

CRIIRAD

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et d'Information Indépendantes
sur la Radioactivité

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CRIIRAD Preliminary Report No. 12-32b

Preliminary results of radiation monitoring

near uranium mines in Namibia

EJOLT Project (DRAFT version)

Context

As a part of the EJOLT¹ project, EARTHLIFE Namibia (Mrs Bertchen Kohrs) and CRIIRAD (Commission for Independent Research and Information about Radiation) have organised visits in areas located in the vicinity of uranium mines in Namibia, especially Rössing

CRIIRAD team (Christian Courbon and Bruno Chareyron) also conducted training activities and lectures about Radioprotection issues and the impact of uranium mining. The lectures took place in Windhoek and Swakopmund between September and October 2011.

In the course of an on site mission carried out between September 22th and October 2nd 2011, scientists from the CRIIRAD laboratory took radiation measurements in situ, and collected :

- 14 samples of top soil (code T in the charts). Results are plotted in tables T1 and T2 of Appendix 1.
- 13 samples of surface sediments of the Swakop, Gawib and Khan rivers (code S in the charts). Results are plotted in tables T3 and T4 of Appendix 2.
- 11 underground water samples in the alluvium of Swakop, and Khan rivers and tap water from Arandis city (code E in the charts). Results are plotted in Appendix 3.
- One sample of asparagus

Solid samples have been analysed at the CRIIRAD laboratory in France (measurements performed by HpGe gamma spectrometry) and water samples have been monitored for main chemicals by LDA 26 laboratory in France and for radium 226 and radon 222 at the CRIIRAD laboratory. The CRIIRAD laboratory accuracy in radiation monitoring is acknowledged by the French Nuclear Safety Authority.

Preliminary findings

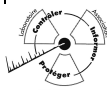
The collected data will be compared later with monitoring results gathered by the mining companies and discussed at various meetings being organised in Windhoek and Swakopmund between April 10th and 19th 2012.

In order to share the preliminary results with Earthlife in view of these various meetings with the mine management and local population some tables, charts and maps have been prepared by CRIIRAD and are enclosed in this document.

The interpretation of all the results will require additional work.

Some of the preliminary findings are summarised below.

¹ EJOLT : Environmental Justice Organizations Liability and Trade is an international project funded under FP7 program of the European Union, Mobilisation and Mutual Learning Actions.



1 / The dose rate measured by CRIIRAD on the **parking of Rössing mine** (sample 34 T, Map 10 page 22) is about 6 times above natural background value (0.9 $\mu\text{Sv/h}$ compared to 0.15 $\mu\text{Sv/h}$). The measurements are shown on a video (<http://youtu.be/sQvNEJu7qTU>)

This radiation is probably due to the use of radioactive tailings from Rössing mill as the analysis of top soil (sample 34 T) performed by CRIIRAD show a radium 226 / uranium 238 ratio of 2.5. Uranium 238 activity in the sample is 730 Bq/kg while radium 226 activity is 1 800 Bq/kg. This last value is 19 times above the natural concentrations measured in soil samples collected in Swakopmund area and near to the Moon Landscape.

2 / The management of **waste rock dumps** needs to be improved.

Some waste rocks are dumped on the banks of Khan river (at the intersection with Dome Gorge) without fencing and confinement. The radiological impact of this activity has to be studied in detail but preliminary measurements show various impacts on the environment.

- The finest fraction of the radioactive rocks is washed down by rain water and **contaminates the sediments** of Khan river as illustrated by sample 29 TS in which uranium 238 activity is 1 200 Bq/kg and radium 226 activity is 1 400 Bq/kg (see graphs on pages 20 and 21). These values are 10 times above those measured in sediments 31 S collected in Khan river upstream Rössing mine.
- The gamma and beta-gamma **dose rates** measured by CRIIRAD on contact with the waste rocks is well above background values (130 $\mu\text{Sv/h}$ of beta-gamma dose to the skin measured with an electronic dosimeter which is about 1 300 times above typical background values). The gamma irradiation from the waste rock dump is detected at distances exceeding 150 meters. CRIIRAD calculated that people spending only 30 minutes to 35 hours at a distance below 25 meters from the waste rock dump would receive an external irradiation dose above the trivial dose value of 10 microSieverts per year. This kind of impact has not been taken into consideration by NECSA, the Nuclear Energy Council of South Africa, that was contracted to evaluate the Radiological public hazard assessment for the Expansion of Rössing Uranium Mine (report dated 2011-05-23).
- Preliminary monitoring of **radon gas** activity in the ambient air near the waste rocks shows high readings (722 Bq/m³ when the Alphaguard radon monitor is located on the rocks. This value is 48 times above typical mean natural radon activity in the open air).

3 / The finest fraction of the radioactive **tailings** dumped on Rössing tailings dam is **blown away** by the wind and contaminates the surrounding environment as shown by the contamination of top soil plotted on the graphs of pages 25 and 26.

Radium 226 activities range between 960 Bq/kg and 7 400 Bq/kg in samples 1T, 20T, 23T and 24T collected up to 2 km away from the tailings dam fence. In all four samples the radium 226 / uranium 238 ratio is between 2.3 and 5.

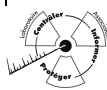
This shows that the material dispersed by the wind is not made of natural uranium bearing rocks but consists of tailings that are radioactive waste from the mills where uranium 238 has been extracted from the ore. In this case the uranium 238 residual activity in the waste is lower than the radium 226 activity.

4 / The high **uranium concentration in underground water** collected downstream Rössing uranium mine in the Khan river and Swakop river alluvium raises the question of the origin of this uranium.

In Khan river upstream Rössing Mine and in Swakop river upstream the confluence with the Gawib river (Langer Heinrich mine potential influence), the uranium 238 concentrations are quite low (0.2 $\mu\text{g/l}$ and 7.8 $\mu\text{g/l}$ respectively).

In the Khan river alluvium immediately downstream Dome Gorge waste rocks dump the uranium² concentration is 430 $\mu\text{g/l}$. This may be due to the fact that a fraction of the uranium

² The WHO guideline for drinking water is 15 $\mu\text{g/l}$ (recently changed to 30 $\mu\text{g/l}$ as a provisory value).

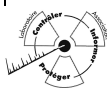


contained in the waste rocks is dissolved by rain water and eventually reaches the groundwater.

The impact of the leakages occurring below the tailings dam also has to be studied in detail. The uranium concentration in the underground water samples collected by CRIIRAD downstream the tailings dam is high (554 to 3 174 µg/l). Rössing has a network of "dewatering wells" and trenches designed to allow pumping back these contaminated waters to the tailings dam. But the question of the efficiency of this system and its durability in the future has to be studied.

All these points will probably be discussed with the mining companies, competent authorities, local population and concerned NGO's.

Written by Bruno Chareyron, nuclear physics engineer, Director of the CRIIRAD laboratory.



ANNEX 1: Analysis of top soil samples collected by CRIIRAD in the course of the September-October 2011 mission to Namibia

Table T 1 / Top soil analysis / uranium 238 decay chain

				Gamma radiation flux (c/s DG5)							
Code	Location	Time of sampling	Type	Contact	1 m above ground	Uranium 238 (Bq/kg)	Thorium 230 (Bq/kg)	Radium 226 (Bq/kg)	Ra 226 / U238	Lead 210 (Bq/kg)	Lead 210 / Ra 226
NA 37 T	Swakop river camel farm, 44 km from Rossing mine	October 1st 2011	Soil surface : crust dry clay (< 5 mm)	190	180	93 ± 35	< 160	72 ± 12	0,8	125 ± 40	1,74
NA 5 T1	Etango prospecting area	Sept 24th 2011	Soil surface crust (1.5 mm)	200	180	97 ± 33	< 140	92 ± 14	0,9	233 ± 48	2,53
NA 5 T2	Etango prospecting area	Sept 24th 2011	Fine clay under soil surface crust (3 cm)	200 (after removal of 1.5 mm crust)	180	103 ± 30	< 70	83 ± 12	0,8	72 ± 19	0,87
NA 14 T	Arandis, north of town	Sept 26th 2011	Soil surface : crust dry clay (< 2 mm)	380	350	61 ± 24	< 230	89 ± 13	1,5	243 ± 45	2,73
NA 13 T	Arandis, catholic church yard	Sept 26th 2011	Soil surface : sand and gravel (< 1 cm)	470	380	92 ± 35	< 180	75 ± 12	0,8	70 ± 26	0,93
NA 12 T	Arandis, south of railway	Sept 25th 2011	Soil surface : crust dry clay (3 mm)	1 000	560	119 ± 38	< 110	102 ± 16	0,9	188 ± 38	1,84
NA 32 T	9 km N-E of tailings dam , near B2 road	Sept 30th 2011	Soil surface : crust dry clay (< 2 mm)	240	260 (influence of nearby rocks)	130 ± 50	< 250	133 ± 22	1,0	360 ± 70	2,71
NA 33 T	3 km N-E of tailings dam , near Rossing private road	Sept 30th 2011	Soil surface : dry soil near bush (< 2 mm)	800	600	200 ± 60	< 230	216 ± 31	1,1	140 ± 60	0,65
NA 1 T	Western fence of Tailings dam	Sept 23rd 2011	Soil surface : crust dry clay (5 mm)	1 600	1 000	1 560 ± 270	8 600 ± 2 200	7 400 ± 800	4,7	7 400 ± 800	1,00
NA 20 T	2 km S-W West of tailings dam	Sept 29th 2011	Soil surface : crust dry clay (< 2 mm)	400	260	410 ± 70	970 ± 370	960 ± 110	2,3	1 070 ± 140	1,11
NA 23 T	1.7 km S-W of tailings dam (Rossing) / near solar pannel	Sept 29th 2011	Soil surface : dry sand and clay (< 5 mm), near bushes	800	480	580 ± 110	3 600 ± 900	2 880 ± 300	5,0	2 740 ± 320	0,95
NA 24 T	700 m S-W of tailings dam (Rossing) / solar pannel area	Sept 29th 2011	Soil surface : dry sand (< 5 mm), near bushes	1 100	600	590 ± 120	3 300 ± 1 000	2 460 ± 270	4,2	2 380 ± 290	0,97
NA 34 T	Rossing parking (main entrance)	Sept 30th 2011	Soil surface (< 2 mm)	1 700	(1700 is measured a few meters away)	730 ± 130	1 700 ± 700	1 800 ± 200	2,5	1 500 ± 190	0,83
NA 22 T	3 km S-W from Open Pit / Panner Gorge (Rossing) / Sand pit	Sept 29th 2011	Soil surface : crust dry clay (< 5 mm)	1 600	1 300	3 620 ± 490	3 100 ± 1 100	3 070 ± 340	0,8	2 930 ± 380	0,95

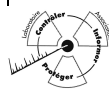
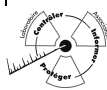


Table T 2 / Top soil analysis / other radionuclides

Code	Location	Time of sampling	Type	U 235(Bq/kg)	Th 227 (Bq/kg)	Lead 212 (Bq/kg) (Th 232 decay chain)	Potassium 40 (Bq/kg)	Be7 (Bq/kg)	Cs 137 (Bq/kg)
NA 37 T	Swakop river camel farm, 44 km from Rossing mine	October 1st 2011	Soil surface : crust dry clay (< 5 mm)	< 13	< 10	101 ± 14	820 ± 140	< 8	6 ± 2
NA 5 T1	Etango prospecting area	Sept 24th 2011	Soil surface crust (1.5 mm)	< 11	< 9	76 ± 11	970 ± 150	< 31	8 ± 2
NA 5 T2	Etango prospecting area	Sept 24th 2011	Fine clay under soil surface crust (3 cm)	< 9	< 5	89 ± 11	800 ± 110	< 4	< 1
NA 14 T	Arandis, north of town	Sept 26th 2011	Soil surface : crust dry clay (< 2 mm)	< 10	< 8	157 ± 19	960 ± 140	< 7	6 ± 2
NA 13 T	Arandis, catholic church yard	Sept 26th 2011	Soil surface : sand and gravel (< 1 cm)	< 13	< 10	397 ± 46	1 060 ± 150	< 8	< 1
NA 12 T	Arandis, south of railway	Sept 25th 2011	Soil surface : crust dry clay (3 mm)	< 12	< 8	143 ± 19	830 ± 130	< 6	< 2
NA 32 T	9 km N-E of tailings dam , near B2 road	Sept 30th 2011	Soil surface : crust dry clay (< 2 mm)	< 20	< 16	61 ± 11	920 ± 170	40 ± 18	< 7
NA 33 T	3 km N-E of tailings dam , near Rossing private road	Sept 30th 2011	Soil surface : dry soil near bush (< 2 mm)	< 19	< 12	1 130 ± 130	920 ± 150	< 10	< 2
NA 1 T	Western fence of Tailings dam	Sept 23rd 2011	Soil surface : crust dry clay (5 mm)	< 150	380 ± 90	387 ± 49	1 350 ± 230	< 21	< 3
NA 20 T	2 km S-W West of tailings dam	Sept 29th 2011	Soil surface : crust dry clay (< 2 mm)	< 47	80 ± 23	116 ± 15	890 ± 140	36 ± 14	< 2
NA 23 T	1.7 km S-W of tailings dam (Rossing) / near solar pannel	Sept 29th 2011	Soil surface : dry sand and clay (< 5 mm), near bushes	< 60	190 ± 43	212 ± 26	1 080 ± 160	< 11	< 2
NA 24 T	700 m S-W of tailings dam (Rossing) / solar pannel area	Sept 29th 2011	Soil surface : dry sand (< 5 mm), near bushes	< 28	124 ± 41	187 ± 24	1 380 ± 200	< 15	< 2
NA 34 T	Rossing parking (main entrance)	Sept 30th 2011	Soil surface (< 2 mm)	< 48	106 ± 29	187 ± 24	1 120 ± 160	< 12	< 2
NA 22 T	3 km S-W from Open Pit / Panner Gorge (Rossing) / Sand pit	Sept 29th 2011	Soil surface : crust dry clay (< 5 mm)	< 220	170 ± 60	247 ± 34	680 ± 140	< 17	< 3



ANNEX 2: Analysis of sediments collected by CRIIRAD in the course of the September-October 2011 mission to Namibia

Table T 3 / Sediments / uranium 238 decay chain

				Gamma radiation flux (c/s DG5)							
Code	Location	Time of sampling	Type	Contact	1 m above ground	Uranium 238 (Bq/kg)	Thorium 230 (Bq/kg)	Radium 226 (Bq/kg)	Ra 226 / U238	Lead 210 (Bq/kg)	Lead 210 / Ra 226
Sediments (Khan River)											
NA 31 S	Khan River / Upstream Rossing, downstream Valencia project	Sept 30th 2011	Surface sediment (dry clay) / (< 5 mm) / river bed	280	220	< 120	< 390	130 ± 20		213 ± 45	1,64
NA 29 T S	Khan River / Dome Gorge, Waste Rock dump (Rossing)	Sept 30th 2011	Surface sediment (dry clay, blue color) / (< 5 mm) / washing of waste rocks	800	650	1 200 ± 190	< 1 900	1 400 ± 160	1,2	1 410 ± 180	1,01
NA 25 S	Khan River, downstream Rossing (Panner Gorge)	Sept 29th 2011	Surface sediment (dry clay) / (< 2 mm) / on top of ancient deposit	340	260	360 ± 70	< 700	414 ± 50	1,2	440 ± 70	1,06
NA 4 S	Khan River, downstream Rossing (Panner Gorge)	Sept 23rd 2011	Surface sediment (dry clay) / including black heavy minerals (2 mm)	400	270	420 ± 90	< 900	780 ± 90	1,9	260 ± 50	0,33
NA 19 S	Khan river entering Swakop river	Sept 28th 2011	Surface sediment (dry clay) / (5 mm) / middle of river bed	270	240	133 ± 41	< 100	147 ± 21	1,1	380 ± 60	2,59
Sediments (Swakop River)											
NA 11 S	Swakop river upstream Gawib river (LHU)	Sept 24th 2011	Surface sediment (wet clay) / (1-2 mm) / on top of ancient deposit	160	140	< 70	< 150	52 ± 10		58 ± 26	1,12
NA 9 S	Gawib river downstream LHU	Sept 24th 2011	Crust made of clay (a few cm) attached to rocks	350 (near granite rocks 270 c/s)	280	510 ± 100	< 1 600	620 ± 70	1,2	690 ± 110	1,11
NA 8 S	Swakop river downstream Gawib river (LHU)	Sept 24th 2011	Surface sediment (dry clay) / (< 1. mm) / on top of ancient deposit	180	160	165 ± 42	< 80	62 ± 11	0,4	71 ± 22	1,15
NA 6 S	Swakop river downstream Gawib river (LHU)	Sept 24th 2011	Surface sediment (dry clay) / (1.5 mm)	250 (influence of nearby rock)	270 (influence of nearby rocks)	106 ± 36	< 100	66 ± 12	0,6	87 ± 25	1,32
NA 27 S	Swakop river upstream confluence with Khan River (farm)	Sept 29th 2011	Surface sediment (dry clay) / (< 2 mm) / on top of ancient deposit	220	200	146 ± 40	< 600	123 ± 17	0,8	135 ± 34	1,10
NA 18 S	Swakop river downstream Khan river (downstream Palmerhorst)	Sept 28th 2011	Surface sediment (dry clay) / (1mm) / on top of ancient deposit	260 (influence of rocks 800 c/s)	260 (influence of rocks)	141 ± 44	< 420	93 ± 15	0,7	183 ± 44	1,97
NA 16 S	Swakop river upstream camel farm (sand pits)	Sept 28th 2011	Surface sediment (dry clay) / (7 cm) / on top of ancient deposit	200	130-180	111 ± 39	< 90	95 ± 15	0,9	199 ± 39	2,09
NA 15 S	Swakop river mouth at Swakopmund	Sept 28th 2011	Surface sediment (dry clay) / (< 2 mm)	140	130	< 100	< 90	63 ± 11		66 ± 22	1,05

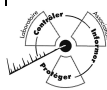
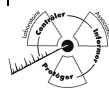


Table T 4 / Sediments / other radionuclides

Code	Location	Time of sampling	Type	U 235(Bq/kg)	Th 227 (Bq/kg)	Lead 212 (Bq/kg) (Th 232 decay chain)	Potassium 40 (Bq/kg)	Be7 (Bq/kg)	Cs 137 (Bq/kg)
Sediments (Khan River)									
NA 31 S	Khan River / Upstream Rossing, downstream Valencia project	Sept 30th 2011	Surface sediment (dry clay) / (< 5 mm) / river bed	< 13	< 8	133 ± 25	920 ± 150	< 7	< 8
NA 29 T S	Khan River / Dome Gorge, Waste Rock dump (Rossing)	Sept 30th 2011	Surface sediment (dry clay, blue color) / (< 5 mm) / washing of waste rocks	< 100	73 ± 27	159 ± 21	1 010 ± 160	< 13	< 2
NA 25 S	Khan River, downstream Rossing (Panner Gorge)	Sept 29th 2011	Surface sediment (dry clay) / (< 2 mm) / on top of ancient deposit	< 70	< 42	149 ± 19	1 070 ± 150	< 6	6 ± 2
NA 4 S	Khan River, downstream Rossing (Panner Gorge)	Sept 23rd 2011	Surface sediment (dry clay) / including black heavy minerals (2 mm)	< 100	< 22	2 480 ± 260	460 ± 80	< 10	< 1
NA 19 S	Khan river entering Swakop river	Sept 28th 2011	Surface sediment (dry clay) / (5 mm) / middle of river bed	< 13	< 8	173 ± 22	1 000 ± 150	< 6	11 ± 3
Sediments (Swakop River)									
NA 11 S	Swakop river upstream Gawib river (LHU)	Sept 24th 2011	Surface sediment (wet clay) / (1-2 mm) / on top of ancient deposit	< 11	< 9	72 ± 10	640 ± 110	< 7	< 1
NA 9 S	Gawib river downstream LHU	Sept 24th 2011	Crust made of clay (a few cm) attached to rocks	< 30	< 60	180 ± 24	1 000 ± 170	< 12	< 8
NA 8 S	Swakop river downstream Gawib river (LHU)	Sept 24th 2011	Surface sediment (dry clay) / (< 1. mm) / on top of ancient deposit	< 11	< 6	70 ± 10	600 ± 100	< 5	< 1
NA 6 S	Swakop river downstream Gawib river (LHU)	Sept 24th 2011	Surface sediment (dry clay) / (1.5 mm)	< 12	< 6	100 ± 14	780 ± 130	< 6	< 1
NA 27 S	Swakop river upstream confluence with Khan River (farm)	Sept 29th 2011	Surface sediment (dry clay) / (< 2 mm) / on top of ancient deposit	< 11	< 8	169 ± 21	950 ± 150	< 7	5 ± 2
NA 18 S	Swakop river downstream Khan river (downstream Palmerhorst)	Sept 28th 2011	Surface sediment (dry clay) / (1mm) / on top of ancient deposit	< 13	< 10	138 ± 18	1 080 ± 170	< 8	10 ± 3
NA 16 S	Swakop river upstream camel farm (sand pits)	Sept 28th 2011	Surface sediment (dry clay) / (7 cm) / on top of ancient deposit	< 12	< 7	107 ± 14	920 ± 140	< 5	12 ± 3
NA 15 S	Swakop river mouth at Swakopmund	Sept 28th 2011	Surface sediment (dry clay) / (< 2 mm)	< 11	< 7	91 ± 18	750 ± 120	< 6	< 3



ANNEX 3: Analysis of water samples collected by CRIIRAD in the course of the September-October 2011 mission to Namibia

A1 / Description of the samples and results of monitoring of radioactive substances

1 / Sample description

Note : all samples have been collected by CRIIRAD laboratory technician (1 liter plastic container with special cap)

Sample Code (on site)	NA-2-E	NA-3-E	NA-21-E	NA-10-E	NA-7-E
Lab Code	051011A1	051011A2	051011A6	051011A4	051011A3
Location	Downstream Rossing tailings dam	Downstream Rossing tailings dam	Downstream Rossing tailings dam	Swakop river (upstream Gawib river and Langer Heinrich mine	Swakop river (first borehole located downstream Gawib river)
Water type	underground water - borehole DW 14 (Dewatering)	underground water - borehole PA 6	Underground water / Trench E (Panner Gorge)	underground water / Extraction borehole	underground water / monitoring borehole N°1182
GPS coordinates	S22 27.243 E15 00.852	S22 28.220 E15 00.383	S22 30.846 E15 01.848	S22 43.786 E15 22.596	S22 43.919 E15 14.726
Sampling time	23/9/11 13:50	23/9/11 14:50	29/9/11 12:15	24/9/11 17:45	24/9/11 16:15

pH and conductivity (laboratory measurements) *

pH	7,00	7,90	7,60	8,05	7,80
Water T°C when pH was measured	21,9	20,0	20,0	21,9	21,9
Conductivity at 25 °C (µS/cm)	14 680	19 620	23 690	3 1 25	1 998
Conductivity at 20 °C (µS/cm)	13 154	17 581	21 228	2 8 00	1 790

Uranium *

Uranium 238 (µg/l)	3 164	789,0	554,1	7,8	20,0
Calc. U238 activity (Bq/l)	40	9,9	6,9	0,10	0,25
Uranium 235 (% uranium 238)	0,72	0,69	0,69	0,71	0,70

Radon 222 **

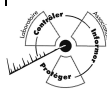
Radon 222 (Bq/l)	82 ± 34	< 50	140 ± 32	< 19 (a)	210 ± 60
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Gamma emitting artificial radionuclides ***

Gamma emitting artificial nuclides (Bq/l)	< DL	< DL	< DL	< DL	< DL
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Gamma emitting natural radionuclides ****

Th 234 (Bq/l)	18,5 ± 3,5	6,4 ± 2,1	6,6 ± 3,7	< 3,2	< 4,3
Ra 226 (Bq/l)	< 0,44	< 0,40	< 0,7	< 0,35	< 0,31
Pb 210 (Bq/l)	< 1,4	< 1,7	< 1,5	< 1,5	< 1,4
U 235 (Bq/l)	2,8 ± 1,1	< 0,7	< 1,6	< 1,4	< 1,3
Pb 212 (Bq/l)	<0,17	< 0,17	< 0,16	< 0,17	< 0,23
K40 (Bq/l)	<5	< 4,2	< 4,3	< 2,6	< 2,3



B1 / Results of the chemical analysis (anions and cations)

Note : all samples have been collected by CRIIRAD laboratory technician (1 liter plastic container with special cap)

Sample Code (on site)	NA-2-E	NA-3-E	NA-21-E	NA-10-E	NA-7-E
Lab Code	051011A1	051011A2	051011A6	051011A4	051011A3
Location	Downstream Rossing tailings dam	Downstream Rossing tailings dam	Downstream Rossing tailings dam	Swakop river (upstream Gawib river and Langer Heinrich mine	Swakop river (first borehole located downstream Gawib river)
Water type	underground water - borehole DW 14 (Dewatering)	underground water - borehole PA 6	Underground water / Trench E (Panner Gorge)	underground water / Extraction borehole	underground water / monitoring borehole N°1182

Anions and cations (semi-quantitative screening by ion chromatography) *

	NA-2-E	NA-3-E	NA-21-E	NA-10-E	NA-7-E	WHO guideline for drinking water
Ammonium mg/l	26,5	ND	ND	ND	ND	
Bromates mg/l	ND	ND	ND	ND	ND	25 µg/l
Bromides mg/l	2,6	ND	ND	ND	ND	
Calcium mg/l	587	833	1 432	213	130	
Chlorate mg/l	ND	ND	ND	ND	ND	
Chlorite mg/l	ND	ND	ND	ND	ND	200 µg/l
Chloride (chlorures) mg/l	2 287	4 771	7 713	654	387	250 mg/l
Fluoride (fluorures) mg/l	10	6,3	ND	ND	0,072	1,5 mg/l
Magnesium mg/l	717	198	508	61	28	
Nitrates mg/l	158	331	157	9,2	4,9	50 mg/l
Nitrites mg/l	15	0,08	0,02	0,05	ND	200 µg/l
Orthophosphates mg/l	ND	ND	ND	0,071	0,136	
Potassium mg/l	67	81	112	23	24	
Sodium mg/l	2 526	4 261	4 369	389	248	200 mg/l
Sulfates mg/l	6 023	4 236	2 994	393	165	250 mg/l

* Analysis conducted by LDA 26, commissioned by CRIIRAD.

< DL = below detection limit / ND : Not Detected

WHO Guidelines for drinking water are from "Directives de qualité pour l'eau de boisson , OMS 1994" and Guidelines for Drinking-water Quality, WHO, 2008".

Figures in red color are exceeding WHO guidelines for drinking water

C1 / Results of the chemical analysis (metals)

1 / Sample description

Note : all samples have been collected by CRIIRAD laboratory technician (1 liter plastic container with special cap)

Sample Code (on site)	NA-2-E	NA-3-E	NA-21-E	NA-10-E	NA-7-E
Lab Code	051011A1	051011A2	051011A6	051011A4	051011A3
Location	Downstream Rossing tailings dam	Downstream Rossing tailings dam	Downstream Rossing tailings dam	Swakop river (upstream Gawib river and Langer Heinrich mine	Swakop river (first borehole located downstream Gawib river)
Water type	underground water - borehole DW 14 (Dewatering)	underground water - borehole PA 6	Underground water / Trench E (Panner Gorge)	underground water / Extraction borehole	underground water / monitoring borehole N°41182

Métaux / semi-quantitative evaluation by ICP * / results in µg/l

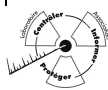
	Ag	Al	As	B	Ba	Be	Cd	Co	Cr	Cu	Fe	Li	Mn	Mo	Ni	Pb	Sb	Se	Sn	Sr	Te	Ti	Tl	U	V	Zn	WHO guideline for drinking water
	0,1	35,3	0,6	2 560	7,4	1,9	0,5	16,2	0,4	5,0	4,8	1 150	29 700	16,5	38,2	ND	ND	12,4	0,1	8 190	0,2	8,5	0,1	3 160	9,6	30,9	-
	0,1	90,7	0,6	3 840	22,9	ND	0,1	0,4	1,0	4,8	3 220	275	32,1	24,6	1,2	0,3	ND	14,7	0,1	15 000	0,4	15,1	ND	789	40,4	16,2	200 µg/l
	0,1	1,9	1,8	2 500	26,8	ND	0,1	0,1	0,6	5,6	17,5	249	0,9	57,2	0,7	ND	0,1	36,2	ND	21 100	0,8	10,7	ND	544	19,9	8,8	10 µg/l
	ND	4,6	1,2	126	59,3	ND	0,1	0,1	0,3	1,7	4,4	8,0	98,5	6,4	1,0	0,1	ND	0,7	ND	1 490	ND	5,5	ND	7,8	8,3	148	300 µg/l
	ND	2,1	1,9	141	27,6	ND	ND	0,1	0,1	2,7	1,3	6,8	25,1	4,5	0,7	ND	0,1	2,1	ND	873	ND	6,1	ND	20,0	15,6	3,5	15 then 30 µg/l
				300 µg/l	700 µg/l		3 µg/l		50 µg/l	2 000 µg/l	300 µg/l		500 µg/l	70 µg/l	20 µg/l	10 µg/l	5 µg/l	10 µg/l	-								3 000 µg/l

* Analysis conducted by LDA 26, commissioned by CRIIRAD (semi-quantitative screening by ICP-MS : inductively coupled plasma – mass spectrometry)

< DL = below detection limit / ND : Not Detected

WHO Guidelines for drinking water are from "Directives de qualité pour l'eau de boisson , OMS 1994" and Guidelines for Drinking-water Quality, WHO, 2008".

Figures in red color are exceeding WHO guidelines for drinking water



A2 / Description of the samples and results of monitoring of radioactive substances

1 / Sample description

Note : all samples have been collected by CRIIRAD laboratory technician (1 liter plastic container with special cap)

Sample Code (on site)	NA-30-E	NA-28-E	NA-26-E	NA-17-E	NA-36-E	NA-39-E
Lab Code	051011A9	051011A8	051011A7	051011A5	051011A10	051011A11
Location	Khan river (upstream Rossing and downstream bridge to Valencia)	Khan river (downstream Rossing Dome Gorge waste rock dump)	Khan river (downstream Rossing - Panner Gorge)	Palmerhorst (near Swakop river, downstream confluence with Khan river)	near Swakop river (camel farm)	Arandis city
Water type	underground water / borehole DBH2	underground water / borehole K	underground water / borehole 16-A	underground water / Private well / (water sampled upstream water purification system)	Private well (no more used)	Tap Water inside a private house
GPS coordinates	S22 25.728 E15 07.145	S22 29.289 E15 04.732	S22 31.701 E15 01.764	S22 41.604 E14 53.372	S22 38.527 E14 38.304	S22 25.212 E14 58.341
Sampling time	30/9/11 16:20	30/9/11 12:00	29/9/11 16:15	28/9/11 16:30	1/10/11 12:10	2/10/11 11:20

pH and conductivity (laboratory measurements) *

pH	8,35	7,70	7,75	7,40	8,10	8,10
Water T°C when pH was measured	21,7	20,0	21,7	21,8	21,6	21,6
Conductivity at 25 °C (µS/cm)	8 330	7 810	3 358	9 380	1 7 470	1 789
Conductivity at 20 °C (µS/cm)	7 464	6 998	3 009	8 405	1 5 654	1 603

Uranium *

Uranium 238 (µg/l)	0,2	430,5	45,6	148,4	404,0	15,6
Calc. U238 activity (Bq/l)	0,00	5,38	0,57	1,86	5,1	0,20
Uranium 235 (% uranium 238)	ND	0,70	0,69	0,70	0,68	0,69

Radon 222 **

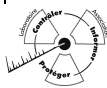
Radon 222 (Bq/l)	< 4	37 ± 14	< 5	< 24	< 5	< 3
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Gamma emitting artificial radionuclides ***

Gamma emitting artificial nuclides (Bq/l)	< DL	< DL	< DL	< DL	< DL	< DL
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Gamma emitting natural radionuclides ****

Th 234 (Bq/l)	< 1,2	6,0 ± 3,7	< 1,4	< 1,9	4,8 ± 3,5	< 4,1
Ra 226 (Bq/l)	< 0,39	< 0,30	< 0,33	< 0,33	< 0,31	< 0,29
Pb 210 (Bq/l)	< 1,5	< 1,6	< 1,7	< 1,7	< 1,5	< 1,4
U 235 (Bq/l)	< 0,6	< 3,2	< 0,8	< 0,8	< 1,3	< 2,5
Pb 212 (Bq/l)	< 0,16	< 0,16	< 0,12	< 0,17	< 0,16	< 0,15
K40 (Bq/l)	< 4,3	< 2,4	< 4,4	< 4,4	< 3,6	< 2,3



B2 / Results of the chemical analysis (anions and cations)

1 / Sample description

Note : all samples have been collected by CRIIRAD laboratory technician (1 liter plastic container with special cap)

Sample Code (on site)	NA-30-E	NA-28-E	NA-26-E	NA-17-E	NA-36-E	NA-39-E
Lab Code	051011A9	051011A8	051011A7	051011A5	051011A10	051011A11
Location	Khan river (upstream Rossing and downstream bridge to Valencia)	Khan river (downstream Rossing Dome Gorge waste rock dump)	Khan river (downstream Rossing - Panner Gorge)	Palmerhorst (near Swakop river, downstream confluence with Khan river)	near Swakop river (camel farm)	Arandis city
Water type	underground water / borehole DBH2	underground water / borehole K	underground water / borehole 16-A	underground water / Private well / (water sampled upstream water purification system)	Private well (no more used)	Tap Water inside a private house

Anions and cations (semi-quantitative screening by ion chromatography) *

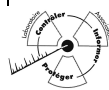
							WHO guideline for drinking water
Ammonium mg/l	2,8	ND	ND	ND	ND	ND	
Bromates mg/l	ND	ND	ND	ND	ND	ND	25 µg/l
Bromides mg/l	7,5	2,4	1,7	ND	ND	ND	
Calcium mg/l	474	635	229	589	1 211	98	
Chlorate mg/l	ND	ND	ND	ND	ND	ND	
Chlorite mg/l	ND	ND	ND	ND	ND	ND	200 µg/l
Chloride (chlorures) mg/l	2 963	1 882	805	2 668	5 627	364	250 mg/l
Fluoride (fluorures) mg/l	ND	2,4	1,0	1,4	ND	0,53	1,5 mg/l
Magnesium mg/l	234	142	67	208	285	27	
Nitrates mg/l	ND	98	ND	59	12	16	50 mg/l
Nitrites mg/l	0,02	0,02	ND	0,05	0,06	ND	200 µg/l
Orthophosphates mg/l	ND	ND	ND	ND	0,9	ND	
Potassium mg/l	37	45	21	43	100	11	
Sodium mg/l	1 073	984	375	1 453	3 044	235	200 mg/l
Sulfates mg/l	ND	1 302	336	998	1 755	100	250 mg/l

* Analysis conducted by LDA 26, commissioned by CRIIRAD.

< DL = below detection limit / ND : Not Detected

WHO Guidelines for drinking water are from "Directives de qualité pour l'eau de boisson , OMS 1994" and Guidelines for Drinking-water Quality, WHO, 2008".

Figures in red color are exceeding WHO guidelines for drinking water



C2 / Results of the chemical analysis (metals)

1 / Sample description

Note : all samples have been collected by CRIIRAD laboratory technician (1 liter plastic container with special cap)

Sample Code (on site)	NA-30-E	NA-28-E	NA-26-E	NA-17-E	NA-36-E	NA-39-E
Lab Code	051011A9	051011A8	051011A7	051011A5	051011A10	051011A11
Location	Khan river (upstream Rossing and downstream bridge to Valencia)	Khan river (downstream Rossing Dome Gorge waste rock dump)	Khan river (downstream Rossing - Panner Gorge)	Palmerhorst (near Swakop river, downstream confluence with Khan river)	near Swakop river (camel farm)	Arandis city
Water type	underground water / borehole DBH2	underground water / borehole K	underground water / borehole 16-A	underground water / Private well / (water sampled upstream water purification system)	Private well (no more used)	Tap Water inside a private house

Métaux / semi-quantitative evaluation by ICP * / results in µg/l

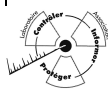
	NA-30-E	NA-28-E	NA-26-E	NA-17-E	NA-36-E	NA-39-E	WHO guideline for drinking water
Ag	ND	ND	ND	ND	ND	ND	-
Al	6,9	6,4	5,0	1,6	8,5	3,8	200 µg/l
As	0,1	0,9	0,1	0,8	3,4	5,1	10 µg/l
B	46,3	733	258	734	514	281	300 µg/l
Ba	239	32,2	75,6	30,3	40,3	79,7	700 µg/l
Be	ND	ND	ND	ND	ND	ND	-
Cd	ND	0,1	0,6	0,1	0,3	ND	3 µg/l
Co	ND	0,1	0,6	1,2	0,6	ND	-
Cr	0,1	1,0	ND	0,4	0,9	1,4	50 µg/l
Cu	2,5	4,1	2,6	2,2	9,3	3,2	2 000 µg/l
Fe	362	20,1	42,3	33,4	20,4	9,6	300 µg/l
Li	104	211	57,8	123	36,3	44,7	-
Mn	473	2,2	192	679	12,0	0,3	500 µg/l
Mo	0,5	42,9	4,7	10,5	18,2	3,4	70 µg/l
Ni	0,4	0,6	0,9	0,9	2,2	0,1	20 µg/l
Pb	0,1	0,1	1,0	ND	0,3	0,1	10 µg/l
Sb	0,1	0,1	0,1	ND	0,3	0,1	5 µg/l
Se	0,1	13,1	0,4	9,3	37,4	1,5	10 µg/l
Sn	ND	ND	ND	ND	ND	ND	-
Sr	5 740	5 050	1 930	5 790	9 780	1 360	-
Te	0,3	0,1	0,1	0,2	0,4	ND	-
Ti	2,8	8,7	3,9	7,8	11,4	6,4	-
Tl	ND	ND	ND	ND	0,1	ND	-
U	0,2	431	45,6	148	404	16	15 then 30 µg/l
V	0,3	10,5	0,4	10,2	12,3	14,4	-
Zn	4,1	29,1	2 900	0,9	24,0	29,5	3 000 µg/l

* Analysis conducted by LDA 26, commissioned by CRIIRAD (semi-quantitative screening by ICP-MS : inductively coupled plasma – mass spectrometry)

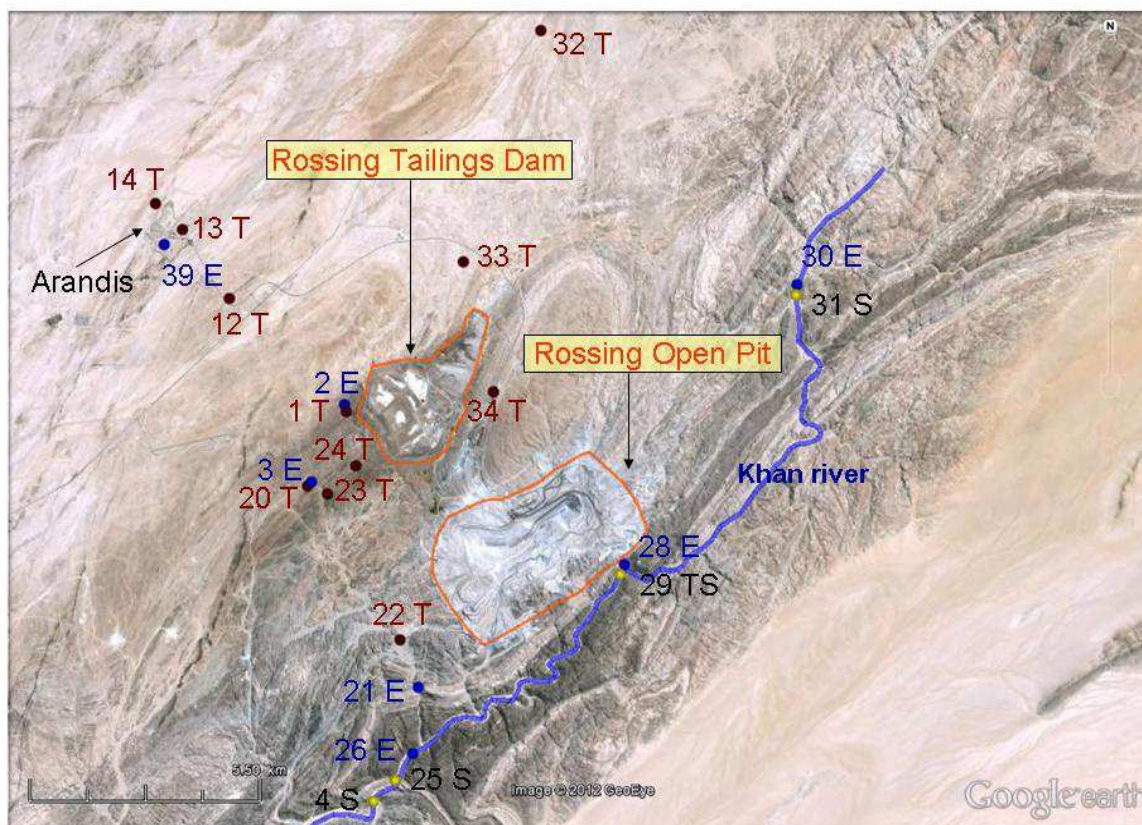
< DL = below detection limit / ND : Not Detected

WHO Guidelines for drinking water are from "Directives de qualité pour l'eau de boisson , OMS 1994" and Guidelines for Drinking-water Quality, WHO, 2008".

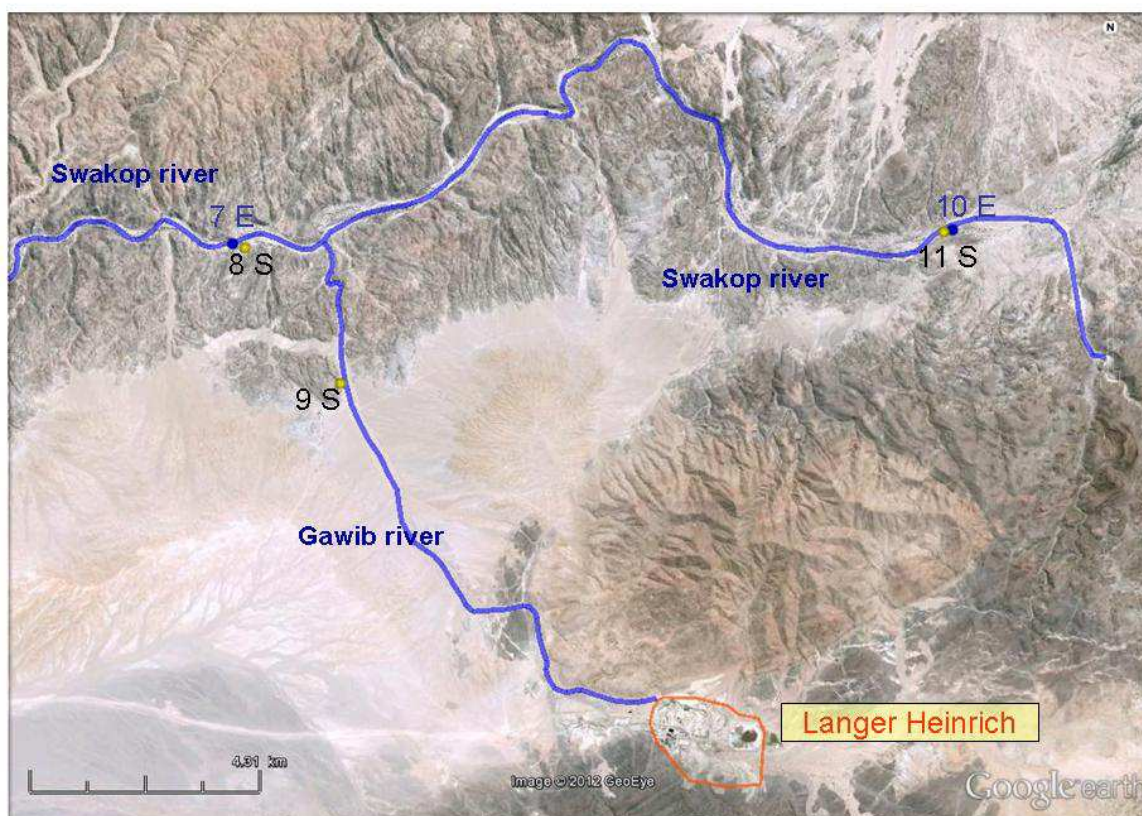
Figures in red color are exceeding WHO guidelines for drinking water



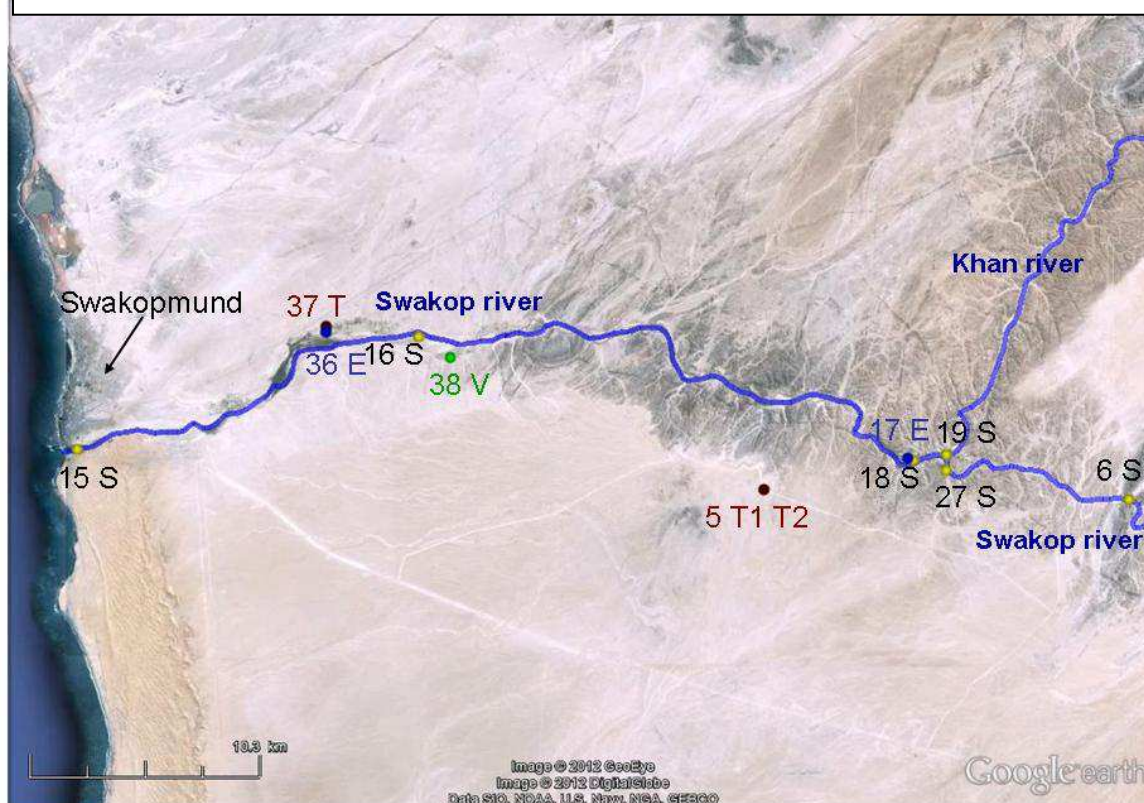
Map 1 / location of samples near Rössing Mine



Map 2 / Location of samples near Langer Heinrich mine



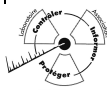
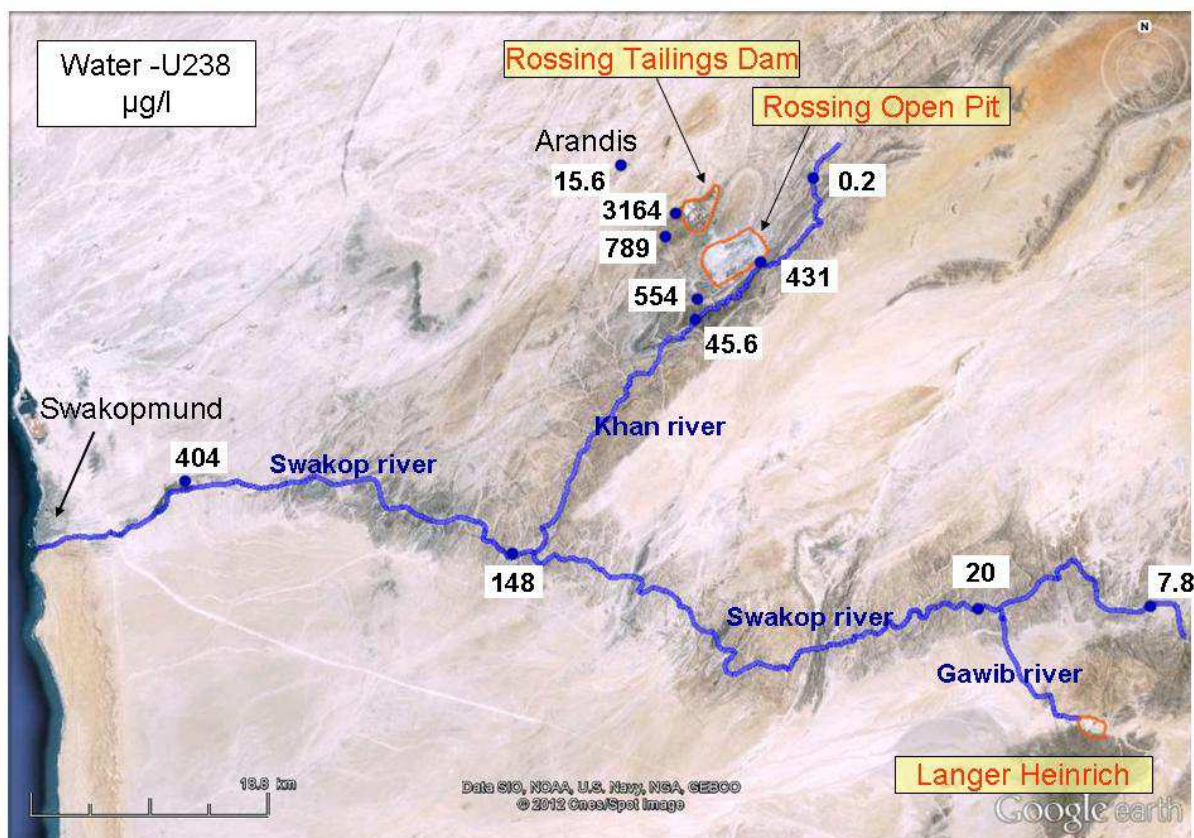
Map 3 / Samples at the confluence of Khan and Swakop rivers and near Swakopmund



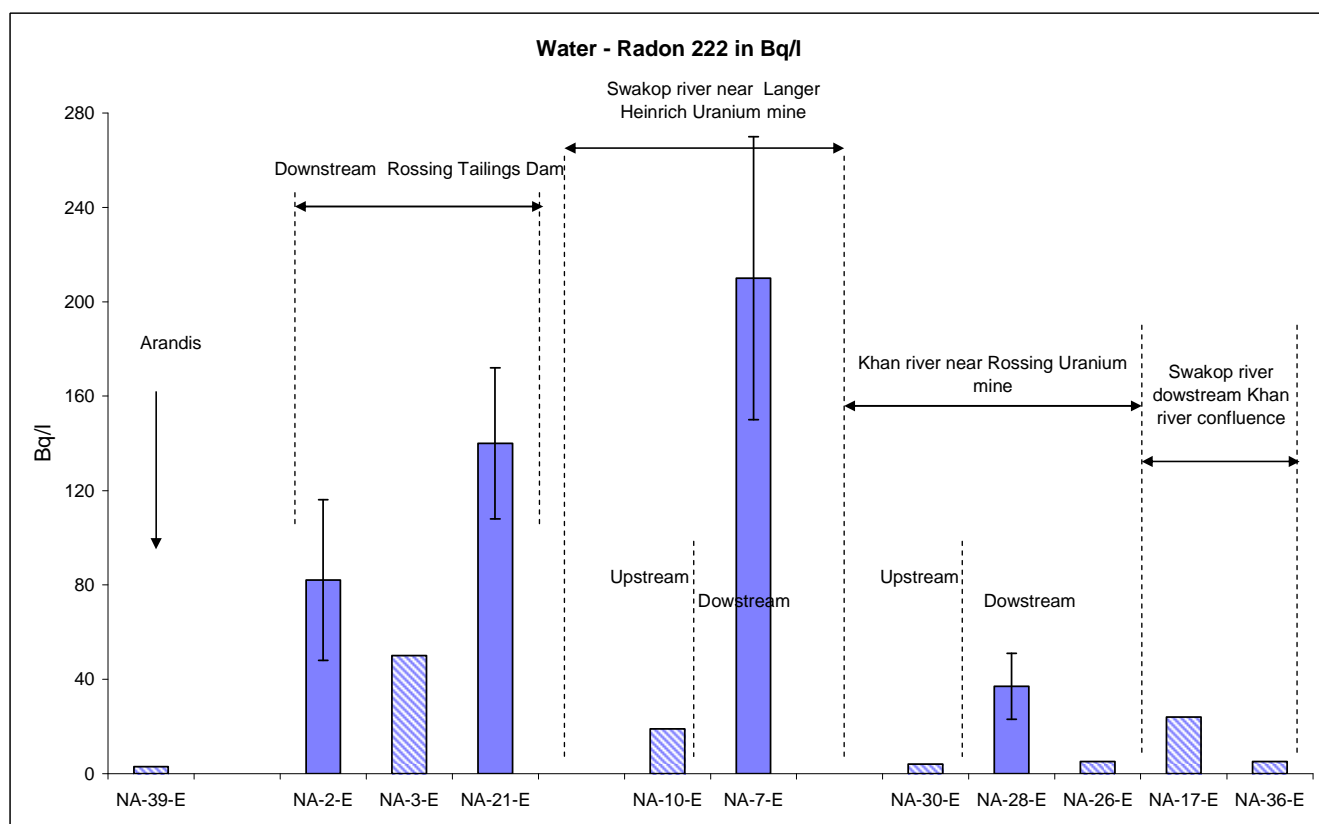
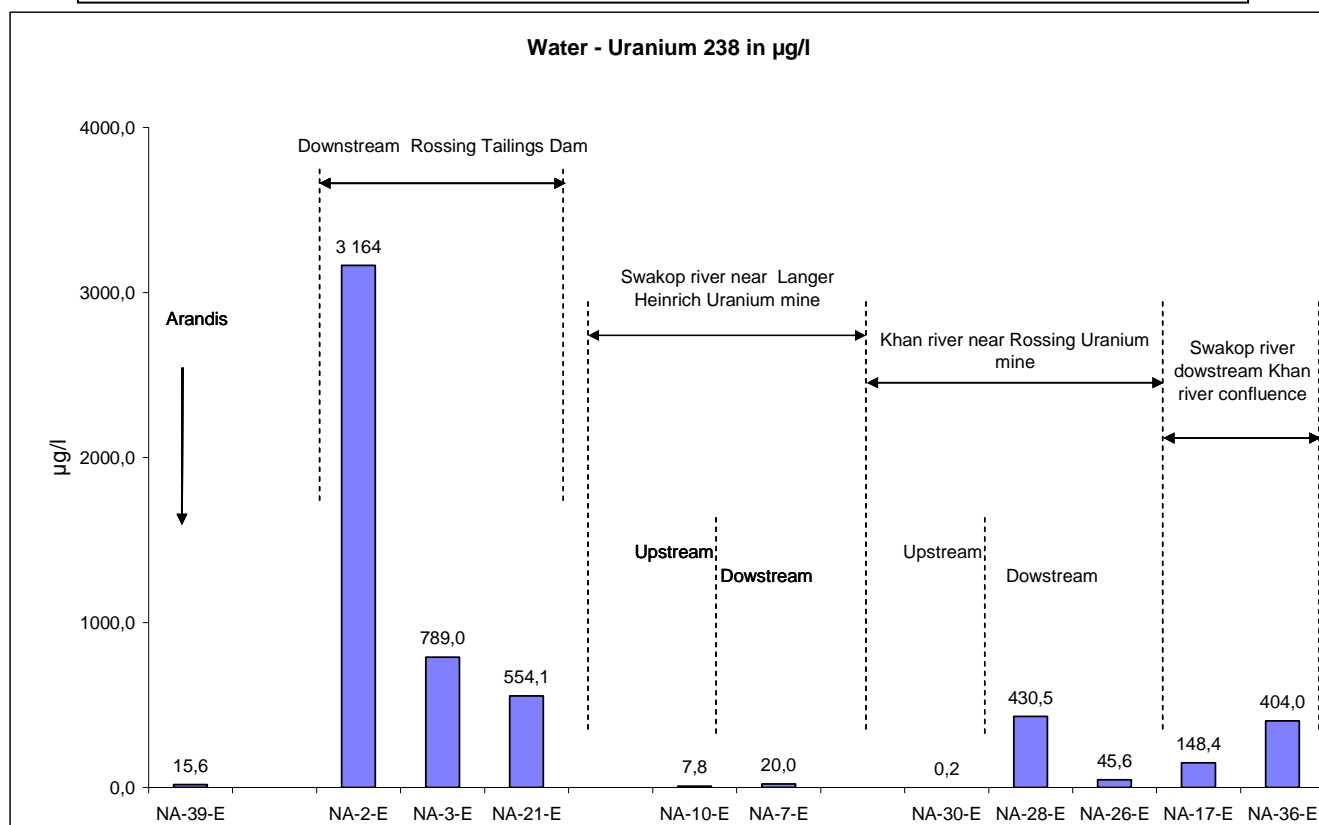
Map 4 / location of underground water samples



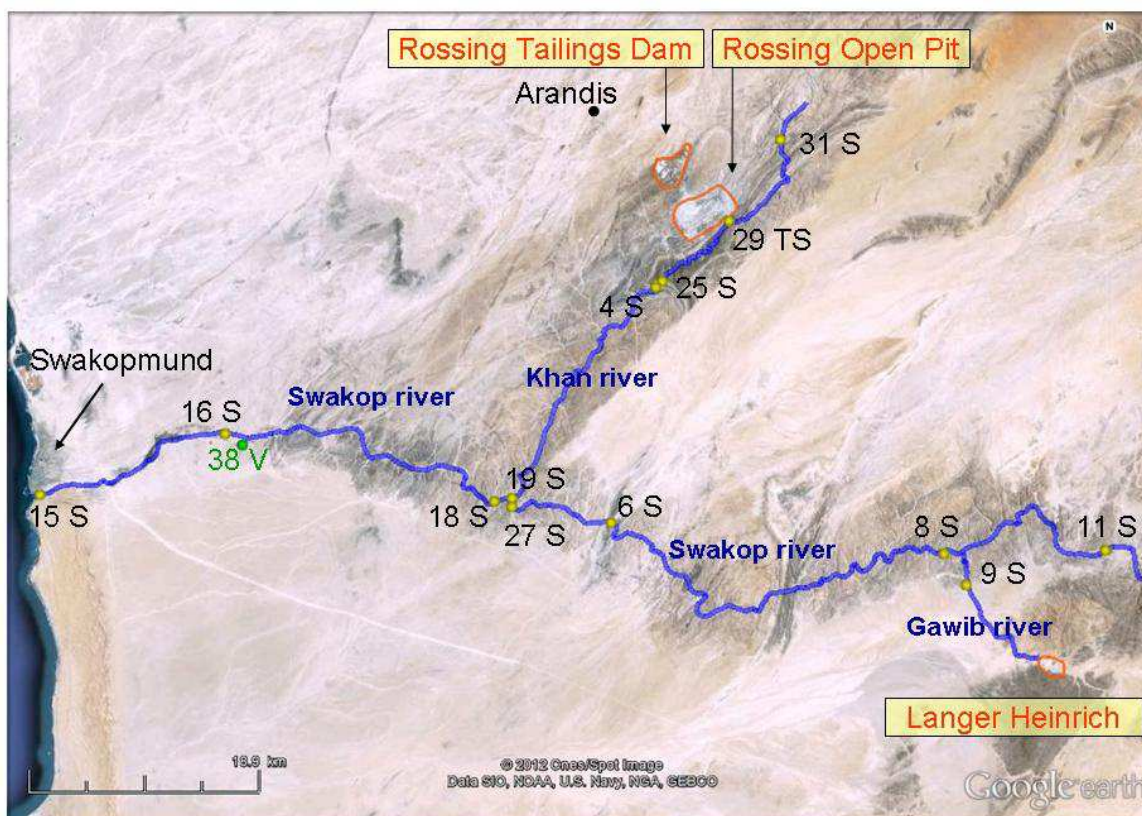
Map 5 / uranium 238 concentration in underground water samples



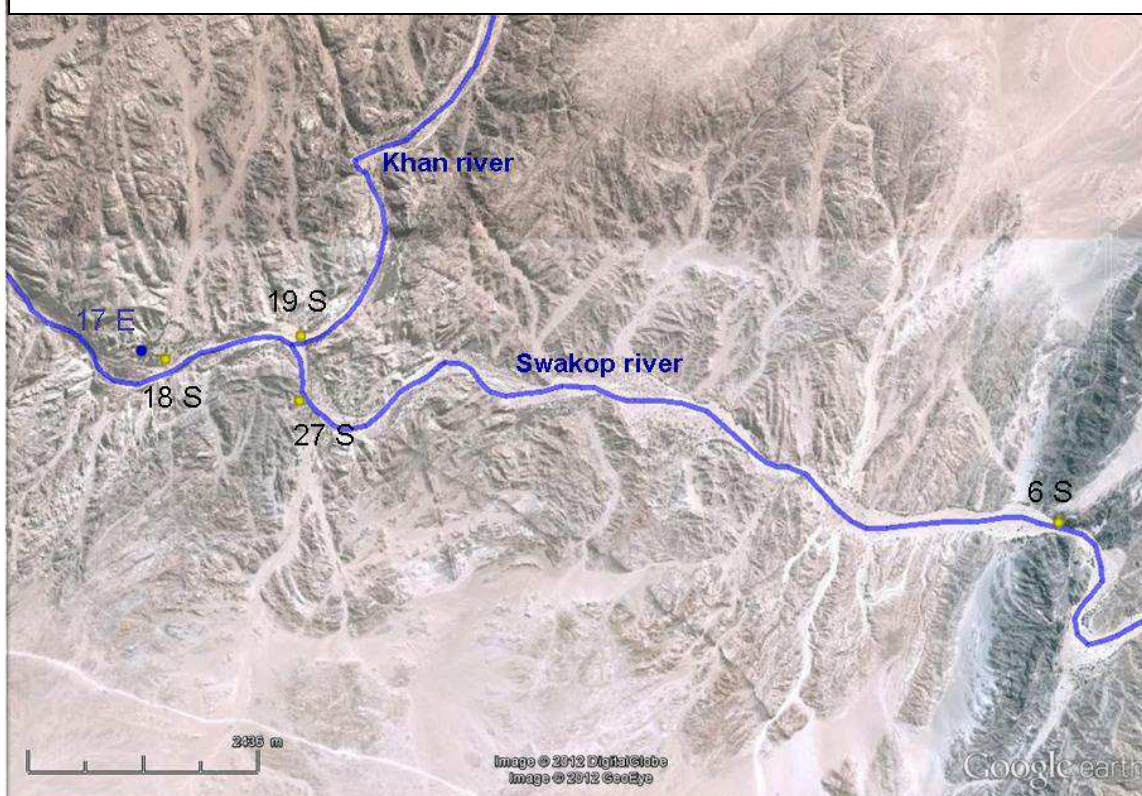
G1 / uranium 238 and radon 222 in underground water samples



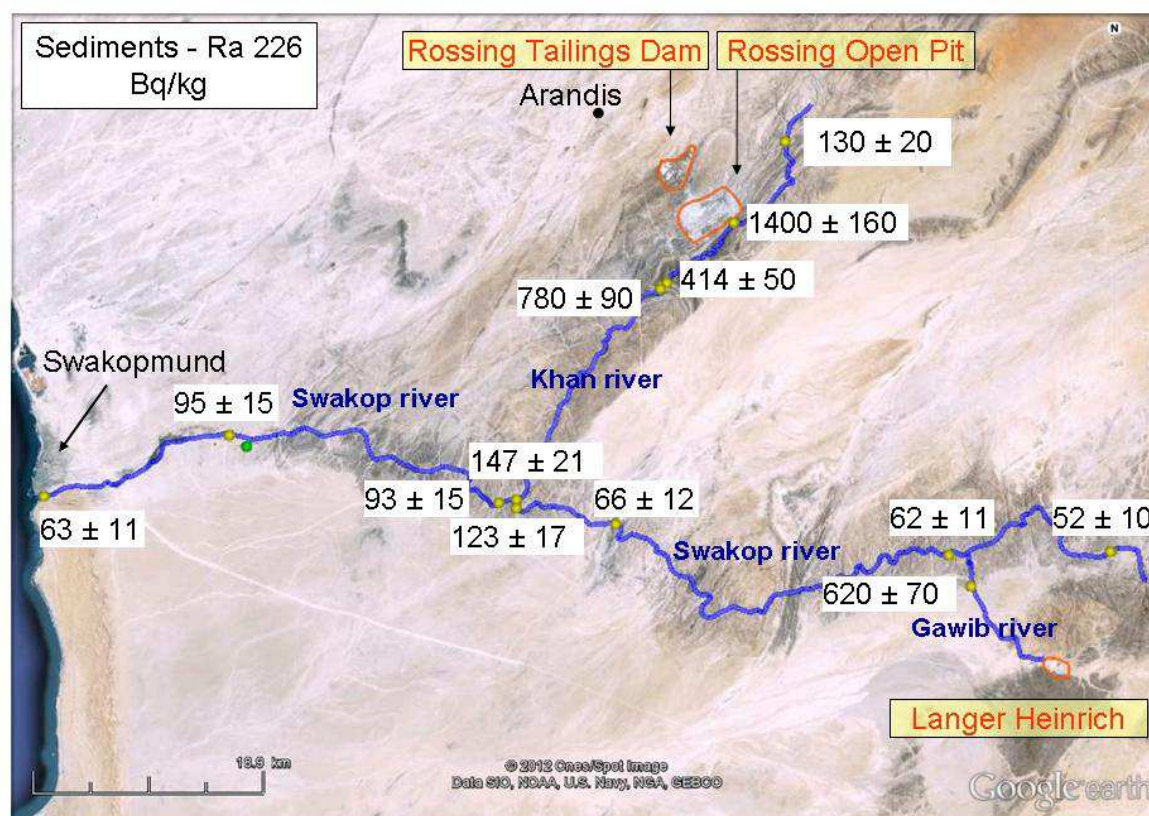
Map 6 / Location of sediments and asparagus (38 V)



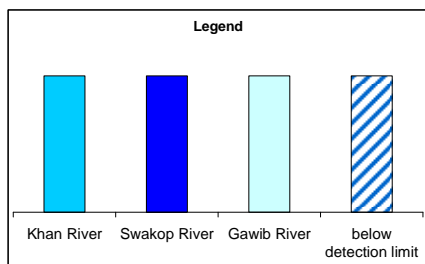
Map 7 / location of sediments and underground water samples at Khan and Swakop rivers confluence



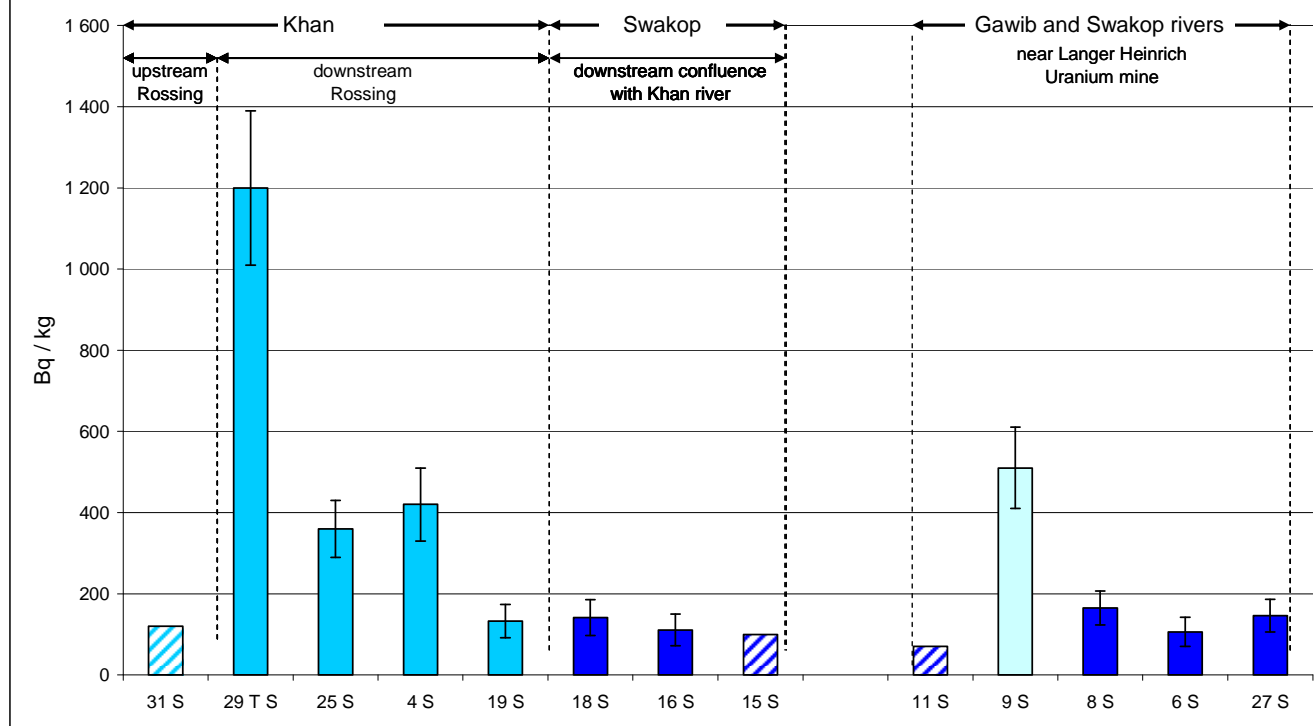
Map 8 / Radium 226 activity in sediments of the Swakop, Gawib and Khan rivers



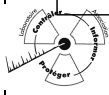
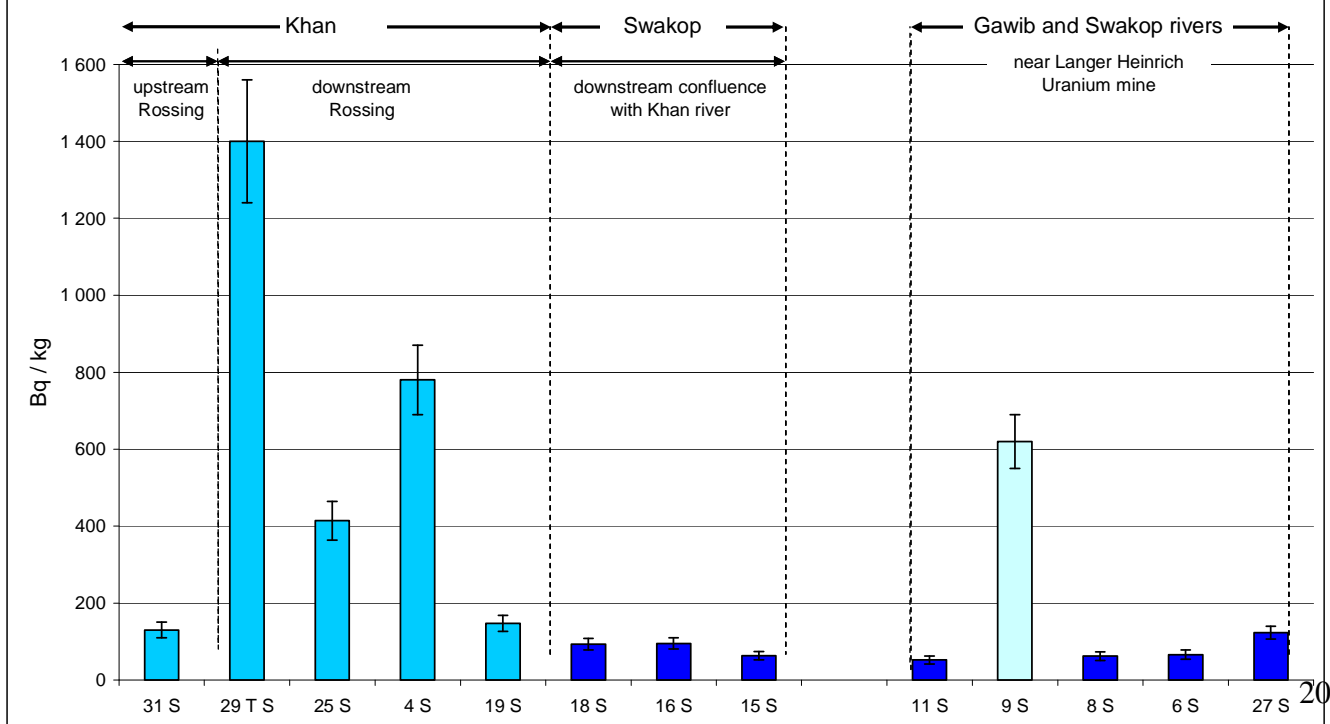
G2 / uranium 238, radium 226 and lead 210 activities in sediments

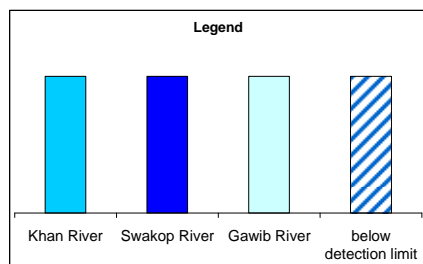


Sediments - Uranium 238 (Bq/kg)

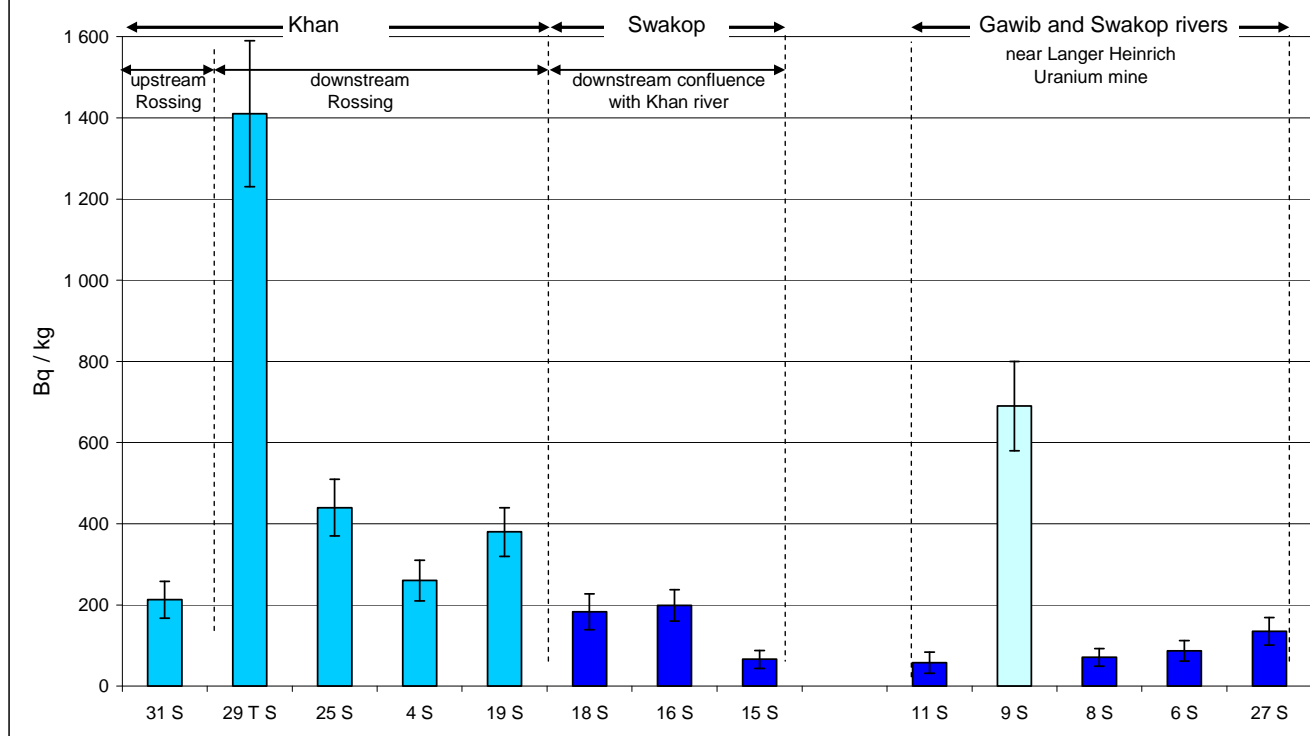


Sediments - Radium 226 (Bq/kg)

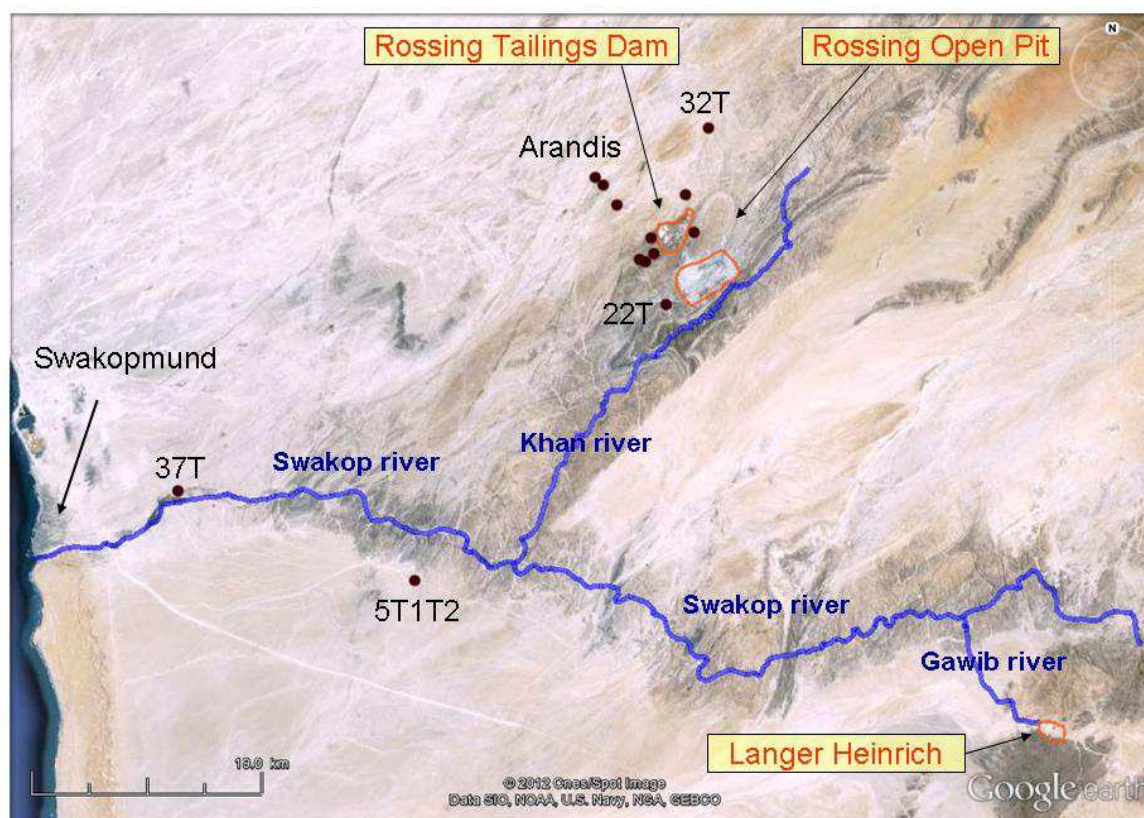




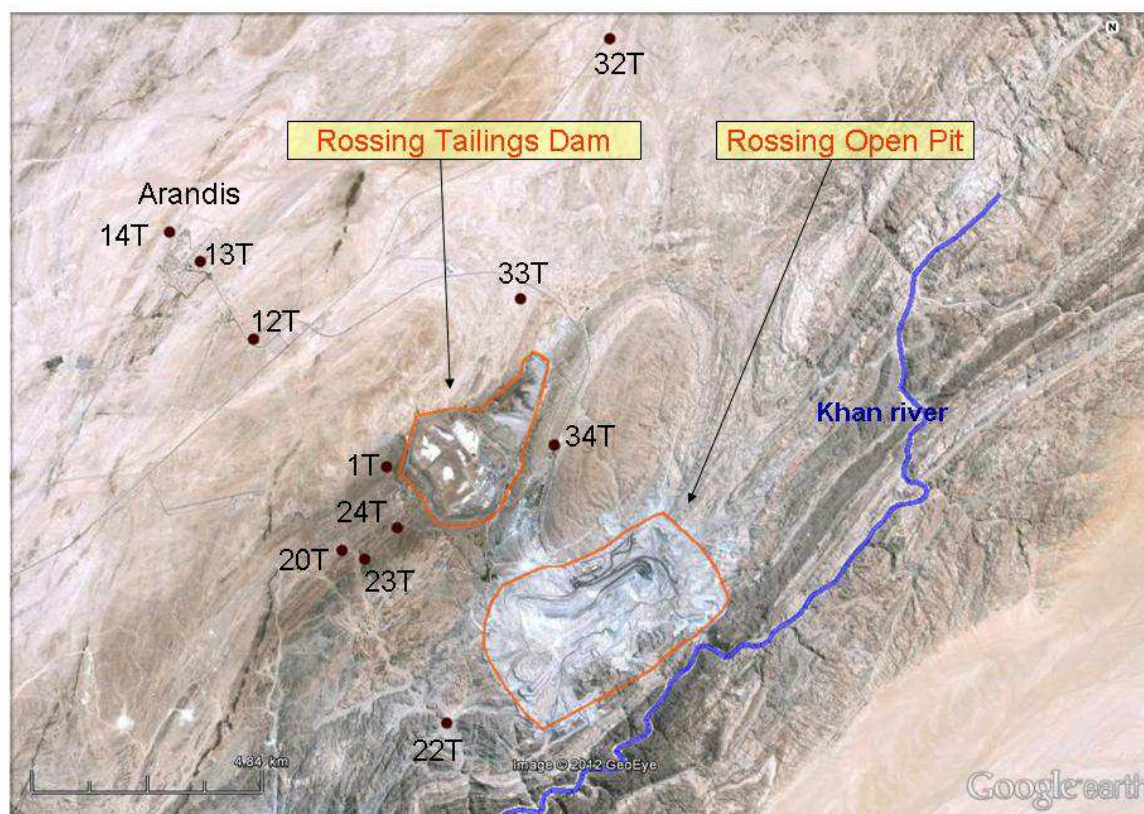
Sediments - Lead 210 (Bq/kg)



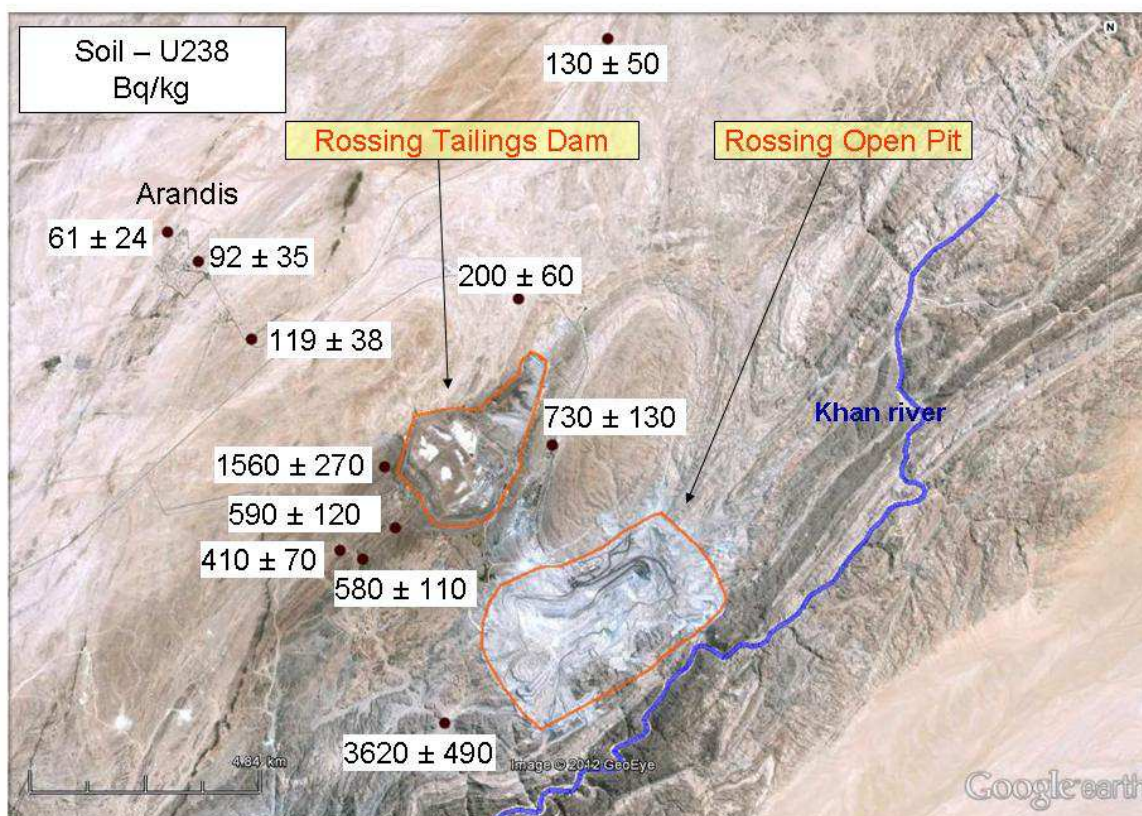
Map 9 / location of top soil samples (general view)



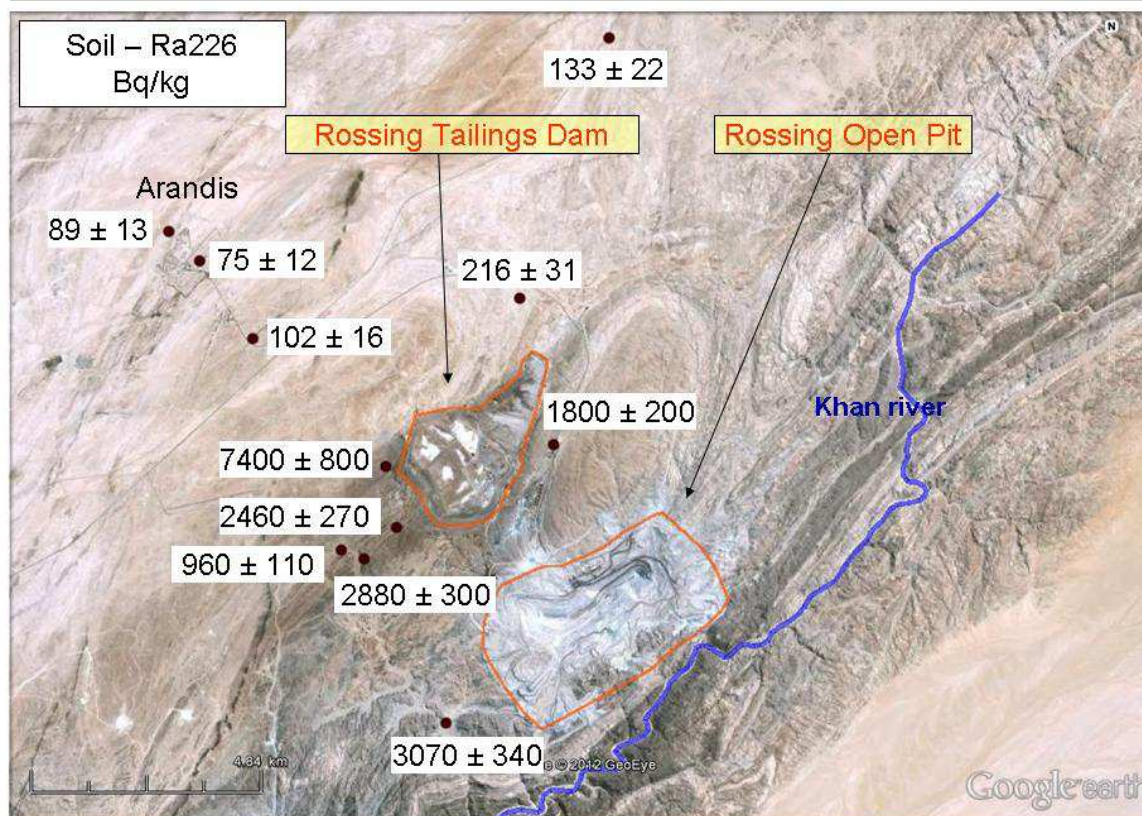
Map 10 / location of top soil samples (zoom near Rössing mine)



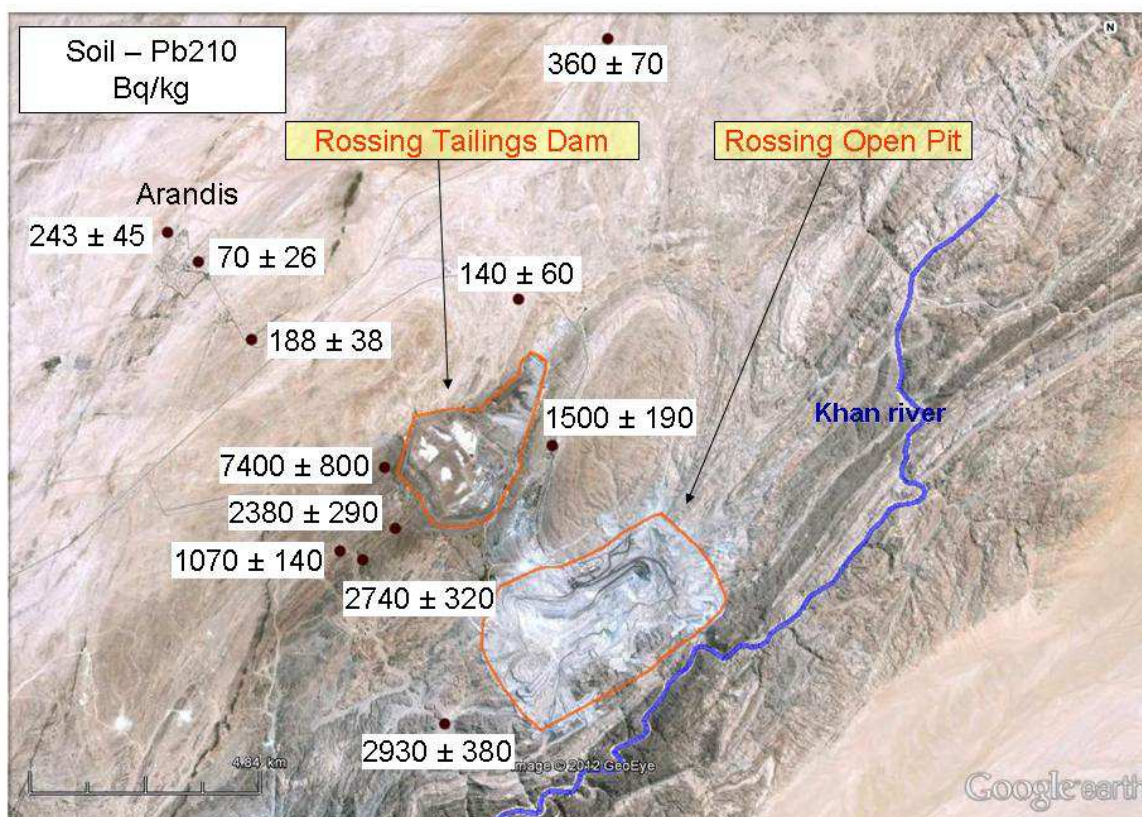
Map 11 / Uranium 238 activity in top soil samples (zoom near Rössing mine)



Map 12 / Radium 226 activity in top soil samples (zoom near Rössing mine)



Map 13 / Lead 210 activity in top soil samples (zoom near Rössing mine)



G3 / radium 226, uranium 238 and lead 210 activities in top soil

