INSTITUTO DE RADIOPROTEÇÃO E DOSIMETRIA

CNEN Comissão Nacional de Energia Nuclear

Assessing the radiological impact of the Caetité uranium production center (Brazil) on local water resources

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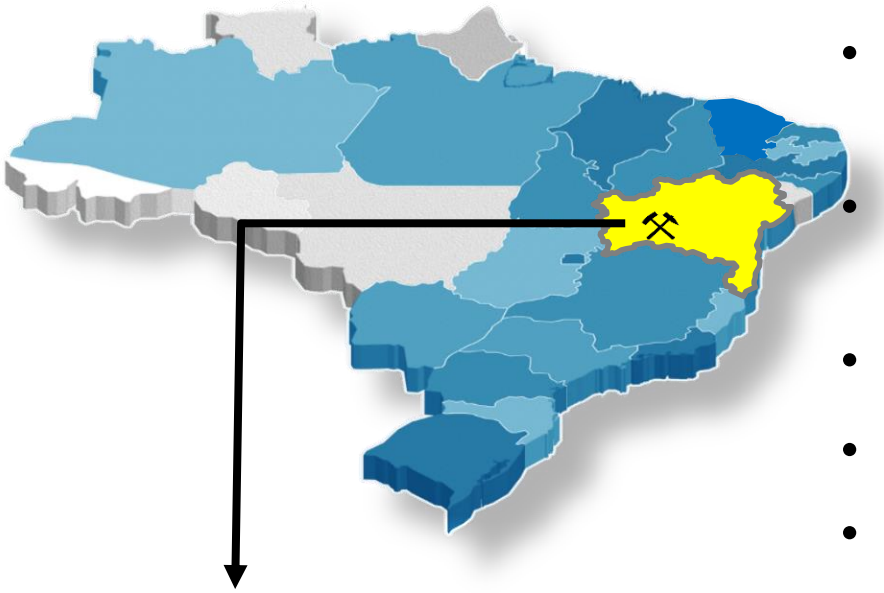
Background & Relevance



Unit of Uranium Concentration (URA)

- The only uranium production center in Brazil → URA;
- Operated by state-owned company → Brazilian Nuclear Industries (INB);
- U → supply the domestic demand;
- Strategic for the BNP;
- Semi-arid climate → Water conflict;
- Main water resource → fractured aquifer;
- Groundwater must be protected;
- Overexploitation and contamination;
- **Public perception** → high radionuclide concentrations in waters from some wells are caused by the mining operations;
- Social license;

Main Questions

The high uranium concentrations found in groundwater (in some wells) are natural or anthropogenic?

What are the human health risks arising from the consumption of this water?

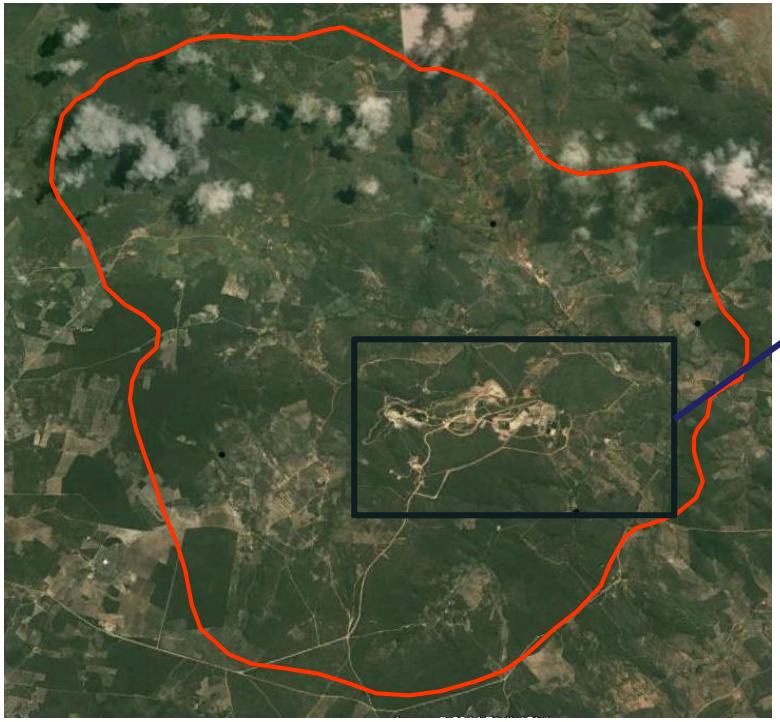
Objectives

- Assess the potential contamination of groundwater based on the location of the main source-terms of the URA;

- Perform human health risk assessment due to ingestion of groundwater;

Study Area

- **CEB – Caetité Experimental Basin**



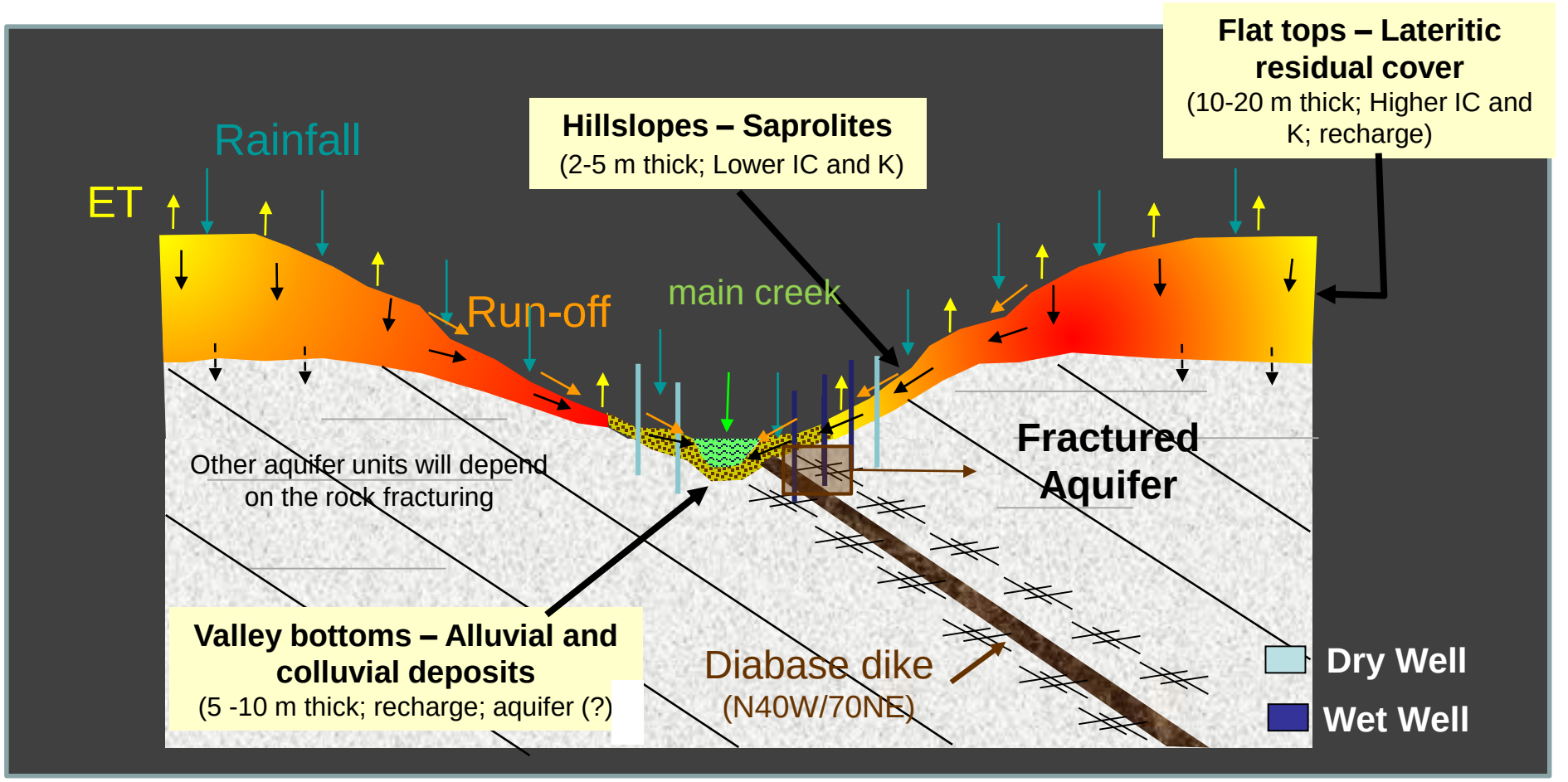
Area = 75 km²

- **URA – Unit of Uranium Concentration**

- **Surface water**
- **Groundwater**
- **URA's source-terms (Open pit; Waste deposit; Tailing ponds; Chemical plant)**

Hydrogeological system

- Characterized by smooth landscape, supported by crystalline rocks (granites and gneisses).
- The main aquifer in the CEB is related to intrusion of diabase dike, and is located on the left side of the main creek.
- The mean annual rainfall is ~ 700 mm/y (semi-arid condition)



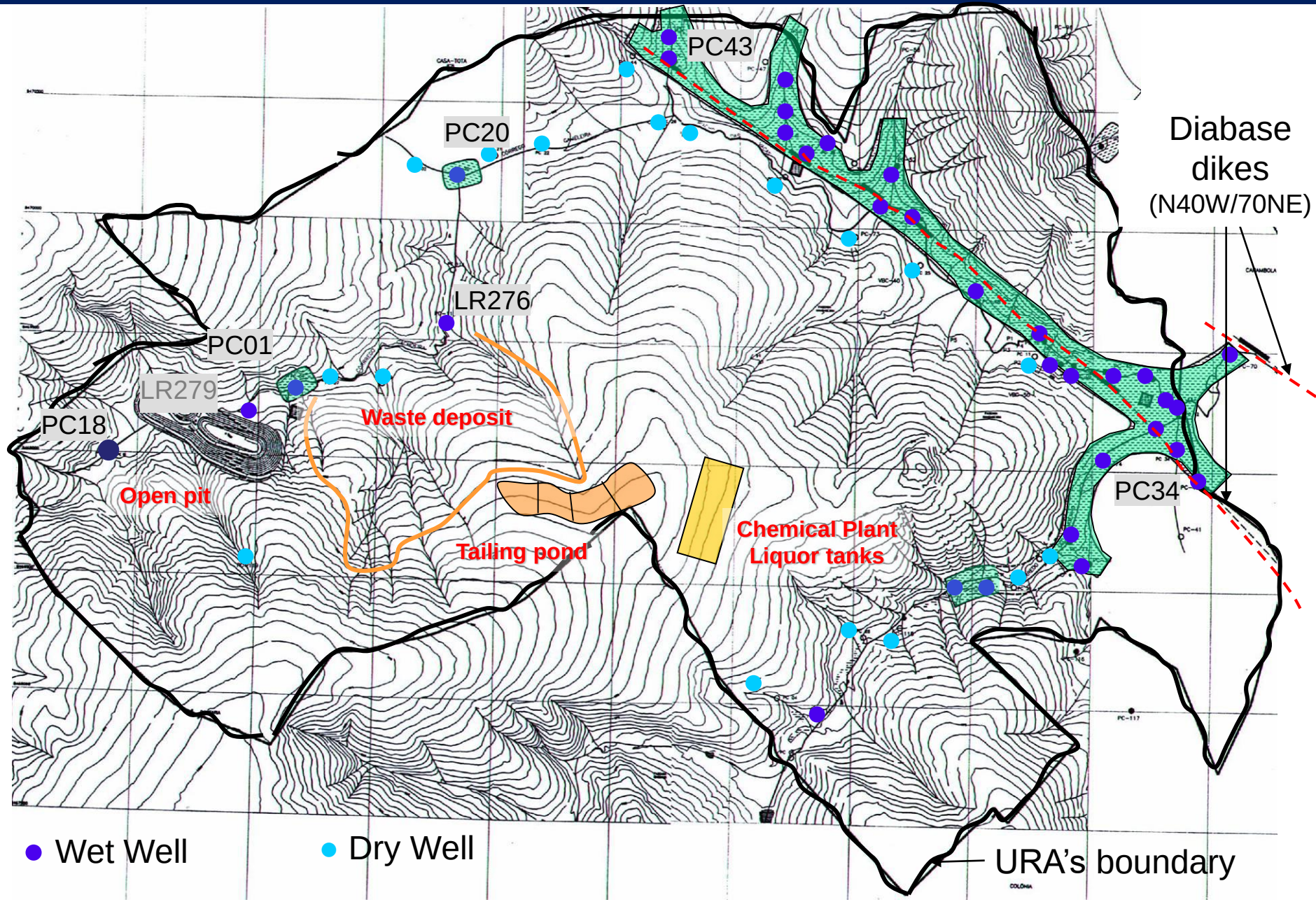
Assessing the uranium concentration in groundwater

in the CEB (direct influence of the URA)

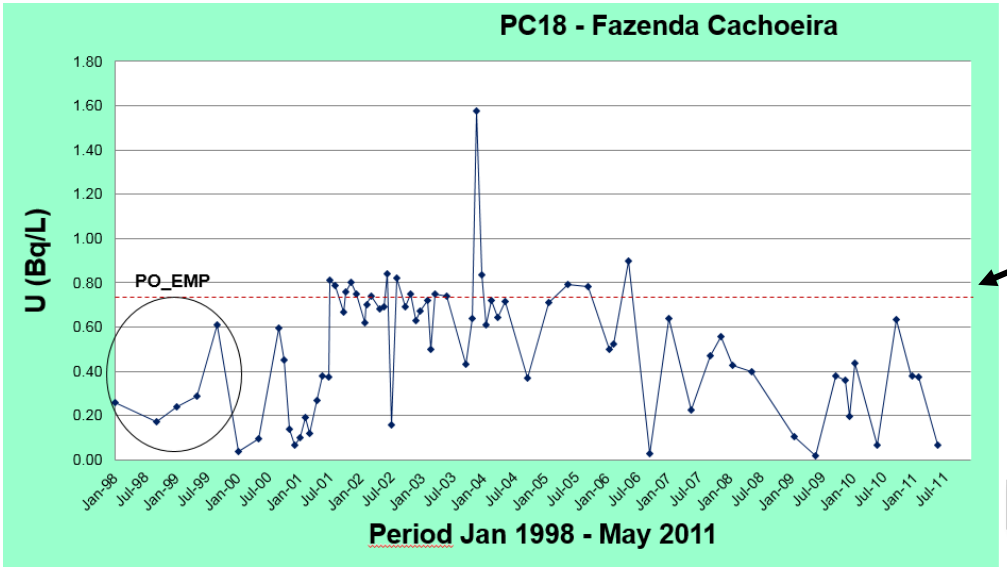
Surrounding communities (indirect influences of URA)

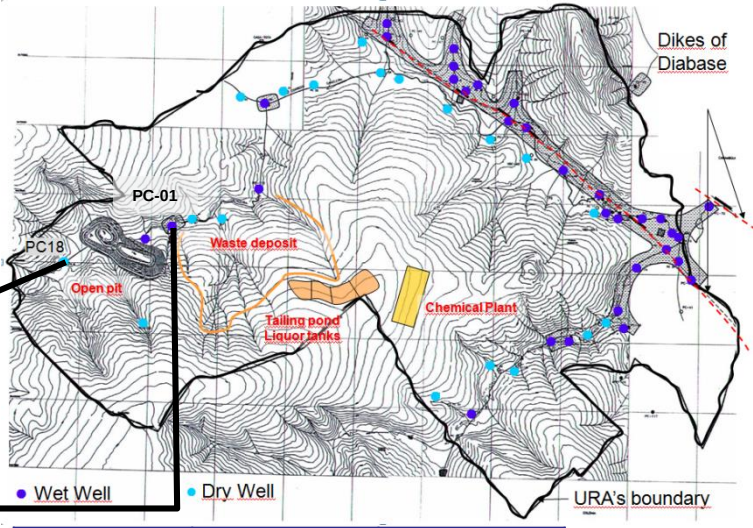
Source data: mining company – INB monitoring program (^{238}U, ^{226}Ra, ^{228}Ra, ^{210}Pb, ^{232}Th)

GW assessment - direct influence of the URA



Upstream the open pit

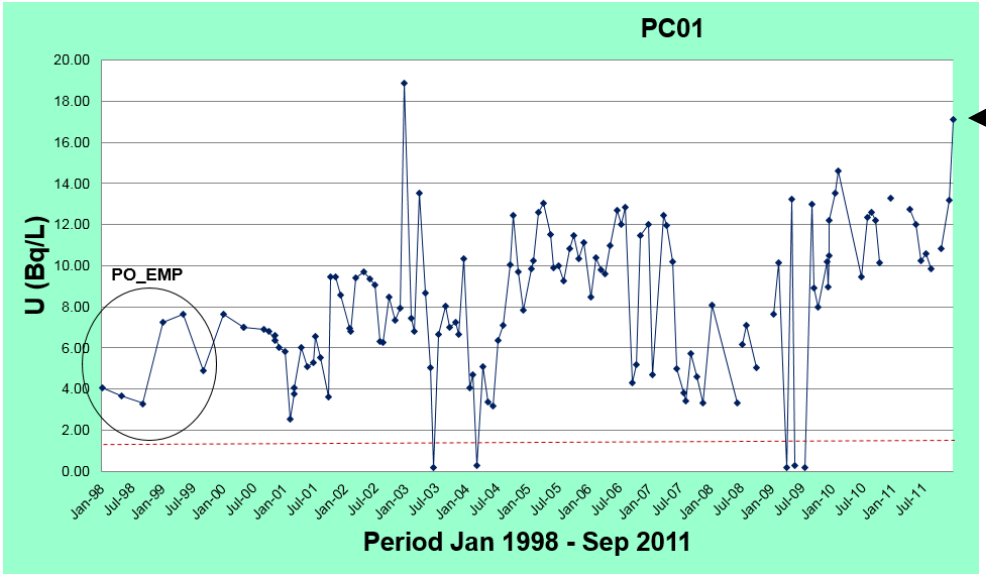




	Bq/L	mg/L
N	72	72
Min	0.017	0.001
Max	1.574	0.062
Mean	0.502	0.020
Median	0.539	0.021

$Dose_{PC18}$ → 0.17 mSv/y

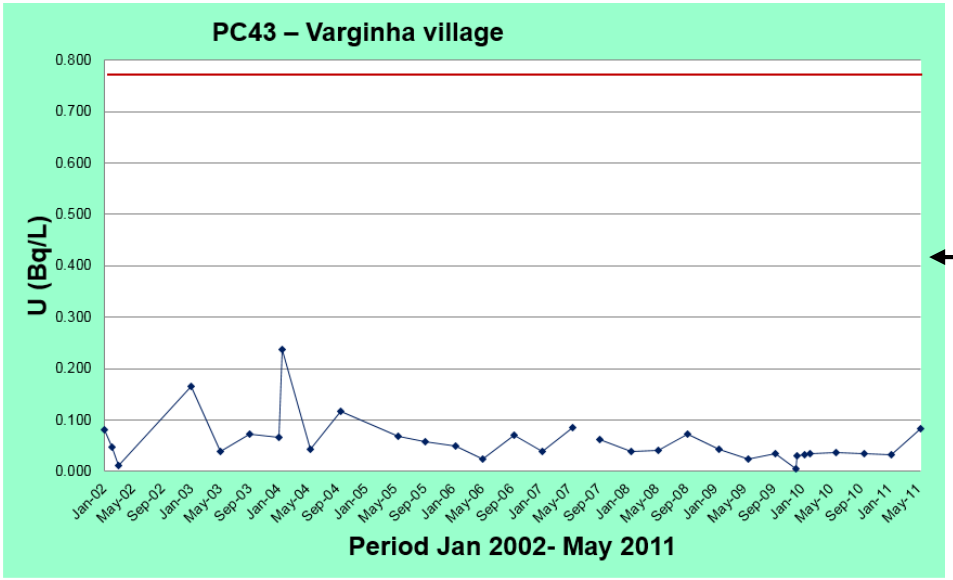
Downstream the open pit

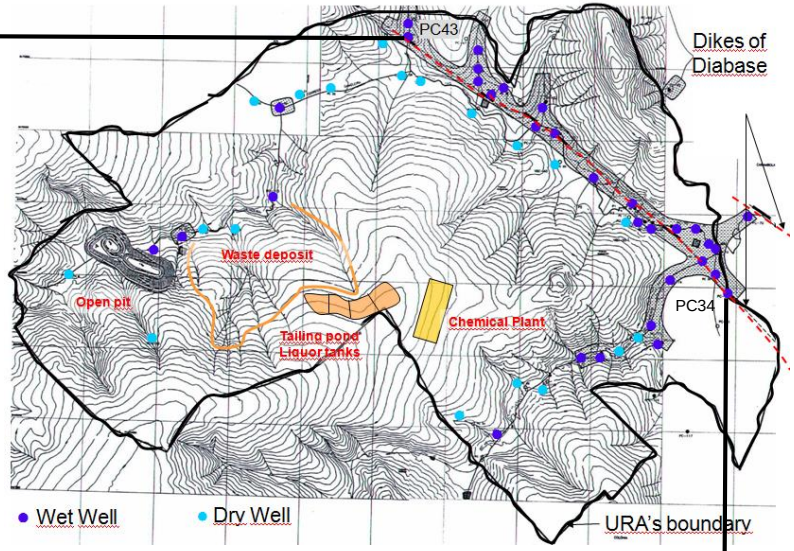


	Bq/L	mg/L
N	131	131
Min	0.17	0.01
Max	18.87	0.74
Mean	8.18	0.32
Median	8.03	0.31

$Dose_{PC01}$ → 0.50 mSv/y

Varginha village

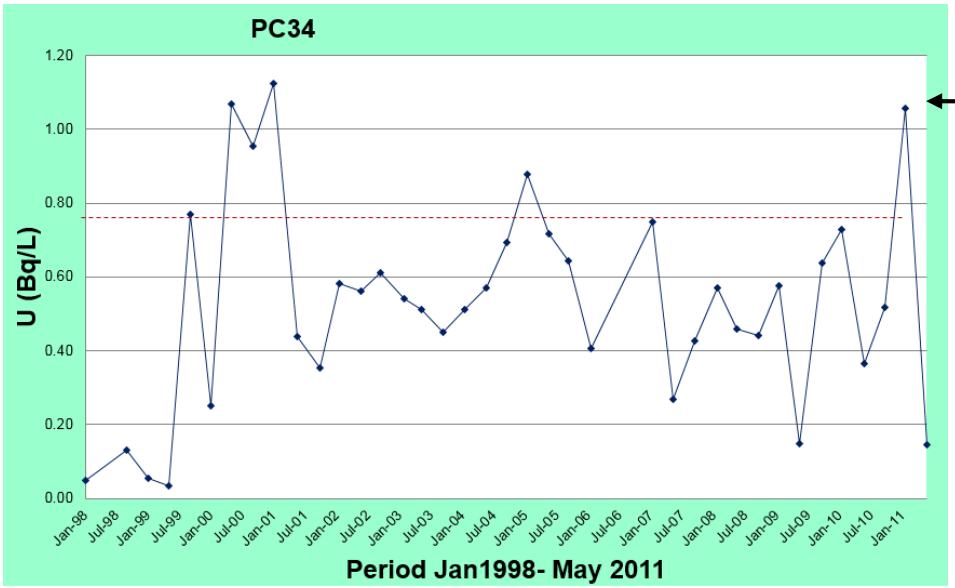




	Bq/L	mg/L
N	32	32
Min	0.0055	0.0002
Max	0.2367	0.0093
Mean	0.0586	0.0023
Median	0.0431	0.0017

$Dose_{PC43}$ → 0.06 mSv/y

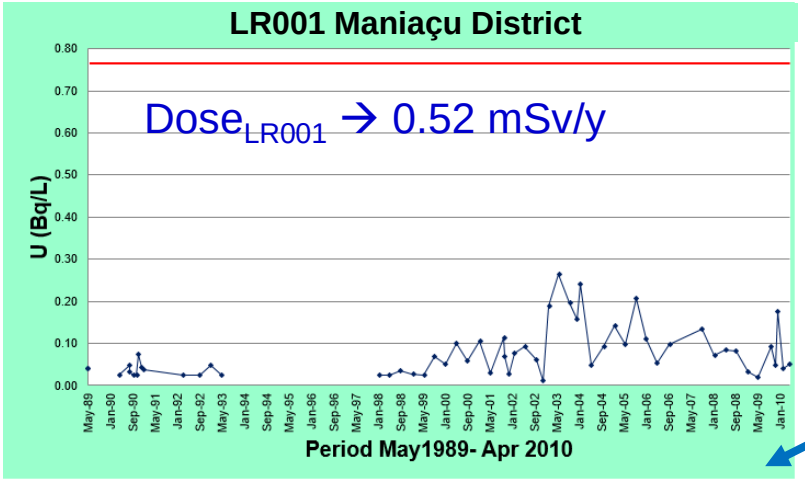
Outflow of the CEB

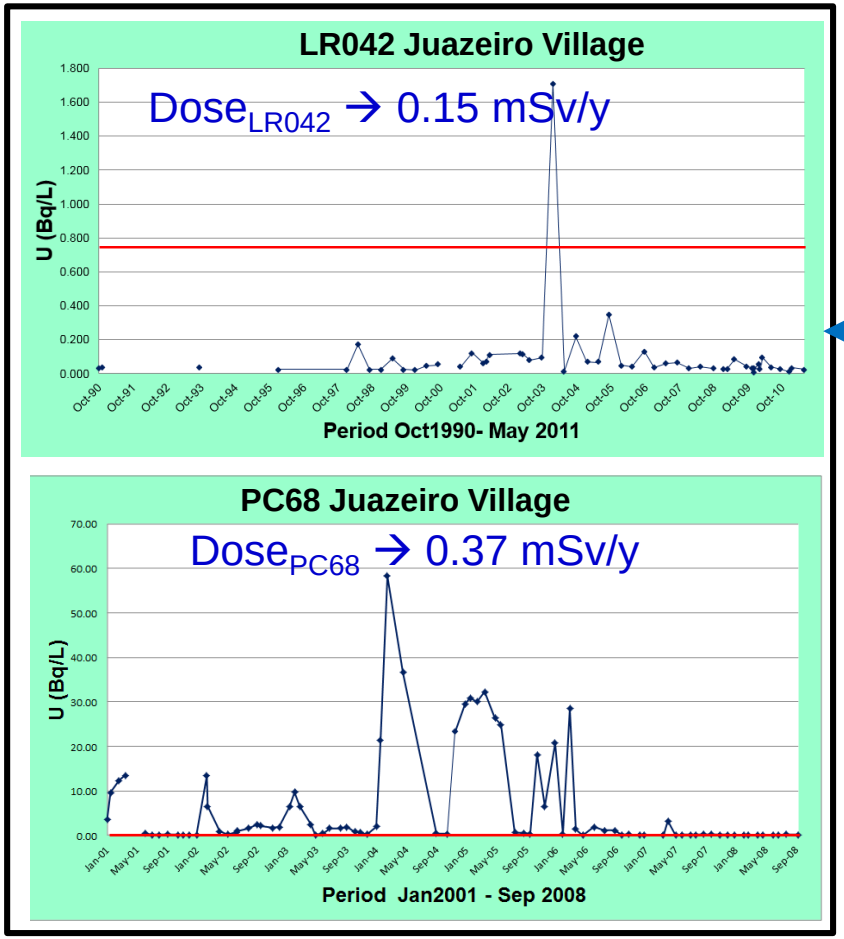


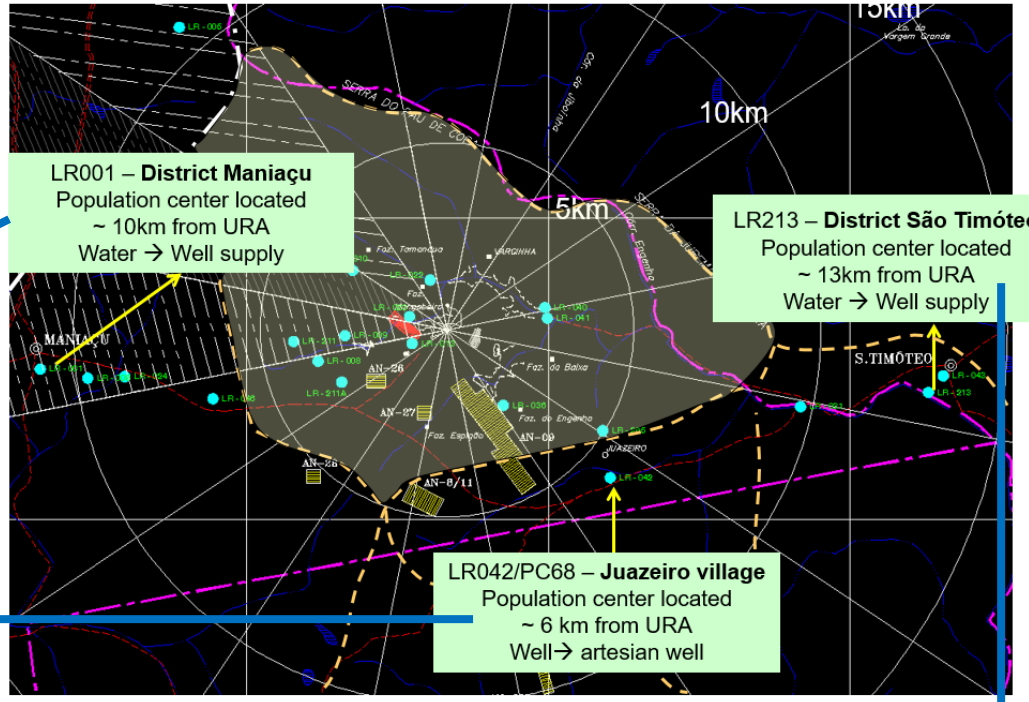
	Bq/L	mg/L
N	38	38
Min	0.034	0.001
Max	1.124	0.044
Mean	0.526	0.021
Median	0.528	0.021

$Dose_{PC34}$ → 0.15 mSv/y

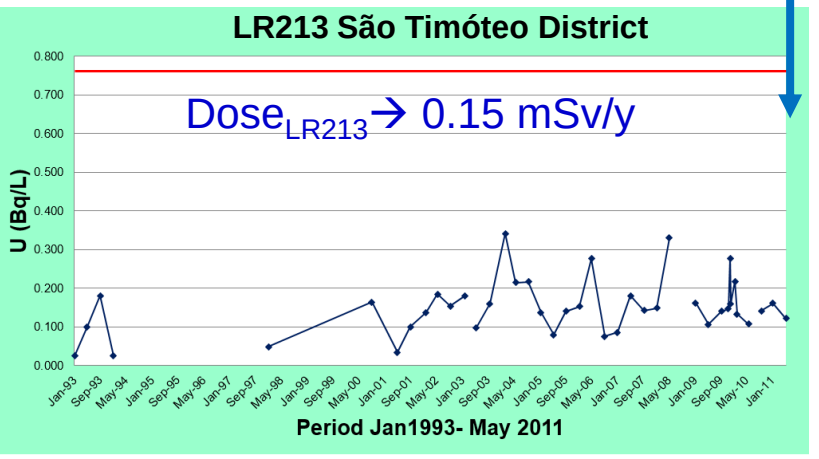
GW assessment → indirect influence of the URA



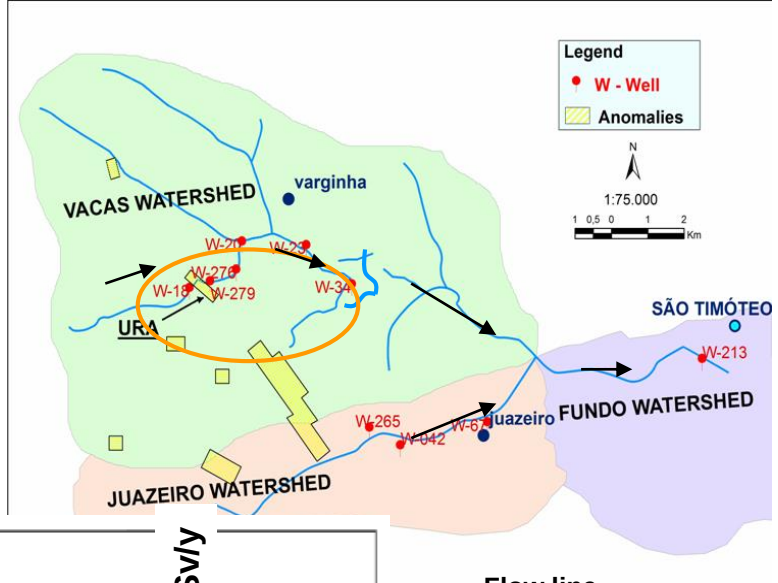


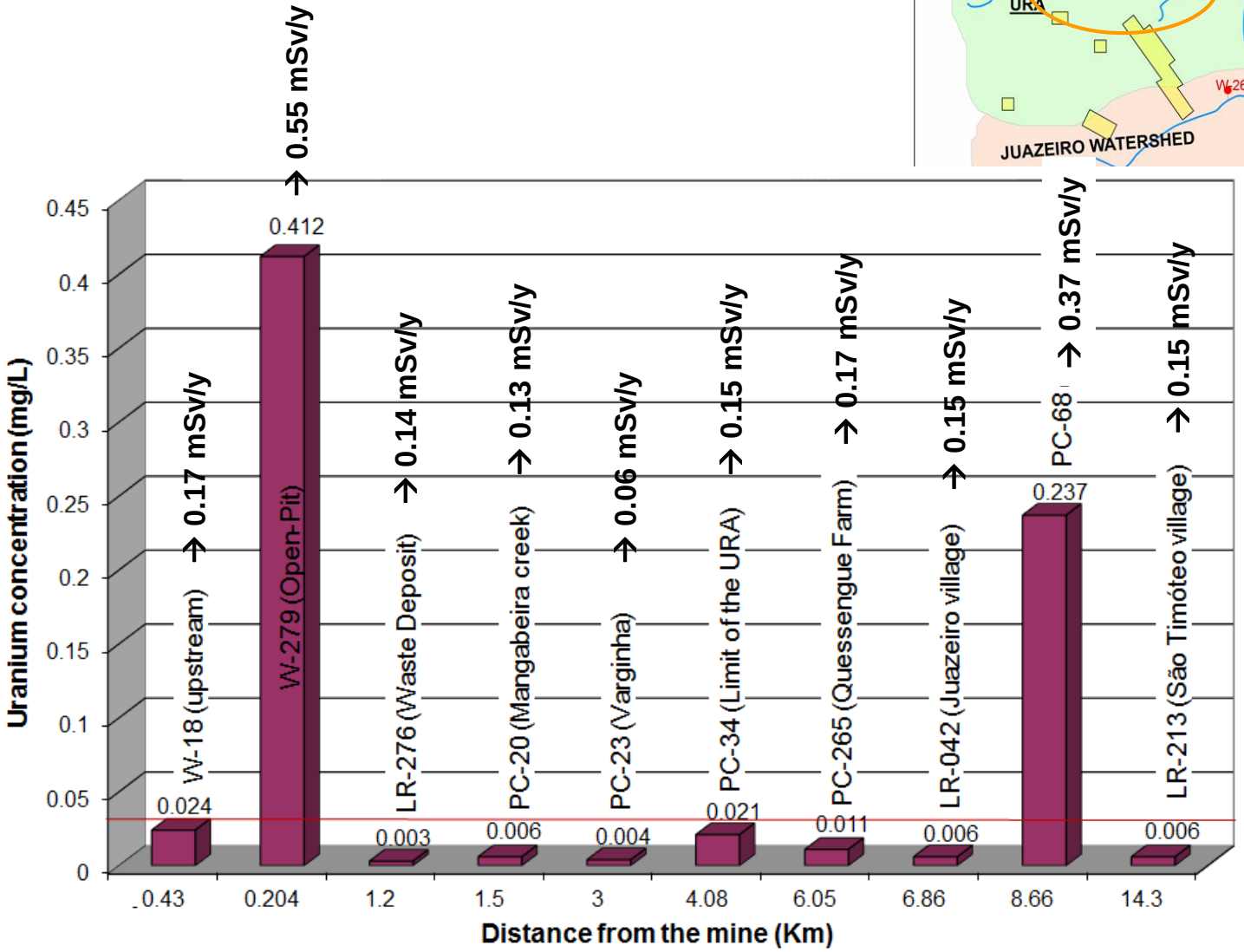


Uranium anomalies (36? Mapped – 1200 km^2)



Summary


Legend
W - Well
Anomalies
1:75.000
VACAS WATERSHED
varginha
URA
W-18
W-279
W-276
W-34
SÃO TIMÓTEO
W-213
Juazeiro
FUNDO WATERSHED
W-265
W-042
JUAZEIRO WATERSHED
Flow line


Uranium concentration (mg/L)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
W-18 (upstream) → 0.17 mSv/y
0.024
W-279 (Open-Pit) → 0.55 mSv/y
0.412
LR-276 (Waste Deposit) → 0.14 mSv/y
0.003
PC-20 (Mangabeira creek) → 0.13 mSv/y
0.006
PC-23 (Varginha) → 0.06 mSv/y
0.004
PC-34 (Limit of the URA) → 0.15 mSv/y
0.021
PC-265 (Quessengue Farm) → 0.17 mSv/y
0.011
LR-042 (Juazeiro village) → 0.15 mSv/y
0.006
PC-68 → 0.37 mSv/y
0.237
LR-213 (São Timóteo village) → 0.15 mSv/y
0.006
0.43
0.204
1.2
1.5
3
4.08
6.05
6.86
8.66
14.3
Distance from the mine (Km)

MAC

Dose Calculation and Risk Analysis

Methodology

29 wells used by the population
14 villages
506 samples

Source data: mining company – INB monitoring program

Ba, Fe, Al, Mn, F, NO_3, NO_2, Zn, U-nat

^{238}U, ^{234}U, ^{226}Ra, ^{228}Ra, ^{210}Pb, ^{232}Th

We use a screening approach:

This approach comprises:

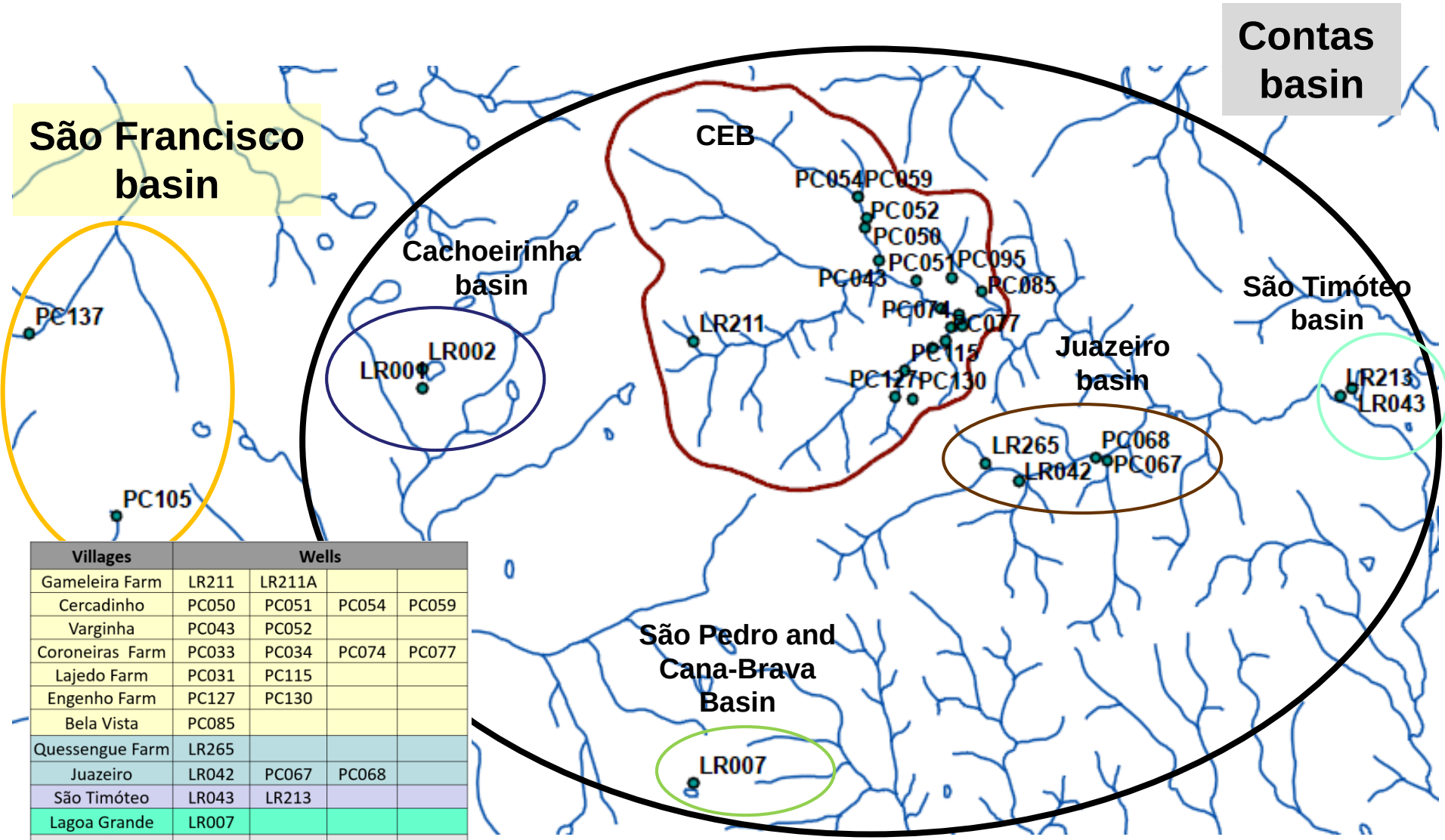
- **CONSERVATIVE** – Overestimate the exposure →identify contaminants and exposure pathways that have a **low priority for further investigations.**
- **NON-CONSERVATIVE** – "Realistic" exposure → identify contaminants and pathways that would have a **high priority for further investigations.**

	Conservative	Non-Conservative
Concentration distribution	UCL95%	Mean
Water ingestion rate (L/day)	2	1
Exposure time (showering- hours/day)	0.30	0.15
Meat Ingestion Rate (Kg/day)	0.082	0.041
Milk Ingestion Rate(L/day)	0.164	0.082
Vegetable Ingestion Rate (Kg/day)	0.548	0.274

Radioactive and nonradioactive pollutants:

- **Non-carcinogenic → Hazard Index (HI) = 1** was used as the noncarcinogenic screening criteria (HI is the ratio of the daily intake of the contaminant and the Reference Dose);
- **Carcinogenenic → Dose of 1 mSv/year** was used as the screening criteria to distinguish between low priority, potentially high priority and high priority contaminants and pathways.

Localization of wells by villages



Villages	Wells			
Gameleira Farm	LR211	LR211A		
Cercadinho	PC050	PC051	PC054	PC059
Varginha	PC043	PC052		
Coroneiras Farm	PC033	PC034	PC074	PC077
Lajedo Farm	PC031	PC115		
Engenho Farm	PC127	PC130		
Bela Vista	PC085			
Quessengue Farm	LR265			
Juazeiro	LR042	PC067	PC068	
São Timóteo	LR043	LR213		
Lagoa Grande	LR007			
Maniaçu	LR001	LR002	LR301	
Olho D'agua	PC105			
Pinga	PC137			

Analysis of non-radioactive pollutants

Potentially high priority HI>1.0

- **Contaminants: Ba, Fe, Al, Mn, F, NO_3, NO_2, Zn, Unat**
- **Exposure pathways: water ingestion, dermal contact, milk and meat ingestions**

		Adult exposure Water Ingestion	
	Villages	CONSERVATIVE	NON-CONSERVATIVE
Rio de Contas Basin	CEB – Gameleira	Ba	
	CEB – Cercadindo	-	
	CEB – Varginha	-	
	CEB – Coroneira	F	
	CEB – Lajedo	Mn, Fe, F	
	CEB – Engenho	NO_3	
	CEB – Bela Vista	F, NO_3	
	Quessenguê	F	
	Juazeiro	F, U_{nat}, NO_3	
	São Timóteo	-	
	Lagoa Grande	Al	
	Maniaçu	NO_3	NO_3
São Francisco Basin	Olho D´água	-	
	Pinga	-	

Analysis of radioactive pollutants

Radionuclides: U_{238}, U_{234}, Ra_{226}, Ra_{228}, Pb_{210}, Th_{232}

Villages	Dose (mSv/year)	
	CONSERVATIVE	NON- CONSERVATIVE
Gameleira	0.74	0.47
Varginha	0.09	0.04
Coroneira	0.20	0.13
Lajedo	0.15	0.11
Quessenguê	0.23	0.14
Juazeiro	0.53	0.27
São Timóteo	0.19	0.13
Maniaçu	0.69	0.53
Olho d`agua	0.18	0.10
Pinga	0.12	0.07

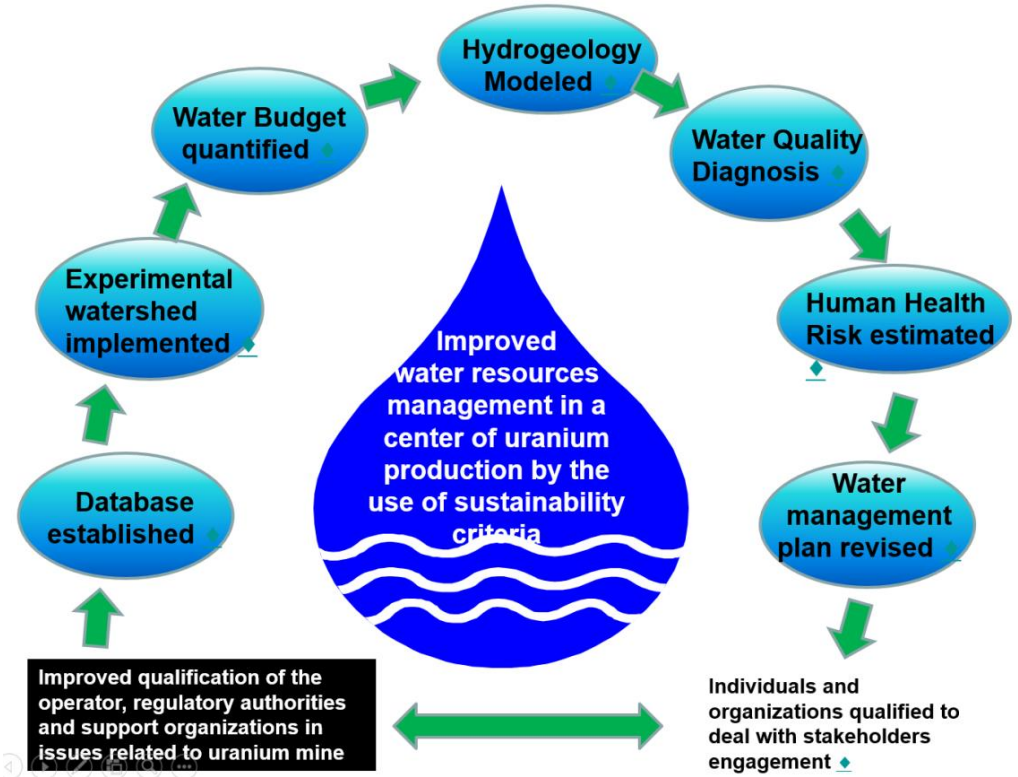
Conclusion 1.1

- The geologic framework of the CEB works as a barrier to the flow (limiting contamination);
- The dynamic of water in the CEB depends on a complex system of fracture connection (not all wells in the basin are connected to each other).
- In mineralized areas, when we analyze the constituents of groundwater, it is not always possible to distinguish what is of anthropogenic origin and what is natural:
  - Most wells show natural variation in uranium concentration over time;
  - **CEB:** PC-01 ($r^2=0.15$) and PC-29 ($r^2=0.20$) showed a weak tendency of increase in uranium concentration over time;
  - **Surrounding areas:** The high uranium concentrations found in some wells in Juazeiro village (PC-68) reflect natural geochemical processes and not the influence of the URA activities.

Conclusion 1.2

- Temporal variations in rainfall and in the hydrodynamic patterns (pumping regime) may affect the radionuclides concentration and should be investigated in more detail;
- All the estimated doses are below 1mSv /a (associated with low risk);
- However, several wells show uranium concentrations above the maximum allowable limit, taking into account only the chemical toxicity of this radionuclide.
- Analysis of non-radioactive pollutants show that only nitrate was identified as a high priority pollutant.

National Project – BRA7010
Sustainable Water Resources Management in an Uranium Production



Thank you for your attention !!!!!

Team – Field trip July/2012