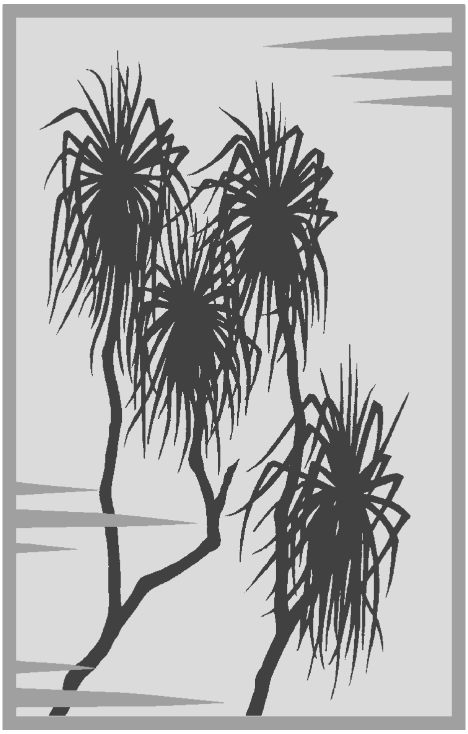
Australian Government

Department of the Environment, Water, Heritage and the Arts

Supervising Scientist

SUPERVISING SCIENTIST



Annual Report

2008-2009

This report should be cited as follows:

Supervising Scientist 2009. *Annual Report 2008–2009*. Supervising Scientist, Darwin.

ISSN 0 158-4030
ISBN-13: 978-1-921069-11-6

The Supervising Scientist is part of the environmental program of the Australian Government Department of the Environment, Water, Heritage and the Arts.

Contact

The contact officer for queries relating to this report is:

Ann Webb
Supervising Scientist Division
Department of the Environment, Water, Heritage and the Arts
Postal: GPO Box 461, Darwin NT 0801 Australia
Street: DEWHA Building, Pederson Road/Fenton Court, Marrara NT 0812 Australia

Telephone 61 8 8920 1100
Facsimile 61 8 8920 1199
E-mail enquiries_ssd@environment.gov.au

Supervising Scientist homepage address is www.environment.gov.au/ssd
Annual Report address: www.environment.gov.au/about/publications/annual-report/ss08-09/index.html

For more information about Supervising Scientist publications contact:

Publications Inquiries
Supervising Scientist Division
Department of the Environment, Water, Heritage and the Arts
GPO Box 461, Darwin NT 0801 Australia

Telephone 61 8 8920 1100
Facsimile 61 8 8920 1199
E-mail publications_ssd@environment.gov.au

Design and layout: Supervising Scientist Division
Cover design: Carolyn Brooks, Canberra
Printed in Canberra by Union Offset on Australian paper from sustainable plantation timber.

Australian Government

Department of the Environment, Water, Heritage and the Arts

Supervising Scientist

The Hon Peter Garrett AM MP
Minister for the Environment, Heritage and the Arts
Parliament House
CANBERRA ACT 2600

15 October 2009

Dear Minister

In accordance with subsection 36(1) of the *Environment Protection (Alligator Rivers Region) Act 1978* (the Act), I submit to you the thirty-first Annual Report of the Supervising Scientist on the operation of the Act during the period of 1 July 2008 to 30 June 2009.

Yours sincerely

Alan Hughes
Supervising Scientist

ABN 34190894983

Darwin Office

GPO Box 461 Darwin NT 0801 Australia
Tel (08) 8920 1100 Fax (08) 8920 1199
E-mail: enquiries_ssd@environment.gov.au
Internet: www.environment.gov.au/ssd

Jabiru Field Station

Locked Bag 2 Jabiru NT 0886 Australia
Tel (08) 8979 9711 Fax (08) 8979 2076
E-mail: enquiries_ssd@environment.gov.au
Internet: www.environment.gov.au/ssd

Photos (clockwise from top left): fish popnetting in Magela Creek; taking groundwater standing-water levels at Rum Jungle; running snail tests in the ecotoxicology laboratory; examining continuous monitoring equipment at Magela Creek; popnetting for fish communities in a lowland, shallow billabong; checking monitoring equipment at Ranger; making fish cultures in the ecotoxicology laboratory; Routine Periodic Inspection (RPI) at Ranger mine.

CONTENTS

Tables

Figures

FOREWORD

Subsection 36(1) of the *Environment Protection (Alligator Rivers Region) Act 1978* requires the Supervising Scientist to provide an Annual Report to Parliament on the operation of the Act and on certain related matters. The Act requires the following information to be reported:

- all directions given to the Supervising Scientist by the Minister for the Environment, Heritage and the Arts;
- information on the collection and assessment of scientific data relating to the environmental effects of mining in the Alligator Rivers Region;
- standards, practices and procedures in relation to mining operations adopted or changed during the year, and the environmental effects of those changes;
- measures taken to protect the environment, or restore it from the effects of mining in the region;
- requirements under prescribed instruments that were enacted, made, adopted or issued and that relate to mining operations in the Alligator Rivers Region and the environment;
- implementation of the above requirements; and
- a statement of the cost of operations of the Supervising Scientist.

SUPERVISING SCIENTIST'S OVERVIEW

The Supervising Scientist plays an important role in the protection of the environment of the Alligator Rivers Region of the Northern Territory through the supervision, monitoring and audit of uranium mines in the Region, as well as research into the possible impact of uranium mining on the environment of the Region.

Ranger is currently the only operational uranium mine in the Region, and is owned and operated by Energy Resources of Australia Ltd (ERA). Production commenced at Ranger in August 1981, and current plans will see mining of the Ranger 3 deposit cease in 2012 with milling of stockpiled ore expected to continue through until 2020. Recent proposals by ERA to include a heap leach facility at Ranger has not affected the current mining and milling operations timetable but could potentially increase production over the same period.

As the time of mine closure and rehabilitation draws closer, the work of the Supervising Scientist includes a focus on these themes as well as operational issues. Staff have been engaged with stakeholders in discussions and research activities associated with rehabilitation and closure.

Apart from rehabilitation and mine closure planning, staff of the Division remain active in ongoing supervision, inspection and audit, radiological, biological and chemical monitoring, and research activities in relation to both present and past uranium mining activities in the Region. Significant work has continued in developing improvements to the Supervising Scientist's surface water monitoring program. This program is relevant to both the operational and rehabilitation phases of mining.

During the year there were no reported incidents that resulted in any environmental impact off the immediate minesite. The extensive monitoring and research programs of the Supervising Scientist Division confirm that the environment has remained protected through the period.

At Ranger mine the 2008–09 wet season was below average with rainfall of 1186 mm. As a result there was less pressure on the pond water component of the mine's water management system than for the previous three years and this has allowed the pond water inventory to be significantly reduced. However, due to delays in commissioning of the process water treatment facility, process water levels remain high.

A further three metre lift of the walls of the Ranger tailings storage facility to RL 54 m was completed and an application to increase the maximum operating level is under consideration. In addition to operational flexibility for ERA, this lift provides an enhanced level of environmental protection in process water management following the decommissioning of Ranger Pit 1 as the active tailings storage facility late in 2008 and pending commissioning of process water treatment, which should commence during the latter half of 2009.

During the year there were concerns raised that seepage from the Ranger tailings storage facility (TSF) of the order of 100 cubic metres per day had the potential to impact on Kakadu National Park. Monitoring by ERA, the NT Department of Regional Development, Primary Industry, Fisheries and Resources and SSD indicates that lateral seepage from the TSF is of a significantly lower volume than this and confirms that its extent is restricted to within a few hundred metres of the dam impoundment along a number of discrete geological structures. There is no evidence of seepage extending from the base of the TSF into Kakadu National Park. The potentially larger proportion of seepage indicated by modelling would be located below the floor of the TSF and this water will need to be recovered and treated following the decommissioning and during rehabilitation of the facility. Independent reviews of the operation and modelling of the tailings facility commissioned separately by ERA and by SSD concur with the view on the restricted lateral distribution of seepage. ERA has undertaken to conduct an electrical geophysical survey over the perimeter of the dam that will map the current distribution of seepage plumes and permit an informed review of the current groundwater monitoring program.

The Jabiluka project remains in long-term care and maintenance, and the next stage of the project is a matter for discussion between ERA and the area's traditional Aboriginal owners.

The Nabarlek mine in western Arnhem Land was decommissioned in 1995 and the rehabilitation of this site remains under ongoing assessment. During the year Uranium Equities Limited's new Mining Management Plan for operations on the site was approved and a revised rehabilitation bond posted under the provisions of the Northern Territory *Mining Management Act*.

Details on research outcomes of the Environmental Research Institute of the Supervising Scientist (***eriss***) are published in journal and conference papers and in the Supervising Scientist and Internal Report series. Some important programs have been described in this annual report.

In particular, the water quality monitoring program continues to be improved with refinements to the operation of continuous monitoring of pH, electrical conductivity and turbidity in Magela and Gulungul Creeks upstream and downstream of Ranger mine. From the continuous monitoring results indications are that water quality variations, both natural and mine-related, can occur on a shorter time base than weekly and the continuous monitoring program therefore has potential to be superior to the weekly grab sampling technique that is currently employed. Further research is in progress to determine what, if any, implications this may have in regard to trigger levels for responses to observed pulse events.

The principal biologically-based toxicity monitoring approach from 1991 until 2008 was creekside monitoring in which a continuous flow of water from the adjacent Magela Creek is pumped through tanks containing test animals. As indicated last year, assessment of the parallel creekside and in situ monitoring (test organisms deployed directly in containers within the creek itself) determined that the in situ method is as effective as the creekside method and the creekside program was discontinued in favour of the more efficient in situ method during the 2008–09 wet season. It is planned to extend this in situ monitoring program to include Gulungul Creek during the 2009–10 wet season.

Comparison of the composition of minesite waters with composition of the water from Magela Creek upstream and downstream of the mine enables a risk assessment to be made of those metals that are of most potential concern. A detailed chemical assessment of the full trace metal profile of minesite waterbodies and major catchment runoff lines had not been carried out since the cessation of mining of Ranger 1 and the start of mining of Ranger 3 in 1996. Since that time the exposed waste stockpiles have come to be dominated by material from Ranger 3, and it is possible that the trace element composition of runoff and seepage water could have changed as a result of the different provenance of this second orebody. Consequently, contemporary trace element data have been collected and the results analysed. The results from this study provide a high degree of confidence that the routine water quality and bioaccumulation sampling programs conducted by SSD are not omitting any potential metals that could be of concern from either toxicological or bioaccumulation perspectives.

Determination of radionuclide levels in mussels from Mudginberri Billabong has been a continuing element of the SSD monitoring program downstream of Ranger. Over the years samples have been collected from a variety of locations within the billabong and the question of the significance of the location of the sampling has been posed. During the past year research has found subtle variations in the relative contribution of radionuclides in the tissue of freshwater mussels which appear to be mainly influenced by the proportion of fine sediments at the sampling site. Importantly, ^{226}Ra and ^{210}Pb activity concentrations in mussels, which dominate the dose received via the ingestion of mussels, are not statistically different among sites and it is concluded that the data of previous mussel collections that have been conducted from several locations in the billabong over the years can be directly compared, taking into account factors such as mussel condition, timing of mussel collection or the duration and intensity of the preceding wet season.

A trial landform was constructed by ERA during late 2008 and early 2009 adjacent to the north-western wall of the tailings storage facility at Ranger mine. The trial landform will be used to test landform design and revegetation strategies to be used once mining and milling have finished. SSD is involved in erosion studies on the trial landform to assist in longer term modelling of the performance of ultimate landform created during rehabilitation of the site.

In May 2006, the Australian Government announced funding of $7.3 million over four years to undertake rehabilitation of former uranium mining sites in the South Alligator River Valley in the southern part of Kakadu National Park. The Supervising Scientist Division continues to provide advice and assistance to the Director of National Parks as the rehabilitation works progress.

The Alligator Rivers Region Technical Committee (ARRTC) continues to play a vital role in assessing the science used in making judgements about the protection of the environment from the impacts of uranium mining. The Committee concluded revision of its definitive 'Key Knowledge Needs'(KKNs) document during 2007–08 and a copy of the revised KKNs is appended to this report.

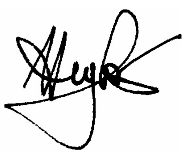
Professor Colin Woodroffe from the University of Wollongong was appointed to ARRTC as the independent scientific member with expertise in geomorphology replacing Professor Jonathan Nott, who resigned from ARRTC last year.

During the reporting period, SSD has provided advice to the Approvals and Wildlife Division of DEWHA on referrals submitted in accordance with the EPBC Act for proposed new and expanding uranium mines associated with the following projects:

- Nolan's Bore Project, NT
- Crocker Well Project, SA
- Olympic Dam Expansion, SA
- Ranger Mine Heap Leach proposal, NT
- Ranger Mine Exploration Decline proposal, NT
- Beverley Four Mile Project, SA

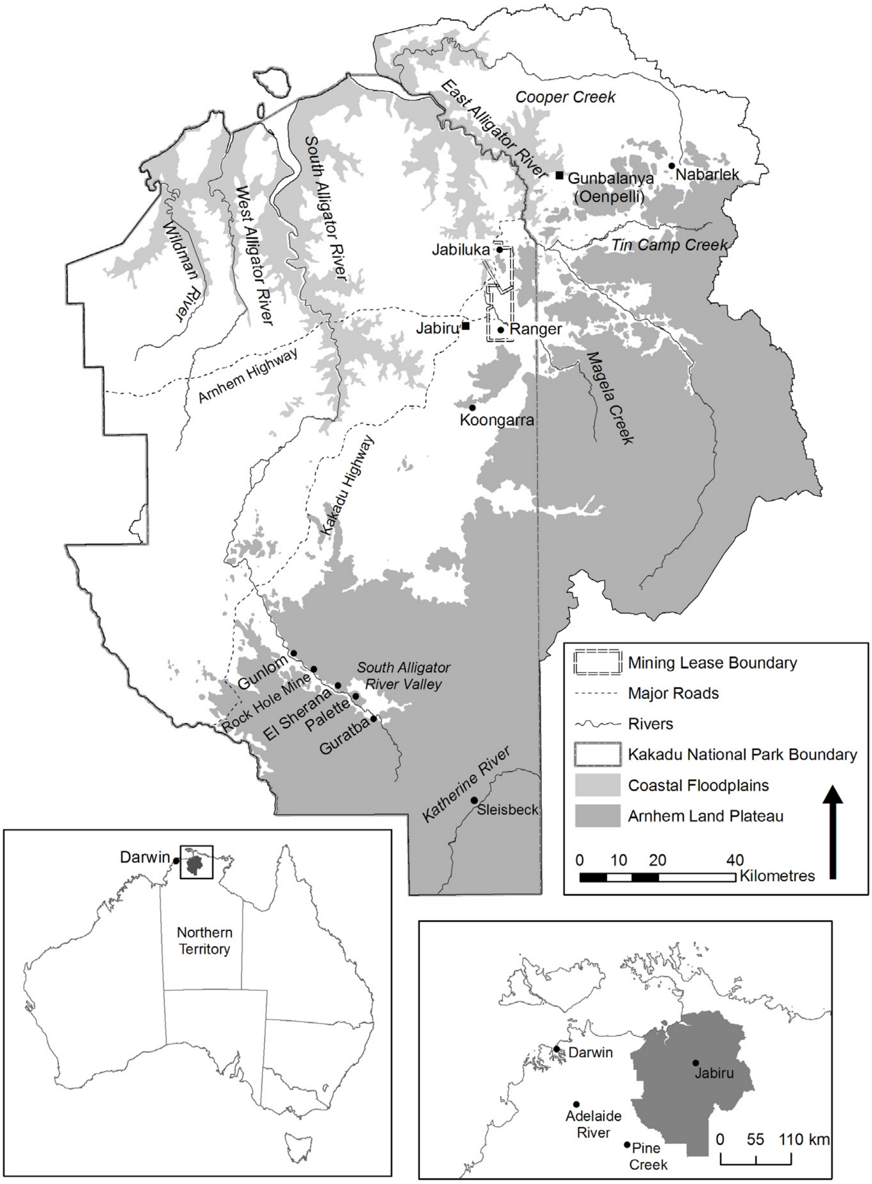
In 2008, a working group of representatives from the NT Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR), NT Department of Natural Resources, Environment, the Arts and Sport (NRETAS), Commonwealth Department of Resources, Energy and Tourism (DRET), the Northern Land Council (NLC) and SSD was formed to review the environmental status of the former Rum Jungle minesite located near Batchelor to the south of Darwin. Funds have been provided in the 2009–10 Federal Budget for a four-year program to progress and implement environmental maintenance activities, conduct appropriate environmental monitoring programs and develop contemporary site rehabilitation strategies. The Rum Jungle Technical Working Group (RJTWG) has now convened and some activities have been initiated. SSD has participated in the work of the RJTWG.

Finally, I would like to offer my personal thanks to all the staff of the Supervising Scientist Division for their enthusiasm and efforts during the year. The commitment and professionalism of the Division's staff remains a vital factor in the Division being able to fulfil its role in environmental protection.

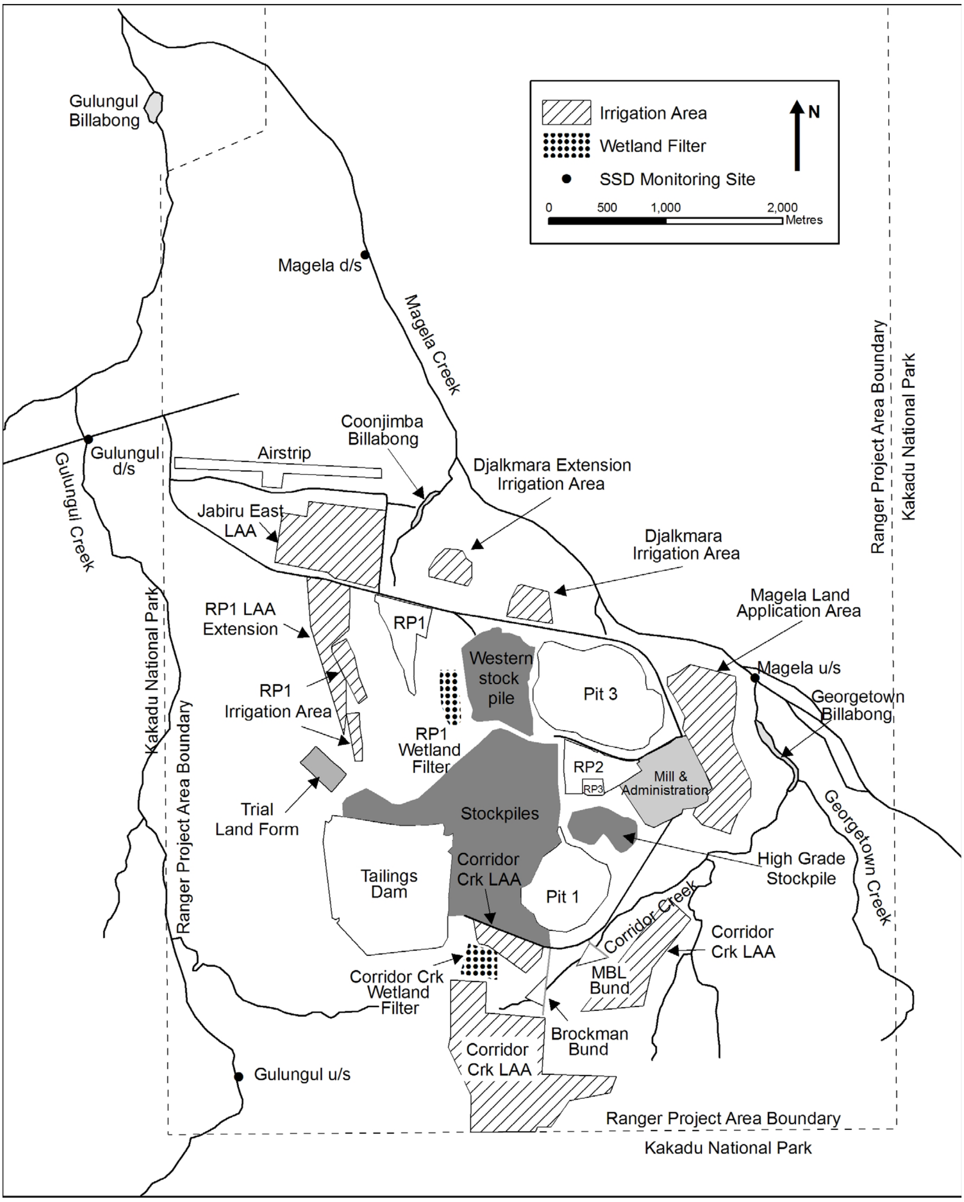


Alan Hughes

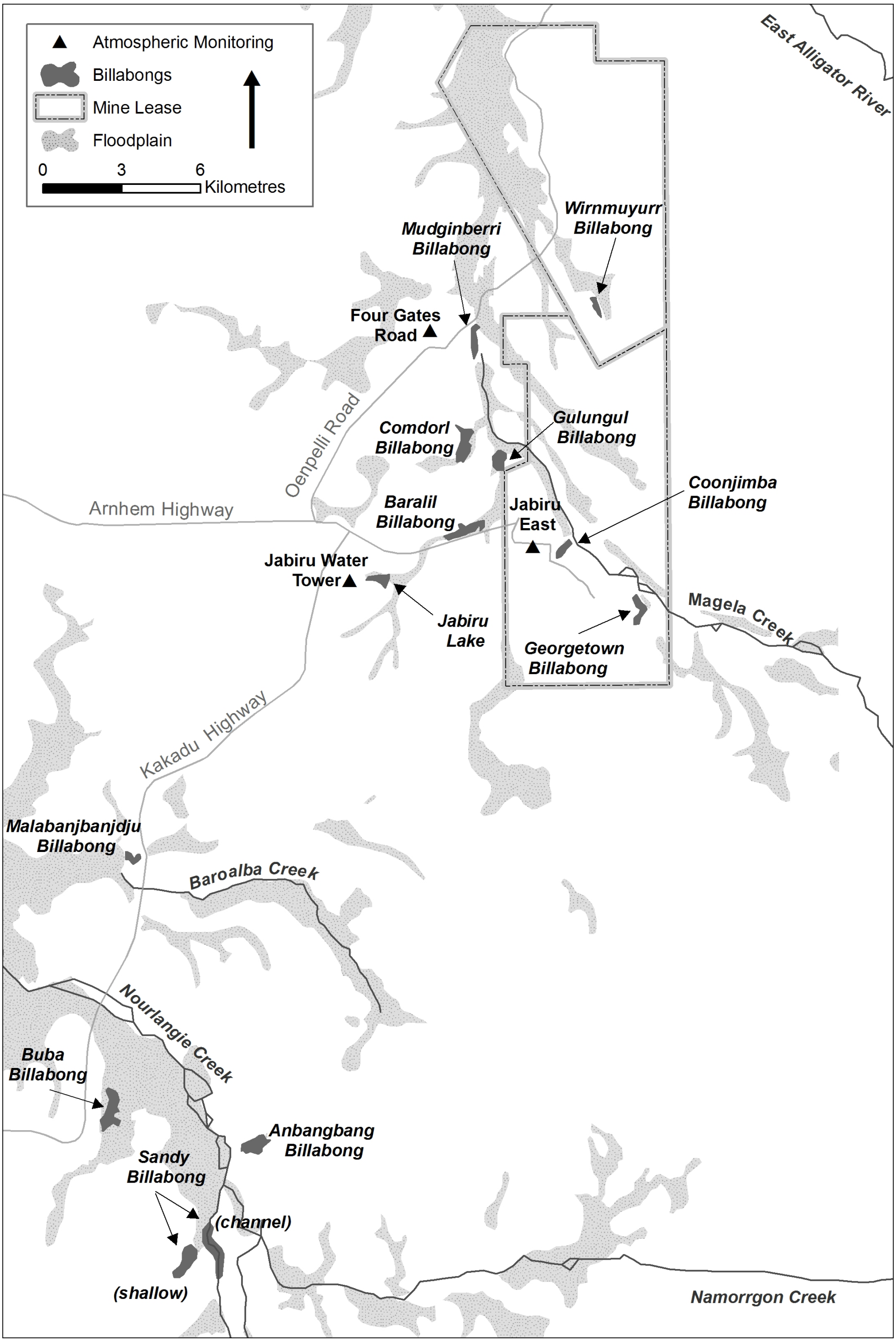
Supervising Scientist



Map 1 Alligator Rivers Region



Map 2 Ranger minesite



Map 3 Sampling locations used in SSD's research and monitoring programs

ABBREVIATIONS

ARR	Alligator Rivers Region
ARRAC	Alligator Rivers Region Advisory Committee
ARRTC	Alligator Rivers Region Technical Committee
DEWHA	Department of the Environment, Water, Heritage and the Arts
DRET	Department of Resources, Energy and Tourism
DRDPIFR	Department of Regional Development, Primary Industry, Fisheries and Resources
EMS	Environmental Management System
ERA	Energy Resources of Australia Ltd
eriss	Environmental Research Institute of the Supervising Scientist
ERs	Environmental Requirements
EWLS	Earth Water Life Sciences Pty Ltd
G8210009	Magela Creek d/s (downstream) gauging station
GAC	Gundjeihmi Aboriginal Corporation
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiological Protection
KKN	Key Knowledge Needs
LAA	Land application area
MCUS	Magela Creek u/s (upstream) site
MTC	Minesite Technical Committee
NLC	Northern Land Council
NRETAS	Department of Natural Resources, Environment, the Arts and Sport
oss	Office of the Supervising Scientist
RJTWG	Rum Jungle Technical Working Group
RL	Reduced Level – the number after RL denotes metres above or below a chosen datum
RMC	Rockhole Mine Creek
RPI	Routine Periodic Inspection
SSAR	Supervising Scientist Annual Report
SSD	Supervising Scientist Division
TRaCK CERF	Tropical Rivers and Coastal Knowledge Commonwealth Environmental Research Facilities
TRIAP	Tropical Rivers Inventory and Assessment Project
TSF	Tailings Storage Facility
UEL	Uranium Equities Limited

GLOSSARY

1s – 7s	When referring to ore and stockpiles indicates the amount of extractable uranium in the ore (grade). At Ranger, 1s indicates the lowest grade (waste) and 7s indicates the highest grade ore.
airborne gamma survey	Aerial measurements of the terrestrial gamma radiation using a large volume sodium iodide (NaI) detector on board an aircraft.
alpha radiation (α)	A positively charged helium (He^{2+}) nucleus (two protons + two neutrons) that is spontaneously emitted by an energetically unstable heavy atomic nucleus (such as ^{226}Ra or ^{238}U).
application	A document stating how the mining operator proposes to change the conditions set out in the mining Authorisation. These changes need to be approved by all MTC stakeholders.
authorisation	For mining activities authorisation is required under the Northern Territory *Mining Management Act* (MMA) for activities that will result in substantial disturbance of the ground. It details the authorised operations of a mine, based on the submitted mining management plan and any other conditions that the Northern Territory Minister considers appropriate.
becquerel (Bq)	SI unit for the activity of a radioactive substance in decays per second [s^{-1}].
beta radiation (β)	A high energy electron or positron emitted when an unstable atomic nucleus (such as ^{90}Sr or ^{40}K) loses its excess energy.
bioaccumulation	Occurs when the rate of uptake by biota of a chemical substance, such as metals, radionuclides or pesticides is greater than the rate of loss. These substances may be taken up directly, or indirectly, through consumption of food containing the chemicals.
bioavailable	The proportion of the total present (in water, sediment, soil or food) of metals and radionuclides, that can be taken up by biota (see also bioaccumulation).
biodiversity (biological diversity)	The variety of life forms, including plants, animals and micro-organisms, the genes they contain and the ecosystems and ecological processes of which they are a part.
biological assessment	Use and measurement of the biota to monitor and assess the ecological health of an ecosystem.
bund	Embankment or wall designed to retain contents (usually liquids) in the event of leakage or spillage from a storage facility.
biological community	An assemblage of organisms characterised by a distinctive combination of species occupying a common environment and interacting with one another.

concentration factor	The metal or radionuclide activity concentration measured in biota divided by the respective concentration measured in the underlying soil (for terrestrial biota) or water (for aquatic biota).
damp-proof course	A waterproof barrier comprising bitumen and aluminium.
direct seeding	Vegetation is established by broadcasting seed across the area to be revegetated.
dissolved organic carbon	Natural organic material from plants and animals that has broken down and is able to pass through a very fine (0.45 micrometre) filter.
dose coefficient	The committed tissue equivalent dose or committed effective dose Sievert [Sv] per unit intake Becquerel [Bq] of a radionuclide. See definition of Sievert and Becquerel.
dose constraint	The International Commission on Radiation Protection (ICRP) defines dose constraint as '*a prospective restriction on anticipated dose, primarily intended to be used to discard undesirable options in an optimization calculation*' for assessing site remediation options.
early detection	Measurable early warning biological, physical or chemical response in relation to a particular stress, prior to significant adverse affects occurring on the system of interest.
flume	A channel control structure with known cross-sectional area used to measure flow rate of runoff water.
fulvic acid	A component of dissolved organic carbon that is especially reactive and forms strong complexes with metals. Fulvic acids account for a large part of the dissolved organic matter in natural water.
gamma radiation (γ)	High energy electromagnetic radiation emitted by excited nuclei (for example after an alpha or beta decay) in their transition to lower-lying nuclear levels.
grab sampling	Collection of a discrete water sample for chemical analysis
Gray (Gy)	Name for absorbed dose 1 Gray = 1 Joule·kg^{-1}. The absorbed dose gives a measure for the energy imparted by ionising radiation to the mass of the matter contained in a given volume element.
half-life	Time required to reduce by one-half the concentration (or activity in the case of a radionuclide) of a material in a medium (eg soil or water) or organism (eg fish tissue) by transport, degradation or transformation.
Hydstra	Hydrology data management software package.
IC50	The concentration of a compound that causes a 50% inhibition in a particular response (eg growth, reproduction) of an organism relative to that of a control organism (ie an organism not exposed to the compound).

ionising radiation	Sub-atomic particles (α, β) or electromagnetic (γ, x-rays) radiation that have enough energy to knock out an electron from the electron shell of molecules or atoms, thereby ionising them.
land application	A method for management of excess accumulated water by spray irrigation. The method depends on the evaporation from spray droplets, and from vegetation and ground surfaces once its reaches them.
laterite	In the Ranger mine context, laterite is a local term used to describe well weathered rock and soil profile material that consists primarily of a mixture of sand and silt/clay size particles. It may or may not exhibit characteristics of a fully-developed laterite profile.
LC50	The concentration of a compound that causes the death of 50% of a group of organisms relative to that of a control group of organisms (ie a group of organisms not exposed to the compound).
MOL	Maximum Operating Level. The maximum level at which a liquid containing impoundment can be operated.
ore	A type of rock that bears minerals, or metal, which can be extracted.
permeate	The higher purity stream produced by passage of water through a reverse osmosis (RO) treatment process.
polished	Water that has been passed through a wetland filter.
pond water	Water derived from seepage and surface water runoff from mineralised rock stockpiles as well as runoff from the processing areas that are not part of the process water circuit.
potable water	Water suitable for human consumption.
process water	Water that has passed through the uranium extraction circuit, and all water that has come into contact with the circuit. It has a relatively high dissolved salt load constituting the most impacted water class on site.
radiologically anomalous area	Area that displays significantly above background levels of radioactivity.
radionuclide	An atom with an unstable nucleus that loses its excess energy via radioactive decay. There are natural and artificial radionuclides. Natural radionuclides are those in the uranium (^{238}U), actinium (^{235}U) and thorium (^{232}Th) decay series for example, which are characteristic of the naturally occurring radioactive material in uranium orebodies.
radium	A radioactive chemical element that is found in trace amounts in uranium ores.
radon	Colourless, odourless, tasteless, naturally-occurring radioactive noble gas formed from the decay of radium.
Sievert (Sv)	Name for equivalent dose and effective dose 1 Sievert = 1 Joule·kg^{-1}. In contrast to the Gray, the Sievert takes into account both the type of radiation

	and the radiological sensitivities of the organs irradiated, by introducing dimensionless radiation and tissue weighting factors, respectively.
sonde	A water quality instrument that is immersed in water for measuring (typically) electrical conductivity, pH, turbidity and dissolved oxygen.
speciation (of an element)	The forms in which an element exists within a particular sample or matrix.
stable lead isotopes	Lead has four stable isotopes, three of which, ^{206}Pb, ^{207}Pb and ^{208}Pb, are end members of the natural uranium, actinium and thorium decay series, respectively. ^{204}Pb is primordial only.
tailings	A slurry of ground rock and process effluents left over once the target product, in this case uranium, has been extracted from mineralised ore.
thoriferous	Containing thorium.
toxicity monitoring	The means by which the toxicity of a chemical or other test material is determined in the field over time. The monitoring comprises field toxicity tests which are used to measure the degree of response produced by exposure to a specific level of stimulus (or concentration of chemical).
tube stock	Seeds are germinated in a plant nursery and the young seedlings are then planted out.
uraniferous	Containing uranium.
uranium oxide	An oxide of uranium which occurs naturally or is produced by a uranium extraction process. This is the product from the Ranger mine.
water treatment plant (WTP)	The process system that removes undesirable chemicals, materials, and biological contaminants from water thereby decreasing its ability to harm the environment.

1 INTRODUCTION

1.1 Role and function of the Supervising Scientist

The position of Supervising Scientist was established under the Commonwealth *Environment Protection (Alligator Rivers Region) Act 1978* (the EPARR Act) in response to a recommendation of the second and final Fox Commission report in May 1977.

The roles and responsibilities of the Supervising Scientist are to:

- develop, coordinate and manage programs of research into the effects on the environment of uranium mining within the Alligator Rivers Region;
- develop standards, practices and procedures that will protect the environment and people from the effects of uranium mining within the Alligator Rivers Region;
- develop measures for the protection and restoration of the environment;
- coordinate and supervise the implementation of requirements made under laws applicable to environmental aspects of uranium mining in the Alligator Rivers Region;
- provide the Minister (the Australian Government Minister for the Environment, Heritage and the Arts) with scientific and technical advice on mining in the Alligator Rivers Region;
- on request, provide the Minister (the Australian Government Minister for the Environment, Heritage and the Arts) with scientific and technical advice on environmental matters elsewhere in Australia.

The Supervising Scientist heads the **Supervising Scientist Division (SSD)** within the Department of the Environment, Water, Heritage and the Arts. The Division comprises two branches.

The **Office of the Supervising Scientist (*oss*)** undertakes supervision, audit and assessment activities and provides policy advice to the Australian Government in relation to the environmental performance of uranium mines in the Alligator Rivers Region. ***oss*** also provides business and administrative support to the Supervising Scientist Division.

The **Environmental Research Institute of the Supervising Scientist (*eriss*)** undertakes environmental monitoring and scientific research into the impact of uranium mining on the environment within the Alligator Rivers Region to support the work of the Supervising Scientist. ***eriss*** also conducts research into the sustainable use and environmental protection of tropical rivers and their associated wetlands.

1.2 Performance summary

As a Division of the Department of the Environment, Water, Heritage and the Arts, SSD is funded under the Portfolio's departmental output appropriation and contributes to the delivery of the Department's Outcome 1:

> The environment, especially those aspects that are matters of national environmental significance, is protected and conserved.

Outcome 1 is divided into five Outputs. During the 2008–09 financial year, the Supervising Scientist contributed to Sub-output 1.2.4 *Tropical wetlands research* under Output 1.2 *Conservation of the land and inland waters* and Sub-output 1.5.3 *Supervision of uranium mines* under Output 1.5 *Response to the impacts of human settlements.*

Further details on SSD activities during 2008–09 contributing to Sub-output 1.2.4 are provided in Chapters 3 and 5 of this Annual Report. Details on SSD activities contributing to Sub-output 1.5.3 are provided in Chapters 2 and 3.

Communicating the outcomes of research, monitoring and supervision activities to relevant stakeholders and the broader scientific community is a key part of the work of the Division. Of particular importance is the ongoing communication and consultation SSD undertakes with the Aboriginal people living in the Alligator Rivers Region. Further details on SSD communications activities during 2008–09 are provided in Chapter 5.

1.3 Business planning

SSD undertakes a strategic business planning approach to ensure outputs are achieved in the most effective and efficient way. SSD prepares an annual Business Plan that outlines the main goals and challenges for the Division over the coming year, the range of activities and programs to be undertaken and associated performance measures. Progress against strategic priorities and key result areas is assessed on an ongoing basis.

1.4 The Alligator Rivers Region and its uranium deposits

The Alligator Rivers Region is located some 220 km east of Darwin and encompasses an area of approximately 28 000 km^2 (see Map 1). The Region includes the catchments of the West Alligator, South Alligator and East Alligator Rivers, extending into western Arnhem Land. The World Heritage listed Kakadu National Park lies entirely within the Alligator Rivers Region.

The Ranger, Jabiluka and Koongarra uranium deposits within the Alligator Rivers Region are not, and never have been, located within Kakadu National Park. Nabarlek is situated to the east of Kakadu National Park within Arnhem Land.

Ranger is currently the only operational uranium mine in the Region. Mining ceased at Jabiluka in 1999 and the site is under long-term care and maintenance. Mining at Nabarlek ceased in 1980 and the site has been decommissioned and is subject to ongoing rehabilitation. Development of the Koongarra uranium deposit is subject to traditional owner approval as required under the Commonwealth *Aboriginal Land Rights (Northern Territory) Act 1976*. There are also a number of former uranium mines in the South Alligator River Valley that operated during the 1950s and 1960s which are currently being rehabilitated.

1.4.1 Ranger

Energy Resources of Australia Ltd (ERA) operates the Ranger mine, which is located approximately 8 km east of the township of Jabiru. The mine lies within the 78 km^2 Ranger project area, adjacent to Magela Creek, a tributary of the East Alligator River. Ranger is an open cut mine and commercial production of uranium concentrate (U_3O_8) has been under way since 1981. Orebody No 1 was exhausted in late 1994 and excavation of Orebody No 3 began in 1997.

Current ERA planning is for mining at Ranger to cease in 2012 with processing of stockpiled ore to continue until 2020.

1.4.2 Jabiluka

The Jabiluka mineral lease abuts the northern boundary of the Ranger project area and the Jabiluka site is situated some 20 km north of the Ranger minesite. It is also owned by ERA.

Unlike the Ranger and Nabarlek deposits, the Jabiluka orebody lies beneath a cover of cliff-forming sandstone. It is in the catchment of the East Alligator River, adjacent to Ngarradj (Swift Creek), which drains north to the Magela floodplain. The Australian Government completed its assessment of ERA's Environmental Impact Statement, which provided for milling of Jabiluka ore at Ranger, in 1997.

Development work at Jabiluka took place in the late 1990s but ceased in September 1999, at which time the site was placed in an environmental management and standby phase that lasted until 2003.

During 2003, discussions commenced between ERA, the Commonwealth and Northern Territory Governments, the Northern Land Council (NLC) and the Gundjeihmi Aboriginal Corporation (GAC), which represents the area's traditional Aboriginal owners, the Mirarr people. Following these discussions, an agreement was reached between the parties that resulted in Jabiluka being placed in long-term care and maintenance. This agreement included an undertaking by ERA not to engage in mining activities at Jabiluka without the consent of the Mirarr people. The agreement was endorsed by the NLC in 2004 and was approved by the then Australian Government Minister for Immigration and Multicultural and Indigenous Affairs in 2005.

1.4.3 Nabarlek

Nabarlek is located approximately 280 km east of Darwin. Queensland Mines Ltd undertook mining at Nabarlek during the dry season of 1979, and milling of the ore continued until 1988. Some 10 857 t of uranium concentrate (U_3O_8) was produced while the mill was operational.

Decommissioning of the mine was completed in 1995 and the performance of the rehabilitation and revegetation program continues to be monitored by SSD.

In early 2008, Uranium Equities Limited (UEL) bought Queensland Mines Pty Ltd, thereby acquiring the Nabarlek lease, and have since developed plans to further explore the lease, clean up the site and continue revegetation and rehabilitation works.

1.4.4 Koongarra

The Koongarra deposit is located approximately 25 km south-west of Ranger, in the South Alligator River catchment. The Koongarra deposit is owned by Koongarra Pty Ltd, a subsidiary of the French company AREVA. The site is subject to the provisions of the Commonwealth *Aboriginal Land Rights (Northern Territory) Act 1976*, which requires that traditional owner approval must be obtained before any application for a mining title can be made to the Northern Territory Government.

1.4.5 South Alligator Valley mines

During the 1950s and 1960s, several small uranium mines and milling facilities operated in the South Alligator River Valley, in the southern part of the Alligator Rivers Region. Mining occurred at several locations in the valley, principally at El Sherana, El Sherana West, Rockhole Creek and Coronation Hill (Guratba). Milling occurred at Rockhole Creek within the South Alligator Valley as well as at nearby Moline, which lies outside the Alligator Rivers Region.

Output from these mines was relatively small. It is estimated that less than 1000 t of uranium concentrate was produced at the Rockhole Creek and Moline mills from the ore mined in the South Alligator Valley during this period.

These sites, excluding Moline, are the responsibility of the Australian Government Director of National Parks and are administered through Parks Australia.

SSD is assisting Parks Australia with the implementation of the $7.3 million four year project for rehabilitation of abandoned uranium mining sites in the valley, announced by the Australian Government in May 2006. Further details on SSD involvement in this project are provided in Section 2.5.1 of this Annual Report.

2 ENVIRONMENTAL ASSESSMENTS OF URANIUM MINES

2.1 Supervision process

The Supervising Scientist utilises a structured program of audits and inspections, in conjunction with the Northern Territory Government and the Northern Land Council, to supervise uranium mining operations in the Alligator Rivers Region. The outcomes of these activities are considered by the Supervising Scientist, together with environmental monitoring data and other information, to draw conclusions regarding the effectiveness of environmental management at uranium mining sites.

2.1.1 Minesite Technical Committees

Minesite Technical Committees (MTCs) have been established for Ranger, Jabiluka and Nabarlek. The MTC meetings provide an effective forum for stakeholders, including Supervising Scientist Division staff, to discuss technical environmental management issues, especially in connection with the assessment of applications and reports submitted by mining companies for approval under Northern Territory and Commonwealth legislation. Each MTC is made up of representatives from the Northern Territory Department of Regional Development, Primary Industry, Fisheries and Resources (DRDPIFR – which provides the Chair), the Office of the Supervising Scientist (***oss***), the Northern Land Council (NLC) and the relevant mining company. A representative from the Gundjeihmi Aboriginal Corporation is invited to attend each Ranger and Jabiluka MTC meeting. Other organisations or experts may be co-opted from time to time as required to assist MTC members.

2.1.2 Audits and inspections

The Supervising Scientist, in consultation with the applicable MTC members, has developed and implemented a program of environmental audits and inspections at Ranger mine, Jabiluka project area and Nabarlek mine.

Routine Periodic Inspections (RPI) take place monthly at Ranger, being the only operating minesite in the region, and quarterly at Jabiluka, which is currently in long-term care and maintenance. The RPIs are intended to provide a snapshot of environmental management as well as an opportunity for the inspection team to discuss environmental management issues with staff on site. These discussions may include any unplanned events or reportable incidents and any associated follow-up actions. The inspection team is made up of representatives from ***oss***, DRDPIFR and the NLC.

The abandoned minesites at South Alligator Valley are also routinely inspected at least once annually.

The environmental audits are conducted by a team of qualified audit staff from ***oss***, DRDPIFR and the NLC and are undertaken in general accordance with ISO Standard 19011:2003

(*Guidelines for quality and/or environmental management systems auditing*) and are consistent with current best practice in environmental assessments.

The annual environmental audits of Ranger and Jabiluka occur in April or May to assess each site under 'end of wet season' conditions. The final audit report is tabled at the following meeting of the Alligator Rivers Region Advisory Committee (ARRAC). Audit findings are followed-up as required through the RPI process. The Nabarlek program is slightly different in that an inspection is carried out early in the dry season and the annual environmental audit is conducted later in the year.

The audit outcomes are described later in this annual report.

2.1.3 Assessment of reports, plans and applications

The Authorisations for Ranger mine and the Jabiluka project area are issued under the Northern Territory *Mining Management Act 2001.* The Act provides for alterations to the Authorisation to be issued by the Northern Territory Government. The Authorisations require that ERA seeks approval for certain activities from the Northern Territory regulatory authority, through DRDPIFR, which then grants approval or not after ***oss*** and the NLC have assessed the proposal and provided feedback. This provides the primary mechanism for the Supervising Scientist's participation in the regulatory processes of the Northern Territory Government and is supported by section 34 of the Act which requires the Northern Territory Government to act in accordance with the advice of the Commonwealth Minister.

The main reports and plans assessed by the Supervising Scientist during 2008–09 included:

- Ranger Amended Plan of Rehabilitation No 34
- Ranger Mine Water Management Plan
- Ranger Mine and Jabiluka Project Annual Environmental Reports
- Ranger Mine and Jabiluka Project Wet Season Reports
- Ranger Mine Annual Tailings Dam Inspection Report
- Ranger Mine and Jabiluka Radiation Protection Monitoring Program Quarterly and annual reports
- Jabiluka Project Plan of Rehabilitation No 12
- ERA weekly environmental monitoring data and quarterly reports submitted in accordance with the Authorisations
- Applications by the mining companies for amendments to their Authorisations

2.2 Ranger

2.2.1 Developments

Mining and milling of uranium ore at Ranger continued throughout 2008–09, with further development of the orebody in Pit 3. The Ranger mill produced 5678 tonnes of uranium oxide (U_3O_8) during 2008–09 from 2 042 251 tonnes of treated ore (Table 2.1). Production statistics for the milling of ore and the production of U_3O_8 at Ranger for the past five years are shown in Table 2.2.

TABLE 2.1 RANGER PRODUCTION ACTIVITY FOR 2008–2009 BY QUARTER

	1/07/2008 to 30/09/2008	1/10/2008 to 31/12/2008	1/01/2009 to 31/03/2009	1/04/2009 to 30/06/2009	Total
Production (drummed tonnes of U_3O_8)	1349	1633	1213	1481	5678
Ore treated ('000 tonnes)	450	499	494	597	2042

TABLE 2.2 RANGER PRODUCTION ACTIVITY FOR 2004–2005 TO 2008–2009

	2004–2005	2005–2006	2006–2007	2007–2008	2008–2009
Production (drummed tonnes of U_3O_8)	5544	5184	5261	4926	5678
Ore treated ('000 tonnes)	2231	1960	2136	2001	2042

On-site activities

Ranger Heap Leach Proposal

In March 2009 ERA submitted a referral under the *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act) for the construction of a heap leach facility to treat low grade ore at Ranger. This referral was determined to be a controlled action and is to be assessed by an environmental impact statement (EIS) managed under a bilateral agreement by the Northern Territory Government. Guidelines for the EIS are currently being prepared by the NT Government in consultation with ***oss*** and other key stakeholders.

Ranger Exploration Decline Proposal

In April 2009 ERA submitted a referral for the proposed construction of an exploration decline to provide exploration access to mineralisation in the Ranger 3 deeps area. In May 2009 this proposal was deemed not to be a controlled action and will not require further assessment under the EPBC Act. A decision on the assessment level of the exploration decline proposal under NT legislation is yet to be handed down by the NT Minister.

Exploration

ERA is continuing to conduct exploration drilling near the eastern edge of Pit 3 (Ranger 3 deeps), and in other areas within the Ranger project area.

Water Treatment Plant

A Water Treatment Plant (WTP) was built in 2005 to treat both process and pond water prior to their release from site. (The two different types of water and their management are described in section 2.2.2, Water management.) Commissioning of pond water treatment was undertaken in December 2005 with permeate being released to the Corridor Creek wetland filter. Towards the end of the reporting period, the WTP was treating an average of 4.60 ML of pond water each day, before being turned off on 10 April 2009 due to the reduced pond water inventory. Commissioning of the Osmoflo water treatment plant (OWTP) commenced in May 2008 and was completed in August 2008 within a closed circuit. The OWTP was turned off on 24 August 2008 as pond water inventory volumes did not require OWTP operation. The OWTP released water to the receiving environment for the first time on 9 January 2009 and was treating an average of 5.53 ML of pond water each day. The OWTP was turned off on 8 April 2009 due to the reduced pond water inventory.

Tailings storage in Pit 1

ERA is currently authorised to store tailings in Pit 1 to RL12 as an interim operational strategy. If the interim strategy is not proven to meet the requirements of the MTC for final containment, the Supervising Scientist has advised that tailings should be removed from Pit 1 to a scientifically justifiable level approved by the Supervising Authorities. Deposition of tailings to Pit 1 ceased during the fourth quarter of 2008. Tailings and waste management are discussed in more detail in section 2.2.2.

Tailings storage facility lift

On 15 May 2008 ERA applied to raise the walls of the tailings storage facility (TSF) from RL51.0 to RL54.0. As the finalised lift will take the dam crest above the original design height, ***oss*** commissioned an independent expert consultant to review the design to ensure it is consistent with current standards of best practice. Subsequently the lift was approved by the Supervising Authority and was completed to ~RL53.0 prior to the onset of the 2008–09 wet season and the final stages of lift construction were completed during the second quarter of 2009.

In April 2009 ERA submitted an application to raise the maximum operating level (MOL) of the TSF. In response to this application, ***oss*** commissioned an independent consultant to review ERA's groundwater modelling associated with the proposed MOL increase. The application remains under consideration by the Supervising Authority.

Radiometric Sorting Plant and Laterite Processing Plant

ERA received approval to construct and commission both plants on 6 November 2007. The Radiometric Sorting Plant will enable ERA to selectively increase the ore grade of lower grade ores prior to feeding into the process circuit, and the Laterite Plant will enable ERA to treat lateritic ore that is unsuitable for inclusion in the current process circuit due to its high clay content. Both plants have completed final stages of commissioning and are anticipated to be fully operational early in the third quarter of 2009.

Trial landform

ERA has previously undertaken small scale rehabilitation trials across the Ranger site to gain further understanding of geomorphic behavior and revegetation of waste rock landforms. However, as the closure model now includes provision for mixing of fine-grained material (laterite) with the rock, rather than using waste rock alone, and as knowledge has increased about the distribution of plant species to be used for rehabilitation, additional rehabilitation test work is needed. Discussions with stakeholders over the design and scope of a long-term trial landform to address the above knowledge needs commenced in 2005.

In September 2008, ERA notified stakeholders of their proposal to construct a trial landform to the north west of the TSF (see Map 2). ERA aims for the trial landform to provide a visual demonstration of their rehabilitation and revegetation capabilities as well as to further test and optimise options for mine closure and rehabilitation in the future. Clearing the footprint for the 8 ha trial landform commenced in the third quarter of 2008. Construction of the landform required approximately 500 000 m^3 of material, incorporating weathered 1s laterite and primary/unweathered 1s waste rock. The landform design incorporates runoff and catchment management features and is monitored by ERA and SSD to provide data on water quality and erosion processes to inform future decision making around the final landform design. Further detail on the trial landform is provided in chapter 3, section 3.8 'Design and construction of erosion plots on the Ranger trial rehabilitation landform'.

2.2.2 On-site environmental management

Water management

All water on-site is managed in accordance with the approved Water Management Plan which is updated annually and subject to MTC assessment before approval. The plan describes the systems for routine and contingency management of the three categories of water, ie process, pond (described below) and potable. Where possible, clean surface run-off is diverted away from the site to minimise the site water inventory.

Water management remains critical at Ranger mine. The higher than average rainfall of the 2005–06 and 2006–07 wet seasons resulted in the pond and process water inventories being greater than forecast going into the 2007 dry season. As shown in Figure 2.1, the 2008–09 wet season was below average with Jabiru Airport recording 1186 mm. This has allowed the pond water inventory to be significantly reduced. However, due to the delayed commissioning of the process water treatment facility, process water levels remain high.

Process water system

Under the Commonwealth Environmental Requirements, water that is in direct contact with uranium ore during processing (process water) must be maintained within a closed system. It may only be released by evaporation or after treatment in a manner and to a quality approved by the Supervising Scientist. Process water is currently stored in the TSF and in Pit 1. There were no releases of process water to the surrounding environment during the reporting period.

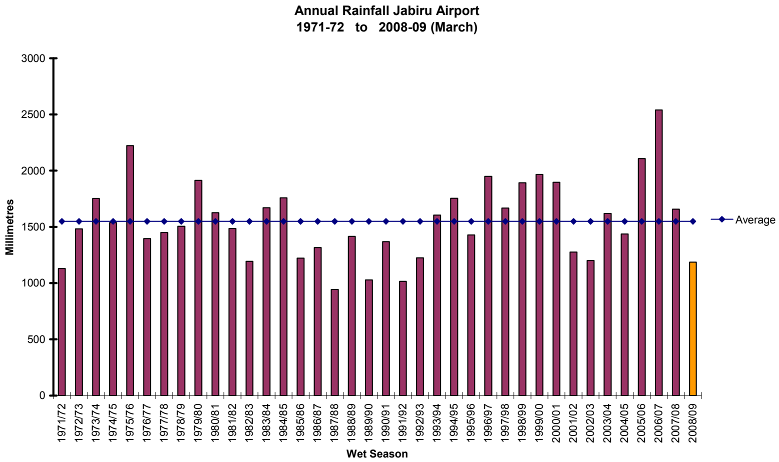


Figure 2.1 Annual rainfall Jabiru Airport 1971–72 to 2008–09 (data taken from Bureau of Meteorology)

Above average rainfall in the 2005–06 and 2006–07 wet seasons resulted in a substantial increase in the process water inventory. The lift of the TSF to RL54 will provide additional storage capacity for both tailings and process water during the 2009–10 wet season. The lift was completed to ~RL53 prior to the onset of the 2008–09 wet season, with the final portion of the lift completed in the second quarter of 2009.

At the end of the reporting period, the process water inventory was 9982 ML, of which 9789 ML is stored in the TSF.

Pond water system

The pond water system contains water that has been in contact with stockpiled mineralised material and operational areas of the site other than those contained within the process water system. Water is managed within this system by quality. The pond water system consists of Retention Pond 2 (RP2), Retention Pond 3 (RP3) and Pit 3. Water from RP2, RP3 and Pit 3 may not be released without prior treatment through wetland filtration and/or irrigation. At the end of the reporting period 892 ML was contained within the system.

Methods of disposal of pond water

Ponding of Retention Pond 2 water on the Southern 2s stockpiles

ERA continued to utilise shallow evaporation basins on stockpiles throughout the 2008 dry season to reduce pond water inventory in the lead up to the 2008–09 wet season.

Passive release water

Rainfall runoff discharges from the Ranger site during the wet season via Gulungul Creek, Corridor Creek and Coonjimba Creek with minor overland flow direct to Magela Creek. Retention Pond 1 (RP1) and the Corridor Creek wetland filter act as sediment traps prior to outflow from the site. The Corridor Creek wetland filter receives runoff from specially prepared sheeted areas of low grade and waste rock stockpiles designed to minimise infiltration and hence contribution of additional water to the pond water system. RP1 also receives sheeted runoff from the northern waste rock stockpiles and overflows passively via a constructed weir into Coonjimba Creek every wet season. Controlled discharge of RP1 via siphons occurred during late January and early February 2009 to assist with the removal of poorer quality water during periods of higher flow. Passive release of water over the RP1 weir occurred from mid-February through to mid-March 2009 and was managed by use of sluice gates on the weir. In Corridor Creek, passive release of waters retained upstream of GC2 occurred throughout the 2008–09 wet season. ERA also manually control the discharge of runoff water via four sluice gates along the Ranger access road. Release from these gates occurred on two occasions during the 2008–09 wet season.

Stockpile sheeting

Runoff from sheeted stockpiles into the Corridor Creek wetland filter generated from the first 200 mm of rainfall continues to be diverted into the pond water system. This initial runoff generally contains higher levels of mine-derived solutes due to the leaching of solutes that occurs in the early stages of the wet season, from freshly mined rock.

Wetland filters and land application areas

Two wetland filter systems operated during 2008–09: the Corridor Creek system and the RP1 constructed wetland filter in the RP1 catchment.

Corridor Creek and RP1 land application areas were operational during late November and early December 2008. The Jabiru East land application area was operated for only one day during the reporting period. No other land application areas were operational during the reporting period due to the reduced pond water inventory on site.

Tailings and waste management

Tailings

From August 1996 to December 2008 no process residue from the milling of ore was deposited into the TSF, with Pit 1 the sole receptor. Over this period 20 M of tailings were deposited in Pit 1 including 1.8 M transferred from the TSF by dredging. Transfer of tailings into Pit 1 from the milling and processing of ore from Pit 3 ceased in December 2008 when tailings reached the maximum permitted level of RL12. Tailings are now discharged to the TSF via a floating discharge pipe that is moved regularly to achieve an even deposition of tailings across the dam.

The average density of tailings in Pit 1 at May 2009 was 1.37 t/m^3, which exceeds the minimum target density of 1.2 t/m^3.

Audit and Routine Periodic Inspections (RPIs)

Eleven inspections and one audit were undertaken at Ranger during the 2008–09 reporting period. A review of the audit findings from the May 2008 environmental audit was conducted in November 2008, and an audit of the Water Management Plan was conducted in May 2009. RPIs were carried out for each other month of the 2008–09 reporting year. Table 2.3 shows the focus areas for the audit and RPIs for the year.

TABLE 2.3 AUDIT AND RPI

Date	Inspection type	Foci
9 July 2008	RPI	TSF efflorescence, Magela Creek
20 August 2008	RPI	Water treatment plant, RP2, RP3, TSF, Pit 1, trial landform, sewage treatment facilities
10 September 2008	RPI	Exploration in Magela Land Application Area, western stockpile, tailings corridor, Pit 3, clarifier
15 October 2008	RPI	Clarifier, sand filters, GCMBL, TSF and tailings corridor, Corridor Creek Land Application Area, radiation laboratories, fly-in fly-out camp, trial landform
12 November 2008	Audit Review	Outstanding findings from the 2008 audit of applications and proposals 2004–2007
	RPI	RP1, RP1 wetland filter, TSF and tailings corridor, Pit 1, trial landform
10 December 2008	RPI	RP1, RP2, RP3, GCMBL, southern 2s stockpile, TSF and tailings corridor, western 1s stockpile, evaporation ponds, Pit 3, Ranger 3 deeps exploration, access road culverts
14 January 2009	RPI	RP1, southern 2s stockpile, TSF and tailings corridor, Ranger 3 deeps exploration, trial landform
17 February 2009	RPI	Tailings corridor, RP1, GCMBL, trial landform, Magela Creek
17 March 2009	RPI	Product packing, lime storage silos, leach tanks, grinding circuit, tailings corridor
21 April 2009	RPI	Admin building, potable water tanks and potable water system, radiation clearance procedures, RP1, TSF, Pit 3
11–14 May 2009	Audit	Commitments in the 2008–09 Water Management Plan
16 June 2009	RPI	Radiometric sorter and laterite treatment plants, primary crusher, processing plant

Audit outcomes

2008 audit review

The 2008 audit review followed up outstanding actions from the May 2008 environmental audit of a range of applications and proposals submitted to the Supervising Authority by ERA between 2004–2007. Four items from the audit that were ranked as either a category 2 non-conformance or conditional were followed up. The category 2 non-conformance was ranked against criteria relating to the operation of land application areas. The non-conformance was ranked according to:

- Irrigation rates exceeding 9 mm per day
- Surface pooling in land application areas
- Bunding not instated at Jabiru East land application area.

The audit review found all criteria acceptable.

Three criteria ranked as conditional during the audit were reinvestigated at the audit review. These criteria related to inductions and monitoring equipment in the Pit 1 catchment. The audit review found these criteria acceptable.

May 2009 environmental audit

The 2009 environmental audit of Ranger mine was held on 11–14 May 2009. The audit team was made up of representatives from the NLC, DRDPIFR and ***oss***. The subject of the 2009 audit was the 2008–09 ERA Ranger Water Management Plan.

Seventy-two commitments were audited against the ranking system shown in Table 2.4. Use of this ranking system ensures the outcomes of the Ranger auditing process are consistent with other mines in the Northern Territory.

TABLE 2.4 GRADING SYSTEM

Category 1 Non-Conformance (CAT 1)	A Category 1 non-conformance refers to a situation where an identified activity is not in compliance with the Authorisation, approval document or applicable legislation and could result in a high risk or is a persistent Category 2 non-conformance.
Category 2 Non-Conformance (CAT 2)	A Category 2 non-conformance relates to an isolated lapse of control or an identified activity that is not in compliance with the Authorisation, approval document or applicable legislation that could result in a low or moderate risk.
Conditional (C)	This includes items that have been identified during planning that meet the established criteria and have commenced but have yet to be completed.
Acceptable (A)	This includes items that have been identified during planning that meet the established criteria and have been completed.
Not Verified (NV)	This is where compliance with the item has not been assessed. This may also include items that have been identified during planning but have yet to commence.
Observation (O)	An area that has notably improved or has the potential to be improved, or is outside the scope of the audit but is notable.

The audit team was satisfied that Ranger complied with 66 of the 72 commitments audited. The six remaining commitments were determined as follows:

- 1 category 2 non-conformance
- 5 conditional

The criteria ranked as a category 2 non-conformance related to measures in place to control impacts resulting from failure of the tailings delivery or return water pipelines. The audit found that the pipeline sleeve on the tailings delivery pipeline did not cover the pipe completely to the bunded area. This was ranked as a category 2 non-conformance as it is recognised as an isolated lapse in control and presents a low risk of impact to the receiving environment in the event of pipeline failure (due to the presence of additional controls).

The audit team viewed RP1 discharge records which showed that discharge via siphon and pump occurred on two occasions in January 2009 when flow in the creek measured 8 m^3/s and 6 m^3/s respectively. The commitment in the Water Management Plan refers to discharge when there is 'adequate' flow in Magela Creek. ERA provided the 2008–09 wet season rainfall chart to compare the level of rainfall at the times of discharge from RP1. The audit team was not satisfied that 8 m^3/s and 6 m^3/s constituted adequate flow and as such this criteria was ranked as conditional.

The Water Management Plan contains a range of commitments to ensure the potable water system remains isolated from the process and pond water systems at Ranger. The audit found that significant progress has been made towards achieving these commitments, however, a potable water fitting without a non-return valve was located at the tailings neutralisation bund and some of the new boot washes, connected to the potable water system, were unlabelled. This criteria was ranked conditional on ERA completing all the required labelling and installing a non-return valve on the potable water line identified above.

The Water Management Plan requires that land application rates are capped at 9 mm per day, and during land application a daily inspection of the areas under operation is made to detect any water logging, seepage or visible adverse effects. Document review during the audit found that pooling was observed in the land application areas on several days when the irrigation system was operating. Further review found that on days immediately following observations of pooling, the irrigation system was switched off to prevent further pooling and overland flow. This criteria was ranked as conditional because it was not clear how different ERA staff were defining 'pooling' of irrigated waters.

ERA's Water Management Plan states that its groundwater sampling program aligns with the requirements of the Australian Standard with the exception of low recharge bores that may require micro-purging. Due to this deviation, this criteria was ranked as conditional on ERA implementing necessary changes to achieve alignment with the relevant Australian Standard.

The Water Management Plan implies that bunding exists on the borders of all land application areas. ERA informed the audit team that bunding is not required on all land application areas and is not in place in all areas. This criteria was ranked as conditional on ERA updating the Water Management Plan to correctly reflect the requirements for each LAA. (ERA stated that bunding is required when Jabiru East, Magela and Djalkmara Land Application Areas are operational.)

A range of control measures are stated in the Water Management Plan to manage potential impacts to downstream water quality in the event that poor water quality is detected in the lower reaches of Corridor Creek. This criteria was ranked conditional upon the installation of the EC alarm for GCMBL in the real time environmental monitoring system.

oss will follow up on the identified non-conformances through the RPI process.

Minesite Technical Committee

The Ranger Minesite Technical Committee met six times during 2008–09. Dates of meetings and issues discussed are shown in Table 2.5. Significant agenda items discussed at MTCs included updates from ERA on site activities, updates from the Ranger Closure Criteria Working Group, the status of the Authorisation and the tailings storage facility lift. The Ranger Closure Criteria Working Group reconvened in June 2008. Terms of reference have been established for the group, which aims to develop and agree upon closure criteria for Ranger. Throughout 2008–09, the working group met following each Ranger and Jabiluka MTC.

TABLE 2.5 RANGER MINESITE TECHNICAL COMMITTEE MEETINGS

Date	Significant agenda items in addition to standing items
4 July 2008	Annual Plan of Rehabilitation (APR) 33, incident investigations, 2008 Audit report
26 August 2008	Exploration at anomaly 4 and Ranger 18 East, APR 33, efflorescence investigation, new SSD sampling locations in Magela Creek, trial landform
1 October 2008	Efflorescence investigation, final tailings level in Pit 1, exploration in Ranger 3 deeps, RP1 wetland filter performance, TSF and associated water management
10 November 2008	Efflorescence investigation, RP1 wetland filter performance, ERA application to optimise the radiation and atmospheric monitoring plan, Jabiru accommodation, Ranger Expansion Project, land application
16 February 2009	Water Management Plan, ERA application to optimise the radiation and atmospheric monitoring plan, tailings delivery system, EC event measured in Magela Creek (western channel), TSF excavation seeps, APR 34
7 May 2009	Water Management Plan, ERA application to optimise the radiation and atmospheric monitoring plan, revised application to raise the TSF MOL, efflorescence incident investigation, heap leach and exploration decline referrals, APR 34

Authorisations and approvals

There were no changes to the Ranger Authorisation 0108-10 during the reporting period.

ERA's application to the Supervising Authority to raise the MOL of the TSF will require alteration of the Authorisation, however, this application is still under consideration by the Supervising Authority. ERA is yet to finalise an application to optimise the radiation and atmospheric monitoring plan.

Incidents

Background to incident investigation

Since 2000, ERA has undertaken to provide stakeholders with a comprehensive list of environmental incidents reported at its Ranger and Jabiluka operations on a regular basis. The regular monthly environmental incident report is additional to reports made to meet the statutory requirements for incident reporting. This regime of reporting all recorded environmental incidents is undertaken voluntarily by ERA in response to concerns expressed by stakeholders about the establishment of suitable thresholds of incident severity for reporting.

Immediately upon receipt of notification of any incident, ***oss*** assesses the circumstances of the situation and a senior officer makes a decision on the appropriate level of response. Dependent on the assessment, this response will range from implementation of an immediate independent investigation, through seeking further information from the mine operator before making such a decision. In those cases where immediate action is not considered to be required, the situation is again reviewed on receipt of a formal incident investigation report from the operator.

Prior to each routine periodic inspection (see section 2.1.2), the inspection team reviews the previous month's environmental incident report summary (EIRS) and any open issues. Where incidents are considered to have any potential environmental significance or represent repetitions of a class of occurrences, an on-site review is scheduled as a part of the routine inspection protocol.

oss determined that no incidents that occurred during the reporting period were of a serious enough nature to warrant a separate independent investigation, however, the following incidents were followed up as part of the routine periodic inspections.

TSF Efflorescence

In June 2008, SSD was advised that an area of salt efflorescence had been observed along a track to the west of the TSF. SSD officers visited the site and obtained samples of the salt material during the July RPI. Analysis of the salts was somewhat confounded due to soil contamination as the salts were crusted onto the soil making it impossible to obtain a completely clean sample. Analysis of Mn levels and Mg/SO_4 and NH_3/NO_3 ratios in the salts indicated that they were unlikely to be sourced from process water, and more likely from rainfall shed from the outer walls of the TSF which are composed of fresh waste rock. ERA has now installed a series of swale drains around the toe of the TSF such that all runoff water is directed to specific drainage points at which point it can be tested for quality and pumped back if necessary.

Controlled area vehicles

Two incidents were reported to the Supervising Authority during the reporting period relating to the operation of controlled area vehicles outside controlled areas. The first such incident occurred on 27 July 2008 when two ERA staff were observed driving a controlled area vehicle along the access track to Radon Springs, south of the Ranger lease. The second incident occurred on 29 September 2008 and involved ERA staff driving a controlled area vehicle off site via the gate house entrance. These incidents were followed up through review of radiation management procedures during the RPI process. It was determined that neither incident resulted in a credible risk of radiation exposure to the public or the environment. ERA identified that there was potential for staff to be unaware of the vehicles designation if signage on the exterior wasn't clear. All controlled area vehicles now have prominent internal signage to ensure all occupants are aware they are travelling in controlled vehicles.

Minsup potable water connection

A minsup fitting was attached to the potable water system as a result of ERA staff failing to follow procedure. This incident was reported to stakeholders in the November 2008 EIRS. ***oss*** reviewed this incident with ERA during subsequent RPIs. All potable water fittings on site have subsequently been reviewed and altered where necessary to ensure fitting of minsup couplings cannot occur.

Airstream helmet failure

ERA reported that an employee was unblocking a rotary valve at the base of the calciner which involved removal of the hatch covers above and below the rotary valve. In doing this, product build up against the covers fell out on the ground causing a dust cloud. The employee felt some dust in their eye when tilting their head to look for further blockages in the area after the dust had settled. ERA determined the cause of this incident to be failure of the seal on the air stream helmet and implemented further corrective actions to prevent recurrence of this incident. ***oss*** reviewed the corrective actions and incident details with ERA during the RPI process. A worst case dose assessment conducted by ERA indicated the employee may have been exposed to a maximum dose of approximately 700 µSv, as compared with the annual limit for designated workers of 20 000 µSv (20 mSv).

Product bin clean-out

On 18 October 2008, water passed through the calciner and into the final product hopper in the product packing area at Ranger mine. This caused the product hopper to become clogged necessitating a clean-out operation over several days. Subsequent to these works, SSD undertook a dose assessment which determined that doses to employees were likely to be in the order of 20 µSv compared with the annual limit for designated workers of 20 000 µSv (20 mSv). SSD, however, retained some concerns with the management of the operation and the Supervising Scientist wrote to ERA in this regard.

2.2.3 Off-site environmental protection

Surface water quality

Under the Authorisation, ERA is required to monitor and report on water quality in Magela and Gulungul Creeks adjacent to Ranger mine. Specific water quality objectives must be achieved in Magela Creek.

The Authorisation specifies the sites, the frequency of sampling and the analytes to be reported. Each week during the wet season, ERA reports the water quality at key sites at Ranger, including Magela and Gulungul Creeks, to the major stakeholders (the Supervising

Scientist, DRDPIFR and NLC). A detailed interpretation of water quality across the site is provided at the end of each wet season in the ERA Ranger Annual Wet-season Report.

In addition to ERA's monitoring program, the Supervising Scientist conducts an independent surface water quality monitoring program that includes measurement of chemical and physical variables in Magela and Gulungul Creeks, and biological monitoring in Magela and Gulungul Creeks as well as other reference creeks and waterbodies in the region. Key results (including time-series charts of key variables of water quality) are reported through the wet season on the Internet at www.environment.gov.au/ssd/monitoring/index.html. The highlights of the monitoring results are summarised below.

Chemical and physical monitoring of Magela Creek

The Supervising Scientist Division (SSD) modified its wet season monitoring program in 2008–09 to enhance the ability of SSD to independently detect changes while reducing replication of monitoring activities that are already carried out by other agencies (see chapter 3, section 3.1).

From the 2008–09 wet season (and hereafter), there has been close integration of the grab sampling water quality monitoring program with continuous water quality monitoring and in situ toxicity monitoring programs. Routine water chemistry weekly grab sample collections were relocated to SSD's upstream and downstream continuous monitoring and in situ toxicity monitoring sites to provide better overlap between these methods. These weekly samples, as for previous seasons, are measured for key mine site analytes, including physicochemical parameters. Map 2 shows the location of the upstream and downstream sites and key Ranger mine features. More details about the technical basis for these changes are provided in chapter 3, section 3.1.

The downstream site incorporating chemistry (continuous and grab) and in situ toxicity monitoring is located in the west channel of Magela Creek whereas the previous downstream chemistry grab sampling site was located in the central channel of Magela Creek at the GS009 compliance location.

The west channel has historically shown elevated solute levels when compared with the central channel, particularly in relation to discharges of water from Ranger Retention Pond 1 (RP1). Water released from RP1 enters Coonjimba Billabong, which drains into the west side of Magela Creek. Continuous and grab sample electrical conductivity monitoring in previous years shows that the water from RP1 mixes incompletely in the west channel and preferentially follows the side near the western bank, particularly during low flow periods.

Statistical comparisons (ANOVA) of water chemistry of the downstream central channel site with the west channel downstream site for similar sampling periods over the last six years (water chemistry data from the creekside toxicity monitoring program) show that there are differences between these two sites, with the west channel site having slightly higher concentrations of uranium, magnesium and sulfate than the central channel site (see chapter 3, section 3.1). However, these differences are minor and are not regarded as sufficient to affect the decision to relocate the sampling sites, particularly as sampling at the west channel site will result in a more conservative assessment of the contribution of the minesite to solutes in Magela Creek.

The first water chemistry samples for the Supervising Scientist's 2008–09 wet season surface water monitoring program were collected from Magela Creek on 26 November 2008 immediately after commencement of surface flow. Weekly sampling continued throughout the season with the last samples collected on 10 June 2009. On 16 June 2009, MTC stakeholders agreed that continuous surface flow had ceased in Magela Creek and monitoring of the creek was no longer required.

On 11 February 2009, electrical conductivity (EC) of 45 µS/cm was measured in the grab sample from the downstream site (Figure 2.2), which exceeds the statistically derived guideline value of 43 µS/cm. This corresponded with elevated magnesium (3.3 mg/L) and sulfate (12.2 mg/L). Continuous monitoring data (Figure 2.3) showed that this value corresponded with the peak of an EC event that lasted 30 hours and for which EC remained above 43 µS/cm for 5 hours.

SSD considers the pulse of magnesium and sulfate had likely originated from RP1 (via Coonjimba Billabong). It is likely that an increase in flow (and water level) in Magela Creek that occurred on 8–9 February had initially restricted flow from Coonjimba Billabong. As the Magela Creek water level dropped between 9 and 11 February, water held back in Coonjimba Billabong drained out causing the increase in EC at the downstream site (Figure 2.3).

Ecotoxicological research conducted by SSD suggests that there has been no detrimental environmental impact from this short-lived event.

On 18 February, uranium was approximately 6% of the limit and measured 0.37 µg/L at the SSD downstream site compared with 0.028 µg/L at the upstream site (Figure 2.4). This concentration is similar to uranium concentrations measured by the creekside field toxicity monitoring program on two occasions in 2002–2003 and once in the 2006–2007 wet season. On each of these occasions, field toxicity monitoring (including the in situ test conducted 16–20 February 2009) showed no detectable biological effects.

The routine grab sample on 18 March 2009 coincided with another EC event at the downstream site (Figure 2.2). The values of EC, magnesium and sulfate measured in this sample were 44 µS/cm, 3 mg/L and 10 mg/L, respectively. Continuous monitoring data (Figure 2.3) showed that this event peaked at 47 µS/cm and lasted about 20 hours, with EC exceeding 43 µS/cm for 8 hours. There had been increased discharge in Magela Creek during the previous day (from increased rainfall in the catchment) and the resultant water level decrease on 18 March would have led to increased drainage from Coonjimba Billabong back into Magela Creek, and hence explains the increase in EC.

From mid-April, typical end of season trends were apparent as the water level decreased. Manganese concentrations at the downstream site increased as groundwater influences started to dominate, and electrical conductivity between the upstream and downstream sites became similar as minesite influences decreased.

Overall, the data from continuous monitoring and grab sample monitoring programs suggest that water quality in Magela Creek was comparable with previous seasons (for the west channel). Figure 2.5 shows that uranium concentrations for the 2008–09 wet season were comparable with previous seasons for the downstream west channel environment.

The results from the in situ toxicity monitoring program using freshwater snails (see later in this section) provided reassurance that the aquatic environment of Magela Creek remained protected from activities at Ranger mine.

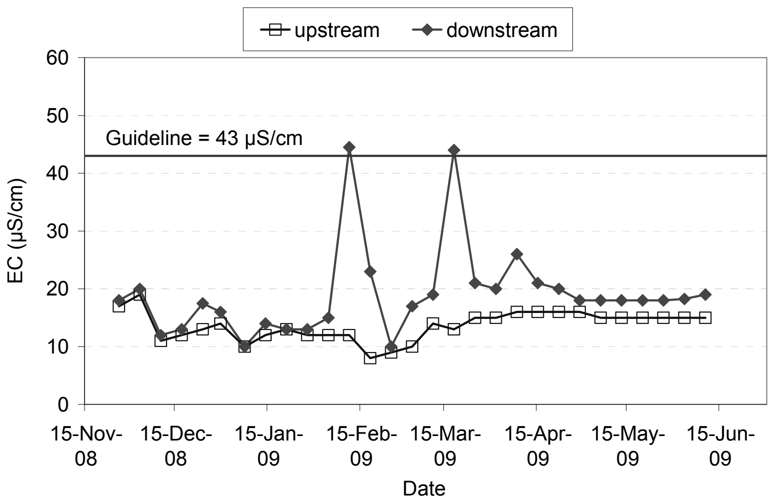


Figure 2.2 Electrical conductivity measurements in Magela Creek (SSD data) between November 2008 and June 2009

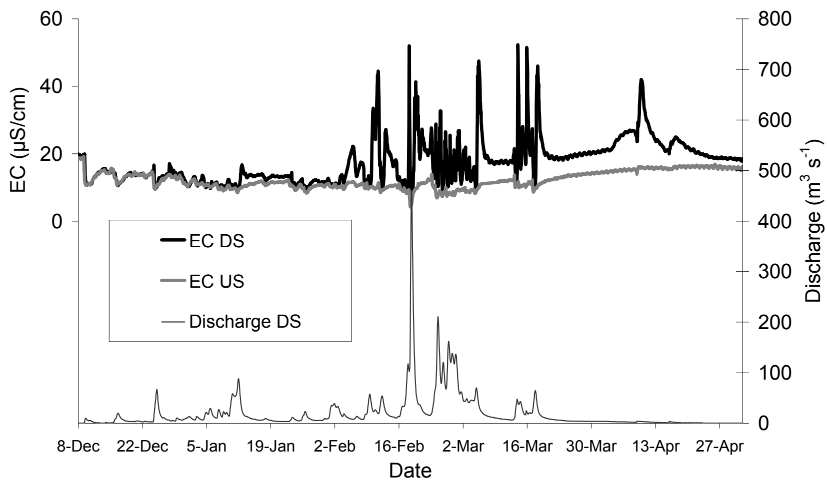


Figure 2.3 Electrical conductivity and discharge measurements in Magela Creek between December 2008 and April 2009 – continuous monitoring data

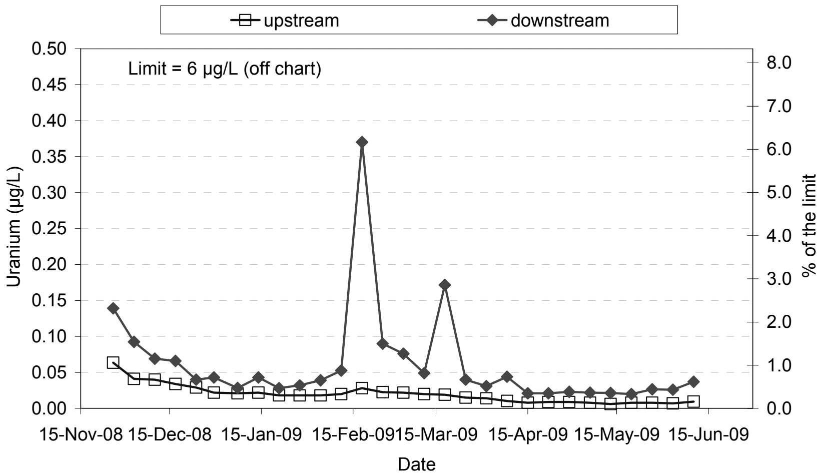


Figure 2.4 Uranium concentrations measured in Magela Creek by SSD between November 2008 and June 2009.

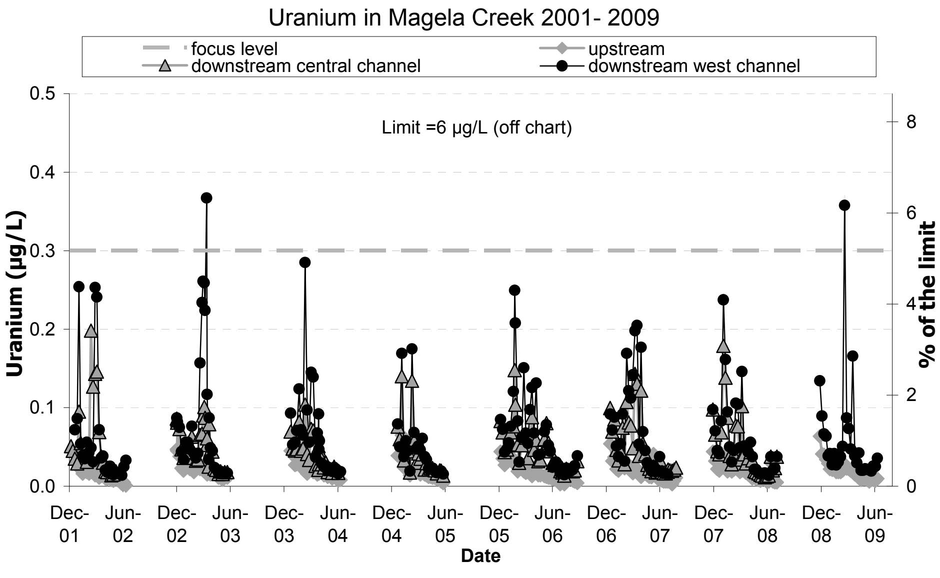


Figure 2.5 Uranium concentrations in Magela Creek since the 2000–01 wet season (SSD data)

Radium in Magela Creek

Radium-226 (^{226}Ra) results for the 2008–09 wet season can be compared with previous wet season data from 2001–02 through to 2007–08 (Figure 2.6). The data from sample composites (weekly collected samples were combined from 2006–07 onwards to give monthly averages) show that the levels of ^{226}Ra are very low in Magela Creek, including downstream of Ranger mine. The anomalous ^{226}Ra concentration of 8.8 mBq/L in a sample collected from the control site upstream of Ranger in 2005 was probably due to a higher contribution of ^{226}Ra-rich soil or finer sediments that are present naturally in Magela Creek. This has previously been explained in the 2004–05 Supervising Scientist annual report.

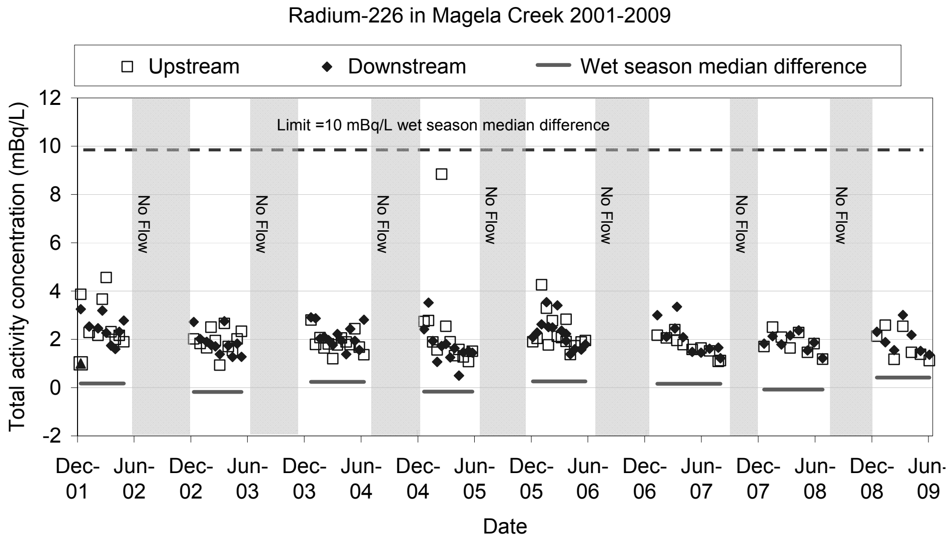


Figure 2.6 Radium-226 in Magela Creek 2001–09 (SSD data)

The limit for total ^{226}Ra activity concentration has been defined for human radiological protection purposes. The median of all ^{226}Ra data collected over the 2008–09 wet season is calculated for both the upstream and the downstream sites. The median of the upstream data is then subtracted from the median of the downstream data. This difference value, called the 'wet season median difference', should not exceed 10 mBq/L.

All wet season median differences (shown by the grey solid line in the graphs) from 2001 to 2009 are close to zero, indicating that ^{226}Ra levels at both sites in Magela Creek are due to the natural occurrence of radium in the environment. Thus, it is concluded that there is no significant input of ^{226}Ra from the Ranger minesite into Magela Creek.

Chemical and physical monitoring of Gulungul Creek

Weekly grab sampling for routine analysis of water chemistry variables at the upstream site was discontinued for the 2008–09 wet season, as this site does not represent a useful reference location for the Gulungul catchment. Water chemistry data measured at this site indicate that upstream (natural) catchment influences compromise its effectiveness for assessing downstream impacts from the mine. Weekly grab sample monitoring continued at the downstream site. Continuous monitoring of electrical conductivity (EC) and turbidity was maintained at both the downstream and upstream sites.

The first water chemistry samples for SSD's 2008–09 wet season surface water monitoring program were collected from Gulungul Creek on 30 December 2008, immediately after commencement of surface flow. Weekly sampling continued throughout the season with the last samples collected on 20 May 2009. On 22 May 2009, MTC stakeholders agreed that continuous surface flow had ceased in Gulungul Creek and monitoring of the creek was no longer required.

There was considerable work carried out during the 2008 dry season on the Ranger mine tailings storage facility (TSF) with substantial quantities of waste rock used to raise the TSF wall. Water run-off from this waste rock may have contributed to the observed elevations in EC (Figure 2.7 and Figure 2.8), uranium (Figure 2.9) and sulfate concentrations at the Gulungul Creek downstream site compared with recent years. In addition, discharge in Gulungul Creek (Figure 2.8) was lower than previous years due to less rainfall in the catchment (Figure 2.1), and hence dilution of solutes may have also have been less compared with previous years.

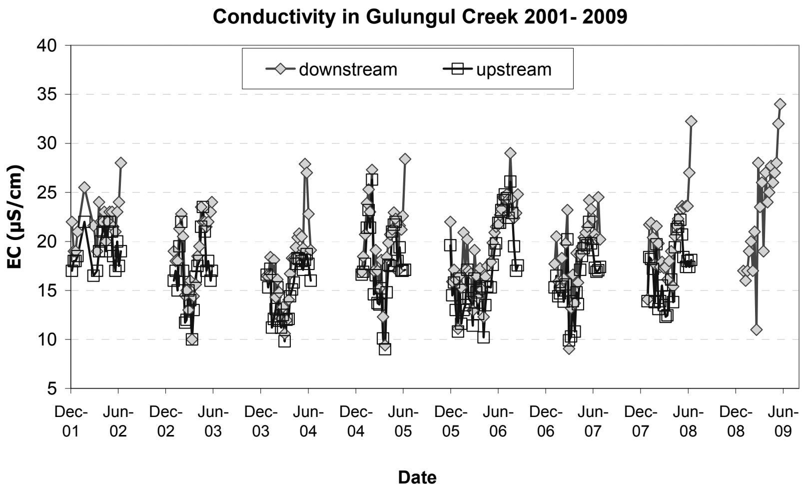


Figure 2.7 Electrical conductivity measurements in Gulungul Creek for the 2008–09 wet season

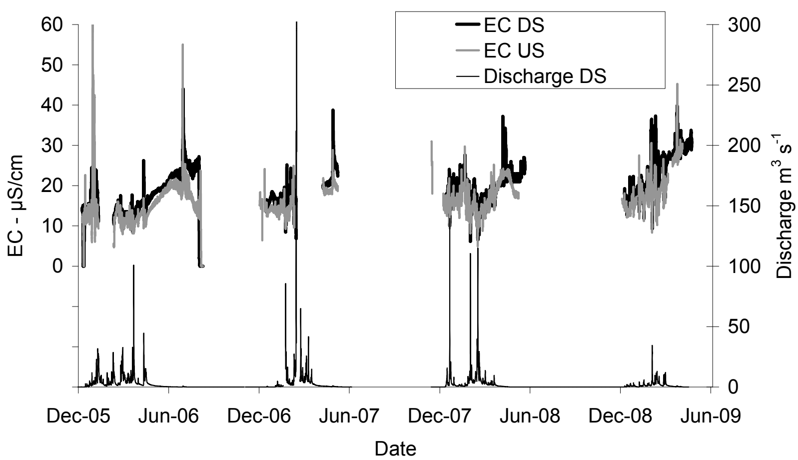


Figure 2.8 Electrical conductivity and discharge in Gulungul Creek 2005–2009 – continuous monitoring

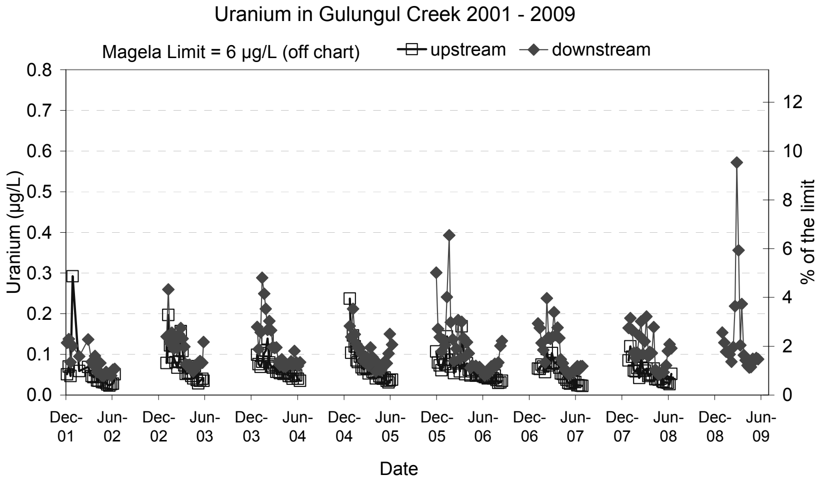


Figure 2.9 Uranium concentrations in Gulungul Creek between 2000 and 2009 (SSD data)

On 25 February 2009, a uranium value of 0.57 µg/L (Figure 2.10) measured at the downstream site (<10% of the Magela Creek limit) coincided with slightly elevated electrical conductivity (28 µS/cm) and sulfate concentration (2.7 mg/L). On 4 March 2009, uranium measured 0.36 µg/L at the downstream site (Figure 2.10), again coinciding with slightly elevated EC (24 µS/cm) and sulfate concentration (2.7 mg/L). Since the results of biological monitoring of macroinvertebrates in Gulungul Creek (see later in this section) show no evidence of impact and the chemical variables are less than the guidelines and limits set for Magela Creek, it is considered that none of these excursions are environmentally significant.

After mid March 2009, uranium decreased to concentrations less than 0.2 µg/L (< 2% of the limit) which is comparable with previous seasons' measurements (Figure 2.9).

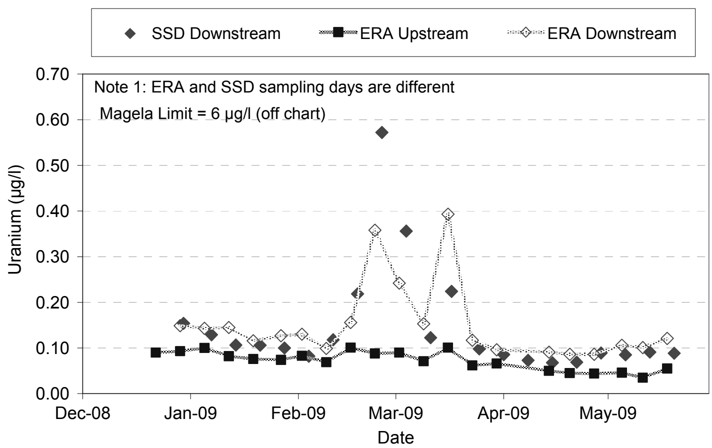


Figure 2.10 Uranium concentrations measured in Gulungul Creek by SSD and ERA during the 2008–09 wet season

From early April, recessional flow characteristics became apparent with electrical conductivity at the upstream and downstream sites becoming more similar and manganese concentrations increasing as groundwater inputs started to dominate.

Overall, the water quality of Gulungul Creek suggests that the aquatic environment in the creek remained protected from activities at Ranger mine for the 2008–2009 season.

Biological monitoring in Magela Creek

Based on research conducted by the Environmental Research Institute of the Supervising Scientist (***eriss***) since 1987, biological monitoring techniques have been developed that can be used to assess the impact of uranium mining on aquatic ecosystems downstream of Ranger mine. Two broad approaches are used: early detection studies and assessment of overall ecosystem-level responses.

Early detection of effects in Magela Creek is assessed using two techniques: (i) toxicity monitoring used for detection at a weekly timescale of effects arising from inputs of mine waters during the wet season, and (ii) bioaccumulation, used to measure over a seasonal timescale a potential developing issue with bioavailability of mine-derived solutes (metals and radionuclides) in aquatic biota. For *ecosystem-level responses*, benthic macroinvertebrate and fish community data from Magela and Gulungul Creek sites are compared with historical data and data from control sites in streams unaffected by contemporary mining. The findings from toxicity monitoring, bioaccumulation, and fish and macroinvertebrate community studies conducted during the 2008–09 wet and early dry seasons are summarised below.

Toxicity monitoring

In this form of monitoring, effects of waters dispersed from the Ranger minesite on receiving waters are evaluated using responses of aquatic animals exposed in situ to creek waters. The response measured is reproduction (egg production) in the freshwater snail *Amerianna cumingi*. Each test runs over a four-day exposure period. This species has been shown to be among the most sensitive, to both uranium and magnesium, of SSD’s suite of six local species, as assessed under laboratory toxicity testing conditions.

For wet seasons in the 1990–91 to 2007–08 period, toxicity monitoring was carried out using the ‘creekside’ methodology, in which a continuous flow of water from the adjacent Magela Creek was pumped through tanks containing test animals located under a shelter on the creek bank. There were a number of practical constraints with this method, including high staff demands, reliance on complex powered pumping systems (in an area of high electrical storm activity) and vulnerability to extreme flood events. These constraints led to a rigorous evaluation of the viability of an in situ testing technique whereby floating containers are deployed in the creek itself. This method offered the potential of substantially lower staffing, infrastructure and maintenance requirements. The 2007–08 Supervising Scientist annual report (chapter 3, section 3.2) describes in detail the results of the two-year creekside versus in situ comparative assessment that demonstrated that the in situ technique is scientifically robust and constitutes an appropriate replacement for the creekside methodology. During the 2008–09 wet season, in situ toxicity monitoring was undertaken for the first time as the sole toxicity monitoring procedure.

Nine in situ toxicity tests were conducted on a fortnightly basis (ie every other week) over the 2008–09 wet season, the first commencing on 4 December 2008 and the final test commencing 30 March 2009. Snail egg production at upstream and downstream sites was generally similar across all nine tests (Figure 2.11A) and the pattern of egg production across all tests was similar to that observed in previous wet seasons. Importantly, the mean upstream-downstream difference value across the nine wet season tests plots around the running mean (since 1991–92 wet season, Figure 2.11B) while individual difference values (Figure 2.11A) are within the maximum and minimum values recorded over this time series (full dataset not shown here).

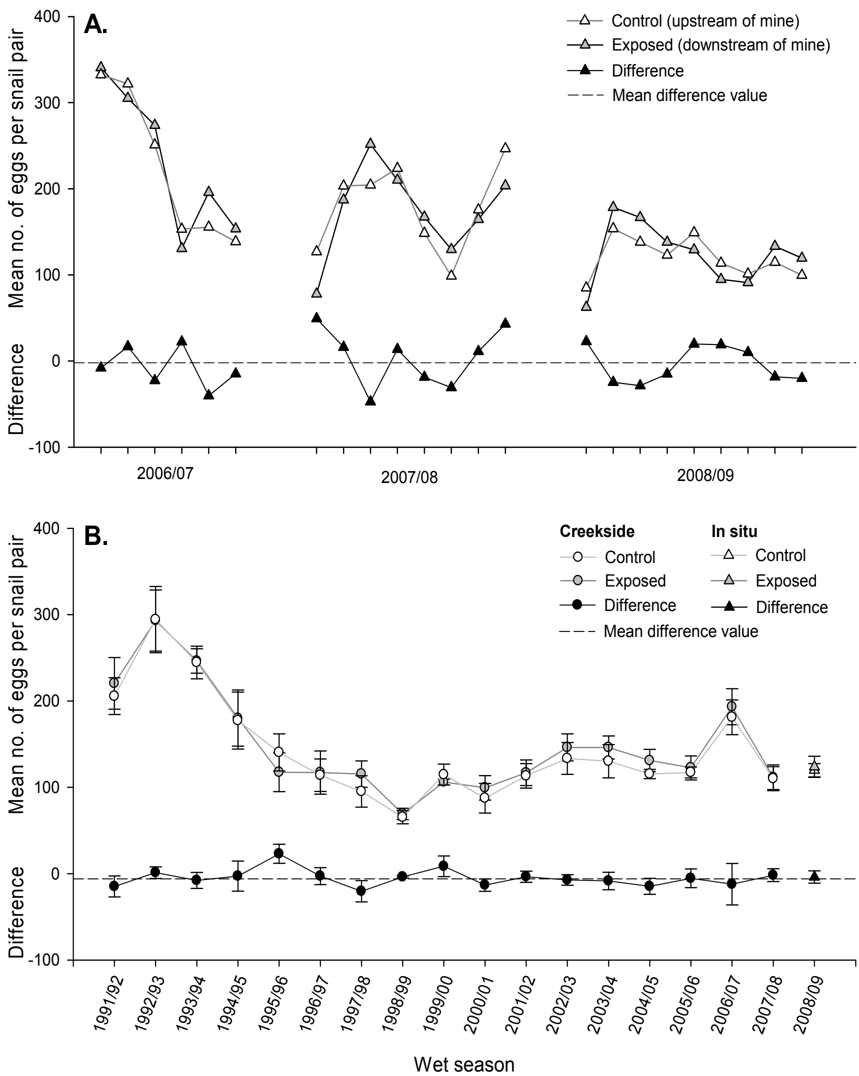


Figure 2.11 A. In situ toxicity monitoring results for freshwater snail egg production for past three wet seasons. B. Toxicity monitoring results by way of the average freshwater snail egg production for each wet season between 1992 and 2009. Error bars represent standard errors about the mean.

Improvements to the statistical analysis of toxicity monitoring data using Analysis Of Variance (ANOVA) testing were described in the 2007–08 Supervising Scientist annual report (chapter 2, section 2.2.3). The most important of the ANOVA factors tests for differences in the upstream-downstream difference values between two time periods – in this case and, in particular, test results for the current (2008–09) wet season versus all pre-2008–09 test data. No significant difference was found between the 2008–09 data and data from previous wet seasons ($p = 0.886$), confirming the visual assessment made on the graphical results. From these results it is concluded that no adverse effects on freshwater snails from inputs of Ranger minesite waters to Magela Creek occurred during the 2008–09 wet season.

Bioaccumulation in freshwater mussels

Mudginberri Billabong is the first major permanent waterbody downstream (12 km) of Ranger mine (Map 3). Local Aboriginal people harvest aquatic food items, in particular mussels, from the billabong and hence it is essential that they are fit for human consumption. Consequently, concentrations of metals and/or radionuclides in the tissues and organs of aquatic biota attributable to mine-derived inputs to Magela Creek must remain within acceptable levels. Enhanced body burdens of mine-derived solutes in biota could also potentially reach limits that may harm the organisms themselves as well as provide early warning of bioavailability of metals and radionuclides. Hence the bioaccumulation monitoring program serves an ecosystem protection role in addition to the human health aspect.

Mussel bioaccumulation data have been obtained intermittently by SSD from Mudginberri Billabong from 1980 to 2001. From 2002 onwards, there has been regular (annual) sampling from Mudginberri and a control site in the nearby Nourlangie catchment (Sandy Billabong). Only data from 2000 onwards (where methods are standardised and control sites have been included) will be discussed in this report. The data prior to 2000 have been presented and discussed in previous SSD annual reports.

Bioaccumulation of uranium and radium in freshwater mussels

Uranium concentrations in freshwater mussels, water and sediment samples collected concurrently from Mudginberri and Sandy Billabongs are shown in Figure 2.12. The mean concentrations of uranium in mussels from both Mudginberri and Sandy Billabongs are very similar from 2000 onwards, with no evidence of an increasing trend in concentration in Mudginberri mussels over time.

The lack of any increase in concentration of U in mussel tissues through time, with essentially constant levels observed between 1989 and 1995 (as reported in previous reports), and consistently low levels from 2000 to the last sample taken in October 2008, indicates absence of any significant mining influence.

Concentrations of Ra in mussels are age-dependent (Figure 2.13) and also appear to be related to growth rates, seasonal soft body weights, water chemistry and sediment characteristics (chapter 3, section 3.3, 2007–08 Supervising Scientist annual report, and chapter 3, section 3.6 of this report). A longitudinal study along the Magela Creek catchment conducted in 2007 measuring uptake of radium and uranium in mussels showed that radium uptake was largely due to natural catchment influences rather than a mining-related feature (Supervising Scientist annual report 2007–08).

The average annual committed effective doses calculated for a 10-year old child who eats 2 kg of mussel flesh, based upon average concentrations of ^{226}Ra and ^{210}Pb from Mudginberri Billabong mussels collected between 2000 and 2008 is approximately 0.2 mSv. The average for Sandy Billabong mussels collected between 2002 and 2008 is approximately 0.1 mSv.

The generally consistent relationship between mussel age and Ra concentration for each billabong (Figure 2.13) currently provides a robust baseline against which any future mine-related change in Ra concentrations can be detected.

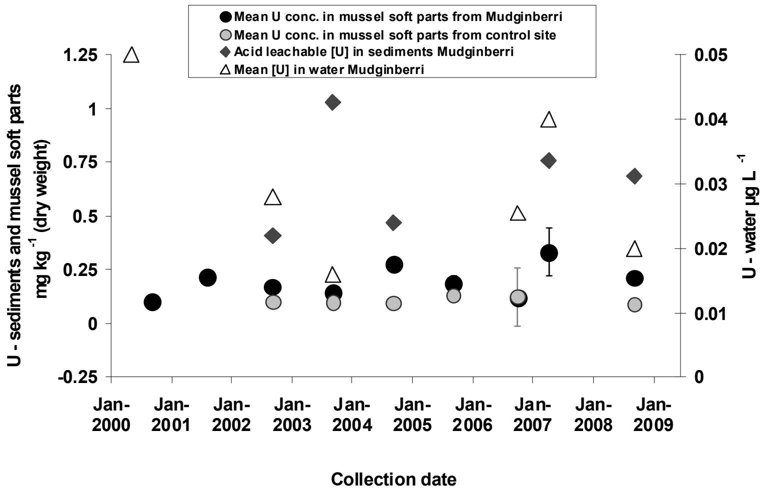


Figure 2.12 Mean concentrations of uranium measured in mussel soft-parts, sediment and water samples collected from Mudginberri Billabong and Sandy Billabong since 2000

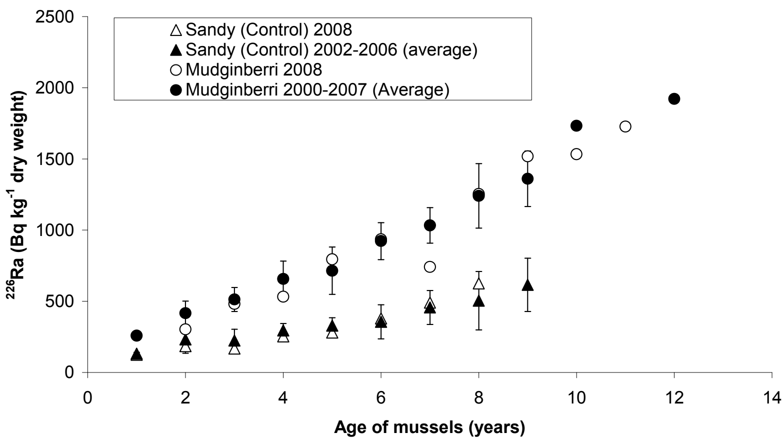


Figure 2.13 ^{226}Ra activity concentrations in the dried flesh of freshwater mussels collected from Mudginberri Billabong 2000–2008 and Sandy Billabong 2002–2008. Mussels were not collected from Sandy Billabong in 2007. The error bars are ± 1 standard deviation.

In 2008, a longitudinal study of radium and uranium uptake in mussels in Mudginberri Billabong was undertaken to determine if the location of sampling in the billabong had a significant effect on the levels of Ra and U measured in mussels. The findings from this work are presented in chapter 3, section 3.6 of this annual report.

Monitoring using macroinvertebrate community structure

Macroinvertebrate communities have been sampled from a number of sites in Magela Creek at the end of significant wet season flows, each year from 1988 to the present. The design and methodology have been gradually refined over this period (changes are described in the 2003–04 Supervising Scientist annual report, chapter 2, section 2.2.3). The design is now a balanced one comprising upstream and downstream sites at two 'exposed' streams (Gulungul and Magela Creeks) and two control streams (Burdulba and Nourlangie Creeks).

Samples were collected from each site at the end of each wet season (between April and May). For each sampling occasion and for each pair of sites for a particular stream, dissimilarity indices are calculated. These indices are a measure of the extent to which macroinvertebrate communities of the two sites differ from one another. A value of 0% indicates macroinvertebrate communities identical in structure, while a value of 100% indicates totally dissimilar communities, sharing no common taxa.

Disturbed sites, including those impacted by activities other than mining, may be associated with significantly higher dissimilarity values compared with undisturbed sites. Compilation of the full macroinvertebrate dataset from 1988 to 2008, and data from the paired sites in the two 'exposed' streams, Magela and Gulungul Creeks, for 2009, have been completed with results shown in Figure 2.14. This figure plots the paired-site dissimilarity values using family-level (log-transformed) data, for the two 'exposed' streams and the two 'control' streams.

Improvements to the presentation and statistical analysis of macroinvertebrate data were described in the 2007–08 Supervising Scientist annual report (chapter 2, section 2.2.3). Multi-factor ANOVA can be used to test whether or not macroinvertebrate community structure has altered significantly at the exposed sites for the recent wet season of interest, using dissimilarity values derived for each of the five possible randomly-paired upstream and downstream replicates. Only data gathered since 1998 have been used for this analysis. Data gathered prior to this time were based upon different and less rigorous sampling and sample processing methods, and/or the absence of any sampling in three of the four streams. (Sampling in Gulungul Creek and the control streams only commenced in 1994.)

Inferences that may be drawn from the data shown in Figure 2.14 are weakened because there are no baseline (pre-1980) data upon which to assess whether or not significant changes have occurred as a consequence of mining. Notwithstanding, a four-factor ANOVA based upon replicate, paired-site dissimilarity values and using the factors Before/After (BA; fixed), Control/Impact (CI; fixed), Year (nested within BA; fixed) and Site (nested within CI; random) showed no significant difference (in dissimilarity) between the control and exposed streams from earlier years (back to 1998) compared with those from 2008 (ie the BA x CI interaction is not significant). While the Year x Site (BA CI) interaction is significant in the same analysis ($p = 0.014$), this simply indicates that dissimilarity values for the different streams – regardless of their status (Before, After, Control, Impact) – show differences through time. The dissimilarity plots shown in Figure 2.14 corroborate these results, showing reasonable constancy in the mean dissimilarity values for each stream across all years.

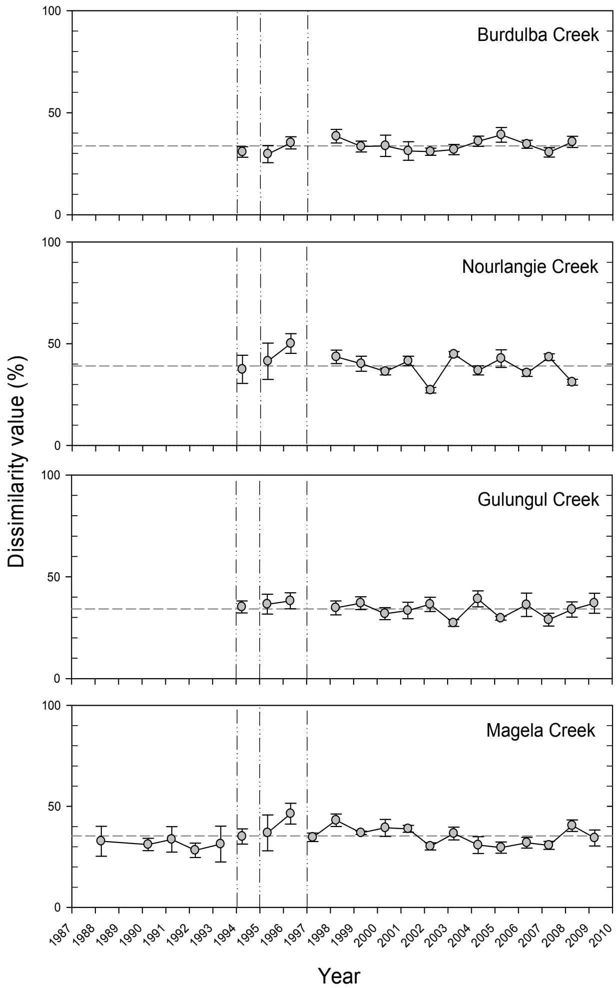


Figure 2.14 Paired upstream-downstream dissimilarity values (using the Bray-Curtis measure) calculated for community structure of macroinvertebrate families in several streams in the vicinity of Ranger mine for the period 1988 to 2009. The dashed vertical lines delineate periods for which a different sampling and/or sample processing method was used. Dashed horizontal lines indicate mean dissimilarity across years. Dissimilarity values represent means (± standard error) of the 5 possible (randomly-selected) pairwise comparisons of upstream-downstream replicate samples within each stream.

Dissimilarity indices such as those used in Figure 2.14 may also be 'mapped' using multivariate ordination techniques to depict the relationship of the community sampled at any one site and sampling occasion with all other possible samples. Samples close to one another in the ordination space indicate a similar community structure. Figure 2.15 depicts the ordination derived using the *pooled* (average) within-site macroinvertebrate data (unlike the replicate data used to construct the dissimilarity plots in Figure 2.14). Data points are displayed in terms of the sites sampled in Magela and Gulungul Creeks downstream of Ranger for each year of study (to 2009), relative to Magela and Gulungul Creek upstream (control) sites for 2009, and all other control sites sampled up to 2008 (Magela and Gulungul upstream sites, all sites in Burdulba and Nourlangie). Because the data-points associated with these two sites are generally interspersed among the points representing the control sites, this indicates that these 'exposed' sites have macroinvertebrate communities that are similar to those occurring at control sites. This was verified using ANOSIM (ANalysis Of SIMilarity, effectively an analogue of the univariate ANOVA) testing, to determine if exposed sites (Magela and Gulungul downstream) are significantly different from control sites in multivariate space. ANOSIM conducted on pooled (within-site) data from all years to 2009 showed no significant separation of exposed and control sites for the respective comparisons ($P>0.05$).

Collectively, these graphical and statistical results provide good evidence that changes to water quality downstream of Ranger as a consequence of mining in the period 1994 to 2009 have not adversely affected macroinvertebrate communities.

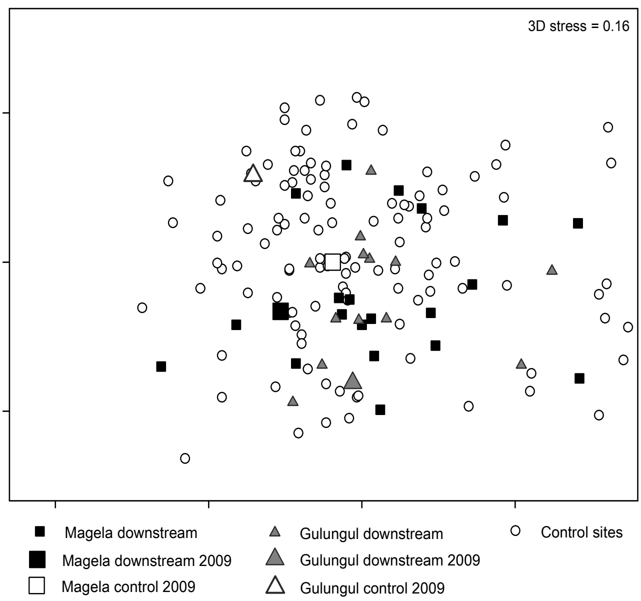


Figure 2.15 Ordination plot of macroinvertebrate community structure data from sites sampled in several streams in the vicinity of Ranger mine for the period 1988 to 2009. Data from Magela and Gulungul Creeks for 2009 are indicated by the enlarged symbols.

Monitoring using fish community structure

Assessment of fish communities in billabongs is conducted between late April and July each sampling year. Data are gathered using non-destructive sampling methods, from 'exposed' and 'control' sites in deep channel billabongs annually, and shallow lowland billabongs dominated by aquatic plants, biennially (every other year). Details of the sampling methods and sites were provided in the 2003–04 Supervising Scientist annual report, chapter 2, section 2.2.3. These programs were reviewed in October 2006 and the refinements to their design detailed in the 2006–07 and 2007–08 Supervising Scientist annual reports (shallow and channel billabong fish communities respectively).

For both deep channel and shallow lowland billabongs, comparisons are made between a directly-exposed billabong (Mudginberri) in the Magela Creek catchment downstream of Ranger mine versus control billabongs from an independent catchment (Nourlangie Creek and Wirnmuyurr Creek). The similarity of fish communities in exposed sites to those in control sites is determined using multivariate dissimilarity indices, calculated for each sampling occasion. The use of dissimilarity indices has been described and defined above ('Monitoring using macroinvertebrate community structure'). A significant change or trend in the dissimilarity values over time could imply mining impact.

Channel billabongs

The similarity of fish communities in Mudginberri Billabong (directly exposed site downstream of Ranger in Magela Creek catchment) and Sandy Billabong (control site in the Nourlangie Creek catchment) was determined using multivariate dissimilarity indices calculated for each annual sampling occasion. A plot of the dissimilarity values from 1994 to 2009 is shown in Figure 2.16.

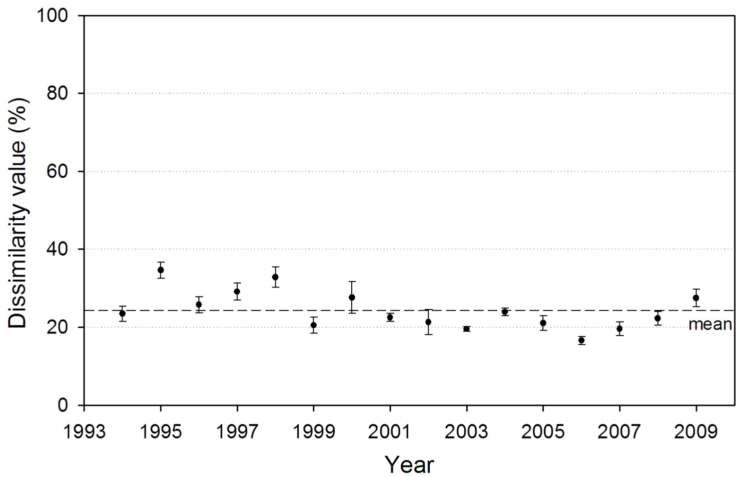


Figure 2.16 Paired control-exposed dissimilarity values (using the Bray-Curtis measure) calculated for community structure of fish in Mudginberri ('exposed') and Sandy ('control') Billabongs in the vicinity of Ranger mine over time. Values are means (± standard error) of the 5 possible (randomly-selected) pairwise comparisons of transect data between the two billabongs.

In the Supervising Scientist annual report for 2003–04, a decline in paired-site dissimilarity measures over time was noted. This decline in dissimilarity remains significant over the full dataset (1994 to 2009, $P < 0.001$), despite the increase in dissimilarity that has occurred since 2006 (Figure 2.16). In the Supervising Scientist annual report for 2007–08, a change in method procedure between the visual canoe (1989–2000) to the visual boat (2001–present) was identified as an issue that required closer scrutiny in the context of the changes seen in the dissimilarity index. This change potentially confounds the observed decline over time due to a significant increase in the time taken to complete each replicate visual count since 2001. The increase in transect times (since 2001) corresponds with a significant step down in the community dissimilarity value, which could potentially explain the overall decline over time. Increased transect times have typically resulted in increased observations of the more cryptic species. Theoretically, this could alter the paired-site community dissimilarity values between the two billabongs, particularly where observations of these less common species are more pronounced in one of the billabongs relative to the other billabong. To date, however, it has not been possible to characterise and quantify the effect, if any, that altered transect times have had on the community dissimilarity values. This is largely due to the complexities of changes in species abundances and their influence over fish community structure over time.

Notwithstanding, the dissimilarity observed in 2009 – the highest recorded since the introduction of the visual boat in 2001 – has occurred without change in sampling method, suggesting that transect times accompanying the change in observation method may not be so influential in determining dissimilarity values. The paired-site fish community dissimilarity value has increased since 2006 and may suggest that natural shifts in community structure over time are occurring. If this is the case, the nature of the community shift should become more evident over the next few years, leading to a possible explanation for the previously-identified decline or step down over time in community dissimilarity values.

In the Supervising Scientist annual report for 2004–05 (chapter 3, section 3.6.1), the chequered rainbowfish (*Melanotaenia splendida inornata*) was identified as the species that has had most influence on the change in the paired-billabong dissimilarity value. This species, due to its habit, appears unaffected by differences in transect times coinciding with the change to the observation method (Supervising Scientist annual report 2007–08) and as such, the abundances of this species may be regarded as reliable for the entire period that sampling has been conducted in Mudginberri Billabong, from 1989 to 2009. Chequered rainbowfish declined significantly in abundance after about 1996 with relatively low abundances sustained until 2008 (Figure 2.17) (Supervising Scientist annual report 2007–08). The elevated abundance in rainbowfish in 2009 (Figure 2.17) provides insights as to the possible cause of population fluctuations, and by association, therefore, the possible cause of interannual changes to the paired-billabong dissimilarity values.

For example, one of the environmental correlates identified in the decline in rainbowfish between 1989 and 2008 is the increase in grasses, and in particular the exotic para grass (*Urochloa mutica*), on Magela floodplain (Supervising Scientist annual report 2004–05). These grasses are still expanding on the floodplain yet rainbowfish abundances in 2009 have returned to values akin to those observed pre-1996 (Figure 2.17), suggesting the habitat conditions on Magela floodplain which is the recruitment source for these fishes, may not be overly important.

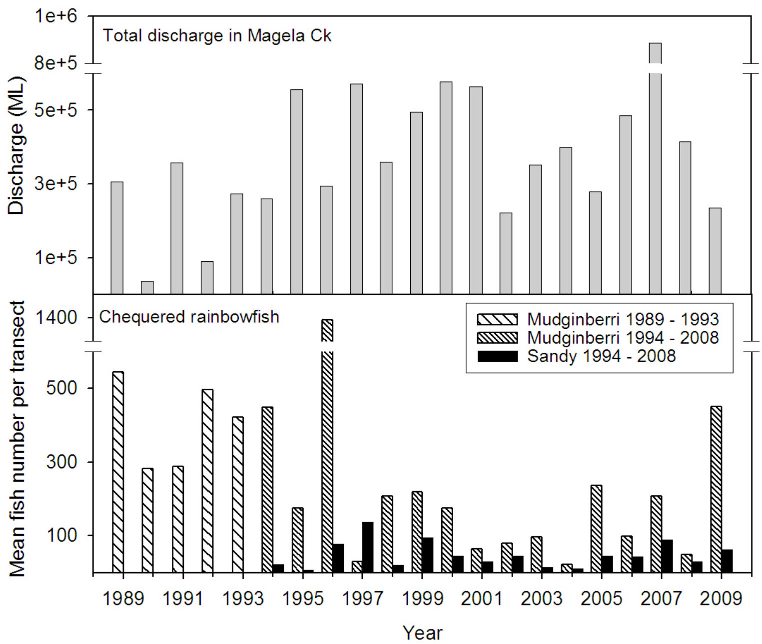


Figure 2.17 Relative abundance of chequered rainbowfish in Mudginberri and Sandy billabongs from 1989 to 2009 with associated total discharge in Magela Creek (gauging station G8210009)

In the Supervising Scientist annual report for 2004–05 (chapter 3, section 3.6.1) and Supervising Scientist annual report for 2007–08 (chapter 2, section 2.2.3) measures of wet season discharge in Magela Creek were identified as correlates of rainbowfish abundance. Rainbowfish abundance from 1989 to 2009 remains negatively correlated with wet season discharge (total monthly discharge in January ($p = 0.016$), February ($p = 0.016$) and the wet season total ($p = 0.029$)), supporting the suggestion that wet season intensity is a factor controlling the population numbers. Thus rainbowfish abundance is higher following wet seasons of relatively low rainfall (Figure 2.17).

A possible explanation for this relationship was proposed in the Supervising Scientist annual report for 2004–05 (chapter 3, section 3.6.1). In field toxicity monitoring tests, larval rainbowfish have been observed to be relatively intolerant of naturally low solute (including nutrient) concentrations that characterise surface waters in wet seasons of high stream discharge. Another causal link may relate to the greater dispersion of fish in wet seasons of higher discharge. In wet seasons of low discharge, stimuli for migration (flood pulses) are reduced, which may lead to fish concentrating more in lowland channel billabongs (Supervising Scientist annual report for 2007–08, chapter 2, section 2.2.3).

Importantly, the abundance of rainbowfish does not appear to be related to any change in water quality over time as a consequence of water management practices at Ranger mine. The net input of magnesium (Mg) from Ranger has been used as a reasonably reliable surrogate measure of mine water inputs to Magela Creek (see Supervising Scientist annual report 2004–05, chapter 3, section 3.6.1 for further information). For the wet seasons over the period of record from 1988–89 to 2008–09, no significant relationship has been observed between the mine contribution of Mg and corresponding rainbowfish abundance in Mudginberri Billabong. This is not surprising as concentrations of U and Mg in Magela Creek arising from mine waste water discharges are at least two orders of magnitude lower than those known to adversely affect larval fishes including, in the case of uranium, chequered rainbowfish (Supervising Scientist annual report 2003–04, chapter 3, section 3.4.1 & Supervising Scientist annual report 2004–05, chapter 3, section 3.6.1).

Shallow lowland billabongs

The monitoring program for fish communities in shallow billabongs is conducted biennially in six billabongs, comprising three 'control' versus 'exposed' billabong pairs. In a similar manner to fish communities in channel billabongs (discussed above), the similarity of fish communities in the directly exposed sites downstream of Ranger on Magela Creek (Georgetown, Coonjimba and Gulungul Billabongs) to those of the control sites (Sandy Swamp and Buba Billabongs on Nourlangie Creek and Wirnmuyurr Billabong – a Magela floodplain tributary) was determined using multivariate dissimilarity indices calculated for each sampling occasion. A plot of the dissimilarity values of the control-exposed site pairings – Coonjimba-Buba, Georgetown-Sandy Swamp and Gulungul-Wirnmuyurr Billabongs – from 1994 to the present, is shown in Figure 2.18.

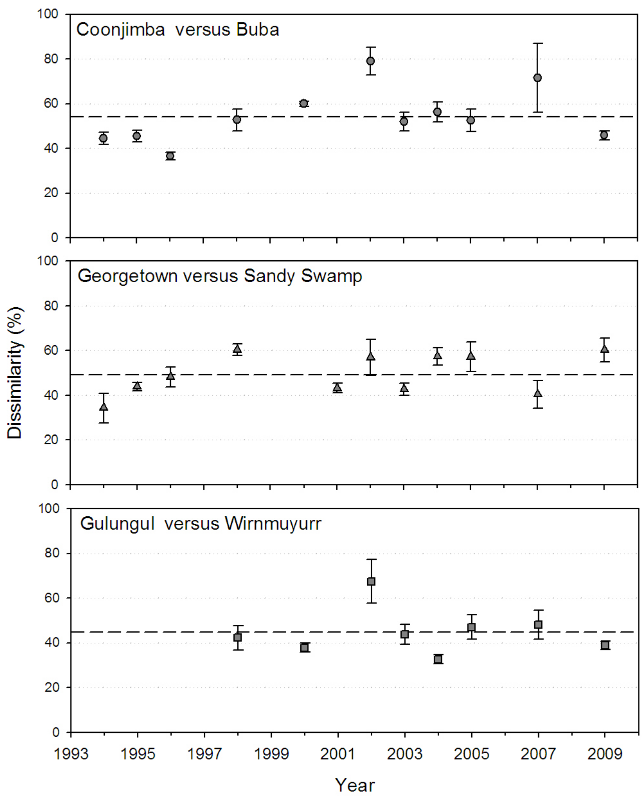


Figure 2.18 Paired control-exposed site dissimilarity values (using the Bray-Curtis measure) calculated for community structure of fish in 'directly-exposed' Magela and 'control' Nourlangie and Magela Billabongs in the vicinity of Ranger mine over time. Values are means (± standard error) of the 5 possible (randomly-selected) pairwise comparisons of average trap enclosure data between the pairwise billabong comparisons, Coonjimba-Buba, Gulungul-Wirnmuyurr and Georgetown-Sandy Billabongs.

The paired-site dissimilarities shown in Figure 2.18 average between 40% and 60% indicating fish communities in each of the billabongs comprising a site pairing are quite different from one another. In the Supervising Scientist annual report for 2006–07 (section 2.2.3) it was identified that the particularly high dissimilarity values observed in the Coonjimba-Buba pairing for 2002 and 2007, and the Gulungul-Wirnmuyurr site pairing for 2002 (Figure 2.18) were attributable to high densities of particular aquatic plant types in one or both of the billabongs. Excessive plant densities are unfavourable for fish communities as fish movement, and hence residency, is physically prevented. The influence of aquatic plants on fish community structure is further supported by the slightly increased dissimilarity observed in the Georgetown-Sandy Swamp pairing in 2009. The increased dissimilarity appears to be related to an increase in the density of the emergent aquatic plant *Eleocharis* sp in Georgetown Billabong, combined with reduced plant density (dominated by emergent lilies), in Sandy Billabong. The divergence in aquatic plant habitats between the two billabongs appears to have resulted in reduced similarity (increased dissimilarity) in fish community structures between these locations (Figure 2.18).

In the Supervising Scientist annual report for 2006–07, chapter 2, section 2.2.3, an increase over time was observed in the paired Coonjimba-Buba billabong dissimilarity values, irrespective of the removal of years 2002 and 2007 for which high values are associated with unusually high aquatic vegetation density in one or other of the billabongs (discussed above). The reduced dissimilarity found for 2009 has allayed concerns of increasing dissimilarity over time, as a weak relationship only is now present when the years 2002 and 2007 are included in data analysis ($p = 0.03$).

2.3 Jabiluka

2.3.1 Developments

The site continues to be maintained under the long-term care and maintenance regime of management. There has been no change to the statutory monitoring program undertaken by ERA in Swift Creek (Ngarradj) during the reporting period. SSD continues to monitor downstream water quality at Ngarradj.

2.3.2 On-site environmental management

Water Management

The site continues to be maintained as a passive discharge site.

Audit and Routine Periodic Inspections (RPIs)

Three inspections were undertaken at Jabiluka during 2008–09 (Table 2.6). A review of audit findings from the May 2008 audit was undertaken in November 2008 in the format of an RPI. An environmental audit was held in May 2009 and RPIs were held in August and March.

TABLE 2.6 RPI FOCUS DURING THE REPORTING PERIOD

Date	Inspection type	Foci
20 August 2008	RPI	Access road, helipad area, Interim Water Management Pond (IWMP), choke structure, revegetation on hardstand/portal area
10 November 2008	RPI	Access road, helipad area, main site/portal area, IWMP, vent raise, JSC monitoring point, Djarr Djarr Camp
17 March 2009	RPI	Helipad area, main site/portal area, choke structure

2008 Audit review outcomes

Observations from the June 2008 Environmental Audit were followed up through the RPI process.

The IWMP liner was identified as having been repaired at the March 2009 RPI. ERA has reaffirmed its commitment to convert the vent raise to a sampling point and there have been no further issues identified with the reporting of water chemistry data.

2009 Audit outcomes

The annual environmental audit of Jabiluka was held in May 2009 and tested compliance against 29 specific commitments taken from ERA's *Application to prepare the Jabiluka site for long-term care and maintenance.* The information collected against each criteria was assessed and given a ranking as per the grading system provided in Table 2.4. The audit process found evidence to grade two criteria as conditional while all other criteria was found to be either acceptable or no longer applicable. The two conditional findings related to:

- The conversion of the vent rise to a decline water sampling point. ERA indicated that work is underway to convert the vent rise to a sampling point. This criteria has been ranked conditional on ERA completing this work.
- Capping of redundant boreholes in mine valley. ERA informed stakeholders that approval has been granted from GAC, and more recently the AAPA, to access the bore sites in Mine Valley. ERA has previously notified the audit team (via MTCs) of work that has progressed towards meeting this commitment, however the physical rehabilitation works are yet to be completed. This criteria is ranked conditional on ERA completing the rehabilitation works during the 2009 dry season.

Minesite Technical Committee

The Jabiluka MTC met six times during 2008–09. Dates of meetings and significant issues discussed are shown in Table 2.7.

TABLE 2.7 JABILUKA MINESITE TECHNICAL COMMITTEE MEETINGS

Date	Significant agenda items
4 July 2008	Jabiluka ERs, Groundwater monitoring, Authorisation review
26 August 2008	Mine Valley drill holes, Authorisation review, Jabiluka Annual Amended Plan of Rehabilitation 11, Authorisation review
1 October 2008	Jabiluka Annual Amended Plan of Rehabilitation 11, Groundwater monitoring
10 November 2008	Mine Valley drill holes, Jabiluka Annual Amended Plan of Rehabilitation 11
16 February 2009	Jabiluka Annual Amended Plan of Rehabilitation 11
7 May 2009	Jabiluka Annual Amended Plan of Rehabilitation 12, Mine Valley drill holes

Authorisations and approvals

No applications to alter the Jabiluka Authorisation, 0140-5, were received during the reporting period.

Incidents

No incidents were reported for the 2007–08 period.

2.3.3 Off-site environmental protection

Surface water quality

In accordance with the Jabiluka Authorisation, ERA is required to monitor a range of surface and ground waters on the lease and to demonstrate that the environment remains protected. Specific water quality objectives (criteria thresholds were described in Supervising Scientist annual report 2003–04) must be achieved. Each month during the wet season, ERA reports the water quality in Ngarradj (Swift Creek) to the major stakeholders (SSD, DRDPIFR and NLC). A detailed interpretation of water quality across the site is provided at the end of each wet season in the ERA Jabiluka Annual Wet-season Report.

In addition to the ERA program, the Supervising Scientist conducts monthly chemical and physical monitoring in Ngarradj Creek.

The SSD biological monitoring program for Jabiluka ceased in 2004, commensurate with the low risk posed while the site is in long-term care and maintenance mode. Results from six-years (1999–2004) of fish community structure studies were reported in Supervising Scientist annual report 2003–04 along with results for macroinvertebrate community structures.

Key water quality data from SSD and ERA routine monitoring of Ngarradj are reported at www.environment.gov.au/ssd/monitoring/ngarradj-chem.html. Highlights and a summary of the data collected in the 2008–09 wet season are reported below.

Chemical and physical monitoring of Ngarradj Creek

Jabiluka has been in a long-term care and maintenance phase since late 2003 and poses a low risk to the environment. As a consequence of this low risk and the good dataset acquired over the last six years indicating the environment has been protected, the monitoring program has been systematically scaled down. Since 2007–08, the Supervising Scientist Division has collected monthly samples (with automatic recordings of turbidity and hydrological data at 6-minute intervals being collected for research purposes by ***eriss***) from the downstream statutory compliance site only. Energy Resources of Australia (ERA) also samples monthly but to a different schedule and from both the upstream and downstream sites. These independent programs complement each other, providing approximately fortnightly water sampling and a combined dataset to assess the water quality at Ngarradj.

Ngarradj Creek commenced flow late December 2008 with the first water samples collected at the downstream site by SSD on the 23 December 2008. The last water sample was collected on 15 April 2009. Flow in the creek had ceased by 7 May 2009.

All variables are consistent with measurements from previous seasons with uranium less than 4% of the limit (Figure 2.19). As observed in previous seasons, uranium was elevated in the first part of the seasonal flow, decreasing as the season progressed.

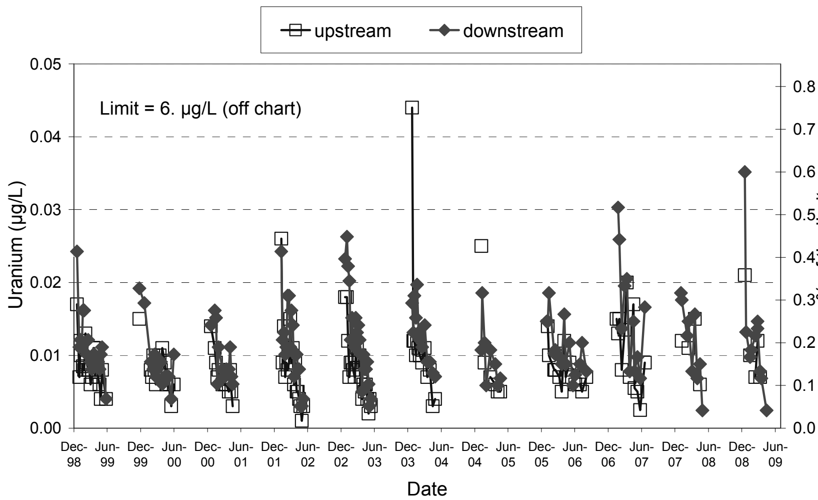


Figure 2.19 Uranium concentrations in Ngarradj since the 1998–99 wet season (SSD data 1998–99 to 2004–05, SSD & ERA data 2004–05 onward)

ERA and SSD data collected during the 2008–09 wet season are in good agreement, as shown by measured uranium concentrations in Figure 2.20.

All variables were within guidelines or limits (set by stakeholders to protect the aquatic environment) during the 2008–09 wet season providing reassurance that the aquatic environment of Ngarradj remained protected from any impacts from the Jabiluka site.

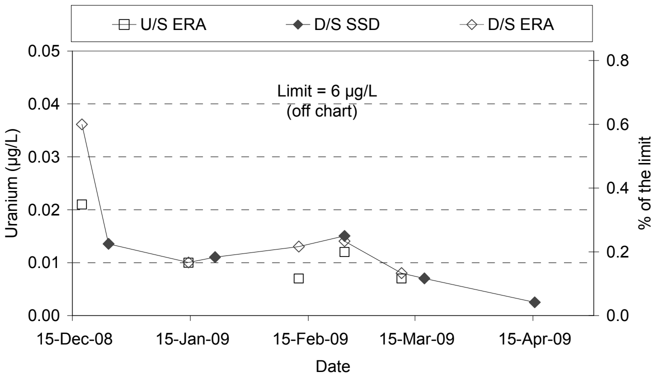


Figure 2.20 Uranium concentrations measured in Ngarradj by SSD and ERA in the 2008–09 wet season

Radium in Ngarradj

Since monitoring data from previous years have shown that human health has been protected and there has been no significant difference between upstream and downstream values, and the absolute values are in any case very low, monitoring at the upstream site has been discontinued while Jabiluka remains in long-term care and maintenance. From the 2007–08 wet season onwards, visual comparisons of the charted downstream data will be made with previous seasons' data to confirm that there are no significant upward deviations from this control record.

Radium-226 (^{226}Ra) results for the 2008–2009 wet season at the Ngarradj downstream site (monthly samples) are comparable with previous years as shown in Figure 2.21, giving confidence that the downstream environment has remained protected from any inputs from Jabiluka.

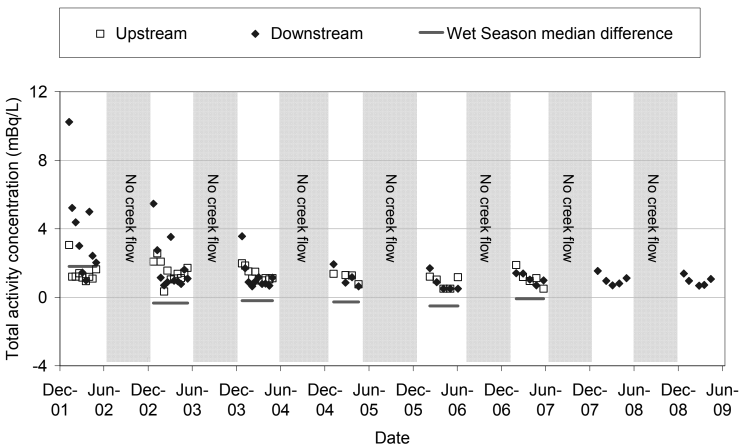


Figure 2.21 Radium-226 in Ngarradj 2001–09 (SSD data). The first season is the only season that the wet season median difference (solid lines) – the downstream median for the season minus the upstream median for the season – is greater than zero, indicating that this was the only season when ^{226}Ra is higher downstream of Jabiluka compared with upstream. Even in that season, the wet season median difference was very low indicating human health was not at risk from the presence of ^{226}Ra in Ngarradj.

2.4 Nabarlek

2.4.1 Developments

In early 2008, Uranium Equities Limited (UEL) bought Queensland Mines Pty Ltd, thereby acquiring the Nabarlek lease, and has since developed plans to further explore the lease, clean up the site and continue revegetation and rehabilitation works. A new Mining Management Plan (MMP), including revised rehabilitation bond calculations, was submitted to the Supervising Authority for approval in May 2008. The new MMP was approved in September 2008 and UEL commenced drilling operations within the fenced area in late 2008. Based upon the September 2008 MMP the Nabarlek rehabilitation bond was set by DRDPIFR at $1 800 000.

Minesite Technical Committee

The Nabarlek Minesite Technical Committee met once during the reporting period. The MTC met on 22 August 2008 and discussed the following topics:

- Rehabilitation bond
- Remediation of the radiologically anomalous area
- Water sampling and associated training for field staff
- Removal of the fence
- Closure and ongoing rehabilitation works
- Worker facilities at the airstrip
- Remediation of the old camp area

In addition to the MTC, UEL met with stakeholders in February 2009 to provide an update on rehabilitation progress and planned works for 2009. UEL informed stakeholders that it had conducted some re-contouring works during the 2008 dry season and was intending to plant 2500 seedlings during the 2008/09 wet season. Additionally UEL has generated a weed map of the site and is continuing with ongoing weed control activities including spraying and controlled burns.

Authorisations and approvals

There was no change to the Authorisation during 2008–09.

Incidents

There were no incidents reported at Nabarlek during 2007–08.

2.4.2 On-site conditions

Staff from ***eriss*** continue to undertake research programs at Nabarlek and the site is subject to at least two formal visits from ***oss*** staff during the year. In addition, ***oss*** may carry out opportunisitic site inspections if in the area on other business (eg exploration inspections).

The formal site inspections carried out at Nabarlek each year are:

- Post-wet season inspection – the intent of this inspection is to check site stability and erosion following the wet season and to plan works for the coming dry season;
- Annual audit (pre-wet season) of compliance with the Nabarlek Mining Management Plan.

Audit outcomes

The 2008 audit was held on 21 August 2008 and tested compliance with 34 commitments taken from the 2008 Nabarlek Mining Management Plan as submitted by UEL. Of these, 15 were graded as 'acceptable' while the remainder were not able to be verified due to a delayed start to the drilling program.

Post-wet season inspection

Stakeholders inspected Nabarlek on 17 June 2009 with site operators UEL. NT WorkSafe had recently undertaken a site inspection and consequently several areas are now restricted due to asbestos and other safety concerns (the old camp, a hard stand near the tanks and the top of the diesel tank are now inaccessible). UEL plans to tender for contractors to remove asbestos waste in the camp area this dry season and then construct a disposal facility on site and complete clean up works in the following dry season.

The camp at the airstrip includes more facilities than were present at the audit in August 2008. A kitchen and ablutions block has been established as well as air conditioned sleeping quarters.

Two new revegetation plots were planted in February 2009. Fourteen hundred and fifty seedlings were planted across the two revegetation plots, comprising mainly *Corymbia* sp, *Eucalyptus miniata* and *E. tetradonta*. Seedlings were sun-hardened prior to planting and were planted with fertiliser granules and water crystals to assist survival rates. Intensive weed control works (spraying and controlled burning regimes) were undertaken during the 2008–09 wet season.

The former waste rock runoff pond has been graded and re-contoured in an effort to manage weeds in the area. UEL have established a larger road network across the site which has facilitated increased weed control works by providing access to previously inaccessible areas.

Radiologically anomalous area (RAA)

The area of the RAA is approximately 0.4 ha and is located immediately south-west of the former pit area. The RAA exhibits elevated levels of radioactivity and has been identified to contribute about one-quarter of the total radon flux from the rehabilitated minesite and three-quarters of the radionuclide flux from the site via the erosion pathway (more detail is provided in Supervising Scientist annual report 2004–05).

UEL has conducted a detailed gamma survey of the area and is currently evaluating remediation strategies for the RAA which will be put to the MTC for approval once finalised. UEL plans to characterise the RAA during the 2009 dry season with a view to disposing of the material with higher radiological signature in a disposal pit on site during the 2010 dry season.

2.4.3 Off-site environmental protection

Statutory monitoring of the site is the responsibility of DRDPIFR and the operator, UEL. DRDPIFR carries out all surface and groundwater monitoring on and off site, including surface water monitoring downstream of the mine in Kadjirrikamarnda and Cooper Creeks, and reports the results of this monitoring in the six-monthly Northern Territory Supervising Authorities Environmental Surveillance Monitoring in the Alligator Rivers Region reports.

SSD continues to undertake research programs at Nabarlek including radiation assessments, revegetation success and monitoring techniques, and erosion and contaminant transport. The research is aimed at enabling an overall assessment of rehabilitation success at Nabarlek. Progress on these programs is reported in chapter 3 of this annual report and in the SSD Internal Report series.

2.5 Other activities in the Alligator Rivers Region

2.5.1 Rehabilitation of the South Alligator Valley uranium mines

In 1991–92, the Commonwealth Government conducted hazard reduction works to reduce the radiological and physical hazards of the old (1950s & 1960s) uranium milling and mining sites in the South Alligator Valley (SAV). Radiologically contaminated materials from the sites were buried in several containment sites in the valley (Battery bund, El Sherana Weighbridge Station, El Sherana, Saddle Ridge and SAV village).

Since the remediation works, the Supervising Scientist Division has conducted an ongoing program of monitoring through bi-annual inspections of these sites (with visual inspections for signs of erosion or interference and spot readings of radiation signals compared with background) and triennial radiation grid-surveys of each of the containment sites.

During the 1999 survey, previously buried tailings were found to have been exposed in the course of road works at the Rockhole tailings site. The site was remediated, with loose tailings and contaminated soil stored in drums in a custom-built above-ground containment facility (SAV Village Containers) awaiting long-term disposal. The remaining tailings were left in situ and stabilised with a layer of rock armouring to prevent any further dispersal until a permanent solution could be put in place. The armoured tailings are referred to as the Rockhole tailings or Gunlom Road residues.

In June 2006, the Hon Greg Hunt MP, Parliamentary Secretary to the Minister for the Environment and Heritage, announced funding of 7.3 million dollars over 4 years for phased rehabilitation of the abandoned uranium minesites in the South Alligator Valley.

The first phase involved rehabilitating the old Sleisbeck and Coronation Hill mines during the 2007 dry season and the removal of some drill core and infrastructure from the El Sherana village. In subsequent years the other remaining sites will be rehabilitated. The most extensive works will involve rehabilitating the Gunlom Road residues and earlier containment sites. The material currently located at these sites will be recovered and transferred to a purpose built containment in the vicinity of the old El Sherana airstrip. This containment will be constructed during the 2009 dry season (see below).

eriss conducted several projects through 2008–09 to identify and characterise volumes of materials to be remediated and to characterise groundwater behaviour in the vicinity of the site that has been identified for the long-term containment of low-level radiologically contaminated material. The major projects were:

1. Collecting and validating terrestrial gamma radiation data to provide a pre-containment baseline for the external gamma exposure of members of the public who may access the site.
2. Collecting radon exhalation data from the El Sherana airstrip to provide a pre-containment baseline.
3. Finalising the collection of baseline data for groundwater (seasonal standing water levels, radionuclide activity and metal concentration) in the vicinity of the planned containment.
4. Analysing the radionuclide and metals data obtained from Rockhole Mine Creek over the past 20 years to determine whether drainage from the Rockhole Mine adit needs to be remediated (see chapter 3, section 3.9, of this report).
5. Radiological ground surveys of the El Sherana and Palette minesites to identify areas that need to be remediated in situ or else excavated and placed in the new containment (see chapter 3, section 3.9, of this report).

oss inspected the containment sites in the South Alligator Valley, including Gunlom Road Residues, on 14–15 July 2008 and 30 June 2009. All sites were found to be sound and gamma radiation was generally at background levels or comparable with previous years.

oss will continue to conduct annual inspections of the existing containments until rehabilitation is complete.

During the reporting period, Parks Australia (PA) submitted a referral to DEWHA in accordance with the provisions of the *Environmental Protection and Biodiveristy Conservation Act 1999*. The referral was submitted to allow PA to undertake works to rehabilitate abandoned mines and associated infrastructure in the South Alligator Valley. This action was determined not to be a controlled action and consequently did not require further assessment under the EPBC Act. The action involves the construction of a new containment facility located in the vicinity of the El Sherana airstrip to contain excavated material from the following existing facilities:

- South Alligator Village containment
- El Sherana Camp containment
- El Sherana Weighbridge containment
- Battery Bund containment

In addition to this, all material with readings measured in excess of 1.25 μSv/h (±20%) from the following locations will be placed in the new containment facility:

- Rockhole uranium processing plant tailings residues
- Containers at South Alligator Village
- El Sherana mine
- Palette stockpile area

Work on construction of the containment will start early in the second half of 2009.

2.5.2 Exploration

oss undertakes a program of site inspections at exploration sites in west Arnhem Land where Cameco Australia Pty Ltd (Cameco) and UEL are exploring for uranium. During the reporting period, this entailed inspections of Myra Falls and King River Camps and their respective exploration activities. The inspections were held on 8–9 September 2008, when the camps were operating and exploration was being actively undertaken.

There were no drill rigs operating within reasonable proximity to Myra Falls Camp to enable inspection during the site visit. Stakeholders inspected an operational rig in the Wellington Range exploration area, close to the King River Camp. There was no significant issues identified with the drilling operations or the operations at either camp.

2.6 Radiological issues

2.6.1 Background

Applicable standards

The radiation dose limit for workers recommended by the International Commission on Radiological Protection (ICRP) and adopted in Australia by the National Health and Medical Research Council (NHMRC) is 100 milliSieverts (mSv) in a five-year period with a maximum of 50 mSv in any one year. The radiation dose limit to the public from a practice such as uranium mining recommended by the ICRP is 1 mSv per year. This limit applies to the sum of all sources and exposure pathways. As outlined in the 'Code of Practice and Safety Guide on Radiation Protection and Radioactive Waste Management in Mining and Mineral Processing' (2005), it is the operator's and employer's responsibility to 'ensure that the workplace and work procedures are designed, constructed, and operated so as to keep exposures to ionising radiation as low as reasonably achievable'.

The Code further recommends to separate radiation workers into designated and non-designated, where designated workers are those who may be expected to receive an occupational radiation dose exceeding 5 mSv in one year. These workers are monitored more intensely than the non-designated workers.

Consequently, there are three levels of radiation dose limits to distinguish, which specify the annual radiation dose limit from other-than-natural sources:

- the public (1 mSv)
- non-designated workers (5 mSv)
- designated workers (20 mSv per year over 5 years with a maximum of 50 mSv in any one year).

In addition, the ICRP (2006) recommends the use of dose constraints for the optimisation of radiation protection:

> The principle of optimisation is defined by the Commission as the source related process to keep the magnitude of individual doses, the number of people exposed, and the likelihood of potential exposure as low as reasonably achievable below the appropriate dose constraints, with economic

and social factors being taken into account. According to the Commission's revised recommendations, this process of optimisation below constraint should be applied whatever the exposure situation; ie planned, emergency, or existing. [1]

Monitoring and research programs

ERA conducts statutory and operational monitoring of external gamma exposure to employees (through the use of gamma dose badges), radon decay products and long lived alpha activity (dust) in the air, and surface contamination levels. The statutory aspects of the program are prescribed in Annex B of the Ranger Authorisation with results reported to MTC members on a quarterly basis.

The Supervising Scientist conducts routine monitoring of the atmospheric pathways of radiation dispersion from Ranger and a number of radiation research projects for human and environmental protection.

An application to optimise the Radiation and Atmospheric Monitoring Plan was submitted to the MTC in November 2008. Comments have been provided from SSD to DRDPIFR, however pending approval of the revised Plan, Annex B of the Authorisation remains in force.

All ERA 2008 quarterly reports were received and reviewed by the Office of the Supervising Scientist.

2.6.2 Radiation at and from Ranger

Radiological exposure of employees

The three primary pathways of radiation exposure to workers at Ranger are:

- inhalation of radioactive dust
- exposure to external gamma radiation
- inhalation of radon decay products (RDP).

Table 2.8 shows the annual doses received by designated and non-designated workers in 2008, and a comparison with the average doses from the year before as reported by ERA. The average and maximum radiation doses received by designated workers in 2008 were approximately 6.5% and 23% respectively of the recommended ICRP (2007) annual dose limits.[2]

---

[1] ICRP 2006 *Assessing dose of the representative person for the purpose of radiation protection of the public and the optimisation of radiological protection: broadening the process*. International Commission on Radiation Protection Publication 101, Elsevier Ltd.

[2] ICRP 2007. *The 2007 recommendations of the International Commission on Radiological Protection*. International Commission on Radiological Protection Publication 103, Elsevier Ltd.

TABLE 2.8 ANNUAL RADIATION DOSES RECEIVED BY WORKERS AT RANGER MINE

	Annual dose in 2007		Annual dose in 2008	
	Average mSv	Maximum mSv	Average mSv	Maximum mSv
Non-designated worker	Not calculated[1]	0.6	Not calculated	0.6
Designated worker	1.3	4.2	1.3	4.5

1 A hypothetical maximum radiation dose to non-designated employees is calculated using the gamma exposure results of employees of the Emergency Services Group, and dust and radon results measured at the Acid Plant. Consequently, the dose is conservative and would exceed actual doses received by non-designated employees, and are hence considered maximum doses.

Processing maintenance and production workers and electricians received the majority of their radiation dose from the inhalation of radioactivity trapped in or on dust, with processing production workers receiving a larger dose from dust this year (average of 1.4 mSv) compared with last year (average of 0.8 mSv). The majority of the radiation dose received by employees in the mine area was from external gamma radiation. Radon decay product concentrations are highest for workers in the mine area but generally contribute a small fraction only to the annual effective radiation doses.

Radiological exposure of the public

The ICRP (2007) recommends that the annual dose received by a member of the public from a practice such as uranium mining and milling should not exceed 1 milliSievert (mSv) per year. This dose is on top of the radiation dose received naturally, which averages approximately 2 mSv per year in Australia, but which ranges from 1–10 mSv per year, depending on location. The ICRP furthermore recommends a dose constraint to be selected below 1 mSv per year according to the situation to allow for exposures to multiple sources.

There are two main pathways of potential exposure to the public during the operational phase of a uranium mine and Ranger is the main potential source of additional (to natural levels) radiation exposure to the community in the Alligator Rivers Region. The two pathways are the inhalation pathway, which is a result of dispersion of radionuclides from the minesite into the air, and the ingestion pathway, which is caused by the uptake of radionuclides into bush foods from the Magela Creek system downstream of Ranger.

Inhalation pathway

Both ERA and SSD monitor the two airborne pathways:

- radioactivity trapped in or on dust (or long lived alpha activity, LLAA)
- radon decay products (RDP).

The main areas of habitation in the vicinity of Ranger and Jabiluka are Jabiru, Mudginberri and Jabiru East. Consequently, SSD monitoring focuses on those three population centres in the region (Map 3). Airborne RDP and LLAA concentrations are measured monthly and the results compared with ERA's atmospheric monitoring results from Jabiru and Jabiru East.

Of the two airborne pathways, RDP accounts for most of the dose received by the public. In 2008, Ranger reported that there was no significant difference between background and mine derived airborne RDP concentration at Jabiru.

Figure 2.22 shows Jabiru and Jabiru East RDP data and a comparison with ERA data from July 2004 up to March 2009. RDP concentrations measured by SSD and ERA show the expected seasonal trend with higher values during the dry and lower values during the wet season. Lower concentrations are expected in the wet season due to wet soil allowing less permeation of radon into the atmosphere and due to the frequency of storms with associated turbulent atmospheric conditions. Differences in sampling time and location may be the cause of the differences in RDP concentrations observed when comparing ERA and SSD data. Annual term averages are similar and shown in Table 2.9.

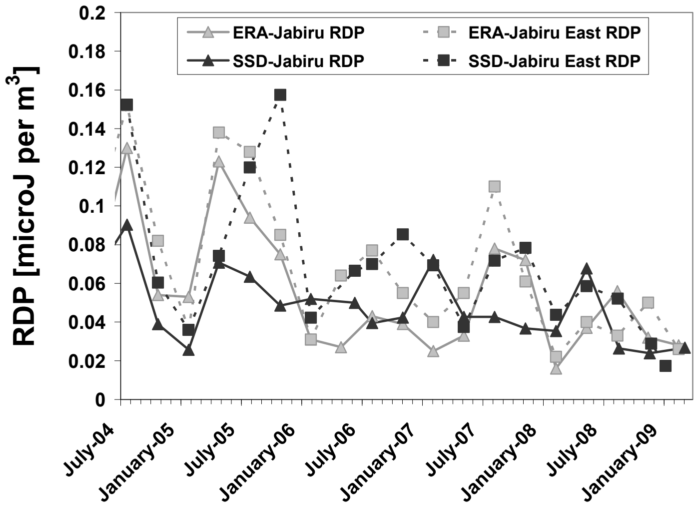


Figure 2.22 Radon decay product concentration measured by SSD and ERA in Jabiru and Jabiru East from January 2004 to March 2009

Table 2.9 also shows the average annual doses received from the inhalation of radon decay products in the air, as calculated from the RDP concentration data from ERA and SSD (in brackets) at Jabiru. This is assuming an occupancy of 8760 h (one year) and a dose conversion factor for the public of 0.0011 mSv per $\mu J \cdot h/m^3$. Mine derived annual doses from the inhalation of radon progeny, as reported by ERA, are shown in this table as well.

Ingestion pathway

Radium in Magela Creek waters is routinely monitored by both ERA and SSD and the limit for radium in Magela Creek is based on dietary uptake of the Aboriginal people downstream of the mine. Local Aboriginal people have expressed concern about the radionuclide concentration in mussels from Mudginberri Billabong. Consequently, SSD routinely monitors the aquatic aspects of the ingestion pathway and bioaccumulation monitoring samples have been collected each year and analysed for both radionuclides and heavy metals. The collections include yearly collections of mussels at Mudginberri Billabong (the potentially contaminated site) and Sandy Billabong (control site in the Nourlangie catchment). In addition, a detailed study of radionuclide and metal uptake in mussels in Mudginberri Billabong was conducted in 2008 and results are presented in chapter 3, section 3.3, of this report.

TABLE 2.9 RADON DECAY PRODUCT CONCENTRATIONS AT JABIRU AND JABIRU EAST, AND TOTAL AND MINE DERIVED ANNUAL DOSES RECEIVED AT JABIRU IN 2006–2008. NUMBERS IN BRACKETS REFER TO SSD DATA.

		2005	2006	2007	2008
RDP concentration [μJ/m³]	Jabiru East	0.097 (0.097)	0.071 (0.066)	0.059 (0.064)	0.033 (0.046)
	Jabiru	0.088 (0.052)	0.039 (0.046)	0.038 (0.049)	0.037 (0.038)
Total annual dose [mSv] Jabiru		0.85 (0.50)	0.38 (0.44)	0.37 (0.47)	0.36 (0.37)
Mine derived dose [mSv] at Jabiru		0.037	0.003	≈ 0	0.001

Routine monitoring results from 2000–2008 show that on average the ^{226}Ra activity concentration in mussel flesh from Mudginberri Billabong is higher than at Sandy Billabong and the committed effective dose from the ingestion of ^{226}Ra and ^{210}Pb in mussels from Mudginberri Billabong is about twice the committed effective dose from the ingestion of Sandy Billabong mussels (results for the 2008 collection are discussed in chapter 2, section 2.2.3). Historical data, however, show that there is no indication of an increase of ^{226}Ra (or uranium) activity concentrations in mussel flesh in Mudginberri Billabong over time and thus the difference is unlikely to be mine-related. Reasons for the higher ^{226}Ra activity concentrations measured include the mineralised nature of the Magela Creek catchment area and the associated naturally higher ^{226}Ra content in Mudginberri Billabong sediments and water, and the lower Ca and Mg concentration in water compared with Sandy Billabong. In addition, differences in mussel growth and health may affect radium uptake (see chapter 3, Supervising Scientist annual report 2007–08, for more detail).

With the rehabilitation of Ranger there will be radiological protection issues associated with the land use by local Aboriginal people and a shift towards terrestrial food sources. These foodstuffs include both terrestrial animals and plants. Over the last 25 years, SSD has gathered radiological concentration data on bush foods throughout the Alligator Rivers Region in the Northern Territory. New data, in particular for terrestrial food items, are acquired on an ongoing basis and are used to replace IAEA default radionuclide concentration factors with locally derived values. This provides a more reliable estimate of ingestion doses. Chapter 3, section 3.3, of this report shows some of the results from this work.

2.6.3 Jabiluka

Radiological exposure of employees

The Jabiluka Authorisation was revised in July 2003 and the statutory requirement of quarterly reporting of radiological monitoring data for Jabiluka was removed. The current Authorisation requires reporting of radiation monitoring data only if any ground disturbing activities involving radioactive mineralisation occur on site. No ground disturbing activities took place during this reporting period.

Radiological exposure of the public

Although there were no activities reported at the Jabiluka minesite, the population group that may, in theory, receive a radiation dose due to future activities at Jabiluka is a small community approximately 10 km south of Jabiluka at Mudginberri, comprising around 60 individuals.

The Supervising Scientist has a permanent atmospheric research and monitoring station at Four Gates Rd radon station a few kilometres west of Mudginberri (see Map 3). Radon decay product (RDP) and long lived alpha activity (LLAA) concentrations are measured there on a monthly basis. Figure 2.23 shows the quarterly averages of RDP and LLAA concentrations measured at Four Gates Rd radon station by SSD up to June 2009. LLAA data for the first quarter of 2009 are not available due to problems with the equipment this wet season. The average airborne radionuclide concentrations measured in 2008 would translate into an annual total effective dose, including natural background, of 0.3 mSv from RDP ~ 0.01 mSv from LLAA. Only a small fraction of these doses would be due to mine derived radionuclides.

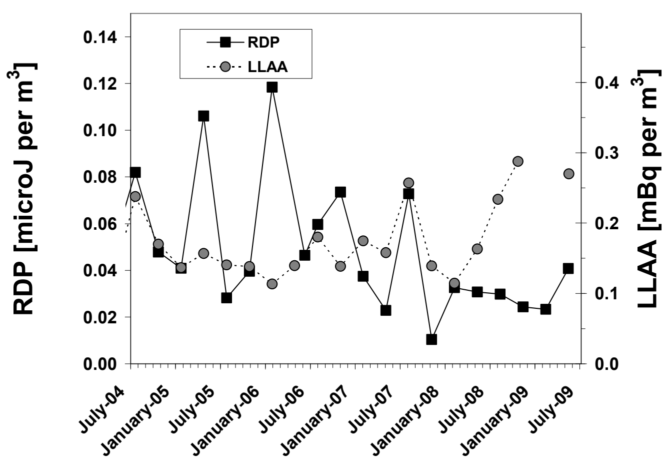


Figure 2.23 Radon decay product (RDP) and long lived alpha activity (LLAA) concentrations measured at SSD's Mudginberri Four Gates Rd radon station from July 2004 to June 2009

2.7 EPBC assessment advice

During the reporting period, ***OSS*** has provided advice to the Approvals and Wildlife Division (AWD) of DEWHA on referrals submitted in accordance with the EPBC Act for new and expanding uranium mines. ***OSS*** has provided coordinated responses from SSD on the following projects:

- Nolan's Bore Project, NT
- Crocker Well Project, SA
- Olympic Dam Expansion, SA
- Ranger Mine Heap Leach proposal, NT
- Ranger Mine Exploration Decline proposal, NT
- Beverley Four Mile Project, SA

3 ENVIRONMENTAL RESEARCH AND MONITORING

The *Environment Protection (Alligator Rivers Region) Act 1978* established the Alligator Rivers Region Research Institute (ARRRI) to undertake research into the environmental effects of uranium mining in the Alligator Rivers Region. The scope of the research program was widened in 1994 following amendments to the Act. The Alligator Rivers Region Research Institute was subsequently renamed the Environmental Research Institute of the Supervising Scientist (***eriss***).

The core work of ***eriss*** comprises ongoing monitoring and conduct of research to develop and refine best practice monitoring procedures and standards for the protection of people and the environment, focusing on the effects of uranium mining in the Alligator Rivers Region (ARR). The expertise of the Institute is also applied to conducting research on the sustainable use and environmental protection of tropical rivers and their associated wetlands.

The content and outcomes of the ***eriss*** research program are assessed annually by the Alligator Rivers Region Technical Committee (ARRTC) using identified Key Knowledge Needs (KKN). These KKNs define the key research topics within each of the geographic domains in the ARR relating to monitoring, closure and rehabilitation for current (Ranger and Jabiluka), rehabilitated (Nabarlek) and legacy (South Alligator River Valley) sites. The charter and activities of ARRTC are described in chapter 4 of this annual report and the current list of KKNs is provided for reference in Appendix 1.

eriss contributes to the addressing of each of the Key Knowledge Needs by applying a broad range of scientific expertise across the research fields of:

- Ecotoxicology
- Environmental radioactivity
- Hydrological and geomorphic processes
- Monitoring and ecosystem protection
- Spatial sciences and remote sensing

A selection of highlights from the 2008–09 research program is presented in this report, with a summary introduction to these topics below.

As reported previously, SSD has been undertaking an intensive evaluation of the use of continuous monitoring equipment to provide essentially real time coverage of changes in water quality upstream and downstream of the minesite. The effort represents a major investment of Divisional resources and has the potential to result in substantially improved surveillance capacity compared with the historical weekly grab sampling approach to monitoring water quality. The continuous electrical conductivity data (a surrogate for total dissolved solids) can be used together with the flow data to calculate both progressive and total loads of salts through the wet season. These data enable the time sequencing of inputs from the minesite to be discerned as well as enabling the influence of the wet season type (that is, how much rain falls and how it is distributed) on solute loads to be determined. In this report the findings from the continuous data record for the current wet season are compared with the previous three wet seasons. The 2008–09 wet season rainfall of 1186 mm was well below the running average of 1583 mm, with decreasing annual rainfall having now been recorded over the past three years (2006–07, 2540 mm; 2007–08, 1658 mm).

Acquisition of the continuous water quality monitoring data downstream of Ranger over three wet seasons (2005–06 to 2008–09) has enabled quantification of the magnitude, duration and frequency of transient magnesium (Mg) concentrations resulting from mine water discharges. These pulses occur over timescales of minutes to hours, with a maximum exceedence duration of the current EC-based guideline of approximately four hours. In contrast, the ecotoxicity tests from which the Mg provisional limit has been derived are based on chronic exposure over three to six days (depending on the test species). Hence, it was unknown if the shorter duration exceedences would have an adverse effect on aquatic biota. To address this key knowledge gap an assessment of the toxicity of Mg under a pulse exposure regime was initiated. The results from the first phase of this assessment are reported below.

Ongoing optimisation of existing monitoring methods is one of the processes followed by SSD to ensure that best practice continues to be employed for detection of possible impacts arising from the Ranger mining operation. To this end, some significant changes were implemented in the Ranger stream monitoring program starting in the 2008–09 wet season. These changes which involve co-location of water quality grab sampling and continuous monitoring sites were made to integrate all elements of the water quality monitoring program, thereby reducing replication of effort and the possibility of inconsistent results between the different locations and monitoring methods.

One of the features of the research section in previous annual reports has been the development of an in situ ecotoxicological test method that uses the numbers of egg masses laid by the freshwater snail *Amerianna cumingi* as the test endpoint. The successful conclusion of this test work was documented in the 2007–08 annual report, where it was stated that the in situ method would replace the previous creekside monitoring system, starting with the 2008–09 wet season. This was done and the test results are reported in chapter 2 of this annual report, now that the in situ method has become part of the routine monitoring program.

In 2008–09, the effect of dissolved organic carbon (DOC)-rich natural water from a natural billabong in Kakadu National Park on toxicity of uranium to three aquatic test species was assessed. Attenuation of uranium toxicity by DOC is likely to be particularly important in impacted billabongs on the Ranger lease, where DOC concentrations can reach 20 mg/L, considerably higher than those of Magela Creek (eg ~1–5 mg/L). Consideration of the effects of DOC will be required as part of the process for the setting of water quality closure criteria for uranium in these waterbodies.

Concentrations of radium in mussels in Mudginberri Billabong downstream of Ranger mine have been measured annually over the past 20 years by SSD to ensure that the radiation dose to indigenous people consuming the mussels is well below the most rigorous of international standards. In the 2007–08 annual report, the findings from a longitudinal survey of ^{226}Ra in mussels along Magela Creek were reported. The results showed that the minesite is making only a minor contribution to the radiogenic load in mussels in Mudginberri Billabong. This left one outstanding question relating to the effect of the location of sampling in the billabong itself on the loads of ^{226}Ra in mussels. This is an important question to answer because not only do the indigenous people collect mussels from different locations but so too has SSD over the past 20 years of collecting mussels for radiological dose analysis. This matter has now been largely resolved and the findings are reported here.

An eight hectare trial landform was constructed during late 2008 and early 2009 by Energy Resources of Australia Ltd (ERA) adjacent to the north-western wall of the tailings storage facility (TSF) at Ranger mine (Map 2). The trial landform will be used to test landform design and revegetation strategies to be used once mining and milling have finished. SSD will be measuring rates of erosion from the different treatments used in the trial, and has invested considerable time installing erosion plots and associated monitoring infrastructure in preparation for the 2009–2010 wet season. It is anticipated that erosion data will be collected over several years. This information will be input into computer models being used to assess the long-term integrity of the final constructed landform.

Over the past decade SSD has been assisting Parks Australia to characterise the rehabilitation requirements of the small abandoned uranium minesites in the South Alligator River Valley located in the southern part of the Alligator Rivers Region (Map 1). This work is now nearing completion as the final phase of the rehabilitation of these sites is being achieved by an extensive program of works managed by Parks Australia.

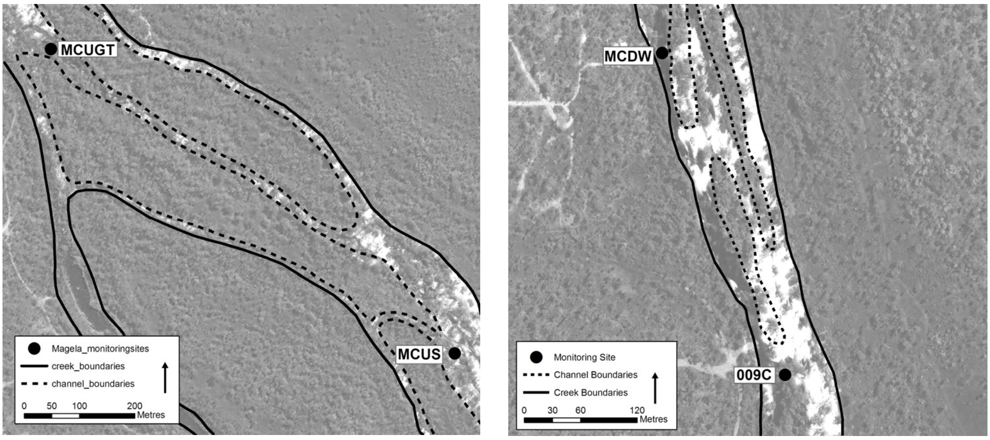
More comprehensive descriptions of research outcomes are published in journal and conference papers and in the Supervising Scientist and Internal Report series. Publications by Supervising Scientist Division staff in 2008–09 are listed in Appendix 2. Presentations for the year are listed in Appendix 3. More information on the Division's publications, including the full list of staff publications from 1978 to the end of June 2009, is available on the SSD web site at www.environment.gov.au/ssd/publications.

3.1 Enhancements to SSD's stream monitoring program for Ranger

Ongoing optimisation of existing monitoring methods is one of the processes followed by SSD to ensure that best practice continues to be employed for detection of possible impacts arising from the Ranger mining operation. To this end, some significant changes were made to the Ranger stream monitoring program commencing in the 2008–09 wet season.

3.1.1 Relocation of sampling sites in Magela Creek

The key change made to the water quality monitoring program has been to relocate the Magela Creek sites at which weekly surface water chemistry grab samples have been historically collected. The upstream reference and downstream impacts detection sites, formerly MCUS and 009C (respectively), have been moved to be co-located with the continuous monitoring and in situ toxicity (biological) monitoring pontoon sites – MCUGT and MCDW, respectively (Figure 3.1). The reason for this change is to provide complete integration among the elements of SSD’s water quality monitoring program and thereby reduce replication of effort and possible inconsistency of results between the different locations and monitoring methods. The MCDW downstream site provides a more sensitive location for detecting impacts from the minesite and thus complements rather than replicates the grab sample data produced by the compliance monitoring program carried out by Energy Resources Australia Ltd and the check monitoring performed by the Department of Regional Development, Primary Industries, Fisheries and Resources.



A Upstream monitoring sites on Magela Creek

B Downstream monitoring sites on Magela Creek

Figure 3.1 Upstream and downstream monitoring sites used in the SSD’s water chemistry (grab sampling and continuous) and toxicity monitoring programs. Channel boundaries are indicated by the continuous or broken (water-level-dependent) lines.

To examine the potential effect of changing the locations of the grab sampling sites on the ability of SSD’s program to detect impacts from the minesite, chemical data gathered weekly from MCUGT and MCDW between the 2001 and 2008 wet seasons as part of the toxicity monitoring program were compared with corresponding data collected from MCUS and 009C (the historical reference and compliance sites, respectively) as part of the routine grab sample monitoring program between 2001 and 2008. Concentrations of the key analytes – magnesium, sulfate and uranium – were compared statistically between the sites using Analysis Of Variance testing.

The concentrations of the three analytes were shown to be statistically similar between the new upstream reference site (MCUGT) and the historical upstream reference site (MCUS) ($p>0.05$).

In contrast, the concentrations measured at the proposed new downstream site (MCDW) were found to be significantly higher ($p<0.05$), albeit by only a small margin, than those from the compliance site (009C). This is because the compliance site is located in the central channel of Magela Creek while the new site is located in the west channel of Magela Creek. Contaminant levels downstream of Ranger have historically been higher in the west channel compared with the central channel, particularly in relation to discharge events emanating from Ranger Retention Pond 1 (RP1). Water released from RP1 enters Coonjimba Billabong, which eventually drains into the west side of Magela Creek. Results from continuous and grab sample electrical conductivity monitoring in previous years show that RP1-contributed water mixes incompletely in the west channel and preferentially follows the western bank, particularly during low flow periods.

While the concentrations measured at the MCDW location are statistically higher than values at the compliance site 009C further upstream, the actual magnitude of the difference is only minor, and is not regarded as being sufficient to affect any assessment of inputs from the minesite. Indeed, sampling in the west channel at the location of the current continuous monitoring and toxicity monitoring will result in a more conservative assessment of the contribution of Ranger mine to solutes in Magela Creek.

3.1.2 Other changes to SSD's weekly grab sampling program in Magela Creek

Commencing with the 2008–09 wet season, physicochemical parameters such as electrical conductivity, turbidity and pH are being measured in the field only. This decision has been taken following several years of good agreement between concurrent field and laboratory measurements, demonstrating that it is possible to obtain reliable measurements in the field with well-calibrated instruments equipped with probes optimised for use in very low EC media.

To provide a further integrity check on the field measurement, the field technician is now comparing the readings taken from the field meter with those being recorded at the same time by the continuous monitoring sonde (data are remotely accessible in the laboratory). If there is good agreement (allowing for known systematic offsets in the continuous readouts), then the field measurement is recorded as valid and reported to stakeholders. If there is disagreement (ie the difference between the two measurements is outside of pre-determined tolerances), then a backup sample of water that was also collected in the field is checked in the laboratory. During the 2008–09 wet season, out-of-tolerance differences between the in situ and field probe measurements occurred on only three occasions. If the discrepancy is attributable to the field measurement, then the continuous monitoring value is reported. If the continuous monitoring measurement is deemed to be inaccurate, then the field technician will report the concern to the continuous monitoring team to allow it to correct any issues. In all three cases the lack of agreement between the continuous monitoring and field meter occurred with pH at the low ionic strength waters of the upstream control site in Magela Creek.

The research emphasis for the water quality monitoring program during the 2008–09 wet season was placed on event-based sampling to capture episodes of 'high' electrical conductivity (ie high inputs of solutes from the minesite). The data produced by this targeted program of sampling are currently being analysed to determine if there is a functional correlation between EC and uranium (U) at higher EC values. If such a relationship is found then it may be possible to use this to infer U concentrations from the continuous EC trace during periods of high EC events.

Due to the remote location of the continuous monitoring autosamplers, there is often a time lag (up to 1 week) between sample collection and the physical retrieval of the sample from the field (and subsequent filtration and processing in the laboratory). Alterations to the chemical characteristics of water samples may occur when they are sitting for extended periods, which can lead to loss of dissolved metals (ie in the <0.45 µm fraction) by binding to particulate matter or sample bottle walls. This process causes an artificial reduction in the concentration of metals in the dissolved fraction and the sample is no longer representative of field conditions. To assess how the composition of Magela Creek water changes over time, a desk top study will be conducted using historical water quality monitoring data and more recent data acquired from samples collected using the autosamplers. The key objective of this study is to investigate how the dissolved (<0.45 µm) U in a sample changes over time and as a function of turbidity (suspended sediment concentration). The results from this analysis will provide the basis for determining if event-based sampling (using the continuous monitoring system and autosamplers) can provide reliable, representative samples for assessment of U levels.

3.1.3 Changes to the weekly grab sampling program in Gulungul Creek

Commencing with the 2008–09 wet season, weekly grab sampling for routine analysis of water chemistry variables has been discontinued at the upstream location, as this does not represent a useful reference site (ie water chemistry measured at this site may reflect upstream (natural) uraniferous catchment influences that compromise its effectiveness for assessing downstream impacts from the mine). Weekly monitoring has continued at the downstream site (GCH). Continuous monitoring of EC and turbidity is being maintained at both the downstream and upstream sites.

3.1.4 Use of in situ testing for ongoing toxicity monitoring

As reported in the Supervising Scientist annual report for 2007–08 (section 3.2), a comparative assessment was made between the results from two methods for toxicity monitoring: firstly, creekside monitoring conducted for 17 wet seasons since 1992; and secondly, in situ testing that has been trialed for the past three wet seasons. Both methods of toxicity monitoring use the number of eggs produced by the freshwater snail *Amerianna cumingi* as the test endpoint.

Creekside monitoring, which involves pumping a continuous flow of water from the creek through tanks containing test animals located under shelters on the creek's bank, has much higher staff and infrastructure resourcing needs than in situ testing. Comparative testing of the two methods was conducted over two wet seasons. The results showed greater snail egg production in the in situ method compared with the creekside method but no differences in the upstream-downstream difference values (the critical comparative measure and response end-point) between the two methods. This finding led to the decision to replace creekside with in situ toxicity monitoring, commencing in the 2008–09 wet season.

The in situ toxicity method is providing a more environmentally-relevant testing regime compared with the creekside procedure, while requiring substantially reduced staff time and eliminating the need for maintenance-intensive, complex infrastructure.

3.1.5 Continuous monitoring intranet reporting

An automated intranet reporting system was developed prior to the start of the 2008–09 wet season to enable daily upload of raw continuous data collected across all SSD continuous monitoring sites (Magela Creek, Gulungul Creek, Ngarradj Creek, Georgetown Billabong, Ranger mine trial landform) to the Department's intranet site to provide immediate access by those SSD staff who require the data for supervision and assessment or research purposes. Quality-assessed, validated data are uploaded to the intranet on a monthly basis. The data, which include EC, pH, turbidity, stage height, discharge and rainfall, are presented in the form of time-series plots enabling visual assessment of each parameter (Figure 3.2).

SSD's continuous monitoring intranet reporting system will be reviewed during the 2009 dry season to ensure timely production and reporting of good quality data plots.

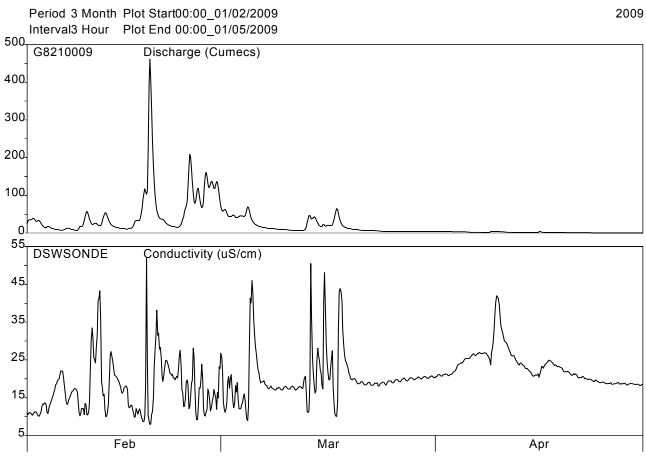


Figure 3.2 Time-series plot showing validated discharge and electrical conductivity data measured at the upstream site on Magela Creek from February to April

3.2 Results from continuous monitoring of water quality in Magela Creek

3.2.1 Background

Continuous monitoring of surface waters around Ranger mine is conducted by both SSD and ERA and the data are used for the assessment of potential impacts arising from activities carried out at the minesite. In situ sensors are maintained by SSD at key sites in the receiving waters of Magela Creek upstream and downstream of the mine (sites MCUGT and MCDW, respectively), and by ERA in two minesite tributaries, Coonjimba Creek and Corridor Creek (at GC2 and RP1weir). The locations of these sites are shown on Map 2. A critical attribute of SSD's continuous monitoring network is the ability to remotely monitor (via 3G telemetry) events in the creek system to provide early warning of increases of inputs of sediments or solutes from the minesite. The data are also used to quantify annual loads of solutes and sediment, with the aim of tracking overall performance of the mine's water management system from year to year.

During the wet season months, mine-derived waters containing elevated (relative to upstream Magela Creek) concentrations of magnesium (Mg) are passively and actively released into Magela Creek via the Coonjimba Creek and Corridor Creek catchments, which include Coonjimba Billabong and Georgetown Billabong, respectively (see Map 2). These tributaries only connect with Magela Creek during the wet season months, at which time their water quality is dominated by inflow of surface runoff from waste rock dumps and low grade ore stockpiles located on the minesite. Additional non-point sources of Mg include wet season induced leaching of polished and unpolished RP2-derived water applied to the footprints of a number of land application areas (LAAs) during the preceding dry season. See Map 2 for locations of the LAAs. The applied water infiltrates the soil profile, and a proportion is flushed out during the subsequent wet season. Previous solute budgetting for the site suggested that most of the Mg is washed out during the wet season period. However, this assessment was based on the results from weekly grab samples, rather than a continuous monitoring record.

The flow conditions in each of the minesite tributaries and in Magela Creek depend on rainfall occurring both in the upper Magela catchment and in the vicinity of the minesite. Annual total rainfall measured at Jabiru airport (by BOM) and cumulative annual flow volumes for Magela Creek since inception of the continuous monitoring program are shown in Table 3.1. These data show the variability in annual rainfall and resultant discharge.

TABLE 3.1 JABIRU RAINFALL AND MAGELA CREEK WET SEASON FLOW CONDITIONS SINCE 2005

Year	Annual cumulative rainfall (mm)	Annual cumulative discharge (GL)
2005–06	2107	485.4
2006–07	2540	845.2
2007–08	1673	416.6
2008–09	1186	235.2

Prior to the 2005–06 wet season, event-based solute loads and subsequent derivation of total annual solute loads in Magela Creek were estimated from chemical analysis of weekly grab samples and therefore contained a high degree of uncertainty. More recently (from 2005–06 onwards) Mg loads with improved accuracy have been derived each wet season using continuous data recorded at 10 minute intervals. By comparing the total mass of solutes measured downstream of the mine in Magela Creek with the mass of solutes from point and diffuse sources from upstream of the mine, a dynamic assessment of the intra- and inter-seasonal fluxes of salts in the system can be made.

3.2.2 Electrical conductivity – magnesium relationships

Relationships between EC and Mg at each of the four locations described above have been derived by correlating Mg concentrations in grab water samples with concurrent measurements of in situ EC. There are statistically very strong relationships between Mg concentration and EC at the four continuous monitoring locations. Prior to the 2008–09 wet season, the dataset for MCDW lacked higher EC (>35 µS/cm) data points to provide a sufficiently high level of confidence in the fit of the data in this region of the relationship.

This issue was addressed during the 2008–09 wet season by carrying out an event-triggered sampling program designed specifically to target the higher EC end (values of 45 µS/cm or greater) of the relationship. The data from MCDW along with data collected at MCUGT, RP1 and GC2 over the 2008–09 wet season, have been used to refine the EC-Mg relationships at each of the sites. This was particularly important for RP1 as Mg concentrations have been on an upward trend over the past few years. Inclusion of the higher concentrations of Mg in the Magela downstream and RP1 datasets has resulted in the relationships of best fit changing from linear to a slightly curved (quadratic) (Figure 3.3). A linear relationship is still the best fit for the Mg-EC relationships for Magela upstream and GC2 (Figure 3.3).

Different EC-Mg relationships exist for each of the sites as a result of different Mg sources, concentration ranges and relative contributions of the constituent major ions present at each of the sites. The slope of the regressions for RP1 and GC2 are similar for EC <500 µS/cm, consistent with the similarity of major ion compositions at both sites. The non-linear relationship for RP1 for EC >500 µS/cm is caused by the formation of the zero-charged ion pair ($MgSO_4^0$) which occurs in waters with higher solute concentrations. A neutral ion pair does not contribute to the measured EC. Solution speciation modelling using the thermodynamic computer model MINTEQA2 indicates that at the highest concentrations of Mg measured in RP1, the neutral ion pair accounts for about 25% of the Mg present. A quadratic relationship best describes the proportion of Mg present as the neutral ion pair from the lowest to the highest Mg concentration measured in RP1.

The slopes for the Magela Creek upstream and downstream sites are similar for periods of flow characterised by EC values of 0 to 20 µS/cm, during which periods the solute load is dominated by water from upstream. This condition can occur when there is little or no input from the minesite, or during flood flows where total load is dominated by solutes coming from upstream. For EC >20 µS/cm, the slope for the downstream site is higher, indicating a greater influence of Mg on EC compared with other solutes present, as is expected with input of Mg dominated mine waters. The existence of these two regimes at the downstream site is a result of variable mixing of upstream waters with mine waters; the resultant composite fit for the EC-Mg relationship is best described by a quadratic function.

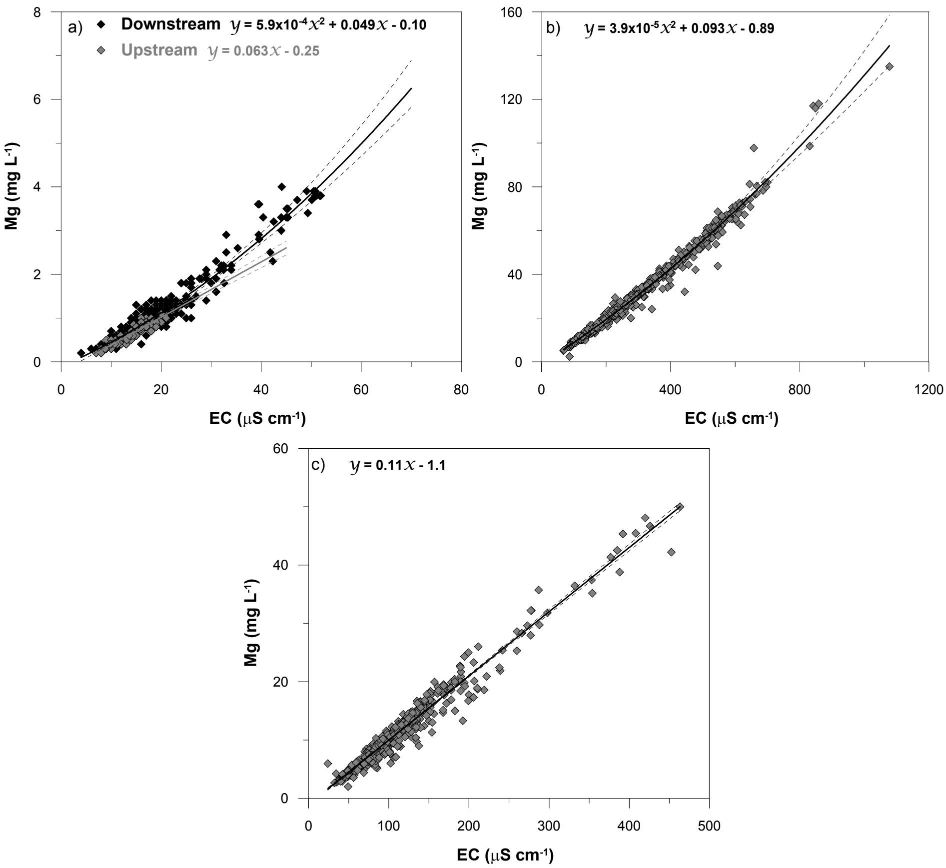


Figure 3.3 Relationships between EC and Mg concentration and upper and lower 95% confidence limits for the a) upstream (R^2 = 0.86, P<0.0001) and downstream (R^2 = 0.94, P<0.0001) sites on Magela Creek, b) RP1 (R^2 = 0.99, P<0.0001) in the Coonjimba Creek catchment and c) GC2 (R^2 = 0.96, P<0.0001) in the Corridor Creek catchment

3.2.3 Magnesium loads

The Mg concentrations predicted from the continuous EC data collected over four past wet seasons have been used together with discharge data to estimate Mg loads input to Magela Creek via the mine site tributaries as well as loads transported along Magela Creek. Magnesium load is calculated using equation (1), where t is time (s), i is a defined period of time (in this case, 10 min), $[Mg]$ is instantaneous magnesium concentration (mg/L) and Q is instantaneous discharge (L/s).

$$\text{total load} = \int_{t=0}^{t=i} [Mg]\ Q\,\mathrm{dt} \qquad (1)$$

By multiplying Mg concentration by the corresponding discharge at each 10 min interval and then summing each of these load increments over time, the total mass of Mg over a specified interval can be calculated.

Minesite

Point sources

The Mg concentrations predicted using the continuous EC measurements in the minesite tributaries have been used together with the measured flows at these locations to calculate Mg loads moving down these catchment lines through each wet season since 2005–06 (Table 3.2).

TABLE 3.2 ESTIMATED MG LOADS (T) EXPORTED FROM COONJIMBA (RP1) AND CORRIDOR CREEKS (GC2) FOR THE 2005–06 TO 2008–09 WET SEASONS

Year	RP1		GC2	
	Volume discharge (GL)	Mg load (t)	Volume discharge (GL)	Mg load (t)
2005–06	1.4	55	2.6	14
2006–07	3.4	110	4.9	17
2007–08	3.1	160	3.4	20
2008–09	0.35	61[1]	1.3	29

1 Total is made up of the sum of the load passively discharged (46 t) over the RP1 weir and the load discharged from pumping and siphoning (15 t)

The Mg loads in Table 3.2 are within the range of previously reported values for RP1 (derived using interpolated weekly grab sample data), with the low value for the 2008–09 wet season reflecting the well below average wet season rainfall. The increased annual Mg load exported from GC2 during 2008–09 is due to additional Mg inputs to the Corridor Creek system, including dry season surface flows from the Pit 1 catchment works and a period of pumped discharge of water (7.05 ML) from RP1 into the upper Corridor Creek catchment during February 2009.

Diffuse sources

To provide an estimate of the Mg load potentially available for export to Magela Creek from the LAAs via shallow groundwater flow during a given wet season, the Mg load added to each of the LAAs during the antecedent dry season has been estimated using water systems management data supplied by ERA in its Annual Wet Season and Annual Environment Reports. The total annual load of Mg applied to each LAA has been estimated using monthly irrigation volumes taken from Ranger Annual Environment Reports (October 2005 to July 2009) and mean monthly Mg concentrations in irrigation waters (RP2 for MLAA and JELAA and cell 9 of RP1WLF for Djalkmara LAA) (Table 3.3).

TABLE 3.3 MG LOADS (TONNES) APPLIED TO THE MAGELA, JABIRU EAST AND DJALKMARA LAAS

Antecedent dry season	Magela LAA	Jabiru East[1]	Djalkmara	Total Mg load
2005	69.5	-	37.4	106.9
2006	75.1	57.2	55.1	187.4
2007	86.3	56.2	64.5	207.0
2008	0.2	2.8	5.4	8.4

[1] Jabiru East was commissioned in 2006

Magela Creek

Magnesium loads in Magela Creek have been calculated over the past four wet seasons using the continuous EC data measured at the upstream (MCUGT) and downstream (MCDW) sites and total Magela discharge measured at GS8210009 (Table 3.4).

TABLE 3.4 MG LOADS (T) MEASURED IN MAGELA CREEK (UPSTREAM AND DOWNSTREAM OF THE MINE) AND MINE WATERS (RP1 AND GC2) AND APPLIED TO LAAS

Time period	Magela Creek		Minesite		
	US	DS	RP1	GC2	LAAs
2005–06	174	405	55	14	106.9
2006–07	140	592	114	17	187.4
2007–08	145	371	163	20	207.0
2008–09	82	203	61	29	8.4

US = Upstream; DS = downstream

The Mg loads measured coming from the upper Magela Creek catchment during the 2008–09 wet season are much lower than for previous years which is consistent with the much lower rainfall and consequent runoff (Table 3.4) experienced in the region during this period. The loads measured at RP1 and GC2 are consistent with values from previous years. The lower loads applied to the LAAs during the 2008 dry season reflect the lower rainfall (and hence runoff) of the preceding wet season.

3.2.4 Load balance at Magela Creek downstream

The total annual Mg load measured in Magela Creek downstream of the mine (*DS*) in any given wet season should be described by equation 2. *US* is the natural background Mg load for the Magela Creek catchment upstream of the mine site. *RP1* is the Mg load input from the Coonjimba Creek catchment including RP1. *GC2* is the Mg load input from the Corridor Creek catchment. *ROC* is the Mg load from the rest of the catchment which should be dominated by wet season washout of shallow groundwater from the LAAs on the minesite that are adjacent to Magela Creek (Magela LAA, Djalkmara LAAs and Jabiru East LAA). Note that LAAs on mine site tributaries (RP1 LAA and Corridor Creek LAA) are assumed to report to Coonjimba Creek or Corridor Creek upstream of the monitoring points RP1 and GC2, respectively, and hence are accounted for in the loads estimated at these point sources.

$$DS = US + RP1 + GC2 + ROC \qquad (2)$$

Currently, there are essentially two unknowns or unconstrained terms in the above equation. Firstly, the Mg load estimated at the downstream site is a potential overestimate since it is derived using EC data from the west channel only, and Magela flow across all three channels (described below). Secondly, the extent of inter-seasonal washout of Mg from the soil profile in the LAAs has to be inferred as there is no direct measure of this. If there was complete washout, the difference between the loads at the upstream site and the downstream site should equate to the input of mine-derived solutes. Table 3.5 compares the difference between the upstream and downstream Mg loads in Magela Creek with the sum of potential inputs from mine sources.

TABLE 3.5 COMPARISON OF THE DIFFERENCE BETWEEN MEASURED AND PREDICTED DOWNSTREAM Mg LOADS (TONNES)

Time period	Measured DS load	Predicted DS load (US + RP1 + GC2 + ROC)	RPD%
2005–06	405	350	131
2006–07	592	458	142
2007–08	371	535	58
2008–09	203	180	123

DS = Magela Creek downstream

US = Magela Creek upstream

RPD% = relative % difference between measured and predicted DS Mg load

The RPD between the measured and predicted downstream Mg loads is typically >100% (with the exception of the anomalous 2007–08 season), with the measured downstream load being greater than the sum of mine-derived inputs. This is likely to be because the loads estimated at the downstream site are overestimates by virtue of the cross-channel gradient in EC that occurs at low to medium flows at this location (see 2007–08 Supervising Scientist annual report).

At MCDW, the continuous monitoring infrastructure is located in an anastomosed section of the stream that has three distinct channels, each separated by sand banks (see Figure 3.1). Mine inputs to Magela Creek occur from the western side during periods of decreasing flow in the creek. Under these conditions mine-derived water previously held back in Coonjimba and Georgetown Billabongs discharges, releasing higher EC waters along the west bank. The channelled nature and hydraulic conditions of Magela Creek result in incomplete lateral mixing causing the formation of a Mg concentration gradient across the stream cross-section. Higher concentrations of mine-derived waters occur in the western-most channel and lower EC, catchment-derived (background) waters predominate in the eastern most channel.

This flow-dependent lateral distribution of mine-derived Mg has implications for deriving the total Mg load for the creek (across all channels), *DS*, as the apportioning of the total stream discharge (and EC) between the three channels has not previously been well-defined as a function of flow. Since the Mg loads estimated at MCDW have been calculated by multiplying the total flow across Magela Creek by the characteristically higher Mg measured in the western channel, the loads derived using this procedure are likely overestimates.

This particular issue was addressed during the 2008–09 wet season by measurement of cross channel EC profiles and concurrent discharge in the western channel at MCDW. An Acoustic Doppler Current Profiler (ADCP) was acquired by SSD to facilitate routine measurement of cross channel stream discharges in Magela Creek. To determine the proportion of flow travelling down the western channel at MCDW, the discharge measured in this channel alone was compared to the total discharge measured concurrently at GS8210009 (Magela Creek discharge across all three channels). The data obtained for the 2008–09 wet season (8 gaugings carried out at MCDW over 5 days) show that a log relationship ($R^2 = 0.98$) exists between the flow at the two sites (Figure 3.4). Up to 60% of the total Magela flow travelling down the western channel at MCDW under low flow conditions ($\leq 20\ m^3/s$) (Fig 3.5). The proportion of total Magela flow travelling in the western channel at MCDW decreases with increasing total flow. Under high flow conditions, greater proportions of the total Magela flow travel along the central and eastern channels.

While there is a significant non-linear relationship between total Magela Creek flow and the flow in the western channel at MCDW for measurements made between January and March 2009, more data from high flow events are needed before flow measured at G8210009 can be used as a reliable predictor under the full range of flow conditions for west channel flow at MCDW.

During the 2008–09 wet season, ERA carried out some cross-sectional EC profiling in Magela Creek at the compliance site G8210009, located a few hundred metres upstream of MCDW. The data provided by ERA showed that when Magela flow was between 20 and 120 m^3/s, there was a definite EC gradient across the stream, with higher EC measured close to the west bank compared with the EC measured along the cross section profile towards the central channel. More intensive cross sectional EC profiling will be carried out by SSD during the 2009–10 wet season at both G8210009 and MCDW.

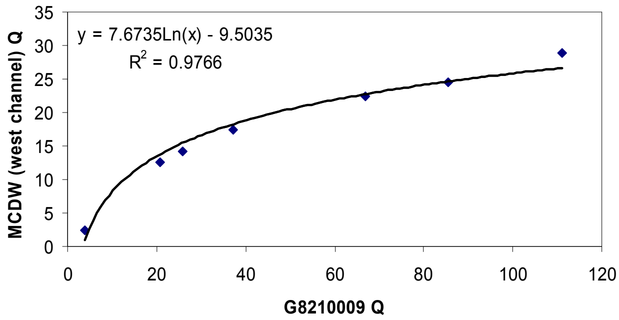


Figure 3.4 Discharge measured in the western channel at MCDW against total Magela Creek discharge measured at G8210009

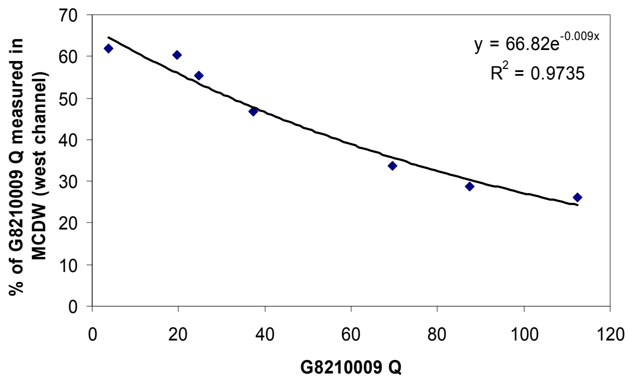


Figure 3.5 Percentage of discharge travelling along the western channel as a function of total Magela Creek discharge measured at G8210009

3.2.5 Summary and future work

Construction of a reliable load balance is dependent on resolving one or both of the unknowns in equation 2. Recent analysis of flow gaugings carried out at MCDW has shown that it may be possible to use the continuous discharge measured at G8210009 to predict flow in the western channel at MCDW, thereby increasing the reliability of the Mg loads calculated at this site. However, gaugings will need to be conducted over a much greater range of flows to determine if the current relationship holds for higher flows. This work will be done during the 2009–10 wet season.

The total Mg load transported in Magela Creek downstream of the mine, *DS*, will then be able to be calculated by adding the loads measured at MCDW and the loads estimated in the central and eastern channels (using the distribution of flow between the three channels and the concentration of Mg from upstream). Once the *DS* loads have been adjusted accordingly, then equation 2 can be rearranged to solve for *ROC* which will allow quantification of Mg inputs derived from the LAA and any other potentially diffuse sources.

3.3 Review of solute selection for water quality and bioaccumulation monitoring

The suite of trace metals measured by SSD as part of its surface water chemistry monitoring and bioaccumulation monitoring programs was initially selected on the basis of a number of assessments carried out prior to commencement of mining, and during the mine's initial operational period. Baseline data were collected as early as 1975 to characterise natural inputs to Magela Creek. Potential metals of concern for the future mining operation were identified by comparing metal concentrations in samples of ore and waste with 'background' concentrations from unmineralised areas, coupled with the results from a leaching study conducted on a pad of material from the Ranger 1 orebody. The suite of metals identified by these early studies has largely been maintained to the present day in the routine analysis of water samples collected by SSD. However, the reason why some of these metals continue to be analysed is no longer for environmental impact assessment but for reasons of sample quality control. The latter aspect is discussed in more detail below.

There are many metals/metalloids that have historically been identified worldwide as having a potential to bioaccumulate. They are (listed in order of decreasing potential to bioaccumulate) cadmium, mercury, selenium, arsenic, beryllium, chromium, cobalt, copper, iron, lead, manganese, silver, uranium, vanadium and zinc. Rather than simply continuing to analyse, a priori, for all of these metals in biota collected in Magela Creek and billabongs downstream of Ranger, it was determined that a risk assessment should be carried out, using the results from chemical analysis of catchment drainage lines contributing metals to the system. This takes the assessment of relevant metals beyond that based on simple comparison of mineralised and unmineralised rock since it will identify those metals that are actually being dissolved by contact with water and hence potentially capable of being transported downstream along minesite catchments.

Comparison of the composition of minesite waters with composition of the water from Magela Creek upstream and downstream of the mine enables a risk assessment to be made of those metals that are of most potential concern. It is those metals that are present at higher-than-background levels downstream of the mine that should be considered more closely for inclusion in the routine water quality monitoring program.

A detailed chemical assessment of the full trace metal profile of minesite waterbodies and major catchment runoff lines had not been carried out since the cessation of mining of Pit 1 and the start of mining of Pit 3 in 1996. Since that time, the waste stockpiles have come to be dominated by material from Pit 3, and it is possible that the trace element composition of runoff and seepage water could have changed as a result of the different provenance of this second orebody. Consequently, contemporary trace element data were required since the previous data would not provide a sufficiently robust basis upon which to carry out the metals risk assessment.

To this end, comprehensive chemical analysis of on-site waterbodies, catchment drainage waters and Magela Creek upstream and downstream of the minesite was undertaken during the 2005–06 wet season. A range of analytes was identified to be of potential environmental concern, based upon: i) concentrations present in mine waterbodies relative to background concentrations; ii) attenuation by natural processes in catchment drainage lines; and iii) likely or inferred potential for biological impact.

3.3.1 Ranger mine and Magela Creek

The minesite is located within the Magela Creek catchment area which runs through the north-east corner or the Ranger Project Area. During the wet season months, Magela Creek receives mine-derived waters that are passively released along Coonjimba and Corridor Creek catchment lines, as well as mine-related constituents that are remobilised from the land application areas (LAAs) in the vicinity of these creeks (see Maps 1 & 2 for locations of these sites).

Both the Coonjimba and Corridor Creek catchment lines have been substantially modified, with the construction of wetland filters and various bunds and weirs to assist with flow control and measurement. The Ranger Water Management System Operational Manual outlines the company's water management practices and provides details of the components of the site water management system. In summary, the management system is divided into three components based on the source of the water and degree of interaction between the water and mining or milling processes.

- **Process water:** Confined to the tailings dam and Pit 1, process water has to be retained on site and can only be disposed of by evaporation or following treatment to a prescribed level.
- **Pond water:** Runoff and seepage from the mill and mine areas, including the low grade ore stockpiles, are directed to Ranger retention pond 2 (RP2). If RP2 capacity is reached, the excess water flows via a spillway structure into Pit 3. Pond water is currently disposed of or treated by a combination of methods, including wetland filtration, land application and treatment in a Microfiltration/Reverse Osmosis (MF/RO) plant.
- **Sediment control water:** Runoff from waste rock dumps and natural woodland areas that reports to RP1 (northern part of the minesite) and the Corridor Creek wetlands (southern part of mine site), which ultimately discharge into Magela Creek via the Corridor Creek and Coonjimba Creek flow lines, respectively.

Only the pond and sediment control waters can impact directly, or indirectly, on water quality in Magela Creek.

3.3.2 Study design

Sampling sites

Surface water samples were collected from a number of tributaries and constructed waterbodies on the Ranger lease as well as upstream (control) and downstream (exposed) locations in Magela Creek (Table 3.6).

Minesite waterbodies that discharge to Magela Creek during the wet season were the focus of this study.

TABLE 3.6 SAMPLING SITES

Site	Description	Major inputs
MCUS	Magela Creek upstream	Undisturbed areas of Magela catchment upstream of Ranger mine
009C & 009W	Magela Creek downstream, central channel and west channel, respectively	MCUS, Corridor Creek via Georgetown Billabong, RP1 via Coonjimba Billabong and land application area runoff
VLGCRC2	Very Low Grade Cross Road Culvert	Runoff from waste rock and low grade ore stockpile
CCWLF (Cell 1)	Corridor Constructed Wetland Filter	VLGCRC2, land application area runoff
GC2	Corridor Creek downstream	CCWLF, land application area runoff
RP2	Retention Pond 2	Water from Pit 3, runoff and seepage from stock piles, processing and milling area and haul roads
RP1	Retention Pond 1	RP1 Constructed Wetland Filter, land application area runoff and seepage from bunded structures in the upper catchment

Methods

During the 2005–06 wet season, samples were collected on four occasions (Table 3.7) over the period of initial, mid and recessional creek flow, to determine the extent to which the composition of the waters changed over the course of the wet season, and the effect, if any, this would have on the risk assessment process.

TABLE 3.7 SAMPLING OCCASIONS

Date	Sites		
	Status of discharge to Magela Creek	Mine lease area	Magela Creek
21 Dec 2005	Prior to release of RP2 and GC2 water to Magela Creek	RP2, RP1, GC2, CCWLF	MCUS, 009C, 009W
19 Jan 2006	Initial period of release form RP1 and GC2	RP2, RP1, GC2, VLGCRC2	MCUS, 009C, 009W
22 & 23 Mar 2006	Release flow established at RP2 and GC2	RP2, RP1, GC2, VLGCRC2	MCUS,009C, 009W
20 & 21 Jun 2006	After cessation of RP1 and GC2 water to Magela Creek	RP2, RP1, GC2	MCUS, 009C, 009W

On each sampling occasion, pH, electrical conductivity (EC), temperature, dissolved oxygen (DO) and turbidity were measured in situ and in the laboratory. Water samples were filtered in the field at time of collection and acidified at SSD's Jabiru Field Station prior to analysis for an extensive suite of dissolved trace metals, using quantitative element scans produced by Inductively Coupled Plasma Mass Spectrometry (ICPMS).

3.3.3 Chemical characteristics of minesite water and Magela Creek

The mean values of pH and EC measured in the Ranger retention ponds, GC2 and at the upstream and downstream sites in Magela Creek during the 2005–06 wet season, are shown in Table 3.8. Each of the waterbodies studied showed some variation in pH over the wet season, most notably in RP1 and RP2, where pH decreased during the rainfall months. The locations sampled on the minesite had higher mean EC values compared with Magela Creek, reflecting the much higher concentrations of major ions in these site waters.

TABLE 3.8 MEAN AND STANDARD DEVIATION OF pH, EC AND TURBIDITY FROM EACH SITE

Site	pH		EC	
	Mean	*SD*	Mean	*SD*
RP2	5.7	*1.2*	1252	*25*
RP1	7.2	*0.9*	423	*178*
GC2	6.4	*0.3*	101	*46*
009C	5.8	*0.5*	15	*4*
MCUS	5.8	*0.5*	13.5	*3.5*

Any metals measured in the mine-derived waters at concentrations less than the corresponding analytical detection limits were considered to present negligible risk to the environment. Hence they will not be discussed further. The mean concentrations of metals/metalloids present at higher than detection limits in mine waters and in Magela Creek over the 2005–06 wet season are presented in Table 3.9. For each element the sites are arranged in descending order of mean concentrations values, with the standard deviations associated with each mean shown in parentheses.

The data in Table 3.9 show that the concentrations of metals in RP2 and VLGCRC2 are much higher than in RP1 and GC2. VLGCRC2 and RP2 both receive surface runoff and seepage from waste rock and low grade ore stockpiles and contain metals dissolved by water in direct contact with high surface areas of exposed rock. Although many metals are present in RP2 at elevated concentrations, they are not of direct risk to the surrounding environment as untreated RP2 water is not discharged into Magela Creek.

In contrast, RP1 and GC2 receive waters that are 'polished' by passage through wetland filters as well as being further diluted by water from cleaner sub-catchments. RP1 and GC2 also receive runoff and seepage from land application areas, where metals initially present in the RP2 water are attenuated by absorption in the soil profile.

TABLE 3.9 SUMMARY OF RESULTS FROM ONE-WAY ANOVAS AND TUKEY'S *POST HOC* TESTS ON DIFFERENCES IN ELEMENT CONCENTRATIONS MEASURED IN MINE WATERBODIES AND IN MAGELA CREEK

Element	df	F	*P*	Tukey's HSD multiple comparison test			
Aluminium	3	3.903	0.030	GC2 109 (61.0)	MCUS 55.4 (39.7)	009C 55.3 (40.2)	RP1 20.0 (15.7)
Arsenic	3	4.316	0.022	RP1 0.23 (0.098)	GC2 0.183 (0.058)	009C 0.095 (0.057)	MCUS 0.079 (0.046)
Boron	3	12.67	<0.000	RP1 18.8 (7.16)	GC2 12.7 (3.75)	009C 8.20 (0.570)	MCUS 8.00 (0.837)
Barium	3	34.87	<0.000	RP1 36.6 (17.7)	GC2 15.3 (11.8)	009C 3.11 (0.498)	MCUS 2.86 (0.493)
Cadmium	3	38.32	<0.000	RP1 5.86 (2.21)	GC2 2.10 (1.10)	009C 0.480 (0.192)	MCUS 0.467 (0.225)
Copper	3	5.889	0.007	GC2 1.32 (0.767)	RP1 0.406 (0.375)	MCUS 0.238 (0.231)	009C 0.190 (0.123)
Iron	3	5.9	0.007	GC2 213 (75.7)	009C 124 (32.9)	MCUS 113 (24.2)	RP1 64.0 (45.6)
Magnesium	3	135.2	<0.000	RP1 58.8 (24.5)	GC2 9.27 (3.67)	009C 0.860 (0.313)	MCUS 0.650 (0.274)
Lead	3	8.01	0.002	GC2 0.237 (0.035)	RP1 0.072 (0.078)	MCUS 0.03 (0.024)	009C 0.023 (0.022)
Rubidium	3	111.8	<0.000	RP1 9.84 (3.51)	GC2 3.76 (1.49)	009C 0.492 (0.095	MCUS 0.432 (0.088)
Sulfate	3	152.1	<0.000	RP1 223 (89.2)	GC2 30.2 (20.0)	009C 1.2 (1.03)	MCUS 0.300 (0.089)
Uranium	3	242.0	<0.000	GC2 11.4 (3.85)	RP1 7.55 (3.69)	009C 0.059 (0.021)	MCUS 0.0207 (0.008)

Sites joined by a common line are not significantly different from each other.

Concentrations are in µg/L except for magnesium and sulfate which are in mg/L.

Variables that were similar amongst all sites (not significantly different) have not been included in the table. Sample sizes: RP1, n = 5; GC2, n = 3; 009C, n = 5; and MCUS, n = 6.

The elements that may pose the greatest potential risk to the natural receiving aquatic system are those that are present in substantially higher concentrations in RP1 and GC2, relative to upstream Magela Creek, as water from both of these minesite locations ultimately discharges into Magela Creek. However, it must also be recognised that there are natural billabongs located between the mine discharge points (RP1 and GC2) and Magela Creek that provide additional polishing of discharge waters. In the case of GC2 it is Georgetown Billabong, and in the case of RP1 it is Coonjimba Billabong (see Map 2 for locations).

The log-transformed concentration data produced from the four wet season sampling occasions were analysed using ANOVA, followed by a Tukey's test to distinguish significant differences ($P < 0.05$) between sites. It is important to note that the low sample sizes and high standard deviations associated with data arising from seasonal sampling over the 2005–06 wet season will somewhat reduce the power of the statistical analyses.

The results of these statistical analyses are presented in Table 3.9. Aluminium, As, B, Ba, Ca, Cu, Fe, Mg, Pb, Rb, SO_4 and U were present in RP1 and/or GC2 at concentrations significantly higher ($P < 0.05$) than those measured upstream in Magela Creek. However, uranium and SO_4 were the only analytes that were significantly elevated ($P < 0.05$) at the downstream site in Magela Creek compared with the upstream site.

To further refine the above analysis, Student t-tests were used to compare the Magela upstream and downstream weekly water quality monitoring data measured between 2001 and 2009 (a large dataset, $n > 200$). The current routine suite of water quality analytes for Magela Creek comprises Mg, Ca and SO_4 as the major ions, with Al, Cu, Fe, Pb, Mn, U and Zn as the measured trace elements. Concentrations of Ca, Fe, Mg, Mn, SO_4 and U observed downstream of the mine were significantly ($P < 0.05$) higher than values observed at the upstream site. The remaining analytes (Al, Cu, Pb and Zn) were not significantly different between the upstream and downstream sites. This indicates that while there are many elements present at concentrations greater than background in the mine waters at source, the majority of these elements are essentially completely attenuated during passage of the water through the tributary creek lines, in Georgetown and Coonjimba Billabongs and by dilution or adsorption on particulates present in Magela Creek.

The current suite of analytes clearly includes all of the potential 'risk' metals/solutes identified above, as well as some additional ones, namely Al, Pb and Zn. It should be noted that these additional metals continue to be analysed primarily for quality control purposes, rather than for environmental impact assessment. because they provide sensitive markers of sample contamination during collection or in the chemical analysis laboratory. A high value for either one or all of these three metals provides a warning that the rigorous (clean) procedures involved in collection or handling a sample for trace metal analysis have been compromised.

Results from this study provide a high degree of confidence that the routine water quality and bioaccumulation sampling programs conducted by SSD are not omitting any potential metals that could be of concern from either toxicological or bioaccumulation perspectives. A full trace metal profile (as described above) of relevant mine waters and upstream and downstream sites in Magela Creek will be conducted at least once per wet season in future. This will provide a quality control check to ensure that all mine-related metals that might (now or in the future) pose a risk to the receiving waterways are included in the routine monitoring suite.

3.4 Effects of magnesium pulse exposures on aquatic organisms

Acquisition of continuous water quality monitoring data in Magela Creek downstream of Ranger over three wet seasons (2005–06 to 2007–08) has enabled quantification of the magnitude, duration and frequency of transient magnesium (Mg) concentrations resulting from mine water discharges (Section 3.1, Supervising Scientist annual report 2007–2008). The mine discharge signal is tracked using Electrical Conductivity (EC) as a surrogate for Mg concentration. This is possible since a strong relationship between EC and Mg concentration has been established in grab samples collected over many years for water quality analysis.

The monitoring data show that peak Mg concentrations associated with pulse events at times exceed the provisional limit of 4.6 mg/L[3], and have, on one occasion, reached a maximum Mg concentration of approximately 11 mg/L. However, these pulses occur over timescales of only minutes to hours, with a maximum exceedence duration of approximately four hours. In contrast, the ecotoxicity data upon which the Mg provisional limit was derived are based on continuous exposures over three to six days (depending on the test species). Consequently, it was unknown if these shorter duration exceedences were having adverse effects on aquatic biota. Therefore an assessment of the toxicity of Mg under a pulse exposure regime was initiated.

Initial test work has focused on assessing the effects of a single Mg pulse of four hours duration (corresponding to the maximum duration pulse above the provisional limit) to three species previously found to be highly sensitive to Mg (van Dam et al in press[4]). Green hydra (*Hydra viridissima*), duckweed (*Lemna aequinoctialis*) and a cladoceran (*Moinodaphnia macleayi*), were exposed to a four hour pulse over a range of Mg concentrations. For these initial experiments, the pulse was administered at the beginning of the test, after which time the organisms were returned to natural Magela Creek water for the remainder of the standard test period (four to six days). In addition, because the cladoceran test protocol involves tracking individuals from newly hatched neonate to reproducing adult, it was possible to investigate the influence of the effect of pulse timing with respect to test organism developmental stage. Consequently, an additional test was conducted for this species where the four hour pulse was administered around the time of the onset of reproductive maturity when the juvenile cladocerans were 27 h old and developing their first brood offspring (approximately 24 h into the experiment). The results were compared with those from tests where the organisms were continuously exposed to Mg throughout the standard test period.

---

3 van Dam R, Hogan A, McCullough C & Humphrey C 2008. Toxicity of magnesium sulfate in Magela Creek water to tropical freshwater species. In ***eriss*** *research summary 2006–2007*, eds Jones DR, Humphrey C, van Dam R & Webb A, Supervising Scientist Report 196, Supervising Scientist, Darwin NT, 11–14.

4 van Dam RA, Hogan AC, McCullough C, Houston M, Humphrey CJ & Harford AJ (in press). Aquatic toxicity of magnesium sulphate, and the influence of calcium, in very low ionic concentration water. *Environmental Toxicology and Chemistry*.

Toxicity test data for each species are presented in Table 3.10 and Figure 3.6. For all three species, the toxicity of a single four hour Mg pulse at test commencement was consistently lower than when the organisms were continuously exposed to Mg. The relative toxicity across tests was determined by comparing the concentrations that caused a 50% inhibition of the test endpoint (IC50s; based on hydra or lemna growth rate and cladoceran reproduction). Magnesium was approximately half as toxic to *H. viridissima* under the pulse regime compared with the continuous exposure. No response was observed when the duckweed *L. aequinoctialis* was exposed to a pulse of up to 4.2 g/L Mg. The Mg pulse was approximately an order of magnitude less toxic to *M. macleayi* than the continuous exposure. However, in the experiment where *M. macleayi* was exposed to the pulse at the onset of reproductive maturity, Mg was only approximately two times less toxic than for the continuous exposure, indicating that the timing of the pulse is a key factor for this species.

TABLE 3.10 TOXICITY OF PULSE EXPOSED MAGNESIUM COMPARED WITH CONTINUOUS EXPOSURE

Species	IC_{50} (95%CL)[a] mg Mg per litre		
	Continuous exposure	4 h pulse at test commencement[b]	4 h pulse at onset of maturity (24 h into test)
Hydra viridissima (green hydra)	663 (518–746)	1231 (1160–1252) 1393 (1363–1419)	Not applicable
Lemna aequinoctialis (duckweed)	1393 (664–3207)	>4220	Not applicable
Moinodaphnia macleayi (cladoceran)	130 (116–144)	1180 (1070–1321) 1498 (1271–2051)	305 (289–338)

a IC50 = Concentration causing a 50% inhibition of the test endpoint (associated 95% confidence limits).

b The results of two tests are reported for both *H. viridissima* and *M. macleayi*.

For all three species tested thus far, Mg pulse concentrations that exhibited toxic effects were well in excess of the maximum concentration reported in Magela Creek (11 mg/L). Even in the most sensitive test, where *M. macleayi* was exposed at the onset of reproductive maturity, the concentration that caused a 10% inhibition of the test endpoint (IC10; generally considered an 'acceptable' level of effect), of 208 mg/L Mg, was still approximately 20 times higher than the reported maximum Mg concentration.

The work done to date will be extended to assess the effect of a four hour pulse exposure at test commencement on another sensitive species, the freshwater snail *Amerianna cumingi*. This species is of particular interest because it has been used since 1991 in creekside toxicity monitoring and the more recently developed in situ monitoring program (chapter 2, section 2.2.3, Supervising Scientist annual report 2008–09). As such, laboratory derived toxicity data for this species will enable more robust interpretation of results obtained from the in situ field based toxicity measurements.

The next phase of this research will involve other Mg pulse durations and also multiple pulses to fully delineate the responses to the range of Mg concentrations seen in the monitoring record.

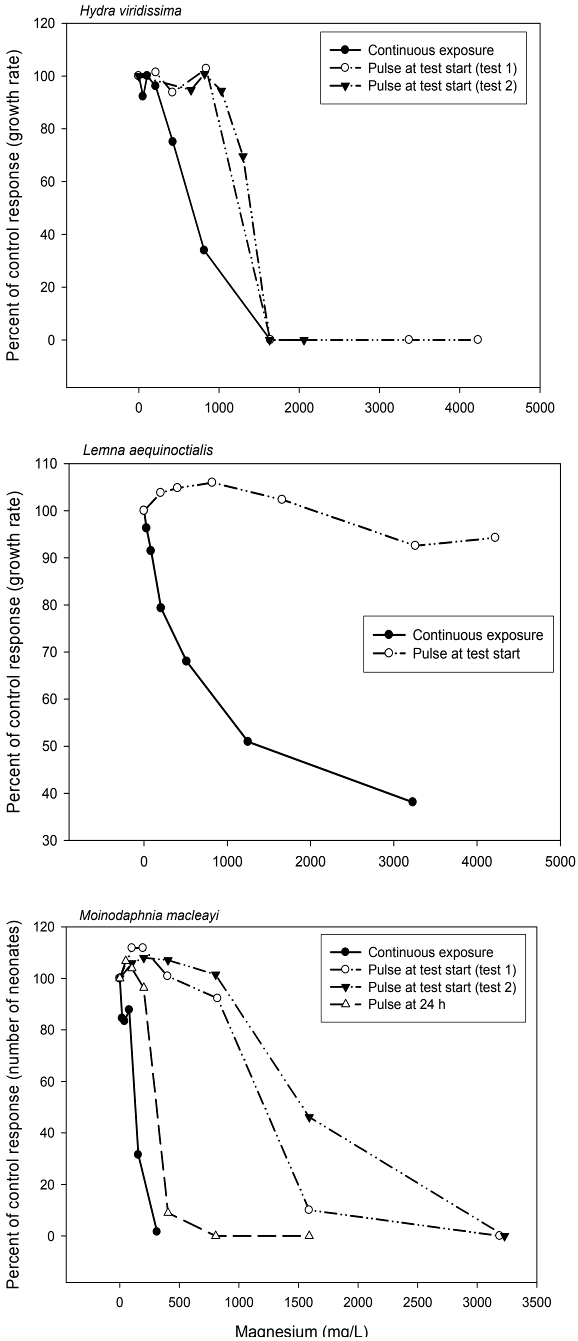


Figure 3.6 Toxicity of magnesium to the green hydra, *Hydra viridissima*, the duckweed, *Lemna aequinoctialis* and the cladoceran, *Moinodaphnia macleayi*. Data from continuous exposure experiments are represented by a solid line while 4 h pulse data are represented by broken lines. Error bars have been omitted to aid visual clarity.

3.5 Amelioration of uranium toxicity by dissolved organic carbon from a tropical Australian billabong

Mining represents one of the potential threats to the quality and biodiversity of freshwater ecosystems in northern Australia. Uranium (U), aluminium (Al) and arsenic (As) are priority metals/metalloids of ecotoxicological concern for the region's mining industry. Uranium is of specific relevance for the Magela Creek system adjacent to the Ranger mine, whilst Al and As are of general concern for mining in the broader northern Australian region.

The objective of this work is to further quantify the influence of dissolved organic carbon (DOC) on the toxicity of U, Al and As. Few studies of the toxicity of these three elements have specifically investigated the effect of dissolved organic carbon (DOC), despite the fact that DOC is known to play a major role in attenuating the toxicity of metallic cations. Four freshwater species are being used for the toxicity testing, which is being conducted under fixed conditions of pH, water hardness and alkalinity.

In 2007–08, the influence of DOC on U toxicity to three Australian tropical freshwater species, northern trout gudgeon (*Mogurnda mogurnda*), green hydra (*Hydra viridissima*) and unicellular green alga (*Chlorella* sp), was measured in synthetic Magela Creek water (SMCW), the composition of which is characteristic of sandy braided streams in tropical Australia. The DOC used for this work was the Suwannee River Fulvic Acid Standard I (SRFA) produced by the International Humic Substances Society (IHSS). The SRFA was selected for initial evaluation of the effects of DOC because it is an international reference material whose composition and properties has been extensively characterised. A fulvic acid (FA) was selected because FAs account for a large proportion of aquatic DOC in natural water. The results obtained for the SRFA were summarised in the 2007–08 Supervising Scientist annual report.

In 2008–09, the toxicity of U to the three species listed above was assessed in DOC-rich natural water from Sandy Billabong (SBW) in Kakadu National Park. This site was selected based on its location within the Alligator Rivers Region and for the DOC content of the water (10 mg/L). The DOC in this water is produced primarily by leaching of leaf litter, and release from coarse particulate matter, soil, bark and twigs. The aim of this work was to evaluate the influence of DOC from the Alligator Rivers Region on the toxicity of U, and to compare it with the SRFA. Different concentrations of DOC (0, 1, 5 & 10 mg/L) in SBW were obtained by diluting SBW with SMCW, which is of very similar ionic composition to SBW but lacking in DOC. Two tests, each comprising the four DOC concentrations in combination with a range of U concentrations, were conducted for each species.

Test durations and endpoints were as follows: *M. mogurnda* 96-h sac-fry survival; *H. viridissima* 96-h population growth rate; *Chlorella* sp 72-h population growth rate. For all tests, water parameters (pH, dissolved oxygen, electrical conductivity) were monitored daily. Water samples were taken for analyses of DOC, alkalinity, hardness and a standard suite of metals and major ions. For each species, response data from two tests were pooled, and concentration-response relationships were determined. Physico-chemical variables were input into the HARPHRQ geochemical speciation computer model to determine the effect of DOC on U speciation, to ascertain if the proportion of U that was bound by the DOC could be related back to U toxicity.

Figure 3.7 shows linear regressions of U toxicity (expressed as IC/LC50) with increasing DOC for each of the species in both SBW and in SMCW with SRFA (used for previous toxicity testing). Summary toxicity data are shown in Table 3.11.

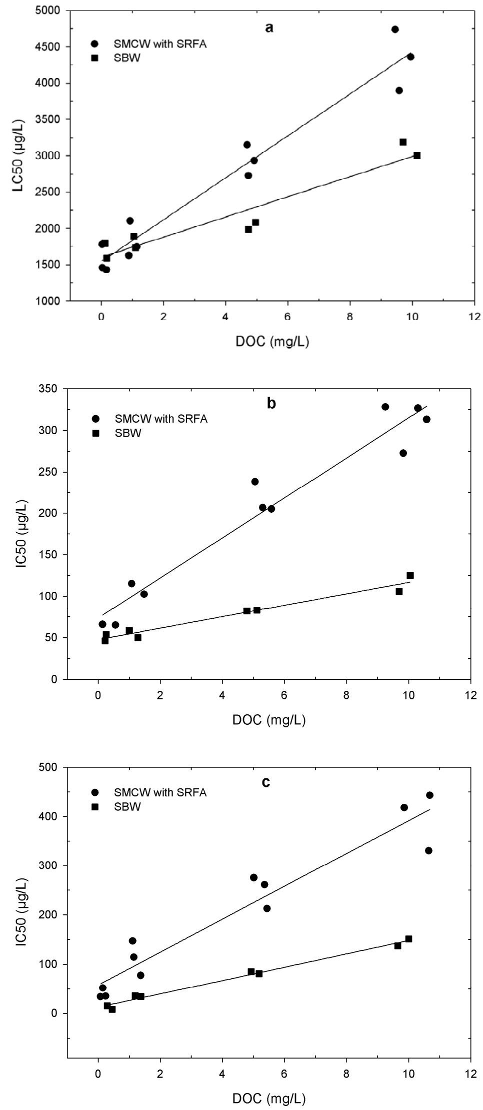


Figure 3.7 Effect of increasing DOC on U toxicity to *Mogurnda mogurnda* (a) *Hydra viridissima* (b) and *Chlorella* sp (c) Linear regressions of uranium toxicity (expressed as the IC50/LC50) against DOC for both SBW and synthetic Magela Creek water (SMCW) with Suwannee River fulvic acid (SRFA)

TABLE 3.11 EFFECT OF TWO DIFFERENT FORMS OF DISSOLVED ORGANIC CARBON (DOC); SANDY BILLABONG WATER AND SUWANNEE RIVER FULVIC ACID STANDARD I, ON THE TOXICITY OF URANIUM TO THREE LOCAL FRESHWATER SPECIES

Species	DOC[a] (mg/L)	IC_{50}[b] (95%CL)[c]		Reduction in toxicity with 10 mg/L DOC increase	
		SBW[d]	SMCW+SRFA[e]	SBW	SMCW+SRFA
Mogurnda mogurnda[f] (northern trout gudgeon)	0	1690 (1499–1964)	1550 (1057–1961)	1.8x	2.8x
	10	3093 (2829–3459)	4330 (4152–4575)		
Hydra viridissima (green hydra)	0	50 (18–81)	65 (8–85)	2.3x	4.8x
	10	115 (44–191)	310 (247–491)		
Chlorella sp (unicellular alga)	0	15 (8–24)	38 (22–69)	9.6x	10.4x
	10	144 (114–168)	394(248–766)		

a DOC: dissolved organic carbon, b IC_{50}:this is the concentration that results in a 50% inhibition of the test response relative to the control response; c 95% confidence limits; d SBW: Sandy Billabong water; e SMCW + SRFA: Synthetic Magela Creek water with Suwannee River fulvic acid; f For *M. mogurnda*, toxicity estimates relate to concentrations that affect percentage survival (as a % of control survival), compared with sub-lethal endpoints, such as growth and reproduction, for the other species

U toxicity was reduced approximately 10 fold for *Chlorella*, and 2 fold for *M. mogurnda* and *H. viridissima*, in SBW containing 10 mg/L DOC compared with SMCW lacking DOC. SRFA resulted in a slightly greater reduction in U toxicity than SBW for all three species (see Table 3.11). Despite the SBW reducing U toxicity to a lesser extent than the SRFA, geochemical speciation modelling showed that both forms of DOC resulted in the formation of similar proportions of UO_2.DOC complex.

To further investigate the reason for the different effects of these DOC sources on U toxicity, the FA fraction was isolated from SBW and its physico-chemical characteristics compared with those of SRFA. The FAs were found to be similar in terms of molecular weight, elemental composition (carbon, nitrogen, hydrogen, nitrogen, sulphur and oxygen) and their proportion of acidic (primarily carboxylate) functional groups responsible for metal complexation. Quantitative measurements of the U-complexing capacity of SBWFA may explain why this FA reduces U toxicity to a lesser extent than SRFA. This work is currently in progress.

Attenuation of U toxicity is especially important in impacted billabongs on the Ranger lease, where DOC concentrations can reach 20 mg/L, considerably higher than those of Magela Creek (eg ~1–5 mg/L). Consideration of the concentrations of DOC will be required as part of the process for the setting of water quality closure criteria for U in these waterbodies.

The U toxicity work will be completed using the freshwater unicellular species, *Euglena gracilis*, and measurements of Al and As toxicity will also be done using all four species of test organisms. The results from this work will be documented in subsequent annual reports.

3.6 A study of radionuclide and metal uptake in mussels from Mudginberri Billabong

3.6.1 Background

An important component of the stream monitoring program for Ranger mine measures uptake of selected metals and radionuclides by freshwater mussels, *Velesunio angasi*, from Mudginberri Billabong (see Section 2.2.3, 'Bioaccumulation in freshwater mussels'). Among the suite of radionuclides measured, radium-226 (^{226}Ra) is of particular relevance as ^{226}Ra in mussels has been identified as the major contributor to the total radiological dose from ingestion of bush foods by local indigenous people.[5] There are several factors contributing to this: (a) freshwater mussels are an integral component of the diet of the Mudginberri Aboriginal community located downstream of the mine, (b) the high concentration factor of 19 000 for radium in freshwater mussels, and (c) the large ingestion dose coefficient for ^{226}Ra of 0.28 µSv/Bq.

In the 2007–08 annual report (section 3.3), results were reported from a longitudinal study of radionuclide and metal uptake in mussels from upstream of the mine down to Mudginberri Billabong in the Magela Creek catchment, a total distance of about 30 km. The study was designed to test the hypothesis that Ranger mine was not contributing to the higher radium activity concentrations found in mussels from Mudginberri Billabong compared with concentrations found in mussels from Sandy Billabong, a control site in another (adjacent) catchment. The study showed that radium and metal body burdens in freshwater mussels along the Magela catchment are driven by a number of factors such as mussel growth rate and (soft) body weight, as well as natural water chemistry gradients along the catchment that are unrelated to current mining activity at Ranger. Three observations led to this conclusion: (i) uranium concentrations in the mussels from sites in the longitudinal study were comparable with pre-mining values from 1980; (ii) ^{228}Ra/^{226}Ra activity ratios in mussel flesh decrease gradually along the catchment, and (iii) stable lead isotope ratios in mussel flesh and sediments change gradually as well, rather than a step change which would be expected for a contemporary (point source) mining-related impact.

To test whether the sampling location and associated variability in the amount of fine sediments have an influence on radium activity and metal concentrations in freshwater mussels from Mudginberri Billabong, mussels were collected for metal, stable lead isotope and radionuclide analyses from the inlet, middle and outlet of the billabong (Figure 3.8). Sampling occurred at the end of the 2008 dry season. The billabong edges were sampled at the inlet and middle portions of the billabong, as the edges are where mussels are typically concentrated and to account for the locations that are actually accessed by local Aboriginal people.

[5] Martin et al 1998. *Journal of Environmental Radioactivity* 40, 37–58.

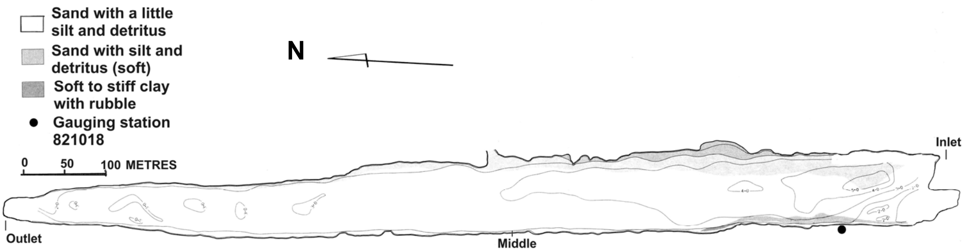


Figure 3.8 Mudginberri Billabong and location of 2008 sampling sites

3.6.2 Radionuclides in mussels

After collection, mussels were transported to the SSD Darwin laboratories and purged for 6–7 days in billabong water before being measured for length and width and weighed and dissected to remove the flesh. Samples were dried and reweighed to determine the dry weight. The age of each mussel was determined by counting the number of annual growth bands (annuli). The dried and ground flesh of each mussel was combined by age class and site, and the average dry weight per age class determined.

Each mussel age class was then measured for the radioisotopes of lead (^{210}Pb), thorium (^{228}Th) and radium (^{226}Ra & ^{228}Ra) by gamma spectrometry. Figure 3.9 shows the average ^{226}Ra activity concentration and the ^{228}Ra/^{226}Ra activity ratio per mussel age class for the recent 2008 collection (inlet, middle and outlet values shown separately) compared with data from previous end of dry season collections. ^{226}Ra activity concentrations in mussels collected in 2008 are comparable with activity concentrations determined previously.

^{226}Ra and ^{210}Pb activity concentrations are positively correlated with age indicating bioaccumulation of these radionuclides, with the ^{226}Ra-age relationship shown in Figure 3.9. Differences in activity concentrations in mussels among the three sites were tested, using analysis of covariance (ANCOVA) which, after taking age into account, tests for differences in regression intercepts and slopes. There was no statistically significant difference in the mussel ^{226}Ra activity concentrations (P=0.49) nor the Ra-age regression slopes (P=0.085) among locations. There was also no difference in the ^{210}Pb activity concentrations (P=0.67) nor the ^{210}Pb-age regression slope (P=0.16), respectively.

^{226}Ra is a member of the uranium decay series and ^{228}Ra of the thorium decay series. Hence the activity ratio of the two radioisotopes provides a measure of the relative contribution of uranium and thorium-rich sources, respectively, to the radium activity concentration in a sample. The lower the ^{228}Ra/^{226}Ra activity ratio is in sediments or mussels, the lower the relative contribution of radium derived from a thorium-rich source and the higher the contribution of radium derived from a uranium rich source, respectively. ANCOVA testing of the ^{228}Ra/^{226}Ra activity ratio measured in aged mussels (Figure 3.9) shows that after taking age into account, there is a significant difference in ^{228}Ra/^{226}Ra (P=0.035) between sites, with mussels collected in the middle exhibiting lower ratios than mussels from the inlet and outlet of the billabong, respectively. The most likely reason for this difference is the higher proportion of fines in the sediments at the middle site, exhibiting lower $^{228}Ra/^{226}Ra$ ratios. At this (western edge) location, wet season water velocities are highest for the billabong cross-section, possibly resulting in scour and exposure of the underlying clay stream bed. In contrast, the coarser and more sandy sediments, such as those at the outlet, naturally have a more thoriferous signature. This is confirmed by the stable lead isotope ratios measured in sediments, which are also less thoriferous in the middle section of the billabong.

Despite the differences in $^{228}Ra/^{226}Ra$ measured in the mussels, it can be concluded that the location in the billabong has no measurable effect on the ^{226}Ra and ^{210}Pb activity concentrations in freshwater mussels. Consequently, differences observed when comparing historical ^{226}Ra and ^{210}Pb data comprising several sampling locations in Mudginberri Billabong must be attributed to other factors, such as the timing of mussel collection (wet versus dry season) or the duration and intensity of the preceding wet season.

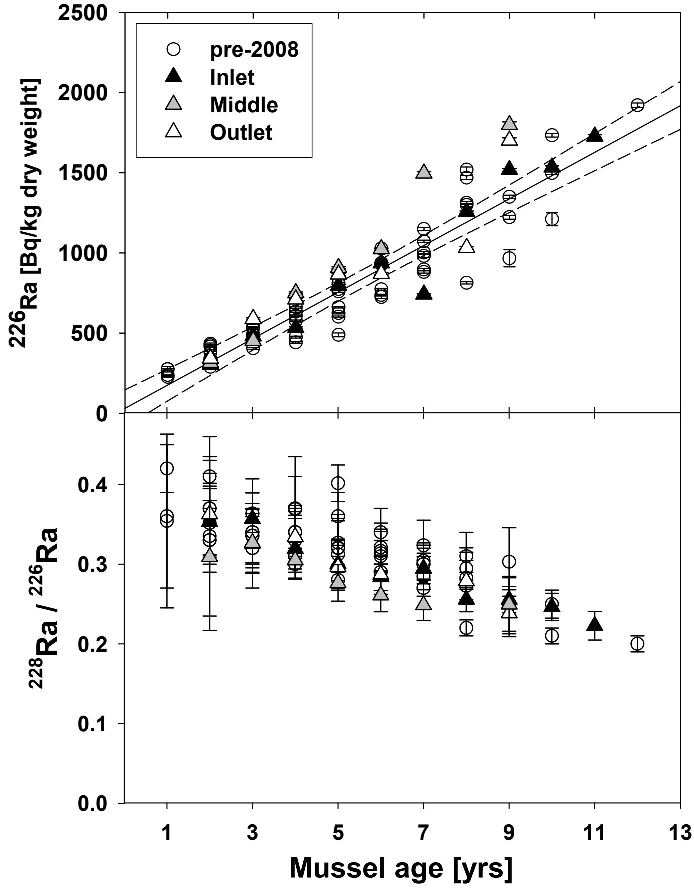


Figure 3.9 ^{226}Ra activity concentrations (top) and $^{228}Ra/^{226}Ra$ activity ratios (bottom) measured in mussels collected in 2008, and a comparison with results from previous end of the dry season collections (open circles). The solid line in the acitvity plot is a linear fit to all of the pre-2008 data, and the dashed lines shows the associated 95% confidence limits for this dataset.

3.6.3 Uranium and stable lead in mussels

Uranium and lead concentrations in water, total sediment, the < 63µm fraction (mud and clays) and in dried mussel flesh combined from each age class, were measured by inductively coupled plasma mass spectrometry.

Both uranium and lead concentrations measured in mussel flesh are positively correlated with age. ANCOVA combined with a Tukey's multiple comparison test showed that this increase with age is highest in mussels from the middle section of the billabong ($P<0.05$) whereas mussels from the inlet and outlet show similar values. This site difference in concentrations cannot be explained by variations in mussel growth rates, which, in agreement with earlier studies from the early 1980s, are highest at the inlet and gradually decrease towards the outlet (growth rate results not reported here).

Measurements of the concentration of uranium and lead in water collected at the three sites showed no difference among the sites. Hence water metal concentration is not responsible for the observed differences in mussel flesh concentration. However, the concentrations of metals in total sediment were generally higher in the middle, as a consequence of the higher proportion of mud and clays (65%) found there compared with the inlet (29%) and outlet (13%) sampling locations in the billabong. It appears that the higher proportion of fines (rather than the concentration of metals in the fine fraction, which for uranium decreases from the inlet to the outlet) is the cause of the higher metal concentrations observed in mussel tissue from the middle of the billabong.

^{206}Pb and ^{207}Pb are the stable end-members of the uranium decay series (^{238}U and ^{235}U, respectively), while ^{208}Pb is the stable end-member of thorium decay (^{232}Th). In Figure 3.10 the $^{206}Pb/^{207}Pb$ isotope ratios measured in mussel tissue are plotted against the $^{208}Pb/^{207}Pb$ ratio and a comparison is made with data measured in the 2007 longitudinal study and from a previous collection in 2005. This method enables the determination of the relative contribution of different sources to the total lead concentration in a sample.

Common lead isotope signatures are for example the PDAC (present day average crustal) with $^{206}Pb/^{207}Pb \approx 1.20$ and $^{208}Pb/^{207}Pb \approx 2.48$), or the Broken Hill and Mt Isa lead isotope signatures ($^{206}Pb/^{207}Pb < 1.04$ and $^{208}Pb/^{207}Pb < 2.32$), respectively. Broken Hill and Mt Isa lead has been used in Australia and worldwide for many decades for the manufacturing of industrial lead products, and contamination with this type of lead can be traced via its low $^{206}Pb/^{207}Pb$ and $^{208}Pb/^{207}Pb$ isotopic fingerprint. In contrast, high $^{206}Pb/^{207}Pb$ and low $^{208}Pb/^{207}Pb$ ratios indicate a contribution from a uranium rich source, whereas high $^{208}Pb/^{207}Pb$ indicates a thorium rich source. As lead isotopes are physically and chemically alike and not discriminated by environmental processes, varying proportions of lead from different sources in a sample will lead to changes in its lead isotopic composition.

Figure 3.10 illustrates that there are within-billabong variations in the lead isotope ratios measured in mussel flesh, although these differences are less pronounced than those observed in 2007 along Magela Creek. While there are only small differences between Pb isotope ratios in mussels collected from the inlet in October 2005 and 2008, mussels collected in May 2007 exhibit a more uraniferous signature. This is most likely caused by a difference in sampling location. Due to accessibility issues at the end of the wet season, mussels were sampled further upstream, closer to the Magela Creek channel in May 2007, and hence the lead isotope ratios are more similar to those measured at G8210009. In contrast, the sampling site in 2008 was influenced to a much greater extent by billabong mud and clays, which typically show Pb isotope ratios closer to PDAC.

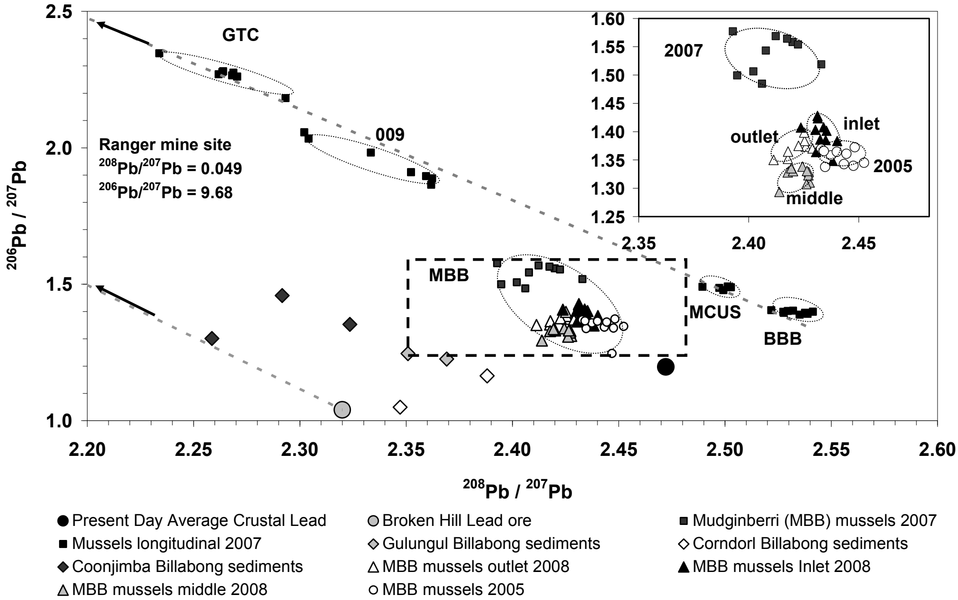


Figure 3.10 $^{206}Pb/^{207}Pb$ plotted versus $^{208}Pb/^{207}Pb$ isotope ratios measured in mussel tissue from Mudginberri Billabong, and previous data from Magela Creek. Trendlines (dashed) assume mixing of radiogenic lead with the Ranger ore signature and lead with an Upper Magela catchment signature and Broken Hill lead, respectively. Each site's mussel lead isotope signature is circled with the site label. BBB: Bowerbird Billabong, MCUS: Magela Creek upstream; GTC: Georgetown confluence; G8210009: Magela Creek downstream; MBB: Mudginberri Billabong (Supervising Scientist, 2007). The inset shows a magnification of the dashed rectangle that shows the Mudginberri Billabong data only.

Lead isotope signatures measured in mussels collected in 2008 from the outlet lie in between those of the inlet and middle isotope ratios. Mussels collected from the middle appear to be influenced by an additional (industrial) source that exhibits lead isotope ratios that can be found in Corndorl Billabong sediments, for example, unaffected by runoff from the Ranger minesite. This is indicative of contamination with lead from sources such as lead shot, fishing sinkers, or other manufactured products containing Pb from commercial Australian orebodies. The sampling site is closest to the boat ramp and would be the site most exposed to runoff from the Mudginberri community as well as from the adjacent paddocks of the historic Mudginberri pastoral station; these factors would place this site at highest susceptibility to contamination with industrial lead.

3.6.4 Conclusion

This study found subtle variations in the relative contribution of sources of lead and uranium in the tissue of freshwater mussels collected from within Mudginberri Billabong: the concentrations of these metals in mussels appear to be mainly influenced by the proportion of fine sediments (< 63 µm) at the sampling site; the lead isotope ratios indicate an additional industrial source of lead, in the middle or western edge of the billabong.

Importantly, ^{226}Ra and ^{210}Pb activity concentrations in mussels (which determine the dose received via the ingestion of mussels) are not statistically different among sites. Thus the site of collection of mussels in Mudginberri Billabong is unlikely to affect the levels of ^{226}Ra and ^{210}Pb measured for the purposes of conducting a dose assessment. The results provide some confidence that the data from previous mussel collections conducted from several locations in the billabong over the years can be directly compared, taking into account factors such as mussel condition, timing of mussel collection and the duration and intensity of the preceding wet season.

3.7 Investigating radium uptake in *Passiflora foetida* (bush passionfruit)

3.7.1 Background

Our current ability to predict radiological dose received via the ingestion of radionuclides in terrestrial plants growing on rehabilitated minesites is limited because uptake mechanisms of radionuclides in plants are not well understood. The most common approach to determine doses is to use concentration factors for each food item and radionuclide to assess radionuclide uptake, and a model diet to estimate the quantity of each radionuclide that is ingested. Reported concentration factors, expressed as the ratio of the radionuclide activity concentration in the food item to the activity concentration measured in the soil in the plant root zone can, however, vary by up to three orders of magnitude, even for individual soil-crop combinations. In addition, although the International Atomic Energy Agency (IAEA) provides default concentration factor values for some food items, the analogies used for local foods in the Alligator Rivers Region (eg potato as an analogy for yam) have been shown to be inaccurate and, in some cases, the concentration factors are different by several orders of magnitude.

The need exists to develop concentration factors specific for a region or even for individual sites to enable a more reliable prediction to be made for radionuclide activity concentrations in plants growing on a rehabilitated minesite. Of particular importance are ^{226}Ra, ^{210}Po and ^{210}Pb that have previously been identified as the main contributors to radiological dose via the ingestion pathway when eating traditional terrestrial bush food items such as fruits and yams in the Alligator Rivers Region.[6]

[6] Ryan et al 2005. *Journal of Radioanalytical and Nuclear Chemistry* 264, 407–412.

Various approaches have been suggested to operationally define the transfer mechanisms of radionuclides from soil to plant, in an attempt to lower variability in concentration factors and account for differences in bioavailability of metals between different soil types and/or sites. Many of these define the 'bioavailable' fraction within the soil by chemical techniques such as sequential extraction. In our study, a soil sequential extraction procedure was developed to assess partitioning of radium within soils in the Alligator Rivers Region. Correlation of $^{226}Ra/^{228}Ra$ activity ratios in soil fractions from the plant root zone with those in the edible fruit was also used to infer the specific sources of radium uptake for the fruit.

3.7.2 Methods

An introduced passionfruit species, *Passiflora foetida* (Figure 3.11), was selected for study since it is eaten by indigenous groups in the Alligator Rivers Region and also commonly eaten by children. This is important because ingestion dose coefficients are higher for children than for adults. *Passiflora foetida* is a shallow rooted, fast growing weed that may flower and fruit at any time of the year. This makes it ideal for short-term studies, and more likely to have a higher uptake of radium when growing in areas where contaminated material is retained in the surface layers.

Figure 3.11 *Passiflora foetida*

Samples of fruit and associated soils were collected from a wide range of sites including: the rehabilitated Nabarlek uranium mine in western Arnhem Land; a historic mine area impacted by uranium mine tailings ('Rockhole residues') in the South Alligator River valley; the land application areas at Ranger mine impacted by mine waste waters; the black plain soils to the south-west of the Ranger tailings dam; and background sites not impacted by mining. The soil was then subjected to a sequential extraction procedure and radium (^{226}Ra and ^{228}Ra) was measured in the soil fractions and fruit to determine concentration factors for the various fractions. The fractions (and extraction techniques) defined by this study were the bioavailable fraction (water followed by a 1 M $MgCl_2$ leach, with the Ra extracted by the two steps being combined); the fraction bound to iron and manganese oxides (1 M HCl leach); the fraction that could be bound by organic complexes, particularly Ra-sulfate (0.2 M EDTA in 1.7 M NH_4OH); and the residual fraction.

3.7.3 Results

^{226}Ra activity concentrations in the soils associated with the collected samples of *Passiflora* vary by more than two orders of magnitude (35–11 700 Bq/kg dry weight). The highest values measured are from the Rockhole residues site in the South Alligator River valley where passionfruit is growing in soil that contains tailings rich in ^{226}Ra. Activity concentrations are also elevated in the soils of the Magela land application area (MLAA) at Ranger mine due to the application of pond waters containing elevated ^{226}Ra, and in soils from the Gulungul catchment. The lowest soil activity concentrations were measured at a site close to Magela Creek, downstream of the minesite. It is noted that the sites sampled cover a range of different origins for the ^{226}Ra, from being applied in solution to the top of the soil profile in the MLAA to residual ^{226}Ra in mine tailings at the Rockhole site. Hence it could be expected that the Ra might be bound in different ways in each of these soil types.

The ^{226}Ra activity concentrations [$Bq \cdot kg^{-1}$ dry weight] measured in the samples of *Passiflora* range from about 3 $Bq \cdot kg^{-1}$ at the Magela Creek site, to 520 $Bq \cdot kg^{-1}$ at the Rockhole residues.

In contrast to ^{226}Ra, the ^{228}Ra activity concentrations in the soils were similar in all sites and reflect typical values seen throughout the region, ranging from 12–84 Bq/kg. The variability of ^{228}Ra activity concentrations in the fruits is very small and ranges from 1.3–5.1 Bq/kg.

Table 3.12 shows the calculated concentration factors derived from the ^{226}Ra activity present in the total soils and in the different selective extraction treatments for the various sites investigated in our study.

TABLE 3.12 ^{226}RA CONCENTRATION FACTORS FOR *PASSIFLORA FOETIDA* MEASURED RELATIVE TO THE VARIOUS LEACH FRACTIONS

Sampling site	Concentration factors relative to			
	Total soil	bioavailable	1M HCl	EDTA + NH_4OH
Rockhole residues	*0.030±0.001*	*0.27±0.012*	*0.201±0.006*	*0.70±0.02*
Nabarlek	*0.086±0.005*	*1.39±0.11*	*0.316±0.017*	*1.59±0.09*
Magela LAA	*0.018±0.001*	*0.45±0.03*	*0.079±0.005*	*0.34±0.02*
Gulungul 1	*0.0050±0.0002*	*0.35±0.02*	*0.010±0.001*	*0.086±0.004*
Gulungul 2	*0.0037±0.0002*	*0.32±0.02*	*0.0068±0.0003*	*0.066±0.003*
Magela DS	*0.238±0.021*	*1.87±0.11*	*1.131±0.074*	*2.86±0.28*

The concentration factor is defined as the activity concentration in the dry fruit divided by the activity concentration in the dry soil or in the leach fraction. Activity concentration in the leach fraction is expressed as the total activity leached divided by the dry soil weight. Uncertainties are one standard deviation based on counting statistics only.

For the concentration factors derived, using total soil and the HCl and EDTA extraction steps, there is an up to a two order of magnitude range of values spanned by the data shown in Table 3.12. However, when the bioavailable fraction is considered, a much smaller variation is observed with values ranging from 0.27–1.87. Critically, the use of the $^{226}Ra/^{228}Ra$ activity ratio as a tracer of the origin of the radium in passionfruit confirmed that the bioavailable fraction represents the most likely source of the radium taken up by the plant. That is, the ratio of $^{226}Ra/^{228}Ra$ in the plant is most similar to the ratio that is found in the bioavailable extraction.

The calculated concentration factor based on the bioavailable fraction is plotted against total soil activity concentration in Figure 3.12. The ^{226}Ra concentration factors are highest at the lowest soil activity concentrations and approach a saturation value of approximately 0.3 at high soil activity concentrations. This suggests that Ra uptake is non-linear – this has previously been suggested for plants from more temperate regions.

The non-linearity of concentration factors has important implications for and further complicates dose models that use concentration factors to derive ingestion doses, as ^{226}Ra activity concentrations in plants may be over or under estimated depending on the degree of contamination of the soil. Site specific concentration factors should be determined relative to the bioavailable fraction of ^{226}Ra in the substrate to increase the confidence in the modelled ingestion doses. Using this approach it is planned to extend the *Passiflora* work to other plant species commonly eaten by indigenous groups in the Alligator Rivers Region.

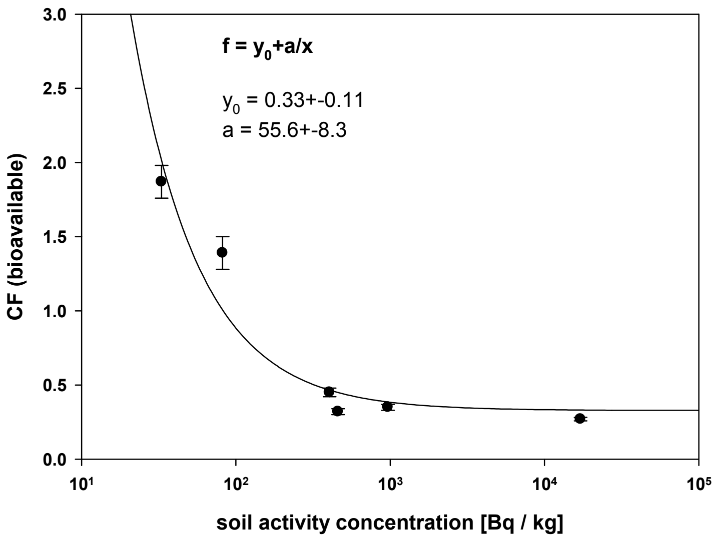


Figure 3.12 Concentration factors based on the bioavailable fraction plotted versus soil ^{226}Ra activity concentration (log scale)

3.8 Design and construction of erosion plots on the Ranger trial rehabilitation landform

3.8.1 Introduction

A trial landform was constructed during late 2008 and early 2009 by Energy Resources of Australia Ltd (ERA) adjacent to the north-western wall of the tailings storage facility (TSF) at Ranger mine. The trial landform will be used to test landform design and revegetation strategies to be used once mining and milling have finished. The trial landform forms an extension of the topography extending out from the TSF wall in a north-west direction (Figure 3.13). It is a rectangular shape of approximately 200 m x 400 m (8 ha) in footprint area.

Figure 3.13 Location of the elevated trial landform (bottom right of photograph) at Ranger mine

The landform was designed to test two types of potential final cover layers:

1 Waste rock alone

2 Waste rock blended with approximately 30% v/v fine-grained weathered horizon material (laterite)

Two thicknesses (2 m and 5 m) of the mixed laterite and waste rock cover type are being evaluated. Though the different thicknesses are unlikely to exhibit any material difference in erosion properties, it is anticipated that they may differ in their long-term ability to sustain mature more deeply rooted vegetation. However, it is the erosion potential that is the focus of the work described here.

The landform is divided into six plots (Figure 3.14). Each plot will be used to test different planting methods and substrate types as follows:

1 Tube stock planted in waste rock mixed with laterite material to a depth of 2 m;

2 Tube stock planted in waste rock mixed with laterite material to a depth of 5 m;

3 Direct seeded in waste rock mixed with laterite to a depth of 2 m;

4 Direct seeded in waste rock to a depth of 5 m;

5 Direct seeded in waste rock material

6 Tube stock planted in waste rock material.

Runoff, sediment concentration and water quality will be measured from four 900 m^2 erosion plots constructed on the landform between February and July 2009. The plot locations are shown in Figure 3.14. These locations allows comparison of erosion and water quality of runoff from a mixed waste rock and laterite substrate vegetated by direct seeding and tube stock and a waste rock substrate vegetated by direct seeding and tube stock.

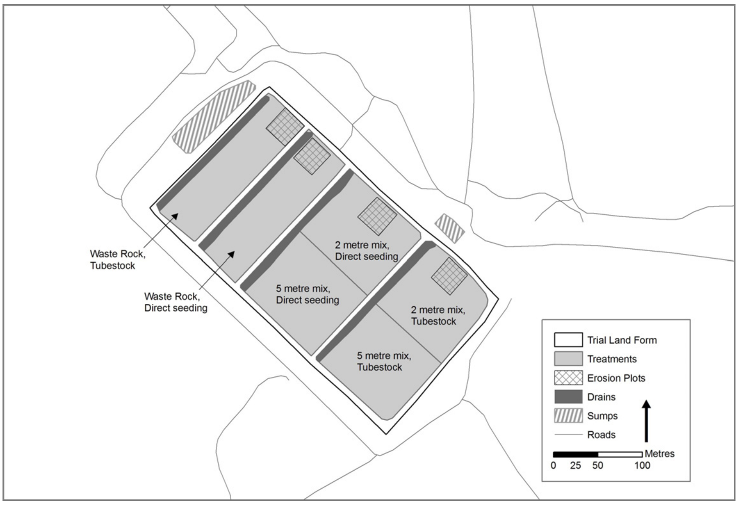


Figure 3.14 Layout of the plots on the trial landform

3.8.2 Plot construction

Each of the 30 m x 30 m erosion plots are physically isolated from runoff from the rest of the trial landform surface area by damp-proof course borders held in place by concrete mortar (Figure 3.15). Half-section 300 mm diameter U-PVC stormwater pipes (Figure 3.15) have been placed at the down slope ends of the plots to catch runoff and channel it through rectangular broad-crested (RBC) flumes (Figure 3.16) where rainfall event discharge will be measured. Transported bed sediment will be trapped in a reservoir constructed upstream of the inlet to the flume (Figure 3.16).

Each flume will be instrumented with: a pressure transducer and shaft encoder to measure stage height; a turbidity probe; an electrical conductivity probe to provide a measure of the concentrations of dissolved salts in the runoff; an automatic water sampler; and a data logger. A rain gauge will be installed near each flume to record the rainfall at each of the plots. The data will be downloaded once a day via mobile phone access and then stored in the hydrological database Hydstra. Decisions on how often the plots will be visited to clear bedload and collect water samples will be made after the plots are in place and there has been an opportunity to observe erosion rates and discharge relative to rainfall event size. The construction and instrumentation of the erosion plots will be completed in the second quarter of 2009, well in advance of the 2009–2010 wet season.

Figure 3.15 Plastic half pipe trough and boundary

Figure 3.16 Reservoir and flume at the outlet of the erosion plot

3.9 Remediation of remnants of past uranium mining activities in the South Alligator River valley

3.9.1 Background

The upper South Alligator River valley in the south of Kakadu National Park is both a popular tourist destination and a region in which past uranium exploration, mining and milling activities have occurred. The locations of these former uranium mine sites are marked on Figure 3.17.

Mining in the area started with the discovery of the Coronation Hill deposit in 1953, and continued through to 1964. During that time, approximately 877 tonnes of U_3O_8 were produced from 13 small scale uranium mines. When mining ceased, no substantial effort was made to clean up and rehabilitate the mine and mill areas or camps.

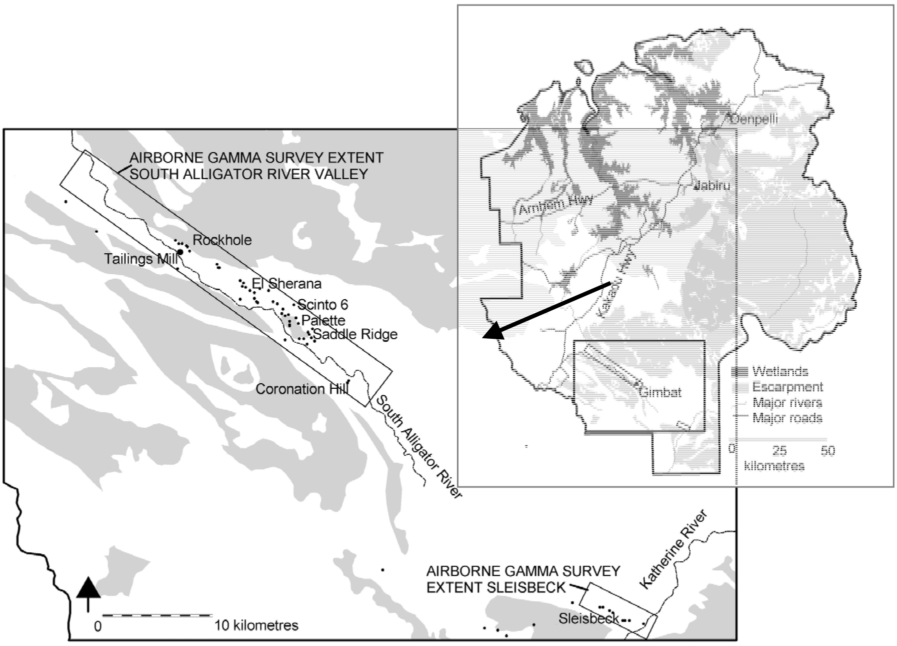


Figure 3.17 Alligator Rivers Region, with a detailed excerpt of the southern area showing the extent of two airborne gamma surveys conducted in 2000 and 2002, the location of known uranium anomalies (from MODAT database) and some historic mining and milling areas (Supervising Scientist Annual Report 2002–03)

Radioactive tailings were discovered by staff from SSD in 1984 during a ground gamma radiation survey, next to the road to the Gunlom waterfall, and close to the South Alligator River. The fine-grained tailings originated from the Rockhole mill, where over 13 400 tonnes of high-grade uranium ore were processed in the 1950s and 1960s. Subsequently, rehabilitation works were conducted in 1990–92, with most of the tailings removed or covered with rock armour (in 2000) to prevent erosion of the material into the river. Other small historic mining sites were, at that stage, not considered a priority for rehabilitation because they were either largely inaccessible to the public, relatively stable and/or did not contain radioactive tailings.

In 1996, land granted to the Gunlom Aboriginal Land Trust was leased back to the Director of National Parks to be managed as part of Kakadu National Park. The lease agreement required the Director of National Parks to implement an environmental rehabilitation plan for the historic minesites and associated workings in the South Alligator River valley. This plan is managed by Parks Australia. SSD is providing specialist assistance with the radiological assessment of the sites.

Airborne gamma surveys were flown over the South Alligator River valley in 2000 and over the Sleisbeck area in 2002. The results from these surveys were used to identify the location, extent and magnitude of residual radiological contamination. Areas exhibiting radiation levels above local background values were subsequently surveyed in more detail by ground measurements. The results of these investigations have aided the development of a rehabilitation strategy for the South Alligator River valley. The works for this are nearing completion.

Radiological assessment of the area continued through 2008–09 to provide final details of those sites that may require additional attention to remove remaining above-background materials. Two historic minesites, Palette and El Sherana, were investigated by grid-surveys. In addition, a post-remediation radiation survey was conducted at the Sleisbeck mine in the Katherine River catchment to document the success of the works that were carried out during the 2007 dry season. The Sleisbeck site is approximately 30 km south-east of Guratba. Figure 3.17 shows the location of these sites.

3.9.2 Status of Palette mine

Palette mine was worked from 1956 to 1961 and produced 119 tonnes U_3O_8 from high grade uranium ore. While mining occurred mainly in open stopes, there are also a number of adits in the area. The mine area is difficult to access. It is located less than 1 km to the east of the Koolpin access track, approximately 220 m above sea level.

The highest gamma dose rate at Palette is 5 $\mu Gy \cdot hr^{-1}$, measured on the top bench, with typical values ranging between 1.4 and 1.7 $\mu Gy \cdot hr^{-1}$. During a meeting between Parks Australia, the Supervising Scientist and consultants involved in the rehabilitation works, a guideline value for the gamma dose rate applicable to the rehabilitation of historic mining and milling sites in the South Alligator River valley was set at 1.25 ± 0.25 $\mu Gy \cdot hr^{-1}$ (which is ~ 10 times higher than background levels). It should be noted that this guideline value was derived purely on the basis of being able to distinguish the radiological signal from the regional background, and it should be regarded as a screening value. Application of this value as a cleanup threshold will result in annual effective doses to members of the public being well below the 10 mSv dose constraint recommended by the International Commission for Radiological Protection (ICRP) for the rehabilitation of existing exposure situations. This applies even in the unlikely case that the cleaned up areas were permanently occupied for a couple of months per year.

About two thirds of the surveyed area at Palette mine, in particular the top bench, has gamma dose rates above the screening guideline value. Consequently, the top bench will be remediated, which will require an area of approximately 1000 m^2 to be disturbed. The surface will be scraped and the material buried at the new containment at the El Sherana Airstrip.

3.9.3 Status of El Sherana mine

The El Sherana mine area was worked from 1956 to 1964 and produced 395 tonnes U_3O_8. The ore grade was lower than at Palette but was still comparatively high at up to 0.82%. Two areas were worked: the El Sherana pit on the hill top and El Sherana West in the valley located approximately 500 m north-east of the El Sherana camp. The airborne gamma survey from 2000 indicated that the El Sherana pit was the main source of above-background radiation in the area and so ground surveys focused on that area.

The highest dose rate on top of the El Sherana pit is 14 µGy/hr, measured over a concrete pad that had supported a battery used to crush some of the high grade ore mined at the site. The next highest readings were obtained from an area without noticeable infrastructure but containing a number of rock and rubble piles. Figure 3.18 shows a contour plot of dose rates measured on top of the pit. It appears that some radiological material is eroding towards the northwest, coincident with flow lines established from the local topography. Approximately 7000 m^2 were surveyed within the fenced area; approximately 4800 m^2 was found to exceed the 1.25 µGy/hr threshold value.

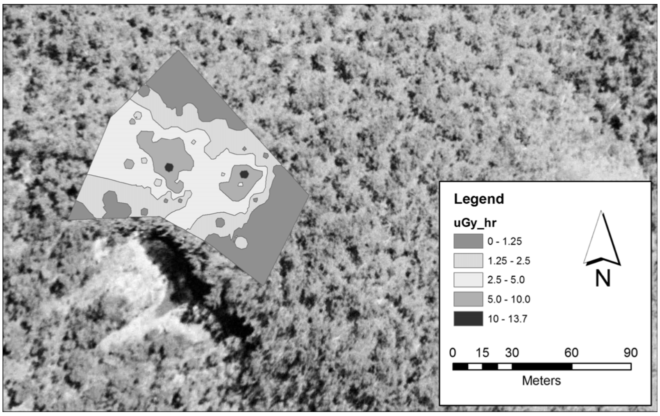


Figure 3.18 Dose rate contours [µGy/hr] on top of the El Sherana pit

The bottom of the El Sherana pit and associated workings, consisting of two waste piles and four benches to the south-east of the pit, respectively, were surveyed in December 2008. Except for the top bench, the remaining three benches, the bottom of the pit, and the two waste piles exhibit average gamma dose rates of about 2 µGy/hr and above. There is a small area of mineralisation accessible from one of the benches that exhibits gamma dose rates of above 7 µGy/hr. To cover the mineralisation and to reduce average gamma dose rates in the area, the material from the two waste piles will be shifted and pushed against the benches to the south-east of the pit, and subsequently covered with background material.

3.9.4 Assessment of the rehabilitated Sleisbeck minesite

The Sleisbeck mine was worked in 1957 but only a little over 2 tonnes of U_3O_8 was produced before the mine was abandoned. The rehabilitation of this site, comprising a water-filled open pit and surface waste dumps with a substantially above background radiological signature was undertaken in the dry season of 2007. The waste rock and low grade material from the truck dumps to the south of the pit were removed and placed into the pit. The pit backfill was shaped to cover a mineralised area in the pit wall that exhibited very high external gamma dose rates of above 30 µGy/hr.

Top cover material with background radiological signature was sourced from old spoil piles located to the east of the Sleisbeck pit. This material was spread over the surface of the backfilled pit in a single layer to a nominal depth of 700 mm. The second source of cover material was from a disused track to the north-east of the pit, which provided material for the final upper 300 mm cover layer. Rehabilitation works were finalised in December 2007.

A detailed ground survey of the rehabilitated footprint was carried out in 2008 to confirm that the radiological objectives of the works had been achieved. Figure 3.19 shows a probability plot of the gamma dose rates. Geometric and arithmetic averages measured across the 7.6 ha surveyed are 0.14 and 0.23 µGy/hr, respectively. Assuming a lognormal distribution, the plot shows that 99% of the area surveyed has gamma dose rates below the screening value of 1.25 µGy/hr. There is a small area immediately to the east of the old access track to the rehabilitated pit where gamma dose rates of above 3 µGy/hr were measured. This area is part of an old access track to the pit, and mineralised material may have been used as road fill. It comprises less than 0.01% of the area.

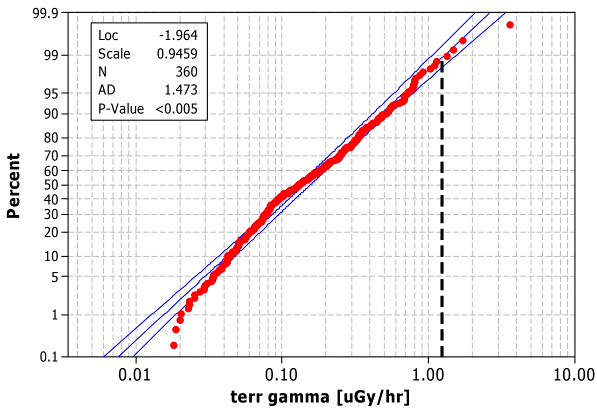


Figure 3.19 Probability plot of terrestrial gamma dose rates at Sleisbeck post rehabilitation. The probability plot shows that ~99 % of the area surveyed exhibits terrestrial gamma dose rates below 1.25 µGy/hr.

The successful rehabilitation of the old truck dumps and pit area at the Sleisbeck mine has reduced the average terrestrial gamma dose rates in the area by about threefold. Assuming the unlikely scenario that the site is occupied for one month per year, the average terrestrial gamma dose rate on site will lead to an effective dose from exposure to terrestrial gamma radiation of ~ 0.1 milli Sievert. Approximately half of this dose will originate from exposure to natural background radiation. These doses are well below the annual dose constraint for the public for existing exposure situations of 10 mSv, and even lower than the 0.3 mSv dose constraint recommended in current ICRP[7] guidelines for prolonged exposure from planned exposure situations.

---

7 ICRP 2007. *The 2007 recommendations of the International Commission on Radiological Protection*. International Commission on Radiological Protection Publication 103, Elsevier Ltd.

3.9.5 Assessment of rehabilitation requirements for Rockhole Mine Creek

In contrast to the situations described above where the primary rehabilitation requirements relate to solid materials produced by mining, Rockhole Mine Creek is a case whereby a receiving waterway is receiving contaminated drainage originating from mine workings.

Rockhole Mine Creek (RMC) is a small tributary of the upper South Alligator River that receives low level inputs of acidic and metal-rich seepage water from the former Rockhole minesite. The water is flowing at a low rate (0.2–0.4 L/s) from the lower adit draining the abandoned Rockhole mine workings (see Figure 3.20).

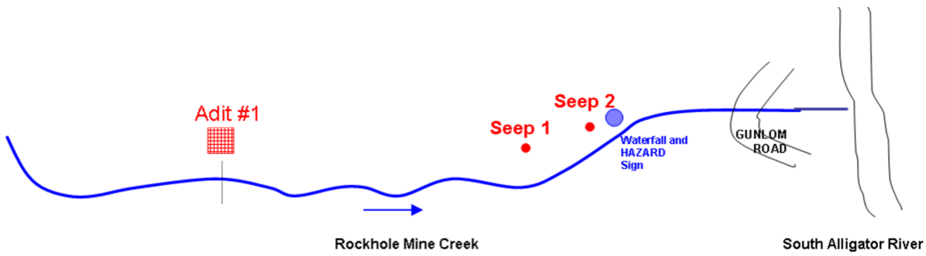


Figure 3.20 Schematic (not to scale) of Rockhole Mine Creek showing the location of Adit 1 and two downstream seeps

SSD has completed an assessment of the downstream effects of this input to advise Parks Australia on whether or not specific remediation is needed. The review draws upon a long history (since 1988) of field investigations, an earlier SSD review prepared for the NT World Heritage Ministerial Council in 2000, the results of field investigations conducted for Parks in 2000 and 2001 by Earth Water Life Sciences (EWLS) Pty Ltd, and subsequent stream monitoring by SSD between 2002 and 2009.

The earlier reviews and reports by SSD and EWLS in the early 2000s concluded that: (i) there were no significant radiological issues in the creek; (ii) although there was substantial iron staining (an aesthetic issue) along the channel of the creek, this iron was also coming from seeps further downstream of the adit (see Figure 3.20); (iii) though there were detrimental effects on the ecology of RMC, these effects did not extend to the South Alligator River; and (iv) RMC was not considered to be of significant cultural value to Traditional Owners. Given this background, it was concluded that unless the risk to the downstream environment could be shown to be increasing through time (viz increasing loads of potentially toxic metals, or inputs of radionuclides), there would be no justification for carrying out specific remediation works at the adit. In particular, and given the multiple inputs of iron to RMC, there was no guarantee that remedial works such as plugging the adit or treating the adit waters would necessarily lead to removal of the iron staining and deposition of iron precipitates.

To determine if contaminant loads were increasing through time, an extended program of monitoring to track the composition of the adit water was carried out by SSD between 2002 and 2009.

The recently-completed review found that over the 20-year water quality record (1988–2009), iron and manganese are the only contaminants that have systematically increased (manganese only slightly) in concentration in the RMC adit outflow. In contrast, the concentrations of the potentially toxic metals, aluminium, copper, lead, zinc and uranium have, overall, decreased significantly on a year by year basis. Subsequent and complementary work conducted by SSD has also shown no significant bioaccumulation of ^{226}Ra in mussels in the South Alligator River as a result of input of adit water to RMC.

Given that concentrations of metals of greatest concern to ecosystem health have declined over time, this finding supports earlier recommendations that no remedial action is required in RMC. While iron concentrations have increased in the adit water, this needs to be considered in the context of substantial amounts of iron also being contributed by seeps downstream of the adit. Given that it will not be possible to stop the flow from these distributed downstream sources, there would be no benefit to be gained by remediating the adit source of iron. SSD has recommended future opportunistic sampling of adit waters to confirm on an ongoing basis that iron continues to be the only contaminant in the water that is significantly affecting RMC.

4 STATUTORY COMMITTEES

4.1 Introduction

During 2008–09, the Supervising Scientist Division provided secretariat and administrative support to two statutory committees: the Alligator Rivers Region Advisory Committee and the Alligator Rivers Region Technical Committee.

These committees play important roles in facilitating discussion and information exchange between stakeholders in relation to the Division's environmental supervision and assessment activities, and facilitating peer review of associated scientific research activities.

4.2 Alligator Rivers Region Advisory Committee

The Alligator Rivers Region Advisory Committee (ARRAC) was established under the Commonwealth *Environment Protection (Alligator Rivers Region) Act 1978*. ARRAC facilitates communication between government, industry and community stakeholders on environmental issues associated with uranium mining in the Alligator Rivers Region.

ARRAC is chaired by Professor Charles Webb, Deputy Vice Chancellor (Teaching and Learning) at Charles Darwin University, and includes members representing the following stakeholder organisations:

- NT Department of Regional Development, Primary Industry, Fisheries and Resources
- NT Department of Natural Resources, Environment, the Arts and Sport
- NT Department of Department of Health and Families
- Office of the Administrator of the NT
- Australian Government Department of Resources, Energy and Tourism
- Australian Radiation Protection and Nuclear Safety Agency
- Energy Resources of Australia Ltd
- Cameco Australia
- Uranium Equities Ltd
- Koongarra Pty Ltd (a subsidiary of AREVA NC)
- Northern Land Council
- Gundjeihmi Aboriginal Corporation
- Environment Centre Northern Territory
- West Arnhem Shire Council
- Parks Australia, Australian Government Department of the Environment, Water, Heritage and the Arts
- Supervising Scientist Division, Australian Government Department of the Environment, Water, Heritage and the Arts

ARRAC offers a valuable forum for stakeholders to exchange views and information relating to the protection and rehabilitation of the Alligator Rivers Region environment from the effects of uranium mining. Public disclosure of environmental performance data through ARRAC is an important means of ensuring transparency and enhancing trust between the various stakeholder organisations.

At each ARRAC meeting, Stakeholders present information reports to ensure transparency and enhance knowledge sharing. Information reports usually include a summary and interpretation of monitoring data and details of periodic environmental reports from mining companies. SSD provides a comprehensive report to each ARRAC meeting covering the outcomes of audit and assessment activities and environmental monitoring.

ARRAC met twice during 2008–09: in Jabiru in August 2008 and in Darwin in March 2009. Key issues considered by ARRAC at these meetings included:

- the status of mine operations, planning and development at Ranger;
- the results of chemical, biological and radiological monitoring for Ranger and Jabiluka;
- SSD communication and research activities;
- the outcomes of environmental audits and assessments of Ranger, Jabiluka and Nabarlek;
- the outcomes of Minesite Technical Committee (MTC) meetings and other regulatory processes;
- the status of mine rehabilitation projects in the South Alligator Valley;
- progress in the Uranium Industry Framework; and
- the Northern Land Council's work with the Alligator Rivers Region stakeholders and traditional owners.

ARRAC meeting minutes are available from the ARRAC web site at www.environment.gov.au/ssd/communication/committees/arrac/meeting.html.

4.3 Alligator Rivers Region Technical Committee

The Alligator Rivers Region Technical Committee (ARRTC) was established under the *Environment Protection (Alligator Rivers Region) Act 1978*.

ARRTC plays an important role in ensuring the scientific research conducted by ***eriss***, ERA, NT Government agencies and others into the protection of the environment from the impacts of uranium mining in the Alligator Rivers Region is appropriate and of the highest possible standard. ARRTC also reviews the quality of the science underpinning regulatory assessment and approval of proposals by uranium mining companies in the Alligator Rivers Region.

ARRTC reports openly, independently and without restriction.

Members of ARRTC are appointed by the Australian Government Minister for the Environment, Heritage and the Arts and include:

- an independent Chair (Mr Ray Evans);
- the Supervising Scientist;
- a number of independent scientific members (including the Chair) with specific expertise nominated by the Federation of Australian Scientific and Technological Societies (FASTS);
- representatives from the Northern Land Council, the NT Department of Regional Development, Primary Industry, Fisheries and Resources, Energy Resources of Australia Ltd (for Ranger and Jabiluka), Uranium Equities Ltd (for Nabarlek) and Parks Australia.

Professor Colin Woodroffe from the University of Wollongong was appointed to ARRTC as the independent scientific member with expertise in Geomorphology in 2008.

ARRTC met twice in Darwin during 2008–09: in October 2008 and March 2009.

Figure 4.1 ERA staff explaining to ARRTC and SSD visitors wet season management of runoff from waste rock stockpiles during a field trip to Ranger mine

The key issues considered by ARRTC during these meetings included:

- current and proposed scientific research activities for ***eriss*** and ERA, in the context of the ARRTC Key Knowledge Needs;
- outcomes of chemical, biological and radiological research and monitoring being undertaken by DRDPIFR, ERA and SSD;
- scientific and technical issues relating to Ranger, Jabiluka and Nabarlek;
- the science underpinning Minesite Technical Committee (MTC) meetings and other regulatory decision making;
- the status of South Alligator Valley rehabilitation activities; and
- activity reports from the various stakeholder organisations.

During 2008-09, ARRTC undertook a gap analysis of its 2008-10 Key Knowledge Needs to ensure they continue to provide a sound basis for prioritising and planning the environmental and mining-related scientific research activities undertaken by the relevant stakeholder organisations going forward. The gap analysis is expected to be finalised in late 2009 and ARRTC will provide advice to the Minister on the outcomes. The ARRTC 2008–10 Key Knowledge Needs are included in Appendix 1 of this Annual Report.

ARRTC meeting minutes are available on the ARRTC web site at www.environment.gov.au/ssd/communication/committees/arrtc/index.html.

5 COMMUNICATION AND LIAISON

5.1 Introduction

Effective communication with all stakeholders is an integral component of the Supervising Scientist Division's functions. Keeping Traditional Owners and other Aboriginal people living in the Alligator Rivers Region informed about SSD activities including the supervisory activities of the Office of the Supervising Scientist (***oss***) and the research and monitoring programs undertaken or managed by the Environmental Research Institute of the Supervising Scientist (***eriss***) is especially important. Communication with research partners and other stakeholders within government, industry, science and the general community is also vital in the context of the research and supervisory functions of the Division.

5.2 Research support and communication

SSD has been involved in community engagement activities such as festivals and school visits within local communities in Kakadu National Park and the Alligator Rivers Region. These activities strengthen SSD's relationship with local indigenous stakeholders, research organisations, non-governmental environmental groups and the general public.

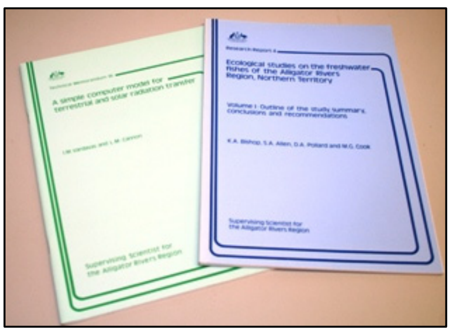
General SSD communications activities are coordinated through the Business Support Unit and communication with indigenous stakeholders is managed by the Jabiru-based Aboriginal Communications Officer in conjunction with Jabiru Field Station and other SSD staff.

Events undertaken in the reporting period include community information, education and conference presentations. Specific and targeted liaison with Traditional Owners and other indigenous stakeholders continued to be a priority.

The 2008–09 program of community engagement activities included display booths at the Mahbilil Festival in Jabiru and the AusIMM conference in Darwin, interactive informal information sessions with local Traditional Owners and hosting visits at the Jabiru Field Station.

The SSD web site is another important means of raising community awareness of the work of the Division and providing public access to some of the Division's scientific data and reports such as the results of the SSD environmental monitoring program. Of note, all Supervising Scientist Reports, Research Reports and Technical Memoranda are now available online in PDF format.

An annual website review has been implemented; research and monitoring sections have been updated.



5.2.1 Indigenous employment and consultation

Indigenous employment for activities such as field research projects gives SSD staff the opportunity to work alongside landowners on their country, sharing knowledge and gaining greater insight into traditional cultural values. It is also an opportunity for indigenous people to gain first hand knowledge and valuable technical skills and understanding of SSD's research and monitoring program.

SSD has maintained regular informal contact with indigenous communities in the Region including the Mirarr people – the Traditional Owners of the land on which Ranger and Jabiluka lie – affording more opportunity for understanding of our role and function and helping us keep the local communities well informed about our monitoring and research programs. Informal contact has also involved visits to and from local communities in the Region, including interested indigenous people observing our monitoring and research activities both in the field and in the laboratory.

The Jabiru Field Station now has a mobile communications unit enabling the transport of display materials to events and/or remote communities. The trailer and the towing vehicle are identified by large magnetic badges showing the SSD logo.

The same weekly water chemistry monitoring results that are available on the SSD website and are presented at local communities have also been published in the Jabiru electronic newsletter, *Kakadu Community Notice*.

In November, Cannon Hill residents expressed concern to the ACO about two-headed long necked turtles – they thought they might be a result of mining activity. Water and sediment samples were collected by the Jabiru Field Station and analysed by the Environmental Radioactivity Program. By early January 2009, SSD was able to reassure the community that there were no adverse mine-related effects. Jabiru Field Station staff will follow up this work, collecting long neck turtles and magpie geese with Cannon Hill residents later in 2009 for analysis.

Figure 5.1 Fieldwork with local Aborginal people

During 2008–09, SSD employed nine Aboriginal people through the Gundjeihmi Aboriginal Corporation to assist with research and monitoring projects, including pop-netting, bush tucker collection and equipment maintenance, and Jabiru Field Station ground and facilities maintenance.

Students involved in the Junior Ranger project visited the Field Station in November to learn about the environmental monitoring and research activities SSD undertakes. In March, the Aboriginal Communication Officer gave a careers talk to 20 indigenous students at the Jabiru Area School about SSD.

An Aboriginal communications procedure has been completed which includes an outline of the role of the Aboriginal Communication Officer.

Cross-cultural training for SSD staff to enable more effective communication and working relations with indigenous people continues to be provided at regular intervals. The most recent course was run in May 2009.

5.2.2 Research protocols for Kakadu National Park

Details of proposed 2009–10 SSD research and monitoring activities within Kakadu National Park were circulated to relevant stakeholders in April 2009, as required under the revised protocols agreed by the Director of National Parks and the Supervising Scientist in 2008.

The protocols define working arrangements for effective and timely communication between ***eriss*** and Parks Australia staff, the Kakadu Board of Management and Traditional Owners in relation to ***eriss*** research and monitoring activities within Kakadu National Park.

During the year, the permit system to undertake research at Jabiluka, Bowerbird Billabong and Ranger mine has been simplified, thus expediting project work by SSD staff.

5.2.3 Internal communication

The Division supports effective internal communication between staff of all levels through regular staff and section meetings. Various working groups (eg Monitoring Support, Spatial Users and Technical Data Management) are convened as required to address important strategic business issues within the Division. The functions of the Spatial Users and Technical Data Management groups were subsumed by the Spatial Sciences and Data Integration Program created in January 2009.

IiP (Investor in People) activities undertaken during 2008–2009 are described in Chapter 6.

SSD's internal newsletter *Newsbrief* is produced fortnightly and is available on the Intranet. It provides information on current Divisional activities in the Darwin and Jabiru offices, including articles on research, conferences attended, field trips and communication activities.

SSD continues to make full use of the Intranet. For example, the Spatial Sciences and Data Integration Program uses the Intranet to share its map collection with SSD staff. In addition, we now have continuous monitoring data from our telemetered stations in the Magela Creek catchment on the SSD intranet and available for staff to access as required. The data are presented as reports and graphs accessible by clicking a station's name on a schematic map of the area around the minesite, and are updated daily after they have been downloaded from the stations. More than half the staff have received intranet training and sections manage their own uploads and edits. A review of the Division's Intranet site is planned for the 09–10 year.

5.2.4 Communication with technical stakeholders and the general community

Coordination of other communication and general public relations activities was facilitated by SSD staff throughout the year.

The Alligator Rivers Region Advisory Committee (ARRAC) and the Alligator Rivers Region Technical Committee (ARRTC) both held two meetings during the period. Further information on ARRAC and ARRTC activities is provided in Chapter 4 of this report.

An information booth was hosted at the AusIMM Uranium Conference in Darwin in June 2009. The SSD brochure and pull-up banner were re-designed and updated with a new selection of images – the two promotional items were unveiled at AusIMM.

Indigenous stakeholders and the Traditional Owners of Kakadu National Park are also kept informed on SSD activities through their involvement in these committees. Gundjeihmi Aboriginal Corporation (GAC) and the Northern Land Council (NLC) are both members of ARRAC. The Director of ***eriss*** is a member of the Kakadu Research Advisory Committee.

The Mahbilil (Wind Festival) at Jabiru was the major community engagement activity for the period. SSD's display at Mahbilil included a self-help desk featuring monitoring results on the SSD web site and the DVD 'Our place', demonstrations of a Geiger counter and an alpha-detector used by the Environmental Radioactivity Program to detect alpha, beta and gamma rays emanating from general household items compared with uranium ore from Ranger, the PAN-***eriss*** research protocol showing our future research program in Kakadu National Park, and a presentation on macroinvertebrate sorting and identification further illustrated by a large fish tank.

These activities served to enhance awareness and understanding of the work and role of the Division and to raise SSD's profile within the local and wider community. These events also enabled SSD staff to provide information to local residents in a 'hands-on' practical manner.

5.2.5 Australia Day awards

In January, Dr Chris Humphrey was a recipient of a departmental Australia Day award for outstanding contribution over two decades to the development of best practice methods for aquatic biological monitoring and to the last major rewrite of the Australian and New Zealand Water Quality Guidelines.

Dr Humphrey has spent the past 26 years investigating tropical freshwater ecosystems of northern Australia, with much of this time as leader of ***eriss***'s Aquatic Ecosystem Protection Program which undertakes the scientific research required to develop, implement and refine through time biological and chemical programs to monitor and assess the impact of mining upon the aquatic ecosystems of the Alligator Rivers Region.

In 1996, ***eriss*** was given the responsibility of revising the Australian and New Zealand Water Quality Guidelines, a task that took five years to complete. Dr Humphrey was technical coordinator of the entire Guidelines revision process for the period 1999 to 2001 as well as being lead author of the section of the aquatic ecosystems chapter on biological assessment, and co-author of the introductory chapter establishing the water quality management framework.

5.3 National and international environmental protection activities

5.3.1 Environmental radiation protection

A seminar on the Supervising Scientist's work at the rehabilitated Nabarlek uranium mine in Western Arnhem Land was given at the German Radiation Protection Agency's office in Berlin-Karlshorst by a Supervising Scientist Division employee. The visit at the German Radiation Protection Agency followed an invitation to present at the Uranium Mining and Hydrogeology Conference of the Technische Universität, Bergakademie Freiberg, Germany. The German Radiation Protection Agency is involved in the rehabilitation of liabilities left behind by the Soviet-German uranium mining operations in Saxony and Thuringia before the German reunification, and common radiation related issues associated with uranium mine rehabilitation were discussed.

5.3.2 Revision of National Water Quality Guidelines

Two ***eriss*** research scientists, Dr Rick van Dam and Dr Chris Humphrey, assisted the Department's Water Reform Division (Water Quality Section) to develop a proposal to revise the *2000 Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (the Guidelines). The Guidelines, which constitute Guideline 4 of the National Water Quality Management Strategy, represent a key source document in Australia and New Zealand for managing natural water quality and protecting aquatic ecosystems. The process to determine the scope of the revision of the Guidelines involved a targeted stakeholder consultation process during 2008, including a stakeholder workshop in Canberra in December 2008. Subsequently, a small working group comprising Departmental (including ***eriss***), New Zealand Ministry of Environment and South Australian Environment Protection Authority personnel developed a detailed Scope of Work for the revision. The revision proposal was approved in May 2009 by the Environment Protection and Heritage Council Ministerial Council, and the revision is expected to commence in mid to late 2009. ***eriss*** will continue to work with the Water Reform Division during 2009–10 on this project.

5.3.3 Basslink

SSD staff, as Australian Government representatives on the Gordon River Scientific Reference Committee, provided comment on the 2007–08 Basslink Monitoring Annual

Report and comment on proposed changes to the 'ramp-down' rule with respect to the effects of seepage erosion on the banks of the Gordon River (Tasmania).

5.3.4 Northern Australian Water Futures Assessment (NAWFA)

The Northern Australia Water Futures Assessment is a multidisciplinary program being managed by the Environmental Water and Natural Resources Branch within DEWHA. The objective is to provide an enduring knowledge base to inform development of northern Australia's water resources, so that development proceeds in an ecologically, culturally and economically sustainable manner

Staff from ***eriss*** have been assisting the Department in three working groups convened to address the priority areas being covered by the Assessment. The names of the working groups and the respective ***eriss*** representatives are Dene Moliere (Water Resources), Dr Rick van Dam (Ecology), and Renée Bartolo (Knowledge Base).

Each of these groups has:

- developed a work plan for acquisition of required new information;
- provided advice on existing information, knowledge and research;
- identified linkages with other Assessment Programs and relevant activities; and
- provided advice on new research/knowledge needs and made recommendations on priorities for future research.

More information about the NAWFA and the products that are being produced by the program can be found at www.environment.gov.au/water/policy-programs/northern-australia/index.html.

5.3.5 Tropical Rivers and Coastal Knowledge (TRaCK) Research Program

The TRaCK research hub headquartered at Charles Darwin University in Darwin is one of the major components of the CERF program being managed by DEWHA. Staff from ***eriss*** are contributing to three of the research theme areas:

- Theme 1: Scenario Evaluation. ***eriss*** is contributing to Project 1.4: Knowledge integration and science delivery. The work involves contributing Digital Elevation Models (DEMs) that underpin catchment water flows analysis and other spatial data and providing advice and support on aspects of spatial data analysis.
- Theme 4: Material Budgets. ***eriss*** is a collaborator in Project 4.1: Catchment water budgets and water resource assessment. The specific engagement is with Task 3 that involves flood inundation mapping for the Mitchell and Daly River catchments using a combination of radar and optical satellite imagery analysis.
- Theme 5: Biodiversity and High Conservation Value Aquatic Ecosystems (HCVAE). ***eriss*** is contributing to Project 5.8: Bioregionalisation conservation priorities and predictive models of aquatic biodiversity. The work involves contributing information

and biological samples that will be used to identify areas or regions of high biodiversity and biological uniqueness.

More information about TRACK can be found at www.track.gov.au/

5.3.6 Special Issue of the Australasian Journal of Ecotoxicology

eriss Research Scientist, Dr Rick van Dam, compiled and edited a special issue of the *Australasian Journal of Ecotoxicology*, focusing on Tropical Ecotoxicology in Australasia. The issue includes eight articles describing soil or water quality related research from Australia and south-east Asia, and is expected to be published in October 2009.

5.3.7 EPBC Compliance Audits

oss staff provided assistance to the Approvals and Wildlife Division in the conduct of compliance audits against approval conditions issued under the Environment Protection and Biodiversity Conservation Act, including leading the following audits:

- Fortescue Metals Cloudbreak Mine – December 2008
- Territory Resources Frances Creek Mine – June 2009

5.3.8 Rum Jungle collaboration

The Rum Jungle mine site is located close to the town of Batchelor. Mining for uranium, copper, nickel and lead occurred between 1954 and 1971. Rehabilitation was undertaken on the site between 1982 and 1986 and additional works since 2003. In 2008, the Rum Jungle Technical Working Group (RJTWG) was formed to progress and implement:

- environmental maintenance activities;
- continuation of appropriate environmental monitoring programs;
- development of contemporary site rehabilitation strategies for the site.

The group consists of representatives from the Supervising Scientist Division, NT Department of Regional Development, Primary Industry, Fisheries and Resources, NT Department of Natural Resources, Environment, the Arts and Sport, Commonwealth Department of Resources, Energy and Tourism (DRET) and the Northern Land Council. Mr Alan Hughes (Supervising Scientist) and Dr David Jones (Director ***eriss***) are the SSD representatives.

During 2008–09, SSD was commissioned by DRET to undertake a comprehensive assessment of groundwater on the site since almost 20 years had elapsed since the last sampling and analysis had been done of groundwater monitoring bores across the site. This work built on an earlier project conducted by SSD to collate all of the available bore data into a GIS-database and to assess the status of contemporary knowledge about groundwater. Bores to be sampled were identified using a combination of water quality data from historical records, representation of the major rock units present on the site, and proximity to waste rock dumps. The final report is due in September 2009.

SSD was also commissioned by DRET to instrument two surface water sites to obtain continuous measurements of flow, EC and pH and to acquire grab sample water quality data to characterise changes in metal concentrations in runoff during the 2008–09 wet season. Staff from the environment section of Compass Resources Ltd provided vital on-ground assistance by collecting fortnightly samples for analysis during the wet season. The results obtained from this work will be used to better define the requirements for on ongoing program of surface water monitoring at the site.

5.3.9 Global Acid Rock Drainage (GARD) Guide

Dr Jones was a member of the International Advisory committee for the development of the Global Acid Rock Drainage (GARD) Guide, sponsored by the International Network for Acid Prevention (INAP). INAP is an industry association with membership comprising nine of the world's largest mining companies.

The GARD Guide is intended to be the premier international state-of-the-art summary of best practices and technology to assist mine operators and regulators to address issues related to the oxidation of mine waste containing sulfide minerals. The Guide deals with the prediction, prevention management and treatment of drainage produced from sulfide mineral oxidation, often termed 'acid rock drainage' (ARD). It also addresses leaching of metals caused by sulfide mineral oxidation.

The Guide has been produced in a web-based wiki format with major subject headings and hyperlinks to more detailed topics – www.gardguide.com/index.php/Main_Page.

5.3.10 Best practice study tour of Canada and Brazil

oss staff undertook an information gathering tour of uranium mining operations in Saskatchewan, Canada, and in Bahia, Brazil, in February/March 2009. The purpose of this trip was to meet with both the regulatory authorities and mining companies operating in these regions to see how operations were managed and regulated and to assist in benchmarking approaches undertaken in the Alligator Rivers Region. The trip also provided an opportunity to visit and assess underground mining operations in Canada, and a uranium Heap Leach Facility in Brazil (currently the only operational uranium heap leach facility in the world), techniques both of which are currently under consideration for operations at Ranger.

In Canada, ***oss*** was hosted by the Canadian Government through the Canadian Nuclear Safety Commission (CNSC) and by Cameco who own and operate a number of facilities in the northern half of Saskatchewan.

During the visit ***oss*** held discussions with CNSC and Cameco staff on a number of issues including best practice regulation and environmental management, and undertook a tour of operations at Cameco's Rabbit Lake underground mine.

In Brazil, ***oss*** was hosted by the Brazilian Government through the Comissão Nacional de Energia Nuclear (CNEN) who is responsible for the regulation of uranium mining and nuclear power plants throughout Brazil.

Figure 5.2 ***oss*** staff inspecting the discharge compliance point at Cameco's Rabbit Lake operations, Saskatchewan, Canada

Figure 5.3 Stockpiling of ore on the heap leach pad at Caetite uranium mine, Bahia, Brazil

During the visit ***oss*** held discussions with CNEN staff and operators of the worlds only uranium heap leach facility on site near Caetite, Bahia state, and at the CNEN head office in Rio de Janeiro, to gain a better understanding of the issues relating to the operation of uranium heap leach facilites. ***oss*** staff also gave presentations to CNEN and to the operators of the heap leach facility to assist in understanding our roles and our information needs.

5.4 Science communication (including conferences)

Results of research and investigations undertaken by the Supervising Scientist Division are made available to key stakeholders and the scientific and wider community through publication in journals and conference papers, and in a range of in-house journals and reports including the Supervising Scientist and Internal Report series – for detailed reporting on scientific projects – and the Supervising Scientist Note series used to showcase specific projects to a wider audience. Other media such as posters and educational or promotional materials are also produced to suit specific requirements or events.

In addition, a number of the Division's staff contribute to external scientific, technical and other professional organisations, including various editorial boards and panels.

The complete Supervising Scientist Report series is now available in PDF format on the SSD web site – the move towards electronic distribution supports the Department's policy of reducing its environmental footprint.

SSD staff helped organise and present at various local conferences, workshops, seminars and lectures, both at our facilities and in partnership with other research organisations and professional bodies, illustrating our commitment to the advancement of professional practice and communication of our work. It is also an important part of our contribution to the local scientific and professional communities. Specifically, SSD staff were involved in organising and participating in the Kakadu National Park Landscape Change Symposium Series, the 14th Australasian Remote Sensing and Photogrammetry conference held at the Darwin Convention Centre in September 2008, and a stakeholder workshop in Canberra in

December to identify revision needs for the Aust/NZ guidelines for fresh and marine water quality (see Section 5.3.2).

SSD staff presented a number of papers at important national and international conferences:

- ten papers were presented at the 5th Society of Environmental Toxicology and Chemistry (SETAC) World Congress in Sydney in August 2008,
- seven papers were presented at the 14th Australasian Remote Sensing and Photogrammetry Conference in Darwin in September/October 2008,
- seven papers were presented at the 10th South Pacific Environmental Radioactivity conference in November 2008 in Christchurch, New Zealand.
- two papers were presented at the AusIMM International Uranium Conference in Darwin in June 2009.

Other events at which SSD staff presented papers included:

- Coast to Coast '08 in Darwin and at the Kakadu Landscape Management Symposia, both August 2008;
- the 14th Meeting of the International Humic Substances Society (on a river boat between Moscow and St Petersburg) and the Uranium, Mining and Hydrogeology conference in Freiberg, Germany (both September);
- the inaugural Asia Pacific Spatial Innovation conference in Canberra (November), and
- Securing the Future and 8th International Conference on Acid Rock Drainage, Sweden (June)

eriss has continued to contribute to the Kakadu National Park Landscape Change Symposia series being run by Parks Australia. The aims of the symposia are to serve as a forum for knowledge exchange between stakeholders in the Kakadu region, including identifying management issues, emerging threats, knowledge gaps and research needs pertaining to landscape management at local, regional and national scales. ***eriss*** staff participated in the Climate Change workshop held in Jabiru on August 6–7, 2008, with Dr David Jones presenting an invited discussion paper on effects of extreme events.

The AusIMM International Uranium Conference was held in Darwin on 10–11 June 2009. The conference focused on a range of technical issues associated with the uranium exploration and mining industry in Australia and globally. SSD had a booth in the conference exhibition to showcase our recently revised banner, brochure and posters, and our publications. The conference also provided a valuable opportunity to raise SSD's profile within the uranium industry and for SSD staff to meet and communicate with a range of other government and industry stakeholders. There was considerable interest in the work of SSD (especially from international delegates) and a range of enquiries from delegates were dealt with including what types of research and commercial activities are undertaken by SSD, and to what extent are Traditional Owners involved in the day-to-day regulation of Ranger and how does SSD ensure that their interests are being addressed. SSD staff also attended and presented papers at both the main conference and a workshop on 'Radiation in Mining and Exploration' immediately following the conference.

Staff of the Division have published articles in a wide range of external journals and presented papers and posters at 20 conferences and workshops. A full list of papers and reports published during 2008–09 is provided in Appendix 2. Papers presented at national and international conferences are listed in Appendix 3.

SSD staff participated in several international conferences, seminars and workshops during 2008–09 (Table 5.1). Attendance at the majority of these events was funded, either partly or fully, from external sources. Participation in international events allows staff to share their knowledge and expertise with peers and maintain awareness of international best practice in relevant areas. Participation is also seen as important in allowing the Supervising Scientist Division to maintain its profile as a part of the broader scientific and technical community.

TABLE 5.1 INTERNATIONAL CONFERENCES, SEMINARS AND WORKSHOPS, 2008–09

Event	Location	Date
Uranium Mining and Hydrogeology V conference of the Technische Universität Bergakademie Freiberg	Freiberg, Germany	September 2008
14th meeting of International Humic Substances Society	Moscow, Russia	September 2008
International Atomic Energy Agency technical meeting on Implementation of sustainable global best practices in uranium mining and processing	Vienna, Austria	October 2008
10th South Pacific Environmental Radioactivity Conference, SPERA 2008	Christchurch, New Zealand	November 2008
Securing the Future and 8th International Conference on Acid Rock Drainage	Skelleftea, Sweden	June 2009

In 2008–09, ***eriss*** staff supervised a number of post-graduate research projects involving students from Charles Darwin University and other universities around Australia. ***eriss*** also hosts researchers from other organisations to undertake collaborative funded projects, or for sabbatical periods.

Dr David Jones has continued as the departmental representative on the steering committee for the Leading Practice Sustainable Development Program for the Mining Industry funded and managed by the Australian Government Department of Resources, Energy and Tourism. The program was established in 2005 to support the sustainable development of the Australian minerals industry, and its outputs are a series of booklets documenting leading practice in sustainable development principles in most of the major social and environmental management areas of concern to the community and to the industry.

6 ADMINISTRATIVE ARRANGEMENTS

6.1 Human resource management

6.1.1 Supervising Scientist

The Supervising Scientist is a statutory position established under the *Environment Protection (Alligator Rivers Region) Act 1978*. Section 8 of the Act requires that the Supervising Scientist be engaged under the *Public Service Act 1999*.

Mr Alan Hughes was appointed to the position in December 2005.

6.1.2 Structure

The Supervising Scientist Division consists of two branches, the Office of the Supervising Scientist and the Environmental Research Institute of the Supervising Scientist.

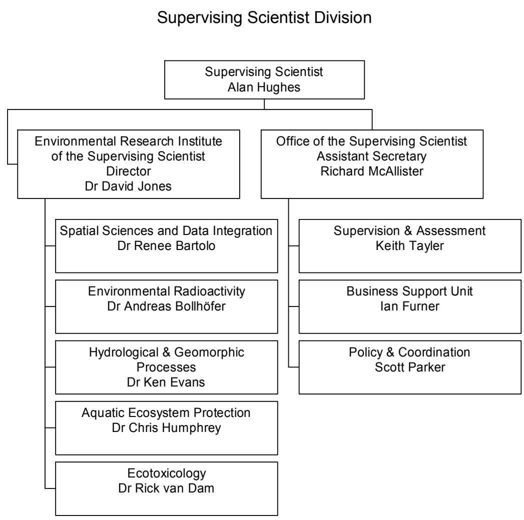


Figure 6.1 Organisational structure of the Supervising Scientist Division (as at 30 June 2009)

The Office of the Supervising Scientist (***oss***) is responsible for supervision, assessment, policy, information management and corporate support activities. Mr Richard McAllister is the ***oss*** branch head.

The Environmental Research Institute of the Supervising Scientist (***eriss***), managed by Dr David Jones, is responsible for scientific research and monitoring activities. During 2008/09 the Ecological Risk Assessment (EcoRisk) program was subsumed into a new Spatial Sciences and Data Integration (SSDI) program to recognise the changing nature of the research program undertaken by ***eriss***. Staff from EcoRisk, spatial and data management specialists from other programs were transferred to the SSDI program.

Staffing numbers as at 30 June 2008 and 30 June 2009 are given in Table 6.1.

TABLE 6.1 STAFFING NUMBERS (1) AND LOCATIONS

	2007–2008	2008–2009
Darwin	44	44
Jabiru	6	6
Total	50	50

(1) Average full time equivalent from 1 Jul to 30 Jun

6.1.3 Investors in People

The Supervising Scientist Division (SSD) has continued to support and promote Investors in People initiatives through embedding the framework within strategies, policies and procedures implemented over the past eight years since the Department was recognised as an accredited Investor in People.

To encourage a culture of continuous improvement the Department has implemented a staff survey every two years enabling the Department and each Division within the portfolio to gain access insight into staff perceptions on the Department's performance against indicators within the IiP framework resulting in the development of Divisional Improvement plans to address and monitor performance on areas of concern for staff. Overall, this information allows the Department to develop strategies to improve organisational performance, promote work life balance initiatives, encourage retention and develop as an 'Employer of Choice'.

Staff have been encouraged and supported by management in the development of skills through training, attendance at conferences and internal opportunities to act in higher level positions. There has also been a significant investment in leadership training and development for all executive level and SES staff. Through the Performance Development Scheme, staff have identified training requirements to help deliver their work plan outcomes. SSD staff have access to Canberra-based seminars and information sessions. Locally hosted seminars, in addition to the SSD Internal Seminar Series, provide staff with a range of topics relevant to SSD business activities.

Effective communication has also been an integral part of achieving outcomes set by the organisation. SSD continues to produce a fortnightly staff newsletter, *Newsbrief*, that attracts a wide range of internal contributors and readership. Management and staff participate in regular structured meetings that ensure information flow within the organisation is maintained. Healthy lifestyle and social activities coordinated by IiP representatives and social club members also enable staff to network in an informal manner.

During 2008–09, SSD staff have had the opportunity to access an improved health and wellbeing program incorporating health screenings, influenza, hepatitis and tetanus vaccinations, on-site fitball and pilates classes, and planned outdoor activities promoting team work such as the 'urban challenge' which involved low-level physical activity and problem-solving, and the GPS challenge that included map reading and using a Global Positioning System (GPS).

Early in 2009 the Department made a commitment to review the way IiP is communicated and promoted to staff. DEWHA Deputy Secretary, Gerard Early was appointed to champion the initiative. And SSD also appointed a new Champion for the Division, Assistant Secretary Richard McAllister. The IiP Action Group membership has had some changes with the recent inclusion of the Policy and Services Section, Parks Australia North, who have been actively participating in health and wellbeing programs, initiatives and the committee. Meetings are held monthly and outcomes reported back to management in regular reports. Information is disseminated through IiP representatives, events, internal newsletters, email and the intranet.

6.1.4 Occupational Health and Safety

The Supervising Scientist Division has continued to maintain a strong commitment to occupational health and safety during 2008–09. In response to the Echelon report (an outcome from the Department's Occupational Health and Safety audit conducted in 2008), an OHS Coordinator for the Supervising Scientist Division was appointed and assigned the role of developing and implementing the Division's Occupational Health and Safety Management Plan (OHSMP) and Chemical Management Plan (CMP) compliant with the *Occupational Health and Safety Act 1991*, AS/NZS 4801 and the Department of the Environment, Water, Heritage and the Arts Health and Safety Management Arrangements (HSMA).

The implementation of the OHSMP has seen a strong focus on risk management within the Supervising Scientist Division with the introduction of an OHS Risk Register, and an Outstanding Actions Register highlighting the current risks that assists in managing the risks identified.

The Occupational Health and Safety Committee is the primary mechanism in place for the discussion of OHS issues, and for the referral of issues to the Division's senior management team. The OHS committee meets on a monthly basis to discuss incidents, hazards, staff training requirements, policy development and any other relevant issues. During 2008–09 there were changes in membership, with new appointments to the roles of OH&S Chairperson, SSD Senior Management Representative, OH&S Coordinator and Field Safety Officer. The Committee reviewed and updated a number of OH&S policies and procedures (SSD Boat handling, Road Travel Policy, Emergency Response Procedures, medical disclosure and Laboratory PPE) and is currently working on the incident reporting and issue resolution procedures.

SSD has developed risk management procedures, and supporting documentation to assist staff with completion of risk assessments on any new tasks undertaken, and any plant or chemicals purchased for use. This new risk management system will be fully implemented in early 2009–10.

SSD Management has a strong commitment to OHS training. Topics that have been covered in 2008–09 include:

- Defensive driving
- 4-wheel driving
- Manual handling
- Risk management
- First aid
- Laboratory and field skills with chemicals (laboratory managers)
- Fire extinguisher operations
- Fire warden training
- Safety inductions
- Auditing OH&S Management systems
- Dangerous goods handling and packaging for road and air transport

In the 2008–09 financial year, SSD had 22 internal incident reports that comprised near miss, incidents or hazards. Of these only 6 were minor incidents that required first aid assistance and one that resulted in a workers compensation claim. SSD has a workplace culture that recognises that all occupational related illnesses are preventable and that there must be consistent and sustained effort to ensure that there are no repeat occurrences of occupational diseases in the workplace.

The strategic direction of OH&S within SSD for 2009–10 will continue to focus on risk management, with a greater emphasis on auditing, management review and achieving new objectives and targets that have been laid out in the new OHSMP.

The licence by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) that is issued to the Supervising Scientist allows SSD to hold certain radioactive and non-ionising radiation sources. These sources and general control, safety and management plans are included in the Radiation Source Control Plan of SSD.

6.2 Finance

The Supervising Scientist Division is part of the Australian Government Department of the Environment, Water, Heritage and the Arts (DEWHA) and full financial statements for the Department are contained in the Department's annual report.

A summary of the actual expenses of the Supervising Scientist against the Department's outputs are provided in Table 6.2.

TABLE 6.2 SUMMARY OF COST OF OUTPUTS

PBS Output*	2007–2008	2008–2009
Output 1.5 Response to the impacts of human settlements		
Sub-output 1.5.3 Supervision of uranium mines	$10 782 000	No longer reported at sub-output level
Output 1.2 Conservation of the land and inland waters		
Sub-output 1.2.4 Tropical wetlands research	$410 000	No longer reported at sub-output level
Total	$11 192 000	$10 978 330**

* From 2009/10 and beyond Supervising Scientist Division will report all activity against Program 1.2 – Environmental Regulation, Information and Research

** Aggregated direct expenses plus departmental corporate overheads

6.3 Facilities

6.3.1 Darwin facility

The majority of the Supervising Scientist Division's staff are situated at the Department of the Environment, Water, Heritage and the Arts Darwin facility adjacent to the Darwin International Airport. This facility consists of office accommodation and laboratories. During the year there were some significant works including rectification work as a result of moisture intrusion into the laboratories, installation of high rise racking into the storage sheds and a complete external and internal repaint.

The office space, library and amenities are shared with Parks Australia, which is also part of the Department of the Environment, Water, Heritage and the Arts.

6.3.2 Jabiru Field Station

A Field Station at Jabiru is maintained to support the activities of the Supervising Scientist Division. The staff consists of the monitoring team that carry out the Supervising Scientist's environmental monitoring program, an employee who is responsible for delivering the Supervising Scientist's Aboriginal communications program in Jabiru, an employee who undertakes

Figure 6.2 JFS site following demolition and removal of buildings

administrative and financial duties, and the Field Station Manager, who has overall responsibility for managing the Field Station as well as supervisory and inspection responsibilities.

Demolition and relocation of four demountable laboratory buildings that were surplus to requirement was completed in October 2008. Removal of some underground utilities, followed by rehabilitation and landscaping is expected to commence in the new financial year. Works have also been undertaken at the Field Station including a physical security upgrade and repairs/modifications to buildings and infrastructure.

6.4 Information management

Information Management activities provide support to staff based in Darwin and the Jabiru Field Station through library services and the co-ordination of records management activities. A total of 382 new files were created in the past year. Work on disposal of inactive files as appropriate under the Archives Act 1983 and other relevant legislation continues, with 762 files being destroyed during 2008/09. Negotiations to transfer other files to the Australian National Archives are continuing.

Library services provided to staff included: media monitoring, reference services, reader education, inter-library loans, and collection development. 620 new items were added to the collection during 2008–09. Though loans of library materials are only available to DEHWA staff, the library is open to the public by appointment.

6.5 Interpretation of Ranger Environmental Requirements

Section 19.2 of the Environmental Requirements of the Commonwealth of Australia for the Operation of the Ranger Uranium Mine provides for the publication of explanatory material agreed to by the major stakeholders to assist in the interpretation of provisions of the Environmental Requirements. No explanatory material was published during 2008–09.

6.6 Ministerial directions

There were no Ministerial Directions issued to the Supervising Scientist under Section 7 of the *Environment Protection (Alligator Rivers Region) Act 1978* during 2008–09.

6.7 Environmental Performance

The Supervising Scientist Division contributes to the department’s sustainability objectives through a range of measures aimed at continuously improving the environmental performance of our business operations and minimising any associated environmental impacts. The division reports on its environmental performance in the department’s 2008–09 annual report.

6.7.1 Environmental Management System (EMS)

In early 2009, it was decided not to proceed with full implementation of the draft EMS at this stage. A range of options for managing the Division's environmental performance were examined including integrating environmental risks into the Division's Occupational Health and Safety risk management framework, use of external third party audits and reviewing existing policies and procedures for field based work to ensure all environmental risks are minimised. It is anticipated that arrangements for managing the Division's environmental performance will be finalised by late 2009.

6.8 Social and community involvement

This year SSD has participated in a number of community events (see Chapter 5).

SSD has continued to employ local Aboriginal people to assist with research and monitoring activities. Assistance has been sought on projects such as the creekside monitoring and aquaculture activities, Jabiru Field Station maintenance, bushtucker and the bioaccumulation project.

SSD also works closely with Traditional Owners providing support to collaborative research projects. For example, SSD allows the greenhouse, storage shed and cool room at the Jabiru Field Station to be used by Kakadu Native Plant Supplies (KNPS), a local business owned and operated by Traditional Owners, for native seed collection and propagation activities.

6.9 National Centre for Tropical Wetland Research

The National Centre for Tropical Wetland Research (***nctwr***) was a collaborative venture between the Environmental Research Institute of the Supervising Scientist (***eriss***), James Cook University, Charles Darwin University and the University of Western Australia. The Centre was disbanded in October 2008 with the unanimous agreement of the parties.

6.10 Animal experimentation ethics approvals

eriss seeks the approval of Charles Darwin University's Animal Ethics Committee (AEC) to undertake scientific experiments involving vertebrate animals. Additionally, the Animal Welfare Branch of the Northern Territory Government grants the ***eriss*** premises a licence to use animals for research purposes. This licence includes the laboratories in Darwin and Jabiru, as well as field work conducted in the Alligator Rivers Region.

A progress report for the project 'Larval fish for toxicity tests at ***eriss***' (Ref no. 97016) was submitted to the CDU AEC in March 2009. This project is due for renewal in March 2010. A final report for the project 'Monitoring mining impact using the structure of fish communities in shallow billabongs' (Ref no A00028) was sent to the CDU AEC in December 2008 and this project has been re-approved until February 2011 (New Ref no. A09001). There are no plans to continue sampling fish for the project 'Metal and radionuclide concentrations of fish and mussels associated with the Ranger mine'

(Ref no A02026), thus there is no need to renew animal ethics for this project; a final report will be submitted in August 2009.

The number of fish used in toxicity tests at ***eriss*** was reported in July 2008 to the Northern Territory Government, as part of our licence requirements granted by them permitting the use of animals for research purposes.

Table 6.7 provides information on new applications, renewals of approvals and approval expiries for projects during 2008–09.

TABLE 6.3 ANIMAL EXPERIMENTATION ETHICS APPROVALS

Project title	Ref no	Initial submission	Approval/latest renewal	Expiry
Larval fish toxicity testing at ***eriss***	97016	26 May 1997	13 Mar 2008	13 Mar 2010
Monitoring mining impact using the structure of fish communities in shallow billabongs	A00028/ A09001	25 Sep 2000	8 Mar 2009	27 Feb 2011
Metal and radionuclide concentrations of fish and mussels associated with the Ranger mine	A02026	31 Oct 2002	30 Aug 2007	23 Aug 2009

APPENDIX 1 ARRTC KEY KNOWLEDGE NEEDS 2008–2010: URANIUM MINING IN THE ALLIGATOR RIVERS REGION

Overall objective

To undertake relevant research that will generate knowledge leading to improved management and protection of the ARR and monitoring that will be sufficiently sensitive to assess whether or not the environment is protected to the high standard demanded by the Australian Government and community.

Background

In assessing the Key Knowledge Needs for research and monitoring in the Alligator Rivers Region, ARRTC has taken into account current mining plans in the region and the standards for environmental protection and rehabilitation determined by the Australian Government. The assumptions made for uranium mining operations in the region are:

- mining of uranium at Ranger is expected to cease in about 2012. This will be followed by milling until about 2020 and final rehabilitation expected to be completed by about 2026;
- Nabarlek is decommissioned but has not reached a status where the NT Government will agree to issue a Revegetation Certificate to the mine operator. Assessment of the success of rehabilitation at Nabarlek is ongoing and may provide valuable data for consideration in the design and implementation of rehabilitation at Ranger;
- Jabiluka will remain in a care and maintenance condition for some years. ERA, the project owner, has stated that further mining will not occur without the agreement of the traditional owners; and
- grant of an exploration title at Koongarra is required under the terms of the *Aboriginal Land Rights (Northern Territory) Act 1976* before the mining company can apply for a mining title. As such, any future activity at Koongarra is subject to the agreement of the traditional owners and the Northern Land Council.

This scenario is considered to be a reasonable basis on which to base plans for research and monitoring, but such plans may need to be amended if mining plans change in the future. ARRTC will ensure the research and monitoring strategy is flexible enough to accommodate any new knowledge needs.

The Australian Government has specified Primary and Secondary environmental objectives for mining at Ranger in the Ranger Environmental Requirements. Similar standards would be expected for any future mining development at Jabiluka or Koongarra.

Specifically, under the Ranger Environmental Requirements (ERs):

> The company must ensure that operations at Ranger are undertaken in such a way as to be consistent with the following primary environmental objectives:
>
> (a) maintain the attributes for which Kakadu National Park was inscribed on the World Heritage list;
>
> (b) maintain the ecosystem health of the wetlands listed under the Ramsar Convention on Wetlands (ie the wetlands within Stages I and II of Kakadu National Park);
>
> (c) protect the health of Aboriginals and other members of the regional community; and
>
> (d) maintain the natural biological diversity of aquatic and terrestrial ecosystems of the Alligator Rivers Region, including ecological processes.

With respect to rehabilitation at Ranger, the ERs state that:

> The company must rehabilitate the Ranger Project Area to establish an environment similar to the adjacent areas of Kakadu National Park such that, in the opinion of the Minister with the advice of the Supervising Scientist, the rehabilitated area could be incorporated into the Kakadu National Park.

The ERs go on to specify the major objectives of rehabilitation at Ranger as follows:

> (a) revegetation of the disturbed sites of the Ranger Project Area using local native plant species similar in density and abundance to those existing in adjacent areas of Kakadu National Park, to form an ecosystem the long term viability of which would not require a maintenance regime significantly different from that appropriate to adjacent areas of the park;
>
> (b) stable radiological conditions on areas impacted by mining so that the health risk to members of the public, including traditional owners, is as low as reasonably achievable; members of the public do not receive a radiation dose which exceeds applicable limits recommended by the most recently published and relevant Australian standards, codes of practice, and guidelines; and there is a minimum of restrictions on the use of the area;
>
> (c) erosion characteristics which, as far as can reasonably be achieved, do not vary significantly from those of comparable landforms in surrounding undisturbed areas.

A secondary environmental objective applies to water quality and is linked to the primary ERs. This ER states:

> The company must not allow either surface or ground waters arising or discharging from the Ranger Project Area during its operation, or during or following rehabilitation, to compromise the achievement of the primary environmental objectives.

While there are many possible different structures that could be used to specify the Key Knowledge Needs, ARRTC has chosen to list the knowledge needs under the following headings:

- Ranger – current operations;
- Ranger – rehabilitation;
- Jabiluka;
- Nabarlek; and
- General Alligator Rivers Region.

'Key Knowledge Needs 2008–2010: Uranium mining in the Alligator Rivers Region' is based on and supersedes a predecessor document, 'Key Knowledge Needs 2004–2006: Uranium mining in the Alligator Rivers Region'. KKNs 2004–2006 remained the operative set during their review and the development of KKNs 2008–2010.

While some KKNs remain essentially unchanged, others contain revised elements or are new in their entirety. Care should be exercised if using KKN numbers alone as a reference because some continuing KKNs have changed numbers in the revised document.

1 Ranger – Current operations

1.1 Reassess existing threats

1.1.1 Surface water transport of radionuclides

Using existing data, assess the present and future risks of increased radiation doses to the Aboriginal population eating bush tucker potentially contaminated by the mining operations bearing in mind that the current Traditional Owners derive a significant proportion of their food from bush tucker.

1.1.2 Atmospheric transport of radionuclides

Using existing data and atmospheric transport models, review and summarise, within a risk framework, dose rates for members of the general public arising from operations at the Ranger mine.

1.2 Ongoing operational issues

1.2.1 Ecological risks via the surface water pathway

Off-site contamination during mine operation (and subsequent to decommissioning – refer KKN 2.6.1) should be placed in a risk-based context. A conceptual model of the introduction, movement and distribution of contaminants, and the resultant biotic exposure (human and non-human) has been developed, and the ecological risks (ie probability of occurrence x severity of consequence) of some of the contaminant/pathway sub-models have been estimated. This process should be completed for all the contaminant/pathway sub-models, noting, however, that the level of effort for each needs to be proportionate to the level of concern of the issue. It is critical that robust risk assessment methodologies are used, and that they explicitly incorporate uncertainty in both the assessment and subsequent decision making processes. Where ecological risk is significant, additional information may be required (eg. mass-balance and concentration dynamics, consideration of possible interactive effects, field data). Further, knowledge gaps preventing reasonable estimation of potential risks (ie with unacceptable uncertainty) must be filled.

The Magela floodplain risk assessment framework developed to estimate and compare mining and non-mining impacts should be revisited periodically, and updated to the current risk profile. It should be revised in the event that either **(i)** the annual monitoring program or other sources indicate that the inputs from mining have significantly increased relative to the situation in 2005, or **(ii)** an additional significant contaminant transport pathway from the minesite is identified, or **(iii)** there is a change in external stressors that could result in a significant increase in likelihood of impacts from the site.

1.2.2 Land irrigation

Investigations are required into the storage and transport of contaminants in the land irrigation areas particularly subsequent to decommissioning. Contaminants of interest/concern in addition to radionuclides are magnesium, sulfate and manganese. Results from these investigations should be sufficient to quantify the role of irrigation areas as part of satisfying KKN 1.2.1, and form the basis for risk management into the future.

1.2.3 Wetland filters

The key research issue associated with wetland filters in relation to ongoing operations is to determine whether their capacity to remove contaminants from the water column will continue to meet the needs of the water management system in order to ensure protection of the downstream environment. Aspects of contaminant removal capacity include (i) instantaneous rates of removal, (ii) temporal performance – including time to saturation, and (iii) behaviour under ‘breakdown’ conditions - including future stability after closure. Related to this is a reconciliation of the solute mass balance particularly for the Corridor Creek System (see KKN 1.2.5).

1.2.4 Ecotoxicology

Past laboratory studies provide a significant bank of knowledge regarding the toxicity of two of the major contaminants, uranium and magnesium, associated with uranium mining in the ARR. Further studies are scheduled to assess (i) the toxicity of manganese and, potentially, ammonia (in the event that permeate produced by process water treatment will contain potentially toxic ammonia concentrations), and (ii) the relationship between dissolved organic matter and uranium toxicity. This knowledge should continue to be synthesised and interpreted, within the existing risk assessment framework (refer KKN 1.2.1), as it comes to hand.

An additional issue that needs to be addressed is the direct and indirect effects on aquatic biota of sediment arising from the mine site. In the first instance, a conceptual model needs to be developed (building on the relevant components of the conceptual model developed under KKN 1.2.1) that describes the movement of sediment within the creek system, including the associated metal-sediment interactions and biological implications. Studies likely to arise from the outcomes of the conceptual model include:

- the effects of suspended sediment on aquatic biota;
- the relationship between suspended sediment and key metals, and how this affects their bioavailability and toxicity; and
- the effects of sediment-bound metals to benthic biota, including, initially, a review of existing information on uranium concentrations in sediments of waterbodies both on- and off the Ranger site, and uranium sediment toxicity to freshwater biota.

Whilst of relevance at present, the above issues will be of additional importance as Ranger progresses towards closure and rehabilitation (refer KKN 2.6.1). Finally, the need for studies to assess the toxicity of various mine waters (treated and untreated) in response to specific supervisory/regulatory or operational requirements is likely to continue.

1.2.5 Mass balances and annual load limits

With the expansion of land application areas and the increase in stockpile sheeting that has occurred in concert with the expansion of the footprints of the waste rock dumps and low grade ore stockpiles, it is becoming increasingly important to develop a solute mass balance for the site – such that the behaviour of major solute source terms and the spatial and temporal contribution of these sources to water quality in Magela Creek can be clearly understood. Validated grab sample and continuous data records are needed to construct a high reliability solute mass balance model.

Related to mass balance is the issue of specifying allowable annual load limits from the site – as part of the site's regulatory requirements. The technical basis for these load limits needs to be reviewed since they were originally developed decades ago. There has since been significantly increased knowledge of the environmental geochemistry of the site, a quantum increase in knowledge about ecotoxicological sensitivity of the aquatic systems and updated data on the diet profile of traditional owners.

1.3 Monitoring

1.3.1 Surface water, groundwater, chemical, biological, sediment, radiological monitoring

Routine and project-based chemical, biological, radiological and sediment monitoring should continue, together with associated research of an investigative nature or necessary to refine existing, or develop new (promising) techniques and models. A review of current water quality objectives for Ranger should be conducted to determine if they are adequate for future water management options for the whole-of-site, including the closure and rehabilitation phase (KKN 2.2.1 and KKN 2.2.2).

ARRTC supports the design and implementation of a risk-based radiological monitoring program based on a robust statistical analysis of the data collected over the life of Ranger necessary to provide assurance for Aboriginal people who source food items from the Magela Creek system downstream of Ranger.

2 Ranger – Rehabilitation

2.1 Reference state and baseline data

2.1.1 Defining the reference state and baseline data

There is a requirement to define the baseline data/reference state that existed at the Ranger site prior to development. This will inform the process of the development of closure criteria which is compatible with the Environmental Requirements. The knowledge need is to develop and perform analysis to generate agreed reference data that cover the range of pre-mining and operational periods.

2.2 Landform

2.2.1 Landform design

An initial design is required for the proposed final landform. This would be based upon the optimum mine plan from the operational point of view and it would take into account the broad closure criteria, engineering considerations and the specific criteria developed for guidance in the design of the landform. This initial landform would need to be optimised using the information obtained in detailed water quality, geomorphic, hydrological and radiological programs listed below.

Current and trial landforms at Ranger and at other sites such as Nabarlek should be used to test the various models and predictions for water quality, geomorphic behaviour and radiological characteristics at Ranger. The detailed design for the final landform at Ranger should be determined taking into account the results of the above research programs on surface and ground water, geomorphic modelling and radiological characteristics.

2.2.2 Development and agreement of closure criteria from the landform perspective

Closure criteria from the landform perspective need to be established at both the broad scale and the specific. At the broad scale, agreement is needed, particularly with the Traditional Owners and within the context of the objectives for rehabilitation incorporated within the ERs, on the general strategy to be adopted in constructing the final landform. These considerations would include issues such as maximum height of the landform, the maximum slope gradient (from the aesthetic perspective), and the presence or absence of lakes or open water. At the specific scale, some criteria could usefully be developed as guidance for the initial landform design such as slope length and angle (from the erosion perspective), the minimum cover required over low grade ore, and the minimum distance of low grade ore from batter slopes. Specific criteria are needed that will be used to assess the success of landform construction. These would include, for example, maximum radon exhalation and gamma dose rates, maximum sediment delivery rates, maximum constituent concentration rates in runoff and maximum settling rates over tailings repositories.

2.2.3 Water quality in seepage and runoff from the final landform

Existing water quality monitoring and research data on surface runoff and subsurface flow need to be analysed to develop models for the quality of water, and its time dependence, that would enter major drainage lines from the initial landform design. Options for adjusting the design to minimise solute concentrations and loads leaving the landform need to be assessed.

There is a need to develop and analyse conceptual models of mine related turbidity and salinity impacts following closure. These models could be analysed in a variety of ways, as a precursor to the development of a quantitative model of potential turbidity and salinity impacts offsite cause by surface and subsurface water flow off the rehabilitated mine site. This analysis should explicitly acknowledge knowledge uncertainty (eg plausible alternative conceptual models) and variability (eg potential for Mg/Ca ratio variations in water flowing off the site) and explore the potential ramifications for the off-site impacts. (see also KKN 2.6.1)

2.2.4 Geomorphic behaviour and evolution of the landscape

The existing data set used in determination of the key parameters for geomorphological modelling of the proposed final landform should be reviewed after consideration of the near surface characteristics of the initial proposed landform. Further measurements of erosion characteristics should be carried out if considered necessary. The current site-specific landform evolution models should be applied to the initial proposed landform to develop predictions for long term erosion rates, incision and gullying rates, and sediment delivery rates to the surrounding catchments. Options for adjusting the design to minimise erosion of the landform need to be assessed. In addition, an assessment is needed of the geomorphic stability of the Ranger mine site with respect to the erosional effects of extreme events.

2.2.5 Radiological characteristics of the final landform

The characteristics of the final landform from the radiological exposure perspective need to be determined and methods need to be developed to minimise radiation exposure to ensure that restrictions on access to the land are minimised. Radon exhalation rates, gamma dose rates and radionuclide concentrations in dust need to be determined and models developed for both near-field and far-field exposure.

The use of potential analogue sites for establishing pre-mining radiological conditions at Ranger should be further investigated to provide information on parameters such as pre-mining gamma dose rates, radon exhalation rates, and levels of radioactivity in dust. This information is needed to enable estimates to be made of the likely change in radiation exposure when accessing the rehabilitated site compared to pre-mining conditions.

2.3 Groundwater dispersion

2.3.1 Containment of tailings and other mine wastes

The primary method for protection of the environment from dispersion of contaminants from tailings and other wastes will be containment. For this purpose, investigations are required on the hydrogeological integrity of the pits, the long-term geotechnical properties of tailings and waste rock fill in mine voids, tailings deposition and transfer (including TD to Pit #3) methods, geochemical and geotechnical assessment of potential barrier materials, and strategies and technologies to access and 'seal' the surface of the tailings mass, drain and dispose of tailings porewater, backfill and cap the remaining pit void.

2.3.2 Geochemical characterisation of source terms

Investigations are needed to characterise the source term for transport of contaminants from the tailings mass in groundwater. These will include determination of the permeability of the tailings and its variation through the tailings mass, strategies and technologies to enhance settled density and accelerate consolidation of tailings, and pore water concentrations of key constituents.

There is a specific need to address the existence of groundwater mounds under the tailings dam and waste rock stockpiles. Models are needed to predict the behaviour of groundwater and solute transport in the vicinity of these mounds and options developed for their remediation to ensure that on-site revegetation can be achieved and that off-site solute transport from the mounds will meet environmental protection objectives. Assessment is also needed of the effectiveness (cost and environmental significance) of paste and cementation technologies for increasing tailings density and reducing the solubility of chemical constituents in tailings.

2.3.3 Aquifer characterisation and whole-of-site model

The aquifers surrounding the tailings repositories (Pits 1 & 3) need to be characterised to enable modelling of the dispersion of contaminants from the repositories. This will involve geophysics surveys, geotechnical drilling and groundwater monitoring and investigations on the interactions between the deep and shallow aquifers.

2.3.4 Hydrological/hydrogeochemical modelling

Predictive hydrological/hydrogeological models need to be developed, tested and applied to assess the dispersion of contaminants from the tailings repositories over a period of 10 000 years. These models will be used to assess whether all relevant and appropriate factors have been considered in designing and constructing an in-pit tailings containment system that will prevent environmental detriment in the long term.

2.4 Water treatment

2.4.1 Active treatment technologies for specific mine waters

Substantial volumes of process water retained at Ranger in the tailings dam and Pit 1 must be disposed of by a combination of water treatment and evaporation during the mining and milling phases of the operation and during the rehabilitation phase. Research priorities include treatment technologies and enhanced evaporation technologies that can be implemented for very high salinity process water. A priority should be evaluation of the potential impact of treatment sludge and brine streams on long term tailings chemistry in the context of closure planning and potential post closure impacts on water quality.

2.4.2 Passive treatment of waters from the rehabilitated landform

Sentinel wetlands may form part of the final landform at Ranger. Research on wetland filters during the operational phase of mining will provide information relevant to this issue. Research is needed to establish the effect of wet-dry seasonal cycling on contaminant retention and release, since this aspect will influence design criteria and whether such wetlands should be maintained as ephemeral or perennial waterbodies There is also the need to assess the long-term behaviour of the physical and biotic components of the wetlands, their ecological health, and the extent of contaminant accumulation (both metals and radionuclides) in the context of potential human exposure routes.

2.5 Ecosystem establishment

2.5.1 Development and agreement of closure criteria from ecosystem establishment perspective

Closure criteria need to be established for a range of ecosystem components including surface water quality, flora and fauna. The environmental requirements provide some guidance but characterisation of the analogue ecosystems will be an important step in the process. Consultation on closure criteria with the traditional owners has commenced and it is important that this process continues as more definitive criteria are developed.

2.5.2 Characterisation of terrestrial and aquatic ecosystem types at analogue sites

Identification and characterisation of analogue ecosystems (target habitats) can assist in defining the rehabilitation objective and developing robust, measurable and ecologically-based closure criteria. The concept of using analogue ecosystems for this purpose has been accepted by ARRTC and the traditional owners. Substantial work has been undertaken on the Georgetown terrestrial analogue ecosystem while there is also a large body of information available on aquatic analogues, including streams and billabongs. Future work on the terrestrial analogue needs to address water and nutrient dynamics, while work on the aquatic analogue will include the development of strategies for restoration of degraded or removed natural waterbodies, Coonjimba and Djalkmara, on site.

2.5.3 Establishment and sustainability of ecosystems on mine landform

Research on how the landform, terrestrial and aquatic vegetation, fauna, fauna habitat, and surface hydrology pathways will be reconstructed to address the Environmental Requirements for rehabilitation of the disturbed areas at Ranger is essential. Trial rehabilitation research sites should be established that demonstrate an ability by the mine operator to be able to reconstruct terrestrial and aquatic ecosystems, even if this is at a relatively small scale. Rehabilitation establishment issues that need to be addressed include species selection; seed collection, germination and storage; direct seeding techniques; propagation of species for planting; fertiliser strategies and weathering properties of waste rock. Rehabilitation management issues requiring investigation include the stabilisation of the land surface to erosion by establishment of vegetation, return of fauna; the exclusion of weeds; fire management and the re-establishment of nutrient cycles. The sustainable establishment and efficiency of constructed wetland filters, reinstated waterbodies (eg Djalkmara Billabong) and reconstructed waterways also needs to be considered (see KKN 2.3.2).

2.5.4 Radiation exposure pathways associated with ecosystem re-establishment

Radionuclide uptake by terrestrial plants and animals on the rehabilitated ecosystem may have a profound influence on the potential utilisation of the land by the traditional owners. Significant work has been completed on aquatic pathways, particularly the role of freshwater mussels, and this now forms part of the annual monitoring program. The focus is now on the terrestrial pathways and deriving concentration factors for Bushtucker such as wallabies, fruits and yams. A project investigating the contemporary diet of traditional owners has commenced and needs to be completed. Models need to be developed that allow exposure pathways to be ranked for currently proposed and future identified land uses, so that identified potentially significant impacts via these pathways can be limited through appropriate design of the rehabilitation process.

2.6 Monitoring

2.6.1 Monitoring of the rehabilitated landform

A new management and monitoring regime for the rehabilitated Ranger landform needs to be developed and implemented. It needs to address all relevant aspects of the rehabilitated landform including ground and surface water quality, radiological issues, erosion, flora, fauna, weeds, and fire. The monitoring regime should address the key issues identified by the ecological risk assessment of the rehabilitation phase (KKN 2.7.1).

2.6.2 Off-site monitoring during and following rehabilitation

Building upon the program developed and implemented for the operational phase of mining, a monitoring regime is also required to assess rehabilitation success with respect to protection of potentially impacted ecosystems and environmental values. This program should address the dispersion of contaminants by surface water, ground water and via the atmosphere. The monitoring regime should address the key issues identified by the ecological risk assessment of the rehabilitation phase (KKN 2.7.1).

2.7 Risk assessment

2.7.1 Ecological risk assessments of the rehabilitation and post rehabilitation phases

In order to place potentially adverse on-site and off-site issues at Ranger during the rehabilitation phase within a risk management context, it is critical that a robust risk assessment framework be developed with stakeholders. The greatest risk is likely to occur in the transition to the rehabilitation phase, when active operational environmental management systems are being progressively replaced by passive management systems. A conceptual model of transport/exposure pathways should be developed for rehabilitation and post rehabilitation regimes and the model should recognise the potential that some environmental stressors from the mine site could affect the park and vice versa. Implicit in this process should be consideration of the effects of extreme events and climate change.

Conceptual modelling should be followed by a screening process to identify and prioritise key risks for further qualitative and/or quantitative assessments. The conceptual model should be linked to closure criteria and post-rehabilitation monitoring programs, and be continually tested and improved. Where appropriate, risk assessments should be incorporated into decision making processes for the closure plan. Outputs and all uncertainties from this risk assessment process should be effectively communicated to stakeholders.

2.8 Stewardship

The concept of Stewardship (including ownership and caring for the land) is somewhat broader and applies to all phases of, in this case, uranium mining. In this context it is considered to be the post closure phase of management of the site, ie after relinquishment of the lease. If the rehabilitation phase is successful in meeting all objectives then this stewardship will effectively comprise an appropriate level of ongoing monitoring to confirm this. Should divergence from acceptable environmental outcomes be detected then some form of intervention is likely to be required. The nature, responsibility for, and duration of, the monitoring and any necessary intervention work remains to be determined.

3 Jabiluka

3.1 Monitoring

3.1.1 Monitoring during the care and maintenance phase

A monitoring regime for Jabiluka during the care and maintenance phase needs to be implemented and regularly reviewed. The monitoring program (addressing chemical, biological, sedimentalogical and radiological issues) should be commensurate with the environmental risks posed by the site, but should also serve as a component of any program to collect baseline data required before development such as meteorological and sediment load data.

3.2 Research

3.2.1 Research required prior to any development

A review of knowledge needs is required to assess minimum requirements in advance of any development. This review would include radiological data, the groundwater regime (permeabilities, aquifer connectivity etc), hydrometeorological data, waste rock erosion, assess site-specific ecotoxicology for uranium, additional baseline for flora and fauna surveys.

4 Nabarlek

4.1 Success of revegetation

4.1.1 Revegetation assessment

Several assessments of the revegetation at Nabarlek have been undertaken; the most recent being completed by ***eriss***. There is now general agreement that the rehabilitated areas require further work. Revised closure criteria are currently being developed through the mine-site technical committee and these should be reviewed by relevant stakeholders, including ARRTC. The required works should then be completed on site with further monitoring leading to the relinquishment of the lease.

4.1.2 Development of revegetation monitoring method

A methodology and monitoring regime for the assessment of revegetation success at Nabarlek needs to be developed and implemented. Currently, resource intensive detailed vegetation and soil characterisation assessments along transects located randomly within characteristic areas of the rehabilitated landform are being undertaken. Whilst statistically valid, these assessments cover only a very small proportion of the site. Remote sensing (satellite) data are also being collected and the efficacy of remote sensing techniques for vegetation assessment in comparison to ground survey methods should continue. The outcomes of this research will be very relevant to Ranger.

4.2 Assessment of radiological, chemical and geomorphic success of rehabilitation

4.2.1 Overall assessment of rehabilitation success at Nabarlek

The current program on erosion, surface water chemistry, groundwater chemistry and radiological issues should be continued to the extent required to carry out an overall assessment of the success of rehabilitation at Nabarlek. In particular, all significant radiological exposure pathways should be identified and a comprehensive radiation dose model developed. Additional monitoring of ground water plumes is required to allow assessment of potential future groundwater surface water interaction and possible environmental effects.

5 General Alligator Rivers Region

5.1 Landscape scale analysis of impact

5.1.1 Develop a landscape-scale ecological risk assessment framework for the Magela catchment that incorporates, and places into context, uranium mining activities and relevant regional landscape processes and threats, and that builds on previous work for the Magela floodplain

Ecological risks associated with uranium mining activities in the ARR, such as current operations (Ranger) and rehabilitation (Nabarlek, Jabiluka, future Ranger, South Alligator Valley), should be assessed within a landscape analysis framework to provide context in relation to more diffuse threats associated with large-scale ecological disturbances, such as invasive species, unmanaged fire, cyclones and climate change. Most key landscape processes occur at regional scales, however the focus will be on the Magela catchment encompassing the RPA. A conceptual model should first be developed to capture links and interactions between multiple risks and assets at multiple scales within the Magela catchment, with risks associated with Ranger mining activities made explicit. The spatially explicit Relative Risk Model will be used to prioritise multiple risks for further qualitative and/or quantitative assessments. The conceptual model and risk assessment framework should be continually tested and improved as part of Best Practice. Where appropriate, risk assessments should be incorporated into decision making processes using advanced risk assessment frameworks such as Bayesian Networks, and all uncertainties made explicit. This risk assessment process should integrate outputs from KKN 1.2.1 (risks from the surface water pathway – Ranger current operations) and the new KKN 2.6.1 (risks associated with rehabilitation) to provide a landscape-scale context for the rehabilitation of Ranger into Kakadu National Park, and should be communicated to stakeholders.

5.2 South Alligator River valley rehabilitation

5.2.1 Assessment of past mining and milling sites in the South Alligator River valley

SSD conducts regular assessments of the status of mine sites in the SAR valley, provides advice to Parks Australia on technical issues associated with its rehabilitation program and conducts a low level radiological monitoring program. This work should continue.

5.3 Develop monitoring program related to West Arnhem Land exploration activities

5.3.1 Baseline studies for biological assessment in West Arnhem Land

ARRTC believes there is a need to determine a baseline for (a) rare, threatened and endemic biota and (b) indicator species or groups such as macroinvertebrates in areas where advanced exploration or proposed mining projects are identified and in line with the current approvals process under the Aboriginal Land Rights Act**.**

5.4 Koongarra

5.4.1 Baseline monitoring program for Koongarra

In line with the current approvals process under the Aboriginal Land Rights Act, a low level monitoring program should be developed for Koongarra to provide baseline data in advance of any possible future development at the site. Data from this program could also have some relevance as a control system for comparison to Ranger, Jabiluka and Nabarlek.

APPENDIX 2 PUBLICATIONS FOR 2008–2009

Published[8]

Bartolo R 2008. Women in remote sensing and photogrammetry – results of the SSI women in spatial survey. In *14ARSPC: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference*, Darwin NT, 30 September – 2 October 2008. USB2.0

Bartolo R, Bayliss P & van Dam R 2008. *Ecological risk assessment for Australia's northern tropical rivers. Sub-project 2 of Australia's Tropical Rivers – an integrated data assessment and analysis (DET18)*. A report to Land & Water Australia. Environmental Research Institute of the Supervising Scientist, National Centre for Tropical Wetland Research, Darwin NT. www.environment.gov.au/ssd/tropical-rivers/triap-sp2.html.

Bollhöfer A 2009. The importance of conducting an early baseline radiation study. In *Radiation in Mining and Exploration Workshop: Presentations.* Darwin NT 12 June 2009, Darwin NT, The Australian Institute of Mining and Metallurgy, Carlton South, Vic, CD.

Bollhöfer A, Martin P, Ryan B, Pfitzner K, Frostick A, Evans K & Jones D 2008. Radiological Assessment of the rehabilitated Nabarlek Uranium Mine, Northern Territory, Australia. In *Uranium Mining and Hydrogeology V conference of the Technische Universität Bergakademie Freiberg*. 14–18 September 2008, eds BJ Merkel & A Hasche-Berger, Freiberg, Saxony, Germany, 363–364.

Bollhöfer A, Pfitzner K, Martin P, Ryan B & Jones DR 2008, The use of remotely sensed radiometric data for the assessment of the radiological status of historic uranium mine sites in the Northern Territory, Australia. In *14ARSPC: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference*, Darwin NT, 30 September – 2 October 2008. USB2.0

Bollhöfer A, Pfitzner K, Ryan B, Martin P, Fawcett M & Jones DR 2008. Airborne gamma survey of the historic Sleisbeck mine area in the Northern Territory, Australia, and its use for site rehabilitation planning. *Journal of Environmental Radioactivity* 99, 1770–1774.

Boyden J, Bartolo R, Bayliss P, Christophersen P, Lawson V, McGregor S & Kennett R 2008. Initial assessment of high-resolution remote sensing to map and monitor change in wetland vegetation on Boggy Plains, World Heritage Area, Kakadu National Park, Australia. In *14ARSPC: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference*, Darwin NT, 30 September – 2 October 2008. USB2.0

Bush M 2009. Assessment of new uranium mines under the *Environmental Protection and Biodiversity Conservation Act 1999*. In *AusIMM International Uranium Conference: Presentations.* 10–11 June 2009, Darwin NT, The Australian Institute of Mining and Metallurgy, Carlton South, Vic, CD.

8 Includes presentations to conferences and symposia that have been externally published in 2008–09.

de Groot R, Finlayson M, Verschuuren B, Ypma O & Zylstra M 2008. *Integrated assessment of wetland services and values as a tool to analyse policy trade-offs and management options: A case study in the Daly and Mary River catchments, northern Australia*. Supervising Scientist Report 198, Supervising Scientist, Darwin NT.

Finlayson CM, Eliott I & Eliott M 2009. A strategic framework for monitoring coastal change in Australia's wet-dry tropics: concepts and progress. *Geographical Research* June 2009 47(2), 109–123.

Hahn T, Stauber J, Dobson S, Howe P, Kielhorn J, Koennecker G, Diamond J, Lee-Steere C, Schneider U, Sugaya Y, Taylor K, van Dam R & Magelsdorf I 2009. Reducing uncertainty in ERA: Clearly defining acute and chronic toxicity tests. *Integrated Environmental Assessment and Management – Learned Discourse* 5(1), 175–177.

Hancock GR, Lowry JBC, Coulthard TJ & Evans KG 2008. A catchment scale evaluation of the SIBERIA and CAESAR landscape evolution models. In *14ARSPC: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference, Darwin NT*, 30 September – 2 October 2008. USB2.0

Hancock GR, Lowry JBC, Moliere DR & Evans KG 2008. An evaluation of an enhanced soil erosion and landscape evolution mode: a case study assessment of the former Nabarlek uranium mine, Northern Territory, Australia. *Earth Surface Processes and Landforms* 33(13), 2045–2063.

Hancock, GR, Lowry JBC, Coulthard TJ, Evans KG & Moliere DR 2009. A catchment scale evaluation of the SIBERIA and CAESAR landscape evolution models. *Earth Surface Processes and Landforms.* (in press)

Harford AJ, Negri A, Wilson S, Hogan AC, Parry DP, Orr J, Houston M & van Dam RA 2008. The development of robust ecotoxicological protocols for tropical marine environments: Knowledge gaps, progress and future needs. Paper presented at Coast to Coast '08, 18–22 August 2008, Darwin. Department of Natural Resources, Environment & the Arts, Northern Territory Government. Available at https://www.coast2coast.org.au/presentation-files.html. Last accessed 13 October 2008.

Hogan AC, van Dam RA, Houston MA, Harford AJ, Nou S 2009. Uranium exposure to the tropical duckweed, *Lemna aequinoctialis*, and pulmonate snail, *Amerianna cumingi*: fate and toxicity. *Archives of Environmental Contamination and Toxicology.* (in press)

Houston M, Ng J, Noller B, Markich SJ & van Dam R 2008. The influence of Suwannee River fulvic acid on the speciation and toxicity of uranium to Australian tropical freshwater species. In *From molecular understanding to innovative applications of humic substances. Proceedings of the 14th meeting of International Humic Substances Society*. Moscow, 13–19 September 2008, eds IV Perminova & NA Kulikova, 421–424.

Johansen K, Phinn S, Lowry J & Douglas M 2008. Quantifying indicators of riparian condition in Australian tropical savannas: integrating high spatial resolution imagery and field survey data. *International Journal of Remote Sensing* 29 (23), 7003–7028.

Jones DR & Webb A (eds) 2009. ***eriss*** *research summary 2007–2008*. Supervising Scientist Report 200, Supervising Scientist, Darwin NT.

Lawrence CE, Akber RA, Bollhöfer A & Martin P 2009. Radon-222 exhalation from open ground on and around a uranium mine in the wet-dry tropics. *Journal of Environmental Radioactivity* 100, 1–8.

Lowry J, Hess L & Rosenqvist A 2008. Mapping and monitoring wetlands around the world using ALOS PALSAR: the ALOS Kyoto and Carbon Initiative wetland products. In *14ARSPC: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference*, Darwin NT, 30 September – 2 October 2008. USB2.0

Lowry J, Staben G & Saynor M 2008. Mapping the distribution of landslides in Arnhem Land using ALOS AVNIR imagery and object-based classification techniques. In *14ARSPC: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference*, Darwin NT, 30 September – 2 October 2008. USB2.0

Moliere DR, Lowry JBC & Humphrey CL 2009. Classifying the flow regime of data-limited streams in the wet-dry tropical region of Australia. *Journal of Hydrology* 367 (2009), 1–13.

Pfitzner K, Esparon A & Bollhöfer A 2008. SSD's spectral library database. In *14ARSPC: Proceedings of the 14th Australasian Remote Sensing and Photogrammetry Conference*, Darwin NT, 30 September – 2 October 2008. USB2.0

Tayler K 2009. The regulation of uranium mining in the Northern Territory. In *Radiation in Mining and Exploration Workshop: Presentations.* Darwin NT 12 June 2009, Darwin NT, The Australian Institute of Mining and Metallurgy, Carlton South, Vic, CD.

Turner K & Tayler K 2009. Research to routine monitoring – best practice water quality monitoring. In *AusIMM International Uranium Conference: Presentations.* 10–11 June 2009, Darwin NT, The Australian Institute of Mining and Metallurgy, Carlton South, Vic, CD.

van Dam RA, Harford AJ, Houston MA, Hogan AC & Negri AP (in press). Tropical marine toxicity testing in Australia: A review and recommendations. *Australasian Journal of Ecotoxicology* 14(2).

van Dam RA, McCullough C, Hogan A, Houston M, Harford A & Humphrey C (in press). Aquatic toxicity of magnesium sulphate, and the influence of calcium, in very low ionic concentration water. *Environmental Toxicology & Chemistry*.

Warne M & van Dam R 2008. NOEC and LOEC data should no longer be generated or used. *Australasian Journal of Ecotoxicology*. (in press)

Wilson GDF, Humphrey CL, Colgan DJ, Gray KA & Johnson RN 2009. Monsoon-influenced speciation patterns in a species flock of Eophreatoicus Nicholls (Isopoda; Crustacea) *Molecular Phylogenetics and Evolution* 51(2), 349–364.

Unpublished papers and reports

ARRAC 2008. Alligator Rivers Region Advisory Committee 27th Meeting, April 2007, Darwin, Meeting papers. Internal Report 540, August, Supervising Scientist, Darwin. Unpublished paper.

ARRAC 2008. Alligator Rivers Region Advisory Committee 28th Meeting, August 2007, Darwin, Meeting papers. Internal Report 541, August, Supervising Scientist, Darwin. Unpublished paper.

Alligator Rivers Region Advisory Committee 2009. Alligator Rivers Region Advisory Committee 29th Meeting, April 2008, Darwin, Meeting papers. Internal Report 542, June, Supervising Scientist, Darwin. Unpublished paper.

Bollhöfer A & Fawcett M 2009. Results of a gamma dose rate survey at the rehabilitated Sleisbeck mine, Northern Territory, Australia. Internal Report 561, April, Supervising Scientist, Darwin. Unpublished paper.

Bollhöfer A, Fawcett M, Staben G, Sellwood J, Fox G, Ryan B & Pfitzner K 2009. Radiation surveys of the historic Palette and El Sherana mines, South Alligator River Valley, Australia. Internal Report 556, March, Supervising Scientist, Darwin. Unpublished paper.

Brazier J & Humphrey C 2009. Ranger stream monitoring program: relocation of surface water chemistry grab monitoring sites in Magela Creek. Internal Report 563, June, Supervising Scientist, Darwin. Unpublished Paper.

Esparon A 2008. Jabiru Field Station radiation dose and surface contamination survey. Internal Report 538, December, Supervising Scientist, Darwin. Unpublished paper.

Hogan A, Houston M, Nou S, Harford A & van Dam 2008. Chronic toxicity of uranium to the tropical duckweed *Lemna aequinioctialis* and the gastropod *Amerianna cumingi*. Internal Report 549, November, Supervising Scientist, Darwin. Unpublished paper.

Jones DR (ed) 2009. ***eriss*** communication and planning workshop – 08/09 workplan and proposed 09/10 directions. Internal Report 550, June, Supervising Scientist, Darwin. Unpublished paper.

Office of the Supervising Scientist, Supervision & Assessment Unit 2009. Ranger mine Routine Periodic Inspections 2002–2004. Internal Report 551, June, Supervising Scientist, Darwin. Unpublished paper.

Office of the Supervising Scientist, Supervision & Assessment Unit 2009. Ranger mine Routine Periodic Inspections 2006. Internal Report 553, June, Supervising Scientist, Darwin. Unpublished paper.

Office of the Supervising Scientist, Supervision & Assessment Unit 2009. Ranger mine Routine Periodic Inspections 2005. Internal Report 552, June, Supervising Scientist, Darwin. Unpublished paper.

Office of the Supervising Scientist, Supervision & Assessment Unit 2009. Ranger mine Routine Periodic Inspections 2007. Internal Report 554, June, Supervising Scientist, Darwin. Unpublished paper.

Office of the Supervising Scientist, Supervision & Assessment Unit 2009. Ranger mine Routine Periodic Inspections 2008. Internal Report 555, June, Supervising Scientist, Darwin. Unpublished paper.

Pfitzner K & Bollhöfer A 2008. Status of the vegetation plots for the spectral library project. Internal Report 546, December, Supervising Scientist, Darwin. Unpublished paper.

Saynor MJ, Houghton R, Hancock G, Staben G, Smith B & Lee N 2009. Soil sample descriptions – Gulungul Creek, Ranger mine site and Nabarlek: Cyclone Monica fieldwork. Internal Report 558, Supervising Scientist, Darwin. Unpublished paper.

Saynor MJ, Staben G, Hancock G, Fox G, Calvert G, Smith B, Moliere DR & Evans KG 2009. Impact of Cyclone Monica on catchments within the Alligator Rivers Region – Data. Internal Report 557, Supervising Scientist, Darwin. Unpublished paper.

Supervising Scientist Division 2008. Consolidated list of publications, reports and conference presentations by staff of and consultants to the Supervising Scientist 1978–30 June 2008. Internal Report 547, August, Supervising Scientist, Darwin. Unpublished paper.

Turner K, Jones D & Humphrey C 2009. Changes in water quality of Rockhole Mine Creek associated with historic mining activities. Internal report 560, June, Supervising Scientist, Darwin. Unpublished paper.

Consultancy reports

Humphrey C, Buckle D & Camilleri C 2009. A macroinvertebrate survey of stream sites associated with Territory Resources' Frances Creek iron ore project, April 2008. Commercial-in-Confidence Report for Earth Water Life Sciences Pty Ltd, March 2009.

Harford A, van Dam R & Hogan A 2009. Ecotoxicological Assessment of Seepage Water from the Savannah Nickel Mines. Commercial-in-Confidence Report for Panoramic Resources Ltd, April 2009.

Humphrey C, van Dam R, Storey A, Chandler L, Hogan A & Buckle D 2008. Assessment of the effects f $MgSO_4$-rich wastewater discharges from Argyle Diamond Mine on downstream aquatic ecosystems: Synthesis of a three year (2006-08) study. Commercial-in-Confidence Report for Argyle Diamonds Ltd, November 2008.

Ryan B & Bradley F 2009. Preliminary report into the characterisation of groundwater at the Rum Jungle mine site. Report prepared for Department of Resources, Energy and Tourism, February 2009, Supervising Scientist Division, Darwin NT.

van Dam R & Harford A 2009. Review of the revision of the nitrate water quality trigger value for fresh surface waters. Commercial-in-Confidence Report for Environment Canterbury, April 2009.

APPENDIX 3 PRESENTATIONS TO CONFERENCES AND SYMPOSIA, 2008–2009[9]

Bartolo R 2008. Spatial information and climate change in a North Australia context. Paper presented at the Asia Pacific Spatial Innovation Conference, 18–19 November 2008, Canberra.

Bollhöfer A 2009. Die Nabarlek Uranmine. The Nabarlek Uranium mine – Studies of the Environmental Research Institute of the Supervising Scientist. Seminar held as part of a seminar series '*Current Topics in Radiation Protection*', German Radiation Protection Agency. 18 September 2008, Berlin, Germany.

Bollhöfer A, Brazier J, Ryan B, Humphrey C & Esparon A 2009. A study of radium bioaccumulation in freshwater mussels, *Velesunio angasi*, in the Magela Creek catchment, Northern Territory, Australia. Paper presented at the 10th South Pacific Environmental Radioactivity Conference, SPERA 2008, 24–27 November 2008, Christchurch, New Zealand.

Brazier J, Ryan B, Humphrey C & Bollhöfer A 2008. Uranium bioaccumulation and lead isotope ratios in freshwater mussels downstream of Ranger uranium mine, Australia. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

Cheng K, Parry D, Hogan A & van Dam R 2008. Chronic toxicity of uranium to the tropical freshwater fish, Mogurnda mogurnda. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

Esparon A & Pfitzner J 2008. Visual gamma – gamma spectrometry analysis software. Paper presented at the 10th South Pacific Environmental Radioactivity Conference, SPERA 2008, 24–27 November 2008, Christchurch, New Zealand.

Esparon A, Pfitzner K, Bollhöfer A & Ryan B 2008. Determination of an analogue site for Ranger uranium mine to extrapolate pre-mining gamma dose rates. Paper presented at the 10th South Pacific Environmental Radioactivity Conference, SPERA 2008, 24–27 November 2008, Christchurch, New Zealand.

Frostick A, Bollhöfer A & Parry D 2009. Investigating potential natural analogues for Ranger Uranium Mine. Paper presented at the 10th South Pacific Environmental Radioactivity Conference, SPERA 2008, 24–27 November 2008, Christchurch, New Zealand.

Frostick A, Bollhöfer A, Parry D, Munksgaard N & Evans K 2008. Spatiotemporal assessment of sediments from Magela Creek, Northern Australia to evaluate the impacts of uranium mining. Paper presented at the 10th South Pacific Environmental Radioactivity Conference, SPERA 2008, 24–27 November 2008, Christchurch, New Zealand.

9 Presentations to conferences and symposia that have been externally published in 2008–09 are included in Appendix 2.

Hahn T, Stauber J, Dobson S, Howe P, Kielhorn J, Koennecker G, Diamond J, Lee-Steere C, Schneider U, Sugaya Y, Taylor K & van Dam R 2008. Sources of variation in environmental hazard assessment of chemicals in aquatic systems: an international analysis. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

Harford AJ, Cheng KL, Costello CE, Hogan AC & van Dam RA 2008. Ecotoxicological assessment of flocculant blocks and their individual constituents. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

Houston M, Ng J, Noller B, Markich SJ & van Dam R. 2008a. The influence of dissolved organic carbon (DOC) on the speciation & toxicity of uranium to Australian tropical freshwater species. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

Hughes A 2008. Regulation of uranium mining in the Northern Territory, Australia. Presentation to an International Atomic Energy Agency technical meeting on Implementation of sustainable global best practices in uranium mining and processing, 15–17 October 2008, Vienna, Austria.

Humphrey C & McGuinness K 2008. Experimental design considerations for monitoring and assessment of mining impacts in tropical seasonally-flowing streams. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

Jones D 2008. Effects of extreme events in the Kakadu region. Paper presented at Kakadu Landscape Management Symposia Series: Climate Change Workshop. 6–7 August 2008, Jabiru.

Jones D 2009. Key issues for 'best practice' regulation of uranium mining. Paper presented at Securing the Future (Mining, Metals and the Environment in a Sustainable Society) and 8th International Conference on Acid Rock Drainage, 23–26 June 2009, Skelleftea, Sweden.

Lu P, Akber R & Bollhöfer A 2009. Challenges in estimating public radiation dose resulting from land application of waters of elevated natural radioactivity at Ranger Uranium Mine, Australia. Paper presented at the International IAEA Conference on Remediation of Land Contaminated by Radioactive Material Residues, 18–22 May 2009, Astana, Kazakhstan.

Medley P, Bollhöfer A, Ryan B & Sellwood J 2008. Derivation of regional concentration factors for radium in bush passionfruit (*Passiflora foetida*) from the Alligator Rivers Region, Northern Territory, Australia. Paper presented at the 10th South Pacific Environmental Radioactivity Conference, SPERA 2008, 24–27 November 2008, Christchurch, New Zealand.

Ryan B, Bollhöfer A & Martin P 2008. A radiation dose assessment for Aboriginal inhabitants downstream of Ranger Uranium Mine in the Northern Territory of Australia. Paper presented at the 10th South Pacific Environmental Radioactivity Conference, SPERA 2008, 24–27 November 2008, Christchurch, New Zealand.

Turner K, Humphrey C, Brazier J, Jones D 2008. Sediment influences on the derivation of mine closure water quality criteria in a tropical waterbody. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

van Dam R, Hogan A, Harford A & Markich S 2008. Toxicity, metal speciation and risk characterisation of waste-water from a legacy gold mine in northern Australia. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

van Dam R, Humphrey C, Storey A, Samaraweera S, Hogan A, Buckle D & Chandler L 2008. Assessment of the effects of $MgSO_4$-rich wastewater discharges from Argyle Diamond Mine on downstream aquatic ecosystems. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

van Dam R, Negri A, Harford A, Hogan A, Adams M, Stauber J, Parry D & Orr J 2008. Using the tropical species *Nitzschia closterium* & *Acropora tenuis* to assess site-specific issues of a tropical marine discharge. Paper presented at 5th SETAC World Congress, 3–7 August 2008, Sydney Convention and Exhibition Centre, Sydney. Society of Environmental Toxicology and Chemistry.

INDEX

Note: Page numbers in italics indicate maps, figures and photographs.

M

N

O

P

Q

R

Feedback on the Supervising Scientist 2008–09 Annual Report

We hope we have presented a comprehensive and informative account of the activities of the Supervising Scientist Division during 2008–2009.

If you have any suggestions for Supervising Scientist activities that you'd like to read more about and/or different ways you'd like to see the existing information presented, we would value your feedback. Please send your views by post or by e-mail to the addresses given below.

You can also access this and previous Supervising Scientist Annual Reports on the Department of the Environment, Water, Heritage and the Arts web site:

www.environment.gov.au/about/publications/annual-report/

More Information

More information about Supervising Scientist Division is available at:
www.environment.gov.au/ssd/

The full list of Supervising Scientist publications is available at:
www.environment.gov.au/ssd/publications

Inquiries about Supervising Scientist Division should be directed to:

Supervising Scientist Division, GPO Box 461, Darwin NT 0801
tel: 08 8920 1100; fax: 08 8920 1199

Street address: Department of the Environment, Water, Heritage and the Arts Building, cnr Pederson Rd & Fenton Ct, Marrara NT 0812

e-mail: enquiries_ssd@environment.gov.au

Internet: www.environment.gov.au/ssd