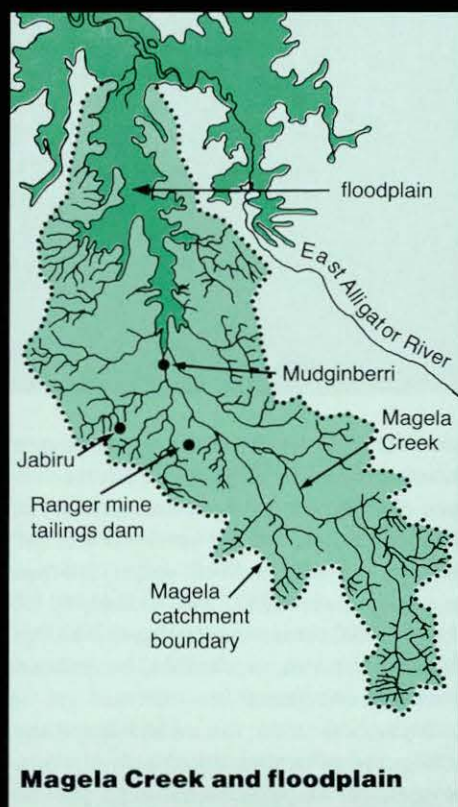




A wet-season shot of the Magela floodplain.



Magela Creek and floodplain

Protecting a Kakadu floodplain from mining waste

In the Kakadu wetlands, industrial pollution seems as far away as the southern cities of Wollongong and Whyalla.

Yet, less than 40 km south of the Magela Creek's confluence with the East Alligator River lies the Ranger uranium mine, a potential source of pollution by sulfate waste from processing of the ore, an assortment of heavy metals, and radioactive isotopes with half-lives of thousands of years.

Since the late 1970s, researchers at the Alligator Rivers Region Research Institute (ARRRI) — part of the Office of the Supervising Scientist (OSS) — have been studying the environmental effects of mining operations in the region, seeking to provide advice that will keep adverse impacts to a minimum both during operations and long

after the mines have been decommissioned and rehabilitated.

By the end of 1991, mining at Ranger will have produced about 11 million tonnes of tailings (the crushed ore from which the uranium has been extracted) that, together with about 28 million tonnes of waste rock, could form a mound 20 m high covering 2 sq. km. Currently, Commonwealth legislation requires that the Ranger mine return its tailings to the pit within 5 years of the end of mining. However, if the Supervising Scientist is satisfied that the environment will be no less well protected, the legislation allows for other ways of storing the tailings, such as stabilising them in the existing tailings dam.



This core drilled from the Magela floodplain shows fresh-water sediment on top of yellowish, oxidised mangrove swamp muds — deposited when the plain was part of a tidal swamp.



The Magela plain at the end of the dry season.



The Ranger mine. The tailings dam is in the background.



Jabiluka Billabong, at the northern end of the floodplain, at the end of the wet season.



Storm over Kakadu.

As part of the larger research effort of the OSS that seeks to provide performance standards for tailings impoundments, a research team co-ordinated by Dr Bob Wasson of CSIRO's Division of Water Resources recently carried out studies to predict where eroding material from Ranger would end up and what impact it could have. Their findings will contribute to the decision on whether the tailings are returned to the pit. They have also shed fresh light on the region's evolutionary history and the likely impact of 'Greenhouse'-induced climatic changes in the region.

Where the mine is

From the point where the Magela Creek joins the East Alligator River, its catchment stretches south over about 1500 sq. km (see the map). The area upstream of the Mudginberri homestead, comprising two-thirds of the Magela's catchment, includes the Ranger mine. Most of this southern catchment has sandy soils supporting grass and

eucalypt woodland. North of the homestead, the creek drains into the Mudginberri corridor (a series of paperbark-lined channels and billabongs) that widens gradually into the Magela's fresh-water floodplain. The clayey plain is mostly covered by sedges, herbaceous swamp vegetation, and paperbark forest.

The region has a typically monsoonal climate. Between late October and early April the Wet inundates the floodplains and swamps, in marked contrast with the Dry. By September, fire and the seasonal drought have killed the grasses, leaving many of the sandy soils largely unprotected from the erosive early rains. Under these conditions even the catchment's gentle slopes can erode; the erosion rate slows as the wet-season rain establishes fresh grass.

The potential for high rates of erosion on disturbed landscapes presents special problems for engineers wishing to stabilise large quantities of low-level radioactive materials for long periods. For, although health

authorities do not consider the tailings a substantial radiological risk, the large volume of mine waste, its potential mobility in wind and water, and the persistence of the risk — the longest-lived major residual isotope, thorium-230, has a half-life of about 80 000 years — mean that the tailings should, as far as practicable, be isolated from the environment.

In practical terms, this means that, if the tailings are not returned to the pit, the capping on the impoundments must protect them from erosion and structural failure for many hundreds of years. To be exact, the Code of Practice on the Management of Radioactive Wastes states that the 'structural life' of the containment structure should be 1000 years.

Where will the sediments end up?

The task for Dr Wasson's team was to predict the precise dispersal patterns and deposition rates of any contaminants from the Ranger mine — and the chemical altera-



Mudginberri corridor — between the mine and the plain — at the end of the Wet.



Drilling for sediment cores.

tion of the eroded sediment — not only under today's typical weather patterns but for those climatic changes and extremes that could be expected to occur over the next 1000 years. That's no small job. So how did they set about it?

Dr Wasson has a particular interest in sediments. He has analysed many right across Australia and has shown that they can be valuable not only for revealing environmental histories but also for predicting the future. Unlike meteorological records that, for remote regions, often reach back a mere decade or two, sediments (if you know what to look for) can tell you what the environmental conditions were like thousands of years ago.

This knowledge of climate variability over the last two or three millennia gives a pretty good guide to what can be expected in the future. If you are an engineer with a brief to design an earthen structure that will last 1000 years in monsoon country, basing the engineering standards on these long-

term indicators is less hazardous than simply extrapolating from the previous 20 years' rainfall data forward to the year 2990.

For this reason, and because the deposition of eroded sediments in the past is also the best guide to where they will lodge in the future, the scientists concentrated on analysing the floodplain sediments. However, they also studied sediments from numerous sites up and down the catchment.

They dated and traced the origin of the samples using a variety of approaches. Some, like radiocarbon-dating of detrital organic remains, are well tried and proved. Other techniques, based for example on the relative decay rates of the radioactive thorium and radium isotopes, were developed during the research. This latter approach proved particularly useful as a means of cross-checking the age of older fresh-water sediments, where the lack of large lumps of wood or charcoal meant that the carbon was only present in tiny pieces of organic matter that could have been con-

taminated by carbon from younger sources.

By comparing the plain's sediments with soils around the mine site and other parts of the catchment, the team developed a model of the rate at which the catchment's soil had been eroded and the route the sediments took to reach the plain.

They concluded that sediment from the tailings dam will move towards the plain in a series of pulses. First it will move onto hill-slopes and then to the alluvial valleys of the mine-site tributaries. Some will remain on these landforms and the remainder will move into outlying billabongs. Again, some storage will occur before the rest of the sediment reaches the Magela Creek. Eventually, sediment from the tailings dam (or any other mine-site sediment source) will reach the Magela plain.

According to the scientists' model, assuming that the annual rate of erosion continues at the region's long-term average (about 20 tonnes per sq. km per year), the Ranger mine tailings would take about 625 000 years to fully erode. At this rate, each year the tailings would represent less than 1% of the present-day level of suspended sediment passing Mudginberri. If the time taken for the tailings to erode proved to be less, that proportion would, of course, increase. For example, if the impoundment were to erode in about 1800 years, the tailings would represent roughly 50% of all the sediment reaching the plain, and if a series of cyclones caused catastrophic erosion in only a few years, massive deposition would be clearly visible on the plain.

Appropriate engineering design of tailings-containment structures should keep erosion rates down to environmentally acceptable levels. Under these conditions the team consider that the most important pollutants would be heavy metals mobilised

Tailings dam seepage

In addition to possible long-term pollution problems from eroded sediments, any seepage from the Ranger uranium mine tailings dam could also pollute the region's groundwater.

To test whether this pollution was occurring, Dr Brian Gulson, Ms Karen Mizon, and Mr Michael Korsch, of CSIRO's Division of Exploration Geoscience, and Dr Barry Noller of the Office of the Supervising Scientist examined the groundwater taken from bores around the dam.

The scientists applied the 'lead isotope fingerprinting' method. This makes use of the fact that the four isotopes of lead (three are the stable end-products of radioactive decay of uranium and thorium) are found in strikingly different proportions in uranium ore from those in the 1800-million-year-old

rocks that surround the deposit. The scientists were able to measure the isotopes in trace amounts of lead (parts per trillion) in water from the tailings dam and from bores surrounding the dam.

Six years after mining commenced they found, apart from a possible minor leak in the southern wall, no movement of heavy metals into the adjacent groundwater.

Recently — 5 years after the original measurements — the project was repeated. As *Ecos* went to press, results were being assessed.

Lead isotopes as seepage indicators around a uranium tailings dam. B.L. Gulson, K.J. Mizon, M.J. Korsch, and B.N. Noller. *Environmental Science and Technology*, 1989, **23**, 290–4.

(made available to plants) by their contact with saturated soils.

With samples of tailings taken from the dam, the scientists studied how the metals reacted when mixed with soil samples from the plain. They found that, at the concentrations of tailings that would reach the plain assuming the natural long-term erosion rate, only lead and radium-226 would show any increase in the quantity mobilised, and the increase would be very small. But if the total erosion occurred in one-third of the time, then the additional mobilisation would rise substantially and would involve manganese and uranium as well as lead and radium-226. Under those circumstances the increase in available heavy metals may well be sufficient to have some biological impact.

In summary, the study indicates that if the tailings erode at the natural denudation rate, the plain's plant and animal life will not be affected. Higher rates may produce a different outcome. Dr Wasson and his colleagues believe this is a strong argument for building the tailings impoundment in a manner that mimics the original landscape — concave slopes formed from a natural grading of particle sizes.

Back to the future

With prospects of the greenhouse effect altering weather patterns and raising sea levels in the next century or so, designing the impoundment to make it robust enough to withstand climatic changes over the next thousand years is obviously a challenge. Fortunately, the plain's sediment history (revealed by combining radionuclide dating with an analysis of pollen), when linked to

known global patterns of previous climate changes such as the Medieval Warm Period and the Little Ice Age, gives an excellent indication of how the Magela plain has responded to climatic change over the last few thousand years.

The team's major discovery was that, in their current form, the Magela fresh-water wetlands are quite young, first appearing somewhere between 1500 and 1000 years ago. The pollen evidence (and that of populations of estuarine and fresh-water diatoms) shows that, previously, the plain formed part of a large tidal swamp dominated by mangroves. The researchers con-

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sider that the reason for the change was the end, about 6000 years ago, of the trend to rising sea levels; fresh-water sedimentation then raised the Magela plain above tidal inundation. The transition appears to have occurred very suddenly, sediment cores indicating a sharp dividing line between the past and present ecosystems.

Closely following the change came an increase in the population of Aborigines living in the vicinity, who would have found the wetlands a rich food source. Perhaps, in turn, they influenced the vegetation through the use of fire. The record in the sediment shows that charcoal started appearing about 700–800 years ago.

And the future? As Earth warms with rising CO₂, the sea level will rise — perhaps by between 30 and 70 cm over the next 100 years. At the same time, the Australian monsoon is likely to intensify and the length of the wet season and its accompanying rainfall will increase. The closest likeness to these conditions, as recorded in the plain's sediments, is the Medieval Warm Period. Sedimentation rates differed little then from those of cooler periods.

As the evidence shows that the rate of natural sedimentation is not very sensitive to climate change, future global warming is unlikely to have much impact on it, although more frequent and more intense cyclones may deliver tailings to the plain at a faster rate. These pollutants will probably not come into contact with sea water because the predicted rise of less than a metre is unlikely to reconnect the sea to the upstream part of the plain where most of the tailings would lodge.

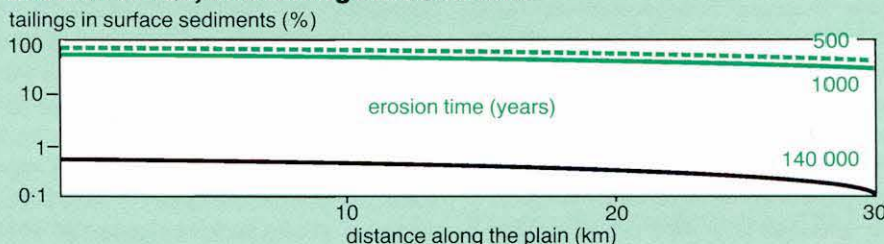
David Brett

More about the topic

Modern sedimentation and late Quaternary evolution of the Magela Creek Plain. R.J. Wasson (ed). *Report to the Office of Supervising Scientist*, 1990.

'Ranger Uranium Environmental Inquiry, Second Report.' (Australian Government Publishing Service: Canberra 1977.)

Erosion times, and tailings in sediment



If Ranger mine tailings erode at the region's long-term average rate they will take more than 600 000 years to fully erode and the tailings will represent a very small fraction of floodplain surface sediments. The graph shows the scientists' estimates of how accelerated erosion rates would increase the tailings' presence in the sediments.