Hydraulics Research
Wallingford

# CHANGES IN WATER PROPERTIES AND SEDIMENT DISTRIBUTION IN THE TIDAL THAMES

## Report on studies made in 1984-85

B V Derbyshire C.ENG,MICE
M P Kendrick BA,MWES

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Registered Office: Hydraulics Research Limited,
Wallingford, Oxfordshire OX10 8BA.
Telephone: 0491 35381. Telex: 848552

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## SUMMARY

This study has been undertaken to determine the relative importance of the factors influencing navigable depths in a single-channel estuary as represented by the tidal Thames.

In March 1983, two reports were published to document the changes that have taken place from the early 1950's through to the late 1970's. The first report, IT 241, presented accretion/erosion charts of five sensitive reaches of the estuary - Bugsbys, Woolwich, Gallions, Barking and Halfway Reaches - which embrace the so-called "Mud Reaches" where the bulk of the estuary maintenance dredging was carried out. The second report, IT 246, provided factual information for the same period on variations in tidal level, fresh water flow, water salinity, and capital and maintenance dredging.

Since 1983, work has been undertaken to extend the documentation of bed level changes down-river, and accretion/erosion charts have been prepared for Erith Reach, Erith Rands and Upper and Lower Long Reach. This information is presented in a third report, SR 45, which also contains accretion/erosion charts resulting from a detailed examination of bed level changes that have occurred in Woolwich Reach during the period of Thames Barrier construction. The accretion/erosion study indicated that superimposed on the cyclical movements of sediment which occur as a result of seasonal variations in river flow and saline intrusion of the estuary, there is evidence of a long-term trend in sediment distribution which was partially masked by large-scale navigation channel maintenance dredging continuously undertaken in Barking Reach up to the mid-1960's. The cessation of dredging produced accretion, especially up-river, where the distribution of the additional sediment was largely determined by the flow resistance afforded by jetties and terminals.

The analysis of data abstracted since the early 1970's demonstrated that each station has a characteristic shape of silt concentration - time curve for each quarter of the year and that changes in the distribution of silt concentration resulting from civil engineering works, such as jetty construction, reclamation or dredging, can be distinguished from changes in concentration due to variations in natural factors such as river discharge and saline intrusion. This has particular significance both in attempts to resolve the recurrent problem of determining the reason for an observed modification to river regime and in predicting the likely, if temporary, effects of a civil engineering activity.

Figures in Report No SR 45 referred to in Section 2

## 1 INTRODUCTION

This is the third in a series of four reports resulting from a study of changes in water properties and sediment distribution in the tidal Thames carried out between April 1982 and March 1985.

The first report (Ref 1) published in February 1983, demonstrated in the form of accretion/erosion charts the bed level changes that had occurred during the sixth, seventh and eighth decades of this century in five sensitive reaches of the estuary which included the "Mud Reaches" where traditionally most of the maintenance dredging was undertaken. The second report (Ref 2), published a month later, presented the results of processing the available data on tidal level, river flow, water salinity and dredging.

Since 1983, the study of bed level changes between 1952 and 1979 has been extended to include Erith Reach, Erith Rands and Long Reach and a detailed examination has been made of the changes that occurred in Woolwich Reach during the period of the Thames Barrier construction from 1974 to 1982. The respective accretion/erosion charts are bound in a fourth report (Ref 3).

Finally an analysis has been made of data abstracted from four silt monitoring stations which have been in continuous operation in the estuary since the early 1970's.

## 2 BED LEVEL CHANGES

The first part of this section of the report describes the bed level changes which occurred in Erith Reach, Erith Rands and Long Reach between 1952 and 1979, changes being assessed from a comparison of successive surveys. The second part of the section deals which Woolwich Reach during the years of Barrier construction from 1974 to 1982. All Figures referred to in this section on bed level changes are to be found in SR 45 (Ref 3). The accretion/erosion charts in Ref 3 are contoured in intervals of 0.6m (2 ft), accretion being shown in red, erosion in blue.

### (i) Erith Reach, Erith Rands and Long Reach, 1952-1979

The changes occurring between 1952/3 and 1957/8 are shown on Fig 1. Moderate depth gains were recorded in the navigation channel and along the north bank of Erith Reach whilst accretion occurred along the south bank at the downstream end. In Erith Rands three zones of accretion occurred across the river at Coldharbour Point: one caused a small depth loss on the northern side of the navigation channel, another was located just beyond the southern edge of the channel, while the third affected the mud bank behind Erith Deep Water Wharf. Another zone of accretion developed in the lee of Crayfordness. Elsewhere in Erith Rands changes were confined to minor patches of erosion and accretion. Dredging records suggest that no capital or maintenance works were carried out during the period in either reach.

Modest bed level changes were recorded in Long Reach which took the form of six erosion zones and four areas of accretion. No dredging records are available for this reach but the indications from the Figure suggest that the bulk of the erosion could be attributed to maintenance dredging works at jetty installations. Two areas of accretion lying on the south side just below Dartford Creek are worth noting, for although they were relatively unimportant in the context of the period 1952-58 they formed part of an extended shoal which developed in subsequent years.

The overall changes recorded between 1952 and 1958 are small, indicating that this section of the estuary was fairly stable at the time.

Between 1958 and 1963 (Fig 2) the area was subjected to widespread moderate accretion. In Erith Reach the navigation channel accreted at the upstream end while along the north bank erosion was recorded. This erosion was probably the result of dredging carried out in the vicinity of the pump-ashore unit at Rainham. In Erith Rands there was widespread reduction in depth of at least 2ft (0.6m) in spite of the removal of 44,000 $m^3$ of silt from the channel in 1962. The accretion in Long Reach was partly the result of deposition in dredged cuts and partly attributable to an extension of the shoal that developed in the vicinity of Dartford Creek between 1952 and 1958 (Fig 1).

Bed level changes between 1963 and 1968 (Fig 3) generally took the form of moderate accretion and erosion. In Erith Reach there was evidence of light accretion in the navigation channel and along the north bank, while in Erith Rands accretion occurred in the channel and along the south bank. Minor improvements in depth were also recorded in these reaches, the greatest concentration being located on the south side between Jenningtree Point and Erith. In Long Reach there was evidence of a further extension of the shoal near Dartford Creek entrance. Elsewhere in the reach the changes of any significance were the result of civil engineering works and modifications to dredging practice. Some jetties on the north side were extended towards the channel to gain the benefit of deeper water. As a result of the cessation of maintenance dredging on the old jetty line, other jetties nearer the river bank started to experience heavier siltation and so they, in turn, were rebuilt further offshore (Ref 4). Fig 3 reflects these events along the north bank, erosion being due to capital dredging on the new jetty line and accretion being the result of deposition in former dredged cuts.

Bed level changes that occurred between 1968 and 1973 are shown on Fig 4. In Erith Reach, mid-river changes were very small but some siltation occurred on the north and south sides. In upper Erith Rands small increases in channel depth occurred whilst there was a reduction in depth off Crayfordness. On the north side of Long Reach there was an up-river extension of bankside accretion. Erosion occurred on the south side in many of the zones that had shoaled during the 1963-68 period. The erosion on the south side in the middle of the reach reflects the capital dredging carried out for the new Littlebrook 'B' power station jetty. At Dartford Creek entrance, further accretion added to that experienced during the preceding two decades.

Fig 5 shows the changes that occurred between 1973 and 1978. In the main navigation channel, depths in all three reaches either remained the same or increased slightly. Along the bank sides there were a number of changes, some of which are readily explained. For example, the damming of Rainham Creek as part of the flood defence measures produced foreshore accretion on the north bank in Erith Reach (Ref 5), whilst maintenance dredging at the Murex jetty and the PLA pump-ashore unit at Rainham further downstream had the reverse effect. On the south side, bankside accretion continued both behind the Erith Deep Water jetty and in the vicinity of the entrance to Dartford Creek at the upper end of Long Reach. Similarly bankside accretion continued behind the jetties on the north side of lower Long Reach, largely because of the reduction in maintenance dredging.

### (ii) Woolwich Reach 1974-82

As part of the Thames Barrier Project the Greater London Council commissioned topographical surveys at regular intervals to monitor river bed levels between the Western Entrance of the Royal Docks in Bugsby's Reach and Royal Victoria Gardens at the eastern end of Woolwich Reach. The first survey was made in March 1974 prior to any river works and the second survey followed in April/May 1975 after the completion of the capital dredging for the Northern Diversion Channel (NDC) which marked the start of the installation of temporary works for Barrier construction. Since then, surveys have been carried out at annual intervals, that following completion of Barrier construction (No 10) being made in December 1982.

Fig 6 shows the accretion and erosion that occurred during the period of NDC dredging. The contours give bed level changes in intervals of 0.5m. The predominant feature is the new dredged cut along the northern side of the river. Also shown are a number of smaller areas of bankside accretion and erosion, e.g. siltation between the Tate and Lyle jetties and pockets of accretion along the south side of upper Woolwich Reach. The remainder of the changes, which are liberally distributed over the river, result partly from small lateral and longitudinal displacements of shallows and deeps arising from sediment redistribution associated with the high freshwater discharge of the winter of 1974/5, and partly from flow changes due to the capital dredging.

Fig 7 shows the bed level changes that had occurred by 1978 when obstruction due to temporary works was greatest. The Figure compares pre-Barrier conditions (survey No 1) with the 1978 survey (No 6). Temporary works occupied the southern half of the river and the northern inter-tidal bank, causing a change in the lateral distribution of flow in Woolwich Reach.

The consequence of this flow redistribution was to increase erosive forces on the north side of the river and reduce them on the south side. Additional scouring occurred in the NDC and along the edge of the northern inter-tidal bank to a depth of about 1m while deposition took place in mid-river and along the south bank.

With the gradual removal of the temporary works, lateral flow distribution tended to revert to the pre-Barrier regime. Fig 8, which compares the pre-Barrier survey (No 1) with the Barrier completion survey (No 10), shows that much of the north-side scour and a significant proportion of the mid-river and south-side deposition had disappeared by 1982.

The main changes in sediment distribution that occurred between the completion of the capital dredging for the NDC and the completion of Barrier construction were a small depth increase at the western end of the NDC and small depth reductions in the NDC above and below the Barrier. The pocket of accretion on the inter-tidal bank from the North abutment out to Pier 3 was due to rock tipping to prevent the cill units of the northern spans from being undermined. The accretion which had occurred between the Tate and Lyle jetties during the period of NDC dredging, continued. On the south side of the river in upper Woolwich Reach a moderate amount of bankside accretion between Murphy's jetty and the Barrier as well as some infilling of the former Charlton barge tiers also continued. Below the Barrier, much of the erosion is attributable to spot dredging operations undertaken to ensure adequate depths for deep-draughted vessels navigating through Span C. At the Barrier site, accretion from Span C to Span G was due to the tipping of rock bed protection around the cills to raise local bed levels to cill level in a naturally deep area.

The changes mentioned above are readily apparent on Fig 9 which shows the accretion and erosion which occurred between the post-NDC dredging survey (No 2) and the completed Barrier survey (No 10).

## 3 SUSPENDED SILT CONCENTRATION, 1970-1984

Since the early 1970's the concentration of suspended silt has been monitored at four stations along the estuary - Tilbury landing stage in Gravesend Reach, Crossness jetty in Halfway Reach and Tate and Lyle and Cory's jetties in Woolwich Reach. Each station is equipped with two optical sensors, one installed 0.6m above the bed, the other at a higher level, just below MLWS, connected to an automatic logging system.

Turbidity is monitored every twelve minutes using an optical-light extinction technique where a beam of light is transmitted through the water to shine on a photo-electric cell. The light intensity reaching the p.e. cell is a function of the light absorbed by silt particles in suspension. Thus the electrical energy emission from the cell is a measure of water turbidity along the light path.

Data are stored on magnetic tape and retrieved from site at 2-4 week intervals depending on the season. The tapes are translated into a computer-compatible format and information added to denote tidal range and times of high and low water. The information is then interrogated, edited to remove spurious readings and finally analysed.

Fig 1 at the end of this report shows mean silt concentrations 0.6m above the bed for each data batch: flood and ebb concentrations are plotted respectively above and below the horizontal axis. The Figure also gives a record of monthly-averaged daily gauged flows at Teddington weir. (From July 1982 flow was recorded by a new ultrasonic flow gauge installed at Kingston, a short distance up-river).

During the first few years of monitoring there was evidence of an annual cycle of turbidity, the form of the cycle varying with position along the estuary. At the two landward stations, turbidity was high during the summer and lower during the winter whilst at Tilbury, the most seaward station, the relationship was reversed. At Crossness, the cycle was less consistent, sometimes resembling the landward stations and sometimes appearing to be more closely related to the seaward station.

From the beginning of the records until the end of 1975, the cyclic variations at the two landward stations resulted mainly from changes in flood tide concentrations. At Tilbury they were mainly due to changes in ebb concentrations. At Crossness there was little difference between the pattern of changes on flood and ebb.

The winter of 1975/6 was abnormally dry and the turbidity cycle exhibited an increase in concentrations at the landward stations during the winter months and a decrease in the summer. Although the fresh water flow returned to a normal seasonal cycle in the winter of 1976/77 (albeit with flow rates significantly higher than the standard 30-year average), restoration of the usual cycle of turbidity occurred only at Tilbury. In 1979, re-establishment began at Cory's, turbidity again being mainly affected by variations in flood-tide concentrations. At Tate and Lyle's, a new condition developed and seasonal changes were affected equally by changes on both half-tides. Crossness responded in the same manner and began to reflect the low winter and high summer concentrations of the landward stations. Tilbury remained unchanged, the form of the annual cycle continuing to be mainly due to changes in ebb concentrations.

There are two possible reasons for the modification of the turbidity characteristics during the period 1976-79 - natural factors and man-made changes. The most important natural factor is fresh water flow which affects the whole of the estuary to a varying degree. Among man-made changes, civil engineering works such as the construction of the Thames Barrier and dredging may introduce local or widespread effects. To assess the relative importance of these natural and artificial changes, river flow data and silt monitor records were processed to show mean values in 3-monthly periods.

Fig 2 gives plots of 3-monthly average turbidity levels throughout the tidal cycle for Tilbury (Station 6) and includes all tides of 6.1m range at London Bridge. The graphs refer to data obtained from 1970 to 1974 (top row), 1975 to 1978 (middle row), and 1979 to 1982 (bottom row). The results demonstrate that in any year the quarterly turbidity characteristics change appreciably during the tidal cycle, and that in any given quarter the turbidity levels vary significantly from year to year.

Fig 3 shows a plot of 3-monthly average daily natural flow in the River Thames together with the corresponding 30-year standard average. During the period 1970-1972, flows were fairly close to the 30-year standard, while 1973 was dryer and 1974 wetter. 1975 was wet for the first half of the year followed by a year of low flow. From 1977 to 1982, with the exception of 1980 which recorded near-standard flow, discharges were generally above average.

Considering the top row of Fig 2 and relating it to the natural fresh water flow data from Fig 3 it emerges that the January-March quarter of 1973 was dry and the same quarter in 1974 wet compared with the 30-year standard discharge. 1973 had a turbidity level that was relatively low on the ebb and high on the flood, yielding a net landward transport of sediment. The converse was true in 1974. Similar reasoning can be applied to the three remaining quarters of the year and to changes recorded during subsequent years. In all cases differences in turbidity observations can be accounted for by natural changes in fresh water flow.

Fig 4 shows the 3-monthly average turbidity characteristics at Cory's (Station 7). In 1973/4 there tended to be a gradual increase in suspended sediment from slack high water to mean tide followed by a gradual decrease to slack low water. Sediment concentrations built up more rapidly on the flood to reach a higher peak level at mid-tide before returning to background concentration level at high water.

In 1973/4 the data from Cory's does not register changes in fresh water flow quite as well as the observations at Tilbury but the events are explicable. In the first quarter of 1974 river flow was high (Fig 3) and much of the readily-erodible bed sediment stored in the river above Cory's would have been flushed downriver. In the second quarter of 1973 and 1974 fresh water flow was comparable but below the 30-year standard. On both occasions net landward transport should have been a consequence and this is confirmed by the Figure: the baseload was, however, lower in 1974 due to the flushing effects of the previous quarter. In the third quarter, flow was quite close to the standard average and little difference would be expected. In the fourth quarter of 1973 flow was low, leading to a net landward movement, but in 1974 it was extremely high, and this should have resulted in a very strong net seaward movement: that it did not may well be a consequence of the large-scale dredging being undertaken on the opposite side of the river for the Thames Barrier NDC. This activity removed a substantial supply of sediment from the system.

A comparison of the data from the top and middle rows of Fig 4 clearly shows that throughout the tide the form of the turbidity curves changed appreciably in 1975 and thereafter concentrations remained low. The bottom row of data also shows reduced turbidity but there is some evidence of a slow progressive return to the 1973/4 state especially in the summer and autumn quarters.

Three-monthly average turbidity values at the Tate and Lyle jetty (Station 5) are shown on Fig 5. As at the Cory jetty, the comparison of data indicates a change in the turbidity characteristics from 1975. Two ebb-tide peaks and one well-defined flood-tide peak become obscured by the superposition of a number of high-frequency harmonics, the pattern becoming still more complex during subsequent years.

The three-monthly average turbidity values for Crossness (Station 1) are shown on Fig 6. The high ebb values during the second quarter of 1977 are uncharacteristic of this site and were not registered on any other monitor. The event is a clear reflection of the river works being carried out between Tate and Lyle's jetty in Woolwich Reach and Crossness in Halfway Reach. During this period sand was being pumped ashore about 2km upstream of Station 1 to reclaim part of the Thamesmead site, and the draining water was pumped back into the river causing disturbance to the bed and an increase in turbidity.

A comparison of the top row of curves with those in the middle and bottom rows indicates that there was a general reduction in turbidity levels during the first two quarters. This is probably due to a deficiency of material from up-river sources. In the third quarter, when net sediment transport was usually in a landward direction the differences in turbidity between the years became less pronounced. In the last quarter, the predominant landward transport of the period 1970-74 was modified to give a more even distribution of turbidity between the flood and ebb half tides, neither a landward nor a seaward transport of sediment being obviously predominant.

The overall conclusion drawn from the data on Figs 2, 4, 5 and 6 is that within a tidal excursion of Woolwich Reach, turbidity levels are currently different from those which obtained in the pre-Barrier period. The main reason appears to be a reduction in the volume of sediment available for re-erosion on the ebb tide, a deficiency having arisen partly as a result of the large-scale capital dredging undertaken for the Barrier and partly as a consequence of the prolonged period (1976 excluded) when river flow was significantly higher than the 30-year standard average.

## 4 TIDAL LEVELS

There is considerable evidence that tidal range and tidal penetration in the Thames have increased in historical times causing significant differences in estuary regime (Ref 5). During the twentieth century, however, changes in tidal range have been more modest, amounting to an increase of about 0.5m at London Bridge on spring tides. Most of this increase has been attributed to subsidence of SE England, the removal of inerodible outcrops from the river and general channel deepening carried out during the first of half of the century (Ref 6). Since 1950, annual average changes in the levels of high water, mean water and low water have been contained within a band width of 0.2m with an overall increase in high water level during the last thirty years of about 0.06m (0.002/yr). A similar trend is also evident in tidal range (Ref 7). The changes recorded since 1950, though progressive, are thus small, and over a 30-year period amount to less than one percent of tidal range.

Regime changes due to tidal level and tidal range must therefore be equally small, and for the period under review can be neglected.

## 5 RIVER FLOW

Large variations in river flow over Teddington weir affect water levels, salinity distribution and siltation.

### (i) Effect on water level

Fig 3 of Ref 2 shows annual averaged daily river flow rates at Teddington for the period 1950-1982. Natural and gauged flows varied widely from year to year while abstracted flow increased progressively. Because of the statistically short sampling period, it was assumed that there was no significant trend in natural flow, but that gauged flow exhibited a decreasing trend to account for the increased abstraction rate.

Comparison of natural and gauged flow curves with plots of annual average low water and mean water (Ref 2, Fig 2) reveals that tidal levels at Tower Pier (30km below Teddington Weir) are significantly influenced by freshwater flow. Between Tower Pier and the landward limit of Teddington, levels become increasingly dependent on gauged upland flow rates.

High gauged flows coincident with spring tides can produce very high water levels in the upper reaches of the estuary. Historically, high flows have been responsible for bank overspill and flooding but with better river management and improvements to tidal defences, damage due to this cause has been reduced in recent years.

Low gauged flows produce low tidal levels in the upper reaches. Between Teddington and Richmond the problem has been relieved by the Richmond Lock and half-tide weir. This structure allows water to be impounded from about two hours after high water until about two hours before the next high water to provide safe navigable water depths upstream throughout the tidal cycle. Below Richmond no further continuous tide control is in operation (although it is now technically possible, using the Thames Barrier as the control structure) and river levels rise and fall with the tide. In recent years the coincidence of low river discharge with spring tides has caused severe concern to commercial boat operators and up-river journeys have required careful planning to ensure adequate water depths during the return trip.

(ii) Effect on salinity and siltation

Variations in river discharge affect salinity intrusion. Figs 3 and 4 of Ref 2 clearly illustrate that salinity at Beckton sewage treatment works varies inversely with natural river flow, Fig 5 Ref 2 demonstrating the relationship at high water derived from data spanning 30 years.

Seasonal variations in river flow are large, ranging from near-zero flow during the 1976 summer drought when water at the tidal limit at Teddington was saline, to a severe winter flood when freshwater can be recorded as far down-river as Barking Reach. From considerations of estuary regime these salinity changes are significant because the physico-chemical properties of water and sediments change with saline strength.

In freshwater, fine clay particles can remain in suspension for indefinite periods even when there is no measurable water movement. In salt water a cation exchange occurs between the water and silts which encourages clay particles to bond together on collision. Subsequent collisions with other particles or clusters of particles from larger units, or flocs, with higher settling velocities which produce deposition in slack water.

Research on the salinity required for the initiation of flocculation has indicated a value of about 1.5 g/l (Ref 8). The process increases rapidly with increasing salinity up to a saline concentration of about 5 g/l: it becomes fully established to 10 g/l and thereafter remains constant.

At Beckton, high water salinity values of 1.5 g/l and 10 g/l respectively correspond to natural river flows of 220 $m^3/s$ and 50 $m^3/s$ (Ref 2, Fig 5). At low water, the corresponding flow rates are 85 $m^3/s$ and 22 $m^3/s$ (Fig 7). Fig 3 shows the 30-year standard average flow rate for the first quarter of the year to exceed 85 $m^3/s$ while in the fourth quarter it is just about 85 $m^3/s$. Fig 8 shows daily low water salinities recorded at Beckton expressed as quarterly averages. In the first quarter of most years and in the second and fourth quarter of some years, salinity has a value of 1.5 g/l or less. The low water salinity at Beckton thus falls to 1.5 g/l or less for approximately 4-5 months of the year.

Since salinity at Beckton falls to 1.5 g/l and less during the lower part of the tide the floc-bonding forces in this part of the river and further landward become very weak. Surface sediment deposits can be partially or wholly deflocculated and silt particles re-entrained into the tidal flow. The material re-entrained can be transported seawards as suspended load to a location where saline strength is adequate to encourage reflocculation, some being redeposited in zones where tidal flow is weak.

From late spring through to early autumn, when river flow reduces due to lower rainfall and run-off, the salinity at Beckton rises well above of 1.5 g/l and for most of the third quarter, values between 5 g/l and 10 g/l are recorded - ideal conditions for flocculation and deposition to occur in slack water zones some distance upstream of Beckton.

During the tidal cycle, current velocities achieve peak strength about two hours after slack water i.e. before mean tidal levels are reached. On the flood tide, water levels are rising from low water and on the ebb they are falling from high water: depths two hours after slack water are therefore shallower on the flood than on the ebb. Even on the assumption that mid-depth peak velocities are the same on both flood and ebb, the shear stresses on the bed during the flood will thus be higher than on the ebb. In fact, flood values are generally higher than ebb values. Furthermore, the duration of the flood flow near the bed is longer than that of the ebb in reaches seaward of central London (Ref 8). (Above London Bridge the sinusoidal shape of the tide curve gives way to increasing asymmetry with distance up-river and the ebb half-tide at all depths begins to last longer than the flood half-tide.) The combination of these factors generates a net up-river drift of eroded bed sediments during average river flows.

In periods of low river flow, both saline intrusion and the zone of net up-river suspend sediment transport move landwards, providing a mechanism for sediment deposition further up-river. During high river flows the converse applies and recently deposited silts in the upper reaches are deflocculated, re-eroded and transported down-river with the ebb tide. This effect is shown on Fig 1 where, in general, sediment concentrations during low flows are low at Tilbury and high at Tate and Lyle and are flood-dominant. During high flows they are high at Tilbury, low at Tate and Lyle and are ebb-dominant.

## 6 CONCLUSIONS

Since 1950, the secular change in annual average tidal level and tidal range at Tower Pier has been small - about 0.002 m/yr. This amounts to an increase of less than one percent in tidal range in the thirty-year period up to 1980. Changes that may have occurred to the distribution of flow or sediment cannot thus be attributed to natural changes in tidal characteristics.

Variations in river flow affect tidal levels at Tower Pier. In the upper reaches, levels are very dependent on gauged upland flow rates. During periods of low flow over Teddington weir the navigable depth at LW between Richmond and Kew is just adequate for commercial river users.

Variations in river discharge affect salinity intrusion, and an inverse relationship exists between river discharge and salinity as recorded at Beckton STW. During times of near-zero flow over Teddington weir (summer drought conditions) saline water may penetrate the estuary to the tidal limit. Under winter flood conditions fresh water can be found as far down-river as Barking Reach.

Variations in river discharge, and hence in salinity intrusion, affect estuarine siltation through a change in physico-chemical properties of the local water. Under low river flow, suspended sediments have a net up-river movement. During higher flows, deposits in the main deposition zone of the Mud Reaches are deflocculated and re-entrained in the ebb tidal flow for deposition in quiescent areas further down-river.

Accretion/erosion charts of the estuary from Bugsby's Reach to Long Reach document the changes in bed levels between successive hydrographic surveys between 1952 and 1978. In the reaches considered, most of the local changes can be attributed to man-made activities such as jetty construction, jetty extension, capital dredging or maintenance dredging.

Although evidence pointed to the existence of a long-term natural trend in sediment distribution, this was to some extent masked by continuous maintenance dredging being undertaken in the navigation channel by the Port of London Authority up to the mid-1960's. Following the cessation of this regular mid-river dredging between Gallions Reach and Halfway Reach, rapid accretion occurred along the north and south banks in Halfway, Barking, Gallions, Woolwich and Bugsby's Reaches. The distribution of accretion was influenced by the flow resistance afforded by the presence of man-made structures. Accretion also occurred seaward of Halfway Reach - mainly along the banks of Erith Reach and Erith Rands - but on a much reduced scale. The dredging activity maintained depths deeper than natural regime values and thus created over-deep areas in which silt was readily deposited, thereby reducing the amount of sediment available for deposition elsewhere.

Near Dartford Creekmouth, progressive accretion was recorded throughout the period. The reason is unknown. It could have been a reduction in creek discharge or some foreshore displacement resulting from increased bankside overburden pressure due to the reconstruction of a substantially improved flood embankment following the disastrous collapse that occurred during the 1953 storm surge.

Analysis of records from continuous silt monitors has confirmed that it is possible by this technique to distinguish changes in local regime due to civil engineering works from those resulting from variations in river flow.

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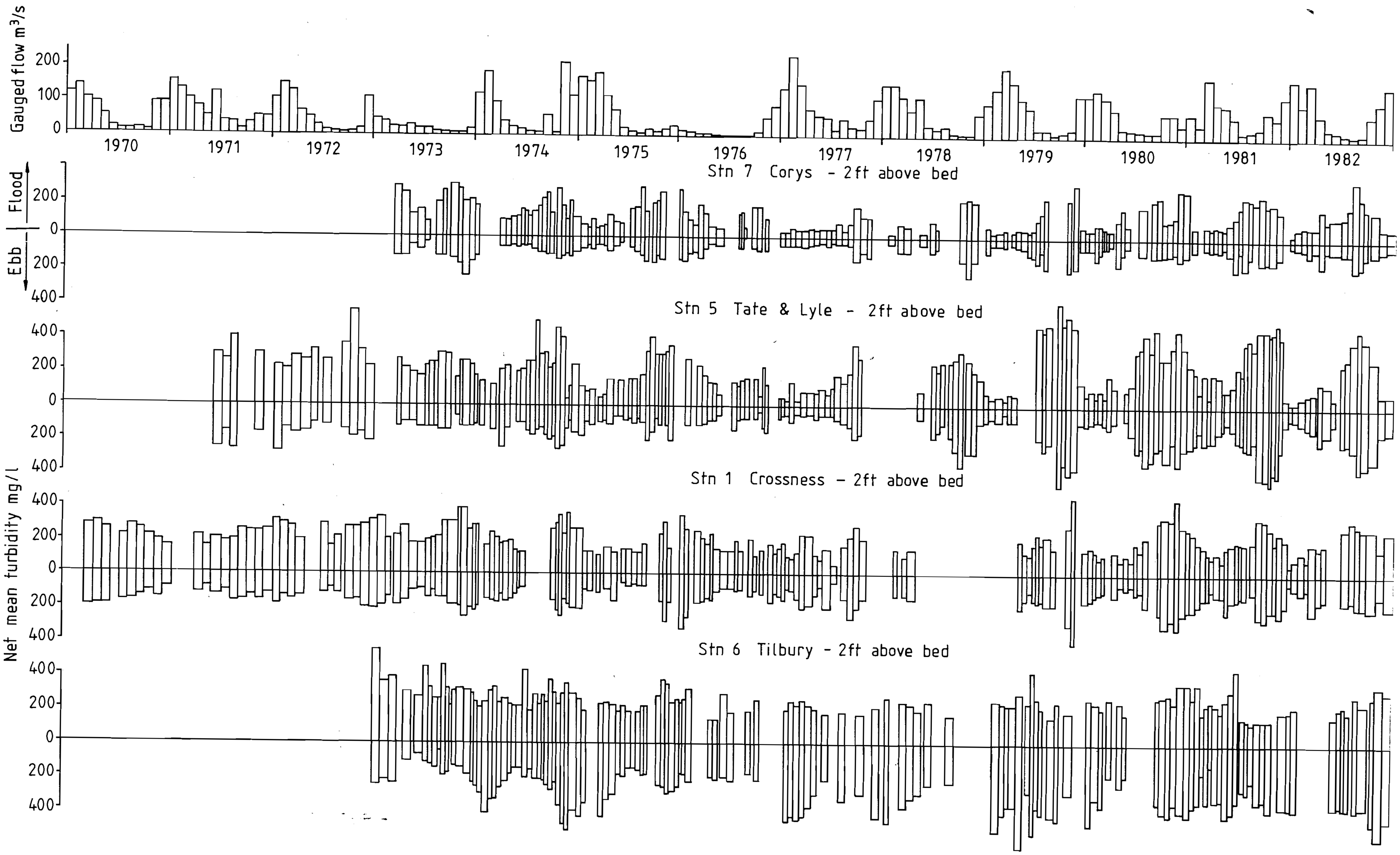
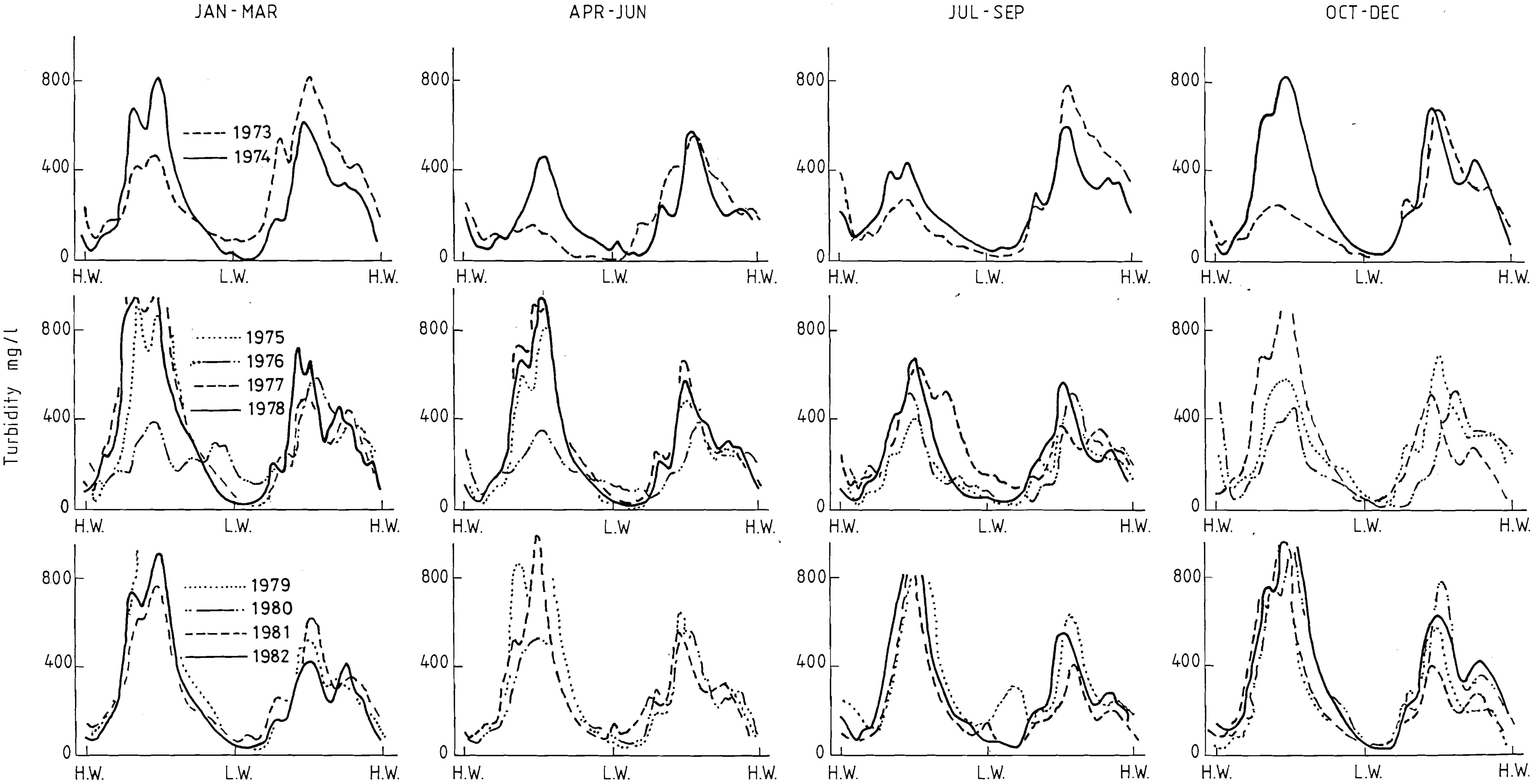


Mean flood & ebb concentration, 1970 - 1982

Fig 1



3-monthly average turbidity over a tidal cycle - Tilbury (Stn 6)

**Fig 2**

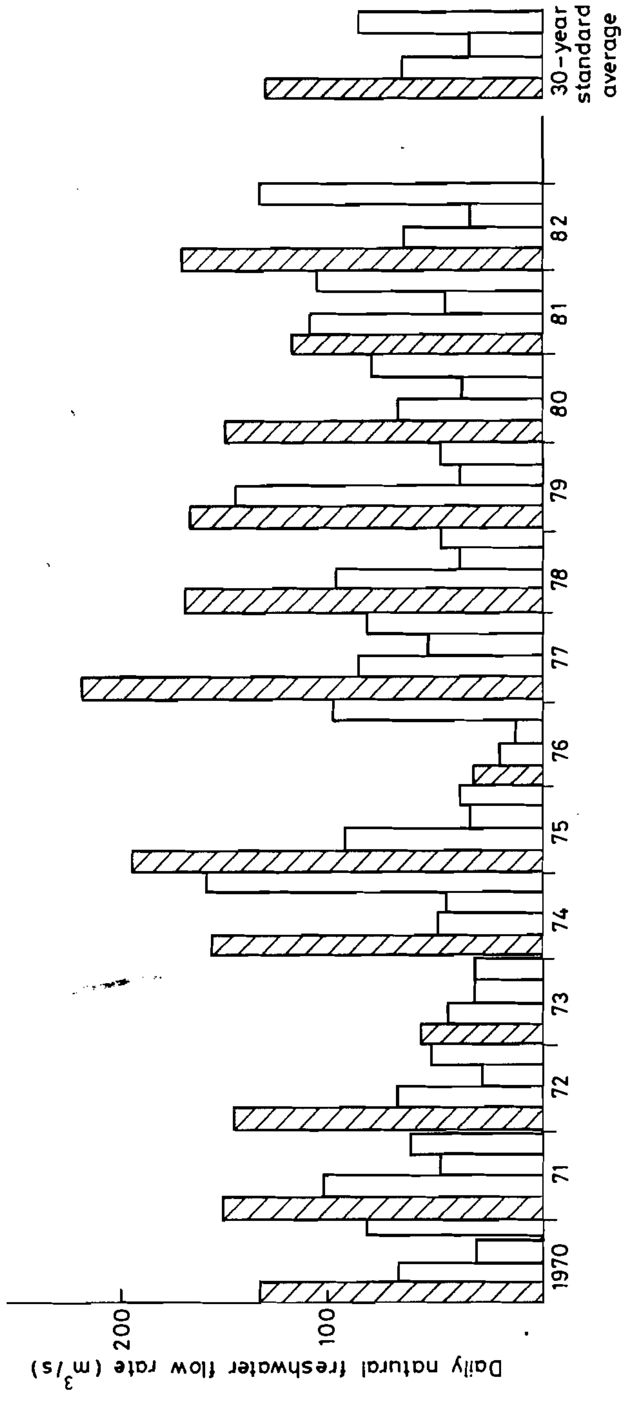
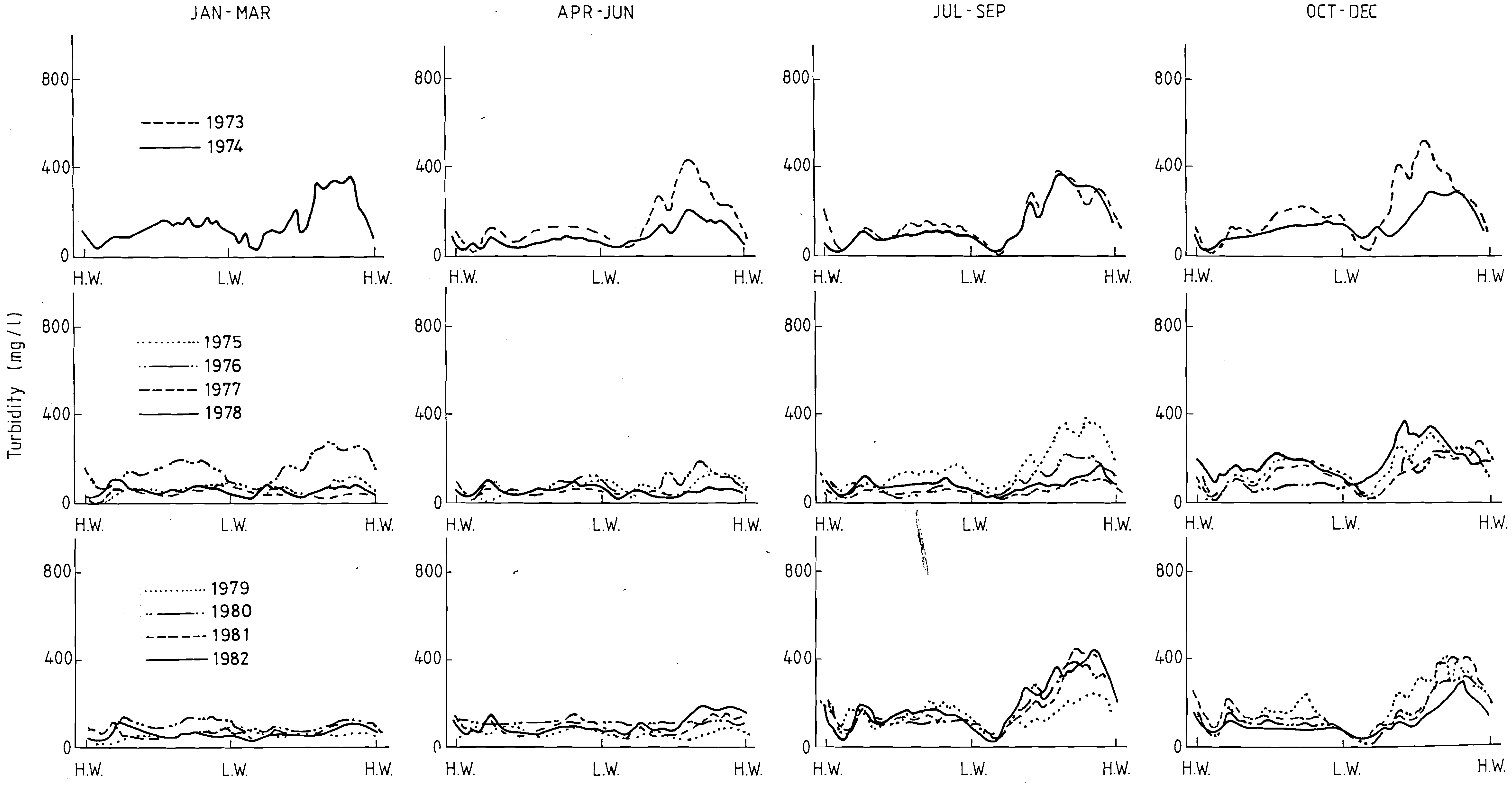
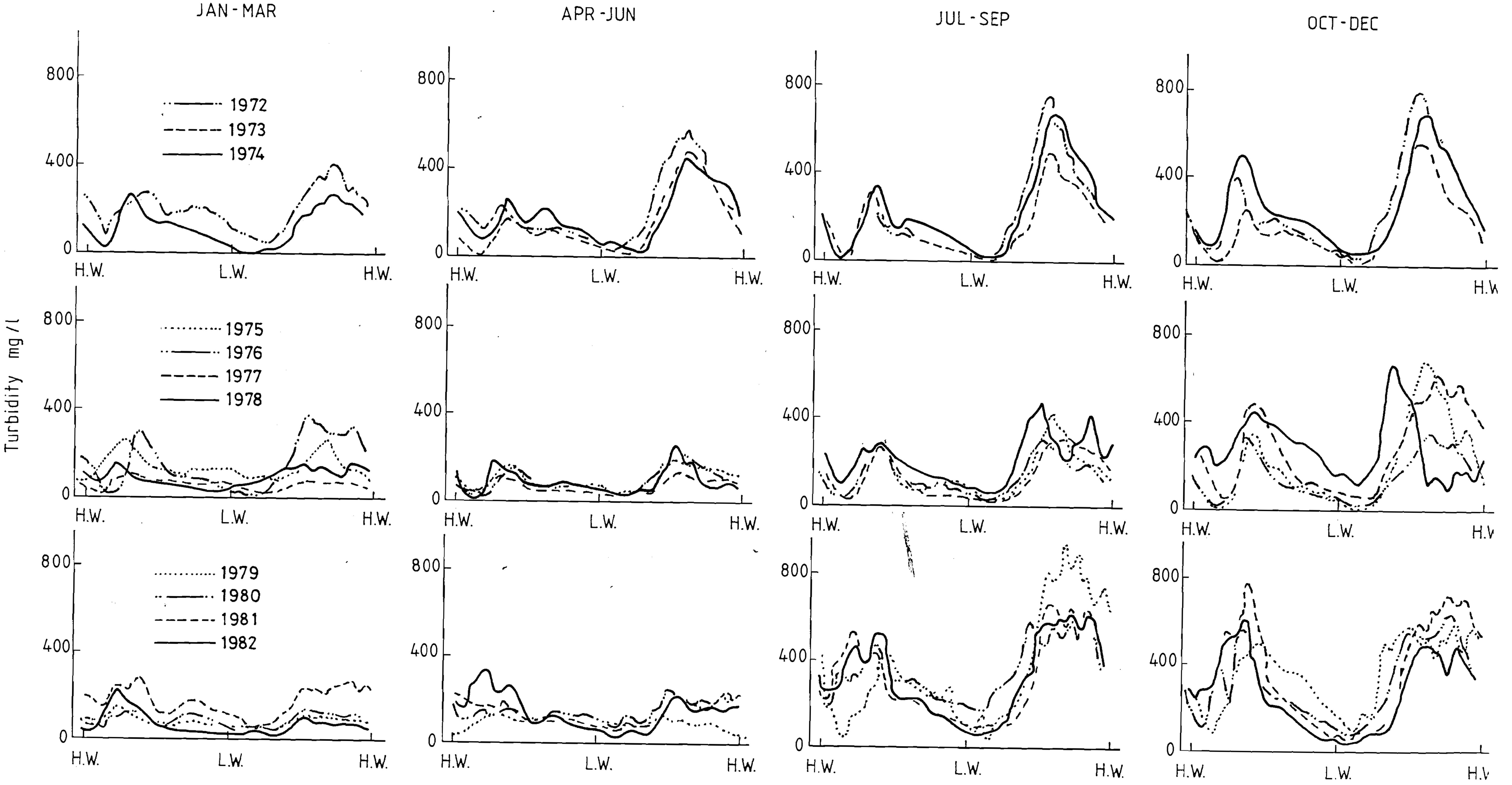


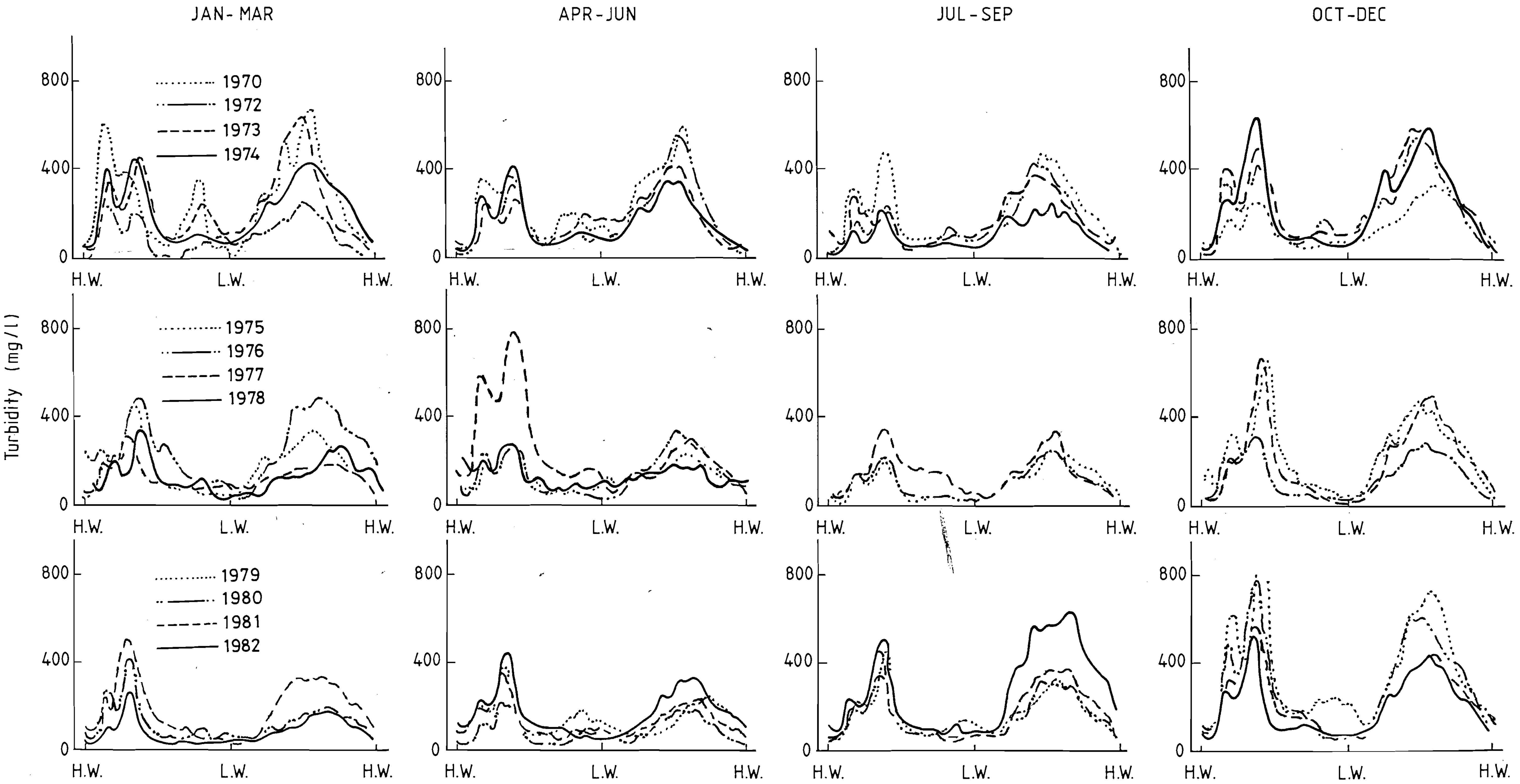
Fig 3 Daily natural river flow at Teddington, 1970 -1982



3-monthly average turbidity over a tidal cycle - Cory's (Stn 7)  Fig 4



3-monthly average turbidity over a tidal cycle - Tate & Lyle (Stn 5) Fig 5



3-monthly average turbidity over a tidal cycle - Crossness (Stn 1) Fig 6

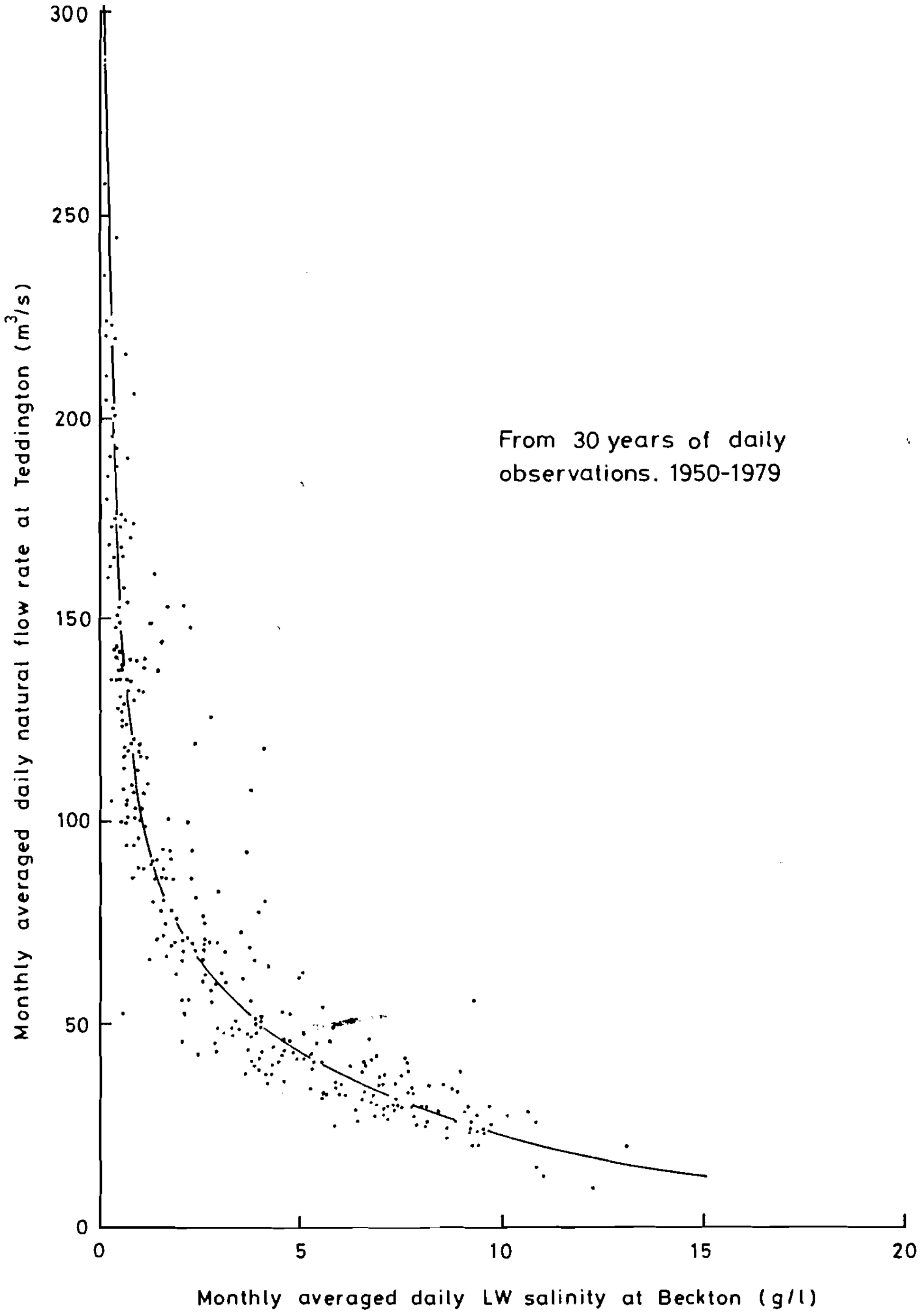


Fig 7 Relationship between natural river flow and salinity at Beckton

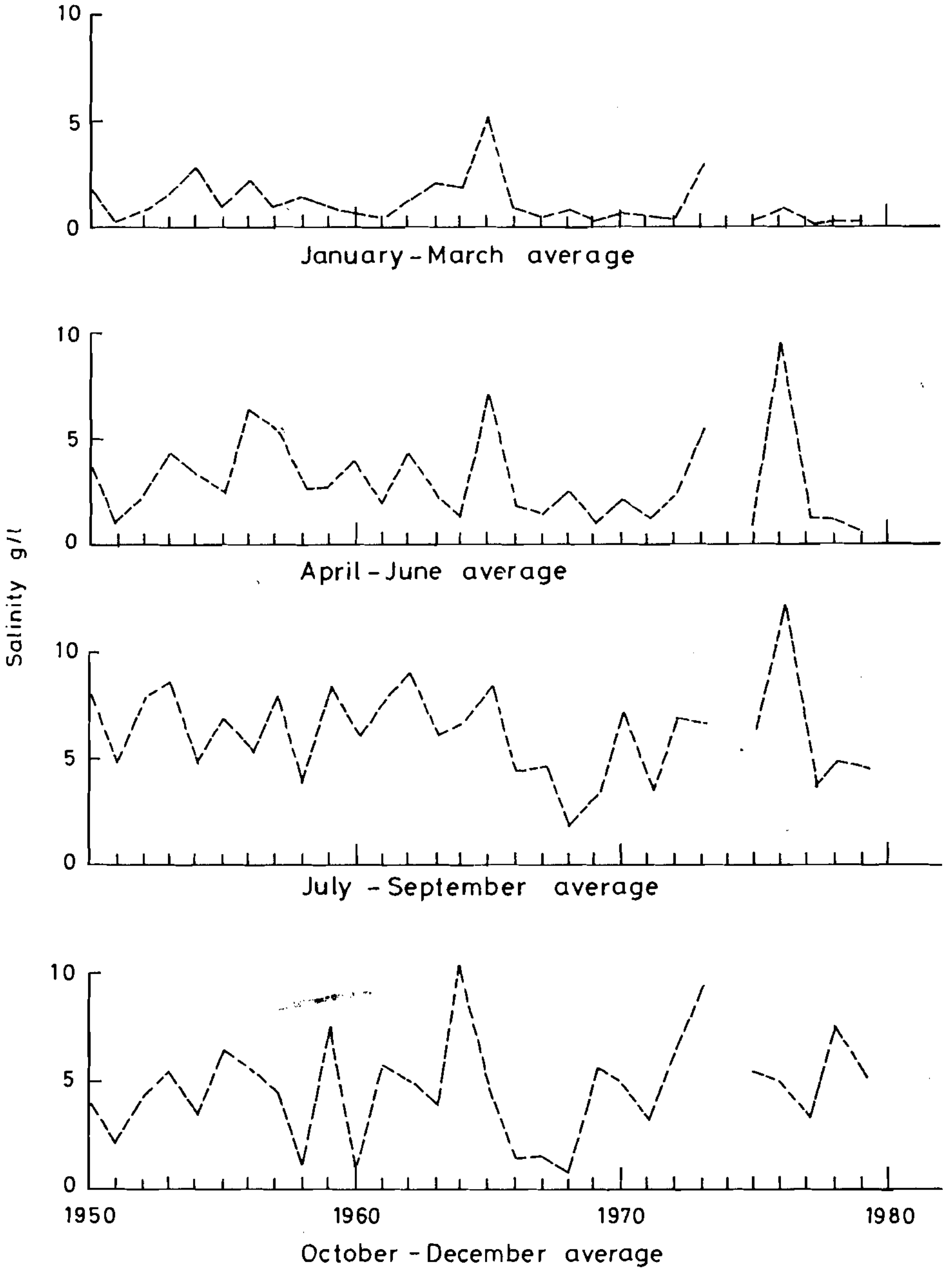


Fig 8 Quarterly averaged daily LW salinity at Beckton. 1950 - 1959