THE NATIONAL COASTAL BASELINE SURVEY
1993, 1994 and 1995

FINAL DRAFT

NRA
*National Centre
for
Instrumentation
and
Marine Surveillance*

~~EA - National~~
NRA ~~EA~~ - National Centres

THE NATIONAL COASTAL BASELINE SURVEY 1993, 1994 and 1995

FINAL DRAFT

EXECUTIVE SUMMARY

General

The National Rivers Authority (NRA) is required by Section 84 (2) of the Water Resources Act 1991, to monitor the extent of pollution of "controlled waters". These include territorial waters within 3 nautical miles (5.6 km) of the coast of England and Wales.

The NRA undertook national coastal baseline surveillance surveys in 1993, 1994 and 1995 in order to measure the levels of water-borne contaminants and assess water quality in the whole of the coastal zone.

These surveys took the form of simultaneous boat and airborne remote sensing surveys in Spring, Summer and Autumn with a boat survey in Winter. The four NRA coastal survey vessels were used to perform the boat work and a light aircraft was chartered for the aerial surveillance work. The NRA National Centre for Instrumentation and Marine Surveillance (IMS) designed, organised and coordinated the surveys. IMS also processed the data from the baseline sampling, *in-situ* monitoring and remote sensing.

This report describes the survey methodology, summarises the results obtained from the surveys and discusses these results.

The Boat Survey

The boat survey was carried out using the NRA coastal survey vessels based in the Northumbria/Yorkshire, Anglian, South Western and North Western Regions. These took samples at 186 pre-arranged sites along the coast of England and Wales, between Berwick on Tweed and the Solway Firth. Sites were situated approximately 15 km apart, with some additional sites at major estuaries (see Appendix A).

The samples were analysed in NRA laboratories ashore for 3 suites of chemicals (listed in Appendix B). These suites included heavy metals, solids, nutrients, chlorophyll-*a* and various organic chemicals.

While underway between sampling points, various parameters (depth, pH, temperature, dissolved oxygen, salinity, chlorophyll-*a* and transmission) were measured continuously by an instrument package and logged together with time and location. This provided information on any changes in water mass between the baseline sampling points, thus enabling the data from the samples to be put into greater context.

Information on nutrient concentrations along the tracks of the vessels was obtained by automatic sampling and analysis on board every 2-3 minutes using continuous flow auto analysers.

Airborne Remote Sensing

An R & D Project (Airborne Remote Sensing of Coastal Waters, published in R & D Report No.4) established the use of the combination of aerial remote sensing and data from boat surveys to obtain information on the coastal waters across the controlled zone. To obtain a synoptic view of the 3 nautical mile zone, remotely sensed data were gathered from an aircraft flying at an altitude of 10,000 ft along a series of 189 straight flight lines of varying length. The aircraft carried a suite of sensors comprising a Compact Airborne Spectrographic Imager (CASI), thermal and colour videos. All CASI data and thermal videos were logged with time and position obtained from GPS.

Data from the analysis of samples and the continuous monitoring by the boats were used as "sea truth data" to allow the calibration and aid the interpretation of the remotely sensed data. Similarly, mixing zones and other water body features revealed by the aerial survey can be used to put into context the data obtained from samples and continuous underway monitoring from the boats.

The data were processed at the National Centre for Instrumentation and Marine Surveillance (IMS) in the South Western Region. Images showing water bodies and distribution plumes were derived and calibrated to show the distribution of chlorophyll-*a* in the coastal waters.

Results

Data collected during the 1993, 1994 and 1995 baseline surveys were processed, collated and stored at the IMS. The data have been analysed to give an indication of the quality of the whole of the UK coastal waters.

A summary of early results and methodology were set out in "A Survey Report - Remote Sensing and Baseline Monitoring of the Coastal Waters of England and Wales, 1992 - 1993". Laboratory data for that period were also distributed within the NRA.

The large amount of data from the surveys over the 3 years makes it impractical to publish all the results of even solely the laboratory analyses in one document. The amount and nature of both the continuous underway monitoring and the remotely sensed data make their presentation in map form from a Geographical Information System (GIS) essential. Therefore all the results have been summarised and are set out in this report in the forms of maps.

However, all the individual results and details of specific areas are held at the IMS at Bath and can be made available to enquirers. The results can be briefly summarised as follows.

Chlorophyll-*a* concentrations around the coastline show the seasonal cycle of phytoplankton, with highest levels in Spring and lowest levels in Winter. Some areas, mainly off the Northumbria/Yorkshire coast, show elevated concentrations in Summer. This may indicate a potential for eutrophication. Each of these areas is associated with elevated nutrient levels.

Analysis of the variation in nutrient data has shown that each of the five nutrients measured follow the anticipated seasonal cycle, with higher values in Winter when the water column is normally thought to be well mixed and productivity is low, reducing to lower concentrations with the onset of the phytoplankton bloom in Spring. Silicate and nitrite show lowest concentrations and the most variable results. Elevated concentrations of all nutrients are noted in industrialised estuarine locations, for example the Bristol Channel, River Thames and Southampton Water.

Concentrations of suspended particulate matter are as anticipated with the highest results found in Winter. Geographically, the highest levels are found in the Upper Bristol Channel in both Winter and Summer, within which a baseline sampling station is situated. Other major estuaries which may have similarly high concentrations such as the Humber and the Thames are not included in the baseline survey

The results from the dissolved metals analysis show that UK coastal waters were generally of high quality during 1993, 1994 and 1995 when compared against the Environmental Quality Standards (EQS) set by the Dangerous Substances Directive. Cadmium and mercury are classed by the EC as List I substances, pollution by which must be eliminated. Cadmium concentrations were well below the EQS in both years. Mercury results showed a decrease from 1993 to 1995. The other metals are defined as List II Dangerous Substances. Each of these has either maintained concentrations well below the EQS or has shown a decrease from 1993 to 1995. The highest and most widespread results found are for dissolved copper and zinc.

Airborne imagery from the Compact Airborne Spectrographic Imager (CASI) and the thermal video system provide rapid wide area coverage. This allows the identification of features and processes which might not otherwise be evident from the *in-situ* sampling procedures. The CASI imagery was calibrated for chlorophyll-*a* using a combination of the Fluorescence Line Height technique (FLH) and the laboratory and continuous data. This allowed the production of maps of chlorophyll-*a* bands around the coast of England and Wales. Calculation of the proportion of coastal waters containing different ranges of concentrations of chlorophyll-*a* can be carried out from this imagery.

The data collected during the past three years by the National Marine Baseline Survey using a combination of different survey techniques provide an overview of the quality of the whole of the coastal waters of England and Wales. They can be used in future to monitor any changes including both short and long term effects. They also provide detailed background information to NRA regions to help with the planning and consideration of the results of more detailed local surveys and water quality problems.

Contents

List of Tables

List of Plates

List of Figures

1. INTRODUCTION

The NRA was established by the 1989 Water Act having statutory responsibilities for water resources, pollution control, flood defences, fisheries, conservation, recreation and navigation in England and Wales. In April 1996, the NRA will become part of the Environment Agency which will have responsibilities and powers across other media, air and land.

The Water Resources Act (1989 and revised in 1991) placed a duty on the NRA "to monitor the extent of pollution in controlled waters". In the marine environment, "controlled waters" covers estuarine and coastal water to the three nautical mile limit. Various activities have been undertaken by the NRA in support of this and other monitoring requirements.

In particular, the National Marine Baseline Survey was conducted four times per year during 1993, 1994 and 1995 to establish the general quality of coastal waters. These surveys provided information on background levels of a full range of determinands, including metals, nutrients and organic compounds, to provide information on the quality of the entire coastal zone. Baseline sampling sites are shown in Figure 1.1.

The surveys consisted of coordinated ship and aircraft campaigns using the four NRA survey vessels together with aerial monitoring equipment mounted on a leased aircraft.

In addition to the requirement under the Water Resources Act, the NRA carries out on behalf of the UK Government, *inter alia*, the monitoring of the relevant estuarine and coastal waters under various EU Directives. This work is carried out by the various NRA Regions and reported elsewhere. The National Coastal Baseline Survey gathers additional information which can usefully show the more widespread effects of some substances in these waters and provide information on the dispersion of discharges and possibilities of eutrophication not readily obtainable by other means.

The European Commission (EC) Dangerous Substances Directive (76/446/EEC) established two lists of compounds, known as List I and List II Dangerous Substances to be monitored and controlled in the environment. List I substances are regarded as particularly dangerous because of their toxicity, persistence and bioaccumulation. Pollution by List I substances must be eliminated and the EC lays down standards for these substances in 'Daughter Directives'. List II substances are less dangerous but may still have a deleterious effect on the aquatic environment. Pollution by List II substances must be reduced to standards set by the EC Member States, in the form of national laws. The Coastal Baseline Surveys measure metals and some organic chemicals which are List I or List II substances, thereby establishing the concentrations of these substances in the coastal waters and following variation with time.

The NRA Regions are also involved with establishing and monitoring areas of coastal waters based largely on their sensitivity to eutrophication. This information is required by the Urban Waste Water Treatment Directive (UWWTD) which defines the degree of effluent treatment required for certain qualifying discharges in different conditions of receiving waters. These areas may be defined as normal, sensitive to eutrophication or areas of High Natural Dispersion (HNDA). The spatial information on dispersion and oceanographic features obtained mainly from the airborne remote sensing can be used by Regions for these purposes.

This report sets out to describe the methods used to carry out the surveys, summarises the results obtained and discusses these results.

Figure 1.1

National Marine Baseline Survey, Laboratory Sampling Sites

NRA
National Centre for Instrumentation and Marine Surveillance

2. THE NATIONAL COASTAL BASELINE SURVEY

2.1 Survey protocol

The NRA undertook national coastal baseline surveillance surveys in 1993, 1994 and 1995 with the objective of making measurements of background levels of contaminants to provide a baseline of water quality in the coastal zone. These surveys took the form of simultaneous boat and airborne surveys in Spring (May), Summer (July) and Autumn (September) and a boat survey in Winter (January/February). The four NRA coastal survey vessels were used to perform the boat work and a chartered light aircraft was used for the aerial surveillance work.

The Spring and Autumn campaigns were timed to coincide with the two main phytoplankton bloom events of the year, when chlorophyll-*a* concentrations were likely to be at their highest. The summer campaigns provided a measure of the background levels of chlorophyll-*a* since they were at a time when natural nutrient levels were expected to be low. It was therefore expected to be possible to distinguish any raised levels that might have been linked with increased discharges, such as areas which have a seasonal increase in population due to an influx of holiday makers. The winter campaigns were carried out only by boat due to the low chlorophyll-*a* previously found in winter, the higher suspended matter in coastal waters in winter and problems associated with airborne surveillance at a time of year with much cloud cover. Winter boat campaigns do however provide important information on natural background nutrient levels around the coast, which are theoretically at their maxima during the winter and linked with the occurrence of phytoplankton blooms in the following Spring and Autumn.

2.2 Sampling strategy

Baseline sampling was carried out at 186 sites along the coast of England and Wales, between Berwick on Tweed and the Solway Firth. Following consultation with NRA Regional staff, sites were situated approximately 15 km apart, with some additional sites at major estuaries. The positions of the baseline sampling sites are shown in Appendix A.

Additional measurements were taken between the baseline sampling points using continuous monitoring systems while underway. These provided information on any changes in water mass between the baseline sampling points, thus placing the baseline results in context.

The remotely sensed data were collected on a series of 189 flight lines along the coast with a swath width sufficient to encompass the area within the three mile limit, the area which the NRA has the responsibility to monitor. These data allowed a description of the oceanography and spatial variations in water quality of the three nautical mile zone to be made, including for example, the presence of frontal systems which might differentiate areas of water quality.

Figure 2.1 shows the positions of the baseline sites and aircraft flightlines for South West region, provided as an example.

2.3 Rationale for measurements made

2.3.1 Spot samples

At each of the identified sites, samples were taken for laboratory analysis ashore. These samples were prepared and stored on board prior to transfer to NRA laboratories for analysis for suites of determinands which included nutrients, metals and various organic chemicals. Appendix B includes a full listing of the determinands measured and the intervals at which the 3 different analysis suites were used.

Ten litre bottles were used to collect single samples which were then subdivided for the other analysis suites except that for organic compounds. Water samples for organics were collected directly into solvent cleaned glass bottles supplied by the laboratories. For dissolved metals, 250 ml samples were filtered into separate bottles and submitted to the laboratory. For total metals, well mixed sub-samples were placed directly into separate bottles. Samples for the measurement of suspended solids were transferred directly from the sampling container and then refrigerated. For chlorophyll-*a* the samples were filtered, the filter paper removed and wrapped in foil. These foil packages were frozen quickly and kept frozen until analysed in the laboratory. Finally, 250 ml samples to be analysed for nutrients were filtered through syringes, the filtered sample frozen immediately and transferred to the laboratory in this state.

Chlorophyll-a

The concentrations of chlorophyll-*a* were measured as means of assessing the level of primary phytoplankton productivity and the likelihood of eutrophication. The concentration of chlorophyll-*a* is linked to the concentration of phytoplankton due to the presence of chlorophyll-*a* in all phytoplankton species. Generally in the marine environment, chlorophyll-*a* concentrations vary with season, usually having a peak in Spring caused by a bloom in the phytoplankton population. Sometimes a second peak is seen in Autumn, due to the presence of an autumnal bloom. Generally, levels are lower during the Summer and Winter.

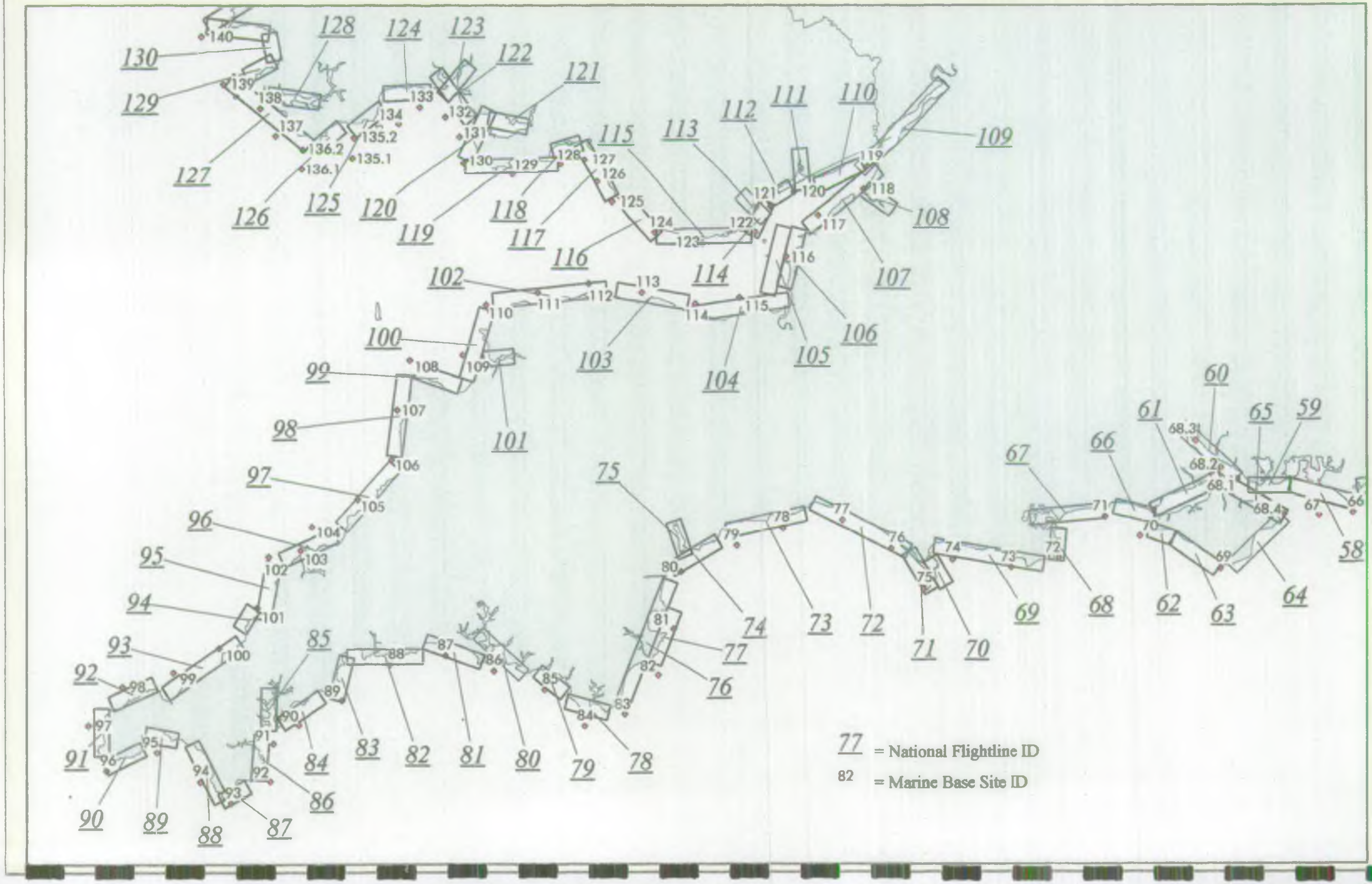
By means of the Urban Waste Water Treatment Directive (UWWTD), the European Union and the UK Department of the Environment have defined a number of parameters which signify that an area is subject to eutrophication. No single factor signifies a eutrophic area, but the presence of a number of these factors taken in geographical and historical context allows a scientific conclusion to be drawn concerning susceptibility to eutrophication.

Three of these factors are concerned with the concentration of phytoplankton. The presence of chlorophyll-*a* concentrations in excess of 10 μg/l signify the presence of an area of high phytoplankton productivity or bloom. If an algal bloom occurs in summer when it would be expected that chlorophyll-*a* concentrations would be lower, then this might suggest a eutrophic region. Other indicators such as dissolved oxygen and nutrient concentrations, in particular ortho-phosphate and nitrate, would support the suggestion.

Figure 2.1

National Marine Baseline Survey, Laboratory Site and CASI Flightline ID's, South West.

NRA
National Centre for Instrumentation and Marine Surveillance



77 = National Flightline ID

82 = Marine Base Site ID

Finally, the presence of scum on the surface of the water and around the coast is another potential indicator of the likelihood of eutrophication.

Measurements of chlorophyll-*a* were therefore taken at four seasons in order to establish if the natural seasonal cycle was being affected by excessive inputs of nutrients.

Nutrients

Nutrients, particularly phosphorus and nitrogen, are essential for the growth of organisms such as phytoplankton in the aquatic environment. The levels of these nutrients also provide an indication of the probability of eutrophication as defined in the UWWTD.

Generally, nutrient concentrations in coastal surface waters are expected to be highest during Winter when the water column is well mixed. In early Spring, stratification occurs and phytoplankton thrive in the upper layer, or eutrophic zone, where high nutrient levels coincide with high light levels. This phytoplankton bloom causes a rapid decrease in nutrient levels over the order of one month. Concentrations are usually expected to remain low during summer, increasing again as the water column begins to mix once more in the Autumn.

Changes in nutrient levels in the coastal zone may be further complicated by inputs from anthropogenic sources such as agricultural run off and sewage effluent. These may increase concentrations being recorded during summer months, for example. Identification of these areas of high nutrient concentration or "hot spots" aids in the identification of areas which might be subject to eutrophication. The UWWTD specifies that nutrient concentrations, particularly nitrate and ortho-phosphate and their relative ratio, must be interpreted in geographical and historical context using expert knowledge of a particular zone or area.

Dissolved metals

A number of dissolved metals were measured at each baseline site. The complete list is shown at Appendix B. Trace metals occur naturally in the marine ecosystem. However, more are introduced as a result of industrial output and levels may even increase to such an extent as to be harmful to aquatic life. It was considered to be necessary to establish the background level of metals and to identify those areas which were "hot spots" to enable these to be linked with particular sources. Most sources of metals discharges were located at estuaries and it was anticipated that the highest concentrations would be found here.

The National Baseline Survey monitors various substances which are listed in the EU Dangerous Substances Directive and for which Environmental Quality Standards (EQS) have been adopted. The metals measured by the National Baseline Survey fall into two classes of this Directive. Mercury and cadmium are List I substances which have been identified as posing a threat to the aquatic environment on the basis of their toxicity, persistence and bioaccumulative properties. The requirement is for environmental concentrations of List I substances to be reduced. The other metals measured by the

National Baseline Survey are List II substances which can have deleterious effects on the aquatic environment and should therefore be monitored. The reporting limit from the laboratories for the National Marine Baseline Survey has been set at 10% of the relevant EQS. The EQS levels for the metals measured during the baseline surveys are tabulated below.

Table 2.1
Environmental Quality Standards for Dissolved Metals

	EQS level μg/l	Reporting level μg/l
Dissolved Lead	25	2.5
Dissolved Mercury	0.3	0.03
Dissolved Cadmium	2.5	0.25
Dissolved Copper	5	0.5
Dissolved Chromium	15	1.5
Dissolved Nickel	30	3
Dissolved Arsenic	25	2.5
Dissolved Zinc	40	4

Suspended particulate matter

Measurements of total suspended particulate matter (SPM) were taken at every baseline site. Although often referred to as suspended sediment, SPM is made up of both inorganic sediment and organic particles such as phytoplankton cells. Additionally, it may have a component of sewage or any other particular matter which may be present in the water. The samples were analysed for total SPM at 105 °C and then heated to 500 °C to remove the organic component, so as to allow the organic/inorganic fraction to be determined.

Measurements of suspended particulate matter may be used in studies of sediment transport and dynamics. The transport of sediment has implications for beach erosion, the formation or removal of sand bars and other natural features which may be hazardous to shipping. In addition the movement of sediment away from areas, for example by erosion, may have implications for flood defences.

High concentrations of suspended matter considerably reduce light transfer through the water and hence limit the numbers of algae even in waters in which nutrients are readily available.

Total metals

Total metals concentrations were measured at every third Baseline site. In addition to providing information on the amount of metals in suspension, these also acted as a check on pre-treatment procedures carried out on the vessels.

Organic compounds

These compounds are mainly introduced to the marine ecosystem by anthropogenic sources. For example, DDT and HCH formerly used in pesticides and PCBs which are a byproduct of many industrial processes. These compounds are harmful to aquatic life and their effects may even be transferred up the food chain with associated risk to human health. Although many of these compounds are no longer in use, they tend to accumulate in the tissue of organisms and as sedimentary material. In these forms they are retained and may be released slowly over a large time scale. It is therefore necessary to monitor these compounds until a negligible level has been recorded for a number of years.

The Baseline Surveys included the measurement of various organic compounds, some of which are List I Dangerous Substances for which Environmental Quality Standards have been defined. Organic compounds were measured at sites of interest selected by the NRA regions as being possible sources of organic pollution. Other sites were selected at anticipated clean regions to establish a background level.

2.3.2 Underway monitoring and measurement

The coastal survey vessels each used 3 main groups of instruments to monitor water quality at and between the sampling points. Systems capable of measuring 7 parameters continuously were towed behind the vessels and 5 channel auto-analysers were used to measure nutrient concentrations at frequent intervals. When stopped at sampling points, 3 parameter probes were used to carry out profile measurements. Further details of these instrument systems are set out in the following paragraphs and Figure 2.2 illustrates how the various ship-borne measurement systems interacted and were logged on the Qubit navigational system.

The towfish systems were towed approximately 10 m behind the vessel at depths of 4 m to eliminate interference from the wake. These systems measured dissolved oxygen, salinity, temperature, pH and depth. In addition, fluorimeters and transmissometers were attached to the fish. The data were integrated with time, date and geographic position within the Qubit system and subsequently analysed at the National Centre for Instrumentation and Marine Surveillance.

Nutrients were measured using a Skalar auto-analyser system on each vessel. These were continuous flow automated analyser systems, in which reagents were added to a flowing stream of sample and, after mixing and heating where required, the concentrations of various nutrients present in the sample were determined colorimetrically using flow-through cells. The system determined nitrite, total oxidised nitrogen, ammonia, ortho-phosphate and dissolved silica. Calibrations were carried out on board using concentrated standards diluted volumetrically to produce concentrations of a similar range to the samples being measured. Periodically, quality control samples consisting of standards diluted in low nutrient sea water were analysed. Data from the Skalar systems were integrated into files containing information on position, date and time and archived at the National Centre for Instrumentation and Marine Surveillance.

2.3.3 Remotely sensed data

2.3.3.1 Principles of operation

The NRA is responsible for monitoring the entire coastal zone as defined by the three nautical mile limit. An R & D project (Airborne Remote Sensing of Coastal Waters, published in R & D Report No.4) established the effectiveness of the combination of aerial remote sensing, continuous underway monitoring and sampling at selected fixed points. Laboratory analysis of samples from the baseline sites give high quality information on the chemical composition of the water sample taken. However, it is important to establish whether this water sample is representative of its surroundings. The underway data from the Qubit and Skalar systems record any changes in water mass along the baseline track. The image data add to this by showing changes in water mass off the survey track and across the three nautical mile zone.

To be apparent in remotely sensed imagery, changes in water quality of the coastal zone must in some way alter the electromagnetic signal reflected or radiated by the water. The two systems used by the NRA operate in two different parts of the electromagnetic spectrum, the visible and thermal bands.

Visible wavelength remote sensing provides information by measuring light reflected from the surface beneath the aircraft thereby obtaining information on the scattering and/or absorption of visible light. Clear ocean water returns little signal as the majority of light is absorbed. Waters of the coastal zone, however, contain large amounts of particulate matter which reflect and scatter light. In addition, the presence of organic matter such as phytoplankton causes selective absorption of some wavebands within the spectrum of the sunlight. It is the interaction of these two processes, scattering and absorption, on the incident sunlight which leads to the reflectance signal recorded at the sensor. The variation of this signal with wavelength may be used to determine the concentration of particulate matter and chlorophyll within the water mass.

Areas of high suspended particulate load may be seen to be associated with riverine inputs and these may account for high levels seen in the baseline survey results. In this way the visible wavelength remote sensing can explain features in the baseline data. Similarly, frontal systems may divide two water masses of different particulate composition and this can be seen in the airborne imagery.

Figure 2.2 **QUBIT NAVIGATION SYSTEM**

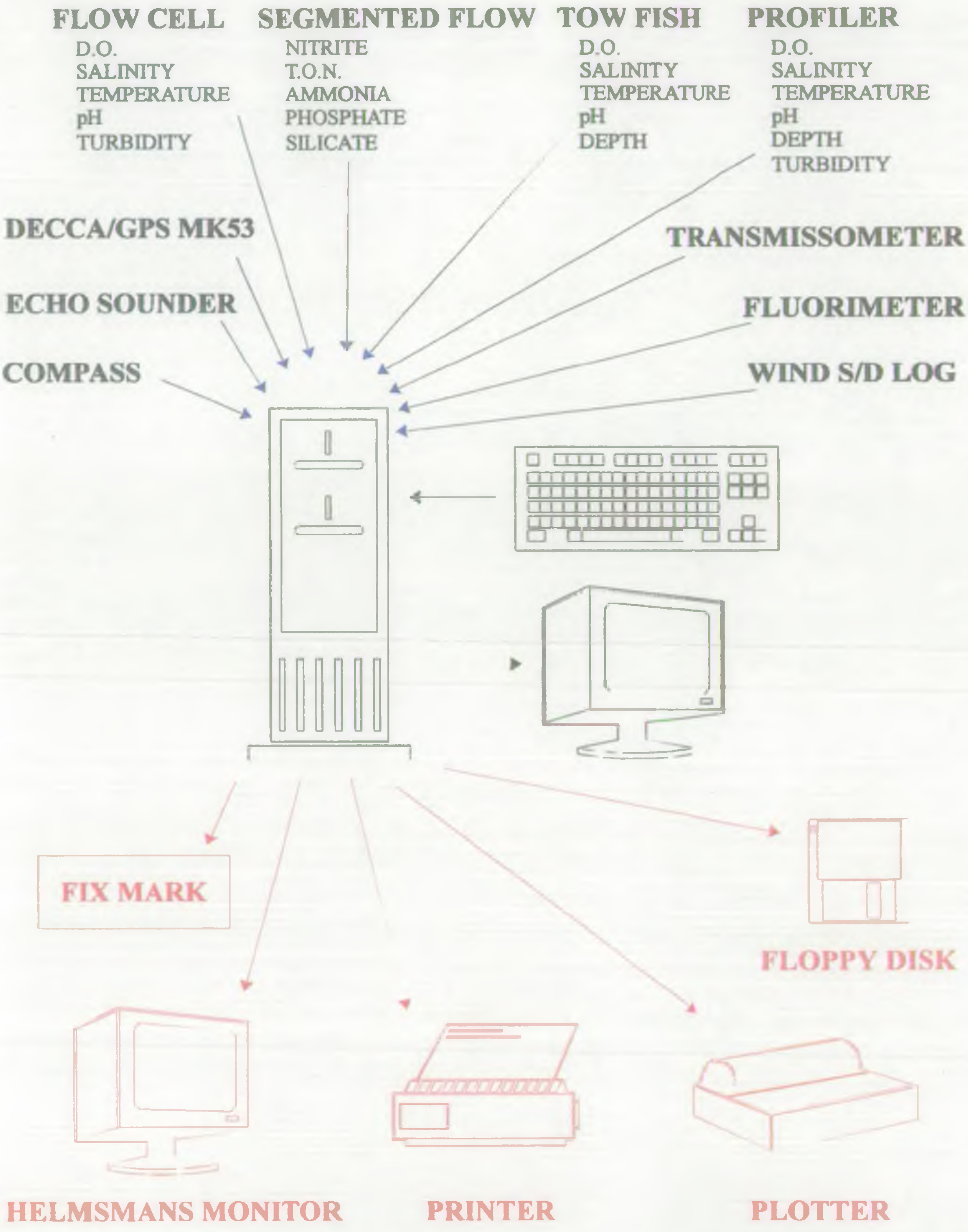
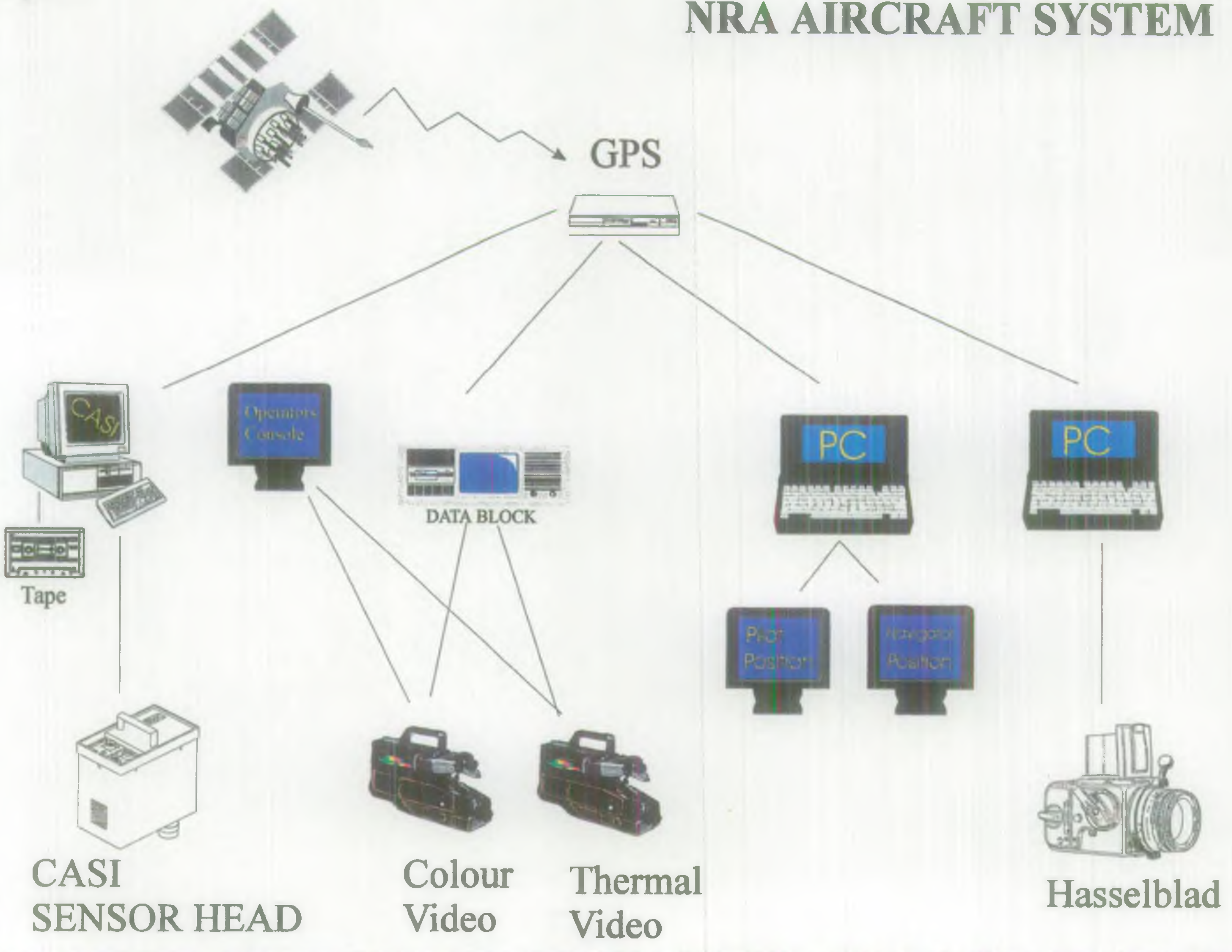


Figure 2.3



NRA AIRCRAFT SYSTEM

Thermal wavelength remote sensing measures the temperature of the surface of the water. Radiation absorbed from sunlight and thermal discharges is re-emitted from this surface layer. Although this temperature is not necessarily representative of the entire water column, it is often able to show the presence of mixing zones around outfalls which have a temperature different to that of the surrounding water mass. This again allows the measurements from baseline sites to be interpreted in relation to surroundings.

Remotely sensed image data is collected from two sensors, the Compact Airborne Spectrographic Image (CASI) and the thermal video scanning system. Figure 2.3 illustrates how the various components of the aircraft data collection system interact.

2.3.3.2 The Compact Airborne Spectrographic Image (CASI)

The CASI is an imaging spectrometer designed and built by Itres Ltd of Calgary, Canada. In use by the NRA, it is flown over the coastal waters in a leased aircraft.

It works on the principle of a series of lines of charged coupled devices (CCDs) which each produce an electrical charge dependant upon the amount of light energy falling upon them. These are packed together into a 3 dimensional array made up of 288 x 512 CCDs. Upwelling light radiation from beneath the aircraft is focused onto the array by a compound lens.

Light entering the system is split into a number of wavebands, each registering on a different CCD or row of CCDs. As the aircraft travels forward, light reflected from a succession of small areas fall onto the array and is split into its wavebands. The minimum size (pixel size) of the areas recorded in the routine coastal surveys was 8 metres square. Other pixel sizes can be recorded by altering height, speed and the focal length of the lens.

The CASI can be operated continuously in 2 modes and intermittently in a third.

The spatial mode was used in the coastal surveys. In this mode the CASI records data in up to 19 selected spectral channels from all the pixels across the swath. Waveband channels appropriate for the observation of chlorophyll-*a*, solids in suspension and vegetation in the coastal fringe were selected and the CASI system was modified by the addition of a supplementary wide angle lens to cover the three nautical mile coastal zone in a single pass. The CASI can also be used in the spectral mode, recording data from across the whole spectrum over 288 wavebands but only for a limited number of pixels across the swath. This mode also allows the collection of spatial mode data in a single waveband to aid in the location of the spectral data.

Finally, the CASI can also be used in short bursts in an enhanced spectral mode to record up to 74 channels over a 300 pixel wide swath. This acts as a middle ground between spectral and spatial modes.

CASI data from the surveys were processed, enhanced and interpreted at the National

Centre for Instrumentation and Marine Surveillance using the PCI image processing package which reads and displays CASI data directly in full 16 bit resolution to produce high resolution images.

2.3.3.3 The thermal video system

The thermal imaging system consists of four parts: the scanning head, the cooling system, the processing electronics/control unit and VTR/monitor. The system operates in the 8-13 micron spectral range. The resultant signals are processed to professional video format. with the addition of a data block containing information on date, time, position and heading.

This system constitutes an inexpensive means of acquiring thermal data and provides a useful means of identifying the location and extent of frontal structures, mixing zones and discharge footprints. However, it is uncalibrated and can determine only relative and not absolute temperatures. Also, because it produces analogue pictorial information, the outputs from the system cannot be merged with the digital data from the CASI or be geocorrected to overlay precisely onto maps or other data. The practicalities of obtaining thermal data in digital form and combining it with the CASI, GPS and aircraft attitude data are being explored.

2.3.3.4 Geometric correction procedure

In addition to progressing along their tracks, aircraft move relative to the ground in pitch and roll motions. Geometric correction procedures eliminate errors in the images caused by the movements of the plane and relate the image coordinates to known geographic coordinates. The resultant images can be overlaid directly onto maps and are of greater use for identifying the location of features. Geometric correction of all survey data will allow changes over time to be accurately mapped and scaled. Images derived from 1995 and future surveys will all be geocorrected.

The geometric correction procedure used by the National Centre for Instrumentation and Marine Surveillance uses the auxiliary data collected by the aircraft during the CASI flights. This data gives information on aircraft motion and geographic location using a Global Positioning System (GPS). Plate 2.1 shows an image from the 1995 survey of the Tees estuary with the two possible correction procedures which may be used.

The first figure is the raw image derived from the uncorrected data. In the second figure the raw image is corrected for the roll of the aircraft. This removes any visual differences, for example straightening the river in the upper half of the image. The image still has an incorrect geometric orientation with the sports stadium in the lower half of the image appearing as a collapsed shape. This is clearly corrected when the full geocorrection procedure is applied, as shown in the final image. Furthermore, geographical coordinates of features of interest may be extracted from the image.

Plate 2.1

True colour CASI data. River Tees, Middlesborough.
Date: 14 June 1995, Time: 15:45GMT, Alt.: 2100ft.

1 Raw CASI data showing errors due to roll and pitch.

2 Roll corrected CASI data showing visually correct imagery but with the wrong geometric orientation.

3 Geo-corrected CASI data showing corrections for heading and geometrically square pixels.

NRA
NATIONAL CENTRE
FOR
INSTRUMENTATION
AND
MARINE SURVEILLANCE

3. DATA ANALYSIS AND REVIEW OF FINDINGS

3.1 Introduction

The data collected during the 1993, 1994 and 1995 baseline surveys have been collated and stored at the National Centre for Instrumentation and Marine Surveillance. In total there are in excess of 60,000 results from the laboratory analysis of the water samples, in addition to continuous monitoring data from the Qubit and Skalar systems. It is therefore not practicable or useful to report the detail of all the results in this document.

The following section describes a summary of the laboratory results which have been interpreted in terms of natural cycles, anthropogenic inputs and their relation to EU and UK Government requirements. In addition, an insight has been provided into the ways in which the different types of data collected during the coastal baseline surveys are being integrated by IMS to provide meaningful information on water quality in the coastal zone. Specific examples have been included to show the principles in reasonable detail.

3.2 Ship measurements

3.2.1 Chlorophyll-*a*

Chlorophyll-*a* concentrations around the coast of England and Wales clearly follow the seasonal cycle of phytoplankton growth, with the Spring bloom evident (Figure 3.1). The highest concentrations are located around the Anglian coastline and the North West coastline. A number of sampling sites show figures above 10 μg/l. The Urban Waste Water Treatment Directive states that this concentration only signifies the presence of a bloom, and is not indicative of eutrophication unless the site shows other indicaters including similar levels in Summer. Observation of the Summer concentrations (Figure 3.2) shows that three areas maintain high chlorophyll-*a* concentration: the Dee and Mersey Estuary, Southampton Water and the Tees Estuary.

Each of these areas coincides with areas of high nutrient levels (see Section 3.2.2). The Tees shows elevated concentrations of ammonia throughout the year from anthropogenic sources. Both the Mersey and Southampton Water show high concentrations of both nitrite and Total Oxidised Nitrogen (TON) at all seasons.

An autumnal bloom is seen in the North West (Figure 3.3). Some raised levels are seen on the Anglian coast but not to the extent seen in Spring. Winter concentrations are very low, with only three sample sites having a mean winter concentration above 6 μg/l (Figure 3.4).

3.2.2 Nutrients

The following diagrams present, in the form of maps of the entire coastline, the average Winter and average Summer concentrations of each of the five nutrients measured in the National Marine Baseline Survey. The Summer figures are a mean of data from July 1993, July 1994 and July 1995. The Winter data is in some cases a mean of only 2 of the 3 years due to operational difficulties experienced at this time of the year as a result of bad weather.

3.2.2.1 Ammoniacal nitrogen

Figures 3.5. and 3.6 illustrate the variation in ammoniacal nitrogen concentration between Winter and Summer. For the south coast from Wales to Kent, the concentrations are higher in Winter than in Summer which is the anticipated natural cycle. On the Northumbria coast there are generally higher concentrations in Summer, illustrating the complexity of anthropogenic sources. Raised concentrations are seen in Summer and Winter associated with the major estuaries of the Tees, Southampton Water and the Thames.

3.2.2.2 Total Oxidised Nitrogen (TON)

Figures 3.7 and 3.8 show the variation in TON concentrations between Winter and Summer. It is immediately apparent that the measured levels of TON are indicative of the natural cycle, with higher concentrations in Winter. The highest concentrations in Winter are located on the Anglian coast and around the Bristol Channel. The Bristol Channel also shows elevated levels in Summer, as do other major estuaries such as the Thames, the Mersey/Dee and Southampton Water.

3.2.2.3 Nitrite

Figure 3.9 shows the mean Winter concentration of nitrite and Figure 3.10 shows the mean Summer concentration. Nitrite is one component of Total Oxidised Nitrogen and as such might be expected to follow the TON patterns. However, as a short lived product of the oxidation of ammonia it is more likely to follow the pattern of that chemical. Levels of nitrite during the baseline survey were low and therefore show great variability. The results show generally higher concentrations in Summer, in particular within the Upper Bristol Channel and along the Northumbria coast. During Winter, Southampton Water, the Thames and the Mersey/Dee all show elevated concentrations.

3.2.2.4 Silicate

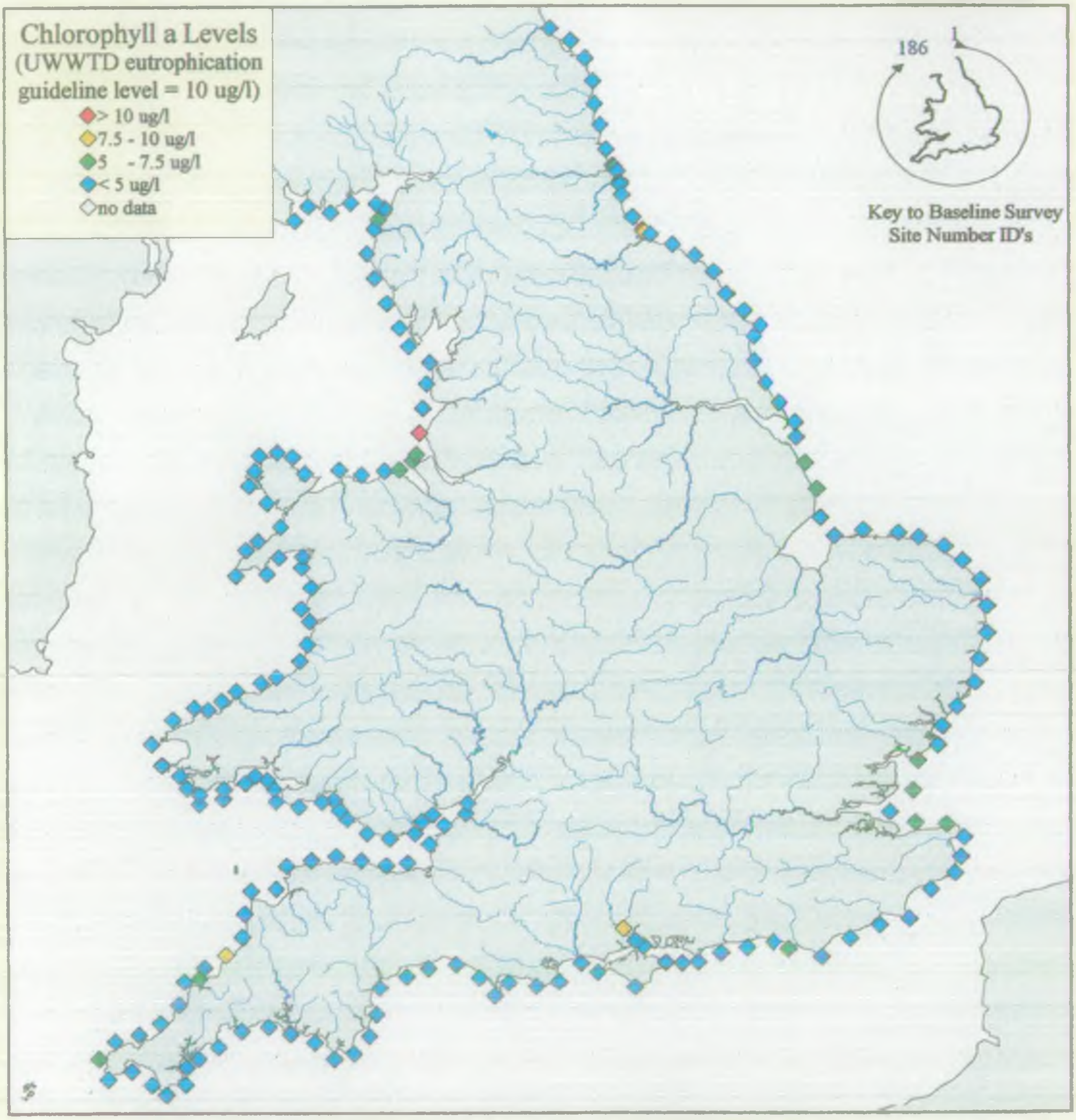
The mean Winter concentration of silicate is shown in Figure 3.11, with the mean Summer results in Figure 3.12. The silica results again show the anticipated natural cycle, with higher concentrations in Winter than in Summer. In Winter all results exceed 80 μg/l. The Winter results show clearly that highest concentrations are to be found along the Anglian coast and from Wales to the North West. This is less easily distinguished in

Figure ~~3.2~~ 6

Chlorophyll a Levels, National Baseline Survey, Summer Average 1993 to 1995.

NRA

National Centre for Instrumentation and Marine Surveillance



Chlorophyll a Levels, Summer Average 1993 to 1995.

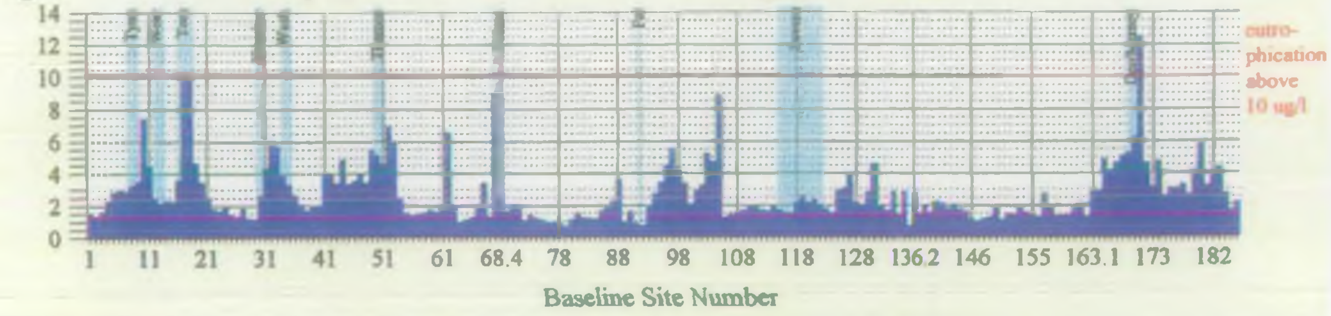
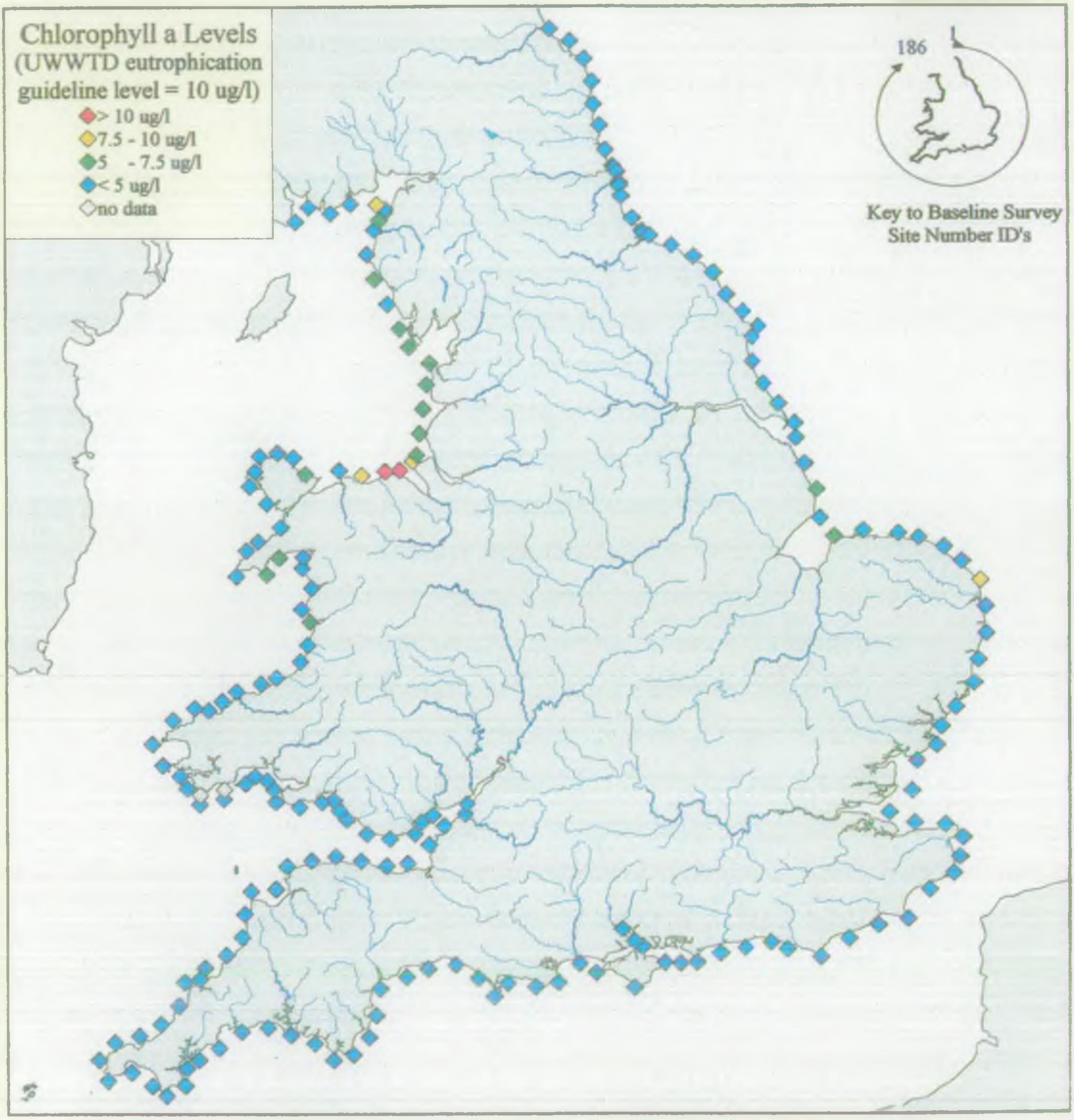


Figure ~~3.3~~ 7

Chlorophyll a Levels, National Baseline Survey, Autumn Average 1993 to 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Chlorophyll a Levels, Autumn Average 1993 to 1995.

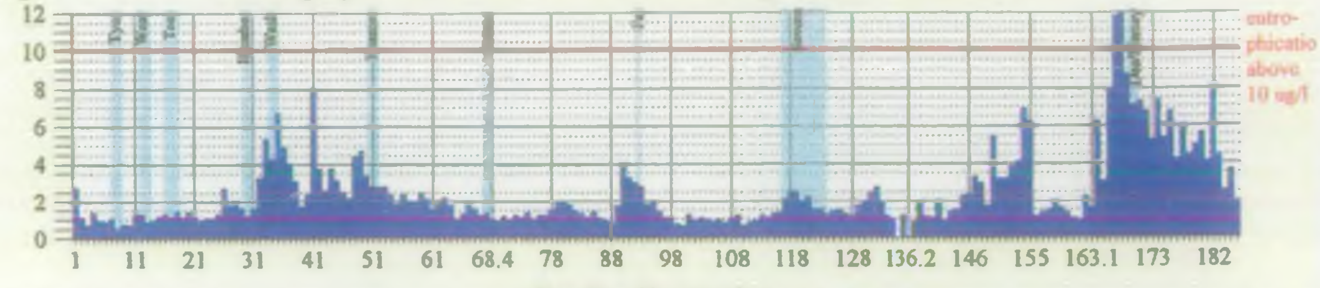
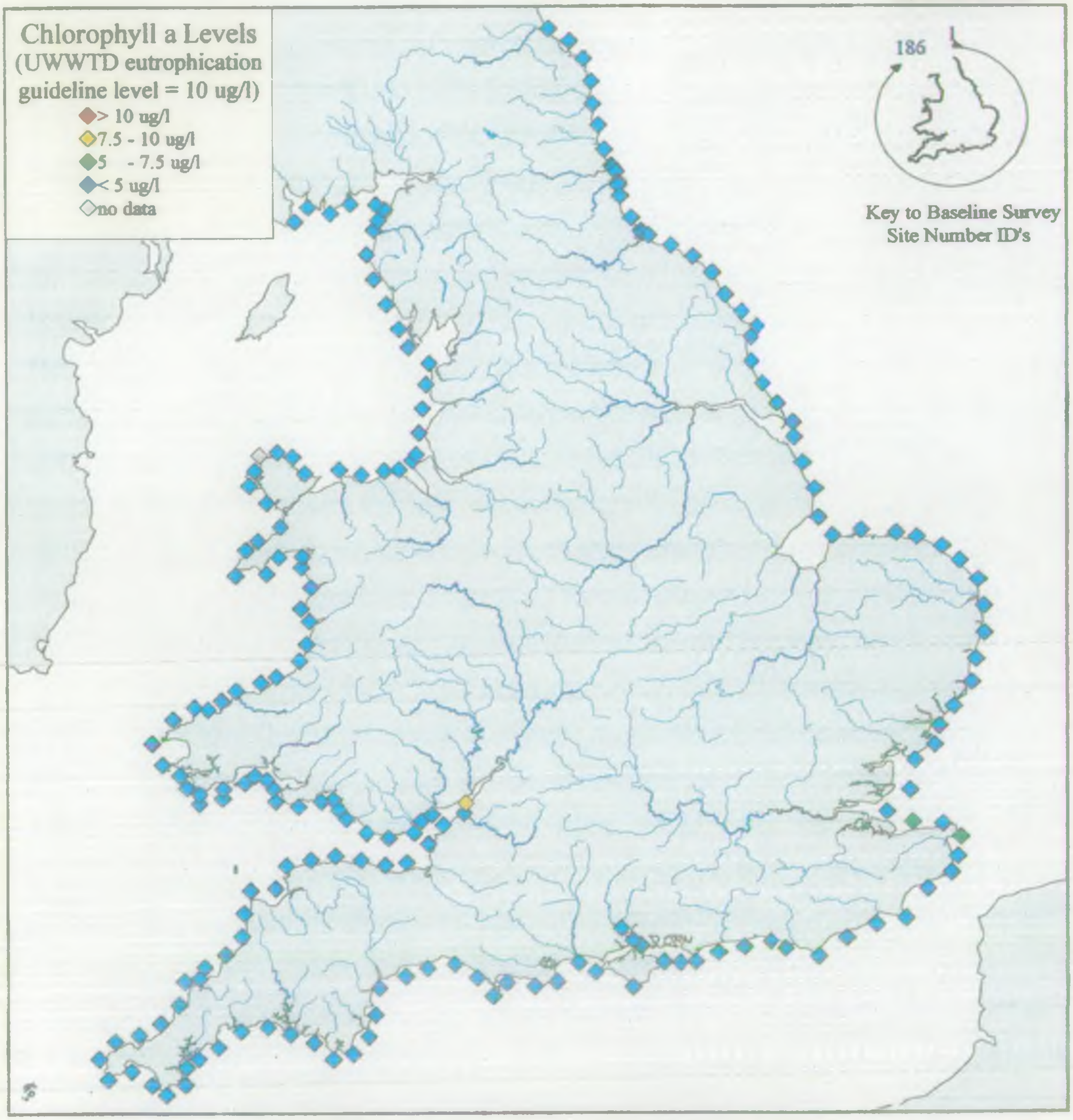


Figure 3.4

Chlorophyll a Levels, National Baseline Survey, Winter Average 1993 to 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Chlorophyll a Levels, Winter Average 1993 to 1995.

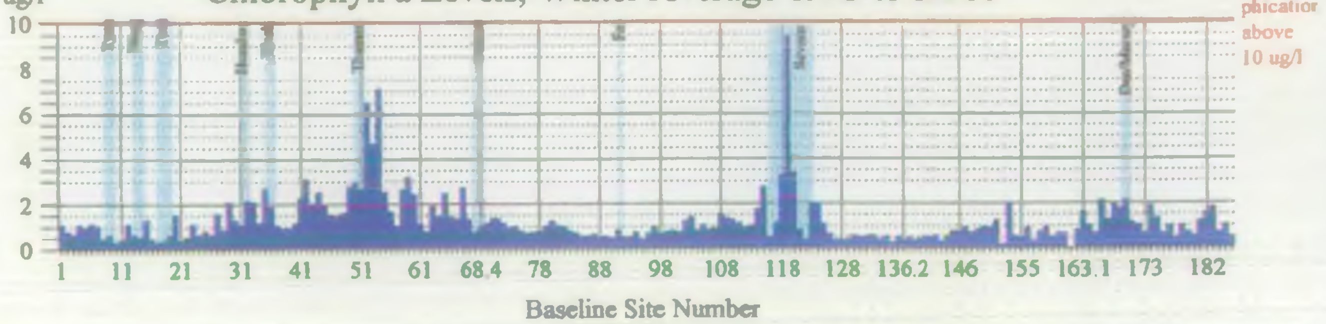
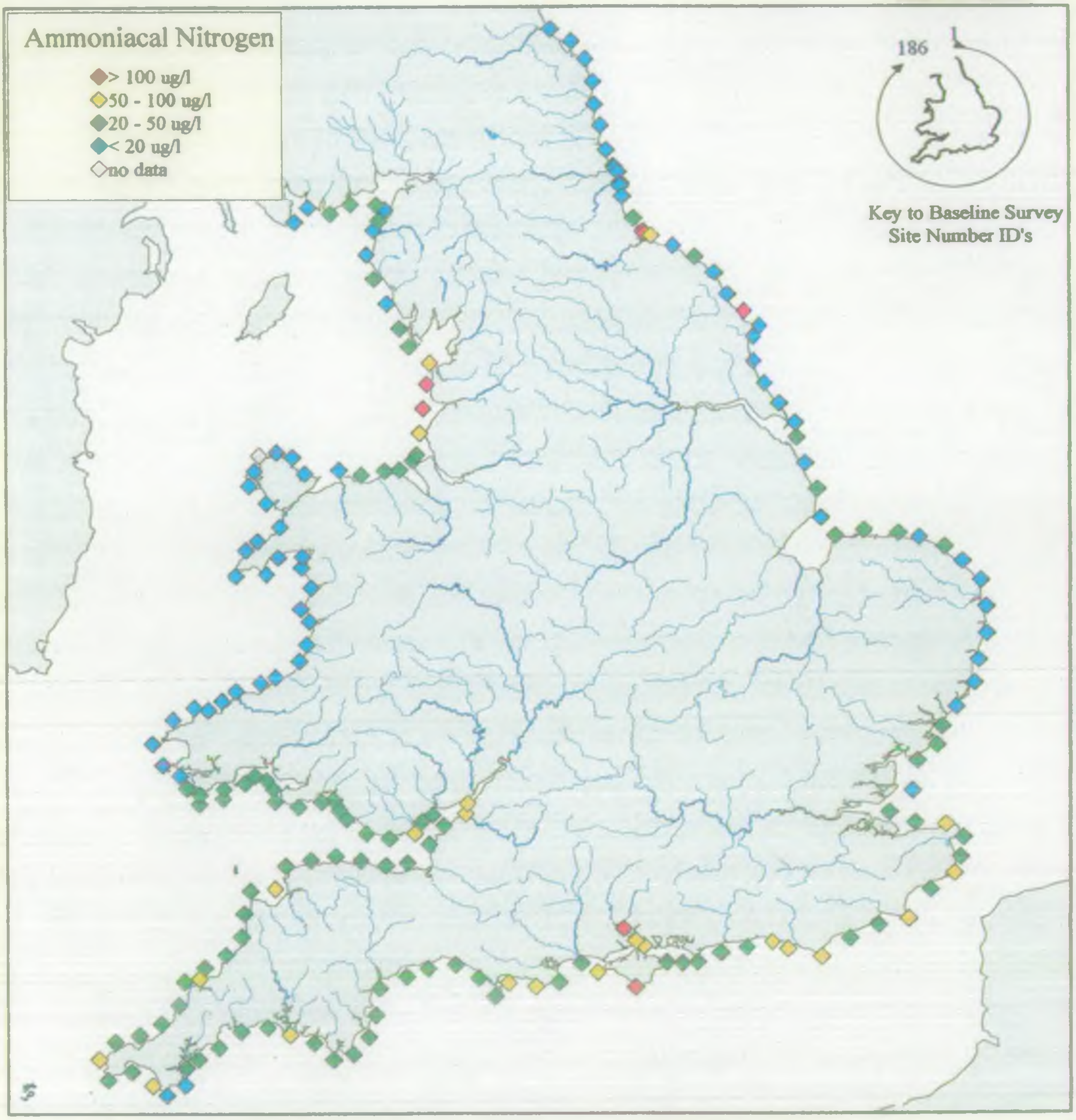


Figure 3.5

Ammoniacal Nitrogen, National Baseline Survey, Winter Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



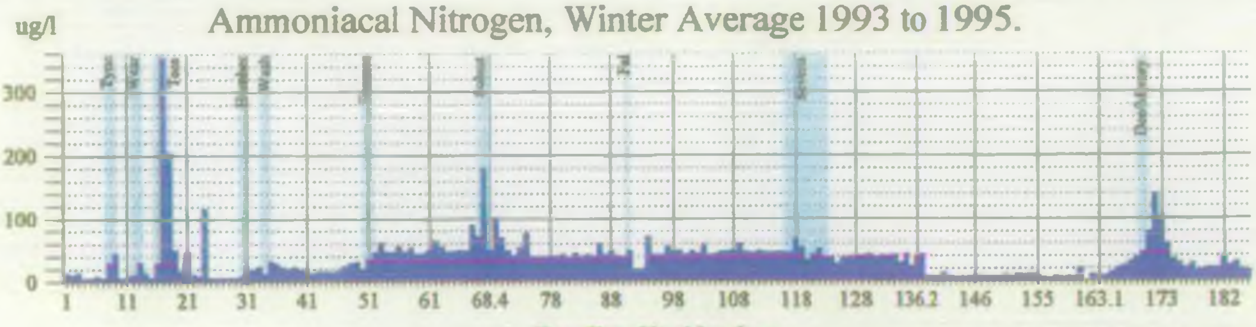
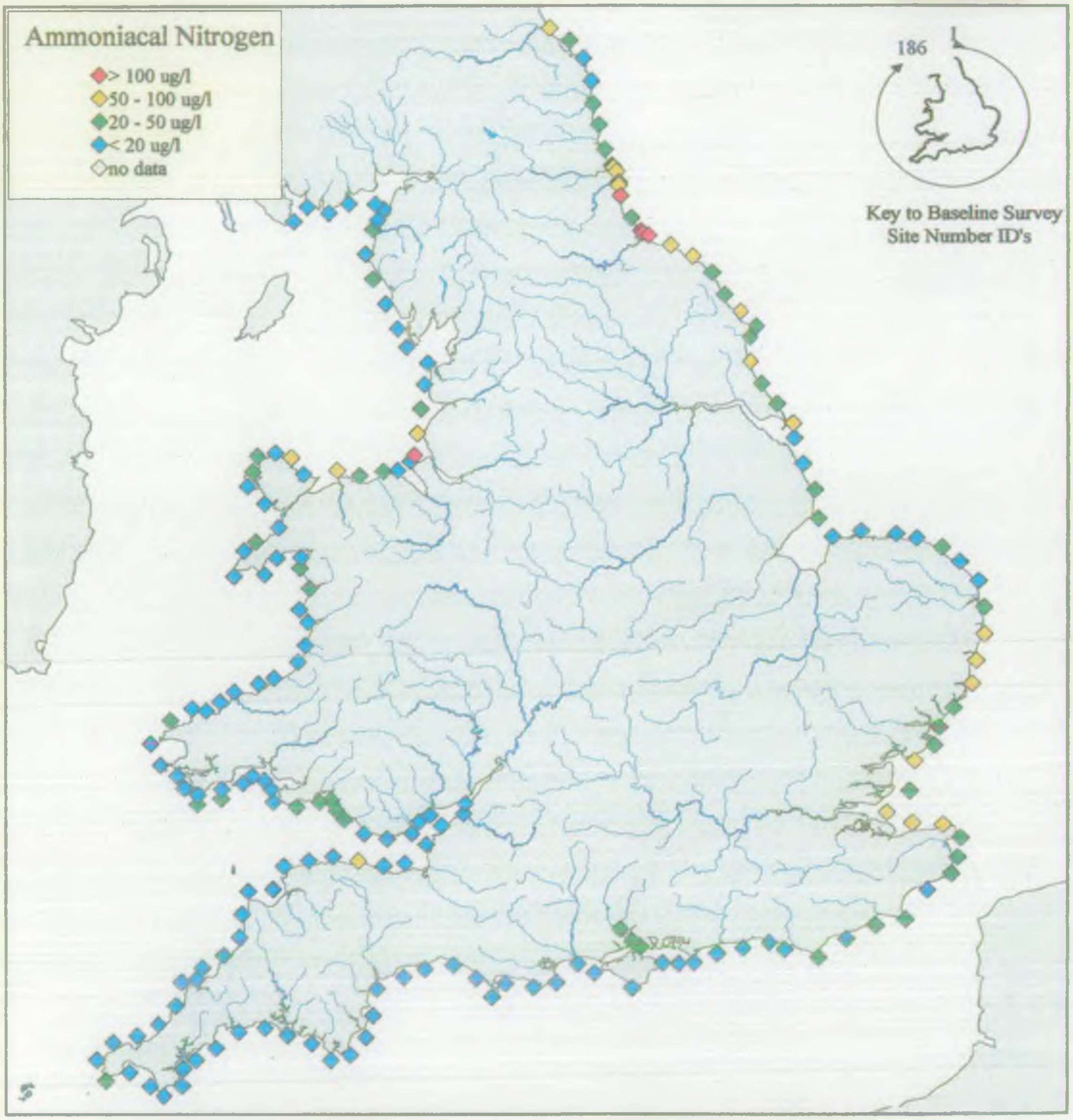


Figure 3.6

Ammoniacal Nitrogen, National Baseline Survey, Summer Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



Ammoniacal Nitrogen, Summer Average 1993 to 1995.

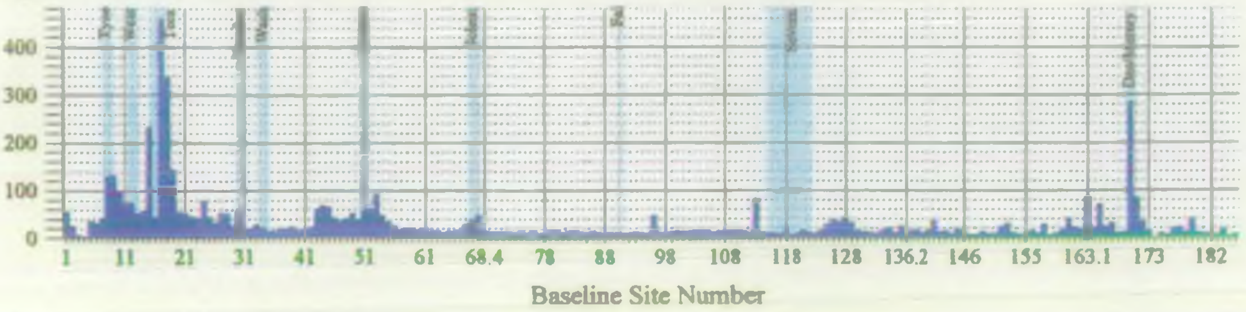
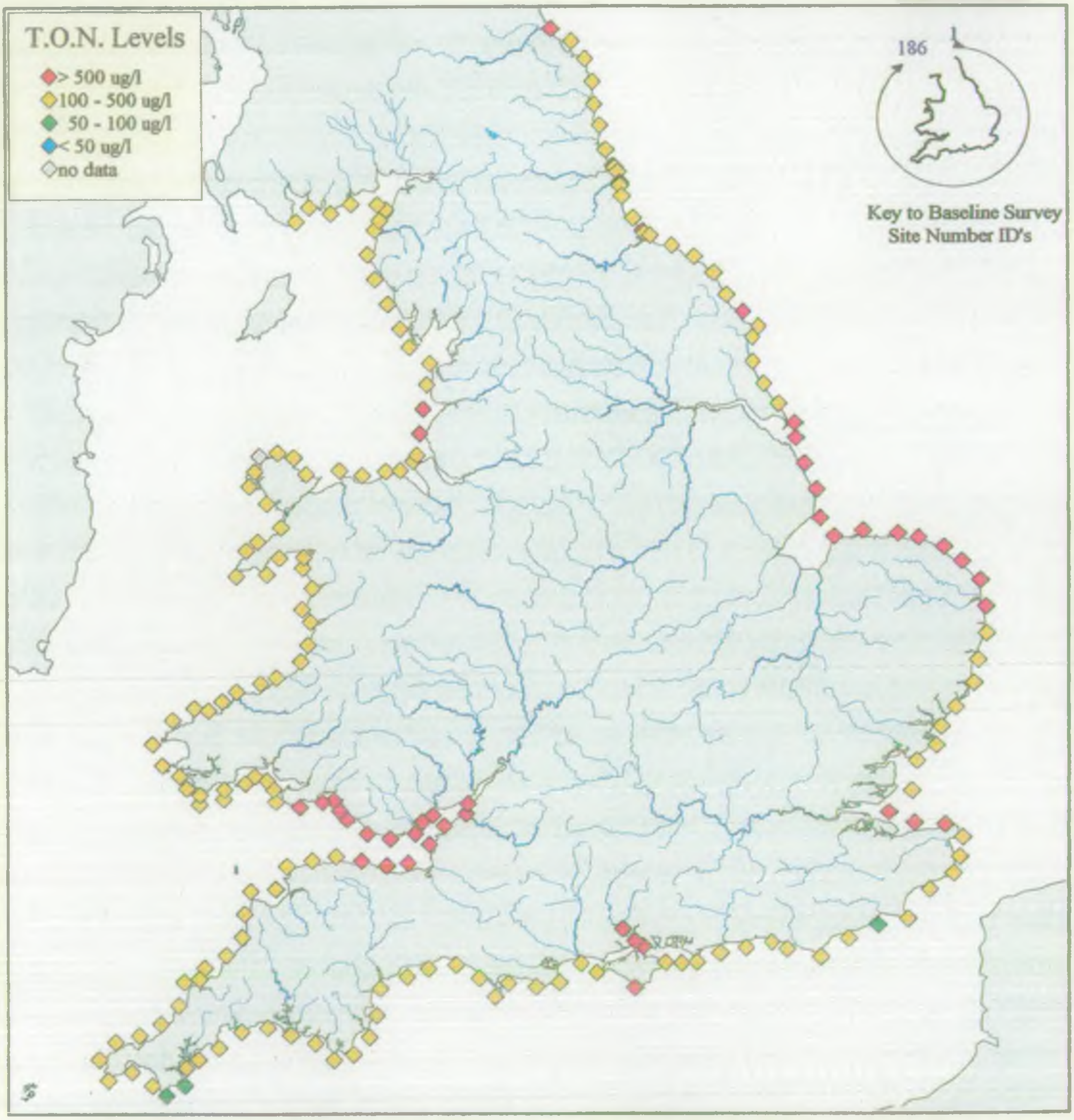


Figure 3.7

T.O.N. Levels, National Baseline Survey, Winter Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



T.O.N. Levels, Winter Average 1993 to 1995.

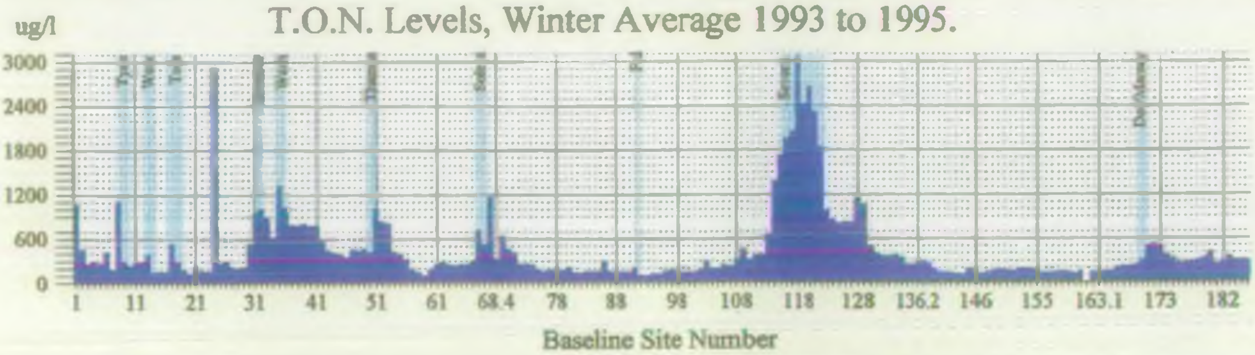
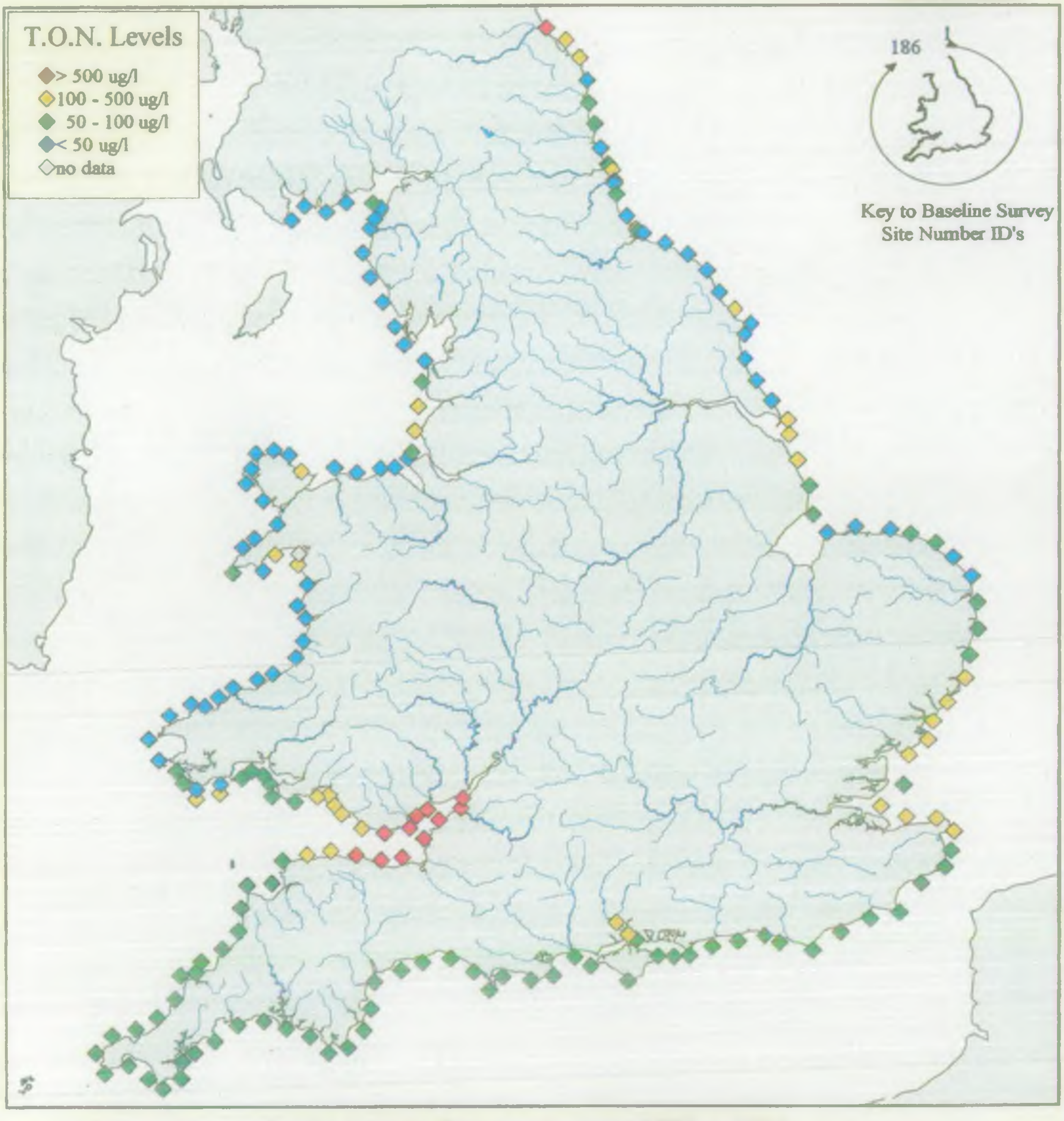


Figure 3.8

T.O.N. Levels, National Baseline Survey, Summer Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



T.O.N. Levels, Summer Average 1993 to 1995.

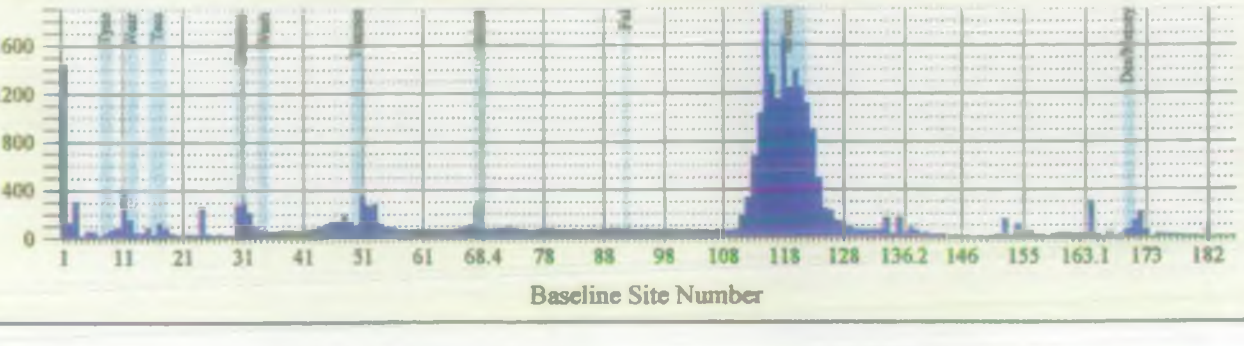
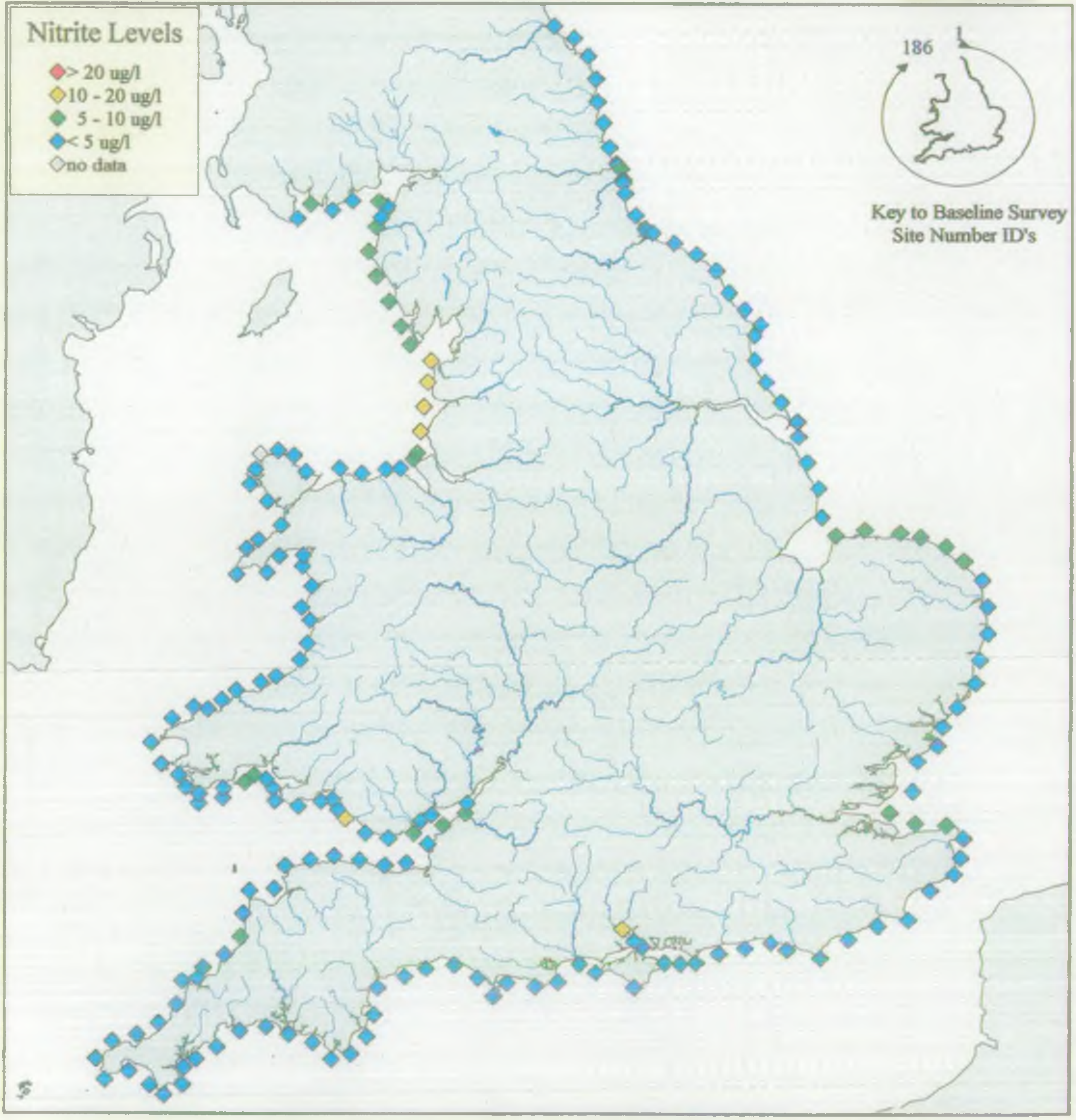


Figure 3.9

Nitrite Levels, National Baseline Survey, Winter Average 1993 to 1995.

NRA
National Centre for
instrumentation and
Marine Surveillance



Nitrite Levels, Winter Average 1993 to 1995.

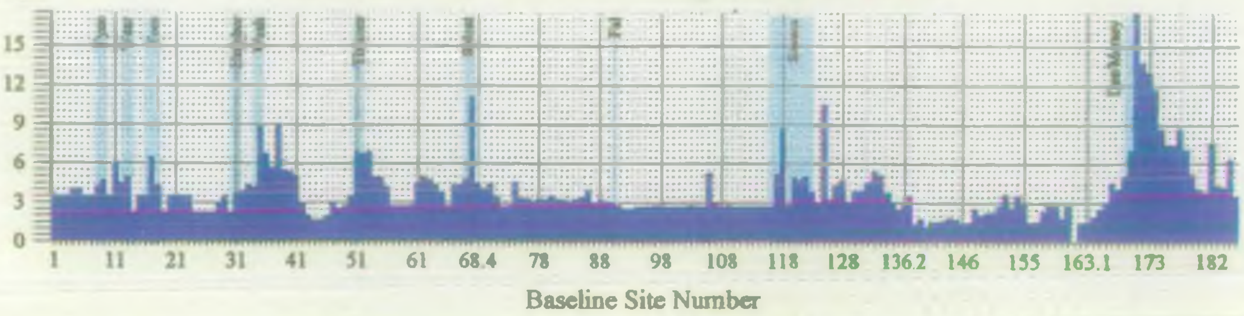
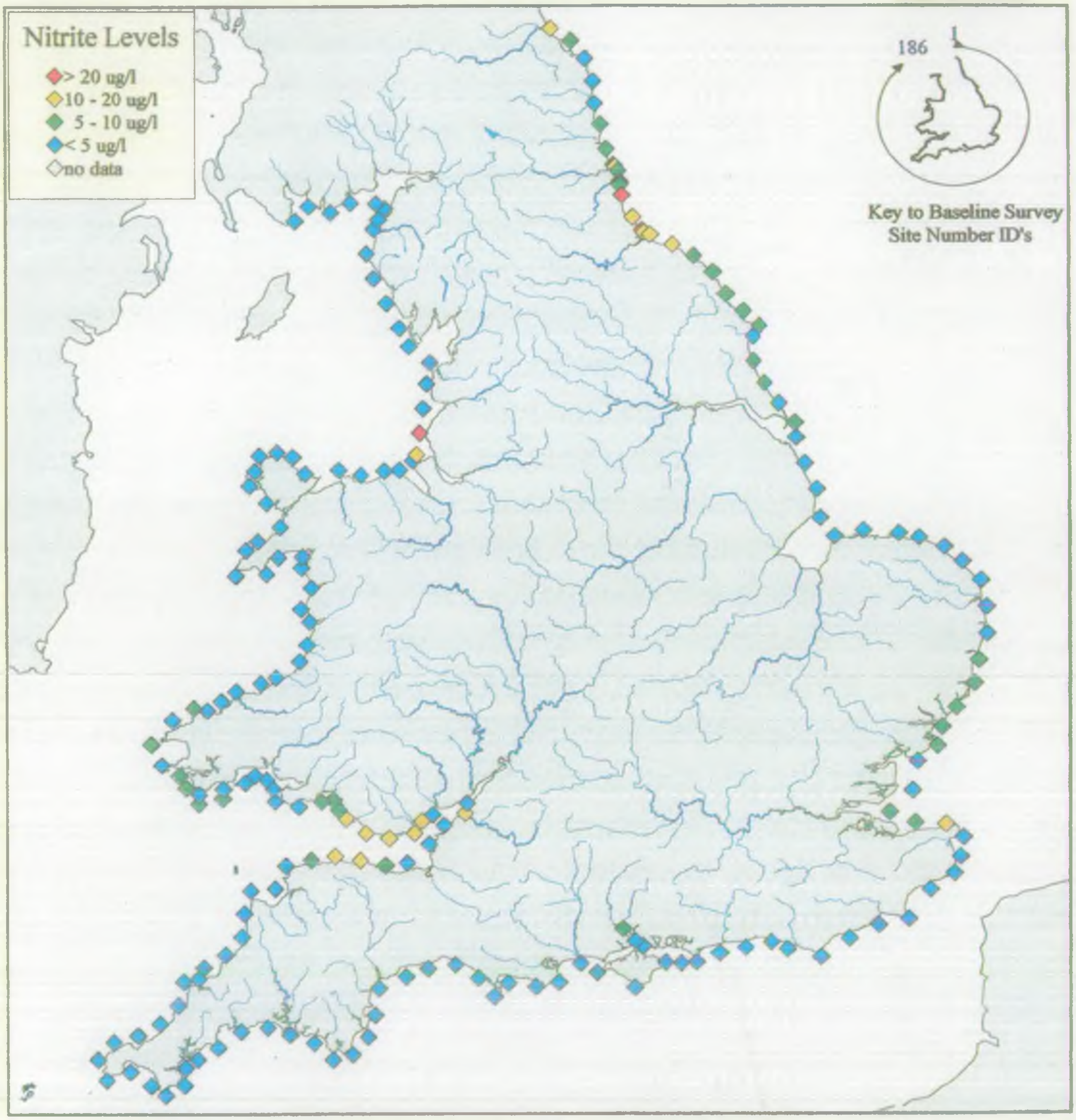


Figure 3.10

Nitrite Levels, National Baseline Survey, Summer Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



Nitrite Levels, Summer Average 1993 to 1995.

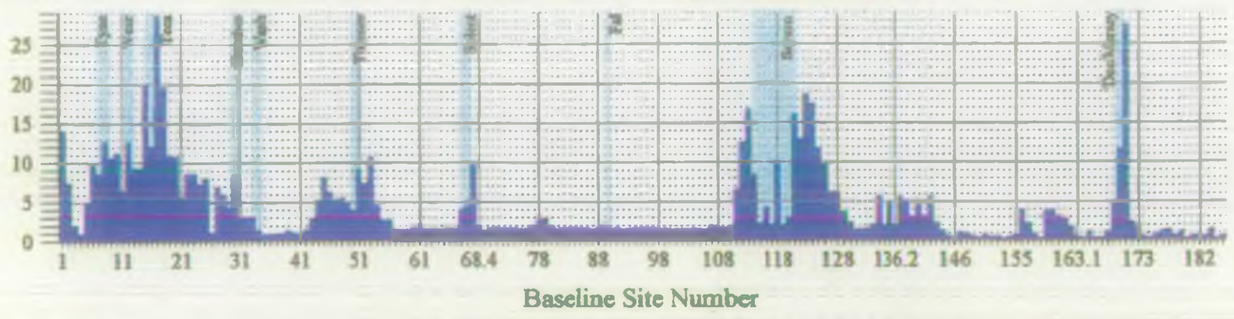
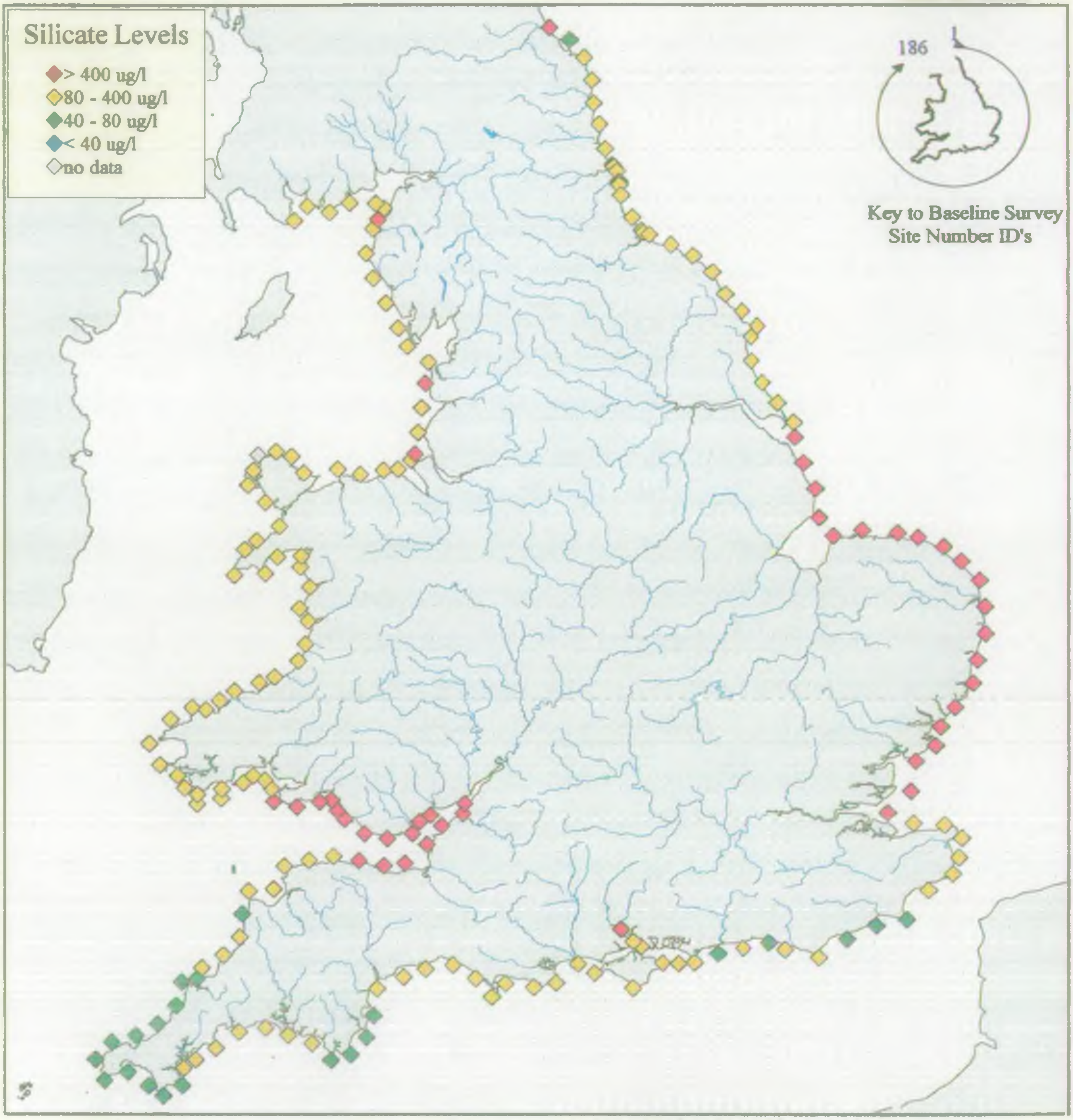


Figure 3.11

Silicate Levels, National Baseline Survey, Winter Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



Silicate Levels, Winter Average 1993 to 1995.

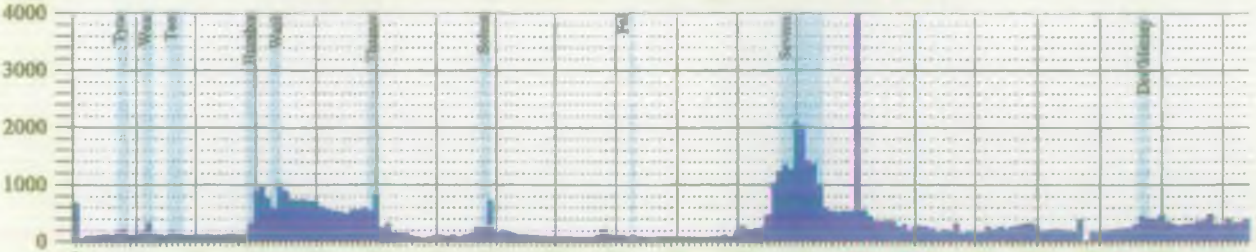
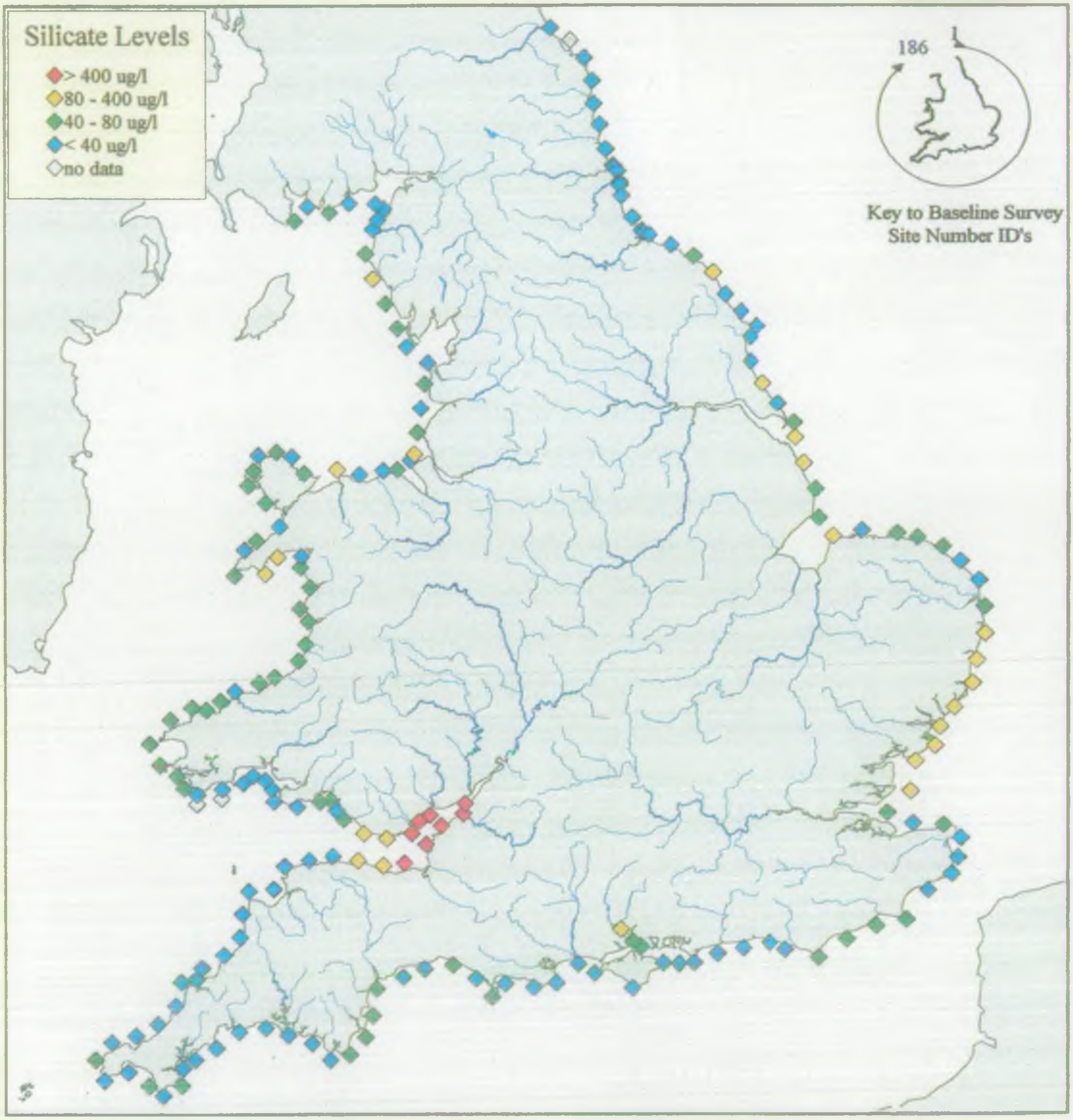


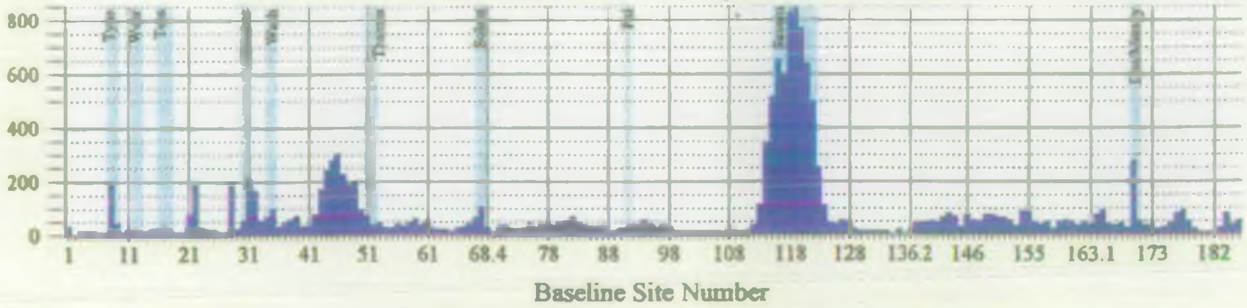
Figure 3.12

Silicate Levels, National Baseline Survey, Summer Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



Silicate Levels, Summer Average 1993 to 1995.



Summer due to the natural variability in lower concentrations. The Bristol Channel records high values in both Summer and Winter.

3.2.2.5 Ortho-phosphate

Figure 3.13 shows the mean Winter concentration of ortho-phosphate for the coastline of England and Wales. Figure 3.14 shows the mean concentrations in Summer. The results again clearly follow the seasonal cycle with concentrations all above 10 μg/l in Winter, and many below this is Summer. The Thames Estuary and Bristol Channel show elevated concentrations of greater than 50 μg/l in both Summer and Winter.

3.2.3 Suspended particulate matter

Figure 3.15 shows the mean concentration of total suspended particulate matter in Winter, with the mean Summer figures being shown in Figure 3.16. The figures show the anticipated results, with higher concentrations in Winter. The Upper Bristol Channel records the highest concentrations in both Summer and Winter, but with those of Winter slightly higher. During Summer, concentrations elsewhere rarely exceed 15 mg/l for the north east coast, south coast and from Wales to the North West. Only Anglian has levels consistently higher than this during Summer, although they are again exceeded by the Winter figures.

3.2.4 Dissolved metals

The Dangerous Substances Directive defines Environmental Quality Standards (EQS) for each of the metals measured in the National Baseline Survey. This EQS value is defined as an annual mean. The results presented below show the annual mean for each dissolved metal in 1993, 1994 and 1995. This allows the comparison of numerical values against the EQS value, and also a comparison of the variation in dissolved metal concentrations between the three years of the survey.

For many of the dissolved metals the annual mean concentrations are below the reporting level (10% of the EQS) for the majority of the coastline. Two exceptions to this are dissolved zinc and dissolved copper which show a significant number of results above the reporting limit and in some cases the EQS. The results for these metals are discussed more fully below.

3.2.4.1 Dissolved zinc concentrations

The annual mean concentrations of dissolved zinc are illustrated for each year of the baseline survey in Figures 3.17, 3.18 and 3.19. For the north east coast concentrations decreased markedly between 1993 and 1994 with these lower levels being maintained in

1995. In 1993, four sites show concentrations above the EQS, whereas none were found in 1994 or 1995. This change is coincidental with the rationalisation of the NRA laboratory service, greater standardisation of sample handling on the survey vessels and problems experienced in some laboratories with zinc being found in filter papers. Zinc concentrations on the remainder of the coastline show no clear trend, the majority of samples in all 3 years being less than half the EQS value of 40 μg/l. At one sampling point at Avonmouth in the Bristol Channel concentrations above half the EQS were recorded in both 1993 and 1995, with the concentration just below half EQS in 1994.

3.2.4.2 Dissolved copper concentrations

The annual mean concentrations of dissolved copper are shown for 1993, 1994 and 1995 in Figure 3.20, 3.21 and 3.22. The majority of results off the Northumbria coast in 1993 are above half the EQS with four sites showing means above the EQS. In 1994 and 1995 all sites in this Region are less than half the EQS. The Bristol Channel shows some elevated concentrations in all three years. The geographical extent of areas with samples over one half of the EQS decreases until in 1995 there is only one site in the Bristol Channel above this level. Other areas, for example the North West coast show an increase between 1993 and 1994, decreasing again in 1995.

3.2.4.3 Other metals

Results for the other measured dissolved metals are briefly discussed below but, because of the large number of sites with annual average concentrations below the reporting limit of 10% of the EQS, distribution maps have not been included except for one example, cadmium.

Results for the annual mean concentration of dissolved cadmium are shown in Figure 3.23, 3.24 and 3.25. It is immediately apparent that the majority of values are less than 10% of the EQS value of 2.5 μg/l. Elevated concentrations are seen in the Bristol Channel in each of the years, with the highest concentrations in 1993. The North Wales coast showed elevated concentrations in 1993 compared to 1994 and 1995. However, these did still not exceed 50% of the EQS.

The other dissolved metals also show low concentrations throughout the three years of the baseline surveys, in relation to their respective EQS levels. Dissolved nickel results show all samples greatly below 50% of the EQS for all three years, with a decrease in absolute concentration apparent in the Bristol Channel, where results are highest, across this period.

Dissolved lead results showed only two sampling points greater than 10% of the EQS level over the three year period.

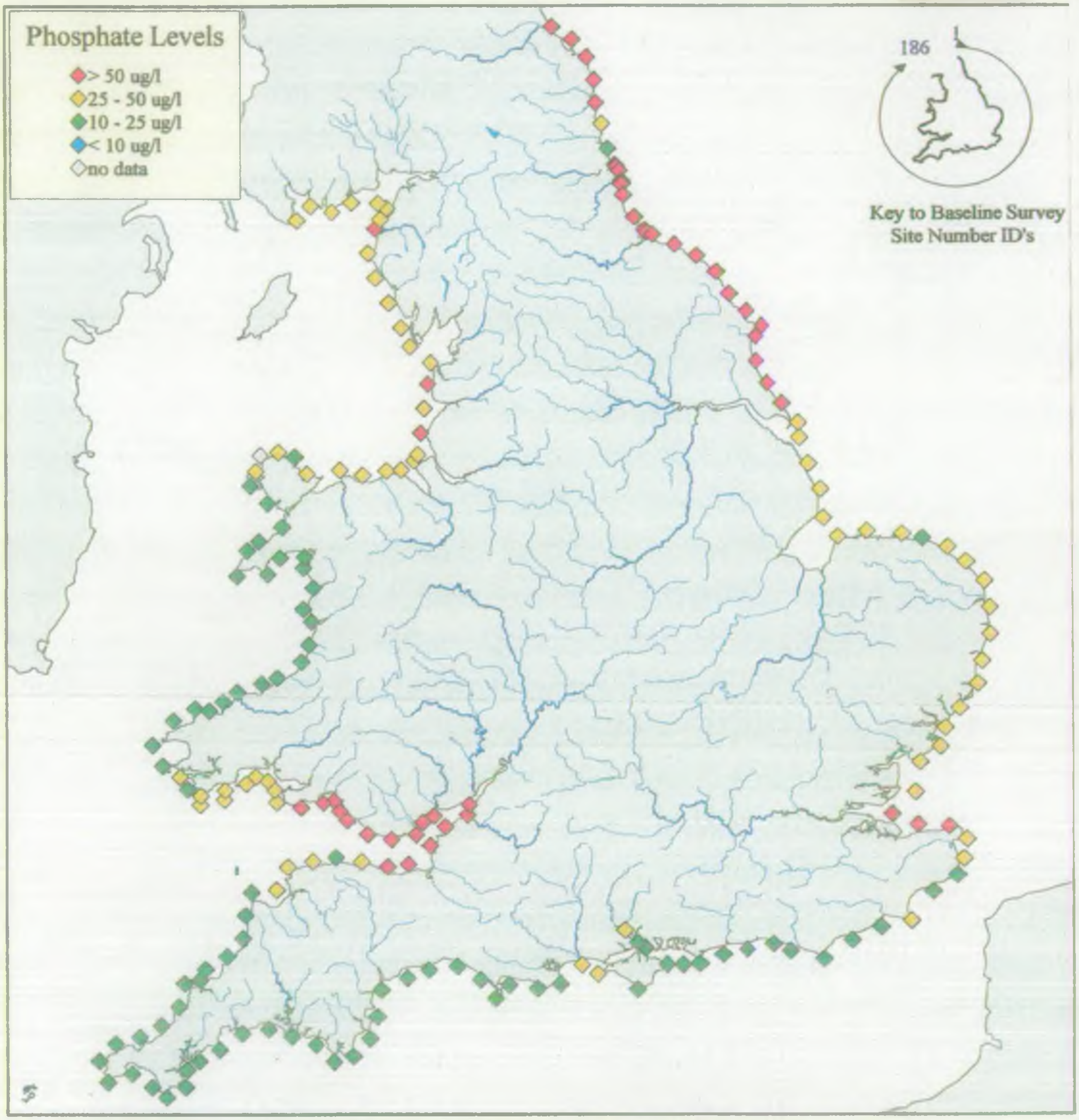
Similarly, there were no sites above 10% of the EQS for dissolved arsenic.

Dissolved chromium show higher concentrations relative to the EQS, but still only two sites were above 50% of the EQS. No particular decline was seen in the concentrations

Figure 3.13

Phosphate Levels, National Baseline Survey, Winter Average 1993 to 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Phosphate Levels, Winter Average 1993 to 1995.

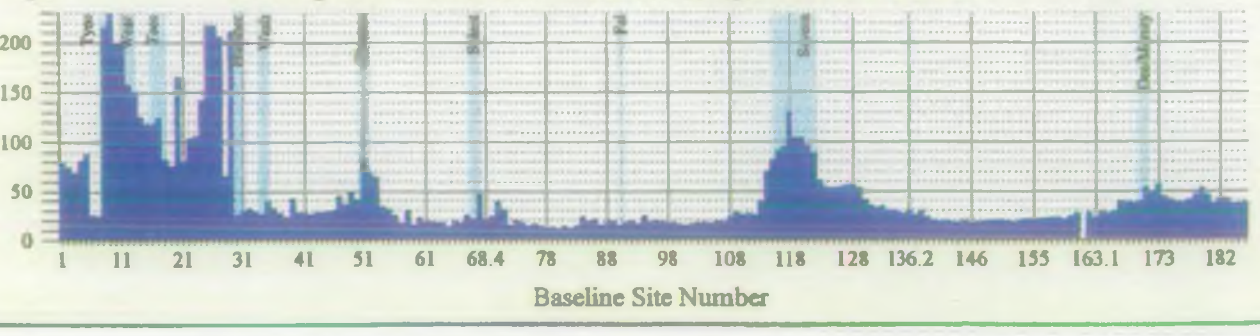
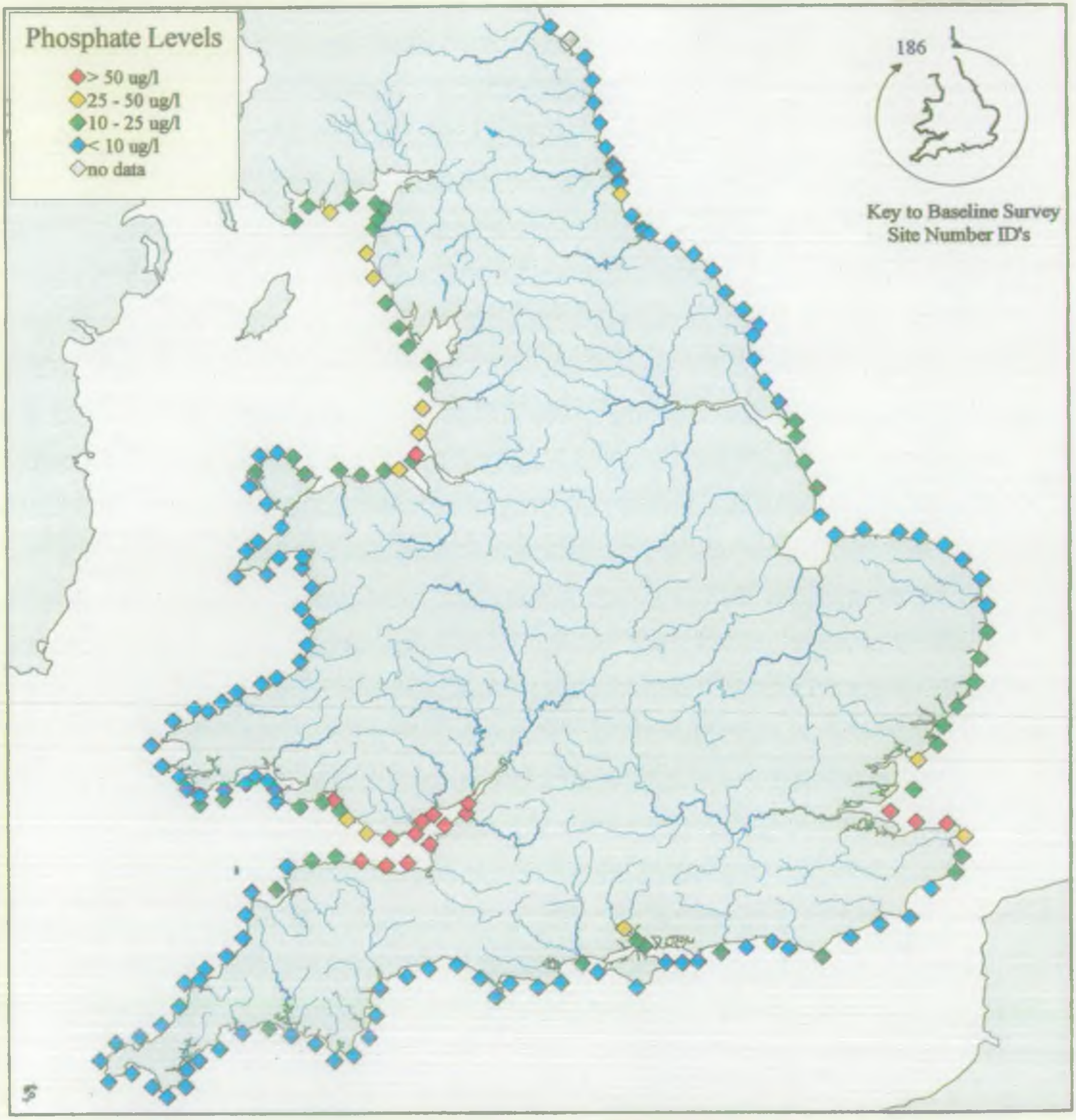


Figure 3.14

Phosphate Levels, National Baseline Survey, Summer Average 1993 to 1995.

NRA
National Centre for
Instrumentation and
Marine Surveillance



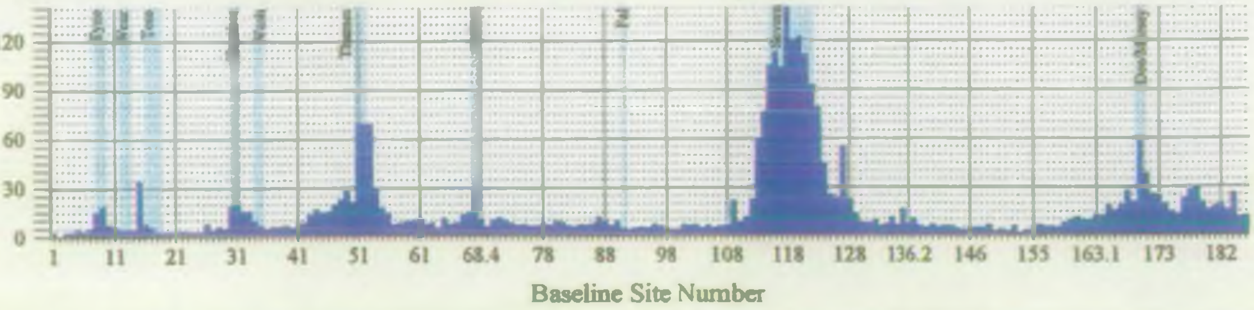
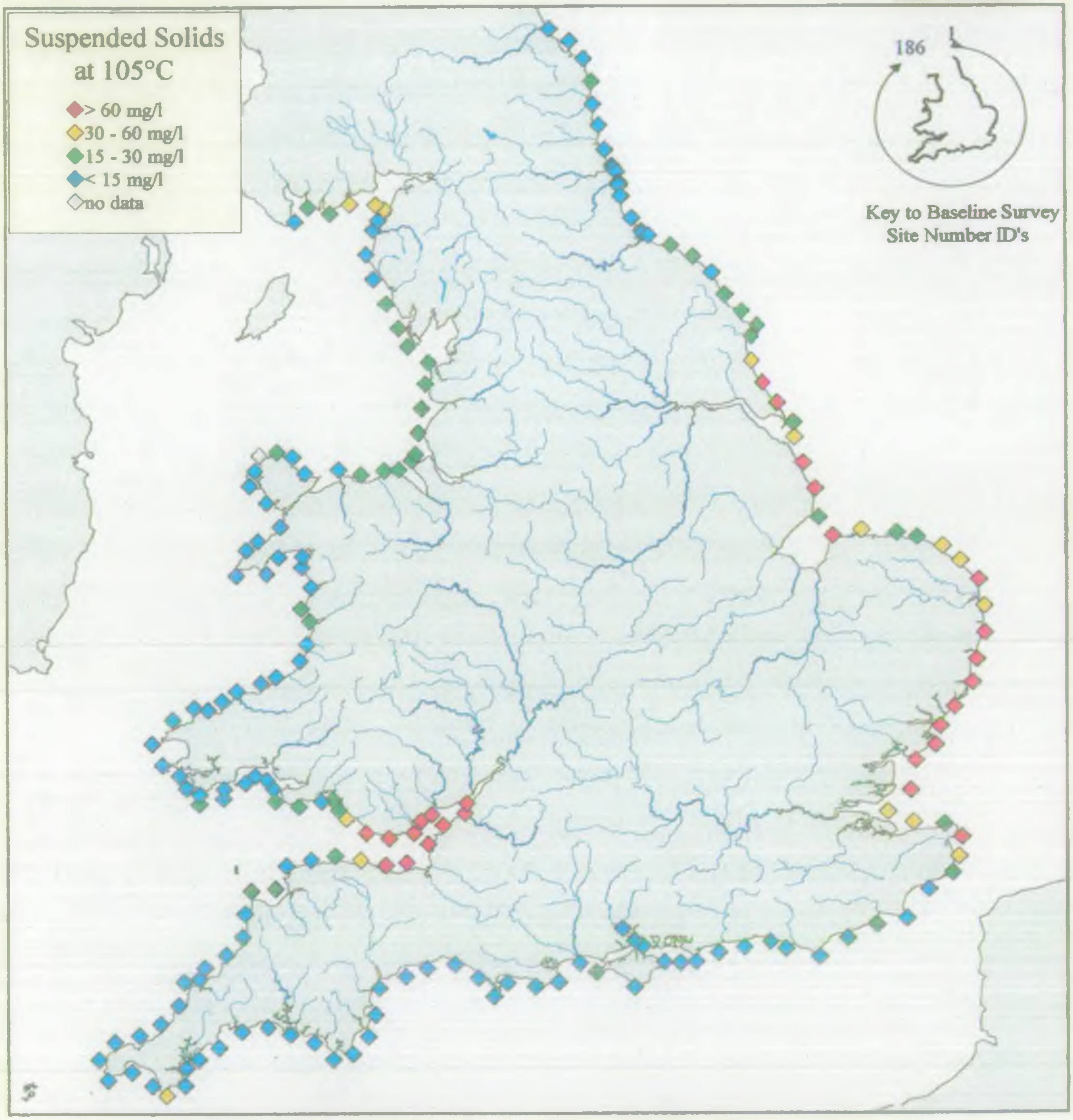


Figure 3.15

Suspended Solids at 105°C, National Baseline Survey, Winter Average 1993 to 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Suspended Solids at 105°C, Winter Average 1993 to 1995.

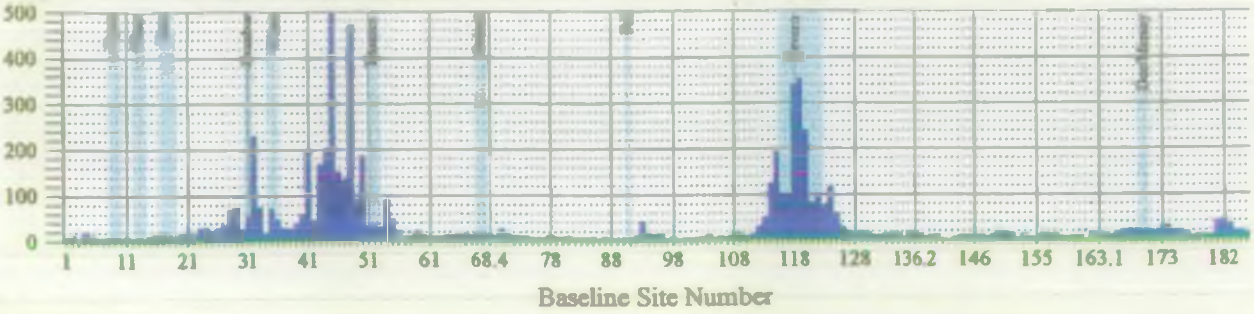
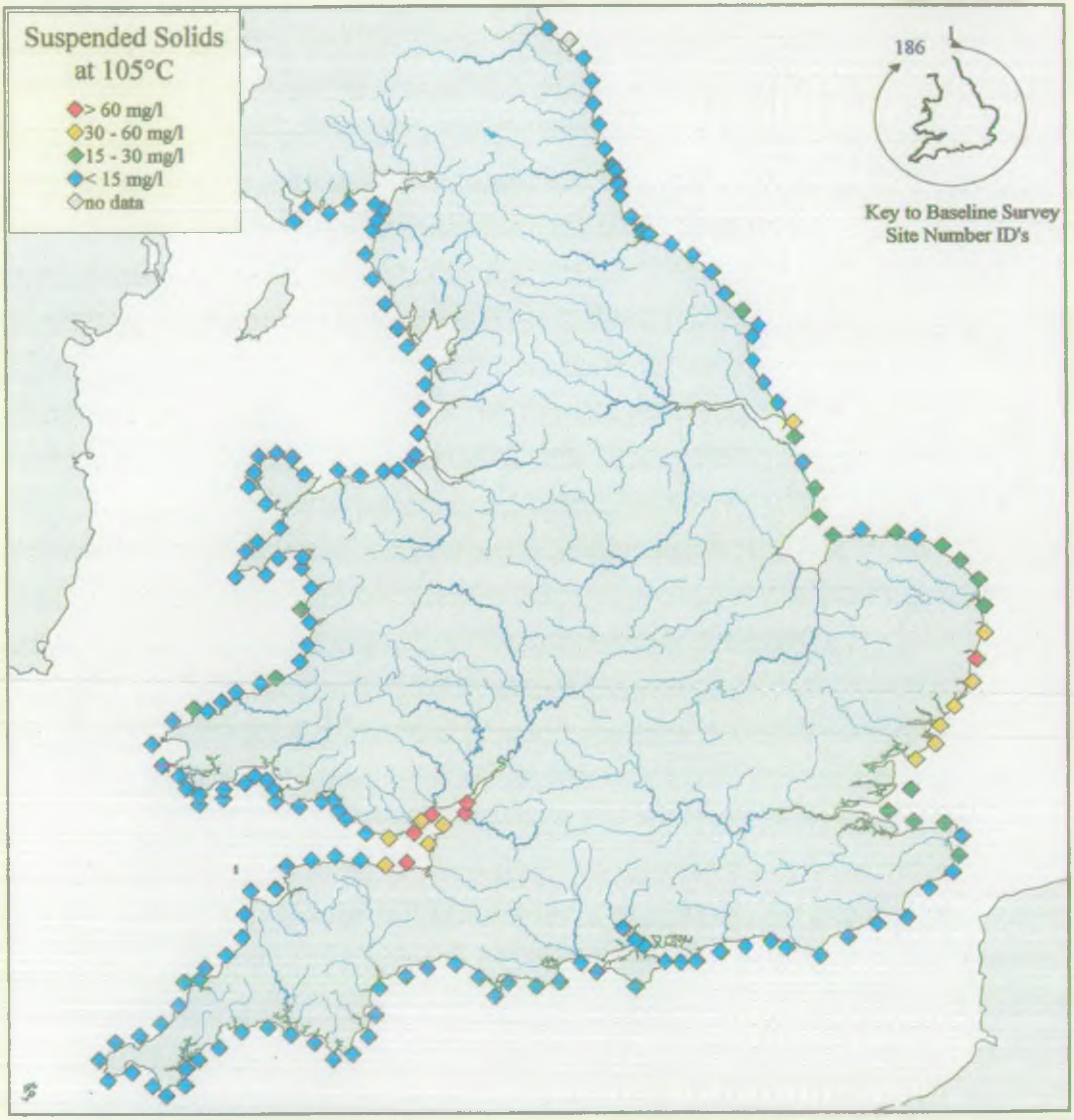


Figure 3.16

Suspended Solids at 105°C, National Baseline Survey, Summer Average 1993 to 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Suspended Solids at 105°C, Summer Average 1993 to 1995.

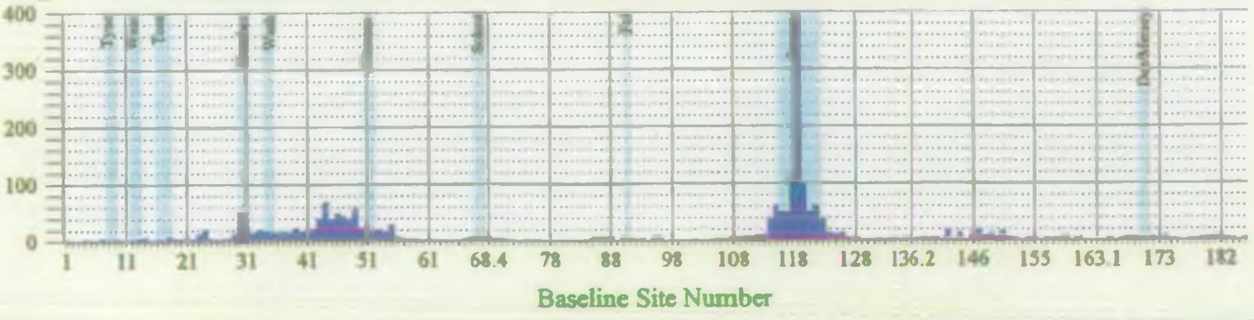
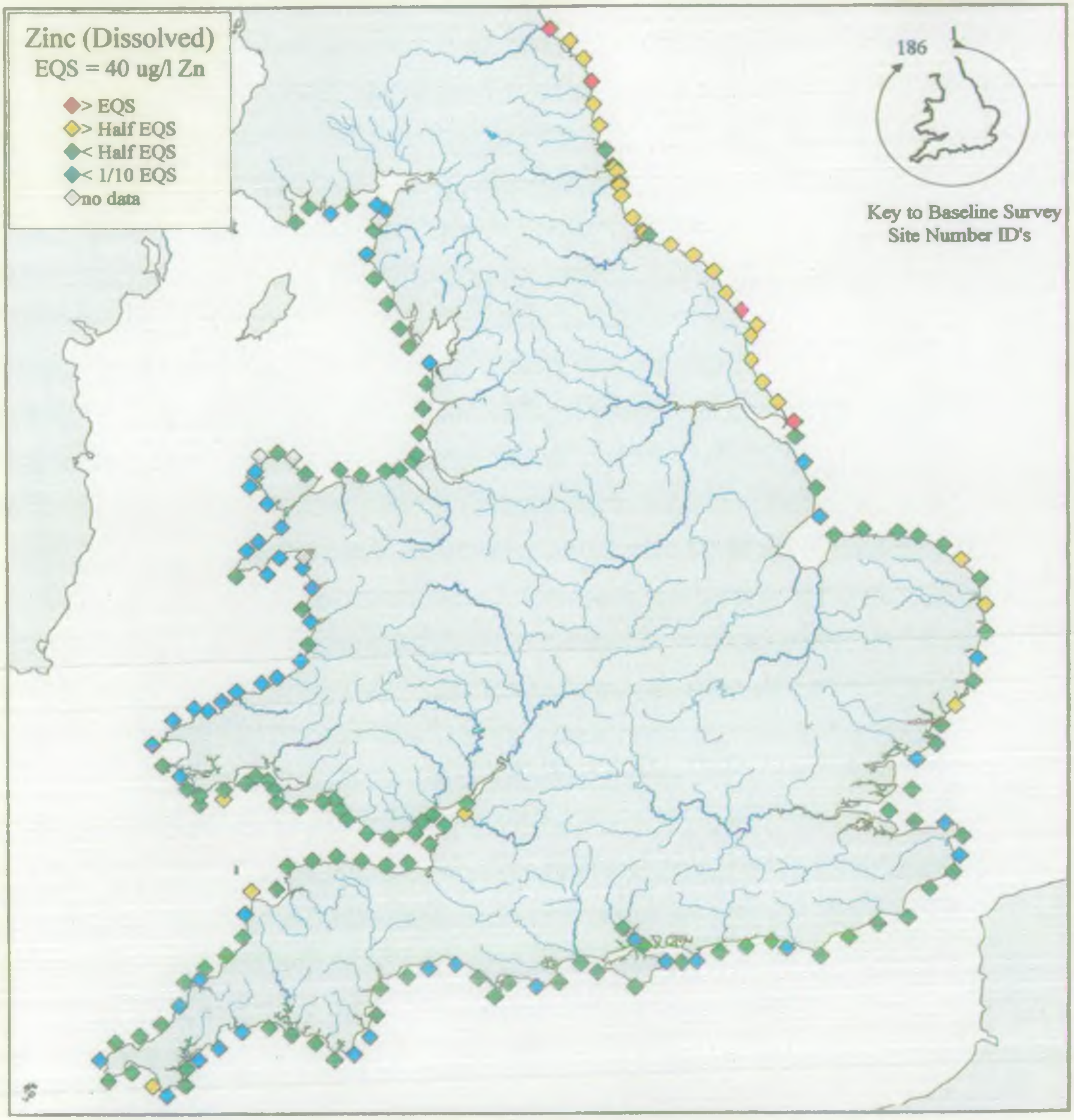


Figure 3.17

Zinc (Dissolved), National Baseline Survey, Annual Average 1993.

NRA
National Centre for Instrumentation and Marine Surveillance



Zinc (Dissolved), Annual Average 1993.

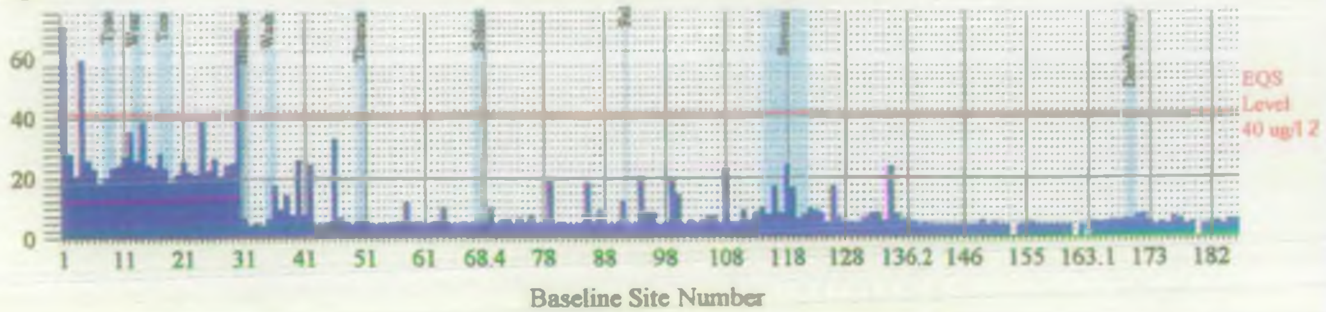
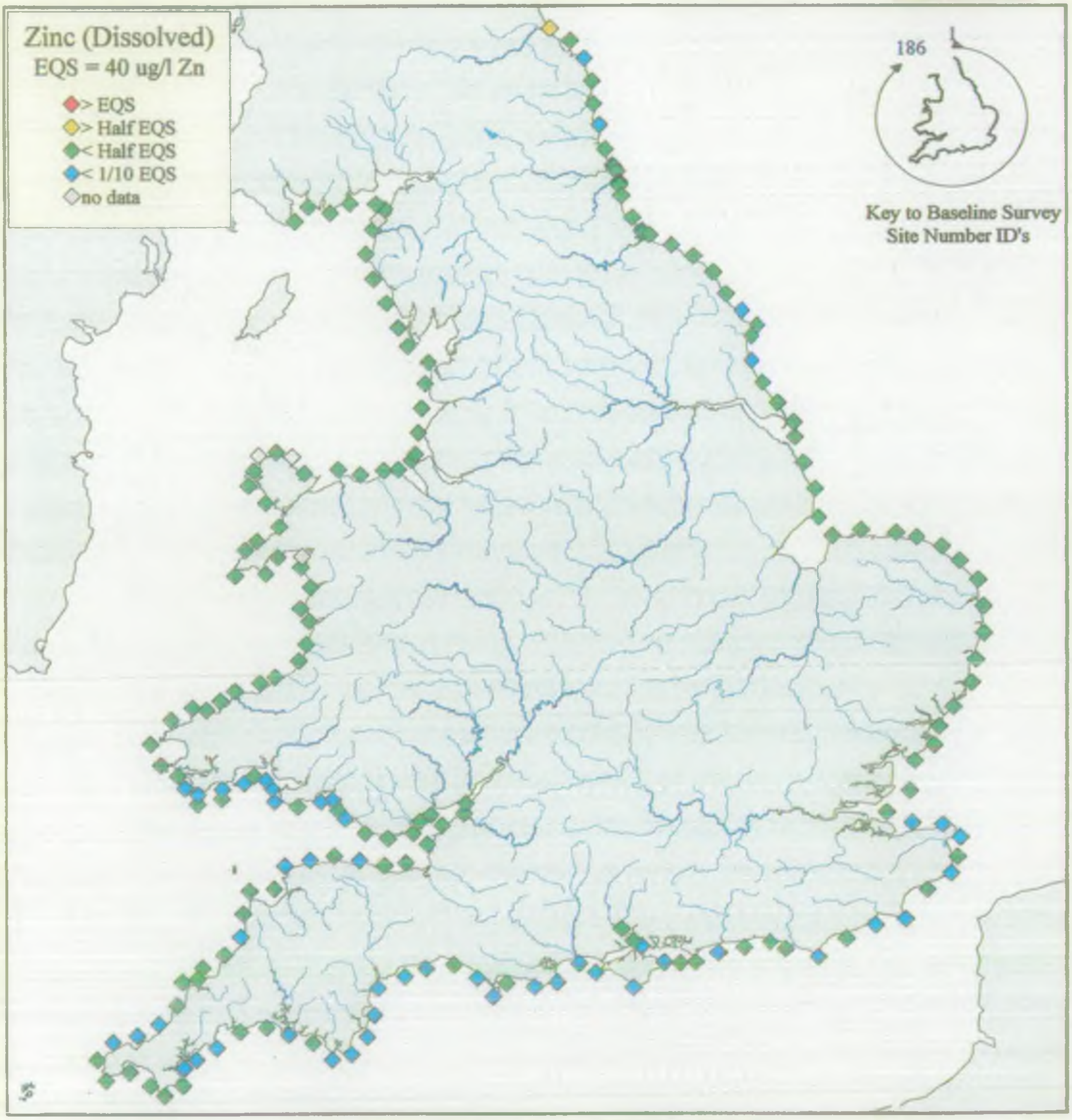


Figure 3.18

Zinc (Dissolved), National Baseline Survey, Annual Average 1994.

NRA
National Centre for Instrumentation and Marine Surveillance



Zinc (Dissolved), Annual Average 1994.

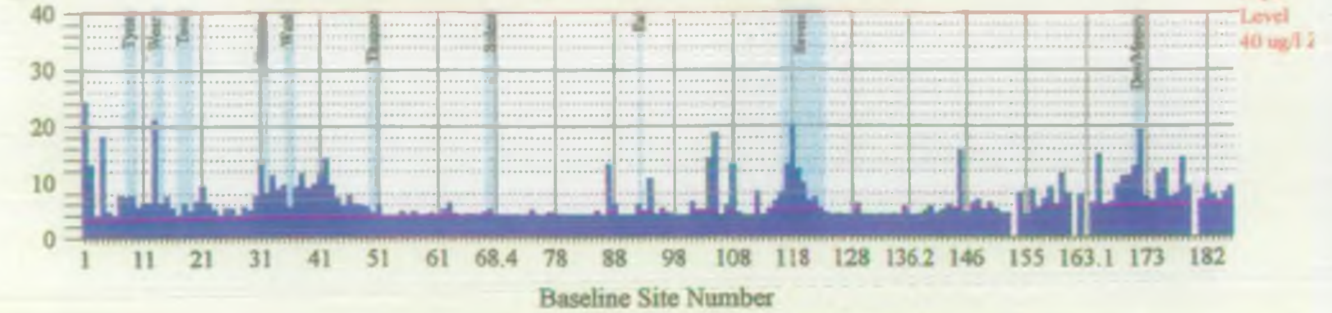
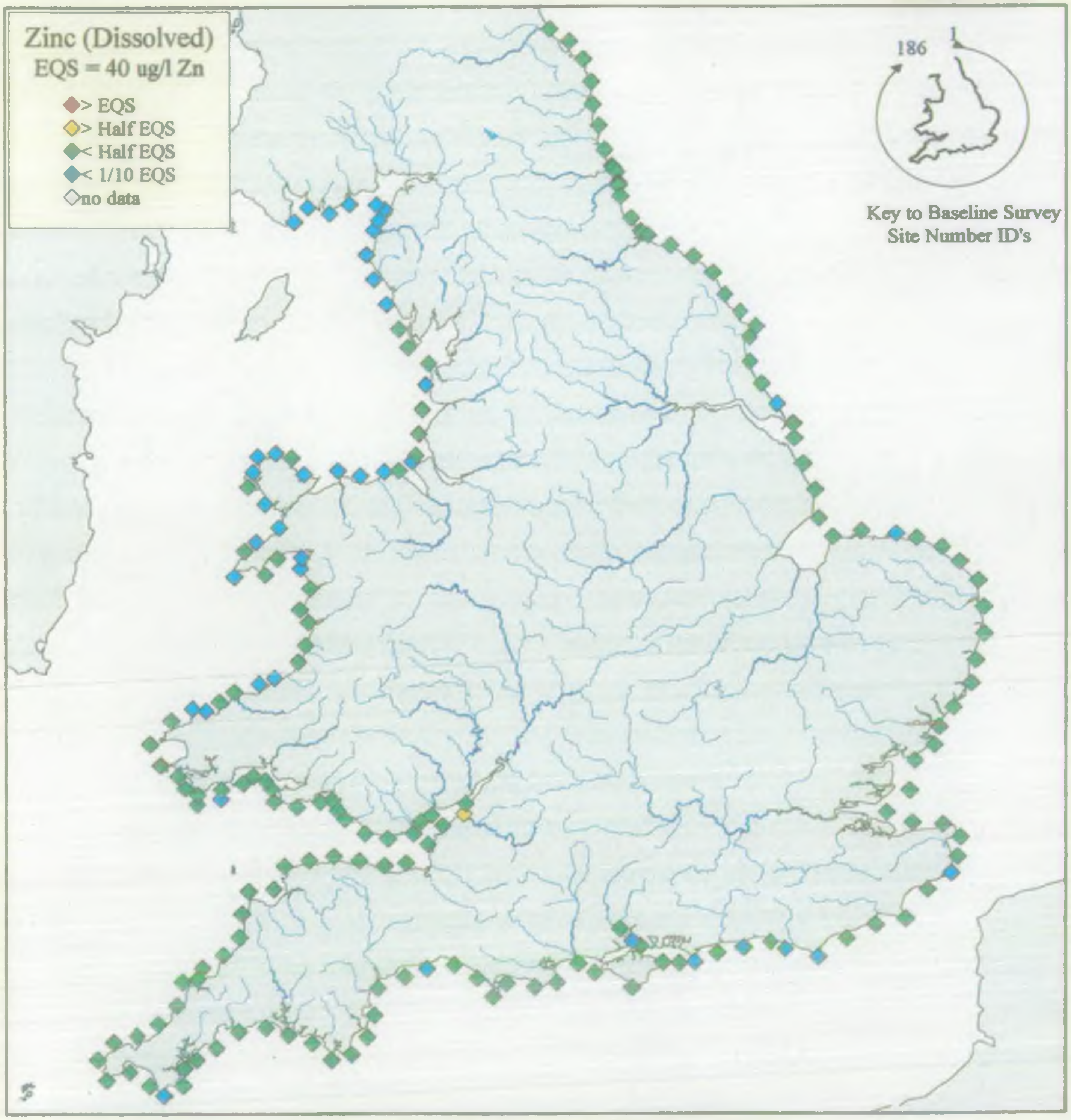


Figure 3.19

Zinc (Dissolved), National Baseline Survey, Annual Average 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Zinc (Dissolved), Annual Average 1995.

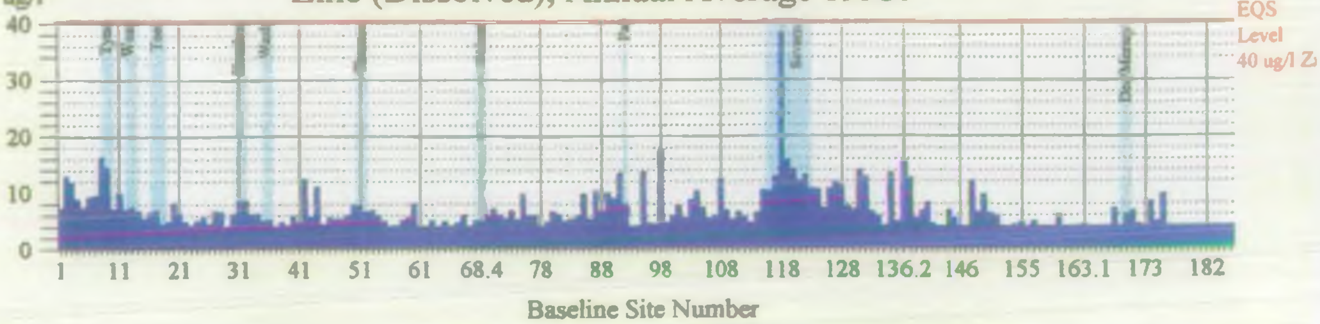
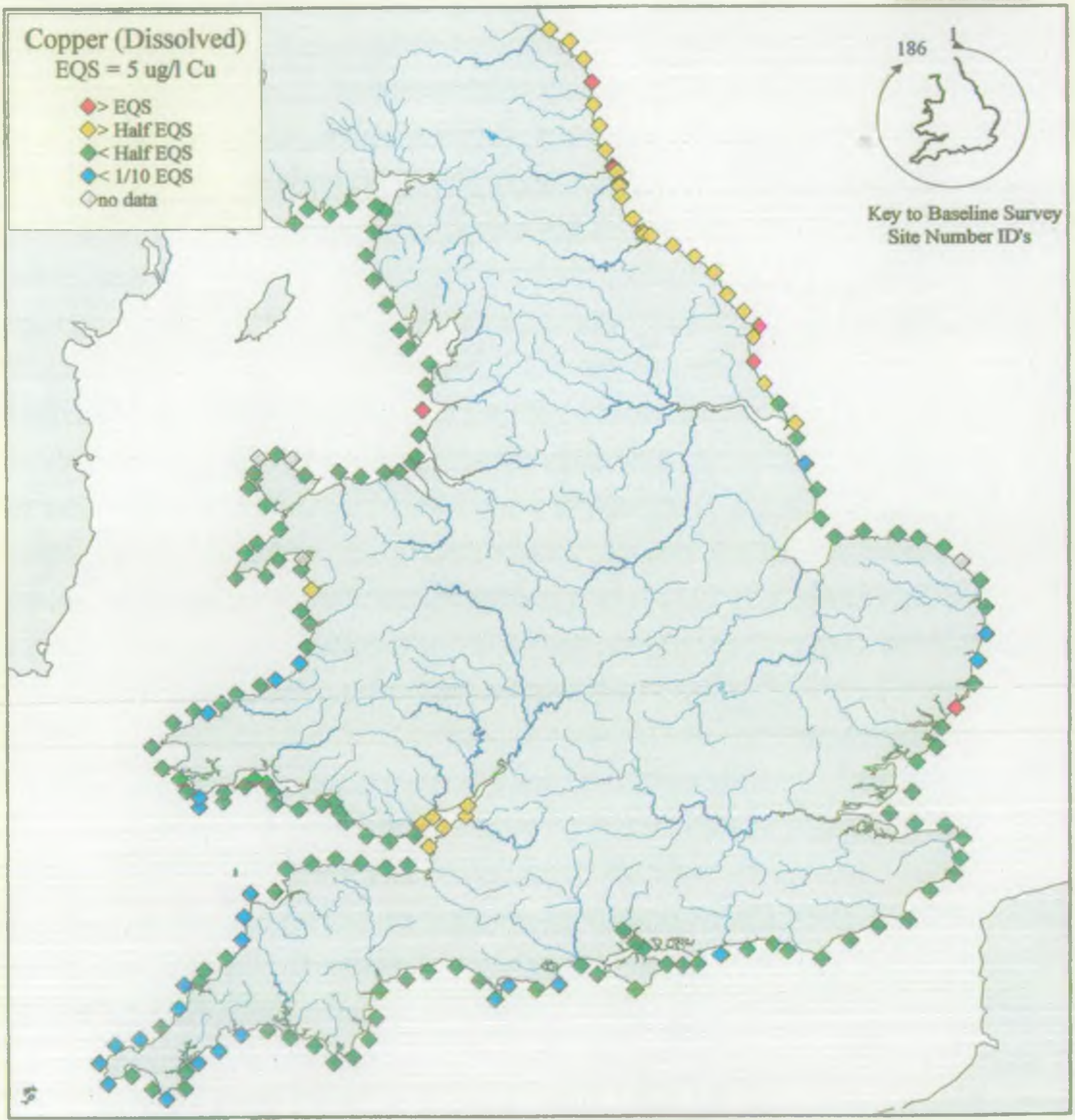


Figure 3.20

Copper (Dissolved), National Baseline Survey, Annual Average 1993.

NRA
National Centre for Instrumentation and Marine Surveillance



Copper (Dissolved), Annual Average 1993.

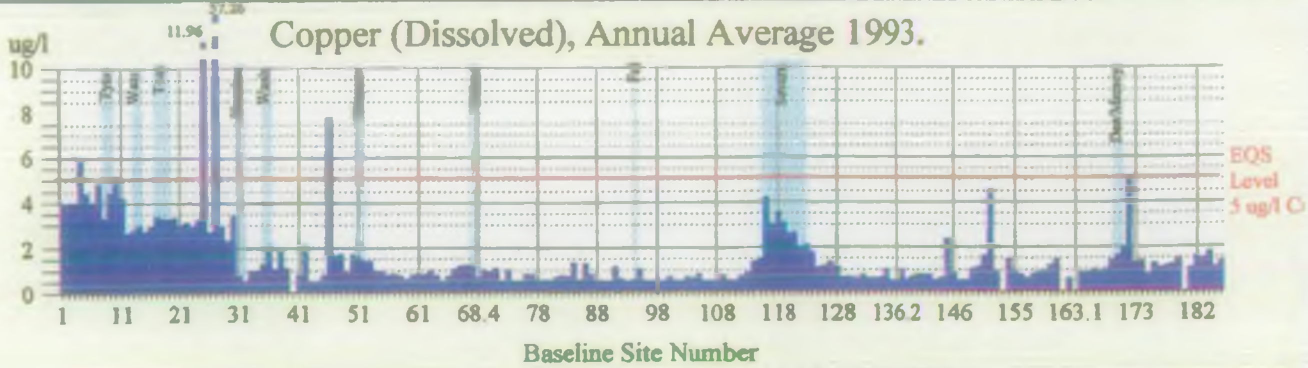
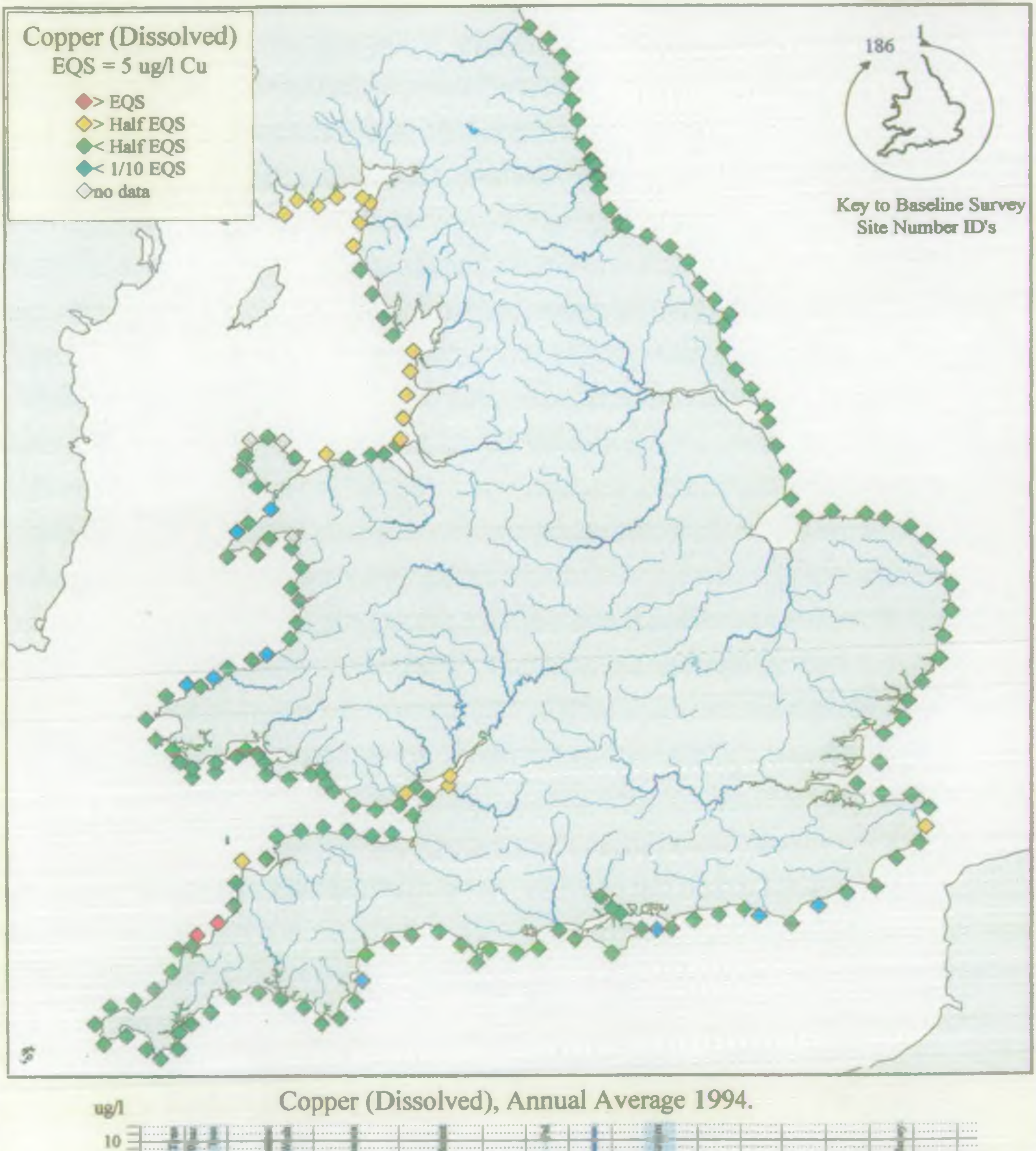


Figure 3.21

Copper (Dissolved), National Baseline Survey, Annual Average 1994.

NRA
National Centre for Instrumentation and Marine Surveillance



Copper (Dissolved), Annual Average 1994.

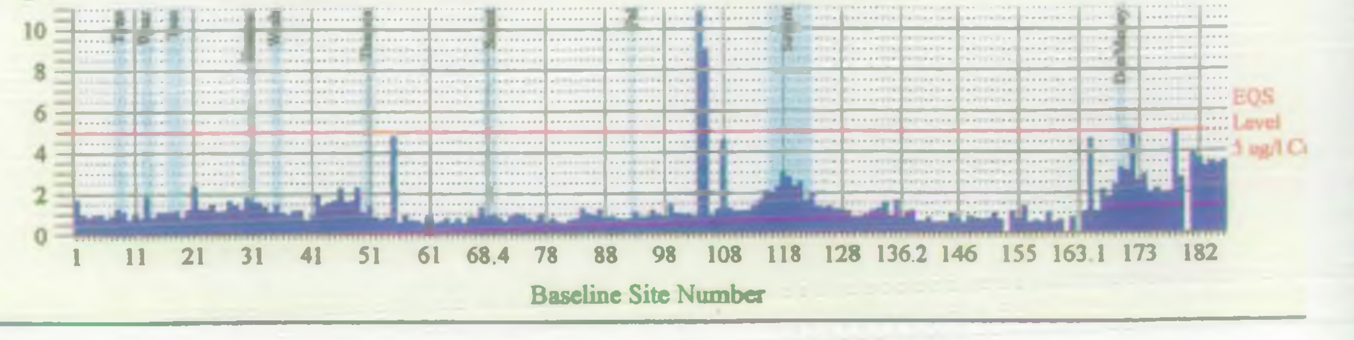
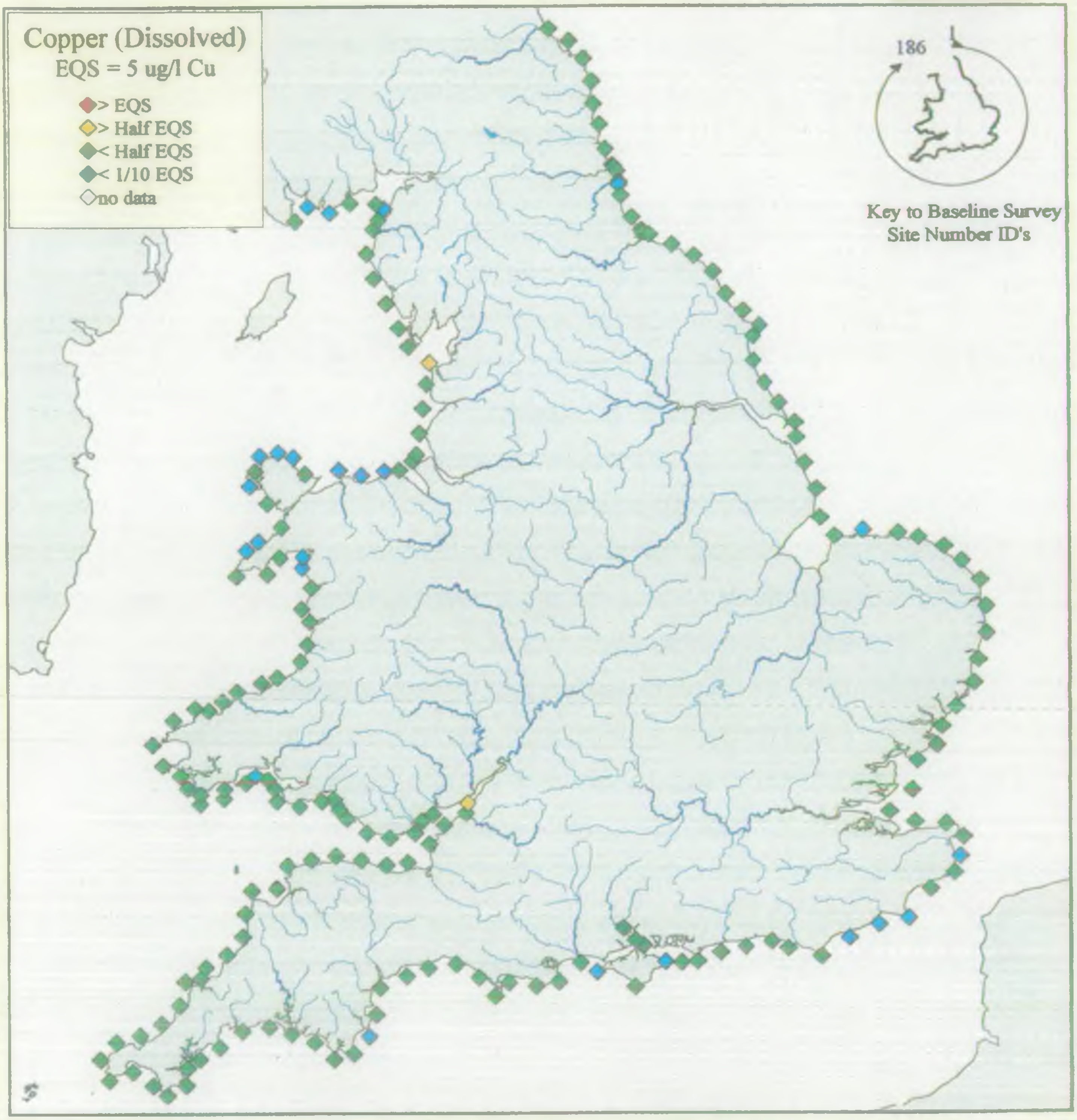


Figure 3.22

Copper (Dissolved), National Baseline Survey, Annual Average 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Copper (Dissolved), Annual Average 1995.

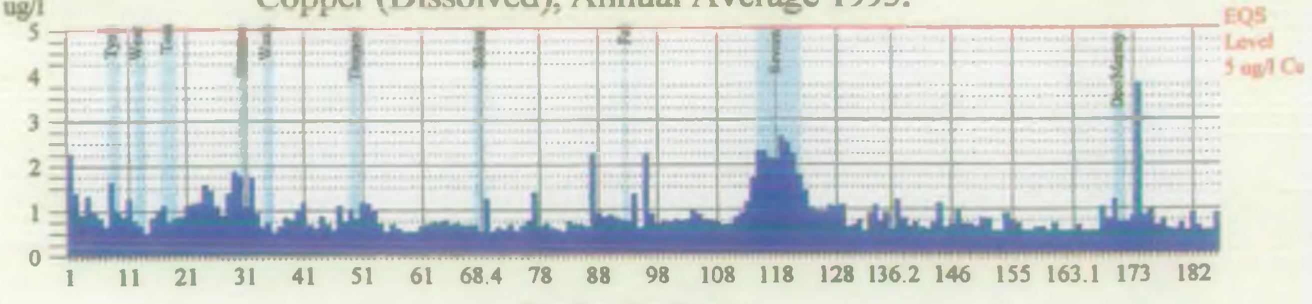
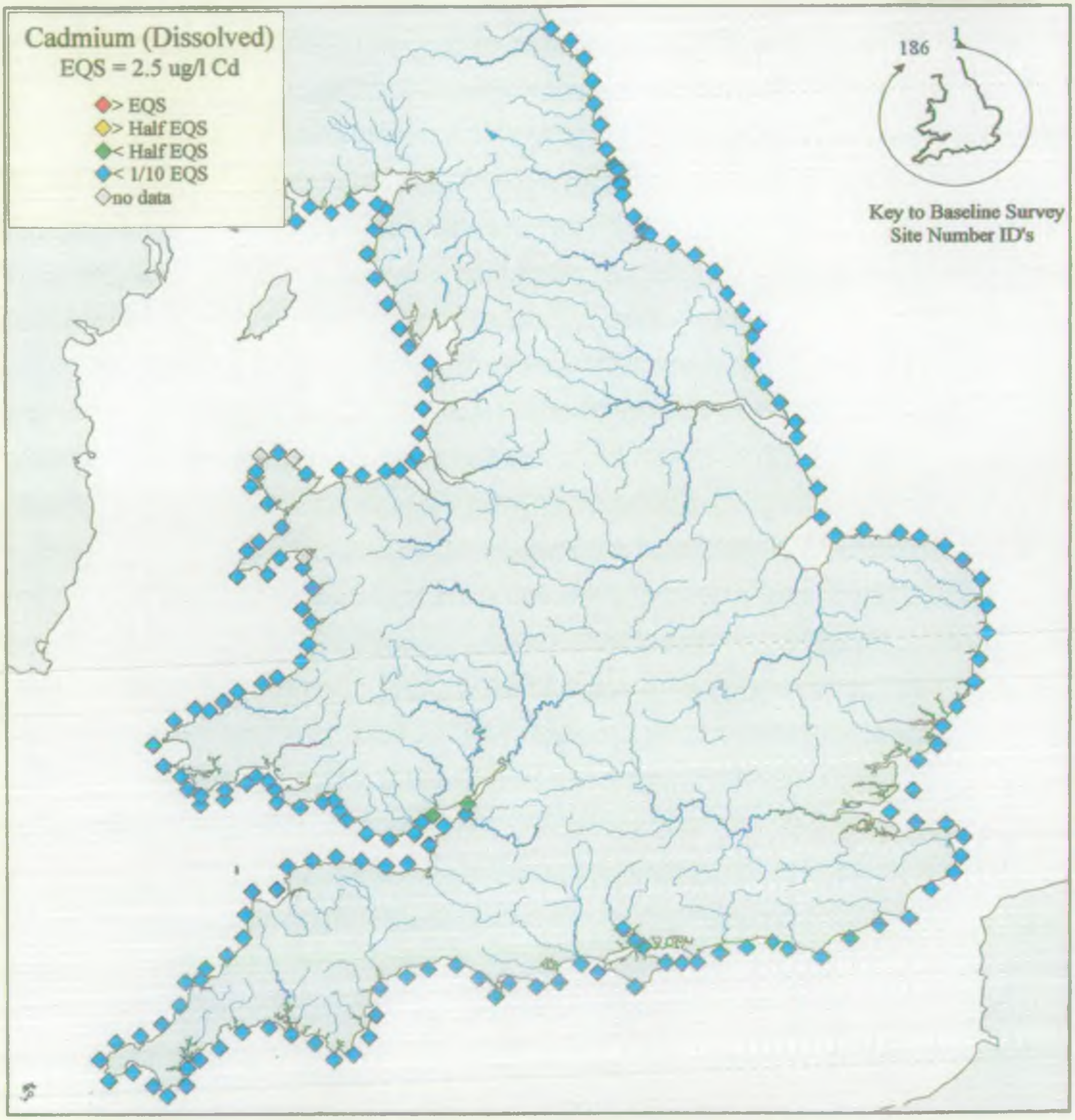


Figure 3.23

Cadmium (Dissolved), National Baseline Survey, Annual Average 1993.

NRA
National Centre for
Instrumentation and
Marine Surveillance



Cadmium (Dissolved), Annual Average 1993.

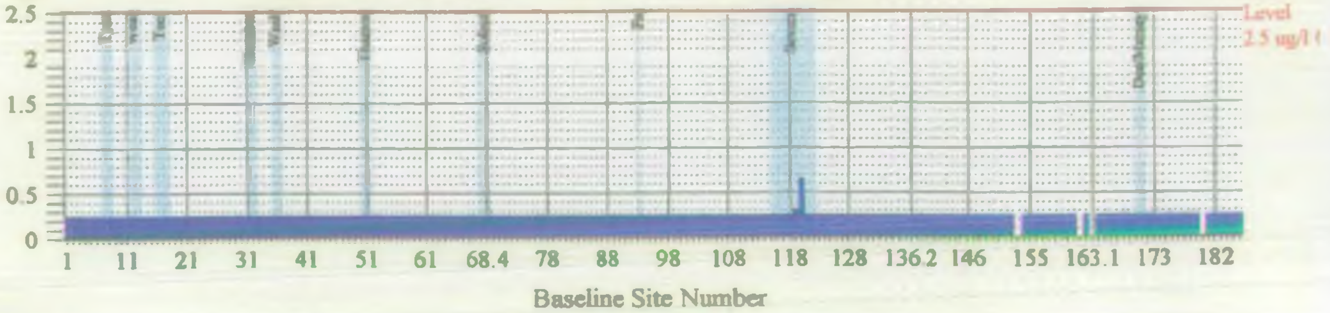
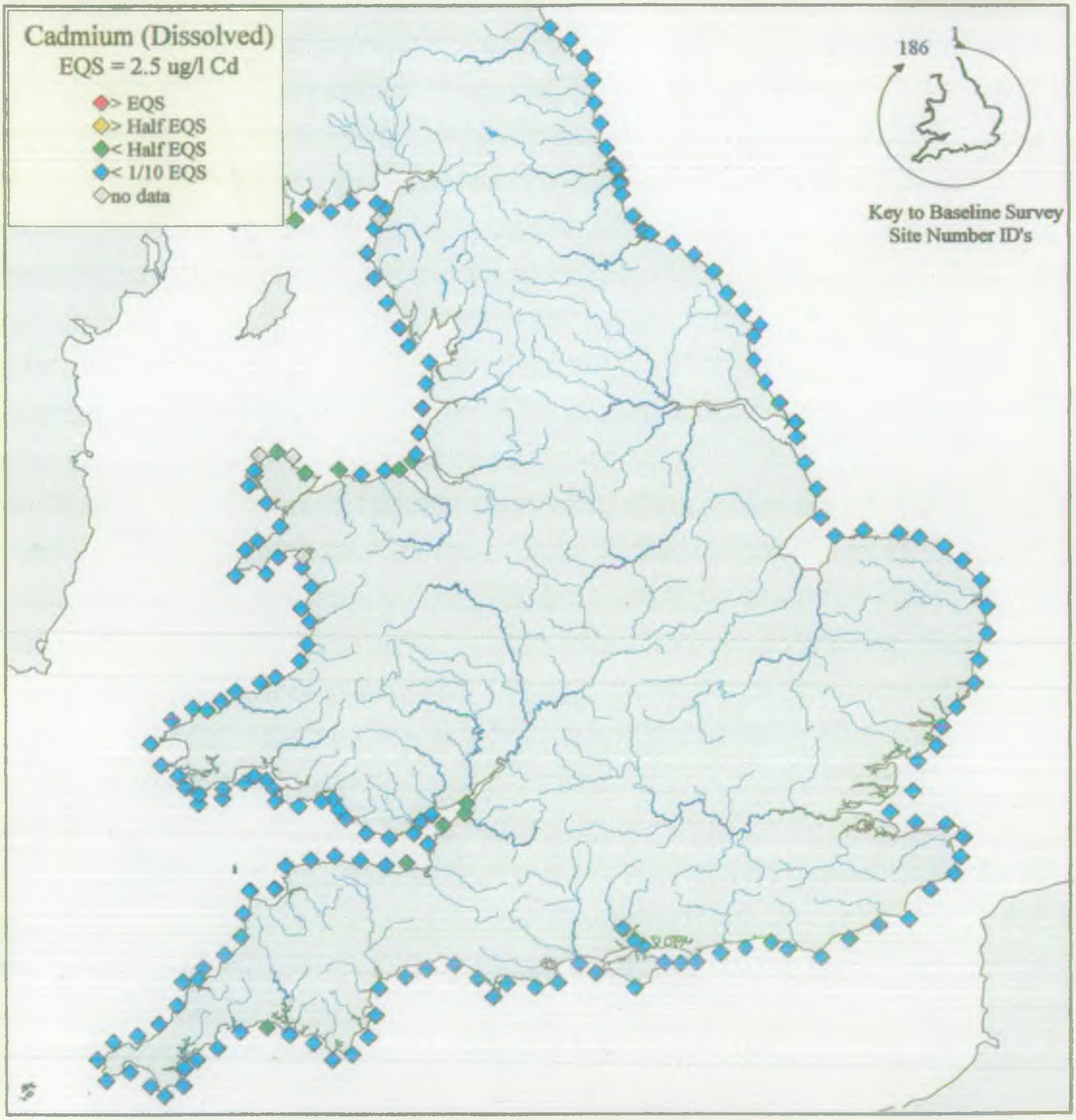


Figure 3.24

Cadmium (Dissolved), National Baseline Survey, Annual Average 1994.

NRA

National Centre for Instrumentation and Marine Surveillance



Cadmium (Dissolved), Annual Average 1994.

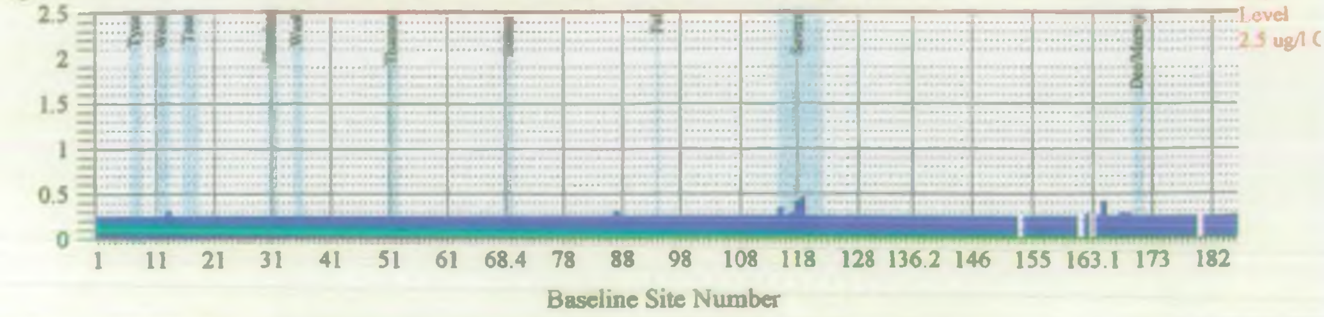
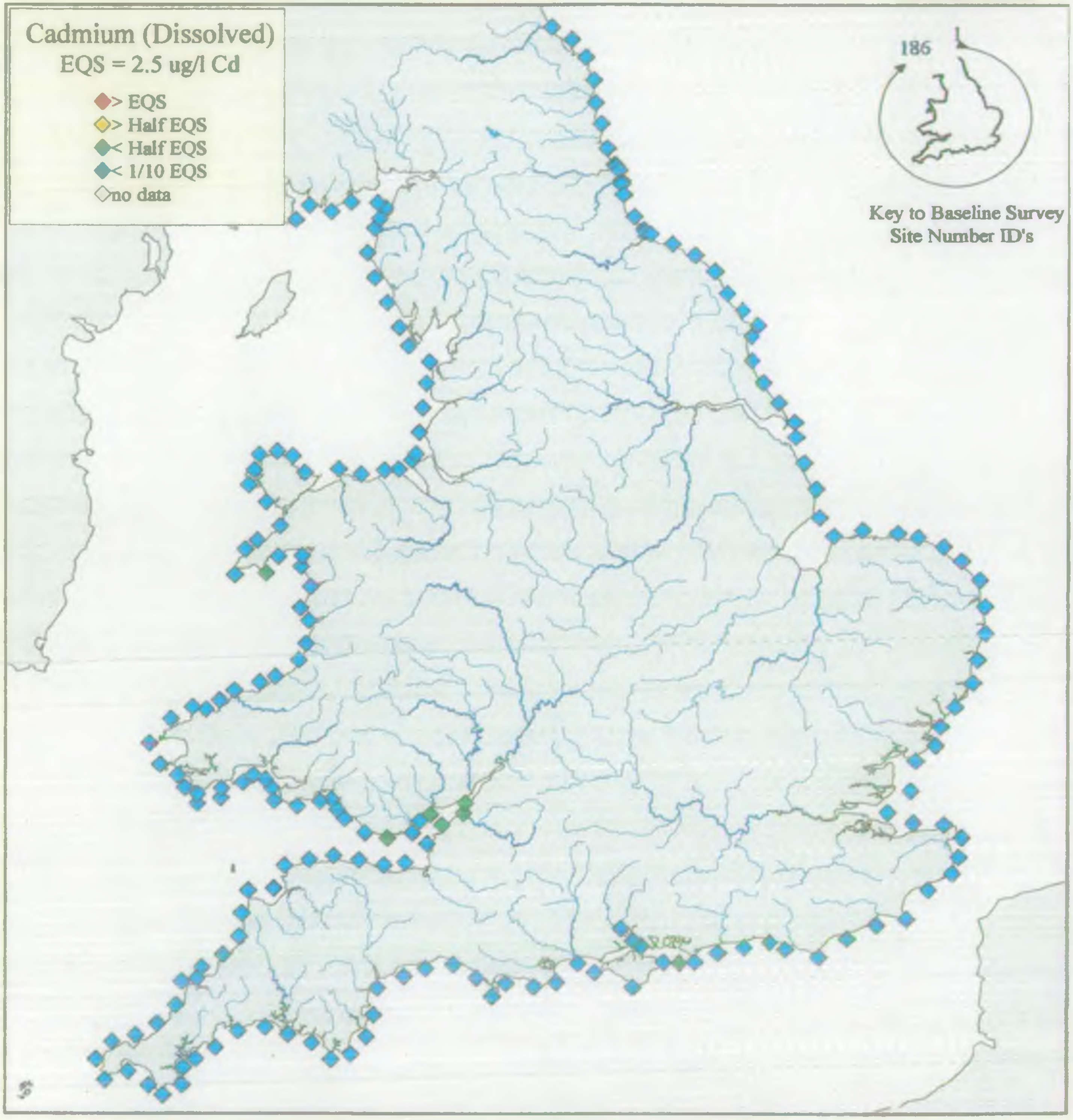


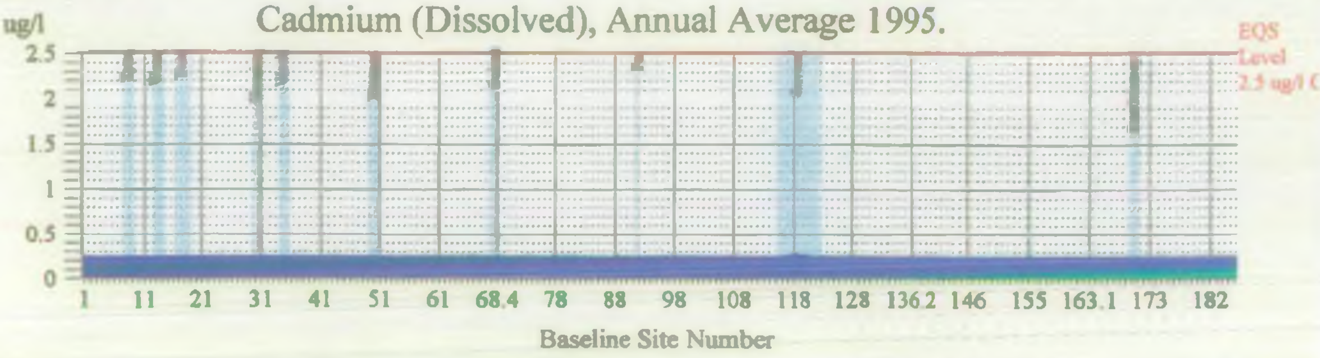
Figure 3.25

Cadmium (Dissolved), National Baseline Survey, Annual Average 1995.

NRA

National Centre for Instrumentation and Marine Surveillance





between the three years, with some individual sites increasing slightly, although, as stated still remaining well below the EQS level.

Neither the dissolved nor total mercury concentrations where taken exceeded the EQS at any site. At many sites there is a decrease with time in the concentrations found.

3.2.5 Organic compounds

Most of the samples analysed for organic compounds during 1993 and 1994 were below the limit of detection of the standard laboratory analyses used (0.01 µg/l). It is not therefore of interest to present the results in the same way as those of the metals or nutrients. Figure 3.33 presents the count of organics found above 0.01 µg/l for each site. The results for these samples are set out in Table 3.1.

No site shows in excess of 7 occurrences of total organic compounds from the total of 23 compounds measured. The highest occurrences are located along the South Wales coast and in the Solway Firth. In numerical terms, no individual samples with actual values were found to exceed the defined annual mean Environmental Quality Standards on any occasion.

Some samples from the 1995 surveys were analysed to much lower limits of detection, typically 0.001 µg/l. No samples were found to contain organic compounds at concentrations over 0.01 µg/l. However, the reduction in detection limit revealed γ-Hexachlorocyclohexane (Lindane) to be widely distributed although at very low concentrations (less than 0.003 µg/l). Even smaller concentrations of α-Hexachlorocyclohexane were also found off the south east, south and south west coasts.

3.3 Airborne measurements

The remotely sensed image data provides coverage of the three nautical mile zone in one single overpass, thus affording an almost instantaneous synoptic view of the processes in this zone. This is temporally superior to boat measurements which may be affected by the changing tidal states encountered within the measurement period.

The spatial characteristics of the airborne data allows a full description of the variability of those aspects of water quality which affect the reflectance signal. The aerial surveys carried out as part of the National Marine Baseline Survey provide wide area quantitative information on chlorophyll-*a* concentration and qualitative information on the spatial extent of mixing zones, HNDAs, discharge footprints, sensitive areas and coastal processes. It also provides a context for the *in-situ* measurements. Furthermore, the data may be used to estimate sediment transport and changes in geomorphology.

The flight lines used in the coastal baseline survey are designed to produce images which include the coastline. This aids the locating of features found offshore. It also results in remotely sensed data being available for the immediate coastal margin, including the intertidal zone.

Geometrically corrected images have been produced to identify various features such as different vegetation surfaces in the form of classifications. Because the data is digital, areas of the features can be measured accurately and previous data can be revisited and reprocessed to reveal additional information. Changes in vegetative cover over time can therefore be accurately assessed.

3.3.1 The production of chlorophyll-*a* maps of the coastal zone.

The Urban Waste Water Treatment Directive defines the presence of elevated levels of chlorophyll-*a* in summer months as one of the potential indicators of the presence of eutrophication. However, the concentrations must be interpreted based on historical and geographical context. Thus maps of chlorophyll-*a* concentration around the coast would provide a background figure against which any local readings might be compared.

The data collected as part of the National Marine Baseline Survey has two potential means of providing this information. Firstly, the underway fluorimeter may be calibrated for chlorophyll-*a* using the laboratory samples in order to produce a continuous line of varying concentration around the coast. The restriction with this technique, however, is that it would provide no spatial information perpendicular to the direction of the ship track. Estimates of the average concentration of the three mile coastal zone would therefore not be representative.

The second method is using the CASI image data. This data may be interpreted for chlorophyll-*a* concentration using a technique called the Fluorescence Line Height (FLH). The FLH technique relies on the *in-vivo* fluorescence of chlorophyll-*a* within phytoplankton

Figure 3.26 Occurence of Organic Chemicals found above their Limit of Detection, National Baseline Survey, 1993 to 1995.

NRA
National Centre for Instrumentation and Marine Surveillance

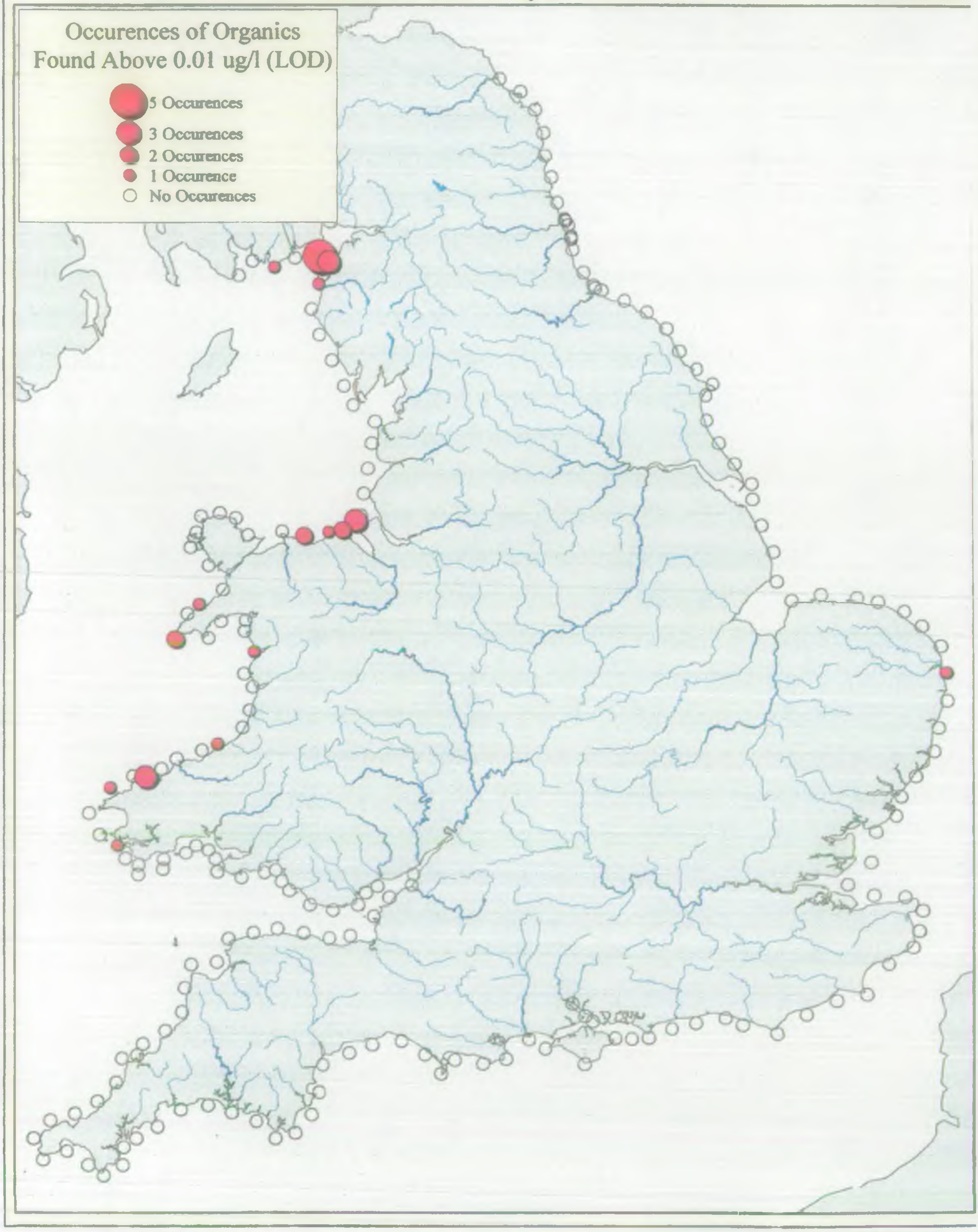


Table 3.1 Occurence of Organic Chemicals found equal or above 0.01 ug/l, 1993 to 1995.

Site Number	Site Name	Source lab	Date	Time	Organic Chemical	Concentration (ug/l)
42	Gorleston	Northumbria	19-May-93	12:55	HCH gamma	0.011
138	St. Anns	Nottingham	09-Jun-94	12:15	Hexachlorobutadiene	0.11
141	Abereiddy	Northwest	15-Feb-93	09:56	PCB 28	0.01
143	Fishguard	Northwest	24-Aug-93	17:13	PCB 28	0.04
		Northwest	24-Aug-93	17:13	PCB 52	0.08
		Northwest	14-Feb-93	17:48	PCB 28	0.01
147	New Quay Head	Northwest	14-Feb-93	15:06	PCB 28	0.01
152	Barmouth	Northwest	14-Feb-93	11:00	HCH gamma	0.014
156	Bardsey	Nottingham	07-Jun-94	16:09	Hexachlorobutadiene	0.13
		Northwest	13-Feb-93	14:22	PCB 28	0.01
158	Dinllaen	Northwest	13-Feb-93	12:30	PCB 28	0.02
166	Llanddulas	Northwest	21-Aug-93	14:32	HCH gamma	0.019
		Northwest	19-May-93	14:56	Hexachlorobenzene	0.09
167	Chester Flat	Northwest	12-Feb-93	14:47	PCB 28	0.02
168	Welsh Channel	Northwest	12-Feb-93	14:00	PCB 28	0.02
		Northwest	19-May-93	13:15	Hexachlorobenzene	0.2
169	HE 1 Buoy	Northwest	19-May-93	10:58	PCB 138	0.01
		Nottingham	21-Mar-94	17:35	Hexachlorobutadiene	0.13
		Northwest	21-Aug-93	12:35	Hexachlorobenzene	0.11
180	Workington	Nottingham	13-Mar-95	18:15	Hexachlorobutadiene	0.25
181	Solway Buoy	Northwest	18-Aug-93	12:30	PCB 153	0.01
		Northwest	18-Aug-93	12:30	PCB 138	0.01
		Northwest	18-Aug-93	12:30	PCB 180	0.02
182	Middle Buoy	Northwest	17-Aug-93	12:00	PCB 180	0.02
		Northwest	17-Aug-93	12:00	PCB 153	0.01
		Northwest	17-Aug-93	12:00	PCB 118	0.02
		Northwest	17-Aug-93	12:00	PCB 138	0.02
		Northwest	17-Aug-93	12:00	PCB 101	0.01
184	Abbey Head	Northwest	09-Feb-93	15:10	Hexachlorobenzene	0.13

cells. The fluorescence signal manifests itself as a peak within the reflectance signal and thus may be measured by the CASI. The calculation measures the height of the peak relative to the background reflectance spectrum: this height being correlated with chlorophyll-*a* concentration.

The procedure used to produce chlorophyll-*a* maps consists of two calibration steps. Firstly the correlation between laboratory measured chlorophyll-*a* and coincident underway fluorimeter measurements is determined. This correlation is derived for specific geographic regions, which allows for changes in fluorimeter operation and water type. The resultant set of correlations is used to calibrate all fluorimeter points such that a continuous track of chlorophyll-*a* is produced for the entire coastline. This track may be interpolated out to the three mile limit and colour coded to show the variation in chlorophyll-*a* concentration.

A second calibration step is applied to the CASI imagery. A grey scale image is produced by carrying out the FLH calculation on each CASI image. The grey scale values are linearly related to the chlorophyll-*a* concentrations which are established by deriving a correlation between the FLH and the underway fluorimeter values for coincident points in the imagery. As above, a series of calibrations are used to allow for changes in the FLH associated with changing water type. For example, the presence of suspended sediment in the water column may affect the FLH value, especially if the suspended matter is coloured red. The image produced from the data after calibration may be colour coded in terms of chlorophyll-*a* concentration and a mosaic technique used to produce a map of the entire coastline.

The image thus produced may be colour coded into any arbitrarily chosen concentration bands to show the chlorophyll-*a* concentration. Images from Spring would be expected to show the greatest variation in chlorophyll-*a* concentration. However, it was not possible to carry out an Aerial survey in Spring 1995 and therefore images from the Autumn 1994 and Summer 1995 are included as examples.

3.3.1.1 Autumn 1994 survey

Figure 3.27 displays the results for chlorophyll-*a* concentration obtained through laboratory analysis of surface water samples. The results of the application of the first calibration step to the entire coastline are shown in Figure 3.28. Comparison of these two figures reveals that the spatial patterns are consistent around the coast with highest values found in North Wales using both techniques, and with elevated concentrations also seen on the Anglian coast. Differences between the absolute values is due to the varying ways in which the two measurements are taken, with the fluorimeter being located at a greater depth to the water bottle sampler.

The results of applying the second calibration step to the CASI imagery are shown in Figure 3.29. It has not been possible to calibrate the FLH values for the east coast as there was a time difference between the ship and aircraft overflights. In other regions the correlation between the CASI derived chlorophyll-*a* concentration and that measured via water samples is good. The overall underestimation of concentration by the CASI is probably indicative of a true decline in phytoplankton concentration between the time of measurement using the ship and the aircraft, which in most cases was a few days. Especially during the autumnal bloom this is a long enough time period to allow such a decline in concentration.

3.3.1.2 Summer 1995 survey

Figure 3.30 shows the laboratory derived chlorophyll-*a* levels for Summer 1995. Concentrations are generally low, with the majority of samples being below 5 μg/l. Some variation does exist however, in particular around the south west coast and the north east region. These results have been used to calibrate the underway fluorimeter, as described in step one above. The results are shown in Figure 3.31. A good correlation is seen between the two measurements, with the same spatial patterns being revealed.

Figure 3.32 shows the calibrated FLH imagery which has been displayed as a mosaic of each flight line. The north east region still shows relatively elevated concentrations, but the numeric value is not as high as shown in the fluorimeter measurements. This is probably due to a time discrepancy between the boat and aircraft measurements, which in this case was approximately 10 days. This difference probably also explains the overall smaller range of concentrations derived from the FLH imagery.

Figure 3.32 also shows two enlarged inserts of the north east coast and the north Kent coast. This allows the variation in concentration of chlorophyll-*a* away from the coast to be seen. This is most obvious in the CASI derived results as this is a truly spatial technique as apposed to an interpolation. For both sub-sections the CASI derived chlorophyll-*a* concentrations are lower than that determined from the fluorimeter. This is due partly to the time difference between the ship and aircraft measurements, but may also be due to a slight damping of the variation inherent in the linear regression technique used. The CASI derived results for the north Kent coast illustrate the advantage of using airborne data collection techniques to survey such areas, the aircraft providing information not available from the survey vessel.

3.3.2 Interpretation of CASI and thermal imagery

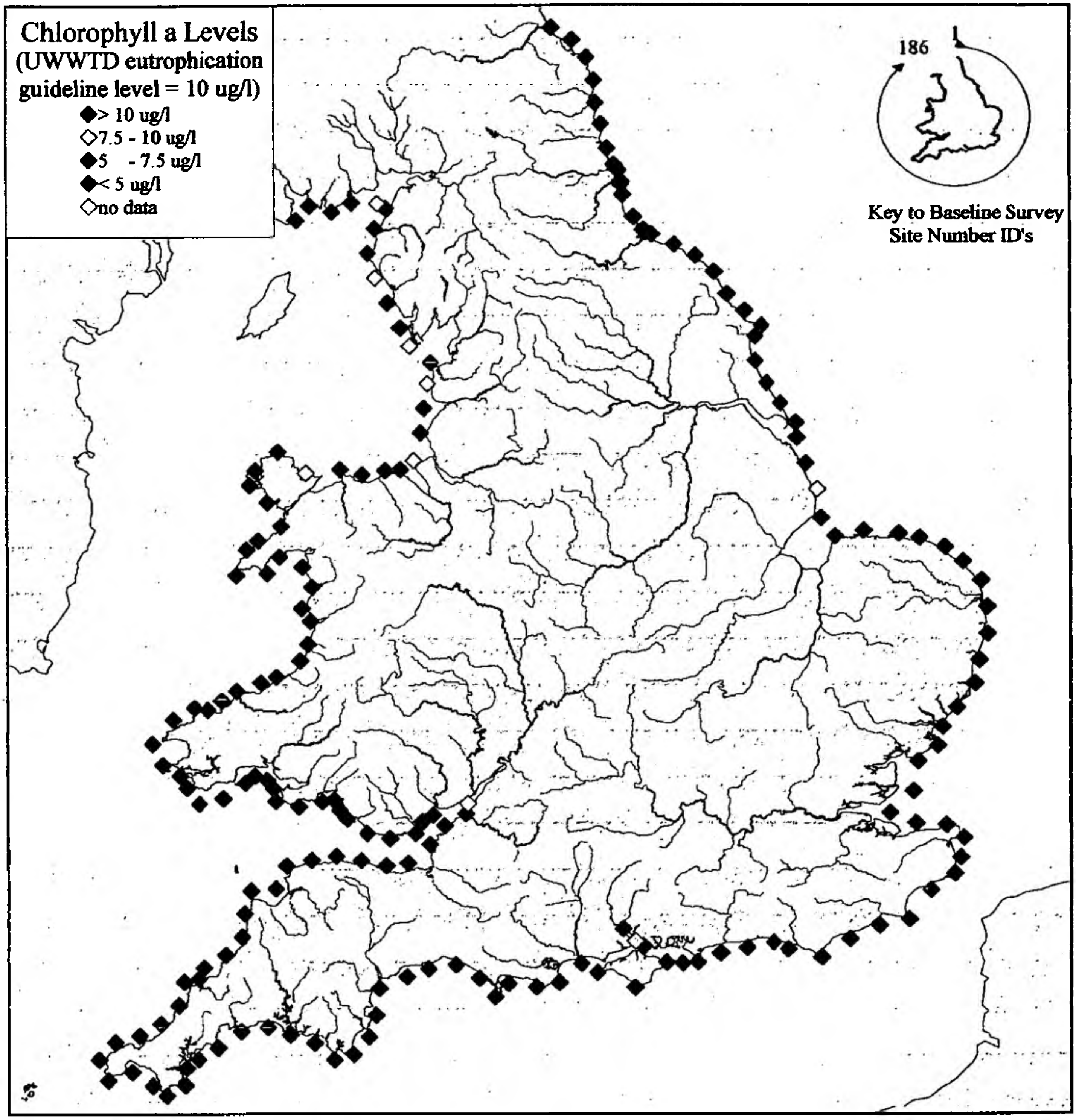
The previous section described how CASI imagery was used to determine information on chlorophyll-*a* concentration on a national basis, allowing statistics to be determined on average concentrations, and the difference between particular geographical locations to be readily assessed. However, the scale of the maps limits the display of the imagery to a narrow line, from which little detailed information may be derived.

This section illustrates the depth of information which may be gained from the imagery. When combined with relevant information on the tidal conditions, the images reveal information on oceanographic processes, which may have implications on the water quality

Figure 3.27

Chlorophyll a Levels, National Baseline Survey, Autumn 1994.

NRA
National Centre for Instrumentation and Marine Surveillance



Chlorophyll a Levels, Autumn 1994.

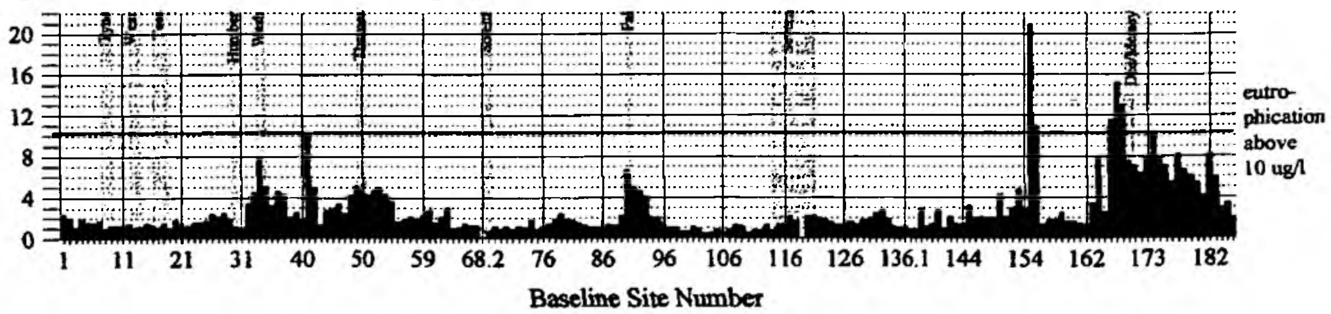


Figure 3.28

Calibrated Continuous Track Fluorimeter, National Baseline Survey, Autumn 1994.

NRA
National Centre for Instrumentation and Marine Surveillance

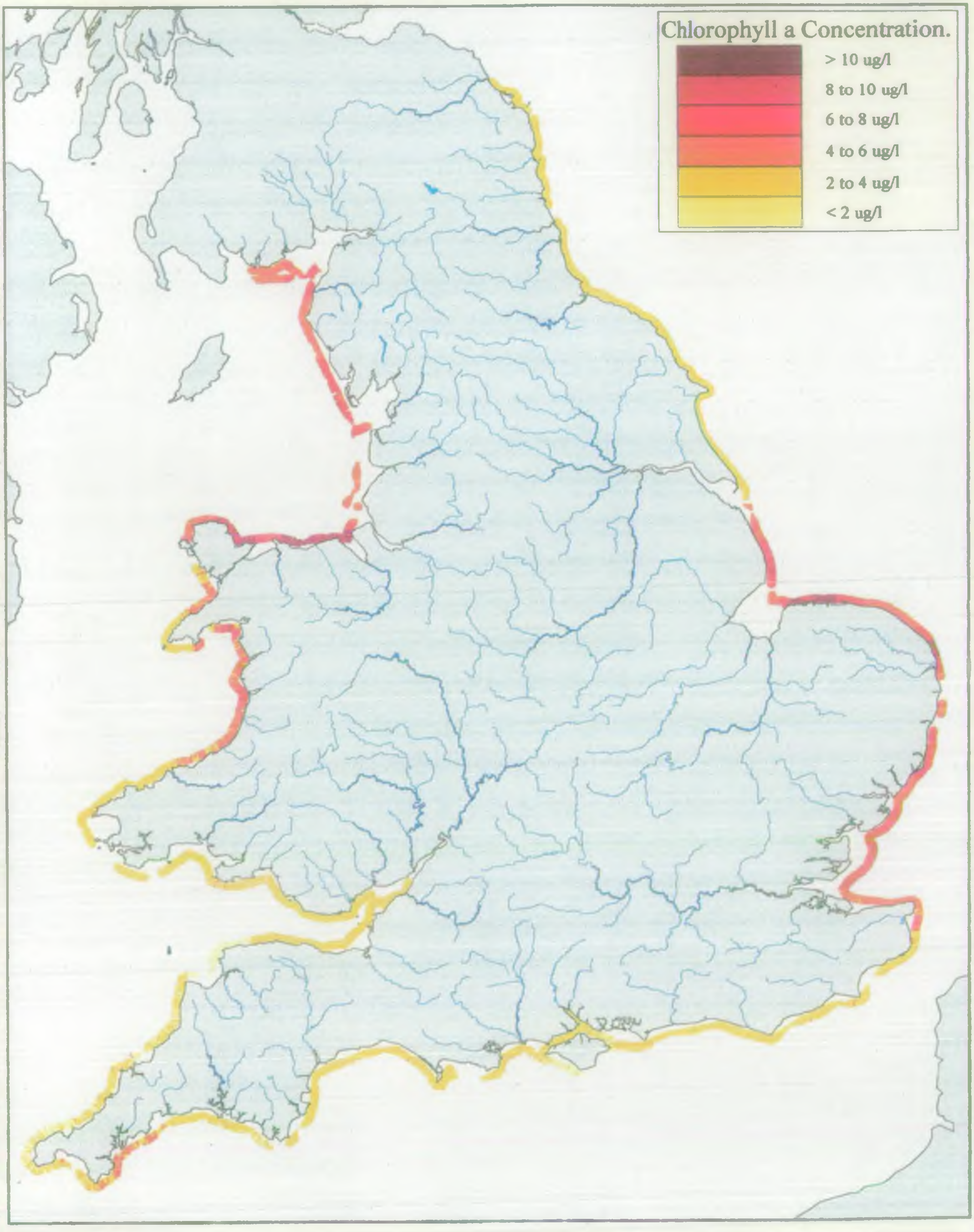


Figure 3.29

Calibrated CASI Fluoresence Line Height Image, National Baseline Survey, Autumn 1994.

NRA
National Centre for Instrumentation and Marine Surveillance

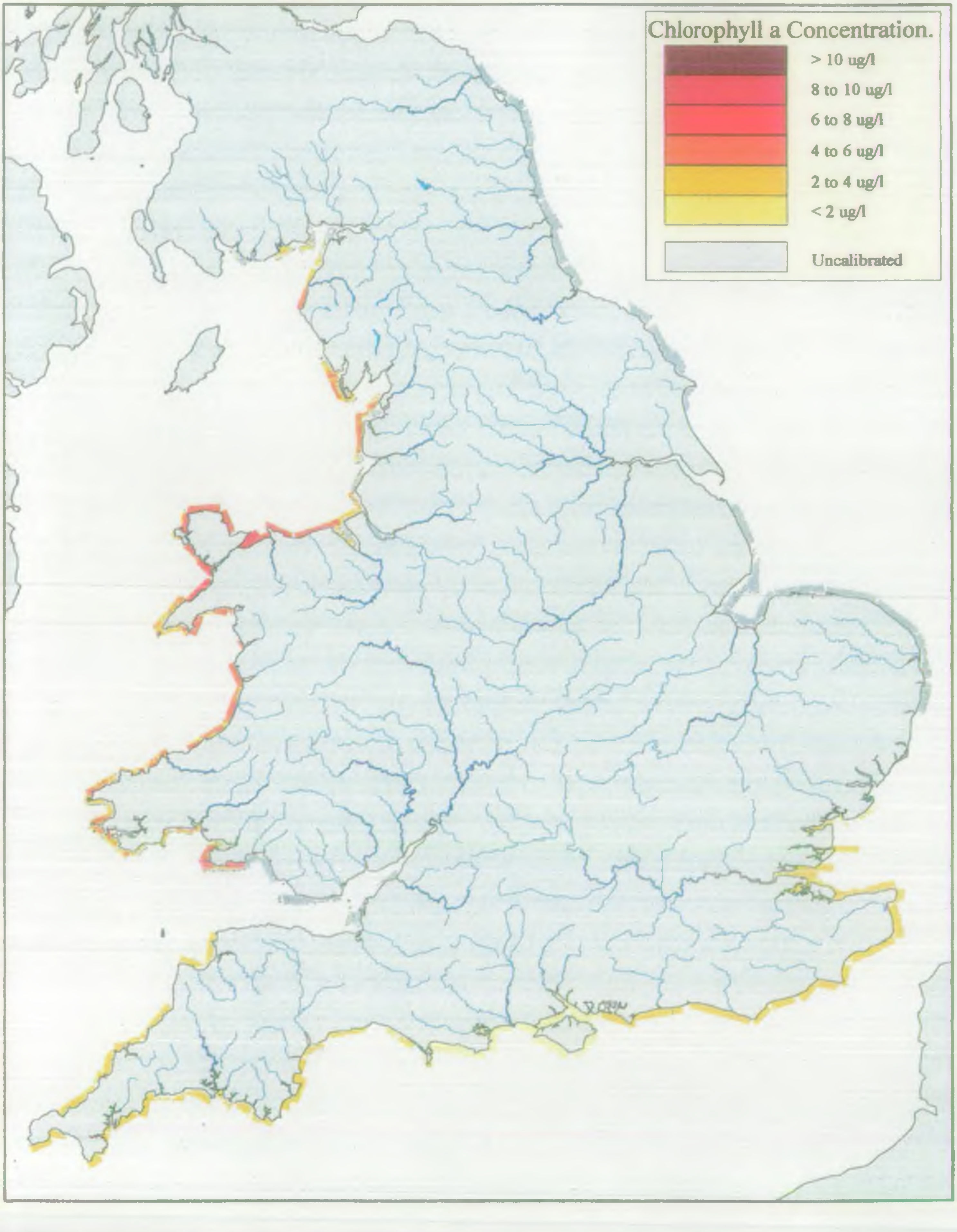
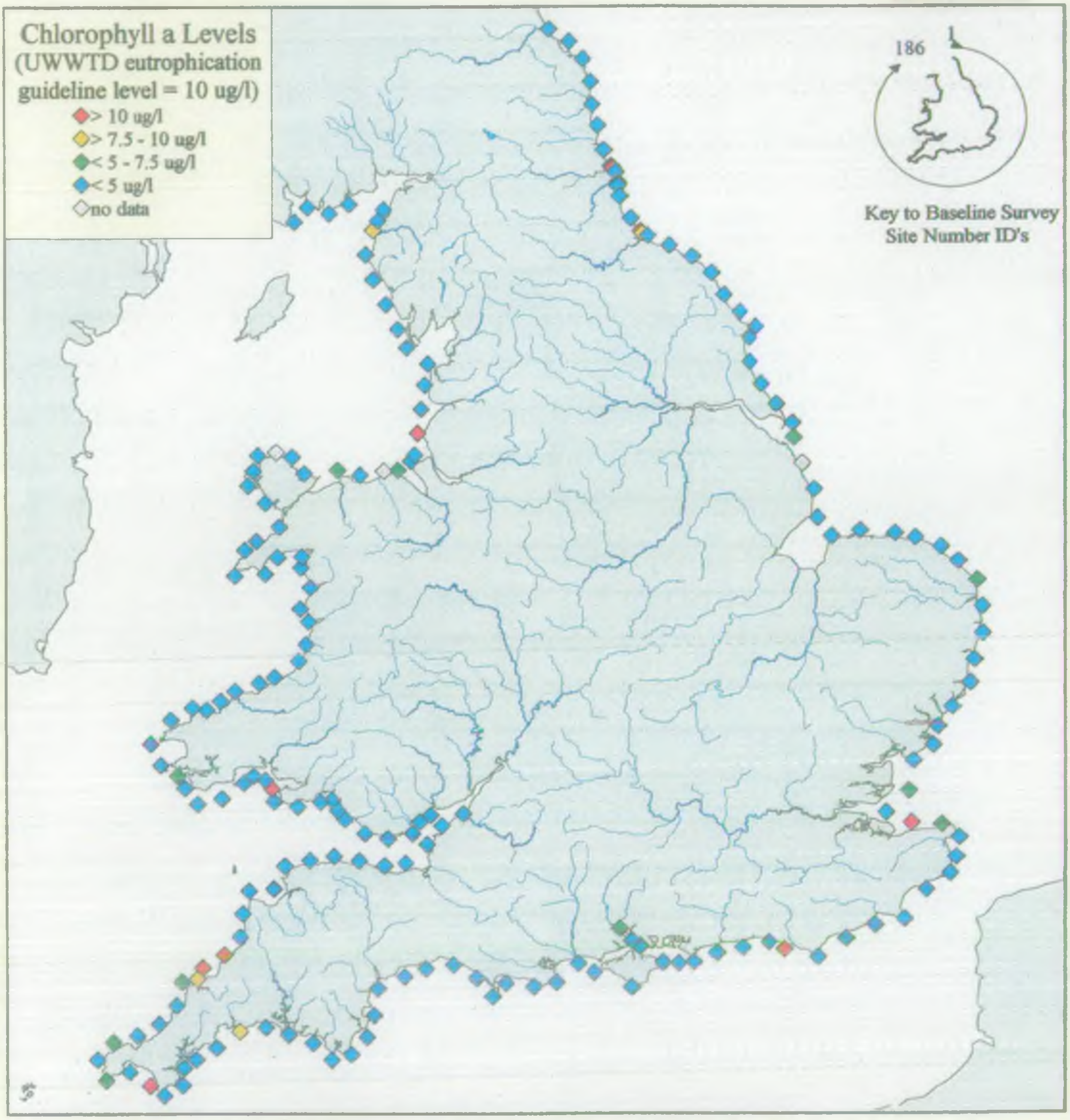


Figure 3.30

Chlorophyll a Levels, National Baseline Survey, Summer 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



Chlorophyll a Levels, Summer 1995 Survey.

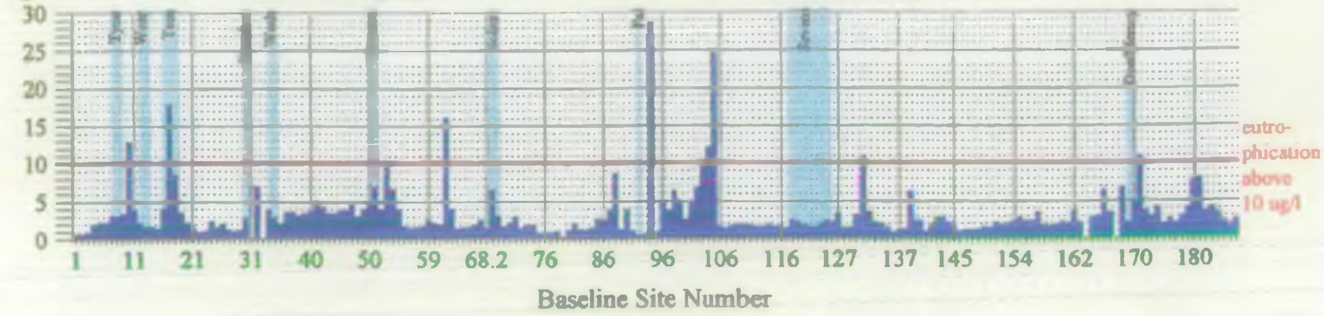


Figure 3.31

Calibrated Continuous Track Fluorimeter, National Baseline Survey, Summer 1995.

NRA
National Centre for Instrumentation and Marine Surveillance

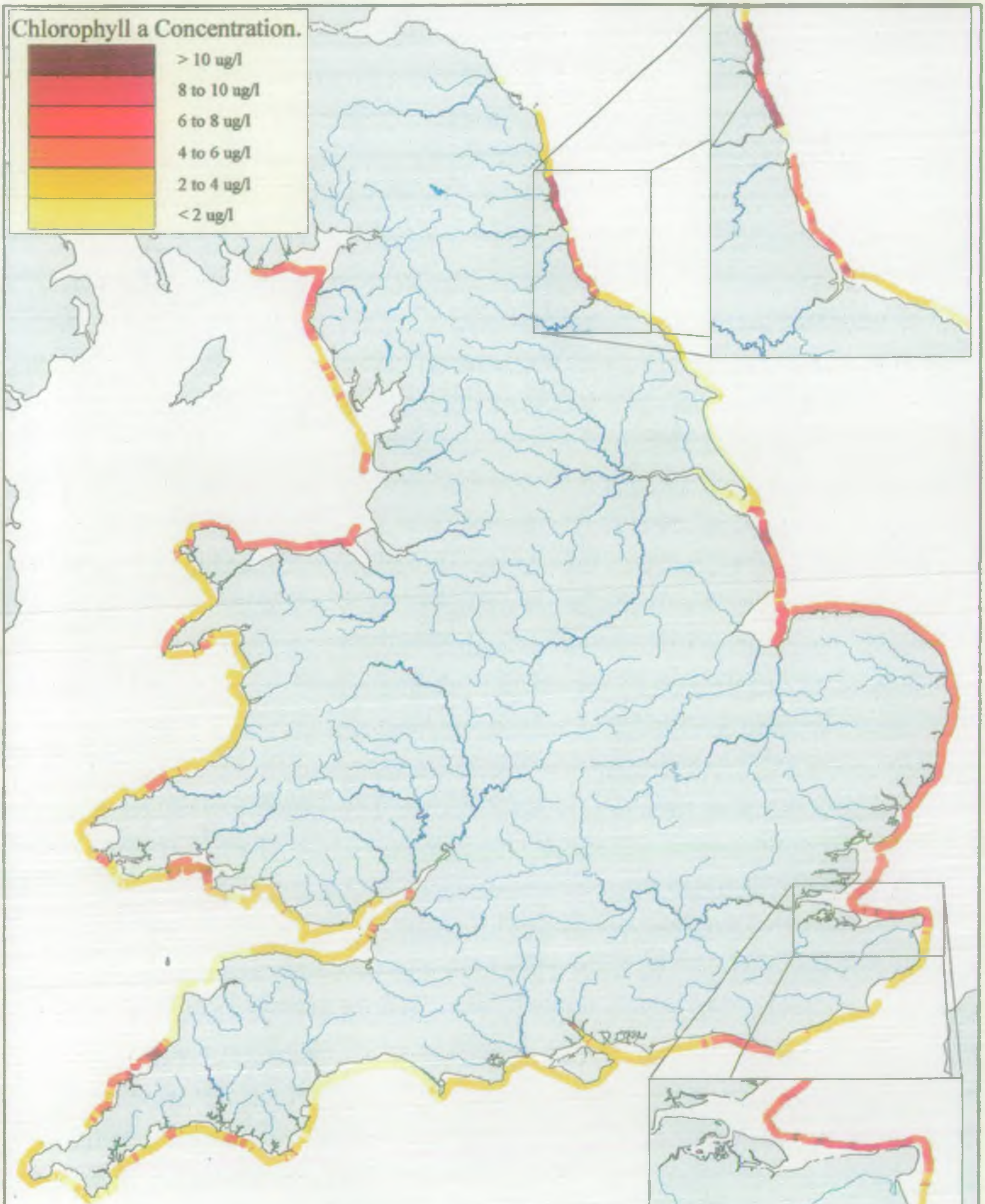
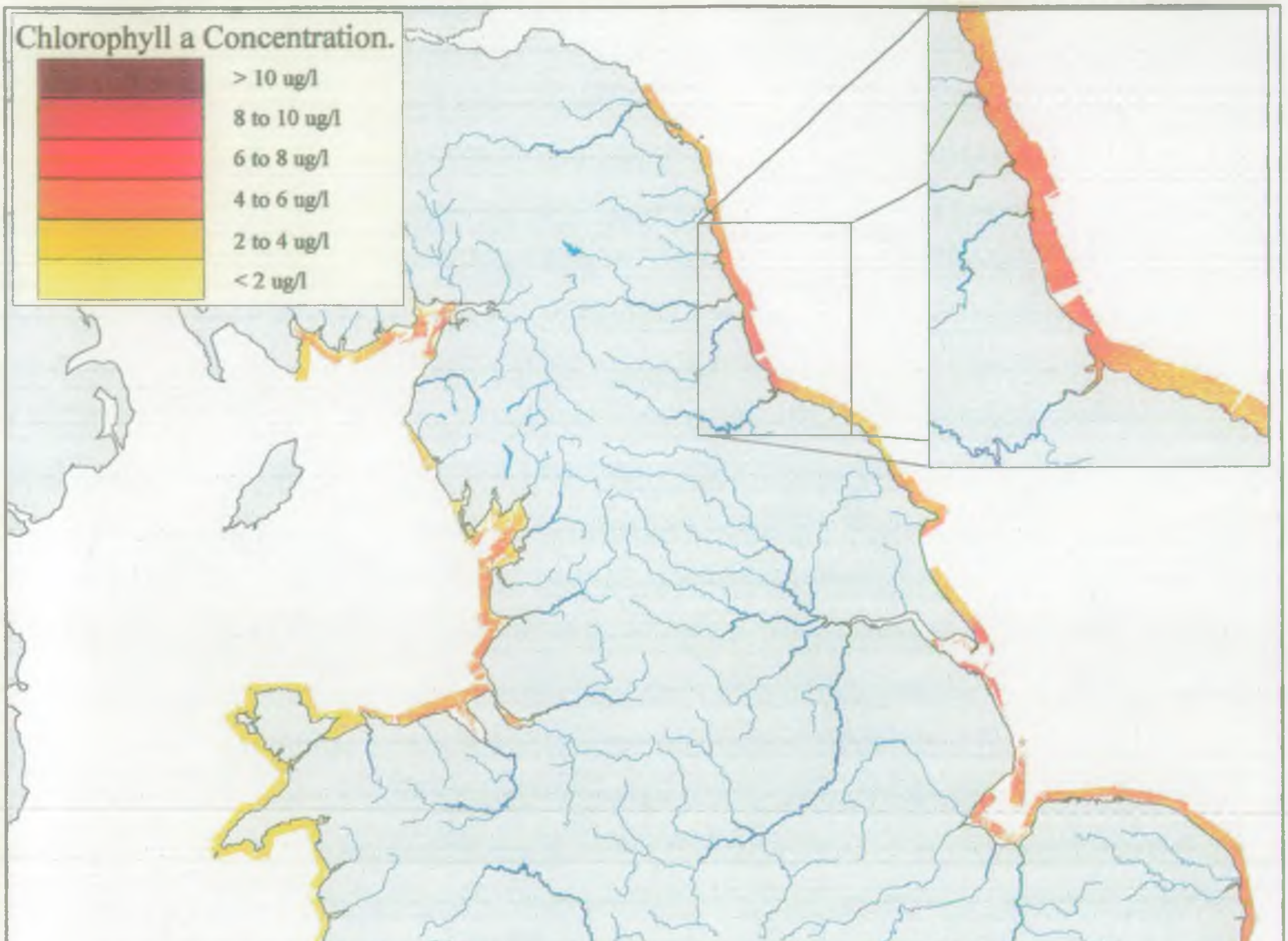


Figure 3.32

Calibrated CASI Fluoresence Line Height Image, National Baseline Survey, Summer 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



of the coastal zone. The area chosen to illustrate this is Flamborough Head on the Yorkshire coast.

Plate 3.1 shows a true colour composite CASI image of Flamborough Head flown as part of the Autumn 1995 baseline survey, on 26th July 1995 at 14:39 GMT. This image is made up of 3 of the available 15 spectral channels representing the red, green and blue parts of the spectrum. This image has been geocorrected according to the procedure described in Section 2.3.3.4 to firstly allow for motion of the aircraft, and secondly to relate the image to the Ordnance Survey grid. This grid has then been overlain on the imagery. This allows the accurate location of features within the coastal zone, for example the plume of higher reflectance material exiting the harbour at Bridlington.

The most marked feature within this image is the eddy located off the southern tip of Flamborough Head. This feature is visible in the imagery because of the difference in reflectance signal caused by the entrapment of suspended solids within the circulating water. The sediment may therefore be used a marker to indicate the oceanographic processes which are occurring in this region. It is important to understand these processes as they ultimately govern the distribution and dispersion of substances from riverine and anthropogenic sources.

Close to the shore it is apparent that there are two distinct sources of suspended sediment of differing spectral characteristics, with that to the south being red in colour, and that to the north having a high reflectance in all wavebands. These two sediments are mixing at the tip of the headland and being swept southwards by the strong tidal streams which are directed towards the south east at this time. The strength and direction of the tidal streams result in the formation of an eddy structure in the lee of the headland where currents are slack.

The thermal video imagery of this region showed signs of the eddy structure, but location was made difficult by the absence of land on the imagery. This is due to the narrower swath of the video in comparison to the CASI.

Plate 3.2 shows thermal video imagery collected during the Spring 1994 baseline survey on 29th May 1994. This imagery shows colder surfaces as lighter, with warmer surfaces shown darker. On this occasion the area was overflown twice, at 10:49 GMT and 13:24 GMT. In thermal images the varying temperature of the water bodies acts as a tracer to the underlying processes in the same way as variation in reflectance may be in the CASI imagery. The tidal streams during this period are opposite to those described above, flowing towards the North West. In the first image, 3 hours after high water, a distinct thermal eddy structure is located on the northern tip of the headland. This feature is still evident in the image collected two and a half hours later but the eddy structure has dispersed to produce a more linear frontal feature. The tidal streams are less intense at this time, resulting in a less pronounced sheltering effect by the headland. The tidal streams will in fact reverse only two hours later, which may produce a structure similar to that seen in the CASI imagery.

CASI imagery and thermal videos collected as part of the baseline survey have therefore been shown to provide insight into underlying oceanographic processes when combined with appropriate tidal information. A further advantage of the spectrally rich CASI information is the ability to calibrate the imagery for geophysical parameters. Plate 3.3 shows a grey scale image of the Fluorescence Line Height determined by the procedure described in 3.3.1. This has been geocorrected and overlain on the Ordnance Survey grid as before. The image shows areas of higher FLH value as white and lower FLH as black. Very high values very close to the coast may be due to shallow water, but a general grading of increased intensity towards the coast is seen. The eddy structure is faintly visible within the image, but is less pronounced than in the colour composite. The major constituent of the reflectance signal within the eddy is suspended solids, the concentration of which is much greater within the eddy. There is however little variation in FLH within this image due to a low variability of chlorophyll-*a* concentration illustrated in Plate 3.4 which has been calibrated for chlorophyll-*a* concentration. This image has been coded for chlorophyll-*a* concentration using the same scale as in Section 3.3.1. Concentrations vary between 4 μg/l and 10 μg/l, with the most obvious grading being an increase closer to the shore.

3.4 Continuous Underway data

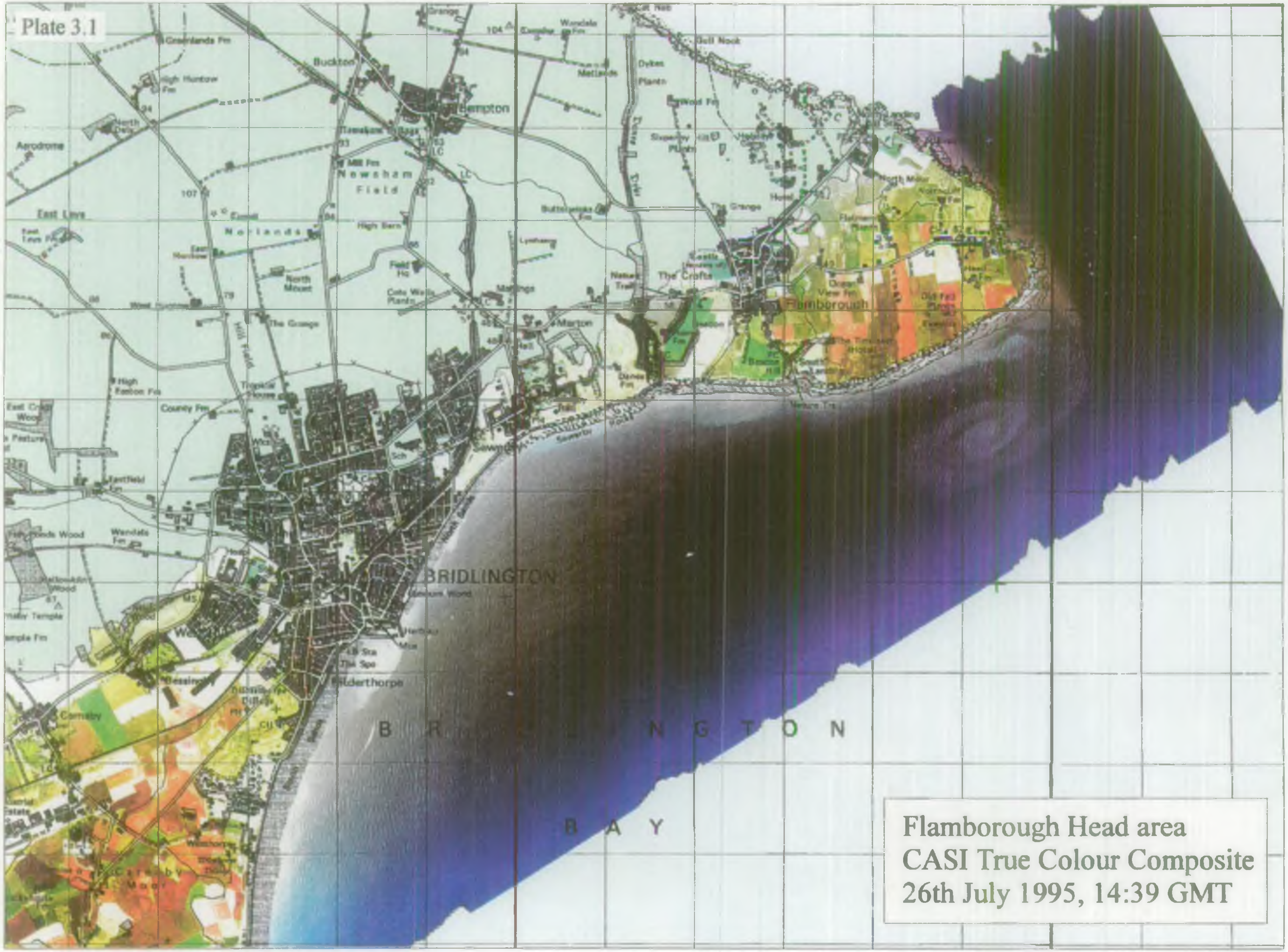
3.4.1 Qubit underway data

Due to the amount of data it is not practical to report all results from the Qubit underway data logger, in either tabular or graphical form. Figure 3.33 illustrates an example of graphical output for the Flamborough Head region during the Summer 1995 survey. The track of the vessel is shown in the top figure, with results for temperature, salinity, dissolved oxygen, transmission and fluorescence (chlorophyll) shown below. Perturbations in the signal are seen at baseline sampling points where the profiling system is removed from the flow cell to undertake vertical profiles. This is particularly evident in the salinity and transmission profiles at baseline site 25.

Between baseline sampling points number 25 and 26, around Flamborough Head there is a clear peak in the temperature profile of 1 °C. This represents a feature such as the thermal eddy seen in the imagery of Summer 1994. However, as the data do not present a two dimensional view, it would be necessary to use the aircraft to gain a further understanding of this anomaly.

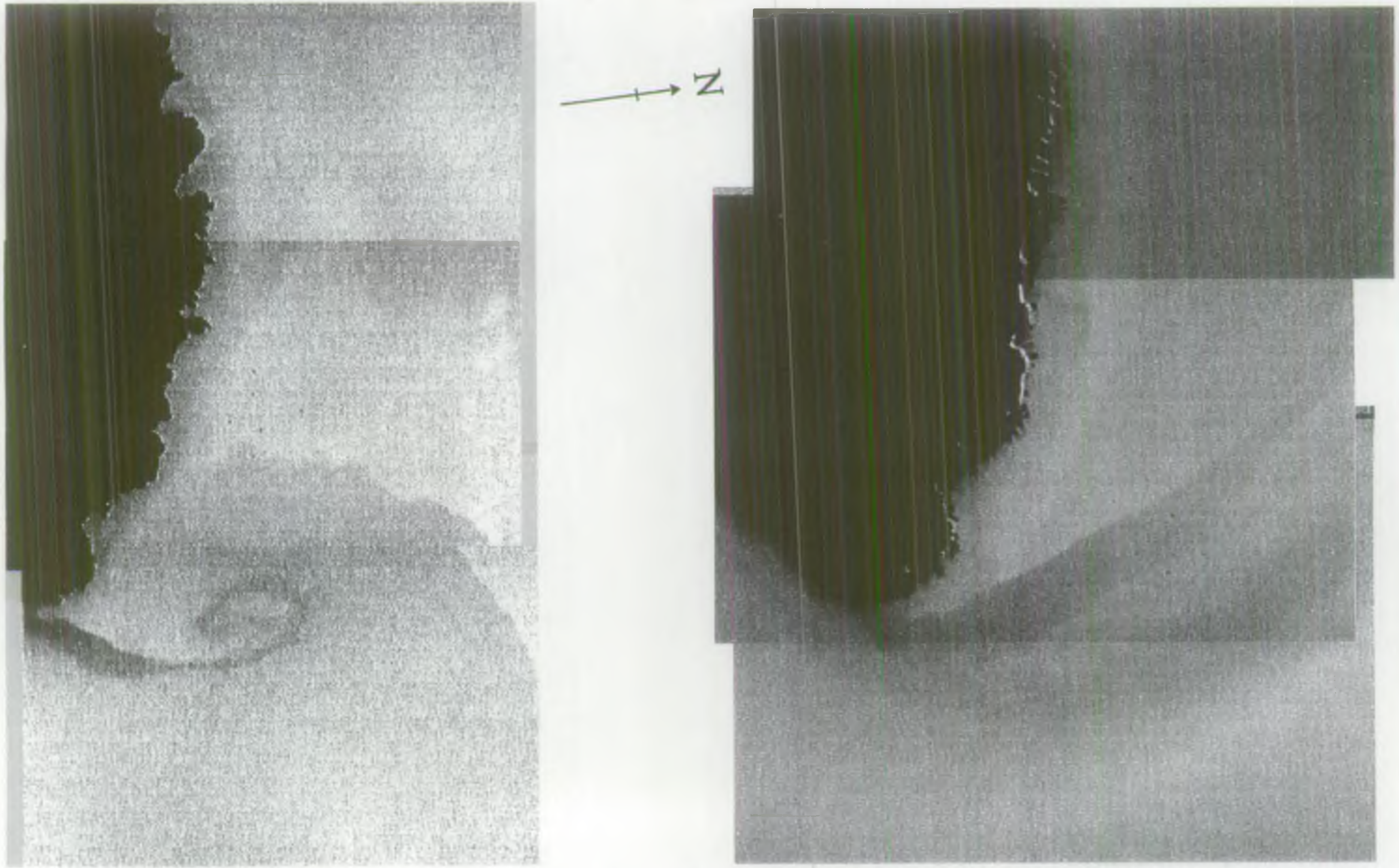
This data provides an example of the way in which data from the continuous underway logging systems may be displayed and interpreted with ease. This data allows results from water samples at baseline sampling sites to be put into the spatial context of the surrounding waters.

Plate 3.1



Flamborough Head area
CASI True Colour Composite
26th July 1995, 14:39 GMT

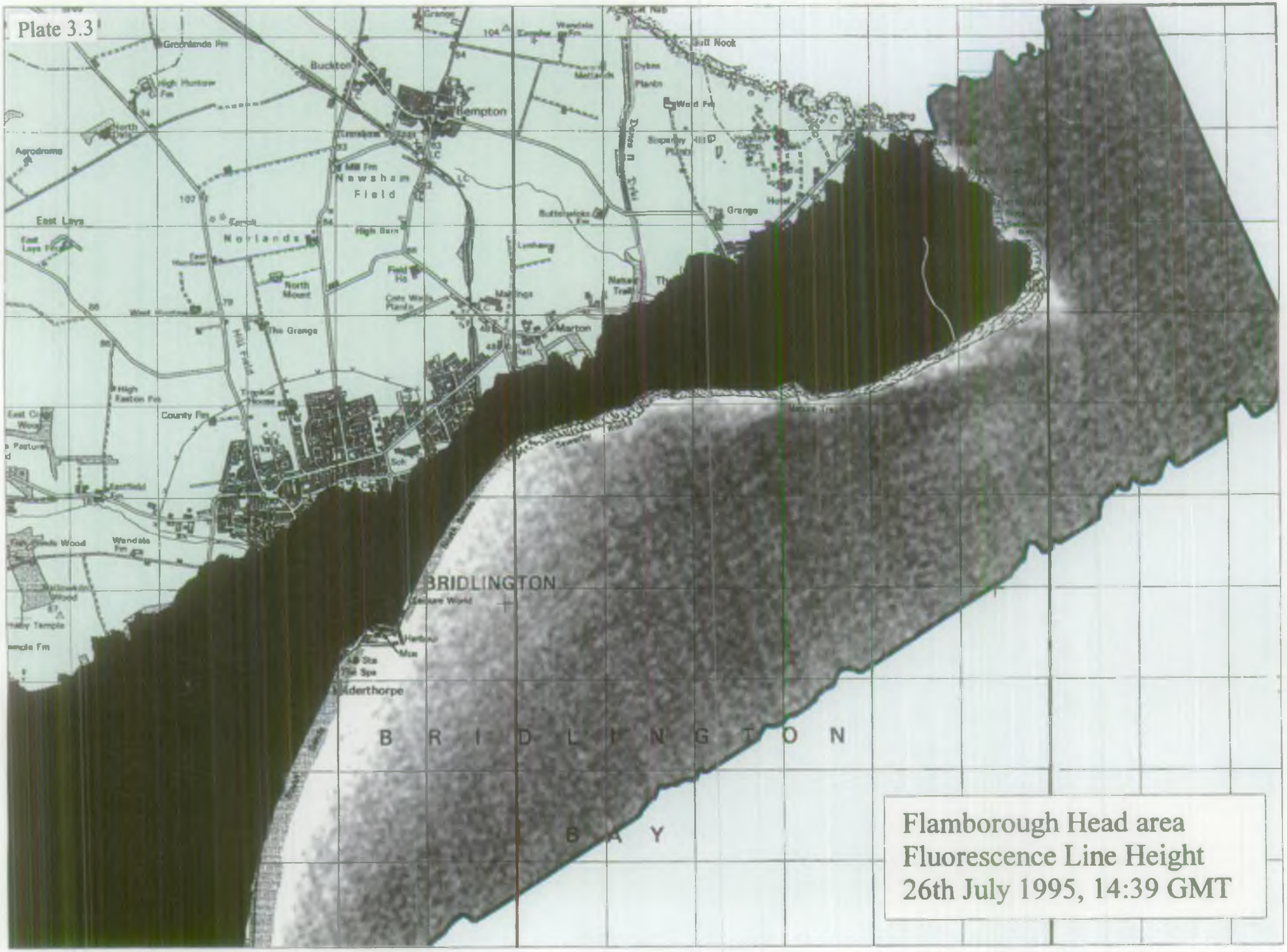
Plate 3.2 Thermal video imagery of Flamborough Head



29th May 1994, 10:49 GMT

29th May 1994, 13:24 GMT

Plate 3.3



Flamborough Head area
Fluorescence Line Height
26th July 1995, 14:39 GMT

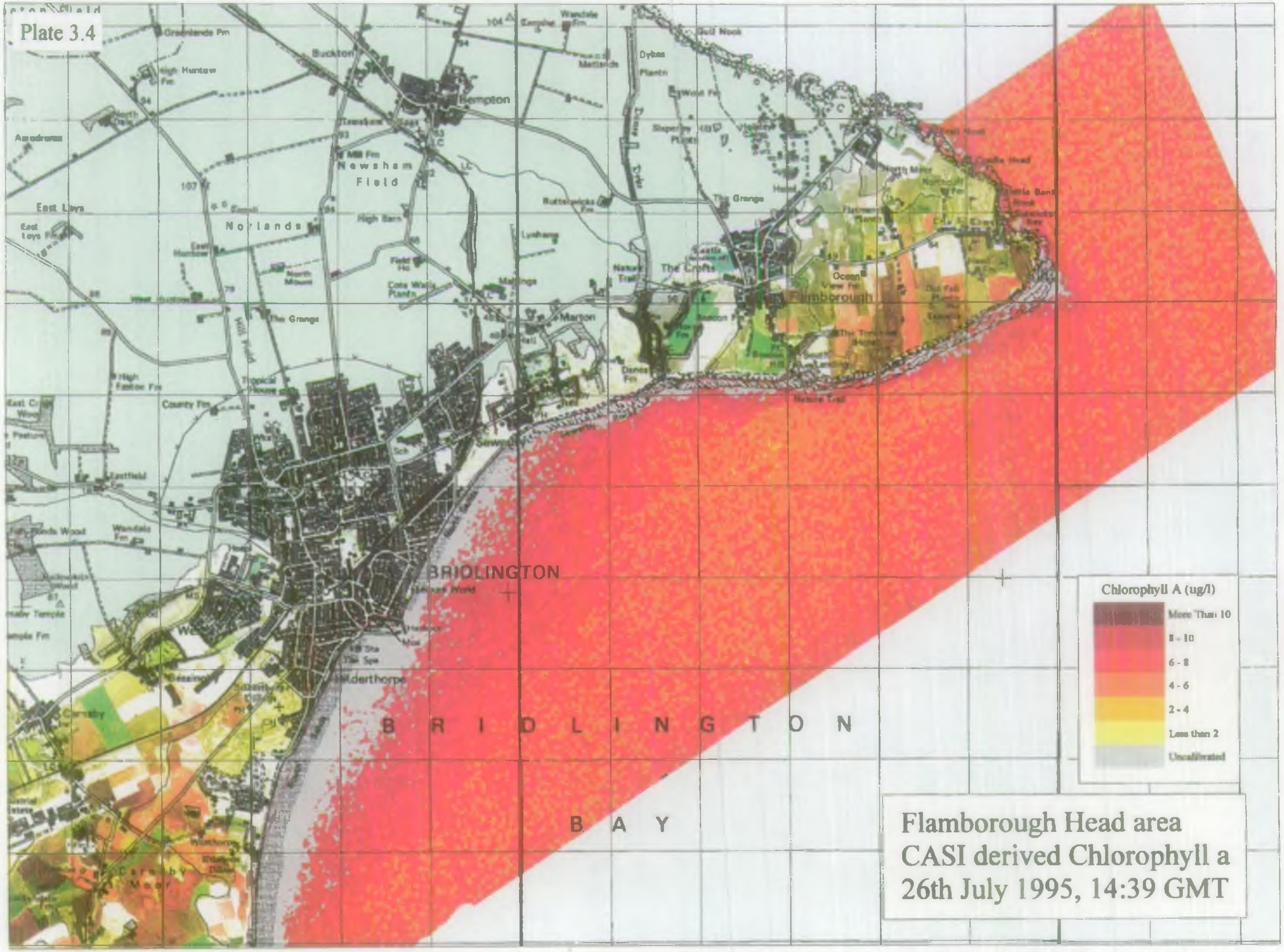
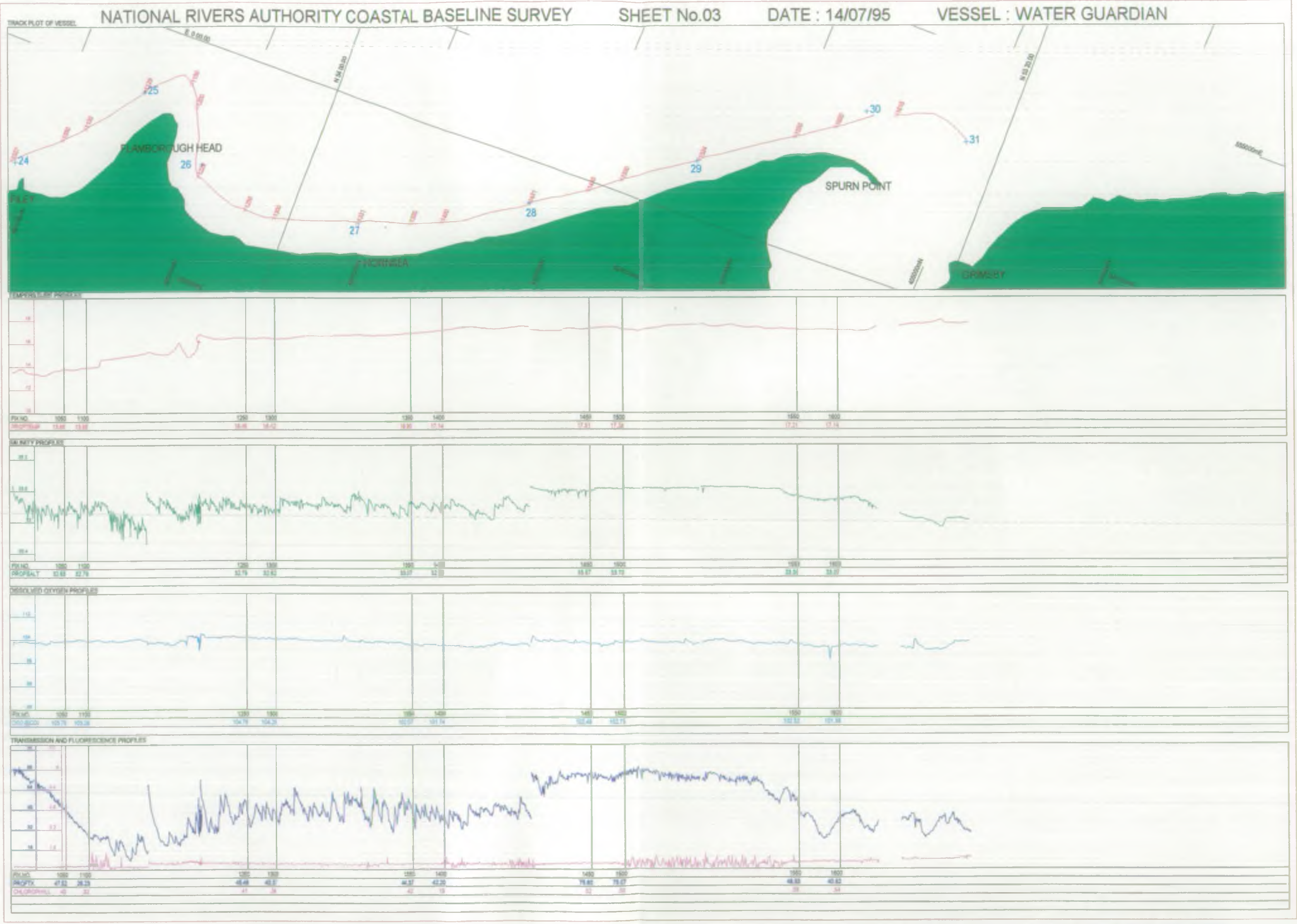


Plate 3.4

Flamborough Head area
CASI derived Chlorophyll a
26th July 1995, 14:39 GMT

Figure 3.33



NATIONAL CENTRE FOR INSTRUMENTATION AND MARINE SURVEILLANCE, RIVERS HOUSE, LOWER BRISTOL ROAD, BATH, BA2 9ES.

3.4.2 Skalar nutrient auto-analyser data

Data from the Skalar nutrient auto-analyser system for Flamborough Head in Summer 1995 recorded very low values as would be anticipated for this season. The example used here to illustrate the data was taken from the same region during the Winter 1995 survey, on the 5th February 1995. The data have been integrated with geographical positions from the Qubit data and plotted geographically, with red values representing high concentrations and blue values representing low concentrations. Four determinands are presented as Figure 3.34.

The data points represent sampling at two minute intervals, with the positions of the baseline sampling stations being shown as gaps in the data, as no Qubit positions are available here. The concentrations in this region are not high in relation to other areas of the coastline, with TON levels, for example in excess of 1000 μg/l at many sites. Ammonia concentrations in particular are very low.

Silicate and TON concentrations follow similar patterns with higher concentrations to the south of the headland. In the ortho-phosphate results the concentrations are higher to the north of the headland, and the ammonia results are variable, with one point showing a high concentration which may be due to outfall activity close to Bridlington.

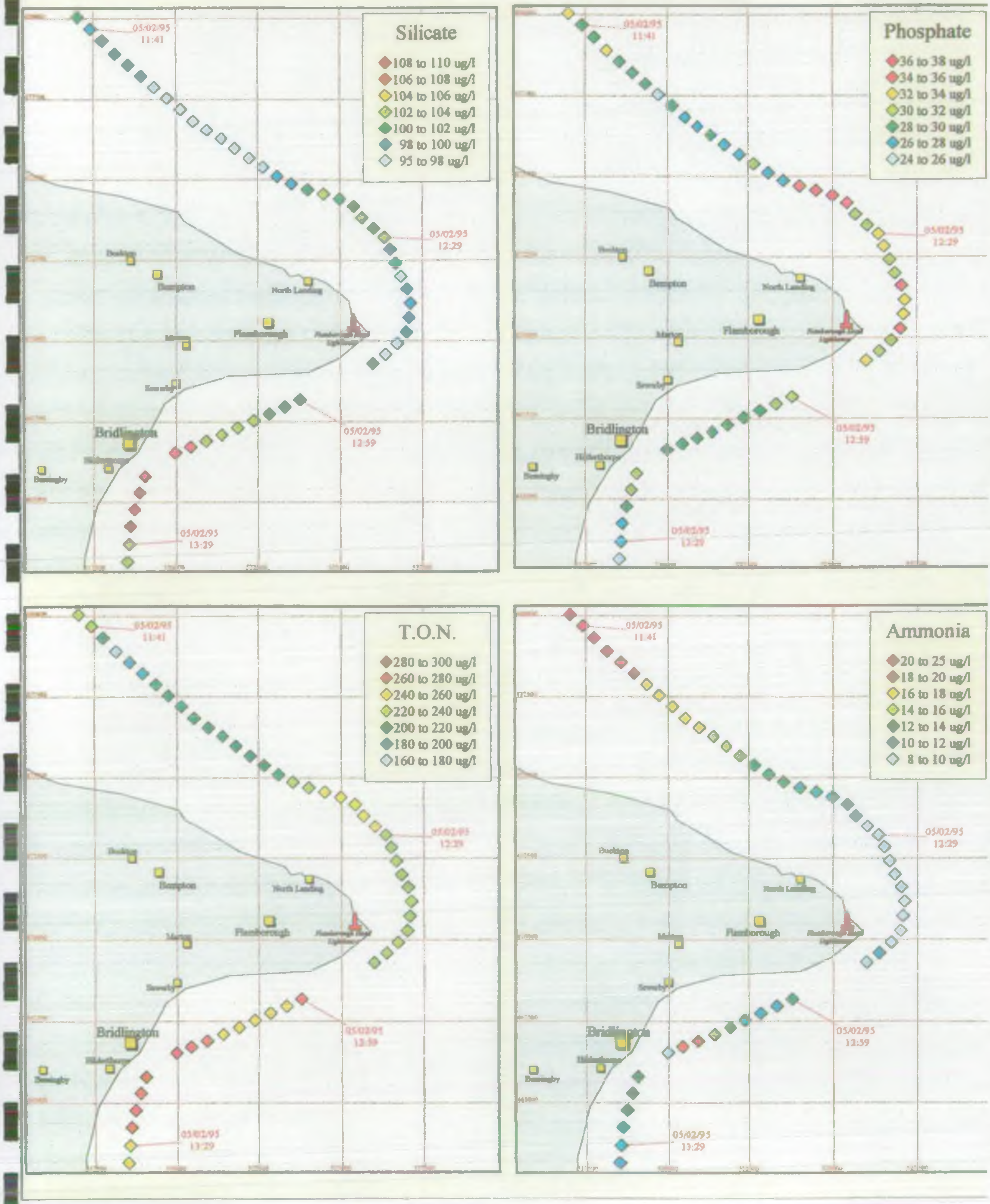
It is not possible to detect the presence of the eddy structure seen in the imagery in this data, as there is no one region which is showing marked variation in nutrient levels. However, application of the FLH procedure showed that chlorophyll-*a* variation across the feature was low and it may therefore be that the feature does not have a nutrient signal. Alternatively, the feature may occur in the region around baseline sampling point 26 where there is a gap in the data.

This data illustrates the way in which nutrient data may be graphically represented, allowing variations along track to be considered and placing the baseline sampling data into the context of nutrient variations in surrounding water.

Figure 3.34

Skalar Nutrient Data from the Flamborough Head Area, Winter 1995.

NRA
National Centre for Instrumentation and Marine Surveillance



4. CONCLUSIONS

The National Marine Baseline Survey was successfully carried out throughout 1993, 1994 and 1995. The data collection and laboratory analysis procedures were continuously refined throughout this period with a consequent increase in data integrity.

The resulting large database represents a unique, nationally consistent record of the coastal waters of England and Wales, which are confirmed to be of generally high quality in respect of nutrients, metals, chlorophyll-*a* and organic contaminants.

The hierarchical approach to data collection using the complementary laboratory, boat and aerial techniques has allowed calibration and verification between the data sets.

Aerial remote sensing can be used to provide information not otherwise practically obtainable on the spatial distribution of chlorophyll-*a*, mixing zones of discharges and areas of riverine influence.

Nutrient and chlorophyll-*a* concentrations generally follow the recognised seasonal cycle, with the following exceptions: high nutrient concentrations are found in the Summer in the Tees, Southampton Water, the Mersey and the Bristol Channel. The first three of these areas are associated with unexpectedly high chlorophyll-*a* concentrations in Summer. The Bristol Channel does not show elevated chlorophyll-*a* concentrations. This is due to the presence of large amounts of suspended matter which prevents the transmission of light.

Aerial CASI data has been calibrated for chlorophyll-*a* concentration using a combination of the Fluorescence Line Height technique, underway continuous fluorimeter monitoring and laboratory analysis of water samples. This gives information on chlorophyll-*a* concentration across the three nautical mile zone.

Concentration Band (µg/l)	**Area of Coastal Waters by Chlorophyll-*a* Concentration Band (%)**	
	Autumn 1994	Summer 1995
>10	0.0	0.0
8-10	0.0	0.3
6-8	3.6	3.7
4-6	19.9	27.3
2-4	57.6	58.5
>2	18.9	10.2

Table 4.1. Classification of coastal waters by chlorophyll-*a* concentration (from CASI FLH)

Table 4.1 presents an overview of the proportion of coastal waters which lie in broad chlorophyll-*a* concentration bands. These results illustrate the use of the combined data sets to provide information on water quality on a National basis.

Dissolved metal concentrations, including the List I metals, cadmium and mercury, are generally significantly below the established EQS levels. Exceptions include dissolved copper and zinc on the Northumbria coast and the Bristol Channel in 1993. Copper concentrations remain high in the Upper Bristol Channel.

Organic contaminants were found to be in very low concentrations at all sites, mostly below the limit of detection of the laboratory technique. The decreased limit of detection for the 1995 data has revealed lindane to be widespread but in very low concentrations.

Because the databases that contain the results from the baseline surveys are so large; this report contains only summaries. The entire datasets are archived at the National Centre for Instrumentation and Marine Surveillance and are readily available.

APPENDIX A

Base	Site name	Easting	Northing
1	Berwick	401443	652107
2	Castlehead Rocks	413450	644616
3	Shoreston Outcars	421779	633985
4	Craster	426513	620379
5	Warkworth	427260	606770
6	Brig Head	430730	594089
7	Blyth	434352	579260
8	Tyne (North)	438454	569686
9	Tyne (Middle)	438895	569078
10	Tyne (South)	439317	568451
11	Marsden	440937	566073
12	Wear (North)	442341	559707
13	Wear (Middle)	442402	558854
14	Wear (South)	442433	557927
15	Pincushon Rock	443338	551556
16	Blackhall	449679	538324
17	Tees (North)	455462	530528
18	Tees (Middle)	456231	529147
19	Tees (South)	459667	527892
20	Skinningrove	472910	521798
21	Sandsend	486288	515059
22	Robin Hoods Bay	497341	505265
23	Scarborough Outfall	504454	492103
24	Filey Brigg	514516	481769
25	Flamborough (North)	524552	472901
26	Bridlington	520418	466428
27	Hornsea	520801	451653
28	Beacon Hill	528006	438358
29	Withernsea	536920	426310
30	Spurn Head	546422	414537
31	Haile Sand Flat	547030	405650
32	Theddlethorpe	552061	390130
33	Chapel St. Leonards	558791	374579
34	Outer Dogs Head	560595	357290
35	Wash	568866	346069
36	Overy, Staithe	585400	349600
37	Cley, Lookout	605700	347800
38	Sheringham	617400	345300
39	Mundesley	632100	339700
40	Lessingham	642300	331000
41	Winterton	652700	319400
42	Gorleston	656000	303600
43	Kessingland	656200	287300

44	Dunwich Cliffs	651400	271400
45	Thorpeness	649000	257600
46	Shingle Street	638759	242982
47	Felixstowe	630400	231200
48	Walton	627500	220000
49	Jaywick	616000	210600
50	Maplin Bank	613300	192600
51	Medway Buoy	600023	179518
52	Shiveringsand Buoy	614810	173220
53	East Margate	632640	172140
54	East Brake Buoy	642560	164290
55	Goodwin Fork Buoy	640780	152520
56	South Foreland	637420	142840
57	Sandgate Bay	623350	133160
58	Dungeness	610960	115460
59	Rye Bay	593690	111730
60	Bexhill	576710	103760
61	Beachy Head	560440	92640
62	Newhaven	541170	97470
63	Brighton	531560	101530
64	Worthing	514840	98340
65	Middleton-on-Sea	499850	95140
66	Selsey Bill	486600	89740
67	Nab Tower	477220	89080
68.1	East Brambles	454500	99090
68.2	Calshot	449950	102320
68.3	Dockhead	442954	109622
68.4	West Princessa	467490	89410
69	St. Catherines	449780	74450
70	The Needles	427320	83450
71	Hengistbury Head	417670	88880
72	Anvil Point	404752	77529
73	St. Aldhelms	391444	74806
74	Weymouth Bay	374897	77068
75	Portland Bill	366887	68905
76	Chesil	357708	80056
77	Bridport	344060	88033
78	Seaton	327371	85782
79	Sidmouth	314357	81023
80	Exmouth	298768	73910
81	Torbay	296654	57937
82	Dartmouth	292251	45010
83	Start Point	282855	34413
84	Salcombe	271484	31174
85	Bigbury Bay	260244	41176
86	Plymouth	246016	46192
87	East Looe	232461	50530
88	Fowey	216744	48055

89	Dodman Point	203301	38283
90	St. Antony Head	191045	31497
91	Falmouth	183960	26360
92	Black Head	183110	15940
93	Lizard	171990	9880
94	Mullion	163430	15910
95	Penzence	151330	23980
96	Runnel Stone	137160	18980
97	Cape Cornwall	132110	31440
98	The Carracks	141640	42920
99	Godrevy Island	156000	45800
100	St. Agnes	168780	52800
101	Newquay	179500	63850
102	Trevose	182760	77920
103	Padstow	191671	79737
104	Port Isaac	194930	86330
105	Boscastle	207848	93942
106	Bude	217387	104811
107	Morewenstowe	218976	118706
108	Hartland Point	222623	132318
109	Bideford	237456	133833
110	Bull Point	244082	147356
111	Combe Martin	258542	150774
112	Foreland	272883	153182
113	Porlock	287856	150676
114	Minehead	302829	147589
115	Bridgwater Bar	315221	149213
116	Weston-super-Mare	328422	160435
117	Clevedon	337342	171688
118	Avonmouth	350046	178825
119	No. 1 Beacon	351230	184940
120	Newport Deep	330560	178100
121	Cardiff Road	323990	174200
122	Lavernock	319740	166990
123	Aberthaw	304980	163990
124	Nash Point	291470	167040
125	Porthcawl	279540	175580
126	Kenfig	275210	180890
127	Port Talbot	271670	187250
128	Mumbles	264920	185970
129	Oxwich	251470	183060
130	Worms Head	237680	186370
131	Llanelli	236580	193880
132	Burry Port	232570	199170
133	Carmarthen	225390	201800
134	Caldey Island	219540	197440
135.1	Old Castle Head (Inner)	206575	187970
135.2	Old Castle Head (Off)	207020	193620

136.1	St. Govans (Inner)	192260	184790
136.2	St. Govans (Off)	192490	190400
137	Turbot Bank	184870	194230
138	St. Anns	180565	201679
139	Skomer	170162	208214
140	South Bishop	164072	220936
141	Abereiddy	176570	235494
142	Strumble Head	189368	242641
143	Fishguard	197672	241368
144	Pwll-Coch	205900	246887
145	Cardigan Island	214591	252771
146	Penly-Badell	229134	257723
147	New Quay Head	238369	261216
148	Pen Pigyn	252332	270982
149	Aberystwyth	256604	281058
150	Aberdovey	258140	294925
151	Pen-Bwch Point	253277	302489
152	Barmouth	259294	315297
153	Shell Island	253581	327524
154	Pwllheli	240180	333514
155	Porth Ceiriad	232708	323561
156	Bardsey	214489	322368
157	Penrhyn Colmon	220695	337909
158	Dinuaen	227616	343224
159	Dylan	241352	352029
160	Aberffraw	232901	366233
161	Penrhos	222588	376813
162	Holyhead	225804	385602
163	Middle Mouse	239518	396995
164	Red Wharf	255740	384043
165	Great Orme	275785	386259
166	Llanddulas	289027	383149
167	Chester Flat	302955	385626
168	Welsh Channel	311290	386391
169	He 1 Buoy	319146	391814
170	North Wirral	321644	395462
171	Formby Point	323261	408435
172	Gut	325516	423234
173	Blackpool	327725	438035
174	Shell Wharf	329673	450801
175	Hilpsford	317047	460468
176	Duddon	311551	471698
177	Selker	304434	486678
178	Calder Hall	297170	501675
179	Whitehaven	292652	516620
180	Workington	297151	531356
181	Solway Buoy	303426	543740
182	Medway Buoy	298653	546533

183	Balcarry	283026	546912
184	Abbey Head	271290	541294
185	Meggerland	258289	545024
186	St. Ninians	250301	536374

APPENDIX B

Determinand	Properties	Units	Limit of Detection
Group 1 - measured at every baseline site			
(Mercury Dissolved)	Dissolved	ug/l	0.03
Mercury Total	Total	ug/l	0.03
Cadmium Dissolved	Dissolved	ug/l	0.25
Suspended Solids 105°C		mg/l	5
Suspended Solids 500°C		mg/l	5
Ortho-phosphate	Filtered	ug/l P	5.0
Chlorophyll a	Total	ug/l	0.2
Ammonia	Filtered	ug/l N	6.0
Nitrite	Filtered	ug/l N	2.0
Silicate	Saline Filtered	mg/l	0.025
Copper Dissolved	Dissolved Saline ppb	ug/l	0.5
Lead Dissolved	Dissolved Saline	ug/l	2.5
Zinc Dissolved	Dissolved Saline ppb	ug/l	4.0
Arsenic Dissolved	Dissolved ppb	ug/l	2.5
Chromium Dissolved	Dissolved Saline ppb	ug/l	1.5
Nickel Dissolved	Dissolved Saline ppb	ug/l	3.0
Total Oxidised Nitrogen	Saline Filtered	mg/l N	0.010
Group 2 - measured at approximately every third baseline site			
Cadmium Total	Total	ug/l	0.25
Copper Total	Total Saline ppb	ug/l	0.5
Lead Total	Total Saline	ug/l	2.5
Zinc Total	Total Saline ppb	ug/l	5.0
Arsenic Total	Total ppb	ug/l	2.5
Chromium Total	Total Saline ppb	ug/l	2
Nickel Total	Total Saline ppb	ug/l	3.0
Group 3 - measured at occasional sites of interest			
Isodrin	Total	ng/l	2.5
Aldrin		ng/l	2.5
Dieldrin		ng/l	2.5
Endrin		ng/l	2.5
Hexachloro-Benzene	Total	ng/l	1.0
Hexachloro-Butadiene	Total	ng/l	1.0

PCB 28	ng/l	1.0
PCB 52	ng/l	1.0
PCB 101	ng/l	1.0
PCB 118	ng/l	1.0
PCB 138	ng/l	1.0
PCB 153	ng/l	1.0
PCB 180	ng/l	1.0
DDE-PP'	ng/l	1.0
DDE-OP'	ng/l	2.0
DDT-OP'	ng/l	1.0
DDT-PP'	ng/l	1.0
HCH-Alpha	ng/l	1.0
HCH-Beta	ng/l	1.0
HCH-Delta	ng/l	1.0
HCH-Gamma	ng/l	1.0
TDE-OP'	ng/l	2.0
TDE-PP'	ng/l	1.0