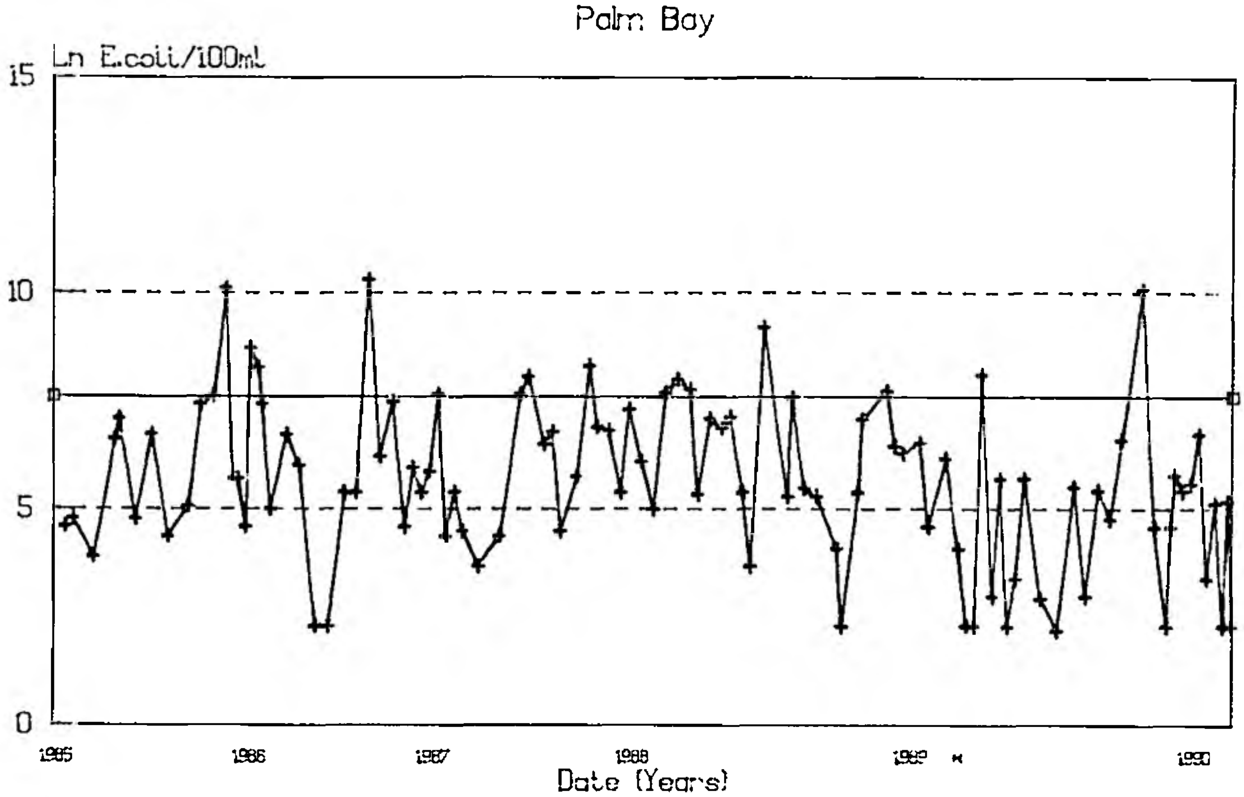
Graph 4



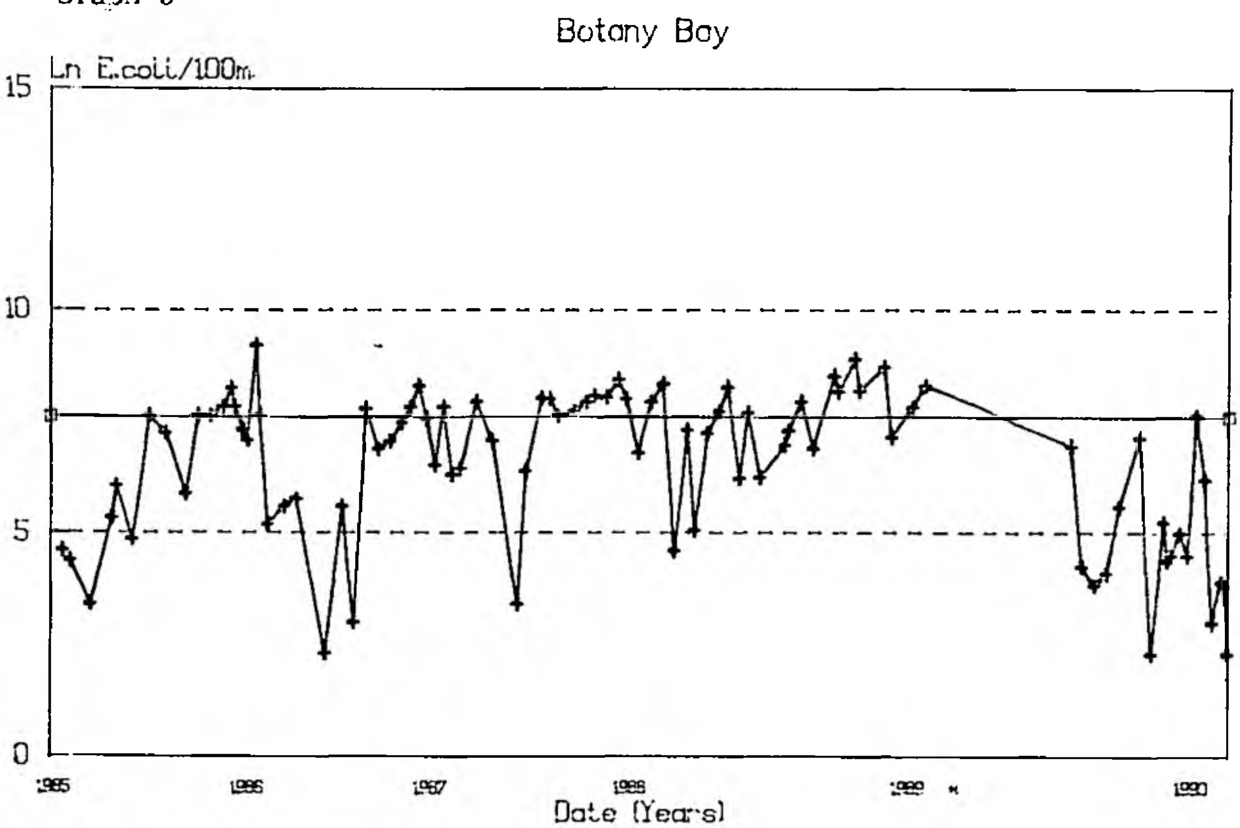
* Long Sea Outfall Commissioned

Graph 5

BATHING BEACH SURVEY
E.coli Numbers 1985 – 1990



Graph 6

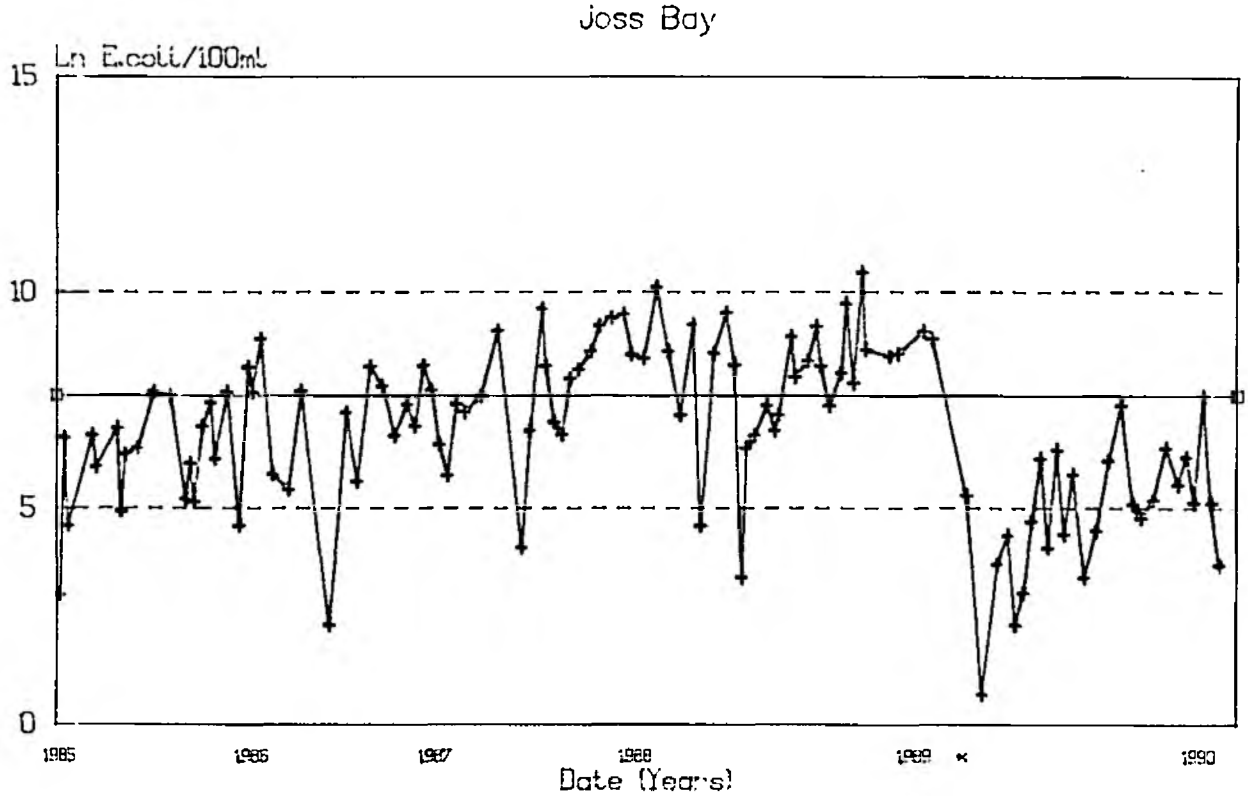


-□- 2000 E.coli/100ml

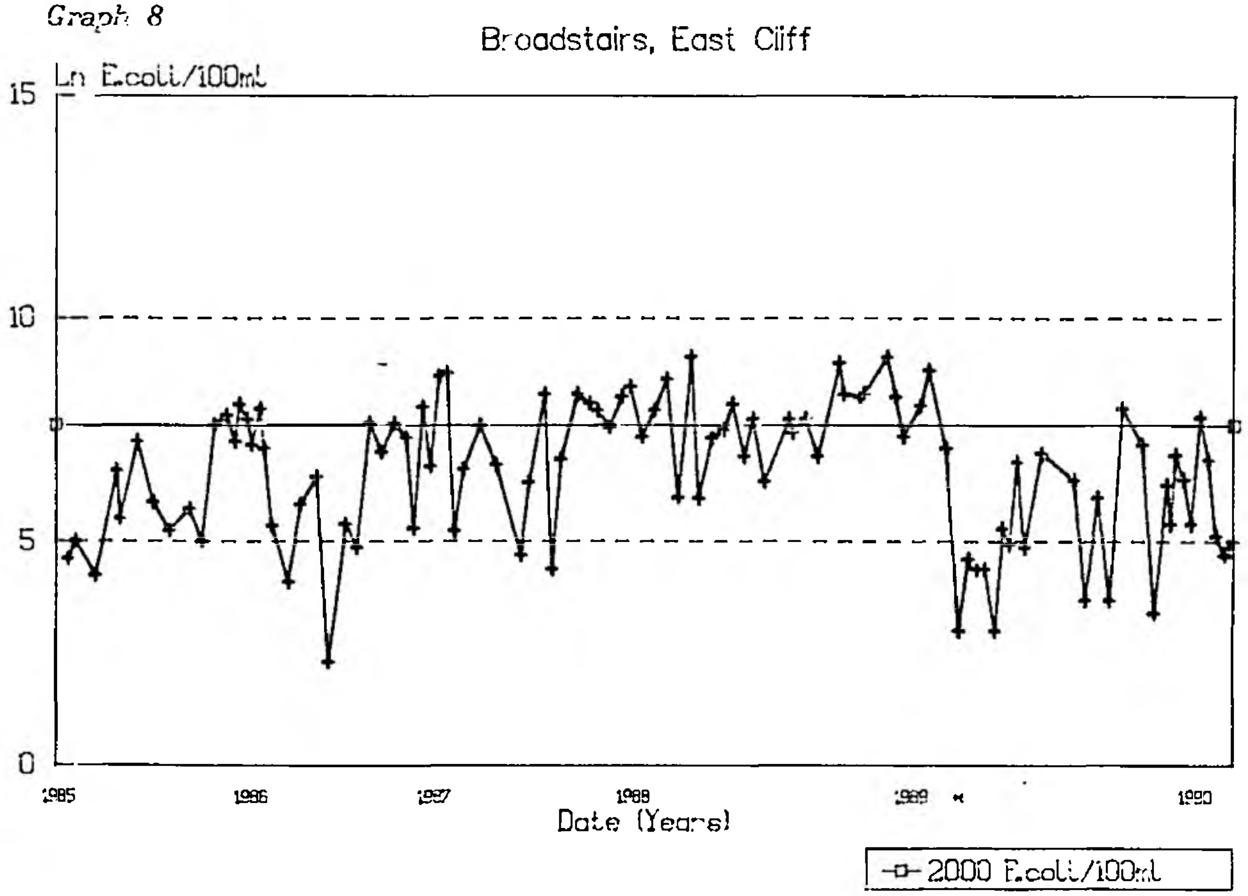
* Long Sea Outfall Commissioned

Graph 7

BATHING BEACH SURVEY
E.coli Numbers 1985 – 1990



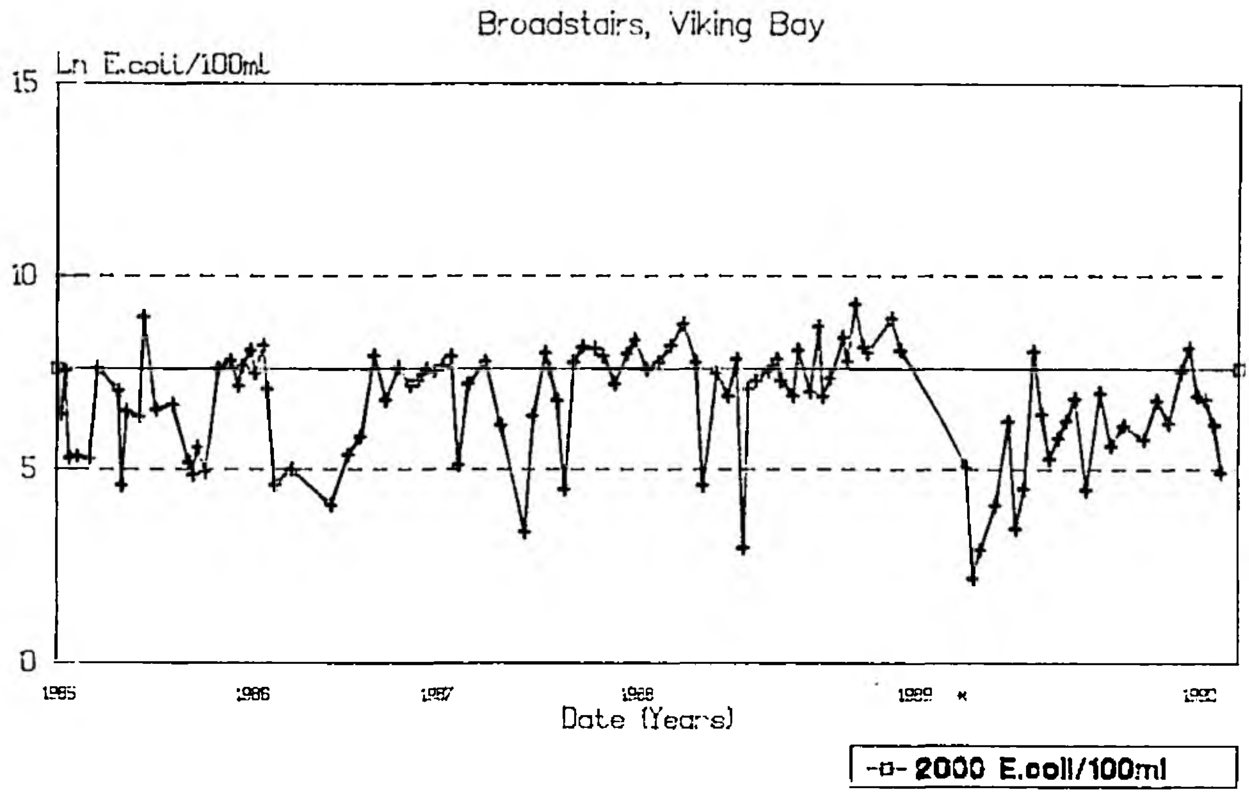
Graph 8



* Long Sea Outfall Commissioned

Graph 9

BATHING BEACH SURVEY
E.coli Numbers 1985 – 1990



* Long Sea Outfall Commissioned

Table 5

STATISTICS FOR MARGATE LONG SEA OUTFALL - Bathing Beach Season Data Only

SITE	PRE COMMISSIONING OF L.S.O.				POST COMMISSIONING OF L.S.O.				Degrees of Freedom (Equal Var)	t-Statistic	Significance Level	Accept / Reject H0 (Diff = 0 at Alpha=0.05)
	No. Obs's	$\bar{x}$	Var.	S.D.	No. Obs's	$\bar{x}$	Var.	S.D.				
8 The Bay, Margate	78	379.9	2.449×10^5	494.90	25	208.1	4.973×10^4	222.99	101	1.6777	0.0965	Accept
9 Margate, Fulsam Rock	63	413.3	8.495×10^5	921.67	26	190.4	2.825×10^5	531.54	87	1.1537	1.2518	Accept
10 Palm Bay	49	1559.4	1.997×10^7	4468.49	22	1206.1	2.595×10^7	5094.01	69	0.2949	0.7690	Accept
11 Botany Bay	43	1276.1	1.480×10^6	1216.43	16	196.4	1.500×10^5	387.32	57	3.4685	1.0034×10^{-3}	Reject
12 Joss Bay	60	2419.9	1.103×10^7	3321.08	26	197.9	1.155×10^5	339.85	84	3.3926	1.0581×10^{-3}	Reject
13 Broadstairs, East Cliff	49	1290.2	3.513×10^6	1874.28	21	413.7	4.719×10^5	686.93	68	2.0768	0.0416	Reject
14 Broadstairs, Viking Bay	60	1449.9	2.776×10^6	1666.25	25	503.1	4.486×10^5	669.80	83	2.7424	7.4703×10^{-3}	Reject

Table 6

STATISTICS FOR MARGATE LONG SEA OUTFALL - Winter and Summer Data

SITE	PRE COMMISSIONING OF L.S.O.				POST COMMISSIONING OF L.S.O.				Degrees of Freedom (Equal Var)	t-Statistic	Significance Level	Accept / Reject H0 (Diff = 0 at Alpha=0.05)
	No. Obs's	$\bar{x}$	Var.	S.D.	No. Obs's	$\bar{x}$	Var.	S.D.				
8 The Bay, Margate	109	706.5	3.588×10^6	1894.14	31	310.4	1.943×10^5	440.75	138	1.1528	0.2510	Accept
9 Margate, Fulsam Rock	92	1096.1	1.258×10^7	3547.34	32	220.7	2.674×10^5	517.08	122	1.3874	0.1679	Accept
10 Palm Bay	80	1652.1	1.985×10^7	4455.50	30	950.8	1.899×10^7	4358.13	108	0.7396	0.4612	Accept
11 Botany Bay	72	2007.6	3.287×10^6	1813.10	24	259.3	2.592×10^5	509.14	94	4.6484	1.0895×10^{-5}	Reject
12 Joss Bay	88	3822.9	3.103×10^7	5570.05	32	258.6	1.978×10^5	444.78	118	3.6060	4.5691×10^{-4}	Reject
13 Broadstairs, East Cliff	80	1987.0	4.551×10^6	2133.34	29	495.9	5.040×10^5	709.96	107	3.6811	3.6563×10^{-4}	Reject
14 Broadstairs, Viking Bay	88	1901.4	3.629×10^6	1905.03	31	661.2	7.154×10^5	845.80	117	3.4977	6.6437×10^{-4}	Reject

5.1.2 HYTHE LONG SEA OUTFALL

Graphs and Statistical Analysis

Graph 10 shows the percentage failures (using the *E.coli* values) that occurred at the sites around the Hythe Long Sea Outfall (sites 33 to 38 inclusive) before and after it was commissioned. All of the sites show an decrease in the percentage failures, after the commissioning of the outfall. Site 34, Sandgate Princes Parade shows the most significant improvement, whereas the sites around Dymchurch (37 and 38) show only a small improvement.

Graphs 11 to 16 show the *E.coli* values from sites 33 to 38 inclusive, from 1985 to the beginning of the 1990 bathing beach season (May).

The statistical analyses (Tables 7 and 8) compare the *E.coli* numbers before the outfall was commissioned, with those obtained after the commissioning date. The null hypothesis is that it can be 95% sure that no difference has been observed. The tables show the number of values, mean, variance and standard deviation of each site studied both before and after commissioning. The t-statistic is then calculated from the equation:

The value obtained from the equation, with the degrees of freedom is then used to see whether the null hypothesis can be accepted, using t-tables (appendix 2). The significance level is also an indication of the validity of the results. (The smaller the number indicating a higher significance.)

Table 7 shows the results of the statistical analysis on the *E.coli* results from sites 33 to 38, during the bathing beach seasons since 1985.

Table 8 shows the results of the statistical analysis on all the *E.coli* results (including non-bathing beach season data) from sites 33 to 38 since 1985.

Significant differences were not observed in the statistical analyses between the data that included all samples taken, and those that only included samples taken during the bathing beach season - Tables 7 and 8.

With reference to the graphs 11 to 16, and the statistical analyses tables 7 and 8, for the *E.coli* values at the sites around the Hythe L.S.O.:-

Although Sandgate Town Centre has had a few failures since the outfall was commissioned, the graph (11) appears to show an improvement after mid - 1989. However, the statistical analysis did not show any improvement.
Hythe West Parade, Dymchurch Hythe Road, Dymchurch Martello Tower and Dymchurch Car Park (graphs 13 - 16) all appear to show little improvement since the commissioning date of the outfall. Graph 13 (Hythe) does show a fall in numbers in 1989, but the counts seem to be rising again. None of these sites show any degree of improvement statistically. (Note should be made of Standard Deviations and significance levels in the statistical analysis.)

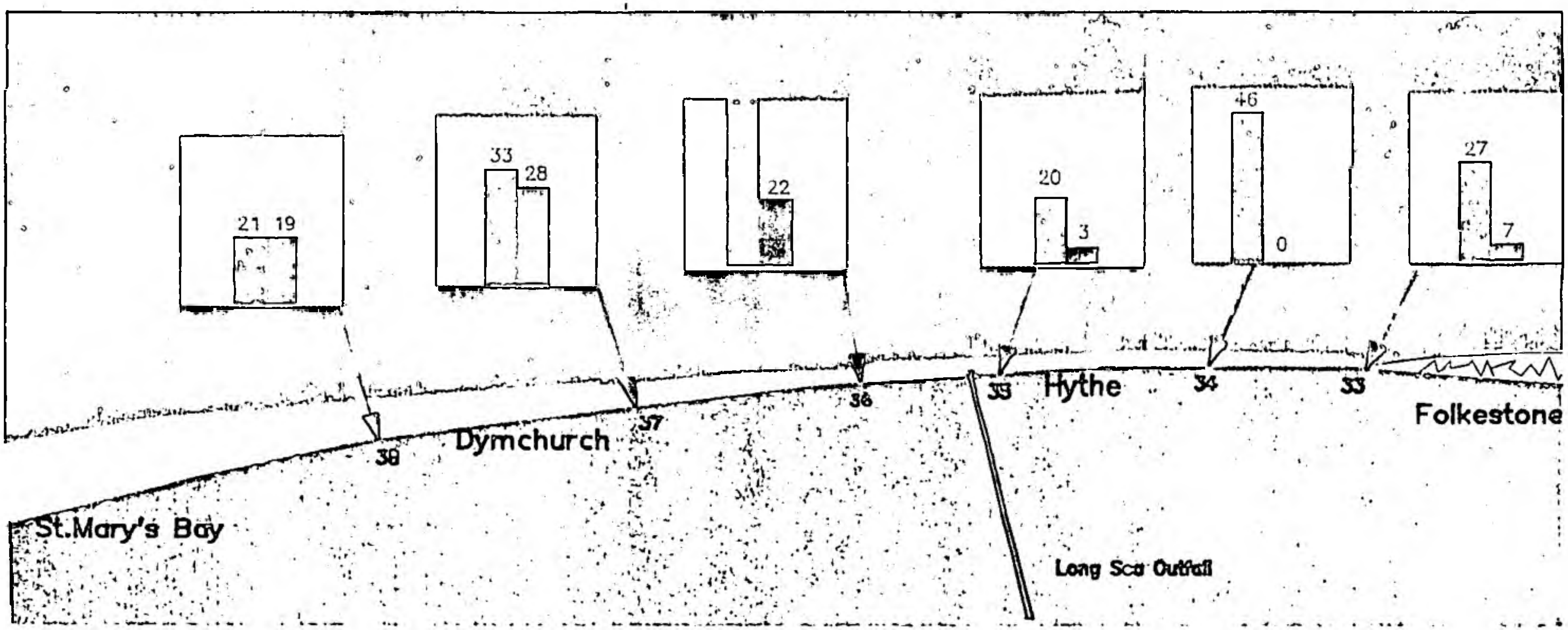
Sandgate Princes Parade is the only site that was studied for the Hythe L.S.O. project, that statistically showed any degree of improvement. Graphically, (graph 12) it is possible to see a fall in *E.coli* numbers, although it is not all that apparent.

Graph 10

GRAPH OF PERCENTAGE FAILURES AROUND HYTHE LONG SEA OUTFALL

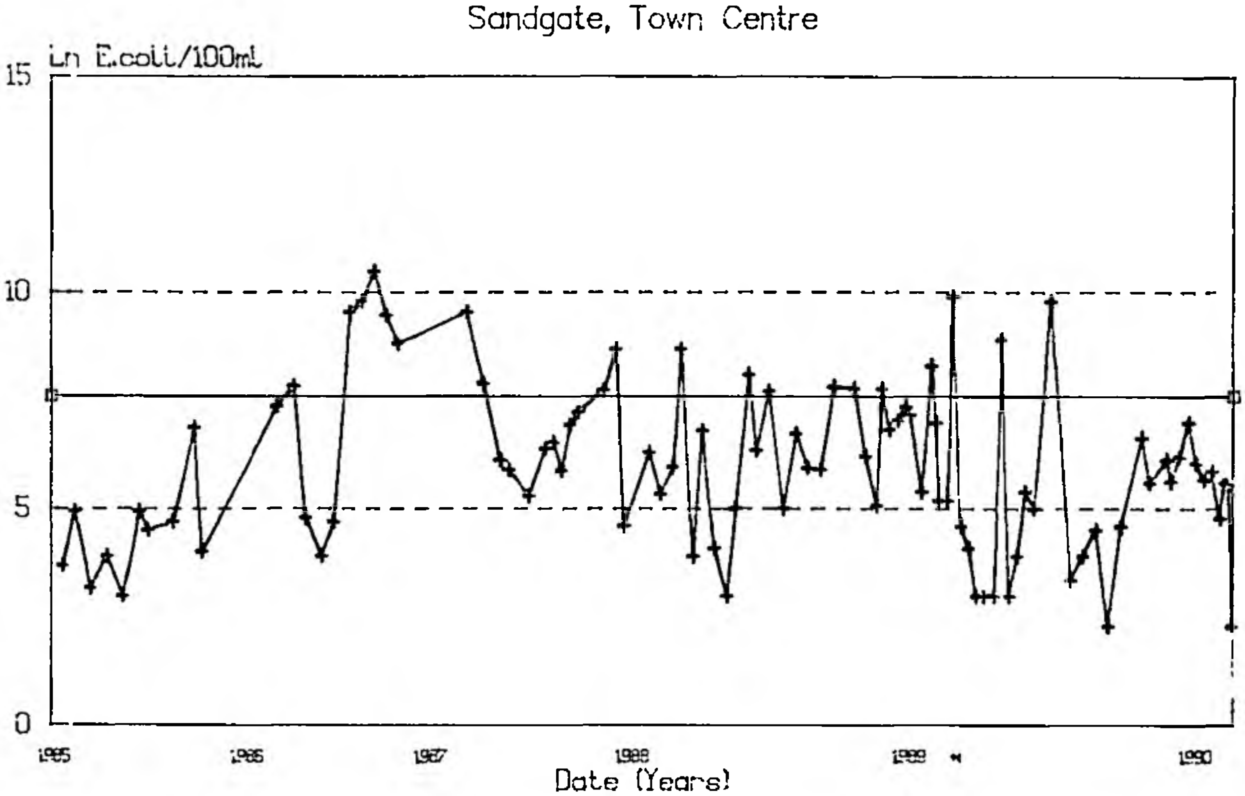
% Failure Before Commissioning — % Failure After Commissioning

33 — Sandgate Town Centre
34 — Sandgate Princes Parade
35 — Hythe West Parade
36 — Dymchurch Hythe Road
37 — Dymchurch Martello Tower
38 — Dymchurch Car Park

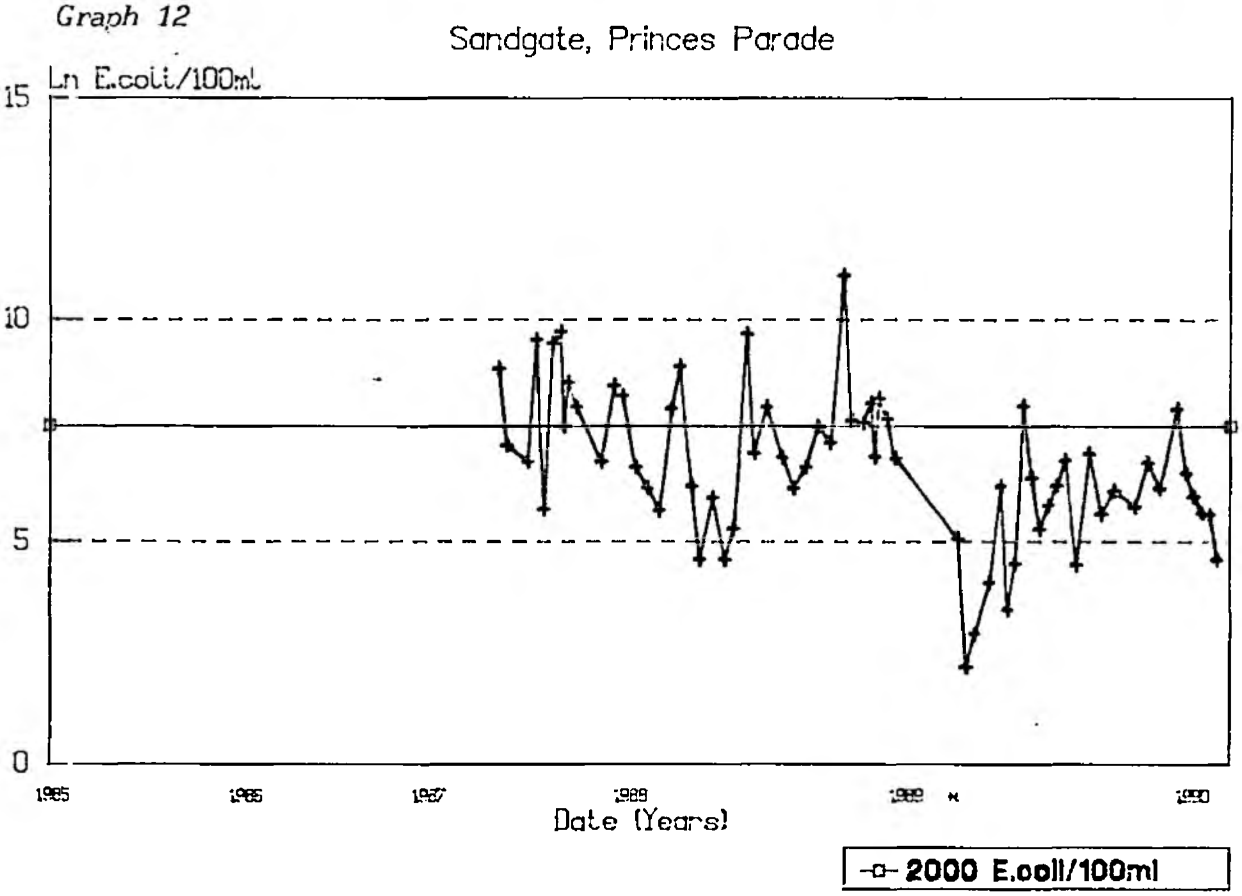


Graph 11

BATHING BEACH SURVEY
E.coli Numbers 1985 – 1990



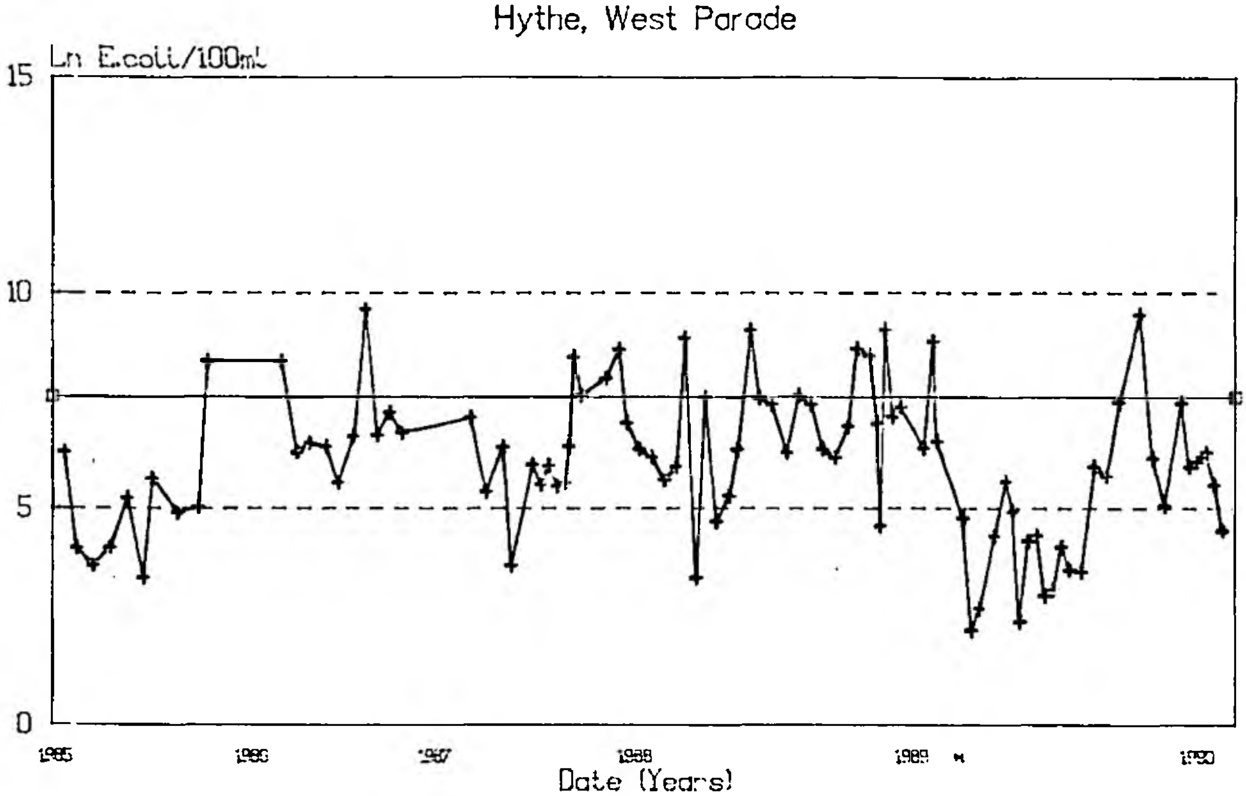
Graph 12



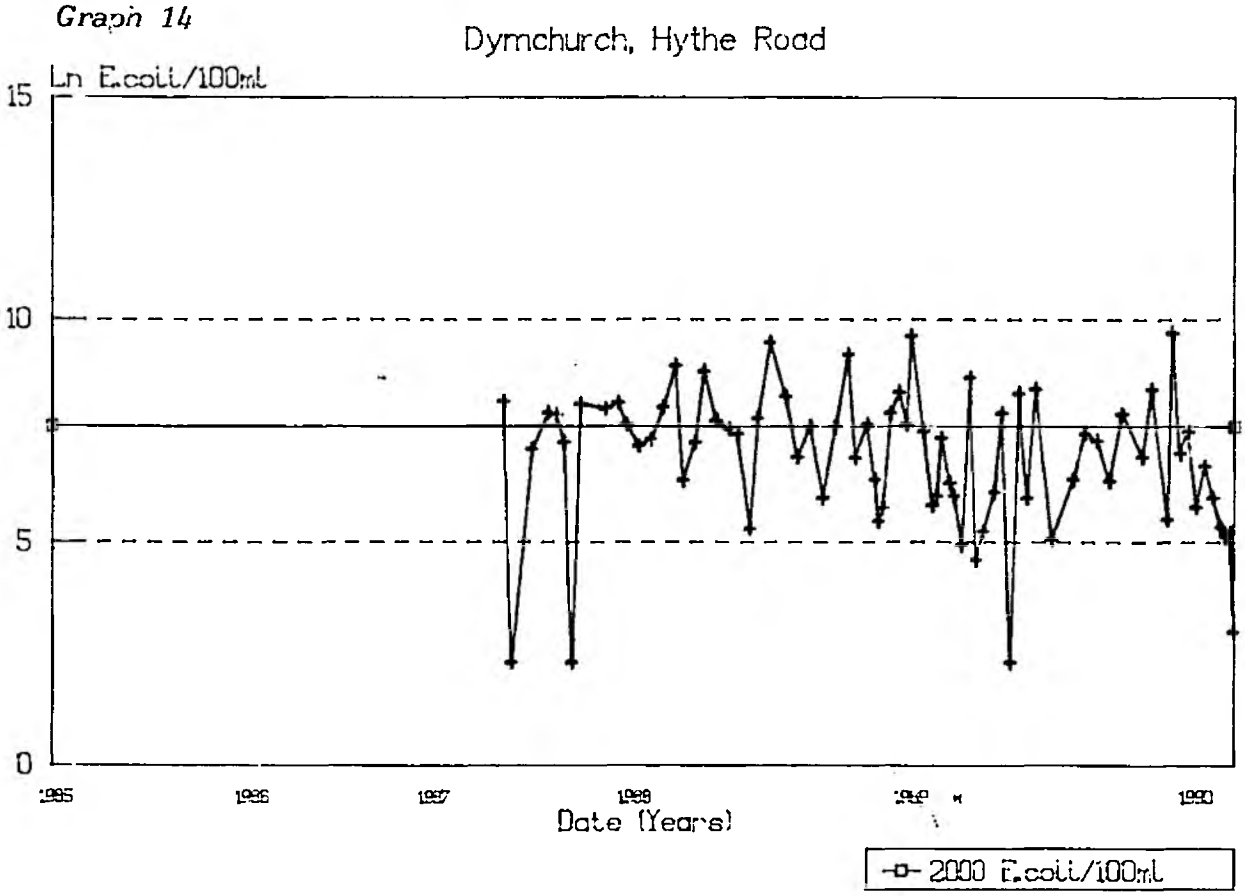
* Long Sea Outfall Commissioned

Graph 13

BATHING BEACH SURVEY
E.coli Numbers 1985 – 1990



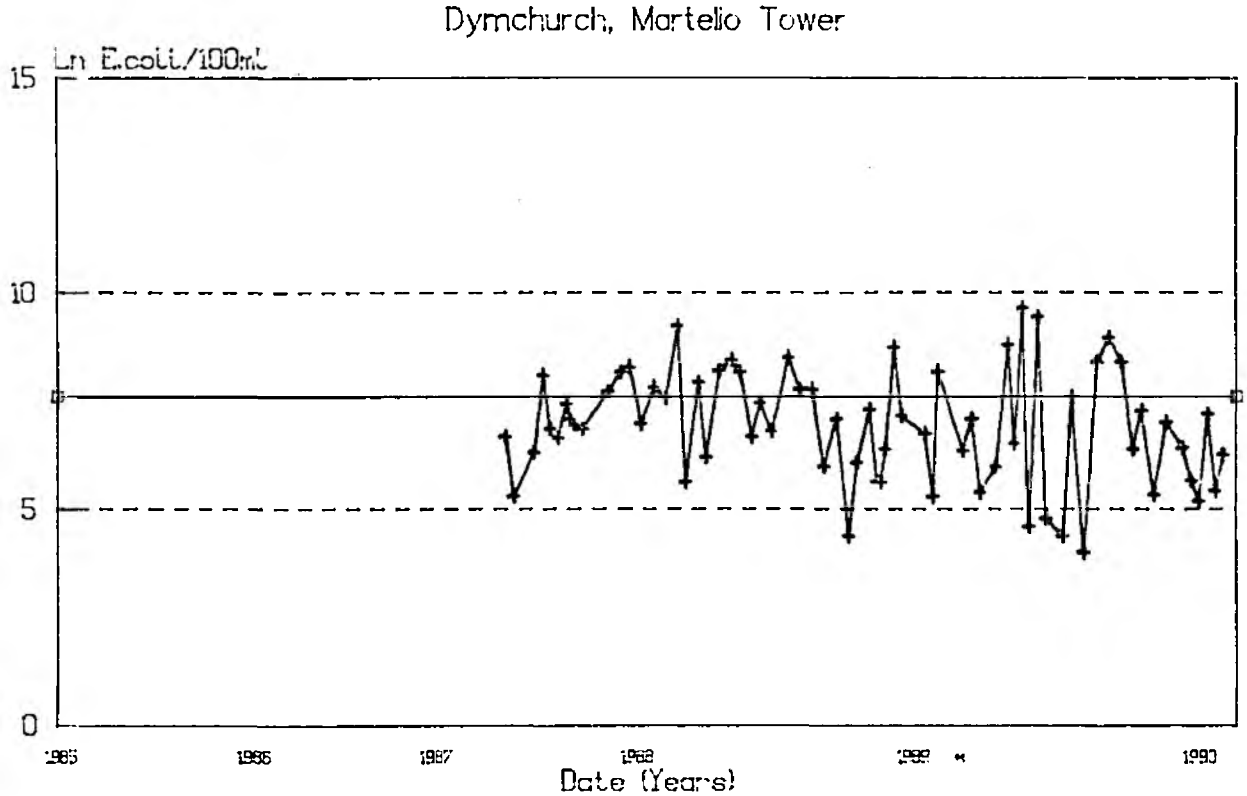
Graph 14



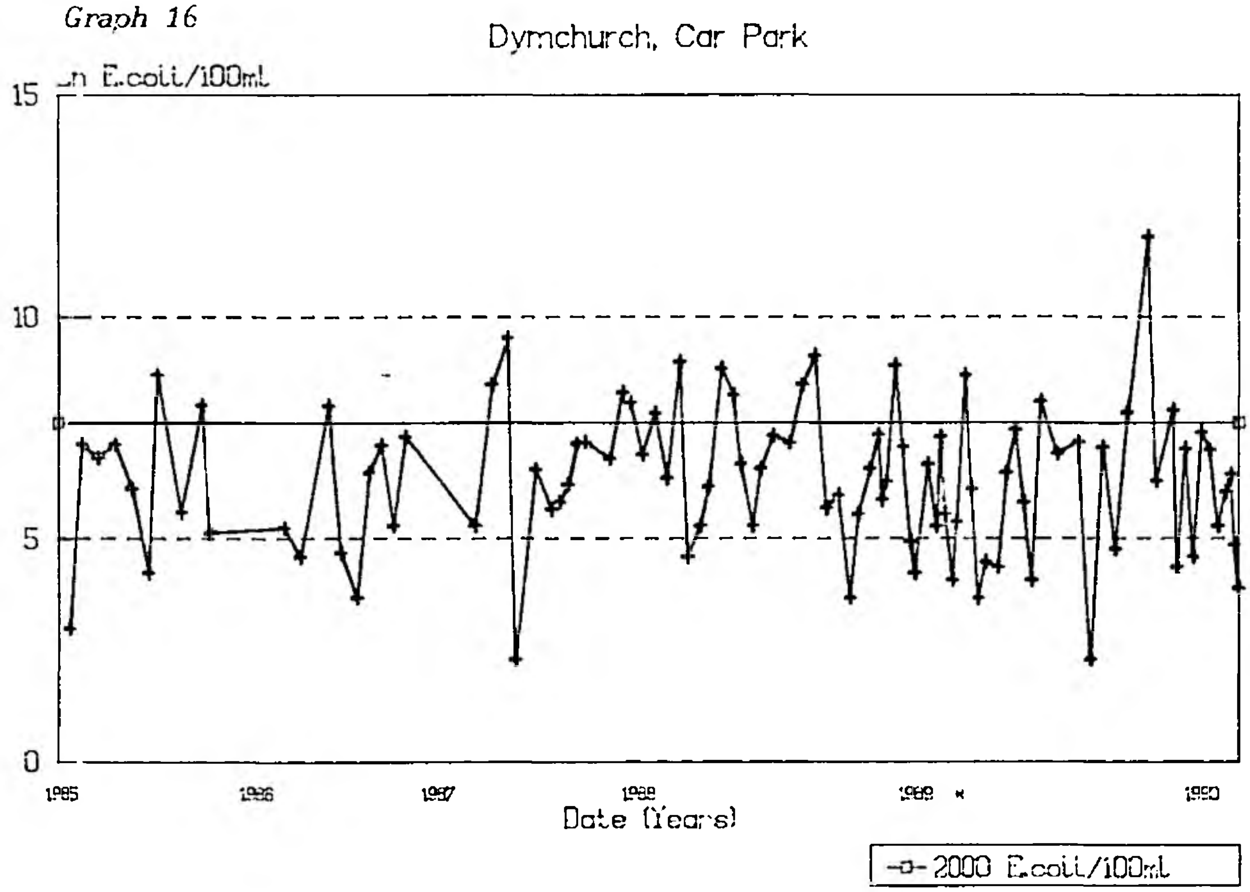
* Long Sea Outfall Commissioned

Graph 15

BATHING BEACH SURVEY
E.coli Numbers 1985 – 1990



Graph 16



* Long Sea Outfall Commissioned

Table 7

STATISTICS FOR HYTHE LONG SEA OUTFALL - Bathing Beach Season Data Only

SITE	PRE COMMISSIONING OF L.S.O.				POST COMMISSIONING OF L.S.O.				Degrees of Freedom (Equal Var)	t-Statistic	Significance Level	Accept / Reject H0 (Diff = 0 at Alpha=0.05)
	No. Obs's	$\bar{x}$	Var.	S.D.	No. Obs's	$\bar{x}$	Var.	S.D.				
33 Sandgate, Town Centre	48	2780.5	4.124×10^{7}	6422.05	23	1219.5	1.577×10^{7}	3971.98	69	1.0695	0.2886	Accept
34 Sandgate, Princes Parade	28	3558.9	2.699×10^{7}	5195.36	26	138.4	3.671×10^{4}	191.59	52	3.3527	1.4983×10^{-3}	Reject
35 Hythe	50	1457.3	7.525×10^{6}	2743.14	25	715.1	7.337×10^{6}	2708.63	73	1.1091	0.2710	Accept
36 Dymchurch, Hythe Road	26	2340.4	7.805×10^{6}	2793.80	23	1156.9	2.317×10^{6}	1522.26	47	1.8067	0.0772	Accept
37 Dymchurch, Martello Tower	28	1584.6	1.890×10^{6}	1374.92	25	2886.6	1.922×10^{7}	4384.53	51	1.4927	0.1417	Accept
38 Dymchurch, Car Park	47	1731.3	7.860×10^{6}	2803.65	23	6629.6	7.840×10^{6}	28000.0	68	1.1962	0.2358	Accept

Table 8

STATISTICS FOR HYTHE LONG SEA OUTFALL - Winter and Summer Data

SITE	PRE COMMISSIONING OF L.S.O.				POST COMMISSIONING OF L.S.O.				Degrees of Freedom (Equal Var)	t-Statistic	Significance Level	Accept / Reject H0 (Diff = 0 at Alpha=0.05)
	No. Obs's	$\bar{x}$	Var.	S.D.	No. Obs's	$\bar{x}$	Var.	S.D.				
33 Sandgate, Town Centre	68	2636.4	3.455×10^{7}	5878.32	31	1012.9	1.172×10^{7}	3423.02	97	1.4288	0.1563	Accept
34 Sandgate, Princes Parade	46	4221.5	8.821×10^{7}	9391.87	26	138.4	3.671×10^{4}	191.59	70	2.2097	0.0304	Reject
35 Hythe	68	1756.7	7.888×10^{6}	2808.64	31	691.3	5.933×10^{6}	2435.82	97	1.8216	0.0716	Accept
36 Dymchurch, Hythe Road	49	2587.8	1.011×10^{7}	3180.00	31	1540.6	9.312×10^{6}	3051.58	78	1.4572	0.1491	Accept
37 Dymchurch, Martello Tower	46	1859.4	3.820×10^{6}	1954.57	31	2431.6	1.630×10^{7}	4037.72	75	0.8294	0.4095	Accept
38 Dymchurch, Car Park	70	1673.0	6.847×10^{6}	2616.62	31	5091.0	5.820×10^{8}	24125.6	99	1.1771	0.2420	Accept

5.2 Relationship between *E.coli* Values and Field Sheet Data.

a) Regression Analysis

The results of the Regression Analysis of various field measurements against the *E.coli* values are given:-

For the Regression Outputs i. to iv. the number of observations was 434, and the Degrees of Freedom 432; for Regression Output v. the no. of observations was 936, and the degrees of freedom 934.

i) Ln *E.coli* against Temperature

Constant		20.58
Std Error of Y Est		4.02
R Squared(Adj,Raw)		0.17
Coefficients	-1.15	
Std Err of Coef.	0.12	

The data that was examined did not exhibit any connection between the temperature measured and the *E.coli* numbers. Graph 17a - the regression of *E.coli* against temperature indicates the lack of any relationship present.

ii) Ln *E.coli* against Sunshine Conditions

Constant		3.61
Std Error of Y Est		1.62
R Squared(Adj,Raw)		0.06
Coefficients	-0.26	
Std Err of Coef.	0.05	

The data that was examined did not exhibit any connection between the sunshine conditions and the *E.coli* numbers. Graph 17b - the regression of *E.coli* against sunshine conditions indicates the lack of any relationship present.

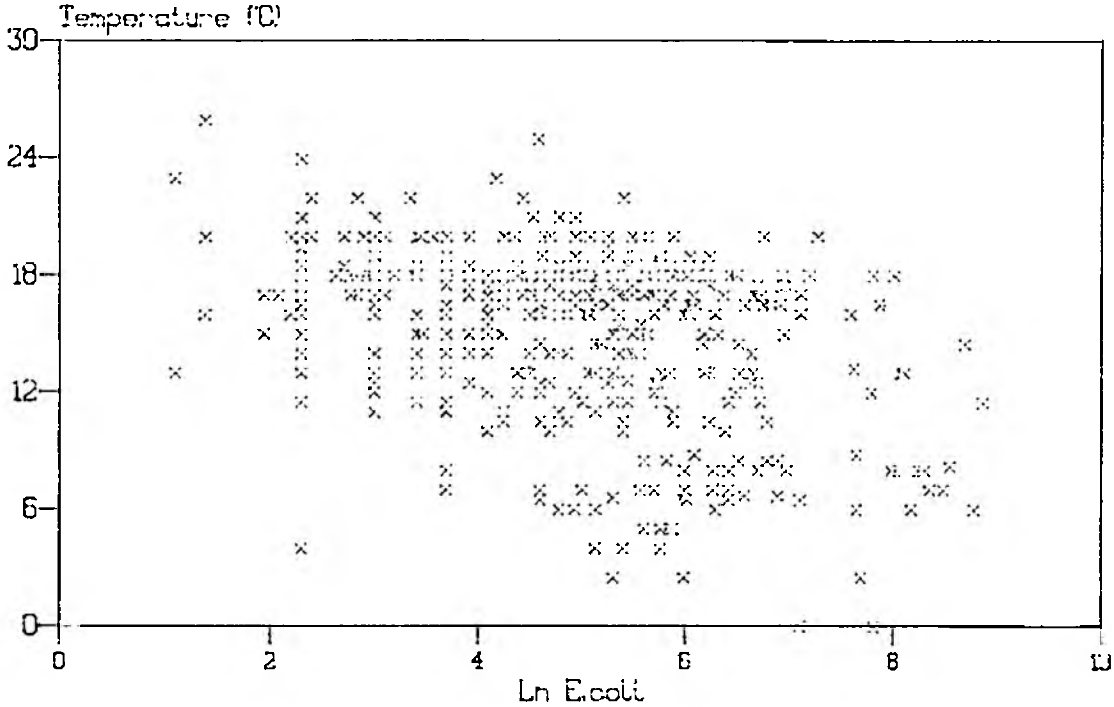
iii) Ln *E.coli* against Tide

Constant		-1.08
Std Error of Y Est		2.04
R squared(Adj,Raw)		0.02
Coefficients	0.16	
Std Err of Coef.	0.06	

Graph 17c - the regression of *E.coli* against Tide indicates the lack of any relationship present.

Graph 17a

Graph Showing the Regression between E.coli and Sea Water Temperature at selected sites around Kent, 1985 - 1990



For selected sites, refer to fig.

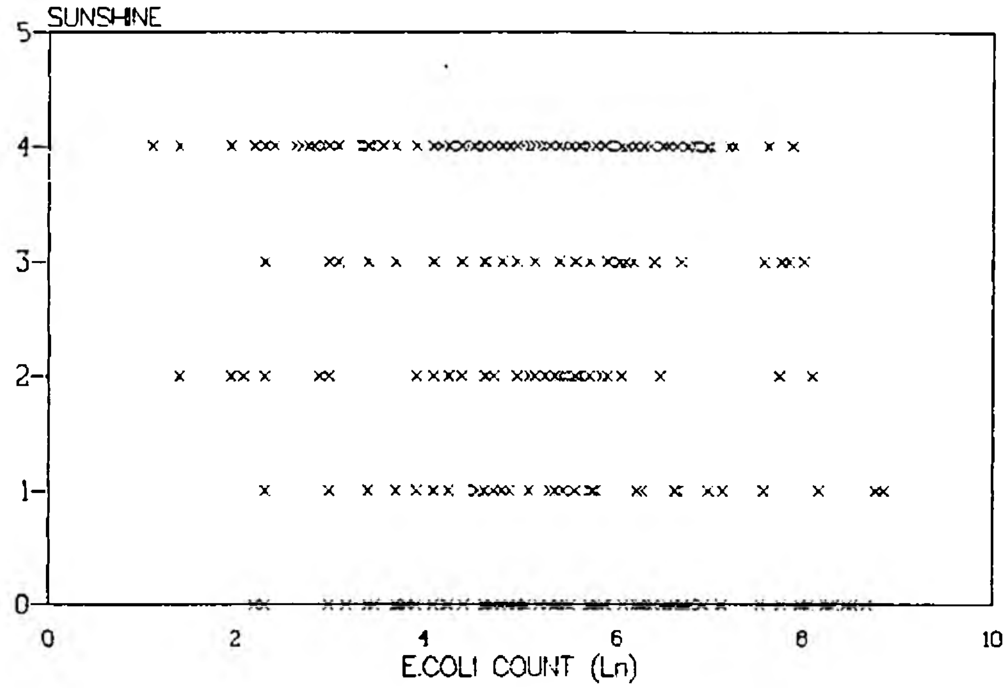
Results of Regression analysis of E.coli against Temperature. (See above graph)

Constant		20.58
Std Err of Y Est		4.02
R Squared(Adj,Raw)	.17	.17
No. of Observations		434
Degrees of Freedom		432
Coefficient(s)	−1.15	
Std Err of Coef.	.12	

A value >0.5 for R squared indicates a significant relationship.

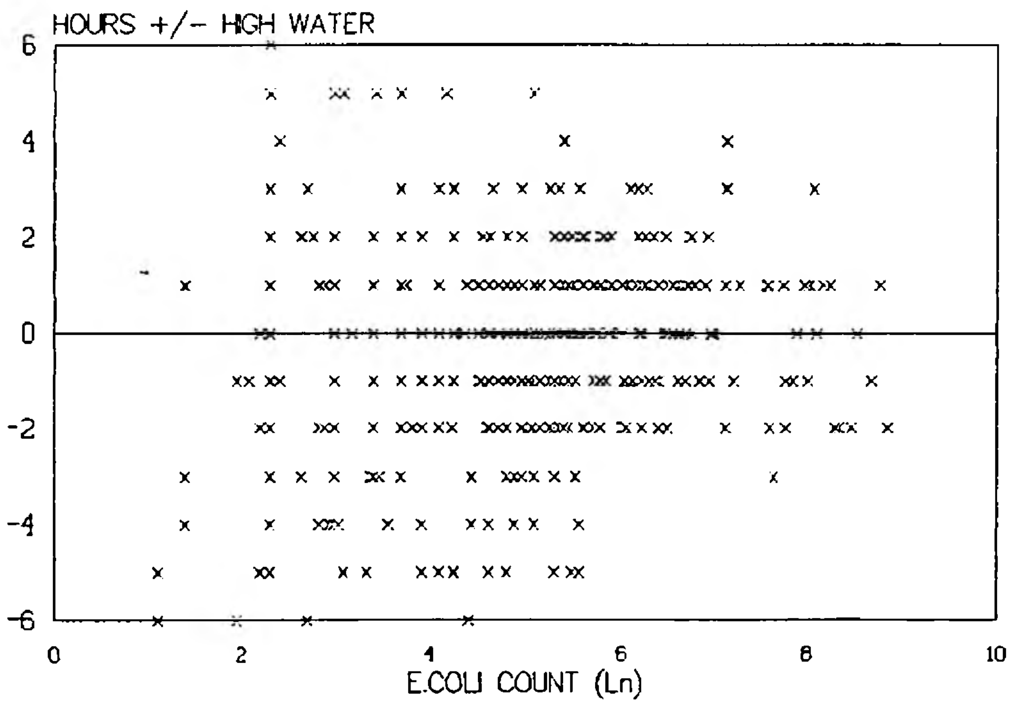
Graph 17b

X-Y SCATTER PLOT OF Ln E.COLI AGAINST SUNSHINE



Graph 17c

X-Y SCATTER PLOT OF Ln E.COLI AGAINST TIDE



iv) Ln *E.coli* against Tide (Negative Integers converted to Positive)

Constant		2.48
Std Error of Y Est		1.34
R Squared(Adj,Raw)		0.05
Coefficients	-0.46	
Std Err of Coef.	0.09	

The data that was examined did not exhibit any connection between the state of the tide and the *E.coli* conditions.

v) Ln *E.coli* against Sea State

Constant		1.94
Std Error of Y Est		1.17
R Squared(Adj,Raw)		0.03
Coefficients	0.0001	
Std Err of Coef.	0.00002	

The data that was examined did not exhibit any connection between the sea state and the *E.coli* conditions.

* An R^2 value > 0.5 indicates a significant relationship.

b) Multivariate Analysis

Results of the stepwise selection on the data of Sunshine Conditions, Temperature and Tide, to establish to what degree they affect the *E.coli* values, and which parameter, if any has the most significant effect.

R - squared	0.11
Adjusted	0.09
MSE	123984
Degrees of Freedom	61

Variables in Model:
Tide;
Coefficient 50.26
F - Remove 7.17
Variables not in Model:
Sunshine Conditions;
P. Correlation 0.16
F - Enter 1.61
Temperature;
P. Correlation 0.07
F - Enter 0.34

Although the Tide was considered to contribute the most to the *E.coli* values, according to the final result of the multivariate analysis, the R^2 value was only 0.11, which is not significant. Therefore, no conclusive relationship was found between the data analysed and the *E.coli* results.

6. Discussion

6.1 Long sea outfall Project

6.1.1 MARGATE LONG SEA OUTFALL

The sites, Margate (EEC), Margate Fulsam Rock and Palm Bay, do not appear to have shown any improvement since the outfall was commissioned. The statistical analyses also indicate this. However, the *E.coli* values for these sites in general fell below the EC limit of 2 000 *E.coli*/100ml seawater, with failures occurring infrequently prior to the commissioning. Botany Bay, Joss Bay, Broadstairs East Cliff and Broadstairs Viking Bay, all failed the EC limit for *E.coli* numbers on a regular basis prior to the outfall being commissioned. Since the commissioning of the new outfall, dramatic improvements have been seen in the quality of all these bathing beaches, with the majority of the samples being well within 2 000 *E.coli*/100 ml seawater. This is supported by the statistical analysis on the data from these sites.

The improvements to the sites at Broadstairs are interesting to note, as these sites are south of the short sea outfall at North Foreland. With the prevailing tide moving north (figure 2), it was unexpected for the Margate Short sea outfall to have had an effect as far south as Broadstairs. However a significant improvement has been observed since the commissioning of the Margate L.S.O. The improvements seen at Broadstairs could be due to other factors, (discussed further in section 6.3), such as higher microbial mortality due to exceptional summers, and mild winters in the period since the commissioning date. If this was the case however, similar reductions in the bacterial levels should be universal in an area receiving similar weather conditions. This is not the case though, as sites 8, 9 and 10s did not show any equivalent improvement.

It appears therefore that the Margate L.S.O. has made wide ranging improvements to the nearby bathing beaches, even including those as far south as Broadstairs. Further study is necessary though for confirmation of this, as only one season's data has been observed since the outfall was commissioned.

From the data, it appears that the short sea outfall at North Foreland does not seem to contribute to any significant degree to the lowering of the quality of the bathing beaches immediately around it. In comparison with the old short sea outfall at Margate, a smaller discharge is made 350m further out to sea and at a greater depth. Therefore, the receiving waters can perhaps cope and dispose of the volume of sewage being discharged adequately. It will be interesting to note any changes that may occur to improve bathing water quality further, when the proposed L.S.O. at North Foreland, which will replace the short sea outfall currently being used, is commissioned.

6.1.2 HYTHE LONG SEA OUTFALL

As only one season's data has been studied since the outfall was commissioned, it is not possible to say with certainty whether the Hythe L.S.O. has changed the quality of the bathing beaches around it. Current analysis however seems to be indicating that it has made little improvement.

An explanation for the continuing high counts that are observed at the sites around Hythe, could be due to the river outfall that exists at Dymchurch (TR 119 309). The sewage treatment works (STW) for Dymchurch (TR 114 318) discharges its effluent into the river, which then discharges into the sea. STW's do not greatly reduce the bacterial counts (there is possibly a 95% reduction - with crude sewage containing 10^6 coliforms/100ml), and it is possible that in the short distance to the sea from the works, that the die - off rate within the river does not sufficiently reduce the bacterial numbers. However, further study would be needed to establish if this discharge is the source of the high counts, or not. (Refer to the General Points, section 6.1.3.)

It is interesting to note that of all of the sites studied around the Hythe L.S.O. that the only site to statistically show any improvement is Sandgate Princes Parade. With additional data available in future years it will be possible to build up a clearer picture of what is happening in this area, and to establish whether this is an anomoly or not.

It is known that Southern Water experienced difficulties with the outfalls since they were commissioned, and that discharges have been made through the storm outfalls since May 1989 - which may indicate a reason why there does not appear to be any significant improvement. However, Southern Water would not disclose the dates on which discharges were being made through the storm outfalls (the old short sea outfalls). Southern Water were only prepared to say whether or not dates with high bacterial counts *could* be due to discharges through the storm outfall. According to Southern Water, none of the observed high counts could possibly have corresponded to dates when these discharges were being made, and therefore cannot be discounted when trying to assess the improvements made to the bathing beaches since the outfall was commissioned.

6.1.3 General Points

Crude sewage normally contains about 10^8 total coliforms/100ml. This will be reduced to 10^6/100ml with 100:1 dilution, and the mortality of bacteria in saline conditions with sunlight should rapidly reduce bacterial numbers further so that the 10^4/100ml of the Directive should be achieved in a relatively short distance. Experimental work carried out by the Water Research Centre shows that times for 90% of bacteria to die off in seawater (T90s) can be as short as 30 minutes.

Other sources of bacterial pollution of a bathing beach may be rivers, storm overflows and gulls. Although the numbers of bacteria entering the sea from such sources may be small in comparison with those from the outfall, their effect may be disproportionately large because of their entering near the shore. Coliform counts in some rivers have been found to greatly exceed the EEC's mandatory (I) values. If the maximum bathing density is near such a river mouth, it may not be possible to comply with the Directive, whatever the means of disposal of the resort's sewage, without changing the quality of the river water. At resorts where large numbers of gulls nest on the cliffs near the shore, the effects of their droppings may also be sufficient to violate the Directive's requirements.

6.2.6 Relationship Between *E.coli* Values and Field Sheet Data

The detailed interpretation of field data relating to bacterial analyses is not simple, because of the many sources of variability. It is difficult to draw any firm conclusions about the effect of more than a few of them.[2]

Although the amount of data analysed (434 observations) is considered sufficient to obtain meaningful results, no significant connections were observed. Firstly, there are limitations with how the field data is recorded, and also limitations with how it is analysed:-

a) Temperature.
The increase in metabolic rate with increasing temperature leads to more rapid death. At 25'C, mortality rates tend to be about an order of magnitude greater than at 0'C.

The temperature at the shore on a gently sloping sandy beach in the summer can be substantially higher than that in the main body of water between the outfall and the shore. It would be necessary to ensure that a reliable method was adopted consistently by those obtaining the samples. Gameson[4] suggests the use of a bucket to collect a sample from an incoming wave at the point where the beach is the steepest. However, in practical terms this may not be possible, and it may be sufficient to ensure that care is taken to obtain what is considered a representative reading.

b) Sunshine Conditions
The mortality rate of sewage coliforms, in sea water exposed to sunshine, is typically some two orders of magnitude greater than in the dark at 20'C. The mechanisms involved are believed to be the disruption of DNA by the shorter (ultraviolet) wavelengths of solar radiation and damage to other chromosomes by the longer (visible spectrum) wavelengths. The overall effect may thus depend on the spectral distribution as well as the intensity of the radiation. The lethality of solar radiation decreases with increasing wavelength.[13]

Currently the sunshine conditions (indicating solar radiation) are measured on a scale 0 - 4. This method is very subjective, and may vary considerably according to the person taking the measurement. This is also true of the cloud cover measurements. It is possible however, that with changeable weather patterns that the conditions at the time the sample was taken are not representative of the conditions immediately prior to collection. Although sunshine records are kept at most coastal resorts, but it would be preferable to obtain information from a standard instrument (such as a Kipp solarimeter) in conjunction with a suitable integrating device. Perhaps additional information from local weather stations on the sunshine hours would be useful.[4]

c) Tide
Tidal state is not entirely unrelated to the time of day, although the time of high water is progressively later from day to day. It may be preferable to express the tidal state as 'tidal percentiles' - the percentage of the time from the previous to the subsequent high water - rather than as hours before or after high water.[10]

The level of high water is related to the time of day at which high water occurs, with high water tending to occur around 7 o'clock at spring tides, and 1 o'clock at neaps. Taking both of these factors into account may increase the relevance of the tidal data.

d) Sea State
The roughness of the sea can affect bacterial counts, although the dominant mechanism involved is not clear; increased turbulence causes more rapid vertical mixing, and is likely to increase turbidity and hence lead to a decrease in bacterial mortality from solar radiation.[2][4]

A similar situation exists with the measurement of the sea state as exists with the measurement of sunshine - the sea state is estimated visually, and there may be considerable variation between samplers.
The sea state is a consequence of the wind speed and direction. However, although this is also recorded at the time the sample is taken, it is by no means clear which wind velocity is relevant: that at the instant of sampling is presumably far less important than the whole wind history during the period of transit from outfall to shore.

e) Multivariate Analysis
With the multivariate analysis, the larger the number of independent variables and the greater the random errors in measuring the parameters, the greater is the amount of data required for obtaining statistically significant results. The experimental data must also extend over a wide range of each independent variable. The possibility of spurious correlation should be recognised when a large number of regression analyses are carried out.[2]

Previous work suggests that relationships have been found to exist between the die-off rate of coliform bacteria and field variables such as temperature and sunshine. It was likely that the experiments were conducted under controlled laboratory conditions.

From the observed data, it was not possible to find any correlation between the measured environmental variables and coliform numbers. This could be due partly to the inability to precisely measure or include the field variables. Another factor to consider is that high *E.coli* values observed may mask an underlying relationship, although no evidence of this was observed.

It was not possible to create a model which would have been able to show whether or not a beach was polluted based on the expected range of values assessed from the field sheets values.

7. Conclusions

7.1 Margate Long Sea Outfall

The outfall appears to have significantly improved the quality of the bathing beaches; Botany Bay, Joss Bay, Broadstairs East Cliff, and Broadstairs Viking Bay. The outfall does not appear to have made any significant improvements to Margate (EEC), Margate Fulsam Rock and Palm Bay.

7.2 Hythe Long Sea Outfall

The outfall does not appear to have improved the quality of the bathing beaches; Sandgate Town Centre, Hythe West Parade, Dymchurch Hythe Road, Dymchurch Martello Tower, and Dymchurch Car Park. A significant improvement however was observed at Sandgate Princes Parade.

7.3 Relationship between *E.coli* Values and Field Sheet Data

No relationships were observed between the *E.coli* numbers and the field sheet variables examined, either singly or in combination. It was not possible therefore to create a model to predict expected coliform numbers for given field variables.

8. AN INVESTIGATION INTO THE BACTERIOLOGICAL QUALITY OF THE RIVER STOUR DOWNSTREAM OF CANTERBURY, AND ITS EFFECTS ON SANDWICH BAY

8.1 Introduction

Sandwich Bay, (designated Bathing beach, Sandwich Bay Car Park TR 358 590) consistently fails the EC Directive (76/160/EEC).

The purpose of this investigation was to establish whether the river Stour contributed, to any significant degree, to the lowering of the bacterial water quality in the bay, and if it did, where the degrading input was along the river.

An additional purpose was to establish what effect, if any the tidal patterns have on the bacterial quality in the river.

8.2 Method

8.2.1 The sampling and analysis methods employed were those that have been described in paragraphs 4.2 and 4.3 (pp)of the Investigation into the Bacterial Quality of the Bathing Beaches.

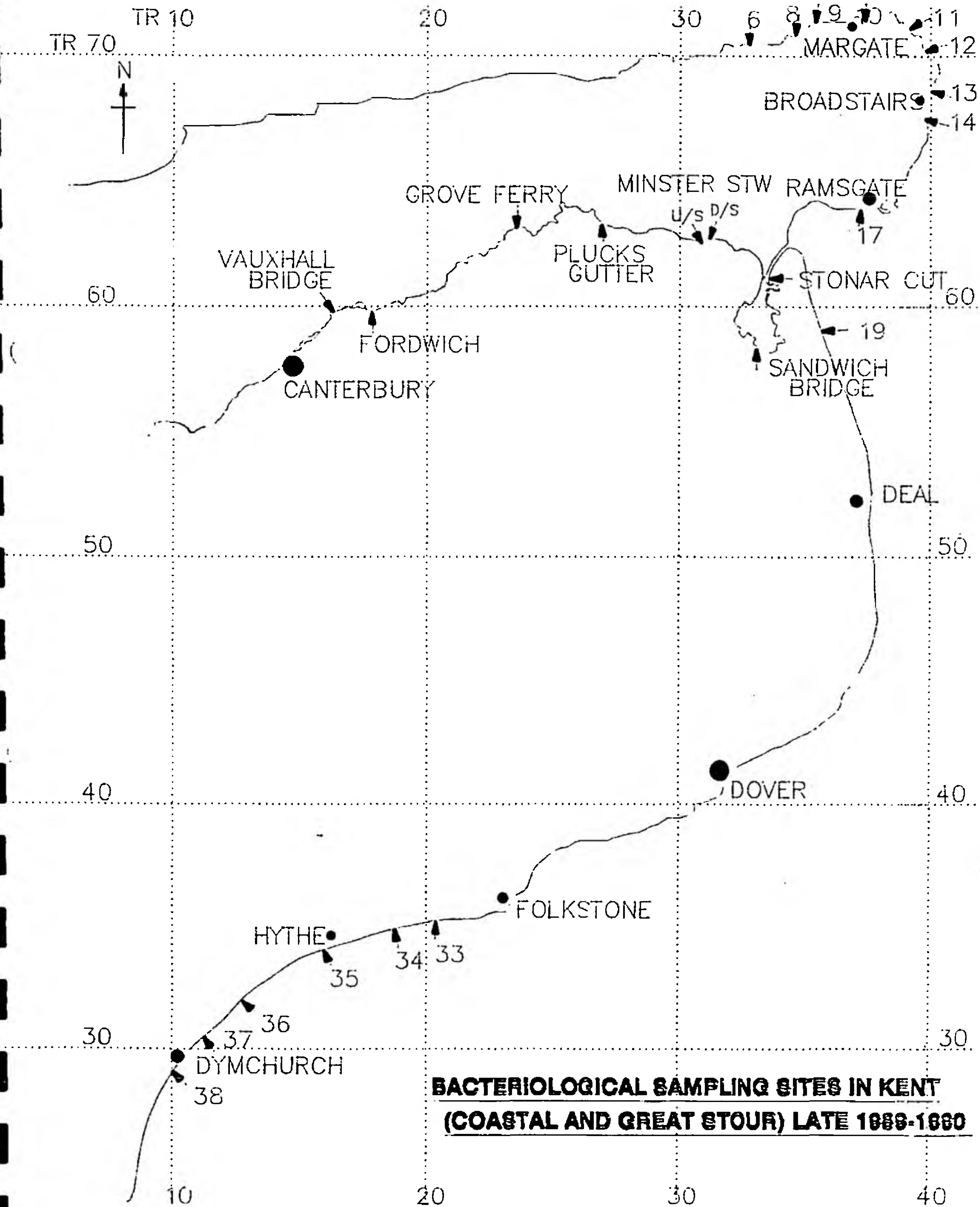
8.2.2 **Sampling Sites and Frequency**

The sites were sampled once a month during the non-bathing beach season October 1989 - April 1990. The monthly samples were taken alternately at low tide and high tide. A standard bathing beach field sheet was filled in for Sandwich Bay Car Park, and at the other sites the temperature and time were recorded.

The sampling sites were:-
(The sites sampled are shown on fig. 3)

Site	Graph Abbreviation	Grid Reference
Sandwich Bay Car Park (Bathing beach site no.19)	S'wich BY	TR 358 590
Stonar Cut	Stonar	TR 334 611
Sandwich Bridge	S'wich Br	TR 331 582
Downstream Minster Sewage Treatment Works	M'ster DS	TR 312 628
Upstream Minster Sewage Treatment Works	M'ster US	TR 320 628
Pluck's Gutter	Pluck's G	TR 269 633
Grove Ferry	Grove F	TR 235 631
Fordwich	F'wich	TR 179 597
Vauxhall Bridge	V'hall Br	TR 163 597

Figure 3



BACTERIOLOGICAL SAMPLING SITES IN KENT (COASTAL AND GREAT STOUR) LATE 1989-1990

8.3 Results

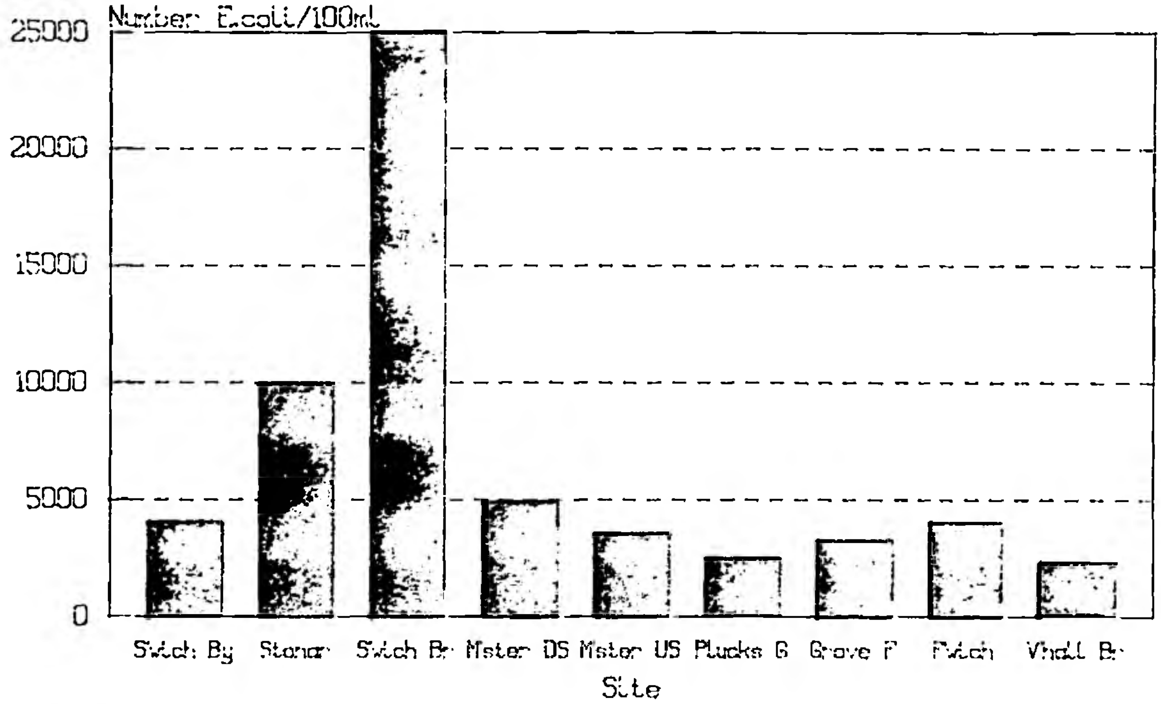
The sites were sampled on seven occasions during the October 1989 - April 1990 period. On three occasions the samples were taken at low tide, and on four occasions at high tide.
A list of results obtained over the period are shown in appendix 3.

Graph 18 shows the mean *E.coli* results that were obtained for the sites at high tide.

Graph 19 shows the mean *E.coli* results that were obtained for the sites at low tide.

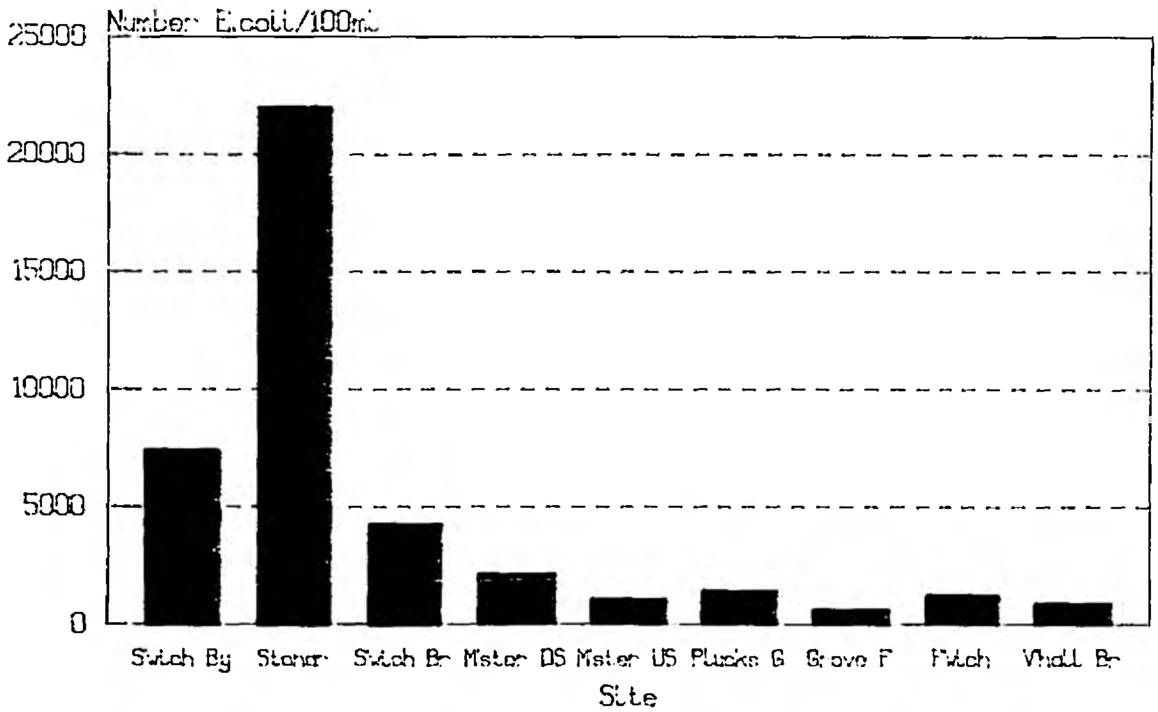
Graph 18

RIVER STOUR BACTERIOLOGY
MEAN E.COLI NUMBERS OF HIGH TIDE SAMPLES



Graph 19

RIVER STOUR BACTERIOLOGY
MEAN E.COLI NUMBERS OF LOW TIDE SAMPLES



8.4 Discussion

As only a total of seven samples sets were taken, three at low tide and four at high tide, it is not possible to statistically prove any trends that may be shown in the data. It is only possible to postulate what the data may show.

With reference to graph 19 , the general trend of the river samples was for the number of *E.coli* to increase downstream of effluent inputs from sewage treatment works (STW), as at Fordwich (d/s Canterbury STW), and Minster. However the increases due to these STW inputs was generally small, and the river returned to a reasonable bacterial level (which was perhaps the natural background level from sources other than STW, such as birds, and farm animals), within a relatively short stretch of the river.

However, a sharp increase in *E.coli* numbers can clearly be seen at the sites around Sandwich. This is due in main to sewage from Sandwich town being discharged, virtually untreated into the river Stour between the Sandwich Bridge site and Stonar cut. The river does not appear to be able to cope with the volume of raw sewage entering it, possibly due to insufficient dilution, or lack of mixing between the fresh water and the saline water. Sewage effluent has a tendency to rise to the surface, and it would remain within the freshwater layer for some time, until mixing occurred, further down the river.The River water at Sandwich, and downstream is very turbid, and this possibly aids the survival of the bacteria by preventing the penetration of UV light to any significant depth.
The combination of these factors can be seen on the graphs, by the high levels of bacteria that are discharged into Sandwich Bay by the river.

The graphs also highlight the effect that the tide has on the river water and the sewage that it contains. This can be seen on graph 18, at high tide, the river water is held back towards Sandwich, and as a result so is the sewage within the water. This is indicated by the higher bacterial count at Sandwich Bridge, and a lower bacterial count at Stonar Cut. At low tide, the river water flows normally to the sea, and the increase in *E.coli* numbers is as would be expected downstream of such an effluent input.

The numbers of *E.coli* present in the river water would not in general pass the EC guidelines on bathing water quality. The increased numbers when compared with sea water are possibly due to the fact that fresh water is not such a hostile environment for faecal coliforms, and therfore the as ultra violet radiation, and temperature, would have a similar effect on the bacteria in fresh water as in seawater.

8.5 Conclusions

8.5.1 The River Stour appears to contribute considerably to the poor bacterial quality of Sandwich Bay, with the most significant input coming from the untreated sewage entering the river at Sandwich.

8.5.2 Tidal patterns do appear to affect the Bacterial numbers, with high tide seeming to reduce the numbers entering the bay as it is held up into the town.

8.5.3 It would be interesting to note the improvements on the bacterial quality of the River Stour and Sandwich Bay, when the STW at Richborough, which will include the sewage from Sandwich, is commissioned in the future. (Proposed 1995).

9.2 REFERENCES

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APPENDIX 1

Total Coliforms

Sites	6	5	8	9	10	11	12	13	
	St Mils	Bwgate B	MargEEC	M'gateFR	Palm B	Botany B	Joss B	B'st EC	B
Dates									
03/08/89					550	5700		1350	
10/08/89					30	70		160	
18/08/89					390	150		1020	
24/08/89					230	60		40	
31/08/89					750	470		2920	
14/09/89					24000	1950		1300	
20/09/89									
21/09/89					410	30		290	
28/09/89					140	310		700	
05/10/89					150	290		370	
01/11/89	220		450	200	750	240	640	2400	
02/11/89									
12/12/89	270		980	130	250	160	660	850	
13/12/89									
10/01/90	5500		700	450	500	110	380	310	
11/01/90									
08/02/90	3500		3200	2900	1800	2500	3100	4700	
12/02/90									
08/03/90	700		660	90	70	540	310	2200	
12/03/90									
09/04/90	480		260	890	850	30	190	220	
10/04/90									
30/04/90		10			10	80		260	
10/05/90		770			400	100		310	
14/05/90		340			10	10		250	
21/05/90		26			110	6		60	
29/05/90		3			2	10		70	
04/06/90		700			91	90		8	
12/06/90		68			18	86		240	
18/06/90		1			3	0		2	
28/06/90		5			62	1		23	

14 'stairs	16 R'gate S	17 Ramsgate	33 S'gate	34 S'gate	35 PPHytne	36 Dym HR	37 Dym MT	38 Dym CP
			120			1050		7800
			1800			9300		600
			630			2200		1580
			20			1950		200
			2860			6300		10100
			1000			1570		165000
			560			9500		550
			1880			1000		9100
			2390			31000		620
3900		8100						
			800	8900	7000	3900	2300	1900
2800		44000						
			3000	1100	780	5000	940	2800
2900		4400						
			690	860	918	1700	530	1730
12700		7550						
			440	480	1100	1800	1363	3300
780		2500						
			630	690	440	1510	510	240
320		4000						
			260	160	190	250	836	773
	610		845			400		1290
	3700		500			881		80
	90		10			180		300
	220		8			10		60
	40		14			350		360
	32		125			1780		600
	300		73			340		5200
	62		7			940		26
	119		32			2600		34

Site	E.COLI 5	6	8	9	10	11	12	13	
	W'gate B	St Mils	BMargEEC	M'gateFR	Palm B	Botany B	Joss B	B'st EC	B
Dates									
03/08/89					250	1050		590	
10/08/89					20	70		40	
18/08/89					230	46		400	
24/08/89					120	60		40	
31/08/89					750	270		2920	
14/09/89					24000	1280		1300	
20/09/89									
21/09/89					100	10		30	
28/09/89					10	190		530	
05/10/89					100	80		220	
01/11/89		230	170	240	330	90	260	1045	
02/11/89									
12/12/89		200	830	80	230	150	490	600	
13/12/89									
10/01/90		5100	410	290	270	90	170	220	
11/01/90									
08/02/90		2000	2300	1290	850	2100	2000	2400	
12/02/90									
08/03/90		440	590	50	30	500	170	930	
12/03/90									
09/04/90		340	120	160	170	20	40	170	
10/04/90									
30/04/90	10				10	50		110	
10/05/90	750				180	46		130	
14/05/90	150				10	10		150	
21/05/90	26				91	6		60	
29/05/90	3				1	9		14	
04/06/90	672				45	55		5	
12/06/90	60				13	41		60	
18/06/90	1				2	0		1	
28/06/90	5				44	0		7	

14	16	17	33	34	35	36	37	38
'stairs	R'gate S	Ramsgate	S'gate	S'gate	PPHythe	Dym HR	Dym MT	Dym CP
			29			610		1320
			50			1700		10
			92			1450		1180
			10			590		120
			100			2645		2560
			770			1010		135000
			270			4600		550
			460			250		2700
			280			16300		80
1900		4000						
			500	8900	1781	1100	620	1136
3500		28000						
			1100	710	400	1800	290	100
1000		2700						
			430	420	450	330	180	1645
900		2200						
			290	290	570	830	1363	1109
480		1230						
			360	280	260	410	230	200
140		1518						
			120		90	210	530	430
	210		270			170		640
	3100		260			190		130
	40		10			20		50
	160		3			5		60
	4		2			84		122
	14		4			320		600
	119		19			60		850
	17		3			155		24
	87		7			390		14

Temperature ('C)

Site	6	5	8	9	10	11	12	
	St Mils	BWgate B	MargEEC	W'gateFR	Palm B	Botany B	Joss B	B
Date								
03/08/89					19.5	19.5		
10/08/89					21.3	21.2		
18/08/89					16.8	17		
24/08/89					18.6	18.2		
31/08/89					18.2	18.2		
14/09/89					16.7	17.2		
20/09/89								
21/09/89					19.1	20.2		
28/09/89					17.3	17.4		
05/10/89					16.8	16.8		
01/11/89	12.6		12.5	12.8	12.6	13	13.4	
02/11/89								
12/12/89	6.6		7	7.2	7.2	7.2	7.2	
13/12/89								
10/01/90	8.2		8.5	8.9	8.9	8.7	8.8	
11/01/90								
08/02/90	8.8		8.8	8.8	8.9	9	9.2	
12/02/90								
08/03/90	8.8		8.5	8.2	8.3	8.6	8.3	
12/03/90								
09/04/90	8.5		8.4	8.5	8.1	8.7	8.7	
10/04/90								
30/04/90		19.4			14.8	16.7		
10/05/90		14			13.1	13.1		
14/05/90		19			17.6	15.9		
21/05/90		15.2			15.2	15		
29/05/90		20			17	17		
04/06/90		16.9			15.8	15.5		
12/06/90		14.9			15.8	14.9		
18/06/90		18.9			17.1	17.7		
28/06/90		20			19.4	18.3		

13	14	16	17	33	34	35	36	37	38
'st EC	B'stairs	R'gate S	Ramsgate	S'gate	S'gate	PPHythe	Dym HR	Dym MT	Dym CP
20				19.5			19		19.5
21.2				19.9			20.2		19.9
17.2				18.6			18.9		18.8
18.4				19.5			19.8		19.1
18.5				18.4			17.8		17
17.6				18			17.8		17
				18.4			18.5		18.8
20.2									
17				17.6			17.3		16.6
16.9				16.4			15		15.2
13	13		13						
				13.8	13.8	13.3	13.3	13.2	13.4
7.1	7.3		6.5						
8.9	8.8		8.4						
				9.2	9.2	9.2	9.3	9.2	9.2
9.4	9.6		9						
				7.6	7.6	7.7	7.5	6.7	6.8
8.6	9.2		8.3						
				9.5	9.5	9.5	9.6	10.2	9.9
8.4	8.3		7.5						
				9.1	9	9.2	8.8	9.2	9.6
18.1		15.2		11.9			13.7		13.9
12.8		12.8		12.8			13.6		13.4
15.2		15.1		13.6			14.3		13.6
15.2		15		13.4			13.5		13.2
16		16		15			16		16
15.5		15.5		14.5			15		14.8
14.7		14.6		14.1			13.9		14.2
17.7		15.2		15.7			16.7		17
17.3		17.7		16.8			17.6		17.2

SEA STATE

Site	8	5	8	9	10	11	12	13	14	16	17	33	34	35	36	37	38
	St Mils	Bwgate B	MargEEC	M'gateFR	Palm B	Botany B	Joss B	B'st EC	B'stairs	R'gate S	Ramsgate	S'gate	S'gate	PPHythe	Dym HR	Dym MT	Dym CP
Dates																	
03/08/89					3	3		3				1			1		2
10/08/89					1	1		1				2			2		2
18/08/89					1	1		1				3			2		2
24/08/89					1	1		1				2			2		2
31/08/89					4	4		4				2			3		3
14/09/89					2	2		2				2			2		2
20/09/89												3			4		4
21/09/89					1	2		2									
28/09/89					5	5		5				3			3		3
05/10/89																	
01/11/89	1		1	1	1	1	1	2	1		1						
02/11/89												6	6	6	6	5	4
12/12/89	3		3	3	3	3	3	4	4		4						
13/12/89												5	5	5	5	5	5
10/01/90	2		2	2	1	2	2	3	2		3						
11/01/90												3	3	3	3	3	3
08/02/90	5		4	5	5	4	4	4	3		5						
12/02/90												4	4	3	3	3	3
08/03/90	1		1	1	1	1	1	2	2		2						
12/03/90												2	2	1	1	1	1
09/04/90	5		5	5	5	5	5	5	5		3						
10/04/90												2	2	1	1	1	1
30/04/90		1			1	1		1		1		1			2		2
10/05/90		2			2	2		2		2		3			3		3
14/05/90		1			1	1		2		1		2			2		2
21/05/90		3			4	4		3		2		1			2		2
29/05/90		1			1	1		1		1		1			2		2
04/06/90		3			2	2		2		2		2			2		2
12/06/90		2			2	2		3		2		1			2		2
18/06/90		2			2	2		2		2		2			2		2
28/06/90		2			1	1		1		1		4			4		4

Sunshine Conditions

Site	6	5	8	9	10	11	12	13
	St Mils	BWgate B	MargEEC	W'gateFR	Palm B	Botany B	Joss B	B'st EC
Date								
03/08/89					0	0		0
10/08/89					0	0		0
18/08/89					4	4		4
24/08/89					4	4		4
31/08/89					1	0		3
14/09/89					2	2		3
20/09/89								
21/09/89					4	4		4
28/09/89					3	3		0
05/10/89					2	2		2
01/11/89	1		1	1	1	1	1	1
02/11/89								
12/12/89	0		0	0	0	0	0	0
13/12/89								
10/01/90	0		0	0	0	0	0	0
11/01/90								
08/02/90	3		3	3	3	3	3	3
12/02/90								
08/03/90	3		3	3	3	3	5	6
12/03/90								
09/04/90	2		2	2	2	2	1	1
10/04/90								
30/04/90		4			4	4		4
10/05/90		1			1	1		0
14/05/90		3			4	4		4
21/05/90		4			4	4		4
29/05/90		4			4	4		4
04/06/90		4			4	4		3
12/06/90		0			0	0		0
18/06/90		4			4	4		4
28/06/90		3			3	3		3

14	16	17	33	34	35	36	37	38
B'stairs	R'gate S	Ramsgate	S'gate	S'gate	PPHythe	Dym HR	Dym MT	Dym CP
			3			3		4
			0			0		0
			4			3		3
			4			4		4
			3			3		3
			3			3		3
			4			4		4
			0			1		1
			2			2		2
1		1						
			0	0	2	2	2	2
0		0						
			0	0	0	0	0	0
0		0						
			0	0	0	0	0	0
3		3						
			4	4	4	4	4	4
6		5						
			4	4	4	4	4	4
1		1						
			4	4	4	4	4	4
	4		4			4		4
	0		0			0		0
	4		4			3		3
	4		4			4		4
	4		4			4		4
	3		3			3		3
	0		0			0		0
	4		4			4		4
	3		3			3		3

Tide Site	6	5	8	9	10	11	12	
	St Mils	BWgate B	MargEEC	M'gateFR	Palm B	Botany B	Joss B	B
Date								
03/08/89					0	0		
10/08/89					-5	-6		
18/08/89					-5	-6		
24/08/89					4	3		
31/08/89					-1	-1		
14/09/89					1	1		
20/09/89								
21/09/89					-4	-4		
28/09/89					1	0		
05/10/89					4	4		
01/11/89	-1		-2	-2	-2	-2	-3	
02/11/89								
12/12/89	1		0	0	0	0	0	
13/12/89								
10/01/90	0		0	0	0	-1	-1	
11/01/90								
08/02/90	1		1	1	1	0	0	
12/02/90								
08/03/90	3		2	2	2	2	2	
12/03/90								
09/04/90	-1		-1	-1	-1	-2	-2	
10/04/90								
30/04/90		-3			-3	-3		
10/05/90		0			0	0		
14/05/90		-2			-2	-2		
21/05/90		4			3	2		
29/05/90		-4			-4	-4		
04/06/90		3			2	2		
12/06/90		-2			-2	-3		
18/06/90		6			5	4		
28/06/90		-3			-3	-4		

13 'st EC	14 B'stairs	16 R'gate S	17 Ramsgate	33 S'gate	34 S'gate	35 PPHythe	36 Dym HR	37 Dym MT	38 Dym CP
-1				-2			-2		-3
-6				-6			-6		5
-6				-1			-1		-2
3				-4			-6		-6
-2				-2			-2		-2
0				0			0		-1
				-4			-3		-3
-4									
-1				-1			-1		-1
3				2			0		1
-3	-3		-1						
				-1	-1	-2	-2	-2	-2
-1	-1		0						
				0	0	0	0	0	0
-1	-1		0						
				0	0	0	-1	-1	-1
-1	-1		0						
				-1	-1	-1	-2	-2	-2
1	1		3						
				-1	-1	-1	-1	-2	-2
-2	-2		0						
				0	0	-1	-1	-1	-1
-4		-2		-4			-4		-4
-1		1		-1			-1		-1
-3		-1		-3			-3		-3
2		3		2			1		1
-4		-3		-5			-5		-6
1		2		1			1		1
-3		-2		-3			-3		-4
4		5		4			3		3
-4		-3		-5			-5		-6

APPENDIX 2

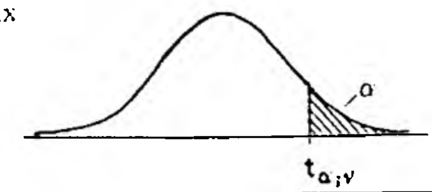
PERCENTAGE POINTS OF THE t DISTRIBUTION

The table gives the value of $t_{\alpha;\nu}$ — the 100α percentage point of the t distribution for ν degrees of freedom.

The values of t are obtained by solution of the equation:-

$$\alpha = \Gamma\{\tfrac{1}{2}(\nu+1)\}\{\Gamma(\tfrac{1}{2}\nu)\}^{-1}(\nu\pi)^{-1/2}\int_t^{\infty}(1 + x^2/\nu)^{-(\nu+1)/2}dx$$

Note. The tabulation is for one tail only i.e. for positive values of t. For |t| the column headings for α must be doubled.



α =	0.10	0.05	0.025	0.01	0.005	0.001	0.0005
ν = 1	3.078	6.314	12.706	31.821	63.657	318.31	636.62
2	1.886	2.920	4.303	6.965	9.925	22.326	31.598
3	1.638	2.353	3.182	4.541	5.841	10.213	12.924
4	1.533	2.132	2.776	3.747	4.604	7.173	8.610
5	1.476	2.015	2.571	3.365	4.032	5.893	6.869
6	1.440	1.943	2.447	3.143	3.707	5.208	5.959
7	1.415	1.895	2.365	2.998	3.499	4.785	5.408
8	1.397	1.860	2.306	2.896	3.355	4.501	5.041
9	1.383	1.833	2.262	2.821	3.250	4.297	4.781
10	1.372	1.812	2.228	2.764	3.169	4.144	4.587
11	1.363	1.796	2.201	2.718	3.106	4.025	4.437
12	1.356	1.782	2.179	2.681	3.055	3.930	4.318
13	1.350	1.771	2.160	2.650	3.012	3.852	4.221
14	1.345	1.761	2.145	2.624	2.977	3.787	4.140
15	1.341	1.753	2.131	2.602	2.947	3.733	4.073
16	1.337	1.746	2.120	2.583	2.921	3.686	4.015
17	1.333	1.740	2.110	2.567	2.898	3.646	3.965
18	1.330	1.734	2.101	2.552	2.878	3.610	3.922
19	1.328	1.729	2.093	2.539	2.861	3.579	3.883
20	1.325	1.725	2.086	2.528	2.845	3.552	3.850
21	1.323	1.721	2.080	2.518	2.831	3.527	3.819
22	1.321	1.717	2.074	2.508	2.819	3.505	3.792
23	1.319	1.714	2.069	2.500	2.807	3.485	3.767
24	1.318	1.711	2.064	2.492	2.797	3.467	3.745
25	1.316	1.708	2.060	2.485	2.787	3.450	3.725
26	1.315	1.706	2.056	2.479	2.779	3.435	3.707
27	1.314	1.703	2.052	2.473	2.771	3.421	3.690
28	1.313	1.701	2.048	2.467	2.763	3.408	3.674
29	1.311	1.699	2.045	2.462	2.756	3.396	3.659
30	1.310	1.697	2.042	2.457	2.750	3.385	3.646
40	1.303	1.684	2.021	2.423	2.704	3.307	3.551
60	1.296	1.671	2.000	2.390	2.660	3.232	3.460
120	1.289	1.658	1.980	2.358	2.617	3.160	3.373
∞	1.282	1.645	1.960	2.326	2.576	3.090	3.291

APPENDIX 3

RESULTS FROM THE RIVER STOUR BACTERIOLOGICAL STUDY

TEMPERATURE

	S'wich	ByStonar	S'wich Br	M'ster DS	M'ster US	Plucks G	Grove F	F'wich	V'hall Br
17/10/89	15.2	13.8	12.4	12.2		11.7	12	12	11
07/11/89	11.2	9.1	8.6	8.3	8.4	7.8	8	9.4	8.4
05/12/89	8	5.2	5	5.1	5.1	5.8	6.6	8.3	7.3
29/01/90	7.8	6	6	6.1	6.1	6.3	6.4	7.5	6.4
19/02/90	8.9	8.7	8.7	8.7	8.7	8.8	8.7	9.6	8.8
14/03/90	13.3	10.4	10.2	10.2	10.1	9.7	9.2	10.4	9.7
18/04/90	9.6	10.4	10.4	10.4	10.3	10.1	10.2	10.1	10.1

TOTAL COLIFORMS

	S'wich	ByStonar	S'wich Br	M'ster DS	M'ster US	Plucks G	Grove F	F'wich	V'hall Br
17/10/89	3820	15800	320000	32000		8820	6180	34000	3400
07/11/89	15500	106000	14200	14700	7900	46000	5180	13200	4100
05/12/89	11363	138181.5	21409	9651.5	7277	6440.5	4900	5665	2550
29/01/90	38000	93000	53000	63000	61000	64500	93600	58200	96000
19/02/90	23000	19000	58000	15000	25000	19000	16000	8640	210000
14/03/90	12700	41000	6000	10300	5900	12000	32000	30000	3600
18/04/90	1600	44000	9090	13000	5600	25000	21000	25000	14000

E.COLI

	S'wich	ByStonar	S'wich Br	M'ster DS	M'ster US	Plucks G	Grove F	F'wich	V'hall Br
17/10/89	1290	5400	83000	3640		790	970	4500	400
07/11/89	7910	29000	2700	2500	1210	3700	800	1230	560
05/12/89	5350	42500	2050	3900	1935	1177	904	772.5	355
29/01/90	5500	16500	7600	8800	6700	5900	4700	4700	6400
19/02/90	15500	1050	10700	1050	870	201	150	2000	1900
14/03/90	5200	7900	470	2100	330	600	4000	2800	290
18/04/90	620	14200	1250	850	170	570	350	730	640

LOW TIDE SAMPLES = 17/10/89 ; 29/01/90 and 14/03/90
HIGH TIDE SAMPLES = 07/11/89 ; 05/12/89 ; 19/02/90 and 18/04/90