



PHD RESEARCH PROGRESS

***Assessing of the impact of on-site sanitation on man-induced recharge and groundwater quality in the Thiaroye aquifer of Dakar, Senegal.***  
***DIAW Mor Talla, UCAD, Senegal***



*Third international AfriWatSan Stakeholders Workshop Kisumu, Kenya*

## **Main Objective**

**Assessing of chemical and microbiological faecal contamination and hydrodynamics processes related to the impact of on-site sanitation**

**1**

**Assess the contribution of on-site sanitation to groundwater-level dynamics (hydrodynamic regional model) ;**

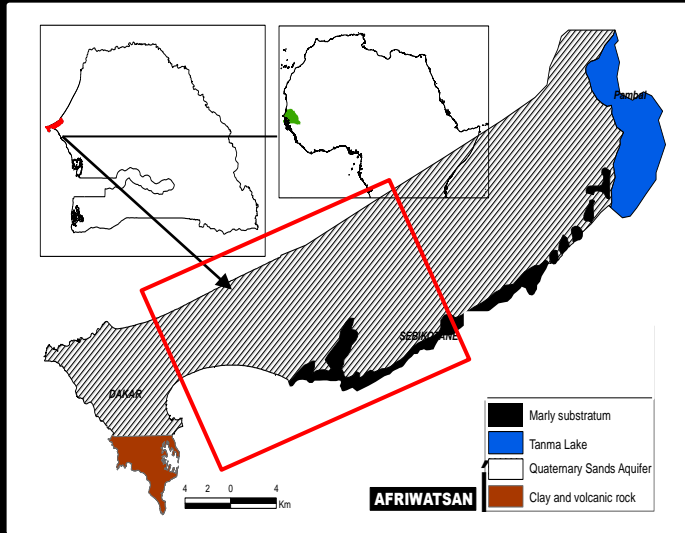
**2**

**Assess the pathways and processes of chemical and microbiological contamination (transport models in miniature, statistics and multi-criteria models) ;**

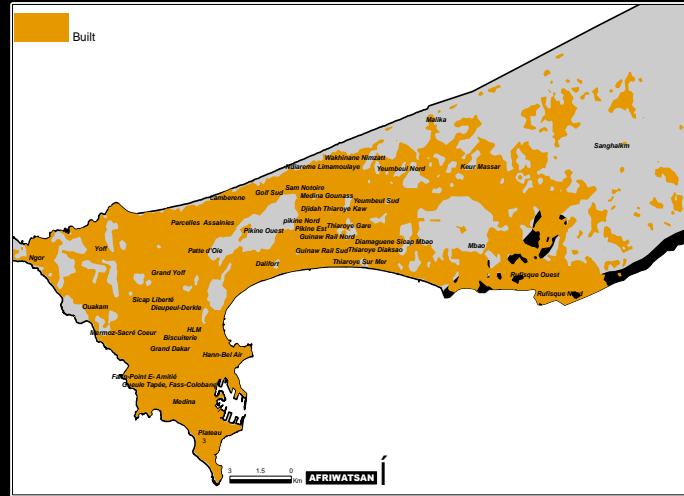
**3**

**Assess variations in faecal contamination of groundwater using hydrochemical and microbiological indicators ( $\text{NO}_3$ ,  $\text{PO}_4$ , *E.coli*) and their relationship to human health outcomes.**

# Thiaroye aquifer (Dakar) & a low-income on-site sanitation area

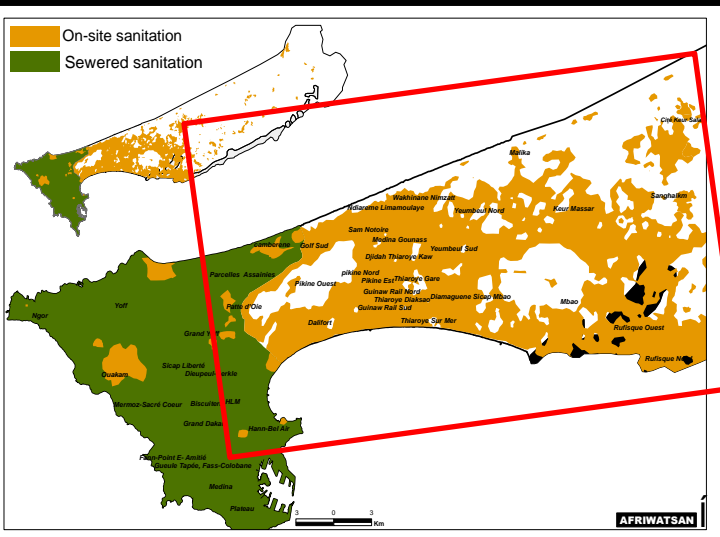


Shallow aquifer, Quaternary sands aquifer, Extreme west of Senegal



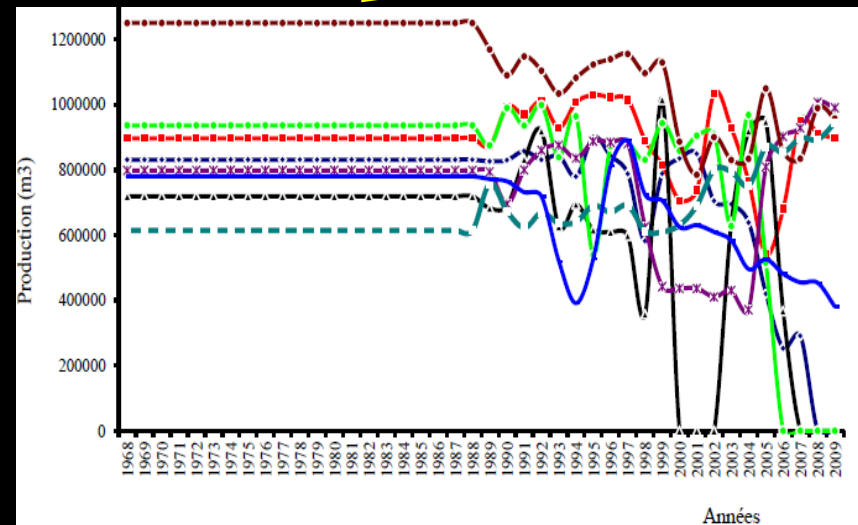
built occupying about 80% of the total area of the urban area

- Aquifer used to account for 10% of the Dakar ' S water supply  
High contamination (NO<sub>3</sub>, Cl) → Supply borehole stops (2008)

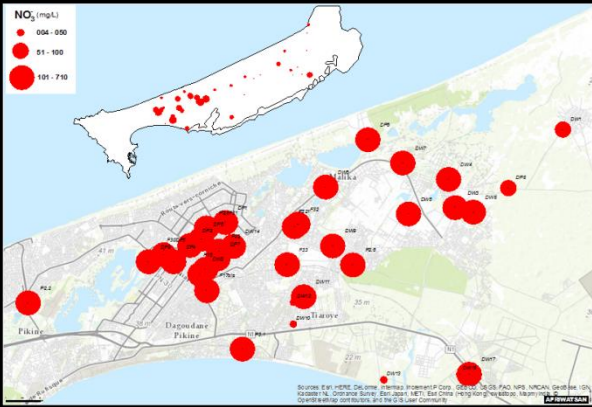


on-site sanitation (septic tanks)

Coverage rate (90 - 95%)

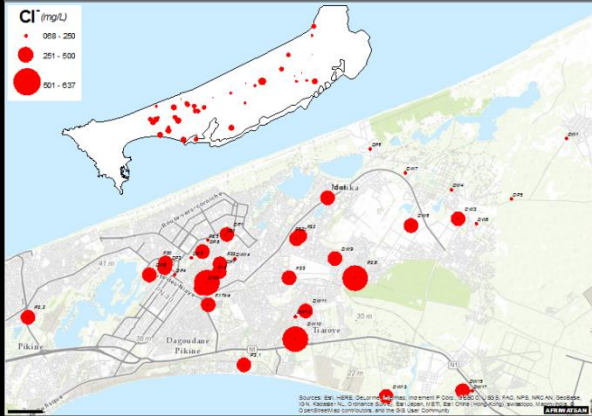


# Hydrochemical and microbiological results

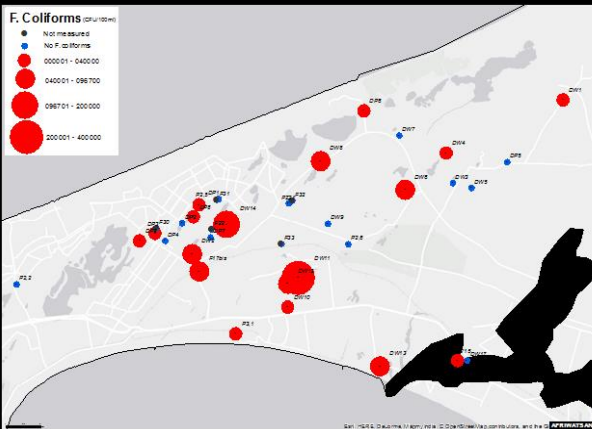


53 % wells > 50 mg/L

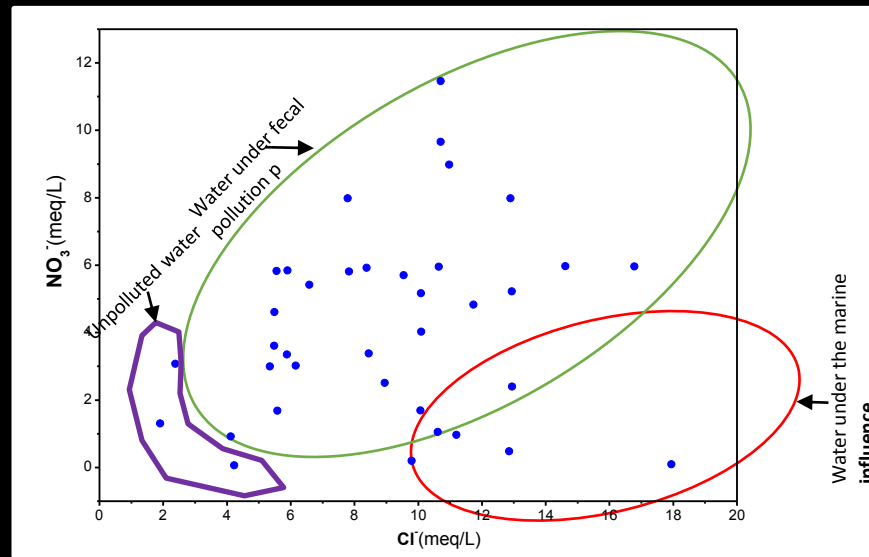
Max 710 mg/L



60 % wells > 250 mg/L

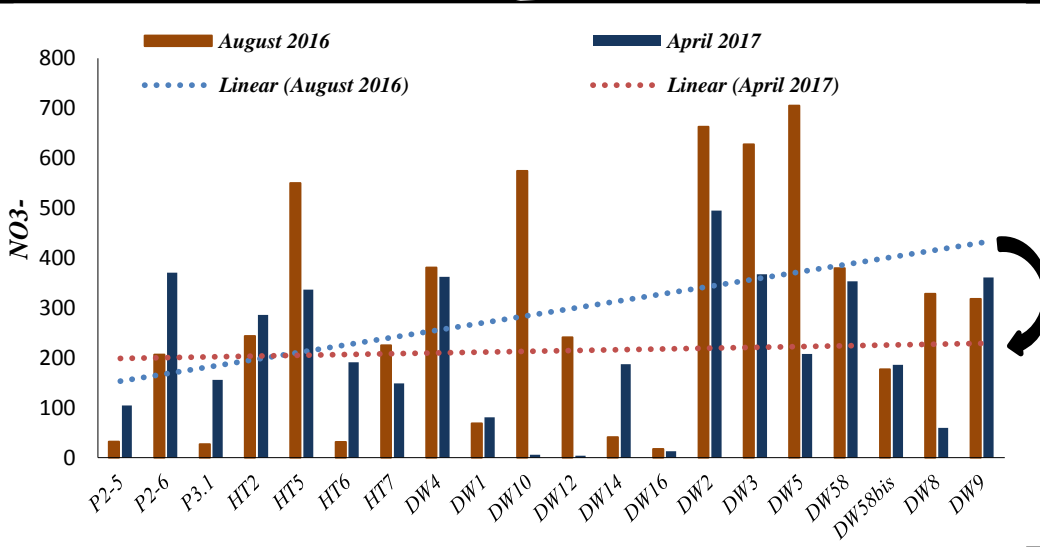


70 % wells > 1 CFU /100 mL



Large number of sites affected by faecal contamination infuced by marine intrusion

- Increase in contamination caused by single injection of septic tanks
- Recharge of rainfall origin Lowers contamination



# On-site sanitation key input (Sanitation facilities)

❑ **Advanced spatial tool for determining the number of septic tank /pit**

- ✓ **Census of the sanitized district communities** *“Actualisation du Plan Directeur d'Assainissement Liquide de Dakar 2025 »*
- ✓ **Object-oriented classification of the Quickbird satellite image (2016)**
- ✓ **3 Auxiliary high resolution satellite image**

<b>Data type</b>	<b>acquisition</b>	<b>Source</b>	<b>Résolution</b>
Satellite image	2003	QuickBird	0.70 (pan-shapping...
Satellite image	2009	Orbview	1.60
HR satellite image	2012	Geoeye	0.60



**SEGMENTATION**



**CLASSIFICATION**



**VALIDATION**

# On-site sanitation input (Sanitation facilities)

Advanced spatial tool for determining the number of septic tank/pit

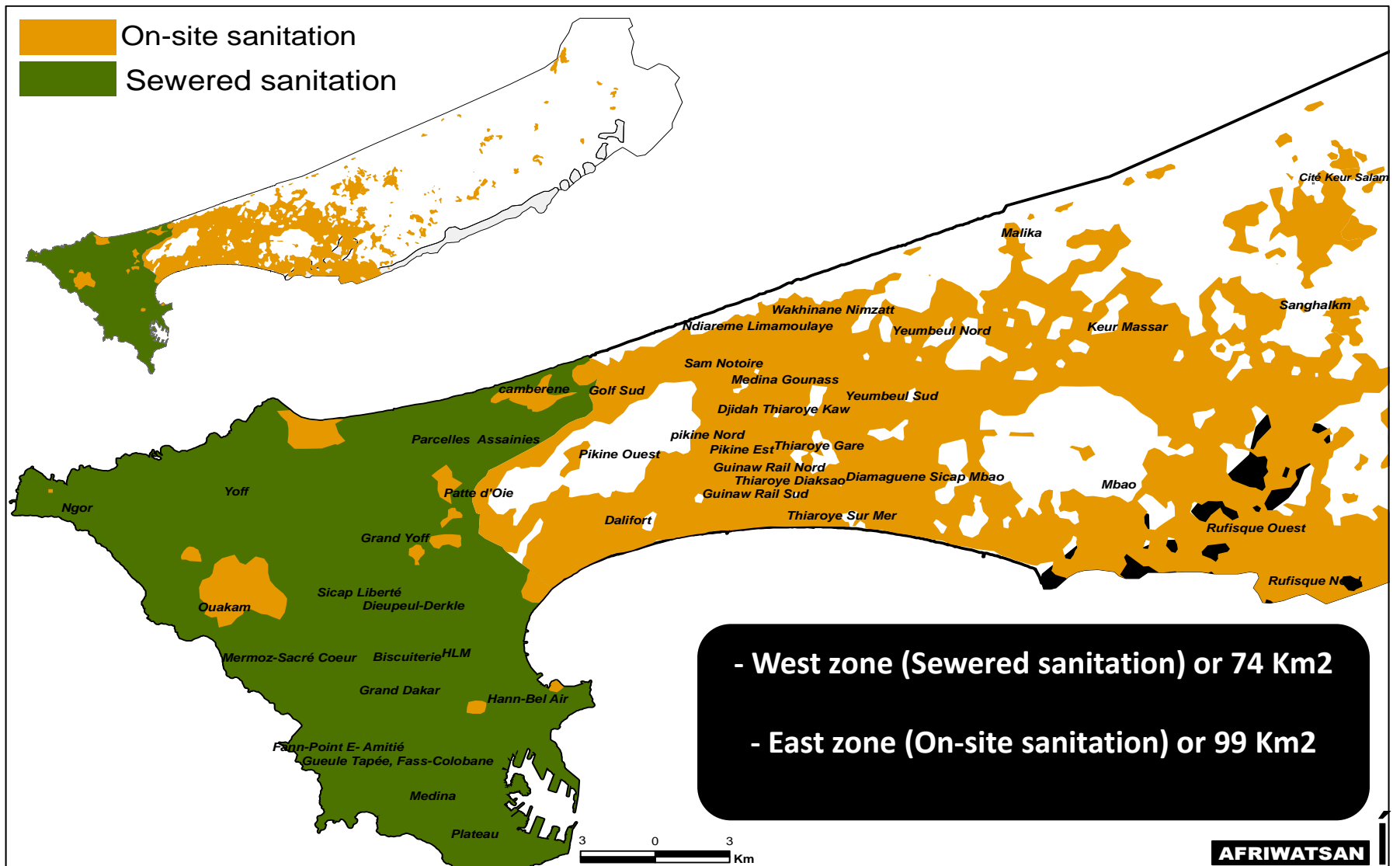
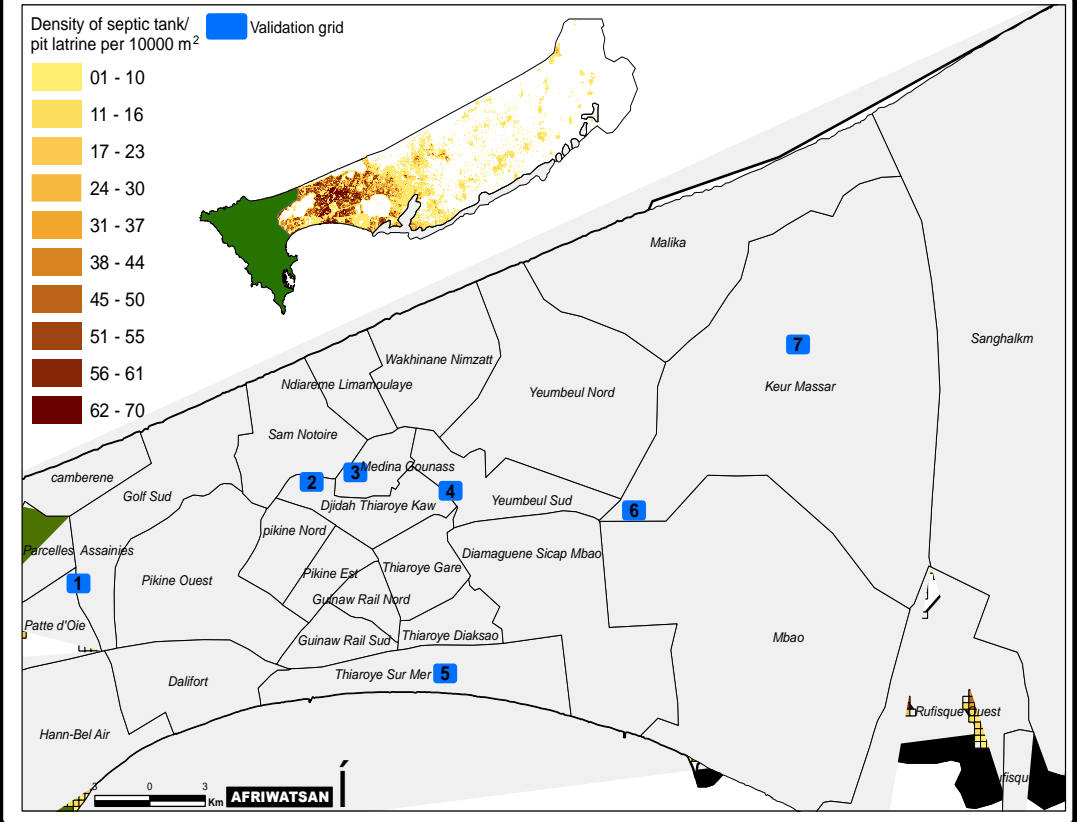
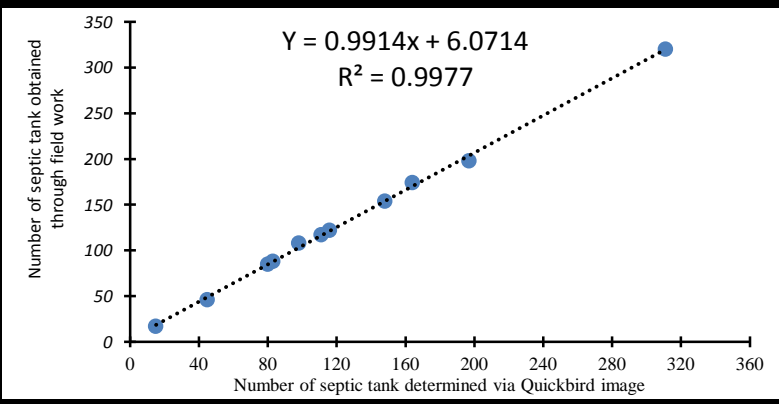
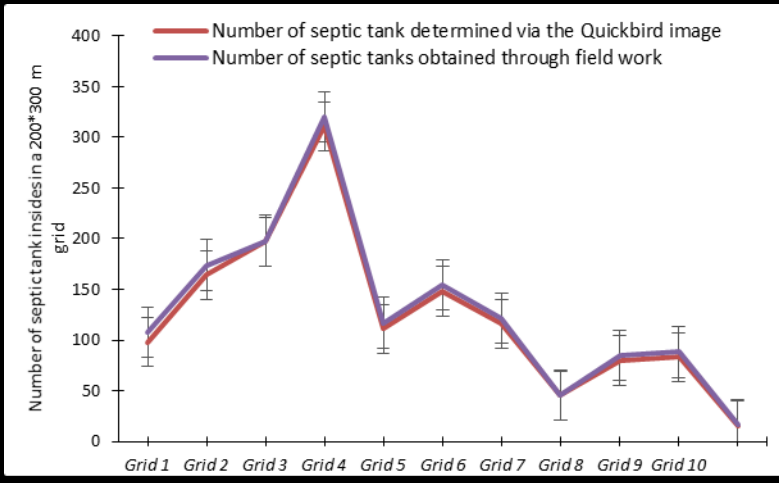


Fig 1: Distribution of sanitation type (DIAW,2017)

# On-site sanitation key input (Sanitation facilities)

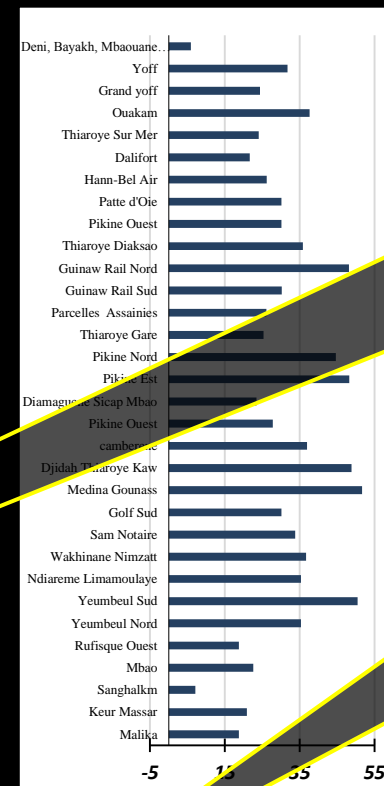
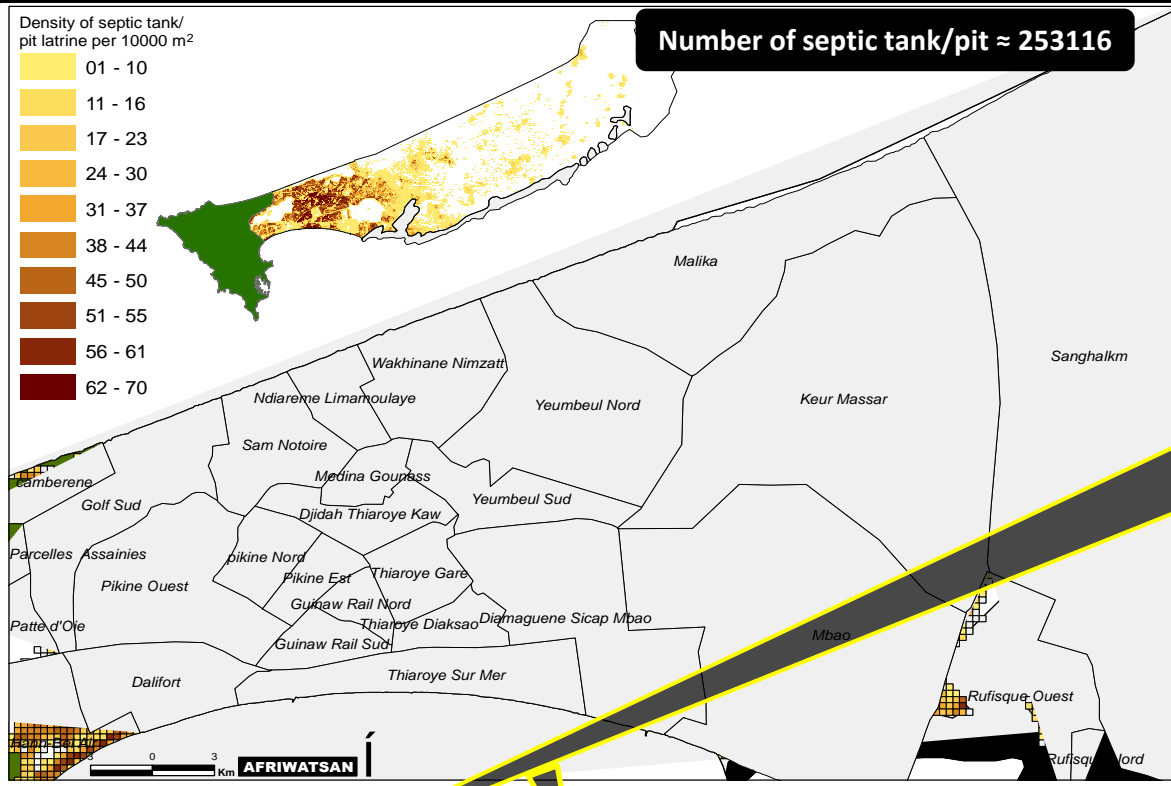
## Advanced spatial tool for determining the number of septic tank/pit

- ✓ **A 100x100 m grid** at the scale of the aquifer
- ✓ **In densely built areas (Spectral and textural characteristics)/size of house**
- ✓ **In low-built areas (Visual interpretation of Geoeye image)**
- ✓ **10 grids of 300 x 200 m for validation**



# On-site sanitation input (Sanitation facilities)

Advanced spatial tool for determining the number of septic tank



High septic tank/pit density in the urban area (overcrowding)

Low septic tank/pit density in the peri-urban area

Fig 2: Density of septic tank or pit (DIAW, 2017)

Fig 3 Average density of septic tank or pit

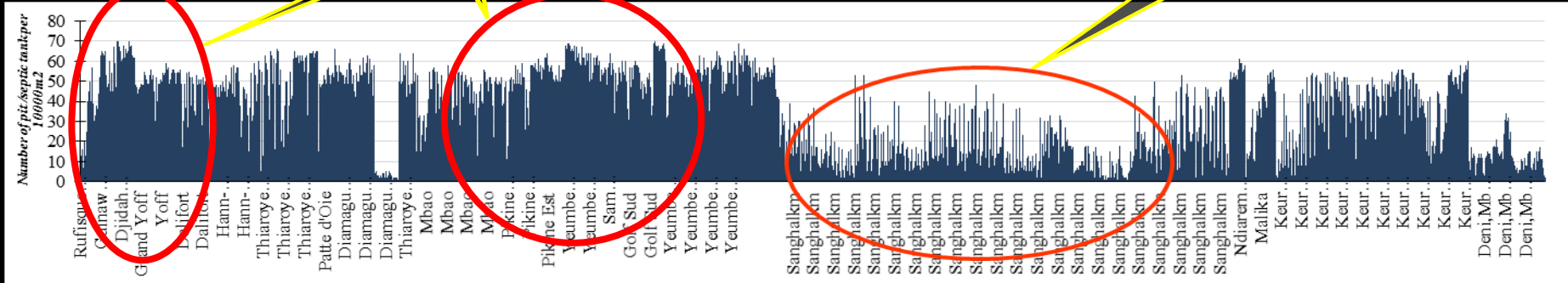
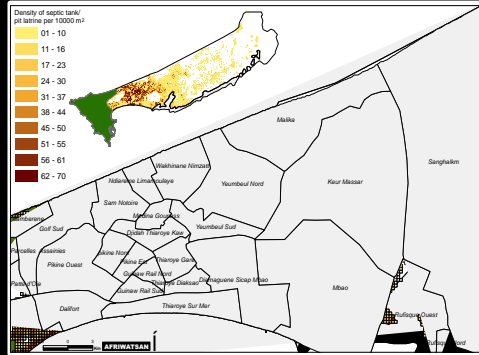


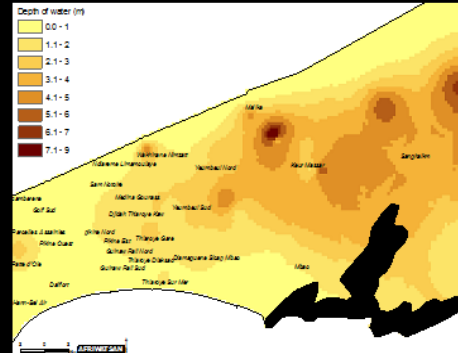
Fig 4: Density of septic tank or pit per district community (DIAW, 2017)

# OBJECTIVE II : ASSESSING THE CONTAMINATION PROCESSES

## Multi-criteria model of vulnerability of aquifer to fecal contamination



Density of septic tank/pit (L1)



Depth of the water (L2)

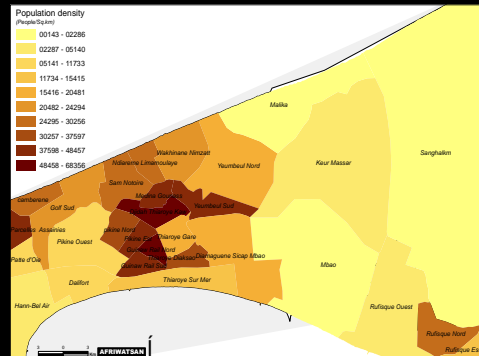
Permeability (OMS,1972 ; Seck,1989)

Not available now

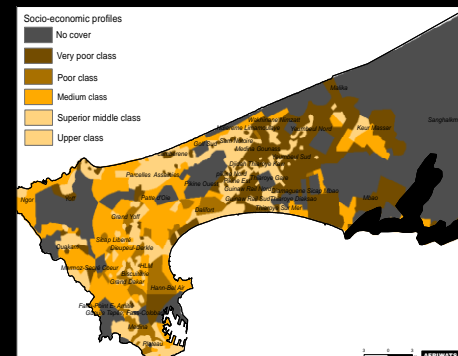
Permeability (L7)

### Criteria

- Density of septic tank/pit (L1)
- Groundwater level (L2)
- Living standards (L3)
- Population density (L4)
- Distribution of wetlands (L5)
- Housing typology (L6)
- Permeability (L7)



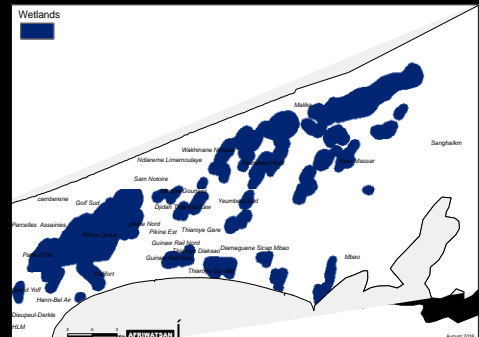
Population density (L4)



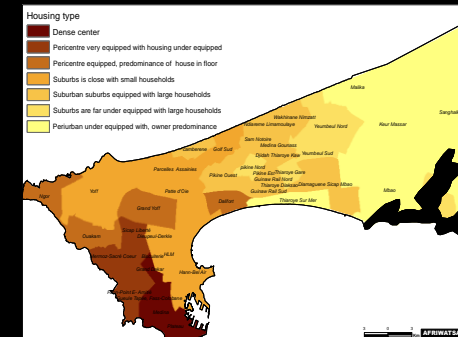
Living standard (L3)

Peer comparison techniques (Saaty,1977)

	L1	L2	L3	L4	L5	L6	L7
L1	1	-	-	-	-	-	-
L2	-	1	-	-	-	-	-
L3	-	-	1	-	-	-	-
L4	-	-	-	1	-	-	-
L5	-	-	-	-	1	-	-
L6	-	-	-	-	-	1	-
L7	-	-	-	-	-	-	1
Weights	-	-	-	-	-	-	-



Wetlands (L5)



Housing type (L6)

Each criteria (rating scale)

Classes	Level of risk	Scale
01	Very low vulnerability	1
02	Low vulnerability	2
03	Medium vulnerability	3
04	High vulnerability	4
05	Very high vulnerability	5

### RESULTS

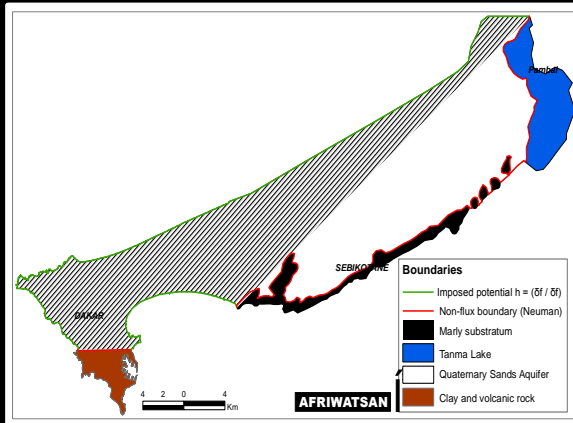
- Decisional maps and graphs of vulnerability of aquifer to faecal contamination
- History of the pollution state / Vulnerable Zones





# OBJECTIVE I : HYDRODYNAMISM AND SANITATION FAILURE

## Uptodating a regional model with **GMS** - *Water-Table Fluctuation models* -



- Contribution of injection of septic tank (Pumping) and salt intrusion

- **Boundary conditions**

- an imposed potential

- a no-flow (Neumann)

- an imposed flow

### □ (2/3) Recharge method estimation

1. Water-Table Fluctuation models
2. Injection rate of septic tank/pit
3. Rainfall recharge by isotopic method (O16, H2)

#### 1. Water-Table Fluctuation models (Curthbert & al., 2010)

$$h_t = h_{(t-\Delta t)} + \left( \frac{R_t - D_t}{S_Y} - s_t \right) \Delta t$$

$$R_t = \frac{S_Y (h_t - h_{(t-\Delta t)})}{\Delta t} + D_t + S_Y s_t$$

#### Piezometry (1948) and Tharoye bassin

- Distance from observation well to downstream perennial stream: **921.11 m**
- Characteristic distance from groundwater divide to perennial stream: **3812.99 m**
- Characteristic distance from lateral groundwater divide to ephemeral stream: **13888.4 m**

#### Input

- Specific yield: **15.5 %**
- Transmissivity: **24.3 m<sup>2</sup>/day**
- Potential evapotranspiration
- Precipitation

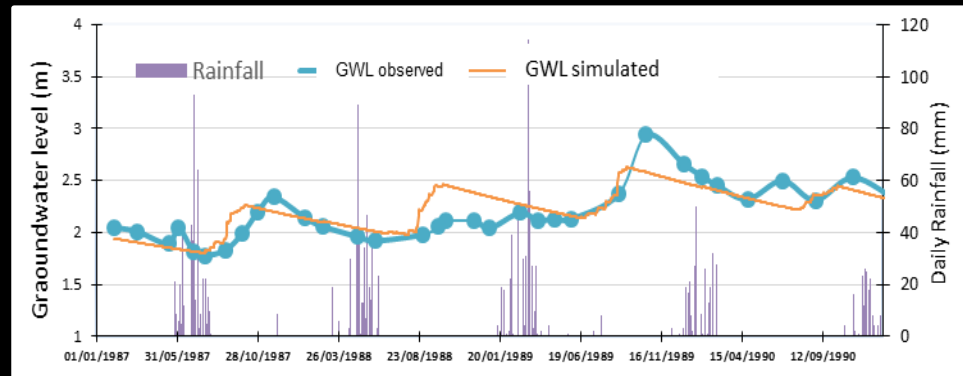


Fig 5: Correlation of simulated and measured heads (Forward Model)

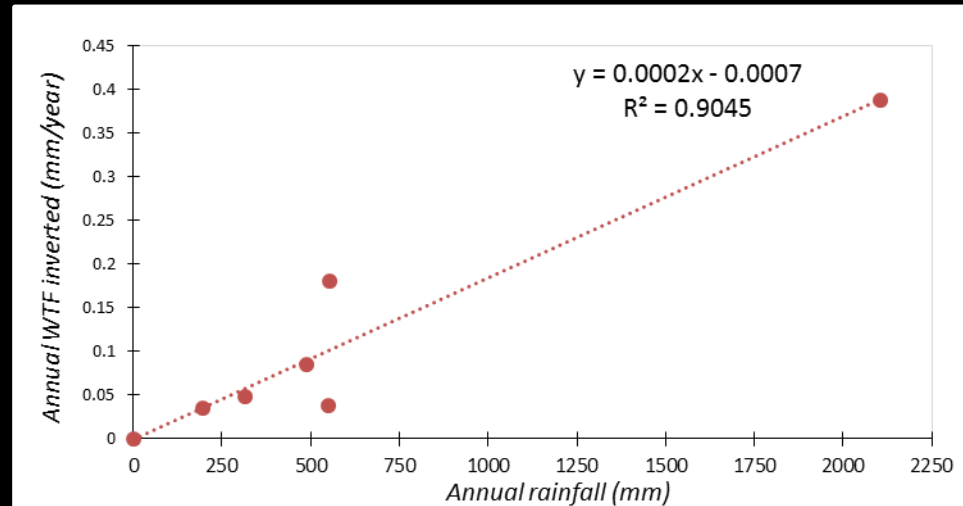


Fig 6 : Annual Determination Coefficient (Inverse Model)

## Results

$$R = 0.00001187P^2 + 0.17374P + 0.01629.$$

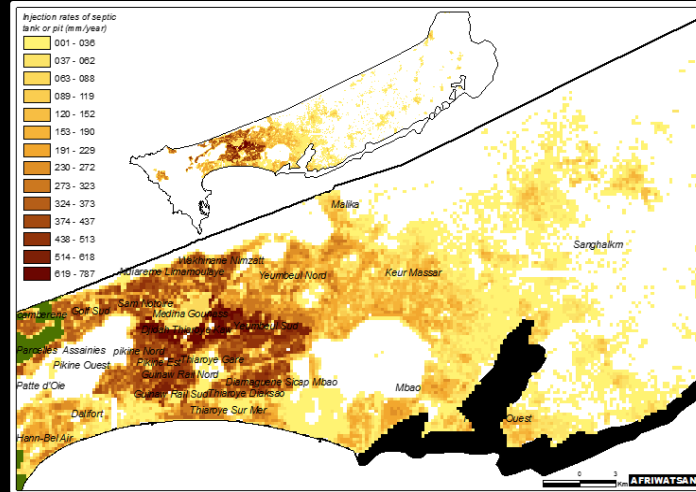
coefficient of determination of 0.905. In other words, Recharge is **17.3%** precipitation.

# OBJECTIVE I : HYDRODYNAMISM AND SANITATION FAILURE

Establish a regional model with **GMS** → *Injection rate of septic tank / pit estimation*

## 2. Injection rate of septic tank/pit

- the number of people per house on average [ANSD,2016;DIAW,2017]
- the consumption of water per people per day is 40 to 68 l / day [OCDE (2006/2007), ASME, 2014, SDE,2014].
- the proportion of water injected into the septic tank which could reach 71 % of the per capita consumption (BELGAQUA, 2008)
- the amount of urine injection which is 1.2 l / day (Mara, 1996)
- the runoff coefficient of 0.8 - 0.95 of cement mortar or cement concrete of the bottom of septic tank (AFNOR, 2013)



High injection rate in the urban area (Max : 787 mm/year)

Injection rates ( Peri-urban area) range from 3.4 to 183 mm / year.

Fig 6: Distribution of injection rate of septic tank at the level of Thiaroye aquifer

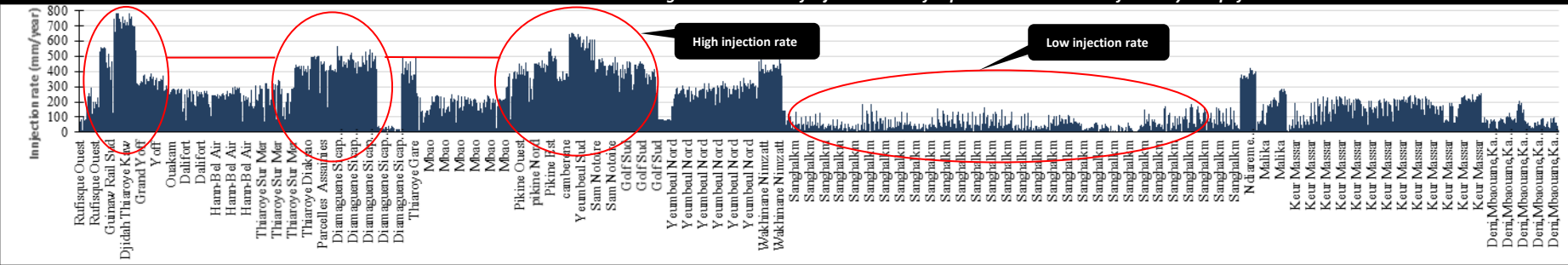


Fig 6: Distribution of injection rate of septic tank at the level of Thiaroye aquifer

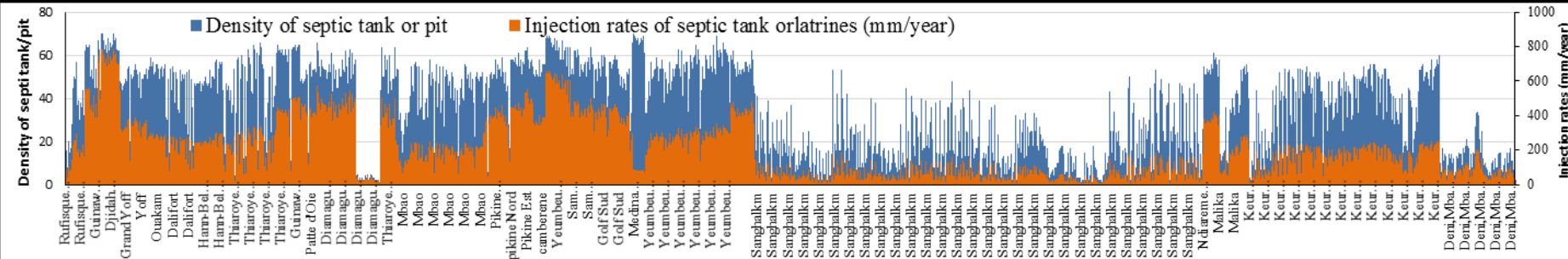


Fig 7: Distribution of injection rate of septic tank dépendant on their density at the level of Thiaroye aquifer

# OBJECTIVE II : ASSESSING THE CONTAMINATION PROCESSES

## Establishment of miniature model with **GMS**

Define a horizontal separation "Septic tank – supply source"

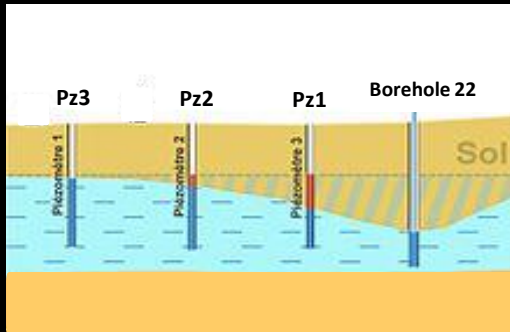
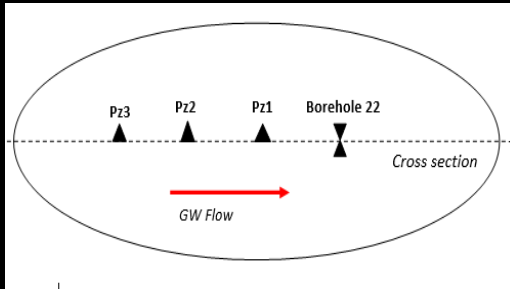
- Semi-analytical particle tracking method (MODPATH)

✓ The pilot site  $\leq 1$  or  $1.5$  km<sup>2</sup>    ✓ Meshing = 10 m    ✓ Recharge

Injection rates of septic tank/pit

Rainfall recharge (O18, H2)

## Construction of shallow piezometer array (3)



- Pumping test,

- Water level

- Tracer tests

key hydrogeological parameters and boundaries conditions

- A reconnaissance campaign of Hydrogeological team

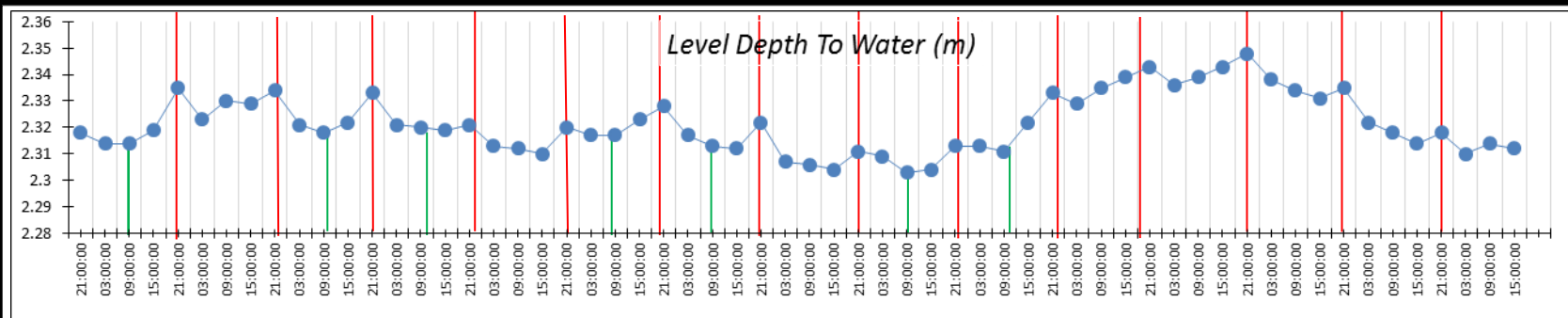


# OBJECTIVE III : Monitoring of fecal contamination indicators (NO3, PO4, E.coli) and Assessing the impact of water quality on human health

- P2.6 localisation ( Density of septic tank : 46 /10000 m2)

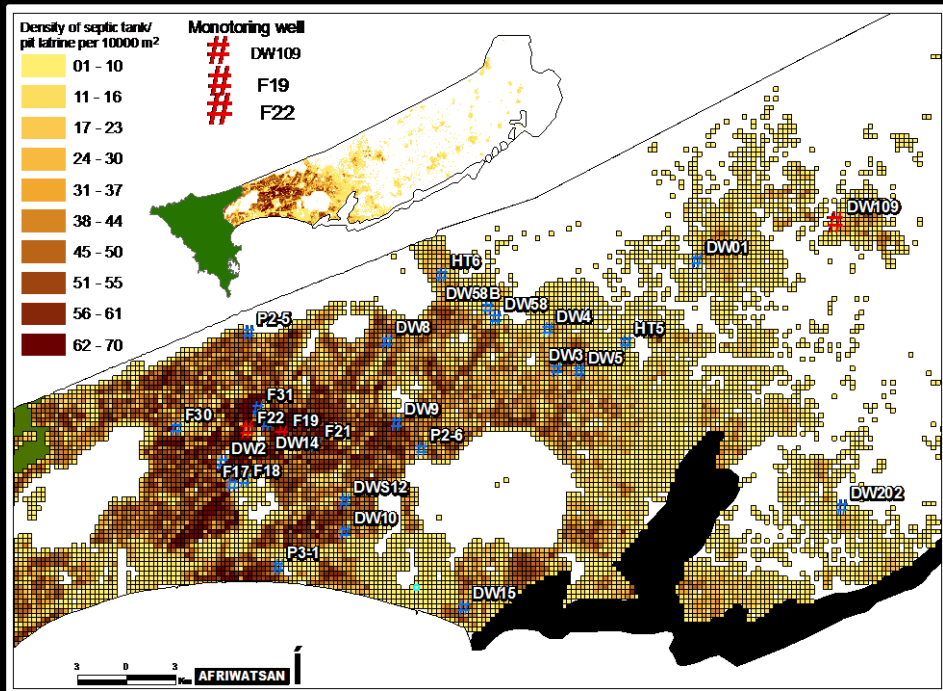
- Increase in level (9 → 21 h) → High injection rate (the day)  
 - Decrease in level (21 → 9 h) → Low injection rate (night)

Very shallow character



- Regular daily evolution

## Monitoring



- DW109, Piezometer (Low density of septic tank)  
 - New Piezometer (High density)

- Next DW109 (Low density)  
 - P2.6 (High density)

- Collection of PO4, NO3 and E.coli samples (Every 30 days)

Chemical evolution

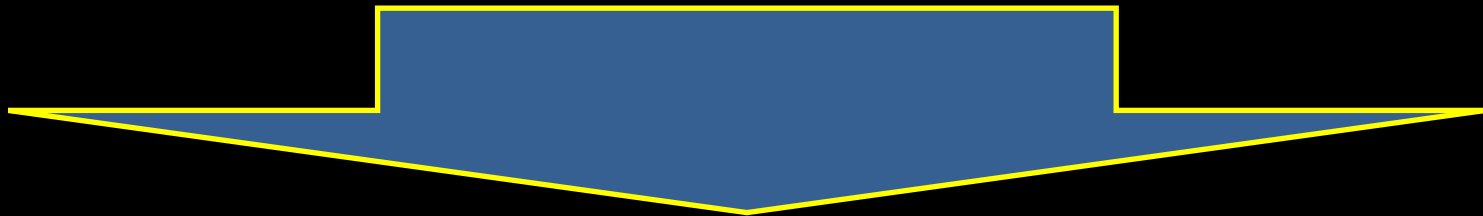
- Measurement of WTF during dry season for monitoring man induced recharge (Dataloggers)

Man-induced recharge processes

- Assessing the impact of water quality on human health

# Conclusion

- ✓ Vulnerability of the aquifer to faecal contamination in order to propose different types (*urine diversion, ecological latrines with compost, latrines on a mound, latrines perched*) according to the degree of Vulnerability
- ✓ Formulation of a "*Safe Distance*" which is a technical prescription crucial for any planner of ecological on-site sanitation systems
- ✓ The density of septic tanks or pit latrine adequate not to exceed the WHO standards recommended for drinking water (*Facilitate strategic orientations for the relevant government institution*)
- ✓ The impact of groundwater level and marine intrusion in the horizon (*t*) according to this scenarios :
  - Pumping at 100 % on-site sanitation coverage rate and Pumping with a diminution of coverage rate of on-site sanitation.



*All outcomes will serve not only as a model for other cities of the Senegal, which the impact of on-site sanitation is in the embryonic stage, but also for major cities of ECOWAS, sub-Saharan Africa and all over Africa.*

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