Appraisal of Groundwater Salinity Problems in Community Water Supply Boreholes in Dar es Salaam

by

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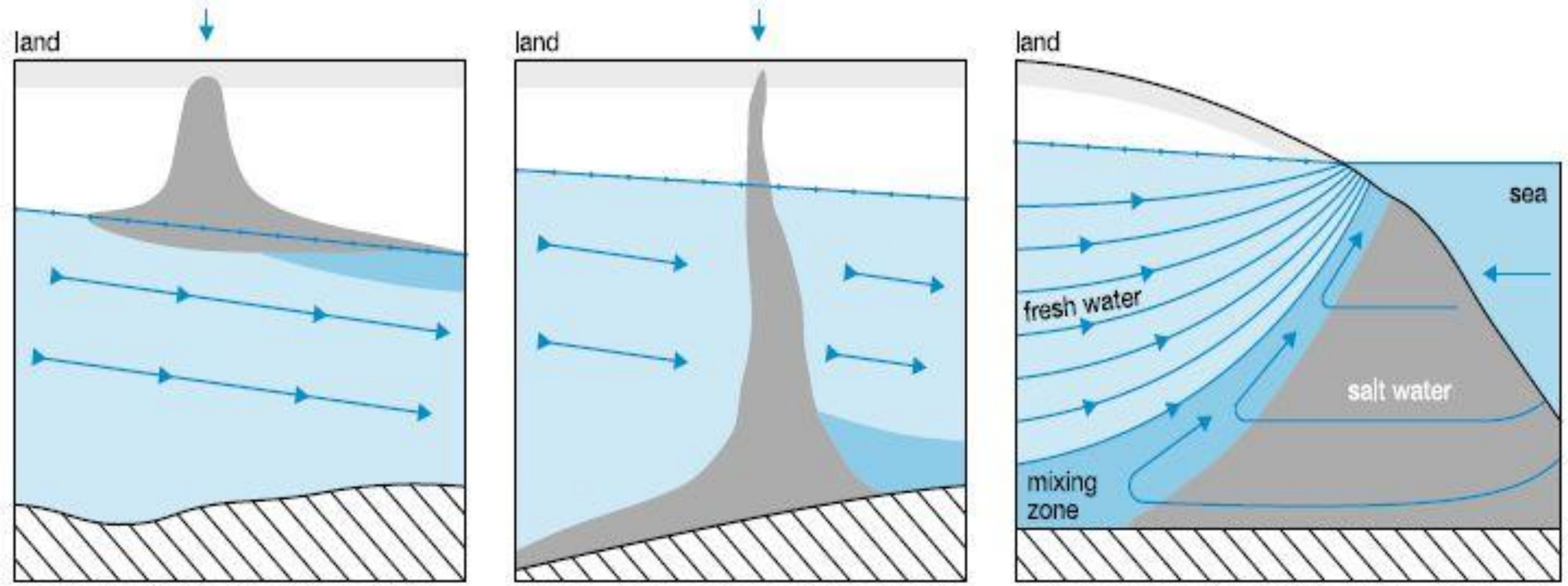
Saline and contaminated water

- Fossil salt water, i.e. water that has remained trapped in the sedimentary layer
- Salt water intrusion from the sea, as a result of over-pumping near the coast, or by reduced recharge
- Water contamination from surface point sources (e.g. pit latrines, dump sites) and usually shallow

Types of water quality contamination

Figure 3: Processes causing major vertical variations in groundwater quality within an aquifer-system which need to be detected through monitoring



spillage of light hydrocarbon fuel which floats on water table with some dissolving into groundwater flow

penetration of immiscible heavy organic solvent after storage tank rupture with accumulation at base of aquifer and with some dissolving into groundwater flow

'classical wedge' of saline intrusion in a coastal aquifer with mixing zone developing along fresh water/saline water interface

Sources of groundwater contamination

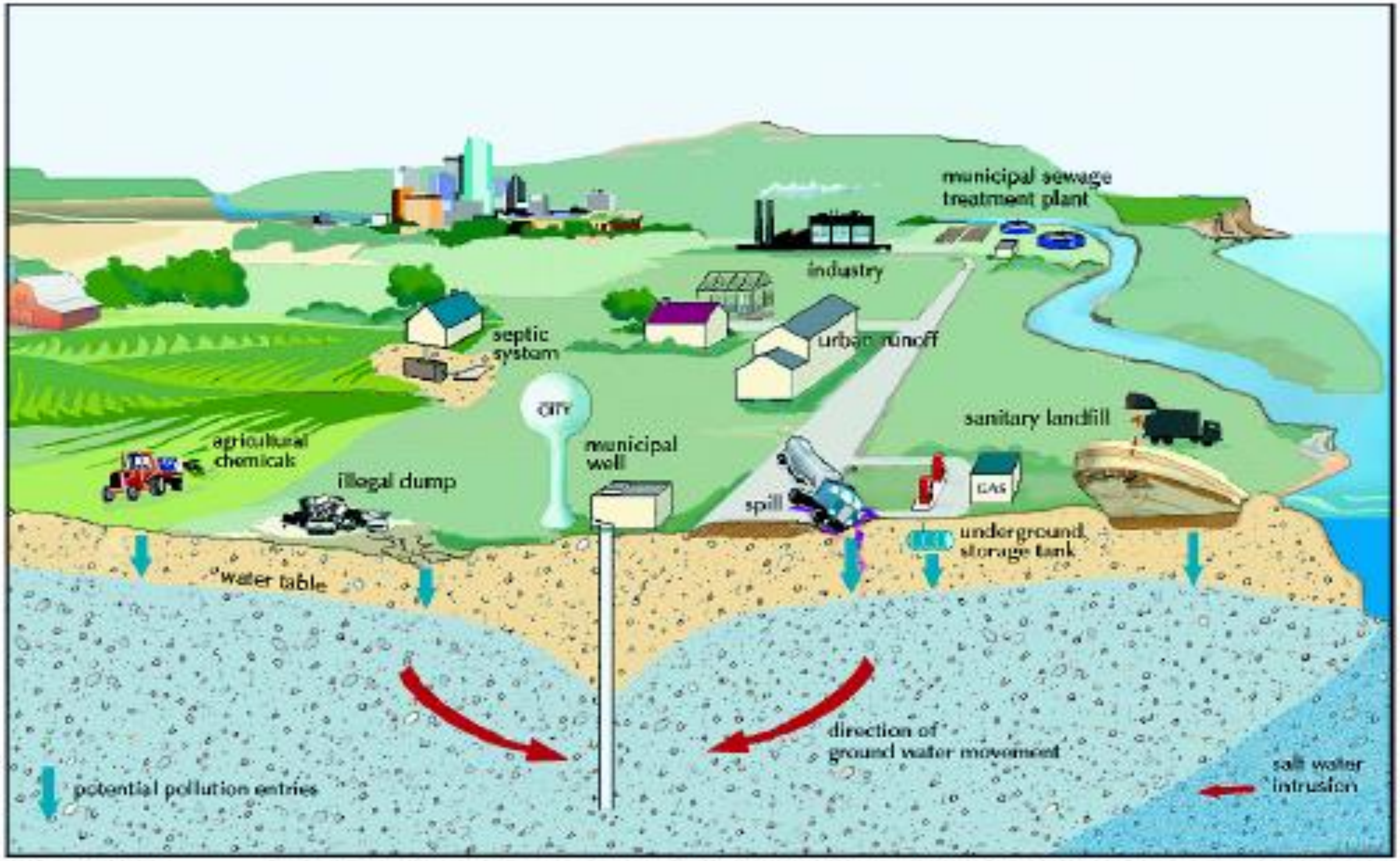
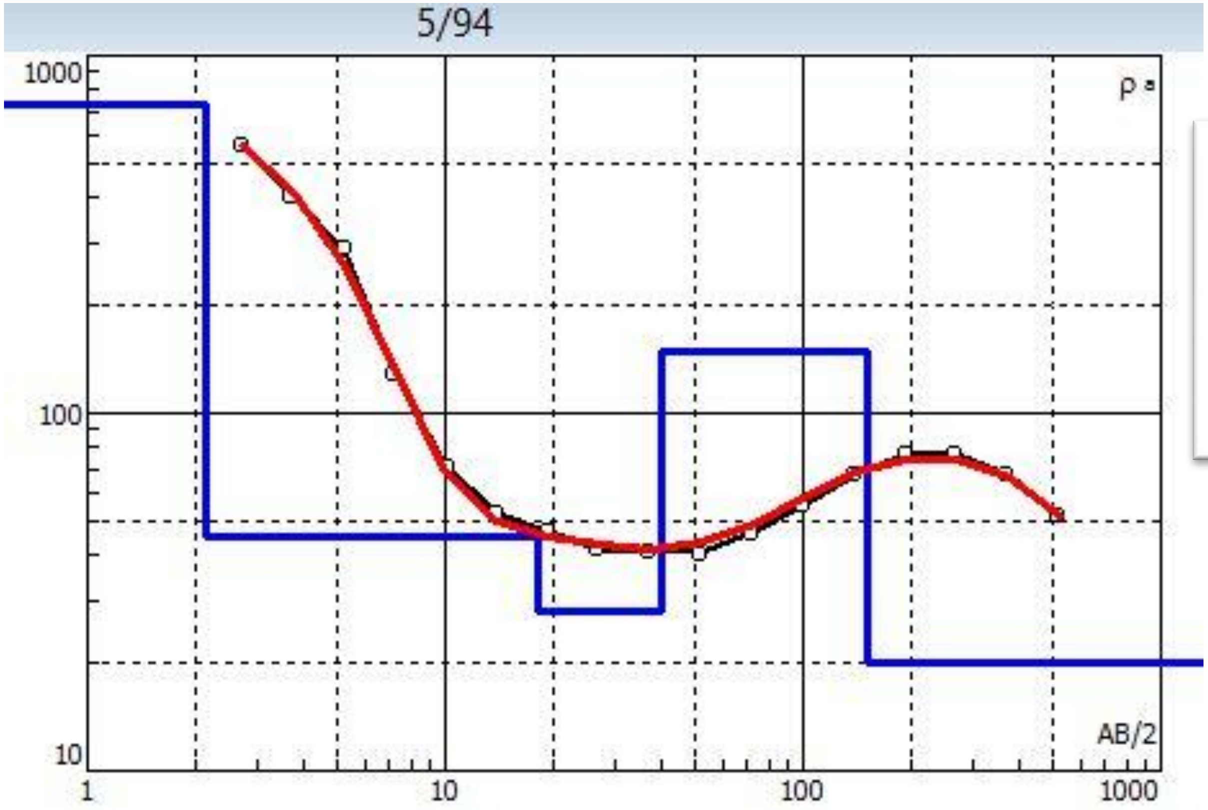


Figure 6.1: Sources of groundwater contamination are numerous and are as diverse as human activities (source: Zaporozec and Miller, 2000 cited in Zaporozec, 2004).

How to detect saline groundwater?

- Carry out a Electrical Resistivity survey with soundings reaching at least 100m depth, i.e. AB/2 of at least 500 metres;
- Analyse the soundings with appropriate software (e.g. ipi2win of Moscow Univ.)
- If resistivity of aquifer is <10 Ohmm, don’t drill!
- Carry out resistivity logging in drilled borehole and select screen depths accordingly

How to map saline aquifer (VES)



N	ρ	h	d	Alt
1	724	2.15	2.15	170.4
2	45	16	18.1	154.4
3	28	22	40.2	132.4
4	150	110	150	22.35
5	20	20	170	2.35
6	20			

dry	silty	clay	fresh	brackish

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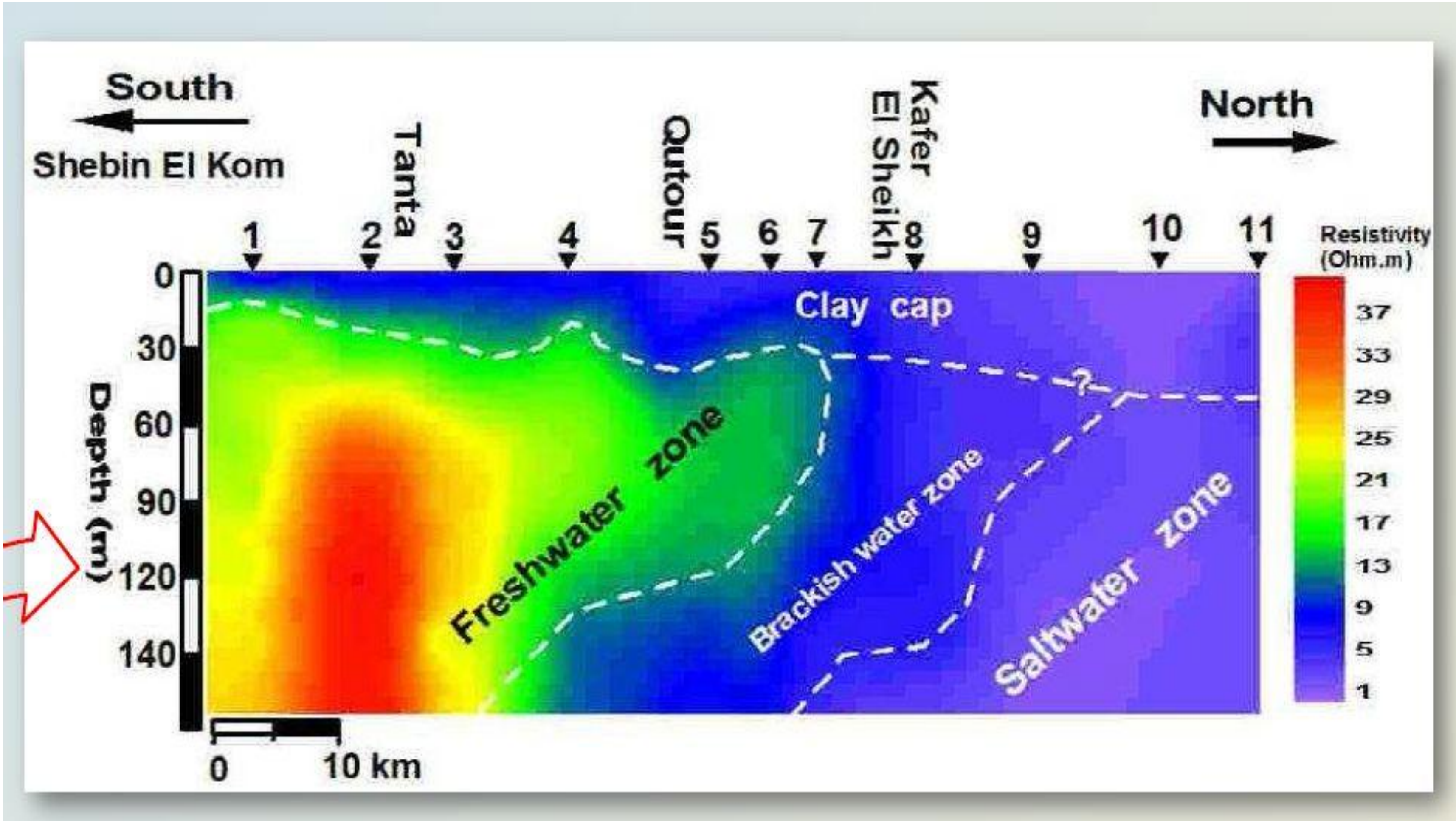
Nile delta – salt water intrusion



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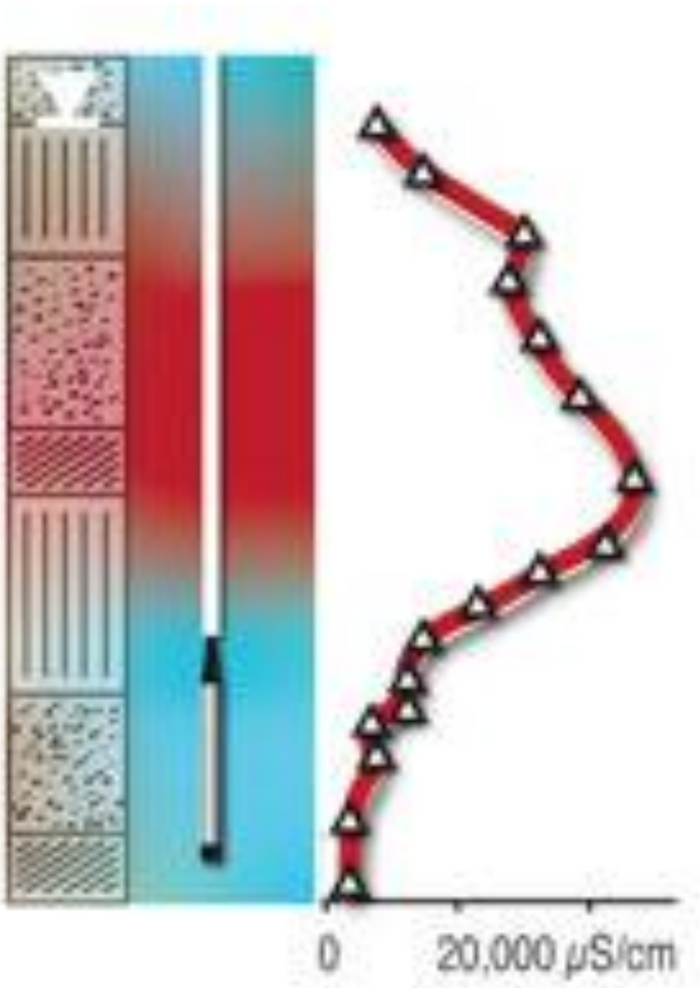
Salinity logger

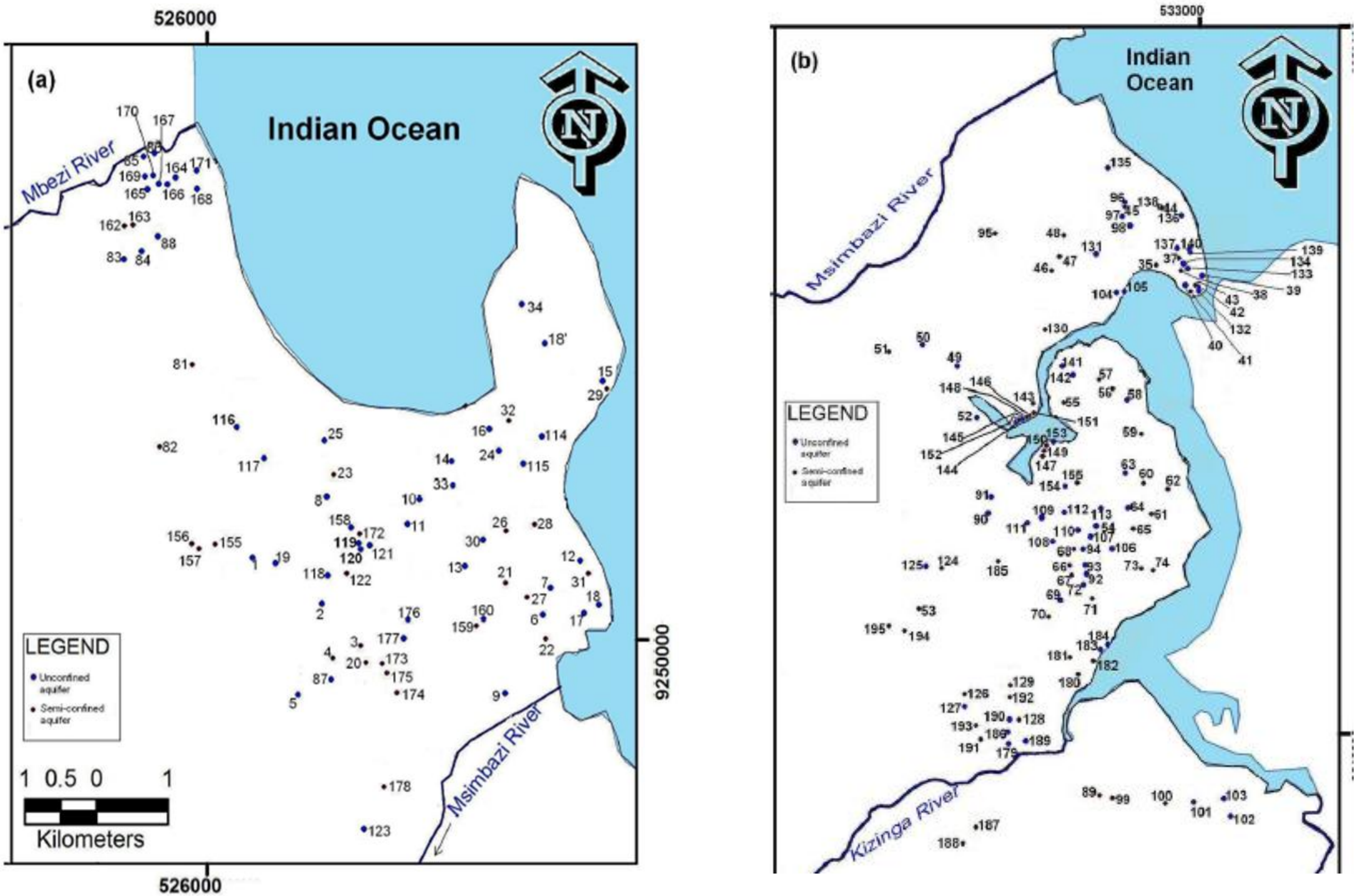


- The TLC logger records temperature, water level and conductivity in wells and open water, for salt-water intrusion studies, and a general indication of contamination levels. The 3/4" (19 mm) diameter probe is attached to PVDF flat tape; accurately laser marked each millimeter. Lengths up to 300 m, mounted on a reel.

Mtoni study (1)

Water samples from 196 boreholes with depths ranging from 1.66 m to100 m below ground surface were tested. Results indicate that the Dar es Salaam quaternary coastal aquifer (DQCA) is experiencing contamination primarily by seawater intrusion due to overexploitation and the use of on-site sewage disposal systems, in particular pit latrines and septic tanks. Dissolution of calcite/dolomite minerals in the aquifer matrix in the recharge areas, as well as cation exchange modify the concentration of ions in groundwater.

Groundwater sampling points (Mtoni)



Mapping fresh-salt water interface

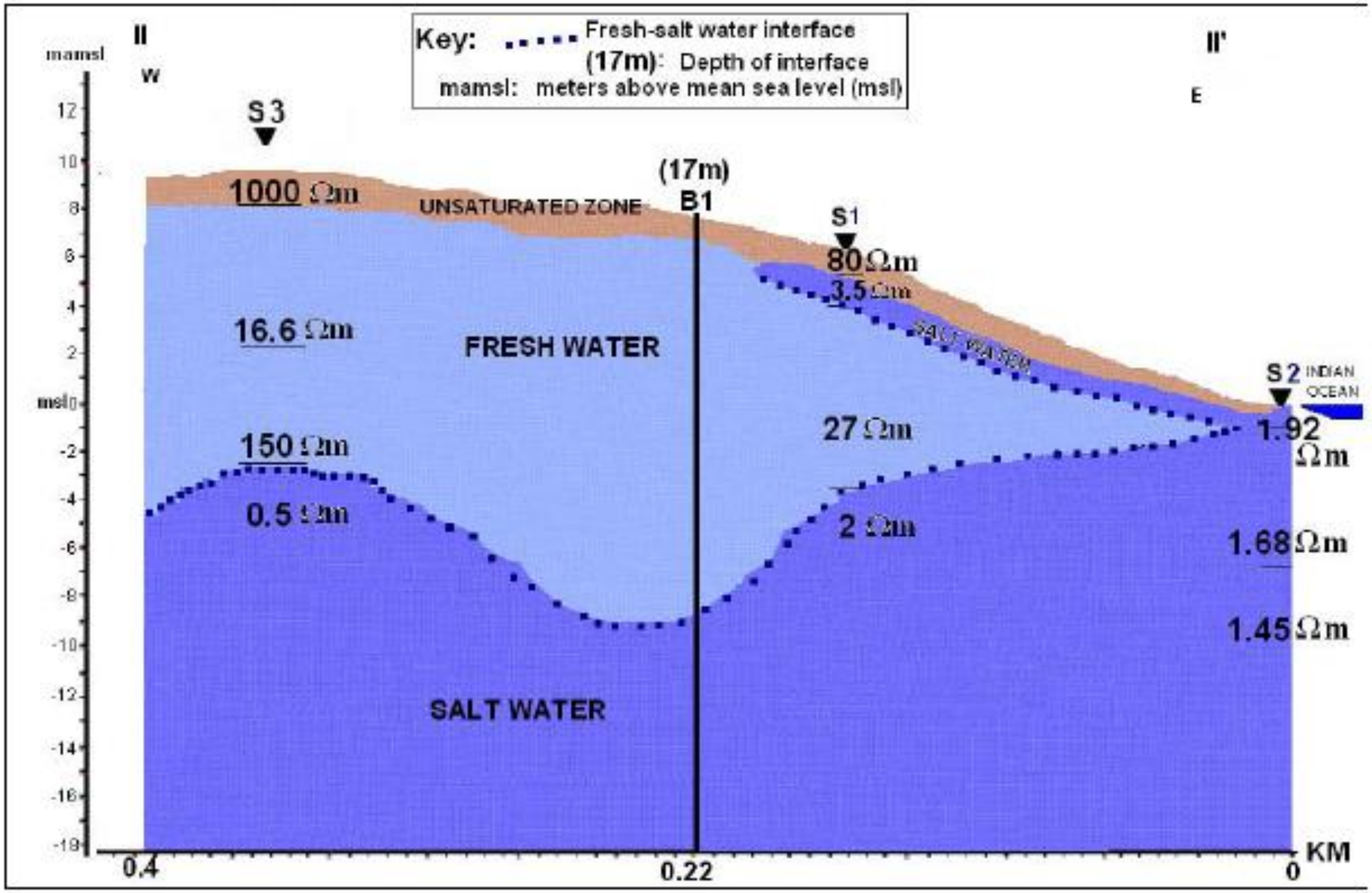


Figure 5.13(d): Fresh- salt water interface (defined by $\rho_t = 12.5\ \Omega m$) based on VES (location of resistivity profile II-II' is indicated in Fig. 5.13a).

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Borehole with fresh and salt water

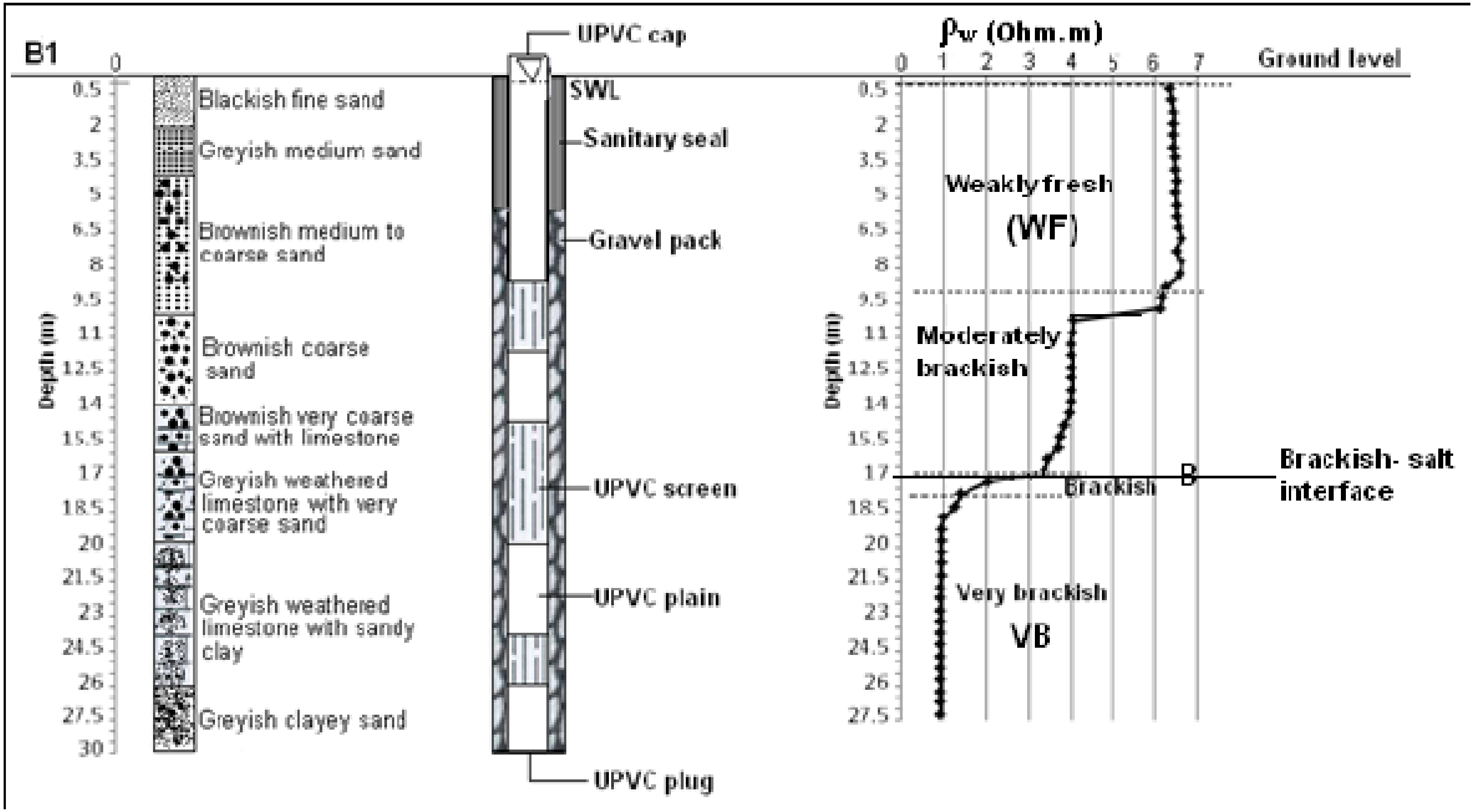
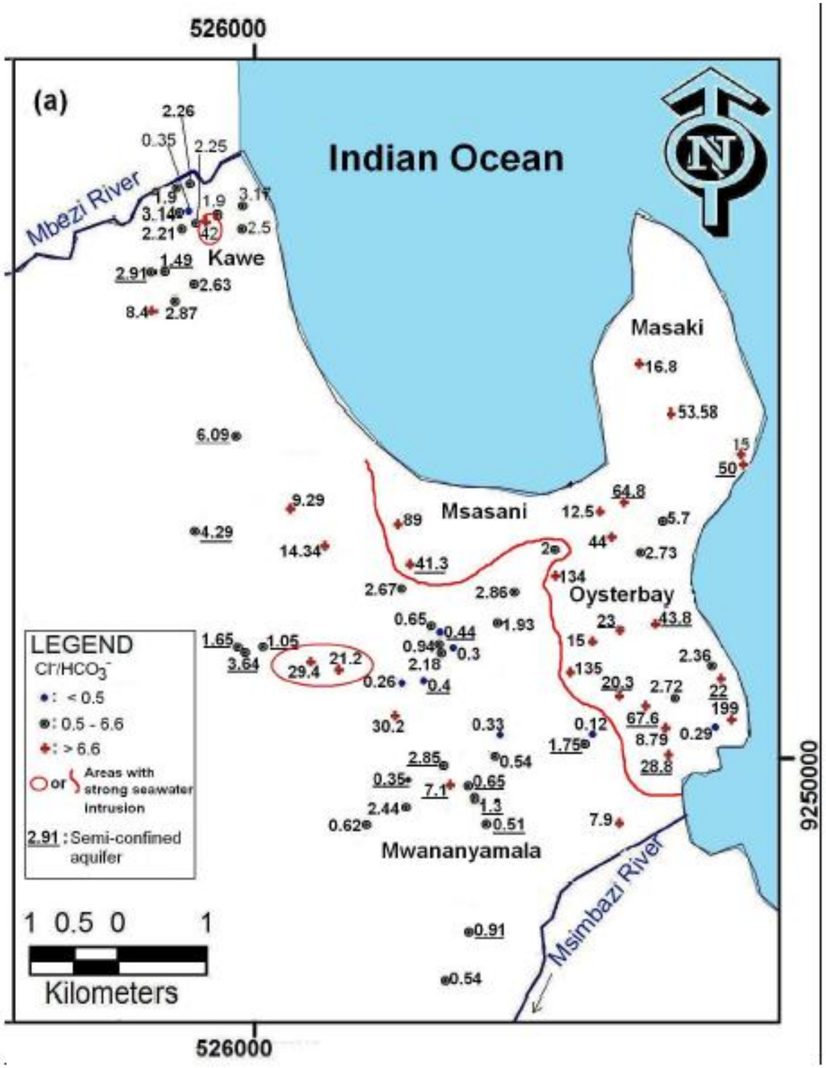


Figure 5.10(a): Resistivity log at observation borehole B1 (location of the borehole is indicated in Fig. 5.7).

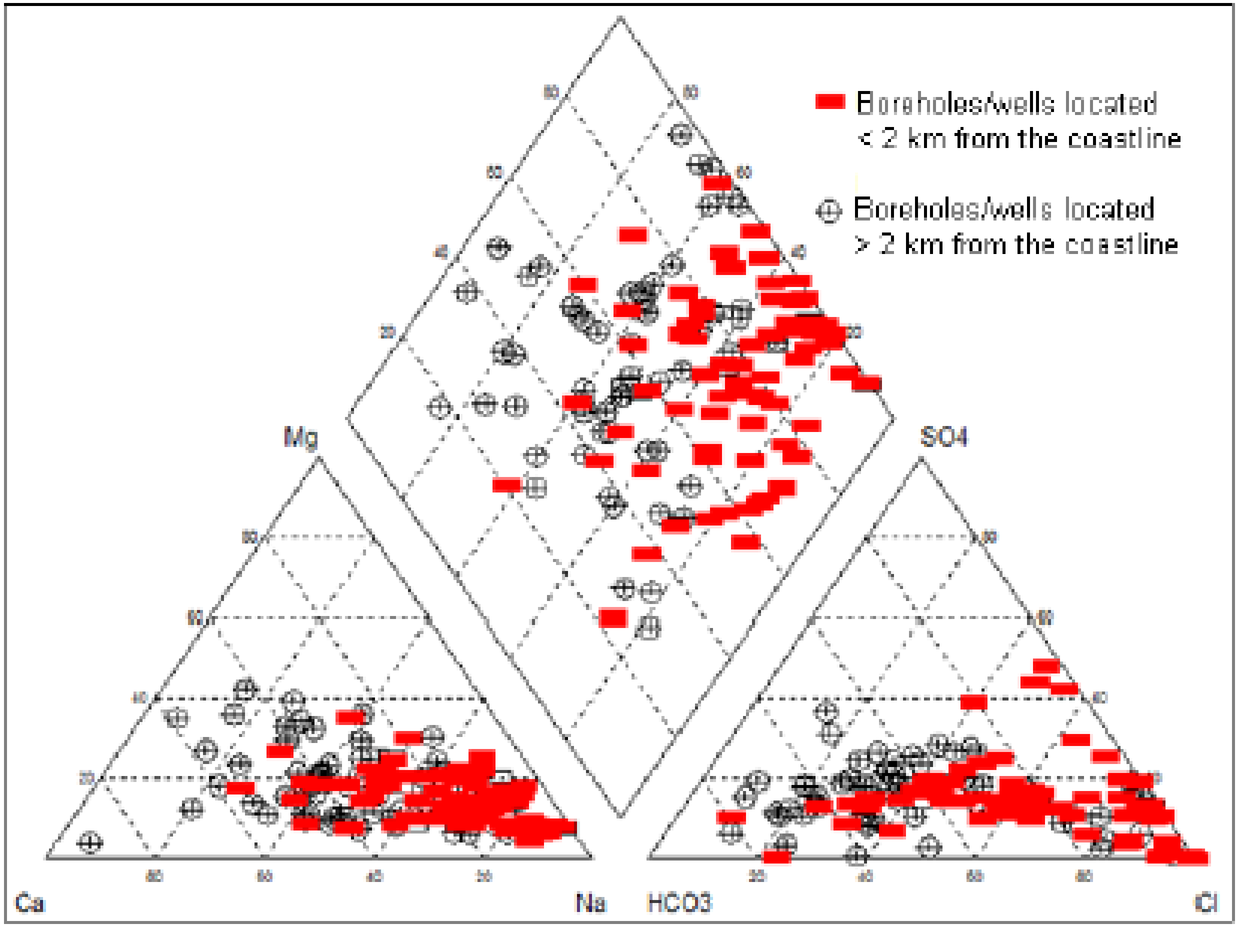
Chloride concentration

Chloride concentration shows a general increase down gradient to the east towards the coastline. Many samples show fresh water (< 150 mg/l) is present beyond 2 km from the sea, but within 1 km from the sea, many boreholes/wells are brackish (300-1,000 mg/l) to brackish-salt (1,000-10,000 mg/l). This evident relation to distance from the sea clearly points to seawater intrusion as the cause of salinity.

Areas with sea water intrusion



Hydrochemical composition (Piper plot)

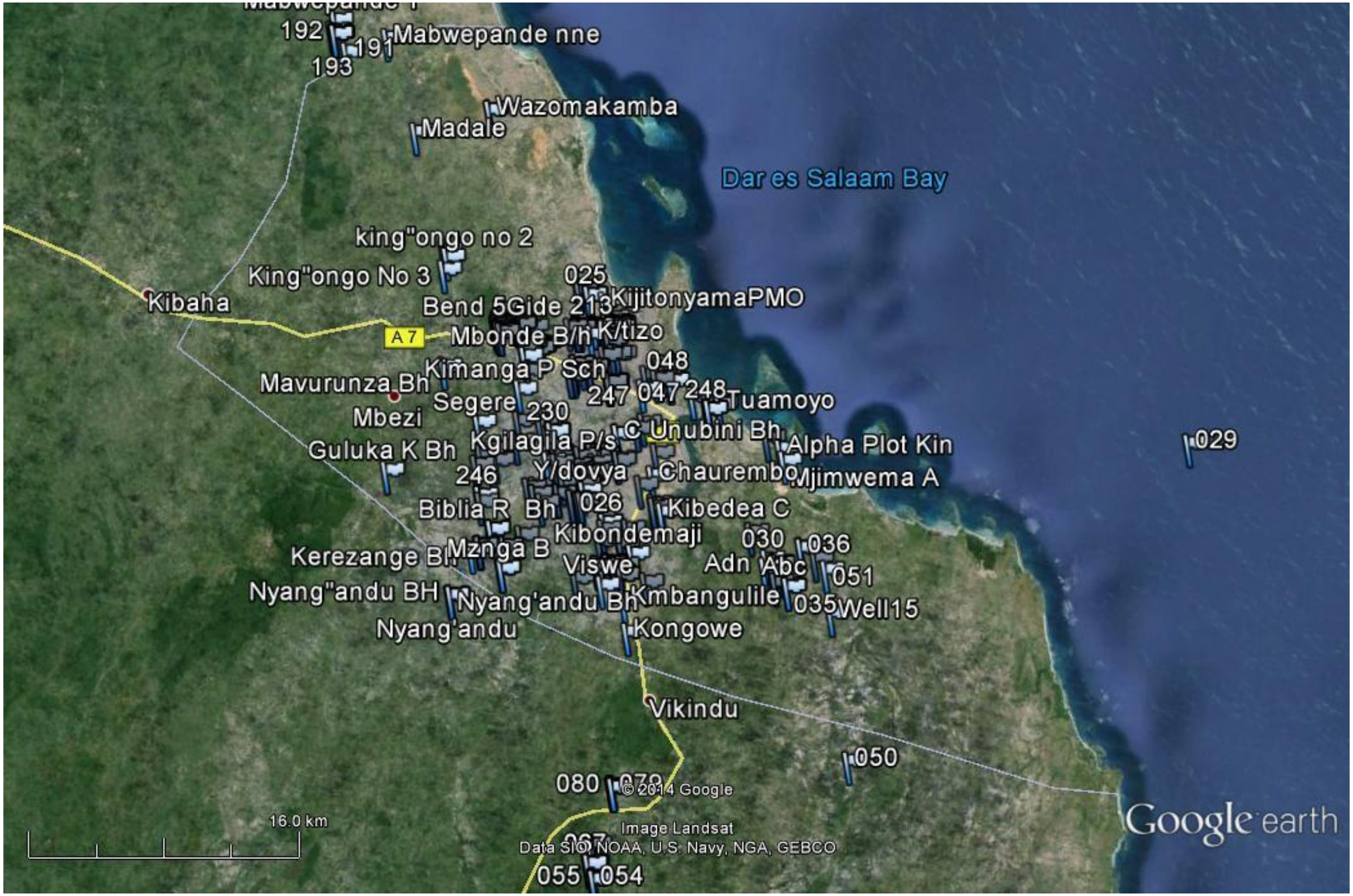


igure 6.34(b): Piper plot showing boreholes/wells (for the first 134 samples) located in close proximity to the coastline (< 2 km) and further from coastline (> 2 km).

Groundwater Management Strategy

- Identification and mapping of sources of pollution
- Establishment of database and GIS
- Generate groundwater vulnerability maps
- Assessing groundwater protection needs
- Initiating monitoring network
- Integrating groundwater protection in urban planning and legislation
- Promoting public awareness and participation

Monitoring boreholes network DAWASA



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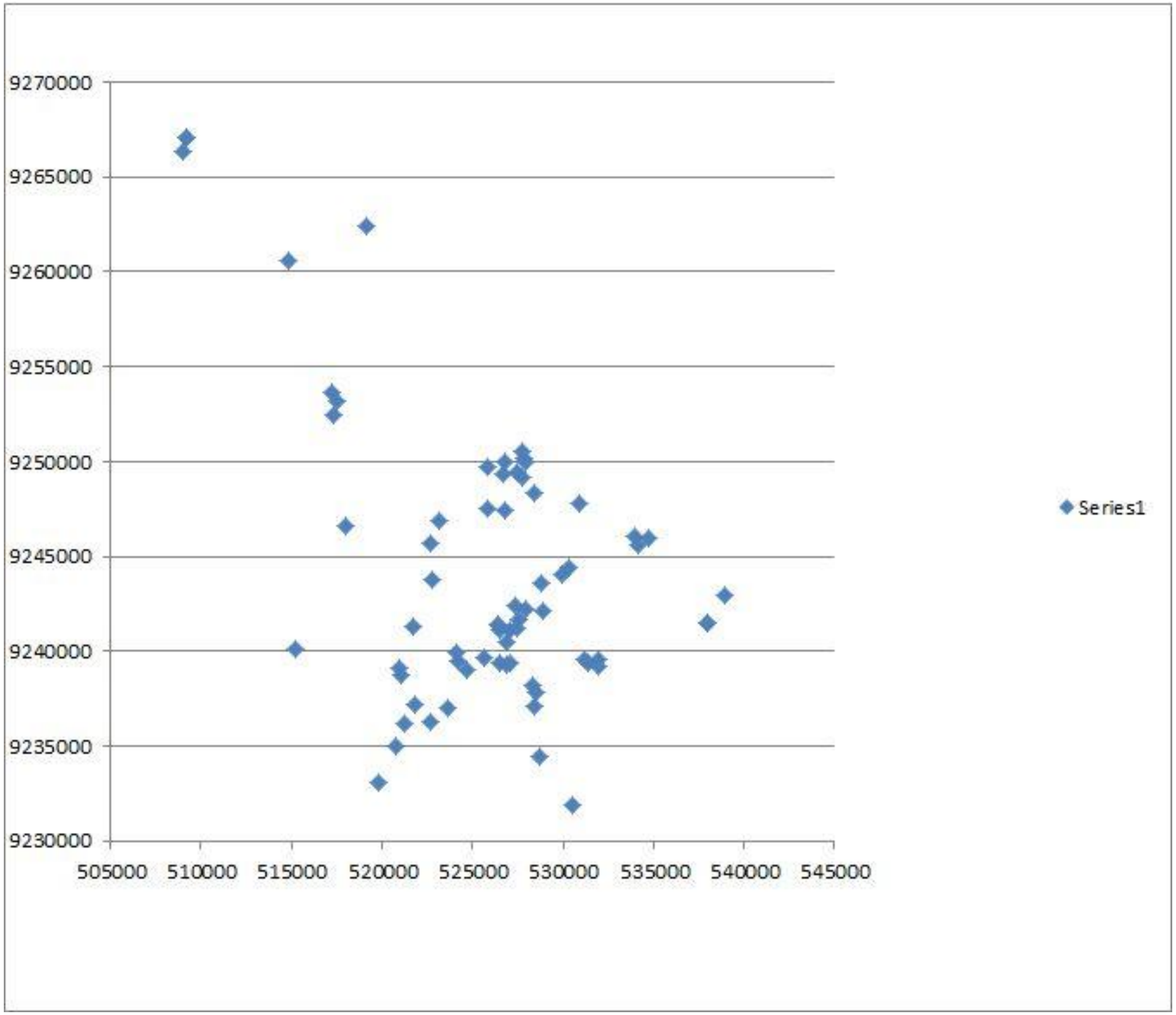
Groundwater monitoring by DAWASA



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Monitoring data DAWASA

		EC range	0-1,500	1500-3000	3-5,000	> 5,000		pH	< 6.5	> 8.5				

Location/BH name	Municipality	Borehole reg. no.	Monitoring date	El.Cond. (µS/cm)	TDS (ppm)	Salinity %	Diss. Ox. (ms/l)	pH	Easting UTM	Northing UTM	Elevation meters	Year drilled	Depth (m)	Yield (m^3/h)
2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Mburahati NHC	KINONDONI			2,530	1,280	1.3	4.5	6.7	526760	9247403	37	2010	70	25.5
Ngilangwa	KINONDONI			2,280	1,144	1.1	5.1	6.7	527752	9249129	35	2005	40	16.5
Olympio P/S	ILALA			878	428	0.4	5.3	7.1	530950	9247774	4	1997	15	24
Temeke Hospital	TEMEKE			500	241	0.2	5.2	6.9	528930	9242083	37	1997	60	23
M'nyamala Ally Maua	KINONDONI			2,840	1,436	1.4	4.2	7.0	526832	9249943	29	1997	45	2
Mbagala viswe	TEMEKE			617	298	0.3	4.8	5.6	528743	9234487	63	1999	60	14
Yombo Kilakala(ccm)	TEMEKE			1,086	530	0.5	5.2	6.0	527066	9241114	34	1997	65	5
King'ong'o No.1	KINONDONI			3,720	1,902	1.9	5.3	7.1	517275	9253612	37	2010	140	13.2
King'ong'o No.2	KINONDONI			4,580	2,360	2.4	2.3	6.8	517497	9253219	37	2010	110	3.5
King'ong'o No.3	KINONDONI			7,830	4,140	4.3	5.1	6.7	517368	9252445	37	2010	120	13.5
Dawasa M'nyamala Office	KINONDONI			3,630	1,842	1.9	5.2	6.9	527830	9250145	37	2004	70	75
Mzinga B	ILALA			485	233	0.2	5.1	6.4	521009	9238757	45	2005	80	5.25
Kimanga P/S	ILALA			1,460	719	0.7	6.14	6.1	522652	9245684	37	1997	70	5
Mwongozo	KINONDONI			368	1,740	0.1	4.2	5.4	523118	9246873	29	2004	55	7.2
Buguruni moto	ILALA			2,600	1,314	1.3	1	6.2	526376	9241428	37	1997	57	8
Kitunda 'C'	ILALA			662	320	0.3	5.3	6.4	523617	9337012	60	1997	71.5	14
Biblia Relini	ILALA			720	349	0.3	4.5	6.7	521822	9237172	53	2006	70	6.6
Kigamboni Ferry	TEMEKE			2,260	1,129	1.1	4.8	7.1	534002	9246059	6	1997	35	15
Mpeta	TEMEKE			1,643	812	0.8	5.3	6.5	524658	9239035	51	2006	42	3.5
Mzinga A	KINONDONI			1,911	905	0	5.6	6.1	522695	9236256	37	2005	62	7.2

Artificial Groundwater Recharge

The coastal aquifer in Dar es Salaam is clearly overexploited. Utilizing runoff (which otherwise drains off) will bring great benefits for improving groundwater levels (which have dropped due to overexploitation). With Artificial Groundwater Recharge (AGR), storm water can be collected from large buildings and allowed to infiltrate, to increase groundwater storage and reducing surface run-off.

Example: specific bye-laws in Indore (India)

Kimbiji aquifer – water quality

Table 6.12: Hydrochemical parameters of groundwater at Kimbiji well (Neogene aquifer).

Parameter	WHO international standards (2004)	Kimbiji well
Ca^{2+} (mg/l)	200	1.49
Mg^{2+} (mg/l)	150	2.1
Na^{+} (mg/l)	200	157
K^{+} (mg/l)	200	6.5
SO_4^{2-} (mg/l)	250	14.54
HCO_3^{-} (mg/l)	240	301.95
Cl^{-} (mg/l)	250	66.12
NO_3^{-} (mg/l)	50	2.77
EC (µS/cm –25 °C)	1500	867
pH	6.5-9.2	8.62
TDS	600	581.6

Mtoni study (2)

The findings show that the aquifer, bordering the Indian Ocean, is vulnerable to the influence of seawater intrusion, and is heavily affected by human influence due to groundwater over-pumping. Over-abstraction of groundwater to meet fresh water demand has contributed to the deterioration of the water quality by seawater intrusion.

Mtoni study (4)

Improved groundwater protection regulations are needed to limit the increasing saltwater intrusion and anthropogenic aquifer contamination. Application of rational integrated groundwater management practices (IWRM) is crucial in attaining the sustainability of groundwater resources in the area.

Recommendations = Kimbiji aquifer

Decreasing of groundwater supply from the Quaternary aquifer can be compensated by exploitation of the Kimbiji Neogene aquifer which has good quality water. However important questions pertaining to the aquifer geometry, source of water recharge, groundwater flow, groundwater quality and sustainable abstraction rates must be dealt with.

Establishing a groundwater monitoring program is very important, based on which, measures may be taken to avoid the advancement of seawater intrusion.

Proposed Groundwater Management

- Mapping of sources of pollution
- Establishment of database and GIS
- Generate groundwater vulnerability maps
- Groundwater modelling
- Design groundwater IWRM
- Assessing groundwater protection needs
- Initiating monitoring network
- Promote RWH, artificial groundwater recharge
- Integrating groundwater protection in urban planning and legislation
- Promoting public awareness and participation

Draft Concept (1)

RESULTS	Implementing agency	Supported by
Result 1 – Identification and mapping of sources of pollution completed	ARDHI	DAWASA, ITC
Result 2 – Design of database and GIS system (software) completed	ITC	DAWASA
Result 3 – Groundwater vulnerability maps prepared	NEMC	ARDHI, ITC
Result 4 – Groundwater modelling study carried out	ITC	ARDHI, NEMC
Result 5 – Design prepared for integrated urban groundwater resources management		
Result 6 – Assessment made of groundwater protection needs	NEMC	ITC, ARDHI
Result 7 – Monitoring network design completed	ITC	DAWASA, UN-Habitat

Draft Concept (2)

RESULTS	Implementing agency	Supported by
Result 8 – Procurement & installation monitoring equipment completed	ITC	DAWASA, UN-Habitat
Result 9 – Data collection from monitoring network and storage fully operational	DAWASA	
Result 10 – Promote RWH at public and commercial buildings and create Artificial Groundwater recharge	DAWASA	UN-Habitat
Result 11 – Integrated Urban Groundwater Recharge Monitoring system operational	DAWASA	NEMC, ITC
Result 12 – Integration of groundwater protection in urban planning and legislation established	DAWASA,	NEMC
Result 13 – Promotion of public awareness and participation carried out	UN-Habitat	DAWASA

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THANK YOU!