

## **Part 3: Jabiluka**

The Jabiluka site is currently in long-term care and maintenance. Several projects relating to assessment of long term changes in morphology of the stream channel in Swift Creek are currently being finalised and will be reported on in the next annual *eriss* Research Summary.

## **Part 4: Nabarlek**

There are no research papers this year in the Nabarlek key knowledge needs theme. The taking over of management of the site by Uranium Equities Limited and the requirement for conduct of monitoring and progressive rehabilitation activities as part of the mine management plan have meant that the involvement of SSD has been reduced following completion of the suite of projects that had been initiated to define for stakeholders the rehabilitation status of the site.

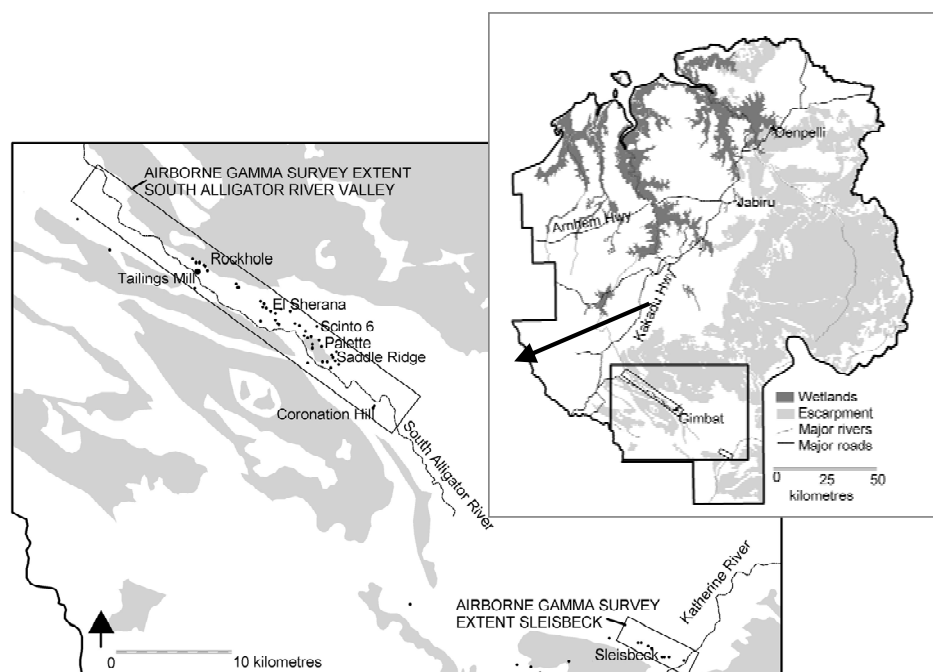
## **Part 5: General Alligator Rivers Region**

# Assessing the success of remediation works at former uranium mining and milling sites in the South Alligator River valley

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## Introduction

In the 2009 dry season major works commenced in the South Alligator River valley (SARV) to rehabilitate remnants of historical uranium mining and milling activities in the area. The works included the removal of contaminated material from areas affected by historical mining (Sleisbeck, El Sherana and Palette mines) and milling (Rockhole Residues) activities. Other areas that were remediated included the old containments at the South Alligator village, the El Sherana village, and the El Sherana weighbridge. At these sites contaminated material that had previously been buried was excavated and transferred to a purpose built containment located on the site of the old El Sherana airstrip. The remediation works were finished prior to the start of the 2009–10 wet season, with approximately 20 000 m<sup>3</sup> of material having been moved to the new containment. The locations of the main historical mining and milling sites are shown in Figure 1.



**Figure 1** 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 2003)

Descriptions of the historical mining and milling sites, and past remediation activities in the area, are contained in Fisher (1968), Waggitt (2004) and Bollhöfer et al (2007, 2009a&b).

The latest remediation works were carried out to address the terms of the 1996 lease agreement between the Gunlom Aboriginal Land Trust and the Director of National Parks.

This lease agreement required the Director of National Parks to implement an environmental remediation plan for all historic minesites and associated workings in the SARV. The remediation plan was managed by Parks Australia, with SSD providing specialist assistance with the radiological assessment of the sites.

The results from the radiological assessments and other investigations carried out by SSD informed the development of a remediation strategy for the SARV. The gamma dose rate guideline value to be used as the remediation threshold for historic mining and milling sites in the SARV was set at  $1.25 \pm 0.25 \mu\text{Gy}\cdot\text{hr}^{-1}$  (approximately 10 times higher than background levels). This guideline value was derived on the basis of being able to clearly distinguish, by field measurement, the radiological signal of mining-derived material from the regional background, whilst ensuring that likely annual doses to the public are well below the reference level (10 mSv/y) imposed by ARPANSA for remediated sites in the South Alligator River Valley.

Radiological assessments of the Rockhole Residues site, and Palette and El Sherana mines were conducted before remediation and results are published in Bollhöfer et al (2007, 2009a&b). Additional historical information on the Palette and El Sherana minesites can be found in Bollhöfer et al (2010).

This paper presents the results of gamma dose rate surveys conducted in the 2010 dry season at the Rockhole Residues, Palette and El Sherana sites (Doering et al in prep) and compares the results with those from the earlier pre-remediation survey to assess the success of the remediation works.

## Methods

Gridded gamma surveys were conducted at the Rockhole Residues site and at Palette (top bench only) during July 2010, and at El Sherana (pit and access tracks, top area to the north of pit, and top areas to the south and west of pit) during September 2010. Two environmental dose rate meters of the same type were used for the surveys at each site.

The spacing of the measurements was approximately 15 m at the Rockhole Residues site, 5 m at Palette and 5–10 m at El Sherana. The geospatial coordinates – eastings and northings – of each measurement point at each site was determined by global positioning system (GPS) in the WGS84 coordinate system within Zone 53. At the Rockhole Residues site only, the visual boundary of the remediated area was walked on foot and the trace recorded using GPS.

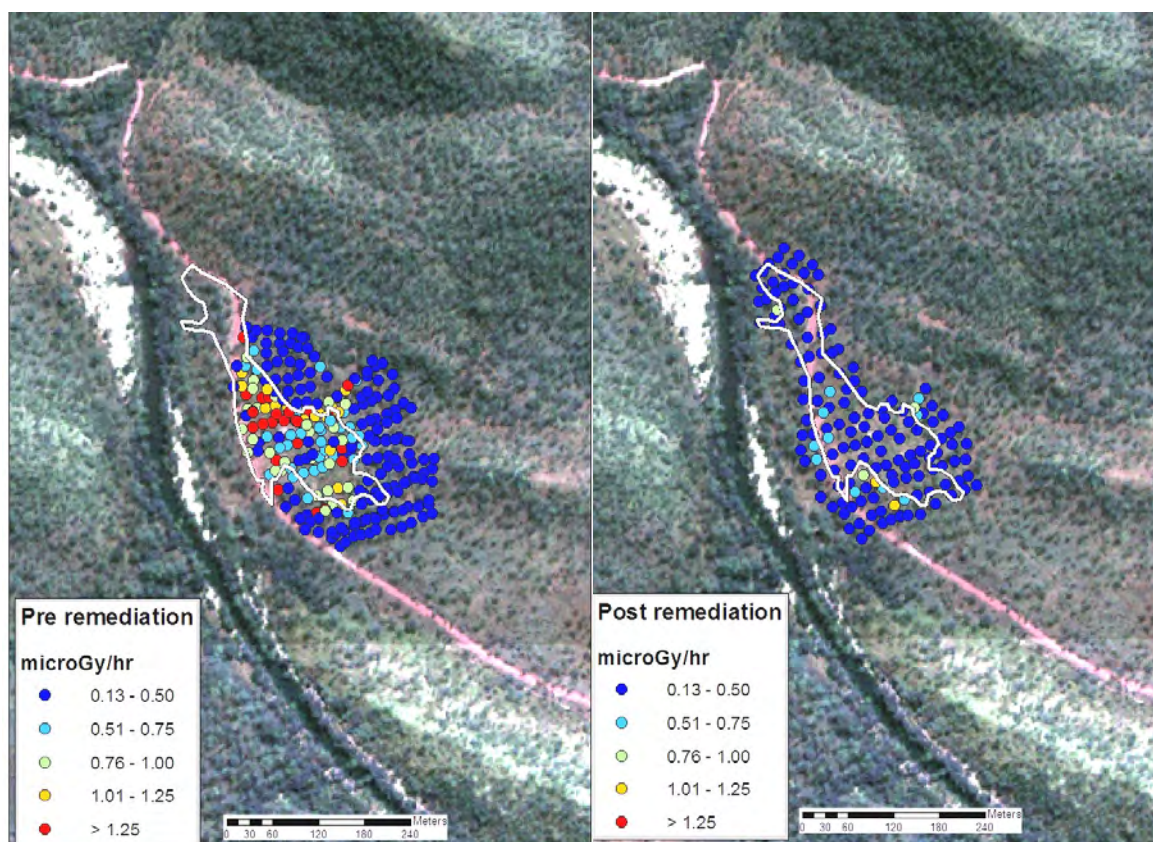
## Results

### Rockhole Residues

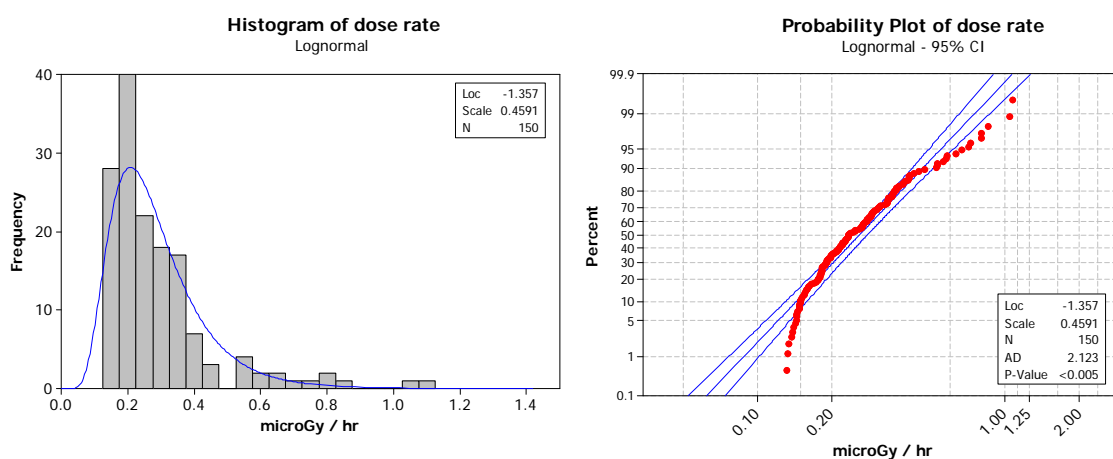
Figure 2 shows the location of the individual measurement points and the magnitude of the calculated absorbed gamma dose rates (including the cosmic component) at the Rockhole Residues site before and after remediation. The figure also shows the visual boundary of the remediated area, overlaid on a Quickbird satellite image of the area acquired in 2004. It can be seen that absorbed gamma dose rates have been substantially reduced following remediation of the area.

The total area that was remediated at the Rockhole Residues site in 2009–10 was approximately 2.5 ha. None of the 150 dose rate measurements taken across the area in 2010 exceeded the specified radiological threshold value of  $1.25 \pm 0.25 \mu\text{Gy}\cdot\text{hr}^{-1}$ . Figure 3 provides a frequency and probability plot for the dose rates measured at the site. The dose frequency

plot for the Rockhole Residues site (Figure 3) exhibits a lognormal distribution. From the probability plot it can be concluded, with 95% confidence, that 99.9% of the dose rates measured at the site were below the guideline value.



**Figure 2** Pre- and post remediation gamma dose rates at the Rockhole Residues site overlaid on a Quickbird satellite image. The white line shows the approximate outline of the remediated area.



**Figure 3** Histogram and probability plot of the dose rates measured at the remediated Rockhole Residues site

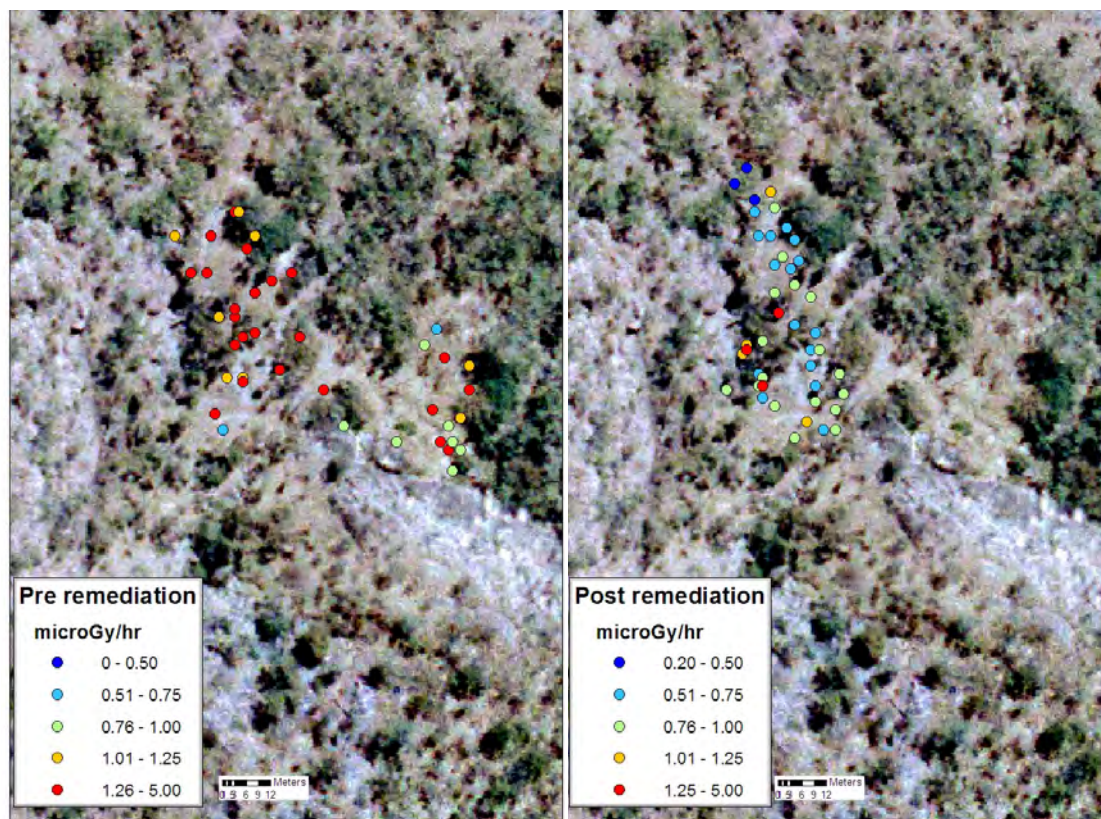
## Palette mine

Figure 4 shows the pre- and post-remediation gamma dose rates measured at the Palette site in 2008 (Bollhöfer et al 2009b) and 2010, respectively. Whereas in 2008 the lower bench was easily accessible, the track to the lower bench was not accessible in 2010 due to the

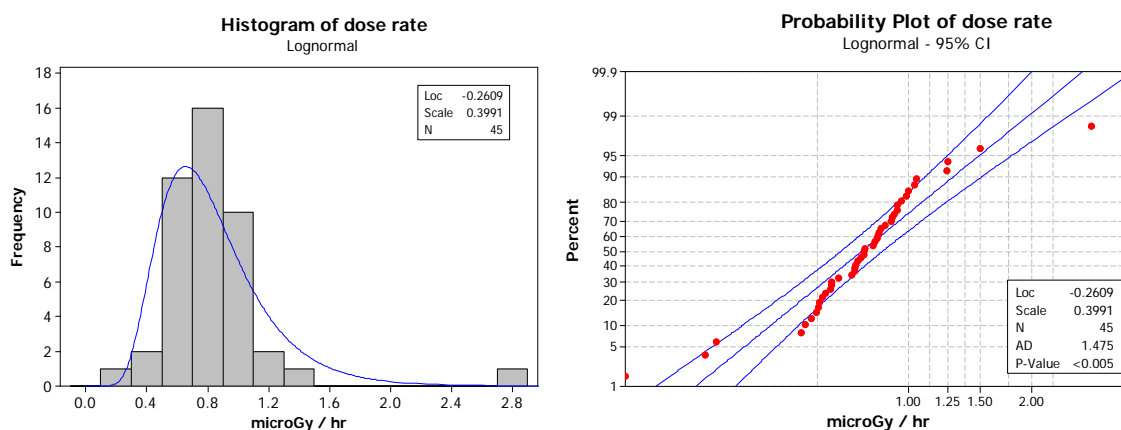


remediation works and the presence of large boulders. Consequently, only the top bench (to the west or left of image) was surveyed as it was considered unlikely that the lower bench will be accessed by people for habitation for extended periods of time.

The dose rate frequency plot for Palette (Figure 5) appears to define a lognormal distribution. The probability plot for the site indicates that 90% of the locations measured post remediation have gamma dose rates less than the guideline value of  $1.25 \pm 0.25 \mu\text{Gy}\cdot\text{hr}^{-1}$ , compared to only 25% pre-remediation (Bollhöfer et al 2009b). Generally, readings above  $1 \mu\text{Gy}\cdot\text{hr}^{-1}$  correspond to locations near the cliff face on the top bench. There was one measurement above the guideline value, which was due to the presence of a single small piece of mineralised material (approximately  $5 \text{ cm}^3$ ), believed to be pitchblende, lying on the ground surface.



**Figure 4** Measured pre- and post remediation gamma dose rates at Palette mine overlaid on an aerial photograph of the area

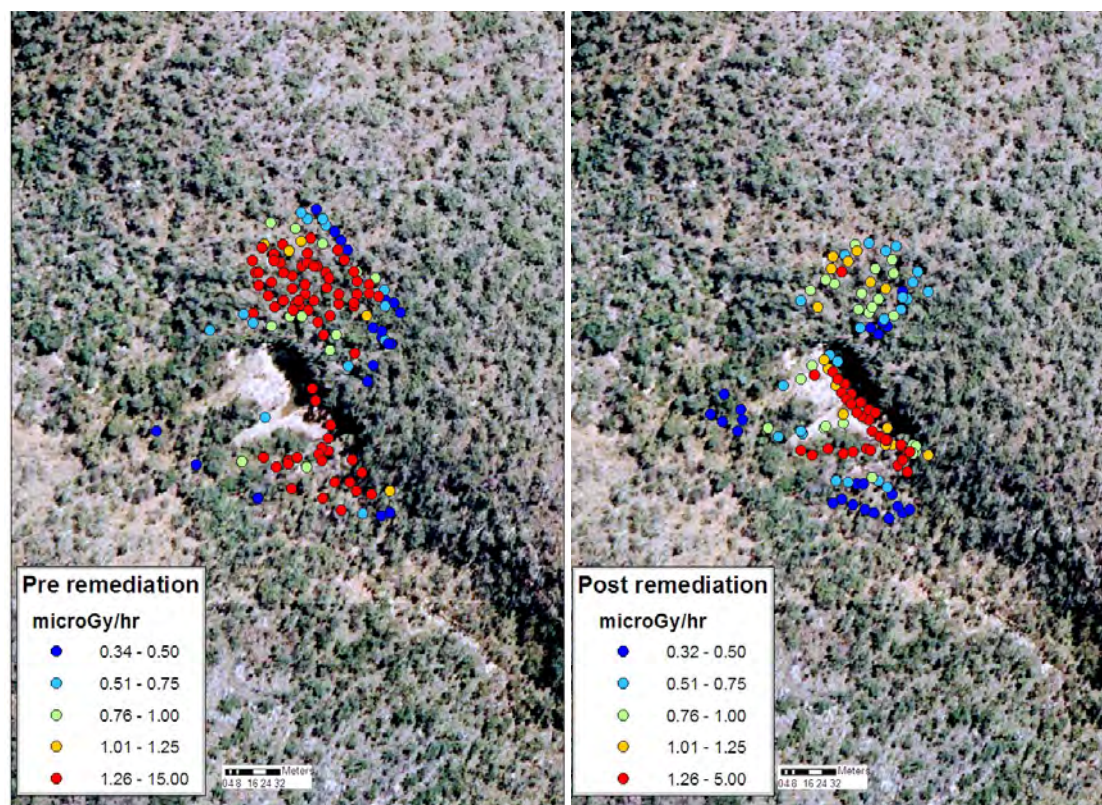


**Figure 5** Histogram and probability plot of the dose rates measured at the remediated Palette mine



## El Sherana mine

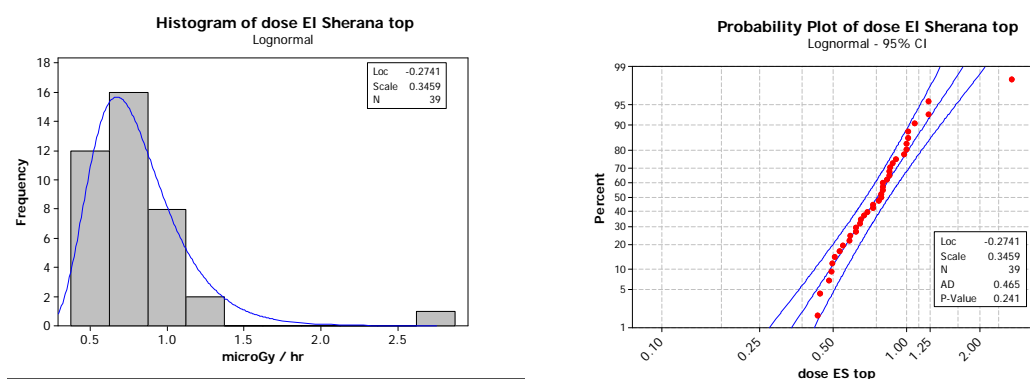
The highest pre-remediation dose rate on top of the El Sherana pit (to the north) in 2008 was  $14 \mu\text{Gy}\cdot\text{hr}^{-1}$ , measured over a concrete pad that had supported a battery used to crush some of the high grade ore mined at the site. The next highest readings were obtained from an area without noticeable infrastructure but containing a number of rock and rubble piles (see Bollhöfer et al 2009 for details). Figure 6 compares pre- and post-remediation gamma dose rates measured at El Sherana. Gamma dose rates on top of the pit were substantially reduced after remediation. Only one reading in 2010, at  $2.7 \mu\text{Gy}\cdot\text{hr}^{-1}$ , was above the guideline value and was associated with a number of small fragments of mineralised material.



**Figure 6** Measured pre- and post remediation gamma dose rates at El Sherana mine overlaid on an aerial photograph of the area

The bottom of the pit was surveyed in 2008 prior to remediation, and some areas were found to have elevated gamma signatures. These areas consisted of two waste piles and four benches in the pit wall to the southeast of the pit. The bench on top of the pit wall exhibited gamma dose rates of approximately  $1 \mu\text{Gy}\cdot\text{hr}^{-1}$ . The remaining three benches, the bottom of the pit, and the two waste piles exhibited average gamma dose rates of about  $2 \mu\text{Gy}\cdot\text{hr}^{-1}$  or more. In particular and prior to remediation, there was a small area of mineralisation accessible from one of the benches that exhibited absorbed gamma dose rates of above  $7 \mu\text{Gy}\cdot\text{hr}^{-1}$ . As part of the remediation at El Sherana, the material from the two waste piles was shifted and pushed against the benches to the southeast of the pit, thereby covering the small area of mineralisation and reducing average gamma dose rates in the area.

Figure 6 shows that post-remediation gamma dose rates were lower after removal of the two waste piles south of the pit. However, dose rates were still generally higher in the pit and along the upper small access track compared with other areas, due to remnant mineralised material. The highest dose rates ( $3\text{--}4 \mu\text{Gy}\cdot\text{hr}^{-1}$ ) were measured immediately to the southeast of the pit, in an area that was not subject to remediation.



**Figure 7** Histogram and probability plot of the dose rates measured on top of the remediated El Sherana mine

Figure 7 shows frequency and probability plots of the dose rates measured on top of the remediated El Sherana mine. Assuming a log-normal distribution of the absorbed gamma dose rate measured on top of the El Sherana pit, approximately 95% of the locations investigated post remediation are characterised by levels below the  $1.25 \pm 0.25 \mu\text{Gy}\cdot\text{hr}^{-1}$  guideline value, compared with only 40% pre-remediation (Bollhöfer et al 2009b).

The average gamma dose rate on top of the pit has been reduced substantially and typical post remediation values are  $0.7\text{--}0.8 \mu\text{Gy}\cdot\text{hr}^{-1}$ . At the bottom of the pit and on access tracks not subjected to remediation, values have not changed and are typically around  $1.2\text{--}1.4 \mu\text{Gy}\cdot\text{hr}^{-1}$ .

## Summary

Table 1 provides a statistical summary of the pre- and post-remediation absorbed gamma dose rates measured at the Rockhole Residues site, and the remediated Palette and El Sherana mines.

It can be seen that remediation generally reduced the gamma dose rates at the remediated sites by about a factor of 2, to values well below the  $1.25 \pm 0.25 \mu\text{Gy}\cdot\text{hr}^{-1}$  threshold. Mean gamma dose rates within the El Sherana pit and access tracks, which were not subjected to remediation activities, are close to the guideline cleanup threshold value of  $1.25 \pm 0.25 \mu\text{Gy}\cdot\text{hr}^{-1}$ .

**Table 1** Statistics for post- and pre-(brackets) remediation absorbed gamma dose rates measured at the Rockhole Residues, Palette and El Sherana sites

Statistic	Rockhole Residues	Palette (top bench)	El Sherana (pit and access)	El Sherana top (N of pit)	El Sherana (S and W of pit)
Median	0.23 (0.35)	0.78 (1.66)	1.27 (1.87)	0.79 (1.47)	0.40
Mean	0.29 (0.57)	0.83 (1.88)	1.39 (1.85)	0.81 (2.62)	0.44
Geo mean	0.26 (0.40)	0.77 (1.66)	1.28 (1.47)	0.76 (1.57)	0.43
Min	0.13 (0.13)	0.21 (0.56)	0.70 (0.33)	0.44 (0.34)	0.32
Max	1.08 (3.89)	2.79 (4.34)	4.07 (7.28)	2.70 (13.63)	0.76
N	150 (258)	45 (20)	60 (60)	39 (90)	23

<sup>1</sup> Pre-remediation values for the Rockhole Residues site were calculated from Bollhöfer et al (2007), and those for Palette and El Sherana sites from Bollhöfer et al (2009b).

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