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The Mersey Estuary

A Report on Environmental Quality

WATER QUALITY SERIES NO 23

NRA

National Rivers Authority

Guardians of the Water Environment

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The Mersey Estuary
a Report on Environmental Quality

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EXECUTIVE SUMMARY

1 Introduction

The Mersey Estuary is widely regarded as one of the most polluted estuaries in Europe. It drains an area of 5,000 square kilometres which includes the major conurbations of Liverpool and Manchester. Pollution of the Estuary is a long standing problem with its roots going back to the days of the Industrial Revolution and the birth of the British chemical industry. The Mersey basin continues to be a focal point for a wide range of manufacturing activities, and retains its status as a major port. The Estuary is important in terms of leisure and recreational pursuits, as well as a large area being classified as a Site of Special Scientific Interest. In recent times, the extent of pollution from discharges into the Estuary has been reduced as a result of multi-million pound investment in sewage treatment, the sewerage infrastructure, and by industry.

After more than 200 years of neglect, much of the Estuary still has poor water quality and will remain unsatisfactory for some time to come. However, through the participation of industry, the North West Water Company and the public, significant improvements have been made and the tide of pollution has clearly turned.

Achievements to date include:

- Over £1 billion has been invested in the Mersey Basin clean-up and more is planned.
- Increasingly stringent controls have been applied to both direct industrial and sewage discharges to the Estuary and rivers within the Mersey catchment.
- Liverpool's first waterside sewage treatment works, costing £40 million, is now operational.
- Industry has been encouraged to discharge biodegradable waste to sewage treatment works giving more effective treatment.
- There has been major involvement by industry in environmental improvement projects.
- The pollution load in rivers flowing into the Mersey Estuary has been reduced by more than 80% over the last 25 years.
- Mercury discharges have been reduced by more than 90% over the last 15 years.
- The concentrations of heavy metals deposited in salt marsh sediments bordering the Estuary, which have been dated by radiometric techniques, have reduced significantly, in some instances to near pre-industrial levels.
- The Mersey Estuary has become a haven for wildfowl and waders with numbers rising by more than 60% over the last decade. Increasing numbers of fish are now returning to the Estuary, with more than 35 species having been found in recent years.
- The benefits of the Mersey Basin clean-up have played an integral part of promoting waterside development.

2 The regulatory framework

The problems of the Mersey Estuary are inextricably linked to the Industrial Revolution of the 18th century. As long ago as 1865, the Government of the day had recognised that the problems of pollution created by new industries and their supporting population were severe. The Rivers Pollution Prevention Act of 1876 was the beginning of much legislation designed to stem the tide of pollution. Further examples include Pollution Prevention Acts between 1951 and 1961 which set limits on the nature of effluents to be discharged to inland waters and to estuarine waters, powers which were extended by the Control of Pollution Act, 1974. Whilst domestic legislation has been progressively tightened, a new dimension was introduced as a result of the UK joining the EEC. The European legislation programme has established a system of Directives which require member states to comply with community-wide environmental and discharge standards.

3 The processes which influence estuarine water quality

Tidal action is fundamental to water quality in the Mersey Estuary. Even though water bodies are moved considerable distances during each tidal cycle, pollutants discharged to the upper and middle Estuary may remain within the Estuary for several weeks. The rate at which pollutants leave the Estuary is termed the 'flushing time' and is predominantly governed by the freshwater flow. Dissolved oxygen is also crucial to water quality as it is vital to the biological health of the Estuary. Concentrations vary both spatially and on a number of time-scales. The most pronounced oxygen sags are found during the summer spring tides, with much better conditions observed during the corresponding neaps.

4 Pollution of the Mersey Estuary

Pollution of the Mersey Estuary can be attributed to inadequate sewage treatment facilities, intermittent discharges from combined sewer overflows, industrial discharges, and run-off from agriculture and contaminated land. There have been clear and demonstrable reductions in the loads of various pollutants discharged to the Mersey Estuary from specific discharges and the main freshwater inputs at Howley Weir in Warrington. Reductions in biochemical oxygen demand and ammonia concentrations are paralleled by an impressive rise in the level of dissolved oxygen found at Howley Weir. Clear reductions are also evident for a range of organic pollutants and heavy metals. Examples include the chlor-alkali industry which now discharges a mercury load of less than 1 tonne per year as compared to nearly 60 tonnes in the mid 1970s. The impact of this reduction is reflected in the levels of mercury found in the Estuary sediments.

5 Quality status of the Mersey Estuary

The Mersey Estuary is predominantly of poor and bad quality as classified by the National Water Council Scheme. Dissolved oxygen concentrations are a major criteria of quality assessment. Measured values at high water throughout the Estuary illustrate that both the scale and location of an 'oxygen sag' is dependent on whether measurements are made during a spring or a neap tide. Seasonal effects are clearly illustrated by considering the major nutrients in the Estuary throughout the year. Monitoring sites within the Estuary complied with environmental quality standards for contaminants classed as Dangerous Substances.

6 The biology of the Mersey Estuary

Estuaries are amongst the most fertile and productive environments. One of the main objectives of improving the water quality of the Mersey Estuary is to increase the diversity and abundance of estuarine life. Much work has been carried out to define a baseline upon which future changes can be measured. As it stands, the Mersey is nationally and internationally important for a number of bird species. In addition, NRA beam trawling, studies by other organisations and angler reports have proven that fish are gradually returning to the Estuary. However, the increased angling activity has caused concern in that, although fish may now be able to survive in the Estuary, contaminants may still accumulate in the fish flesh and render them unsuitable for human consumption.

7 Future prospects for the Mersey Estuary

Objectives are clearly focused on tackling the pollution problems associated with large quantities of organic matter being discharged via the public sewerage network, and the discharges of larger industrial complexes. Throughout the 1970s, extensive work was undertaken to calibrate and utilise a mathematical model of the Estuary. By 1980 it was possible to use the model to determine a strategy for investment to achieve the objectives. The culmination of this work was the Mersey Estuary Pollution Alleviation Scheme, which established a programme of necessary work on the sewage disposal facilities, matched by corresponding improvements in industrial discharges. Whilst substantial progress has been made, the enhanced treatment facilities in the Upper Estuary are still awaited. The EC Urban Waste Water Treatment Directive has imposed additional requirements which will have to be met within the next 5 years. The Mersey Basin Campaign has commissioned a plan which aims to achieve an appropriate balance between development needs and the protection of estuary resources for future generations.

It is fair to claim, therefore, that after more than 200 years of neglect, the tide of pollution has turned and the process of real improvement is well established.

Plate 1.1: **The Mersey Estuary**

Reproduced Courtesy of Mersey Docks and Harbour Company

CHAPTER 1

1 An introduction to the Mersey Estuary

1.1 Geography

Figure 1.1: **The Mersey Estuary**

The Mersey Estuary receives drainage from one of Britain's most extensive catchments. The drainage area of some 5000 square kilometres includes the major conurbations of Liverpool and Manchester. The Estuary and its hinterland saw the birth of the British chemical industry and the growth of major manufacturing centres at Ellesmere Port, St. Helens, Warrington and Widnes. The Mersey Estuary continues to be a focal point for a wide range of manufacturing activities, and retains its status as a major port. The population of the Mersey Basin has increased dramatically since the Estuary was recognised as an important trade route in the 18th century, and the basin now supports a population of over 5 million.

Table 1.1: **The Mersey Estuary: Statistics**

Total Area	8,914 ha
Inter-tidal Area	5,607 ha
Shore length	102.6 km
Tidal range mean	8.9 m
extreme spring	10.4 m
extreme neap	4.0 m
Estuary volume high water spring tide	6.5×10^8 m^3
Population of Mersey Basin	>5 million
Population living within 1km of the shore	834,000

The freshwater limit of the River Mersey is at Howley Weir in Warrington, although this may be over-topped during large tides. From here, the Estuary extends for approximately 50 kilometres to the sea in four main sections (see Figure 1.1):

a) The Upper Estuary, between Warrington and Runcorn is a narrow meandering channel, widening briefly up-stream of a north to south sandstone ridge constricting the Estuary at the Runcorn Gap.

b) The Inner Estuary, below the Gap, opens into a large basin with extensive inter-tidal banks and extensive salt marsh on its southern margin. This section of the Estuary supports nationally significant bird populations.

c) The Narrows further downstream of the Inner Estuary are characterised by changes in geology and the Estuary becomes a straight narrow channel with depths of up to 30m even at low water, and fierce tides of up to six knots.

d) The Outer Estuary consists of a large area of inter-tidal sand and mud bank through which the Crosby and Queens Channels are constrained by training walls and maintained by dredging.

The banks of the Inner Estuary are unstable and constantly moving. For example, at Oglet Bay on the northern shore, the salt marsh is depositing, whilst on the southern shore it is eroding. These changes are dynamic and may vary in the future.

1.2 Hydrography

In contrast with normal estuaries, the Mersey has an unusual shape with a 'bottle neck' outlet to the sea. This produces a water flow pattern with distinctive characteristics. The Estuary widens from less than 1km at Widnes to nearly 5 km at Hale, and then narrows again to 1km at New Brighton. The narrow mouth gives rise to high tidal water velocity, giving the Estuary channels a strong tidal scour and high levels of suspended particulate matter. This is assisted by training walls which flank the channel out into Liverpool Bay for some 16km. These were constructed to direct and control the waters and maintain the navigable channel.

The flood tide pushes water from the Narrows and Inner Estuary upstream into the Upper Estuary. On smaller tides, the saline water only penetrates to just beyond Widnes, but on the higher tides, it reaches almost up to the tidal limit at Warrington.

In the Upper Estuary, the smaller volume of water available provides only limited scope for dilution of effluents and the polluted water from the non-tidal river. It can then take more than thirty days for water to travel from the tidal limit at Howley Weir to the mouth of the Estuary.

In common with most estuaries, it is known that the Mersey is gradually accreting sediments and consequently the volume of the Estuary between the mouth and the tidal limit is slowly reducing. The bulk of this material is coarse sand transported from Liverpool Bay. Apparently, this process was accelerated by the construction of the training walls to improve the approach channel to the Port.

The finer materials, derived mainly from the non-tidal river and discharges, are either deposited in areas where the currents are weak or pass out of the Estuary in suspension. The resuspension of sediments occurs over the whole of the Estuary, but is particularly marked during spring tides in the shallower reaches upstream of Eastham.

In the Inner Estuary, the position of the low water channel is constantly changing. These meanderings move many thousands of tonnes of material and may lead to the formation or erosion of salt marshes. This mechanism acts as a 'source' or 'sink' of contaminants such as heavy metals, which are either locked-up or released back into the environment.

1.3 Freshwater Inputs

There are a number of rivers discharging into the Mersey Estuary. Most have received polluting inputs from non-tidal reaches, adding to the polluting load discharged into the Estuary.

1.3.1 Riverine Inputs

Figure 1.2 lists the significant inputs of water to the Mersey Estuary from riverine sources

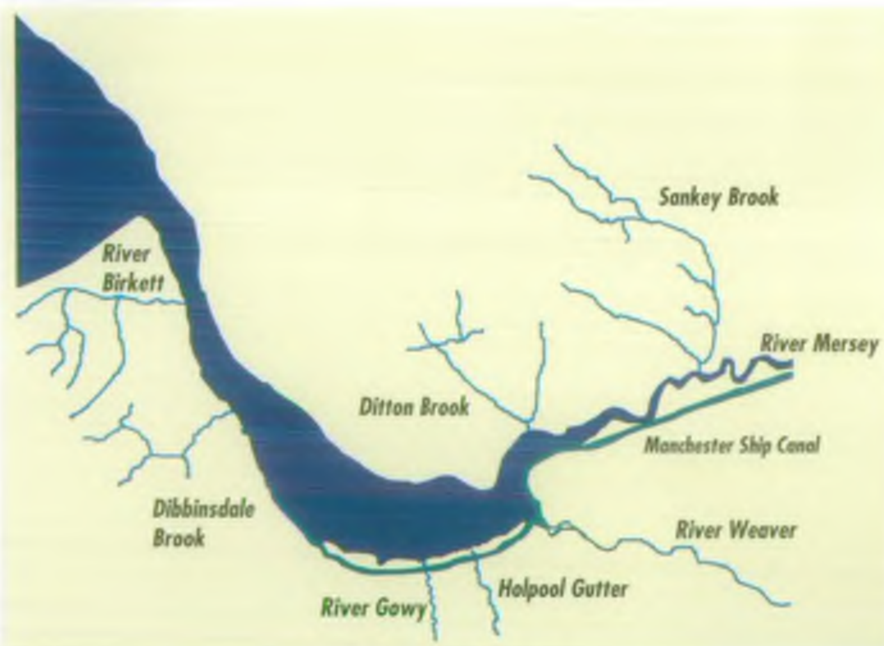
1.3.2 Manchester Ship Canal Flows

Water from the Manchester Ship Canal can enter the Mersey Estuary via the locks at Eastham or the Weaver Sluices below Runcorn.

Water movement from the canal to the Estuary at Eastham is a mixture of lockage and leakage through two locks and associated sluiceways.

The operation at the Weaver Sluices is more complex. The primary purpose of the sluices is to discharge excess water entering the canal from the River Weaver catchment to the Mersey Estuary. The River Weaver has to pass through the Ship Canal to reach the sluices which stimulates a degree of mixing.

Figure 1.2: **Riverine Inputs to the Mersey Estuary**



Watercourse	Modal Flow (Megalitres/day)
River Mersey	1620
Sankey Brook	344
Manchester Ship Canal (including River Weaver)	1010
Ditton Brook	85
Holpool Gutter	19
River Gowy	108
Dibbinsdale Brook	33
River Birket	40

In the past, any tide in the Mersey greater than the level in the Canal could enter unimpeded through the locks at Eastham. This excess water was returned to the Estuary via the Weaver Sluices. This process was called 'levelling' and it effectively flushed the Manchester Ship Canal between Eastham and the Weaver Sluices on any high spring tide. In 1989, additional gates were provided at Eastham to close off the Canal from the River Mersey, thus eliminating levelling and reducing the ingress of estuarine silts.

Cessation of routine levelling has reduced the average salinity of the Canal, and may have further encouraged mixing between Canal and Weaver water in the vicinity of the sluices by reducing density differences. The absence of levelling has also lowered the dilution available for any pollutants discharged to the Canal.

1.4 A Historical Perspective of the Mersey Estuary

1.4.1 Early Development and Growth

The Port of Liverpool was granted its charter in 1207. However, the Mersey Estuary only rose to prominence when the silting-up of the Dee Estuary in the 15th century caused a decline in trade at the port of Chester and boosted the trade at the port of Liverpool. In 1700 the population of Liverpool was estimated at being around 5,000. By 1750 it had increased to 20,000, and at the first Census in 1801, Liverpool's population was around 78,000. This rapid population growth throughout the 18th century is attributable to the forging of trading links with the Americas. It was not only local industry in Merseyside that used the Mersey Estuary as a gateway to the rest of the world, but also industry from further afield such as the Cheshire salt fields, the Pennines textile industry and the metal working industry of the Midlands. All of these contributed to merchandise handled at docks in Liverpool.

By 1841 the population had expanded to 223,000. The influx of Irish immigrants due to famine in Ireland increased this figure to the point of saturation, causing an overspill of growth into surrounding areas. Since the 1930s, the population has declined.

1.4.2 The Industrial Revolution

With the opening of Liverpool's first dock in 1715, the Mersey catchment became a prime location for industrial expansion. It was the advent of mechanised spinning and weaving in the Mersey Basin area in the late 18th century which induced the siting of new mills along watercourses where water-wheels could power the new machines.

The steam age also relied upon the waterways, not only for the abstraction of water but also for the transportation of coal and cotton to the mills and for the distribution of the finished product. Associated with the textile industry was an increase in the bleaching, dying and finishing trades. These industries required large volumes of water, and thus a series of companies were located on the river Mersey and its tributaries. Supporting industries manufacturing dyestuffs and chemicals which also required large quantities of water, in turn sprang up along the region's waterways.

Allied to the growth of the textile and related industries was the growth of the paper industry which satisfied the demand which the increase in business had caused. Heavy chemical and glass industries grew around Widnes, the Wirral and St. Helens, using salt from Cheshire as a raw material.

Plate 1.2: **Liverpool Docks, present day**

Reproduced Courtesy of Mersey Docks and Harbour Company

The south bank of the Mersey failed to thrive until the arrival of the first steamships around 1815. Originally just a destination for pleasure trips from Liverpool, Birkenhead on the Wirral developed a boiler making and shipbuilding yard. In 1801 its population was 110; by 1841 this had grown to more than 8,000. After the opening of the first docks at Birkenhead in 1847, the population continued to expand to provide a workforce for engineering works, a fertiliser plant, a sugar refinery, cement works, vegetable oil refiners and oil-cake mills. The Laird shipyard expanded following the opening of the docks and by 1851 the population of Birkenhead was 24,000. To add to the growth of the area, Lever Brothers soap factory was founded at Port Sunlight in 1888.

The industrialisation of the Ellesmere Port and Stanlow area was assisted by the development of the Shropshire Union Canal. This allowed the transportation of materials from further afield, and the growth of new industries using these materials. The oil refining activities of the North West developed on land reclaimed from the Gowy marshes by German prisoners in the first World War, and the first oil dock was built on drained land. This marked the beginning of Shell's activities at Stanlow which, many years later, were to provide a vivid example of what can happen when fragile ecosystems and industry operate in close proximity. On the 19th August 1989, 150 tonnes of crude oil were spilt into the Mersey Estuary from a fracture in a pipeline operated by Shell. Fortunately this was before the arrival of migratory bird populations which, together with the aid of prevailing physical conditions, made the ecological effects relatively small. The NRA has now developed an action plan in conjunction with the Marine Pollution Control Unit to minimise the impact of similar future incidents.

Plate 1.3: **Shell's Complex at Stanlow**

Plate 1.4: **Oil Spill, August, 1989**

Mirroring the growth of Liverpool and the later development on the opposite bank of the Mersey, were the three major towns of the upper Mersey: Widnes, Runcorn and Warrington. In 1801, Warrington was second only to Liverpool, with its roots firmly grounded in various forms of manufacturing. Warrington's population grew throughout the 19th century reflecting the growth of iron founding, wire working and brewing in the later half of the century. Tanning was another trade common to the area with tannery effluents being a major pollutant in local water courses. When compared to Runcorn and Widnes, Warrington was not a centre for the chemical industry, although soap was (and still is) made there.

In 1801, the inhabitants of Widnes numbered 1063; by 1901, its population stood at 32,000. This rapid growth in population is attributable to the siting of chemical works at a prime industrial position between the Lancashire coalfields to the north and the Cheshire salt fields to the south, with the nearby Mersey Estuary to carry away the waste products. The development of the chemical industry, which peaked around 1875, overshadowed the more traditional metal crafts of Widnes, but these soon returned when it was found that copper could be extracted from the pyrites used in the chemical works. Runcorn began to develop as a major centre for the chemical industry with the establishment of the Castner-Kellner Alkali Company in 1897. This Company produced caustic soda and chlorine by the electrolysis of brine. In 1926, a nation-wide merger resulted in the formation of ICI. Despite some major developments in the 1960s and 70s, Widnes has tended to be overshadowed by Runcorn in the post-war period.

While the effect on the rivers was most marked in the manufacturing areas around Manchester, the heavily polluted waters arriving in the Mersey Estuary were further contaminated by the expanding chemical industry at Widnes and Runcorn, and sewage from the populous port of Liverpool.

The opening of the Manchester Ship Canal in 1894 resulted in further deterioration of Estuary water quality. The re-direction of a large body of water caused the salt marsh to the south of the canal to dry up.

The Estuary continued to support a major fishery until the 19th century. By the 1850s, a decline in fishing was recorded. Commercial fishing had ceased by 1940.

1.5 Land Use Patterns around the Estuary

Most of the north/east bank of the Estuary is urban, with major industrial use. The south/west shore is similar in the lower reaches but upstream from Eastham the Estuary is isolated from the hinterland by the Manchester Ship Canal. This area is characterised by extensive areas of sand, inter-tidal mud flats and salt marsh.

Plate 1.5: **Eastham Locks, Manchester Ship Canal**

Reproduced Courtesy of Manchester Ship Canal Company

Although much reduced in area from former times, the Liverpool Dock system still extends 8km upstream from the mouth of the Estuary and handles near record cargo tonnage. On the Wirral shore, Birkenhead and Wallasey docks extend across the peninsula following the course of the reclaimed Wallasey Pool. As well as extensive wharfs and docks on the Ship Canal, there are smaller port operations at Garston and Bromborough.

Industry is found extensively throughout the region. Major centres for manufacturing industry are:

Liverpool: vehicles, edible oils, electroplating;

Birkenhead: edible oils, lubricating oils, tanning;

Bromborough: soaps and detergents, edible oils;

Ellesmere Port: vehicles, paper, general chemicals;

Stanlow: oil refining and petrochemicals, dyestuffs, organo-lead compounds:

Runcorn: chlorine, chlorinated solvents, plastics;

Widnes: general chemicals, pesticides and herbicides, industrial chemicals, food products;

St Helens: glass, general chemicals;

Warrington: soaps and detergents, general chemicals;

Non-industrial use is increasing with the conversion of disused dock areas for residential and leisure purposes. The construction of marinas has encouraged sailing and other water sports.

1.5.1 Ownership

Much of the upper Estuary is owned by the Crown Estate and the Duchy of Lancaster. The docks and retaining walls are owned by the Mersey Docks and Harbour Company, Mersey Development Corporation, Associated British Ports, Manchester Ship Canal Company and other industrial concerns. Certain tidal areas around Ince and Stanlow, which are covered only at high spring tides, are owned by a local farmer.

1.5.2 Recreation

The Mersey Estuary and its surrounding land is an important area for leisure and recreational pursuits as detailed in Figure 1.3. Land based areas owned and managed for recreational activities in the vicinity of the Mersey Estuary include golf courses, country parks, caravan sites and picnic areas. Every year, from 1st September to 21st February, wildfowling takes place on the Estuary with the main areas for shooting being on Ince Bank and Frodsham Score. The sporting rights are owned by the British Association for Shooting and Conservation (BASC) who have strict regulations on shooting.

The Estuary itself is a major tourist focus, and the Mersey Ferries regularly feature in the North West's 'top ten' list of attractions.

1.5.3 Conservation Status

A large proportion (over 6,700 hectares) of the Estuary is covered by the Mersey Estuary Site of Special Scientific Interest (SSSI) (see Figure 6.1), which imposes significant restrictions on specified activities within the area.

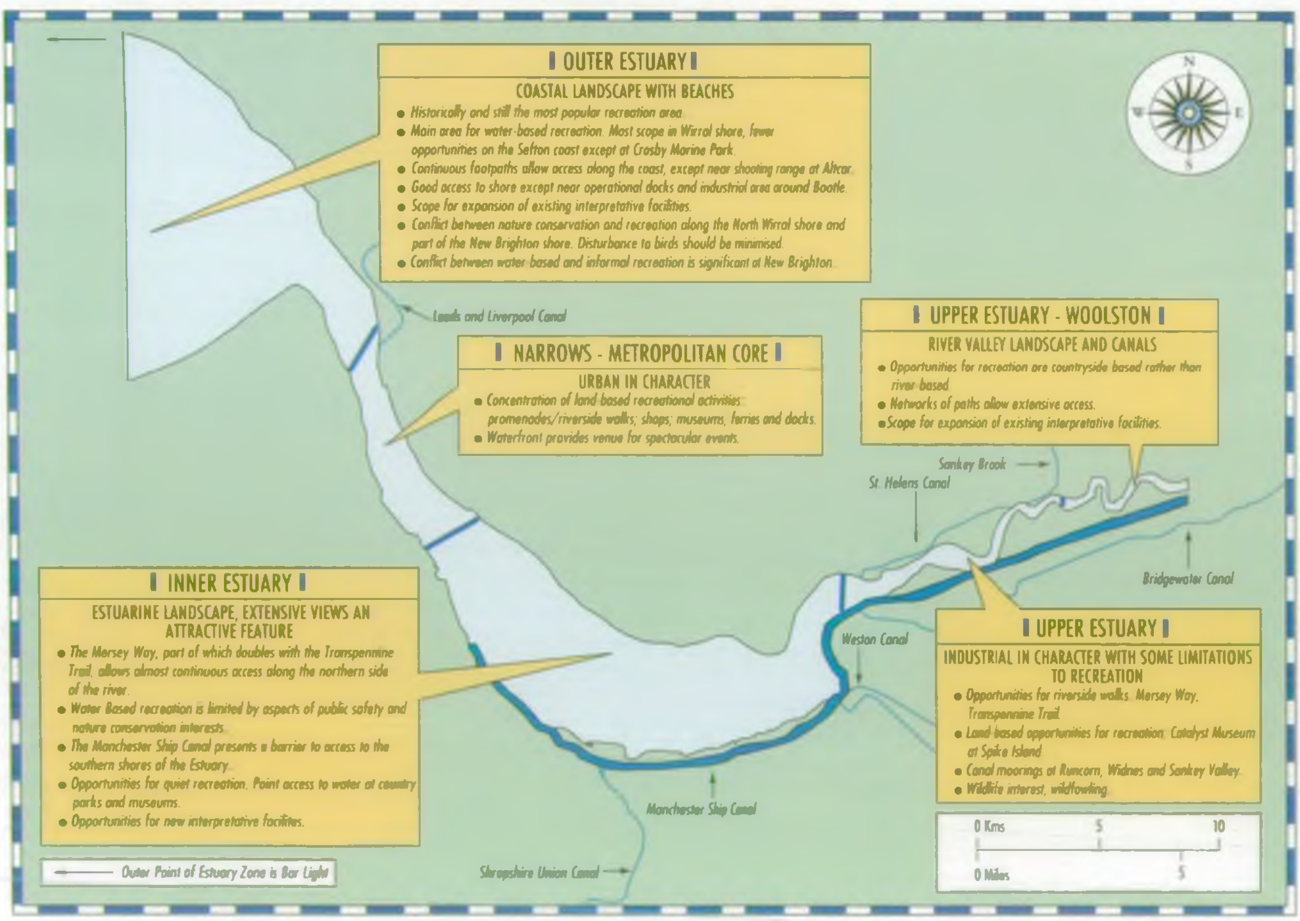
There are two established County Wildlife Trust reserves on the Estuary. These are Hale Duck Decoy managed by the Cheshire Wildlife Trust and Seaforth Pools, a Lancashire Trust for Nature Conservation reserve.

Another important reserve is at Manisty Bay. This reserve is protected by the Merseyside Naturalists Association in agreement with the Manchester Ship Canal Company. Although there is no active management in this reserve, it is very important for both roosting and feeding waders and wildfowl as it contains a large no-shooting area.

On the northern side of the Mersey, wildfowling rights are rented from various landowners by small shooting associations including a private reserve at Fiddler's Ferry power station.

The internationally important numbers of water-fowl, which regularly exceed 20,000 in winter, qualifies the Mersey Estuary as a proposed Wetland of International Importance under the Ramsar Convention. The Estuary has also been proposed as a Special Protection Area (SPA) under the EC Birds Directive. The proposed SPA/Ramsar site covers approximately 6,702 hectares. The boundary co-incides with the Mersey Estuary SSSI, except for the exclusion of a small strip of land to the south of the Manchester Ship Canal.

Figure 1.3: **Recreational Uses of the Mersey Estuary**



Reproduced from 'Mersey Estuary Management Plan', University of Liverpool, Courtesy of Mersey Basin Campaign

CHAPTER 2

2 The regulatory framework

2.1 Introduction

As illustrated in the previous chapter, the problems of the Mersey Estuary are inextricably linked to the Industrial Revolution of the 18th century. By 1865, the Government of the day recognised that the pollution problems created by the new industries and their supporting population were severe. Queen Victoria appointed three commissioners in 1868 to report. They described in lurid terms a sampling exercise undertaken in 1869 thus:

"When taking samples at Throstlenest Weir below Manchester at 5 a.m. on 21 July 1869, we saw the whole water of the River Irwell, there 46 yards wide, caked over with a thick scum of dirty froth, looking like a solid sooty crusted surface. Through this scum here and there, at intervals of 6 to 8 yards, heavy bursts of bubbles were continually breaking, evidently rising from the bottom and, where every yard or two of the scum was cleared away, the whole surface was seen simmering and sparkling with a continuing effervescence of smaller bubbles rising from various depths in the midst of the water, showing that the whole river was fermenting and generating gas. The air was filled with the stench of this gaseous emanation many yards away. The temperature of the water was 76°F and that of the air 54°F."

The commissioner's final report was published in 1874 and resulted in the Rivers Pollution Prevention Act, 1876.

2.1.1 The Rivers Pollution Prevention Act, 1876

This Act introduced powers requiring sewage discharges to be rendered inoffensive prior to discharge into an inland watercourse. Unfortunately, the power to enforce this Act was initially handed to the local sanitary authorities who were the principal polluters and who were also competing locally for increased development. It is perhaps not surprising that only minimal changes in practices took place until, in 1888, the County Councils were established and the powers transferred to them.

Primarily as a result of concerns that the Manchester Ship Canal, which was then under construction, would be heavily polluted, because its main water feeds are the Irwell and the Mersey, the Mersey and Irwell Joint Committee was formed to enforce the Act. It was intended to embrace all the rivers draining to the Mersey Estuary, but due to the refusal of the then Cheshire County Council to participate, the principal of catchment management in pollution control had to wait until 1965 before it could be established under the control of the River Authorities created at that time.

The Joint Committee held its first meeting in 1891 and acquired additional powers in 1892. They achieved some notable improvements due to their adoption of new technology and sought to develop the systems of the time.

In 1893, percolating filters were installed at Salford Sewage Works using a fixed spray distribution system and this was developed in the region such that by the turn of the century the more familiar revolving distribution system was operational at Rochdale sewage works. The activated sludge process was also developed locally with the first large scale deployment being at Withington Sewage Works in 1917. This is now known as Davyhulme and remains one of the largest sewage works in the country. Other local developments include the Kessner Brush which was first deployed at Stockport in 1939.

These developments certainly stabilised and turned the tide of ever increasing domestic pollution, but they did not tackle the problems of industrial pollution, against which there were no legal sanctions, and the early part of the 20th century saw other problems that reduced the impact of any "green" lobby of the time.

Not surprisingly the two "World Wars" and the intervening "Great Depression" were not conducive to major progress on pollution issues, but the Public Health Acts of 1936 and 1937 established rights and controls on the discharge of trade effluent to public sewer.

The next significant development had to wait until hostilities ceased and the nation settled down into a more stable existence. Thus it was 1951 before the next significant step was taken with the passing of The Rivers (Prevention of Pollution) Act.

2.1.2 Pollution Prevention Acts, 1951-1961

The Rivers (Prevention of Pollution) Act, 1951, gave new powers to a newly created regulatory body, the Mersey River Board (established by the Rivers Board Act of 1948). The Act required new dischargers of trade or sewage effluent to inland waters to acquire a 'discharge consent' from the river authority. This was a legal document setting limits as to the nature, composition, temperature and volume of the effluent permitted to be discharged. In addition, it became an offence to cause or knowingly permit any poisonous, noxious or polluting matter to enter a river. The Act applied only to new discharges to inland waters and discharges to estuaries and coastal waters remained exempt from regulation.

The Clean Rivers (Estuaries and Tidal Waters) Act, 1960 extended the requirements to cover new discharges to tidal and estuarial waters. Again, it applied only to new or altered discharges and those discharges being made before 1960 still escaped regulation. Thus almost all of Liverpool's and the Wirral Peninsula's sewer outfalls were outside the 1960 legislation. Similarly, most of the industrial discharges, which had grown considerably after the end of World War II, also escaped regulation.

The Rivers (Prevention of Pollution) Act, 1961 extended the application of the 1951 Act to cover all discharges to inland waters, including those which had been made prior to 1951, but discharges to estuarine and coastal waters which had commenced prior to 1960 remained exempt.

The Mersey and Weaver River Authority, which was established in 1965, was given the power to implement these pollution prevention measures throughout the "Mersey Basin" and it certainly proved effective for new discharges. Improving long standing discharges was more difficult as local authorities, who controlled the sewage disposal systems, were reluctant to spend money and impose costs (via rates) on local industry. As the Board of the Rivers Authority had a large measure of local authority representation, this reluctance was transferred to that body. Despite this, progress was made and many municipal and industrial treatment plants were improved.

2.1.3 Water Act, 1973

This Act is important, not for new pollution prevention measures, but for the wholesale re-organisation of the sewage disposal (and, incidentally, the drinking water supply) industry. It removed responsibility for disposal systems from the numerous local authorities and placed them with the newly created water authorities. The Mersey came under the control of the North West Water Authority (NWWA) which was able to raise revenue specifically for sewage disposal improvement schemes.

2.1.4 Control of Pollution Act, 1974

One of the most significant steps forward in pollution control legislation was the Control Of Pollution Act (COPA), 1974. This act finally extended controls so that existing and new discharges to inland, underground, tidal or coastal waters out to the three mile limit were covered. COPA introduced public participation in decisions, established public registers of information and allowed for private prosecutions which had previously been effectively excluded. However, the full provisions of COPA did not come into force for nearly 10 years, partly due to Government worries over the economic costs of bringing in the new controls.

It was not until 1985 in the Mersey, and 1986 elsewhere, that the main measures of the Act were implemented and all discharges became the subject of legal control. Initially this control could only be exercised at the levels existing at the time, thereby preventing any further deterioration, as substantial investment was required to raise the standards of the discharges.

2.1.5 North West Water Authority

Although constrained by the inadequate legislation prior to 1985, NWWA, building upon the previous work of the Steering Committee on Pollution of the Mersey Estuary, set about establishing a strategy for bringing the region's watercourses back to an acceptable condition. As a first step, they entered into a public consultation exercise which, in 1979, established the water quality objectives for the region as:

To improve the quality of all classified watercourses in the region to at least fair standard by the year 2010 and to upgrade as much as possible of the existing fair quality water to good.

Objectives for the Mersey Estuary were also declared as:

- all parts of the Estuary should maintain a minimum of 10% saturation of dissolved oxygen at all times.

- the beaches and foreshores should not be fouled by crude sewage or solid industrial waste.

2.1.6 The Mersey Basin Campaign

In 1981, the problems of the region were brought into sharp political focus by public disorder and riots in Toxteth, an area of Liverpool, and resulted in direct intervention by the then Secretary of State for the Environment, Michael Heseltine. Problems associated with Merseyside were highlighted, including the pollution of the Estuary.

Following on from this, in November 1982, the Department of the Environment published "A consultation paper on tackling water pollution in the rivers and canals of the Mersey catchment and improving the appearance and use of their banks", and convened a "Mersey Conference" in the spring of 1983 to pursue the issues. In his foreword to the paper, the Secretary of State declared:

"But today the river is an affront to the standards a civilised society should demand of its environment. Untreated sewage, pollutants, noxious discharges all contribute to water conditions and environmental standards that are perhaps the single most deplorable feature of this critical part of England."

This consultation process resulted in the creation of "The Mersey Basin Campaign," the aims of which are to harness the efforts of public authorities, private investors end voluntary organisations to revitalise the area by concentrating efforts on water quality and bankside redevelopment. The Campaign was formally launched in 1985 and adopted the water quality objectives as determined by NWWA at an estimated cost of £4 billion for the 25 year programme. In addition, the Campaign has an objective of reclaiming the derelict and neglected land on the river banks to encourage attractive waterside developments as a stimulus for economic regeneration.

At the inauguration, Kenneth Baker, who had taken over as Secretary of State for the Environment, gave his and the Government's full support:

"In the Mersey Basin it is essential that we stop polluting the river system and remedy two centuries' abuse of both watercourses and waterfront."

The campaign has been further endorsed by Michael Heseltine who stated that:

"Individuals, authorities and businesses continue to support the Campaign because it demonstrates a responsible attitude to the environment, and because action is essential to the regeneration of the economy in this part of the country."

2.2 International Legislation

2.2.1 European Community Directives

Whilst domestic legislation has been progressively tightened, a new dimension was introduced when the United Kingdom joined the European Economic Community (EEC), now known as the European Union (EU).

The European Commission which sets the legislative programme for the EU, has recognised the potential global impact of pollution as well as the purely economic aspects of different effluent standards applying to "competitors". They have established a system of Directives which require member states to comply with certain environmental and/or discharge standards. Directives are given statutory effect in England and Wales through regulations issued under the Water Resources Act, 1991 (see Appendix 1).

Generally, the Directives establish emission standards for effluent quality from specified processes or industries and/or quality objectives. The term 'environmental quality objective' in these directives accords more closely with the meaning of the term 'environmental quality standard' (EQS) as commonly used in the UK, that is the concentration of a substance in the receiving water which must not be exceeded if the water is to be suitable for a particular purpose or use, or to achieve a certain level of protection for aquatic life. EQSs that currently apply in the Mersey Estuary are as follows:

2.2.1.1 Dangerous Substances

EQSs are set, based on toxicity, persistence and bioaccumulation, for a number of dangerous substances giving effect to the Dangerous Substances Directive (76/464/EEC). These EQSs are shown in Appendices 2 and 3. The standards must be achieved in all waters.

2.2.1.2 Bathing Waters

These standards give effect to the Bathing Water Directive (76/160/EEC). The purpose of this directive is to protect the environment and public health, to reduce the pollution of bathing waters, and to protect these waters against further deterioration. The standards relate to bacteriological and sanitary parameters. The sites nearest to the Mersey Estuary identified as bathing waters are on the Wirral at Meols, Moreton, and New Brighton, and at Formby to the north of the Estuary. A summary of compliance with the standards is shown in Appendix 4.

2.2.2 North Sea Conference Declarations

The first North Sea Conference was held in 1984, as an international forum to make policy on the reduction of pollution of the North Sea. At the second conference in 1987, the North Sea States committed themselves to reducing inputs of toxic, persistent and bioaccumulative substances to the North Sea by 50% by 1995, using 1985 values as a baseline. The UK has produced a list of 23 substances which is known as the Red list, to which these reductions must apply (see appendix 5). The UK undertook to impose this measure on all of the UK coastline, not just the North Sea.

At the third North Sea Conference in 1990, the UK, along with other participating states, undertook to apply this measure to an extended list of substances (shown in appendix 6), known as Annex 1A. Additionally, the North Sea states agreed to reduce inputs to all environmental media (i.e. air, water and land) of dioxins, mercury, cadmium and lead by 70% within the 1985-1995 period.

The declaration included an undertaking, in principle, to end dumping of polluting materials in the North Sea at the 'earliest practicable' date. The UK subsequently declared that the dumping of all sewage sludge at sea would cease by the end of 1998. Industrial waste dumping and incineration at sea ceased in 1991. In the context of the Mersey, sludges arising from effluent treatment works in the Greater Manchester area and from the new Sandon Dock facility, are currently disposed of in Liverpool Bay. In 1993, this amounted to 64,200 tonnes/year dry weight, which is approximately 50% of the sewage sludge produced in the North West region.

2.3 The Water Act, 1989 and Water Resources Act, 1991

The National Rivers Authority (NRA) was established under the Water Act, 1989. This Act was superseded by the Water Resources Act (WRA), 1991 which consolidated certain amendments arising from the Environmental Protection Act (EPA), 1990 and all other water legislation prior to the 1989 Water Act. The primary pollution control duties of the NRA specified in the WRA are the achievement of Water Quality Objectives and the assessment of pollution in controlled waters. The Act consolidates earlier pollution legislation and maintains the primary offences of discharging trade or sewage effluent to a controlled water, unless it complies with standards laid down in a consent.

2.4 The Environmental Protection Act, 1990

Part 1 of the Environmental Protection Act (EPA) introduced Integrated Pollution Control (IPC) as a new system to control discharges to all media from the most complex and polluting industrial processes. Phased implementation began in 1991 and will be complete in 1995. Her Majesty's Inspectorate of Pollution (HMIP) are the enforcing body. The main objectives of IPC are two-fold:

i) to prevent or minimise the release of prescribed substances and to render harmless any such substances which are released;

ii) to develop an approach to pollution control, based on process controls at source, that considers discharges from industrial processes to all media in the context of the effect on the environment as a whole.

No prescribed process may be operated without prior authorisation from HMIP after the date specified in the regulations. It should be noted that sewage treatment plants are not designated as prescribed processes.

2.5 Future Initiatives

2.5.1 Urban Waste Water Treatment Directive

On 21 May, 1991, agreement was reached in the Council of Ministers on a Directive concerning urban waste water treatment. The Directive sets out minimum treatment standards for sewage discharges throughout the EU. For the Mersey Estuary this means that all the significant existing sewage discharges which at best only receive settlement will, by the end of year 2000, have to have secondary treatment installed.

2.5.2 Integrated Pollution Prevention and Control

On the 30th September, 1993, the Commission of the European Communities issued a proposal for a new directive concerning Integrated Pollution Prevention and Control (IPPC).

This proposal is aimed at preventing and reducing pollution from existing industrial installations which have a major impact on the environment. The draft directive introduces a system of integrated pollution prevention and control (IPPC) which is similar to the integrated pollution control (IPC) system now operating in the UK under the Environmental Protection Act 1990.

Pollution control in many European countries has traditionally treated emissions to air, water and land separately, but has recently shown a more integrated approach since the 1987 report of the World Commission on the Environment and Development. The proposal aims to provide for the implementation of an integrated approach, achieving a high level of protection for both the environment as a whole and for human health, requiring industrial installations in specific categories with a potential to cause pollution to obtain a permit to allow them to operate. As with the UK version of IPC, the permits under this directive are to specify conditions relating to the process. Member states are required to make sure that the permit 'shall include all necessary measures to achieve a high level of protection for the environment as a whole'.

3 The processes which influence estuarine water quality

Figure 3.1: **Tide Curves in Open Sea**

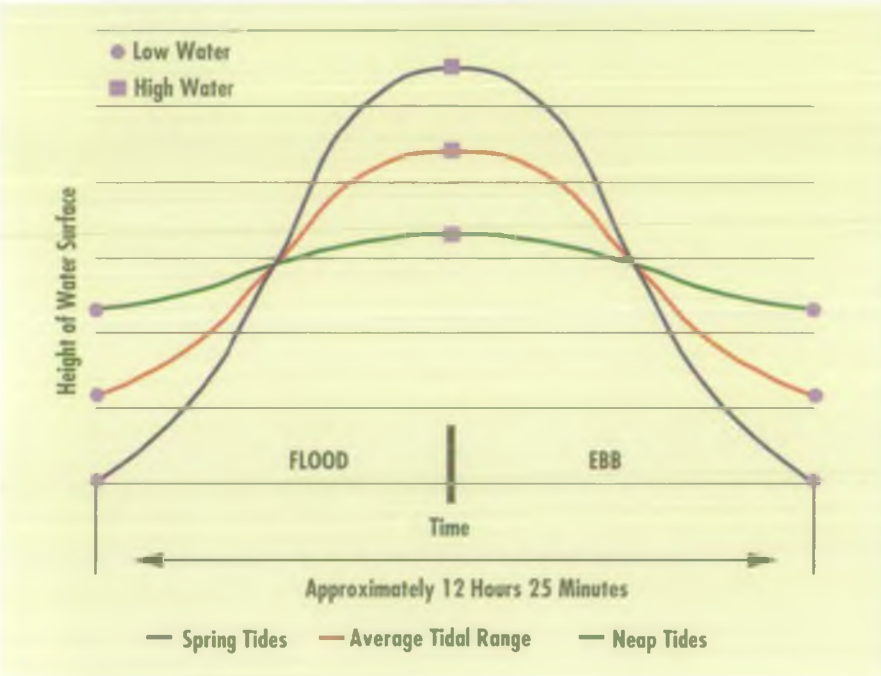
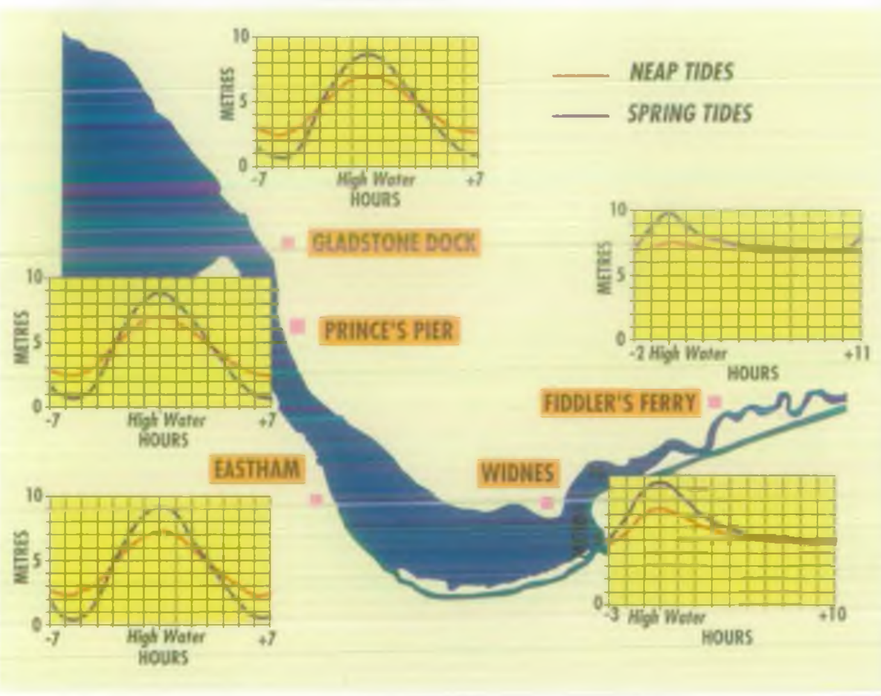


Figure 3.2: **Tide Curves in the Mersey Estuary**



3.1 Introduction

Estuaries are highly dynamic environments where waters of very different compositions meet, mix and subsequently undergo further changes induced by physical, chemical and biological processes. Whilst these are common to all estuarine systems, it is their relative magnitude and hence significance that gives each estuary its individual character.

The complex interactions between these processes determine the variations in water quality. Clearly, in order to be able to devise a sensible monitoring strategy or to assess the impact of a proposed development, a good understanding of how these mechanisms operate needs to be developed.

3.2 Physical Processes

3.2.1 Tides

The action of the tides gives rise to the most obvious difference between inland rivers and estuaries. Most people are familiar with the ebb and flow of the tide and the corresponding rise and fall in water levels. Nowadays, tidal phenomena are very well understood and the tides can be predicted with remarkable precision.

In the open sea, the water surface rises and falls so that there is almost an identical duration for both the flood and the ebb (see Figure 3.1).

In shallower water, and particularly in estuaries, the effects of friction with the bed and the shore line modify this regular pattern and the tide curves (elevation versus time) become progressively more distorted. Data from several stations from the mouth of the Mersey to the head of the Estuary demonstrate this very clearly as shown in Figure 3.2. It can be seen that as you travel inland, the duration of the flood tide becomes progressively shorter and the ebb tide longer.

There are two further important effects of friction:

i) a delay in the time of local high water moving up the estuary from Liverpool to Warrington, so that high water at Warrington occurs over 60 minutes later than at Liverpool (see Table 3.1);

Table 3.1 : **Time Differences in Minutes between Local High Water and High Water at Prince's Pier**

	MHWS	MHWN
Gladstone Dock	–9	–6
Prince's Pier	0	0
Eastham	+21	+27
Hale Head	+31	+27
Widnes	+40	+43
Fiddler's Ferry	+59	+75
Warrington	+68	–

MHWS = Mean High Water Spring
MHWN = Mean High Water Neap

ii) the height of the tide increases upstream.

For example, a tide which would rise 10m at Prince's Pier would reach nearly 11m about 1 hour later at Howley Weir, Warrington.

The tidal range on any day depends on the relative positions of the moon and the sun. Over the period of a lunar-month (28 days) there will be tides with a large range (spring tides) and tides with a much smaller range (neap tides). At Liverpool, the tidal ranges are typically between 10.5m (extreme spring) and 3.5m (extreme neap).

3.2.2 The Impact of Tides on Water Quality
The tides in the Estuary affect water quality in three important ways:

i) they move the different water bodies back and forth. This gives rise to the quite different conditions that can be observed over a tidal cycle at fixed points along the Estuary;

ii) they provide most of the energy to mix the fresh and saline water;

iii) they have a very important role in the transport of material suspended in the water and influence where different types of sediment and their associated contaminants are found.

3.2.3 Tidal Excursions
With the Mersey's long and continuing importance as a port, much information exists relating to the bathymetry and the tides. For over a century the Mersey Dock and Harbour Company and its predecessors have carried out bathymetric surveys. Similarly, detailed tidal reduction tables (giving tidal heights and times relative to predictions for Prince's Pier) have been produced by the Liverpool Observatory and Tidal Institute (now the Proudman Oceanographic Laboratory).

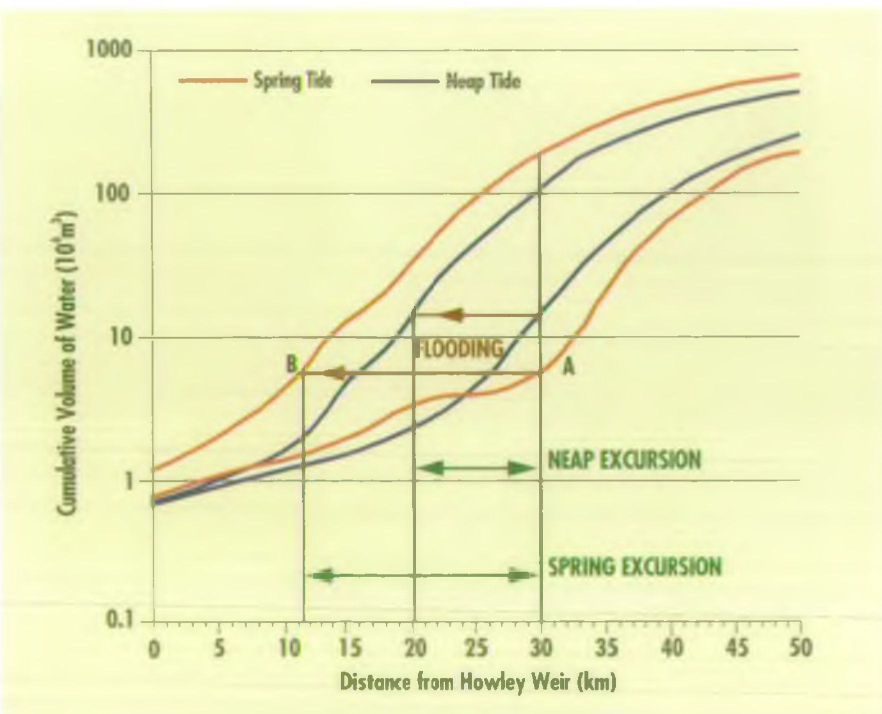
These data have been used to calculate the volume of water seawards of Howley Weir at high and low water for a spring (9.3m) and a neap (7.4m) tide as shown in Figure 3.3.[1] The volume entering the Estuary through the Narrows during these tides is $450x10^6m^3$ and $260x10^6m^3$ respectively.

In the Upper Estuary, the height of low water on a spring tide is slightly above that found at low water on a neap tide. This contrasts with the more usual situation found near the mouth of the Estuary (see Figure 3.2). The most likely explanation is that during the spring tide period there is insufficient time for the water which enters on the flood to leave on the ebb before the start of the next flood.

It is often assumed that because the water moves considerable distances and that very little actually remains in the Inner and Upper Estuary at low tide, pollutants discharged in this vicinity are rapidly carried out to sea. Unfortunately, this is not the case and materials remain in the Estuary for many days oscillating to and fro with the tide before ultimately being carried out into Liverpool Bay.

The term given to this movement of a water body between high and low waters is the tidal excursion. Figure 3.3 illustrates how the excursion varies between spring and neap tides. To help understand this, imagine that you are at point 'A', 30 kilometres downstream from Howley Weir, near Eastham. At low water on a spring tide, the upstream volume between this

Figure 3.3: **Volumes of Water Upstream of Given Points in the Estuary at High and Low Water**



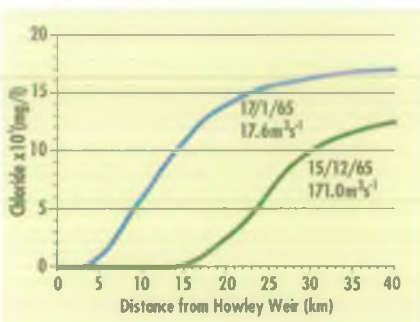
point and Howley Weir is just less than $10x10^6m^3$. If we consider that this volume remains as a single 'body' of water, where will it be at high water after it has been pushed upstream by the tide? From the diagram we can see that the 'same volume' is now found at point 'B', about 12 km from Howley Weir. This same body of water now occupies a smaller length of river and the depth of water has increased. The distance between points 'A' and 'B' gives the spring excursion of approximately 19km.

Similarly, for a neap tide the corresponding distance is 10km. The excursion for any point in the Estuary can be calculated in a similar manner.

3.2.4 Freshwater Run-off

The Mersey Basin is probably the most highly exploited catchment in the UK. Effluent from sewage treatment works and industry combine to make fresh water discharged to the Mersey Estuary of poor quality. During its passage through the Estuary, the fresh water gradually mixes with cleaner sea-water and the elevated initial concentrations of the contaminants are reduced to the much lower levels found in Liverpool Bay. Clearly, one of the factors which influences the distribution of many contaminants is the magnitude of and variation in the freshwater flow.

Figure 3.4: **Effect of Freshwater Flow on the Distribution of Salinities**



Variations in flow at Howley Weir have been reported to lie between $<10m^3s^{-1}$ and $600m^3s^{-1}$. These extreme values occur infrequently and more typical flows lie in the range $20\text{-}40m^3s^{-1}$. Increased flows will tend to move the upper limit of the saline intrusion further seawards and reduce the longitudinal gradient. Both these effects are shown in Figure 3.4 which illustrates the impact of a 10-fold increase in flow on tides of similar range.

3.2.5 The Flushing Time of the Estuary

Although tidal movements are large, pollutants in the water do not miraculously disappear when the tide goes out. They do move a considerable distance, but only to return most of the way with the next tide. Consequently it is important when considering the impact of discharges to the Estuary, to obtain an estimate of the length of time the materials spend within it before eventually being transported out to sea.

The seaward drift of the water is due to the input of freshwater at the head of the Estuary, tributaries discharging along its length and to flows from effluent outfalls. The rate with which the freshwater and associated contaminants pass out to sea will depend to a large extent on the size of estuary and the relative volume of freshwater discharged into it.

The shape of the Mersey with its narrow mouth is rather unusual. This, however, is not the reason why pollutants are only "flushed-out" relatively slowly. This depends essentially on the rate of freshwater run-off and the volume of the estuary; increased river flows leading to a more rapid replacement of the accumulated freshwater. The freshwater flow of the Mersey is relatively small for the size of the Estuary.

The flushing time has been calculated at over 30 days under normal conditions for water flowing over Howley Weir to reach New Brighton. At times of high and low flow this can be shortened to less than 20 days and increased to over 50 days.[2] The times for shorter reaches are illustrated in Figure 3.5.

Figure 3.5: **Average Flushing Times in the Mersey Estuary** [2]

Warrington to Widnes	2.0 Days
Widnes to Hale	3.5 Days
Hale to Mount Manisty	9.5 Days
Mount Manisty to Dingle	12.3 Days
Dingle to Rock Light	5.1 Days
Warrington to Rock Light	32.4 Days

3.2.6 The Behaviour of Dissolved Constituents

In the estuary mixing occurs between waters of very different chemical composition and physical properties. During the mixing process, and as the water is gradually transported seawards, the constituents present may undergo chemical transformations. A useful way of determining how the dissolved substances react is to compare their behaviour with that of a substance which does not undergo any chemical changes, i.e. behaves 'conservatively'.

The frequently used conservative parameters are the chloride concentration or the salinity. When the concentration of a constituent is plotted against the conservative parameter, which is a measure of the relative proportions of fresh and salt water and is only subject to physical mixing, the resultant plot will be a straight line (see Figure 3.6).

The slope of the line will be either positive or negative depending on whether the substance is more concentrated in the sea water or fresh water respectively. Any significant deviations above the line indicate addition of the substance from external sources or in-situ production. A deviation below the line indicates removal from the water. Some examples are presented in the following section.

3.3 Chemical Processes

3.3.1 Types of Chemical Reaction

The chemical reactions taking place in the river essentially fall into two categories:

i) those which are abiotic (i.e. are not influenced by living organisms);

ii) those which are biologically mediated.

In the first category are processes which are the consequence of changes in the physico-chemical properties of the water, such as the increase in the ionic strength and variations in pH. These include the removal of, and changes in the speciation of, some dissolved metals. The classic example frequently studied is the removal of soluble iron from the river water which occurs in the early stages of mixing with saline water.

Biologically controlled reactions have received most attention in the last 20 years as they, almost exclusively, determine the oxygen balance in the river. These are presented in more detail below.

3.3.2 Oxygen Demanding Reactions

When organic matter, in sewage or from industrial sources, is discharged to a watercourse there is a reduction in dissolved oxygen content in the receiving water. This is because bacteria in the receiving water and effluent use oxygen to break down the organic matter in the discharge. The organic content, and hence the polluting potential of a discharge, is measured in terms of Biochemical Oxygen Demand (BOD). Experimental evidence indicates that it takes several days for many of the effluents studied to be completely broken down. Due to the long residence time mentioned earlier, a large proportion of this BOD will be satisfied before the diluted effluents are flushed out to sea.

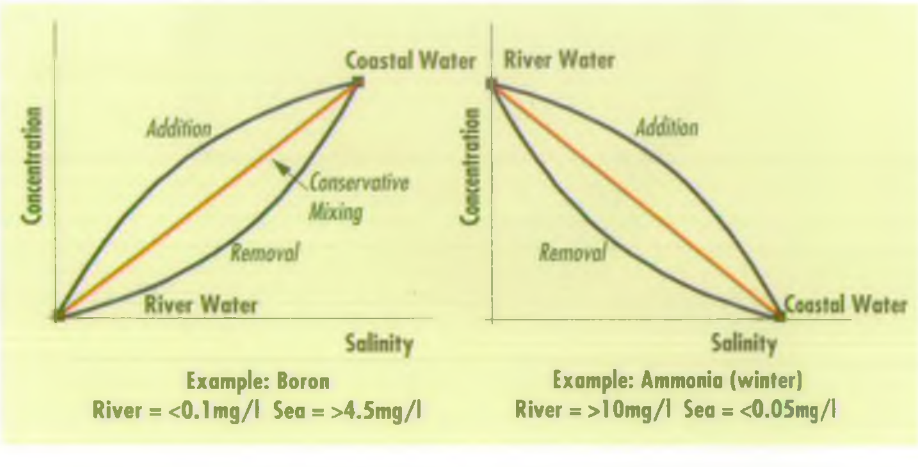
Sewage and many industrial wastes contain ammonia. Microbiological processes oxidise the ammonia, further depleting dissolved oxygen. This process is called nitrification.

The kinetics of these oxygen determining reactions were studied in detail as part of a comprehensive investigation into the pollution of the Thames Estuary.[3] The findings of this work were later utilised in the early 1970s during the development of a mathematical model to simulate the prevailing conditions in the Mersey.[1]

Regular monitoring of the Estuary over the last two decades revealed that our understanding of the oxidation of ammonia, either discharged as such or produced in-situ (by the hydrolysis of organic nitrogen compounds), was not adequate and needed to be improved. Accordingly, a detailed study of the kinetics of nitrification has recently been undertaken on behalf of the NRA.[4]

In addition to its importance in removing oxygen from the water, ammonia can be toxic to fish and other marine life. Levels of unionised ammonia, the toxic form, are governed by pH, salinity and temperature.

Figure 3.6: **Behaviour of Dissolved Constituents during Mixing**



Moreover, ammonia, along with phosphorus and silica, is a nutrient stimulating primary productivity. This is a photosynthetic process by which energy from the sun converts carbon dioxide (CO_2) into carbon compounds and releases dissolved oxygen (O_2) to the water.

3.3.3 Temporal Variations in the Oxygen Regime

The dissolved oxygen content of the water varies considerably at all points along the estuary. These differences are significant on three distinct time-scales:

i) seasonal

ii) inter-tidal (between neap and spring tides)

iii) intra-tidal (during a single tidal cycle)

3.3.3.1 Seasonal Effects

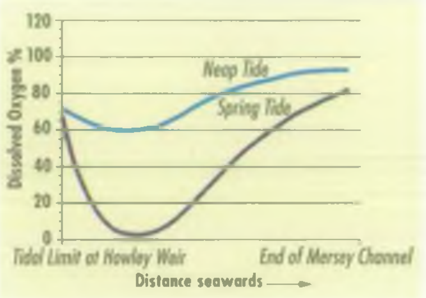
The most obvious seasonal differences in the Estuary are reflected in the water temperatures. The temperature of the water is important since it affects the rotes of chemical reactions, influences the rate at which oxygen is dissolved from the atmosphere and determines the absolute amount of oxygen that can be dissolved in water of a given salinity. Thus, even in the absence of oxygen demand from organic matter, the maximum dissolved oxygen concentrations will be lower in summer than in winter. With the additional effects resulting from the degradation of organic matter from effluent discharges, the oxygen concentrations are substantially worse in the summer months than in winter. The term given to a reduction in dissolved oxygen is an 'oxygen sag'. Even though there have been reductions in effluent loads in recent years, anoxic conditions still occasionally prevail, albeit over smaller reaches than in former times.[5]

3.3.3.2 Inter-tidal Differences

Since the late 1970s, intensive water quality surveys have been carried out at approximately two-month intervals from early spring to late autumn. The prime aim of this work was to observe and rationalise the differences in quality occurring over a complete tidal-cycle at several fixed points along the whole length of the Estuary.

Water samples were collected to provide information on both neap and spring tides. On all occasions, significantly higher dissolved oxygen concentrations were observed during the neap tide (see Figure 3.7). If we assume that most of the influencing factors such as river flows, temperature profiles and effluent loads were reasonably constant, then it would appear that the marked differences seen in the surveys were 'tidally-induced'.

Figure 3.7: **Typical Observed Differences in Dissolved Oxygen Between Spring and Neap Tides**

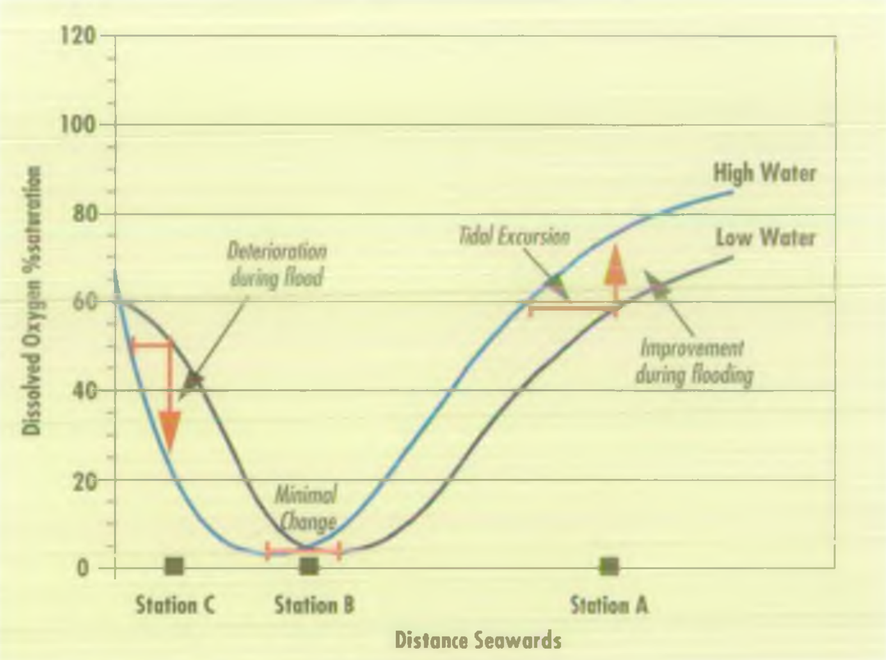


The intriguing question then is "by what mechanism does this take place?" Other observations revealed that the material in suspension was vastly different during the respective tidal-cycles with very much higher concentrations in the water during spring tides. Some of the resuspended material has a significant organic content and is therefore acting as an enhanced oxygen demand on the system. This "sediment oxygen demand" appears to be discernible, to a greater or lesser degree, at most times of the year.

3.3.3.3 Intra-tidal Differences

The fundamental consequence of tidal advection is that observers sited at fixed points along the Estuary will witness the passage of different bodies of water during the tidal cycle. How this manifests itself to the surveyors can be appreciated by consideration of the idealised data for a polluted estuary presented in Figure 3.8. Near to the mouth of the estuary (Station A) the flood tide brings water with a higher oxygen content from further off-shore past the observer. The dissolved oxygen reaches a peak at high-water and then returns to the low-water condition as the tide ebbs.

Figure 3.8: **Effect of Tidal Advection on Dissolved Oxygen Levels**



In the middle reaches (Station B) there are minimal changes over the cycle with very poor quality at all states of tide.

Towards the head of the estuary (station C), as the tide comes in there is a pronounced deterioration in dissolved oxygen. These results emphasise the importance of careful planning when devising monitoring programmes. Since 1980, the majority of routine surveys of the Mersey Estuary have been carried out on spring tides at monthly intervals to monitor the conditions when the dissolved oxygen concentrations are anticipated to be at a minimum.

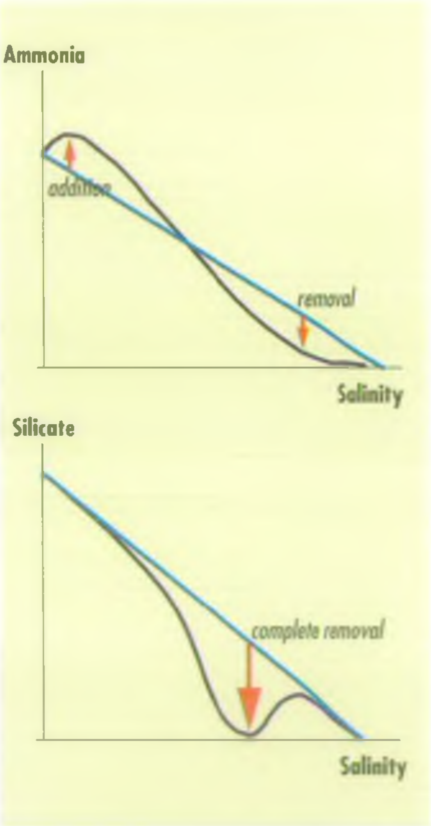
3.3.4 Primary Production and Nutrient Dynamics

In the winter months, the effects of biological activity are insignificant due to the low temperatures and limited light. Dilution plots of ammonia and silicate exhibit very little deviation from conservative mixing lines. A decade ago it was believed that primary production was of little or no relevance in the Mersey upstream of the "Narrows", even in the summer. It was felt that the water was either too turbid or too heavily polluted to sustain a healthy phytoplankton population.

Data from recent tidal-cycle surveys have shown that this is not the case. On occasions in the middle reaches (Eastham to Widnes), there have been plankton blooms during neap tides, when the suspended load is reduced and the clarity of the water improved. Plots of ammonia and silicate in Figure 3.9 show removal from solution.

In the case of silicate, there has been at least one occasion of total removal from the water in this part of the river. The removal of ammonia was almost certainly the result of nitrification by bacteria and also probably due to uptake by the diatoms. The diatoms would have been solely responsible for the removal of silicate. During these blooms it was also observed that the dissolved oxygen was in excess of the saturation value.

Figure 3.9: **Typical Ammonia and Silicate Depletion Patterns during a Plankton Bloom**



3.4 Summary

The tides are fundamental to water quality in the Mersey Estuary.

Even though water bodies are moved considerable distances during each tidal cycle, pollutants discharged to the Upper and Inner Estuary may remain within the Estuary for several weeks.

The rate at which pollutants leave the Estuary is termed the 'flushing time' and is predominantly governed by the freshwater flow.

If dissolved constituents are 'conservative', their concentrations are governed by the freshwater mixing with the saline water. In other cases, constituents may be added to or removed whilst within the Estuary.

Dissolved oxygen is crucial to water quality as it is vital to the biological health of the Estuary. Values vary greatly both spatially and on a number of time-scales. The most pronounced oxygen sags are found during the summer spring tides, with much better conditions observed during the corresponding neaps.

CHAPTER 4

4 Pollution of the Mersey Estuary

4.1 Introduction

Pollution of the Mersey Estuary can be attributed to inadequate sewage treatment facilities; intermittent discharges from combined sewer overflows; industrial discharges, and run-off from agriculture and contaminated land. These problems are not new and, perhaps surprisingly, they have been recognised for many years. The discharge of crude sewage and industrial effluents has caused considerable concern for well over a century. Indeed as long ago as 1848, the Borough Engineer of Liverpool reported that:

"the whole of the sewage is still thrown into the river, much of it indeed, into the basins and all of it at such points as to act very prejudicially on the health of the town."

This chapter summarises reductions in input loads of organic pollution (as measured by BOD, ammonia and dissolved oxygen), heavy metals, and certain dangerous substances discharged to the Estuary from rivers, crude or treated sewage, and industrial discharges.

4.2 Biochemical Oxygen Demand

Sewage contains waste waters of domestic origin, effluent from industrial and trade processes and urban run-off (drainage from roads etc.). The various types of sewage treatment are shown in Table 4.1.

The benefits of the various types of treatment in terms of BOD removal are shown in Table 4.2.

Since the mid 1980s, discharges from crude sewers in the Widnes, Warrington and Liverpool areas have been progressively diverted to sewage works affording at least primary treatment. The BOD load discharged to the Estuary is shown in Figure 4.1

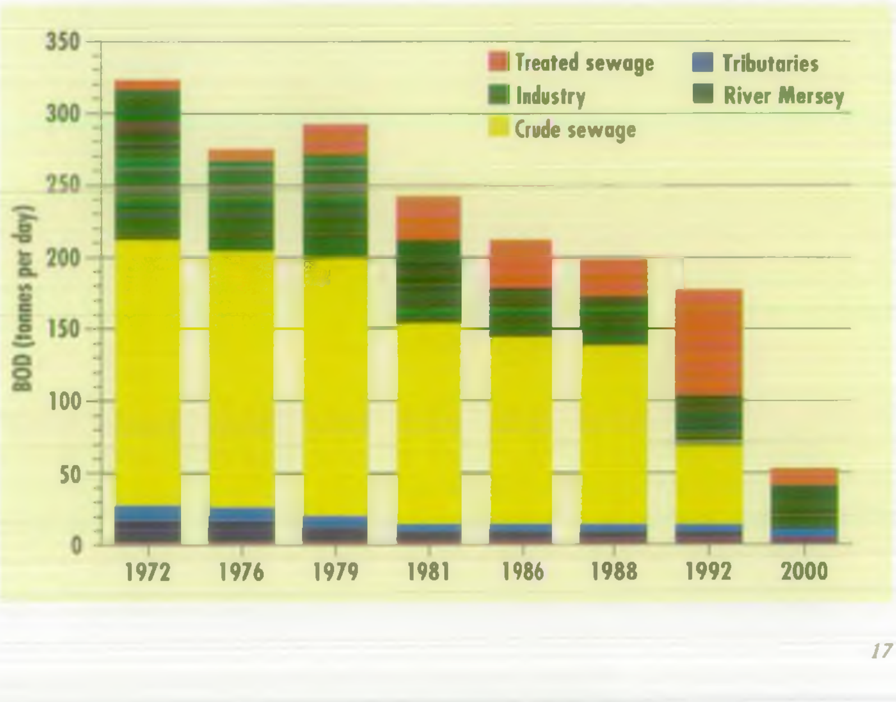
Table 4.1: **Types of Sewage Treatment**

Sewage Treatment	
Stage	Process
Preliminary	Screening to remove gross solids
Primary	Precipitation or settlement of organic and other matter
Secondary	Biological treatment
Tertiary	Any further stage including filtration, nutrient removal or disinfection

Table 4.2: **Biochemical Oxygen Demand Reductions through Sewage Treatment**

Type of Treatment	Typical BOD Reduction
Preliminary	5%
Primary	30-40%
Secondary	90-95%

Figure 4.1: **Biochemical Oxygen Demand, Mersey Estuary**



4.3 Ammonia

Improved process control at industrial sites has reduced the direct input of ammonia to the Estuary so that the dominant input is from the non-tidal Mersey. Figure 4.2 shows the reductions made in recent decades. A further stepwise reduction will occur once nitrification is installed at Davyhulme STW, Manchester.

4.4 Dissolved Oxygen

At sites between Widnes and Warrington, reductions in BOD and ammonia loads to the Estuary have resulted in an impressive increase in dissolved oxygen concentration. Despite this substantial improvement, zero dissolved oxygen levels can still be found in certain circumstances. Improvements in water quality at Howley Weir can be seen in Figure 4.2. Minimum dissolved oxygen levels within the Estuary occur on spring flood tides when the high tidal velocities resuspend organic-rich sediments.

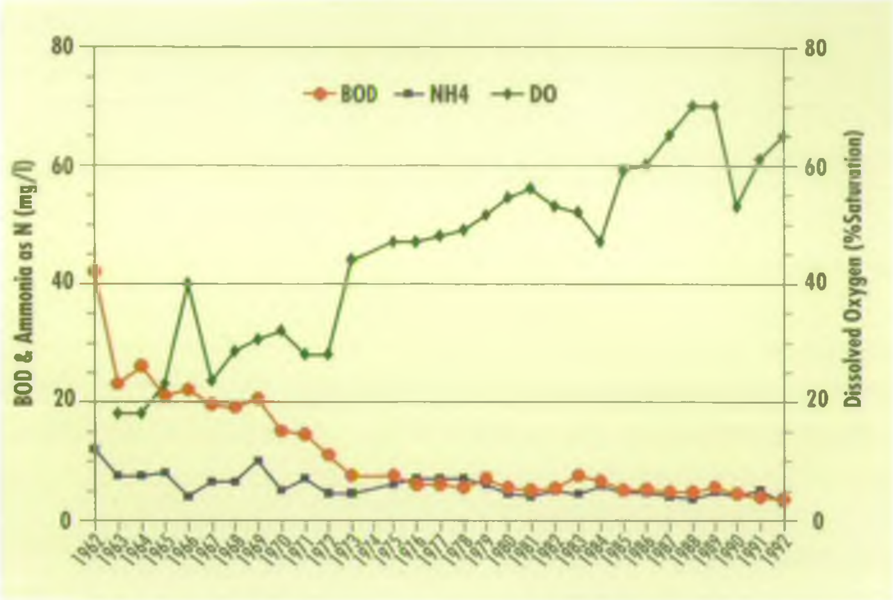
4.5 Heavy Metals

4.5.1 Mercury

The major source of mercury entering the Estuary is from the substantial chlorine production facilities situated in Runcorn and Ellesmere Port. Most of these are chlor-alkali plants which produce chlorine by the electrolysis of brine. Much chlorine production on the Estuary is still largely based on the flowing mercury cathode cell. Waste brine from the process becomes significantly contaminated with mercury.

Since the early 1970s, when scientific attention was focused on the impact of mercury on the environment, there has been substantial investment by industry to reduce the amount of mercury discharged to tidal tributaries of the Mersey Estuary. The largest producer of chlorine in the UK is ICI, with its main manufacturing base at Runcorn. A £25 million investment in improved effluent treatment processes to reduce the quantity of mercury discharged in waste brine has brought about a dramatic reduction in the amount of mercury discharged over the past 15 years. In the mid-1970s, the load of mercury discharged from the ICI Runcorn site was estimated to be nearly 60 tonnes/year (te/yr); this has been progressively reduced and the Company now discharge less than 1.0 te/yr.

Figure 4.2: **Improvements in Water Quality at Howley Weir (Mean Annual Values)**



Another chlor-alkali plant discharging mercury was that of Associated Octel at Ellesmere Port, which discharged approximately 0.3 te/yr of mercury to the tidal Manchester Ship Canal. This has been replaced by a £10m membrane cell chlorine plant, which is a mercury free process. The reductions in input loads of mercury from chlor-alkali plants to the Estuary and its tidal tributaries are shown in Figure 4.3.

Although there has been a substantial reduction in the amount of mercury discharged to the

Figure 4.3: **Reductions in Load Inputs of Mercury to the Mersey Estuary from Chlor-Alkali Plants**

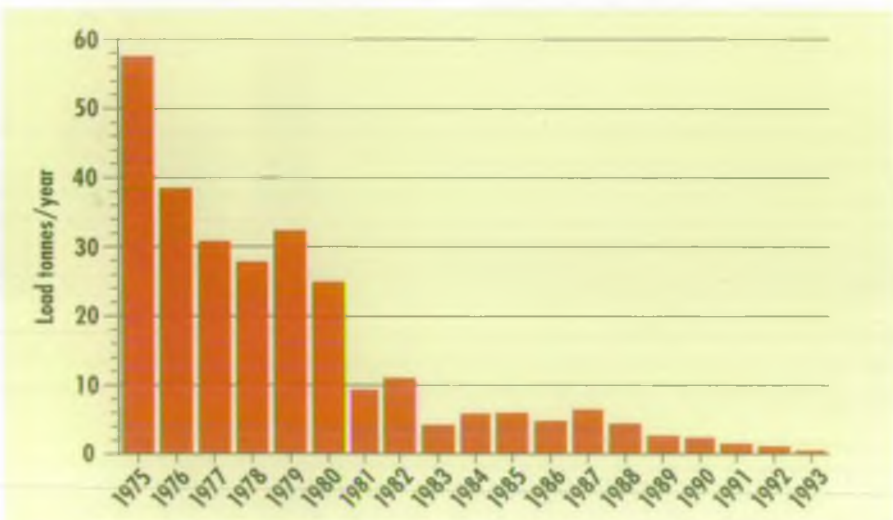


Plate 4.1: **ICI Runcorn, overlooking the Mersey Estuary**

Estuary , there remains an accumulated reservoir of mercury in Estuary sediments (Figure 4.4). The apparent increase in concentration between 1987 and 1992 may be due to movement of the low water channel, cutting into and exposing older sediments which were laid down when the load to the Estuary was higher. A small but significant proportion of this mercury is present in the methylated form which is accumulated in biota.[6]

Certain species of fish such as eels and flounder taken from sites within the Estuary contain levels of mercury which exceed recommended limits for contaminants in fish. Long lived fatty species such as eels, which feed on organisms present in Estuary sediments, are particularly likely to accumulate pollutants such as mercury in their body tissues whilst resident in the Estuary. Data showing the levels of mercury and lead present in fish taken from Inner Estuary sites, at Eastham and New Brighton, are shown in Figure 4.5.[7]

Some of the mercury levels recorded for flounder, and for eels in particular, exceeded the 0.5mg/kg and 1.0mg/kg standards specified in the recently adopted European Community Decision (93/351/EEC) which sets maximum limits for mercury in fishery products (see section 6.2.2).

Figure 4.4: **Mercury in Mersey Estuary Sediments** ***(normalised to 40% silt)***

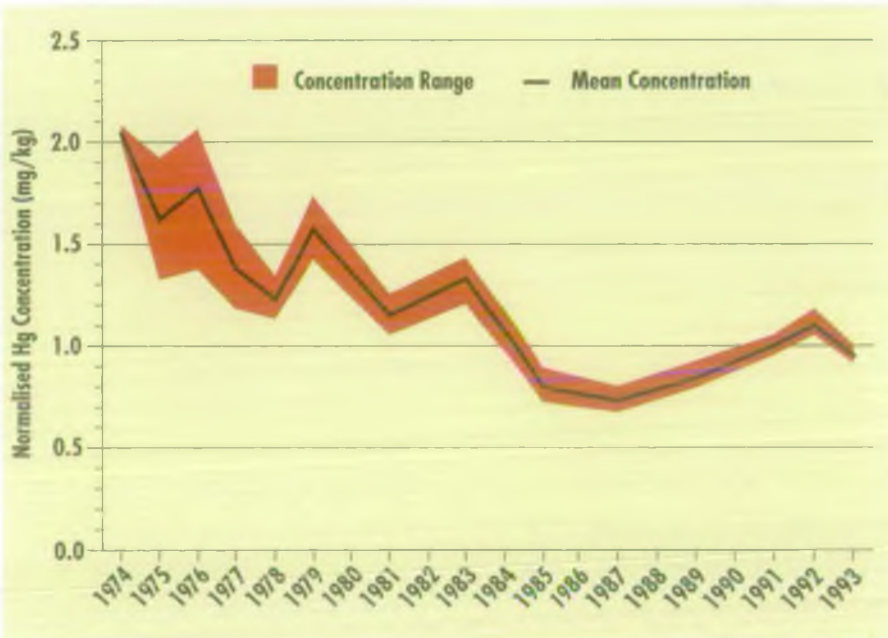
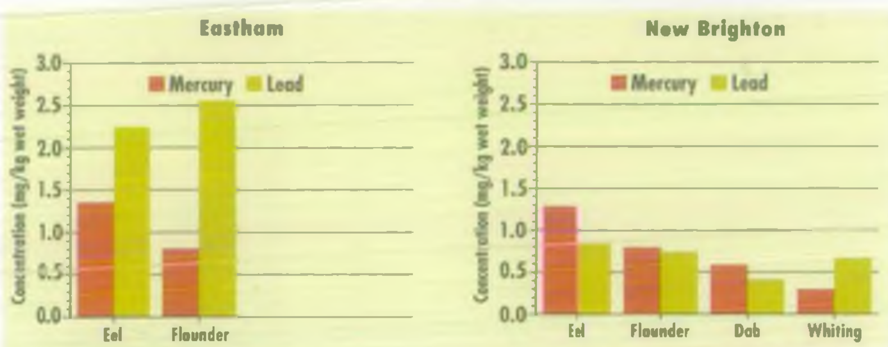


Figure 4.5: **Mercury and Lead in Mersey Fish, 1992-93** ***(Normalised to 40% silt)***



4.5.2 Lead

An environmentally significant discharge of lead to the Estuary is from the manufacture of tetra-alkyl lead compounds by Associated Octel at Ellesmere Port, for use as anti-knock agents in petrol. This discharge is unusual in containing stable, water soluble, organic lead species.

Organic lead was implicated in a major mortality of over wintering birds in 1979. Unusual flow conditions resulted in a build-up of soluble lead in the Manchester Ship Canal, which was flushed to the Estuary as a shock load, and entered the food chain.

Lead levels in eel and flounder taken from Eastham in 1992/3 showed the average exceeded the 2.0mg/kg wet weight standard for fish specified in the Lead in Food Regulations 1989.

4.5.3 Cadmium

Substantial reduction in inputs of cadmium to the Estuary has been achieved since implementation of an EC directive in 1985 which required discharges of cadmium to be controlled. Reductions have been achieved as a result of better operational practices, use of alternative specifications, alternative disposal methods and better regulation.

In 1985 there were 10 industrial concerns, mainly electroplaters, discharging cadmium to the Estuary via untreated sewers.

Table 4.3: **Estimated Loads of Cadmium Discharged to the Estuary**

Year	tonnes/year
1985	0.282
1988	0.091
1991	0.052

4.5.4 Other Heavy Metals

Table 4.4 lists reductions of other 'heavy metals' from direct industrial discharges to the Mersey Estuary. There are few remaining major point sources of these metals, and the input to the Estuary is dominated by the non-tidal riverine contributions. Historical records of metals in dated salt marsh sediment cores from the Mersey Estuary are shown in section 4.7.

Table 4.4: **Causes for Reduced Discharges of some Heavy Metals to the Mersey Estuary**

Nickel	Reduced use as a hydrogenation catalyst
Zinc	Reduced use as a corrosion inhibitor Clean up of effluent by flocculation or hydroxide precipitation techniques
Chromium	Reduced use as a corrosion inhibitor Reduction in chrome plating industry
Copper	Reduced use of copper for cable manufacture Use of aluminium conductors, and fibre optic cables

4.6 Organic Pollutants

4.6.1 Pentachlorophenol

A major industrial source of pentachlorophenol (PCP) in the North West is textile finishing where PCP has been traditionally used as a rot-proofing agent after the bleaching and dyeing process.

Most of the textile finishing firms within the region are based in East Lancashire and discharge their trade effluents to sewer. In 1988, when an EC directive controlling PCP discharges came into force, it became apparent that a number of watercourses, downstream of sewage treatment works receiving textile finishing wastes, were failing to meet the required environmental quality standard (EQS).

Discussions with the industry led to changes in working practices at sites to minimise losses of PCP; improved flow balancing; off site disposal of spent liquors; and in some cases, cessation of use. These actions resulted in lower concentrations of PCP entering sewers and rivers downstream of the receiving sewage works.

A further problem was identified in that substantial amounts of PCP were present in the scour liquors from the raw cloth, much of which was imported to the UK from the Far East.

Figure 4.6: **River Irwell - Pentachlorophenol EQS Monitoring**

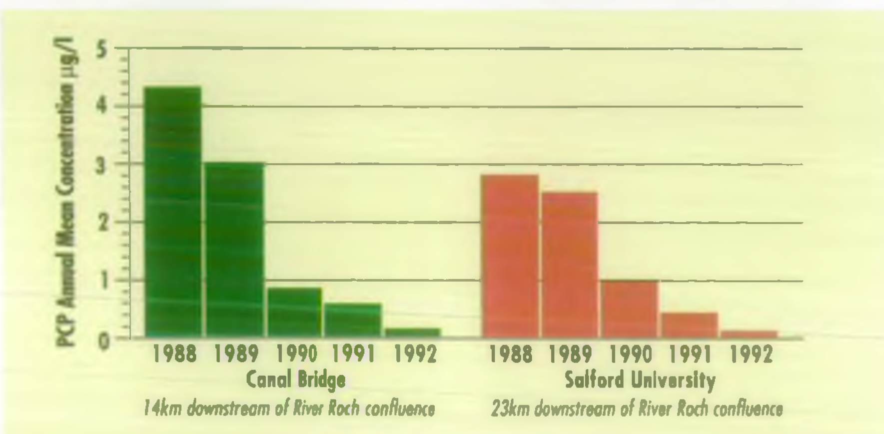
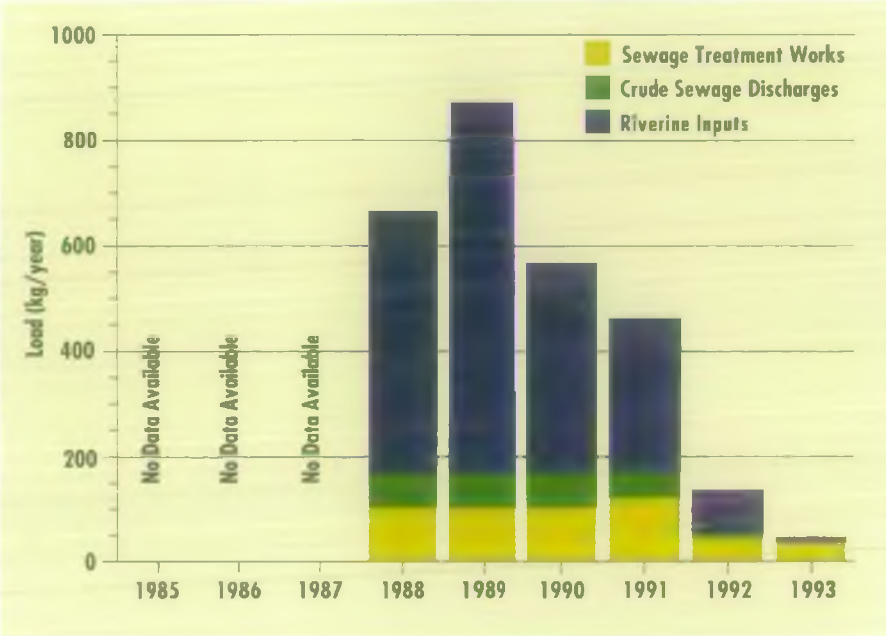


Figure 4.7: **Inputs of Pentachlorophenol to the Mersey Estuary**

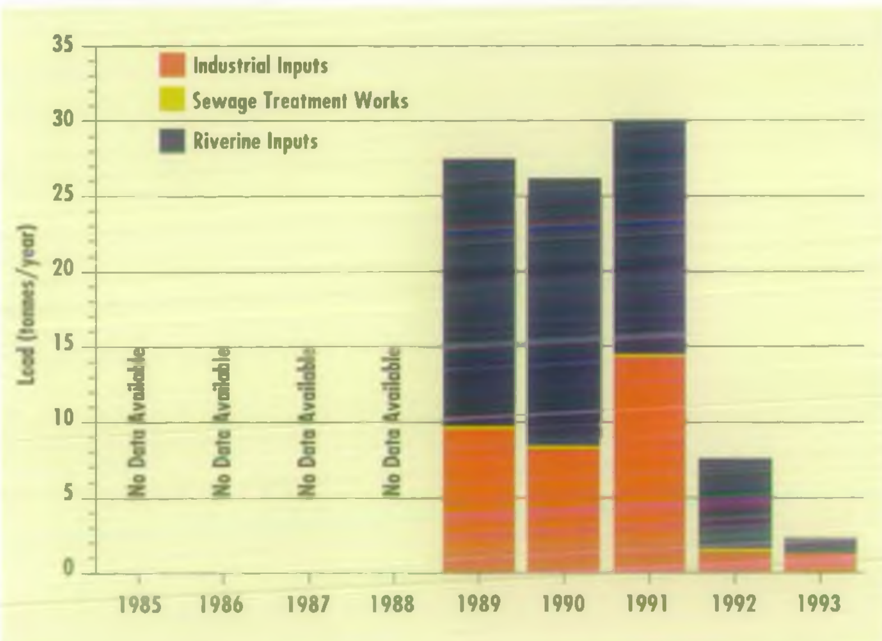


Pressure brought by the textile finishing industry on importers has resulted in better control over the levels of PCP in imported cloth.

These improvements have resulted in the rivers Roch and Irwell complying with the EQS. Further downstream, a significant reduction in the amount of PCP discharged to the Mersey Estuary can be demonstrated. In 1988 an estimated 900 kg/yr of PCP entered the Estuary compared with 180kg/yr in 1992.

Monitoring for PCP first commenced in 1988 and load input reductions to the Mersey Estuary since this time are shown in Figure 4.6 and 4.7.

Figure 4.8: **Inputs of Carbon Tetrachloride to the Mersey Estuary**



4.6.2 Carbon Tetrachloride

The manufacture of Alloprene, a chlorinated rubber, was a major use of carbon tetrachloride. Closure of processes for the manufacture of Alloprene at ICI Widnes and ICI Lostock, together with the cessation of manufacture of carbon tetrachloride at ICI Runcorn in 1992, has substantially reduced the load discharged to the Mersey Estuary.

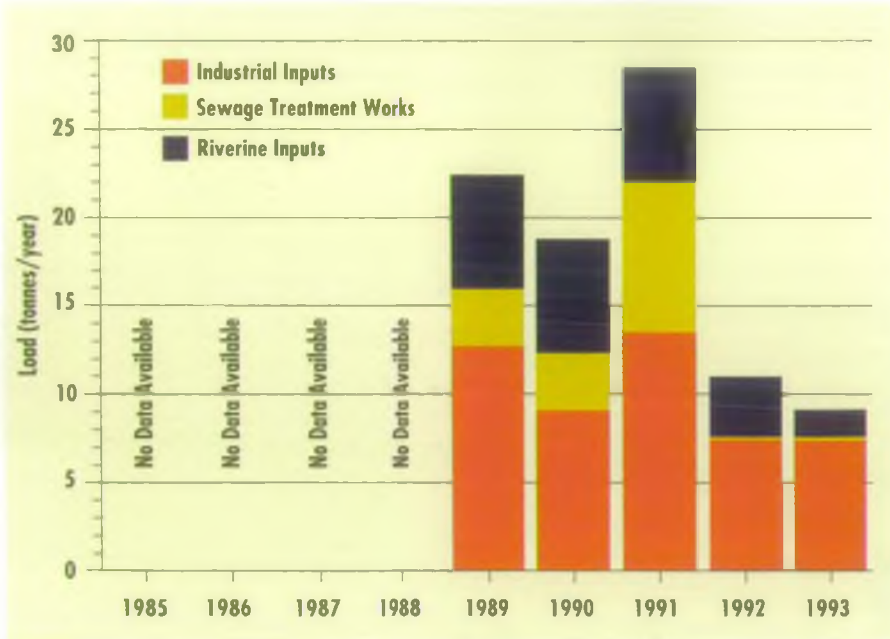
The reductions in input loads of carbon tetrachloride discharged to the Mersey Estuary have reduced from an estimated load of 26 te/yr in 1989 to considerably less than 5 te/yr in 1993. These reductions are shown in Figure 4.8.

4.6.3 1,2-Dichloroethane

Dichloroethane (DCE) is a commonly used solvent. It is also used in the chemical manufacture of vinyl chloride and tetra-alkyl lead compounds. There are three significant discharges of DCE to the Mersey Estuary: ICI Runcorn where it is manufactured, Associated Octel where it is used in the manufacture of alkyl lead compounds, and Halewood sewage treatment works which receives a trade effluent containing DCE.

Various effluent improvement programmes, usually involving lagoon treatment prior to discharge, have significantly reduced the amount of DCE discharged to the Mersey Estuary. In 1993 less than 10 te of DCE was discharged to the Estuary compared with 22 te in 1989. These reductions are shown in Figure 4.9.

Figure 4.9: **Inputs of 1,2-Dichloroethane to the Mersey Estuary**



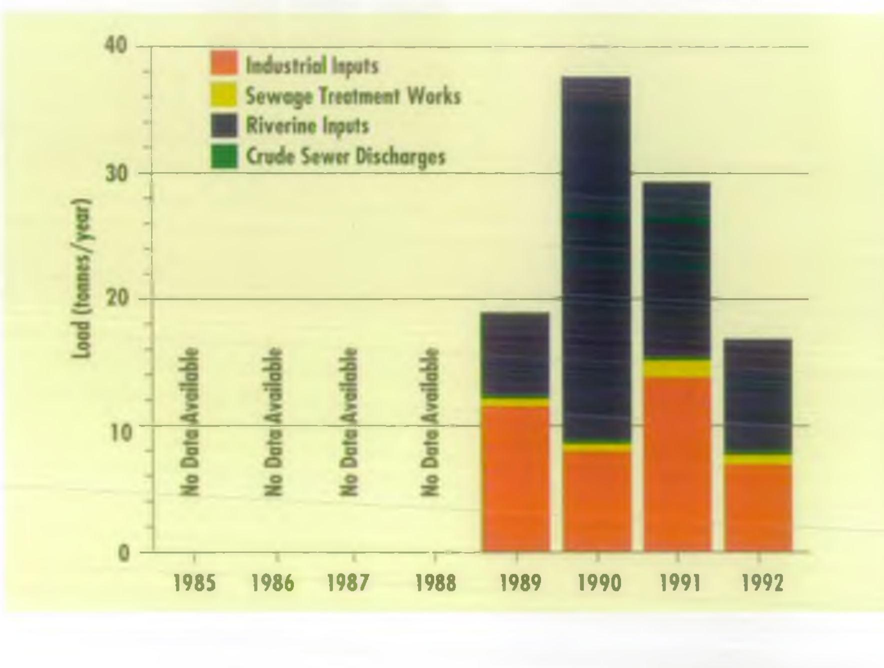
4.6.4 Other Chlorinated Hydrocarbons

Other significant discharges of chlorinated hydrocarbons (CHCs) to the Mersey Estuary include perchloroethylene, trichloroethylene and chloroform. The major source of these substances is the chlorinated organics production unit at ICI Runcorn. In recent times, the effluent discharged from the chloromethanes plant has been diverted to lagoon. This, coupled with improved housekeeping, has brought about a reduction in the amount of CHCs discharged.

Further improvements are expected following the Company's decision to install a packed tower air stripping facility to remove CHCs from their effluent. The resulting vapour will be burnt in an incinerator. Planning permission and IPC authorisation have recently been granted for this £32 million project which is expected to reduce current CHC emissions by 90%. This will include proportionate reductions in the quantities of hexachlorobenzene, hexachlorobutadiene and trichlorobenzene released, since these substances are present as impurities in the chlorinated solvents discharged.

Changes in the amount of chloroform discharged to the Estuary since 1989 are shown in Figure 4.10.

Figure 4.10: **Inputs of Chloroform to the Mersey Estuary**



4.7 Historical Records of Metals in dated Salt Marsh Sediment Cores

Between 1992 and 1994, the Industrial Ecology Research Centre at Liverpool University and the Westlakes Research Institute in Cumbria conducted a detailed study of sediment core profiles recovered from the Mersey Estuary in order to examine the historic deposition of trace metals.

Sediment cores to depths of 1 metre were collected using specialised power driven corers. These samples were subsequently sub-divided into 3cm units prior to analysis and dating by radiometric methods. A relationship was built up between the deposition of metal contaminants and contemporary industrial activity, enabling a qualitative picture to be developed of the metallic emissions record of the Mersey region as far back as 1860.

The pollutant pattern is remarkably informative and individual historical events can be determined accurately from the metals' signature. For example, the initiation of copper smelting in the north-west in 1870, the deployment of mercury cathodes for the commercial production of chlorine on Merseyside in 1897, the rise in commercial importance of zinc as a corrosion protection agent for steel products in the 20th century, and the turn-of-the-century output of arsenic as a pollution by-product of smelting copper concentrates from South-West England and the Americas can all be traced in the sediment cores.

Details showing the concentrations of metals in core samples taken from Widnes Warth are shown in Figures 4.11 and 4.12.

Figure 4.11: **Concentration of Metals in Widnes Warth Core Sample 1**

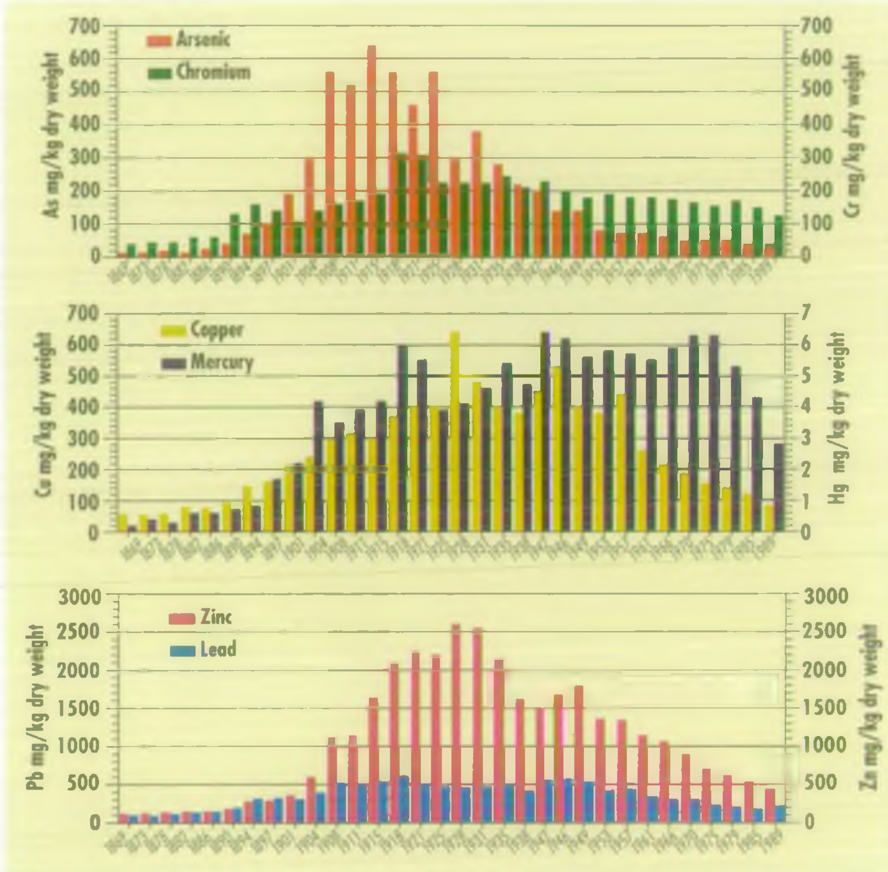
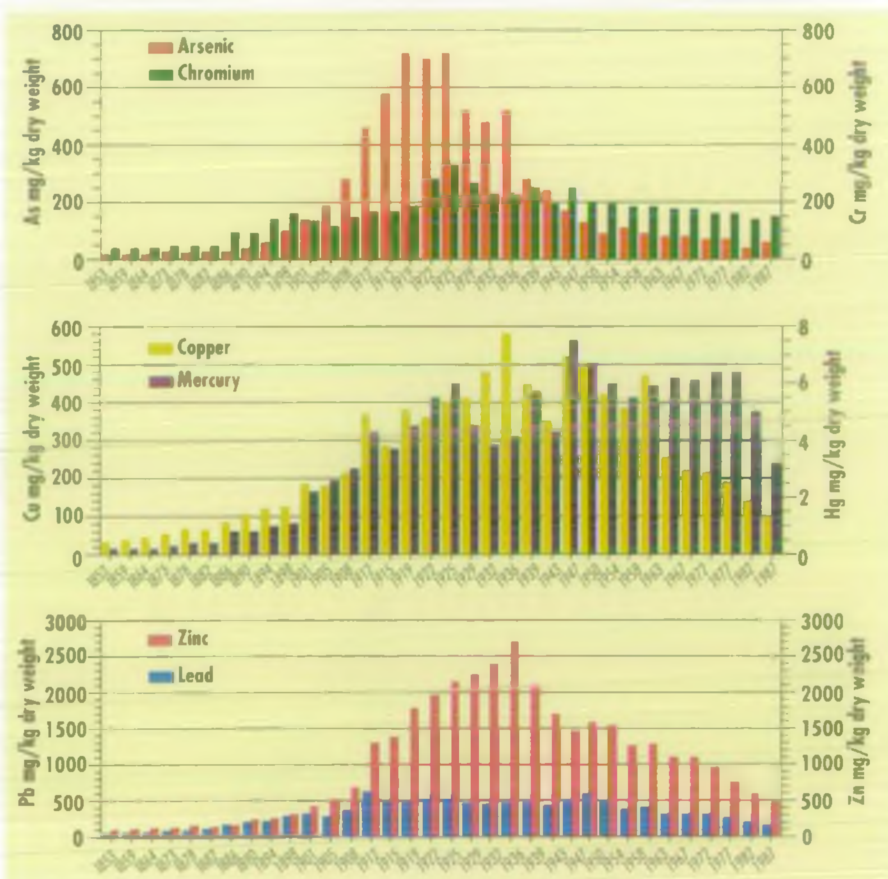


Figure 4.12: **Concentration of Metals in Widnes Warth Core Sample 2**



CHAPTER 5

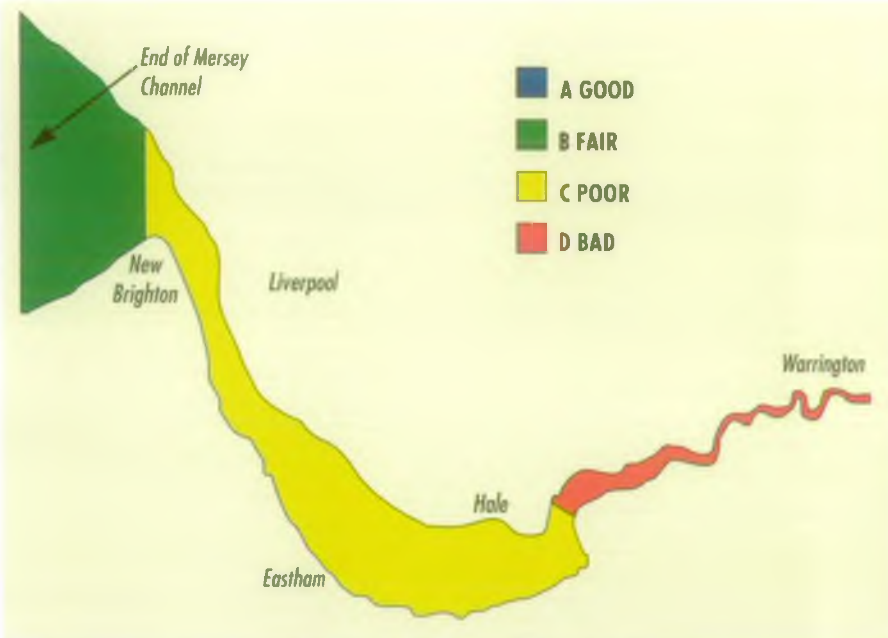
5 Quality status of the Mersey Estuary

5.1 Estuary Classification

Estuaries are classified on the basis of quality, according to the scheme devised by the Department of the Environment and the National Water Council. The scheme is highly subjective and classifies estuaries into good, fair, poor, and bad quality classes (A-D) based on points awarded under the headings of biological, aesthetic, and chemical quality. The scheme is currently being re-evaluated by a NRA national working group.

The Mersey is predominantly of poor (class C) and bad (class D) quality as shown below.

Figure 5.1: **Mersey Estuary Classification**



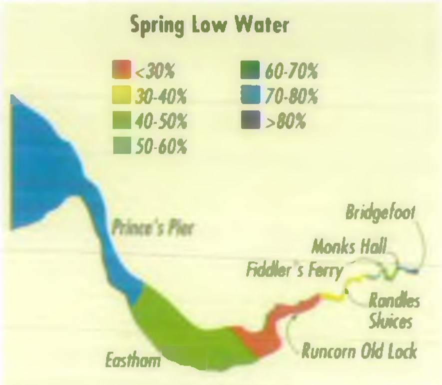
Class	Length (km)	Stretch
Good (A)	-	-
Fair (B)	23.8	New Brighton to end of Mersey Channel
Poor (C)	26.2	Hale Head to New Brighton
Bad (D)	20.6	Warrington to Hale Head

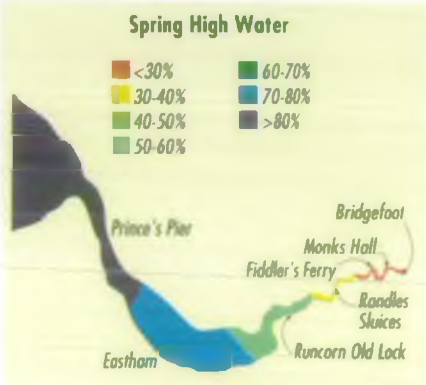
5.2 Dissolved Oxygen

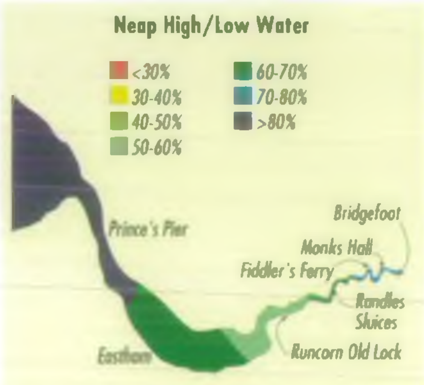
As long ago as 1976, North West Water set the objective of eliminating Dissolved Oxygen values below 10% within the Estuary. As stated in chapter 3, the tide has a large influence on both the minimum values to be found, and where they are to be located. Figure 5.2 shows typical values measured within the Estuary during 1993. On spring tides, large differences exist between high and low water. Because of the similarity between values found at high and low water on a neap tide, one map covers both situations.

It is clear that despite the reductions in effluent loads over recent years, substantial stretches of the Estuary still develop a marked oxygen 'sag' at certain states of tide. On occasion, these develop into anoxic conditions.

Figure 5.2: **Dissolved Oxygen Profiles**



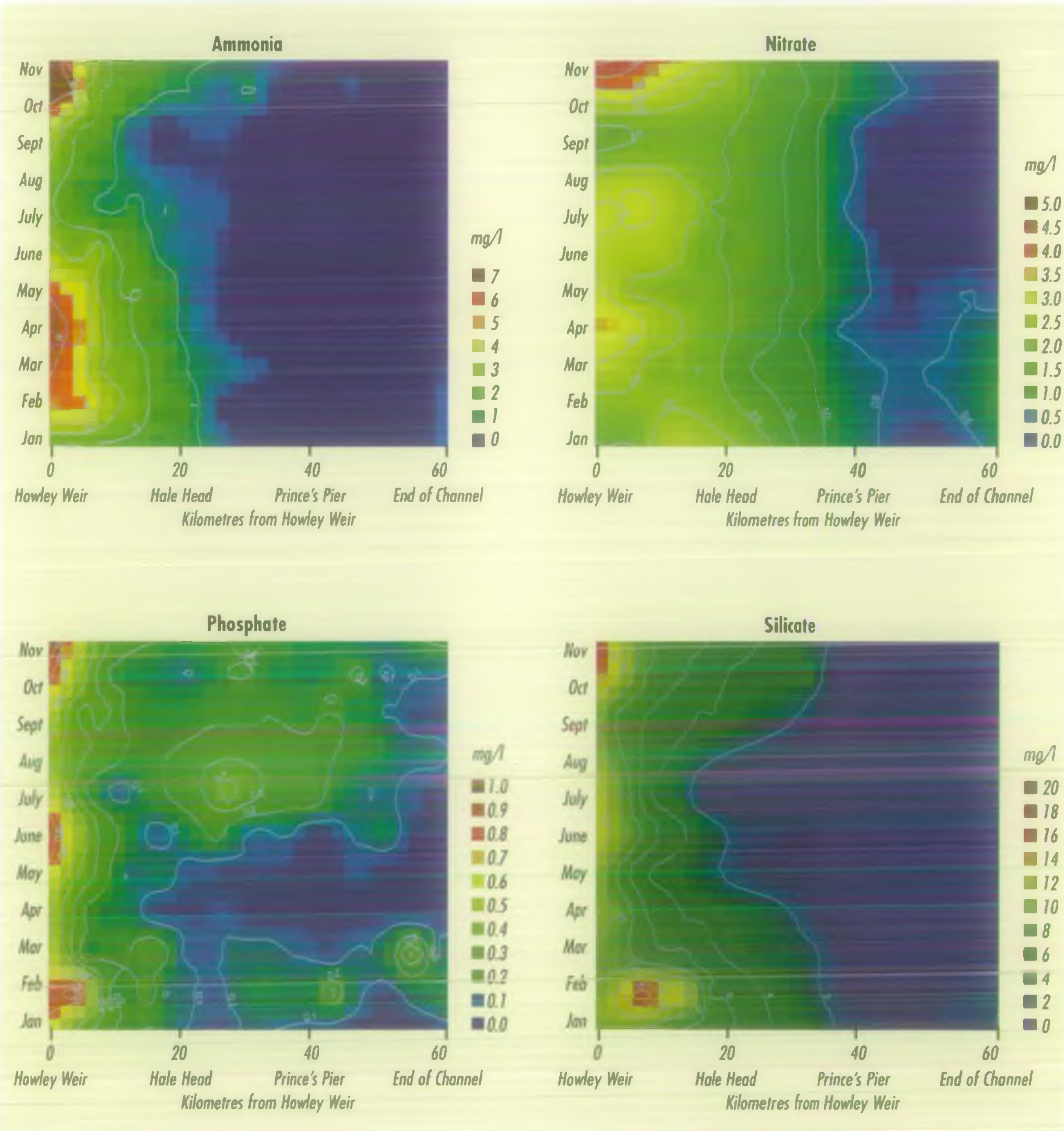




5.3 Nutrients

The important role played by nutrients in the chemical processes within the estuary has been discussed in chapter 3. The temporal and seasonal variations of the major nutrients are shown in Figure 5.3. As you progress up the graph you are moving through the year. As you move across the graph you are moving from the top of the estuary (Howley Weir) out towards the sea (end of the channel). The actual values at any point in space and time are given by the colour which corresponds to the scale on the right.

Figure 5.3: **Temporal and Spatial Variations of the Major Nutrients in the Mersey Estuary, 1993**



5.4 Compliance with Environmental Quality Standards (EQSs)

5.4.1 List I Dangerous Substances

The Surface Waters (Dangerous Substances) (Classification) Regulations, 1989, prescribe a scheme for classifying inland, estuarine and coastal waters according to the presence of concentrations of certain dangerous substances. The Secretary of State for the Environment has issued a Notice defining water quality objectives for all controlled waters based on the standards specified in the Regulations.

The Regulations give statutory effect to the EC Dangerous Substances Directive (76/464/EEC) and set standards for List I substances which have been identified as posing a threat to the aquatic environment on the basis of their toxicity, persistence and bioaccumulative properties. The standards, which are expressed as annual mean concentrations, together with 1993 monitoring data for the Estuary are shown in Table 5.1. During 1993, all four discharge-related saline monitoring sites complied with regulatory standards for List I Dangerous Substances.

Table 5.1: **Mean Concentrations of List I Substances in the Mersey Estuary, 1993**

		Monitoring Site			
Substance	EQS pg/l	Seacombe Ferry	Buoy E1	Runcorn Old Lock	Fiddler's Ferry
Mercury	0.3*	0.08	0.07	0.08	0.06
Cadmium	2.5*	0.16	0.18	0.12	0.06
Carbon Tetrachloride	12	0.46	1.6	4.1	3.5
Chloroform	12	0.46	0.46	0.55	0.76
1,2-Dichloroethane	10	0.5	0.5	0.78	0.77
Trichloroethylene	10	0.5	0.5	0.5	0.5
Tetrachloroethylene	10	0.46	0.45	0.45	0.45
Hexachlorobenzene	0.03	0.02	0.02	0.02	0.02
Hexachlorobutadiene	0.1	0.02	0.02	0.02	0.02
Pentachlorophenol	2	0.09	0.07	0.07	0.07
DDT	0.025	0.010	0.002	0.002	0.002
Aldrin	0.01	0.006	0.006	0.009	0.002
Dieldrin	0.01	0.002	0.002	0.002	0.002
Endrin	0.005	0.003	0.003	0.003	0.003
Lindane	0.02	0.004	0.005	0.017	0.003

* Dissolved metal

5.4.2 List II Dangerous Substances

The EC Dangerous Substances Directive requires Member States to take measures to reduce pollution by List II substances. These are substances which can have deleterious effects on the aquatic environment and include the heavy metals: lead, zinc, copper, chromium and nickel.

The Department of the Environment has established national quality standards for these metals. The standards, which are expressed as annual mean concentrations, together with 1993 monitoring data for the Estuary are shown in Table 5.2. During 1993, the four EQS monitoring sites for the Estuary complied with national standards for List II metals.

Table 5.2: **Mean Concentrations of List II Metals in the Mersey Estuary, 1993**

			Monitoring Site		
Substance	EQS μg/l	Seacombe Ferry	Buoy E1	Runcorn Old Lock	Fiddler's Ferry
Lead	25*	1.4	1.6	2.6	2.7
Zinc	40*	22.4	12.1	18.3	19.5
Copper	5*	3.9	2.7	3.2	3.0
Chromium	15*	0.4	0.6	0.4	0.5
Nickel	30*	1.5	2.3	5.8	7.1

* Dissolved metal

CHAPTER 6

The biology of the Mersey Estuary

6.1 Introduction

Estuaries are amongst the most fertile and productive environments in the world, sustaining an abundant and varied wildlife. The diverse physical, chemical and biological conditions found in an estuary create a vast array of subtidal, inter-tidal and terrestrial habitats, each having an associated community of plant and animal species.

The Mersey Estuary is no exception, providing a complex mixture of many distinctive habitat types including the subtidal, inter-tidal mud flats, inter-tidal sand flats, rocky shores, salt marsh, coastal grazing marsh and dune systems. These habitats do not exist in isolation, however, the continual transport of sediments transfer of nutrients and other fluctuating processes serve to link them all.

The importance of the Estuary for wildlife is shown in the number of international and national designations in place to protect a great deal of the Estuary (Figure 6.1). Primarily to protect birds, the designations recognise it is also necessary to protect the habitat and food supply on which the birds depend.

6.2 Water Quality

One of the main objectives of improving the water quality of the Mersey Estuary is to improve the diversity and abundance of estuarine life. The biology of an estuary can also give an important indication of its health. In the most severe cases, the absence or death of species con be the first indication that something is wrong. At a sub lethal level, the presence, abundance and diversity of communities can also indicate the health of an estuary.

Communities of animals and plants in estuaries

Figure 6.1: **International and National Designations on the Mersey Estuary**

Reproduced from 'Mersey Estuary Management Plan', University of Liverpool, Courtesy of Mersey Basin Campaign are exposed to a wide and fluctuating range of conditions. Some specialised plants and animals depend entirely on estuarine conditions for their survival throughout their lives. Others, particularly the more mobile organisms such as birds and fish, depend on estuaries for part of their lifecycle, or may even migrate into an estuary daily with the tide.

The constantly changing conditions which occur naturally within the Estuary make it difficult to gauge the effect of water quality on populations of species. It is important to recognise the difference between variation caused by natural processes and variation caused by other factors such as water quality. For some species over the years it has been all too obvious. Before the industrial revolution salmon were a common sight in the Mersey, but by the end of the 1940s fish were recorded as absent.

A large number of studies on Mersey wildlife have been carried out over the years, although few have been directed at the specific effects of water quality. The health of an estuary, however, is indicated by its wildlife and the following brief accounts highlight the importance of good water quality for sustainable populations of birds, fish and invertebrates.

6.2.1 Birds of the Mersey Estuary

The Mersey is important nationally and internationally for a number of bird species and this is reflected in the number of conservation designations situated on the Estuary. Birds are the most obvious inhabitants of the Estuary, depending on the diversity of habitats for food, shelter and breeding grounds. The inter-tidal mud flats, sand flats and salt marshes provide an abundance of invertebrates and act as an essential feeding ground for over wintering species. The salt marshes, sand dunes and grasslands also provide important breeding habitats and shelter adjacent to the feeding grounds.

The great majority of bird populations in the Inner Estuary frequent the Ince and Stanlow Banks and the mud and sand flats off Hale, Oglet and Frodsham Score. The Outer Estuary also supports large populations of birds including the sand flats and dunes towards Formby point.

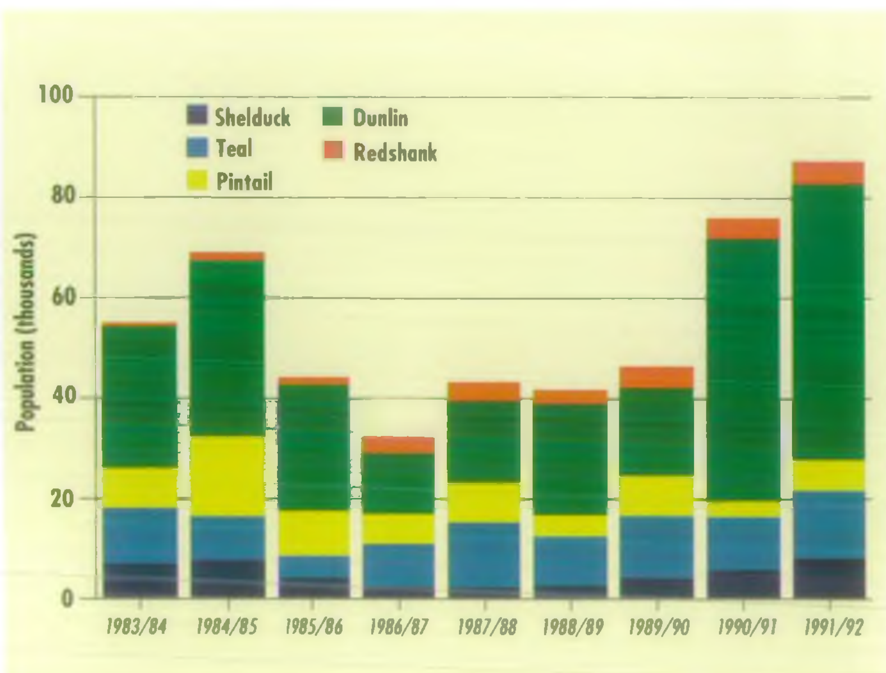
Three groups of birds frequent estuaries, namely, waders, wildfowl and seabirds, although migrant waders and wildfowl which congregate during non-breeding seasons are termed waterfowl. Many waterfowl that breed across vast areas of Arctic, sub-Arctic and temperate regions crowd onto the Mersey in winter. A large proportion of the international breeding population of many species can therefore be vulnerable if changes in the Estuary occur.

There is a great deal of information regarding the abundance and diversity of species from year to year on the Estuary. This information is obtained by such organisations as the British Trust for Ornithology (BTO), Wildfowl and Wetlands Trust and English Nature.

The Mersey Estuary is currently internationally important for shelduck, teal, pintail, dunlin and redshank. It is nationally important for widgeon, grey plover, black tailed godwit and curlew. The Mersey is the most important estuary in Britain for teal and widgeon, and the second most important for shelduck. The dunlin is the most abundant wading bird on the Mersey, with a wintering population of approximately 10% of the total in the British Isles.

Estuarine birds are good indicators of the health of an estuary. They are at the top of the food chain and can therefore be vulnerable to the accumulation of pollutants. An unfortunate example occurred in 1979/80 when approximately 2,500 birds were found dead in the Middle Estuary. Over 20 species of bird were affected showing symptoms of muscular tremoring, bright green droppings and loss of co-ordination. Analysis of bird tissue and of a common bivalve (*Malcoma balthica*), a regular prey item of estuarine birds, revealed high levels of alkyl lead. This indicated that the contamination was in the water and was probably a result of industrial discharge. The discharge of lead to the Estuary has subsequently been significantly reduced.

Figure 6.2: **Winter Maxima of Bird Populations on the Mersey Estuary**



6.2.2. Fish of the Mersey Estuary

Estuaries are essential for the survival of many species of fish, providing migration routes, spawning and breeding areas, and habitat for all or part of their lives. Fish that regularly use the Estuary during part of their life cycle can be divided into three groups, estuarine, anadromous, and catadromous. Estuarine species are dependent on estuarine conditions in order to complete their life-cycle (e.g. grey mullet). Anadromous fish migrate from the sea into freshwater to breed (e.g. salmon), whereas catadromous migrate from freshwater to seawater to breed (e.g. eels). Although over 350 species of fish have been recorded in and around the British Isles only 18 belong to the above three groups. The total number of species caught in estuaries can be much larger, however, with a number of freshwater fish surviving in the upper reaches of an estuary and similarly a large number of marine species penetrating the lower reaches.

Most fish require a high water quality to survive. Apart from direct toxicity effects from industrial waste, fish are indirectly affected by organic pollution, such as sewage, which depletes the amount of oxygen in the water. Before the industrial revolution, the Mersey had a thriving fishery including pollution sensitive species such as salmon and sturgeon. By the start of this century, however, salmon were absent and a number of species were in serious decline. The dramatic industrial developments around the Estuary in the 1940s caused further deterioration such that throughout the 1950s and early 60s anoxic conditions in the Estuary were common and fish were almost absent from the Estuary.

Improvements in water quality were first recorded in the 1960s and there has been a gradual return of fish to the Estuary. From 1976 - 1989, fish were recorded from water intake screens on the Manchester Ship Canal which draws water from the Mersey. Beam trawl surveys were initiated in the Inner Estuary in the 1980s, and angler reports provided information for the mouth of the Estuary. In 1989 a summary of fish studies in the Mersey was produced collating information from a variety of sources. For the Inner Estuary over 35 marine, estuarine and migratory fish have been recorded, although most only occurred occasionally. Four species (sand goby, herring, sprat and whiting) were common in the Inner Estuary although in any one year a range of 9 - 14 different species would be recorded. A number of species were regularly recorded in the outer Estuary including cod, whiting, bass, dab, flounder, sole, eel, conger, dogfish and rockling.

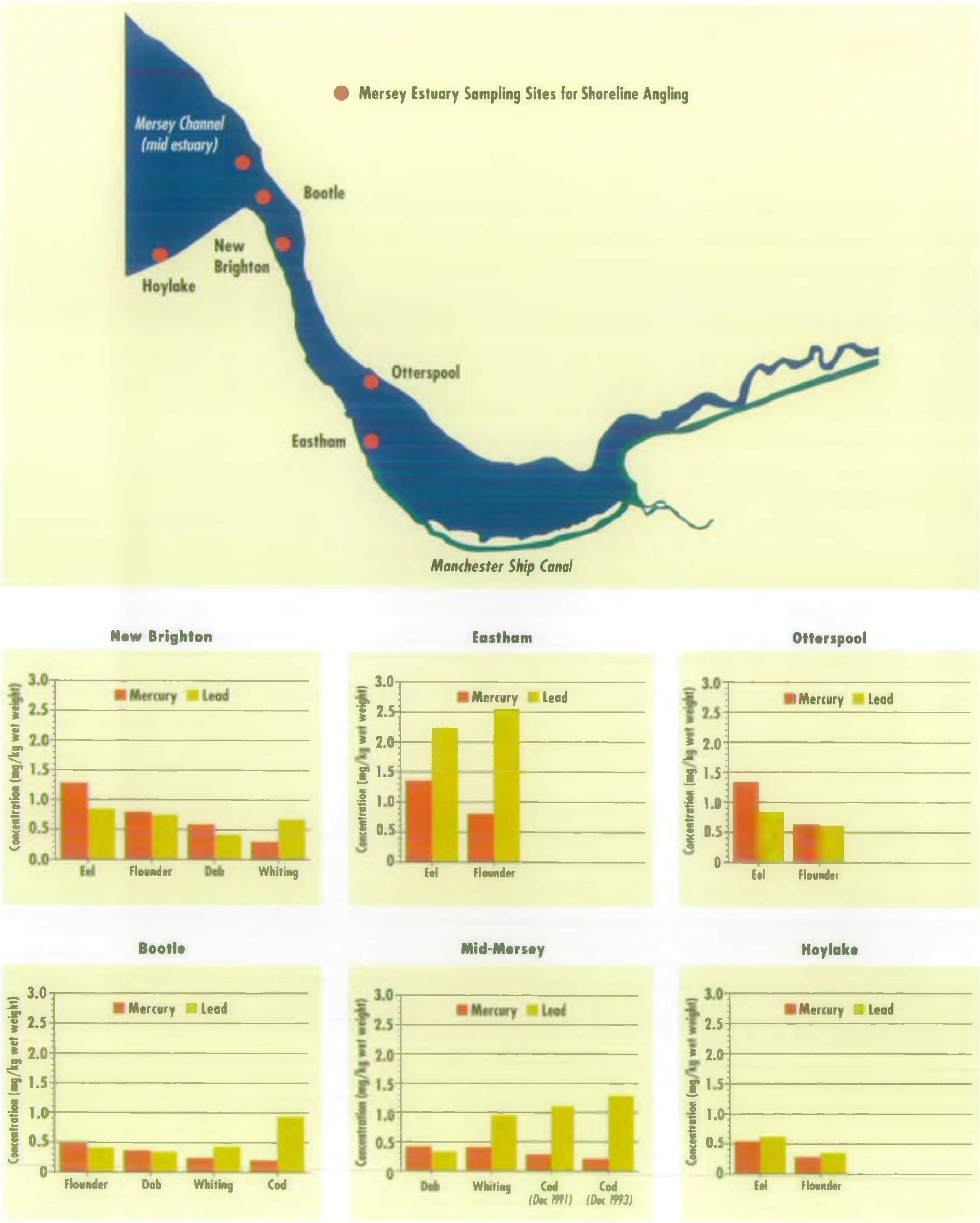
Since 1989 the NRA has continued with regular beam trawling activities on the Mersey and combined with outside studies and anglers reports it is clear that the Mersey Estuary is supporting a sustained fish population.

With improving water quality and the return of fish in significant numbers to the Estuary, the focus of the NRA studies altered slightly. Concern had been raised that although fish may now be able to survive in the Estuary, pollutants may still accumulate in the fish flesh and render the fish unsuitable for human consumption. The NRA therefore funded research by Liverpool University to assess this potential problem and to investigate potential contaminants in the flesh of angler-caught fish.

About 700 fishing permits are current at any one time for the Liverpool shoreline and in a recent winter one day boat match, 2,580 fish were caught. The species composition of the catch from any part of the Mersey Estuary coastline, and from boating activities, varies greatly with season, tide and location as well as angling variables such as type of bait used. In winter, main angling activity is devoted to fishing for codling, whiting and a few dab. In spring, the catch is dominated by plaice, changing to flounder in summer. Fishing for eels is carried out along much of the coastline but in particular off Otterspool promenade from June to September.

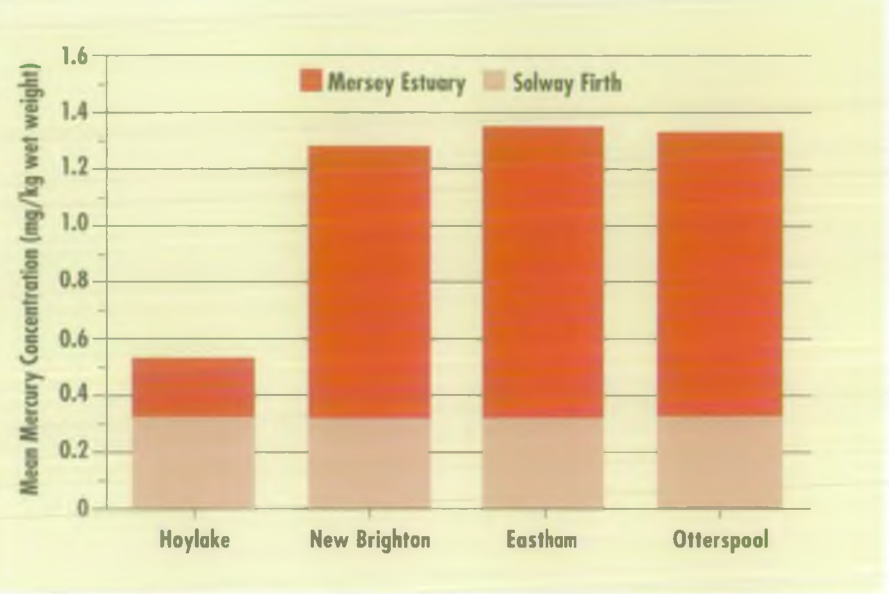
Initially, Liverpool University investigated the concentration of heavy metal pollutants present in angler-caught fish taken from the Mersey Estuary and inshore Liverpool Bay. It specifically looked at mercury, lead, arsenic, cadmium, copper, zinc, and chromium. The species chosen were eel, flounder, dab, plaice, whiting, and cod, reflecting the most frequently caught fish. For comparison, samples of the same six species were obtained from the Solway Firth, which is recognised as an unpolluted estuary. Samples were collected from the popular angling sites within the Mersey Estuary i.e. Hoylake, New Brighton, Eastham, Bootle, the mid-Mersey Channel and Otterspool. The sampling sites, together with the mercury and lead results, can be seen in Figure 6.3.

Figure 6.3: **Mean Metal Concentrations found in Fish Tissue from the Mersey Estuary**



The results of the analysis showed that for some species the concentrations of certain heavy metals in the muscle tissue of fish caught in the Mersey Estuary are elevated compared with levels found in fish taken from other UK estuaries. This is particularly true for mercury and to a lesser extent, lead and arsenic. Concentrations present in fish taken from the Inner Estuary sites were generally higher than those levels detected in fish taken from off-shore sites. Highest levels were found in eels with concentrations exceeding the 1.0mg/kg recommended in the EC Decision (93/351/EEC) for fishery products.[6] Mercury levels in some flounder, tope and skate also exceeded recommended limits.

Figure 6.4: **Mercury Levels present in the Muscle Tissue of Eels taken from the Mersey Estuary and the Solway Firth**



A requirement under the EC Mercury (chlor-alkali) Directive (82/176/EEC) is that the concentration of mercury in a representative (mixed) sample of fish flesh chosen as an indicator must not exceed 0.3mg/kg wet flesh.

Following this work, the NRA informed anglers to heed the advice given by the Ministry of Agriculture, Fisheries, and Food (MAFF), which states that it is inadvisable to eat fish caught in polluted rivers.

Liverpool University also turned its attention to chemicals which have long residence times in the environment and have toxicological implications for biota and, ultimately, human health. More specifically, they looked at chlorinated hydrocarbons which accumulate in the environment and can be transferred to fish through the food chain. Included in this group are the polychlorinated biphenyls (PCBs) which have been implicated in reducing the effectiveness of the immune system of seals. Organochlorines in general have been implicated in the reproductive failure of certain seal and fish species. This work was undertaken under the umbrella of a partnership between industry, the NRA and Liverpool University; collectively termed the Mersey Estuary and Liverpool Bay Environmental Research Consortium (MELBERC). Muscle tissue was analysed from flatfish (plaice, flounder, dab and Dover sole), and roundfish (i.e. cod, whiting). Invertebrates (mussels, whelk, shrimps and starfish) were also included.

This research concluded that fish and shellfish from the Mersey Estuary and Liverpool Bay region contained elevated levels of certain persistent organochlorines, the concentrations of which show a trend towards higher levels within the inner Estuary. The concentration of total PCB in flatfish in the Estuary is at the upper end of concentrations found in the Joint Monitoring Programme of the Oslo and Paris Commissions (regulating disposal of wastes). Concentrations of total DDT are also significantly elevated, especially in flounder from the inner Mersey Estuary. Concentrations of most organochlorines in Irish Sea fish are, however, very low and gave no cause for concern.

The results gave no indication that fish and invertebrates from the Estuary contained significant concentrations of a large range of regulated substances (heptachlor, methoxychlor, mirex, chlordane, aldrin, endrin, hexachloroethane, hexachlorobenzene, the trichlorobenzenes, and the dichlorobenzenes).

PCB and DDT concentrations aside, the fish in the Mersey are seemingly no more contaminated than the same species in the Thames, the west of Scotland, and the Seine and Loire estuaries in France. It is also notable that the Mersey Estuary levels of total PCB in fish flesh are lower than for the Seine and the Elbe in Germany, although this only presents a perspective and is not justification for the levels found. There are still a large number of unidentified organo chlorine compounds in Mersey fish that are not found in fish taken from clean estuaries. These are currently under investigation, but at this stage their toxicological significance is not fully understood.[8]

6.2.3. Estuarine Communities of the Mersey Estuary

Estuaries support a rich and varied plant and animal life. Each type of habitat has an associated community which is adapted to the substrate type, the salinity regime, the position on the shore and the wave exposure. The invertebrate communities of estuaries have been well studied and the typical community for a habitat type can be predicted.

Many studies have been carried out in the past on the communities of the Mersey Estuary but unfortunately every survey has been different and comparisons are difficult. These differences relate to objectives, site selection, collection techniques, taxonomic expertise and analytical methods. In 1989 the past studies were reviewed and it was possible to deduce that the Estuary had an abundance of invertebrate life but there was room for improvement. The outer or seaward end of the Estuary is representative of full marine conditions and the widest variety of invertebrate life can be found there; rocky substrata is colonised by barnacles, mussels, periwinkles, and dogwhelks, whilst the sands contain ragworm, numerous polychaete worms, amphipod crustacea, and the clam *Macoma*, to name but a few. Invertebrate variety decreases naturally in an inland direction due to the fall in salinity but the additional impact of pollution is also apparent. The abundant fauna was restricted to species such as the ragworm, the clam *Macoma* and a number of oligochaete worms that can thrive on organic pollution (sewage). Other species were present such as gammarus shrimps, cockles, the large bivalve *Scrobicularia*, and barnacles, but only at a few sites. At this time a poor quality freshwater fauna was also recorded at Warrington, just below the tidal limit.

One of the features of the Mersey is the rapidity with which the physical characteristics of individual sites can change, so long-term comparisons of the fauna at an individual site can be misleading. When the NRA was established in 1989, it became obvious that surveys had to be carried out on estuarine communities which could be repeated at a later date, and any change recorded reflect changes in water quality. Before any effects can be measured, however, it is important to establish the initial state of the biological communities. These are termed baseline studies.

6.2.3.1. Biological Status of Inter-tidal Sediments

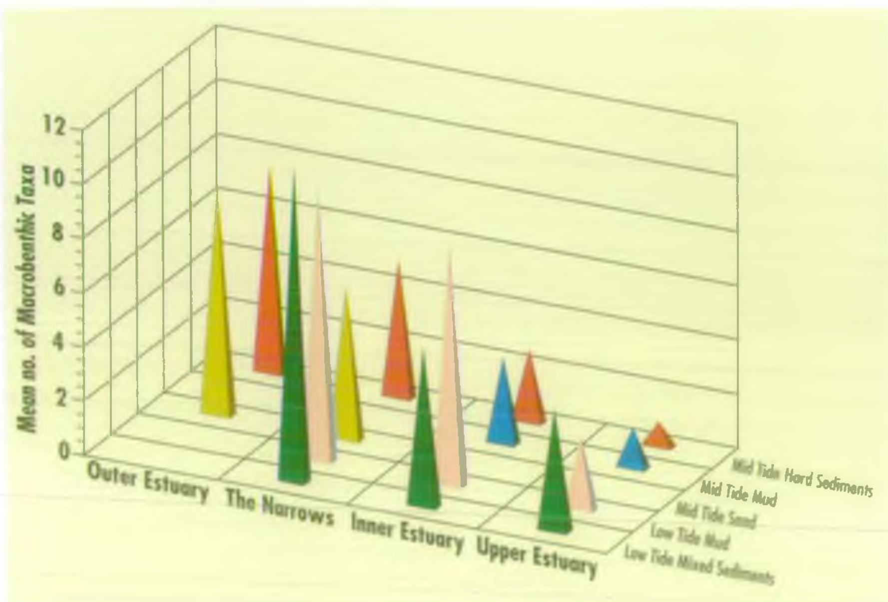
The fauna that inhabits inter-tidal sediments can provide useful information in relation to pollution, so the NRA funded WRc to assess the biological status of the sediments of the Mersey Estuary. The main objective of the study was to establish a quantitative baseline against which comparisons could be made to detect any improvement in the fauna as a result of the initiatives to reduce pollution.

Invertebrate communities are susceptible to natural temporal variations such as year and season, and also spatial variation such as salinity range, substratum type, and position on the shore. To ensure that changes recorded in future years could be attributed to either natural or man made variations, the survey had to be carefully designed. The methodology accounted for temporal factors by repeating surveys in spring and autumn for three years. To account for spatial variation, the Estuary was first divided into four zones (outside, outer, middle and inner Estuary) and within these zones samples were taken at mid and low tide levels, and from hard surfaces, sand, mud, and mixed sediment (Figure 6.5). The surveys provided an extensive database of species presence, abundance and diversity along the Estuary.

Analysis of the results by statistical modelling revealed that the objective of providing a robust baseline for the fauna of the sediment had been achieved. Furthermore, by comparing the trends of species abundance and diversity with studies in other industrialised estuaries it was possible to predict the effect of improved water quality on the fauna. Improvements in water quality (and therefore quality of the sediment) should be reflected by certain changes in the fauna such as recolonisation of denuded habitats (demonstrating an increase in the number of species) and an increased stability of communities (demonstrating an increase in diversity).

The inner zone of the Mersey Estuary was found to be the most impoverished (Figure 6.5) of the four zones and evidence suggested that the quality of the water and sediments was the poorest in this part. Although the salinity regime in this zone may account for a proportion of the decline in numbers, improvements in water quality in the Estuary would still be expected to be reflected in an increase in the abundance and diversity of species. Such a change in the communities present in the inner Estuary would provide one of the most environmentally relevant indications that the ecology of the Mersey Estuary has improved as a result of pollution abatement schemes.

Figure 6.5: **Distribution of Macrobenthos in different Substrata in the Mersey Estuary (May 1988)**



6.2.3.2. Bioaccumulation Study.

Traditional methods of measuring water quality involve chemical sampling of the sediment and water column. To assess the direct effect of pollutants on the biota, however, samples of tissue from various organisms can also be analysed to detect concentrations of chemicals present. An advantage of this biological monitoring is that organisms integrate metal concentrations over a period of time.

During the 1980s, the North West Water Authority funded a number of surveys by the Plymouth Marine Laboratory to examine the concentration of metals in the biota of the Mersey Estuary. In 1989/90, the NRA funded a further survey to compare with previous surveys, and to provide a comprehensive baseline on which future improvements in water quality could be measured.

The studies investigated the concentration of metals within the tissues of various animals and plants. The metals in question were silver, arsenic, cadmium, chromium, copper, iron, mercury, manganese, nickel, lead, selenium, tin and zinc. All these metals were known to be discharged into the Mersey.

The earlier studies had established which organisms provided the most useful comparative information on environmental quality. More than one organism is required as no single species thrives along the whole length of the Estuary. Furthermore, the effects of various metals differs according to the species of plant and animal. For example, one species may be able to regulate a particular metal and excrete it, whilst in another species the metal may concentrate in its tissues. It is also very useful to use different species, such as seaweeds, suspension feeders and deposit feeders, in order to reflect that the chemical can be found in the water, attached to suspended solids and in sediments.

Taking the availability of organisms in the Mersey into account, the species chosen for the surveys were :

1) The seaweed *Fucus vesiculosus*, which quickly takes up available dissolved metals
2) The winkle *Littorina littorea* which feeds on *Fucus*
3) The suspension feeding bivalves *Mytilus edulis* (mussel) and *Cerastoderma edule* (cockle)
4) The deposit feeding clams *Macoma balthica* and *Scrobicularia plana*
5) The ragworm *Nereis diversicolor*, one of the few abundant species in the upper Estuary.

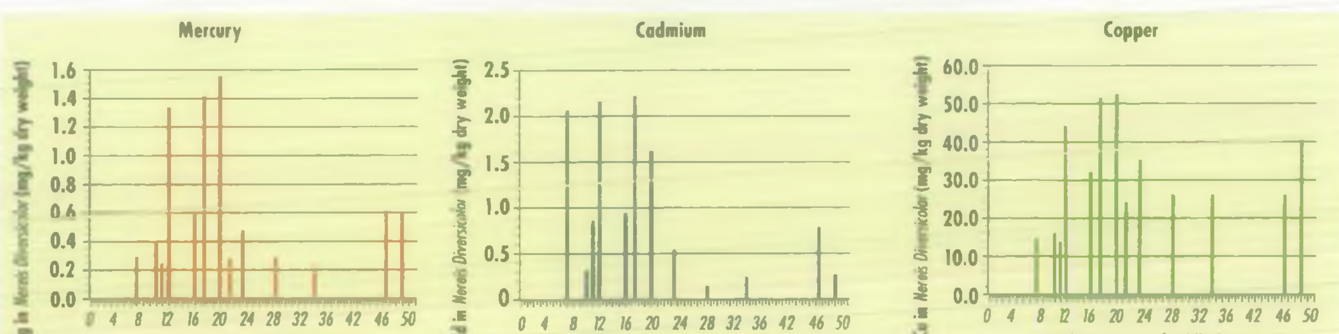
The extensive number of monitoring sites chosen covered over 50km from Fiddler's Ferry upstream, to Hoylake, on the Wirral, and Hightown, on the Formby shores. This report includes only a brief synopsis of a data set that would yield a lengthy data analysis and which provides an invaluable baseline for future research.

The ragworm (*Nereis diversicolor*) is the most valuable of indicator species by virtue of its extensive distribution throughout the Estuary. It is an important component of the diet of several wading birds, particularly in the upper Estuary where other macro invertebrates are absent. Consequently it is likely to be significant in the transfer of metals through the food chain. It should be noted that the ragworm is a poor accumulator of metals when compared to some other species. It has the ability to regulate iron and zinc and therefore will not accumulate these metals.

The ragworm can, however, provide an appreciation of the differences in some metal contamination throughout the Estuary. The most impacted sites in the early 1990s were in the mid to upper region of the Estuary, particularly 10 - 20 km downstream of Fiddler's Ferry. For some elements, such as cadmium, copper and mercury this was further localised along the south shore at the Ince/Stanlow bank (Figure 6.6). Chromium and nickel concentrations tend to increase more consistently with distance upstream of Eastham locks, whereas lead and tin show elevated levels just below Eastham locks.

The majority of other organisms tested have a more restricted range along the Estuary but give a valuable indication of the bioavailability of metals at particular sites. For example, suspension feeders such as mussels (*Mytilus edulis*) are restricted to sites towards the mouth of the Estuary, but form a significant proportion of the inter-tidal biomass where they do occur, and are important food items for many predators. The majority of metal concentrations found in suspension feeders appear to increase significantly in individuals collected further upstream.

Figure 6.6: **Metals in *Nereis diversicolor* in the Mersey Estuary 1991**

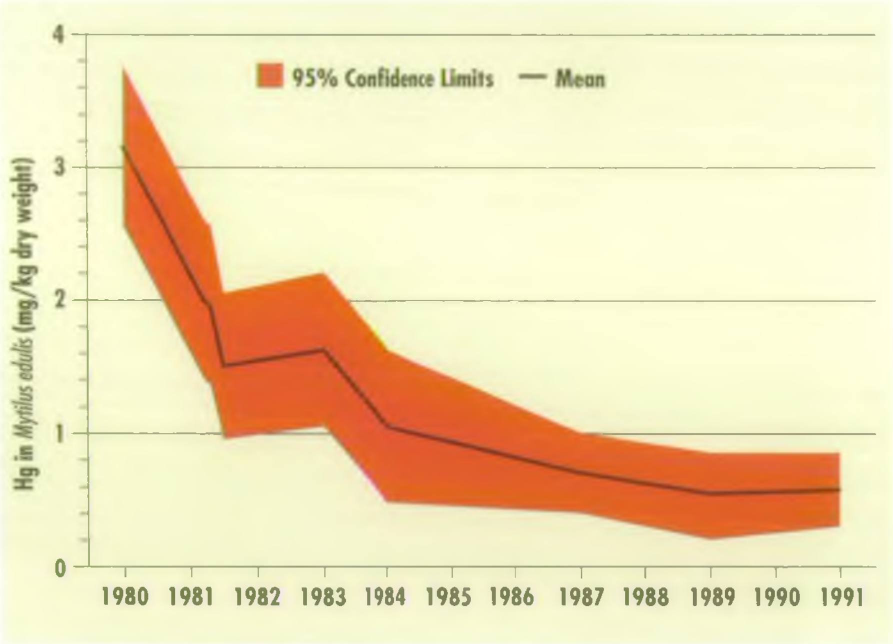


The seaweed (*Fucus*) is presumed to uptake metals that are dissolved in the water column and it also responds fairly quickly to changes in metal concentration. Metal levels in the seaweed declined in a seaward direction and this was reflected in the winkle (*Littorina littorea*) which often feeds on *Fucus*.

Major reductions in the tissue concentrations of mercury and lead occurred in most species in the early 1980s corresponding to industrial initiatives to curb inputs of these metals at this time. From 1984 onwards reduction declined at a lower rate and approached a "steady state" level over the following years (Figure 6.7).

A similar pattern occurred for zinc whereas for other metals there has been a continual decline in tissue burdens over the years.

Figure 6.7: **Mercury Levels in *Mytilus edulis* 1980 to 1991**



6.3. The Future

It is obvious from the preceding chapters that the Mersey Estuary is undergoing a major improvement in water quality which will, in time, be reflected in continuing improvements in sediment quality. These improvements are also expected to be reflected in the diversity and abundance of fauna and flora of the Estuary. Unsubstantiated reports have already indicated that there is an improvement in the inner Estuary in terms of additional species being found. The lugworm *Arenicola marina* has been found in the inner Estuary, and although common at this position in other UK estuaries, it has not been recorded in the Mersey inner Estuary since 1933.

As part of a government initiative, the Marine Pollution Monitoring Management Group has been established to co-ordinate marine and estuarine surveys around England and Wales. Included in this programme in 1995 is an initial assessment of the invertebrates of the Mersey Estuary from Fiddler's Ferry out into Liverpool Bay.

The NRA is also currently researching a classification for estuaries similar to the classification used in freshwaters. This will enable all estuaries to be surveyed chemically and biologically in a nationally consistent manner, allowing comparison between estuaries and ease of reporting. As part of this classification, the use of ecotoxicological methods has been suggested as a means of measuring the toxicity of effluents to the fauna. These methods are already in use abroad and have proved exceedingly useful in detecting the effects on the fauna of complex effluents.

CHAPTER 7

7 Future prospects for the Mersey Estuary

7.1 Quality Objectives for the Estuary

Whilst of increasing concern throughout the century, pollution of the Estuary only began to attract specific attention towards the end of the 1960s, resulting in the formation of the "Steering Committee on the Pollution of the Mersey Estuary". This Government supported committee drew together the River Authority, local authorities and industries with a vested interest in the Estuary. It commenced the preparatory work for the detailed studies and proposed solutions of the enormous pollution legacy. Their contribution to subsequent initiatives was a substantial set of data and a mathematical model of the Estuary which was to play a major part in defining the improvements needed in the future.

In progressing the needs of the Estuary, the North West Water Authority remained conscious of the requirements of the rest of the region and concluded that a complete solution to the manifest problems of the Estuary was not an immediate or even medium term prospect. It did, however, establish the initial objectives of the Steering Committee as the minimum necessary to stop the Estuary being offensive to its users.

These objectives are:

i. that all parts of the Estuary should a maintain a minimum of 10% saturation of Dissolved Oxygen at all times.

ii. that the beaches and foreshores should not be fouled by crude sewage or solid industrial waste.

Objective (i) is of primary importance to the Upper Estuary and objective (ii) of primary importance to the Inner and Outer Estuary.

7.1.1 Achievement of Objectives

These objectives are clearly focused towards tackling the large scale pollution problems of large quantities of organic matter being discharged via the public sewerage network and the larger industrial complexes. These discharges totalled 67 crude sewage outfalls and 44 industrial discharges in 1974, the sewage accounting for 50% of the total oxygen demand and industry some 27%. The remainder is accounted for largely by the River Mersey as it enters the Estuary over Howley Weir at Warrington.

Throughout the 1970s, extensive work was undertaken to calibrate and utilise the mathematical model of the Estuary and by 1980 it was possible to use the model to determine a strategy for investment to achieve the objectives.

For the lower part of the Estuary, this work culminated in the Mersey Estuary Pollution Alleviation Scheme (MEPAS), which established a programme of necessary work on the sewage disposal facilities, matched by corresponding improvements in industrial discharges.

The essential components of the strategy are:

- ***interception of all crude outfalls;***
- ***additional treatment at Davyhulme (Manchester) sewage works;***
- ***works to nitrify (oxidise) the ammonia content of the effluent;***
- ***secondary (including nitrification) treatment for Warrington;***
- ***the first sewage treatment plants for Widnes and Runcorn;***
- ***a new primary plant for Liverpool;***
- ***fine screening plants on the Wirral bank.***

Whilst substantial progress has been made towards providing the new infrastructure, the enhanced treatment facilities in the Upper Estuary are still awaited.

The Urban Waste Water Treatment Directive has imposed additional requirements which will have to be met by the end of the year 2000. These amount to:

- ***secondary treatment at Liverpool;***
- ***secondary treatment plants on the Wirral to replace the screening facilities;***
- ***secondary treatment at Halewood (which will probably be by transfer to Liverpool).***

7.2 Improved Effluent Treatment for Industrial Discharges

Parallel to the construction of new or improved sewage treatment facilities, local industries have been required to match the improvements made. In some cases this has involved connection to sewer for treatment, whilst others have installed their own treatment facilities. This programme has been directed towards the oxygen consuming aspects of their effluents. In addition, however, the need to meet the requirements of the EC Dangerous Substances Directive has introduced additional demands on treatment systems and required much higher levels of technology to be introduced.

Although EQS values are largely met, the levels of certain dangerous substances present in biota leave no room for complacency and further reductions in inputs of dangerous substances are still required from a range of industrial sectors.

7.2.1 Waste Minimisation

Progress on cleaning up such a vast legacy of pollution is inevitably slow and consumes considerable financial resources. One method of accelerating the rate of progress and actually reducing costs to industry is waste minimisation. This is a simple concept which essentially revolves around the idea that if waste is not created, the time and cost of cleaning it up is saved.

Following 'Project Catalyst' (a successful pilot study sponsored by the Department of Trade and Industry and others which commenced in 1993), it is clear that the concept has considerable potential, not just for water pollution, but for all aspects of the environment.

Options for minimising environmental impact of discharges include:

- ***reducing pollution at source by product or process changes;***
- ***on-site recycling or re-use of waste;***
- ***off-site recycling and treatment to render discharges harmless.***

Several new projects are underway in the area, and in nearly all cases, worthwhile savings in operating costs are being realised. It is expected that such initiatives will play an ever increasing part in reducing pollution in the future.

7.3 Recreational Activities

As the Estuary continues its slow but significant recovery process, the recreational opportunities will increase in parallel, but will also accentuate some continuing difficulties.

Angling and boating are the primary recreational uses of estuaries, and both are practised within the Mersey. Angling in particular has been re-established in the lower Estuary as fish return in significant numbers.

The increase in these activities is not without its problems as, for example, the concentration of certain heavy metals in fish tissues exceed levels deemed suitable for human consumption. This demonstrates that even after major reductions in inputs, there remains a reservoir of contaminants contained in the sediments of the Estuary which will only subside over a longer period.

Similarly, as the appearance of the beaches and the water continues to improve, more extensive use for sailing, paddling and other recreational pursuits can be anticipated. This will inevitably lead to calls for reductions in bacterial levels.

These pressures will ensure that the drive to clean up the Estuary will not abate until its potential is fully realised.

7.4 The Mersey Estuary Management Plan

There is a growing need to achieve an appropriate balance between development needs and the protection of Estuary resources for future generations. This will be achieved by the Mersey Estuary Management Plan which will provide an advisory framework for the future management of the Estuary.

The plan, which was commissioned by the Mersey Basin Campaign in 1992, is being produced in consultation with all parties who have an interest in the management of the Estuary.

The Draft Management Plan was launched for public consultation in October 1994. Its main aspirations are best summed up by the following quote:

"The Management Plan is based on a vision of the future of the Mersey Estuary as one of the cleanest developed estuaries in Europe, where the quality and dynamics of the natural environment are recognised and respected by a high quality built environment, a vibrant maritime economy, and an impressive portfolio of estuary-related tourism and recreational facilities."

The National Rivers Authority supports this exciting initiative and will assist its future implementation in partnership with others.

7.5 Conclusion

A substantial amount of work has been completed and much more is scheduled to take place before the end of the century. It is fair to claim, therefore, that after more than 200 years of neglect, the tide of pollution has turned and the process of real improvement is well established.

If there is a cloud it is the reservoir of contamination in the sediments which could be slow to disperse, but the ongoing drive to reduce the inputs of these persistent materials will ensure that progress is continuous and will be successful.

Plate 7.1: **Sailing on the Mersey Estuary**

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GLOSSARY OF TERMS

Anaerobic....processes which take place in the absence of free oxygen.

Anoxic....devoid of free oxygen.

Anthropogenic....as a consequence of human action.

Biochemical Oxygen Demand (BOD)....is the amount of dissolved oxygen consumed by chemical and microbiological action when a sample of effluent is incubated for 5 days at 20°C. (a test originally devised by the Royal Commission on Sewage Disposal in 1912).

Bathymetry....is the measurement of the depth of water in the channels, and the height of any banks which may be exposed at low tide. This is usually with respect to a locally defined datum.

Conservative parameter....is a substance which does not undergo any chemical or physical change. For example salinity, which is a measure of the relative proportions of fresh and salt water and is only subject to physical mixing.

Ebb tide....is the part of the tidal cycle from high water to low water, i.e. when the level falls and the water flows seawards.

Environmental Quality Objectives (EQOs)....are categories relating to the use of particular stretches of water. For each use, an associated series of quantitative standards applies.

Environmental Quality Standards (EQSs)....are concentrations of substances in the receiving water which must not be exceeded if the water is to be suitable for a particular purpose or use, or to achieve a certain level of protection for aquatic life.

Flood tide....is the part of the tidal cycle from low water to high water, i.e. when the water level rises and off-shore water flows into the estuary.

Flushing time....is the time taken for the freshwater and associated contaminants to pass out to sea. It depends to a large extent on the size of estuary and the relative volume of freshwater discharged into it.

Heavy metals....is a general term for those metals which are toxic when present in elevated concentrations. These include elements such as zinc, copper, cadmium, lead, nickel and mercury, all of which are commonly used by industry.

Hydrography....is the study of water bodies and their movements.

Inter-tidal....refers to differences occurring between tides.

Intra-tidal....refers to differences occurring within tides.

Ionic strength....is a measure of the concentration of dissolved constituents. High ionic strengths give rise to more reactions in the water.

Neap tides....are smaller tides which occur when attractive forces of the moon and sun are not acting together (approximately at the first and third quarter of the lunar month-7 days apart from spring tides).

Nitrification....the bacterial oxidation of ammonia to form nitrate, a process which uses dissolved oxygen.

Oxidation....is the breakdown of complex compounds by bacteria.

pH....is a measure of the balance of acidity or alkalinity of the water.

Prescribed process....is a process or part of a process which releases at least one prescribed substance at a level greater than background.

Prescribed substance....is any substance, the release of which into the environment is subject to control under the EPA (1990). The list of prescribed substances for release to water is essentially the same as the UK 'Red List' which can be seen in appendix 5.

Primary production....is the conversion of energy from the sun into carbon compounds by photosynthesis.

Spring tides....are the larger tides occurring when the attractive forces of the Moon and Sun are working together (at new and full moon-7 days apart from neap tides).

Tidal cycle....is the time between successive low or high waters, typically about 12 hours 30 minutes.

Tidal excursion....is the distance travelled by a body of water between low and high tide.

Tidal range....is the difference in height between low and high tide.

APPENDIX 1

Regulations Implementing EC Directives in England and Wales

The Surface Waters (Dangerous Substances) (Classification) Regulations 1989. SI 1989/2286

The Surface Waters (Dangerous Substances) (Classification) Regulations 1992. SI 1992/337

The Bathing Waters (Classification) Regulations 1991. SI 1991/1597

The Urban Wastewater Treatment (England and Wales) Regulations 1994. SI 1994/2841

APPENDIX 2

Dangerous Substances Surface Water Regulations 1989 and 1992

EQSs for List I Substances under the Classification of Coastal Waters and Relevant Territorial Waters (DS2 and DS3)

Substance	Annual Mean Concentration (μg/l)
Aldrin	0.01
Dieldrin	0.01
Endrin	0.005
Isodrin	0.005
Cadmium and its compounds	2.5 (dissolved cadmium)
Carbon Tetrachloride	12
Chloroform	12
DDT (all isomers)	0.025
para-para-DDT	0.01
Hexachlorobenzene	0.03
Hexachlorobutodiene	0.1
Hexachlorocyclohexane (all isomers)	0.02
Mercury and its compounds	0.3 (dissolved mercury)
Pentachlorophenol and its compounds	2
1,2 Dichloroethane	10
Trichlorobenzene	0.4
Trichloroethylene	10
Perchloroethylene	10

APPENDIX 3

National Environmental Quality Standards for List II Metals for the Protection of Salt Water Life

Substance	Annual Mean Concentration (pg/l)
Lead	25 (dissolved)
Chromium	15 (dissolved)
Zinc	40 (dissolved)
Copper	5 (dissolved)
Nickel	30 (dissolved)
Arsenic	25 (dissolved)
Vanadium	100 (total)

APPENDIX 4

Bathing Water Directive 76/160/EEC.

Compliance Assessment (1989 - 1994).

Mandatory Coliform Standards: $\leq$ 10,000 total coliforms per 100ml

$\leq$ 2,000 faecal coliforms per 100ml

Bathing Water	1994	1993	1992	1991	1990	1989
Meols						
Moreton						
New Brighton						
Formby						

Compliant:

Non-compliant:

APPENDIX 5

UK Red List

- • Mercury and its compounds
- • Cadmium and its compounds
- • Gamma - Hexachlorocyclohexane
- • DDT
- • Pentachlorophenol
- • Hexachlorobenzene
- • Hexachlorobutadiene
- • Aldrin
- • Dieldrin
- • Endrin
- • 1,2 - Dichloroethane
- • Trichlorobenzene
- Polychlorinated biphenyls
- Dichlorvos
- Atrazine
- Simazine
- Tributyltin compounds
- Triphenyltin compounds
- Trifluralin
- Fenitrothion
- Azinphos - methyl
- Malathion
- Endosulfan

• EC List I Substance

APPENDIX 6

Annex 1a Substances

Mercury	1,2 - Dichloroethane
Cadmium	Dichlorvos
Copper	Atrazine
Zinc	Simazine
Lead	Tributyltin compounds
Arsenic	Triphenyltin compounds
Chromium	Fenitrothion
Nickel	Azinphos - methyl
Drins	Azinphos - ethyl
HCH	Fenthion
DDT	Malathion
Pentachlorophenol	Parathion
Hexachlorobenzene	Parathion - methyl
Hexachlorobutadiene	Trichloroethylene
Carbon tetrachloride	Tetrachloroethylene
Chloroform	Trichlorobenzene
Trifluralin	Trichloroethane
Endosulfan	Dioxins

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