Regional Water Laboratory,
Butts Green,
Kilkenny.

A REPORT ON
WATER QUALITY IN THE
SUIR/BARROW/NORE ESTUARY
1999

Michael Neill.
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ENVIRONMENTAL PROTECTION AGENCY
An Ghiomháireacht um Chaomhnú Comhshaoil
Environmental Protection Agency,
Regional Water Laboratory,
Butts Green,
Kilkenny.

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Introduction

An estuary is a semi-enclosed coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with freshwater drainage from land.

The Suir/Barrow/Nore river system is the second largest in the country with a catchment area of over 9,000 km² and the Estuary of this river system consists of a network of long and narrow channels with few islands (Figure 1). The tidal reaches extend far inland; the river Suir is tidal to a point upstream of Carrick-on-Suir some 60 km along the estuary from Hook Head. The tidal limits of the Barrow and Nore are just upstream of St. Mullins and Inistioge respectively both of which are approximately 55 km from Hook Head. The water surface area of the Estuary is approximately 80 km². Overall it is relatively shallow but there are some deep sections at Waterford, in the Kings Channel and in Waterford Harbour.

The estuary is bounded by counties Tipperary, Kilkenny and Carlow to the north and west, by Wexford to the east and by Waterford to the south. There are a number of major population centres on the estuary with Waterford City being the largest. The estuary is a highly productive natural resource. It provides valuable quantities of varied seafoods, functions as a major hub for shipping and commerce, supplies a large natural habitat for wildlife and offers a wide variety of recreational opportunities for residents and visitors. These beneficial uses are discussed in detail in Volume 4 of the Draft Water Quality Management Plan for the Estuary (Ref. 1).

Tides, River Flows and Salinity

There is strong tidal action in the Suir/Barrow/Nore Estuary. The mean spring tidal range varies from 3.6m at Dunmore East to 3.9m at New Ross and the mean neap tidal range varies from 2.2m at Dunmore East to 2.4m at New Ross. The tidal prism at the mouth of the estuary varies from approximately 168 x $10^6$ m³ at neap tide to about 280 x $10^6$ m³ at spring tide.

The large catchment areas of the Suir/Barrow/Nore rivers contribute mean freshwater flows of the order...
of 63 m$^3$/s, 30 m$^3$/s and 36 m$^3$/s at the heads of the respective main channels of the estuarine network.

Freshwater has a salinity of 0°oo (°oo = parts per thousand) and the salinity of open ocean water is about 35°oo; salinity is used as a measure of the salt-water/freshwater ratio in estuarine waters. Under conditions giving maximum saline influx (i.e. spring tide and low freshwater flow) sea water extends some 37 km inland. The average salinity distribution in the estuary under these conditions varies from 34°oo at the ocean boundary to 25°oo at Cheekpoint, to 50°oo at Mount Congreve on the Suir and to 20°oo at New Ross on the Barrow. In relation to water quality, the benefits accruing from the combination of these factors are large water volume turnover, large tidal excursions and a well mixed estuary with short retention times.

The range and average salinity results for the 1999 surveys are graphed in figure 2. The freshwater flows were not particularly low during the 1999 surveys and further influx of saline water has been recorded at other times - the most critical period being low freshwater flows and spring tides.

With regard to water quality in the Suir/Barrow/Nore Estuary, the most crucial period is at neap tides and low freshwater flows (which are more likely to occur during summer months). However the winter is also important as this period is characterized by minimal biological activity and a high level of nutrient run-off in surface waters (especially nitrate).
Survey Description

The 1999 surveys included the following sampling and analyses.

(a) Samples were taken on three dates in 1999 (19 May, 26 July and 4 October).

(b) Samples were taken at various times in order to cover as many stages of the tide as possible. Two vans were used for shore and bridge samples and a boat was used to sample the reach between Waterford City and Hook Head.

(c) 236 water samples from 39 locations throughout the estuary were taken for chemical analyses. Nine of these locations were freshwater and the remainder were brackish or saline. The sampling locations are listed with the map (Figure 1 and fold-out map at the back of the report).

(d) Chemical analyses included: temperature, dissolved oxygen (DO), salinity (or chloride and conductivity in the case of freshwater), biochemical oxygen demand (BOD), pH, total ammonia, nitrate, o-phosphate and chlorophyll 'a'. Transparency (Secchi disc) readings were also taken with the boat samples. Un-ionised ammonia values were calculated from total ammonia, temperature and pH. Samples taken on 18/5/99 were also analysed for total organic carbon (TOC) and total nitrogen.

Shore and bridge samples were taken at the water surface. Boat samples were taken at three depths (surface, mid and 1 meter above the bottom) - temperature, dissolved oxygen and salinity were measured for each depth and the samples from the three depths were then composited for the other chemical parameters.

(e) Four sediment samples and three mussel samples (Mytilius edulis) were taken on 19 May 1999 for trace metals analyses including: chromium, lead, copper, zinc, cadmium, nickel and manganese (see Tables 4 and 5).

(f) 98 water samples from 17 locations (each taken 30 cm below the surface) were analysed for Total and Faecal Coliform bacteria.

(g) The results of analyses for each sampling station are given in the appendix and graphs showing the range and mean values for each sampling station are presented for salinity, BOD, TOC, dissolved oxygen, chlorophyll 'a', ammonia (total and un-ionised), nitrate, o-phosphate, pH, temperature, transparency (Secchi disc) and Total and Faecal Coliforms.

The graphs also serve to summarize the results.

(h) Sample station numbers are the same as those used in the Water Quality Management Plan (W.Q.M.P., Ref. 2) for the Estuary and the station numbers have been arranged for ease of comparison with Table 4 of Vol. 5 of the Draft W.Q.M.P. (Ref. 1) and with previous reports on Water Quality in the Suir/Barrow/Nore Estuary for 1989, 1991, 1993/95 and 1997 (References 3, 10, 13 and 21).
The Estuary, for the purposes of this report, has been divided into five sections (as in the WQMP) as follows:

Section A: River Barrow (Graiguenamanagh to Suir confluence).
Section B: River Nore (Inistioge).
Section C: River Suir (Carrick-on-Suir to Waterford).
Section D: River Suir (Waterford to Cheekpoint).
Section E: Suir Estuary (Cheekpoint to Hook Head).

The stations sampled by boat are located using a satellite navigation Geographical Positioning System (GPS). The sample station references are entered into the GPS as way-points as follows:

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Way-Point Reference</th>
<th>Latitude (north)</th>
<th>Longitude (west)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>W50</td>
<td>52°15.86'</td>
<td>7°07.03'</td>
</tr>
<tr>
<td>51C</td>
<td>W51C</td>
<td>52°15.45'</td>
<td>7°05.93'</td>
</tr>
<tr>
<td>52</td>
<td>W52</td>
<td>52°15.07'</td>
<td>7°05.20'</td>
</tr>
<tr>
<td>53</td>
<td>W53</td>
<td>52°15.04'</td>
<td>7°04.12'</td>
</tr>
<tr>
<td>57</td>
<td>W57</td>
<td>52°15.36'</td>
<td>7°03.07'</td>
</tr>
<tr>
<td>58</td>
<td>W58</td>
<td>52°15.45'</td>
<td>7°02.13'</td>
</tr>
<tr>
<td>59</td>
<td>W59</td>
<td>52°15.37'</td>
<td>7°01.76'</td>
</tr>
<tr>
<td>60</td>
<td>W60</td>
<td>52°16.33'</td>
<td>7°00.72'</td>
</tr>
<tr>
<td>21</td>
<td>W21</td>
<td>52°16.89'</td>
<td>7°00.30'</td>
</tr>
<tr>
<td>61</td>
<td>W61</td>
<td>52°16.44'</td>
<td>6°59.24'</td>
</tr>
<tr>
<td>62</td>
<td>W62</td>
<td>52°15.48'</td>
<td>6°59.44'</td>
</tr>
<tr>
<td>63</td>
<td>W63</td>
<td>52°14.32'</td>
<td>6°57.59'</td>
</tr>
<tr>
<td>64</td>
<td>W64</td>
<td>52°13.21'</td>
<td>6°56.76'</td>
</tr>
<tr>
<td>66</td>
<td>W66</td>
<td>52°11.95'</td>
<td>6°56.11'</td>
</tr>
<tr>
<td>69</td>
<td>W69</td>
<td>52°10.72'</td>
<td>6°55.60'</td>
</tr>
<tr>
<td>70</td>
<td>W70</td>
<td>52°10.71'</td>
<td>6°54.30'</td>
</tr>
<tr>
<td>71</td>
<td>W71</td>
<td>52°09.72'</td>
<td>6°58.20'</td>
</tr>
<tr>
<td>73</td>
<td>W73</td>
<td>52°09.12'</td>
<td>6°55.06'</td>
</tr>
<tr>
<td>74</td>
<td>W74</td>
<td>52°08.61'</td>
<td>6°59.07'</td>
</tr>
<tr>
<td>75</td>
<td>W75</td>
<td>52°08.08'</td>
<td>6°57.53'</td>
</tr>
<tr>
<td>76</td>
<td>W76</td>
<td>52°07.60'</td>
<td>6°56.17'</td>
</tr>
</tbody>
</table>
Water Quality Standards

Water Quality Standards for the Estuary are given in appendix A of the Water Quality Management Plan (W.Q.M.P.) for the Suir/Barrow/Nore Estuary (Ref. 2) and a synopsis of these standards is given in Table 1 below.

Table 1: Water Quality Standards - A synopsis.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Standards</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>&lt; 21.5</td>
<td>Except for natural occurrences</td>
</tr>
<tr>
<td>Dissolved Oxygen</td>
<td>mg/l O₂</td>
<td>50% &gt; 7</td>
<td>General Standard</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95% &gt; 5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100% &gt; 4</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>% saturation &gt; 80%</td>
<td>Guide-line for shellfish areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&gt; 70%</td>
<td>Mandatory for shellfish areas</td>
</tr>
<tr>
<td>BOD</td>
<td>mg/l O₂</td>
<td>95% &lt; 4</td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>6.5 - 8.5</td>
<td></td>
</tr>
<tr>
<td>Total Ammonia</td>
<td>mg/l N</td>
<td>95% &lt; 0.3</td>
<td>Guide-line</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95% &lt; 0.8</td>
<td>Mandatory for fresh water parts of the Estuary.</td>
</tr>
<tr>
<td>Un-ionised Ammonia</td>
<td>mg/l N</td>
<td>95% &lt; 0.004</td>
<td>Guide-line</td>
</tr>
<tr>
<td></td>
<td></td>
<td>95% &lt; 0.02</td>
<td>Mandatory</td>
</tr>
<tr>
<td>Nitrate</td>
<td>mg/l N</td>
<td>95% &lt; 1.0</td>
<td>Guide-line</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>for outer Estuary.</td>
</tr>
<tr>
<td>E.coli Coliforms</td>
<td>/100ml</td>
<td>80% &lt; 5,000</td>
<td>Bathing Areas</td>
</tr>
<tr>
<td>S. coli Coliforms</td>
<td>/100ml</td>
<td>80% &lt; 1,000</td>
<td>Bathing Areas</td>
</tr>
<tr>
<td></td>
<td>/100ml</td>
<td>75% &lt; 300</td>
<td>Shellfish Waters</td>
</tr>
<tr>
<td>Chromium</td>
<td>mg/l Cr</td>
<td>&lt; 0.05</td>
<td>Mariculture Areas</td>
</tr>
<tr>
<td></td>
<td></td>
<td>&lt; 0.1</td>
<td>Elsewhere</td>
</tr>
<tr>
<td>Lead</td>
<td>mg/l Pb</td>
<td>&lt; 0.1</td>
<td>General Standard.</td>
</tr>
<tr>
<td>Copper</td>
<td>mg/l Cu</td>
<td>&lt; 0.05</td>
<td>General Standard.</td>
</tr>
<tr>
<td>Zinc</td>
<td>mg/l Zn</td>
<td>&lt; 0.1</td>
<td>General Standard.</td>
</tr>
<tr>
<td>Cadmium</td>
<td>mg/l Cd</td>
<td>&lt; 0.005</td>
<td>General Standard.</td>
</tr>
<tr>
<td>Mercury</td>
<td>mg/l Hg</td>
<td>&lt; 0.0001</td>
<td>General Standard.</td>
</tr>
</tbody>
</table>
Water Quality in the Suir/Barrow/Nore Estuary - 1999

Individual results of analyses for each sampling station are given in the appendix and graphs showing the range and mean values are presented for salinity, temperature, transparency (Secchi disc), biochemical oxygen demand (BOD), ammonia (total and un-ionised), o-phosphate, nitrate, total nitrogen, chlorophyll 'a', dissolved oxygen, pH, total organic carbon (TOC) and Total and Faecal Coliforms.

The graphs also serve to summarise the results.

Water Quality Standards for the Estuary are given in appendix A of the Water Quality Management Plan (W.Q.M.P.) for the Suir/Barrow/Nore Estuary and a synopsis of these standards is given in Table 1 of the present report. These standards were referred to when preparing the comments on water quality below.

Chemical Data

Temperature

Water temperature in an estuary is a major influence on the rate of biological growth and productivity.

Temperature in Irish estuarine waters is largely controlled by the seasons and by weather, however naturally elevated temperatures may be observed at times in localised areas with shallow depths.

There were no prolonged hot weather spells in summer 1999 and river flows were generally normal or slightly higher than normal. Water temperature readings in the Estuary were as naturally expected and there were no measurable effects from industrial or municipal discharges.

The temperatures measurements are for May-October only and ranged from 9.5°C to 20.3°C. The average sea temperature at the harbour mouth (Station 76 - with an average salinity of 33.45 °/oo) during the three survey dates was 11.8°C, 14.2°C and 14.0°C (on 19 May, 26 July and 4 October respectively). Individual water temperature results for each sampling station for 1999 are given in the appendix and the range and average results for each station are shown in the graph.
Transparency (Secchi Disc)

Transparency is measured by the depth at which a 30 cm diameter white disc (Secchi Disc) is no longer visible when lowered into the water column. Transparency is related to the attenuation of light through water and may therefore be used as an indicator of the quantity of light available for photosynthesis. Transparency depends on the presence of dissolved and suspended material in the water and may also reflect the presence of dense algal blooms of phytoplankton. The transparency of shallow estuarine waters can also be affected by wave action and tidal movement which may cause sand/sediment to become re-suspended. Maximum Secchi depths in the coastal waters of the Irish Sea are normally around 5-6 meters, while in the Atlantic coastal waters maximum Secchi depths may approach 20 meters.

Transparency readings were taken at the boat sampling locations only. Individual results for each station are given in the appendix and the range and average results are summarised in the graph. Transparency increased from less than 1 m at Waterford city to a maximum of 8.5 m at Hook Head.

The relationship between Transparency and chlorophyll was examined however there was no obvious correlation observed.

Biochemical Oxygen Demand (BOD)

The BOD test is a measure of the amount of oxygen consumed by micro-organisms in breaking down organic matter in water, the test is carried out under standard conditions for 5 days at 20°C in the dark. Respiration by phytoplankton or their decay, especially when present in high concentrations, can also lead to oxygen depletion during the test resulting in a high BOD value. Natural sea-waters are likely to have a BOD value <2 mg/l O₂ and freshwaters <3 mg/l O₂. Values significantly above 4-5 mg/l O₂ indicate probable pollution or eutrophic conditions. The W.Q.M.P. for the Estuary has a standard of 4.0 mg/l O₂ for BOD.

A total of 236 BOD measurements were made during the 1999 surveys. The range and average BOD result for each sampling location are summarised in the graph.
Slightly elevated BODs were recorded at stations 32 to 43 (near Suir Lodge) however these sample locations also had high chlorophyll'a' levels which may have contributed to the BOD (in the absence of a corresponding high ammonia it is unlikely that the high BOD was due to the discharge from the tannery near Portlaw).

Otherwise all of the BOD results were less than 5 mg/l O₂ and only 10 results exceeded the 4.0 mg/l O₂ W.Q.M.P. standard. This represents an overall 95.8% compliance with the W.Q.M.P. standard. 93.2% of the results had a BOD of <3.0 mg/l O₂.

**Ammonia (Total)**

Ammonia occurs naturally in water bodies, including estuarine and marine waters, arising from the microbiological decomposition of nitrogenous organic matter. Ammonia is also excreted by fish and other aquatic organisms. Therefore, unpolluted waters contain small amounts of ammonia, usually <0.1 mg/l N. However natural seasonal fluctuations can occur due to the death and decay of aquatic organisms, especially phytoplankton and bacteria in eutrophic waters (Ref.15).

Conversely, ammonia may also be discharged directly into water bodies by some industrial processes or as a component of domestic sewage or animal slurry. Ammonia can also arise in waters from the decay of discharged organic
waste. Ammonia levels >0.2 mg/l N may therefore be an indication of organic pollution in water.

A total of 236 determinations for total ammonia \((\text{NH}_3 + \text{NH}_4^+)\) were made during the 1999 surveys. All of the ammonia results (including saline/brackish samples) complied with the mandatory ammonia standard of 0.8 mg/l N recommended in the W.Q.M.P. for the tidal fresh-water areas of the Harbour. With the exception of the St.Johns river, all of the ammonia results also complied with the lower guide level of 0.3 mg/l N.

A moderate increase in ammonia levels downstream of Waterford City is evident from the data (see the graph).

**Un-Ionised Ammonia**

The un-ionised ammonia fraction is the form of ammonia that is toxic to fresh-water fish. The relative proportions of ionised \((\text{NH}_4^+)\) and un-ionised \((\text{NH}_3)\) ammonia in solution depends on temperature and pH and to a lesser extent on salinity. The concentration of \(\text{NH}_3\) becomes greater with increasing temperatures and pH and with decreasing salinity. Un-ionised ammonia in fresh-water is calculated from total ammonia, pH and temperatures using the following formula (Ref.16).

\[
\text{Un-Ion Ammonia} = \frac{(\text{Total Ammonia mg/l N}) \times 17/14}{1 + 10^{[0.09018 + (2729.92/\text{Temp}^\circ K) - \text{pH}]}}
\]

However in salt-waters there is up to one fifth less un-ionised ammonia at the same pH and temperature (Ref.17). The above formula was used to estimate the concentrations of un-ionised ammonia in each sample (including brackish and saline samples but without any correction for salt content). Individual results are given in the appendix and these are summarised in the graph.

The standard for un-ionised ammonia in the Fresh-water Fish Directive (78/659/EEC, Ref.18) is 0.025 mg/l NH\(_3\) while the recommended guide level is 0.005 mg/l NH\(_3\). The standard given in the Irish Salmonid Waters Regulations (Ref.19) is 0.02 mg/l NH\(_3\).

Data on the effects of ammonia on marine species is limited and there is no standard for un-ionised ammonia in brackish/saline waters given in...
either the Directive or in the W.Q.M.P. for the Harbour.

All of the un-ionised ammonia results (including those for saline/brackish water samples) complied with the mandatory standard of 0.02 mg/l N (= 0.024 mg/l as NH₃) given in the W.Q.M.P. for the tidal fresh-water areas of the Harbour. However the lower guide level of 0.004 mg/l N (= 0.0048 mg/l as NH₃) is exceeded in the Carrick-on-Suir to Suir Lodge area and in some of the tributaries (see graph). The highest levels (max 0.02 mg/l NH₃) were recorded in the St. Johns river.

**ortho-Phosphate**

There are no standards for ortho-Phosphate in estuarine waters given in the W.Q.M.P. for the Estuary. The minimum phosphorus concentration for threshold algal growth in sea water is 0.003 mg/l P (Ref.30) and the background winter time sea-water phosphorus concentration is 0.025 mg/l P (Ref.31). Based on the monitoring experience at the Kilkenny Laboratory, the median concentration for ortho-phosphate in estuarine waters in the south-east region is approximately 0.02 mg/l P and 95% of samples have o-phosphate concentrations of <0.1 mg/l P.

River water quality monitoring has shown increased eutrophication (enrichment leading to increased weed and algal growth) in most of the rivers in the south-east region over the past few years. This is caused essentially by increased phosphorus levels arising from run-off from agricultural land and farm yards as well as from municipal and industrial effluent discharges. However, because o-phosphate can be quickly assimilated by algae and other aquatic plants during growth, the concentration of o-phosphate in water can be low even in eutrophic conditions, especially where phosphorus is the limiting nutrient.

Slightly elevated o-phosphate levels were recorded at New Ross (max 0.44 mg/l P). Otherwise the o-phosphate levels in water samples appear to be generally satisfactory throughout the Estuary. However, as o-phosphate is one of the nutrients which is freely removed from water by living plants, increases in phosphorus in the estuarine ecosystem is not always evident from the analyses of o-phosphate in water samples.
Nitrate

The nitrate concentrations in the Estuary are generally inversely proportional to the salinity but vary according to freshwater flow, stage of tide and time of year.

Nitrate levels in river waters vary on an annual basis and are lowest in July/August and highest in January/February (when the river flows are also normally higher), nitrate levels in the Estuary are therefore greater in winter than in summer. Average nitrate results for freshwater reaches of the rivers Suir, Barrow and Nore during the present surveys were 2.4, 2.8 and 2.6 mg/l N respectively and nitrate concentrations at Dunmore East/Hook Head were < 0.1 mg/l N.

River monitoring data show that nitrate concentrations in freshwaters in the south-east region are increasing (mainly as a result of changing farm practices) and river nitrate levels have nearly doubled since 1980.

The W.Q.M.P. recommends a guide-line of 1.0 mg/l N for nitrate in the outer harbour and all of the samples from south of Passage East complied with this limit. Overall levels of nitrate were satisfactory.

Samples taken on 19/5/1999 were also analysed for Total Nitrogen (74 measurements) and the range and mean result for each sample are summarised in the graph. This is the first time that total nitrogen was analysed in water.
samples from the Estuary and there is no standard for total nitrogen. The total nitrogen results are presented in the graph as baseline data (using the same scale as the nitrate graph above for comparison purposes).

**Nutrient Balance and Phytoplankton Production**

Salinity largely controls the distribution of living organisms, including plants, in an estuary by excluding those species which are adapted only to full freshwater or to fully marine conditions. The relationship between nutrients and plant production in estuaries is further complicated by the natural cycles of the living plants and by climatic and weather conditions. Phytoplankton require sunlight for photosynthesis which in turn can be affected by the transparency or turbidity of the water. In the open sea, phytoplankton are never entirely absent but generally experience spring and autumn peaks of abundance, the spring peak usually being the greater.

Living plants contain nitrogen and phosphorus in a ratio of $N:P = 16:1$ approximately (in addition to other elements). This is regarded as the ideal balance between these two nutrients for algal production. If the N:P ratio in water deviates significantly from 16:1 then one or other nutrient becomes limiting for growth. Phosphorus is usually the limiting nutrient in freshwaters while in marine waters nitrogen is usually the nutrient in shortest supply.

Eutrophication in estuarine waters can arise from the marked increase in nutrient supply leading to increased growth of plants, particularly phytoplankton. Plants undergo respiration at all times but during daylight hours they also undergo photosynthesis. This process results in a net output of oxygen during the day and a net intake of oxygen by the plants at night. The exchange of oxygen between plants and water can, in eutrophic conditions, cause diurnal variations (i.e. variations over a 24-hour period) in dissolved oxygen (DO) leading to high (frequently super-saturated) levels of DO during the day but DO levels can decline seriously during the hours of darkness. The critical period for DO in eutrophic waters occurs just before dawn (i.e. after maximum hours of darkness). There are corresponding but inverse effects on CO$_2$ levels which in turn can alter the pH.

Nutrients are freely removed from water by plants and algae especially during the spring/summer/autumn period. Therefore increases in eutrophication are not always evident from the analyses of nutrients in water samples. In many instances eutrophication is more evident from the biomass of weed and algae and from the effects of plant respiration and photosynthesis on dissolved oxygen.

**Chlorophyll 'a'**

Chlorophyll 'a' is a natural constituent of plant life, including phytoplankton, in estuarine waters. Chlorophyll 'a' gives a reasonable indication of the biomass of phytoplankton present in water.

The Water Quality management Plan (W.Q.M.P.) for the Estuary does not give a standard for chlorophyll 'a'. Un-enriched coastal waters normally exhibit summertime chlorophyll 'a' levels of approximately 10 mg/m$^3$, although particular climatic and local conditions may...
occasionally result in concentrations above this limit. A chlorophyll 'a' value of 30 mg/m³ is taken to indicate significantly enhanced phytoplankton growth; a body of coastal water can be considered eutrophic if this level is regularly approached or exceeded during summer. Chlorophyll 'a' concentrations >100 mg/m³ are considered to be very high. Therefore, for the purposes of this report, chlorophyll 'a' levels >30 mg/m³ are considered to be high and levels >100 mg/m³ are very high.

Wind and surf action tend to concentrate plankton and other flotsam at the water edge and this can result in high chlorophyll 'a' concentrations in samples taken from the shore, especially where the shore is shallow and sloping. Therefore, samples taken at the shore may be important locally (e.g. in bathing areas or shellfish areas) however, they may not be representative of the greater body of water off-shore.

A total of 184 chlorophyll 'a' determinations were made. Individual results are given in the appendix and these are summarised in the graph. 14 results (7.6%) were greater than 30 mg/m³ and 6 values (3.2%) were greater than 100 mg/m³.

The chlorophyll results were highest in the Fiddown/Suir Lodge reach of the river Suir (maximum 320 and 146 mg/m³ Chlorophyll at Stations 32 and 41 respectively) and to a lesser extent in the lower reaches of the river Barrow (Mountgarret Bridge to New Ross). Those samples with high chlorophyll 'a' concentrations during the three 1999 surveys were all mainly freshwater. While the freshwater discharging to the Estuary moves in and out with the tide and eventually disperses into the Estuary, it is contained upstream of the tidal wedge for a time and during this period phytoplankton can grow in the freshwater as it would in a lake without being flushed away as in a river situation.

During surveys prior to 1999 the highest chlorophyll concentrations in the estuary also occurred in the stretch downstream of Fiddown and in water with low salinity, but not necessarily zero salinity.

Chlorophyll levels also very high in the tidal freshwater reaches of the river Clodiagh at times. This was probably mainly due to tidal run-up from the river Suir rather than freshwater inputs from the Clodiagh itself.
Chlorophyll'a' levels are satisfactory at all sampling stations in the reach between Waterford City and Hook Head inclusive. However the data indicate elevated levels of chlorophyll'a' in the upper Suir estuary (Fiddown to Suir Lodge) and in the lower reaches of the rivers Barrow and Clodiagh (see graph). Because monitoring of the Estuary only started in the 1980's, it is not known to what extent the elevated chlorophyll'a' levels are due to natural processes or to anthropogenic influences.

Conservative and Non-Conservative Behaviour of Freshwater Inputs

Where a component of freshwater passes through an estuary without undergoing any reaction, except for dilution with saline water, then the component is said to act conservatively and a graph of the component vs salinity is an inverse straight line (sometimes called the theoretical or ideal dilution line). However if the component reacts by physical, chemical or biological process, as it passes through the estuary then the component is said to behave non-conservatively and the graph deviates from a straight line and becomes curved. The curve is inward where the component is removed from the system and outward if more of the component becomes available. This concept is particularly important for investigating the removal of nutrients (e.g. nitrogen, phosphorus or silica) from estuarine waters by living plants or for investigating the increase in these nutrients from recycling from
sediments or from the decay and breakdown of plant and animal material. More complex graphs are produced where reactions take place mainly at one end of the salinity range and trends are also effected by seasonal, climatic and weather conditions.

In the Suir/Barrow/Nore Estuary the process of conservative or non-conservative behaviour is further complicated by the fact that two major river systems (the Suir and the Barrow/Nore) discharge to the Estuary. Graphs for nitrate and o-phosphate vs salinity for the three sampling dates are shown above.

Nitrate levels throughout the Estuary are generally inversely proportional to salinity - indicating largely conservative behaviour for nitrate.

In the graphs above the o-phosphate data are more scattered than those for nitrate. Also the o-Phosphate results are generally on the inside of the conservative line in May and on the outside of the conservative line in October. This could be due to the removal of o-phosphate from the system by growing phytoplankton in May while in October there is a net increase in o-phosphate - possibly resulting from phytoplankton decay.

**Dissolved Oxygen (DO)**

Dissolved Oxygen (DO) is essential for the survival of fish and other aquatic life and the DO test is one of the most important indicators of pollution or eutrophication in surface waters, including estuarine waters.

The solubility of oxygen in estuarine waters is governed by the water temperature and salinity and, to a lesser degree, by the atmospheric pressure. Natural water in equilibrium with air is saturated with oxygen (i.e. at 100 % Saturation) and DO can be expressed either as % Saturation or in concentration terms as mg/l O₂.

However the water characteristics and substances present in the water may cause deviations in DO from 100 % Saturation and there may also be a time lag before the DO in the water regains its equilibrium with the air above. Deviations in DO are caused by:

- Changes in temperature.
- Changes in salinity.
- Consumption of oxygen by micro-organisms in breaking down organic matter, including waste, present in the water. This can lead to an oxygen sag where a sufficient amount of organic matter is present (see BOD above).
- Eutrophication (q.v.) - The exchange of oxygen between plants and water in eutrophic waters can cause diurnal variations in DO leading to high (frequently super-saturated) levels of dissolved oxygen during the day but dissolved oxygen levels can decline seriously during the hours of darkness with the critical period for dissolved oxygen in eutrophic waters occurring just before dawn (i.e. after maximum hours of darkness).
- Stratification - the separation of deeper surface waters into
distinct layers or strata especially in calm weather conditions. The strata are usually characterised by warm water on top and colder water on the bottom with an intermediate transition band or "thermocline" that seals off the bottom layer. DO can naturally diminish in the lower layer which may, in some situations, become anaerobic (i.e. contain zero oxygen). Another form of stratification can also occur in estuaries where fresh water floats over salt water.

The range and average results for DO (as % saturation) for each of the sampling locations are summarised in the graph.

DO was also calculated in mg/l \(O_2\) units in order to complete table 2 below.

A total of 481 DO measurements were made during the surveys and 208 of these measurements were taken in the outer estuary (south of Cheekpoint inclusive).

The overall percentage compliance of DO with the W.Q.M.P. standards along with the percentage compliance of samples from the outer estuary (d/s Cheekpoint) were as follows:

**Table 2  Dissolved Oxygen - compliance with standards**

<table>
<thead>
<tr>
<th>Standard</th>
<th>% compliance</th>
<th>% compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>General Standard</td>
<td>50% &gt; 7 mg/l (O_2)</td>
<td>94.8%</td>
</tr>
<tr>
<td>General Standard</td>
<td>95% &gt; 5 mg/l (O_2)</td>
<td>100%</td>
</tr>
<tr>
<td>General Standard</td>
<td>100% &gt; 4 mg/l (O_2)</td>
<td>100%</td>
</tr>
<tr>
<td>Guide for Shellfish areas</td>
<td>&gt; 80% sat.</td>
<td>92.1%</td>
</tr>
<tr>
<td>Mandatory for Shellfish areas</td>
<td>&gt; 70% sat.</td>
<td>99.0%</td>
</tr>
<tr>
<td>Guide-line for bathing areas</td>
<td>70 -120% sat.</td>
<td>97.1%</td>
</tr>
</tbody>
</table>

Elevated DO levels were recorded in the Carrick-on-Suir area (Stations 23 and 24) are indicative of eutrophic conditions (the samples at station 23 are taken from the river bank and not in the main flow and the DO may be affected by weed growth in the river near the bank).

A maximum DO of 167 %Sat. in the St.Johns river Nore is indicative of eutrophic conditions.

Otherwise the DO results were satisfactory.
**pH**

pH is a measure of the acidity of water. The pH of sea-water is generally around 8.0 because of its uniform composition; freshwater pH is more variable depending on the geology of the river catchment and on river flow and on wastewater discharges. pH can also be influenced by biological processes, chiefly carbon dioxide uptake by plants during photosynthesis. In eutrophic waters, diurnal variations of pH follow the diurnal variations in dissolved oxygen.

The highest pH values were recorded in the freshwater reaches of the Suir (range 8.1 to 8.8) and Nore (range 8.1 to 8.7). These slightly elevated levels are probably due to eutrophic conditions (i.e. plants in the rivers removing carbon dioxide from the water during photosynthesis).

The standard for pH given in the W.Q.M.P. is 6.5 to 8.5. A total of 235 pH measurements were made and all of the results were in the range 7.5 to 8.8 with a 97% compliance with the standard. In saline/brackish samples (148 samples with salinity > 0.1 °/oo) all of pH results were within the range 7.5 to 8.5 and all complied with the pH standard.

**Total Organic Carbon (TOC)**

The 1997 Report on Water Quality in the Suir/Barrow/Nore Estuary (Ref.21) was the first to contain data on Total Organic Carbon. Carbon is a main constituent of organic waste and it is also a main constituent of phytoplankton. There are no standards available for TOC in surface waters (fresh or saline) and there is limited comparable data for TOC in other estuaries. For the present study TOC was measured in samples taken on 19/5/99 only (due to problems with laboratory instrumentation). The TOC data is given in the appendix as further baseline data and without comment on its implications regarding
water quality.

A total of 79 TOC measurements were made during the May survey of which 28 values (35.4%) were <5.0 mg/l C and 72 values (91.1%) were <10.0 mg/l C.
Trace Metals

Small concentrations of certain metals (trace metals) exist naturally in the environment and living organisms require trace amounts of particular metals in order to exist. However some trace metals can be hazardous to the environment if background levels are significantly exceeded.

The imprecise term "heavy metals" is often applied to trace metals. Heavy metals are an undefined group of trace metals most of which have high atomic weights (but not all) and that are generally toxic when present at concentrations above background levels. "Heavy metals" may comprise Hg, Pb, Cd, Cr, Be & Ni plus other metals and even some non-metals such as As and Se.

The trace metals analyses of mussels (Mytilus edulis) and sediments for the present report included: chromium, lead, copper, zinc, cadmium, nickel and manganese (see Tables 4 and 5).

Water samples were not analysed for trace metals during the 1999 survey as such analyses are subject to interference from the high salt content in marine waters and are therefore very time consuming and demanding on resources. Composite water samples from fourteen sampling locations were analysed for trace metals (Cr, Pb, Cu, Zn, Cd and Hg) for the 1989 report on water quality in the Estuary (Ref. 3).

Mussel Samples (Mytilus edulis)

Trace metals present in dilute concentrations in water (in solution or in suspension) are biologically concentrated in the living tissue of filter feeding shellfish such as mussels - a process known as bioaccumulation. Mussels are therefore a useful indicator of the long term concentrations of certain trace metals in the aquatic environment.

Mussel samples were taken at four locations on 19 May 1999. All of the mussel samples were from the stretch between Barrow Bridge and Duncannon, other locations were also searched for mussels (including Waterford City and Dunmore East) but none were found. The results of analyses are given in Table 4 along with the results for other locations which are given for comparison purposes. The 1999 results are compatible with those for other locations and are generally satisfactory.

Sediment Samples

Estuarine sediments include deposits of mud, silt, clay, sand, etc. and sediments may also contain accumulated organic and/or inorganic materials. The sediments in the Suir/Barrow/Nore Estuary vary from grey/black muds (with high organic matter content) in the upper reaches of the Estuary to sand in the outer harbour.

Background trace metals in estuarine sediments generally reflect the occurrence and abundance of metals in the geological formations of the drainage area of the estuary. Trace metals discharged to estuarine waters (in particulate form or in solution and either directly or via rivers) are commonly adsorbed onto the surface of suspended matter and the heavier of these suspended particles can settle out in the slower moving waters of the estuary as part of the sedimentation process.

Therefore, trace metals in estuarine sediments are usually related to
Table 1. Trace Metals in Mussel Samples.

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Sampling Location</th>
<th>Manganese (mg/kg Mn)</th>
<th>Zinc (mg/kg Zn)</th>
<th>Copper (mg/kg Cu)</th>
<th>Cadmium (mg/kg Cd)</th>
<th>Lead (mg/kg Pb)</th>
<th>Nickel (mg/kg Ni)</th>
<th>Chromium (mg/kg Cr)</th>
<th>Mercury (mg/kg Hg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>Barrow Br</td>
<td>11.4</td>
<td>18.8</td>
<td>1.6</td>
<td>0.18</td>
<td>0.8</td>
<td>1.1</td>
<td>1.0</td>
<td>0.73</td>
</tr>
<tr>
<td>61</td>
<td>Cheek Point</td>
<td>12.1</td>
<td>16.9</td>
<td>1.9</td>
<td>0.26</td>
<td>1.0</td>
<td>1.1</td>
<td>1.1</td>
<td>0.14</td>
</tr>
<tr>
<td>63</td>
<td>Passage East</td>
<td>14.5</td>
<td>44.9</td>
<td>6.2</td>
<td>0.28</td>
<td>5.2</td>
<td>4.1</td>
<td>2.4</td>
<td>0.18</td>
</tr>
<tr>
<td>64</td>
<td>Duncannon</td>
<td>6.9</td>
<td>20.9</td>
<td>1.9</td>
<td>0.27</td>
<td>1.2</td>
<td>0.9</td>
<td>1.0</td>
<td>0.19</td>
</tr>
<tr>
<td></td>
<td><strong>Average Result</strong></td>
<td><strong>11.2</strong></td>
<td><strong>25.4</strong></td>
<td><strong>2.9</strong></td>
<td><strong>0.25</strong></td>
<td><strong>2.1</strong></td>
<td><strong>4.5</strong></td>
<td><strong>1.4</strong></td>
<td><strong>0.56</strong></td>
</tr>
</tbody>
</table>

Other results (for comparison purposes)
Arthurstown 1995 (Fisheries Research Centre, Ref 14) --- 12.0 7.6 0.14 0.38 --- 0.17 0.01
Mean for 9 Irish Coastal waters, 1995 (Ref 14) --- 16.9 4.1 0.21 0.11 --- 0.34 0.02
Mean for 29 Irish coastal waters, 1976 (Ref 4) 1.6 12.3 0.8 0.31 0.34 --- 0.61 ---
Mean for Suir/Barrow/Nore Estuary 1997 3.0 14.2 1.6 0.20 0.67 0.6 0.77 ---
Mean for Suir/Barrow/Nore Estuary 1991 --- 13.6 1.1 0.28 0.15 --- 0.81 ---
Mean for Suir/Barrow/Nore Estuary 1989 --- 8.7 0.6 0.03 0.25 --- <0.25 <0.01
Mean for Wexford Harbour 1998 15.60 2.20 0.30 1.30 2.30 4.00 ---
Mean for Wexford Harbour 1996 9.30 26.60 2.10 0.20 1.00 1.10 1.30 ---
Mean for Wexford Harbour 1990 --- 11.7 4.2 0.12 0.42 --- <0.07 ---
Mean for Wexford Harbour 1988 --- 25.5 0.8 0.25 0.07 --- <0.07 0.04

Results are given on a wet weight basis (flesh only) assuming a moisture content of 75%.
The samples were taken on 19 May 1999.
Other locations were also searched for mussel samples but none were found.

Method of analyses
The mussel samples (Mytilus Edulis) were kept cool and moist and were transported directly to the laboratory where they were immediately depurated for 14 hours in water which was taken from Duncannon.
The mussel samples were de-shelled and the flesh was dried at 60°C for 3 days. The dried samples were powdered (using an electric coffee grinder) and weighed portions were digested with HNO3/H2O2. The digest was analysed at the EPA Dublin laboratory using Inductive Coupled Plasma (ICP).

* Note: Disregard the mercury results, these results were given in error in the original reports. The mercury results were deleted (struck out) in reports issued after 2 June 2000.
<table>
<thead>
<tr>
<th>Station Number</th>
<th>Sampling Location</th>
<th>Station Number</th>
<th>Sampling Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Waterford Bridge</td>
<td>52</td>
<td>Smelting House</td>
</tr>
<tr>
<td>58</td>
<td>Kings Channel</td>
<td>61</td>
<td>Checkpoint</td>
</tr>
</tbody>
</table>

Results of Analyses:

<table>
<thead>
<tr>
<th>Station Number</th>
<th>Organic Matter % w/w</th>
<th>Chromium mg/Kg Cr</th>
<th>Lead mg/Kg Pb</th>
<th>Copper mg/Kg Cu</th>
<th>Zinc mg/Kg Zn</th>
<th>Cadmium mg/Kg Cd</th>
<th>Mercury mg/Kg Hg</th>
<th>Manganese mg/Kg Mn</th>
<th>Nickel mg/Kg Ni</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>7.4</td>
<td>72.2</td>
<td>38.9</td>
<td>16.5</td>
<td>96</td>
<td>0.3</td>
<td>764</td>
<td>53.8</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>9.2</td>
<td>75.8</td>
<td>50.7</td>
<td>20.3</td>
<td>102</td>
<td>0.3</td>
<td>760</td>
<td>54.0</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>7.2</td>
<td>35.5</td>
<td>28.1</td>
<td>15.5</td>
<td>71</td>
<td>&lt;0.18</td>
<td>760</td>
<td>51.7</td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>1.7</td>
<td>23.4</td>
<td>17.7</td>
<td>6.9</td>
<td>62</td>
<td>&lt;0.18</td>
<td>556</td>
<td>36.7</td>
<td></td>
</tr>
</tbody>
</table>

Average Results for 1999:

<p>| | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>51.7</td>
<td>33.9</td>
<td>14.8</td>
<td>83</td>
<td>0.25</td>
<td>---</td>
<td>710</td>
<td>49.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Results for previous years and for other locations (for comparison purposes):

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average for Suir/Barrow/Nore Estuary</td>
<td>32.6</td>
<td>24.6</td>
<td>14.2</td>
<td>83.8</td>
<td>1.0</td>
<td>---</td>
<td>676</td>
</tr>
<tr>
<td>Average for Suir/Barrow/Nore Estuary</td>
<td>32.5</td>
<td>29.0</td>
<td>16.5</td>
<td>79.8</td>
<td>0.6</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Average for Suir/Barrow/Nore Estuary</td>
<td>33.7</td>
<td>42.9</td>
<td>28.6</td>
<td>133.5</td>
<td>0.8</td>
<td>&lt;0.16</td>
<td>---</td>
</tr>
</tbody>
</table>

Wexford Harbour (1996) average 18 samples:

| Wexford Harbour | 20.7 | 25.5 | 12.2 | 76.1 | 0.8 | --- | 16.6 |     |

Dungarvan Harbour (1996) average 46 samples:

| Dungarvan Harbour | 42.3 | 29.3 | 8.7 | 64.0 | 0.6 | --- | 24.1 |     |

Firth of Clyde (control area) (a):

| Firth of Clyde | 33.0 | 42.0 | 16.0 | 85.0 | 1.6 | 0.10 | --- |     |

Avon Estuary (control area) (a):

| Avon Estuary | 90.0 | 50.0 | 44.0 | 102.0 | 0.1 | --- | --- |     |

Solway Firth (b):

| Solway Firth | 35.0 | 37.0 | 13.0 | 65.0 | <1.0 | --- | 360 | 38.0 |

Average Content of Earth's Crust (c):

| Average Content of Earth's Crust | 200 | 16.0 | 13.0 | 132.0 | 0.2 | 0.50 | 1000 | 80.0 |

Average Content of Continental Crust (a):

| Average Content of Continental Crust | 100 | 12.5 | 55.0 | 70.0 | 0.2 | 0.10 | 850 | 35.0 |

Average Content of Nearshore Sediment (b):

| Average Content of Nearshore Sediment | 100 | 20.0 | 48.0 | 95.0 | --- | --- |     |     |

Method of Analyses:

The samples were taken on 19/5/1999 using a Van-Ween sediment sampler from the boat in mid-channel.

The samples were dried at 180°C. The portions passing through a 180 um sieve were digested with HNO3/H2O2 and the metals contents were determined on the extract at the EPA laboratory in Dublin using Inductive Coupled Plasma (ICP/MS). The results are expressed as mg/kg on a dried sample basis.

Blanks and quality control standards as well as certified reference materials were analysed along with the samples.

Organic matter was determined from the loss on ignition at 550°C.

References:

(c) Handbook of Chemistry & Physics, C.R.C., 60th edition, p F200.
Bacteriological Survey

Coliform bacteria are the universal microbiological indicators of water quality.

The faecal coliform bacterial count is a specific indicator of contamination originating from human or animal intestines and so is an indication of the possible presence of enteric pathogenic organisms.

Coliform bacteria other than faecal coliforms also occur in water as a result of run-off from soil or from growth on decaying vegetation. Analysis for these total coliforms gives an indication of the general level of microbiological quality of water.

Bacteriological Criteria for Estuarine Waters

The bacteriological standards given in the W.Q.M.P. for the Estuary (Ref.2) are for recognised bathing areas and for shellfish waters only. There are no general bacteriological standards applicable to the other parts of the Estuary. A synopsis of the standards is as follows:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>Standards</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Coliforms</td>
<td>/100ml</td>
<td>80% &lt; 5,000</td>
<td>Bathing Areas</td>
</tr>
<tr>
<td>Faecal Coliforms</td>
<td>/100ml</td>
<td>80% &lt; 1,000</td>
<td>Bathing Areas</td>
</tr>
<tr>
<td>Faecal Coliforms</td>
<td>/100ml</td>
<td>75% &lt; 300</td>
<td>Shellfish Waters *</td>
</tr>
</tbody>
</table>

* The standard for shellfish applies to waters from which shellfish are taken for immediate consumption by man.

The EC (Quality of Surface Water Intended for the Abstraction of Drinking Water) Regulations, 1989, (Ref.22), contains three classifications of standards - including standards for total and faecal coliform bacteria. These freshwater standards are based on the level of treatment that the water receives before distribution as drinking water as follows:

<table>
<thead>
<tr>
<th>Class</th>
<th>Prescribed Water Treatment</th>
<th>Total Coliform/100ml Standard</th>
<th>Faecal Coliform/100ml Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>Simple physical treatment and disinfection.</td>
<td>5,000</td>
<td>1,000</td>
</tr>
<tr>
<td>A2</td>
<td>Normal physical and chemical treatment and disinfection (eg. coagulation, flocculation, filtration and disinfection).</td>
<td>25,000</td>
<td>5,000</td>
</tr>
<tr>
<td>A3</td>
<td>Intensive physical and chemical treatment, extended treatment and disinfection.</td>
<td>100,000</td>
<td>40,000</td>
</tr>
</tbody>
</table>

There are no water abstractions for drinking water in the locality covered by the present study and hence these Regulations do not formally apply. Nevertheless, as an general indicator of water quality, it is reasonable to expect that freshwaters in general should comply with the standards for Class A2 waters (including bacteriological parameters) as outlined in the table above.
grain size and generally represent the background (or geological) concentration plus additional amounts that are roughly proportional to the amount of organic matter present in the sediment.

The 1999 results of trace metals analyses for the four sediment samples (taken on 19 May) are given in Table 4 - these results refer to the part of the sediment passing the 180 μm sieve. The results for other locations and for other years are also given in the table for comparison purposes. Overall the trace metals in the Suir/Barrow/Nore Estuary are as expected for the level of organic matter in each sediment sample - see graphs of trace metals vs organic matter contents below.
The total and faecal coliform counts for unpolluted salt-water samples are generally <100 and <50 per 100ml respectively (salinity > 34°/oo).

If there were no discharges of sewage etc. to the Estuary, then the total and faecal coliform counts throughout the Estuary would be dependent only on natural decay and on the ratio of freshwater to salt water (i.e. on salt water dilution). However there are discharges of sewage to the Estuary - especially at Waterford City and at New Ross.

It is also known that bacteriological levels in riverine inputs (and hence in estuarine waters) can vary greatly and are often highest during winter.

The criteria used in the present study to assess the overall bacteriological quality of waters throughout the Estuary are as follows:

<table>
<thead>
<tr>
<th></th>
<th>Total Coliforms per 100 ml</th>
<th>Faecal Coliform per 100 ml</th>
</tr>
</thead>
<tbody>
<tr>
<td>Freshwater</td>
<td>25,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Salt Water (&gt;34°/oo)</td>
<td>100</td>
<td>50</td>
</tr>
</tbody>
</table>

For transitional waters (i.e. waters between freshwater and full salt water) the bacteriological criteria vary relative to the salinity of the sample on a pro-rata basis.

**Classification of Shellfish Waters**

Shellfish production areas are classified by the Department of the Marine and Natural Resources (DoM&NR) under Statutory Instrument No. 147 of 1996 (Ref.27) which implements the EU Council Directive 91/492/EEC on laying down the health conditions for the production and placing on the market of live bivalve molluscs (Ref.26). The Directive and Regulations include bacteriological standards for mollusc flesh and intervalvular fluid - however they do not include any bacteriological standards for shellfish waters.

Note: The earlier EC Directive and Irish Regulations concerning the Quality of shellfish waters (Ref.24 and 25 respectively) do contain a standard of 300 faecal coliforms per 100 ml for shellfish waters. However this was only intended as an interim standard pending the adoption of Directive 91/492/EEC (Ref.26).

The shellfish production areas of Waterford Harbour were classified by the DoM&NR in November 1998 as Class B - i.e. the shellfish from this area require purification in an approved plant for 48 hours prior to sale for human consumption (Ref.28).

**Bacteriological Results - Discussion**

Total and faecal coliforms counts were determined in 98 samples from 17 locations for the present study. The results for individual sampling stations are given in the appendix and results exceeding the bacteriological criteria as defined above are highlighted (arrowed) in the table. The range and average result for total and faecal coliforms for the 17 sampling locations are also graphed, because of the very
large variations in coliform counts (range 1 to 68,000) the vertical axes in the coliform graphs are presented as log_{10} scales.

Coliform counts are high at Carrick-on-Suir (freshwater). Coliform numbers decrease at Fiddown and Suir Lodge but increase again at Waterford City. Samples from Carrick-on-Suir and Waterford City exceed the bacteriological criteria at times. There is a steady reduction in coliform numbers (total and faecal) between Waterford City and Dunmore East (see Coliform graphs).

Coliform counts in freshwater samples from the river Nore at Inistiogue and from the river Barrow at New Ross comply with the criteria for Class A2 waters for the abstraction of drinking waters as outlined above and are therefore satisfactory.

All of the samples from the lower Estuary and Harbour (between Giles’s Quay (Station 53) and Hook Head inclusive) complied with the bacteriological criteria outlined above and are therefore deemed satisfactory.

Notes: The EC Bathing Water Directive (Ref. 29) requires fortnightly sampling of water at designated bathing areas for total and faecal coliforms during the bathing season. The present study does not assess compliance with the Bathing Water Directive.
Total Coliforms/100ml (Log Scale)
Range and average values for each sampling station
Suir/Barrow/Nore Estuary 1999.

Faecal Coliforms/100ml (Log Scale)
Range and average values for each sampling station
Suir/Barrow/Nore Estuary 1999.
Summary of Main Findings

Section A: River Barrow, Graiguenamanagh to Barrow Bridge.

High chlorophyll 'a' and elevated o-phosphate levels were recorded in the Barrow Estuary at times. Otherwise quality was satisfactory in this reach. There is some salt-water intrusion at New Ross at times and salinity increases rapidly between New Ross and the Suir confluence at Barrow Bridge.

Section B: River Nore at Inistioge.

There were indications of moderate eutrophication (elevated DO and pH levels), otherwise all results indicate satisfactory quality.

Section C: River Suir, Carrick-on-Suir to Waterford City.

Water quality was impaired at Carrick-on-Suir where eutrophic conditions exist and large variations in dissolved oxygen were recorded (maximum 161% saturation). Elevated Coliform bacteria counts were also recorded.

Very high chlorophyll 'a' levels were measured at Fiddown (maximum 320 mg/m^3) and at Suir Lodge and in the Clodiagh river during the July survey, these samples from the upper reaches of the tidal limits were mostly freshwater samples.

Water quality improves towards Waterford City.

Section C: Tributaries.

Water quality was unsatisfactory in the St. John's river. High ammonia levels were recorded (max 0.48 mg/l N) and there were significant variations in dissolved oxygen (range 69 to 167% saturation). The St. Johns river comprises < 0.1% of the total freshwater flow into the Estuary.

Eutrophic conditions in the tidal reaches of the river Clodiagh also lead to elevated BOD and pH levels. This was probably mainly due to tidal back-up from the river Suir rather than freshwater inputs from the Clodiagh itself.

Apart from indications of eutrophic conditions, water quality is generally satisfactory in the lower reaches of the other tributaries (Lingaun, Dawn and Blackwater).

Section D: River Suir, Waterford City to Cheekpoint.

There is an increase in coliform bacterial counts (total and faecal) and a slight increase in o-phosphate and ammonia at Waterford City.

Conditions were fairly satisfactory between station 52 (Smelting House, downstream of Waterford City) and Cheekpoint.

Section E: Cheekpoint to Hook Head.

Water quality was generally satisfactory in the lower Estuary and further downstream of Cheekpoint.
Conclusions

It is concluded that water quality in the greater part of the Estuary is reasonably satisfactory.

However there are problems with eutrophication (excess weed/algal growth) in the upper freshwater reaches of the Estuary - especially in the Fiddown/Suir Lodge reach of the river Suir (maximum 320 mg/m³ chlorophyll at Fiddown Bridge) and in the tidal reaches of the river Clodiagh (station 38) and to a lesser extent in the river Barrow (Mountgarret Bridge to New Ross).

Coliform bacteriological counts (total and faecal) are elevated at Carrick-on-Suir and in the vicinity of Waterford City.

The most serious pollution is confined to the St. John's river in Waterford City. The St. Johns river comprises < 0.1% of the total freshwater flow into the Estuary.

Water quality is generally satisfactory in the lower Suir and Barrow Estuaries and in the outer Harbour (i.e. at all sample locations downstream of stations 52 and 21 inclusive).
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