EA-NCEDS Box 3

National Marine Baseline Survey 1995

Littoral Cell 2 Flamborough Head to the Wash

ENVIRONMENT AGENCY

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National Centre for Environmental Monitoring and Surveillance
Rivers House
Lower Bristol Road
Twerton
Bath
BA2 9ES

Dr. Alison Matthews, Oceanographer
Alastair Duncan, Data Officer

Foreword

In recent years we have carried out National Baseline Surveys of the coastal zone which have involved analysis of samples taken at specific locations in coastal waters around England and Wales for a wide range of determinants. These data have been supplemented by further continuous analysis from the Coastal Survey Vessels and by spatial data from airborne remote sensing operations.

The dissemination of information from these data in an easily digestible form has proved to be a difficult task. To try to overcome this problem the data for the 1995 surveys have been distilled into a summary for each littoral cell.

The information in these summaries is meant to reflect the main features of the littoral cell. More extensive data as well as data collected in previous surveys are held at the National Centre and can be made available on request.

David Palmer

DAVID PALMER
MANAGER, NATIONAL CENTRE

ENVIRONMENT AGENCY
135439

Introduction

The object of this report is to present an overview of the results of the four 1995 surveys in a compact form. The report is accompanied by the full laboratory analysis results and a catalogue of image data stored on CD-ROM and video. In total there are seventeen parts to the report, and those parts included in this pack are listed at the end of this section.

The coastline has been divided into coastal cells, known as littoral cells using the procedure developed by HR Wallingford (Motyka and Brampton, Report SR 328, January 1993). A map of the divisions between these cells is shown in Figure (i). The rationale of these cells means that any changes within a cell should not affect adjacent cells. In addition each cell has a significantly different character to adjacent cells, in terms of geology or biology. The divisions were defined principally for coastal defence construction, but the position of boundaries have implications on water quality variations. For example, effects from effluent outfalls should not be transferred across boundaries.

The water chemistry results for each cell have been reviewed for each season. In particular the nutrient results have been investigated for high concentrations in Summer which may be linked to anthropogenic sources, and which may result in eutrophic waters. In parallel with this the chlorophyll-*a* concentrations have been studied for any increases which are linked to high nutrient values, by two techniques. Firstly, the individual samples have been investigated, and secondly, maps of the entire coastal zone have been produced to allow spatial estimates of eutrophic waters to be made.

The absolute concentration of chlorophyll-*a* is compared with a concentration of 10 µg/l. This is the level suggested as representative of a bloom event by the Department of the Environment in their document "Criteria and Procedures for Identifying Sensitive Areas and Less Sensitive Areas" which was produced as a response to the EC Urban Waste Water Treatment Directive. Although this level signifies the presence of a phytoplankton bloom, it must be associated with other indicators to show that waters are effected by eutrophication.

Dissolved metals concentrations have been investigated in terms of their relation to the Environmental Quality Standard (EQS) levels. These levels are established in response to the EC Dangerous Substances Directive. The definition of the EQS level is as an annual mean. This has been calculated for any sites in which an individual sample exceeds the EQS. Organic contaminants have also been compared with EQS levels where they exist.

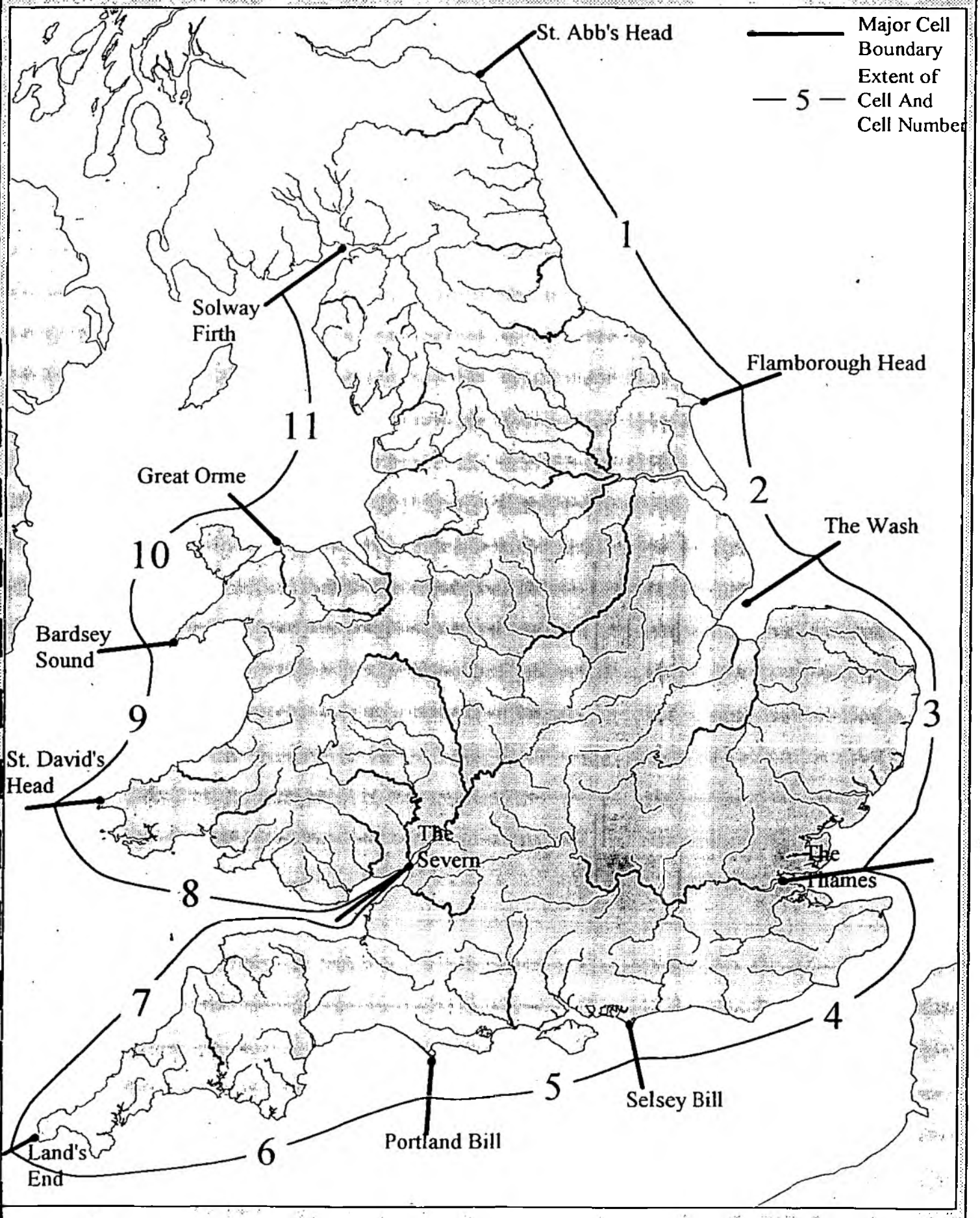
Consideration has been given to the position of the baseline sampling sites in relation to estuaries or major oceanographic features.

The image data and underway data have been investigated for major oceanographic features and changes in water quality. These may be manifested in the image data in two ways. Features are seen in the CASI imagery if they result in an alteration in the ocean colour signal. This usually requires a change in the amount of light scattered or absorbed by particles in the water column. Features such as estuarine plumes have higher particulate matter loading which increases the ocean colour sighal. Phytoplankton blooms increase the absorption of light in selected wavebands and moreover result in fluorescence being detected in other wavebands. Some features do not record a CASI signal but have a difference in water temperature. The thermal video systems used in the baseline survey record only the surface temperature of the water, but clearly show features such as effluent discharges and outfalls from power station cooling systems, in addition to river plumes.

The underway data illustrates changes in temperature, salinity, dissolved oxygen, transmission and fluorescence. The longitudinal profiles from the underway systems have been investigated for major changes which may be associated with estuarine inputs or fronts between different water bodies. Data from the Skalar continuous monitoring nutrient analyser have been investigated to determine the geographical extent of elevated samples in the laboratory analyses.

Summaries have been produced for each littoral cell which provide a statement on the water quality of the region recorded by the baseline survey. The key local oceanographic features are also summarised.

Figure i. The Major Littoral Cells of England and Wales, After Motyka and Brampton; 1993.



* Motyka, J.M. and Brampton, A.H. (1993), "Coastal Management, Mapping of Littoral Cells", HR Wallingford.

Littoral Cell 2: Flamborough Head to The Wash

Executive Summary

This littoral cell extends from Flamborough Head in the North to the Wash in the South. Its predominant characteristics are the heavily industrialised Humber Estuary and the Wash embayment which in the past has shown a propensity for eutrophication.

Laboratory analysis of water samples and underway continuous monitoring both showed the region directly to the South of the Humber and the Wash to have elevated nutrients and chlorophyll-*a* concentrations. Dissolved metals concentrations were not abnormally high with respect to Environmental Quality Standard (EQS) levels but high concentrations were clustered to the South of the Humber Estuary. Trace organic concentrations were low other than γ-HCH, which still did not exceed the EQS level.

The remotely sensed imagery and underway data showed the major oceanographic features within the region. Imagery of Flamborough Head showed the presence of an eddy having higher suspended solids concentration. In addition the underway data detected the beginning of the larger scale feature of the Flamborough Frisian front. The Humber plume was seen to vary in position by changes in salinity and temperature. Bathymetric features were seen along the coast between the Humber and the Wash. Coastal waters close to the Wash were shown to be highly productive in Spring and Autumn, though with no elevation in Summer. The shallowness of the Wash itself precluded examination by coastal vessels and limited the usefulness of the remote surveillance images for the determination of water quality.

1. Introduction

This littoral cell extends from Flamborough Head in the North to the Wash in the South, as shown in Figure 1. This constitutes approximately 1500 km^2 within the coastal zone for which the Environment Agency has responsibility for controlled waters, of which 950 km^2 are estuarine waters if all the waters of the Wash are included. During 1995 data collection was carried out jointly between Water Guardian and Sea Vigil, with surveys being varied out in Winter (January/February), Spring (May/June), Summer (July) and Autumn (September). Data were collected from aircraft in July and September.

2. Water chemistry results

2.1 Background

Littoral cell 2 extends from Flamborough Head to the Wash as illustrated in Figure 1, and its major features are the Humber Estuary and the Wash. There are eleven baseline sampling sites within this littoral cell, extending from Flamborough Head to the Wash, whose positions are shown in Figure 1.

2.2 Nutrients and chlorophyll-*a*

2.2.1 Total oxidised nitrogen (TON)

TON concentrations showed a clear seasonal cycle with maximum values in Winter, for example 1514 µg/l N at Haile Sand Flat (31) and 1210 µg/l N in the Wash (35); and minimum values in the Spring, often below the minimum reporting value of 2.5 µg/l N. Summer TON concentrations remained low, but Autumn levels began to rise, particularly close to the Wash, with a concentration of 1102 µg/l N recorded at Outer Dogs Head (34).

2.2.2 Silicate

Silicate concentrations showed a similar seasonal dependence with greatest values in the Winter, for example 916 µg/l Si at Haile Sand Flat (31); and lowest concentrations in Spring, when concentrations only exceed the minimum reporting value (MRV) of 1 µg/l Si in the northerly deflection of the estuarine plume of the Humber (sites 30 and 31). Concentrations of silicate remained low in Summer, but an increase was recorded in Autumn, for example 154 µg/l Si at Haile Sand Flat (31).

2.2.3 Orthophosphate

Orthophosphate results also showed seasonal cycling, but less pronounced geographical separation than TON and silicate. Lowest concentrations were found in the Spring, for example a maximum of 17µg/l P at Haile Sand Flat (31); with highest concentrations in the Winter, for example 402 µg/l P at Withernsea (29).

2.2.4 Total Ammoniacal Nitrogen (Ammonia)

Ammonia results for this littoral cell were low. In Winter the highest recorded concentration is only 33 µg/l N, compared with a national maximum of 292 µg/l N. The position of the highest values varied between surveys, with no geographical pattern.

2.2.5 Nitrite

Nitrite concentrations were low for all seasonal surveys. In Spring concentrations only exceeded the laboratory MRV of 0.5 µg/l N in the Humber plume at Spurn Head (30) and Haile Sand Flat (31). In Autumn the Outer Dogs Head (34) sampling site recorded a high concentration of 68 µg/l N.

2.2.6 Chlorophyll-a

Winter concentrations of chlorophyll-*a* were all below 2 µg/l, except at Theddlethorpe (32), where the concentration was 2.17 µg/l. Spring concentrations rose to a range of 1.77 µg/l to 14.24 µg/l, with the maximum at Chapel St Leonards (33). Chlorophyll-*a* concentrations were

higher South of the Humber than to the North although this may be a result of survey timing with the northern sites being sampled on 1st June, which is potentially after the peak in phytoplankton. In Summer, the only site to record an elevated concentration in Haile Sand Flat (31) at 6.92 µg/l. In Autumn the Wash sampling site (35) shows the presence of a small autumnal bloom, with concentrations of 10.26 µg/l.

2.2.7 Nutrients/chlorophyll-a Summary

The seasonal nutrient cycling with maxima in the Winter and minima in the Spring is consistent with the initial phytoplankton bloom developing in early Spring due to the particularly warm season, and this bloom depleting nutrient concentrations prior to the Spring survey. The Humber Estuary is a major source of TON, silicate and orthophosphate to the coastal zone. Ammonia and nitrite concentrations were low at the time of survey. As expected, chlorophyll-*a* concentrations were highest to the South of the Humber within the residual direction of flow of the nutrient-rich Humber water.

2.3 Suspended solids

The coastal region between the Humber Estuary and the Wash, which is the area receiving the residual flow from the Humber, recorded the highest suspended solids concentrations. Surprisingly, the Humber Estuary itself only recorded a high concentration in the Summer, but the low values on the other occasions can be explained by the tidal state during sampling, with the tidal stream directed up the estuary.

2.4 Metals

2.4.1 Total Mercury

Mercury analyses did not exceed the laboratory MRV of 0.008 µg/l Hg for any site in Winter and only a few concentrations greater than this noted in the rest of the year. The maximum observed concentration was 0.492 µg/l Hg at Bridlington (26) in the Spring. This value exceeds the EQS of 0.3 µg/l Hg for dissolved mercury.

2.4.2 Dissolved Cadmium

Dissolved cadmium concentrations did not exceed the laboratory MRV of 0.042 µg/l Cd for any site in Winter. Cadmium levels increased in the Humber Estuary in Spring and Summer, reaching an Autumn maximum of 0.068 µg/l Cd, which was nevertheless still less than one tenth the EQS value of 2.5 µg/l Cd.

2.4.3 Dissolved Copper

In Winter maximum concentrations occurred at Flamborough (25), equal to 2.36 µg/l Cu, and Theddlethorpe (32), equal to 2.65 µg/l Cu. Spring values were higher with a maximum of 4.5 µg/l Cu. In Summer the maximum concentration was 2.31 µg/l Cu at Theddlethorpe (32), with the Autumn maximum equal to 2.08 µg/l Cu at Flamborough (25). All concentrations were below the EQS level of 5 µg/l Cu.

2.4.4 Dissolved Lead

Lead concentrations remained low throughout the four surveys, seldom exceeding the

laboratory MRV of 0.024 µg/l Pb.

2.4.5 Dissolved Arsenic

All sample analyses were lower than the laboratory MRV of 2 µg/l As.

2.4.6 Dissolved Zinc

Dissolved zinc results are high in Winter, with the maximum values found at Haile Sand Flat (31) and Theddlethorpe (32), equal to 15.1 µg/l Zn and 14.6 µg/l Zn respectively. The Spring results are lower, but with the maximum still found at Theddlethorpe (32), equal to 9.3 µg/l Zn. Similar values are found in Summer and Autumn, with the maximum at Outer Dogs Head (34) in Summer equal to 10.5 µg/l Zn and Hornsea (27) in Autumn equal to 7.9 µg/l Zn. No samples exceed the EQS level of 40 µg/l Zn.

2.4.7 Dissolved Chromium

Dissolved chromium concentrations were low throughout the four surveys, never exceeding the EQS of 15 µg/l Cr. The highest Winter and Spring values were at Haile Sand Flat (31), equal to 1.74 µg/l Cr and 0.68 µg/l Cr respectively. In Summer, a single high value is found at Beacon Hill, equal to 6.64 µg/l Cr.

2.4.8 Dissolved Nickel

Dissolved nickel concentrations were low throughout the four surveys, seldom exceeding the laboratory MRV of 0.058 µg/l Ni. The highest recorded concentration was 1.44 µg/l in Autumn at Haile Sand Flat (31) and Theddlethorpe (32), which is still less than one tenth of the EQS level of 30 µg/l.

2.4.9 Metals Summary

The metals concentrations showed some geographical pattern with Haile Sand Flat (31) and Theddlethorpe (32) generally recording the highest levels. A probable explanation is that the Humber Estuary is the major source, giving rise to significant residual metal concentrations in the water column from the previous tide, although samples were taken on ingoing tides.

2.5 Organic determinands

Water samples were analysed for twenty three trace organic determinands at five baseline sites within this littoral cell, at Hornsea (27), Spurn Head (30), Haile Sand Flat (31), Chapel St Leonards (33) and the Wash (35). With the exception of a small number of PCB results, only γ-HCH gave positive analyses. The other 22 determinands were not detected at their laboratory MRVs of 0.001 µg/l for the entire survey.

In the Winter survey, the Hornsea (27) site records a value of 0.001 µg/l for PCB 180 and the Wash (35) records a value of 0.001µg/l for HCH gamma. In Spring all the sites to the North of the Humber show results for HCH gamma, with the highest being 0.024 µg/l at Spurn Head (30). In Summer all the sites show results for HCH gamma, with concentrations between 0.001 and 0.002 µg/l. In Autumn HCH gamma results are found at most sites, but in this case are lower, being 0.001 µg/l. These γ-HCH results are some of the highest in the national survey and may benefit from a local investigation of the potential sources.

3. Spatial chlorophyll-*a* results

The CASI imagery has been used in combination with the laboratory baseline samples and the underway fluorimeter to produce maps of chlorophyll-*a* concentration of the coastal zone. The technique used involves calculation of the Fluorescence Line Height (FLH) of the imagery and correlation of the three measuring techniques.

Figure 2 shows the chlorophyll-*a* concentration during Summer 1995 for this littoral cell, as derived from the FLH technique. Data are missing in some areas due to the very high suspended solids concentrations, which effect the action of the algorithm. There was a clear division between waters to the North and the South of the Humber Estuary, with higher concentrations to the south. The dividing point was close to the Withernsea sampling point (29). The chlorophyll-*a* concentration around the Humber Estuary and to the South was generally between 6 and 8 µg/l, with no areas found to be in excess of 10 µg/l. Concentrations to the North of the cell were between 2 and 4 µg/l.

Figure 3 shows the chlorophyll-*a* concentration calculated from the continuous flow fluorimeter. This reading has been interpolated to represent the concentration for the three nautical mile zone. This map shows the same geographical pattern as Figure 2, but with greater variability. This is due to an artifact of the FLH technique which results in some smoothing, particularly of high and low concentrations.

The waters to the North of Spurn Head showed concentrations less than 2 µg/l, with those to the South, close to Mablethorpe having concentrations of greater than 10 µg/l. Again this clearly shows the residual flow direction of water from the Humber, and indicate that this region is potentially subject to the effects of eutrophication.

The samples from the outer waters of the Wash are mainly between 6 and 8 µg/l. Although this is not in excess of 10 µg/l, the consistently elevated concentrations support the hypothesis that this region is a potentially sensitive area with respect to the Urban Waste Water Treatment Directive.

4. Local oceanographic descriptions

Underway measurements have been investigated in order to show which areas within this littoral cell show most variability in the underway parameters measured, namely temperature, salinity, fluorescence, transmission and dissolved oxygen. In addition the imagery has been studied for variation in ocean colour signal and temperature signal, or where discrete bathymetric and oceanographic features are visible during either July or September. These areas will be discussed in more detail below, in terms of results from remote sensing imagery, laboratory sampling and underway measurements. This will provide an overview of the results for this section of coastline. The areas are as follows.

1. Flamborough Head
2. The River Humber plume
3. Chapel St Leonards coast
4. The Wash

4.1 Flamborough Head

CASI imagery from the southern Flamborough Head flightline in July 1995 shows the presence of an eddy off the tip of the headland, approximately 3 km in dimension (Plate 1(i)). This eddy has been noted previously on thermal imagery in 1994, and is known to change position from the North to the South of the headland depending on the tidal streams acting at the time. In September 1995, no clear eddy structure was seen, with instead a transitional stage as a result of the collection of imagery at slack water (Plate 1(ii)).

The presence of such a large eddy within this region, and its varying position has implications on the collection of water quality samples, in particular those for suspended solids, which will vary markedly depending on whether the sample is taken within the eddy, which has higher suspended solids concentration.

Underway data collected during the 1995 surveys shows variability around Flamborough Head, although the scale may mean that a different feature is being represented here. Flamborough headland marks the beginning of the Flamborough Frisian front which extends across the North Sea. In both the Winter and Summer surveys a thermal front is seen off the headland, with warmer water to the South, as illustrated in Figure 4. This data from Summer 1995 shows the possible presence of both features, with a generally higher temperature to the South, but with a further feature superimposed.

4.2 The River Humber plume

The presence of the Humber estuarine plume within the coastal zone is noted in both the remote sensing imagery and the underway data. The features detected in the imagery are variation in temperature, and the presence of varying concentrations of suspended solids, shown by a variation in reflectance in the CASI imagery. The underway data shows variation in temperature, salinity, and transmission.

In the CASI imagery from both July and September higher reflectance is seen to the North of Spurn Head as shown in Plate 2. This represents a northerly flow of water around Spurn Head from the higher sediment concentrations within the Humber, which is in accordance with the tidal streams for the time of the images. In addition, the imagery shows small scale sediment circulation close to the coast.

This coastline is undergoing continual erosion, with erosion rates being the highest on any part of the coastline of England and Wales. The CASI data does not show the process of erosion, but clearly shows the transport of this eroded sediment along the coast.

Thermal video imagery shows a small eddy of warmer water being deflected North around Spurn Head during September. Parallel bands of thermal data are also seen on the inner side of the spit (Plate 3). The position and shape of Spurn Head will alter greatly over the next few years as coastal protection works are suspended. CASI imagery could provide an ideal means of monitoring the movement of sand features within this region.

Underway data does not show the presence of a marked plume in three of the surveys. This is because the Humber marks the point at which data collection was split between two survey vessels during the 1995 surveys. As such the surveys tends to have been taken on an ingoing tide, when the features seen within the mouth of the estuary are residual, and there is no marked outflow of Humber water.

During the Spring survey there was an outgoing tide from the Humber with the tidal stream direction outside the Humber being northwards around Spurn Head. This is clearly shown in the underway data which shows a decrease in salinity as far North as Withernsea (29). The laboratory samples from the Withernsea (29) sampling station in Spring show increased nutrient concentrations which would be expected in the Humber plume. In addition, the maximum suspended solids concentration is seen at Spurn Head (30) which is to the North of the estuary. In other surveys, the Haile Sand Flat (31) sampling point to the South of the estuary shows higher concentrations, which is the residual flow direction of estuarine waters from the Humber.

Thus the position and direction of estuarine flow from the Humber may have an effect on the water quality samples from this region. The higher nutrient concentrations within the plume could have implications for the development of phytoplankton blooms within this region, which has been discussed in Section 3. The Humber plume is particularly high in TON concentration suggesting that outfalls and sources are located further upstream with breakdown of ammonia having already taken place within the estuary. Local investigations would be required to establish if outfalls or agriculture were the source of the high TON concentrations recorded. The spatial chlorophyll-*a* results show that the region to the South of the Humber has high chlorophyll-*a* concentrations during the Summer survey.

Plate 4 shows imagery from the Humber Estuary on 23rd September close to Cleethorpes, This image clearly illustrates the presence of the titanium dioxide outfall, marked X, which is dispersing over a length of approximately 2 kms. This is the only outfall of titanium dioxide to the coastal zone, and has been noted in other CASI imagery previously. In addition there is a further outfall closer inshore, marked Y which is seen to be dispersing over a fairly short distance.

4.3 Chapel St Leonards coastline

CASI imagery from the coastline between Mablethorpe and Chapel St Leonards shows the utilisation of ocean colour data in detecting minor changes in bathymetry (see Plate 5). The features marked in the imagery are potentially a result of two processes. Such features may be due to suspended sediment within the water column increasing the particulate scattering, or

to underlying bathymetry. Investigation of the local bathymetry suggests that these features are in fact bathymetry.

Data from July shows the deep water of the Trusthorpe Overfalls, which have a depth of 10 m as apposed to 5m depth in the surrounding waters. In addition, both images show a further area of deeper water located as marked. This area is shown on the Admiralty charts as having a depth 1.5 m deeper than surroundings. Thus the CASI is able to detect even such small differences in bathymetry.

This region of coastline shows elevated concentrations in some metals and nutrients, particularly at the Theddlethorpe (32) baseline sampling site which is shown on the images. This is due to the position of this site in relation to the Humber Estuary. Donna Knook to the North of the image marks a divide in littoral flow. The residual flow is to the South from Donna Knook. Assuming some transfer of contaminants across the flow divide at Donna Knook, then high metals concentrations would be expected here.

4.4 The Wash

The shoreline of the Wash is covered by three CASI flight lines. The survey vessel, however, does not pass into the area due to shallow water. Two baseline sampling sites are located at the mouth of the Wash to the North and South.

CASI imagery was collected close to Low Water in September showing wide exposure of sandbanks. In July, the tide is higher, however the imagery is still dominated by sandbanks. Thus the CASI imagery reveals little information on water quality. The imagery is of use in determining the position of channels which are highly mobile in this region. CASI imagery also shows the position and extent of saltmarshes. Modification of the bandset allows the classification of CASI imagery into major algal classes. This area could be worked up in future if required.

The Wash is an area which is potentially subject to eutrophication. The underway data extending past the mouth of the Wash shows the presence of more highly productive water with a higher fluorescence signal, particularly during the Spring survey. The laboratory sampling sites show high chlorophyll-*a* concentrations from Chapel St Leonards (33) down to the Wash sampling site. In Autumn the Wash sampling site (35) also records an elevated concentration of chlorophyll-*a*.

Spatial chlorophyll-*a* results for Summer 1995 show enhanced chlorophyll-*a* concentrations within the Wash, equal to between 6 and 8 µg/l. These are not in excess of 10 µg/l which may be taken as an indication of the presence of a phytoplankton bloom. These concentrations are, however, elevated with respect to the national average concentration for this season. This supports the potential for the designation of the Wash as a Sensitive Area under the Urban Waste Water Treatment Directive.

This is further supported by continuous monitoring Skalar nutrient results for this region,

which are shown in Figures 5 to 8. The scales of these figures have been determined from results from the entire baseline survey, and as such national comparisons may be made. Nutrient concentrations are high in Winter particularly for TON and silicate, and are also high in Autumn. More importantly, the samples within the Wash itself in Summer (Figure 6), when the vessel was making passage for port, clearly showed elevated concentrations, for example concentrations greater than 250 µg/l N for TON and greater than 40 µg/l P for orthophosphate.

The sewage outfall at Heacham has been raised as a potential reason for the failure of bathing beaches in this region. CASI images from July and September both show the presence of the discharge at this point, marked by increased surface roughness (see Plate 6). The flow direction is towards the North which is consistent with tidal flow. The magnitude of the discharge in this imagery would not suggest that this outfall has major effects on the local beaches, although dissolved matter would not be detected by CASI.

The baseline data is able to provide an overview of the water quality of the Wash and surrounding coastal waters. The bathymetry of the region, however, precludes the vessel from passing into the Wash itself on a routine basis, and as such intensive surveys with smaller vessels are more suited to this region. In addition, CASI overflights across the open water area would aid in eutrophication studies, allowing the chlorophyll-*a* concentration for the entire region to be estimated as described in Section 3.

5. Conclusions

This littoral cell has variable water quality, with a clear division at Spurn Head. To the North of Spurn Head the quality is high, with low chlorophyll-*a* concentrations and low nutrient concentrations. To the South of the Humber, extending to the Wash, the chlorophyll-*a* and nutrient concentrations are much higher, with both areas having potentially eutrophic waters in terms of their chlorophyll-*a* concentration. Nutrient concentrations are particularly high within the influence of the Humber estuarine plume, with a maximum TON concentration of 1514 µg/l in Winter at Haile Sand Flat (31).

Spatial chlorophyll-*a* results clearly showed this division, with concentrations consistently greater than 10 µg/l to the South of the Humber Estuary. The lower water quality to the South of the Humber reflects the direction of residual flow of water from this highly industrialised catchment.

Dissolved metals concentrations were not abnormally high with respect to EQS levels but high concentrations were clustered to the South of the Humber Estuary. Trace organic concentrations were low other than γ-HCH, which still did not exceed the EQS level.

Flamborough Head marks the position of two key oceanographic features of differing scales. Firstly, there is a clear tidally dependent eddy feature off Flamborough Head. This illustrates the complexity of water quality sampling in this region. In addition, the underway data shows the possible development of the Flamborough Frisian front.

Other oceanographic features were connected with the Humber plume, which results in the division of water quality described above, and the Wash, which is a further major input of nutrients to the coastal zone. The underway fluorimeter and nutrient data lend support to the designation of the Wash as a Sensitive Area under the Urban Waste Water Treatment Directive.

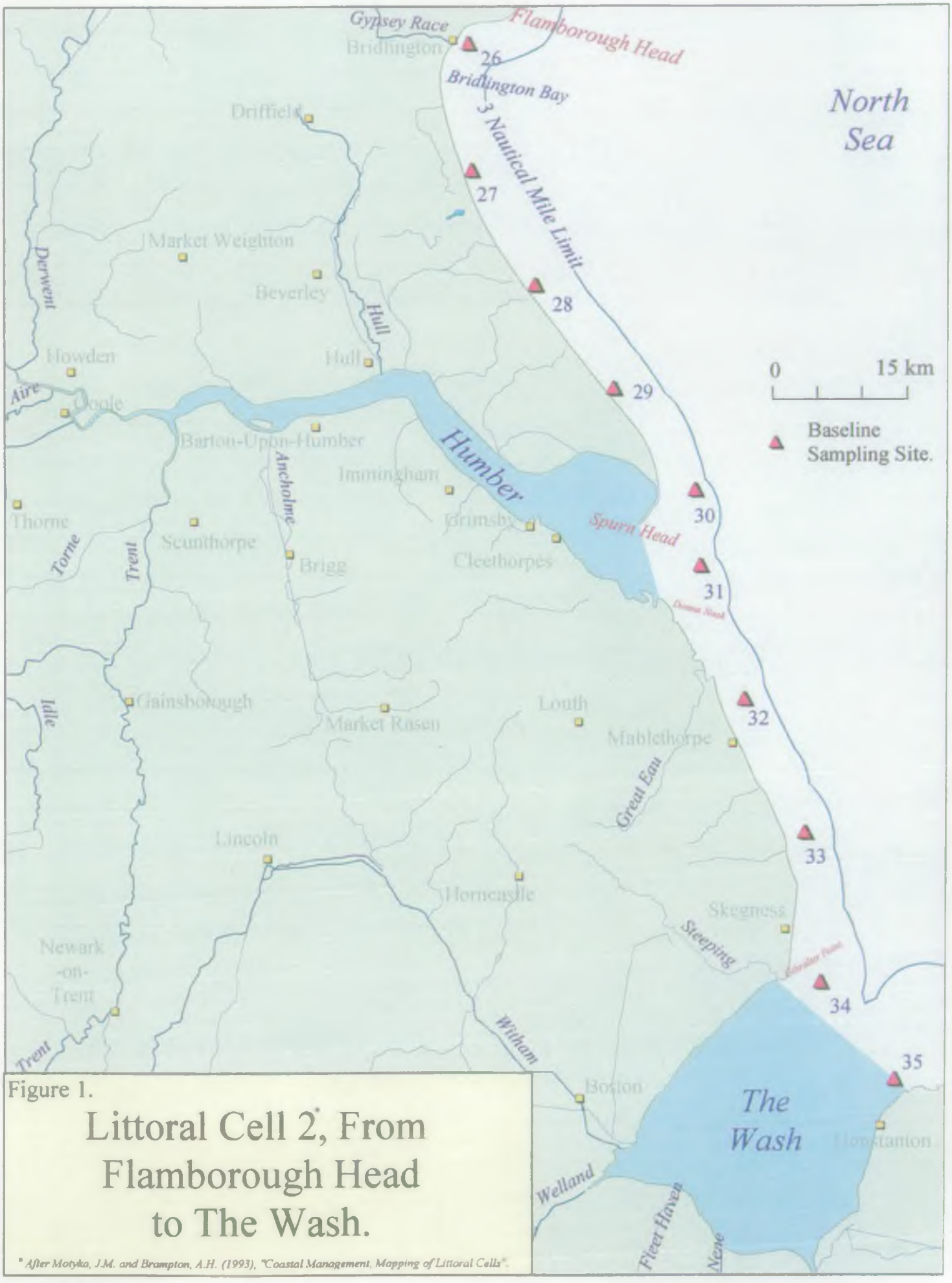


Figure 1.

Littoral Cell 2*, From Flamborough Head to The Wash.

* *After Motyka, J.M. and Brampton, A.H. (1993), "Coastal Management, Mapping of Littoral Cells".*

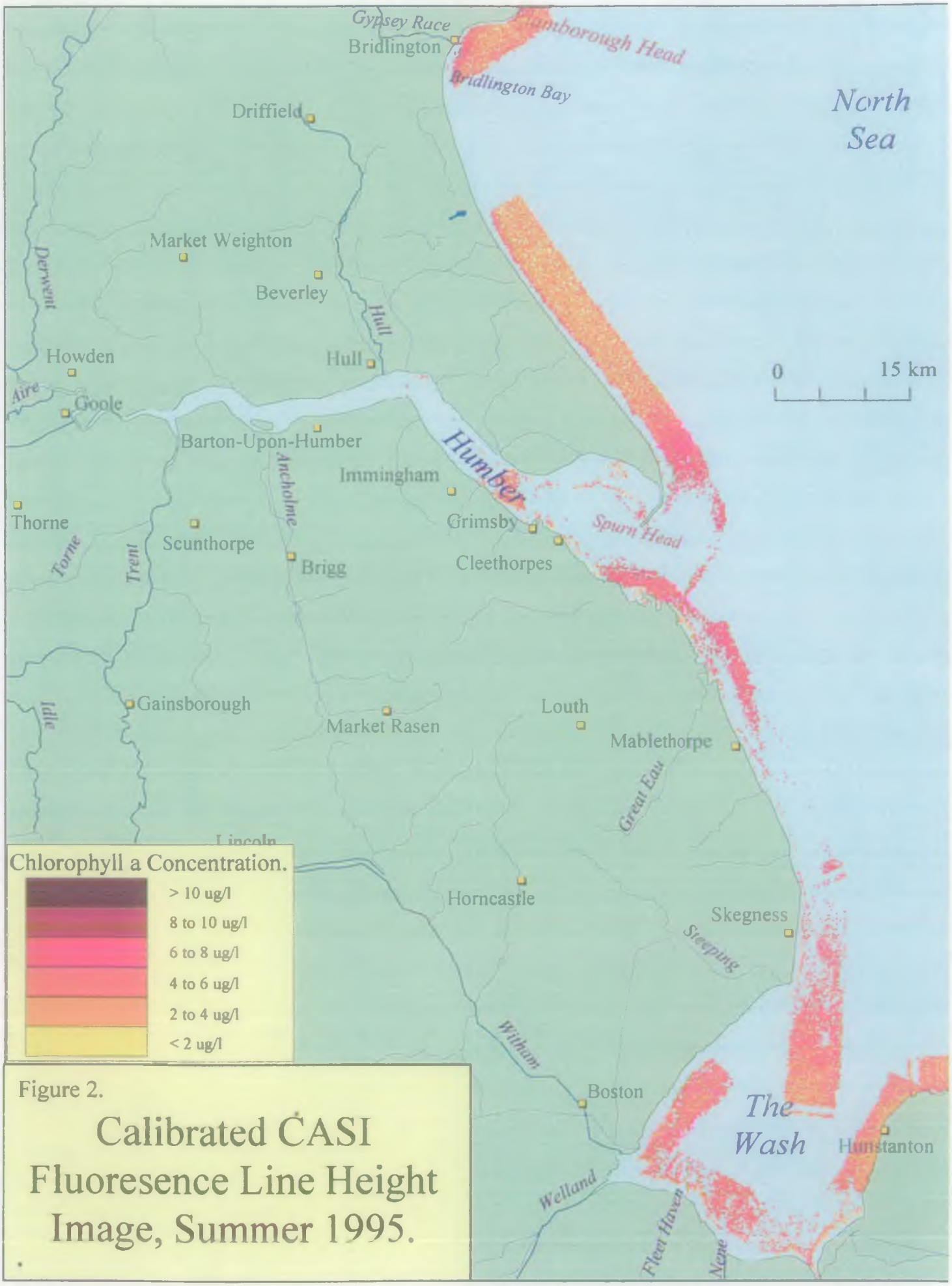


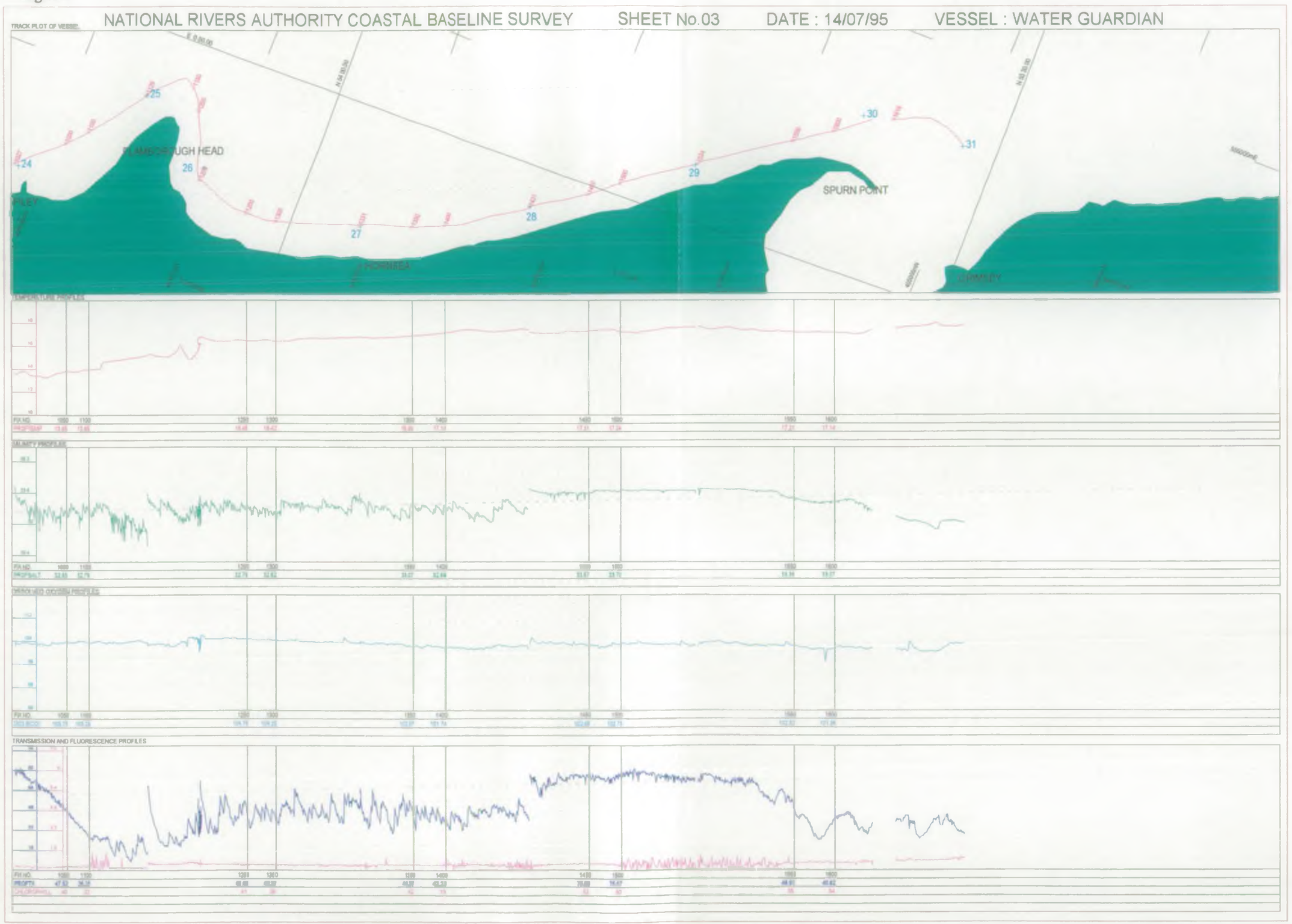
Figure 2.

Calibrated CASI Fluoresence Line Height Image, Summer 1995.

Figure 3.

Calibrated Continuous Track Fluorimeter, Summer 1995.

Figure 4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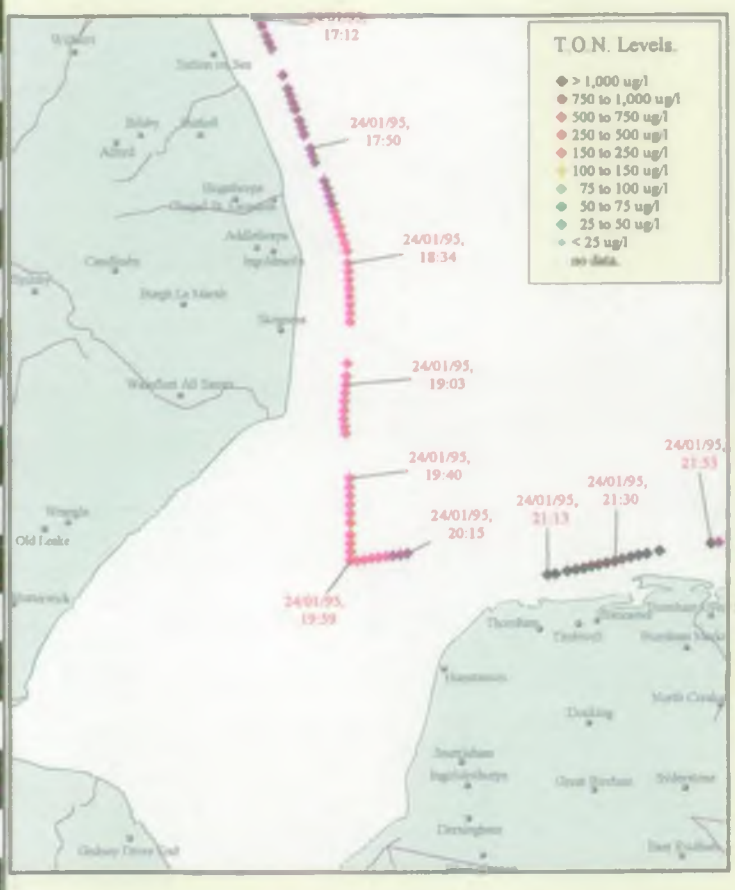
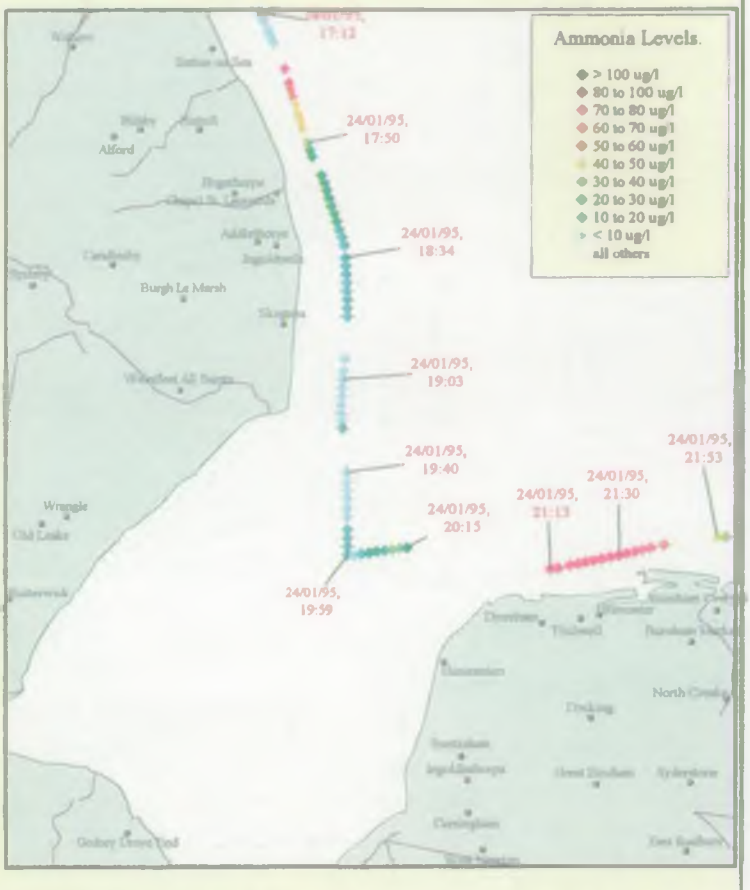
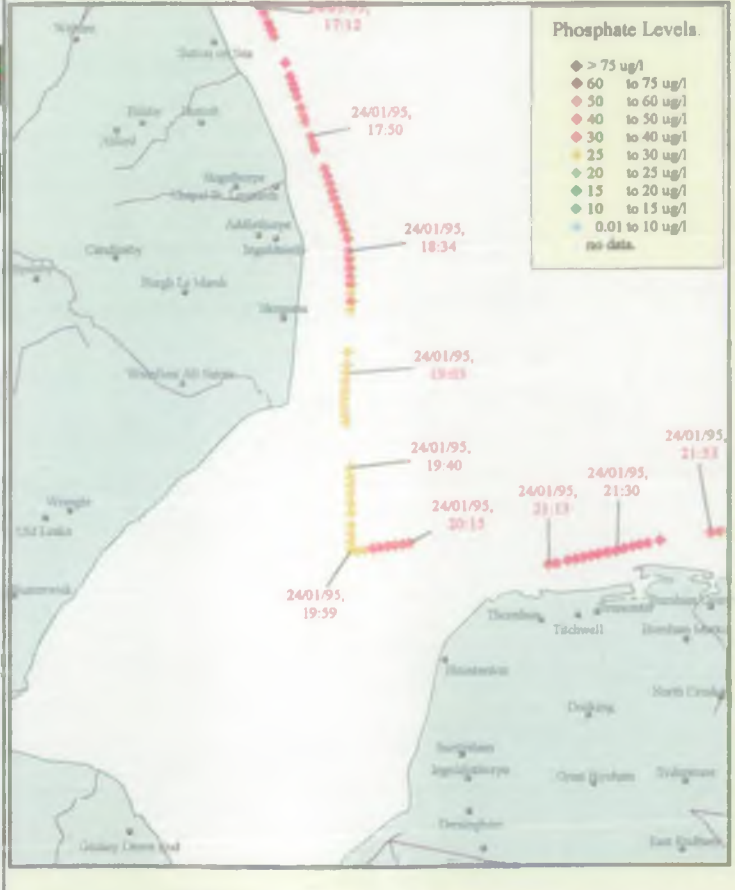
FLAMBOROUGH HEAD
SPURN POINT
HORNSEA
WITHERNSEA
TEMPERATURE PROFILES
SALINITY PROFILES
DISSOLVED OXYGEN PROFILES
TRANSMISSION AND FLUORESCENCE PROFILES

Figure 5.

Skalar Nutrient Data, The Wash , Winter 1995.







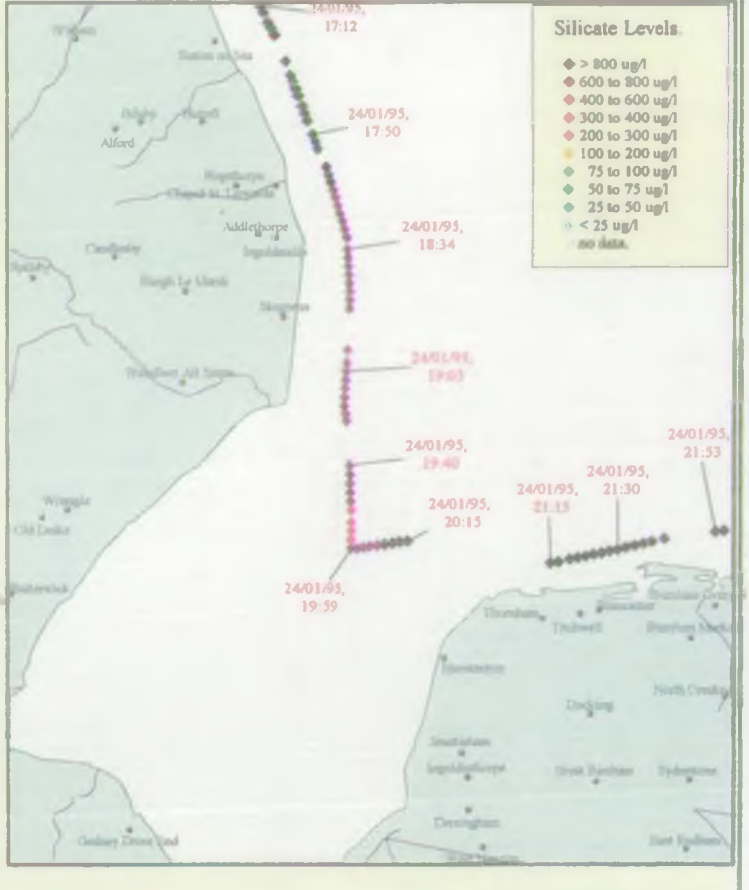


Figure 6.

Skalar Nutrient Data, The Wash , Spring 1995.

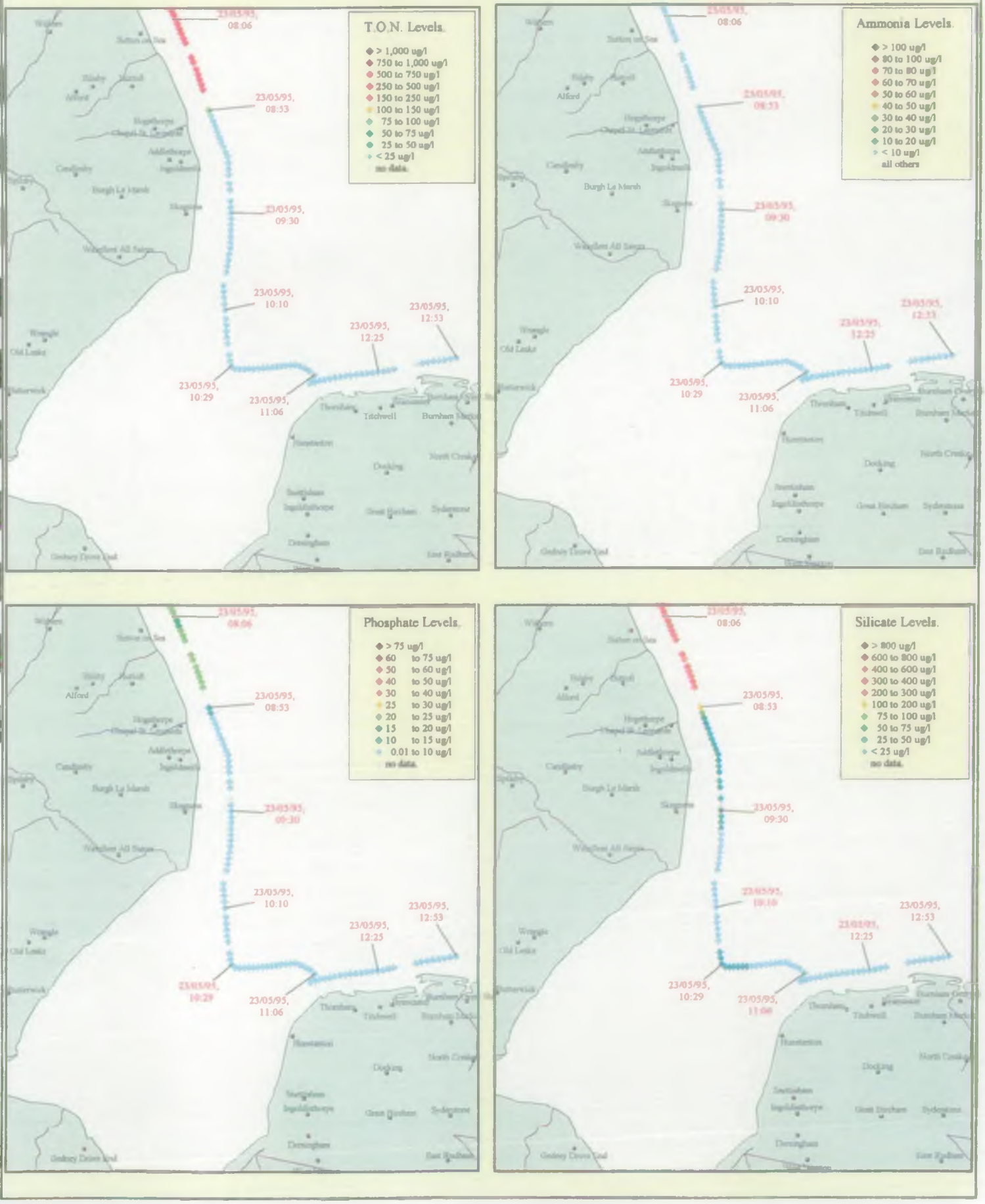


Figure 7.

Skalar Nutrient Data, The Wash , Summer 1995.

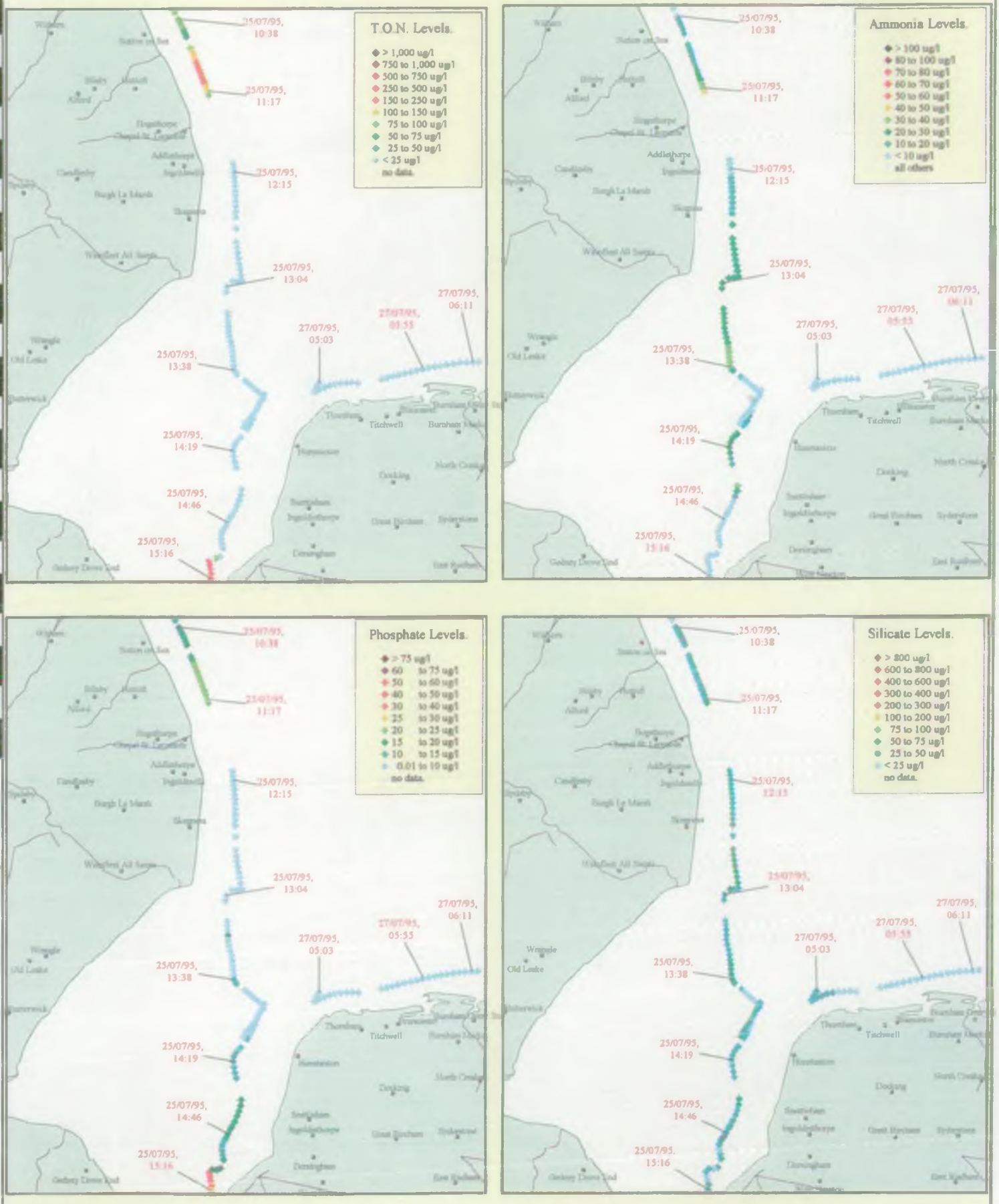
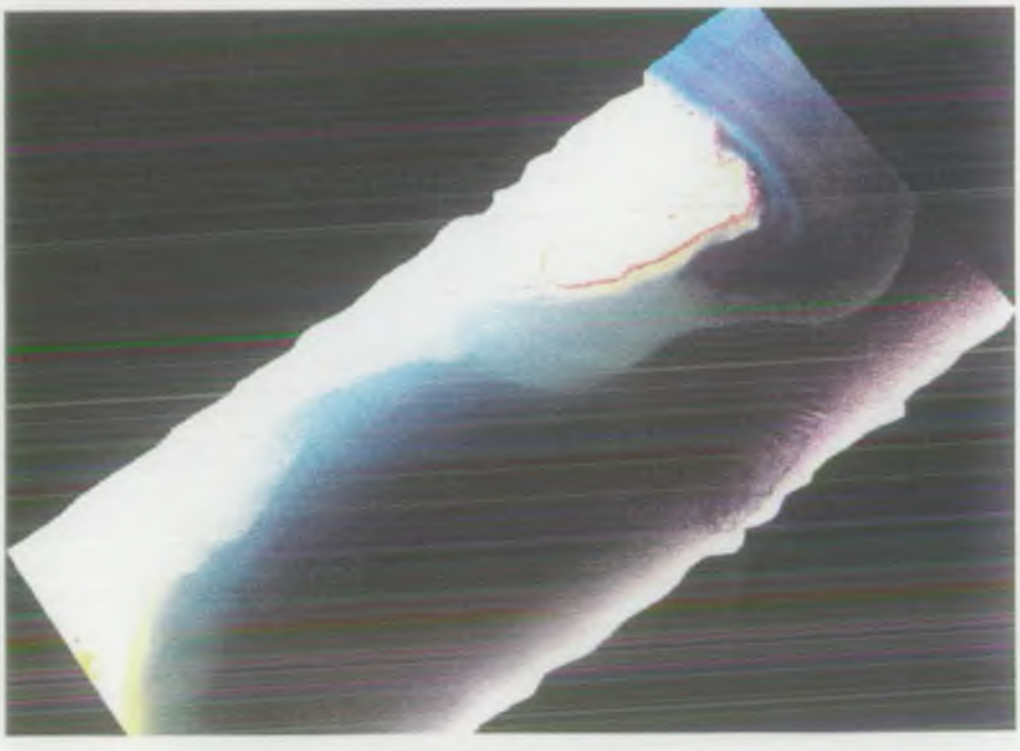


Figure 8.

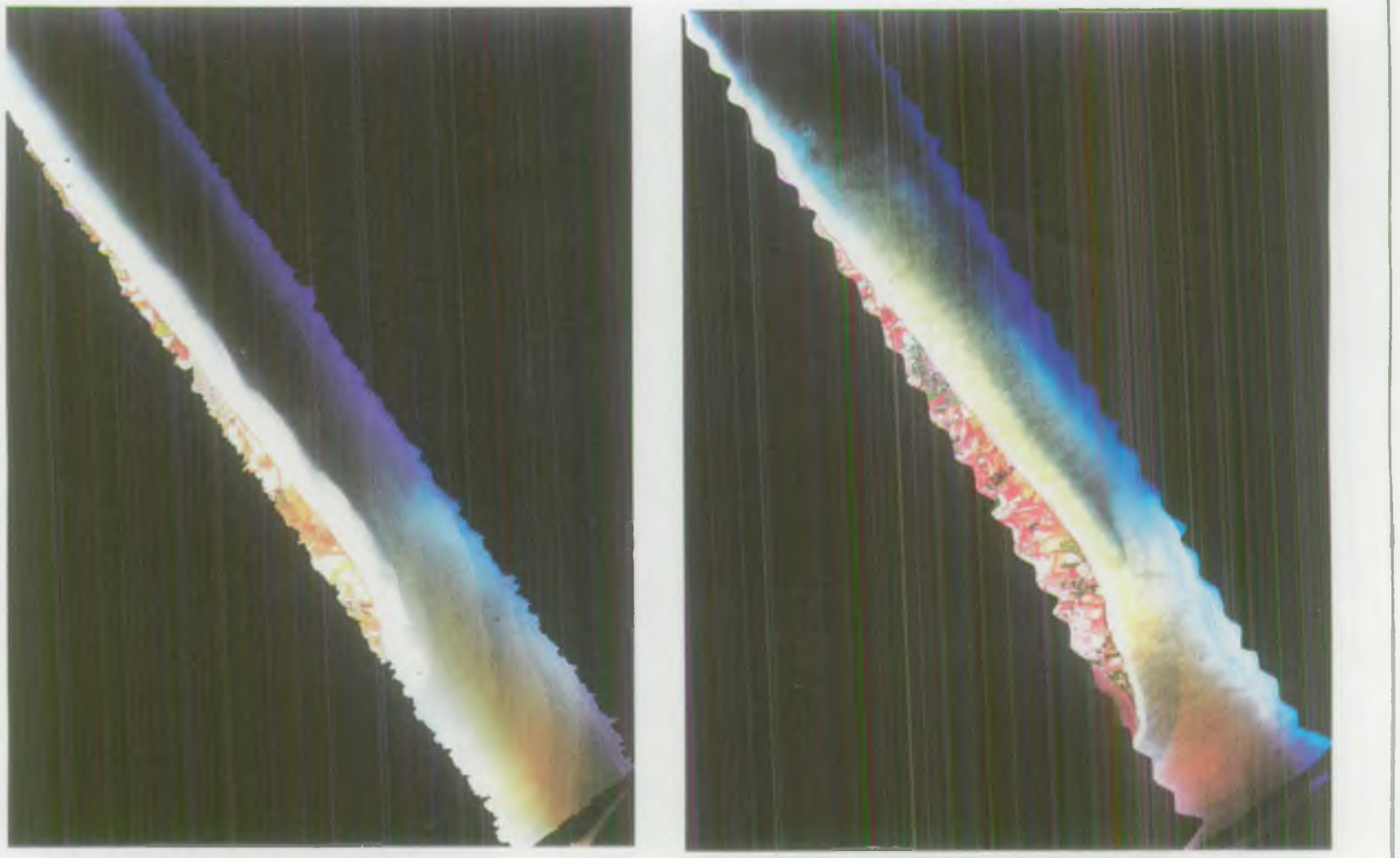
Skalar Nutrient Data, The Wash , Autumn 1995.

26th July 1995, 14:39 GMT



21st September 1995, 10:02 GMT

Plate 1: Flamborough Head
CASI enhanced true colour composite images



27th July 1995. 12:35 GMT

21st Septmber 1995, 09:47 GMT

Plate 2: Holderness Coast
CASI enhanced true colour composite images

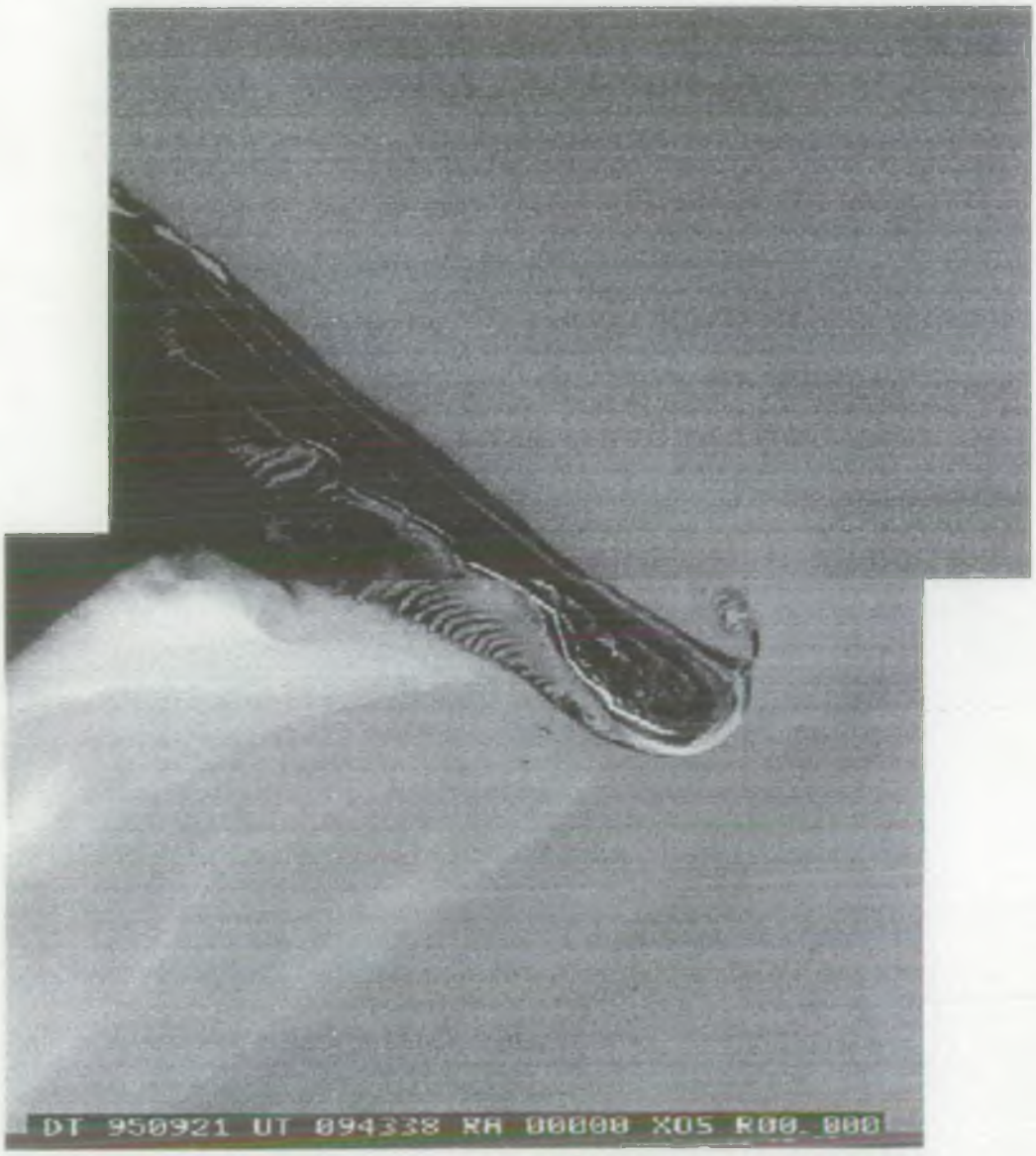


Plate 3: Spurn Head
Thermal video image composite
21st September 1995, 09:43 GMT

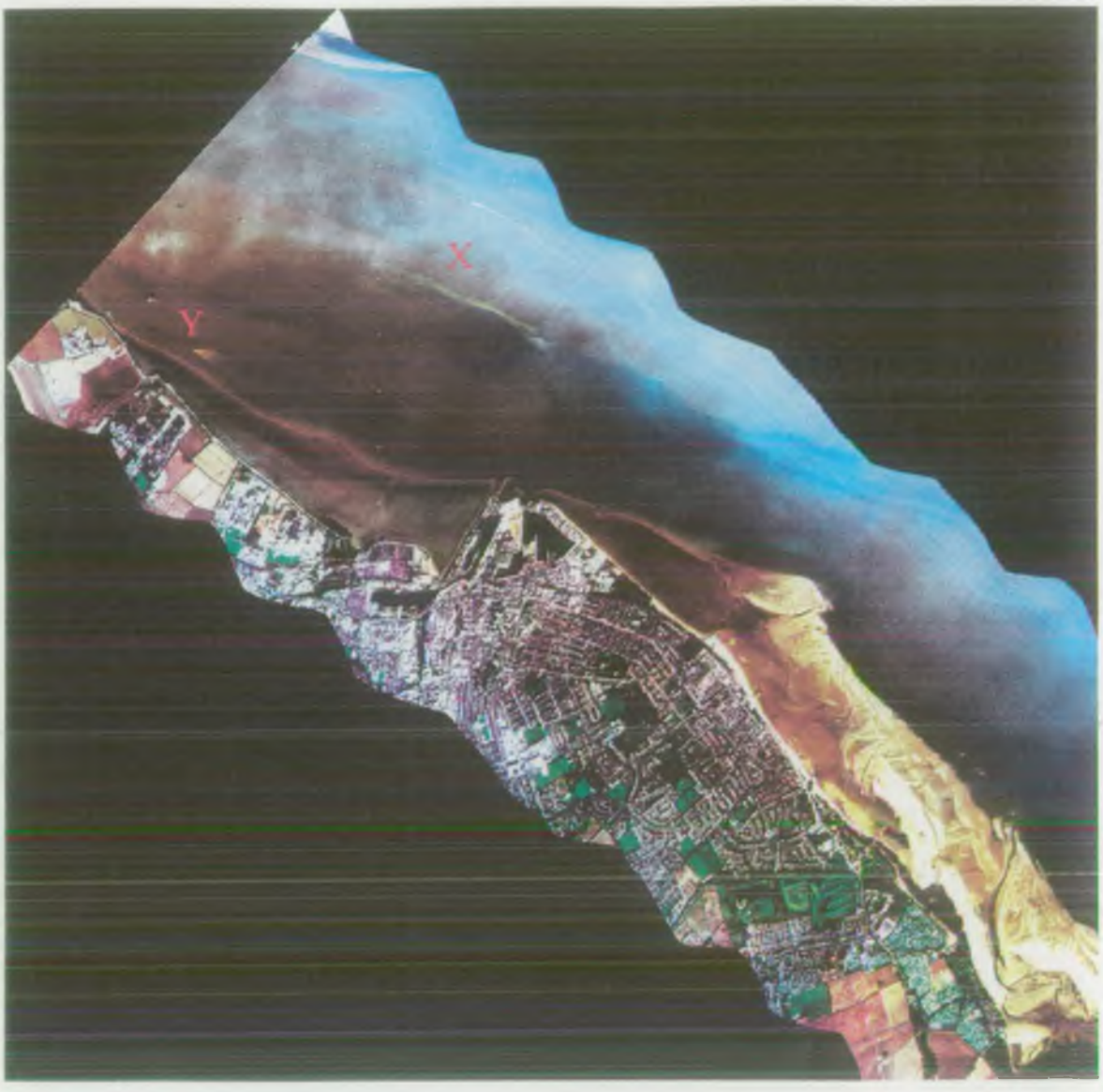


Plate 4: Humber Estuary
CASI enhanced true colour composite image
23rd September 1995, 09:33 GMT

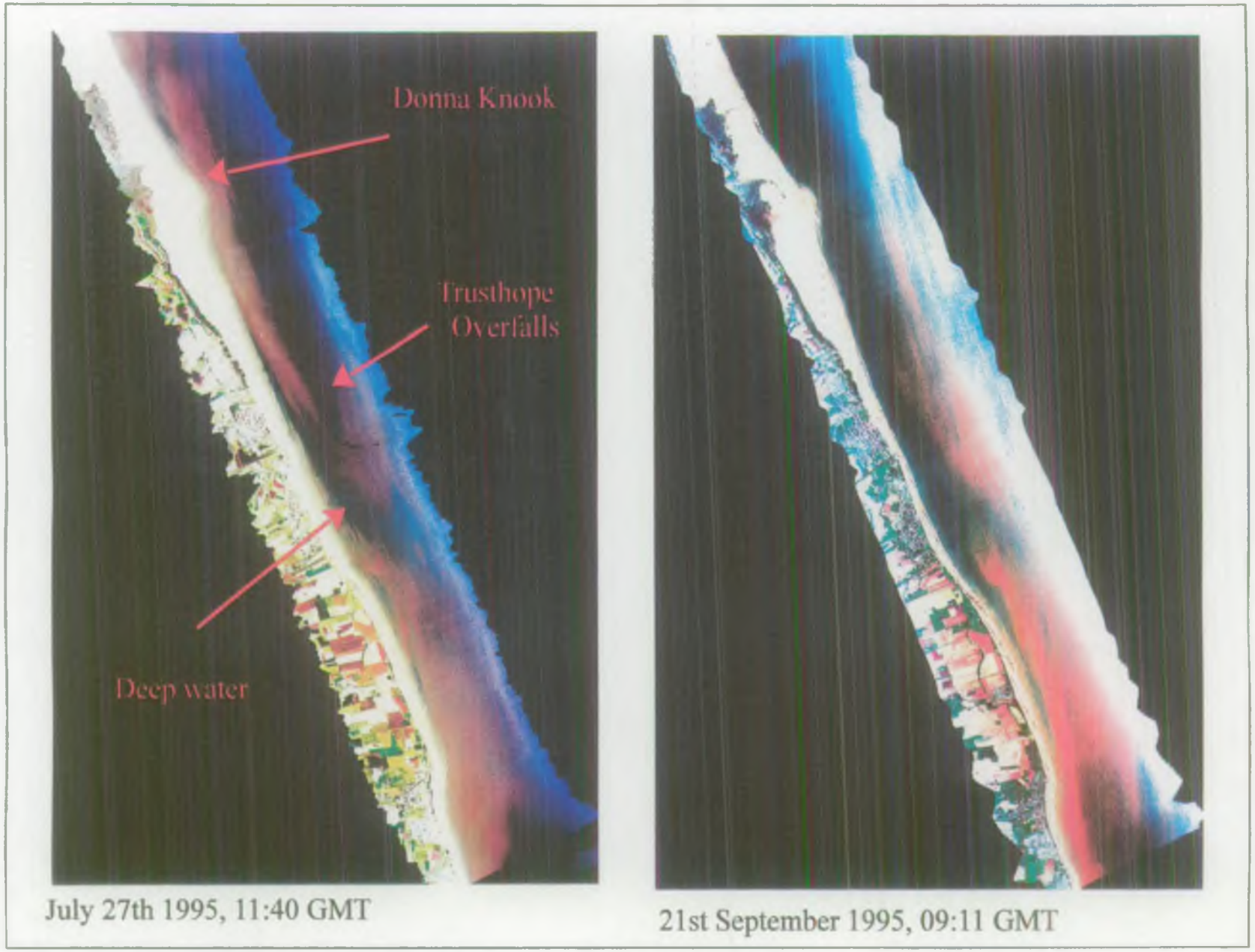
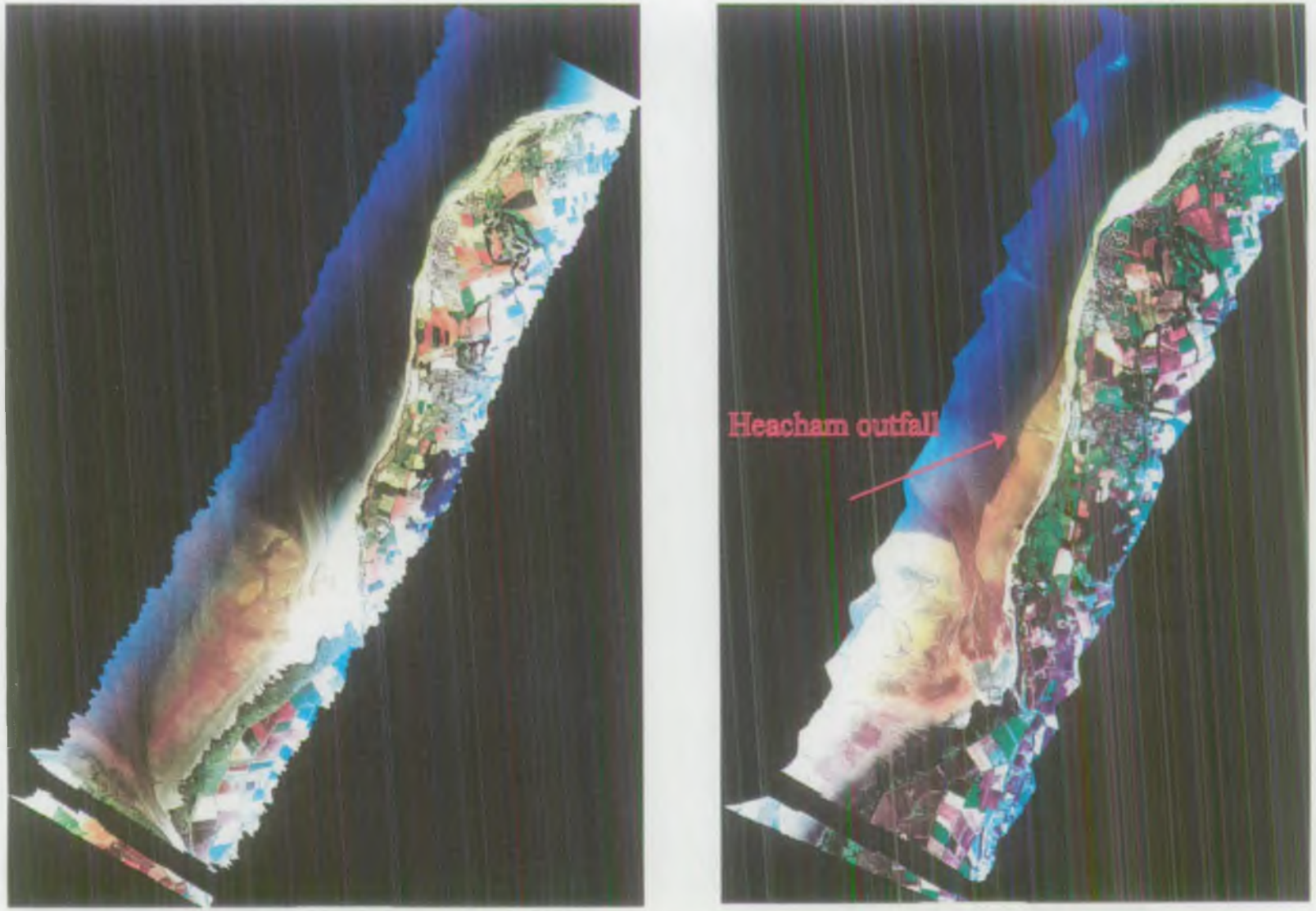


Plate 5: Chapel St Leonards coastline
CASI enhanced true colour composite images



30th July 1995, 10:14 GMT

23rd September 1995, 09:33 GMT

Plate 6: The Wash
CASI enhanced true colour composite images