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
- 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 indigenous 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 indigenous 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 caused 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 porewater 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.

[*Note: KKN 5.4 will be reviewed at the November 2011 sitting of ARRTC in light of the recent inclusion of Koongarra on the World Heritage register*.]

APPENDIX 2 PUBLICATIONS FOR 2010–2011

Published[2]

Bartolo R, van Dam R & Bayliss P 2012. Regional ecological risk assessment for Australia's tropical rivers: Application of the Relative Risk Model. *Human and Ecological Risk Assessment.* (in press)

Bartolo R, Ward D & Jones D 2010. Flood inundation mapping of tropical river catchments in northern Australia using optical and Alos-Palsar data. In *Proceedings 15th Australian Remote Sensing and Photogrammetry Conference (ARSPC)*, 14–16 September 2010, Alice Springs, Published online at www.15.arspc.com/proceedings

Bayliss P, van Dam R & Bartolo R 2012. Quantitative ecological risk assessment of Magela Creek floodplain on Kakadu National Park: comparing point source risks from Ranger uranium mine to diffuse landscape-scale risks. *Human and Ecological Risk Assessment.* (in press)

Bollhöfer A, Brazier J, Humphrey C, Ryan B & Esparon A In press. A study of radium bioaccumulation in freshwater mussels, *Velesunio angasi*, in the Magela Creek catchment, Northern Territory, Australia. *Journal of Environmental Radioactivity*: Available online 28 April 2010 doi:10.1016/j.jenvrad.2010.04.001.

Bush M 2010. Stakeholder cooperation: Regulating a uranium mine with multiple statutory approvals. In *Uranium 2010: 'The future is U'*, Proceedings of the 3rd international conference on uranium, vol 2, 15–18 August 2010, eds Lam EK, Rowson JW & Özberk E, Canadian Institute of Mining, Metallurgy & Petroleum, Quebec, Canada, 617–624.

Bush M & Turner K 2010. Leading practice water quality monitoring in Northern Australia. In *Uranium 2010: 'The future is U'*, Proceedings of the 3rd international conference on uranium, vol 2, 15–18 August 2010, eds Lam EK, Rowson JW & Özberk E, Canadian Institute of Mining, Metallurgy & Petroleum, Quebec, Canada, 721–729.

Chalmers AC, Erskine WD, Keene AF & Bush RT in press. Relationship between vegetation, hydrology and fluvial landforms on an unregulated sand-bed stream in the Hunter Valley, Australia. *Austral Ecology*. (in press)

Erskine WD in press. Geomorphic controls on historical channel planform changes on the lower Pages River, Hunter Valley, Australia. *Australian Geographer*. (in press)

Erskine WD, Keene AF, Bush RT, Cheetham M & Chalmers AC in press. Influence of riparian vegetation on channel widening and subsequent contraction on a sand-bed stream since European settlement: Widden Brook, Australia. *Geomorphology*. (in press)

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Erskine WD, Saynor MJ & Townley-Jones M 2011. Temporal changes in annual rainfall in the 'Top End' of Australia. In *Hydro-climatology: Variability and change*. eds SW Franks, E Boegh, E Blyth, DM Hannah & KK Yilmaz, International Association of Hydrological Sciences, Wallingford, 57–62.

Frostick A, Bollhöfer A & Parry D 2011. A study of radionuclides, metals and stable lead isotope ratios in sediments and soils in the vicinity of natural U-mineralisation areas in the Northern Territory, Australia. *Journal of Environmental Radioactivity* 102 (2011), 911–918.

Harford AJ, Hogan AC, Tsang JJ, Parry DL, Negri AP, Adams MS, Stauber JL & van Dam RA 2011. Effects of alumina refinery wastewater and signature metal constituents at the upper thermal tolerance of: 1. The tropical diatom *Nitzschia closterium*. *Marine Pollution Bulletin* 62, 466–473.

Jones DR & Webb A (eds) 2011. ***eriss*** *research summary 2009–2010*. Supervising Scientist Report 202, Supervising Scientist, Darwin NT.

Jones D 2011. Report on 8th International Conference on Acid Rock Drainage, Skelleftea, Sweden. In *Proceedings 7th Australian Workshop on Acid and Metalliferous Drainage*, Darwin Northern Territory 21–24 June 2011, eds LC Bell & B Braddock, JKtech Pty Ltd, Brisbane, 25–37.

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APPENDIX 3 PRESENTATIONS TO CONFERENCES AND SYMPOSIA, 2010–2011[3]

Akber R, Lu P & Bollhöfer A 2010. Distribution of radioactivity in the land application areas at Ranger Uranium mine. Paper presented at the 11th South Pacific Environmental Radioactivity Conference, 31 August – 3 September 2010, Surfers Paradise, Gold Coast, Australia.

Bartolo R, Staben G, Beraldo A, Lowry J & Kirrilly Pfitzner 2011. A systematic high resoloution remote sensing capture for the Magela Creek Catchment: A case study using WorldView 2. Paper presented at NT Spatial 2011 Conference, 2–4 February 2011, Darwin NT.

Batley G, Braga O, Chapman J, Fox D, Hickey C, Stauber J, Van Dam R & Warne M 2011. Recommended revisions of the Australian and New Zealand Water Quality Guidelines for toxicants. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment*. Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 118.

Bollhöfer A, Esparon A, Pfitzner K, Beraldo A 2011. Groundtruthing historic airborne gamma surveys to determine pre-mining radiological conditions at Ranger Mine, Northern Territory, Australia. Paper presented at AusIMM Uranium Conference, Perth Australia 8–9 June 2011.

Bollhöfer A, Ryan B & Doering C 2010. The development of a concentration ratio database for bushfoods in Northern Australia. Paper presented at the EMRAS II Transfer Group meeting (WG5), 6–9 September 2010, International Atomic Energy Agency, Vienna, Austria.

Buckle D, Humphrey C & McGuinness K 2011. Comparison of ANOVA and PERMANOVA analysis techniques to stream community data for BACI-type impact detection designs. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment*. Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 09.

Bush M 2010. Stakeholder cooperation: Regulating a uranium mine with multiple statutory approvals. Paper presented at U2010, Saskatoon Canada, 15–18 August 2010.

Bush M 2011. Uranium legacies: regulation, stakeholders and resources. Australian case studies. Paper presented at US EPA 12th Superfund National Radiation Meeting, Savannah Georgia, USA, 21–25 March 2011.

3 Presentations to conferences and symposia that have been externally published in 2010–11 are included in Appendix 2.

Bush M 2011. Uranium legacies: regulation, stakeholders and resources. Australian case studies. Presentation to the International Working Forum for the Regulatory Supervision of Legacy Sites (RSLS), Vienna Austria, 11–15 October 2010.

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Doering C, Ryan B & Bollhöfer A 2010. ERISS bush foods and wildlife concentration ratio database. Paper presented at the 11th South Pacific Environmental Radioactivity Conference, 31 August – 3 September 2010, Surfers Paradise, Gold Coast, Australia.

Frostick A, Bollhöfer A & Parry D 2010. Assessment of stable lead isotope ratios, radionuclides and trace metals from billabong sediments in the vicinity of a uranium mine in northern Australia. Paper presented at 11th South Pacific Environmental Radioactivity Conference, 31 August – 3 September 2010, Gold Coast, Australia.

Frostick A, Bollhöfer A & Parry D 2011. Trace metal and lead isotope dispersal from a decommissioned gold mine in the Northern Territory, Australia. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment.* Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 22.

Frostick A, Turner K & Tayler K 2011. Implementing a best practice water quality monitoring program. Paper presented at AusIMM Uranium Conference, Perth Australia 8–9 June 2011.

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Hughes A 2010. The Supervising Scientist Division and regulation of uranium mining in Australia. Paper presented at a meeting of state and national regulators, Saskatoon, Canada, 19 August 2010.

Hughes A & Colreavy M 2011. Regulation and environmental management of uranium mining. Paper presented to a delegation of members of the European Union Parliament, 22 February 2011, Parliament House, Canberra ACT.

Humphrey C 2011. Thresholds and regime shifts in Australian freshwater ecosystems: A Wet-dry tropical perspective. Paper presented at *Thresholds and regime shifts in Australian freshwater ecosystems*, Australian Centre for Ecological Analysis and Synthesis (ACEAS) Workshop for Freshwater Ecosystems Working Group, University of Queensland, St Lucia, Brisbane, 23–25 May 2011.

Humphrey C, Davies C & Buckle D 2011. Drawing inference in in-stream toxicity monitoring tests used to assess mining impact in a tropical stream. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment.* Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 55.

Humphrey C, Batley G, Bennett J, Davis J, Edlington C, Fox D, Hunt A, Maher B & Van Dam R 2011. An overview of key features of the revision of the *Australian and New Zealand guidelines for fresh and marine water quality* affecting aquatic ecosystems. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment.* Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 117.

Jones D 2010 Understanding sustainable water management in decommissioning and rehabilitation. Paper presented at Water Management in Mining, 1–2 December 2010, Perth WA.

Jones D, Humphrey C, Van Dam R, Harford A, Turner K & Bollhoefer A 2011. Integrated water quality monitoring for an australian uranium mine a best practice case study. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment.* Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 12.

Lowry J, Beraldo A & Coulthard T 2011. Integrating TLS data with a LEM to assess soil erosion. Paper presented at NT Spatial 2011 Conference, 2–4 February 2011, Darwin NT.

Medley P 2010. Quality assurance in alpha spectrometric measurement of Ra-226 from co-precipitation with barium sulphate. Paper presented at the 11th South Pacific Environmental Radioactivity Conference, 31 August – 3 September 2010, Surfers Paradise, Gold Coast, Australia.

Pfitzner K, Bartolo B, Esparon A & Staben G 2011. Field and laboratory spectrometry for remote sensing applications. Paper presented at NT Spatial 2011 Conference, 2–4 February 2011, Darwin NT.

Saynor M & Lowry J 2011. Trial landform research at the Ranger mine, Northern Territory, Australia. Paper presented at Australian and New Zealand Geomorphology Group Conference, Oamaru, South Island, New Zealand, 31 January – 5 Feb 2011.

Staben GW, Pfitzner K, Bartolo R, Lucieer A 2011. Calibration of WorldView-2 satellite imagery to reflectance data using an empirical line method. Paper presented at 34th ISRSE (International Symposium of Remote Sensing of Environment). 10–14 April 2011, Sydney, Australia.

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Trenfield M, Ng J, Noller B, Markich S & van Dam R 2010. Uranium toxicity to tropical freshwater organisms: amelioration by dissolved organic carbon and linking toxicity with oxidative stress. Paper presented at SETAC North America 31st Annual meeting, Portland, Oregon, 7–11 November 2010.

Trenfield M, Markich SJ, Ng JC, Noller B & Van Dam RA 2011. The influence of dissolved organic carbon on the speciation and toxicity of aluminium to tropical freshwater organisms. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment*. Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 45.

van Dam RA 2010. Applications of ecotoxicology for predicting and assessing contaminant impacts on tropical marine environments. Australian Water Association Northern Territory Branch Annual Conference, Darwin, 22 October 2010.

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Van Dam RA, Hogan AC, Harford AJ, Cheng KC, Costello CE & Trenfield ME 2011. Residual effects of treated mine waters on five tropical freshwater species. Poster presented at *EnviroTox 2011: Sharing knowledge for a healthier environment.* Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 138.

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Warne M, Batley G, Braga O, Chapman J, Fox D, Hickey C, Stauber J & Van Dam R 2011. Proposed changes to methodology for the derivation of toxicant guideline trigger values. Paper presented at *EnviroTox 2011: Sharing knowledge for a healthier environment*. Joint conference of the Royal Australian Chemical Institute and the Society for Environmental Toxicology Australasian Chapter, Darwin NT 17–20 April 2011, Abstract 119.

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Feedback on the Supervising Scientist 2010–11 annual report

We hope we have presented a comprehensive and informative account of the activities of the Supervising Scientist Division during 2010–2011.

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 Sustainability, Environment, Water, Population and Communities 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

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