EA-NCEDS BOX 4

National Marine Baseline Survey 1995

Littoral Cell 7
Lands End to the Severn Estuary

ENVIRONMENT AGENCY

Report NC/MAR/016 Part 9 of 17
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

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.

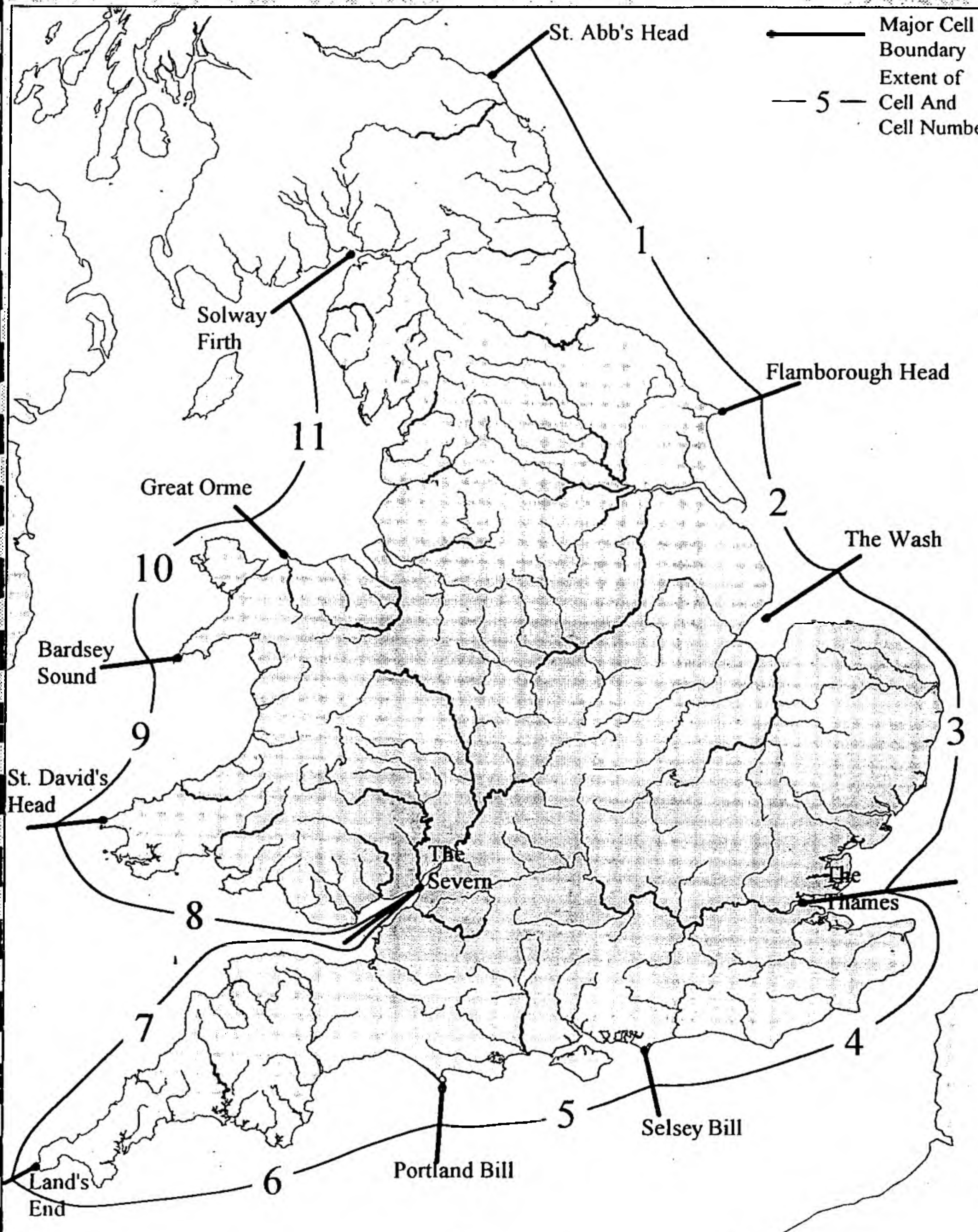
Consideration has been given to the position of the baseline sampling sites in relation to estuaries or major oceanographic features.

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 signal. 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 7: Lands End to Severn Estuary

Executive Summary

This littoral cell extends along the southern side of the Bristol Channel, from Avonmouth in the north to Cape Cornwall in the south west. There is great geographical variability within this cell with higher water quality to the south west. In contrast, the major estuarine source of the River Severn, and the high level of industry in the upper Bristol Channel have some detrimental effects on water quality.

No sites were found to have concentrations in excess of the Environmental Quality Standards for dissolved metals and organic contaminants. Suspended solids measurements were the highest recorded in the whole baseline survey on each occasion.

Spatial chlorophyll-*a* results show that the high nutrient values recorded in the Upper Bristol Channel were not resulting in high chlorophyll-*a* concentrations at the time of survey, which is probably due to the suspended solids preventing light penetration. A phytoplankton bloom was recorded close to Boscastle, Devon, during the Summer survey, which is also shown in the laboratory results.

In terms of local oceanographic features noted during the surveys, examples are seen of the development of headland eddies and other suspended matter transport which may have implications on local water quality. The use of thermal remote sensing data in establishing the extent of influences of power station outfalls is illustrated, as is the use of underway transmission and salinity data in establishing the extent of the Severn Estuary influence.

1. Introduction

This littoral cell extends from Lands End to the Severn Estuary, which represents approximately 2700 km^2 within the coastal zone for which the Environment Agency has responsibility for controlled water, as shown in Figure 1. Of this 750 km^2 are estuarine water, which includes all of the Severn Estuary as the littoral cell boundary does not extend offshore.

During 1995 collection of water samples for laboratory analysis and underway data was carried out by Vigilance. Four boat surveys were conducted in Winter (March/April), Spring (May/June), Summer (July) and Autumn (September). Two aircraft surveys were carried out in July and September.

2. Water chemistry results

2.1 Background

This littoral cell extends from Lands End to Avonmouth, with a total there are 23 laboratory sampling sites in this littoral cell located approximately 15 km apart (see Figure 1). The Severn Estuary is the major determinant of variation in water quality in the cell.

2.2 Nutrients and chlorophyll-*a*

2.2.1 Total Oxidised Nitrogen

TON concentrations recorded a maximum of 3056 µg/l N in early Spring, compared with a survey maximum of 5655 µg/l N. During Spring the more southerly sites recorded concentrations below the minimum reporting value (MRV) of 10 µg/l N. The northerly sites had high concentrations for this season, with a value of 2127 µg/l N at No 1 Beacon (119).

2.2.2 Silicate

Concentrations of silicate showed the same pattern, with a maximum of 1412 µg/l Si recorded at Avonmouth (118) in early Spring. In each survey the highest concentration of silicate was recorded Avonmouth (118) or No 1 Beacon (119)., although the Summer and late Spring surveys recorded lower concentrations than in early Spring and Autumn.

2.2.3 Orthophosphate

Orthophosphate concentrations were highest in Autumn, with a maximum of 331 µg/l P at Avonmouth (118). This site also showed the highest concentration in early Spring and Summer, equal to 105 µg/l P and 166 µg/l P respectively.

2.2.4 Total Ammoniacal Nitrogen (Ammonia)

Ammonia concentrations were generally above the laboratory MRV of 1 µg/l N, but show little geographical dependence, with, for example, the concentrations equal to approximately 100 µg/l N in early Spring at all sites. Concentrations in late Spring are all below the MRV, with typical Summer concentrations of 20 µg/l N and typical Autumn concentrations of 3 µg/l N.

2.2.5 Nitrite

Nitrite concentrations were generally low, with most sites below the MRV of 3 µg/l N even during the early Spring survey. Furthermore there was no geographical pattern in the concentrations recorded.

2.2.6 Chlorophyll-a

Chlorophyll-*a* concentrations were generally low in early Spring and Autumn, except for sites located around the mouth of the Severn which showed elevated concentrations at this time. For example, the Avonmouth site (118) recorded a concentration of 9.37 µg/l in early Spring. The late Spring survey showed relatively low levels in comparison to other areas around the coast of England and Wales, with the maximum being only 5.58 µg/l at The Carracks (98) in Cornwall. During Summer, a region of high concentration was recorded between The Carracks (98) and Boscastle, reaching a peak at Boscastle of 24.77 µg/l, which is the national survey maximum.

2.2.7 Nutrients/chlorophyll-a Summary

The seasonal cycling of nutrients with higher values in early Spring and the lower values in late Spring is consistent with the arrival of the phytoplankton bloom between the two surveys. TON, silicate and phosphate concentrations show a clear geographical pattern with very low concentrations around southern Cornwall, extending to extremely high concentrations, in some cases the maximum recorded during a survey at Avonmouth (118) and in the Severn Estuary.

The Upper Bristol Channel showed relatively low chlorophyll-*a* concentrations due to the high suspended matter loading. The large number of particulates within the water column impede the transfer of light to phytoplankton within the water column. The two baseline sampling sites in the Upper Bristol Channel, at Avonmouth (118) and No 1 Beacon (119) did, however, show high chlorophyll-*a* concentrations in early Spring. This is potentially artificially induced by the high nutrient values at these sites.

2.3 Suspended Solids

Suspended solids concentrations were the highest recorded for the entire coastline of England and Wales in each of the four surveys, with concentrations exceeding 900 mg/l during the Autumn survey. The early Spring survey recorded lower concentrations than the Autumn survey, with a concentration of 687 mg/l at Avonmouth. This is due to the date of the survey in April, when riverine inputs have begun to decrease and there is less agitation of sediment due to weather conditions.

Additionally, a strong geographical pattern is seen, with a rapid increase in suspended solids concentrations as the influence of the Severn Estuary becomes apparent. This is apparent between sites at Bude (106) and Combe Martin (111) depending on season and tidal state.

2.4 Metals

2.4.1 Total Mercury

Total mercury concentrations were in some cases high, which is a result of the high suspended solids concentrations. This is because metals are leached from the sediment prior to analysis for a total metal measurement. The Carracks (98) sampling site recorded a concentration of total mercury equal to 0.42 µg/l Hg during the Summer survey. This is higher than the EQS level for dissolved mercury, and may indicate non-compliance with the EC Dangerous Substances Directive. However the annual mean calculated for the four surveys was below 0.3 µg/l Hg. Elevated concentrations of mercury were found at Avonmouth (118) and No 1 Beacon (119) throughout the four surveys.

2.4.2 Dissolved Cadmium

Dissolved cadmium concentrations were below the EQS level at all times, with very low concentrations levels to the west of Porlock (113), generally less than the MRV of 0.042 µg/l Cd. There is some geographical pattern, with higher results always recorded towards the Upper Bristol Channel, possibly associated with industrial activity at Avonmouth.

2.4.3 Dissolved Copper

Dissolved copper concentrations showed higher values in the Upper Bristol Channel and very low values to the south west of the cell. The maximum value was recorded in early Spring at Bridgwater Bar (115) equal to 2.97 µg/l, compared with an EQS level of 5 µg/l.

2.4.4 Dissolved Lead

Dissolved lead concentrations were low, with many sites below the laboratory MRV of 0.024 µg/l Pb. In addition, there was little geographical pattern. Total lead concentrations were, however, high at Avonmouth (118) in early Spring and Autumn, when the suspended solids concentrations were at their highest.

2.4.5 Dissolved Arsenic

Dissolved arsenic concentrations were all below the MRV of 2 µg/l As.

2.4.6 Dissolved Zinc

Dissolved zinc concentrations were all low with no apparent geographical pattern, but with the highest results seen in Summer. For example the Padstow sampling site (103) showed a concentration of 23.2 µg/l Zn, compared with an EQS of 40 µg/l Zn.

2.4.7 Dissolved Chromium

Dissolved chromium concentrations were low throughout the four surveys, with many sample below the MRV of 0.35 µg/l Cr. Furthermore there was little geographical or seasonal cycle.

2.4.8 Dissolved Nickel

Concentrations of dissolved nickel were low, with concentrations generally below 1 µg/l Ni. This compares with an EQS level of 30 µg/l Ni.

2.4.9 Metals Summary

Concentrations of dissolved metals within this littoral cell showed little geographical pattern, with no clear increase towards the Upper Bristol Channel. Moreover results were not high in comparison to national average figures. Total metals results did, however, record some high concentrations, which is due to the take up of metals by sediments. This may have accounted for the lower dissolved concentrations.

2.5 Organic Determinands

Water samples were analysed for twenty three trace organic determinands at four baseline sites within this littoral cell, at Cape Cornwall (97), Padstow (103), Bideford (109), Bridgwater Bar (115) and No 1 Beacon (119). Only γ-HCH and α-HCH gave positive analyses, whereas the other 22 determinands were not detected at their laboratory MRVs of 0.001 µg/l for the entire survey.

During the early Spring survey, values above the MRV were recorded for γ-HCH and α-HCH, but the total did not exceed the EQS for total HCH. In Spring and Summer only γ-HCH recorded a concentration above the MRV, but at all sites. Concentrations were lowest in Autumn, with only two sites, Bridgwater Bar (115) and No 1 Beacon (119), recording a concentration above the MRV for γ-HCH.

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. There is little variation in chlorophyll-*a* concentration with most regions between 2 and 4 µg/l at the time of survey. Slightly elevated concentrations were seen around Newquay, up to 6 µg/l. In addition slightly lower concentrations were found between Ilfracombe and Lynton, with values less than 2 µg/l. There is little information on the Upper Bristol Channel due to the high suspended solids ooading effecting the action of the algorithm.

Figure 3 shows the chlorophyll-*a* concentration determined from calibration of the underway fluorimeter with laboratory samples. This map shows greater variation, with more information on the Upper Bristol Channel. A region of high concentration is recorded to the south of Bude which represents a phytoplankton bloom (see Section 4). Concentrations in the Upper Bristol Channel are between 2 and 6 µg/l. This shows that the very high nutrient concentrations in this region are not resulting in elevated chlorophyll-*a* concentrations at the time of this survey. This is due to the high levels of suspended sediment shielding light from the phytoplankton.

These two techniques allow the spatial pattern of the chlorophyll-*a* concentration of this region to be assessed. One area, to the south of Bude, had high chlorophyll-*a* concentrations in excess of 10 µg/l at the time of survey. Collection of such data over time would allow a judgement to be made of whether this region often experiences such algal bloom events and is therefore potentially susceptible to eutrophication.

4. Local oceanographic descriptions

The image data collected by the CASI and from the thermal video system during July and September 1995 was investigated for variation in ocean colour signal or temperature signal, and in order to identify key oceanographic features, such as fronts and gyres. Additionally, the underway data from the four campaigns was investigated for variation in any of the parameters measured: temperature, salinity, dissolved oxygen, transmission and fluorescence.

This will allow an overview of the results to be presented and attention to be focused on areas of interest. From this investigation 7 areas were selected as warranting further description:

1. Flow patterns around Lands End
2. Padstow Bay
3. Phytoplankton bloom off Boscastle
4. Flow patterns around Woolacombe

5. Extent of estuarine influence
6. Hinkley Point power station outfall
7. Avonmouth

4.1 Flow patterns around Lands End

The two CASI images collected off Cape Cornwall on the northern tip of Lands End in July and September show different characteristics in terms of the direction of flow of suspended matter off the headlands and islands. Lands End acts as a flow boundary which explains why it is a boundary between littoral cells. There is little or no flow around the headland, with currents either dividing to pass to the north and south, or on the return tide flowing out into the Atlantic. The two images are examples of each of these situations (see Plate 1), with currents in July directed to the north east, and those in September being slacker but directed to the south west. The imagery from July also shows the presence of more wave patterns, which is due to the higher wind speeds recorded on this day in comparison to the September image. The wind direction is from the south east and therefore would not itself cause the observed flow patterns.

This imagery endorses the use of littoral cell boundaries for the comparison of variation in water quality. There is a clear division in water flow at this point which results in differing water quality to the north and south of Lands End.

4.2 Padstow Harbour

The CASI imagery shows the presence of an eddy structure within Harlyn Bay to the east of Trevose Head. This is revealed most clearly in the imagery taken under sun glint conditions as shown in the top image of Plate 2. The lower image, taken just 5 minutes later but at a different flight line orientation still shows the structure but in less detail. This structure is not seen in imagery collected during September and October. The direction of the eddy suggests a north-easterly flow direction. However the predominant flow at this time is south-westerly. This is thus probably a local scale feature caused by the presence of Trevose Head to the west.

The CASI imagery also shows great variations in the flow patterns within Padstow Bay, which may have implications on the interpretation of the results of laboratory analysis from the baseline sampling. Plate 3 shows imagery from 31st July 1995, with a plume of material extending out from the bay. The position of the laboratory sampling site (103) is also shown, and it is obvious that the laboratory samples would be influenced by this plume. In the other two images, the main flow of sediment is along the northern side of the bay and around Pentire Point. In the image from October 8th the flow of sediment extends further past the headland. The tidal stream in this case is greater due to the imagery being recorded close to Spring tides.

Underway data for the early and late Spring surveys show a decrease in %transmission on passage across Padstow Bay coincident with the plume of material exiting the harbour. Data from Summer and Autumn show a drop in transmission associated with passage into the harbour. Results from the laboratory samples show no particularly high values during 1995. Whilst it is not possible to compare directly between the ship and aircraft data as they were collected on different dates it is clear that there is a strong outflow from the River camel, which is not rapidly dissipated at some tidal states. In some cases, it is shown to influence the shoreline around Pentire Point. This area therefore has complex circulation patterns which may have implications on the water quality of the region.

4.3 Phytoplankton bloom off Boscastle Head

The underway data from 24th July 1995 shows the presence of a large phytoplankton bloom situated between Tintagel Headland and Boscastle. This is shown in Figures 4 and 5. Fluorimeter measurements increase four fold as the bloom is traversed, with a corresponding decrease in transmission, as the particulate nature of the phytoplankton bloom decreases the light transmittance through the water column. Laboratory samples taken at Boscastle (103) record a chlorophyll-*a* concentration of 24.77 µg/l, with the sample from Port Isaac (104) having a concentration of 12.14 µg/l.

Both of these concentrations are above the limit of 10 µg/l which has been suggested by the Department of the Environment in their document "Identification of Sensitive Areas" as being an indicator of eutrophication. Nutrient measurements from these sites do not however show a marked variation from neighbouring sites, and the ratio of nitrate to phosphate is unchanged through this region.

Such high chlorophyll-*a* concentrations are unusual for this time of year, and this is one of the largest blooms recorded in the summer survey. Investigations should be carried out to establish whether such blooms are common in this region and whether they cause an environmental nuisance. This bloom is located offshore and their is no sign in the CASI imagery of the effects coming onshore.

4.4 Sediment transport patterns around Woolacombe

CASI imagery from September shows the presence of complex sediment patterns around Baggy Point and Morte Point near to Woolacombe. Plate 4 shows imagery from three different dates during 1995. The image from 20th September shows the formation of an eddy off Baggy Point. The tidal stream at this time is northerly with the eddy being formed in the lee of the headland. The image from 10th October has a similar tidal stream direction, but of much greater magnitude, being closer to Spring tide conditions. This appears to have resulted in a more direct transport of sediment past the headland. Imagery from 25th July shows the development of an eddy on the south side of Baggy Point, due to the reversal of tidal flow at this time.

The baseline laboratory sampling point for this region is located to the north of Morte Point, with is on the northern edge of this imagery. It is possible that the measurements from this site would be affected by the direction of flow off this headland, were it to mimic that seen off Baggy Point. Investigation of the laboratory sampling results, in particular the measurement for suspended solids, shows that this sampling point has a much higher concentration than neighbouring sites in Autumn. Tidal streams for this day suggest that the sampling point is potentially within the influence of an eddy of higher suspended material off the north of Morte Point. However, this feature is also detected in the underway data with a decrease in transmission at this point extending towards Ilfracombe, which points to a larger structure than seen in the imagery.

Patterns of suspended sediment in this region are thus shown to be complex. There is a tendency for sediment to circulate close to the shore, and his should be considered when positioning effluent outfalls. The low suspended sediment concentration immediately offshore indicate little exchange with outer coastal waters.

4.5 Extent of estuarine influence

Underway measurements from Vigilance show a gradual decrease in the %transmittance on transit up the Bristol Channel (see Figure 6). However, a marked decrease is seen in the region of Minehead which marks the extent of flow of sediment from the Severn Estuary. This is also shown in the CASI imagery as the sediment has a characteristic brown colour due to the high clay content. An additional indicator of the estuarine influence is a decrease in salinity to estuarine levels, which is also seen in the underway data.

The extent of this influence is both seasonally and tidally dependent. Assuming a division of 28 psu to indicate salinity similar to that seen within the Severn Estuary, this change is seen close to Minehead in the Winter, Spring and Summer surveys. During September, the salinity remains at 30 psu until north of Avonmouth. This variation is linked to the tidal state, with the September survey measurements being taken at High Water at Avonmouth when estuarine water is backed up into the estuary. The other three samples were taken close to Low Water at Avonmouth. The full extent of the low salinity region is also effected by the rainfall, with higher rainfall in early and late Spring surveys resulting in the low salinity water extending past the baseline measuring site at Minehead (114), compared with a salinity low at Bridgwater Bar (115) in Summer.

The extent of the influence of suspended sediment from the Severn is judged to be where the %transmission decreases to zero. This occurs at approximately the same point in Spring, Summer and Autumn, close to Minehead. In early Spring, however, this occurs at Foreland Head, some 30 km to the west of Minehead. This difference is caused by the greatly increased concentrations of suspended particulate matter throughout the coastal zone in winter which are due to increased riverine input and agitation of sediments.

Laboratory samples also show this geographical variation with the occurrence of generally higher concentrations of metals and nutrients within the region which is under the estuarine influence. This has been discussed more fully in the water chemical results.

The variation in the position of the boundary line between estuarine and coastal water is therefore seen to vary between Minehead and Avonmouth, a distance of approximately 60 km. The variation is dependent on tidal state, season and meteorological conditions.

4.6 Hinkley Point power station outfall

The outfall of cooling waters from Hinkley Point power station is noted on the thermal video imagery in both July and October, as shown in Plate 5. In July the flow is to the West, extending along the coastline towards St. Audrie's Bay. In October the flow is in the opposite direction, extending up the coastline towards the mouth of the River Parrett. This reversal is explained by the different tidal state between the two images. The presence of the outfall is also visible in CASI imagery (see Plate 6), but the effect is less marked being simply shown by the presence of white capping caused by the turbulence of the incoming water. The outfall has no optical signal as only the temperature of the water is changed by the power station.

The October image was taken at three hours after Low Water at Avonmouth, at Spring tides. Thus the extent of influence of the warm water is close to maximum. Examination of the tidal streams for this day, show that the tidal currents should be at their full maximum one hour later. The imagery shows the warm water signal becoming complicated towards the mouth of the River Parrett by the presence of sandbanks, marked A, which themselves cause warming of the shallower water. The warmed water from the power station, however, may be clearly distinguished to the west of these banks, marked B, some seven kilometres from the outfall. At this tidal state, the influence does not extend past the river mouth, but is directed towards it.

In July, the imagery was taken four hours after High Water at Bristol, and four days before Spring tides, thus the extent of the flow is not maximum. In this case the extent of influence of the warmer water is seen to reach St Audrie's Bay, to the east of Watchet. However, the area of warmed water is located offshore at this point, with no warming apparent close to the coast. Clear warming of coastal waters is seen for three kilometres to the west of the outfall at this tidal state.

Thus collection of imagery at two differing tidal states has allowed an assessment to be made of the extent of influence of this cooling water from this power station outfall. It does not, however, link this warming with any detrimental environmental effects, which would require that measurements be taken of the local biology. The system measures only the surface temperature of the water, and vertical profiles would be required to fully assess the effects.

4.7 Avonmouth

Two baseline sampling sites are located close to the industrialised area of Avonmouth, off Avonmouth (118) itself and at Clevedon (117), which is located within the main channel from Avonmouth. CASI imagery of the region shows high levels of variability, with the outfall from the Holes Mouth evident in both images, although not with the same intensity as in previous years (see Plate 7). The tidal state on these two images from July and October is similar being at or around low water at Avonmouth. In both images the flow from the outfall is directed southwards.

The high level of industry is this region is shown in the results from the laboratory analysis of water samples. This has been described in the section on water chemistry.

This area continues to be a challenge with regard to water quality. The influence of industrial outfalls such as Holes Mouth can be assessed using remote sensing techniques over a tidal cycle, possibly associated with dye tracing or other marking methods.

5. Conclusions

Analysis of data from 1995, showed a marked variation in water quality between sampling sites located at the south west of the region and those in the more industrialised area around Avonmouth. No sites recorded concentrations of metals or organic contaminants in excess of the EQS level. Underway data recorded changes in %transmission associated with small scale local features, and in addition clearly showed the progressive increase in turbidity on passage up the Bristol Channel. The fluorimeter data recorded the position and intensity of a phytoplankton bloom off Boscastle Head in Summer.

Spatial chlorophyll-*a* results also show this area of high chlorophyll-*a* concentration. The Upper Bristol Channel is shown to have chlorophyll-*a* concentrations less than 6 μg/l at the time of this survey. This shows that the high concentrations of nutrients recorded in the laboratory samples are not resulting in nuisance phytoplankton blooms at this time.

The oceanography of the region is mainly controlled by the strong tidal flows along the Bristol Channel. These result in the development of eddies around headlands and other sediment transport patterns which due to their reversals with reversing states of the tide may have implications on local water quality. The development of these features may be investigated using CASI data as the eddies pick up water of differing suspended matter concentration which has a different ocean colour signal. The outfall of cooling water from Hinkley Point power station is the most clearly marked feature in the thermal video data, revealing the extent of influence of this anthropogenic sources on water quality.

Figure 1.

Littoral Cell 7,* From Land's End to The Severn.

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

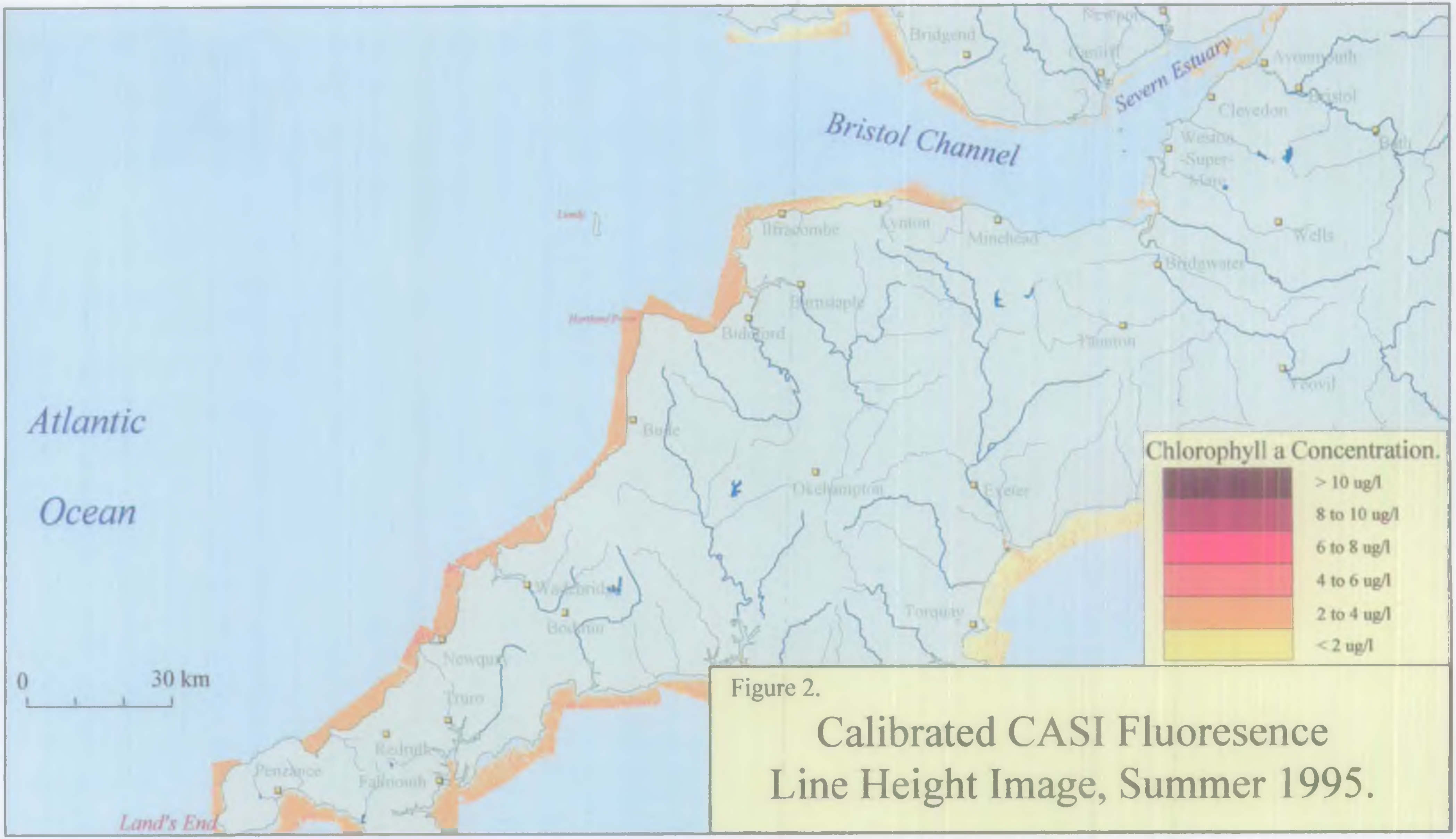


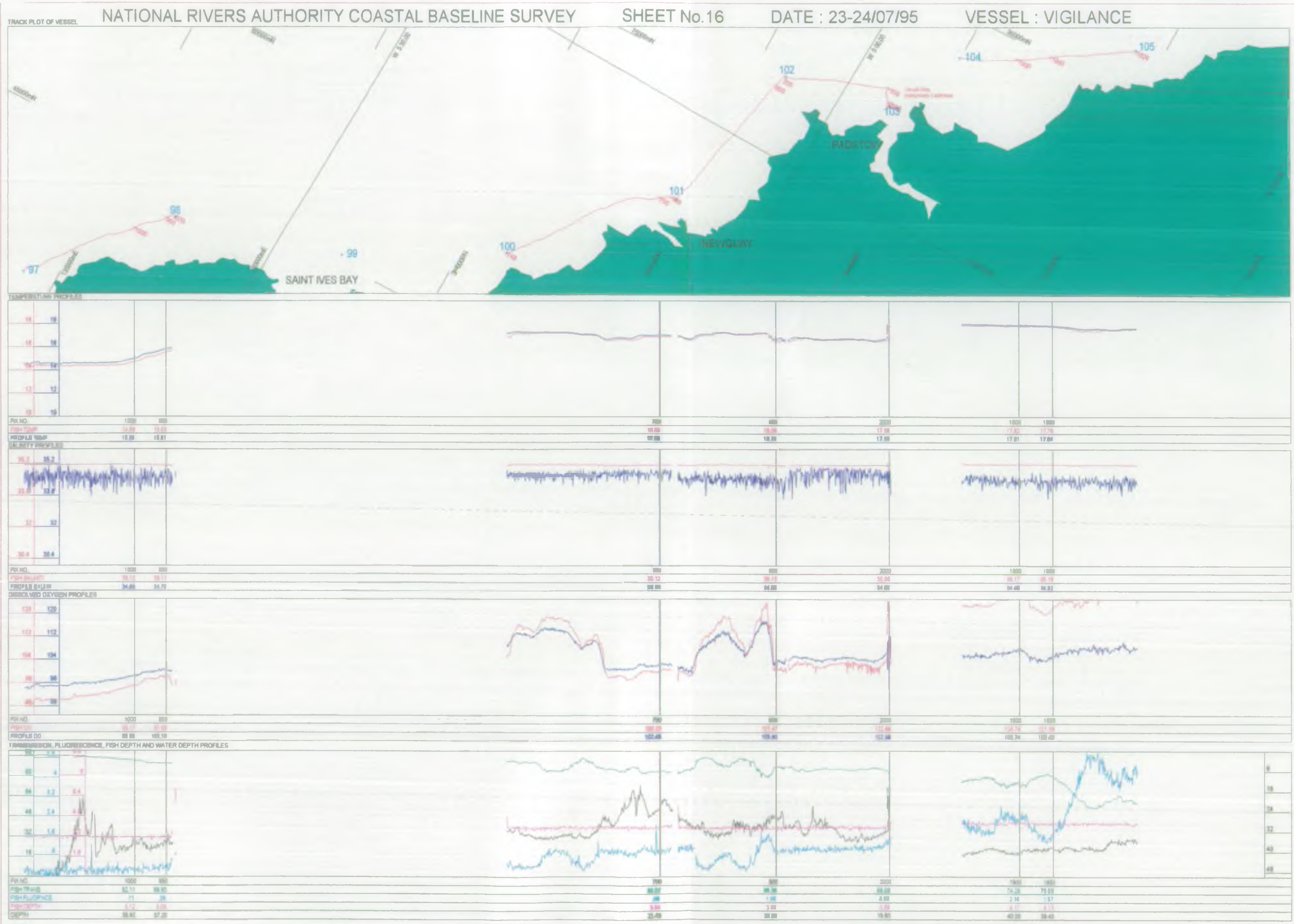
Figure 2.

Calibrated CASI Fluoresence Line Height Image, Summer 1995.

Figure 3.

Calibrated Continuous Track Fluorimeter, Summer 1995.

Figure 4



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

Figure 5

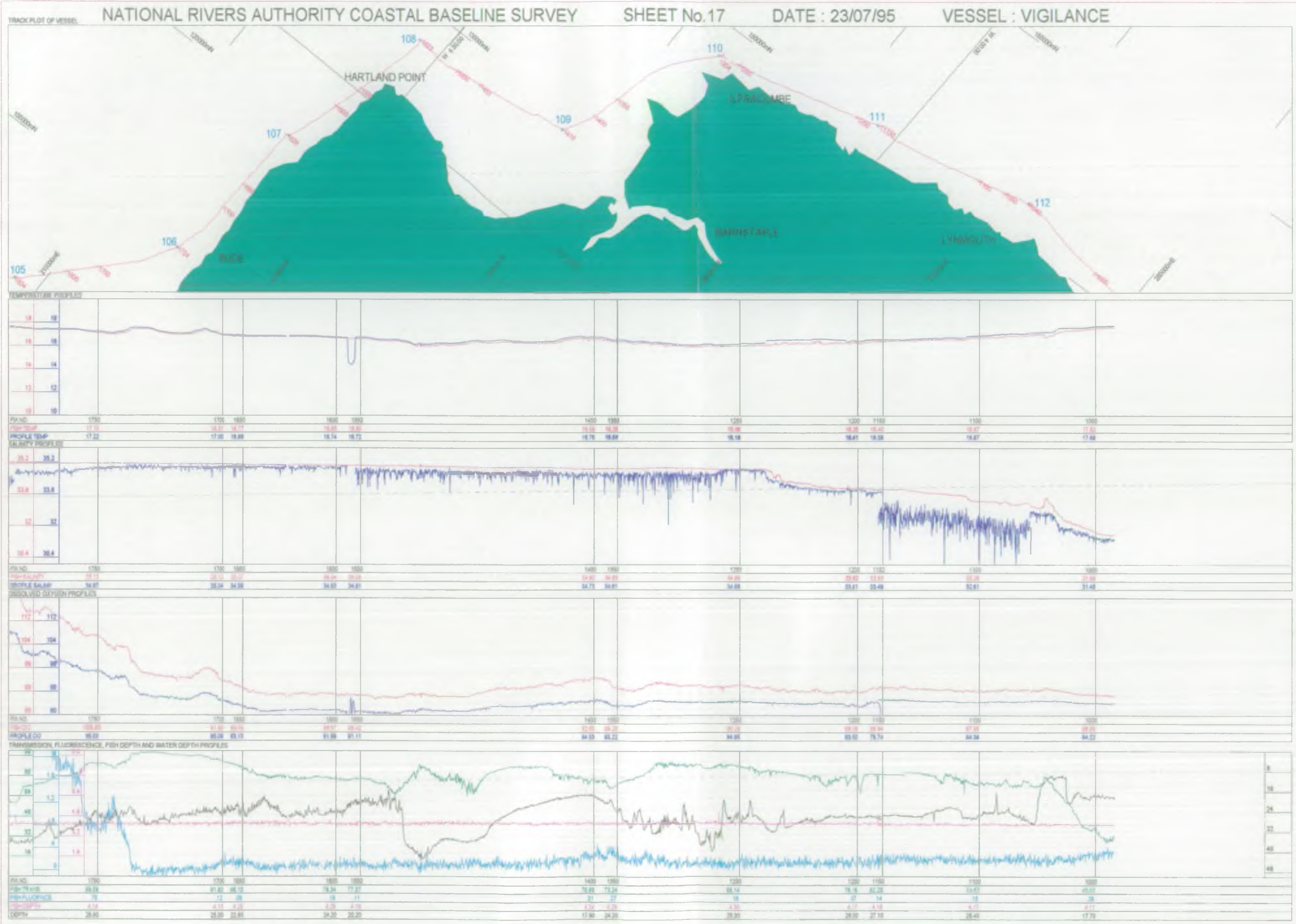


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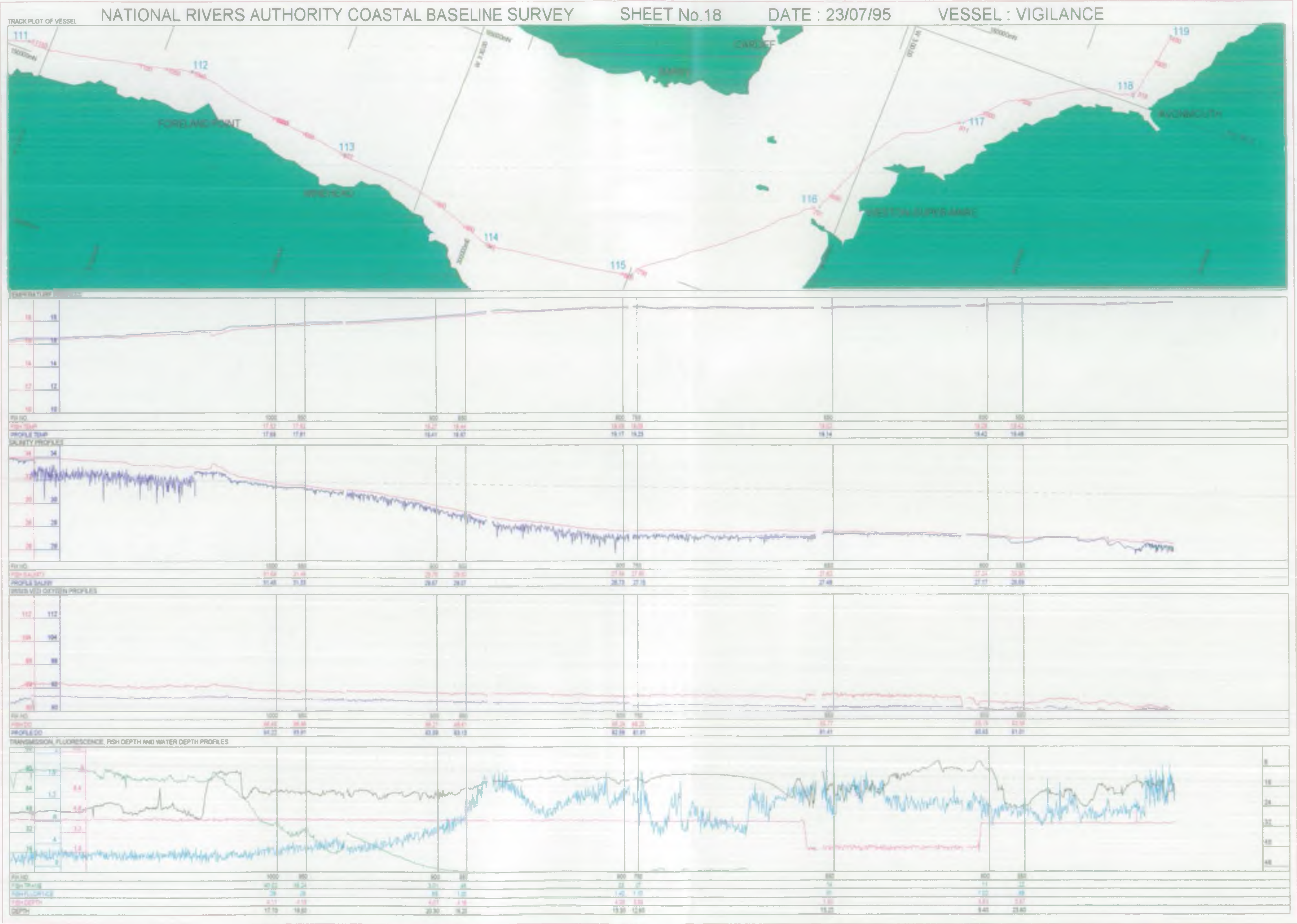
Figure 6



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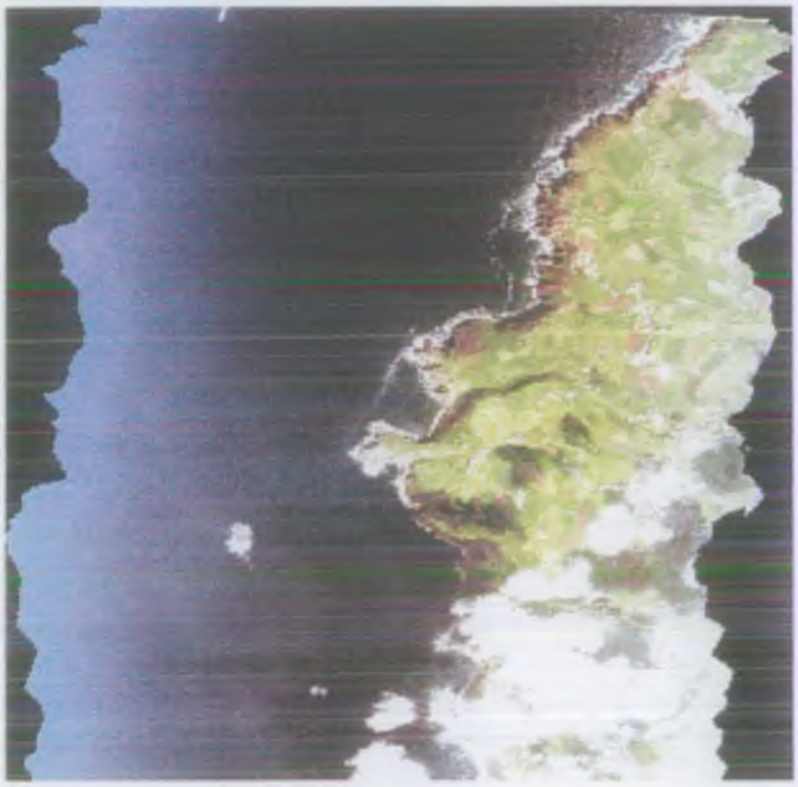
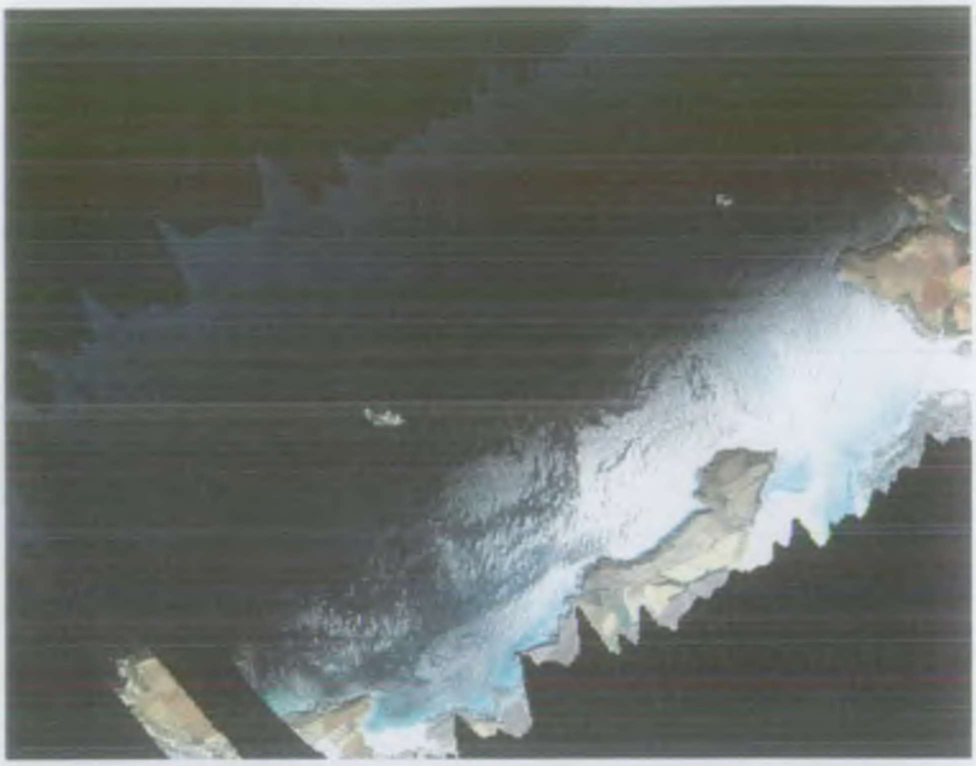
24th July 1995, 11:57 GMT



8th October 1995, 14:22 GMT

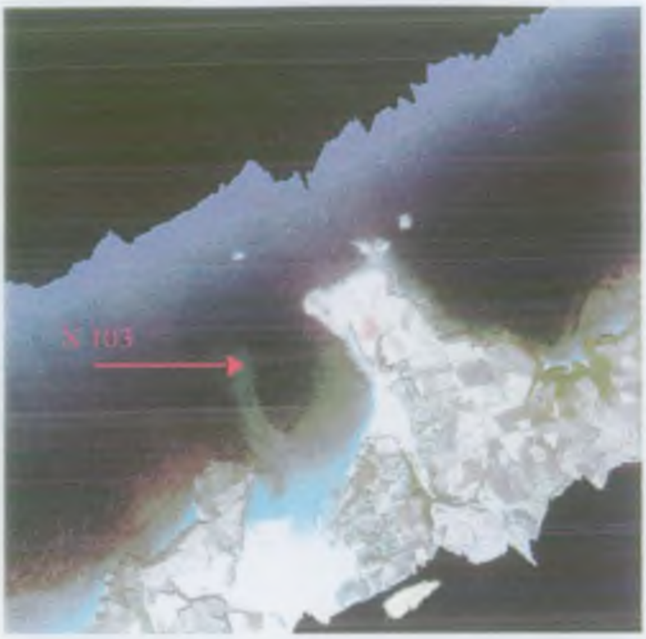
Plate 1: Cape Cornwall, Nr. Lands End
CASI enhanced true colour composite images



31st July 1995, 11:54 GMT

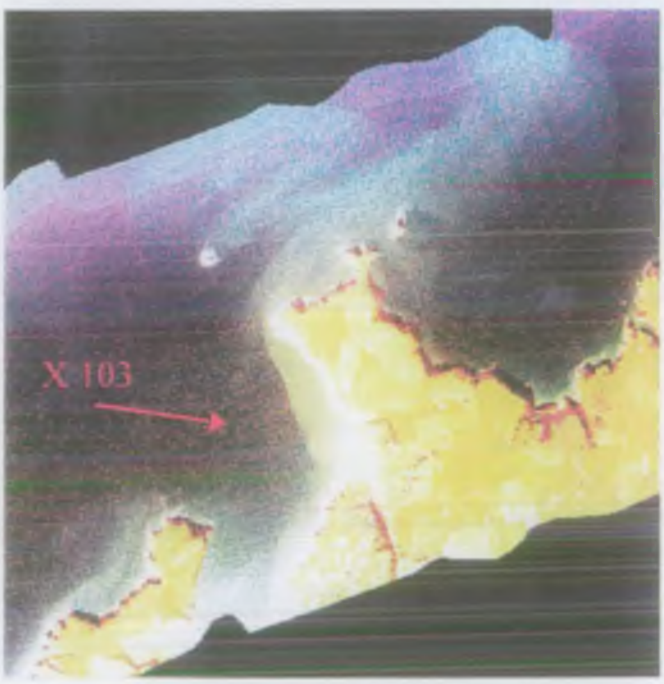
31st July 1995, 12:00 GMT

Plate 2: Harlyn Bay, nr Padstow
CASI enhanced true colour composite images



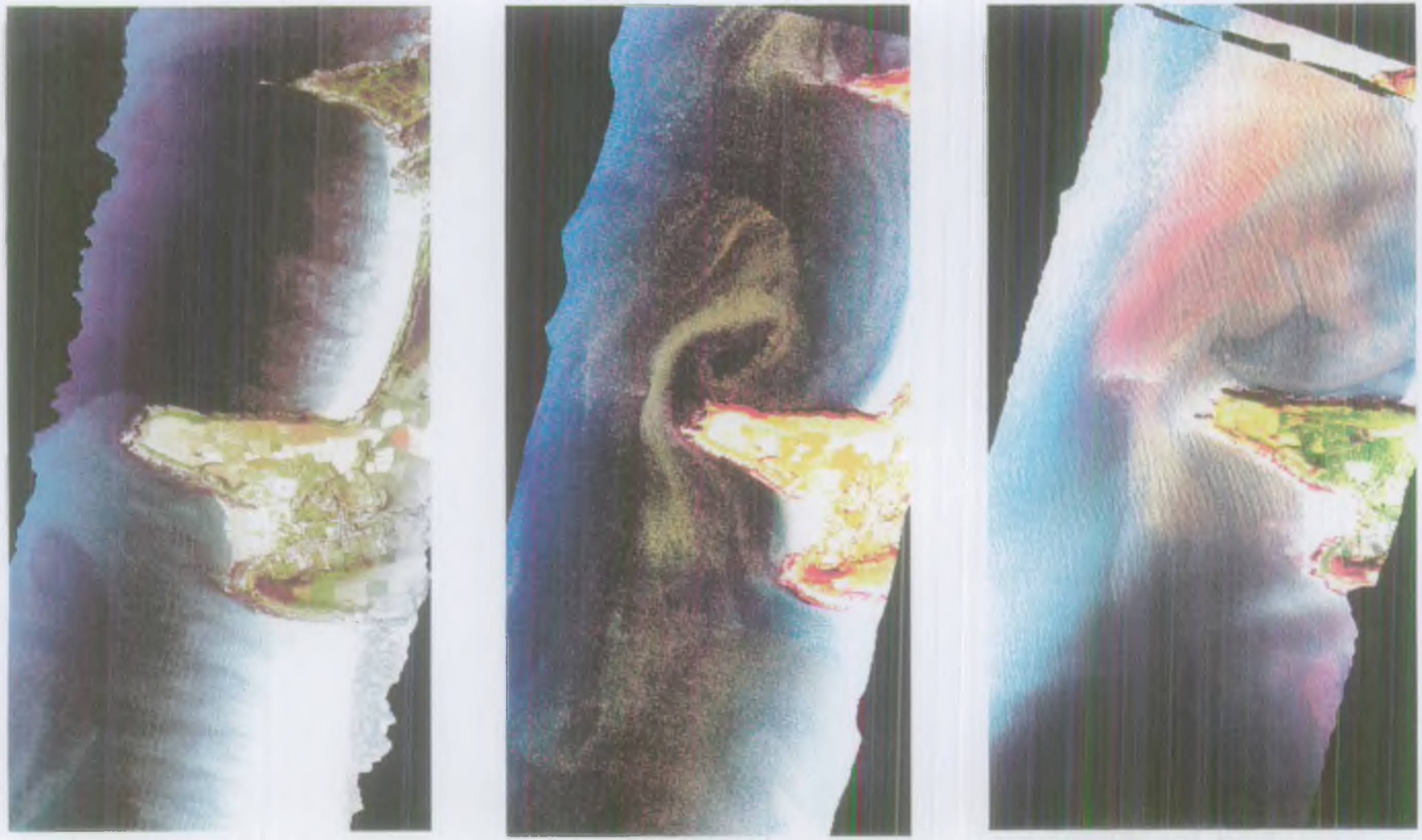
31st July 1995, 12:00 GMT

20th September 1995, 11:51 GMT



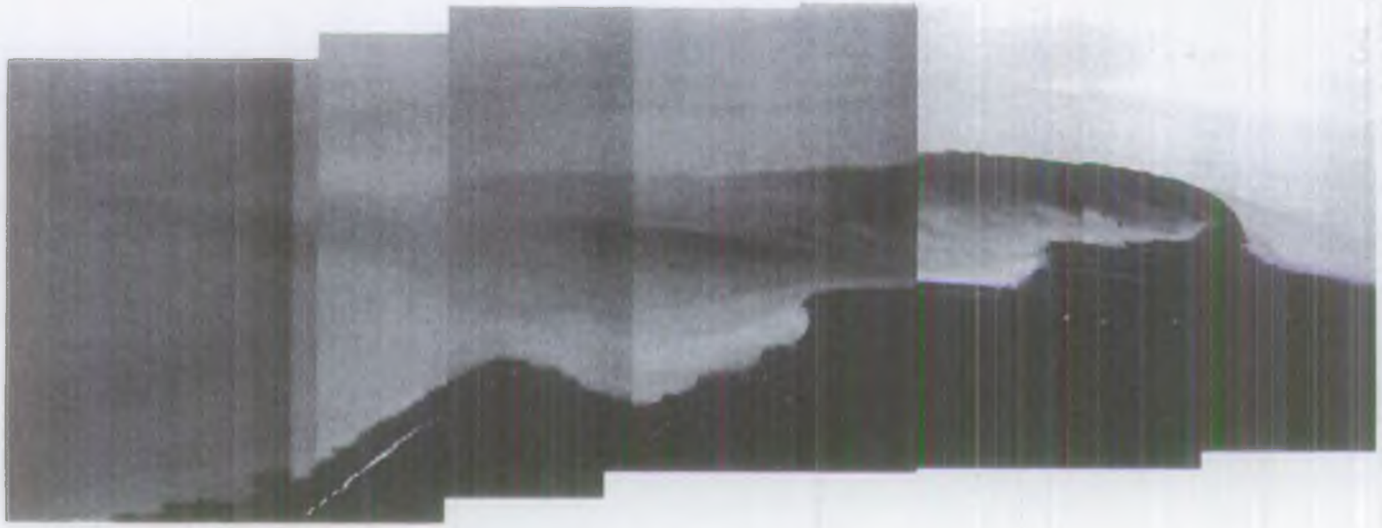
8th October 1995, 14:01 GMT

Plate 3: Padstow Harbour
CASI enhanced true colour composite images
X 103 represents the Padstow baseline sampling site

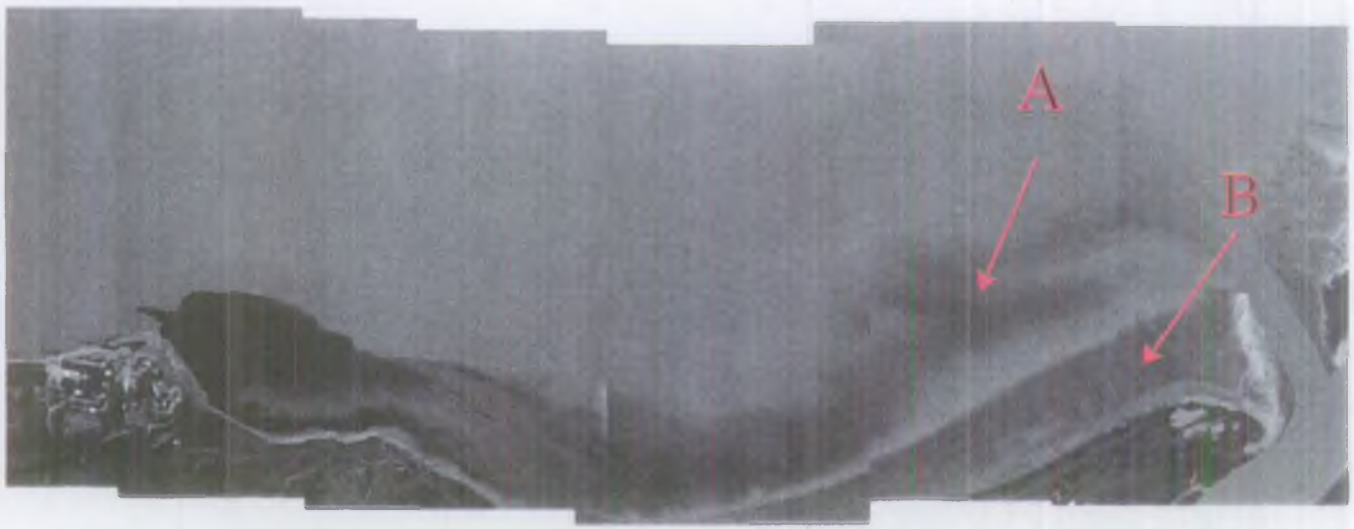


25th July 1995, 09:11 GMT | 20th September 1995, 12:11 GMT | 10th October 1995, 15:42 GMT

Plate 4: Woolacombe Bay, Devon
CASI enhanced colour composite images

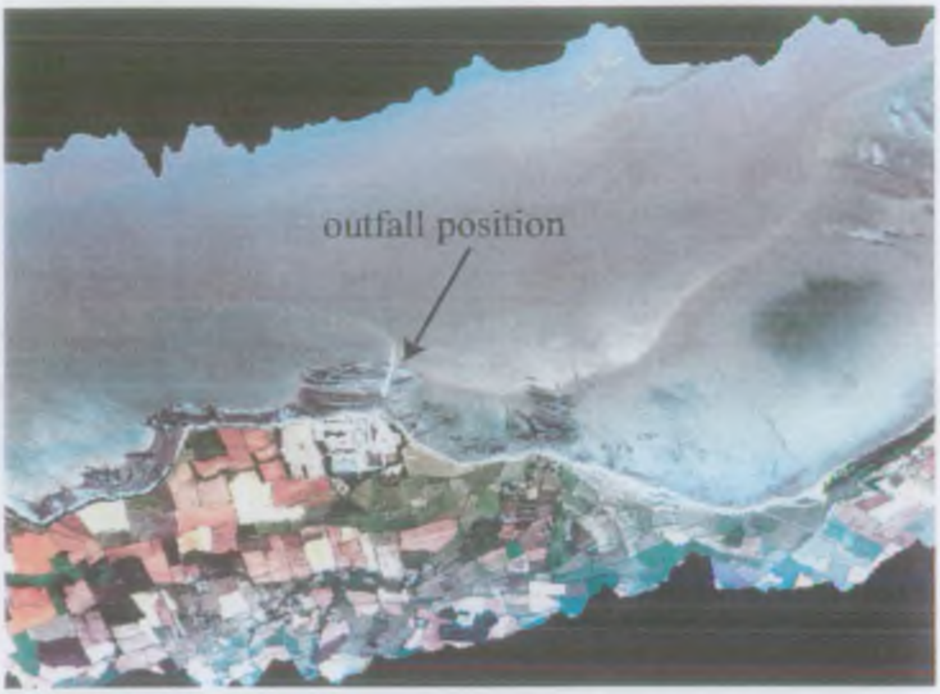


July 25th 1995, 09:54 GMT

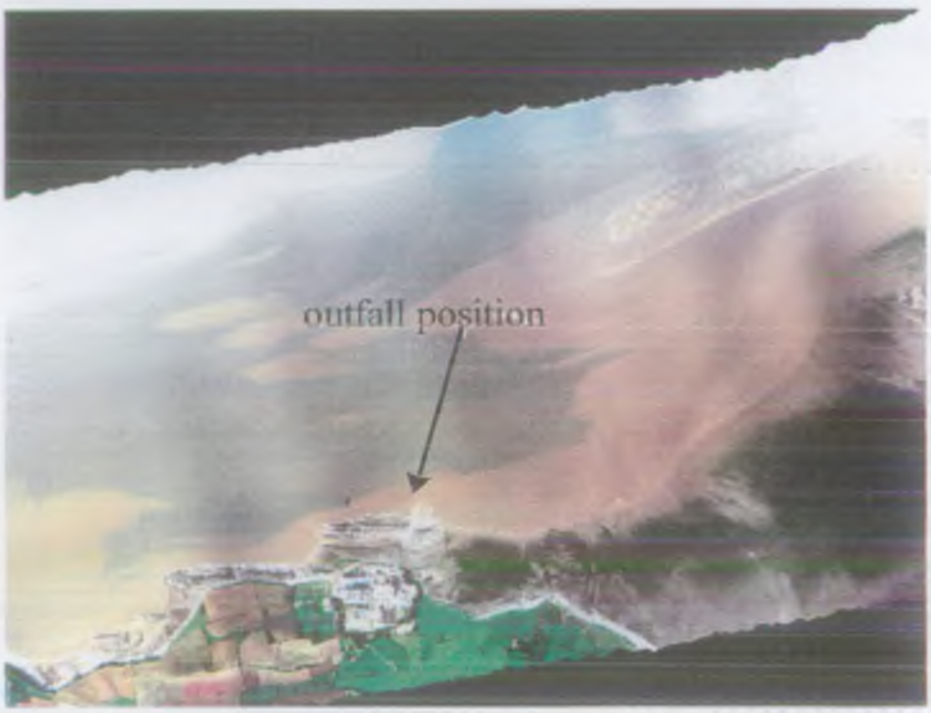


October 10th 1995, 15:18 GMT

Plate 5: Hinkley Point power station outfall
Thermal video image composites



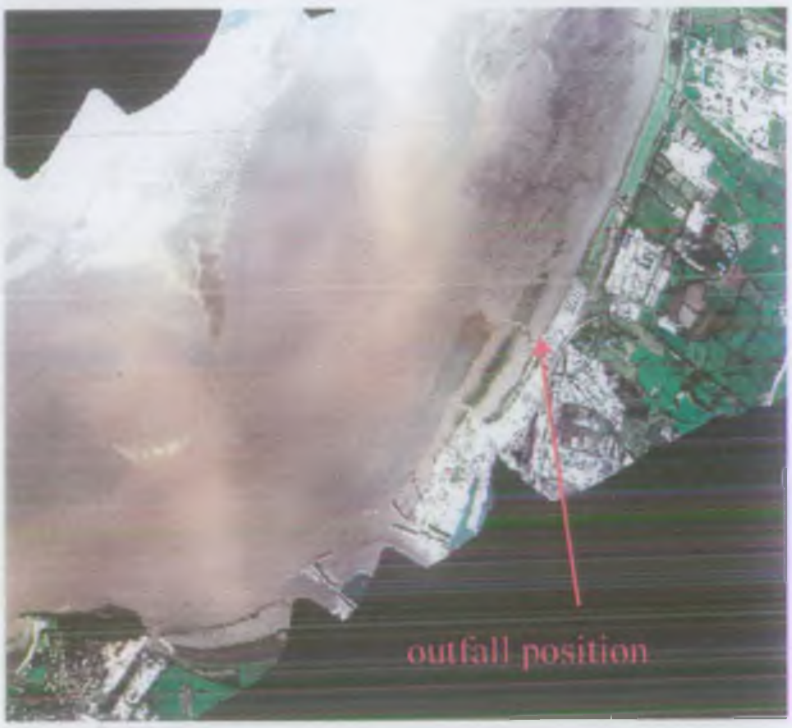
25th July 1995, 09:54 GMT



10th October 1995, 15:18 GMT

Plate 6: Hinkley Point power station outfall CASI enhanced colour composite images

25th July 1995, 10:29 GMT



10th October 1995, 14:53 GMT

Plate 7: Avonmouth, Port of Bristol
CASI enhanced colour composite images