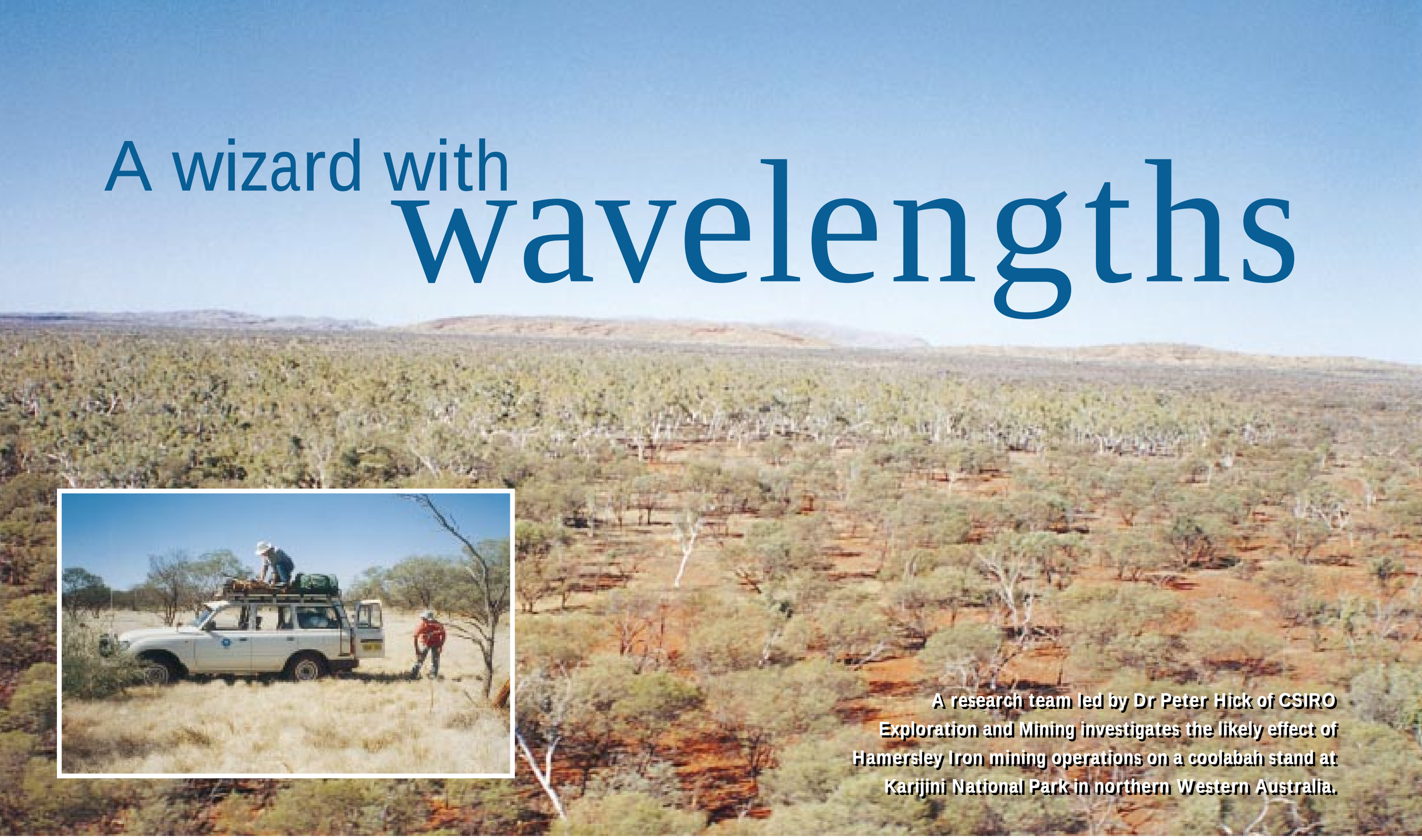
A wizard with wavelengths



A research team led by Dr Peter Hick of CSIRO Exploration and Mining investigates the likely effect of Hamersley Iron mining operations on a coolabah stand at Karijini National Park in northern Western Australia.

***Philip Kofoed** follows the trail of an environmental troubleshooter whose investigative techniques reveal more than the eye can see.*

Songs and stories from our past often mention the coolabah tree, its generous shade providing welcome relief for many a weary traveller through Australia's dry interior. It features in the ill-fated trek of Burke and Wills as the famous 'dig' tree. Our most renowned swaggy even camped beneath one shortly before temptation got the better of him and – well, you know the story.

Yet despite its hardiness, the coolabah at times relies on deep groundwater for survival. If that water supply is threatened, the tree can quickly perish. This poses a problem for Hamersley Iron's Marandoo iron ore mine in Karijini National Park in northern Western Australia. The mine is about to steal water from beneath a large stand of a rare coolabah species, *Eucalyptus coolabah* Aff. Victrix.

The likely effect of Hamersley Iron's mining operations on the coolabah stand is being investigated by Dr Peter Hick of CSIRO Exploration and Mining, a member of CSIRO's Minesite Rehabilitation Research Program.

Hick is an authority on environmental uses of spectral analysis, a science that uses sensitive instruments to analyse the wavelengths of light sources, including light waves we can't see (see story on opposite page). He uses this and other techniques to evaluate the impact of mining on natural ecosystems. His recent work has taken him to Ranger Uranium in the Northern Territory, and to mines in the Pilbara region of northern WA, including Marandoo.

'At Marandoo they may be mining up to 90 metres below the watertable,' Hick says. 'And to stay operational they will have to pump out the water that will inevitably flood the mine. The worry is that the nearby coolabahs might be denied their water.'

Hick says there are two watertables at the site, one at 15-20 metres and a deeper one down to 80 m. 'It's the 80 m watertable that may be affected by the mine, he says. 'The trees probably depend on the shallow one, but if there's a connection between the two, the coolabahs might still be in trouble.'

Members of Hick's research team are looking at tracer isotopes in the bark and leaves of the coolabahs to determine which watertable the trees are using. The mine's environmental manager will then know how best to divert the water: whether to keep it in artificial ponds and allow it to leach gently back into the ground, or pump it directly into groundwater aquifers.

Hick says many mines in the arid Pilbara region are mining below the watertable. 'They're pumping out millions of tonnes of groundwater to keep their mines operational,' he says. 'And their only choice is to run the water down normally dry creek beds.' This causes other problems downstream.

The fragile ecosystem supports an adapted range of eucalypts, but because of the extra water from the mines, the vegetation along the normally dry creeks will become more consistent with aspects of rainforest found along perennial rivers in the north of Australia.

In anticipation of such changes occurring along the intermittent Robe River at Pannawonica, Hick was invited to survey original vegetation below the Robe River iron ore mine. Spectral analysis of aerial images along the river downstream from the mine has provided an accurate record of the types and density of the natural vegetation. With this record as a guide, plant life along the river below the mine will be returned to its original state after the mine's closure.

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Learning by lights unseen

SPECTRAL analysis is the technique of using light-sensitive instruments, or spectrometers, to measure a spectrum of the light energy reflected from materials on the Earth's surface, including minerals and living organisms. This energy is known as the electromagnetic spectrum and consists of a vast range of wavelengths of light, mostly invisible to the human eye.

A spectrometer will show green grass as a peak in the green part of the spectrum. If it also shows a strong peak in the infrared part of the spectrum, the vegetation is likely to be healthy because photosynthesis is related to infrared radiation. We can see the 'invisible' infrared because it is substituted by a colour we can see, usually red.

Every type of material reflects its own unique combination of wavelengths, or 'spectral signature'. It can therefore be spectrally differentiated from other types of materials, such as other plant species or minerals. Similarly, spectral changes can be observed over time, such as the distribution of a plant species, forest degradation and land salinity.

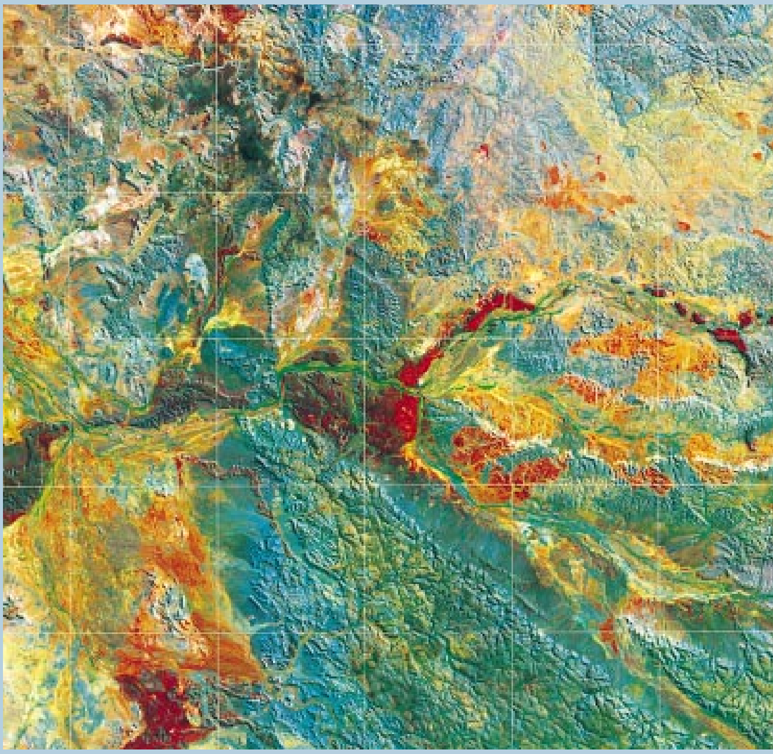
Data collected from spectrometers attached to aeroplanes or satellites is known as remotely-sensed spectral data. Remotely-sensed data are often cheaper than ground measured data and can quickly cover large areas.

Traditionally, aerial photography has been used, but it has limitations including poor spectral detail, and interpretation can be subjective. Spectral technology is now digital. The spectral resolution can be far superior, and computerised data can be directly compared with data collected days, months or years later.

It works like this: wavelengths of light, or photons, strike a detector such as a miniature charge-coupled device and the energy is converted into a voltage which is digitised. Spectrometers are calibrated to be sensitive to wavelengths within specific spectral 'bands' of light energy, depending on which materials they are trying to detect. Some spectrometers cover only a few spectral bands, others cover hundreds.

Remote sensing sounds simple, but that's not all there is to it. Extensive groundwork has to be done not only to determine the spectral signatures of the material of interest, but to determine how variations in the material relate to variations in the remotely-sensed data. Advances in computer technology have made the job of interpreting the data much easier.

Spectrometers are used for an ever-increasing number of applications, including conservation, mineralogy, oceanography and agriculture. Many spectrometers are now small enough to be held in the hand.

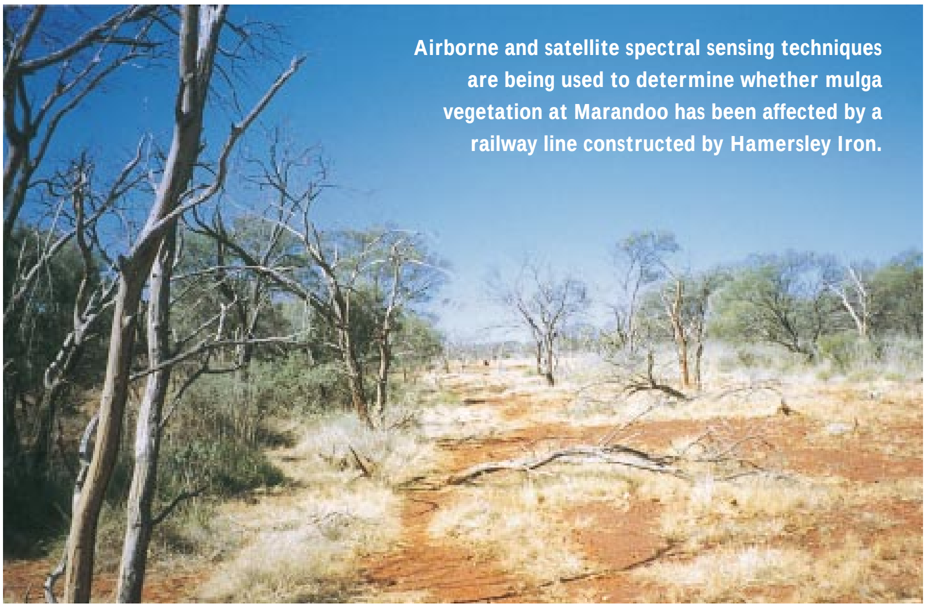


Every type of material reflects its own unique combination of wavelengths or 'spectral signature'. This satellite image is of Western Australia's Pannawonica region. Bright red areas are where iron ore has been mined, and the darker red and black areas are potential ore bodies. The ore deposits follow the course of an ancient river. Blue/green areas are a sign of robust vegetation.

Mulgas under threat?

Another problem for Hamersley Iron at Marandoo is that the mine's railway line may be altering water flows. 'Mulga is the dominant vegetation and it doesn't have a very deep root system,' Hick says. 'It relies on surface sheet-flow in periods of floods and cyclones. If the sheet-flow is impeded, the mulga can die.'

Airborne and satellite spectral sensing techniques are being used to determine whether the mulga, *Acacia aneura*, has been affected since the railway line opened. 'Regular aerial photography can't be used for that sort of thing because we're looking for very subtle hints of trees being under stress,' he says. 'That's done by looking at a combination of spectral



Airborne and satellite spectral sensing techniques are being used to determine whether mulga vegetation at Marandoo has been affected by a railway line constructed by Hamersley Iron.

Field work on constructed wetlands at Ranger Uranium mine in the Northern Territory is using a range of techniques to determine the ability of wetland vegetation to extract metals and contaminants. If the vegetation is not healthy, the decontamination process is impaired.

bands relating to the infrared response of chlorophyll absorption and reflectance.

'The area has had five years of above average rainfall so things are looking pretty good. The company also wants to know what will happen after five years of drought.'

Hick's team is trying to find out whether threats to areas of mulga can be forecast on the basis of soil type and land slope. 'If that's the case, it might need a minor culvert or some other way of fanning the water under the railway line and back into a sheet flow to restore the natural system,' Hick says.

The Minesite Rehabilitation Research Program is also doing field work on constructed wetland ponds at Ranger Uranium mine at Kakadu in the Northern Territory. The ponds are designed to 'polish' or extract metals and contaminants from the site's water. The polishing process is done through bio-remediation, and if the vegetation is not healthy and vigorous, the decontamination process is impaired. After polishing, the water is sprayed on natural vegetation within the lease area.

Hick and his colleagues are determining the spectral characteristics of the vegetation in wetlands. Some of this work is done by submerging specially developed hand-held spectrometers from a boat. The collected data will enable a better assessment of vegetation at the minesite.

Other work at Ranger includes developing monitoring methods to ensure that no radioactive material leaves the site, either through groundwater or seepage. Three remote sensing techniques are used.

The first is airborne spectral analysis: if any water leaves the site it will be shown by altered vigour in the vegetation during the dry season.

Secondly, airborne radiometrics using gamma-ray spectrometery is used. Any

All-seeing satellite on course for 2001

THE WORLD'S first commercial hyperspectral sensing satellite, capable of spotting new mineral-rich regions around the globe and monitoring the environment in unprecedented detail, is being developed by an Australian consortium including CSIRO's Division of Exploration and Mining.

Known as ARIES-1 (Australian Resource and Information Satellite), the satellite will allow fast, effective screening of huge areas of land unhindered by difficult terrain or national boundaries. Partners in its development are Auspace Pty Ltd (the Australian subsidiary of Matra Marconi Space), and ACRES (The Australian Centre for Remote Sensing).

ARIES-1 will orbit the Earth every 104 minutes at an altitude of 450-500 kilometres. Its hyperspectral spectrometer will scan the Earth's surface with 105 spectral bands covering the visible, near-infrared and shortwave infrared spectrum (400-2500 nm).

'We'll be able to give the exploration industry just about everything that's known from the current physics in that wavelength area,' ARIES applications scientist and project instigator, Dr Jon Huntington, says. This information will benefit geological and mapping industries and natural resource managers.

Dr Peter Hick of CSIRO's Minesite Rehabilitation Research Program says ARIES' repetitive coverage will greatly improve minesite monitoring leading to better remediation programs. 'ARIES will mean better characterisation of mine spoils, especially in the coal and alumina industries,' Hick says. 'It will also mean better identification of subtle and unique variations in Australia's vegetation, especially when under stress.'

ARIES has been backed by leading mineral exploration companies and environmental bodies around the world, who helped fund the project's feasibility study during 1997. During the next two and half years an extensive Applications Development Program is planned to prepare users for this new era in earth observation. The planned launch date is early 2001.

During a four-year survey of algal blooms on Western Australia's Swan River, techniques were developed to spectrally map algal species, helping to identify their ideal growing conditions. Painstaking research was required both in the air and the river to determine the spectral make-up of each species, and to distinguish them from other benthic vegetation.

water leakage from retention ponds may show as a radioactive signal.

The third technique is airborne electro-magnetics. This involves the creation of a large electrical loop around the wings of an aircraft, forming an electro-magnetic field beneath it. A sensor is trailed 100 m behind the plane to measure the decay of the electro-magnetic field.

'This technique detects differences in ground conductivity caused by differences in materials and salinity,' Hick says. 'If water in a tailings dam is more saline, any seepage can show as a difference in the conductance.'

Analysing algae

Hick's expertise in spectral analysis have also set him on the trail of blue-green algal blooms. Last year he was part of a team that completed a four-year spectral survey of algal blooms in Western Australia's Swan River.

About 30 species of algae exist in Australia. These include red and brown-coloured species as well as the toxic blue green species, and the Swan River system has most of them. Not all species are toxic, but all have an impact on water quality.

Right: An aerial view of Dampier Salt.

Inset: *Synechococcus* sp, seen here being being poured from an isolate culture, is a bad algae according to Dampier Salt. Slime produced by the bacterium increases the brine viscosity, leading to impurities in salt crystals.

'The Swan River Trust had been monitoring the Swan River,' Hick says. 'But they used bucket and boat sampling techniques which were often inadequate for a river system of that size. They wanted to know if there was a better way of predicting algal blooms and whether blooms were related to point sources.'

Using airborne spectrometers, Hick was able to spectrally map and differentiate species, including identifying their ideal growing conditions. 'Algal blooms can develop very quickly over two or three days.' He says. 'The advantage of airborne detection is that it gives a rapid indication of where blooms are, and are likely to occur.'

The technology is complex and involved painstaking research both in the air and on the river. The spectral make-up of each species had to be determined and differentiated from other benthic vegetation. Many factors contribute to make the right conditions for algae to bloom. They include weather, water temperature, evaporation, water salinity, phosphorous and nitrogen concentrations, other nutrients, wind, sunlight and water depth.

Hick has also had the pleasure of working with good algae. At Dampier Salt on the north-west coast of WA, different types of benthic algal mat have been found to grow in the saltfield concentrating pond system. The company has recognised that some types of mat are beneficial, while others can have a negative impact on the quality of salt produced.

The saltfield is over 12 000 ha in area and the ponds are dominated by the unicellular cyanobacterium *Synechococcus* sp. which produces large amounts of extra-cellular polysaccharide slime. The slime increases the brine viscosity, adversely affecting the salt crystallising process.

Dampier Salt wants to encourage the preferred algal mat. 'We determined how to spectrally separate the preferred and less preferred algae types, and now we're proposing to fly predetermined spectral-band instruments over the ponds,' Hick says.

'All the image data are going into a spatial database where their growth can be monitored along with other factors such as substrate, density and viscosity. This will give the company a much better idea of what's going on.'

abstract

As part of CSIRO's Minesite Rehabilitation Research Program, scientists from CSIRO Exploration and Mining are using a range of techniques, including spectral analysis, to help monitor and manage environmental impacts of mining. Issues investigated have included the effect of groundwater pumping and diverted water flows on native vegetation, the efficiency of bio-remediation in constructed wetlands, and the discharge of toxins from minesites. Other work has developed techniques for spectrally differentiating algal species, as an aid to both environmental management and salt production.

Keywords: Groundwater; environmental monitoring; watertable; spectral sensing; remote sensing; algal blooms; minesites.