Environmental Aspects of Caetite Heap Leach Project - Brazil

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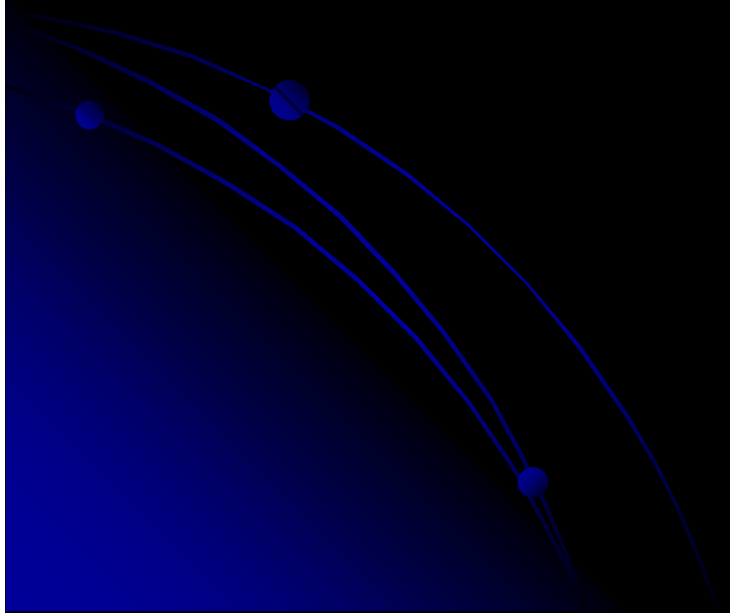

General Overview of thePlant

Process Details (1/3)

- Heap-Leach
  - Ore crushing and addition of H_2SO_4 at 15 $kgH_2SO_4 .t^{-1}$ ore
  - Piles contain 25,000 to 35,000 t of ore
  - Three washing step cycle
    - H_2SO_4 at 25 $g.L^{-1}$ at 0.6 m/t_{ore} at a rate of 30 $L.h^{-1}.m^{-2}$
    - 5 $g.L^{-1}$ H_2SO_4 at 0.3 $m^3.t^{-1}$ at the same percolation rate
    - Raw water at 0.3 m^3 t^{-1} at the same percolation rate

Process Details (2/3)

- Resulting solutions collected in ponds (3 $g.L^{-1}$ of U_3O_8)
- Extraction with organic solvent (7% tertiary amine; 3% tridecanol; 90% kerosene)
- Uranium stripped with NaCl
- Precipitated NH_4OH

Process Details (3/3)

- Effluent is treated with CaO to pH 10.0
- Slurry pumped to high density poly-ethylene (HDPE) lined ponds provided with drains to allow sedimentation
- Supernatant recirculated to the process
- No liquid effluent released into the environment


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Issue: Leakage and Contamination of Groundwater

Uranium

Liquor

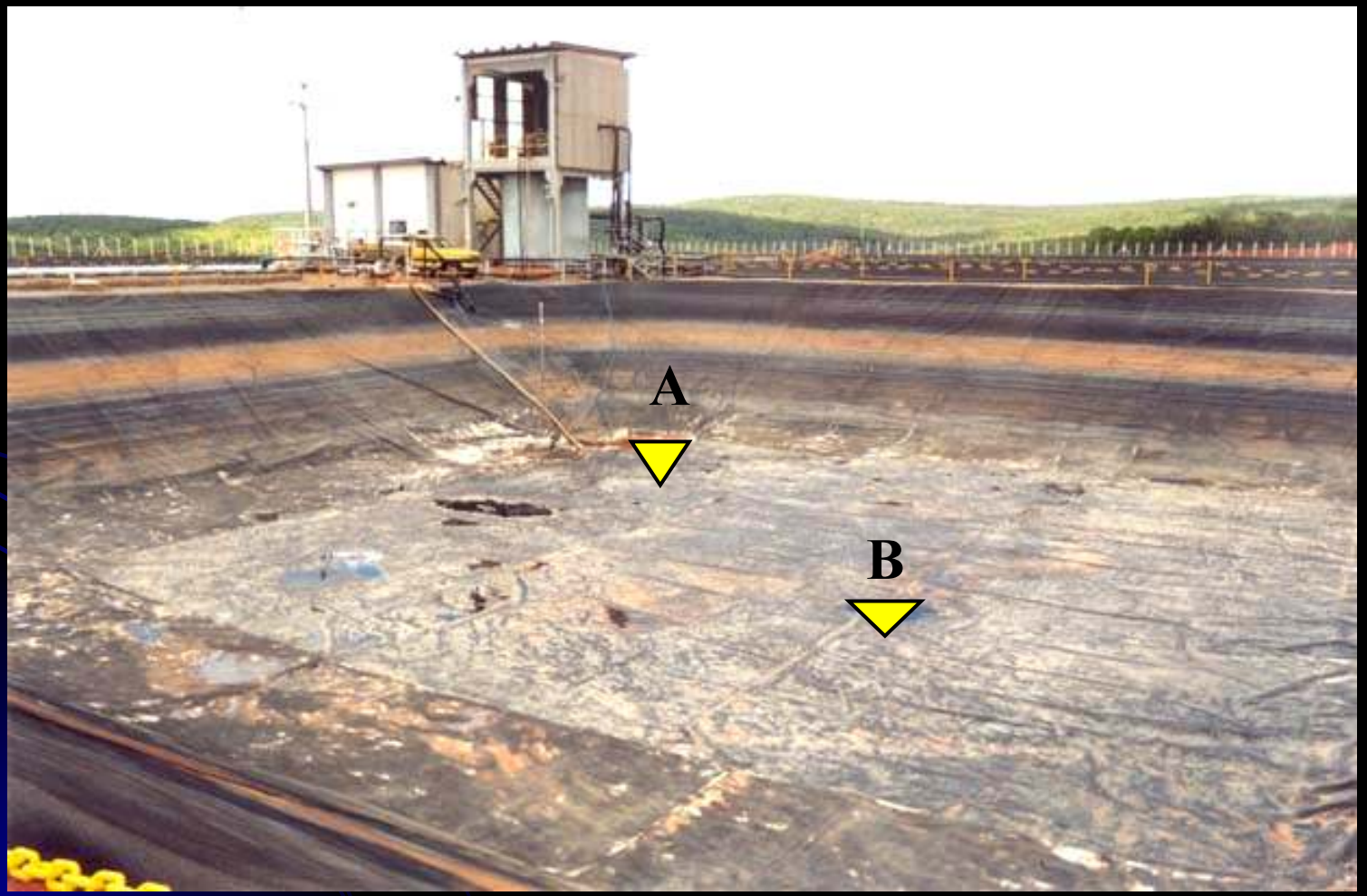
Tanks

TQ-1405

TQ-1405 – detail of the joints

TQ-1405 – Detail of the pumpiong point

Coring of the soil underneath the liners



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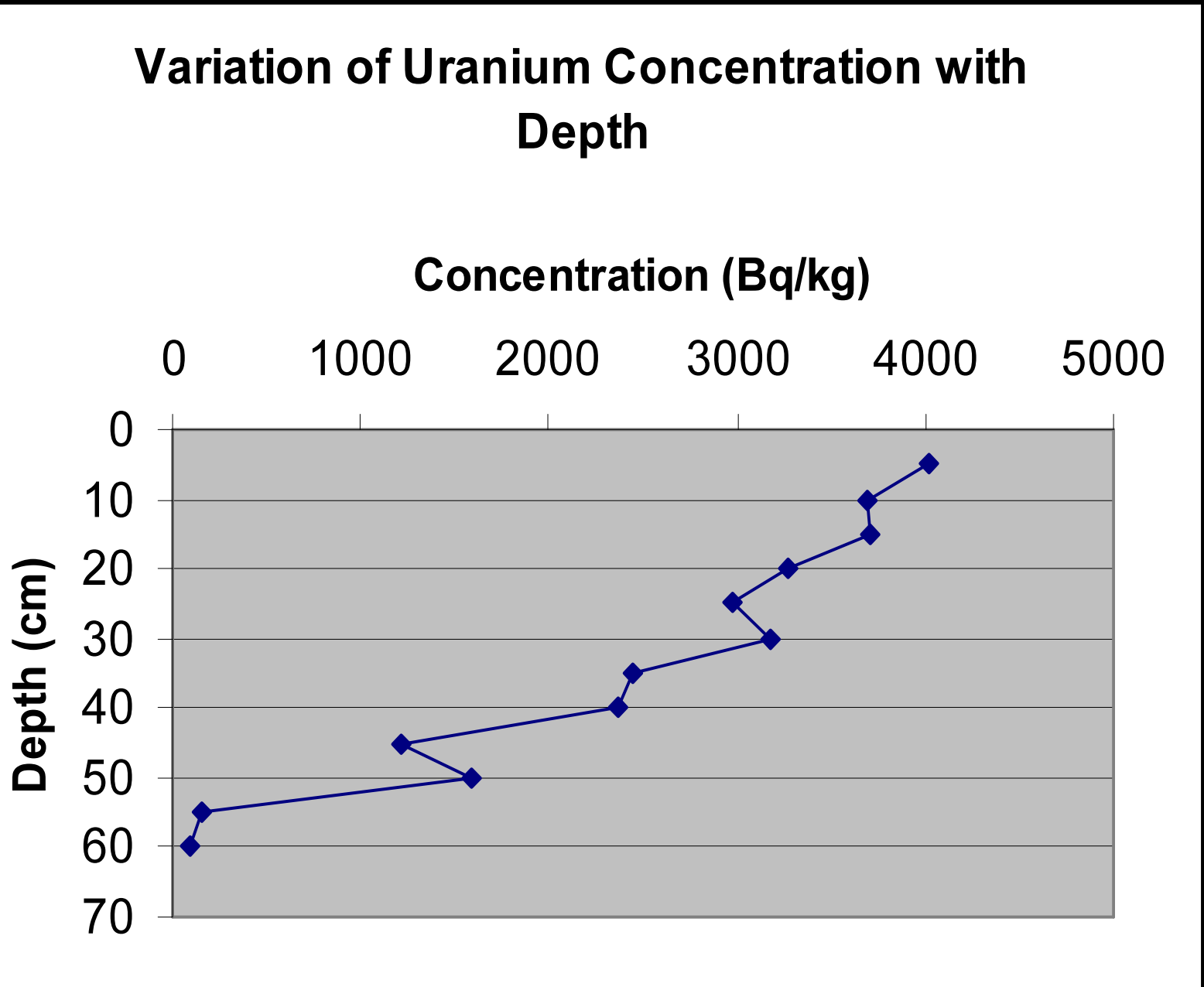
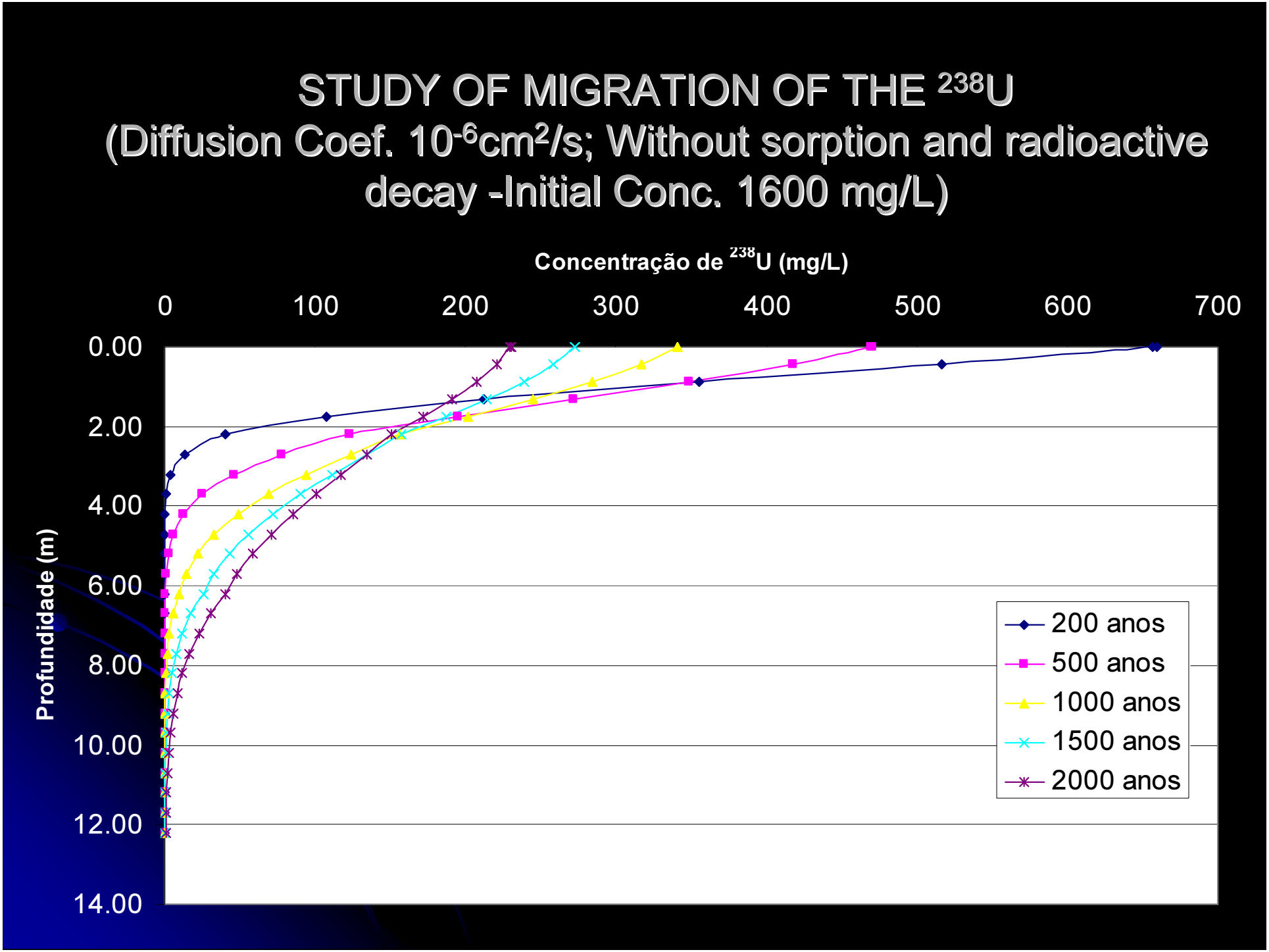
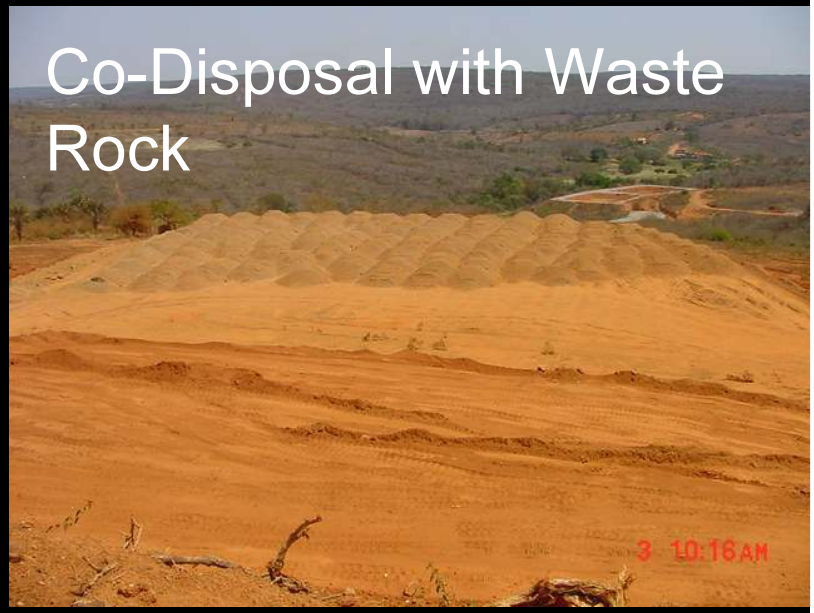

Variation of Uranium Concentration with Depth
Concentration (Bq/kg)
0
1000
2000
3000
4000
5000
Depth (cm)
0
10
20
30
40
50
60
70

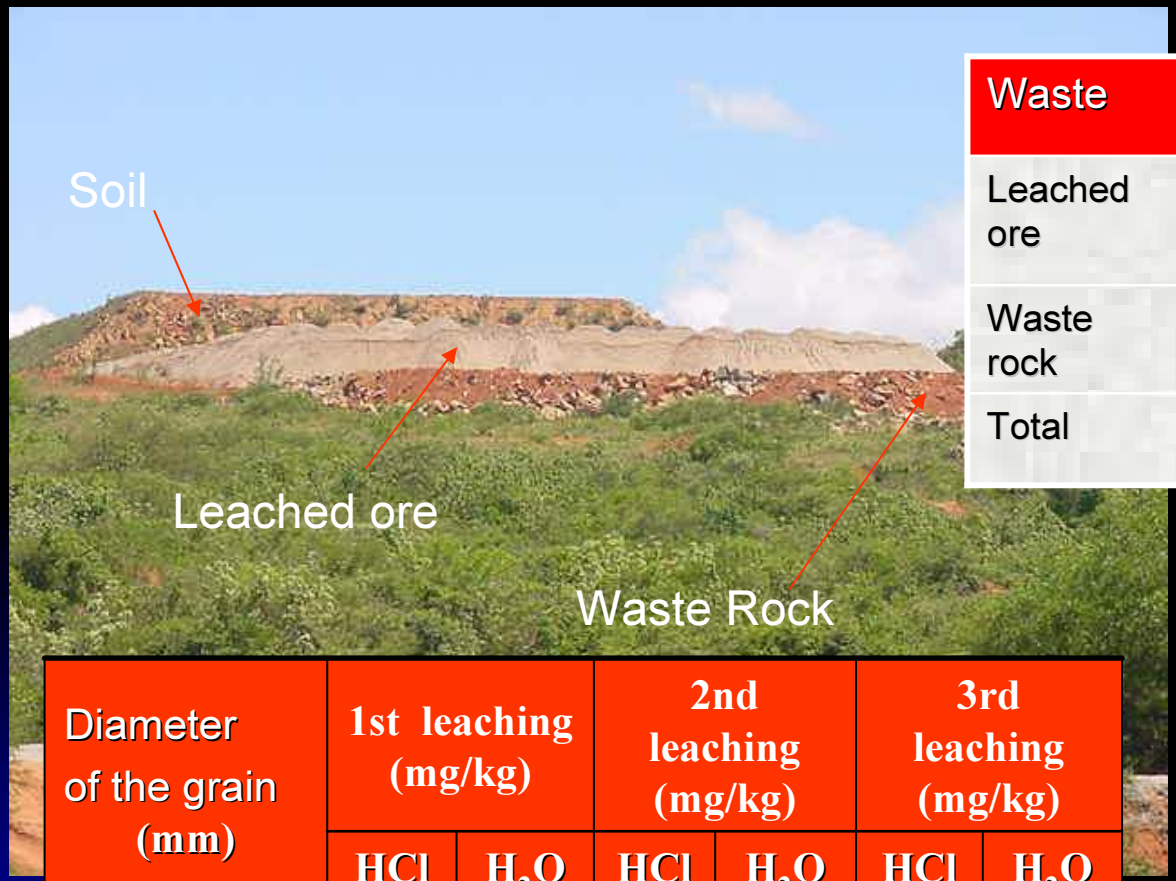
STUDY OF MIGRATION OF THE ^{238}U (Diffusion Coef. $10^{-6}cm^2/s$; Without sorption and radioactive decay -Initial Conc. 1600 mg/L)





Issue: ^{226}Ra Mobilization and Transport into the Environment

Works developed in the waste Deposit



Waste	Mass (t)	U (t)	%	U $
Leached ore	2,14 x 10^6	405	8,44	14 x 10^6
Waste rock	12,2 x 10^6	840	17,46	30 x 10^6
Total	14,34 x 10^6	1245	25,9	44 x 10^6

Diameter of the grain (mm)	1st leaching (mg/kg)		2nd leaching (mg/kg)		3rd leaching (mg/kg)	
	HCl	H_2O	HCl	H_2O	HCl	H_2O
> 0,18	32	0,043	23	0,116	26	< 0,078
0,18>×>1	23	0,031	16	0,119	15	
> 1,0	8,6	0,017	15	0,078	16	

Development of the piles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Details of the waste rock and leached ore co-disposal

Leaching Solutions Characterization

Material	^{238}U	^{226}Ra	^{228}Ra
Ore (Bq/Kg)	53,080 ± 11,975	33,280 ± 9,549	83.0 ± 21.0
Leached Ore $(Bq/Kg)_{seco}$	7,582 ± 3,290	34,520 ± 9,512	75.00 ± 12
Leaching Solution (Bq/L)	157,400 ± 30.770	23.0 ± 4,0	6.0 ± 0,5
1^{rst} Washing Water (Bq/L)	54,840 ± 13,162	16 ± 4.5	2.3 ± 0.6
2^{nd} Washing Water (Bq/L)	526 ± 176	10.0 ± 3,0	< 0,5

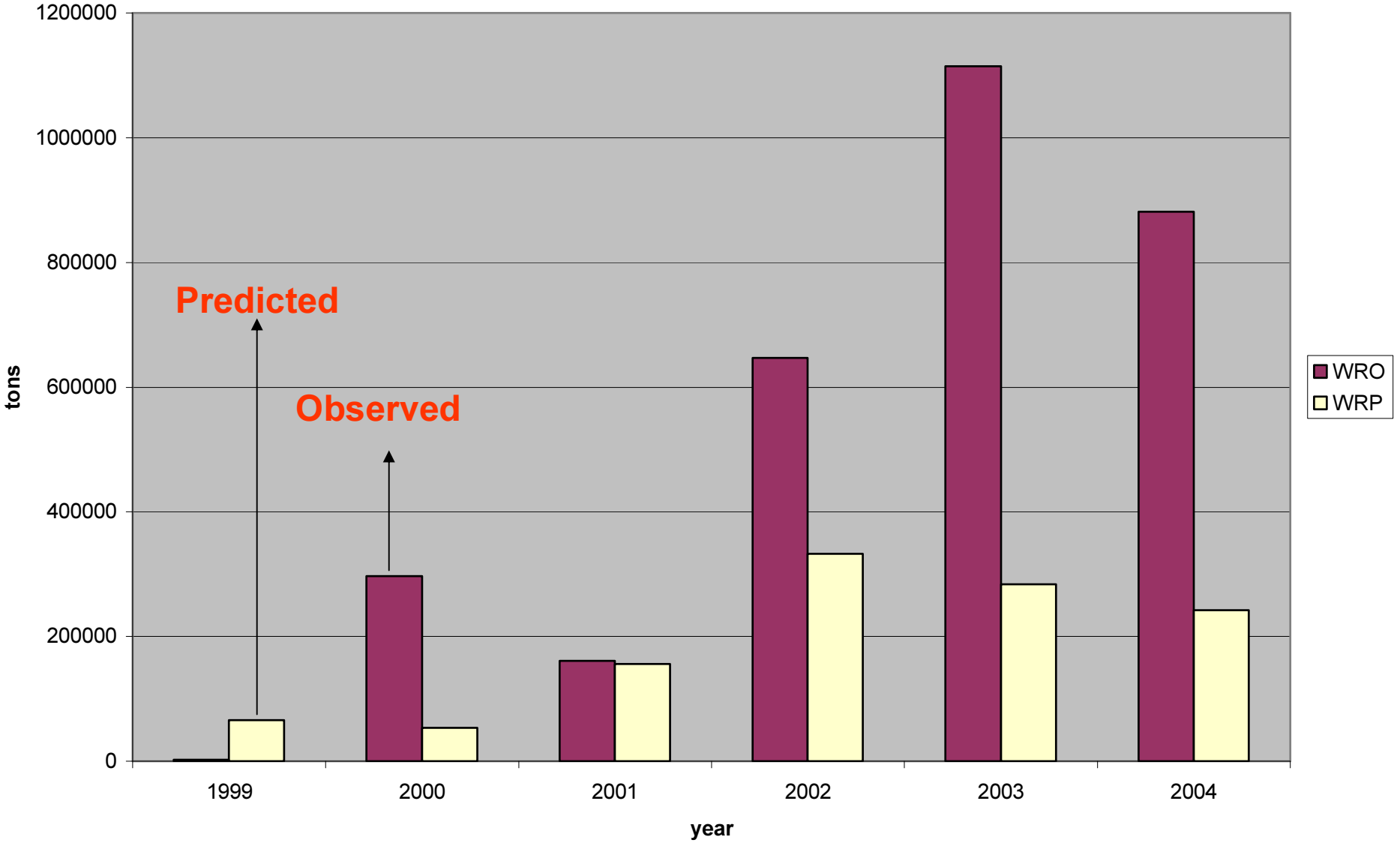
Mine Pit (2004)

Issues:

→Waste Rock Generation

→Dewatering

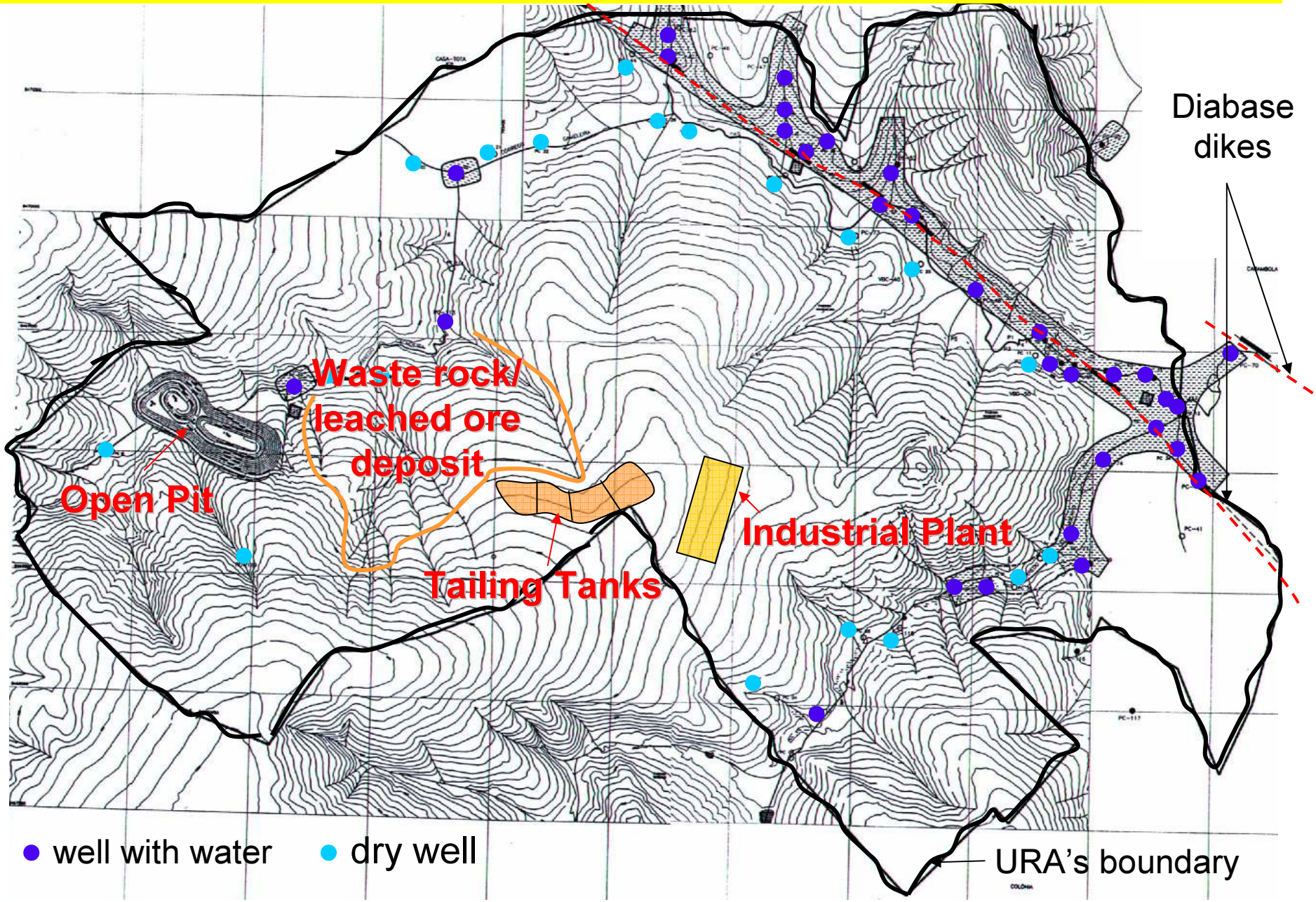
→Groundwater Contamination


Amount of Waste-Rock Material Generated by Mining Operations
1200000
1000000
800000
600000
400000
200000
0
tons
Predicted
Observed
1999
2000
2001
2002
2003
2004
year
WRO
WRP

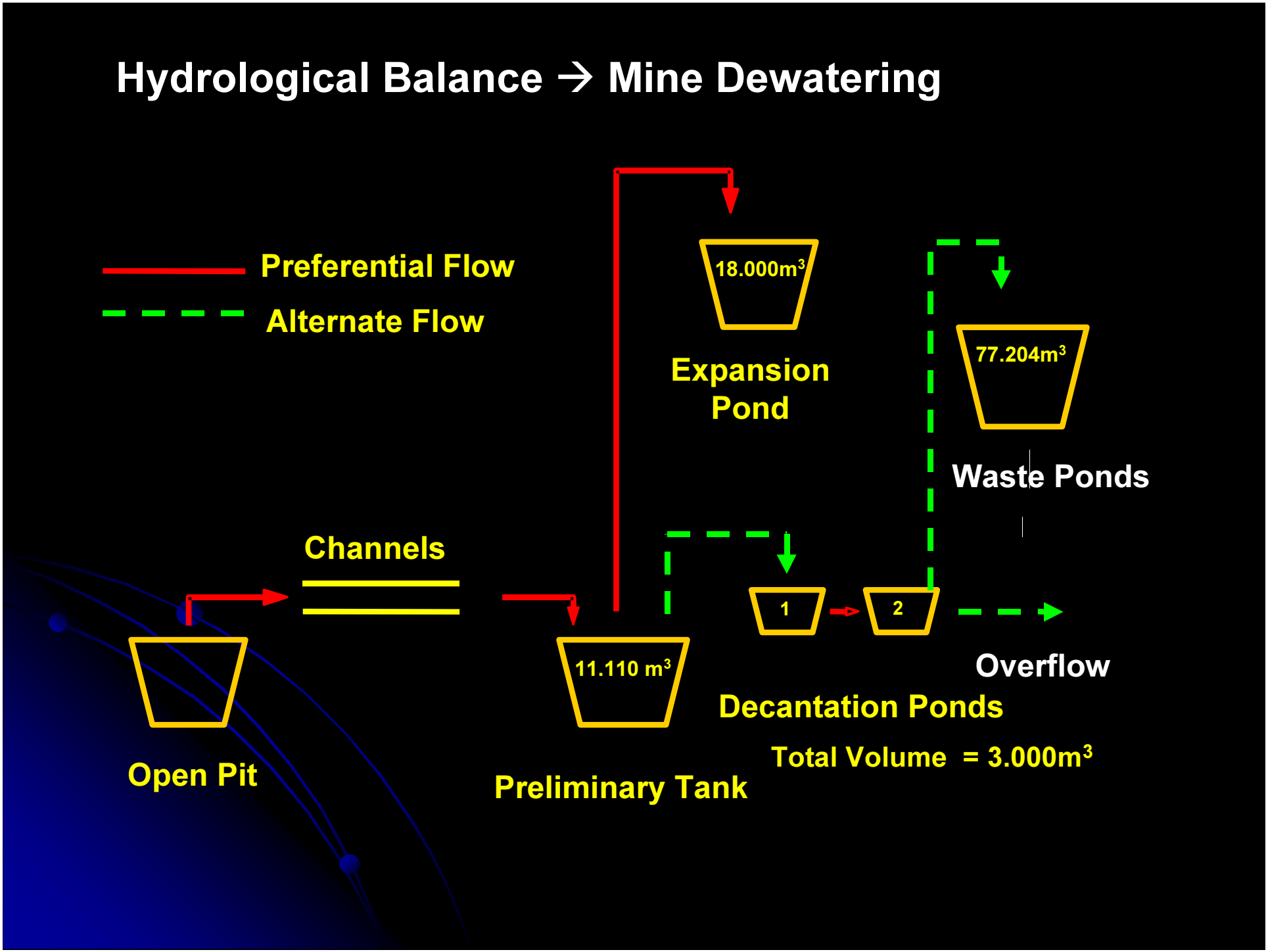
Average values of radionuclides in waters accumulated in the open pit (Bq/L)

Ponto	^{238}U	^{226}Ra	^{210}Pb	^{232}Th	^{228}Ra	pH
Body 01 (n=16)	4,95 ± 5,5	0,15 ± 0,16	0,05 ± 0,03	0,04 ± 0,08	0,05 ± 0,10	8,27 ± 0,66
Body 03 (n=22)	57 ± 6,4 (4,60 mg/L)	2,03 ± 1,29	0,22 ± 0,16	0,21 ± 0,25	0,23 ± 0,25	7,84 ± 0,40

ASSESSMENT OF THE SOURCE TERM AND ZONING RISK REFERING TO THE GROUNDWATER FLOW PATTERN AND WATER QUALITY

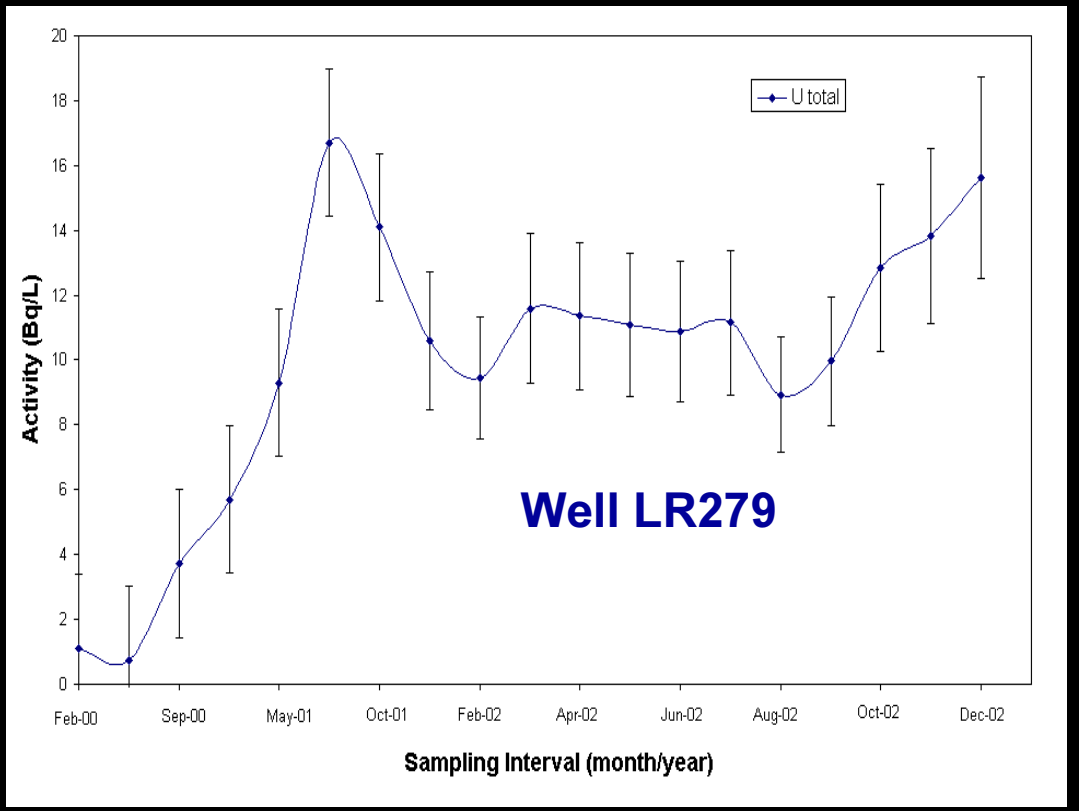


Hydrological Balance → Mine Dewatering



Open Pit - Groundwater

Station – Well LR 279



Groundwater Contamination

^{238}U,^{226}Ra and ^{210}Pb activity Concentrations in the Mine Pit Waters

Ponto	^{238}U	^{226}Ra	^{210}Pb
	Bq/L		
ASUB001 (n=12)	7.30	0.42	0.20
ASUB279 (n=12)	12.3	0.064	0.13
ASUB276 (n=12)	0.09	0.039	0.086
ASUB211 (n=3)	0.15	0.75	0.10

Geochemical Modelling

- ASUB 001 (p H = 6,6)
  - $UO_2(CO_3)$ – 7,4%
  - $UO_2(CO_3)_2^{=}$ - 85%
  - $UO_2(CO_3)_3^{-4}$ = 7,2%
  - pH = 6.60
  - Cl^-= 107
  - HCO_3^- = 288

} Lower Recharge Rate

- ASUB 211 (pH = 4,8)
  - $UO_2(CO_3)$ – 36,7%
  - $UO_2(HPO_4)_2$ – 45,2%
  - pH = 4.80
  - Cl^- = 425
  - HCO^-_3 = 9.90

} Higher Recharge Rates

Physico-chemical Characteriyation of the wells ASUB 001, ASUB 279 e ASUB 211

Constituintes (mg/L)	ASUB001	ASUB279	ASUB211
Na	100	107	176
K	7,67	7,67	6,33
Mg	10,8	7,33	12,9
Ca	81	52	27
Ba	0,32	0,09	6,19
Mn	0,77	0,19	0,67
Fe	1,13	1,79	0,53
SiO_2	57	62	98
PO_4	0,04	0,03	0,05
SO_4	2,4	11	20
F^-	2,13	1,77	0,37
Cl^-	107	173	425
$CaCO_3$	288	194	9,90
U	0,60	-	0,01
Al^{+3}	-	-	0,36
pH	6,6	6,75	4,80

Waste Pond

Issue → Groundwater Contamination

Assessment:

- **Worst case scenario**
- **No Cover on the top**
- **No impermeable and/or compacted clay layer in the bottom**

Pond with Sub-Aerial drains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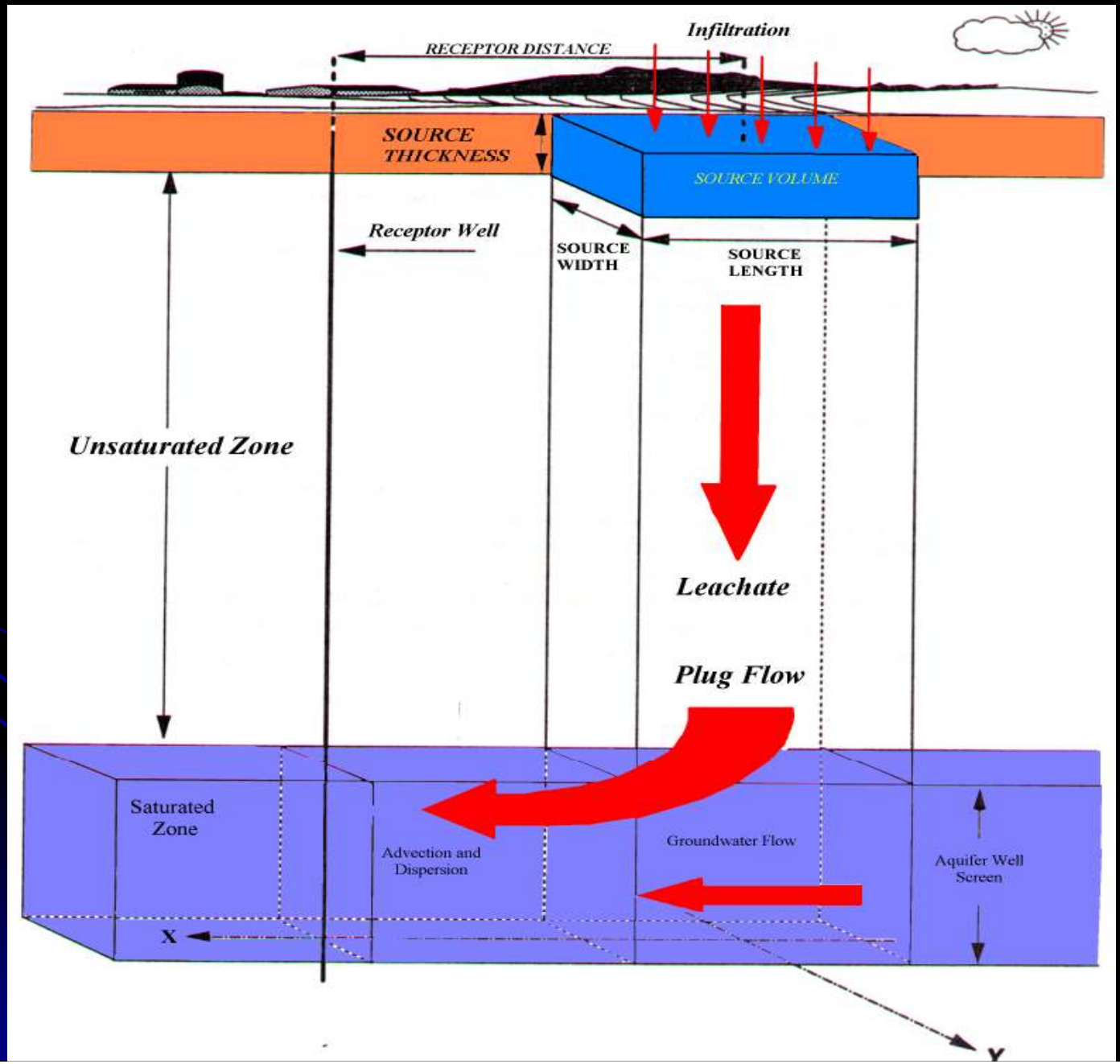
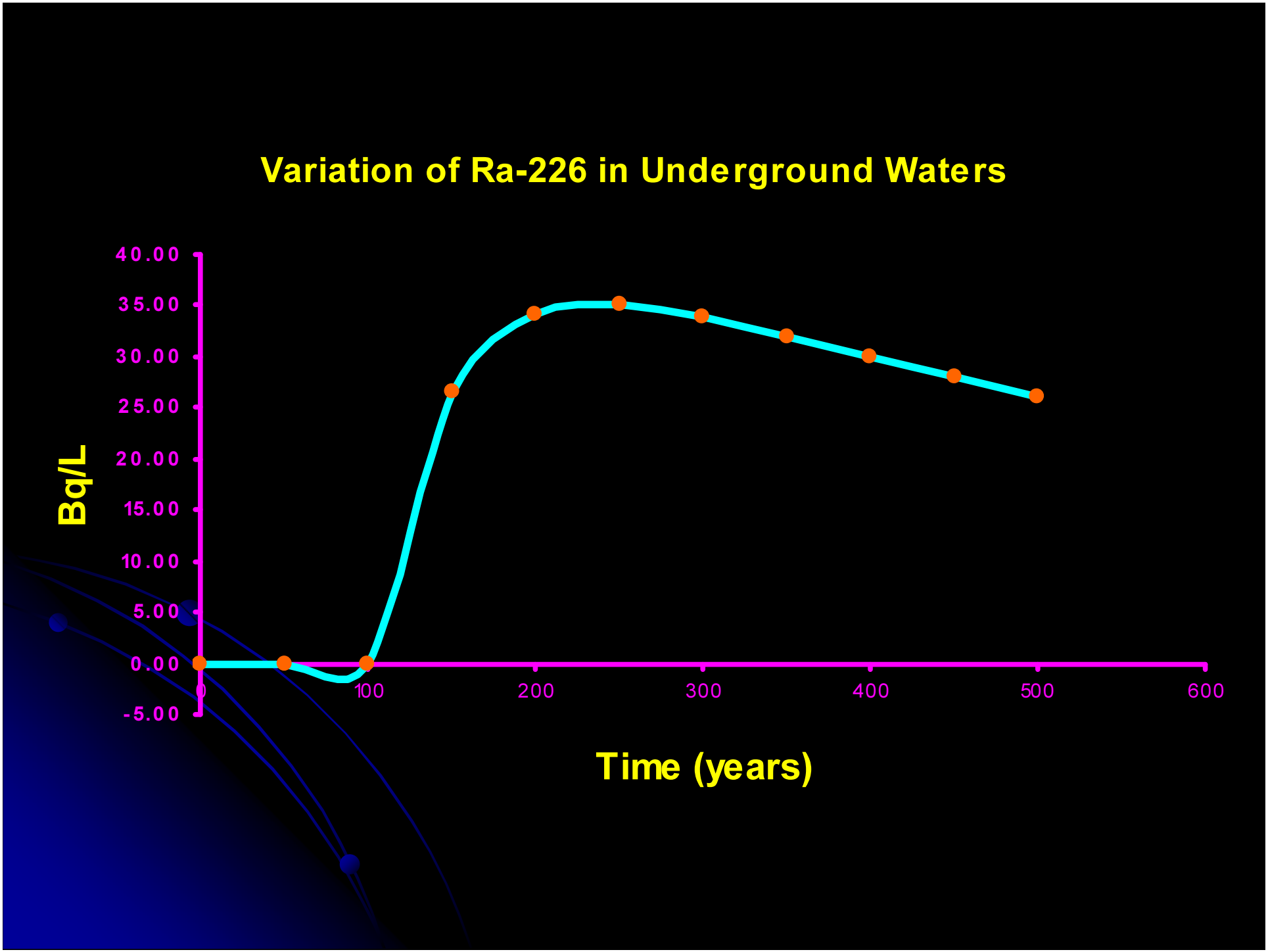
Pond with Sub-Aerial drains

Pond with Sub-Aerial drains

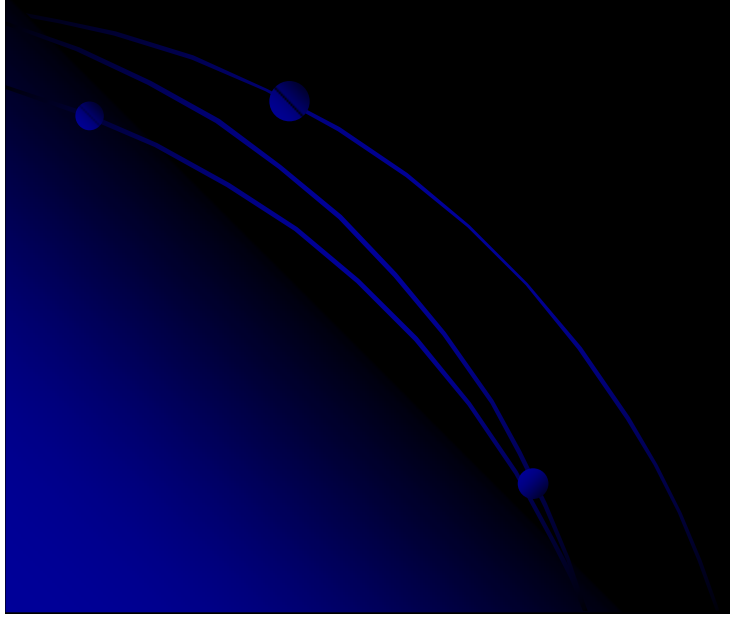
Pond with Sub-Aerial drains

Conceptual Model GWSCREEN




Variation of Ra-226 in Underground Waters
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
-5.00
Bq/L
0
100
200
300
400
500
600
Time (years)

Summary



System	Pocos de Caldas	Caetite
Ore grade (ppm)	800 – 1,200	2,300 – 3,000
U_3O_8 production (tons)	1,200	1,000 (in 4 years)
Ore (ton)	$1{,}76 \times 10^6$	$6{,}0 \times 10^5$ (in four years)
Tailings (tons)	2.05×10^6	$7.2 \times 10^3 – 12 \times 10^3$ (per year) $1.15 \times 10^5 – 1.92 \times 10^5$ (estimated for 16 years)
Tailings Area (km^2)	0.18	0.047
Waste Rock (tons)	105×10^6	3.1×10^6 (in 4 years) 12×10^6 (estimated in 16 years)

Environmental and Climatological Characteristics	•Rainfall – 1,800 mm/year •Well developed agriculture activities •River waters (in which effluents are released) are used for irrigation •No major use of groundwater	•Rainfall – 800 mm/year •Absence of expressive agriculture •Rivers are not perennial (no effluent release is permitted) •Groundwater is used for water consumption (confined fissured aquifers. Low recharge rates)
Potential Environmental Impacts	•Superficial water bodies (operational and post-operational phase); •Groundwater contamination not expected by radionuclides. •Studies need to be developed concerning potential contamination due to the mine pit	•Effluent Releases not allowed in the operational phase. •Potential contamination of superficial water bodies in the post operational phase •Groundwater suspected of being affected by drainage disposed in the open pit and auxiliary holding ponds

Sugestions (1/2)

- **Improvement of the operational efficiency of the tanks of deposition of rejeitos deriving of the industrial plant;**
- **Conduction of hydrogeological studies in the area of influnece of the mining operations.**

Sugestions (2/2)

- Adoption of a EMS (Environmental Management System) for all the operations to improve the environmental performance integrating all operational systems in a logical and efficient form.