DISCOVERING REMOTE SENSING

Teacher Notes
Student Activities

Record 1999/30A

AUSLIG

AGSO
AUSTRALIAN GEOLOGICAL SURVEY ORGANISATION

Geoscience Education

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DEPARTMENT OF INDUSTRY, SCIENCE AND RESOURCES

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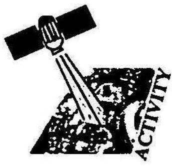

Discovering Remote Sensing

Introduction

Satellite imagery is used to study the Earth's surface and monitor changes in the environment. It is also increasingly being used to explore for new resources and develop better plans on how to utilise those resources. Along with satellite imagery, information about the Earth's surface captured by instruments flown in survey aircraft is adding to the array of data available to the researcher, land manager, forester, environmental scientist, geologist and resource developer.

The analysis of satellite images began in Australia in 1979 and, while this was 20 years ago, the technology used to capture satellite imagery is still not widely understood. The aim of this kit is to provide a basic outline of remote sensing and its applications.

The kit components include:

- *Discovering Remote Sensing* book, including student activities, exam and answers, teacher guide and curriculum links
- 4 overhead projection sheets
- 10 sets of 5 full colour cards printed on both sides (a list of the cards can be found at the back of this text)
- WWW site – Satellite Image Processor

The Teacher Resource Notes contain the basic information to allow the topic of remote sensing to be introduced into the classroom. The notes contain 4-colour overhead projection (OHP) sheets of some remotely sensed images.

The Activity section of the *Discovering Remote Sensing* book contains a range of student activities that highlight aspects of remote sensing. At the end of each section of this book, the activity symbol shown above appears with notes indicating the relevant activities in the back of the book. The activities in this introductory kit are focused on one area – the Tweed Heads region of Northern New South Wales– and provide students with experiences in using images and the information that they can obtain from those images. Suggested answers are included at the back, along with an exam based on the information in this kit.

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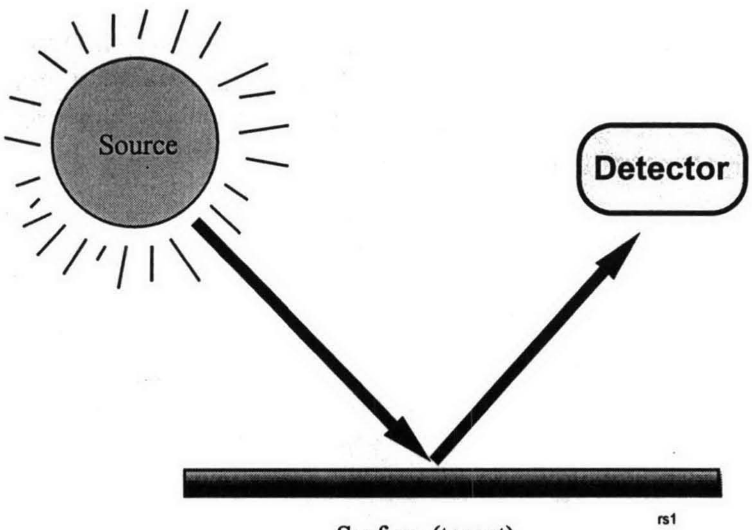
Throughout the *Discovering Remote Sensing* teacher notes and student activities, there are references to the colour cards. A card symbol like the one on the left will appear whenever it is necessary to refer to the cards.

What is remote sensing?

Remote sensing is the science of detecting, measuring and analysing a substance or object from a distance. The recording device is not actually in direct contact with the object being studied, hence the use of the term "remote".

In its simplest form, remote sensing involves radiation (light, heat etc) emitted by a source such as the Sun. Some of this radiation is absorbed by the Earth's surface ("the target") and the rest is reflected, and then measured by the "detector". Different target materials will produce individual responses.



This characteristic is used to identify the nature of the target materials, be they vegetation, soil, rocks, water, buildings or other landuse from a remote distance (often from space).

How remote is remote?

Gathering information on an area from a distance relies on sensors mounted on a platform that can see over the study area. The two major platforms that acquire remotely sensed data are satellites and aircraft. However, data collected on the ground may also be considered to be remotely sensed, especially if the data being collected are about materials below the surface.

History of remote sensing

There has always been an interest in looking beneath the surface of the Earth and the oceans, and far out into space. As early as 1609, information was obtained using simple remote sensing methods when Galileo observed the Moon, Sun and the Milky Way through a spyglass. Technology is now available for detecting and monitoring global-scale change on land, in the atmosphere and the oceans.

For thousands of years information about the topography of the land has been important in military tactics, and as is the case with some other technologies, remote sensing was first used seriously for military purposes.

The first aerial photographer, Gaspard Felix Tournachon, a Frenchman, took his camera aloft in a balloon in 1859. Tournachon's aim was to make land surveys from aerial photographs. The military became interested in Tournachon's work, although his efforts were not a great success.

In 1861, Professor Thaddeus Lowe went aloft in a balloon to make weather observations in Ohio. Once President Lincoln realised land surveys could provide important military information he ordered a balloon army corps to be formed. However, balloons tended to attract enemy fire, so in 1863 the US Army Balloons Corps was deactivated.

Aerial photography was used in the American Civil War (1861–1865). Artillery bombardment and monitoring the damage to housing and landscape were its first uses during that time.

In 1903, a similar outfit to the balloon corps was formed - the Bavarian Pigeon Corps. Each pigeon carried a camera that took a picture every 30 seconds. Unfortunately, the flight paths of the pigeons were very unpredictable!

In 1909 Wilbur Wright's pilot took aerial motion pictures in France. From this time forward the biplane replaced the balloon. Both the US and the Germans used aerial photography to observe enemy positions in the trenches during World War 1 (1914–1918). From the 1920s peace time applications of aerial photography were used to survey natural resources.

Infrared photography was first used in World War II (1939–1945), where it was used mainly to distinguish between camouflage and vegetation. Radar, which was developed in the latter part of the war, detected the movements of aircraft and ships in all weather.

Observations of Earth from satellites began in the early 1960's. The collection of global meteorological data was the primary objective of early satellite missions.
By 1972 NASA had built and launched the first Earth Resource Technology Satellite (ERTS - 1) which contributed to a better understanding of soils, crops, minerals,

urban growth, and Earth processes. The Landsat program has made a major contribution to the archives of Earth observation imagery around the world.

Data and imagery acquired by satellite sensors are now a vital source of information about the condition and constituents of the Earth's land surface, oceans, and atmosphere.

Australian Perspective

Landsat 1, (originally known as Earth Resources Technology Satellite) launched in July 1972 was the first satellite designed to collect data about the Earth's surface and natural resources. The Australian Centre for Remote Sensing (ACRES) has been acquiring and archiving data from the Landsat MSS sensor since 1979 and the Landsat TM sensor since 1986.

The last 20 years has seen significant activity in remote sensing in Australia. This activity includes the development of software to store, process and derive information from the data in a range of applications.

The large area coverage and near infrared information of Landsat data have been extensively applied to geological mapping and mineral exploration in Australia. More recently, a major application of imagery is environmental management. This includes the mapping and management of native and exotic forests. The accurate and current mapping of forests assists in the community response to important environmental considerations such as greenhouse gas measurement, biodiversity and the salinisation of agricultural soils.

The proposal for the Australian Resources Information and Environmental Satellite (ARIES) hyperspectral satellite is an important recent development in Australian remote sensing. At the present time, Australia relies on satellites that are developed and operated by foreign governments and organisations. The development of an Australian satellite will assist us to maintain an involvement in the international business of Earth observation technology. The proposal has been developed by CSIRO, AUSLIG, AUSPACE and several mineral resource companies. Hyperspectral remote sensing makes possible the identification of detailed mineral properties and vegetation characteristics not possible with multispectral remote sensing.

The applications of remote sensing in Australia are world class. Australians are amongst the leaders in the development of software used to process, analyse and interpret satellite data. Satellite imagery is integrated with other information systems used to manage Australian resources.

Satellite imagery is replacing aerial photography in a number of applications, for example the production of topographic maps, thematic maps, and image maps, which utilise a satellite image base with enhanced features and nomenclature.

Satellite imagery provides the only economically viable method of mapping at smaller scales the broad landcover types across the continent. This has enabled Australia to participate in international programs such as The International Geosphere-Biosphere Program: A Study of Global Change. This study was an attempt to identify the global impact of human activity on landcover.

The Australian Bureau of Meteorology relies on satellite data obtained from an international meteorological satellite network. Satellite data are specially important in the forewarning of severe weather conditions such as tropical cyclones, whose effects can be socially and economically important.

Radiation — the remote sensing vehicle

Radiation and light

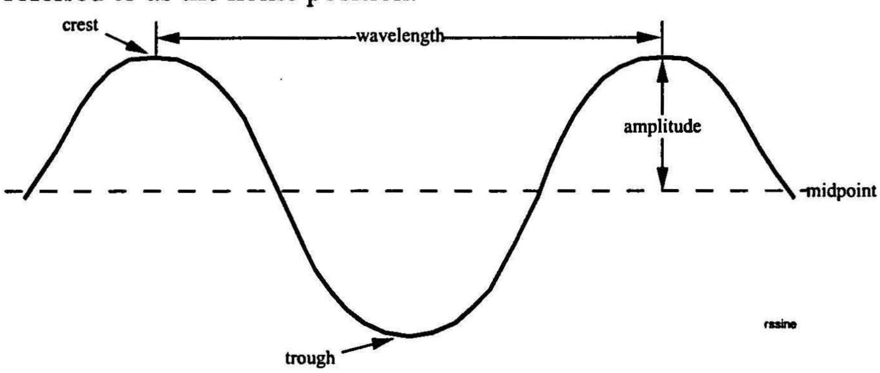
Remote sensing relies totally on radiation emitted from a source. In most cases, this source is the Sun. These waves of energy are part magnetic and part electrical in nature and are referred to as electromagnetic waves or electromagnetic radiation.

The following terms are used to describe the parts of these electromagnetic radiation waves:

Crest: The crest of a wave is its high point.

Trough: The trough is the low point of a wave.

Mid-point: The mid-point of a wave is in the middle of the wave and is also referred to as the home position.



Amplitude: The amplitude is the distance from the mid-point to peak of the crest or the bottom of the trough.

Wavelength: The wavelength of a wave is the distance from successive identical parts of the wave. For example the peak of a wave to the peak of the next wave completes a cycle. Alternatively, the bottom of a trough to the next trough also measures the wavelength. The wavelength of light is usually measured in millionths of a metre, (micrometres, µm), whereas the wavelength of ocean waves is measured in metres.

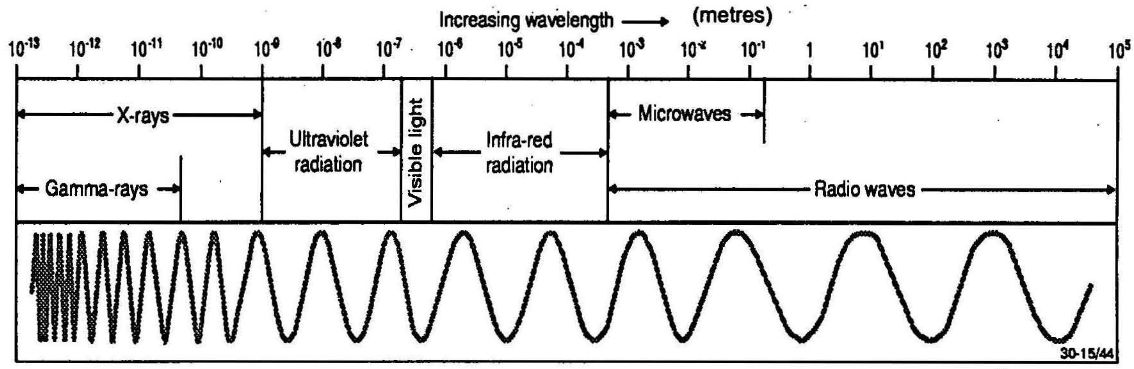
Cycle: A cycle is the movement of one entire wavelength past a point.

Frequency: The frequency of electromagnetic radiation is the number of cycles passing through a fixed point in one second. The unit of frequency is called the Hertz (Hz). (ie 1 hertz = 1 cycle per second.)

Light is the visible form of electromagnetic radiation. Light and all other forms of electromagnetic radiation travel at an extremely fast speed of 300 000 kilometres in one second (km/s) or 3.0×10^{8} m/s.

The Electromagnetic (EM) Spectrum

The electromagnetic (EM) spectrum is the continuous range of electromagnetic radiation, extending from gamma rays (highest frequency & shortest wavelength) to radio waves (lowest frequency & longest wavelength) and including visible light.



The EM spectrum is divided into different regions — gamma rays, X-rays, ultraviolet, visible light, infrared, microwaves and radio waves.

Using the electromagnetic spectrum for remote sensing

Remote sensing involves the measurement of energy in many parts of the EM spectrum. The major regions of interest in satellite sensing are visible light, reflected and emitted infrared, and the microwave regions. The measurement of this radiation takes place in what are known as **spectral bands**. A spectral band is defined as a discrete interval of the EM spectrum. For example the wavelength range of 0.4 μm to 0.5 μm is one spectral band.

Satellite sensors have been designed to measure responses within particular spectral bands to enable the discrimination of the major Earth surface materials. Scientists will choose a particular spectral band for data collection depending on what they wish to examine. The design of satellite sensors is based on the absorption characteristics of Earth surface materials across all the measurable parts in the EM spectrum.

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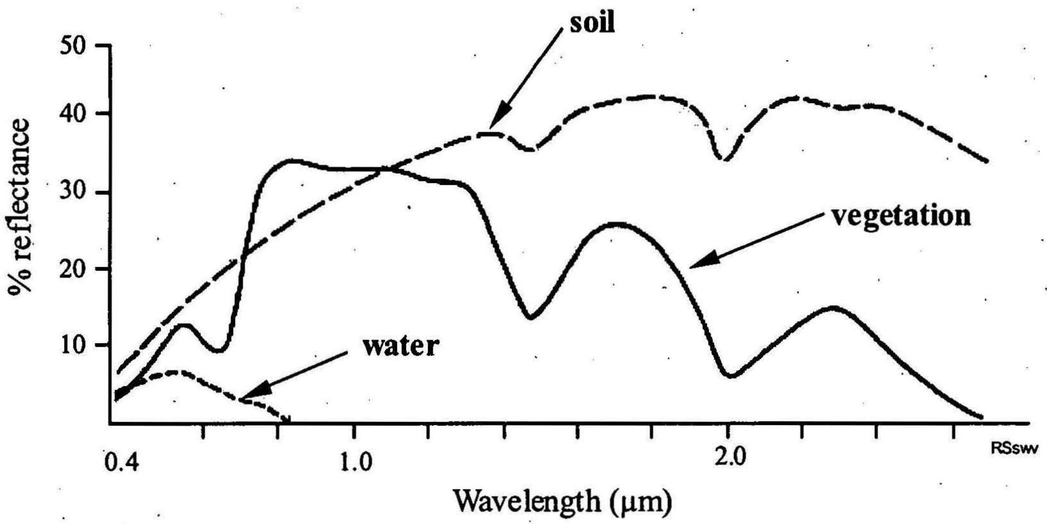
Card 5 illustrates the concept of Landsat TM spectral bands further.

Reflection and absorption

When radiation from the Sun reaches the surface of the Earth, some of the energy at specific wavelengths is absorbed and the rest of the energy is reflected by the surface material. The only two exceptions to this situation are if the surface of a body is a perfect reflector or a true black body. The occurrence of these surfaces in the natural world is very rare. In the visible region of the EM spectrum, the feature we describe as the colour of the object is the visible light that is not absorbed by that object. In the case of a green leaf, for example, the blue and red wavelengths are absorbed by the leaf, while the green wavelength is reflected and detected by our eyes.

In remote sensing, a detector measures the electromagnetic (EM) radiation which is reflected back from the Earth's surface materials. These measurements can help to distinguish the type of land covering. Soil, water and vegetation have clearly different patterns of reflectance and absorption over different wavelengths.

The reflectance of radiation from one type of surface material, such as soil, varies over the range of wavelengths in the EM spectrum. This is known as the spectral signature of the material. All Earth surface features, including minerals, vegetation, dry soil, water, and snow, have unique spectral reflectance signatures, as shown in the following simplified diagram.



Reflectance of radiation by soil, vegetation and water

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Card 5 shows in greater detail the spectral signatures (also known as absorption curves) of some common materials, such as green grass and dry grass. The spectral signatures are relative measurements. Where the EM radiation is being absorbed at a particular wavelength, a relative dip in the spectral signature will appear. Notice that in green grass, for example, there is relatively lower reflectance in the blue and red wavelengths (Landsat TM spectral bands 1 and 3) compared to the green wavelength (Landsat TM spectral band 2). This is because green grass absorbs more radiation in the Landsat TM spectral bands 1 and 3, compared to band 2.

The spectral signature for plants varies as the environmental conditions of a plant change. Compare the spectral signatures of green grass and dry grass. On both of these, relatively higher reflectance occurs in Landsat TM band 5, compared to in the EM spectrum either side of Landsat TM band 5. Note the sharp "dips" in the absorption curve at around 1.4 µm and 1.9 µm. These "dips" are the result of the absorption of EM radiation at those wavelengths by water present in the green grass..

Another interesting phenomenon to observe on Card 5 is the absorption feature of clay in Band 7. This occurs because EM radiation at this wavelength is absorbed by the molecular structure of clay (specifically the hydroxyl bonds). This absorption feature can be used to identify clay materials on the ground.

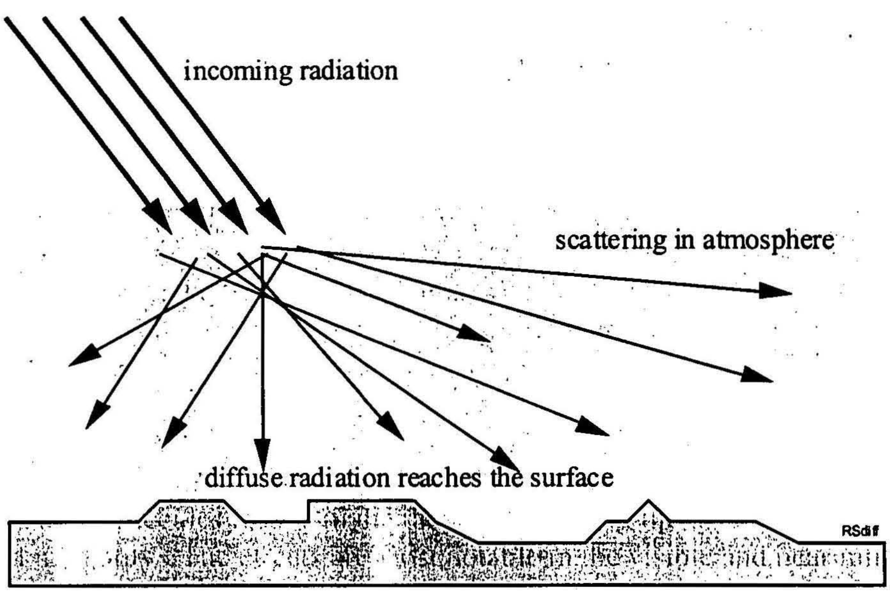
This knowledge about the true spectral signatures for different Earth surface materials is used to choose the spectral bands in detector sensors in order to give the best spectral discrimination between different materials. Additional spectral bands, particularly in the infrared part of the spectrum, can also assist in the better discrimination of Earth surface materials.

Atmospheric effects

Radiation that travels from the Sun to the Earth's surface and then is reflected back to a sensor must travel through the atmosphere. The atmosphere also transmits, absorbs and scatters radiation. Transmitted radiation passes through the atmosphere and reaches the sensor unchanged. The absorbed radiation warms the atmosphere or is re-emitted with altered spectral characteristics.

Atmospheric scattering results when the direction of radiation is changed in an unpredictable manner as it hits particles in the atmosphere. The scattering of radiation by particles and molecules results in the radiation reaching the detector being diminished in quality. The effects are most notable in the visible and near infrared wavelengths.

There are three main types of scattering: Rayleigh, Mie and non-selective.



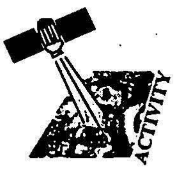
Rayleigh scattering, the most common type, occurs when the wavelength of the radiation encounters particles that are much smaller than the energy wavelength. This effect is most severe in the shorter wavelengths and is the reason the sky appears blue.

Mie scattering occurs when the wavelength of the incident radiation is comparable to the size of the particles or molecules encountered. Water vapour, fumes and dust are the components which scatter radiation in the Earth's atmosphere. This type of scattering tends to influence longer visible wavelengths. Mie scattering is significant when the atmosphere is slightly overcast.

Non-selective scattering affects all visible, near and mid infrared wavelengths almost equally. It occurs when the atmospheric particles causing scattering, such as water droplets and dust, are much larger than the wavelength of the radiation interacting with them. Radiation can be scattered out of or into the field of view of the satellite sensors.

Atmospheric absorption

Data collected by remote sensing can sometimes be masked by atmospheric particles such as haze, water vapour and clouds. Regions of the EM where the atmospheric effects are greatest are unsuitable for remote sensing of the Earth's surface. For example, the range of 0.9–1.5 μm has larger amounts of atmospheric absorption. Regions of the EM spectrum which are unaffected by the Earth's atmosphere are called "atmospheric windows". The Landsat TM bands 1 through to 7 correspond with these atmospheric windows. (See card 5 for an illustration of the Landsat TM spectral bands.)



The activity most relevant to the *Radiaton – the remote sensing vehicle* section is:

Electromagnetic radiation and spectral bands

Remote sensing detectors

Satellites

A satellite is an object that orbits a planet. It can be as small as a football or as large as a small planet. Satellites rotate around the Earth in either a circle or an ellipse and remain in a flat plane called the orbit plane. Satellites can be disturbed by the gravitational attraction of another planet causing them to wobble. The Earth's atmosphere also has an influence on the orbital characteristics of the lower orbiting satellites.

Artificial satellites are placed into orbits around the Earth for a variety of scientific, environmental, commercial and military applications.

Satellites that are used for remote sensing orbit in a range of altitudes from about 500 to 36 000 km. Satellites with higher orbits provide several images of the Earth each day, but with much less detail than satellites in lower orbits. Satellites that orbit at an altitude of 36 000 km are in an equatorial plane (ie above the equator) and remain at the same point above the Earth's surface as they are orbit at the same speed as the Earth rotates. These satellites are known as **geostationary satellites.**

A **Sun-synchronous Earth satellite** has a polar orbital plane that passes over all places of the Earth having the same longitude at the same local time. The orbit altitudes of these satellites are in the range of 500–1000 km.

Types of Satellites

Weather satellites

Many weather satellites provide constant monitoring of the Earth's weather patterns. The data collected contain information about the type, temperature, and distribution of clouds. The image on Card 9 of the kit shows cyclonic activity as captured by the NOAA sensor. Other information collected includes ocean surface temperatures, measured by detectors recording the thermal infrared part of the EM spectrum. This information is used for many meteorological purposes, including the regular weather forecasts available in most countries.

For weather forecasting, the data have to be:

- collected several times a day for the entire Earth;
- consistent and reliably converted to known physical parameters, such as sea-surface and cloud-top temperatures;
- used for a range of applications from a local weather forecast to global climatic models.

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Card 9 shows an example of a NOAA Meteorological Satellite Image.

Earth resources satellites
These satellites provide a vast amount of information about the natural resources of the world and the result of human settlement on these resources. They use a variety of spectral bands that can be used to study changes in vegetation, mineral content, moisture soils etc.

Communication satellites relay a range of telephone, television and other data signals using receivers, transmitters and amplifiers located on the satellite. Many of these satellites are located in a geostationary orbit.

Global positioning satellites (GPS) provide position, velocity and time information to users on the ground, at sea, in the air and in space. For more information on GPS see page 32.

Passive satellite sensor systems

As previously discussed, almost all remote sensing relies on the use of radiation from the Sun, reflected or emitted from the Earth's surface. Sensors mounted on satellites that measure this radiation are known as passive satellite sensor systems.

Some examples of passive satellite sensor systems currently operational are:

Platform	Sensor	Ground Resolution	Spectral Bands	Application
NOAA (National Oceanic and Atmospheric Administration)	Advanced Very High Resolution Radiometer (AVHRR)	1 km	5	Weather monitoring, fire scar mapping, continental and global scale vegetation monitoring, Sea surface temperature.
Landsat 1- 5 (USA)	Multispectral Scanner (MSS)	80 m	4	Vegetation and geological applications.
Landsat-4,5 (USA)	Thematic Mapper (TM)	30 m	7	Wide range of vegetation and geological applications
Landsat-7 (USA)	Enhanced Thematic Mapper (ETM+)	30 m	8	Wide range of vegetation and geological applications
SPOT (Systeme Probatoire d'Observation de la Terre.) French polar orbiting satellites	HRV (High Resolution Visible)	10 – 20 m	4	Earth resources including agriculture, cartography, environmental monitoring and urban planning
***ARIES** (Australian Resource Information and Environment Satellite)	Hyperspectral VNIR (Visible and near infrared) & SWIR (Shortwave infrared)	30 m	126	Detailed mineral mapping, agriculture, and environmental monitoring.

* Planned to be launched in 2002.

Active satellite sensor systems

Unlike passive systems, active systems "illuminate" the terrain with radiation — such as microwave energy generated from the satellite — then measure the reflected radiation. This is like shining a torch to see our way at night; we provide the radiation source (the torch) and measure the reflected radiation with our eyes.

Synthetic Aperture Radar (SAR) systems are the most common example of an active system. SAR systems emit radar pulses from under an aircraft or spacecraft onto a given area. The reflected or backscattered radar signals form an image.

Some examples of active satellite sensor systems are:

Satellite	Sensor	Ground Resolution	Applications
Radarsat (Canadian)	SAR (Synthetic-Aperture Radar) C Band	10-100m	Geology, oil slicks, agriculture, soils, forestry, hydrology, coastal and ice studies.
JERS-1 (Japanese Earth Resource Satellite)	SAR (Synthetic-Aperture Radar) L Band	50m	Vegetation mapping, soil studies
ERS-1 (European Remote Sensing)	SAR (Synthetic-Aperture Radar) C Band	50m	Geology, oil slicks, agriculture, soils, forestry, hydrology, coastal and ice studies.

The word radar comes from radio detection and ranging. Radar guns are electromagnetic devices that detect and locate objects at distances. Radar is not only used in remote sensing, but as an aid for police to catch speeding motorists — a more familiar application to some people! Radar is especially useful in remote sensing because it can detect and locate objects under poor lighting or clouds. Under these conditions the unaided eye and some other satellites are ineffective.

SAR systems operate by transmitting microwaves towards an object. When the object reflects the waves back towards the transmitter, they become known as *receiving waves* or the *echo.* A signal processor (a computer) then amplifies the echo, so that the target object can be displayed on the computer screen.

Diurnal and seasonal changes in radiation emitted or reflected from the Earth's surface do not affect Synthetic Aperture Radar (SAR). Therefore, SAR has an *all weather capability* and has been used successfully in tropical and polar regions.

Case Study: RADARSAT

The RADARSAT satellite was launched in 1995 as the result of a joint venture between the Canadian Government, private industry and NASA. Its primary function is to provide surveillance of the Canadian Arctic, which is characterised by long periods of darkness in the winter and shipping lanes frozen over. Other remote sensing methods were unable to provide the information needed and data were collected by expensive airborne surveys.

RADARSAT is in a sun-synchronous dawn-dusk orbit with a 24-day repeat cycle. This provides coverage over the Canadian Arctic every day and coverage over the equatorial latitudes every 5 days. The satellite beams microwaves on to the Earth's surface then measures the returning reflected microwave radiation.

Radar images are single-frequency representations of the Earth, which highlight changes in the terrain's roughness, relief and moisture levels.

RADARSAT can provide images no matter what the weather or cloud cover is because it is an active system.

Satellite sensor characteristics

The basic functions of most satellite sensors is to collect information about the reflected radiation along a pathway, also known as the field of view (FOV), as the satellite orbits the Earth. The smallest area of ground that is sampled is called the instantaneous field of view (IFOV). The IFOV is also described as the pixel size of the sensor. This sampling or measurement occurs in one or many spectral bands of the EM spectrum.

The data collected by each satellite sensor can be described in terms of spatial, spectral and temporal resolution.

Ground resolution

The ground resolution (also known as spatial resolution) is the ground area imaged for the instantaneous field of view (IFOV) of the sensing device. Ground resolution may also be described as the ground surface area that forms one pixel in the satellite image. The IFOV or ground resolution of the Landsat Thematic Mapper (TM) sensor, for example, is 30 m. The ground resolution of weather satellite sensors is often larger than a square kilometre. Data with a one metre ground resolution are likely to be available from satellite sensors by the end of the millennium.

Spectral resolution

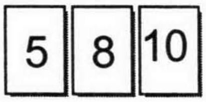
The spectral resolution of a sensor system is the number and width of spectral bands in the sensing device. The simplest form of spectral resolution is a sensor with one band only, which senses visible light. An image from this sensor would be similar in appearance to a black and white photograph from an aircraft. A sensor with three spectral bands in the visible region of the EM spectrum would collect similar information to that of the human vision system. The Landsat TM sensor has seven spectral bands located in the visible and near to mid infrared parts of the spectrum.

Temporal resolution

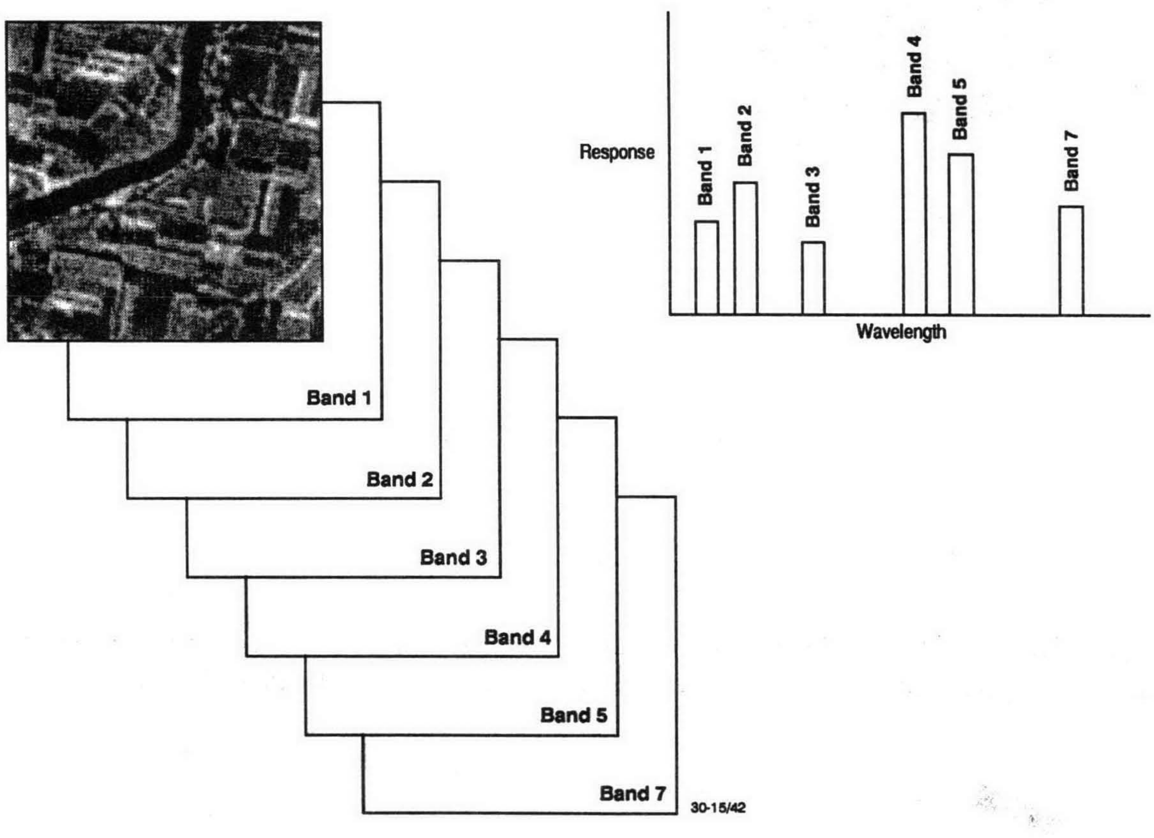
Temporal resolution is a measure of the frequency with which a sensor can revisit the same part of the Earth's surface. The frequency will vary from several times per day, for a typical weather satellite, to 8–20 times a year for a moderate ground resolution satellite, such as Landsat TM. The frequency characteristics will be determined by the design of the satellite sensor and its orbit pattern.

Multispectral systems

Until recently, each satellite or aircraft platform could measure only a small number of spectral bands. For instance, Landsat TM measures radiation from only 7 bands. These systems are referred to as multispectral systems.

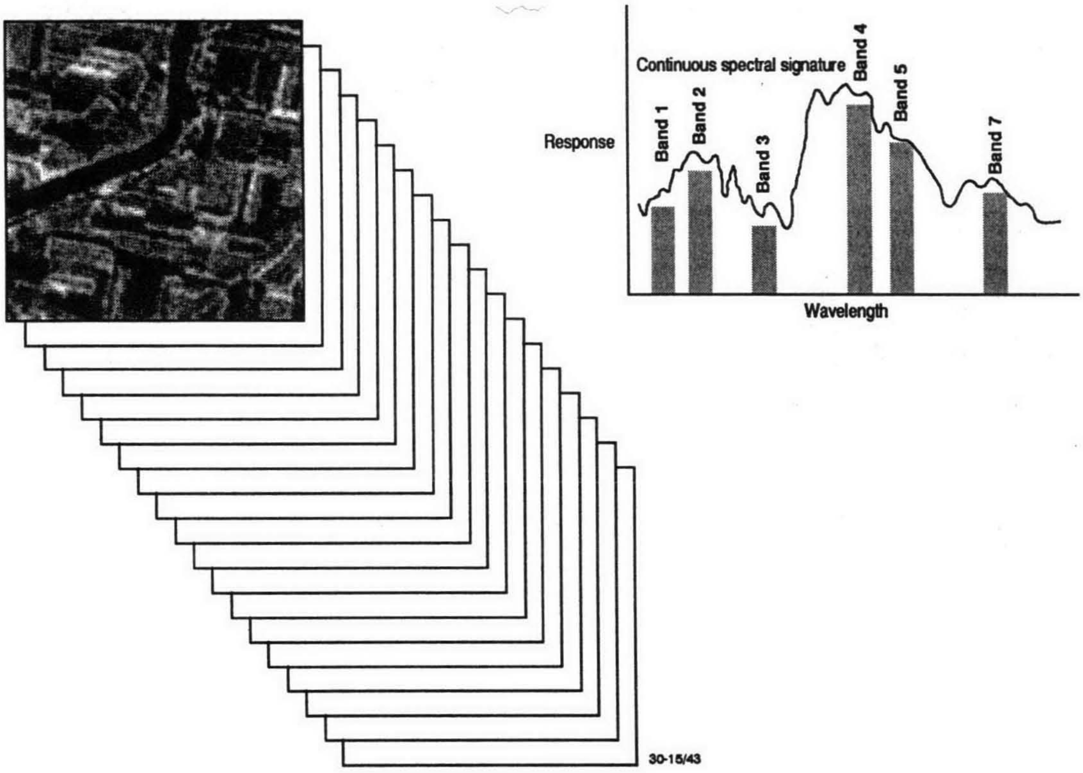


Card 5 shows where these bands are located in the electromagnetic spectrum. Bands 1, 4 and 7 are commonly used in remote sensing. See cards 8 and 10 for some examples of Landsat TM images using these bands.



Hyperspectral systems

The new hyperspectral satellites can provide a continuous spectrum of reflectance over a greater range of wavelengths. Because each target material has a discrete spectral signature, having information about a greater part of that signature enables greater discrimination of surface materials.



The ARIES satellite is a hyperspectral satellite, which can provide more information per pixel because it takes measurements over 126 spectral bands.

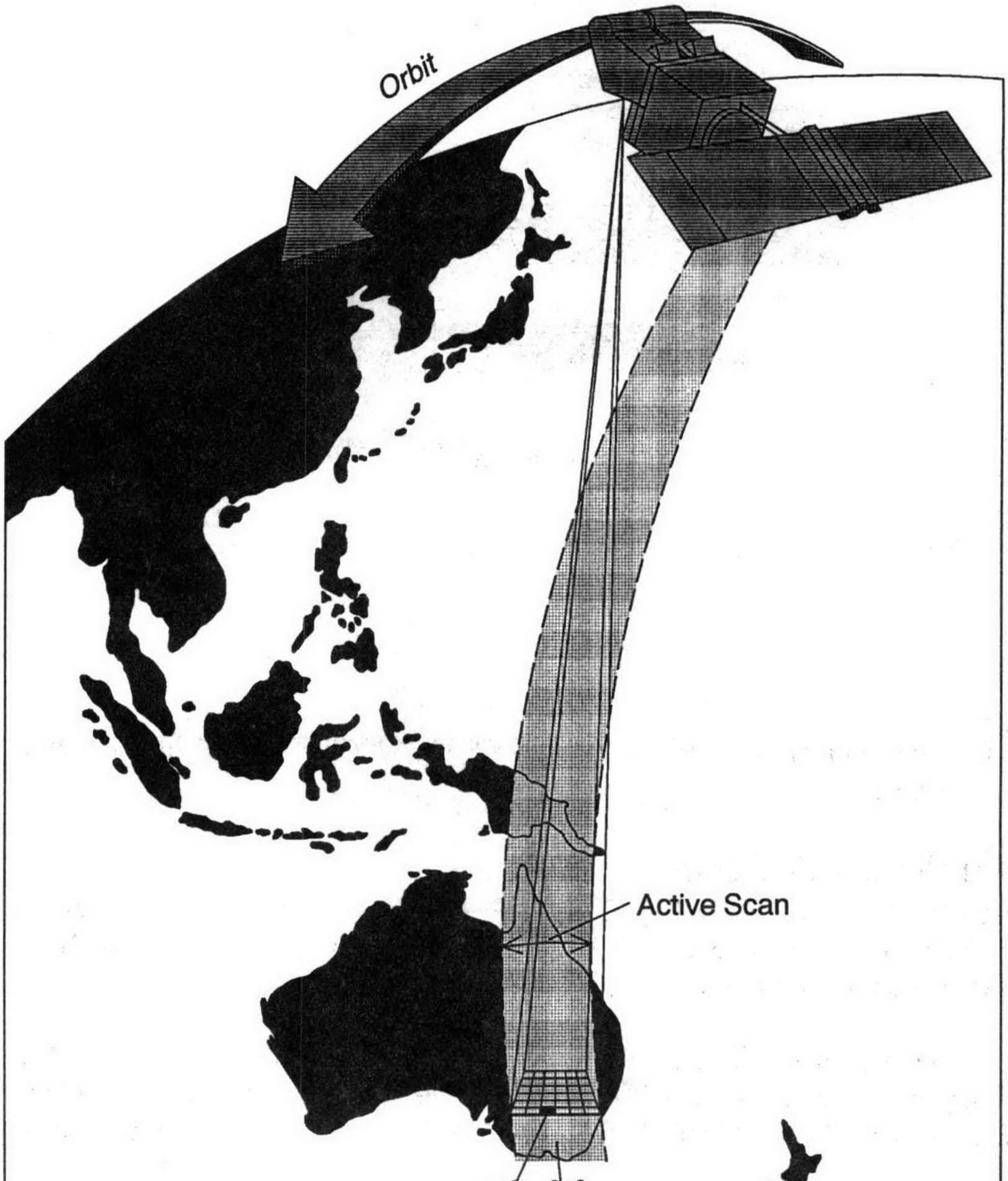
The activities most relevant to the *Remote sensing detectors* section are:

Sights from different heights
NOAA meteorological satellite
SPOT the sand and silt

Pixels, Images and Colours

Pixels

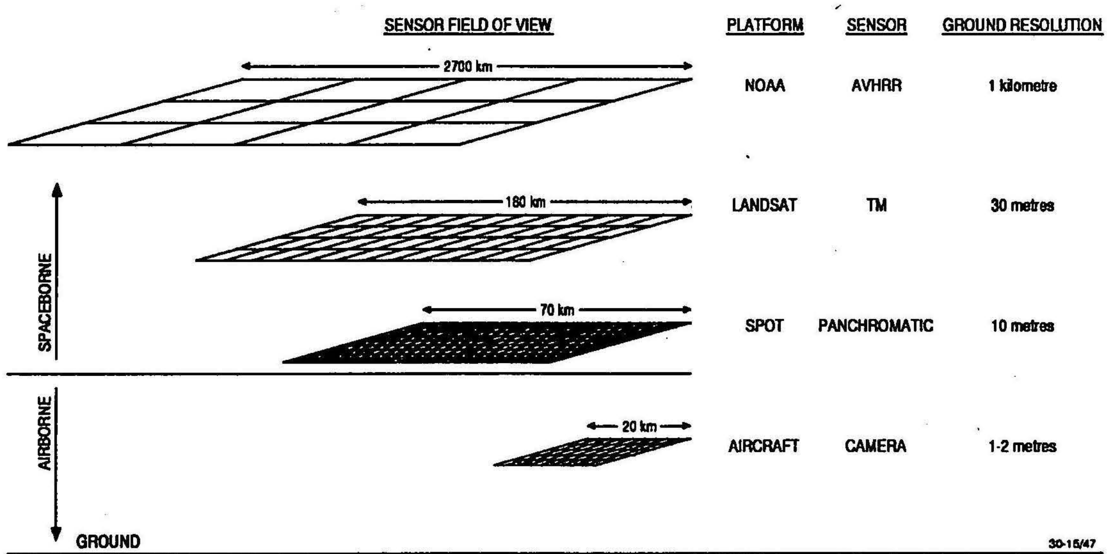
The word pixel is a shortened version of the two words "picture element". The idea of a pixel being a picture element is not restricted to remote sensing. Images on a colour monitor, such as a television screen, are composed of pixels. A pixel has both spatial (positional) and radiometric (brightness) attributes.



Spatial attributes

In remote sensing, a pixel often refers to the smallest element that has been measured on the ground. A pixel area on the ground is usually almost square in shape and can vary from less than a metre square to more than a kilometre square. The smaller the pixel size the greater the detail or resolution of the surface being imaged. SPOT Panchromatic data, for example, has a ground resolution of 10 metres. Landsat TM has a ground resolution of 30 metres. Sensors that image a large area (eg a weather satellite) will usually produce an image with less detail than an image acquired by an aircraft sensor.

Spatial attributes of various remote sensing systems



2

Card 2 demonstrates the effect of increasing scale on an image until pixels are visible.

Radiometric attributes

A radiometric attribute is the brightness value or grey value. The relative brightness value of a pixel is determined by the reflectance or emittance characteristic of the surface material represented in the pixel.

The brightness value of a pixel is measured by the sensor as a digital number (DN). The majority of remote sensing instruments that have eight-bit radiometric resolution (such as Landsat TM) will measure the brightness value as an integer number between 0 and 255.

Images from raw data

Data collected in remote sensing are a stream of numbers that represent the spatial position and the digital number or brightness of each pixel for each spectral band measured. In its simplest form, it is possible to print out an image of one spectral band using a scale of white through greys to black (grey scale). Therefore, each pixel is assigned one shade of grey depending on its digital number.

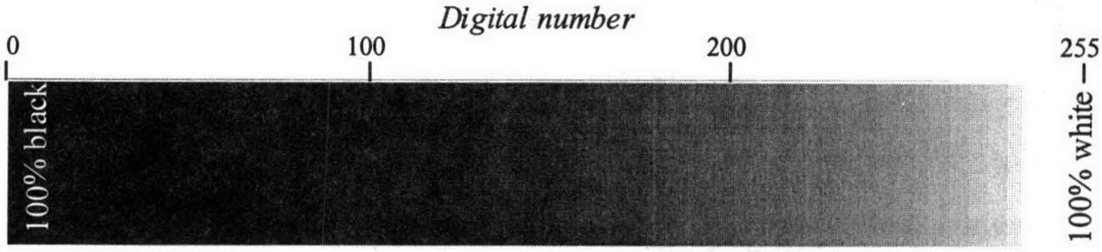


Image grey scale

RSgrey

A typical grey scale image normally has its contrast enhanced to provide an image that highlights the highs and lows in digital numbers. An alternative to grey scale is to use three spectral bands and assign each band one of the three primary colours - red, green, or blue. The three spectral bands' digital numbers are then combined to form a false colour composite image on the monitor. The final colour produced depends on the brightness of each of the primary colours for each pixel.

Colour

When we wish to combine more than one spectral band for display on a monitor or for printing onto paper or film, we need to understand how colour images are formed.

Additive primary colours

The concept of additive primary colours is used for understanding how we add colour to a black monitor. Red, green and blue are the primary additive colours. They are given this name because when they are added together in equal amounts they produce white light. In addition, by varying the proportions of the three primary colours we are able to produce the range of colours that the human eye can distinguish.
The following table gives some examples of this characteristic.

Combination of colours	**Final colour produced**
red + green	yellow
blue + red	magenta
green + blue	cyan

3 5 Cards 3 and 5 and the overhead about colours illustrate the concept of additive primary colours.

Subtractive primary colours
The converse of additive colours are subtractive colours. The concept of subtractive colours is used to describe how colours are created on white paper when the paper is printed with colour inks or dyes.

Yellow, magenta and cyan are the primary subtractive colours. When these colours are mixed in varying proportions, they produce the full range of colours on a white surface.

5

Card 5 and the overhead about colours illustrate the concepts of subtractive primary colours.

Combination of colours	Final colour produced
Magenta + cyan	blue
Yellow + cyan	green
Yellow + magenta	red

If the three spectral bands chosen are in visible part of the EM spectrum and correspond to the red, green and blue areas of light, then the final image will be very close to what we see with our own eyes.

It is possible to use the most appropriate colour to reflect the material that is most reflective in that spectral band. For example, if a spectral band outside of the visible spectrum has been chosen because it highlights vegetation, it could be assigned the green colour. In this way, vegetation may appear to have a greenish tinge in the image.

The use of false colours

It is common for images to be made up of a combination of one or two visible spectrum bands and one or two spectral bands outside of the visible spectrum. These colours are called false colours because they are not the real colours of the objects in the image, although they may in some cases be chosen to be similar to the real colours. A good example of a false colour composite image is the Landsat TM (1, 4, 7) of Tweed Heads on card 10. Band 7 is a near infrared spectral band that discriminates cleared or unvegetated land from heavily vegetated land by using a pink colour. Other Landsat TM images that use false colour include cards 2 and 8.

2 7 8 10

Cards 2, 7, 8 and 10 contain images which use false colours. Card 7 is especially useful in demonstrating the effect of assigning false colours to create a false colour composite image.

Enhancing the data

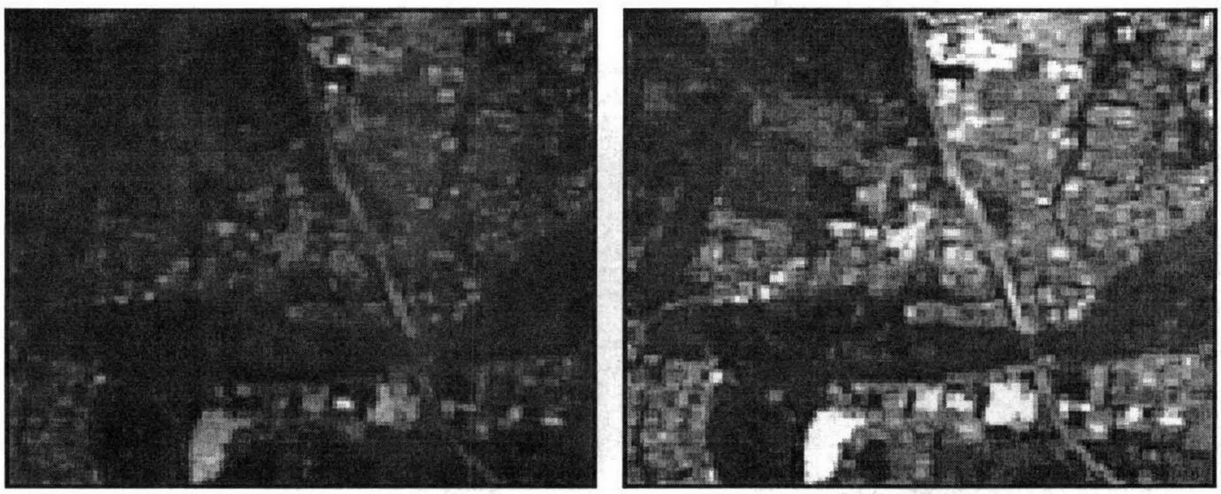
Our interpretation of images depends on contrast to assist in understanding the range of colours in an image. For this reason, remotely sensed data is often enhanced to show greater colour and detail.

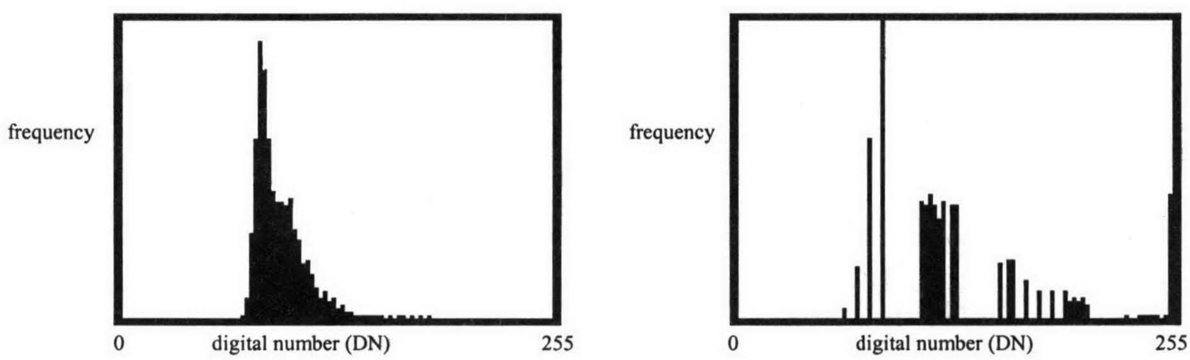
One basic method is to look at the data collected for an area on one spectral band and plot the frequency of each of the possible 256 (0-255) digital numbers on a histogram. Remember, each digital number measures the brightness value of the pixel.

The shape of the histogram provides us with information about the range of digital numbers (brightness values) for data on each spectral band. A narrow histogram indicates a small range of digital numbers and therefore will have a low contrast if displayed without enhancement.

It is possible to enhance an image by stretching the histogram so that the digital numbers are spread across the whole range (0-255). This is known as contrast stretching. Below is an example of an image which has been enhanced using this method.

"raw" image" → enhanced image





"raw" data → enhanced data

More sophisticated image enhancement techniques

Because the information is captured digitally, the images can be enhanced simply by using some basic mathematical algorithms. For example, algorithms have been developed specifically to highlight features on digital images, such as water depth or relative chlorophyll concentrations. (Note: An interactive activity on the WWW developed by AGSO demonstrates this concept very well. Web address: www.agso.gov.au/education/remote_sensing/)

Reducing the effects of atmospheric scattering

The process of minimising distortion due to atmospheric effects is quite complex. However, it may be possible to make a simple correction for atmospheric effects based on the spectral information obtained from very dark areas of an image. One correction technique is based on the knowledge that a surface or object with no reflectance in a given spectral band should have a zero brightness level. Using this knowledge, the brightness values in a spectral band can be adjusted to account for atmospheric effects. This method is often described as the dark-target subtraction method.

Interpreting a remotely sensed image

Image interpretation can be done manually or it can be computer assisted. Although the primary elements of image interpretation are common to both manual and computer assisted procedures, their usage varies. The basic elements that aid image interpretation are size, shape, shadow, tone or colour, texture, pattern and association; however, they are not the only ones. An understanding of the basic elements of image interpretation is essential for effective use of the information contained in satellite imagery.

One or more of the following elements individually or together enable an object to be identified on the image:

Tone or Colour In a black and white image, objects appear in tones or shades of grey and often fail to correspond to an interpreter's perception of familiar objects. Colour imagery facilitates the identification of an object by providing a more familiar view. Satellite images are often displayed using false colour in order to enhance the identification of the features within. Many factors influence an object's colour or tone in an image and, when an interpreter is aware of them, can give clues to its identity. For example, vegetation which usually shows up as red in false colour imagery can be grouped into different categories based on the variations in tone.

Size The size of an object in an image is a very useful clue to an object's identity. Ground resolution or pixel size is an important consideration when comparing the size of objects in an image. An interpreter can identify an object by comparing its size with other objects in the image.

Shape The shape of an object may look quite different on a satellite image compared to what it looks on the ground, but can give conclusive indication of its structure or function. The shape of an object may be so distinctive as to help in its instant identification on the image. A typical example is a runway near an airport.

Texture When a group of objects causes repetition of tones in an image, it gives the visual impression of smoothness or roughness which is called texture. For example, texture in an image can be used to differentiate cropped areas, which generally appear smooth, from forested areas, which often have a rough or grainy texture.

Pattern Spatial arrangement of objects is called pattern. Pattern is a characteristic of many man-made objects and some natural features. A pattern showing a network of roads and built-up areas in an image would help in identifying it as a town or city. Natural drainage patterns which show up in a satellite image may be used to identify areas prone to soil erosion.

Shadow Shadows can be useful in determining the size and shape of objects in an image, but they can also hinder the interpreter by hiding details. Shadows could be useful to a geologist studying surface features as they tend to visually enhance the surface irregularities.

Association The tendency of certain features to occur together and confirm the presence of the other associated features is called association. Association can provide important information to identify man-made installations and also about phenomena that may not be apparent on the surface. For example, the presence of certain geological patterns, vegetation and surface features can be associated with the occurrence of underground water.

Some factors which can dramatically affect the interpretation of an image include scale, texture, contrast and spatial resolution (minimum distance between two objects). The factors listed above are influenced by the interaction of other factors that are dependent on the type of sensor/satellite, time and conditions under which the data were acquired and how the image was produced from the data.

Interpret a remotely sensed image: using card 10 as an example

An airport is made up of a variety of different surface materials (tarmac, mown grass) placed in a regular fashion (straight wide runways and narrower curved taxiways with grass in between). Most runways are at least 1000 m long. Airports will also have large buildings (hangers and terminals) roofed in metal. All these features provide changes in shape, size, contrast, colour and texture that, in association with each other, enable us to recognise an airport in an image.

7 10

Card 7 will be very useful for finding out which features are better distinguished in each Landsat TM spectral band. Study card 7 and card 10. Can you find the airport on card 10?

In understanding an image, such as the Landsat image on card 10, some of the major types of landuse need to be identified, using a similar process. These landuse types are:

- Woody vegetation
- Grass
- Urban areas
- Coast
- Rivers

Urban area

Urban areas contain a variety of materials (concrete, asphalt, tin, grass, and gardens) which combine to provide a reflectance high in band 7 and band 1. As band 7 has been assigned red, and band 1 blue on card 10, the resultant colours for urban areas are pinks and purples. Within the urban areas, major roads and the pattern of housing developments can be seen in some locations. Older suburbs, with more developed gardens and parks, can also be distinguished, as they contain patches of green within the urban pinks.

Coasts

The coastal area can be identified by the association of water (shown as dark blue-black) and sandy beaches (white). Inland from high-tide zone, vegetation starts in a typical sand-dune succession of plants, leaving a green strip. In some places, urban areas (pink-red) have encroached onto the dunes and destroyed this vegetation.

Can you locate an area of coast in which the natural dune vegetation still remains?

Can you locate an area where the urban area has encroached on to the dunes?

Rivers

Rivers and wet-lands both appear dark blue to black. This is due to very low reflectance in bands 7 and 4 and some reflectance in band 1.

Woody Vegetation

Woody vegetation displays very low reflectance in bands 7 and 1. This gives them a distinctive dark green colour. These patches of vegetation, now much cleared in the image on card 10, can still be found along the banks of the rivers and waterways (mangroves) and along some of the hills and ridges.

Grass

Grass can be divided into dry grass & stubble and green grass. Dry grass has high reflectance in band 7 and, therefore, appears red on the image on card 10. Green grass appears as light green, as it has greater reflectance in band 4.

What is the state of the grass between the runways and taxiways at the airport?

Other interesting patterns

Crops — on the image on card 10 at the very bottom centre of the image is a series of red and green polygons. These represent fields in different crop cycles – dry stubble and growing crop.

Based on the information for grass, what colour would you expect the dry stubble to have and why?

Golf courses — golf courses can be identified by their arrangement of woody vegetation and strips of green grass, which take up a considerable area.

Two golf courses can be seen on the image on card 10. Can you pick them?

The activities most relevant to the *Pixels, images and colours* section are:

Landuse—Colours and areas
Pixel size and clarity
Looking at detail—resolution
False colour fields
Satellite image processor on the WWW
Ternary Tester
Colour Concepts

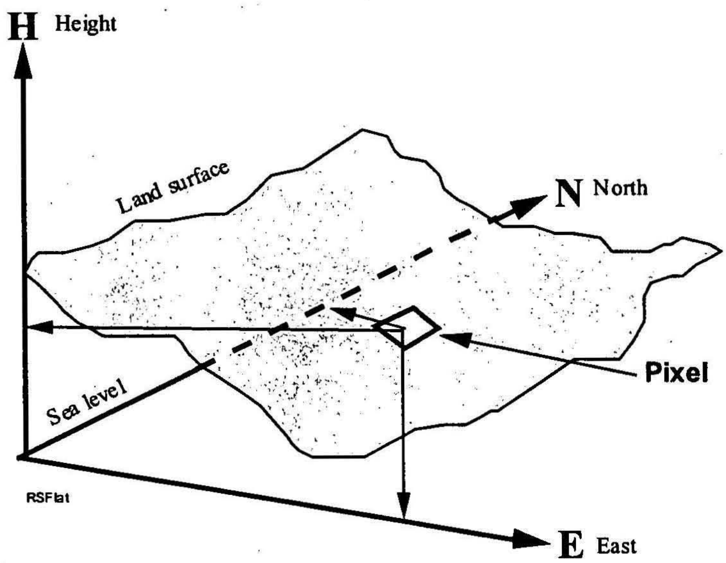
Geodesy, Geodetic Datums and Map Projections

Geodesy

Knowing the exact location of a pixel on the Earth's surface (its spatial location) is an essential component of remote sensing. It requires a detailed knowledge of the size and the shape of the Earth.

The Earth is not a simple sphere. Topographic features such as mountain ranges and deep oceans disturb the surface of the Earth. The ideal reference model for the Earth's shape is one that can represent these irregularities and identify the position of features through a co-ordinate system. It should also be easy to use.

A simple three-dimensional framework, such as the one shown below, is an appropriate reference model for mapping small areas (eg 10km^2). On this "flat Earth" model the horizontal axes are congruous with North and East, and the horizontal plane is parallel with sea level. The height axis (H) is perpendicular to the horizontal plane and coincides with the direction of gravity.



Flat Earth vs curved Earth

The "flat Earth" model is not appropriate when mapping larger areas. It does not take into account the curvature of the Earth.

A "curved Earth" model more closely represents the shape of the Earth. A spheroid best represents the shape of the Earth because it is significantly wider at the equator than around the poles (Unlike a simple sphere). A spheroid, (also known as an ellipsoid) represents the equator as an elliptical shape, rather than a round circle. Surveying and navigation calculations can be performed over a large area when a spheroid is used as a curved Earth reference model.

Sea level and the composition of the Earth's interior
The surface of the sea is not uniform. The Earth's gravitational field shapes it. The rocks that make up the Earth's interior vary in density and distribution, causing anomalies in the gravitational field. These, in turn, cause irregularities in the sea surface. A mathematical model of the sea surface can be formulated; however, it is very complex and not useful for finding geographic positions on a spheroid reference model.

Geodesy is the branch of science concerned with the determination of the size and shape of the Earth. Geodesy involves the processing of survey measurements on the curved surface of the Earth, as well as the analysis of gravity measurements.

Types of geodetic datum

Based on these ideas, models can be established from which spatial position can be calculated. These models are known as geodetic datums and are normally classified into two types — geocentric datum and local geodetic datum.

A geocentric datum is one which best approximates the size and shape of the Earth as a whole. The centre of its spheroid coincides with the Earth's centre of mass. A geocentric datum does not seek to be a good approximation to any particular part of the Earth.

A local geodetic datum is used to approximate the size and shape of the Earth's sea surface in a smaller area. For example, the Australian Geodetic Datum (AGD) is a local datum, which best represents the size and shape of the sea surface in the region of Australia. It is not appropriate for worldwide applications of spatial data.

Presently, there are two Australian Geodetic Datums used in Australia; AGD66 and AGD84. Both versions have been derived from the same geodetic coordinate values, using the Australian National Spheroid. AGD84 is an updated version of AGD66..

Datums and GIS

Having a standard accurate datum set becomes increasingly important as multiple layers of information about the same area are collected and analysed. The layers are developed into geographic information systems (GIS), which enable the relationships between layers of data to be examined.

In order to function effectively, a GIS must possess one essential attribute. It must have the ability to geographically relate data within and across layers. For example, if a dataset about vegetation is being examined against the data sets for topography and soils, the accurate spatial compatibility of the two datasets is critical.

Map projection coordinates

A map projection is a systematic representation of all or part of of the Earth on a two dimensional surface, such as a flat sheet of paper. During this process some distortion of distances, directions, scale, and area is inevitable. There are several different types of map projections. No projection is free from all distortions, but each minimises distortions in some of the above properties, at the expense of leaving errors in others. For example, the commonly used Transverse Mercator projection represents direction accurately, but distorts distance and area, especially those farthest from the equator. Greenland, for example, appears to be much larger than it really is. The Transverse Mercator projection is useful for navigation charts.

Universal Transverse Mercator (UTM)

Universal Transverse Mercator (UTM) is a global spatial system based on the Transverse Mercator projection. UTM divides the Earth into 60 equal zones, each being 6 degrees wide. Each zone is bounded by lines of longitude extending from the North Pole to the South Pole. Imagine an orange consisting of 60 segments. Each segment would be equivalent to a UTM zone.

A rectangular grid coordinate system is used in most map projections. These coordinates are referred to as Eastings and Northings, being distances East and North of an origin. They are usually expressed in metres.

Under the UTM system, each East and North coordinate pair could refer to one of sixty points on Earth — one point in each of the sixty zones. Because of this, the zone number needs to be quoted to ensure the correct point on Earth is being identified.

Finding locations

There are two different references to location on the remote sensing cards enclosed:

- latitude/longitude,
- Australian Map Grid (based on the Universal Transverse Mercator Projection).

Latitude and longitude

Latitude and longitude are a grid system that can be used to locate any point on the surface of the Earth.

Latitude is the distance north or south of the equator and is measured in degrees, minutes and seconds. The Equator is at latitude zero degrees and the South Pole is at latitude 90°S. (The North Pole is at 90°N). Longitude is the distance east or west of an imaginary line that runs from the North Pole to the South Pole, through the Royal Observatory at Greenwich, near London. This is known as the Greenwich Meridian.

Each latitude/longitude degree is divided into 60 minutes and each minute is divided into 60 seconds. Most of the remote sensing cards show only the degrees (°) and minutes (') - with the exception of card 2 and card 10. The border of each card is coloured alternately black, then white. Each black or white section of the border represents a certain number of minutes or seconds, depending on the scale of the card. For example, each black/white section on card 4 represents 30 seconds, whereas each black/white section on card 8 represents 2 minutes.

The latitude of a location is always given first, followed by the longitude. When reading latitude, the first number refers to the whole number of degrees, and the next number refers to the number of minutes towards the next latitude line, or more simply, the number of 60ths towards the next latitude line. The same applies to longitude numbers. If the second number is 00, this means that the location is exactly on the latitude or longitude line.

Grids

Another method of finding locations on the remote sensing cards is to use the grid system that is overlaid on each map.. The units used in grid references are in metres. For this reason the grid reference system is useful for determining scale as well as location. Look at Card 8, for example. Each of the squares marked on this image represents 5 kilometres square. This is obvious when you read the grid references along the bottom of the image: 535^{000} m E, 540^{000} m E. Each reference is changing by 5 km, or 5^{000} m.

The Australian Map Grid (AMG), based on the UTM projection, is used for the production of most topographic maps in Australia.. It lies in UTM Zones 47 to 58. Each zone is then divided by the AMG into areas of 100 kilometre squares, identified by two letters. The Tweed Shield Volcano region lies in UTM zone SH56.

Reading grid references

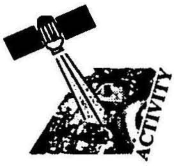
Grid references are a sequence of numbers describing the location of any point on a map. Grid references are divided into two sequences of numbers. The first sequence of numbers refers to the vertical lines on the map (the Eastings). The second sequence of numbers refers to the horizontal lines (the Northings). To read a grid reference for a given place, first find the easting (vertical line) and then find the northing (horizontal line). For example, on Card 1, Hastings Point is located at 557 000E, 6 862 000 N. Each of the remote sensing cards has a different scale, so the scale of the grid references will be different on each card. For example, on card 8 the grid interval is 5 km, or 5^{000} metres. (eg 535^{000}, 540^{000}, 545 etc). On card 1, the grid interval is 10 km, or 10^{000} metres each. (ie 520^{000}, 530^{000}, 540^{000}etc)

Global positioning systems (GPS)

A global positioning system (GPS) is a constellation of satellites. Radio signals from the satellites are used to determine the location of a given point on the Earth's surface. The GPS receiver records the signals of at least three satellites and, using the triangulation method, calculates the exact position of the receiver. Four satellites are needed if an altitude is required, but up to as many as eight satellites can be used for greater accuracy.

Currently, most GPS systems give locations that are accurate to about 25 metres or better. GPS receivers used by the United States Military have access to higher accuracy radio signals, which enable locations to be determined with an error of less than 10 metres.

The use of GPS is rapidly expanding, especially in the 'ground truthing' of remotely sensed data. Ground truthing is the checking of the true material that is producing the reflected signal recorded by the remote sensor. Having accurate spatial data about the location of the checkpoint is important, as it allow the layers of data to be matched.



The activity most relevant to the *Geodesy and Geodetic datum* section is:

Topography of the Tweed

Current applications of remote sensing

Forestry applications
Satellite imagery is used to identify and map: -

- The species of native and exotic forest trees.
- The effects of major diseases or adverse change in environmental conditions.
- The geographic extent of forests.

This application of satellite imagery has led to the extensive use of imagery by organisations that have an interest in a range of environmental management responsibilities at a state and national level.

Greenhouse gases – sinks and sources
Forests are often referred to as *carbon sinks.* This description is used because during photosynthesis, carbon dioxide, the major greenhouse gas, is taken from the atmosphere and converted into plant matter and oxygen.

Climate change has serious implications for Australia and overseas countries alike. Sustainable land management is essential for effective greenhouse gas management; hence, it is important to acquire data on land cover in Australia. Remotely sensed land cover changes are used in calculations of our national emission levels, and data collected on a national scale will enable governments to develop responses to land clearing.

Vegetation health
Vegetation can become stressed or less healthy because of a change in a range of environmental factors. These factors include lack of water, concentration of toxic elements/herbicides and infestation by insects/viruses. The spectral reflectance of vegetation changes according to the structure and health of a plant. In particular, the influence of chlorophyll in the leaf pigments controls the response of vegetation to radiation in the visible wavelength. As a plant becomes diseased, the cell structure of a plant alters and the spectral signature of a plant or plant community will change.

The maximum reflection of electromagnetic radiation from vegetation occurs in the near infrared wavelengths. Vegetation has characteristically high near-infrared reflectance and low red reflectance. Air-borne scanners using narrow spectral bands between 0.4 um and 0.9 um can indicate deteriorating plant health before a change in condition is visible in the plant itself.

Biodiversity
Vegetation type and extent derived from satellite imagery can be combined, with biological and topographic information to provide information about biodiversity. Typically, this analysis is done with a geographic information system.

Change detection

Satellite imagery is not always able to provide exact details about the species or age of vegetation. However, the imagery provides a very good means of measuring significant change in vegetation cover, whether it is through clearing, wildfire damage or environmental stress. The most common form of environmental stress is water deficiency.

Geology

Remote sensing is useful for providing information relevant to the geosciences. For example, remote sensing data are used in:

- Mineral and petroleum exploration,
- Mapping geomorphology, and
- Monitoring volcanoes.

Land degradation

Imagery can be used to map areas of poor or no vegetation cover. A range of factors, including saline or sodic soils, and overgrazing, can cause degraded landscapes.

Oceanography

Remote sensing is applied to oceanography studies. Remote sensing is used, for example, to measure sea surface temperature and to monitor marine habitats.

Meteorology

Remote sensing is an effective method for mapping cloud type and extent, and cloud top temperature.

In many of the applications identified above remotely sensed data are used with a range of other Earth science data to provide information about the natural environment. This analysis of Earth science data from a range of sources is usually done in a geographic information system (GIS). A GIS is a powerful tool for analysing and interpreting data that would not be possible using traditional photo-interpretation techniques.

Benefits and limitations of remote sensing

Some of the possible benefits of using remote sensing are:

- To supplement traditional mapping techniques;
- To study change over time;
- Verifies information originally gathered in the field;
- Gives a large synoptic view;
- Maps of inaccessible areas can be produced;
- Mapping in all weather conditions is possible when using radar;
- Major land cover types can be mapped;
- Range of different spatial and spectral resolutions available;
- No surface destruction when capturing data.

Limitations of remote sensing

Whilst remote sensing is a worthwhile tool as an adjunct to traditional mapping and monitoring techniques, the spatial and temporal resolution is limited for some applications and will need to be supplemented and verified with field-based work. For example, it is not possible to discriminate between all species of vegetation or mineral types. Unless radar systems are used, problems with cloud cover can occur, reducing visibility. It can also be difficult to map sand-covered bedrock unless radar is used.

The activities most relevant to the *Applications of remote sensing* section are:

Landuse —colours and areas
Looking at detail —resolution
NOAA meteorological satellite
Geophysical images activities
Satellite image processor on the WWW

Australian Surveying and Land Information Group

The Australian Surveying and Land Information Group (AUSLIG) was formed in 1987 from an amalgamation of the former Australian Survey Office and the Division of National Mapping. Its origins, however, date back to 1911, when a lands and survey division was formed within the Federal Department of Home Affairs.

AUSLIG now operates within the Department of Industry, Science and Resources as the Commonwealth's primary provider of fundamental land information which underpins the planning and management of land use, infrastructure, mining, agriculture, forestry, environmental, defence and emergency services activities across the nation. AUSLIG manages national mapping, maritime boundary, remote sensing and geodesy programs and is responsible for implementation of the Australian Spatial Data Infrastructure.

AUSLIG's Australian Centre for Remote Sensing (ACRES) receives and processes satellite imagery of the Australian landmass. ACRES' satellite imagery, available in either photographic or digital format, is used by mining companies for exploration, by farmers to improve productivity, and to help manage the environment and natural disasters. ACRES acquires data in real time from four different satellites and acts as a distributor for others. It maintains a national archive dating back to 1979 that can be used for studying changes over time. It is of particular benefit for environmental monitoring.

Satellite data can be purchased from:
ACRES Customer Services
Scrivener Building
Dunlop Court, Fern Hill Park
BRUCE ACT 2617

Ph: 02 6201 4107
Fax: 02 6201 4240
http://www.auslig.gov.au

Australian Geological Survey Organisation

The Australian Geological Survey Organisation (AGSO) was established in 1946 (as the Bureau of Mineral Resources) to provide a national geological survey focus during the post-war boom period. Since this time the organisation has been instrumental in the discovery of numerous mineral and petroleum deposits and continues to provide the very best survey data and geological advice to government, industry and research institutions.

The research which AGSO undertakes covers almost all areas of geoscience, including mineral exploration, onshore and offshore petroleum exploration, and geological hazards. AGSO plays a key role in helping Australia's resource based industries increase their international competitiveness, while observing the principles of sustainable development.

AGSO has considerable expertise in remote sensing and image processing. Remote sensing is integrated with other geographic information systems, in particular, geological maps, geophysical data, field work and laboratory data. Spectral data are used to identify minerals. Associated with this research is the storage and manipulation of geological and geophysical data and the production of cartographic and geographic information system (GIS) products.

Geological Map Sales

Why not obtain the geoscientific image of your own area? Information on the current availability and prices of geological maps and geophysical images can be obtained from:

AGSO Sales Centre
Corner Jerrabomberra Drive and
Hindmarsh Drive, Symonston
Canberra ACT 2609
GPO Box 378 Canberra ACT 2601

Ph: 02 6249 9519 or 02 6249 9642
Fax: 02 6249 9982
http://www.agso.gov.au
email: sales@agso.gov.au

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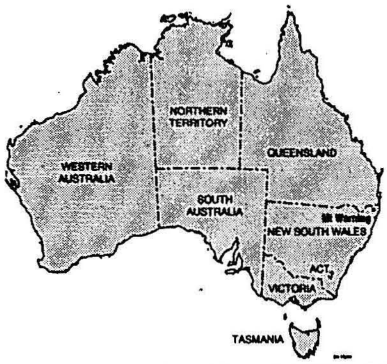
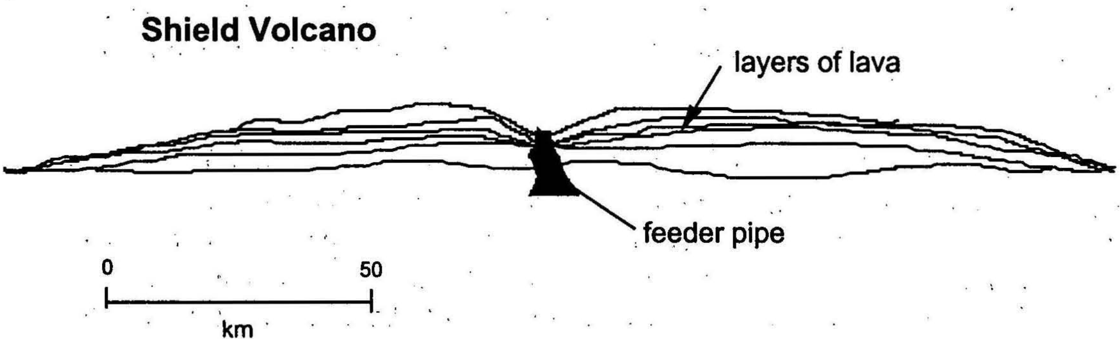
Appendix A — Background information on Tweed Shield Volcano



Geology of the Tweed Shield Volcano

It is thought that volcanoes like the Tweed Shield Volcano were produced as the Australian continent moved over a hot spot in the underlying mantle, which 'melted' through the plate to form the volcano.

Shield volcanoes are typically large volcanoes that erupt large quantities of lava that flows easily. The sides of the volcano have gentle slopes and are relatively low compared to their widths. The shield volcano is so called because the profile or shape of the lava resembles a warrior's shield.



After the explosion of a shield volcano, a large hollow or depression called a caldera forms. A caldera is roughly circular in shape. Due to the mass of magma erupted from the volcano, it collapses in on itself.

The Tweed Volcano is a 100 km wide shield volcano that straddles the coast at the New South Wales - Queensland border. The central plug of the volcano is Mount Warning, which last erupted around 23 to 20 million years ago. At this time, the height of the volcano was twice the present height of Mount Warning. Today, Mount Warning is 1157 metres above sea level and is the first place sun strikes the Australian mainland each day. The volcano's flanks have now mostly eroded away to form an enormous bowl. Most of the eroded Mount Warning volcano consists of coarse-grained igneous rocks, syenite and gabbro (both intrusive rocks). At the central complex of the Mount Warning volcano coarse-grained and fine-grained rocks are found. As the core of the volcano remains, different rates of erosion can be studied as a natural process of weathering.

Lavas from the volcano cover a circular area close to 5200 km^2 stretching from Mount Tamborine in the north to Lismore in the south. Northwards, less eroded plateaus have formed at Springbrook, Lamington and Tamborine.

The arms of the Tweed and Oxley Rivers have formed an erosion caldera around the central plug of igneous rock, removing the lavas and exposing the underlying rocks in the valley floor. Today, the topography is developing by stream erosion guided by the original volcanic slopes and escarpment retreat where changes in resistance to erosion are evident with the different volcanic rocks outcropping.

Factors affecting vegetation
The area of the Tweed Shield Volcano supports some lush areas of vegetation from volcanic soils. Volcanic material mixed with organic matter makes up the richest soil on Earth. Most productive farming land is found in volcanic areas.

Fertility of soils is also dependent on the climate, site, organic activity and time for soil development. But without a starting material that has the necessary chemical components for a fertile soil, the soil will not be very productive. Thus, the 'parent material' determines what chemical elements are initially present in the soil.

The chemical elements that make a soil fertile in the right balance are silicon, aluminium and iron, when combined with calcium, potassium, magnesium and sodium. These chemical components come from the inorganic material or rocks from which a soil develops.

The eastern side of the Great Dividing Range supports pockets of rainforest where the rainfall and humidity are high and soils are more fertile. Rainforests have great biological diversity and are of interest to scientists because rainforest relicts cover little (approximately 0.25%) of the Australian landscape. It is estimated that 1% of Australia's landmass was covered by rainforest prior to European settlement. Hence, its conservation is of great importance.

On the Landsat 147 image of the Tweed Heads (Refer to Card 10) dense vegetation in national parks (for example, Mount Warning National Park) and state forests (for example, Wollumbin State Forest) are shown as dark green. Refer to the Topographic Map of the Tweed Heads region (card 1) to identify these areas. Whereas, cleared grazing land is assigned the false colour — pink to the south east of the caldera.

When climbing to the summit of 1157 metres, subtropical and temperate rainforest, wet sclerophyll forest and heath shrubland are encountered.

Aerial photography and satellite imagery can clearly distinguish vegetation boundaries and land-use.

History

To the indigenous people, Mount Warning remains a significant site. In traditional mythology Mount Warning is called " Wollumbin", meaning 'fighting chief of the mountain'. In 1770, Captain Cook named the mountain to warn future mariners of the offshore reefs.

In 1928, Mount Warning was reserved for public recreation and later dedicated as a national park in 1966. It was in 1986 that Mount Warning was included in the UNESCO World Heritage Listings, which is testament to the area's exceptional natural landscapes. The World Heritage Rainforest Park (2210 ha) provides habitat for many rare and endangered species.

Appendix B — Discovering remote sensing image cards

Card Number	Title
1	Topographic Map of the Tweed Heads Region, Northern New South Wales, Australia.
2	Landsat Thematic Mapper (TM) Bands 1, 4, 7 of Murwillumbah's township, Northern New South Wales, Australia.
3	Additive Primary Colour Ternary Diagram
4	Aerial Photograph of Murwillumbah's Township, Northern New South Wales, Australia.
5	Electromagnetic Spectrum, Landsat TM Reflectance Signatures and Colour Wheel.
6	SPOT Panchromatic Image of Tweed Heads, Northern New South Wales, Australia.
7	Formation of a False Colour Composite Landsat Thematic Mapper (TM) image Bands 1, 4, 7 of Tweed Heads, Northern New South Wales, Australia.
8	Landsat Thematic Mapper (TM) Bands 1, 4, 7 of Murwillumbah, Northern New South Wales, Australia.
9	NOAA Meteorological Satellite image, Queensland Coast, Australia.
10	Landsat Thematic Mapper (TM) Bands 1, 4, 7 image of Tweed Heads, Northern New South Wales, Australia.

Appendix C — Remote sensing Australian curriculum links

National science curriculum

STRAND: Earth and Beyond

COMPONENTS	Level	OUTCOMES
The changing Earth	3.2	Relates changes in the physical environment to physical processes.
	7.2	Describes the role in science in assessing the impact on the surface of the Earth of human intervention in particular places.
	8.2	Identifies and explains indirect measurements used to support scientific theories of the structure of the Earth.
Earth, sky and people	2.1	Records ways we monitor and use information about changes to the Earth.
	3.1	Illustrates ways that use of the Earth's resources changes the physical environment.
	4.1	Examines ways the scientists investigate the Earth, the solar system and the universe.
	5.1	Identifies science ideas that we use in the development of our physical environment.
	6.1	Explains scientific techniques used in monitoring the Earth from space.
	8.1	Presents a critical case study of the application of science to managing a resource.

STRAND: Energy and change

COMPONENTS	Level	OUTCOMES
Energy and change	4.5	Identifies processes of energy transfer and conditions that affect them.
Transferring energy	6.5	Relates observed changes in a receiver to the quantity of energy transferred.
Energy sources and receivers	4.6	Identifies forms and transformations of energy in sequences of interactions.

STRAND: Life and living

COMPONENTS	Level	OUTCOMES
Living together	6.7	Analyses the effect of environmental change on living things and ecosystems.
	7.7	Evaluates scientific evidence about the long-term impact on ecosystems of human intervention.
	8.7	Identifies the role of scientific disciplines in an interdisciplinary approach to understanding and managing ecosystems.

STRAND: Working scientifically

COMPONENTS	Level	OUTCOMES
Using science	4.17	Describes techniques used to extend the senses.
	6.16	Evaluates conclusions in relation to other evidence and sources.
	8.17	Analyses the interaction between scientific developments and the beliefs and values of society.
Processing data	2.15	Identifies patterns and groupings in information to draw conclusions.
	3.15	Argues conclusions on the basis of collected information.
	4.15	Draws conclusions linked to the information gathered and the purpose of the investigation.

	7.14	Takes account of the limitations of techniques and instruments and the influence on the accuracy and reliability of an investigation.
	8.15	Demonstrates rigour in the handling of data.
Acting Responsibly	4.18	Identifies the information needed to make a decision about an application of science.
	8.18	Identifies and reports on the information needed to make a responsible decision about a scientific endeavour.

National curriculum studies of society and environment

STRAND: Place and space

COMPONENTS	Level	OUTCOMES
Care of places	7.6	Analyses the issues related to the careful use of a place or space on the Earth's surface.
Features of places	2.4	Uses symbols to describe the location of places relative to each other.
	3.4	Describes places according to their location and natural and built features.
	5.4	Accounts for similarities and differences between places by identifying factors that may shape their features.
	6.4	Explains and predicts variations in places over time by referring to processes that may affect natural and built features.
	7.4	Analyses patterns and processes to describe spatial variations of features on the Earth's surface.
	8.4	Analyses changing spatial interactions to explain their relationship with the patterns of features on the Earth's surface.
People and places	3.5	Describes how natural features affect the ways people live in particular places.
	6.5	Explains consequences of human modifications of natural and built features.
	8.5	Evaluates the role of planning and management in balancing or deciding among demands for the use of places.

STRAND: Resources

COMPONENTS	Level	OUTCOMES
Use of Resources	7.10	Analyses relationships among resource use, economic growth, living standards and ecological sustainability.
Management and enterprise	8.12	Evaluates resource management in terms of ecologically sustainable development, social justice and democratic process.

STRAND: Natural systems and social systems

COMPONENTS	Level	OUTCOMES
Natural systems	5.13	Explains common and diverse features of various natural systems.
	7.13	Analyses different viewpoints about ecological sustainability and the management of natural systems.

STRAND: Investigation, communication and participation

COMPONENTS	Level	OUTCOMES
Investigation	4.16	Identifies the types of data and sources required by a task and decides how they will be used to gain information.
Communication	4.17	Translates information from one form to another.
	6.17	Discusses the logic of and evidence for an argument or viewpoint.

Discovering Remote Sensing

Activities

Topography of the Tweed

1

Town planners and land managers need to be familiar with the topography of their area and be able to use maps and images which represent the area for which they are responsible. More importantly, they need to be able to find the same ground location on a variety of images and maps and be able to accurately record these for use by others.

You have been asked to become familiar with the area around the Tweed Valley. Use your skills and the information on **Card 1** to complete the following :—

1) Find the following location using the grid reference 5530 000 m E and 6880 000 m N. What physical structure is at this location?

____

2) Locate the summit of the Mount Warning National Park on card 1. What is the:

a) grid reference ____________________

b) latitude and longitude of the summit? ____________________

3) What are the grid references for:

a) Tyalgum ____________________

b) Numinbah ____________________

4) Describe and compare the terrain you would encounter when walking from the summit of Mount Warning to:

a) Tyalgum.

____

____

____

____

b) Numinbah

5) Using the scale provided how many kilometres is it from the summit of Mount Warning to:

a) Tyalgum ____________________

b) Coolangatta airport ____________________

6) Provide a latitude and longitude for a landing ground other than Coolangatta airport.

____

Estimate the elevation of this landing ground ____________________

Sights from different heights

Town planners and resource managers have access to a range of images including street maps, aerial photographs and more recently satellite images. Each type of image has its advantages and limitations.

1) Using card 4 list the features most obvious in the aerial photograph of Murwillumbah.

2) Comparing card 4 and 8 list the advantages of using an aerial photograph over a Landsat Thematic Mapper of Murwillumbah.

3) What are the limitations of the Landsat Thematic Mapper image?

4) Explain why there is greater detail in the aerial photograph of Murwillumbah when compared with the Landsat Thematic Mapper image of Murwillumbah.

5) What is the smallest item you can determine in

a) **Card 4**? ____________________

b) **Card 8**? ____________________

6) Using **Card 4** provide a grid reference for one individual tree found in agricultural land.

7) What benefits does an aerial photograph have over a street map?

Electromagnetic radiation and spectral bands

All

Find the following acronyms in the diagram of spectral curves (Card 5) plotted against electromagnetic radiation measured in microns

VIS	= Visible
NIR	= Near Infrared
SWIR	= Short Wave Infrared
Thermal IR.	= Thermal Infrared

The bands of Landsat are clearly marked. Complete the following table by identifying what part of the electromagnetic spectrum each spectral band fits into.

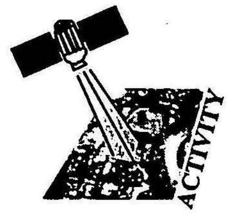
Band	Part of the EM spectrum	Acronym used
1	Visible	VIS
2		
3		
4		
5		
7		

Using cards 1 to 10 provide one example of a card which uses:

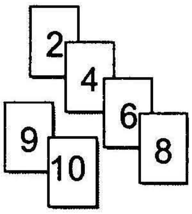
a) Visible spectrum only ____________________

b) NIR, SWIR and one band of the visible spectrum ____________________

Which colour (blue, green or red) has the shortest wavelength? ________________



Looking at detail — Resolution



Complete the table below by using the scale on each card and measure the distance indicated in millimetres.

Card number	Object	Platform	Measurement in mm
2	longest length of the paddock in view at the north west corner near Murwillumbah	Landsat TM	
4	span of bridge over the Tweed River	Aerial photo/plane	
6	maximum length of straight on racecourse near Tweed Heads	SPOT	
8	the width of remnant vegetation a dark green colour from east of this location 28°22'S, 153° 22'E	Landsat TM	
9	eye of cyclone Betsy in SE corner of image	NOAA AVHRR	
10	runway at airport near Tweed Heads	Landsat TM	

2. Using **Card 4 & 8** of Murwillumbah, compare the scale and resolution of a Landsat TM image with an aerial photo. Describe the essential differences between these two images.

____

____

____

3. Read the text at the bottom of **Cards 6 & 10** of the Tweed Heads region. What is the ground resolution of:

a) Landsat TM in card 10 ________________________________

b) SPOT panchromatic in card 6 ______________________________

4. Using **Card 6 & 10** explain using examples what effect ground resolution has on the amount of detail (resolution) in each image.

____

____

____

5. What platforms in the table from question 1 provide the largest coverage but the least detail.

____

6. What satellite provides the smallest coverage but the most detail?

____

7. If you required satellite imagery of a high resolution over a larger area how would this affect the cost of obtaining the final product.

____

____

8. Would SPOT be a satellite which is suited to the use of predicting weather over regional areas? Explain your answer.

____

____

9. Different satellites have specific applications based on properties such as their ground resolution. Provide an example which supports this statement from your knowledge of ground resolution, scales and the coverage.

____

____

NOAA Meteorological Satellite

NOAA—a polar-orbiting satellite
The National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (NOAA AVHRR) is a US polar orbiting satellite which is used for weather predictions. The accurate measurement of four to five spectral channels provides data on which weather predictions can be made. The image swathe (strip of ground surveyed) is very wide —2700km — which enables weather predictions over large areas. The ground resolution is 1100 metres.

Polar-orbiting and geostationary satellites
Polar-orbiting satellites operate in sun-synchronous orbits passing a given latitude at the same solar time providing near global coverage on a regular and predictable basis.

Geostationary satellites move with the same angular velocity as the Earth. These satellites, like Meteostat-2, remain over the same point on the Earth's surface.

Tropical Cyclones
The image clearly shows two different cyclones. Tropical cyclone Betsy north east of Brisbane is an exceptionally large cyclone (category 3) and caused severe beach erosion at Noosa, Queensland. Forty people were rescued at Noosa. Cyclone Mark over the Gulf of Carpentaria did not cause any major damage.

1) Suggest an application which would benefit from the use of a polar orbiting satellite image and why?

2) Suggest an application which would benefit from the use of a geostationary satellite images and why?

3) The 'eye' of a cyclone is an area characterised by calm conditions and often clear skies. What is the latitude and longitude for the 'eye' of tropical cyclone Betsy, Southern Queensland?

4) Measure the radius of Tropical Cyclone Betsy using the scale. Then estimate the diameter assuming that Tropical Cyclone Betsy is symmetrical.

5) Measure the diameter of the mass of cloud of Tropical Cyclone Mark using the scale. How does this compare with Tropical Cyclone Betsy?

6) Is Tropical Cyclone Mark larger than the area captured on Card 6 (use the scales provided on Card 6 and Card 9)?

SPOT the Sand and Silt

Scenario

As a student you have spent some time in the field studying the movement of sand in the northern part of the Tweed River which passes through Tweed Heads. Of particular interest to you is the formation and location of sand bars. You have recently acquired some Landsat and SPOT satellite imagery and are familiarising yourself with the technology available to assist further research.

A sand bar during the late 1960s and early 1970s developed across the mouth of the Tweed River that threatened the commercial and recreational fishing operations in the area. The river had become very dangerous to cross and many boats had to be rescued. Serious flooding threatened the town of Tweed Heads. Over 25 years ago the NSW government built rock walls (groynes) out into the ocean to stabilise the Tweed River and to stop the longshore drift of sand from blocking the river.

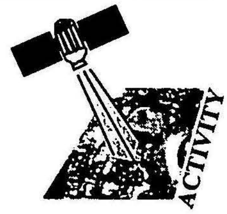
1) Using **Card 1, 6 & 10** locate the Tweed River. Which satellite image provides the longest course of the river?

____

2) Fill in the following table based on your observations of the Tweed Heads region and Tweed River using **Card 1, 6 & 10**. If the feature is present in the image write down the colour, however, if the feature is not present in the field of view write N/A (for not applicable).

Colours of features in maps and satellite imagery

	River	Sand	Major Road	Urban development	Airport	Cloud colour
Topographic Map (card 1)						
Landsat TM (1,4,7) (card 10)						
SPOT Panchromatic (card 6)						



3) Choose one feature from each of **Cards 1, 6 & 10** which is very prominent. Explain why this feature is best represented in that format.

a) Topographic map (**Card 1**)

b) SPOT panchromatic (**Card 6**)

c) Landsat TM of Tweed Heads (**Card 10**)

4) Identify and describe the limitations of each map or image for the purpose of studying sand bars.

a) Topographic map (**Card 1**)

b) SPOT panchromatic (**Card 6**)

c) Landsat TM of Tweed Heads (**Card 10**)

5) Using the scale provided on card 6, calculate the width of the mouth of the Tweed River in kilometres.

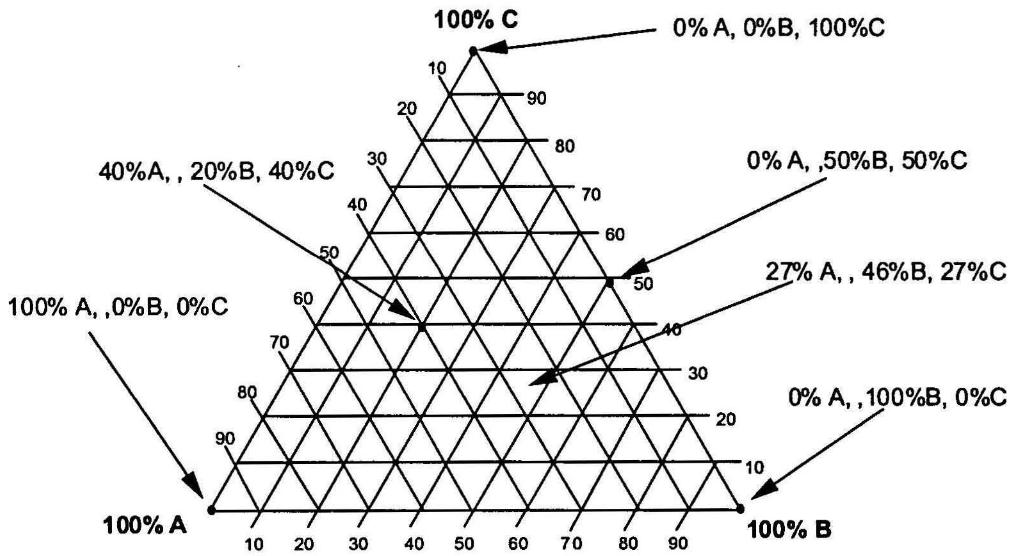
6) What are the locations in eastings and northings of the two widest points of the Tweed River on **Card 6**?

7) Using the scale bar on **Card 6,** how many kilometres is the widest point of the Tweed River?

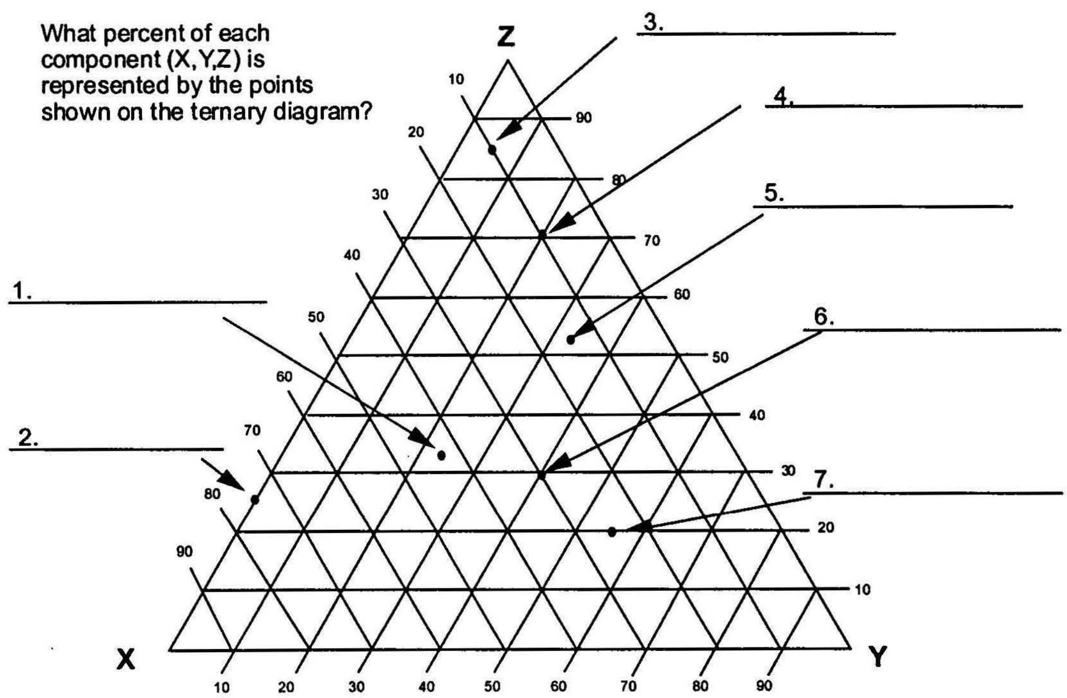
8) Using **Card 6** trace the Tweed River using tracing paper. Indicate on your sketch where the sand bars occur. Suggest reasons why sand and silt builds up in the areas you have identified.

Ternary Tester

The following diagrams are called ternary diagrams. They can be used to calculate the percentage composition where there are three components. Study the examples in the first ternary diagram and then complete the answers to the second ternary diagram.



What percent of each component (X,Y,Z) is represented by the points shown on the ternary diagram?



Plot the following points

8. 12%X, 66%Y, 22% Z
9. 33%X, 33%Y, 33%Z
10. 28%X, 24%Y, 48%Z
11. 35%Z, 0%Y, 65% X.

False colour fields

3 5 8

The image on **Card 8** uses the three Landsat TM spectral bands 7, 4 and 1. Of these only band 1 is in the visible spectrum. Band 4 and 7 are infrared bands. To produce an image, each of these bands have been assigned a colour :

Band 7 = red
Band 4 = green
Band 1 = blue

The resultant image is said to display 'false colours'. Any 'red' colour on the image must be the result of materials present that have Band 7 as the dominant reflectance, any 'green' colour on the image will have Band 4 as the dominant reflectance and any 'blue' colour will have Band 1 as the dominant reflectance.

Card 5 provides the spectral curves of a number of ground substances over the different spectral bands, including 7, 4 & 1. For example, a tilled soil which is high in the iron mineral hematite will give a very strong reflectance in Band 7 and low reflectance in Bands 4 & 1, and therefore show up as red on the image.

Cane Crops
In the upper right hand quarter of the image is a number of sugar cane fields. They contain either; an actively growing crop (similar to green grass) or stubble (similar to dry grass) The reflectance from these fields provides distinctive colours on this image — either bright green or bright red.

Using the graphs on Card 5, what colour would you expect a **growing sugar cane crop** to be on the image on Card 8 and why?

___

___

What would the colour would you expect **stubble** to be on the image on Card 8 and why?

___

___

The soils in the Tweed Valley around Murwillumbah are derived from the weathering of volcanic rocks high in iron. The resultant soils are rich in hematite. If the stubble in the fields were sparse so some of these soils were exposed, how would this alter the colour and/or intensity of the image of these fields?

____

____

The ternary diagram on card 3 shows the resultant colour when red, green and blue are mixed in varying proportions. Using this, calculate the approximate amounts (%) of red, green and blue of the town area of Murwillimbah (which appears a 'pink' colour).

Red : ____________ %   Green : ____________ %   Blue : ____________ %

What is the dominant Band(s) to give this colour? ____________

What types of ground materials would give this type of spectral reflectance in a built-up area?

____

Colour Concepts

3 5 7 8

The aim of this activity is to help you to become familiar with the colours used on Landsat TM images that result from mixing varying percentages of the primary additive colours.

Your interpretation of colours:

Find 33% red, 33% blue and 33% green on the colour ternary diagram. Describe the resultant colour.

____

What would you call the colour made from mixing 45% blue, 55% red?

____

Find 60% red, 40% green. What would you call this colour?

____

Find 60% red, 40% blue. What would you call this colour?

____

Landsat TM image colours

1. **Find the features from the table below on card 8.**
2. **Pinpoint the feature's colour (from the Landsat TM image) on the colour ternary diagram on card 3.**
3. **What percentage of the primary additive colours (red, green and blue) is each of these features on the Landsat TM image?**

Features on the Landsat TM image (card 8)	**% of primary additive colours**
Eg: Tweed River	80% blue, 20% green
Buildings in town centre	
Agricultural plots	
Remnant vegetation	
The border around Box C	

Use cards 5 and 7 to help explain why the agricultural plots appear as a magenta colour on the Landsat TM image.

____

____

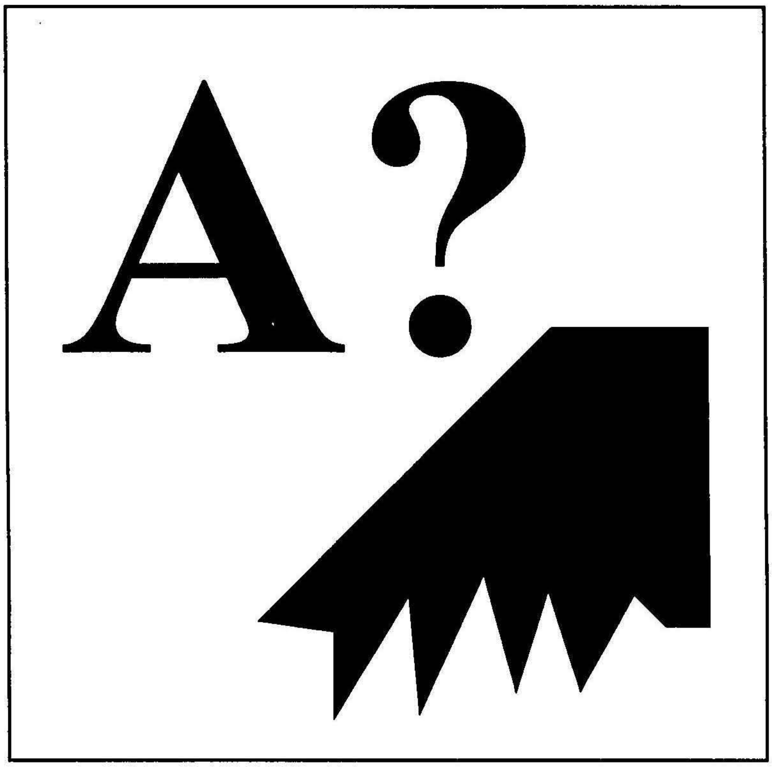
____

Pixel Size and Clarity

As a remote sensing satellite moves above the Earth it measures the reflected radiation from a set area on the Earth's surface. Spatial resolution (ground resolution) can be described as the ground surface area that forms one pixel in the satellite image. The measured reflected radiation from this area is averaged to give a value that is referred to as a picture element or pixel.

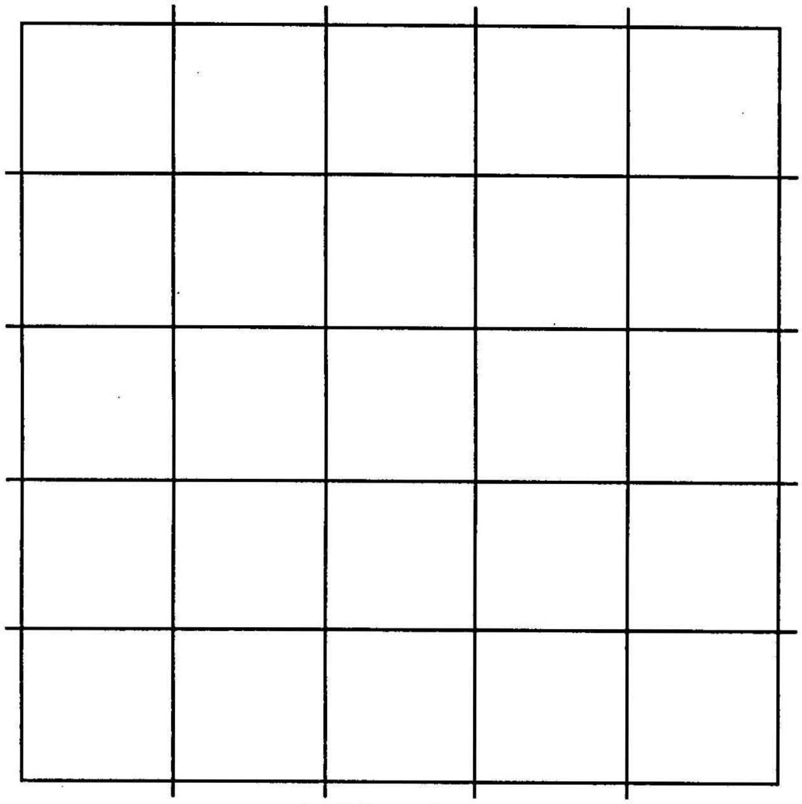
As different remote sensing sensors have different resolutions, then the information recorded by each sensor will differ due to the different size of the area being averaged to obtain a pixel value.

If we look at the image below, we can clearly define the letters and shapes — it has been printed using a series of dots with around 24 dots per millimetre (600 dpi).

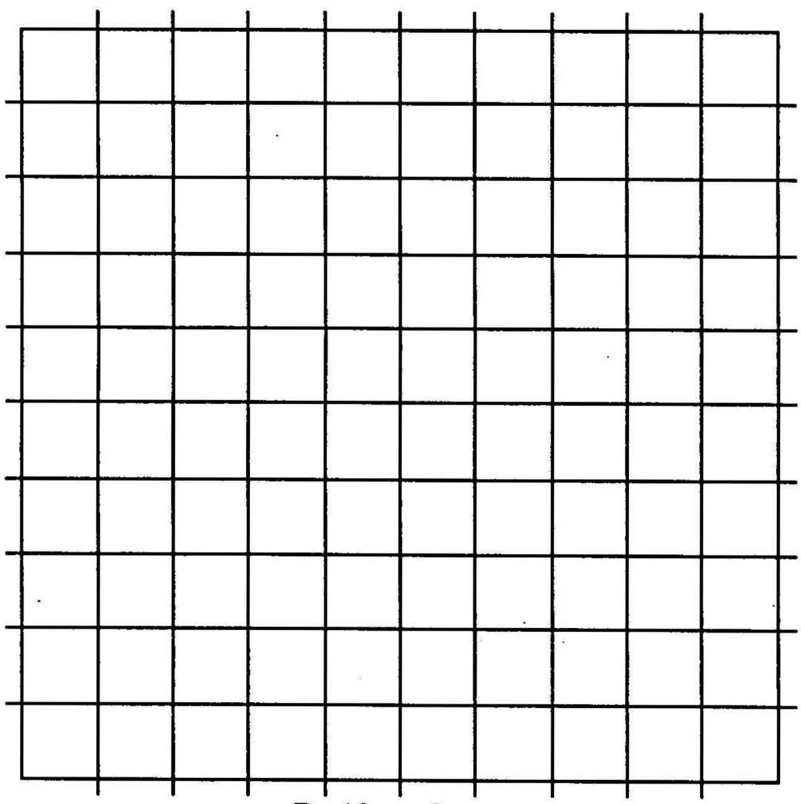


However, if we increase the pixel size, how is the clarity of the image altered?

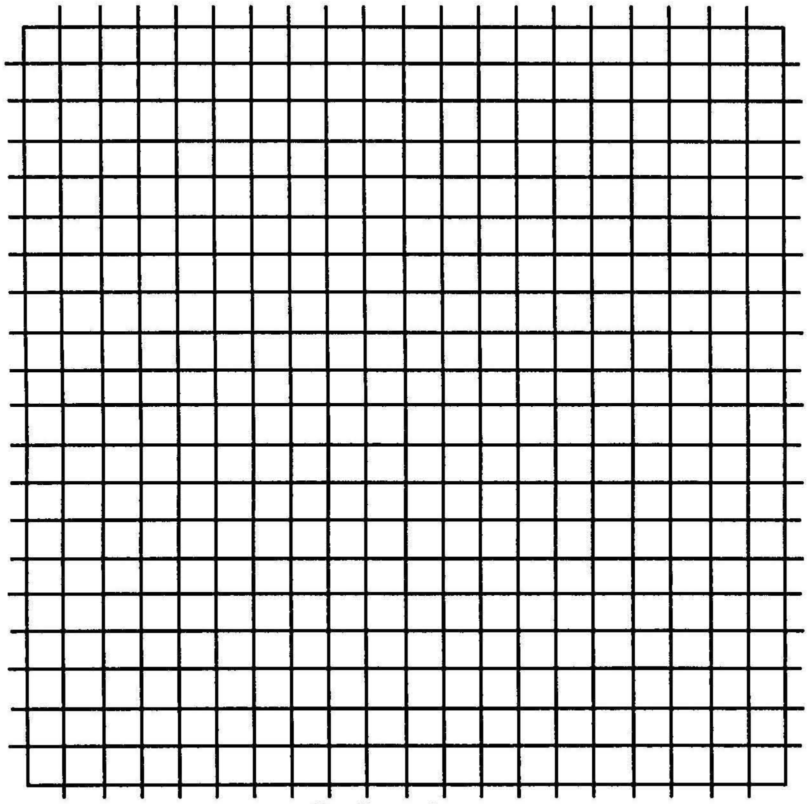
Using the three grided boxes below, create three images of the original image above by overlaying the boxes and only colouring in the squares that have 50% or greater amount of black inside.



A. 20mm boxes



B. 10mm boxes



C. 5mm boxes

1. If the cost of obtaining each of these images was calculated by the cost per pixel, how much more expensive would the image using Box C be over the image using Box A?

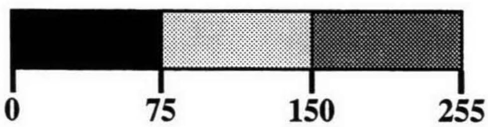
2. If each pixel was costed at $5, how much would it cost to obtain the image in Box B?

3. If on these images, 1 mm = 1m on the ground, what resolution (Box A, B or C) would you require to map a river's course which ranged from 12m to 30m wide and why?

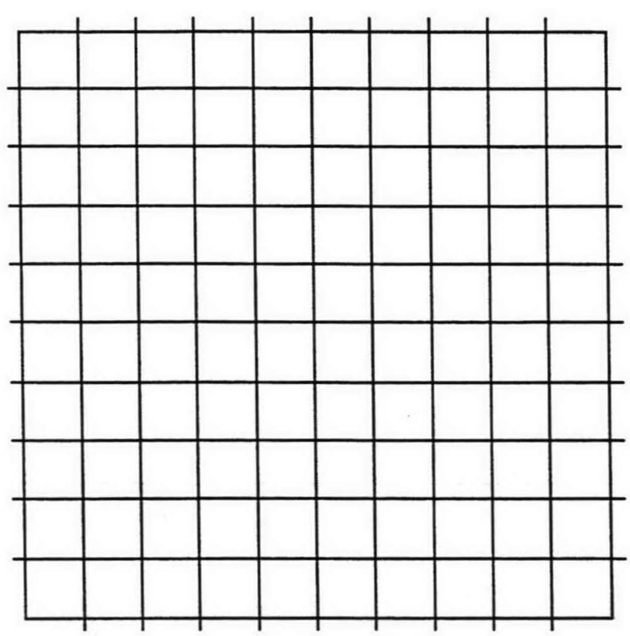
In true remote sensing systems, the reflected radiation is averaged for each spectral band and a brightness value is recorded in a range from 0 to 255.

In the example below, the pixel brightness of a river which contains sand bars has been recorded. The banks of the river are heavily wooded. Field checking has found that the reflectivity of the wooded banks ranged from 0-75 in brightness, sand bars from 75-150 and deep water above 150.

Using the following patterns, create an image from the data on the blank grids below.



71	68	45	51	101	167	153	49	51	48
44	48	53	62	50	135	158	198	45	60
36	51	62	55	49	119	167	211	70	42
65	43	56	66	117	175	223	205	67	66
53	23	34	178	183	197	151	59	67	70
62	67	212	192	201	123	55	48	68	61
57	170	163	171	140	63	59	60	53	70
19	210	180	118	119	58	61	65	61	29
40	220	183	111	125	48	47	49	54	29
68	54	162	172	133	100	51	52	47	33



Satellite Image Processor on the WWW

Introductory activity

AGSO's on-line Satellite Image Processor is a great way to further your understanding of Remote Sensing. Start by going to the web address:

www.agso.gov.au/education/remote_sensing/

When you are ready, press the **start** button!

Notice that the default image uses bands 3, 2 and 1 in the Red, Green and Blue "guns". Later you will experiment changing these bands to enhance different features.

Above the image, click on the word "Instructions", so that you can learn how to manipulate the satellite image. Read through the instructions carefully.
Now you are ready to experiment with some of the functions of the satellite image processor.

Using the "Action" function

Step 1.

Go to the page that displays the image and the image processor.

Step 2

Under the "Action" menu bar, choose **zoom in**, then click on the centre of the image. Notice that after the image reappears, the "Action" function returns to the default "pan". Choose **zoom in** again, and click on the map once more.

At the bottom of the image there is a reference to the image size.

What is happening to the image size as you zoom in?

____

Step 3

Zoom in until the image size is 10km x 10km. This is the maximum resolution of the image, because the ground resolution of a Landsat satellite is 25m.
Continue to zoom in as far as you can.
What is the image size now? ____________________

What happens to the image once you have zoomed in past the maximum resolution of the Landsat satellite?

____

Step 4

Choose the **zoom out** function. Zoom out a couple of times. Then use the default **pan map** function. Simply click on the area of the map that you want to pan over to. Use this function to explore the map. Then click on the **"start again"** button function to zoom out to the original image.

Using the " brighter" and "darker" functions

Step 1

Choose band 2 for each of the colour guns. This will produce a grey scale image.
Click on **"brighter"**. Press **GO** or click on the image.
How does this action affect the image?

What features on the image are enhanced by using this function?

What possible benefit could this function have for the user of this imagery?

Step 2

Choose band 7 for each of the colour guns, then click on "brighter" several times. This will enhance the waterways on the image. Pan the map, locate a semi-circular feature on the upper right hand side of the image, and zoom in on it. What do you think this feature might be?

Step 3

Press the **"start again"** button. This will return the image to the original default settings.

Step 4

Use the **"brighter"** and **"darker"** functions, along with the **zoom** and **pan** functions to locate features on the following features on the image:

- rivers
- lakes
- dams
- the town of Murwillumbah
- ridges
- the Mt Warning shield volcano

Experimenting with the Processing Method

Step 1

Read the "Suggested band combinations" page.

Step 2

Return to the image processor.

What is the default setting for the processing method? ____________________

Note that, when you select any of the processing methods, the RGB scene will remain listed as the default method. This does not mean that the other processing methods have not worked. It just means that you will have to remember which processing method you have selected!

List the 3 types of algorithms available for use on this processor.

____

Step 3

Choose the Vegetation Index from the processor method menu, then press **Go**, or simply click on the image.

What colour does dense vegetation appear using this algorithm? ________________

What colour does sparse vegetation appear using this algorithm? ________________

Step 4

Choose the Water Depth algorithm from the processor method menu, then press **Go**, or simply click on the image.

Describe what you can see using this algorithm.

____

____

Step 5

Choose the Water Chlorophyll algorithm from the processor method menu, then press **Go**, or simply click on the image.

Describe what you can see using this algorithm.

____

____

Satellite Image Processor on the WWW

Enhancing the Image

In this activity you will use the satellite image processor to find out how different spectral bands can be used to distinguish different features on a Landsat image. Use the graph on card 5 showing the reflectance signatures of various substances to help you answer the questions below.

Step 1

Start by going to the web address: www.agso.gov.au/education/remote_sensing
Press the start button.
What is the default selection for the colour guns and spectral bands?

What colour does vegetation appear using these settings?

Step 2

Select:
red = band 7, green = band 4, and blue = band 1

What colour does vegetation appear using these settings?

Refer to card 5. Look at the reflectance signature of green grass, specifically at band 4. Use this information to explain the colour of the vegetation on the Landsat image when bands 7, 4 and 1 are assigned.

The blue/green areas on the Landsat image are most likely mudflats rich in clay materials. Discuss the evidence for this statement by referring to the reflectance signature of clay.

The pink/red areas on the Landsat image are probably pastures where the vegetation has been removed and the surface is rich in iron oxides. Discuss the evidence for this statement by referring to the reflectance signatures on card.

Step 3

Select:

red= band 4, green = band 5, and blue = band 7.

What colour is the vegetation now? Explain why it is this colour.

The iron oxides show up on this image as cyan. Cyan is a mixture of which primary colours?

Explain why the iron oxides are cyan in this image.

What substance is abundant in the green areas on this image? Explain why.

Step 4
Select:
red= band 4, green = band 3, and blue = band 2.

What colour does vegetation appear now and why?

Step 5
Select:
red= band 2, green = band 3, and blue = band 4

What colour does vegetation appear now and why?

Landuse — Colours & Areas

Identification of different types of landuse is one of the most fundamental skills in using remotely sensed images. Identification alone however does not provide all the answers. In some cases the amount of area used for a particular purpose may need to be determined. The landuse in the Tweed area will be studied in this activity.

Materials Required: 2 sheets of 1 mm graph paper and tracing paper.

Stage A

Using **Card 8** describe the features present at:

Location	**Feature**
$28^{0}20'$S $153^{0}24'$E	
$28^{0}18'$S $153^{0}26'$E	

Stage B

Remnant vegetation is defined as vegetation which occurred naturally and has survived human occupation. In these images remnant vegetation is dark green in colour. For example, at 535^{000} m E and 6860^{625} m N you will find remnant vegetation.

Use the following method to calculate the area of remnant vegetation.

Step 1
Using one piece of tracing paper per card identify and outline the:
1) perimeter of each image
b) remnant vegetation cover of each image.

Step 2
Roughly shade all remnant vegetation.

Step 3
Place the tracing paper over the 1mm graph paper. Count how many squares are:
1) shaded (remnant vegetation)
b) total number of squares covered by the perimeter of the image.

Step 4

Use the following formula to calculate the % remnant vegetation.

$$\% \text{ Remnant vegetation} = \frac{\text{Remnant vegetation squares}}{\text{total no. squares}} \times 100$$

Stage C

Follow the same procedure use **Card 8** to fill in the table. Below.

Feature	**Working Out**	**Area %**
Remnant Vegetation Murwillumbah (card 8)		
Agricultural land Murwillumbah (card 8) Note: Agricultural land in Murwillumbah can be two different colours depending on the stage of growth of the sugar cane.		
Area of houses south of the Tweed River as a % of the town's development (card 8) Note : Formula should include the total area of houses only and not the area of the entire image		

Topography of the Tweed

1

Town planners and land managers need to be familiar with the topography of their area and be able to use maps and images which represent the area for which they are responsible. More importantly, they need to be able to find the same ground location on a variety of images and maps and be able to accurately record these for use by others.

You have been asked to become familiar with the area around the Tweed Valley. Use your skills and the information on **Card 1** to complete the following :—

1) Find the following location using the grid reference 5530 000 m E and 6880 000 m N. What physical structure is at this location?

Bridge across Tweed River

2) Locate the summit of the Mount Warning National Park on card 1. What is the:

a) grid reference 527 000 mE 6859 000 mN

b) latitude and longitude of the summit? 28° 24' S 153° 17' E

3) What are the grid references for:

a) Tyalgum 520 000 mE 6863 000 mN

b) Numinbah 525 000 mE 6873 000 mN

4) Describe and compare the terrain you would encounter when walking from the summit of Mount Warning to:

a) Tyalgum.

Dense forest vegetation
Steep downward slope
Creeks, roads
Sparse vegetation

b) Numinbah

Dense forest vegetation
Steep downward slope
River, creek, roads

5) Using the scale provided how many kilometres is it from the summit of Mount Warning to:

b) Tyalgum 8 Km

c) Coolangatta airport 26 Km

6) Provide a latitude and longitude for a landing ground other than Coolangatta airport.

28°20' S 153°25' E (Murwillumbah)

Estimate the elevation of this landing ground 10m

Sights from different heights

4 8

Town planners and resource managers have access to a range of images including street maps, aerial photographs and more recently satellite images. Each type of image has its advantages and limitations.

1) Using card 4 list the features most obvious in the aerial photograph of Murwillumbah.

Waterways, roads, urban areas, fields

2) Comparing card 4 and 8 list the advantages of using an aerial photograph over a Landsat Thematic Mapper of Murwillumbah.

Better resolution and a 'true' image → more detail

3) What are the limitations of the Landsat Thematic Mapper image?

"False" colours and lower resolution → less detail

4) Explain why there is greater detail in the aerial photograph of Murwillumbah when compared with the Landsat Thematic Mapper image of Murwillumbah.

Photo taken at lower altitude, close to subject, better resolution, and visible light used to produce image closer to how our eyes see. Aerial photography has spatial resolution of 1-2m, whereas Landsat TM is 30m.

5) What is the smallest item you can determine in

a) **Card 4?** large buildings in town, trees in paddocks/fields

b) **Card 8?** Small creeks

6) Using **Card 4** provide a grid reference for one individual tree found in agricultural land.

any dark pixel in the fields

7) What benefits does an aerial photograph have over a street map?

Real image - true colour, up to date, relief shown

Electromagnetic radiation and spectral bands

All

Find the following acronyms in the diagram of spectral curves (Card 5) plotted against electromagnetic radiation measured in microns

VIS = Visible
NIR = Near Infrared
SWIR = Short Wave Infrared
Thermal IR. = Thermal Infrared

The bands of Landsat are clearly marked. Complete the following table by identifying what part of the electromagnetic spectrum each spectral band fits into.

Band	Part of the EM spectrum	Acronym used
1	Visible	VIS
2	Visible	VIS
3	Visible	VIS
4	Near Infrared	NIR
5	Short wave infrared	SWIR
7	Short wave infrared	SWIR

Using cards 1 to 10 provide one example of a card which uses:

a) Visible spectrum only 4, 6

b) NIR, SWIR and one band of the visible spectrum 2, 7, 8, 10

Which colour (blue, green or red) has the shortest wavelength? blue (0·45 - 0·52μm)

Looking at detail — Resolution

Complete the table below by using the scale on each card and measure the distance indicated in millimetres.

Card number	Object	Platform	Measurement in mm
2	longest length of the paddock in view at the north west corner near Murwillumbah	Landsat TM	78mm
4	span of bridge over the Tweed River	Aerial photo/plane	9mm
6	maximum length of straight on racecourse near Tweed Heads	SPOT	9 mm
8	the width of remnant vegetation a dark green colour from east of this location 28°22'S, 153° 22'E	Landsat TM	4mm
9	eye of cyclone Betsy in SE corner of image	NOAA AVHRR	4 mm
10	runway at airport near Tweed Heads	Landsat TM	37 mm

2. Using **Card 4 & 8** of Murwillumbah, compare the scale and resolution of a Landsat TM image with an aerial photo. Describe the essential differences between these two images.

Card 4 1:13000 Card 8 1:62500
More fine detail in 4 but 8 has better
contrast

3. Read the text at the bottom of **Cards 6 & 10** of the Tweed Heads region. What is the ground resolution of:

a) Landsat TM in card 10 30m

b) SPOT panchromatic in card 6 10m

4. Using **Card 6 & 10** explain using examples what effect ground resolution has on the amount of detail (resolution) in each image.

SPOT has 10m ground resolution, it shows more
detail such as the sandbars in the waterways

5. What platforms in the table from question 1 provide the largest coverage but the least detail.

NOAA - AVHRR and Landsat TM

6. What satellite provides the smallest coverage but the most detail?

SPOT

7. If you required satellite imagery of a high resolution over a larger area how would this affect the cost of obtaining the final product.

The larger the area, and the higher the
resolution, the bigger the cost.

8. Would SPOT be a satellite which is suited to the use of predicting weather over regional areas? Explain your answer.

No Does not cover large enough area
to determine actual conditions developing that
will produce weather.

9. Different satellites have specific applications based on properties such as their ground resolution. Provide an example which supports this statement from your knowledge of ground resolution, scales and the coverage.

eg NOAA - large scale - weather predictions

NOAA Meteorological Satellite

NOAA—a polar-orbiting satellite
The National Oceanic and Atmospheric Administration Advanced Very High Resolution Radiometer (NOAA AVHRR) is a US polar orbiting satellite which is used for weather predictions. The accurate measurement of four to five spectral channels provides data on which weather predictions can be made. The image swathe (strip of ground surveyed) is very wide —2700km — which enables weather predictions over large areas. The ground resolution is 1100 metres.

Polar-orbiting and geostationary satellites
Polar-orbiting satellites operate in sun-synchronous orbits passing a given latitude at the same solar time providing near global coverage on a regular and predictable basis.

Geostationary satellites move with the same angular velocity as the Earth. These satellites, like Meteostat-2, remain over the same point on the Earth's surface.

Tropical Cyclones
The image clearly shows two different cyclones. Tropical cyclone Betsy north east of Brisbane is an exceptionally large cyclone (category 3) and caused severe beach erosion at Noosa, Queensland. Forty people were rescued at Noosa. Cyclone Mark over the Gulf of Carpentaria did not cause any major damage.

1) Suggest an application which would benefit from the use of a polar orbiting satellite image and why?

See above!

2) Suggest an application which would benefit from the use of a geostationary satellite images and why?

Change detection, land degradation
observations. satellite tracks changes
in the same area.

3) The 'eye' of a cyclone is an area characterised by calm conditions and often clear skies. What is the latitude and longitude for the 'eye' of tropical cyclone Betsy, Southern Queensland?

18°S 163°E

4) Measure the radius of Tropical Cyclone Betsy using the scale. Then estimate the diameter assuming that Tropical Cyclone Betsy is symmetrical.

about 1000 Km

5) Measure the diameter of the mass of cloud of Tropical Cyclone Mark using the scale. How does this compare with Tropical Cyclone Betsy?

about 400 Km
much smaller, less than half

6) Is Tropical Cyclone Mark larger than the area captured on Card 6 (use the scales provided on Card 6 and Card 9)?

Very much so, card 6 area = 4Km across.

SPOT the Sand and Silt

Scenario
As a student you have spent some time in the field studying the movement of sand in the northern part of the Tweed River which passes through Tweed Heads. Of particular interest to you is the formation and location of sand bars. You have recently acquired some Landsat and SPOT satellite imagery and are familiarising yourself with the technology available to assist further research.

A sand bar during the late 1960s and early 1970s developed across the mouth of the Tweed River that threatened the commercial and recreational fishing operations in the area. The river had become very dangerous to cross and many boats had to be rescued. Serious flooding threatened the town of Tweed Heads. Over 25 years ago the NSW government built rock walls (groynes) out into the ocean to stabilise the Tweed River and to stop the longshore drift of sand from blocking the river.

1) Using **Card 1, 6 & 10** locate the Tweed River. Which satellite image provides the longest course of the river?

Card 10 (Landsat TM image)

2) Fill in the following table based on your observations of the Tweed Heads region and Tweed River using **Card 1, 6 & 10**. If the feature is present in the image write down the colour, however, if the feature is not present in the field of view write N/A (for not applicable).

Colours of features in maps and satellite imagery

	River	Sand	Major Road	Urban development	Airport	Cloud colour
Topographic Map (card 1)	light blue	NA	Red	pink	black	N/A
Landsat TM (1,4,7) (card 10)	dark blue	white	Purple	Purple	dark blue	N/A
SPOT Panchromatic (card 6)	grey	white	light grey	white/ light grey	NA	white

3) Choose one feature from each of **Cards 1, 6 & 10** which is very prominent. Explain why this feature is best represented in that format.

a) Topographic map (**Card 1**)

Tweed River Light blue colour readily seen against white background. Red road also attracts attention

b) SPOT panchromatic (**Card 6**)

Race track in top left corner regular shape catches the eye

c) Landsat TM of Tweed Heads (**Card 10**)

Water ways - contrast between colours makes them readily visible.

4) Identify and describe the limitations of each map or image for the purpose of studying sand bars.

a) Topographic map (**Card 1**)

Scale doesn't allow them to be visible Also a "long term" medium. - Long term between sequential views

b) SPOT panchromatic (**Card 6**)

Same colour as clouds, could get them confused.

c) Landsat TM of Tweed Heads (**Card 10**)

Only large scale formations are readily seen due to the resolution and scale of the image

5) Using the scale provided on card 6, calculate the width of the mouth of the Tweed River in kilometres.

0·8 mm = 200m = 0·2Km

6) What are the locations in eastings and northings of the two widest points of the Tweed River on **Card 6**?

554 250 E 6883 600 N / 554 750 E 6883 500 N

7) Using the scale bar on **Card 6**, how many kilometres is the widest point of the Tweed River?

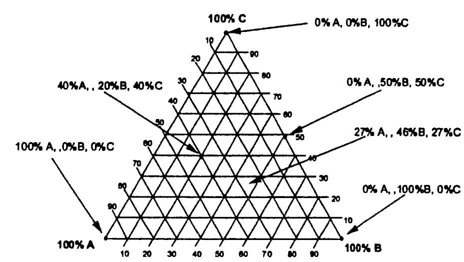
21mm = 525m = 0·525Km

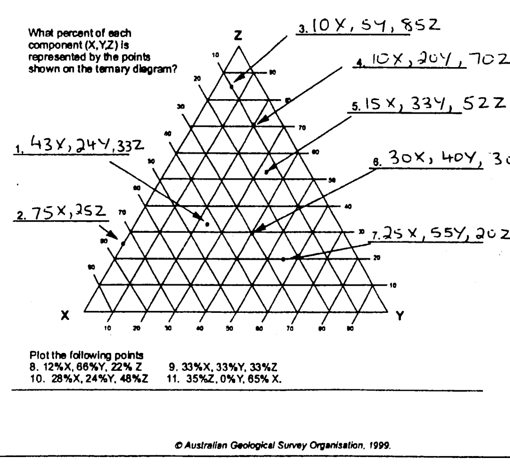
8) Using **Card 6** trace the Tweed River using tracing paper. Indicate on your sketch where the sand bars occur. Suggest reasons why sand and silt builds up in the areas you have identified.

inside of bends or narrowing of river causes water to slow down ⇒ less energy ⇒ sand/silt deposited.

Ternary Tester

The following diagrams are called ternary diagrams. They can be used to calculate the percentage composition where there are three components. Study the examples in the first ternary diagram and then complete the answers to the second ternary diagram. On the following page you will use the ternary diagram on Card 3 to determine the resultant colours after mixing the primary additive colours red, green and blue.





Plot the following points
8. 12%X, 66%Y, 22% Z
9. 33%X, 33%Y, 33%Z
10. 28%X, 24%Y, 48%Z
11. 35%Z, 0%Y, 65% X.

False colour fields

3 5 8

The image on **Card 8** uses the three Landsat TM spectral bands 7, 4 and 1. Of these only band 1 is in the visible spectrum. Band 4 and 7 are infrared bands. To produce an image, each of these bands have been assigned a colour :

Band 7 = red
Band 4 = green
Band 1 = blue

The resultant image is said to display 'false colours'. Any 'red' colour on the image must be the result of materials present that have Band 7 as the dominant reflectance, any 'green' colour on the image will have Band 4 as the dominant reflectance and any 'blue' colour will have Band 1 as the dominant reflectance.

Card 5 provides the spectral curves of a number of ground substances over the different spectral bands, including 7, 4 & 1. For example, a tilled soil which is high in the iron mineral hematite will give a very strong reflectance in Band 7 and low reflectance in Bands 4 & 1, and therefore show up as red on the image.

Cane Crops
In the upper right hand quarter of the image is a number of sugar cane fields. They contain either; an actively growing crop (similar to green grass) or stubble (similar to dry grass) The reflectance from these fields provides distinctive colours on this image — either bright green or bright red.

Using the graphs on Card 5, what colour would you expect a **growing sugar cane crop** to be on the image on Card 8 and why?

Green, equivalent to green grass which has the highest reflectance in band 4 -> green colour

What would the colour would you expect **stubble** to be on the image on Card 8 and why?

Yellow equivalent to stubble which has highest reflectance in band 4 and high reflectance in band 7 = green + red = yellow

The ternary diagram on card 3 shows the resultant colour when red, green and blue are mixed in varying proportions. Using this, calculate the approximate amounts (%) of red, green and blue of the town area of Murwillimbah (which appears a 'pink' colour).

Red : 50 % Green : 10 % Blue : 40 %

What is the dominant Band(s) to give this colour? 1 and 7

What types of ground materials would give this type of spectral reflectance in a built-up area?

Concrete, then bitumen

Colour Concepts

3 5 7 8

The aim of this activity is to help you to become familiar with the colours used on Landsat TM images that result from mixing varying percentages of the primary additive colours.

Your interpretation of colours:
Find 33% red, 33% blue and 33% green on the colour ternary diagram. Describe the resultant colour.

What would you call the colour made from mixing 45% blue, 55% red?

purple

Find 60% red, 40% green. What would you call this colour?

orange

Find 60% red, 40% blue. What would you call this colour?

maroon

Landsat TM image colours

1. **Find the features from the table below on card 8.**
2. **Pinpoint the feature's colour (from the Landsat TM image) on the colour ternary diagram on card 3.**
3. **What percentage of the primary additive colours (red, green and blue) is each of these features on the Landsat TM image?**

Features on the Landsat TM image (card 8)	% of primary additive colours
Eg: Tweed River	80% blue, 20% green
Buildings in town centre	40% blue 40% red 20% green
Agricultural plots	70% red 20% blue 10% green
Remnant vegetation	100% green
The border around Box C	45% green 55% red 10% green

Use cards 5 and 7 to help explain why the agricultural plots appear as a magenta colour on the Landsat TM image.

High hematite content in plots reflects mostly band 7 which has been set to show as red on the image

Pixel Size and Clarity

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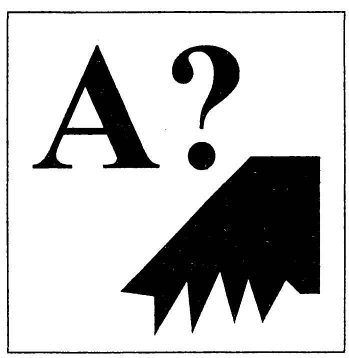

However, if we increase the pixel size, how is the clarity of the image altered?

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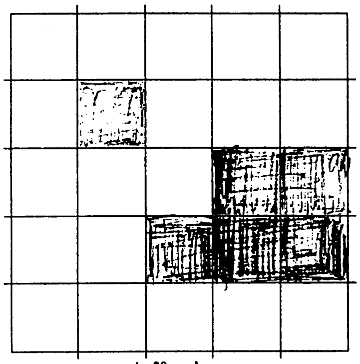
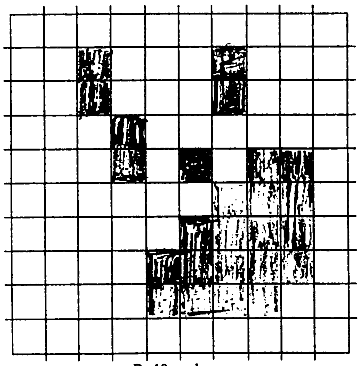
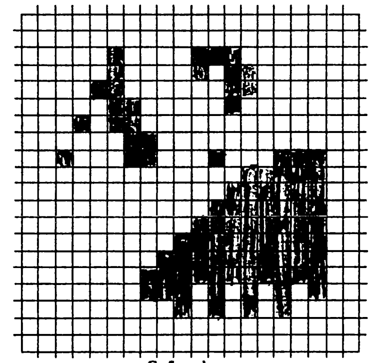


A. 20mm boxes



B. 10mm boxes



C. 5mm boxes

1. If the cost of obtaining each of these images was calculated by the cost per pixel, how much more expensive would the image using Box C be over the image using Box A?

$\frac{C}{A} = \frac{400}{25} = 16$ C is 16 x more expensive than A

2. If each pixel was costed at $5, how much would it cost to obtain the image in Box B?

$5 x 100 pixels = $500

3. If on these images, 1 mm = 1m on the ground, what resolution (Box A, B or C) would you require to map a river's course which ranged from 12m to 30m wide and why?

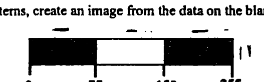
Either Box B or C. A is too low in some situations. eg 12mm may not be picked up at all.

In true remote sensing systems, the reflected radiation is averaged for each spectral band and a brightness value is recorded in a range from 0 to 255.

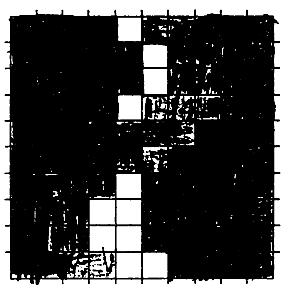
In the example below, the pixel brightness of a river which contains sand bars has been recorded. The banks of the river are heavily wooded. Field checking has found that the

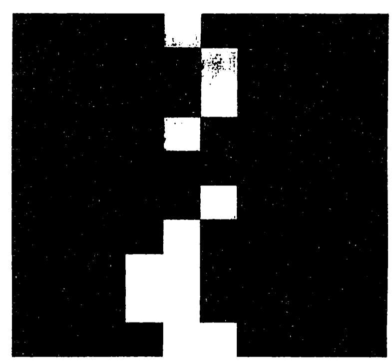
reflectivity of the wooded banks ranged from 0-75 in brightness, sand bars from 75-150 and deep water above 150.

Using the following patterns, create an image from the data on the blank grids below.



71	68	45	51	101	167	153	49	51	48
44	48	53	62	50	135	158	198	45	60
36	51	62	55	49	119	167	211	70	42
65	43	56	66	117	175	223	205	67	66
53	23	34	178	183	197	151	59	67	70
62	67	212	192	201	123	55	48	68	61
57	170	163	171	140	63	59	60	53	70
19	210	180	118	119	58	61	65	61	29
40	220	183	111	125	48	47	49	54	29
68	54	162	172	133	100	51	52	47	33





Excel spreadsheet 10 x 10 grid with cells filled with appropriate shade.

Satellite Image Processor on the WWW

Introductory activity
AGSO's on-line Satellite Image Processor is a great way to further your understanding of Remote Sensing. Start by going to the web address:

www.agso.gov.au/education/remote_sensing/

When you are ready, press the **start** button!

Notice that the default image uses bands 3, 2 and 1 in the Red, Green and Blue "guns". Later you will experiment changing these bands to enhance different features.

Above the image, click on the word "Instructions", so that you can learn how to manipulate the satellite image. Read through the instructions carefully.
Now you are ready to experiment with some of the functions of the satellite image processor.

Using the "Action" function

Step 1.
Go to the page that displays the image and the image processor.

Step 2
Under the "Action" menu bar, choose **zoom in**, then click on the centre of the image. Notice that after the image reappears, the "Action" function returns to the default "pan". Choose **zoom in** again, and click on the map once more.

At the bottom of the image there is a reference to the image size.

What is happening to the image size as you zoom in?

Gets smaller 80 x 80 → 20 x 20 → 10 x 10

Step 3
Zoom in until the image size is 10km x 10km. This is the maximum resolution of the image, because the ground resolution of a Landsat satellite is 25m.
Continue to zoom in as far as you can.
What is the image size now? 2 x 2 Km

What happens to the image once you have zoomed in past the maximum resolution of the Landsat satellite?

It got blurry. squares visible = pixels

Step 3
Choose the **zoom out** function. Zoom out a couple of times. Then use the default **pan map** function. Simply click on the area of the map that you want to pan over to. Use this function to explore the map. Then click on the **"start again"** button function to zoom out to the original image.

Using the " brighter" and "darker" functions

Step 1
Choose band 2 for each of the colour guns. This will produce a grey scale image.
Click on **"brighter"**. Press **GO** or click on the image.
How does this action affect the image?

Increases contrast, makes naturally vegetated areas stand out.

What features on the image are enhanced by using this function?

Naturally vegetated areas

What possible benefit could this function have for the user of this imagery?

Observe change in vegetation cover. Keep tabs on land clearance.

Step 2
Choose band 7 for each of the colour guns, then click on "brighter" several times. This will enhance the waterways on the image. Pan the map, locate a semi-circular feature on the upper right hand side of the image, and zoom in on it. What do you think this feature might be?

It's a water reservoir (Hinze Dam)

Step 3
Press the **"start again"** button. This will return the image to the original default settings.

Step 4
Use the **"brighter"** and **"darker"** functions, along with the **zoom** and **pan** functions to locate features on the following features on the image:

- rivers
- lakes
- dams
- the town of Murwillumbah
- ridges
- the Mt Warning shield volcano

Satellite Image Processor on the WWW

5 8

Enhancing the Image
In this activity you will use the satellite image processor to find out how different spectral bands can be used to distinguish different features on a Landsat image. Use the graph on card 5 showing the reflectance signatures of various substances to help you answer the questions below.

Step 1
Start by going to the web address: www.agso.gov.au/education/remote_sensing
Press the start button.
What is the default selection for the colour guns and spectral bands?

red = band 3 green = band 2 blue = band 1

What colour does vegetation appear using these settings?

green

Step 2
Select:
red = band 7, green = band 4, and blue = band 1

What colour does vegetation appear using these settings?

green

Refer to card 5. Look at the reflectance signature of **green grass, specifically** at band 4. Use this information to explain the colour of the vegetation on the **Landsat** image when bands 7, 4 and 1 are assigned.

green lush vegetation reflects best at band 4 - reflectance signature shows relatively more reflectance in this band, and relatively lower reflectance in the other bands

The blue/green areas on the Landsat image are most likely mudflats rich in clay materials. Discuss the evidence for this statement by referring to the reflectance signature of clay.

Experimenting with the Processing Method

Step 1
Read the "Suggested band combinations" page.

Step 2
Return to the image processor.

What is the default setting for the processing method? RGB scene

Note that, when you select any of the processing methods, the RGB scene will remain listed as the default method. This does not mean that the other processing methods have not worked. It just means that you will have to remember which processing method you have selected!

List the 3 types of algorithms available for use on this processor.

Vegetation Index / Water Depth / Water Chlorophyll

Step 3
Choose the Vegetation Index from the processor method menu, then press Go, or simply click on the image.

What colour does dense vegetation appear using this algorithm? Red / Orange

What colour does sparse vegetation appear using this algorithm? Blue / green

Step 4
Choose the Water Depth algorithm from the processor method menu, then press Go, or simply click on the image.

Describe what you can see using this algorithm.

Similar to water chlorophyll image, except shows water depth and valleys in caldera escarpments are dark blue

Step 5
Choose the Water Chlorophyll algorithm from the processor method menu, then press Go, or simply click on the image.

Describe what you can see using this algorithm.

Little green + yellow dots in black/white/grey land mass. Red dots on coastline. Ocean contains green + blue dots!

Clay has relatively more absorption in band 7, and higher reflectance in bands 1 + 4, meaning that band 7 (red) will be absorbed and green/blue will be the resultant colour

The pink/red areas on the Landsat image are probably pastures where the vegetation has been removed and the surface is rich in iron oxides. Discuss the evidence for this statement by referring to the reflectance signatures on card.

Hematite (iron oxide) reflects relatively more in band 7 so if band 7 is assigned the red gun then the iron oxide will appear more red/pink.

Step 3
Select:
red= band 4, green = band 5, and blue = band 7.

What colour is the vegetation now? Explain why it is this colour.

brown/orange/red We have set the band that best detects vegetation (band 4) to show as red on the image

The iron oxides show up on this image as cyan. Cyan is a mixture of which primary colours?

blue/green

Explain why the iron oxides are cyan in this image.

Iron oxide reflects relatively more in bands 5 + 7, which has been assigned the green and blue guns, resulting in a cyan colour.

What substance is abundant in the green areas on this image? Explain why.

probably clay because it reflects relatively more in band 5 which is assigned the green gun.

Step 4
Select:
red= band 4, green = band 3, and blue = band 2.

What colour does vegetation appear now and why?

Bright red, because vegetation reflects relatively more in band 4 and this has been assigned the red gun

Step 5
Select:
red= band 2, green = band 3, and blue = band 4

What colour does vegetation appear now and why?

blue, because vegetation reflects relatively more in band 4 and this has been assigned the blue gun

Landuse — Colours & Areas

1 8

Identification of different types of landuse is one of the most fundamental skills in using remotely sensed images. Identification alone however does not provide all the answers. In some cases the amount of area used for a particular purpose may need to be determined. The landuse in the Tweed area will be studied in this activity.

Materials Required: 2 sheets of 1 mm graph paper and tracing paper.

Stage A

Using **Card 8** describe the features present at:

Location	Feature
28°20'S 153°24'E	Purple/pink - urban area
28°18'S 153°26'E	green/pink - agriculture regular shapes

Stage B

Remnant vegetation is defined as vegetation which occurred naturally and has survived human occupation. In these images remnant vegetation is dark green in colour. For example, at 535^{000} m E and 6860^{625} m N you will find remnant vegetation.

Use the following method to calculate the area of remnant vegetation.

Step 1
Using one piece of tracing paper per card identify and outline the:
a) perimeter of each image
b) remnant vegetation cover of each image.

Step 2
Roughly shade all remnant vegetation.

Step 3
Place the tracing paper over the 1mm graph paper. Count how many squares are:
a) shaded (remnant vegetation)
b) total number of squares covered by the perimeter of the image.

Step 4

Use the following formula to calculate the % remnant vegetation.

$$\% \text{ Remnant vegetation} = \frac{\text{Remnant vegetation squares}}{\text{total no. squares}} \times 100$$

Stage C

Follow the same procedure use **Card 8** to fill in the table. Below.

Feature	Working Out	Area %
Remnant Vegetation Murwillumbah (card 8)	approx 6200/28 900	approx 21%
Agricultural land Murwillumbah (card 8) Note: Agricultural land in Murwillumbah can be two different colours depending on the stage of growth of the sugar cane.	approx 9500/28900	approx 33%
Area of houses south of the Tweed River as a % of the town's development (card 8) Note: Formula should include the total area of houses only and not the area of the entire image	approx 13/40	approx 32%

Remote Sensing Exam

Instructions:
There are 3 sections in this exam:
Section A: 14 Multiple Choice Questions
(1 mark each)

Section B: 7 Short Answer Questions
(a total of 15 marks)

Section C: Choice of 2 Long Answer Questions
(6 marks each)

The exam is marked out of a total of 41 marks.

During this exam you are allowed access to the Discovering Remote Sensing Cards. Use the answer sheet provided for the multiple choice section. Please do not write on the multiple choice question sheets. When you have completed the test, put your name on every answer sheet and attach them to each other.

Section A: Multiple Choice questions.

Choose the most correct answer and write your answer on the answer sheet provided. **DO NOT** write on this question sheet.

1) The best definition of remote sensing is:

(a) the science of detecting and measuring a substance always within physical contact
(b) the science of detecting and measuring a substance without physical contact
(c) the advancement of aerial photography
(d) looking beneath the Earth using scientific equipment
(e) using satellites to measure radar pulses

2) Wavelength is described as the distance from/between the:

(a) trough multiplied by the amplitude
(b) cycle multiplied by the frequency
(c) successive identical parts of the wave
(d) micrometre plus the height of the crest
(e) trough to the peak

3) Light is an excellent medium for capturing and transmitting information about our planet because light:

(a) is the visible form of electromagnetic radiation
(b) travels at a slow to medium rate
(c) analyses the electromagnetic spectrum
(d) is easily detected through all spectral bands
(e) travels at a fast speed

4) Atmospheric windows are best described as regions of:

(a) the electromagnetic spectrum which are least affected by the Earth's atmosphere
(b) low transmittance, and moderate scattering of electromagnetic radiation
(c) no transmittance, reflection or absorption of electromagnetic radiation
(d) the electromagnetic spectrum which encounter water vapour fumes and dust
(e) diffuse radiation caused by haze, water vapour and clouds

5) Active and passive systems are used in remote sensing. Choose the most correct statement:

(a) active systems measure the absorption and reflection of electromagnetic radiation originally emitted from the sun
(b) passive systems emit a radar pulse from an aircraft or satellite on to a target area
(c) passive systems measure the absorption and reflection of electromagnetic radiation originally emitted from the sun
(d) active systems measure the diurnal and seasonal changes in electromagnetic radiation
(e) passive systems allow the detection of objects under poor lighting and weather conditions

6) Spatial resolution and spectral resolution are terms commonly used in remote sensing. Choose the most correct statement.

(a) spectral resolution is the ground imaged for the instantaneous field of view
(b) spectral resolution is the ground surface area that forms one pixel in the imaging systems
(c) spatial resolution is the ground surface area that forms one pixel in the imaging systems
(d) spatial resolution is the frequency with which a sensor can revisit the same part of the Earth's surface
(e) spectral resolution is the frequency with which a sensor can revisit the same part of the Earth's surface

7) In remote sensing a pixel can be defined as the:

(a) brightness value
(b) grey value
(c) digital number
(d) smallest picture element that has been measured on the ground
(e) largest picture element that has been measured on the ground

8) A radiometric attribute of a pixel is defined as the:

(a) brightness value
(b) smallest picture element that has been measured on the ground
(c) contrast enhanced image
(d) picture element
(e) Uranium, Thorium and Potassium concentration

9) To identify the build-up of sand in the Tweed River the most appropriate imagery to use is:

(a) SPOT
(b) RADARSAT
(c) Landsat Thematic Mapper
(d) Magnetics
(e) Landsat Multispectral Scanner

10) When using bands 1 (blue), 2 (green) and 3 (red) of Landsat TM green vegetation looks green because:

(a) there is an absorption peak at 1.9 µm
(b) relative low reflectance occurs using band 7
(c) there is a higher reflectance at band 2 relative to bands 1 and 3
(d) there is relatively higher absorption of band 2
(e) red and cyan colours have been mixed together

11) When the Normalised Vegetation Index is used to enhance an image on the WWW Satellite Image Processor, areas:

(a) of sparse vegetation appear in red
(b) high in Fe/Mg materials appear in red
(c) of dense vegetation appear in red
(d) of dense vegetation appear in blue
(e) none of the above

12) A satellite image will look similar to a normal aerial photograph when the colour gun and band combinations are:

(a) red = band 7, green = band 4. blue = band 1
(b) red = band 7, green = band 5, blue = band 4
(c) red = band 3, green = band 2, blue = band 1
(d) red = band 1, green = band 1, blue = band 1
(e) red = band 7, green = band 5, blue = band 3

13) Band 7 is a near infrared spectral band that discriminates cleared or non-vegetated land from heavily vegetated land. When using bands 1, 4 and 7 cleared or non-vegetated land will appear:

(a) blue
(b) green
(c) pink
(d) yellow
(e) black

14) Cloud cover:

(a) adversely affect RADARSAT images
(b) adversely affects SPOT images
(c) is a problem in all satellite images except for Landsat TM
(d) adversely affects the quality of NOAA images
(e) adversely affects active sensing systems

Section B: Short Answer questions.

Complete all of the following questions.

1) Complete the following table by writing down what the acronym stands for

Acronym	**Stands for**
VIS	
NIR	
SWIR	
Thermal IR	

(2 marks)

2) Using card 5 and others provide one example of a card that uses:

a) NIR and SWIR

______________________________(1mark)

b) VIS only

______________________________(1 mark)

c) NIR, SWIR and one band of the visible spectrum

______________________________(1 mark)

3) There are some similarities between a topographic map and a Landsat TM image. Explain two main differences between a topographic map and a Landsat TM image using examples from the cards.

____

____

____

____

______________________________(2 marks)

4) Using cards 6 and 10 explain what effect ground resolution has on the amount of detail in each image.

____

____

(2 marks)

5) Explain the relationship between ground resolution and pixel size.

(2 marks)

6) Explain the difference between multispectral and hyperspectral satellite imagery.

(2 marks)

7) Describe two ways remote sensing is used in environmental monitoring.

(2 marks)

Section C: Long Answer

Choose **<u>TWO</u>** of the following questions and answer them on the blank paper provided. The questions are worth 6 marks each.

1) Artificial satellites are placed into orbits around the Earth for a variety of reasons, for example, mineral exploration, military applications, weather and environmental monitoring. Choose one discipline mentioned above and explain how the extra information gained from satellite imagery has provided valuable knowledge in this field.

2) Explain the basis of additive and subtractive colours. Explain how false colours can be used to enhance images using examples from the various cards provided.

3) The capture of Landsat data has changed the way humans view and monitor the Earth. Since 1979 Australia has used remote sensing to capture data of our vast continent. Comment on the benefits and limitations of remote sensing in the context of natural resource management.

Remote Sensing Exam

Multiple Choice Student Answer Sheet

1) (a) (b) (c) (d) (e)

2) (a) (b) (c) (d) (e)

3) (a) (b) (c) (d) (e)

4) (a) (b) (c) (d) (e)

5) (a) (b) (c) (d) (e)

6) (a) (b) (c) (d) (e)

7) (a) (b) (c) (d) (e)

8) (a) (b) (c) (d) (e)

9) (a) (b) (c) (d) (e)

10) (a) (b) (c) (d) (e)

11) (a) (b) (c) (d) (e)

12) (a) (b) (c) (d) (e)

13) (a) (b) (c) (d) (e)

14) (a) (b) (c) (d) (e)

Remote Sensing Exam

Multiple Choice Teacher Answer Sheet

1) b
2) c
3) e
4) a
5) c
6) c
7) d
8) a
9) a
10) c
11) c
12) c
13) c
14) b

Section B: Short Answer questions.

Complete all of the following questions.

1) Complete the following table by writing down what the acronym stands for

Acronym	Stands for
VIS	Visible
NIR	Near Infra red
SWIR	Short wave Infra red
Thermal IR	Thermal infra red

(2 marks)

2) Using card 5 and others provide one example of a card that uses:

a) NIR and SWIR

6 (SPOT) (1mark)

b) VIS only

4 (Aerial photo) (1 mark)

c) NIR, SWIR and one band of the visible spectrum

2, 7, 8, 10 (1 mark)

3) There are some similarities between a topographic map and a Landsat TM image. Explain two main differences between a topographic map and a Landsat TM image using examples from the cards.

① Detail: Landsat TM image reveals more in terms of actual land use eg fields covered in vegetation and those not

② Topography: topo map gives actual values and terrain while Landsat image indicates it only

(2 marks)

4) Using cards 6 and 10 explain what effect ground resolution has on the amount of detail in each image.

Card 6 - SPOT 10m resolution

Card 10 - Landsat TM 30m resolution

The higher ground resolution (SPOT) has more detail in it shown by the greater number of features readily identifiable eg sand bars, race track, streets and buildings. Each pixel in this image represents a smaller area (2 marks)

5) Explain the relationship between ground resolution and pixel size.

Ground resolution is the smallest area over which differences can be recorded by the imaging system. This in turn sets the size of a pixel in a digital image derived by that recorded data. High resolution ⇒ smaller pixel ⇒ higher resolution images showing more detail at smaller scales (2 marks)

6) Explain the difference between multispectral and hyperspectral satellite imagery.

Multispectral imagery uses only a small number of spectral bands eg Landsat TM uses 7. This restricts the amount of info in each pixel.

Hyperspectral imagery uses a much larger number of spectral bands eg ARIES will use 126, therefore giving more information per pixel than multispectral imagery (2 marks)

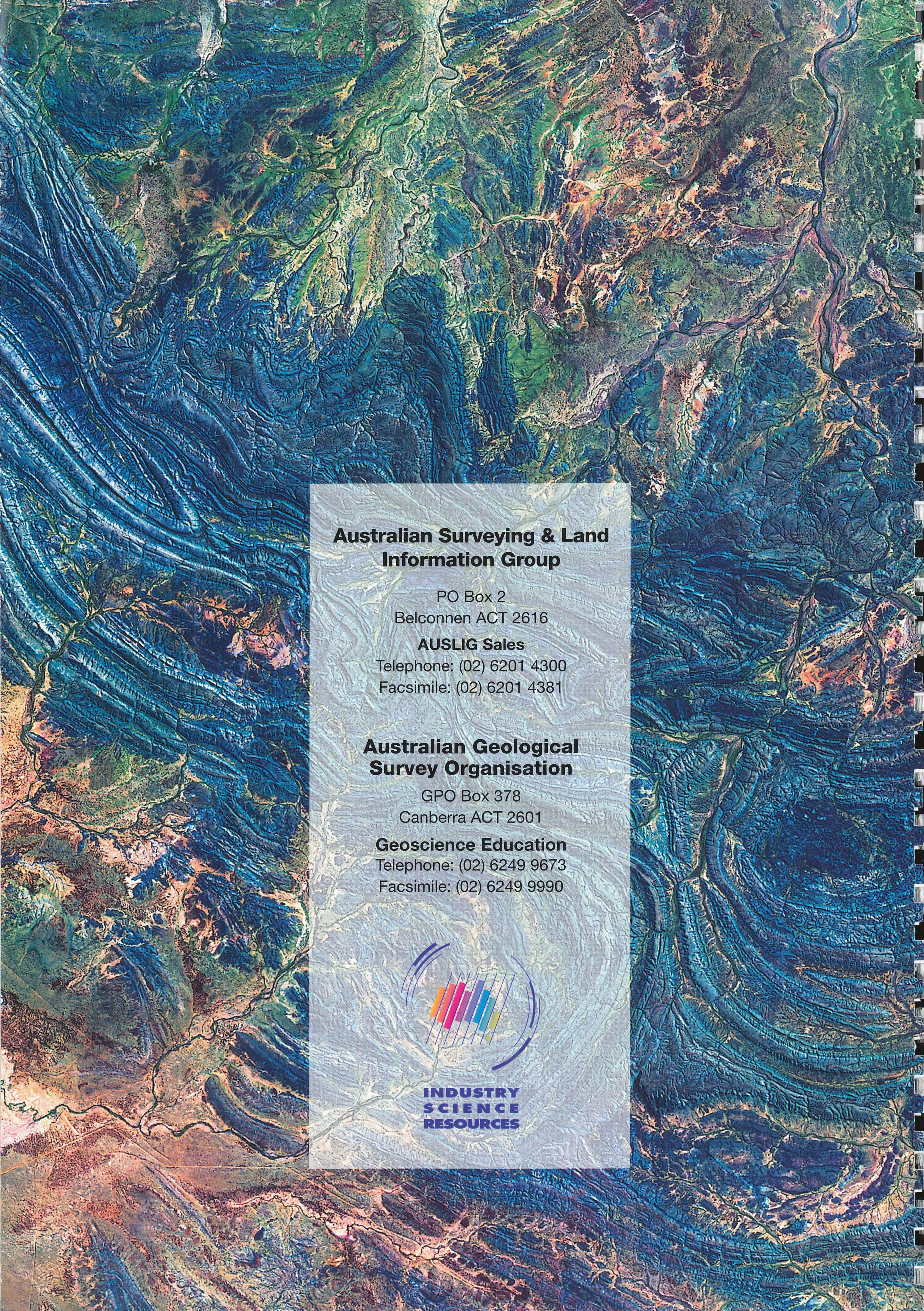
7) Describe two ways remote sensing is used in environmental monitoring.

Forestry - species extent of forests, effects of change

Greenhouse gases - calculating emission levels

Vegetation health - health of plant affects reflectance properties detecting change over large areas in vegetation

degradation of land can be mapped over large areas relatively easily (2 marks)



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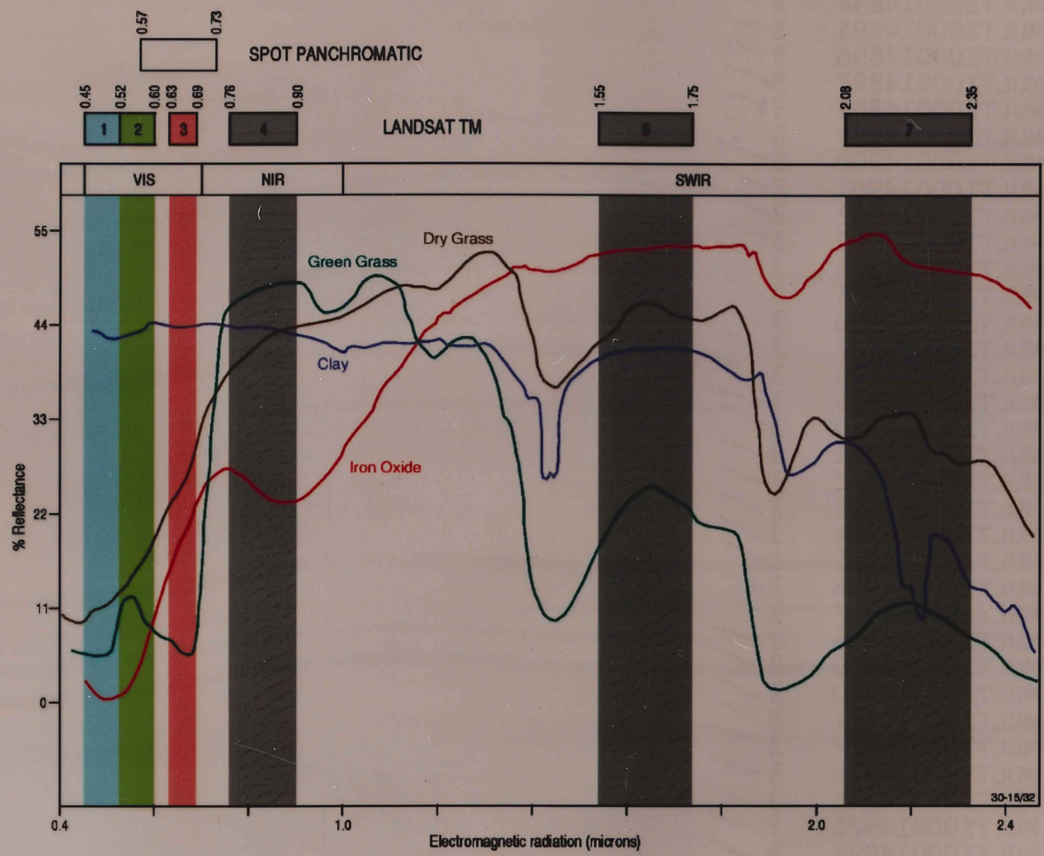
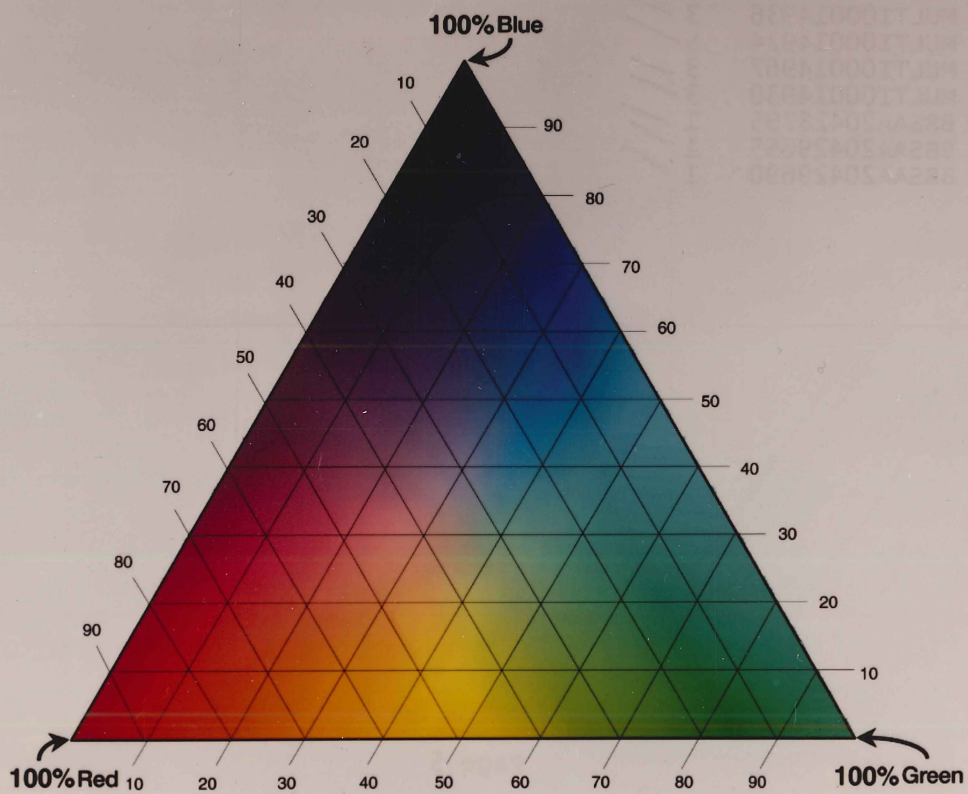
INDUSTRY
SCIENCE
RESOURCES

Electromagnetic Spectrum and Reflectance

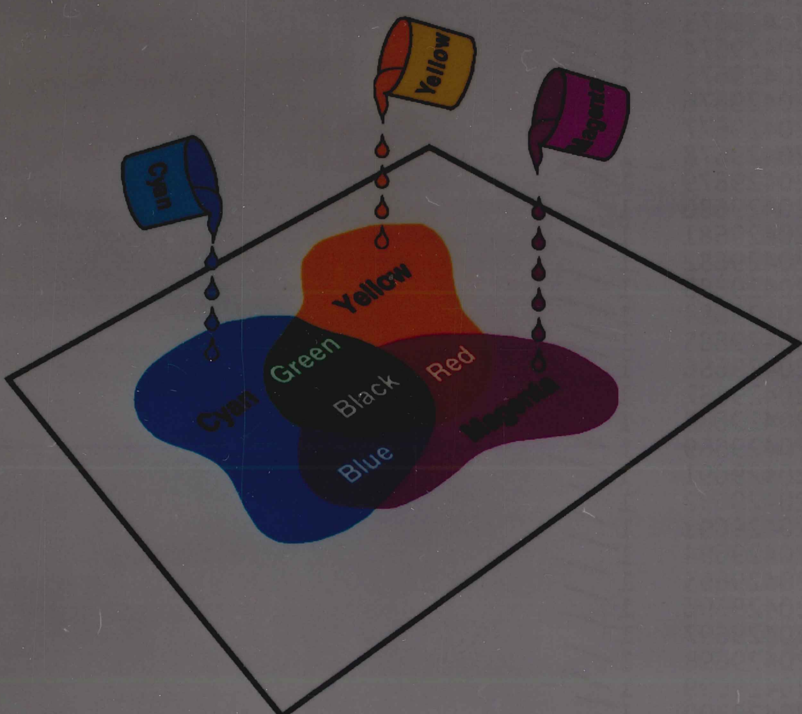


Colour Ternary Diagram—Additive Colours



Additive and Subtractive Primary Colour Mixing

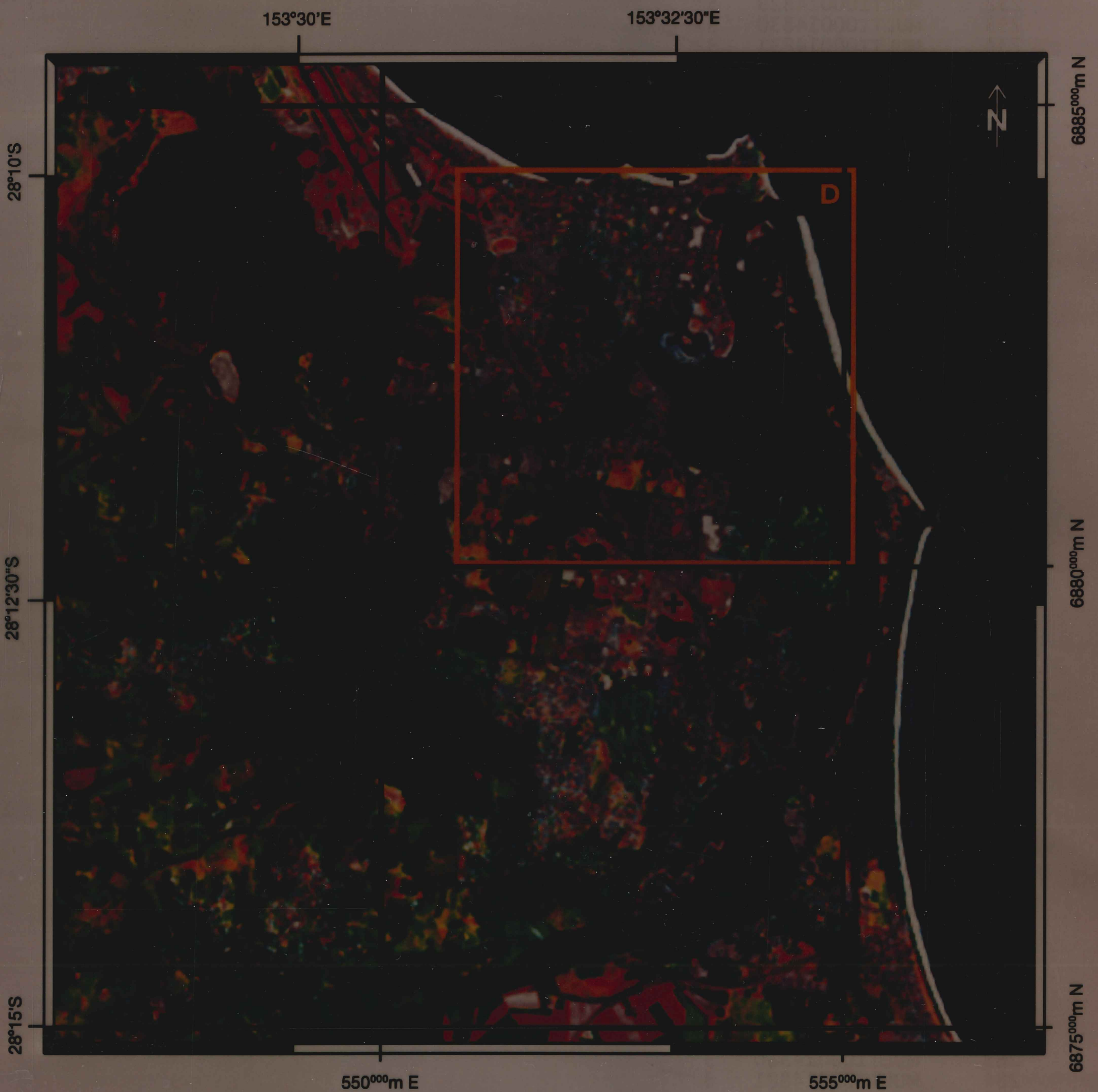
Additive Colour Mixing — Red, green and blue primary colours are added to a black background to give other colours. This method is used to produce colours on a computer monitor.

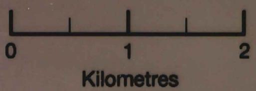


Subtractive Colour Mixing — Yellow, magenta and cyan primary colours subtract from a white background to give other colours. This method is used to produce colours on printed paper.

Landsat Thematic Mapper (TM) Bands 1,4,7 of Tweed Heads

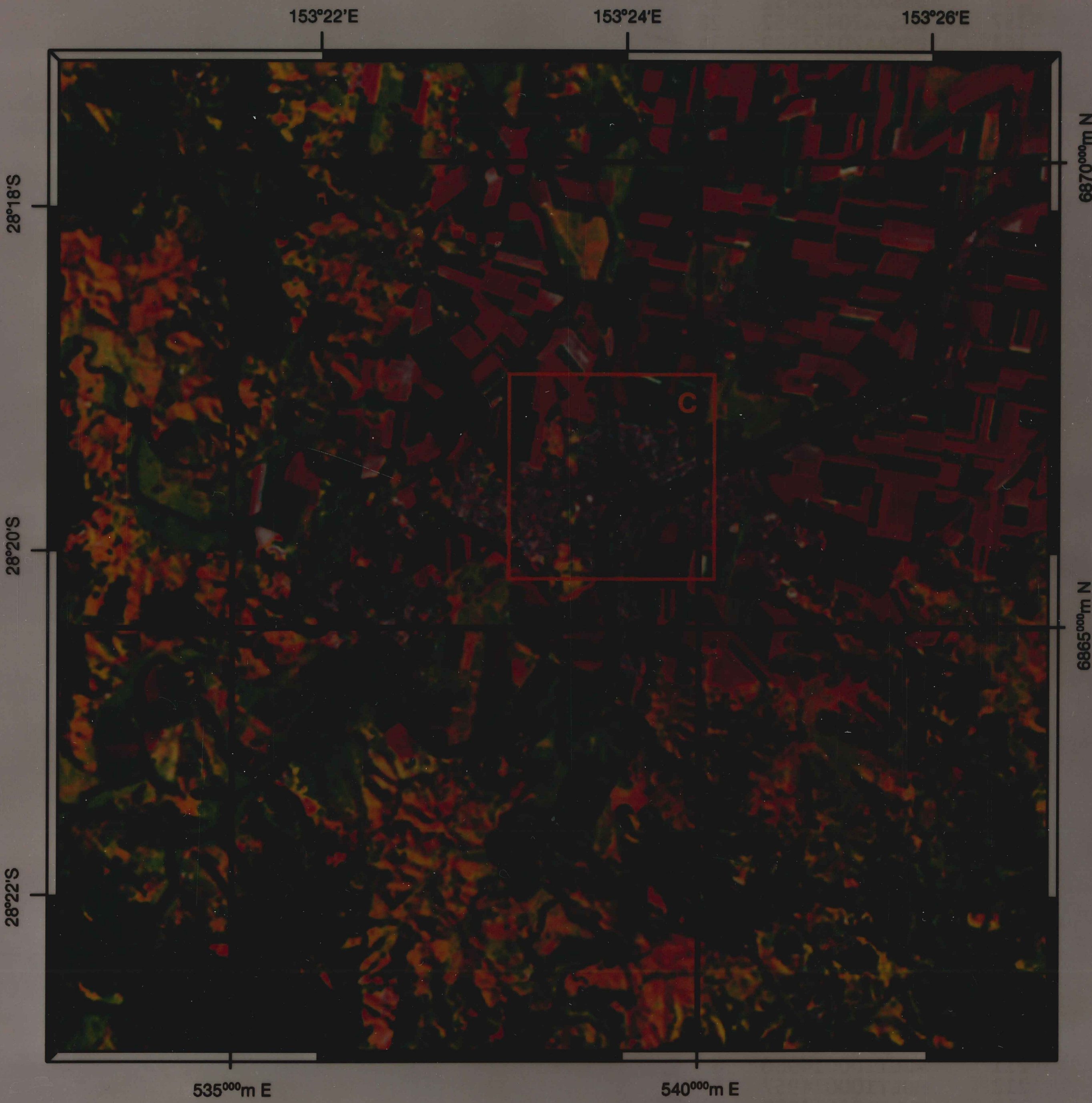
Northern New South Wales, Australia

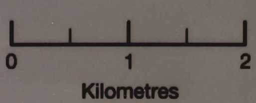




Landsat Thematic Mapper (TM) Bands 1,4,7 of Murwillumbah

Northern New South Wales, Australia

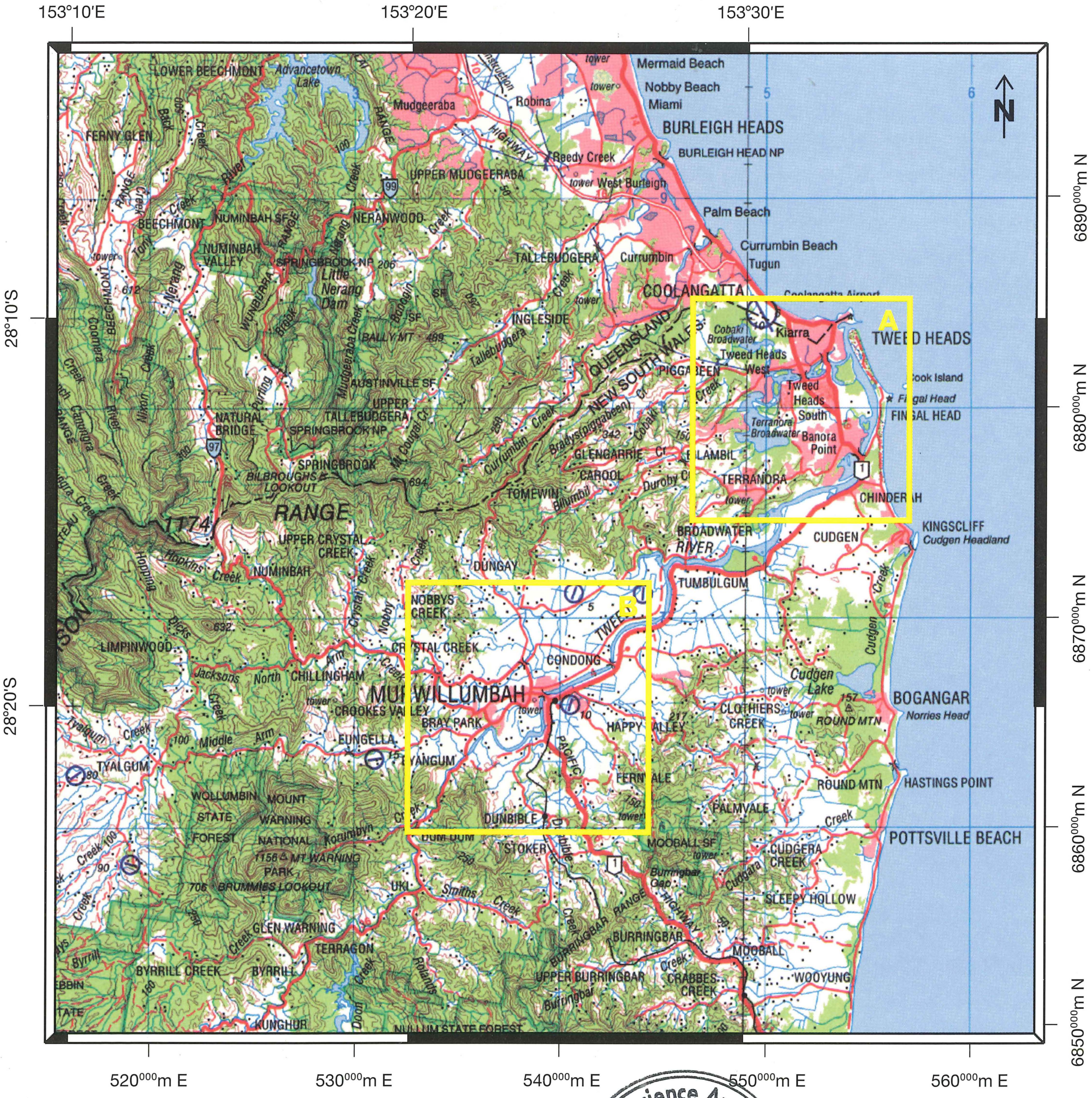




Card 1

Topographic Map of the Tweed Heads Region

Northern New South Wales, Australia.

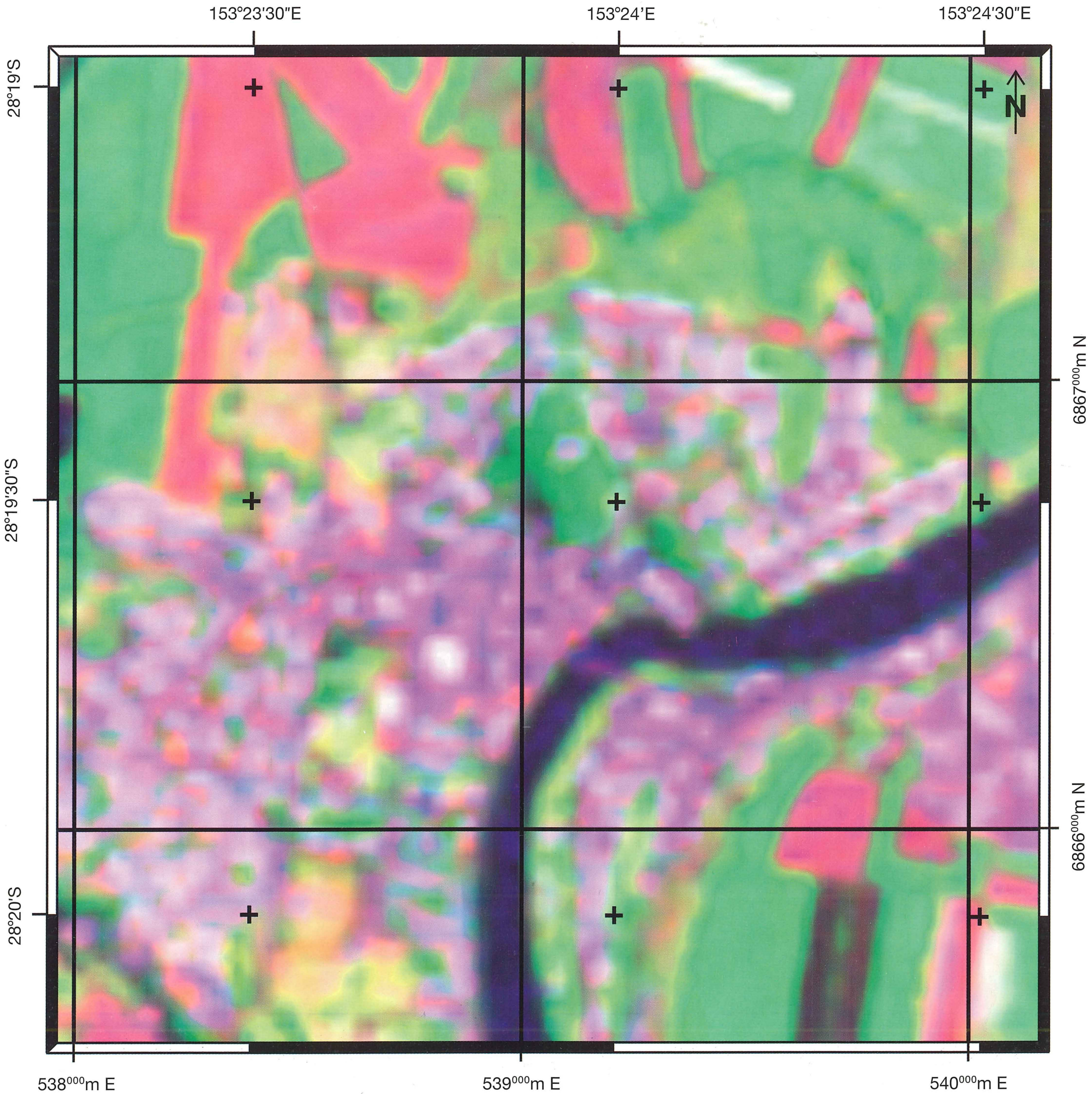


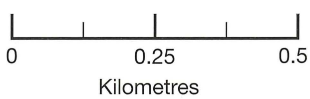
This map shows the main features of the landscape: coastline, mountains, valleys, vegetation cover, waterways and major roads. The two main study sites are indicated: Tweed Heads, (Box A) Murwillumbah (Box B). Box A is the approximate area covered in Card 10; Box B is the approximate area covered in Card 8. Scale 1:280,000. Australian Map Grid Zone SH56. 1996.

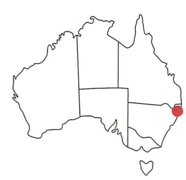
Card 2

Landsat Thematic Mapper (TM) Bands 1,4,7 of Murwillumbah's township

Northern New South Wales, Australia



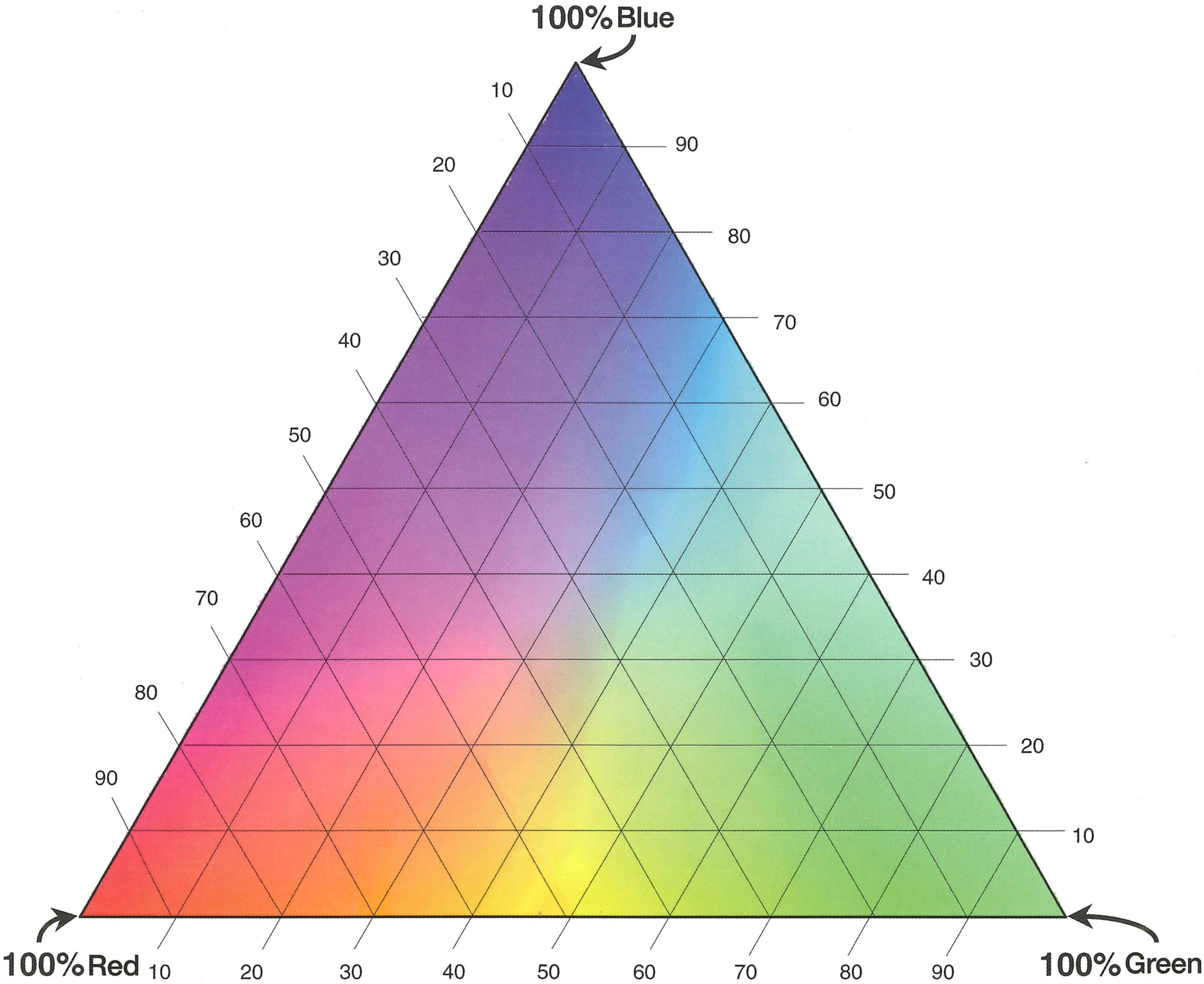




This image of the township of Murwillumbah demonstrates the effect of increasing scale until pixels are visible. Normally the scale used for Landsat TM is such that individual pixels are not apparent and the image is not blurred. Band 1 (Blue), Band 4 (Green) and Band 7 (Red) produce false colours. Box C in card 8 is the approximate area enlarged for this card. Ground resolution 30 metres. Scale 1:13,000. Australian Map Grid Zone SH56. 6 September, 1997.

Card 3

Additive Primary Colour Ternary Diagram



This ternery diagram demonstrates the effect of mixing the additive primary colours blue, green and red. The diagram can be used to calculate the resultant colour from varying percentages of the three additive primary colours.

Card 4

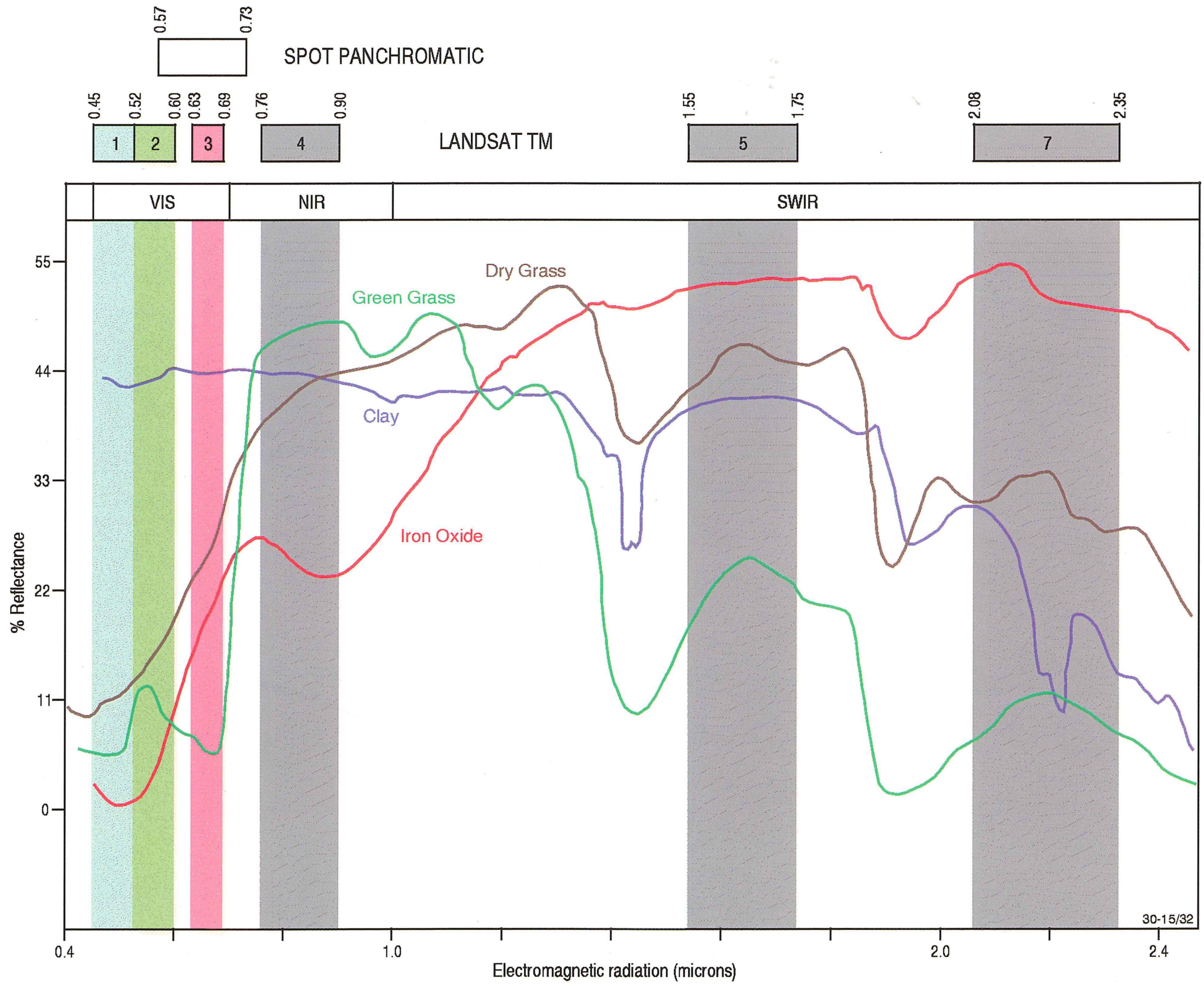
Aerial Photograph of Murwillumbah's Township

Northern New South Wales, Australia.

A closer view of the township of Murwillumbah taken from an aeroplane with the Tweed River dominating the township, Myal Creek to the North alongside agricultural land. Box C in card 8 is the approximate area enlarged for this card. Scale 1:13,000. Australian Map Grid Zone SH56. 6 October, 1989.

Card 5

Electromagnetic Spectrum, Reflectance Signatures and Colour Wheel

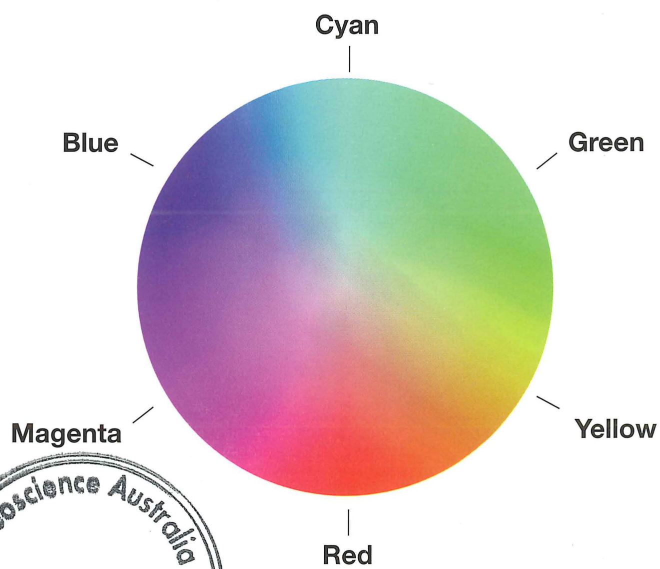


Electromagnetic Spectrum

These spectral curves assist with the interpretation of different surfaces reflecting different amounts of electromagnetic radiation at various wavelengths. Soil, water and vegetation have unique patterns of reflectance over different wavelengths.

Colour wheel

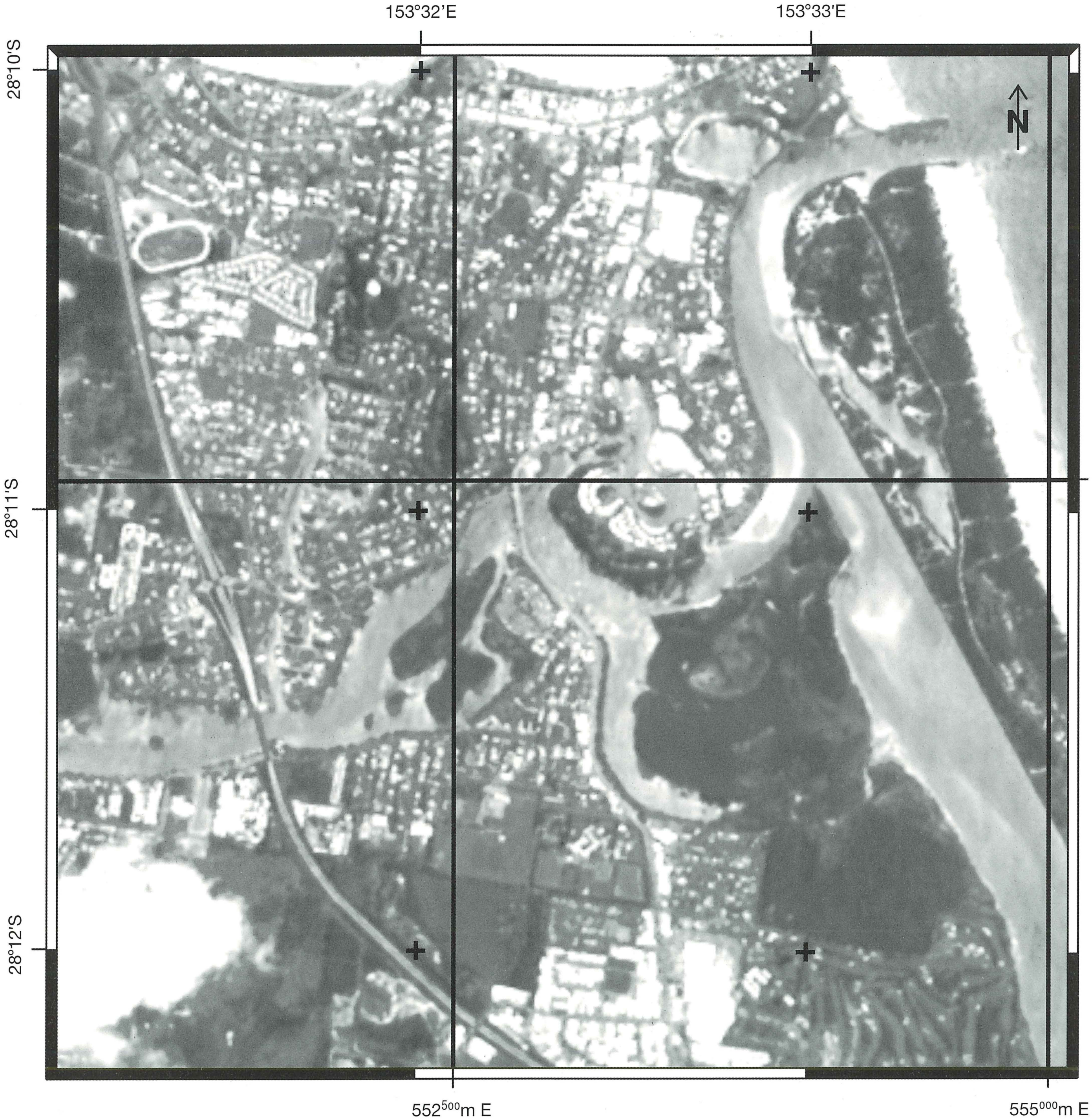
Remotely sensed data applies the theory of additive and subtractive colour. True and false colours are used in a discerning way to enhance particular features. The colour wheel shows the three additive primary colours: blue, green and red. The subtractive primary colours: cyan, yellow and magenta are formed by combinations of pairs of the additive primary colours. When mixing green and blue the colour cyan is formed.



Card 6

SPOT Panchromatic image of Tweed Heads

Northern New South Wales, Australia.



0 0.5 1
Kilometres

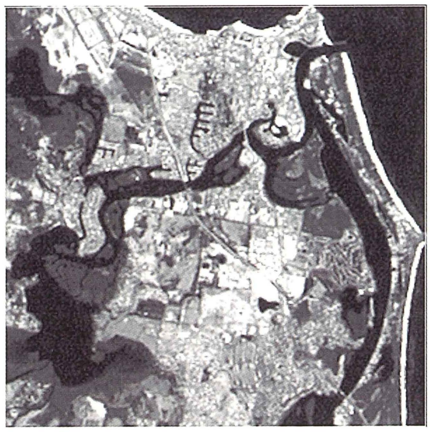
This image shows the suburbia of Tweed Heads, Terranora Broadwater and the Tweed River. Box D of Card 10 is the approximate area covered in this image. Ground resolution 10 metres. Scale: 1:25,000. Australian Map Grid Zone SH56. 11 November, 1997.

Card 7

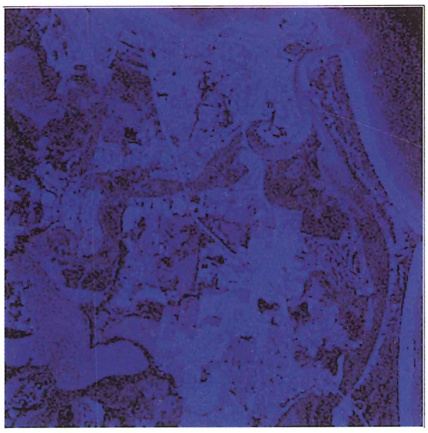
Formation of Landsat (TM) False Colour Composite Image, Tweed Heads, Northern New South Wales, Australia.

Landsat Band 1

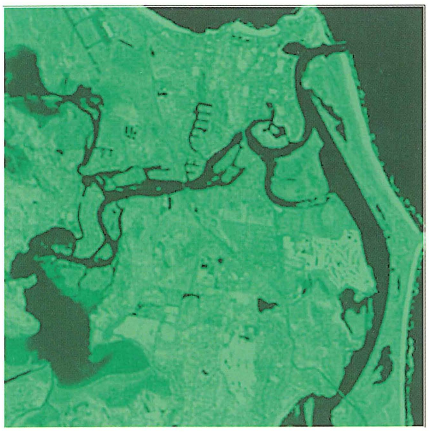
Landsat Band 4



Landsat Band 7



Band 1 – blue gun



Band 4 – green gun

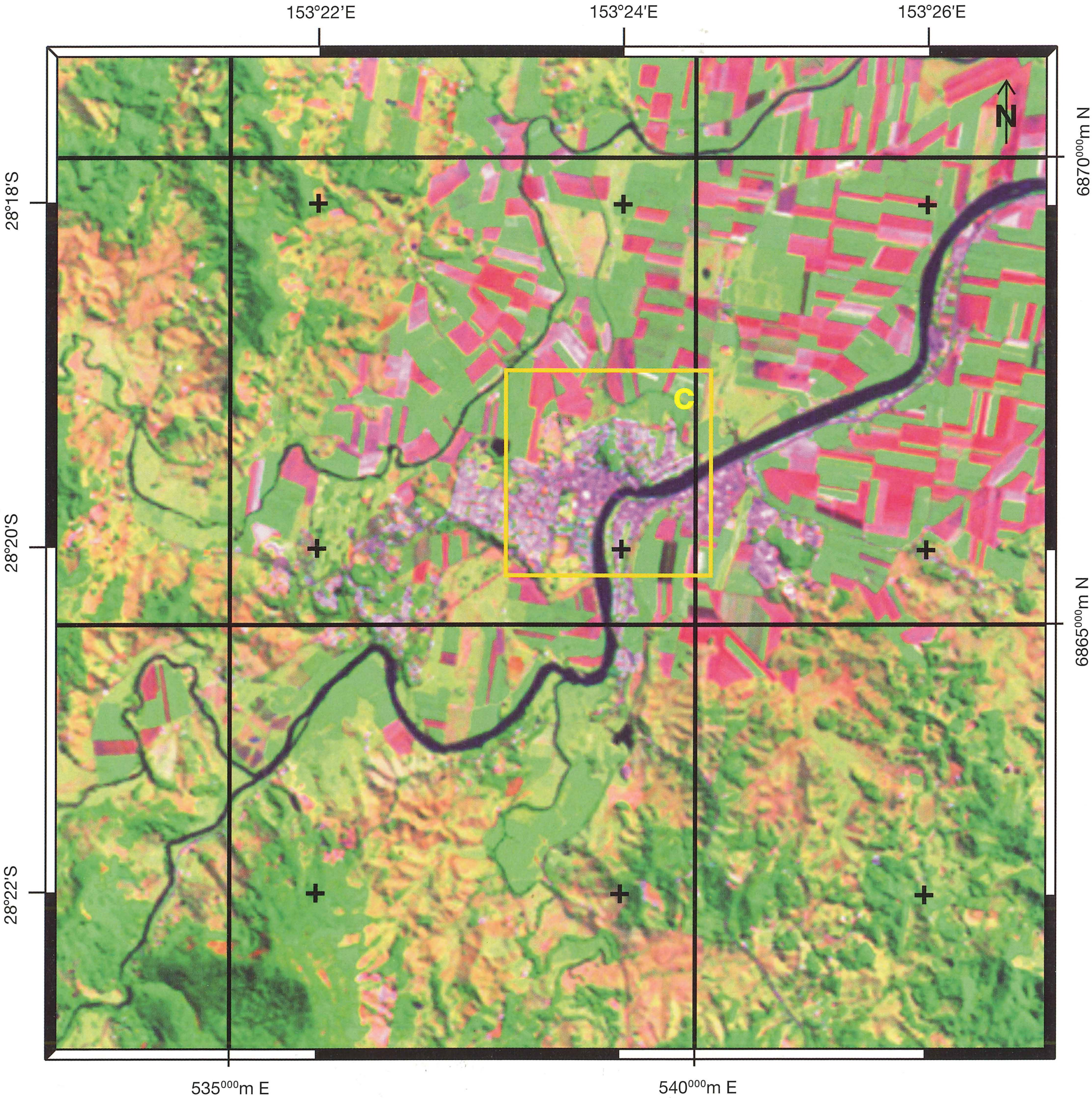
Band 7 – red gun

false colour composite bands
147–BGR

Card 8

Landsat Thematic Mapper (TM) Bands 1,4,7 of Murwillumbah

Northern New South Wales, Australia



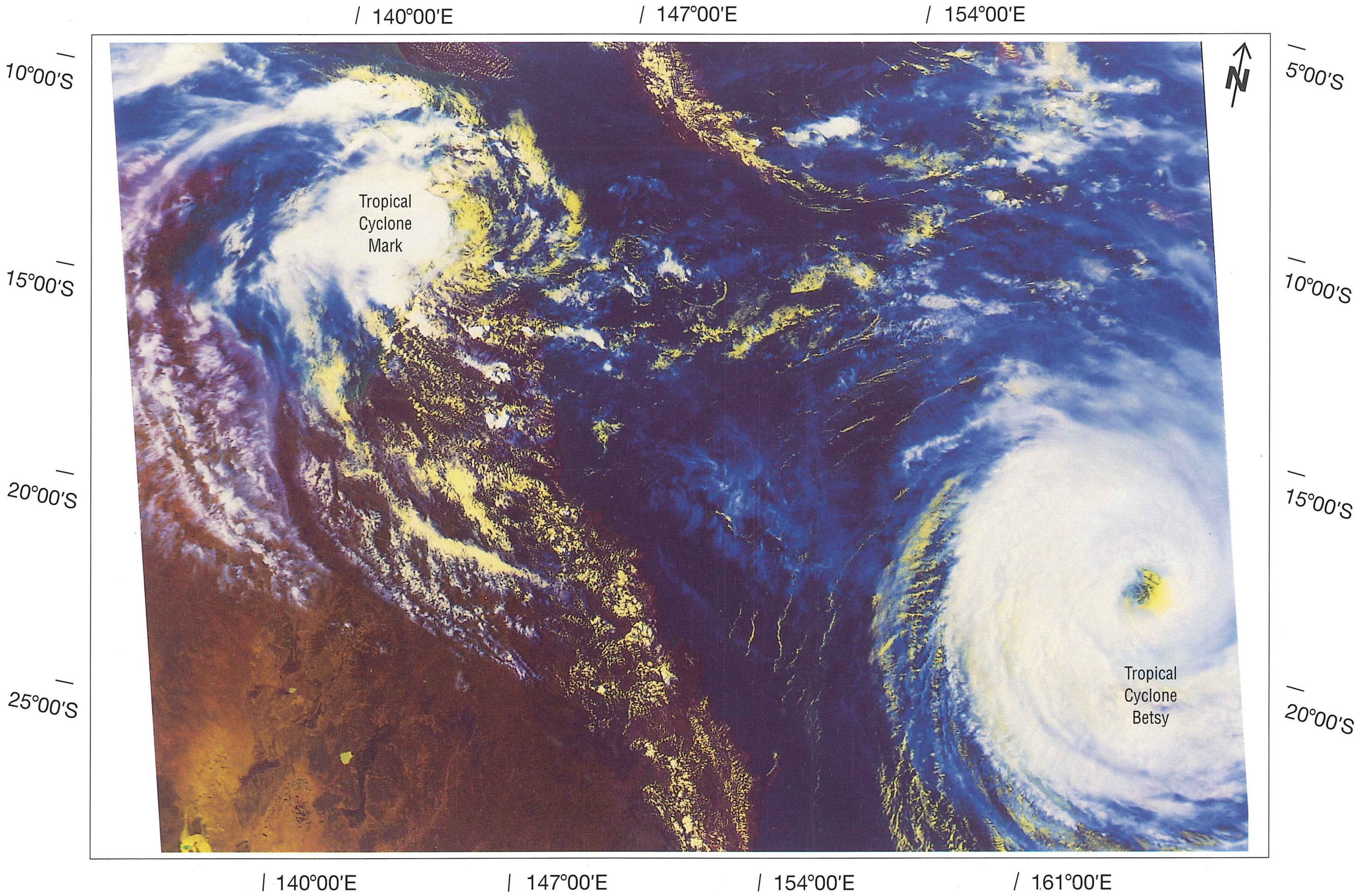
0 1 2
Kilometres

This image shows the extent of the development of a small town hosting over 8 000 people alongside the Tweed River and adjacent agricultural plots using Bands 1 (Blue), Band 4 (Green) and Band 7 (Red). False colours are used. Box C is the approximate area covered in Cards 2 and 4. Ground resolution 30 metres. Scale 1:62,500. Australian Map Grid Zone SH56. 6 September 1997.

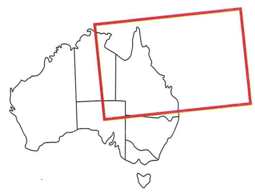
Card 9

NOAA Meteorological Satellite Image

Queensland Coast, Australia.



0 250 500
Kilometres

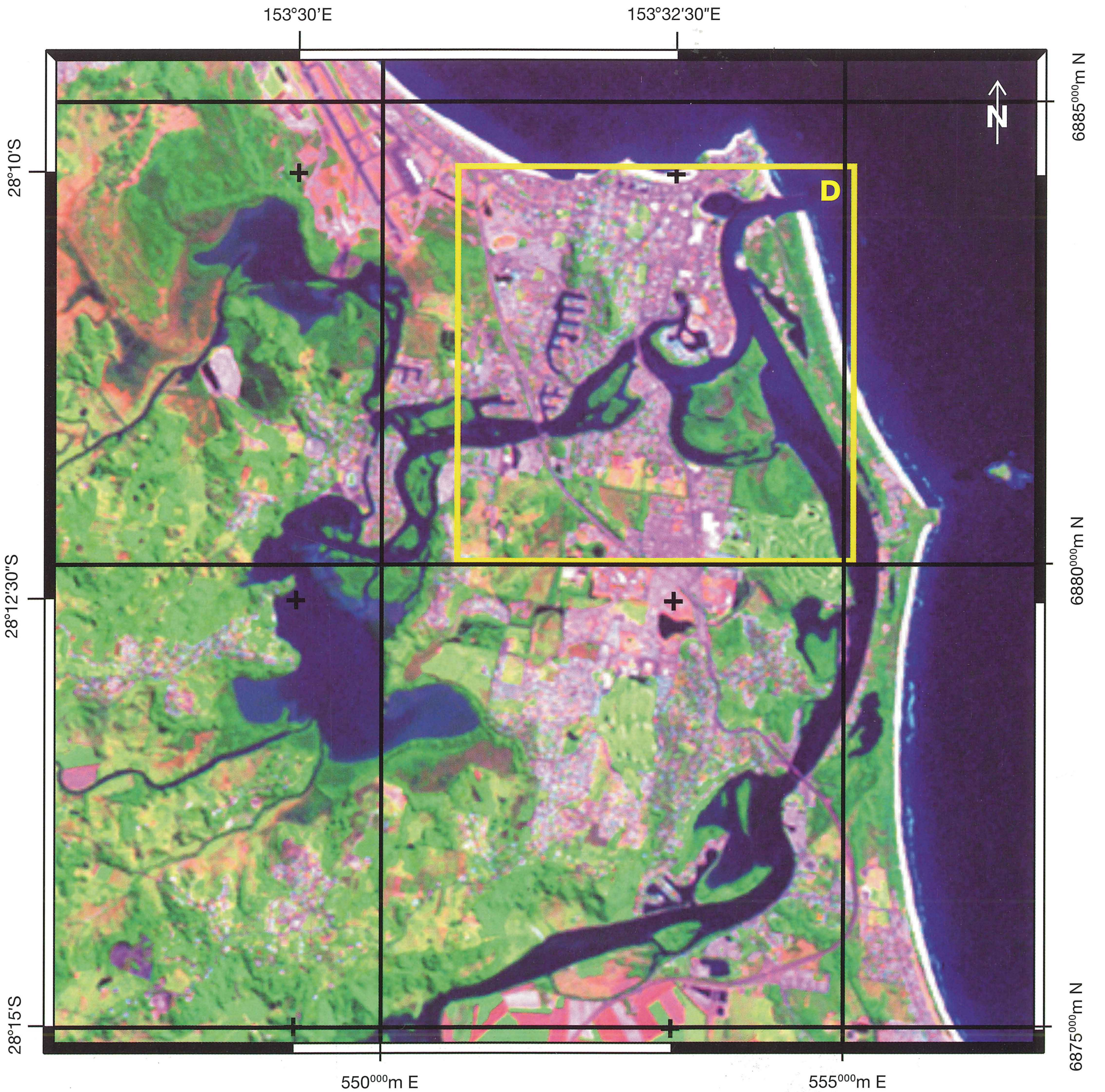


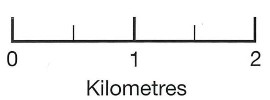
The NOAA (National Oceanic and Atmospheric Administration) satellite carries a sensor AVHRR (Advanced Very High Resolution Radiometer) which helps to monitor and predict weather conditions. Tropical Cyclone Betsy North East of Brisbane is a stronger cyclone than Tropical Cyclone Mark near the Gulf of Carpentaria. Tropical Cyclone Betsy caused severe beach erosion at Noosa. Ground resolution 1,100 metres. Approximate scale 1:18,000,000. 10 January, 1992.

Card 10

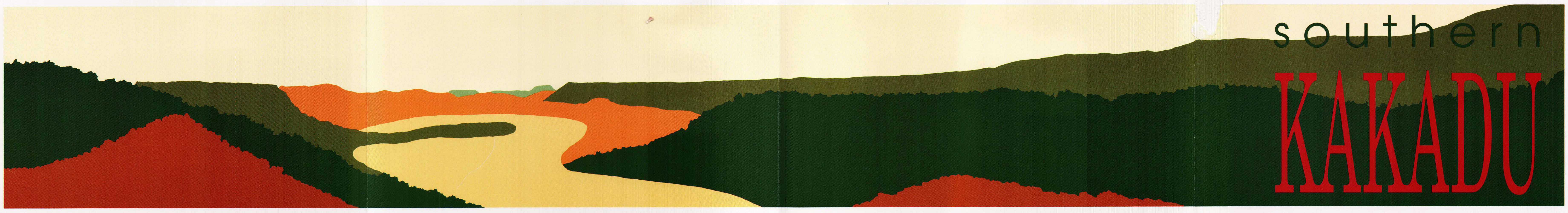
Landsat Thematic Mapper (TM) Bands 1,4,7 of Tweed Heads

Northern New South Wales, Australia

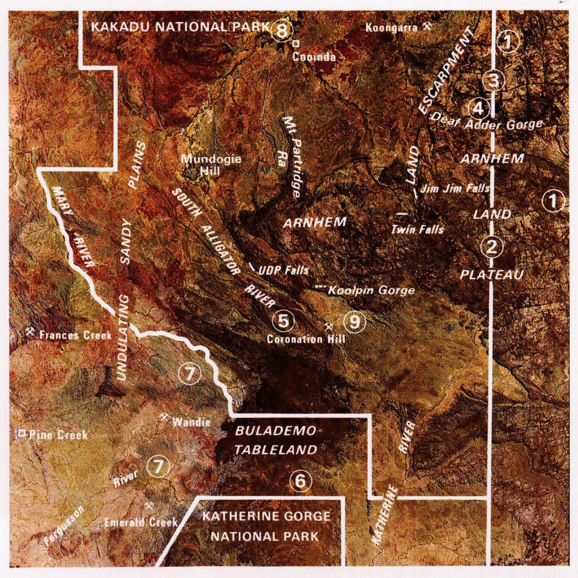




Coastal development surrounding Tweed Heads using Band 1 (Blue), Band 4 (Green) and Band 7 (Red). Box D is the approximate area covered in Card 6. Ground Resolution 30 metres. Scale: 1:62,500 Australian Map Grid Zone SH56. 6 September, 1997.



Location



numbers refer to numbered locations in the text at the bottom of this poster

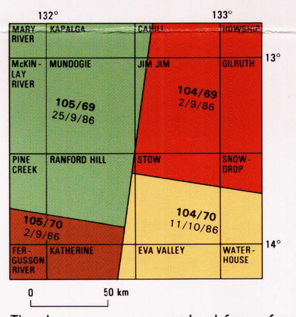
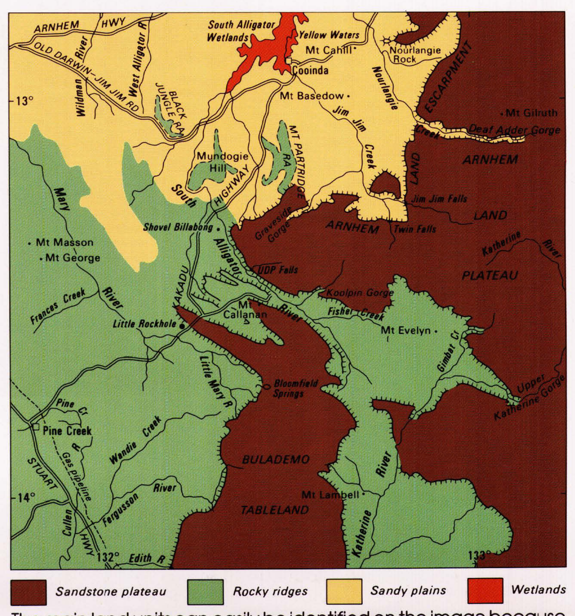


IMAGE PRODUCTION
satellite scene coverage and dates recorded
JIM JIM - reference to 1:100 000 sheet areas

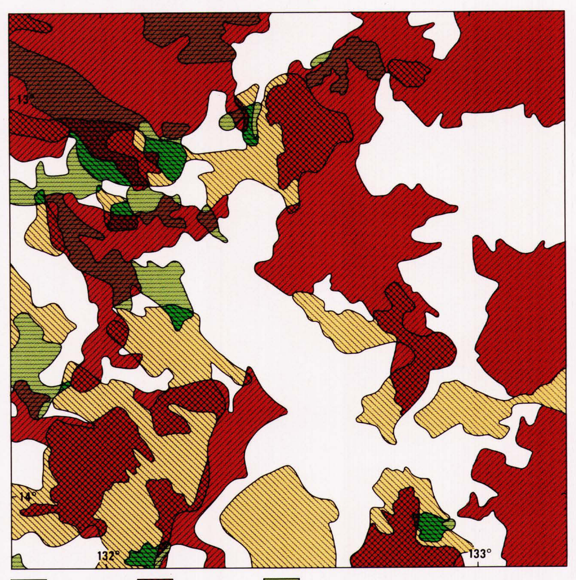
The image was created from four Landsat 5 scenes recorded in 1986 chosen because of the time of year (late dry season, vegetation had largely died off to reveal more of the actual ground surface), and absence of cloud. Three of the six bands of infra-red energy recorded by the satellite were combined to make a false colour image closely mimicking the natural tones of visible light (band 3 as green, 5 as red, and 7 as blue).
The data set was then rectified to fit the Australian National Grid and is produced here at 1:250 000 scale. As each of the four scenes used had different signal levels, they were sampled and averaged by computer to remove these differences to form a unique image with no discontinuities.

Land Units



The main land units can easily be identified on the image because of the variation of reflectivity at different wavelengths of vegetation, soil and rock. The satellite does not sense topography directly, but the shading effect of areas in shadow when the image was recorded clearly shows up the main relief features such as the Arnhem Land Plateau.

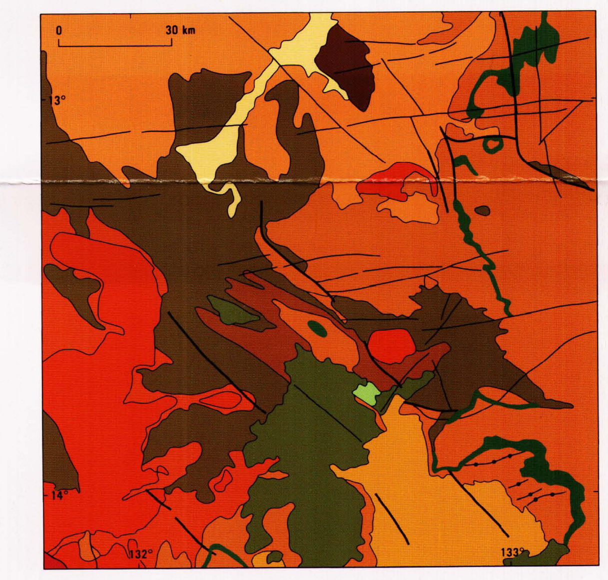
Fire Burn History



Direction of hatching in other colours represents areas burnt in more than one year

Light to dark brown areas mainly in the west were recently burnt by grass fires at the time of the satellite pass. The ages of the burns were identified from the microfiche archive of images of this area held in BMR. Some fire burns more than two years old can still be identified as more subtle green and pale brown colour changes frequently following creeks, rivers, roads or ridge tops.
In the three years before the image was recorded, 70% of the area was burnt at least once; less than 5% was burnt each year, all in the southwest; some areas were burnt twice in one dry season.

Geology - *interpreted from the image*



ROCK TYPES	MILLION YEARS	PERIOD	ERA
Floodplain alluvium	0 – 2	Quaternary	CAINOZOIC
Sandy rises over granite and metamorphics		Tertiary	
Eocene sandstone	65	Cretaceous	MESOZOIC
Mesozoic sandstone and siltstone	140	Jurassic	
Cambrian sandstone and basalt	210	Triassic	
Middle Proterozoic sandstone, basalt lava flows	250	Permian	PALAEOZOIC
Hornfels (contact metamorphic rocks)	290	Carboniferous	
Late Early Proterozoic granite	360	Devonian	
Late Early Proterozoic volcanics	410	Silurian	
Late Early Proterozoic sandstones and volcanics	440	Ordovician	
Early Proterozoic highly deformed metamorphic rocks	500	Cambrian	
Archaean granite	590		
	1000		PROTEROZOIC
	1800		
	2500		ARCHAEAN
	3600		

— *Fault*
—•— *Dyke*
— *Lineament*

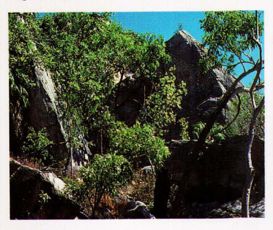
Satellite images to study and understand our environment

Satellite images are used to study many different aspects of our landscape, including rocks, soils, and vegetation. This image of southern Kakadu clearly shows the main landscape features such as the escarpment, plateau, ridgeland and river plains country, information on different rock types and soils, and vegetation density. It also shows information about soil erosion and country burnt by grass fires. Therefore it is a very useful means to integrate our understanding of these different things and their inter-relationships, and so can be used by scientists over a range of disciplines to better understand the land systems of Kakadu. Also, because it identifies so many of Kakadu's well known features, it can help students and park visitors to develop a deeper understanding of this important area of Australia.

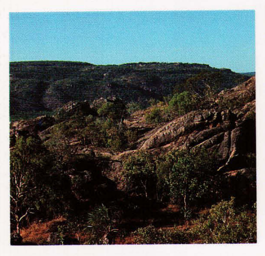
The image covers an area 150 km square centred on the headwaters of the South Alligator River in the Northern Territory, which flows north from the "South Alligator Valley" in the centre, to the seasonally inundated wetlands of Yellow Waters near Cooinda. Its major tributaries flow northwesterly into the wetlands from Jim Jim and Twin Falls and from Deaf Adder Gorge (shown on the "Location" map.)
The southeastern section lies in the catchment of the Katherine River, which at the southern edge of the image is about 20 km upstream from Katherine Gorge.

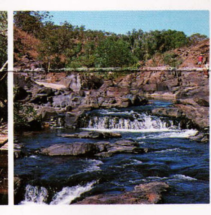
The woodlands of the "Bulademo Tablelands" divide the South Alligator and Katherine Rivers from the more westerly Mary and Fergusson Rivers. The mining town of Pine Creek is close to the western edge.

Land Units



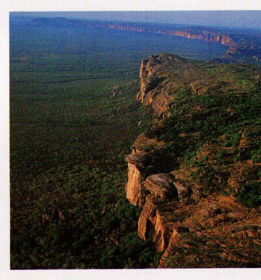
The patterns and colours of the satellite image clearly represent the main physical features of the region (labelled on the "Land Units" map), which are outstanding national park attractions. Many of these extend outside the park boundaries. Brown patches produced by fire burns blot out much of the more subtle features, especially in the western parts.
On the Arnhem Land Plateau, bright white areas (1) are pavements of bare sandstone. Bright greens (2) are relatively thick vegetation supported by patchy sandy soils, and dull greens (3) areas of dark basalt rock. Black areas (4) are shaded slopes in deep ravines and gorges, or dark iron-stained or lichen-covered rocks. Because of this shading effect, the Arnhem Land Escarpment stands out well, particularly where it is high and steep. The sandstone has been gently folded into an ellipse-shaped basin in the centre of the scene (5). The bounding cliffs of this





structure form the main cliffs on the south side of the South Alligator Valley.

The dark greens of the Bulademo Tableland result from the relatively thick woodland growing on a low sand covered plateau of siltstone and sandstone. These rocks are not cut by gorges and ravines and so lack the dark linear features characteristic of the Arnhem Land Plateau. Paler green areas (6) are grassy plains, commonly related to slightly lower lying areas with springs or soaks.



Most of the rest of the scene is covered by undulating sandy plains, generally with open eucalypt forest on low rises and grassy plains along creeks. Rocky ridges and hills of the harder rock types rise above the sandy plains in the Mount Partridge Range, around Mundogie Hill, and either side of the Mary River.
Green tones over most of the sandy plains indicate little influence from the underlying rocks on vegetation or soil composition. In the southwest however, blue, purple and mauve tones (7) show changes in soil composition controlled by the geochemistry of the underlying rocks.

The lime green tones in the north represent the low sedge grasslands of the South Alligator Wetlands (8), and document the limit of landward incursion of brackish waters during the wet season. Except where the reflection of the sun was detected by the space craft, bodies of water are non-reflective and hence black.

Geological interpretation

Because satellite images record information about the chemical make-up of the ground surface by measuring energy levels at different wavelengths outside the visible light spectrum, they are useful in interpreting the geology of a region from the geochemical variations inherent in different types of rocks and soils. Satellite images are therefore being increasingly used to help in mapping the geology of the land surface.

Most of the major geological elements of southern Kakadu can be interpreted from this image, and this interpretation is shown on the "Geology" map. Both the ancient and younger granites can be interpreted from distinctive dendritic drainage patterns and relatively homogeneous texture.

The tightly folded character of the metamorphic rocks is evident where they are well exposed. In the southwest, purple and pink tones in places indicate differences in soil chemistry and rock type, but overprinting by fire burns makes interpretation difficult. Also it is hard to identify the metamorphic rocks in places where they are covered by veneers of sand and soil.
When the younger granites were intruded, the adjacent rocks were baked into dark, fine-grained hornfels. The dark colour and therefore low reflectance, and resistance to erosion of these hard rocks allows the contact metamorphic zone around the granites to be mapped out; this is particularly well expressed in the west, north of Pine Creek.

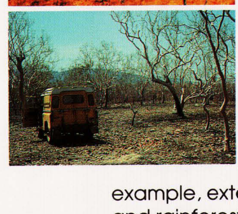
Parts of the sequence of quartz-rich volcanic flows, which in places lie on top of the metamorphic rocks, can be distinguished. These rocks host the gold-platinum-palladium-uranium mineralisation of the Coronation Hill - El Sherana area in the centre of the image. Distinctive dark purplish tones result from the low reflectance of dark lichens which commonly grow on porous gravelly sandstones and deeply weathered friable quartz-rich volcanics. Basalt lavas show olive green tones.

The sandstones of the Arnhem Land Plateau form a thick, mostly flat layer usually between 100 m and 200 m thick over the older rocks. They are light coloured and highly reflective, but this signature is suppressed where thin soils support much vegetation. Brown areas indicate iron enrichment, and interbedded basaltic volcanics show up as dull green. Deep fissures in the plateau have formed by erosion along geological fractures; some of these are important faults which in places can be seen to continue across other rock units in the lowlands as lineaments.

Remnants of a thick layer of sand and laterite which once covered all of the lowland areas still occur in the northwest. These sands were eroded from the Arnhem Land Plateau and transported by rivers to form a sheet which once completely covered the older rocks. Most of the sand has now been removed by modern rivers to once again expose the deeply weathered older rocks.

Impact of non-Aboriginal settlement on the landscape

The image is remarkably devoid of evidence of man's presence. Gravel airstrips at Cooinda and Frances Creek, and most gravel roads, show as white or pale cream tones because of the absence of vegetation and the high silica and clay content of the material. The gravel road trending NNW near Pine Creek is the service road to the Palm Valley - Darwin gas pipeline; the Stuart Highway is much less distinctive as a faint grey trace, because it is sealed with silica-poor basalt quarried from near Katherine.
Pastoral activities are generally not apparent, except for a small area of paddocks with improved pastures in the South Alligator Valley (9). Some white patches in this and other areas are eroded clayey patches formed by soil erosion initiated by overgrazing or by congregation of stock.



Mining is evident as water retention or tailings dams at Frances Creek, Moline, Wandie and Emerald Creek in the southwest. The Enterprise open pit at Pine Creek shows up white, near three dams related to ore treatment and waste disposal. Other white areas east of the mine are related to urban development. There are no features attributable to exploration or mining in the old uranium mining district of the South Alligator Valley, nor at Koongarra in the north.

Park management tool

The way in which information on land forms, rocks, soils, and vegetation is integrated in the satellite image helps to understand the different combinations which lead to the development of various landscapes and ecosystems. The image can therefore be used to map out the distribution of landscapes and ecosystems - for example, extensions of the Arnhem Land Escarpment and waterfalls and rainforest pockets along creeks which cross it.

The escarpment can be classified into active steep, stable, and worn down areas, which helps define escarpment ecosystems and the probable density of Aboriginal art sites. Other features which can be defined include lookout points, permanent waterholes, preferred routing of access roads, areas prone to erosion, etc.

Satellite data are recorded about once a fortnight and so short term as well as long term environmental changes can be closely monitored. One of the most obvious uses would be in monitoring fire burns, as these are very easily identified on the satellite images and their behaviour and effects on the environment are important conservation issues (see "Fire Burn History" map).
Another major advantage of satellite images over conventional aerial photography is that the results of relatively restricted ground surveys can be extrapolated over large areas, because the image provides a single synoptic high-resolution view instead of the distorted low-resolution view offered by mosaics of conventional aerial photography. Images such as this therefore promise to become major tools in effective park management.

Acknowledgements

The Landsat data used to create this image were recorded by the Australian Centre for Remote Sensing, Department of Administrative Services, Canberra. The digital rectifying, merging and rewriting processes necessary to produce the image were undertaken by the Remote Sensing Applications Centre, Department of Land Administration, Perth, W.A.
For more information on this poster and geological aspects of southern Kakadu, contact Mr Stewart Needham, BMR, PO Box 378, Canberra ACT 2601.

Text and interpretation by RS Needham; design and line drawings by BMR Graphic Design Section; photographs by RS Needham, PG Stuart-Smith, C Totterdell and CSIRO National Bushfire Research Unit.

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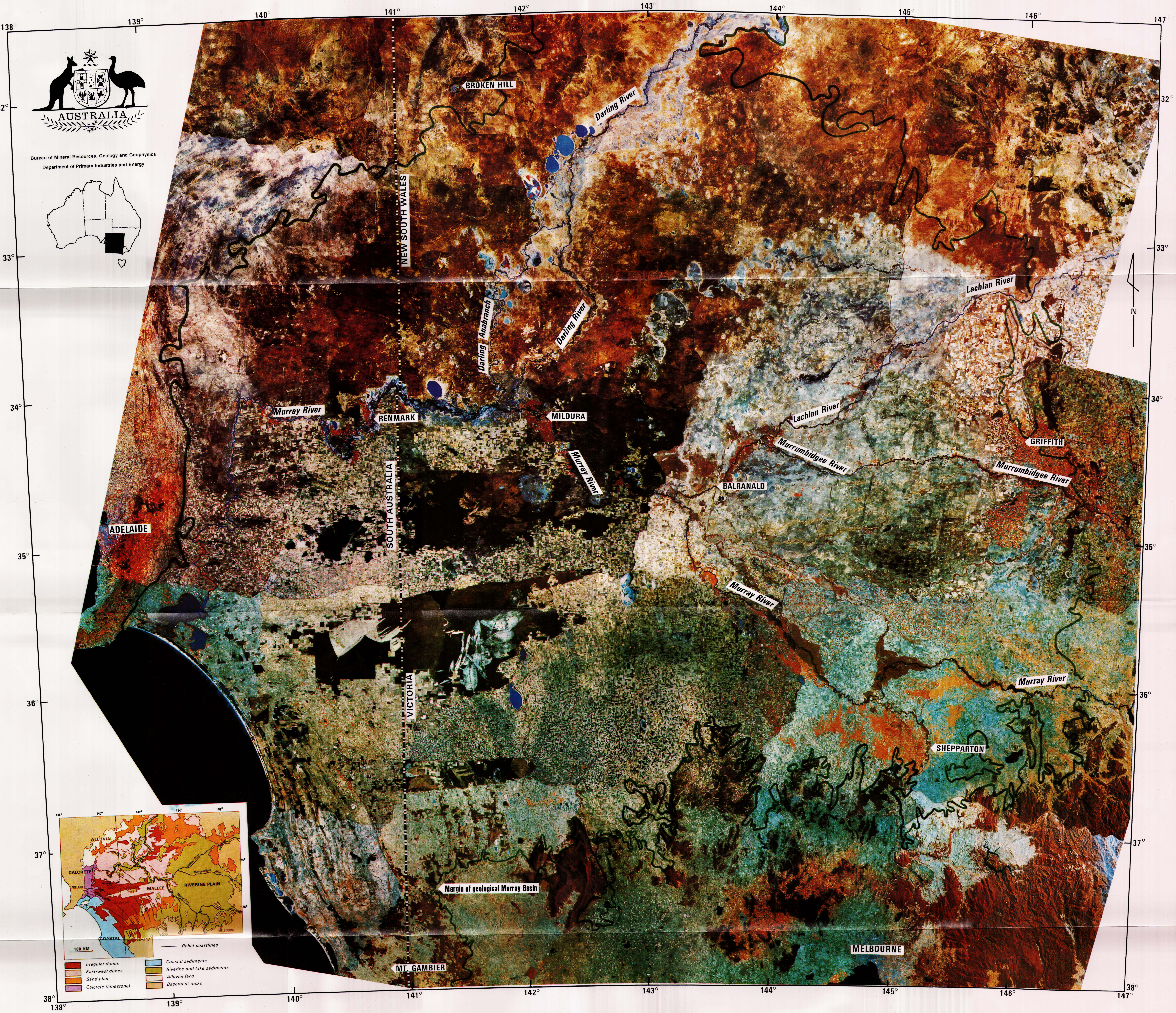
BMR GEOLOGY AND GEOPHYSICS AUSTRALIA

Australian National Parks and Wildlife Service

(1991)



THE MURRAY BASIN, SOUTHEASTERN AUSTRALIA

0 20 40 60 80 100 km

Lambert Conformal Conic Projection with Standard Parallels 32° and 37° South.

The Murray Basin in southeastern Australia contains some of the most important farming land in Australia and annually generates several billion dollars of agricultural income. However, the very practices that turned the Murray Basin into such a rich agricultural region now threaten to destroy it. Clearing of the natural vegetation and irrigation of the land have caused the water table to rise, bringing salty groundwater to the surface, waterlogging and poisoning the roots of trees and plants, and turning formerly productive agricultural land into marshy wasteland. In addition, the saline water seeping into the rivers of the Basin has caused deterioration of drinking water for the many towns and cities, including Adelaide, that depend on the River Murray for their supplies.

The Murray Basin Hydrogeological Project was established jointly by the Australian Government and the States of South Australia, Victoria, and New South Wales. The aim of the project is to improve our understanding of the basin through geological and hydrological studies of the whole region, unencumbered by State boundaries, as a contribution to the development of broad-scale management plans for the basin. The project is being carried out by the Bureau of Mineral Resources and the State geological surveys and water authorities.

A knowledge of the surface and subsurface geology of the basin is basic to the understanding of groundwater and related salinity problems. Investigations of the surface geology have shown that evolution of the landscape can be related to fluctuations in climate and groundwater levels over the past several hundred thousand years. From the distribution of features such as gypsum flats, dry lake beds, and dunes we can tell that salinity has been considerably higher in the recent geologic past than it is today.

Surface geological studies can, therefore, be used to develop an understanding of the processes that result in salinity problems. Mapping can identify those areas that have been affected by salinity in the past and which are likely to be affected in the future if groundwater tables continue to rise.

This Landsat mosaic is an invaluable aid in the interpretation of the link between geology and surface salinity problems. It has been compiled from false-colour enhanced images obtained from the Australian Centre for Remote Sensing. The images were processed from data acquired by the Multi-Spectral Scanner instrument (bands 4, 5 and 7) carried on satellite Landsat 3, which orbits the Earth daily at about 900 km altitude.

Variations in intensity of land use are clearly visible on the mosaic as various patterns and colours, interpreted by the satellite scanner from the reflectivity of the ground surface. Compare the fine rectangular pattern of black and greenish grey colours, indicating areas of intensive farming, with adjacent areas of no farming. Irrigation schemes show up as the reddish brown areas, particularly noticeable, for example, around Mildura and Shepparton on the Murray (and also around Griffith on the Murrumbidgee).

The striking whitish patterns in the black areas straddling the South Australia/Victoria border are burnt areas, the result of bush fires. (The black is not burnt ground, but the natural mallee vegetation; the colour is a product of the false-colour image processing.)

Prepared as a contribution to the joint Commonwealth-States Murray Basin Hydrogeological Project by the Division of Continental Geology, Bureau of Mineral Resources, Geology and Geophysics, Department of Primary Industries and Energy.

Landsat images provided by the Australian Centre for Remote Sensing, Australian Surveying and Land Information Group, Department of Administrative Services.

Copies of this Landsat mosaic can be purchased from BMR Publications Sales, GPO Box 378, Canberra, ACT 2601. Further information on the Murray Basin Hydrogeological Project can be obtained from BMR's Information Section at the above address.

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