internal report 409

IKONOS and ASTER imagery: Ranger Mine and the Magela floodplain area

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1 Introduction

High spatial resolution IKONOS satellite imagery, at ~ 1 m and 4 m pixel sizes, were acquired in June 2001 over Ranger mine and the Magela floodplain area. These data were purchased in order to provide high resolution images for use across the SSD in a variety of projects and applications. In order to spatially rectify the IKONOS data, a digital elevation model (DEM) was compiled from stereo ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) imagery.

The purpose of this report is to:

- describe the characteristics of IKONOS and ASTER satellite data;
- highlight the availability of high resolution IKONOS and ASTER imagery captured over Ranger mine and Magela floodplain area for use in a range of applications;
- document the processing undertaken to date of this data; and,
- make recommendations for future IKONOS imagery purchases based on lessons learnt from the processing required of these data.

This report outlines the geometric, radiometric and terrain displacement corrections applied to the IKONOS imagery in order to provide data suitable for end users, including GIS integration. As ASTER data was acquired to produce a DEM for IKONOS corrections, the basic characteristics of ASTER imagery are also highlighted. The processing and storage of data is described. Finally, the report summarises lessons learnt from the acquisition of such data and recommendations are made for IKONOS specifications should future captures be acquired.

Further reports may describe the suitability of IKONOS data for minesite monitoring and rehabilitation assessment and other applications such as wetland mapping of the Magela floodplain.

2 IKONOS – overview

2.1 Characteristics of IKONOS data – general

The IKONOS satellite was launched in September 1999 with an altitude orbit of 681–709 km. The sensor records ~ 1 m spatial resolution in the panchromatic (black & white) band (0.45–0.90 µm) and ~ 4 m spatial resolution in the multispectral range. The multispectral mode includes four spectral bands of the range 0.45–0.52 µm (blue), 0.52–0.6 µm (green), 0.63–0.69 µm (red) and 0.76–0.9 µm (near–infrared). The 4 m multispectral bands may be ‘sharpened’ with the 1 m panchromatic band to increase the spatial discrimination of multispectral features.

The sensor has an off-nadir pointing angle of ±30° in any direction, sufficient to form both monoscopic and same-pass stereo collections. The panchromatic band is 1 m nominal spacing at < 26 degrees off nadir. This actually varies from 0.8 – 1.2 m Ground Sample Distance (GSD) that is resampled by cubic convolution to 1.0 m map increment. The multispectral bands are 4 m nominal at < 26 degrees off nadir. This is an important consideration if imagery is to be acquired of adjacent swaths at different viewing angles.

The satellite orbit exactly repeats every 140 days, however, IKONOS imagery can be acquired of the same geographic area every 1–3 days, depending on latitude. Data captured of a similar geographical area at temporal scales less than 140 days may be a result of image capture at angles greater than nadir. The swath width is 11 km at nadir.

GEOIMAGE Pty Ltd are the Australian resellers of IKONOS data through Space Imaging International.

The strengths of IKONOS imagery are: fine spatial resolution, true colour and false colour images, possibility of stereo pair imaging acquisition, ease of capturing synoptic large areas, and ease of temporal image collection (being satellite based) for monitoring applications. However, there are different types of IKONOS products, distinguished by their positional accuracy (and cost), which may influence the usability of such data, depending on the application at hand.

2.2 IKONOS products - general

2.2.1 Positional accuracy

The data is available at a range of levels of positional accuracy (which also differ cost-wise).

The ‘Geo’ product is a lower cost, quick look product for visual interpretation that is not orthrectified and has a locational error of up to 50 m, not including any height offset errors.

The ‘Geo Ortho Kit’ provides higher positional accuracy, by including an Image Geometry Model (IGM), which consists of several metadata files that contain rational polynomial coefficient (RPCs) to determine interior and external orientation. The RPCs are a series of coefficients that describe the relationship between the image as it existed when captured and the Earth’s surface, as well as the camera geometry at the time of acquisition. SSD currently has one license of software (ERDAS Imagine Orthobase) that can accurately and (relatively) easily implement the IGM and RCPS to orthorectify IKONOS images.

More precessional accuracies are achieved by the use of imagery collected closer to the vertical, by the capture of digital elevation models from stereo imagery, and by the use of well controlled ground locations. The standard levels of processing are listed in table 1 below:

Table 1 Level of processing of IKONOS products (Source: GeoImage)

Product Name	Horizontal Accuracy CE90%*	Horizontal Accuracy RMSE	Ground Control Points Req’d	US National Map Accuracy Standard
Geo	50 m	23.8 m	No	1:100 000
Reference(GeoOrtho)	25.4 m	11.8 m	No	1:50 000
Pro	10.2 m	4.8 m	No	1:12 000
Precision 4m	6.0 m	2.8 m	Yes	1:7 000
Precision 1m	4.1 m	1.9 m	Yes	1:4 800
Precision Plus	2.0 m	0.9 m	Yes	1:2 400
Reference Stereo	25.0 m	11.9 m	No	1:50 000
Precision Stereo	4.0 m	1.9 m	Yes	1:4 800

* CE90 standard = the location of an object on the image is within the specified accuracy of the real world location of the object 90%of the time

2.2.2 New captures and archived imagery

The collection of IKONOS imagery is not regular (as with Landsat imagery for example). That is, the scanner is not continuously collecting data over an area which it passes in orbit. For new data captures, a request must be made to Space Imaging (through GeoImage). A successful image capture will have less than 20 % cloud cover. A nominal single image is 10.5 km x 10.5 km. A customer may also specify a geographical area of interest (AOI), which may be a rectangle in geographic coordinates, or an ESRI shape file. The IKONOS data is supplied in UTM projection, datum WGS84, GeoTIFF format. Minimum size order for new collections is 100 km^2.

According to GeoImage, available scene sizes include:

- strips of 10.5 km x 100 km up to 10.5 x 1000 km
- image mosaics up to 12 000 km^2
- up to two 10 000 km^2 contiguous area in a single pass within a region
- specified AOI that have a minimum dimension of 5 km x 5 km

The following points should be noted:

Areas wider than 10.5 km East-West or longer than 100 km North-South may be collected as separate satellite images (with different look angles for separate images, unless specified). Areas greater than 100 km x 100 km are collected, processed, shipped and invoiced as separate orders.

In addition to new image captures, where available, archived images may be purchased, which are cheaper in cost. Currently, archived data is defined as data where the capture date is greater than 6 months. To date, more than 50% of Australia has been covered by archive imagery with less than 10% cloud cover (refer to figure 1). Minimum order for Archive Images is 49 km^2. Archived coverages can be graphically searched and previewed using CARTERRA online (http://www.spaceimaging.com). Table 2 highlights the costs of IKONOS imagery as of 2002, when the data was purchased, compared with current prices (for both archived and new capture purchases). With the increase in competitive sensors, such as Quickbird, it is likely that the cost of IKONOS data will continue to decrease in the future. Current prices should be obtained from GeoImage Pty Ltd.

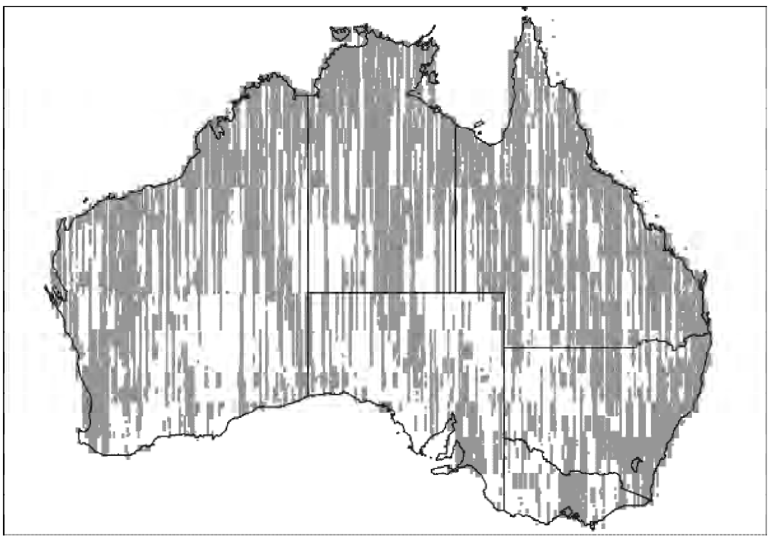

Figure 1 IKONOS imagery coverage with less than 10% cloud cover (Source: Geoimage)

Table 2 IKONOS prices, GST excluded. Source: GeoImage

US $ per sq km	IKONOS prices @ February 2002	IKONOS prices @ January 2003
Archived Geo Product*	US $ 18.00	US $ 10.50
Fresh capture Geo Product*	US $ 27.00	US $ 27.00
Fresh capture Geo-Ortho kit bundle*	US $ 44.00	US $ 32.00

*(1m and 4m multispectral bundle)

2.2.3 IKONOS Licensing agreements

Space Imaging has strict License Agreements. A copy of such agreement can be found on file SG2002/0202. Space Imaging retains all ownership rights in the Product and grants the customer a non-transferable, non-exclusive license to use the Product.

Points to highlight with the 'permitted use' license include:

Customers may:

- make one copy for internal archive or backup;
- distribute the Product on an isolated non-commercial basis in a non-manipulatable format or as part of a hard copy research report or publication; and,
- post a derived product (irreversible processing performed) or degraded (with quality setting of no greater than 50% original product in a JPEG format), on an Internet site with the following credit conspicuously displayed 'Includes material (c) Space Imaging LLC' (and notification of posting must be provided to webmaster@spaceimaging.com).

3 IKONOS and ASTER imagery of Ranger/Magela

3.1 Characteristics of IKONOS data

Five Geo Product archived IKONOS scenes covering Mt Brockman to part of the East Alligator River, including the Ranger lease, were acquired through GeoImage (from Space Imaging). Figure 2 highlights (in red) the locational area of the five IKONOS scenes which are overlaid on a topographical backdrop. Four scenes orientated more or less north-south run from part of the East Alligator in the north (scene 1) to the Mount Brockman Outlier in the south (scene 4), including some of Energy Resources of Australia Ranger Mine (ERARM). The 5th scene covers all of ERARM and its surrounds. The processing level of the archived scenes were 'standard geometrically corrected' in UTM WGS84 S53. Five unmosaiced GeoTIFF type files at 11 bits per pixel were received.

Scenes 1–4 and scene 5 were acquired from the IKONOS satellite at different dates and with different scanning attributes (refer to table 3). Although all scenes were collected in June 2001, the later acquisition date of scene 5 (covering ERARM) highlighted that a fire appeared to have occurred inbetween the acquisition dates. The different look angles between the strip (scenes 1–4) and the single overlapping scene 5, together with the 'Geo Product' characteristics, resulted in standard methods of georectification not being suitable. To produce spatially coherent data, the IKONOS scenes required orthrectification.

A verbal arrangement was made with GeoImage, who agreed to orthorectify the data free of charge, excluding the cost of DEM creation. For the orthorectification process, two scenes of ASTER data were used to create a DEM for orthrectification of the IKONOS imagery.

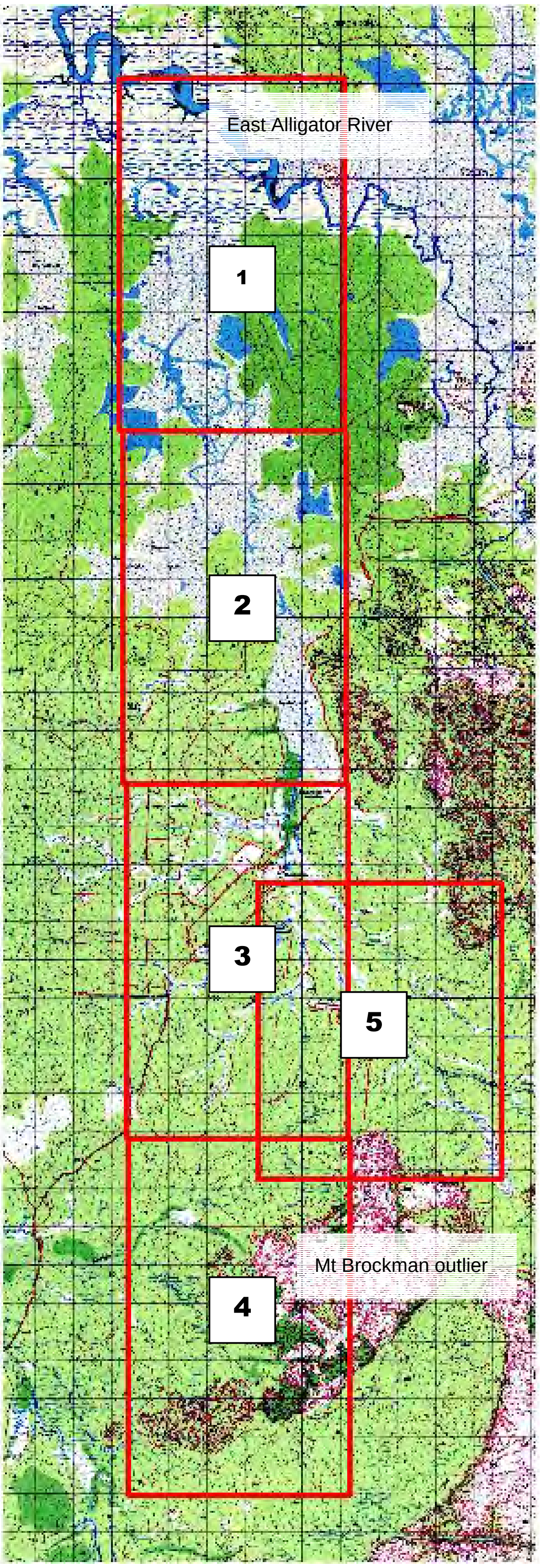

Figure 2 The location area of the IKONOS scenes

Table 3 Comparison of archived data

	Scene 5	Scenes 1-4
Acquisition Date/Time	2001–06–25 01:33 GMT	2001–06–03 01:31 GMT
Cross Scan:	0.93 meters	0.87 meters
Along Scan:	1.03 meters	0.91 meters
Scan Azimuth:	359.99 degrees	179.99 degrees
Scan Direction:	Forward	Reverse
Nominal Collection Azimuth:	340.6079 degrees	336.6913 degrees
Nominal Collection Elevation:	61.57631 degrees	70.42196 degrees
Sun Angle Azimuth:	33.6734 degrees	34.1128 degrees
Sun Angle Elevation:	46.81302 degrees	47.96875 degrees

3.2 ASTER data

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is one of five sensor systems on-board the Terra satellite, with a swath width of 60 km. The sensor records in the visible near-infrared (VNIR), the shortwave infrared (SWIR), and thermal infrared (TIR) regions of the spectrum. Spatial resolution is at 15 m (VNIR), 30 m (SWIR) and 90 m (TIR). Three spectral bands cover the VNIR: red, green and near infrared (0.52–0.60 μm, 0.63–0.78 μm, and 0.78–0.86 μm), and there are 6 SWIR bands and 5 TIR spectral bands.

Table 4 summarises the spectral and spatial resolution of these subsystems. The Visible Near Infra-Red (VNIR) telescope has a backward viewing band capability for high-resolution along-track stereoscopic observation (band 3B in table 4), and thus DEM creation potential.

Table 4 Spectral and spatial characteristics of ASTER data

Subsystem	**Band No.**	**Spectral Range (μm)**	**Spatial Resolution**
VNIR	1	0.52 – 0.60	15 m
	2	0.63 – 0.69	
	3N	0.78 – 0.86	
	3B	0.78 – 0.86	
SWIR	4	1.600 – 1.700	30 m
	5	2.145 – 2.185	
	6	2.185 – 2.225	
	7	2.235 – 2.285	
	8	2.295 – 2.365	
	9	2.360 – 2.430	
TIR	10	8.125 – 8.475	90 m
	11	8.475 – 8.825	
	12	8.925 – 9.275	
	13	10.25 – 10.95	
	14	10.95 – 11.65	

ASTER scenes cost US$60.00 each. Like the IKONOS sensor, ASTER data is not regularly collected. Two scenes captured on 16.09.2000 with central latitudes of 12.3 S and 12.7 S were selected by GeoImage as cloud free and covering the area of interest well. Figure 3 highlights the ASTER coverage, which in itself is a useful dataset, although only includes the VNIR 15 m bands.

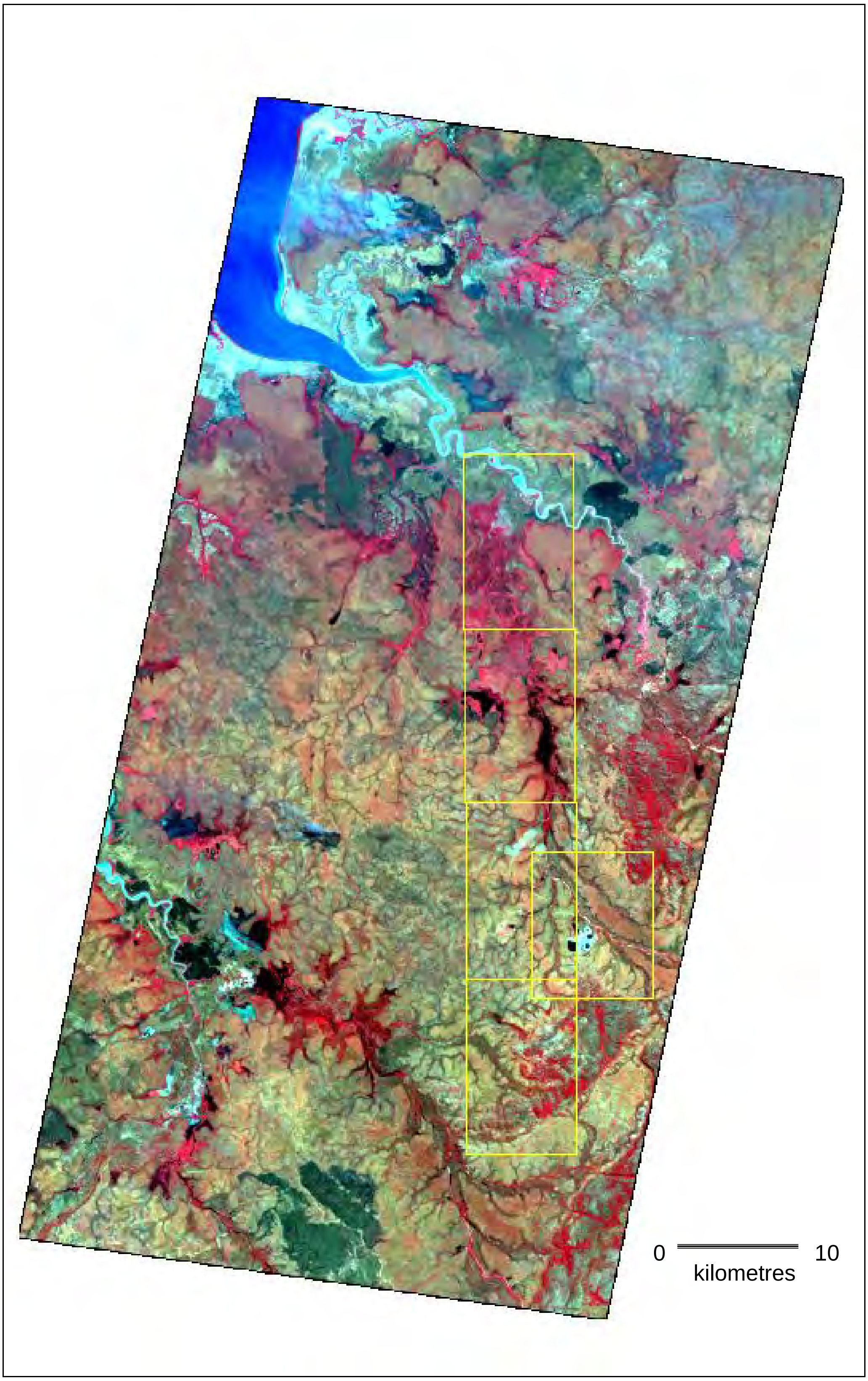

Figure 3 Location area of five IKONOS scenes in relation to the VNIR ASTER coverage

4 IKONOS data processing and management

GeoImage supplied five high spatial precision orthorectified files (using the ASTER created DEM). For information on the orthorectification process performed by GeoImage, refer to the appendix. It should be noted that GeoImage resampled the multispectral data to 1 m pixel size. Management of IKONOS and ASTER files are stored on SSD explorer and suitable for end-user applications, as described below.

The licensing agreement should be referred to prior to data manipulation or export of these files.

4.1 IKONOS data - size and management

An important consideration for users of IKONOS data is that the IKONOS files require large amounts of disc free space. For the Magela/Ranger files obtained, the multispectral and panchromatic files are each approximately 1.61 GB, and 418 MB, respectively. To store the five multispectral files (as an example) requires 7.95 GB of disc free space. This is prior to any data manipulation or processing.

IKONOS files are stored on SSD explorer under:

Spatial Data Management and Storage\

Raster\Satellite Imagery\IKONOS\Alligator Rivers Region/Kakadu\Files

Under files, 5 folders can be seen: Ranger 1, Ranger 2, Ranger 3, Ranger 4, and Ranger 5.

These refer to the five IKONOS scenes, as numbered and illustrated in figure 2. Each file has a 1 m multispectral and 1 m panchromatic file that has the extension .rar. These files are compressed WinRAR files (that have a superior compression to WinZip). WinRAR compresses the multispectral files (from ~1.61 GB) to 418 MB each, and the panchromatic files (from ~ 460 MB) to 190 MB each. These files can be downloaded, uncompressed, viewed and manipulated in software programs such as 'Research Systems ENVI', 'ERDAS Imagine' and 'ESRI ArcView'. Each multispectral file also has a .hdr (ENVI header file), .ers (ErMapper header file), and .aux (ERDAS Imagine). In order to mosaic the five multispectral files (with a sub-sampling of 16 m) requires 12 GB of free space (uncompressed).

4.2 IKONOS 'quick look' data – size and storage

Considering the high disc space required for IKONOS imagery, in addition to the compressed IKONOS data, the multispec 1 m files have been (irreversibly) compressed (0.5) to JPG format for use as 'quick looks'. A histogram equalisation has been applied to these files prior to compression and export. These files should not be used where accurate spectral and spatial resolutions are required. The JPG compressed files are provided for visual interpretations only, and degraded image quality should be expected. These files can be viewed, (and map products made) with the software programs listed above as well as EA's standard 'ESRI ArcExplorer'.

Importantly, it is recommended for applications requiring accurate spectral and spatial resolutions, such as those where interpretations of land cover features are made, that the uncompressed WinRAR files be used. For visual purposes, compressed (0.5) JPG files may be used to reduce computational space and time. These JPG files are also stored on SSD explorer:

Spatial Data Management and Storage\

Raster\Satellite Imagery\IKONOS\Alligator Rivers Region/Kakadu\Files

Under files, 5 folders can be seen: Ranger 1, Ranger 2, Ranger 3, Ranger 4, and Ranger 5.

These refer to the five IKONOS scenes, as numbered and illustrated in figure 2. Each file has a 1 m multispectral file that has the extension .rar (compressed JPG files).

4.3 IKONOS raw data – spatial sharpening of multispectral files

Although the multispectral files were resampled to 1 m spatial resolution by GeoImage for the orthorectification procedure, their true resolution is at 4 m. That is, spectrally, there is a repeat of spectral and spatial components over approximately 4 pixel averages. The multispectral images were sharpened by merging the lower resolution multispectral files with the higher spatial resolution panchromatic files, using the 'Hue, Saturation, Value' (HSV) technique. It should be noted that this procedure is very useful for spatial enhancements, however, resulting images should not be used for direct spectral processing. A histogram equalisation was applied prior to HSV transformation.

The HSV technique is used to convert a 3-band red, green, blue (RGB) input image into HSV colour space and then back to RGB colour. In this case, the value band was replaced with the panchromatic band, with an automatic resampling of the hue and saturation bands to the multispectral data, using a nearest neighbour resampling method (in this case) and a transformation back to RGB colour. Hue ranges from 0–360 degrees (where red is 0 degrees, green is 120 degrees, and blue is 240 degrees) and saturation and value are in the range 0–1 (floating-point) (Research Systems 2000, ENVI User's Guide Version 3.4). This technique produces a spatially sharpened image that merges the colour characteristics of the multispectral data with the spatial characteristics of the panchromatic image. As IKONOS multispectral data is 4-band, the HSV technique was performed on the true colour images separately to the false colour images. These files are stored in the same location as the other IKONOS files in SSD explorer, with the names 'RGB_sharpened' (true colour) and 'IRRG_sharpened' (false colour). Refer to section 4.5 for image examples.

4.4 ASTER data

The VNIR 3-band image and ASTER created DEM are 144 MB and 192 MB (uncompressed), respectively.

ASTER data is stored on SSD explorer under:

Spatial Data Management and Storage\

Raster\Satellite Imagery\ASTER\Alligator Rivers Region/Kakadu\Files

Under files, the VNIR ASTER mosaic and DEM ASTER mosaic are located as WinRAR (compressed) files.

4.5 Example imagery

Figures 4–8 highlight a subset of scene 5 (covering the Ranger mine area). A further subset of the mill area is provided to highlight spatial and spectral differences between the figures. Figure 4 illustrates the multispectral IR, R, G (false colour) bands, figure 5 highlights the same region with the panchromatic band, figure 6 illustrates the false colour JPG resolution of the same area and figures 7 and 8 highlight the true colour and false colour sharpened images respectively. The spectral degradation effect of JPG compression is illustrated by a comparison of figure 4 (uncompressed) with figure 6 (compressed and histogram equalisation applied). The HSV technique results are illustrated in figures 7 and 8, which show the spatial resolution of the panchromatic band (figure 5) with reduced multispectral integrity.

Note these are exported .bmp picture files and therefore some image degradation should be expected in figures 4–8.

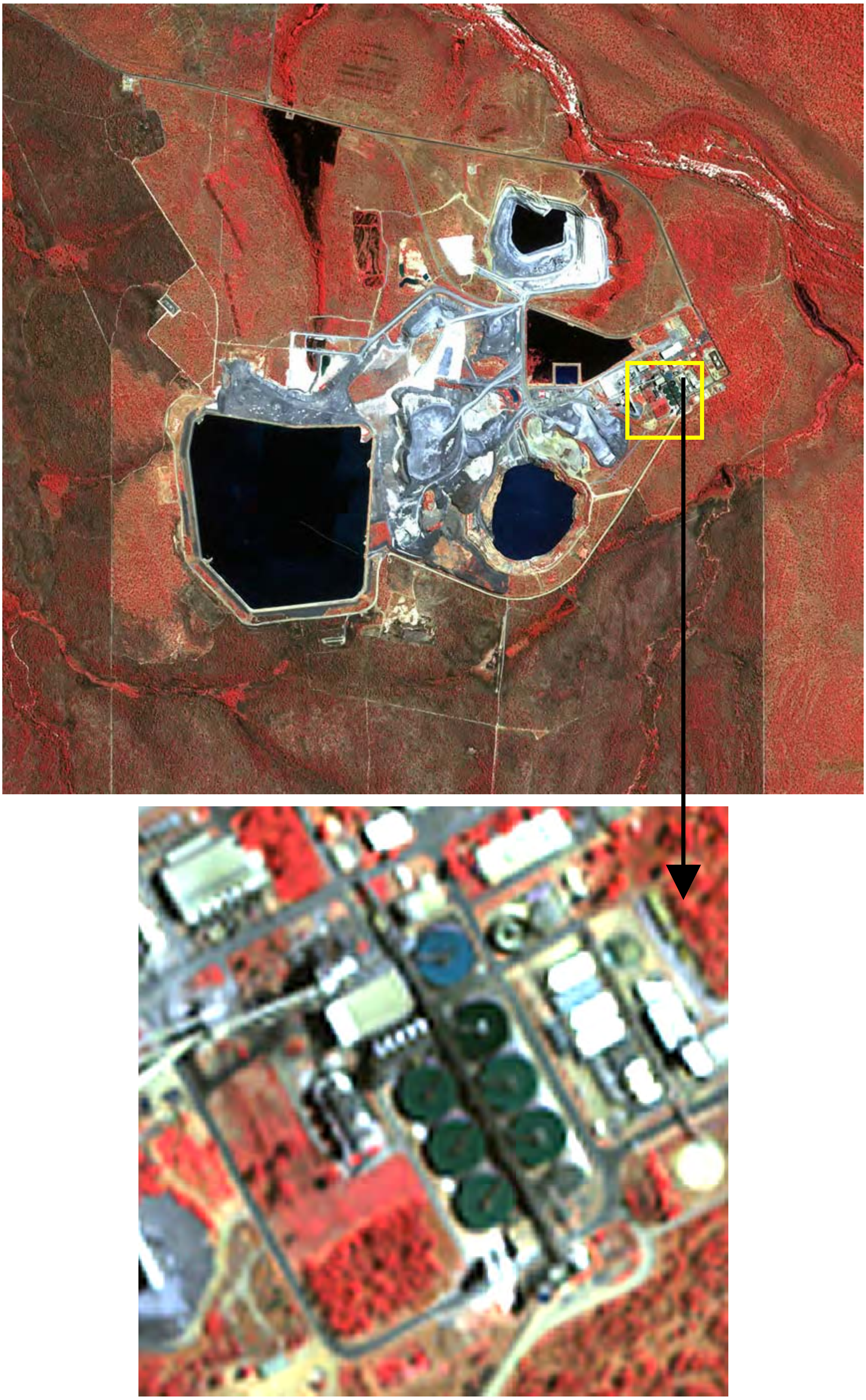

Figure 4 IKONOS (subset of scene 5) False colour multispectral bands 4 3 2

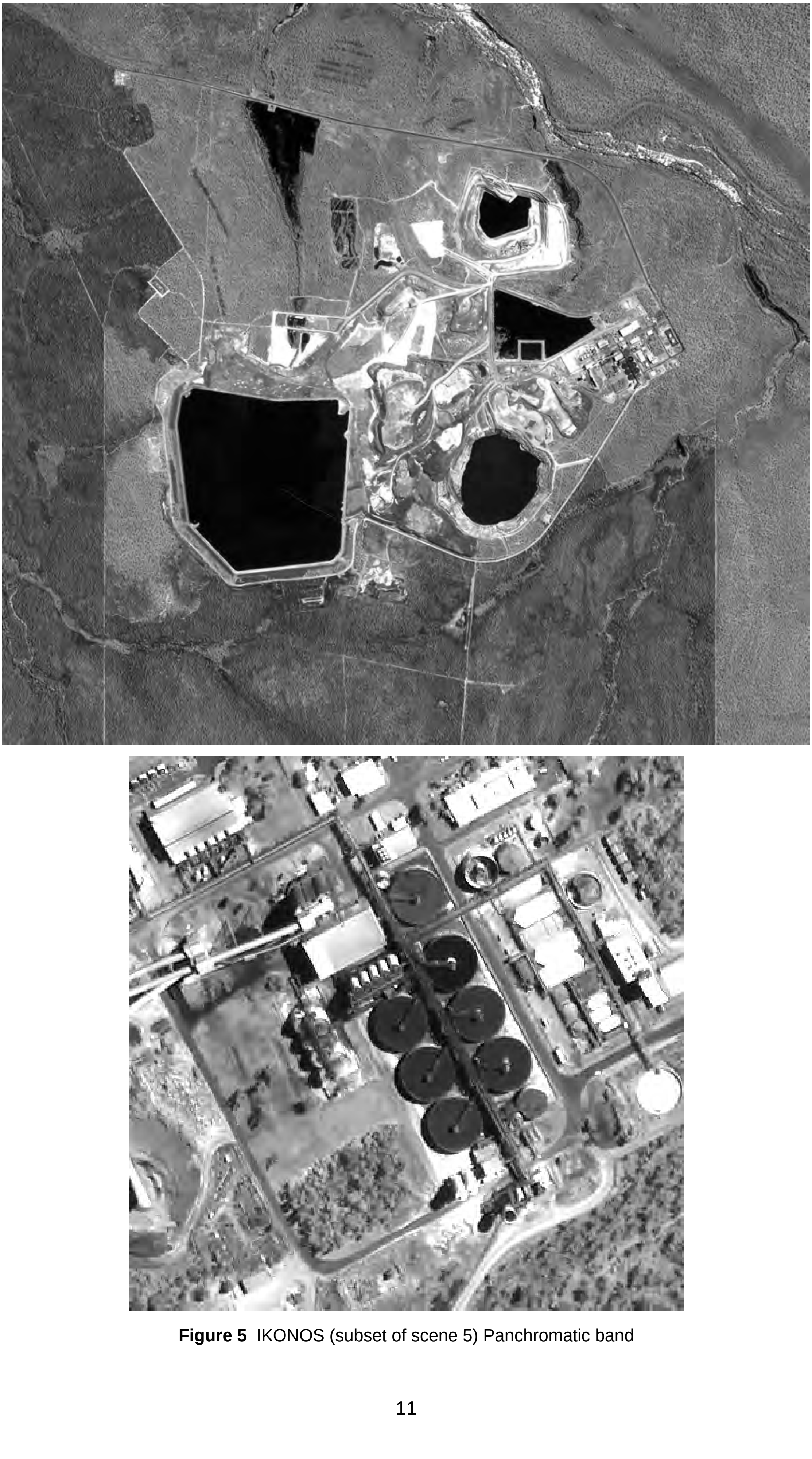

Figure 5 IKONOS (subset of scene 5) Panchromatic band

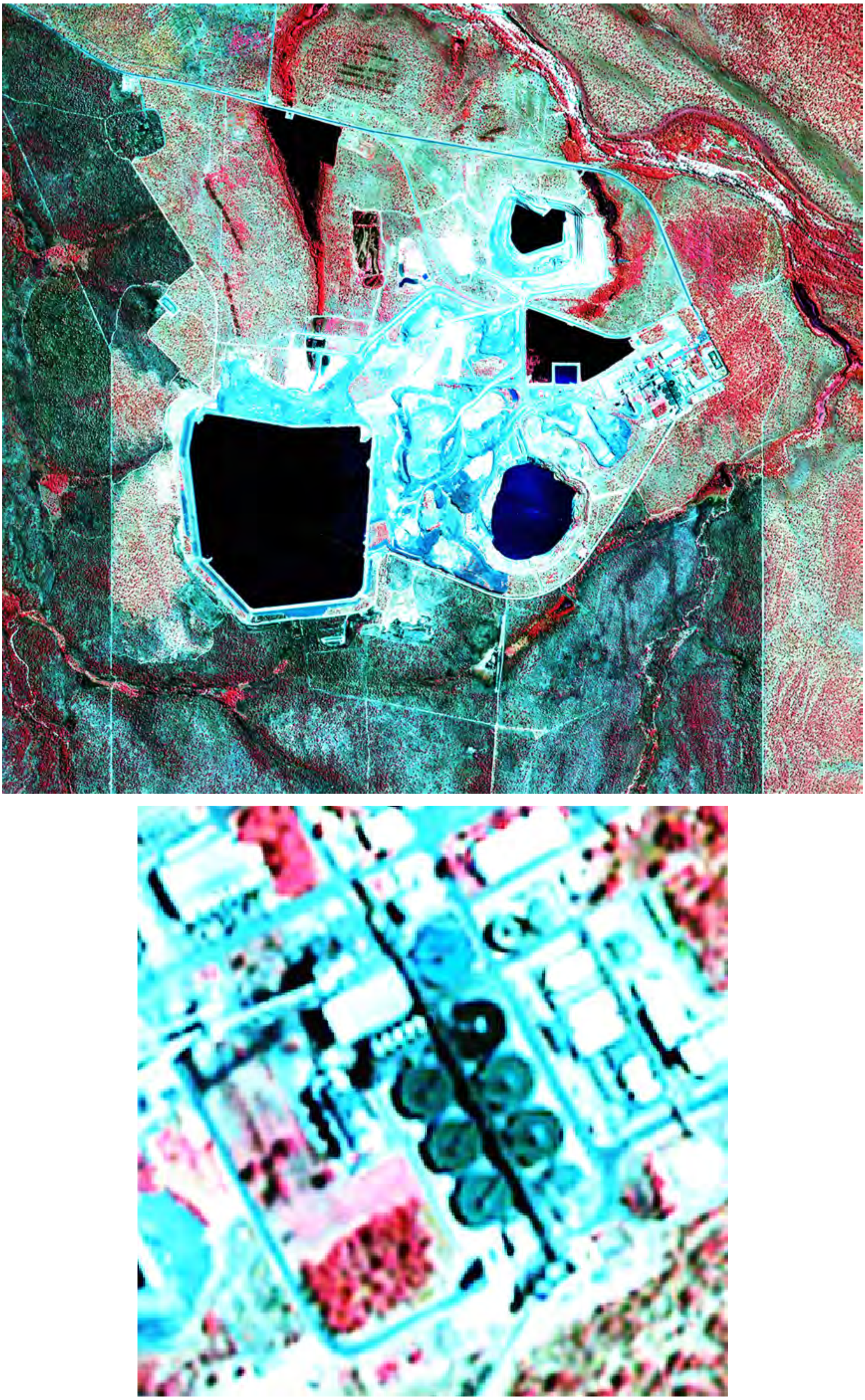

Figure 6 IKONOS (subset of scene 5) False colour multispectral bands 4 3 2 reduced to JPG (0.5)

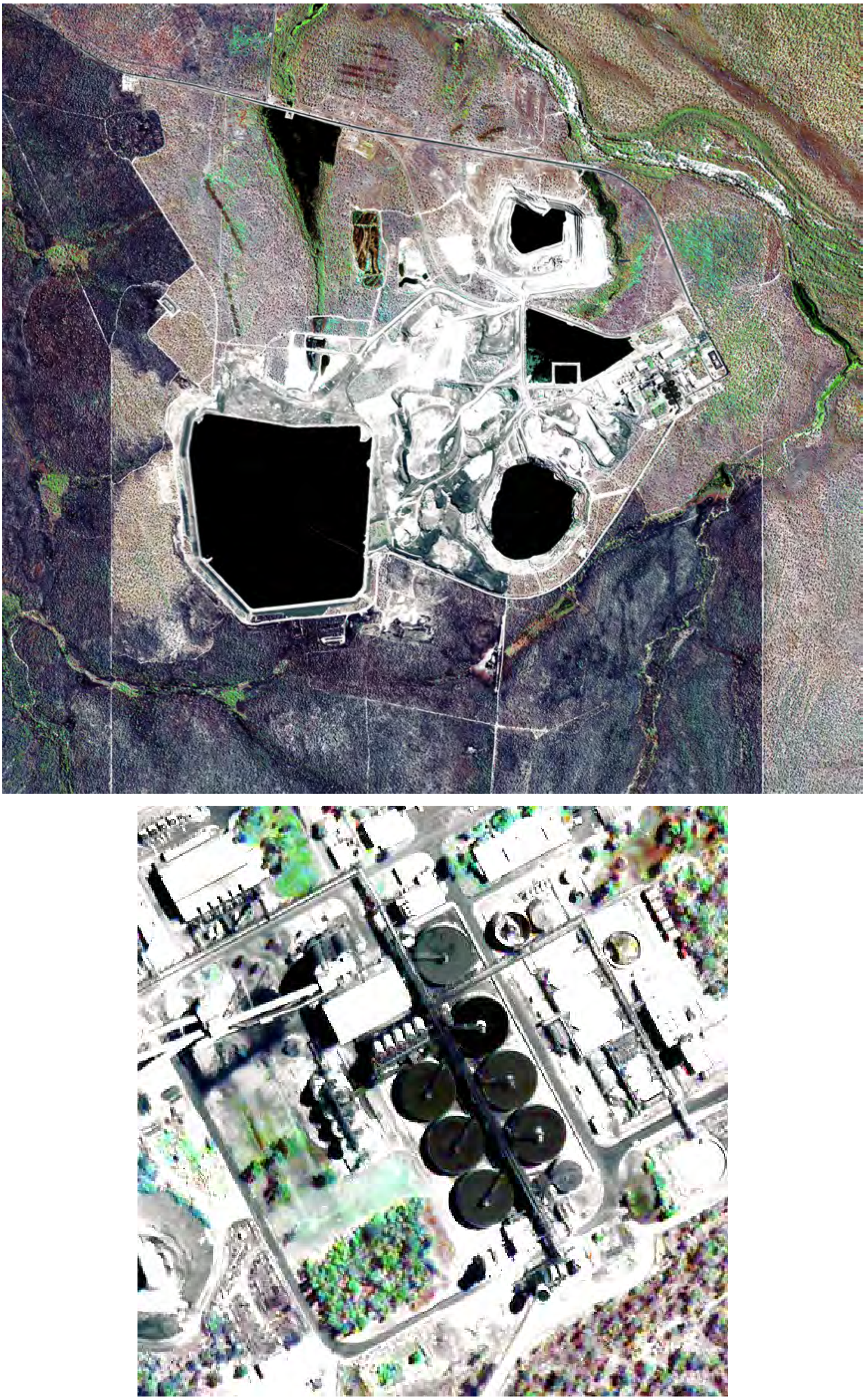

Figure 7 IKONOS (subset of scene 5) True colour multi bands 3 2 1 sharpened with pan band

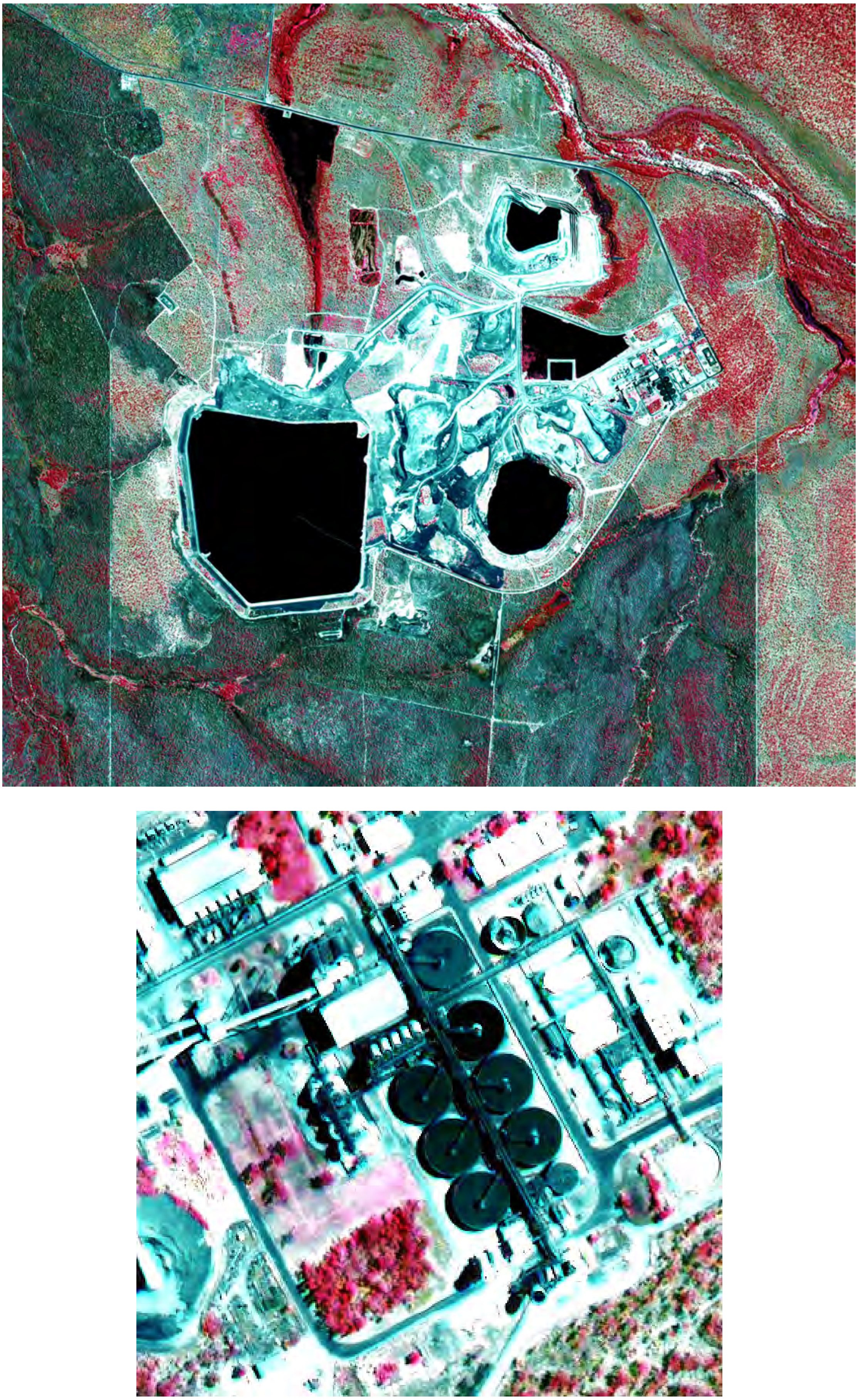

Figure 8 IKONOS (subset of scene 5) False colour multi bands 4 3 2 sharpened with pan band

5 Summary – lessons learnt and points to consider for new capture requests

1 The sensor has an off-nadir pointing angle of ±30° in any direction. The spatial resolution of IKONOS data varies with degrees off nadir.

The panchromatic band is 1 m nominal at < 26 degrees off nadir. This actually varies from 0.8 – 1.2 m Ground Sample Distance (GSD) that is resampled by cubic convolution to 1.0 m map increment. The multispectral bands are 4 m nominal at < 26 degrees off nadir. This is an important consideration if imagery is to be acquired of adjacent swaths at different viewing angles. It is recommended that image capture be requested close to nadir.

2 The satellite orbit exactly repeats every 140 days, however, IKONOS imagery can be acquired of the same geographic area every 1–3 days, depending on latitude.

Data captured of a similar geographical area at temporal scales less than 140 days may be a result of image capture at angles greater than nadir. It should be realised that this would affect the GSD.

3 The data is available in a range of levels of positional accuracy (which also differ cost-wise).

The 'Geo-Ortho' kit that includes RPCs should be the minimum positional product, unless orthorectification will be undertaken by some other means (such as through GeoImage). Note that the free of charge orthorectification process by GeoImage in this case was a one-off.

4 A successful image capture will have less than 20% cloud cover.

For new captures, this means that image captures will be attempted until an acquisition of a scene with 20% or less cloud cover has been acquired. This condition is a risk for new capture requests. For archived imagery, it is possible to view images online prior to purchase. This issue prevented an archived image purchase over the rehabilitated Nabarlek mine area, whereby the scene was captured with < 20% cloud cover, of which most of the scene was cloud-free, except for the Nabarlek mine area (which was obscured).

5 A nominal single image is 10.5 km x 10.5 km - areas wider than 10.5 km East-West or longer than 100 km North-South may be collected as separate satellite images.

Where separate image captures are required, it should be noted that images collected at the same date will be achieved via different look angles and thus varying GSD (on raw data). To acquire separate image captures close to nadir, the date for each scene capture will differ.

6 With the increase in competitive sensors, such as Quickbird, it is likely that the cost of IKONOS data will continue to decrease in the future.

Current prices/quotations should be submitted to GeoImage.

7 There is a choice of 8 or 11 bits per pixel.

Users of 11-bit imagery will require software capable of reading 16-bit file formats, such as Research Systems ENVI. 8 bits results in degraded spectral detail.

8 IKONOS images are large computer files.

IKONOS data requires large amounts of disc free space. Transformations require high processing capabilities. The users of high resolution remotely sensed data might require upgrades in computer capacity.

For the IKONOS data obtained:

- **The quick look JPEG data should only be used for visual purposes and degraded image quality acknowledged. The quick look data should not be used for spatial of spectral classification of boundaries or land cover components.**
- **For enhanced visual analysis, HSV sharpened multispectral data should be utilised. The sharpened data should not be used for spectral classification.**
- **For spectral and spatial classifications of boundaries or land cover components, the orthorectified multispectral and panchromatic data should be used, given ~ 12 GB of free disc space.**

6 Appendix – Processing by GeoImage

*Text and figures are **directly** from GeoImage's summary:*

Two scenes collected on 16.09.2000 with central latitudes of 12.3S and 12.7S were selected as cloud free and covering the area of interest well.

Ground control for the ASTER data was obtained from the RASTER 100k and the two scenes were processed (unfortunately the two scenes although collected on the same date were processed on different dates and could not be joined prior to processing). Problems in the DEMS were most apparent adjacent to the water areas and in the areas of smoke plumes from bush fires. These areas were edited out in the final DEM with the exception of the large smoke plume in the upper scene.

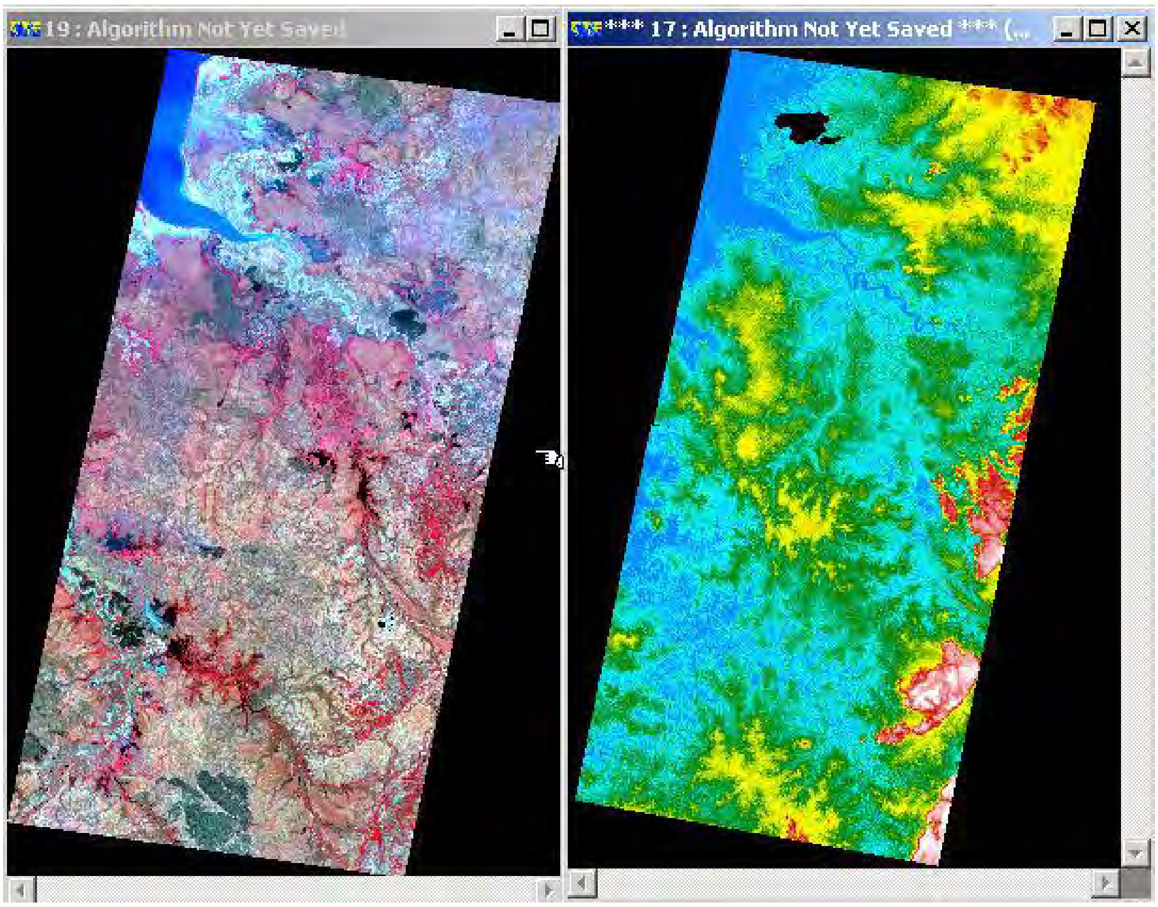

Figure 9 Aster VNIR orthorectified mosaic (left), rainbow pseudocoloured DEM mosaic (right)

The strip of IKONOS data was supplied on 4 CDS and because the number of samples was different on each CD the data could not be joined in PCI before processing.

Vectors of roads , tracks and rivers were supplied by the client and used for ground control. The ground control points were selected in ERMapper using a mosaic of the four pan scene – this mosaic was easily prepared in ERMapper by loading the four pan, tif files as supplied by Space Imaging. Approximately 30 ground control points were selected because it was realised that many of these would be found to be inaccurate when loaded into PCI. The reason is that in the northern section of the image where there were only creeks available for location, the actual bed of the creek could not be seen because of the vegetation, etc. heights were added to the GCP file from the aster DEM.

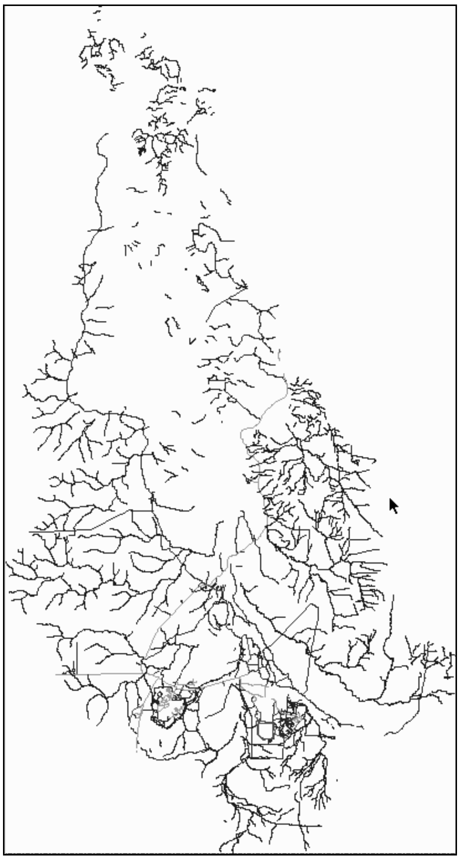

Figure 10 Vector information for ground control

The points were loaded into the most northerly of the IKONOS scenes and points with errors of above 5 m were excluded. The pan image was then orthorectified using the ASTER 15 m DEM. The result showed large areas of poor extrapolation as shown in figure 11.

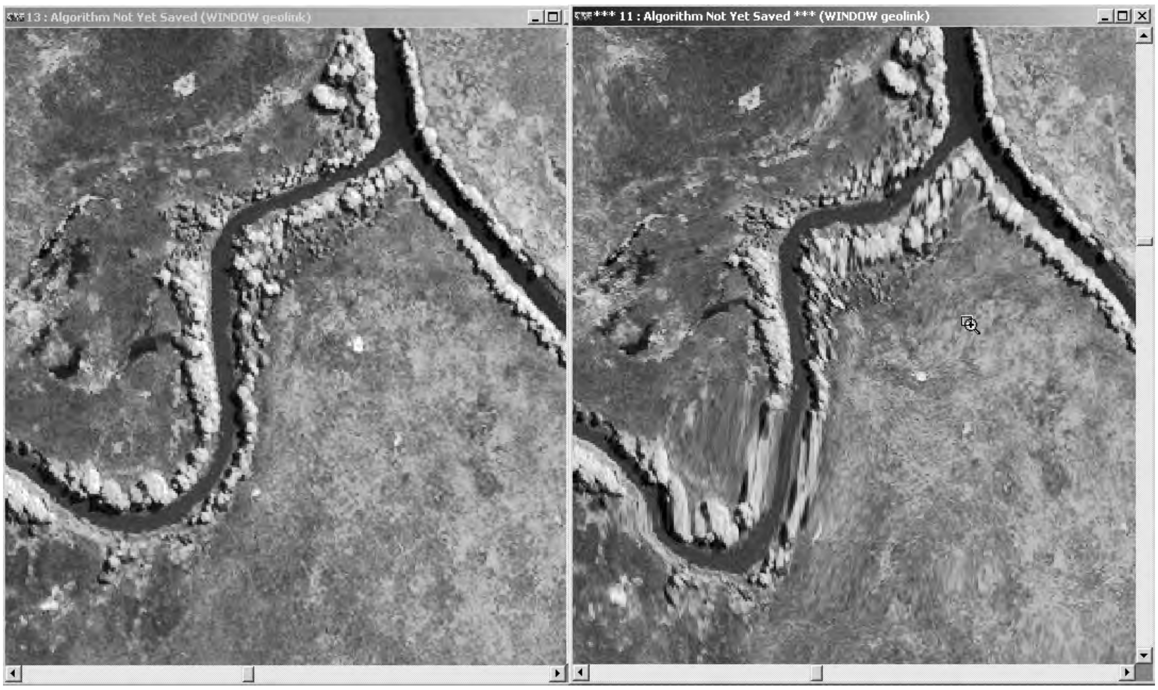

Figure 11 Orthorectified image after streakiness fixed (left image), streaky image (right image)

The problem was overcome by averaging the DEM data over a 15 x 15 pixel window and resampling the data to 4m centres.

The final orthorectified image was checked against the vectors for locational accuracy and the fit was found to be good. The same ground control points were used to orthorectify the other windows from the same strip using the following offsets in sample and lines.

Ranger2	-152	-18483
Ranger3	-308	-37023
Ranger4	-464	-55619

In the case of the multispectral 4 m data, the GCPs were divided by 4 in each of the sample and line directions and the data were re-entered into PCI. However the RMS errors were different from the pan to the multi – it would have been expected that the errors would have been reduced to 25% of the errors in the pan scene. It was therefore decided to process the multi at 1m resolution. This involved expanding the 4 m multi data to 1 m in ERMapper and then adding the data to the pan.pix file as new layers and then orthorectifying it.

Figure 12 Image showing the location accuracy of the northern image (Image is approx 400 m across)

This is done by :

- Reading the data in ERMapper from the original tif files – it has projectional data in it.
- Do a rotational warp with a 0 angle (the data thinks it is 1m so reset the output cell size to 0.25 x 0.25).
- Reset the pixel size of the output to 1 m by 1 m. This appears to be critical as otherwise PCI gets confused.
- Make a copy of the pan.pix file and enter the data into this file by replacing the pan layer with band 1, and adding bands 2 3 and 4. This procedure takes considerable time. In some instances it may be possible to just add the multi layers to the pan file however in this instance the pan file was +400 mb and the multi file was +1600 mb so the final file would have been larger than 2 Gb.
- Exit out of the prj file – otherwise the system will not know it now has 4 bands rather than 1 band.
- Orthorectify using the same GCPs as the pan.

The other pan files were checked against the vector files and found to be ok.

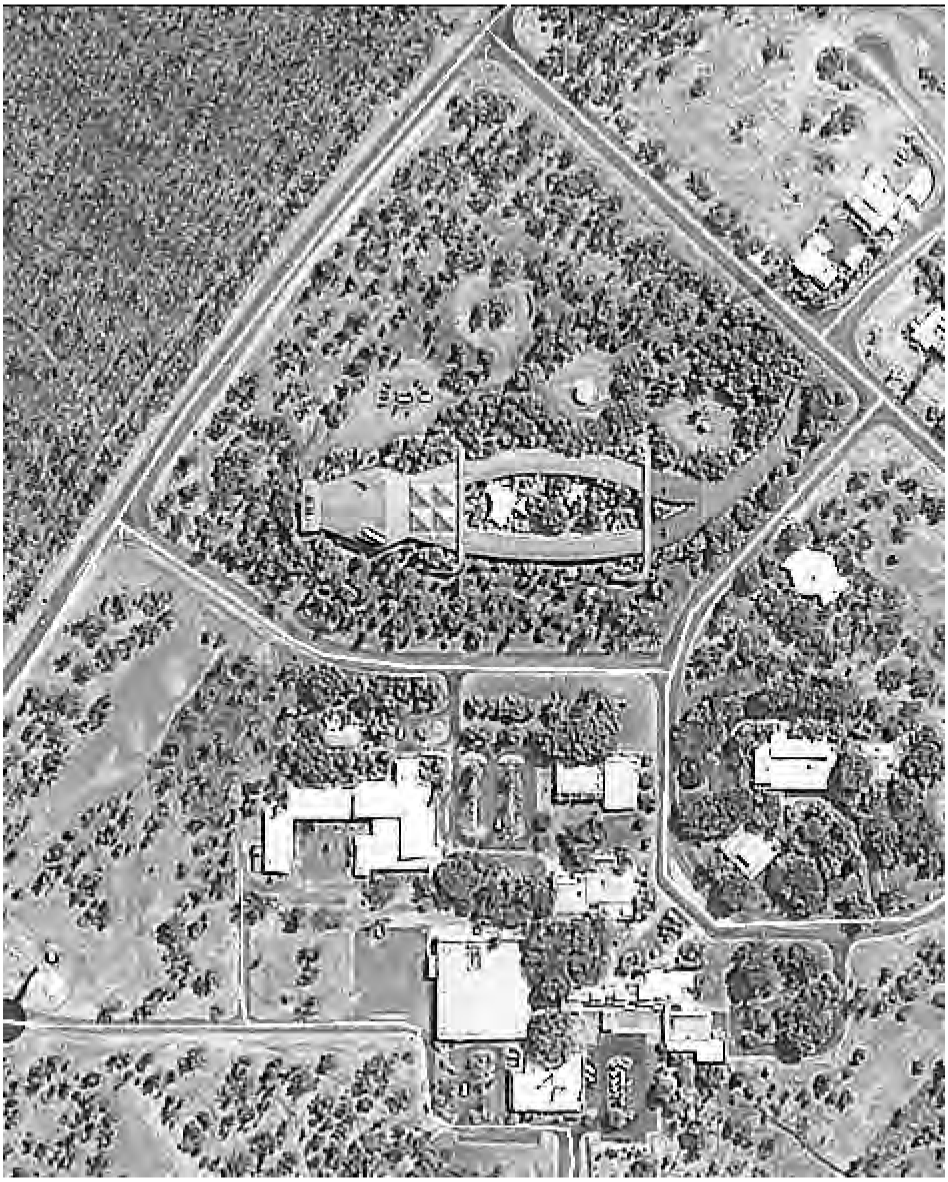

Figure 13 Road vectors on a pan sharpened true colour image

The single IKONOS scene was processed using points in the overlap as the GCPS and approx 20 were selected. Errors were sub-pixel in size. The errors in the final orthorectified image were found to be a maximum of 1 to 2 metres where there was a major change of slope that was not in the DEM – for example on the edges of buildings etc.

Figure 14 Match between the major n–s strip in red and the single Ranger scene in green (Note that the later scene – Ranger 5 appears to have had a fire on the western side of this image)

Figure 15 Similarly at the airport – note the minor problems on the edges of buildings where the height change is not in the ASTER DEM, however, the roads fit perfectly