EA-NCEDS BOX 5

ENVIRONMENT AGENCY

National Centre for
Environmental Data and Surveillance

Walney Channel Inter-tidal Vegetation Study

The Environment Agency wishes to acknowledge the financial assistance of the European Union Life Project in funding this report.

EA - Conservation Box 4

Environment Agency
National Centre for Environmental Data and Surveillance

16 February 1999

Walney Channel Inter-tidal Vegetation Study

Evaluation of the EA's Compact Airborne Spectrographic Imager (CASI) as a practical technique for mapping and assessing changes in the distribution and quality of eel grass beds and saltmarsh vegetation.

The Environment Agency wishes to acknowledge the financial assistance of the European Union Life Project in funding this report.

Background

English Nature as part of their Habitats Directive, European marine site and BAP work have a need for key information regarding the mapping, monitoring and management of eelgrass *Zostera angustifolia* beds and saltmarsh in the South Walney channel. The Environment Agency, which has an interest in mapping inter-tidal habitats, is involved both as a partner and contributor to the overall project.

Three linked programmes of work were proposed:

1. **Evaluation of the Environment Agency's CASI as a practical technique for mapping and assessing changes in the distribution and quality of sea grass beds and saltmarsh vegetation.**

2. **Restoration and future maintenance or enhancement of eelgrass *Zostera angustifolia* beds.**
   A *Zostera* monitoring programme to collect information needed to assess the constraints operating on the recovery, maintenance and enhancement of the eelgrass beds.

3. **Saltmarsh survey of Morecambe Bay European marine site (cSAC/SPA)**
   The mapping of key saltmarsh vegetation (habitats and species) within Morecambe Bay as a baseline for the European marine site management scheme.

This report focuses on the first programme of work which was undertaken by the Environment Agency in September 1998.

Introduction

The objective of this study is to evaluate the applicability of the CASI (Compact Airborne Spectrographic Imager) system for mapping and assessing changes in the distribution and quality of eelgrass beds and saltmarsh vegetation. This study continues the work started in 1997 when the Cumbrian coast was covered by aerial photography for detailed vegetation mapping. CASI was also flown over the Walney Channel to assess the potential for saltmarsh and *Zostera* discrimination but a lack of ground data to validate the CASI imagery limited the work which could be carried out.

A project was proposed in which CASI imagery would be flown over the Walney Channel in the months of August/September 1998 to coincide with saltmarsh/algae vegetation maximum. An initial unsupervised classification of inter-tidal areas was to be carried out immediately so that the images could be used to target the fieldwork. Final classification would then take place with the field data used to interpret the ground cover within the classes.

CASI Overview

The CASI (Compact Airborne Spectrographic Imager) is a passive sensor, which generates imagery by detecting visible and near infrared electromagnetic energy that is reflected from the earth's surface. CASI is designed to provide a flexible system which is easy to transport and straightforward to install and operate in small aircraft. The system operates in a 'pushbroom' configuration, mapping out a swath that lies directly below the aircraft (figure 1). By instantaneously imaging the full swath width at repetitive intervals, a full image is built up line by line.

Imagery produced by the CASI consists of up to 512 pixels across the swath and the spatial resolution (area represented by one pixel) can be varied from ten metres down to less than a metre by adjusting the altitude of the aircraft and the CASI imaging lens. The maximum operational altitude of the aircraft is 10000 feet, restricting the maximum swath width to approximately 5.2 km. If the area to be imaged is larger than the swath width available at the desired resolution, it is possible to obtain a number of adjacent flight lines and join these in order to generate a single large image, or mosaic.

The CASI uses a Charge Coupled Device (CCD) detector to produce hyperspectral imagery which can comprise of up to 288 spectral bands (wavelengths), covering the electromagnetic spectrum from 430 nm (visible blue light) to 900 nm (near infra-red). The number and width of wavelength channels recorded is flexible with more channels providing more detailed spectral profiles of the different ground cover types.

The CASI has three operational modes, which are suited to different applications and should be selected according to the spatial and spectral resolution required of the data. The operational modes are:

> **Spatial Mode**: All 512 swath pixels are recorded in up to 19 wavebands. The wavelengths covered by all the bands and the width of the bands are configurable.
>
> **Spectral Mode**: Data from all 288 bands are recorded from 39 pixels across the swath.
>
> **Enhanced Spectral Mode**: This flexible mode allows a compromise between spatial and spectral modes to be achieved. The exact combination of pixels and bands that is achievable is determined by the amount of ambient light at the time of imaging.

The imagery can be geometrically corrected using data from a vertical gyroscope and a Global Positioning System (GPS) receiver which are mounted on the aircraft. These corrections compensate for variations in the aircraft attitude during image formation.

Review and application of the CASI system for inter-tidal classification to date

Initial research into the use of CASI for inter-tidal classification was carried out by the Institute of Terrestrial Ecology (ITE) as part of a NRA R&D project ('*Further Development of Airborne Remote Sensing Techniques: Cover Classification in Inter-tidal Zones and River Corridors, Institute of Terrestrial Ecology, 1995*'). The objective was to assess the potential role of CASI and to evaluate a number of vegetation and land use classification algorithms applicable to the NRA's operational classification of features in coastal zones. Ground radiometry of key surface types helped determine which parts of the visible and near-infrared spectrum were best for discriminating inter-tidal cover types. This was then used to select an appropriate bandset for airborne CASI radiometry. The report recommended that unsupervised classification be used for inter-tidal mapping since it provided a wide range of class separations and required a minimum of interactive work with moderate amounts of fieldwork.

In 1996 fourteen key estuaries in England and Wales were flown with CASI as part of a project undertaken by the National Centre to assess the value of inter-tidal mapping for EC directives ('*Aerial Surveillance of Fourteen Estuaries in England and Wales, National Centre for Environmental Data and Surveillance, 1997*'). Inter-tidal surfaces were classified for saltmarsh and algae cover with the use of limited fieldwork. The report concluded that the classifications provided accurate digital maps of saltmarsh extent and the mapped cover of green macro-algae was valuable for eutrophication studies. This work is being continued in conjunction with the Environment Agency Southwest region for mapping the extent of algae in areas potentially sensitive under the Urban Waste Water Treatment Directive.

More detailed classifications of broad saltmarsh communities have been carried out in Southampton Water, in conjunction with Associated British Ports, with the objective of monitoring changes to the saltmarsh extent over a 10 year period. Detailed fieldwork in the first year has been used to classify the saltmarsh into Upper, Mid-Upper, Low-Mid and Pioneer marsh groups. This project is currently in its third year of operation with the classification results being validated by ABP.

Further feasibility studies into the use of CASI for habitat monitoring are currently being considered by conservation bodies and other English Nature teams.

Data

The Walney Channel CASI data were flown on the 22 September 1998 at 07:32 to 08:15 GMT. The flying altitude was 5000ft with a narrow angle lens, which gives a 2m spatial resolution. The area was flown early in the morning in order to coincide with Low Water. A fifteen channel bandset was used (see below); this bandset was selected using the ITE report recommendations on which parts of the visible and near infra-red spectral range were best for discriminating inter-tidal cover types.

1998 CASI Estuary Wavelengths (nm):

Band 1:	433 - 453	Band 9:	680 - 685
Band 2:	480 - 500	Band 10:	685 - 695
Band 3:	500 - 520	Band 11:	700 - 705
Band 4:	545 - 565	Band 12:	705 - 715
Band 5:	593 - 603	Band 13:	745 - 755
Band 6:	620 - 630	Band 14:	845 - 870
Band 7:	660 - 665	Band 15:	870 - 890
Band 8:	665 - 680		

The area flown covers the saltmarsh and mudflats to the east of the Isle of Walney. Three study areas containing the key vegetation types were then selected by English Nature for classification.

The weather conditions on the morning of the 22 September 1998 were not ideal with scattered clouds and haze obscuring the ground and affecting the amount of light radiation received by the instrument. In order to capture low tidal conditions the images were flown early in the morning when the light conditions were lower than normal. The predicted further deterioration of the weather later in the month meant that the area had to be flown at the first possible opportunity before the saltmarsh and algae died back.

The presence of atmospheric haze reduces the amount of ground detail seen on the image as well as changing the spectral profiles of the ground cover. The sun's radiation is effectively scattered by the haze particles as it passes through the atmosphere. Low wavelengths, especially the blue part of the spectrum are preferentially scattered and the instrument records increased radiation levels in these spectral channels. The effects of atmospheric scattering can therefore mask subtle changes in true ground radiance.

One feature seen in the images not due to the weather conditions is a dark line of pixels which runs through the length of all the images, this is due to a broken CCD. This line is also seen in the classified images where it has been inaccurately classified as a ground cover type.

Methodology

The image data went through the following steps: i) geocorrection, ii) unsupervised classification, iii) co-registration, iv) ground truth and v) class identification.

i) Geocorrection

Airborne scanner data is prone to geometric distortions that make the comparison of image data with maps and grids difficult. The CASI system collects GPS data to locate the position of the plane geographically and aircraft roll/pitch information using on board gyroscopes. A semi-automatic geocorrection process using the GPS and roll information fits each CASI line of data within the British National Grid at an accuracy of hundreds of metres. This process was applied to each flightline to correct for the aircraft distortion and orientate the images within the BNG with a pixel resolution of 2m.

ii) Unsupervised Classification

The process by which pixels within the image are grouped into land cover categories is known as image classification. Unsupervised classification is used where the land cover is not known by the operator prior to classification as opposed to supervised classification where known land cover areas are used to train the classification to find other areas of the same cover.

Unsupervised classification is an automatic process in which classes are generated based on the inter-band cluster statistics. The Isodata classification used is an iterative method that allocates each image pixel to the cluster with the closest mean value. This is a recognised method adapted by the PCI image processing system from the publication '*Tou, Julius T. and Rafael C. Gonzales, 1974, Pattern Recognition Principles, Addison-Wesley Publishing Co.*'.

Land surfaces such as vegetation, water and sediment are easily mapped by the classifier since they have characteristically different spectral profiles. Separating different species of vegetation is often more difficult since their spectral properties tend to be similar. Differences in the colour, health and leaf structure of the vegetation will reflect in the shape of the spectral profile and the classification if targeted can pick out these changes.

The three study areas were divided into inter-tidal/terrestrial area using the graphic tools available in PCI to digitise the extent of the inter-tidal area from the images. The classification was then run on the inter-tidal area with twenty classes being generated for each site. Each class on the three images was then assigned a colour reflecting whether they were a vegetation or sediment class. This classification was then to be used during the fieldwork to target the ground truth data and facilitate the interpretation of the final classification.

iii) Co-Registration

The three study areas were co-registered to the digital Ordnance Survey 1:10000 topographic map data using the image to image registration facility in PCI. Features which could be identified both on the map and images were used to warp the image to the map. Accurate map registration is necessary when comparing features seen on the image to positional measurements taken on the ground.

iv) Ground Truth

A local saltmarsh expert working under contract to English Nature carried out the ground truth with help from a biologist from the Environment Agency local office. The vegetation species in the three study areas were recorded along transects down the shoreline. The preferred method of using the images and classification to target the ground truth was not used due to a lack of identifiable features on the imagery in the inter-tidal zone. This prevented the person on the ground from locating themselves within the imagery.

A trial method using a differential GPS with submetre accuracy was therefore used to collect an extensive number of data points. Over 163 sample points were collected over the three study sites. These points could then be overlain directly onto the CASI data once the images were fitted to the British National Grid.

v) Class Identification

The ground cover type of each class was determined by analysing a) the ground truth data and b) the spectral profiles within the classes.

The positions of the ground truth points as recorded by GPS were held as an Arcview Shape file. This file was imported into PCI and the positions could be directly overlain on the image as point vectors (figures 2-4).

The recording sheets for the sample points were analysed and each point was assigned a marsh vegetation or substrate category. These categories and a brief description were entered as vector attributes, which could then be displayed when each ground point was selected. Where ground truth points fell within class boundaries the ground type of that class could be established.

Spectral profiles of class pixels through the 15 spectral channels were used to help determine the vegetation cover type of each class. Estuarine vegetation, terrestrial vegetation and sediment all have different characteristic profiles, which can be used to establish the possible content of unknown classes. Those classes with very similar spectral profiles could be merged as this reflects a spectrally comparable ground cover. The use of spectral profiles was particularly useful in determining classes with no ground data points.

Results

The imagery for each of the three study areas is presented as true and false colour composites (figures 5-12). The true colour composites combine 3 bands from the visible red, blue and green wavelengths resulting in an image as the human eye would see it. The false colour composites combine an infra-red band with the green and red bands. This produces imagery which is very effective when looking at vegetated areas. In particular healthy dense vegetation is highlighted in reds, and sparser areas in pinks and oranges.

The classifications for each area are presented with different colours assigned to each class (figures 13-16). The original twenty classes in each classification were examined and merged to establish the following classes:

Biggar Sands

Mud/Sand
Mud/Sparse Algae*
Algae
Sparse Low Marsh
Low Marsh-*Spartina* Dominated
Low/Low-Mid Marsh-*Spartina* Dominated
Low/Low-Mid Marsh-*Puccinellia* Dominated
Low-Mid Marsh
Upper Marsh

Snab Sands

Mud/Sand
Sparse Algae*
Dense Algae (a)*
Dense Algae (b)*
Sparse Low Marsh
Low Marsh
Low Marsh-*Spartina* Dominated
Low/Low-Mid Marsh- *Puccinellia* Dominated
Mid-Upper Marsh
Upper Marsh

Roosecote Sands

Mud/Sand
Sparse Algae*
Dense Algae*
Low Marsh
Low Marsh- *Spartina* Dominated
Low/Low-Mid Marsh
Low-Mid Marsh
Mid Upper Marsh
Upper Marsh

** Classes which could not be clearly identified because there was no ground truth data or clear spectral profile are labelled with the possible ground cover class.*

Data quality:

When atmospheric effects degrade the radiometric quality of the image the spectral properties of pixels in the image are altered making it more difficult to determine landcover types using spectral profiles. Terrestrial vegetation and substrate classes were easily identified, however separation of the marsh vegetation and algae classes was more difficult.

The presence of atmospheric haze at the time the imagery was captured affects the lower bands of the spectral profile. Increased radiation is recorded in these bands, and subtle changes in ground radiance from different vegetation species can be lost. This is demonstrated in figure 17 which shows the spectral profiles from the image data compared with a set of more typical profiles from another area flown in October 1997.

It can also be seen from figure 17 that the spectral response is generally lower across the whole profile. This can be attributed to the fact that the imagery was flown early in the morning in low lighting conditions, which reduces the amount of radiation received by the instrument.

The red band of the spectral profile shows a higher response, and the near infrared bands show a lower response for marsh vegetation than would be expected. This could be because the saltmarsh was in a state of dying back. When vegetation becomes stressed or senescent reflectance increases in the visible wavelengths and near infra-red reflectance decreases. There was also mention of a layer of mud coating some of the vegetation which would affect the reflectance from the vegetation.

Limitations of the ground data:

There were several limitations found in the use of the ground truth data, a) mis-registration between the position of the ground points and their image location, b) distribution of points c) vegetation recording and d) time gap.

The locations of the ground points in relation to the imagery were found to be accurate to approximately +/- 10m. Since the differential GPS provided locations for the points to submetre accuracy this was caused by problems in the registration of the imagery to BNG co-ordinates. This was primarily due to the difficulties in locating a good spread of features in the imagery which could be used to accurately fit them to the Ordnance Survey map. The main part of the imagery was of the inter-tidal zone and contained no such features. Inaccuracies in the positions of features on the Ordnance Survey map will also introduce errors. When recording the position of ground data using GPS the positional accuracy of the image data it is being compared with must be considered.

The ground points followed a transect down the shore, recording vegetation each time the community changed. When these were overlain on the imagery some classes were found to be without ground points. The cloud and haze problems prevented a full mosaic of the CASI flightlines which meant each study area was classified individually and ground truth points from one site could not be transferred to another. Many of the ground points were located in areas where there was a mosaic of small patches of different classes, and on class boundaries, making it difficult to identify which class they fell into due to the problems outlined above. Ideally ground truth points would be located in larger areas of homogenous vegetation.

Vegetation at each point was recorded in detail, including a description of the site, species composition and National Vegetation Classification (NVC) community type. For a few of the points the approximate area of similar vegetation around the sampling point was specified, and this was found to be useful in identifying the vegetation classes. Saltmarsh vegetation can be divided into a range of communities from the upper through to lower marshes, however at the boundaries of these classes the vegetation may be a complex mix due to the transition from one community to the next. When the data recording sheets were analysed it became apparent that some of the points could not be easily assigned a vegetation class as they fell into these transition zones, or had elements of more than one community.

The ground data were collected over 20-22 October; almost one month after the imagery was flown. It is possible that during this period some changes may have occurred in the health and extent of the vegetation and particularly the algae. The actual species distribution of the vegetation across the marsh is unlikely to have changed during this short period. However the time lapse may be a factor in identifying classes at the outer edge of the marsh where algal scum and debris were a component of the ground cover in the samples.

Classification results:

The images produced show a detailed level of classification has been achieved. There were clear algae, low, mid-low, mid-upper and upper marsh zones. In some cases these zones could be further subdivided into dominant species. The detailed structure of the marsh and channels is also apparent in the classified imagery.

Identification of individual eelgrass beds on the mudflats was more difficult. The species of *Zostera* present in Morceambe Bay is found only in small patches and mixed in with other green algae species. The initial classifications were compared with field maps provided by the Natural History Museum for the same year and the class incorporating the eelgrass beds was found to cover both *Zostera* and other green algae classes.

Classification of the areas into individual NVC community types was attempted, but with the limitations of the data described and the heterogenous nature of the saltmarsh it was not possible. Individual communities will only be detected if they are spectrally distinct from their neighbours and cover a reasonable sized area in relation to the spatial resolution of the image.

When assessing the accuracy of the classification the final classes appeared to correspond with the ground truth data. The assessment of accuracy is limited to those areas where ground points were collected, for a wider assessment more ground points in each class and in different areas of the inter-tidal zone would be required.

Conclusions

The study has shown that it is possible to identify and map the distribution of inter-tidal vegetation in the Walney Channel with the use of CASI imagery. Broad saltmarsh communities, algae and sediment were clearly identified, and some areas could be sub-divided into dominant species.

The radiometric quality of the data was a limiting factor in this study, low light levels and haze made detailed analysis of the imagery difficult. In ideal flying conditions interrogation of the data down to NVC categories may be more feasible, although unlikely unless there are clear stands of spectrally distinct vegetation present.

The distribution and quality of the ground truth data is important in these studies. The ground data collected were very detailed and accurately geo-located using GPS, however transferring the position of these point samples to the correct position on the classified image was more problematic. The lack of tie points on the CASI in the inter-tidal zone produced a mis-registration of the CASI data to map data of up to 10 metres. Where ground points fell at the boundaries between classes it was therefore uncertain as to which class they represented.

The positional accuracy of the CASI data must therefore be considered when planning the fieldwork and the dominant ground cover for the surrounding area as well as immediate area must be recorded.

Considering the constraints of the ground data and imagery, a detailed level of classification has been achieved, using the unsupervised classification technique.

Recommendations

CASI images:

1. Although tidal constraints are most important in determining data collection, early morning and low light levels in the autumn should be avoided where possible. It is still possible to classify the images into broad, land cover classes but detailed analysis of ground cover is more problematic.

2. The presence of haze causes increased scattering of the visible part of the spectrum as light travels through the atmosphere. Light levels recorded on the plane are therefore not true representations of the ground radiation levels. If flying in hazy conditions cannot be avoided and species level differentiation is required some form of atmospheric correction would be advised prior to classification.

3. Where possible mosaic flightlines covering the study area so that only one classification for the whole area is necessary. Ground truth information can therefore be transferred from one site in the area to another. Alternatively differences in incident light between flight lines may be reduced using an incident light sensor.

4. The difficulties in registering CASI imagery of inter-tidal areas to the British National Grid should be anticipated when drawing up flightlines. If possible flightlines should cover a good spread of features which can be used as tie points. In addition the improvement of the geocorrection and positioning capabilities of the system could be investigated.

5. When planning a study of this type the time of year should be considered. Annual species in the pioneer zones of the marsh may not show on the imagery if it is captured early in the year. Later in the year there is an increased presence of dead biomass within the marsh which affects the spectral response of the vegetation. Temporal images over a period from June to September may help in the identification of some saltmarsh vegetation.

Ground Truth:

1. Use the imagery or classification to target the ground truth if possible. This should reduce the number of ground points and ensure that all target classes have ground data recorded within them. If the image data are georeferenced to map data prior to the fieldwork, they can then be viewed digitally whilst in the field and used in conjunction

with the positions gained from GPS. Sample points can therefore be taken where possible in the centre of classes to reduce errors due to mis-registration. Transects taken through the image incorporating as many classes as possible are useful to identify major changes in landcover which may not be picked up in the initial classification.

2. The image spatial resolution should be taken into account when planning fieldwork, at a two metre resolution one image pixel represents an area $2m^2$. Patches of ground cover smaller than this will not show on the image unless they have a very different spectral response from their surroundings. When recording a sample ensure that the ground type covers an area larger than the pixel resolution.

Figure 1 Principle of operation of the CASI

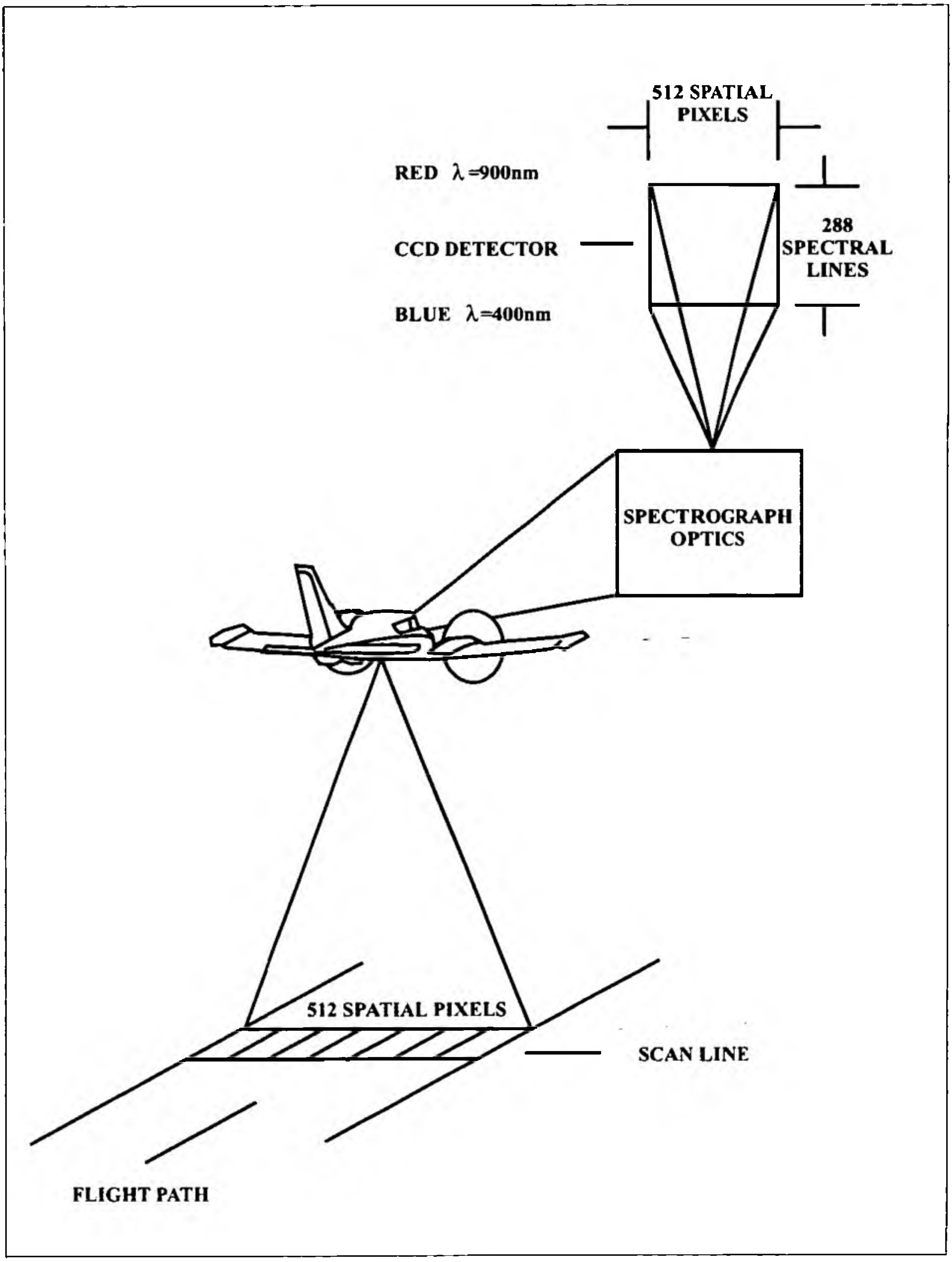


Figure 2 Biggar Sands

Classification with ground data points

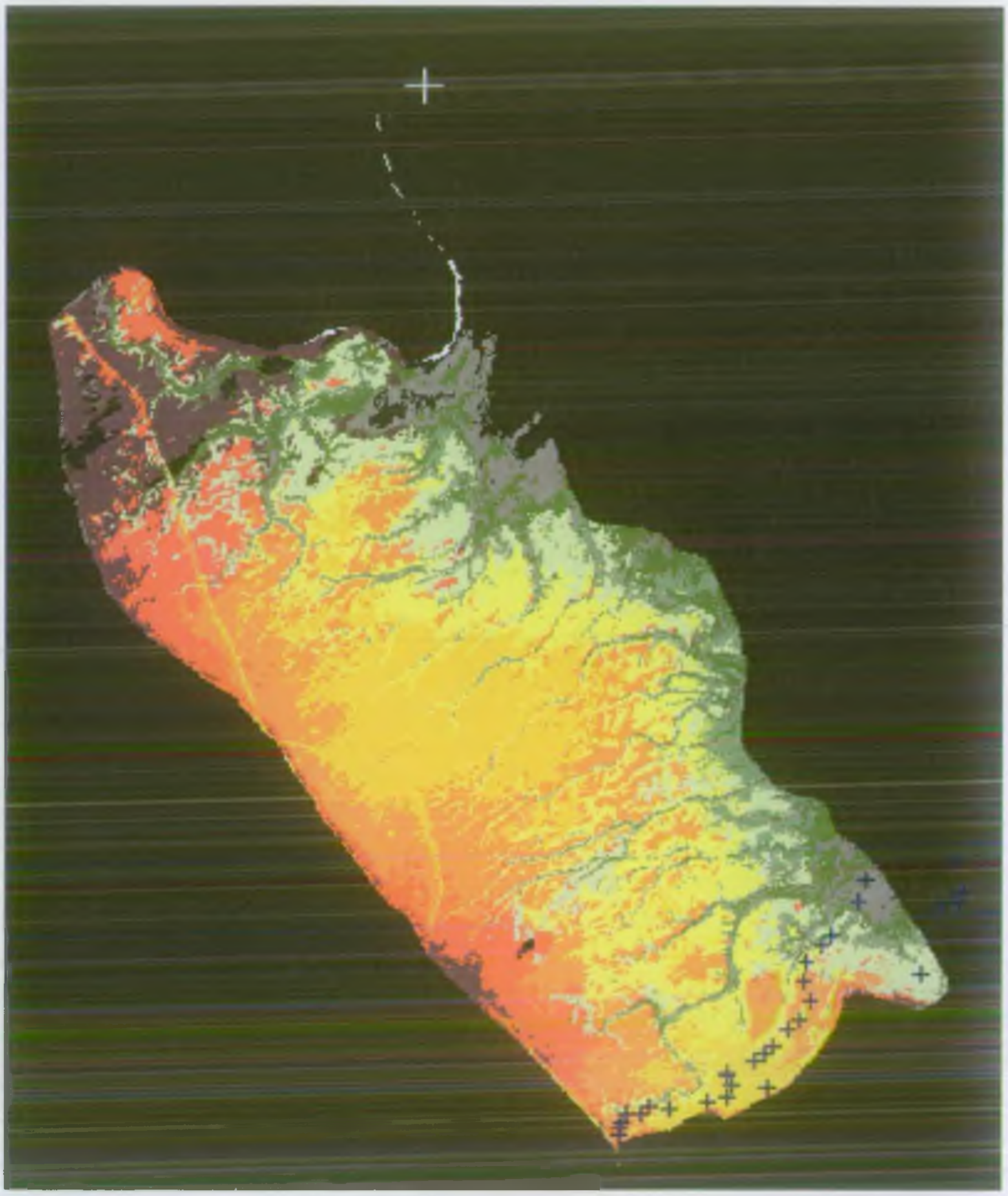


Figure 3 Snab Sands

Classification with ground data points

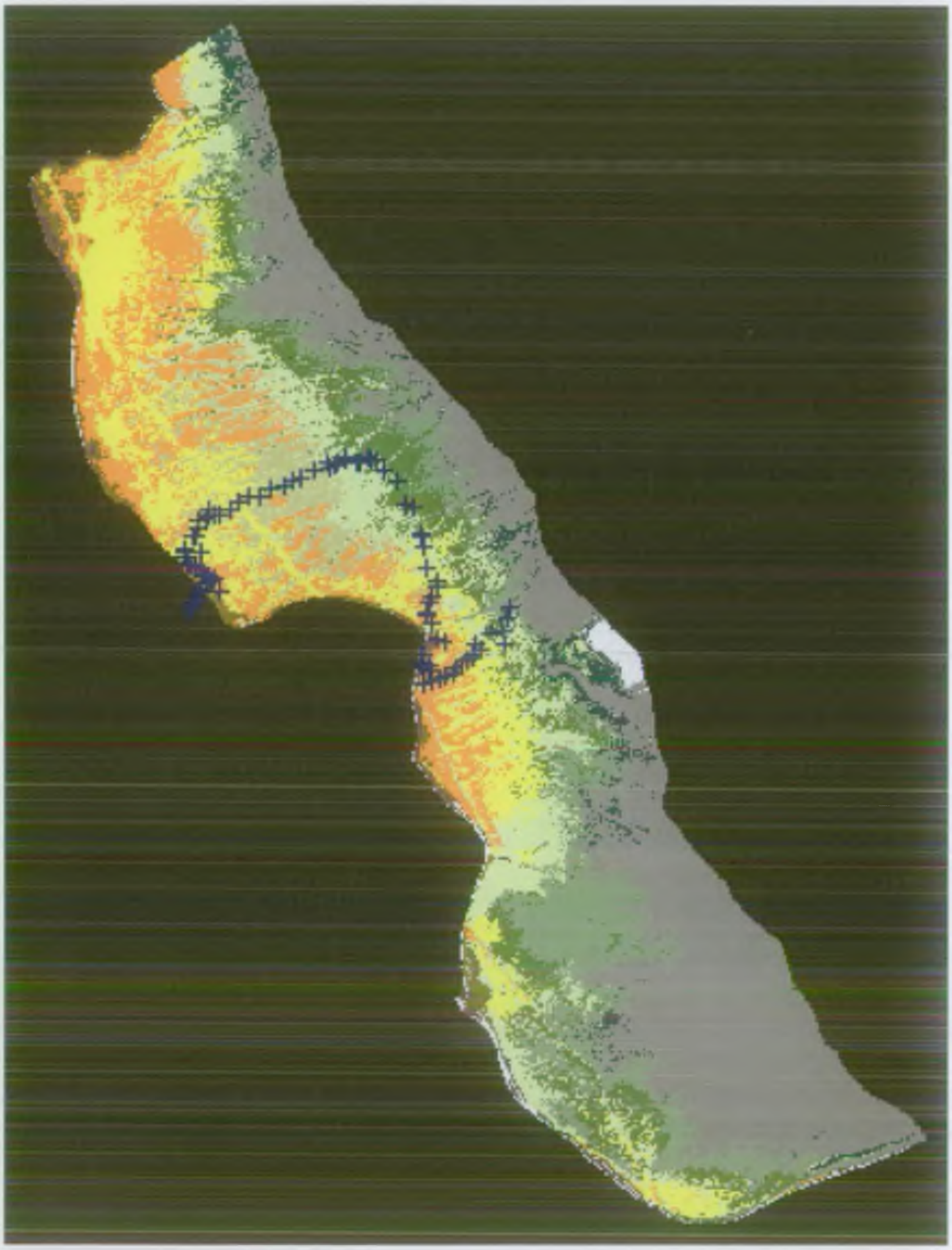


Figure 4 Roosecote Sands

Classification with ground data points

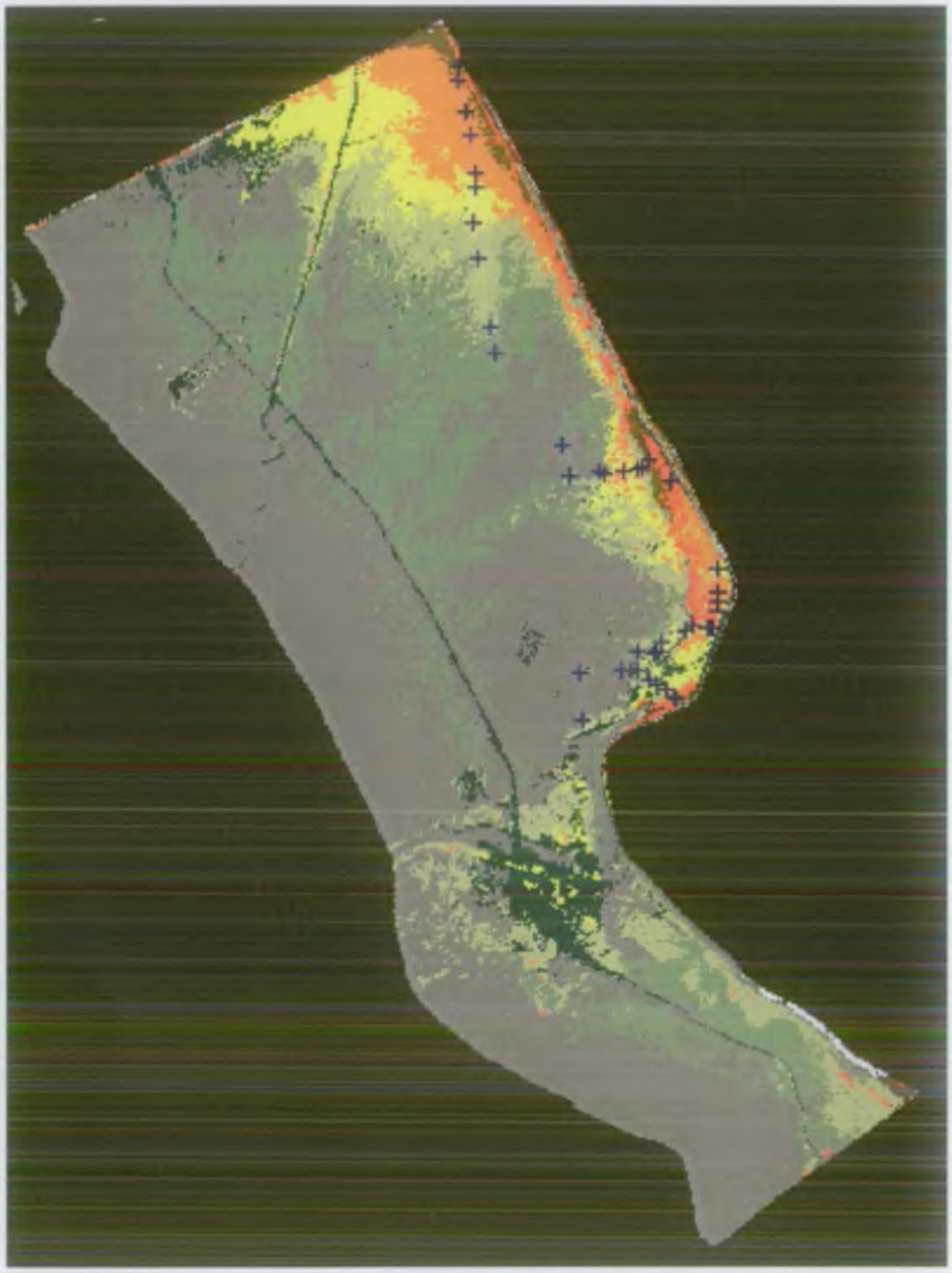


Figure 5 Biggar Sands nr Barrow-In-Furness

CASI True Colour Composite

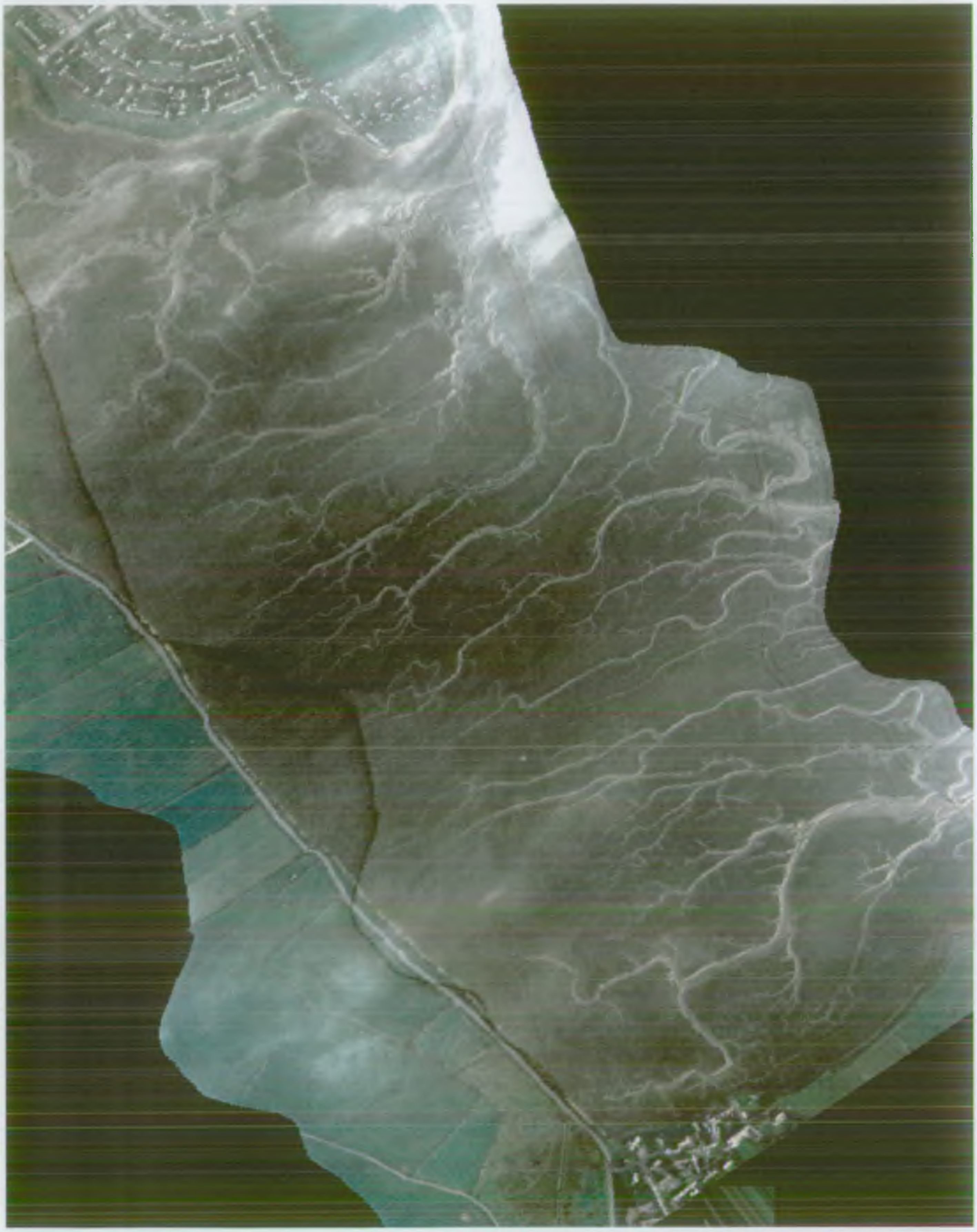


Figure 6 Snab Sands, North

CASI True Colour Composite

Figure 7 Snab Sands, South

CASI True Colour Composite

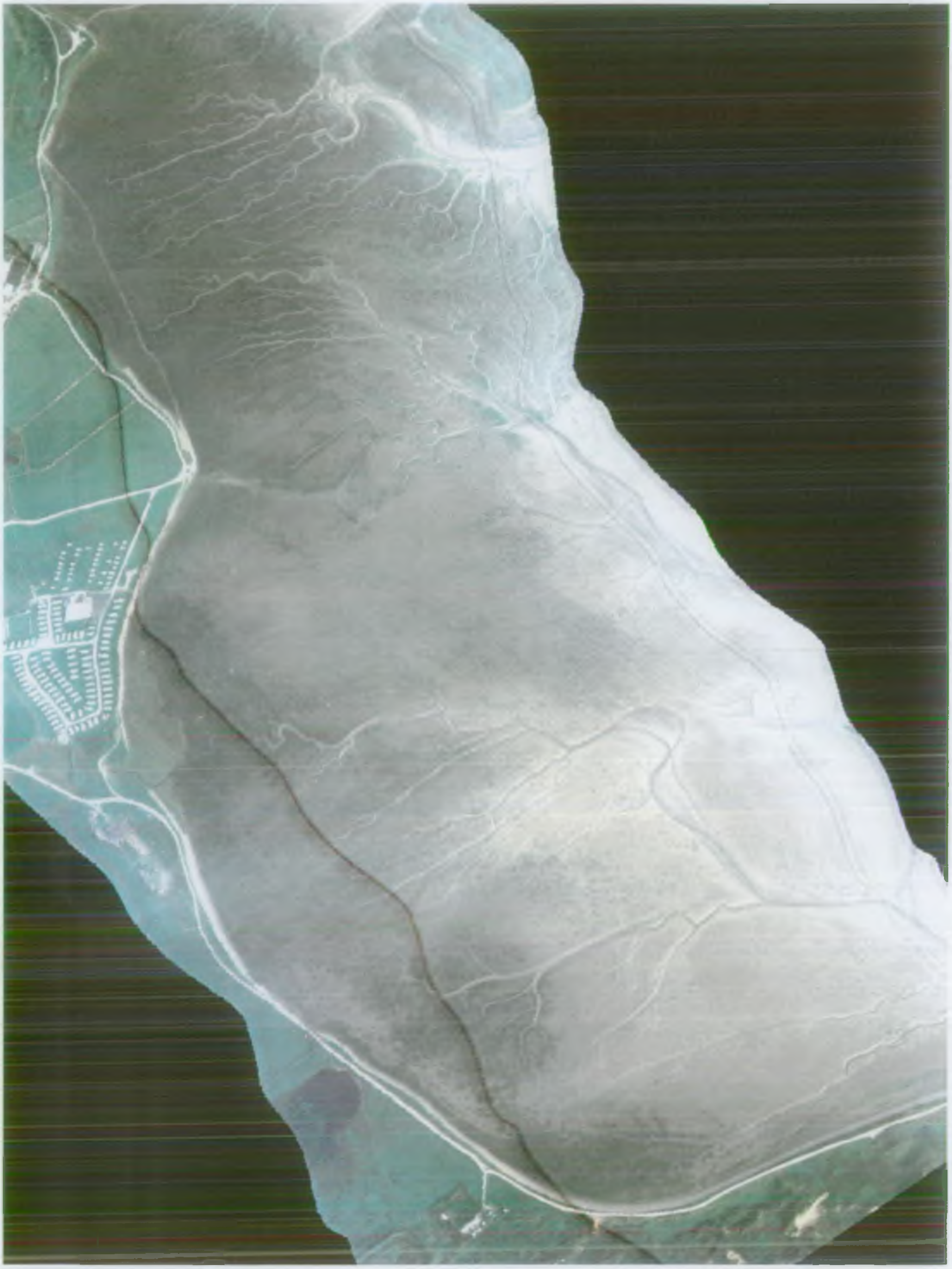


Figure 8 Roosecote Sands nr Barrow-In-Furness
CASI True Colour Composite

Figure 9 Biggar Sands nr Barrow-In-Furness

CASI False Colour Composite

Figure 10 Snab Sands, North

CASI False Colour Composite

Figure 11 Snab Sands, South

CASI False Colour Composite

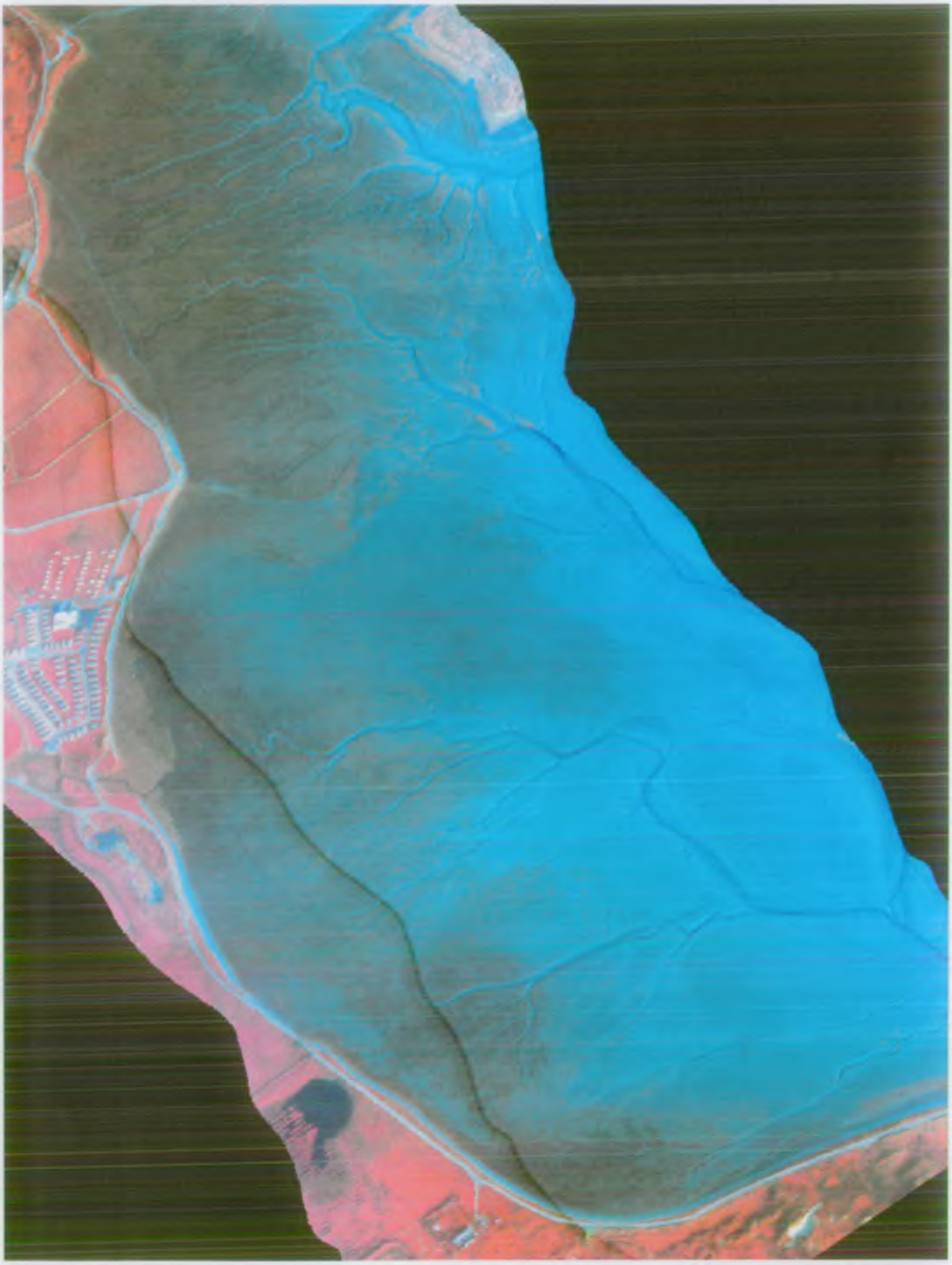


Figure 12 Roosecote Sands nr Barrow-In-Furness

CASI False Colour Composite

Figure 13 Biggar Sands

Unsupervised classification of the inter-tidal area

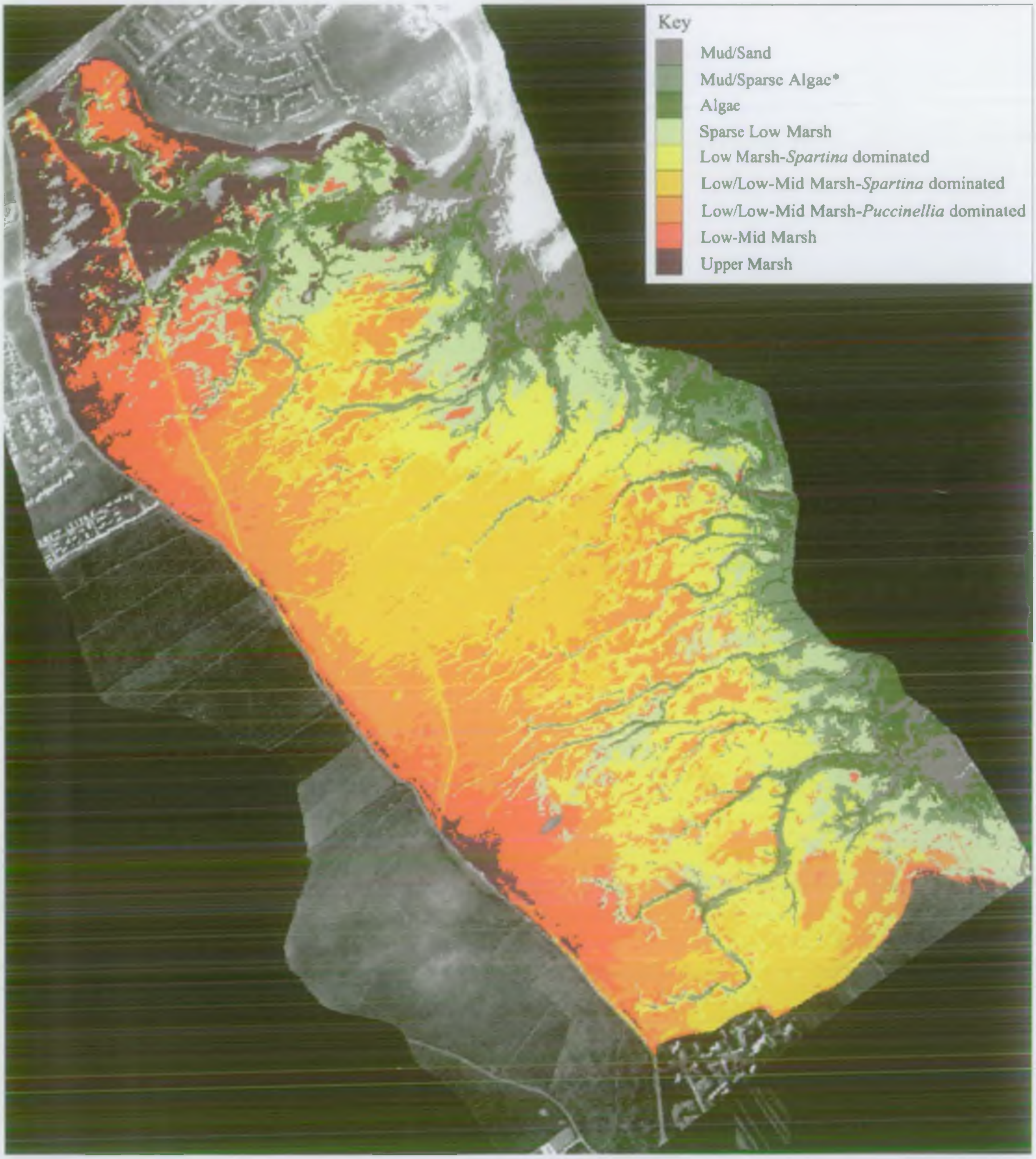


Figure 14 Snab Sands, North

Unsupervised classification of the inter-tidal area

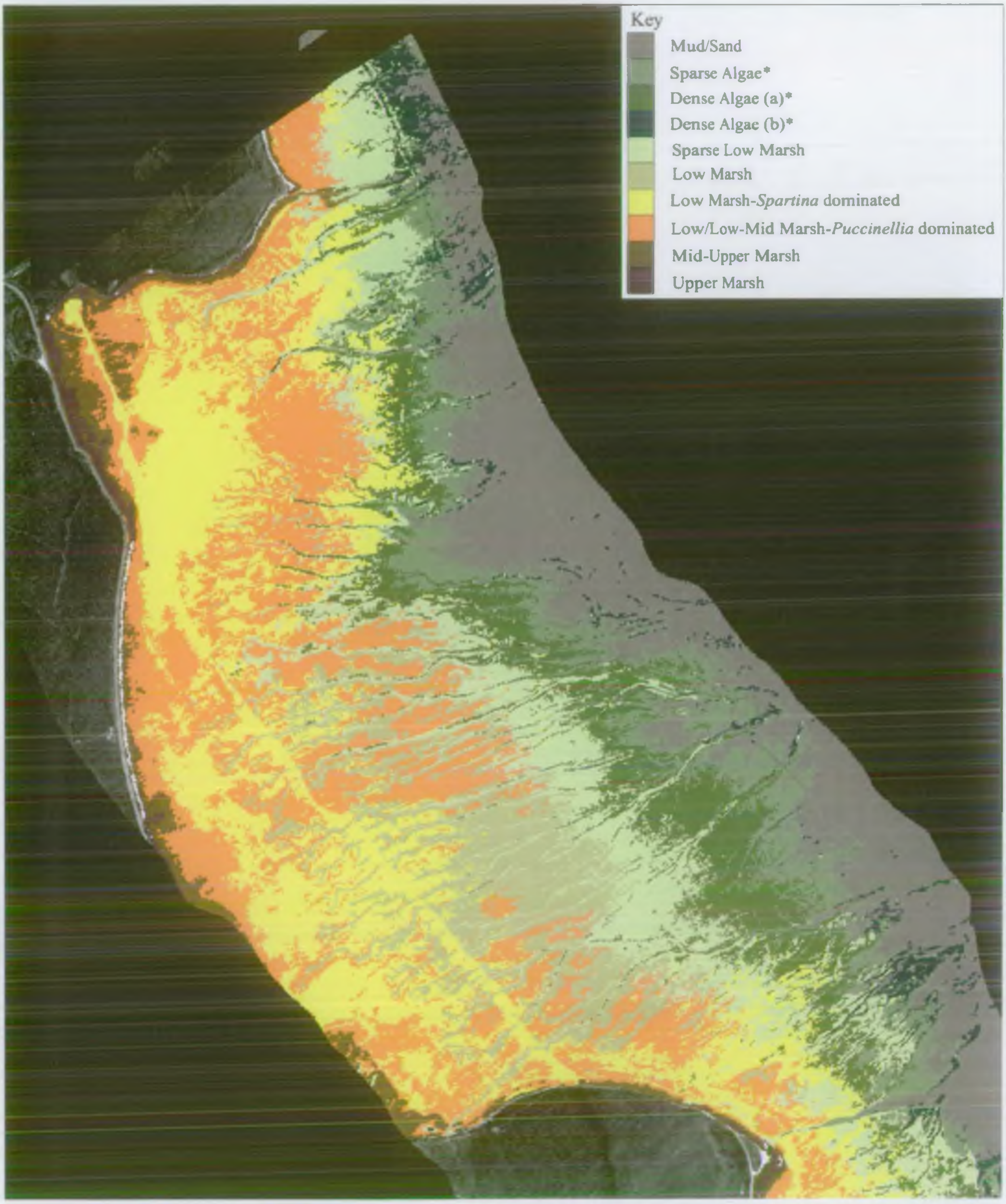


Figure 15 Snab Sands, South

Unsupervised classification of the inter-tidal area

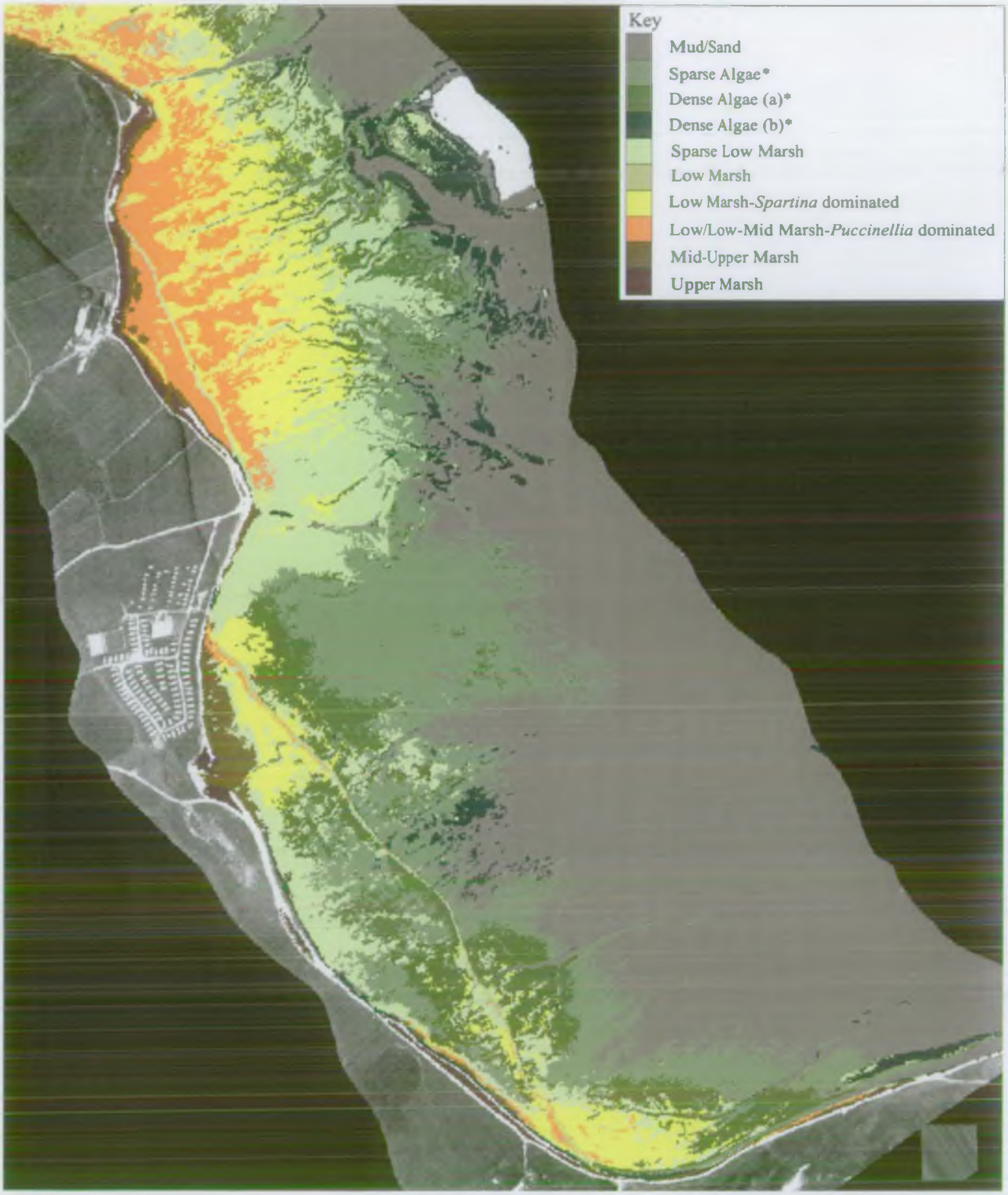
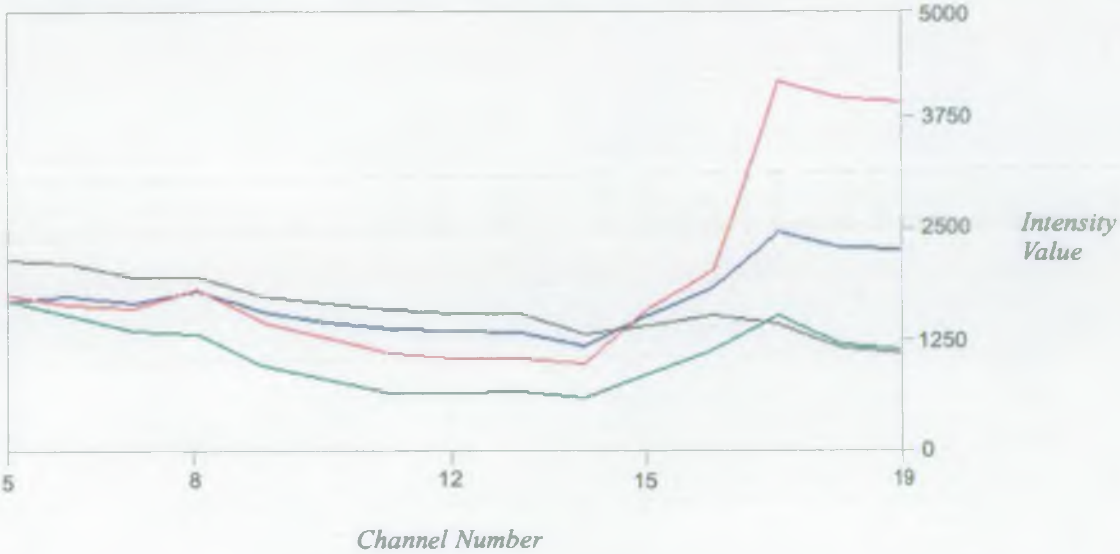


Figure 16 Roosecote Sands

Unsupervised classification of the inter-tidal area

Figure 17 Spectral Profiles

a) Typical Spectral Profiles from Saltmarsh Cover Types



b) Spectral Profiles from Snab Sands Cover Types