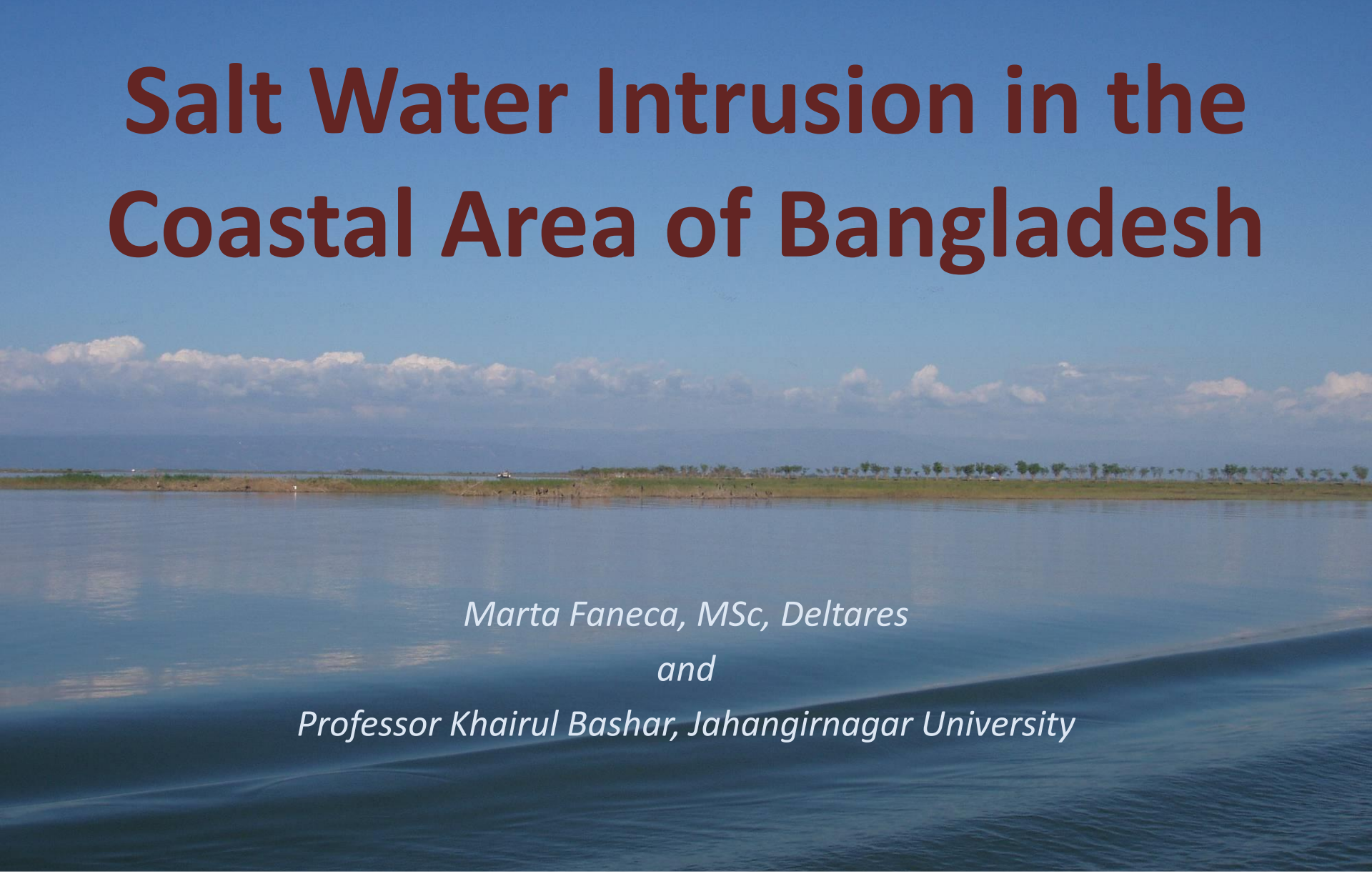
Salt Water Intrusion in the Coastal Area of Bangladesh



Marta Faneca, MSc, Deltares

and

Professor Khairul Bashar, Jahangirnagar University

Deltares
Enabling Delta Life

UNESCO-IHE
Institute for Water Education

IRC International Water and Sanitation Centre

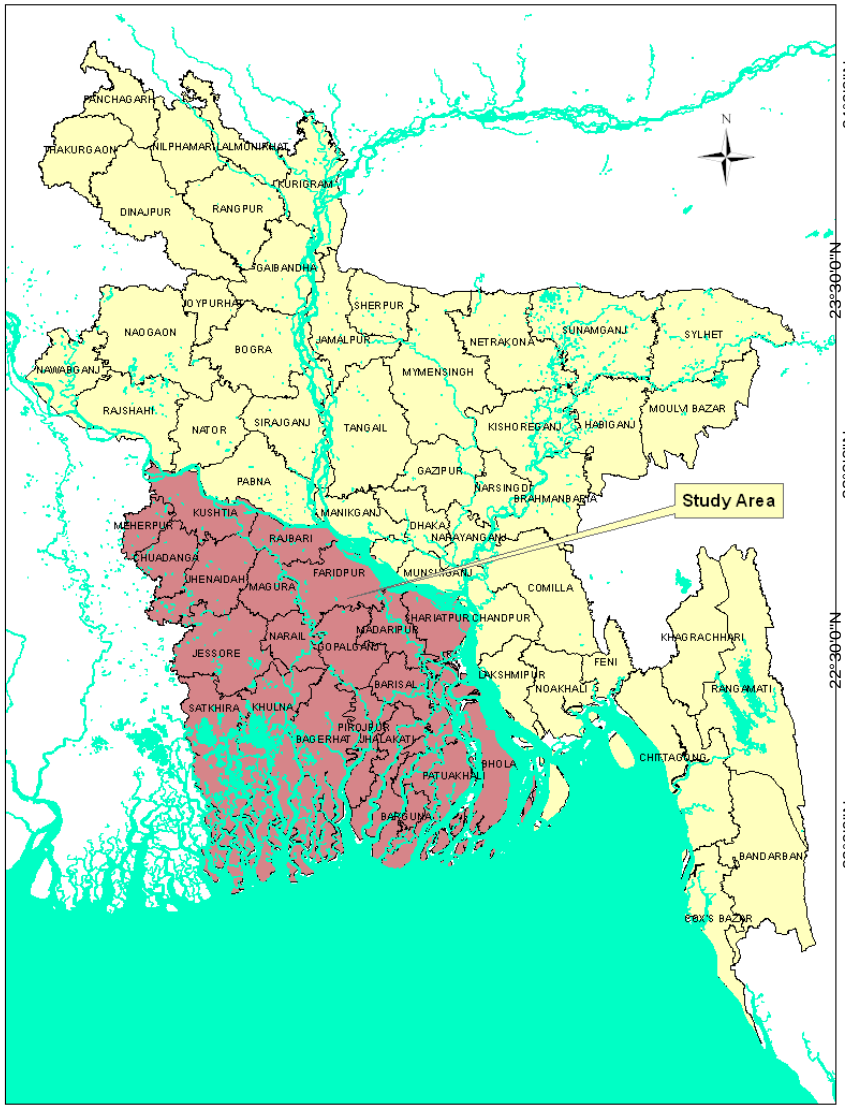
brac

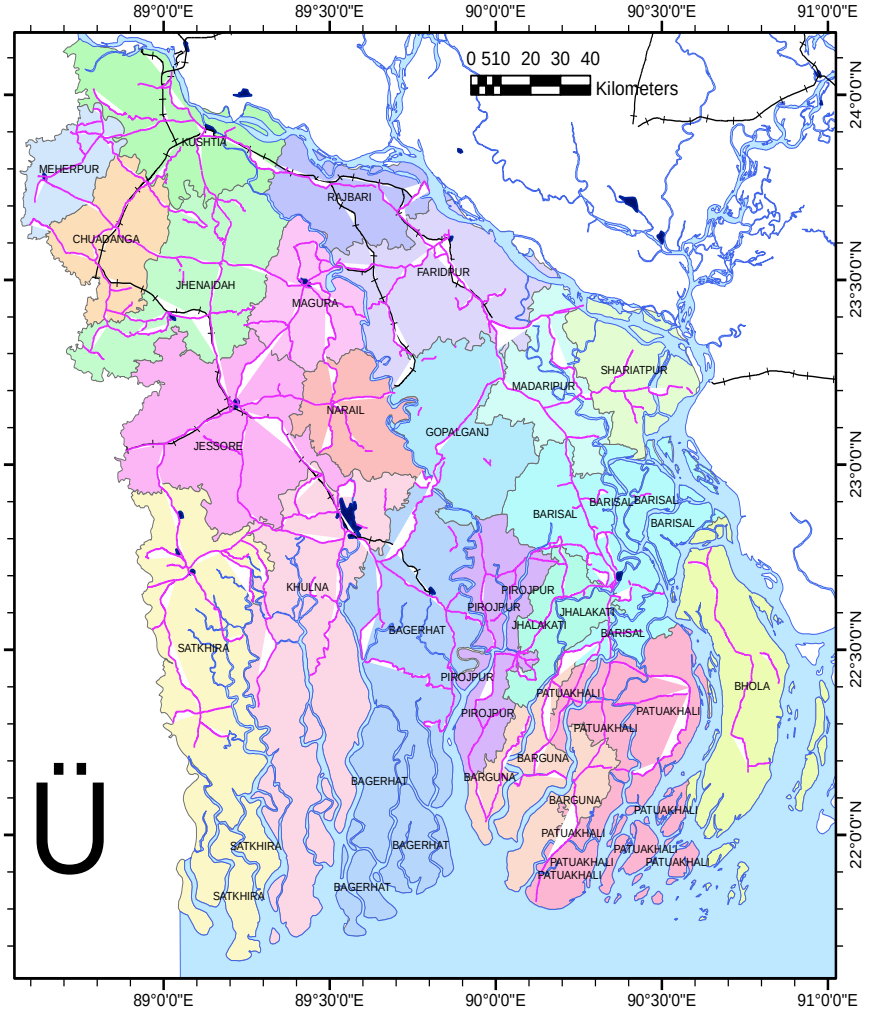
জনস্বাস্থ্য প্রকৌশল অধিদপ্তর
Department of Public Health Engineering

Content

- *The study area*
- *Occurrence of Salt water in the study area*
- *People Affected by high Salinity*
- *Present Drinking Water Supply Scenario in the Study area*
- *Technology in use for water supply*
- *Case study Bagerhat District*
- *BRAC WASH Program Salinity data of Different Upazilas*

The study area





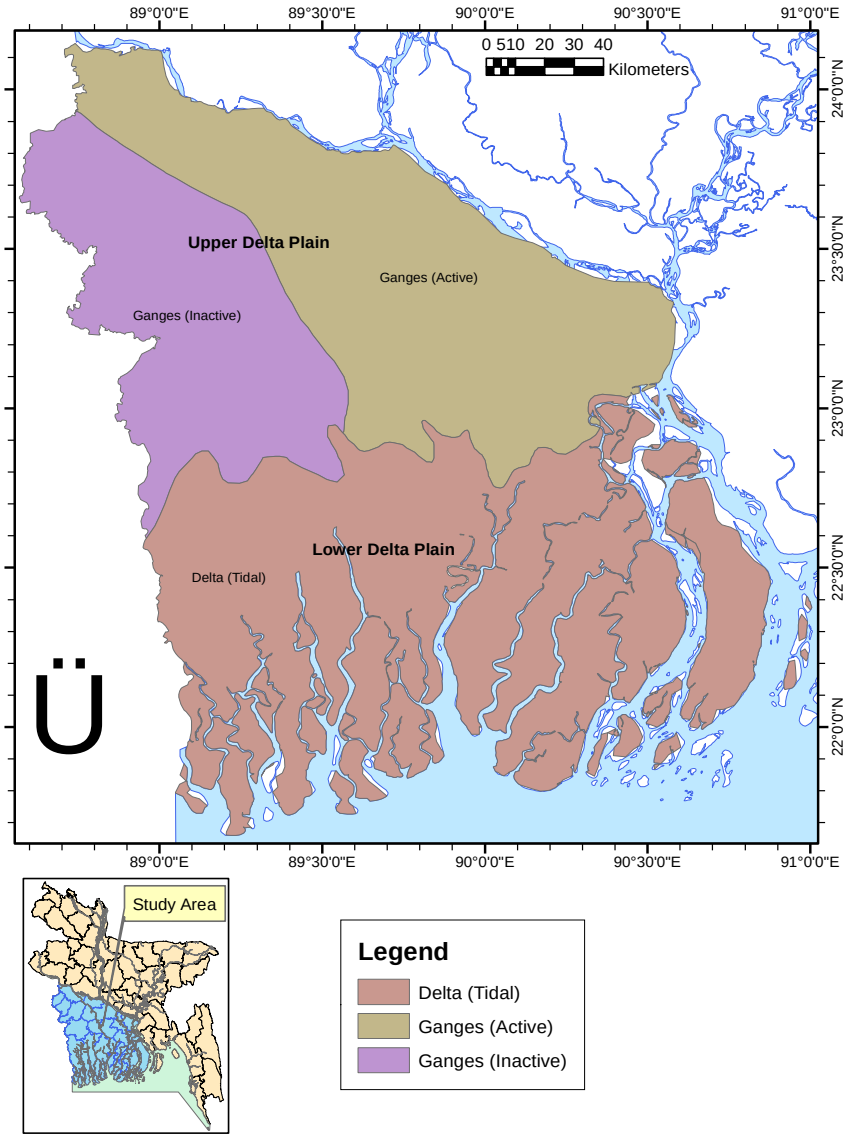
Geomorphological Classification

Upper Delta plain:

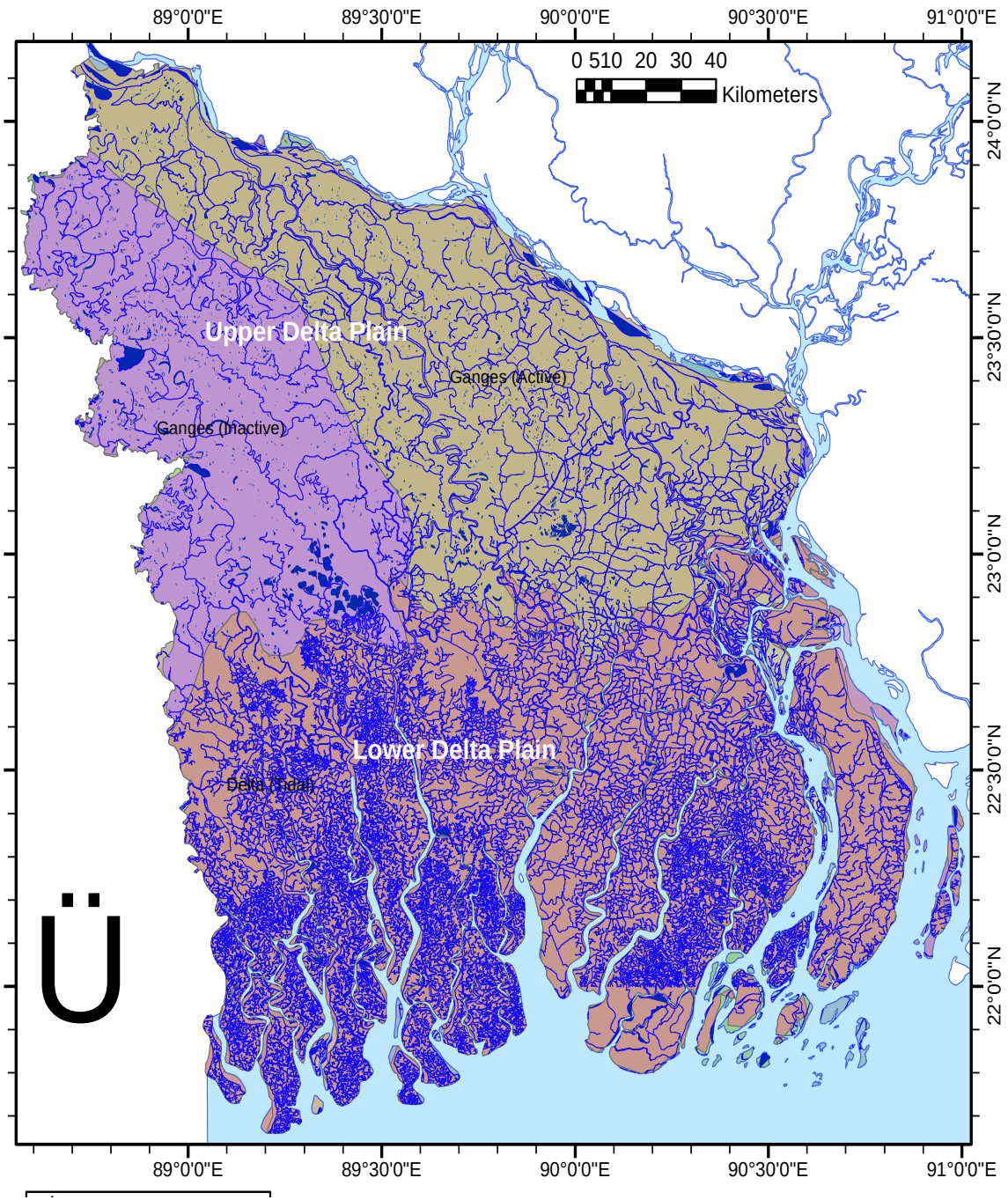
- higher elevation
- land > 3 m above sea level
- dominated by fluvial processes
- freshwater wetlands

Lower Delta plain:

- Lower elevation
- elevations typically < 3 m above mean sea level
- up to 100 to 150 km wide
- maximum limit of saline penetration during periods of low river discharge
- influenced by tides and other marine process
- saline



Detailed River Network

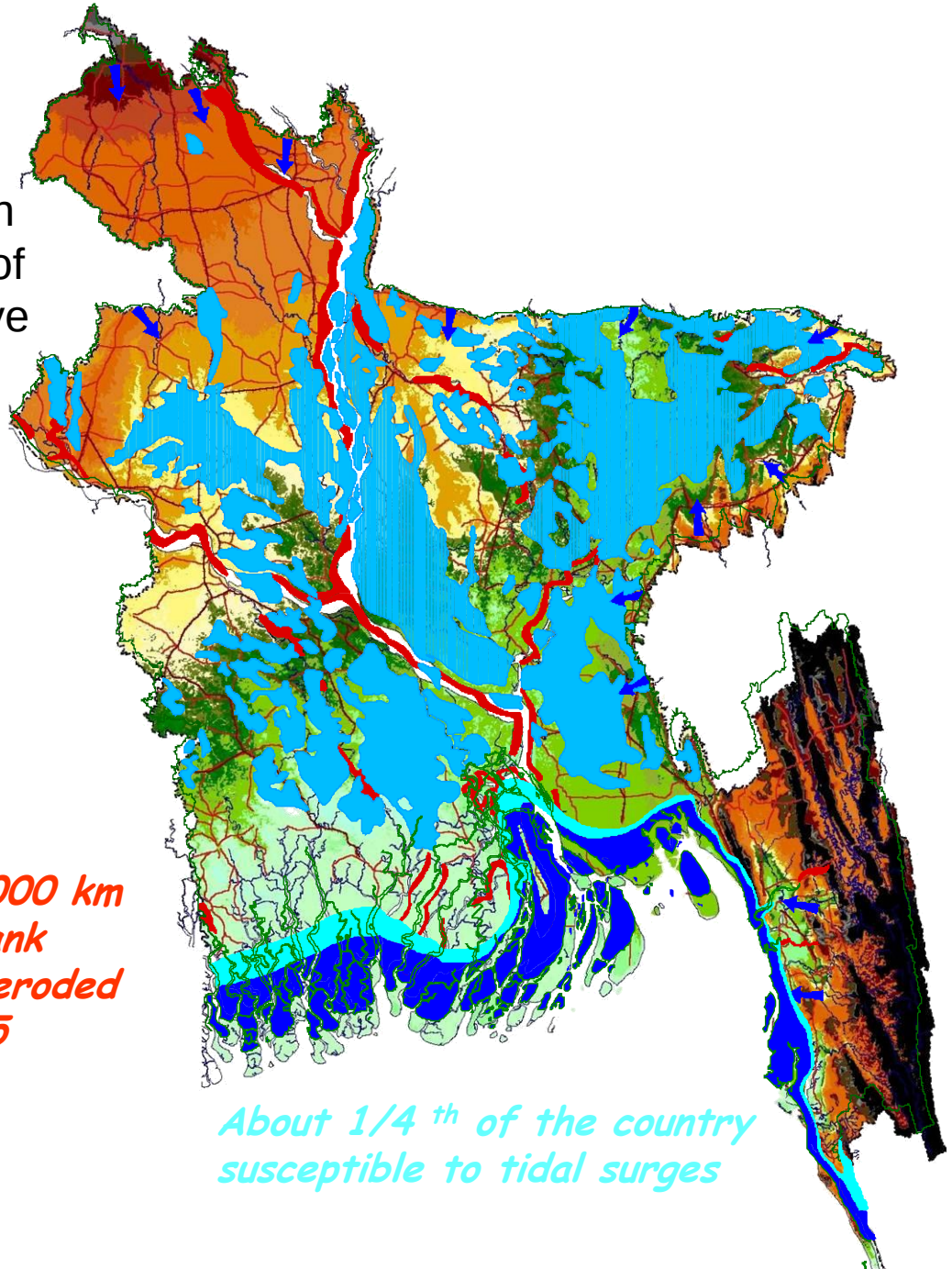


The geographical location and average land levels of Bangladesh are conducive to

Flood

Erosion

Storm Surge



Over 3000 km river bank will be eroded by 2025

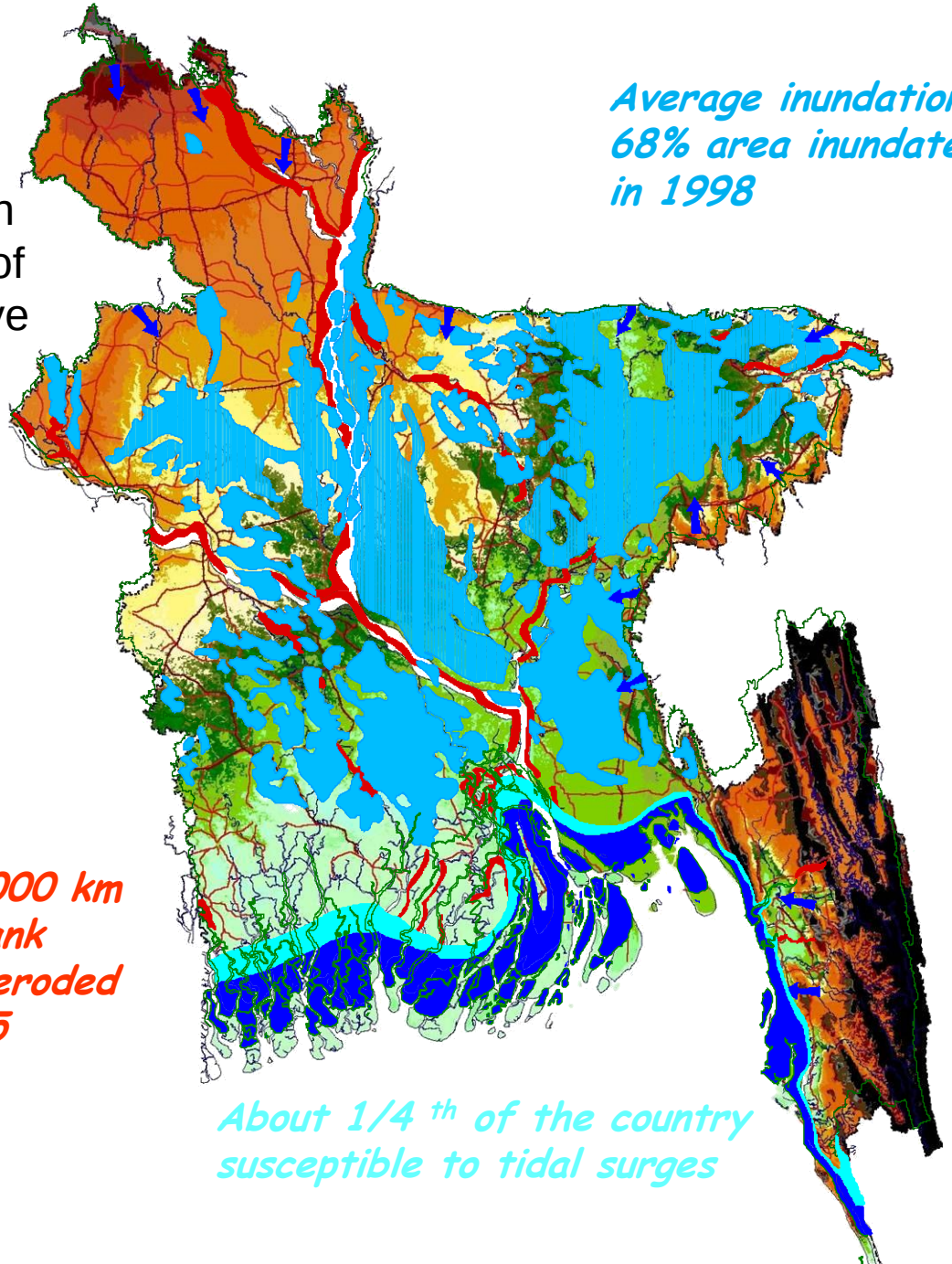
About 1/4 th of the country susceptible to tidal surges

The geographical location and average land levels of Bangladesh are conducive to

Flood

Erosion

Storm Surge



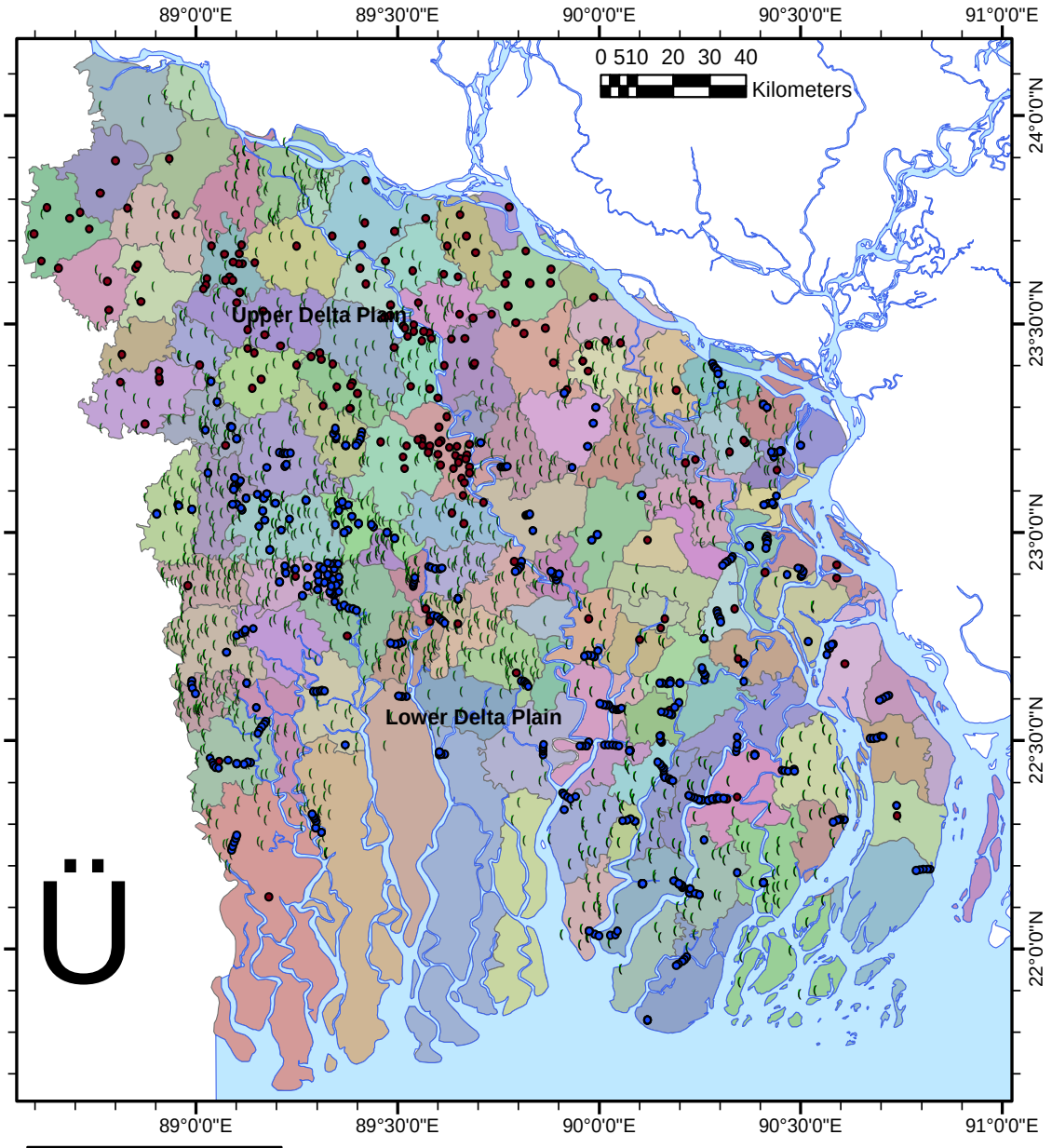
Average inundation 22%
68% area inundated
in 1998

Over 3000 km river bank will be eroded by 2025

About 1/4 th of the country susceptible to tidal surges

Hydrostratigraphy of the study area

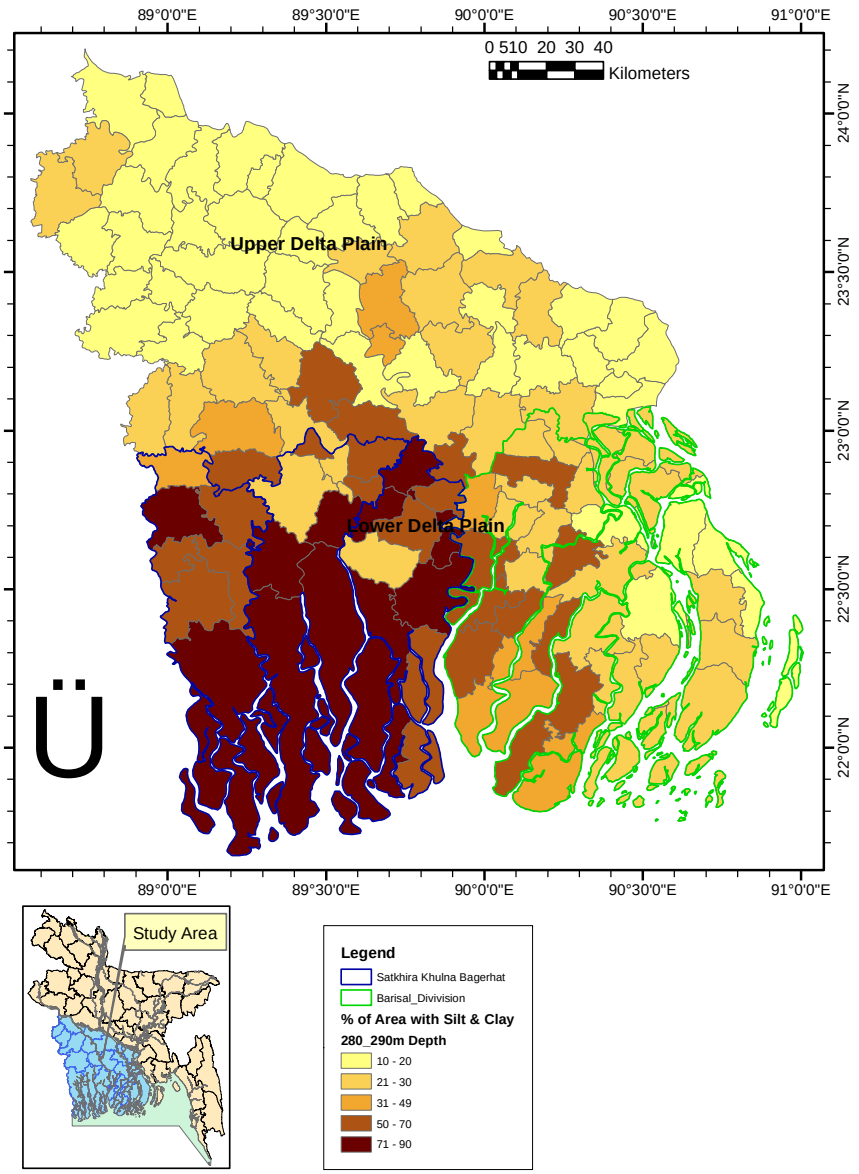
- **2690 borelogs ,**
- **Depth: 15 to 350m**
- **Analysed using RockWorks® 15**



Three fold classification of the study area

Three Classes:

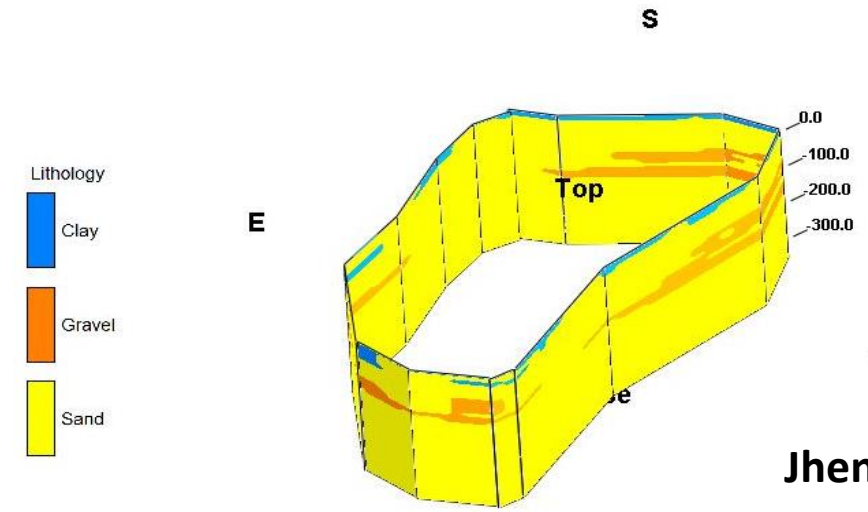
1. **Upper Delta Plain**
2. **Western Lower Delta Plain**
3. **Eastern Lower Delta Plain**



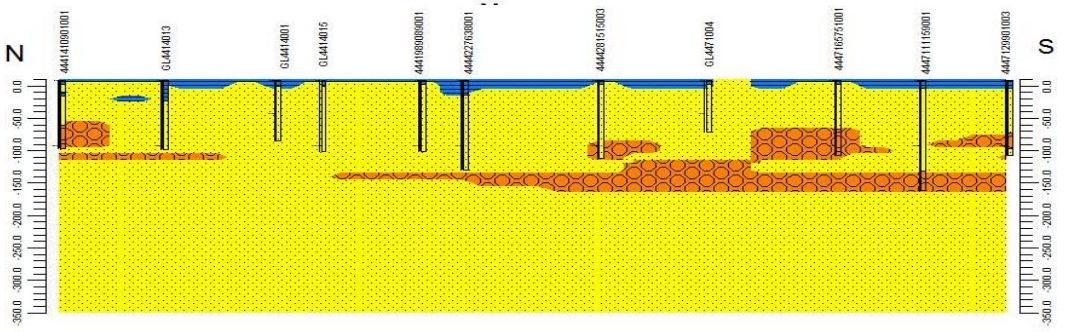
Hydrostratigraphy of The Upper Delta plain

The Upper Delta plain

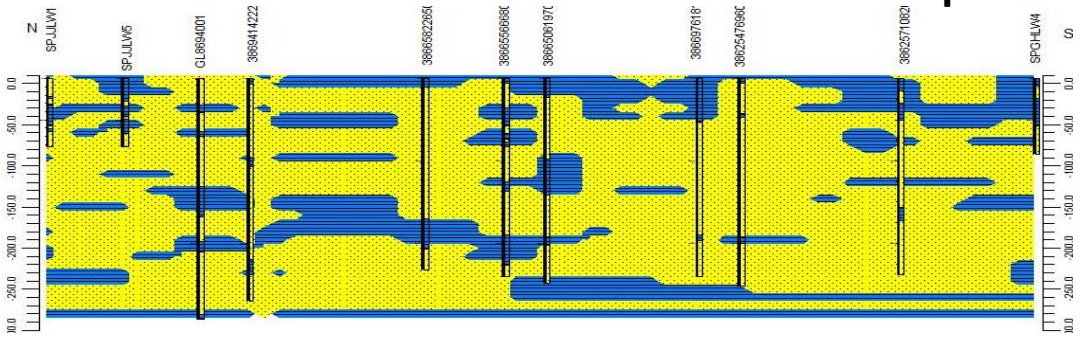
- Upper most clay and silty clay layer varies in thickness from 0 to 10 m
- Sandy up to 300m depth
- Constitutes a single aquifer of sand and gravels.
- Clay or silty-clay aquitards with small areal extent and up to 30m thickness occurs sporadically within the sand aquifer.



Jhenaidaha



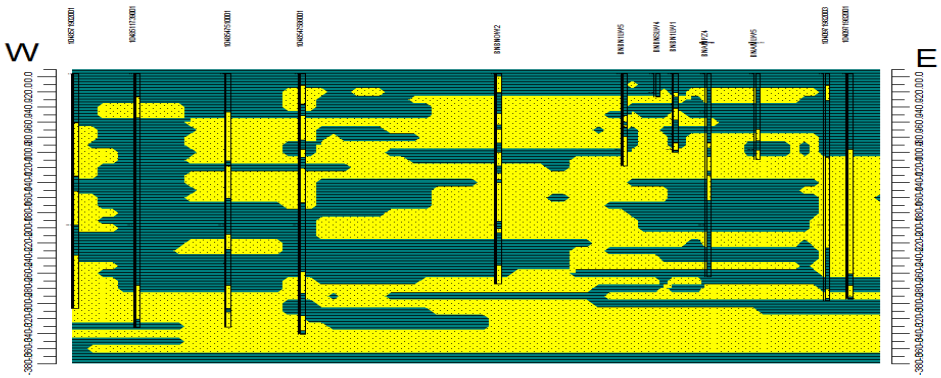
Shariatpur



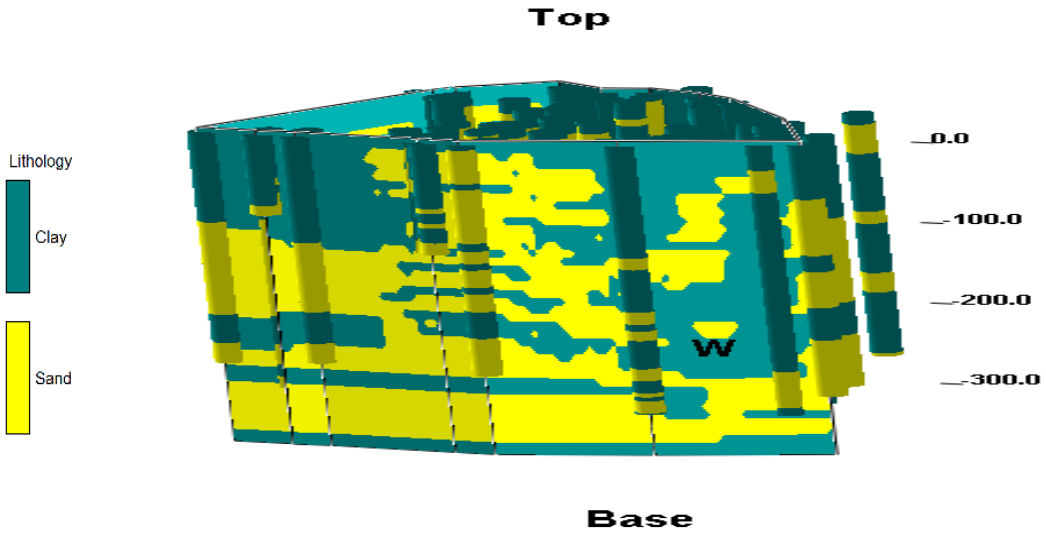
Hydrostratigraphy of The Lower Delta plain

The Lower Delta plain

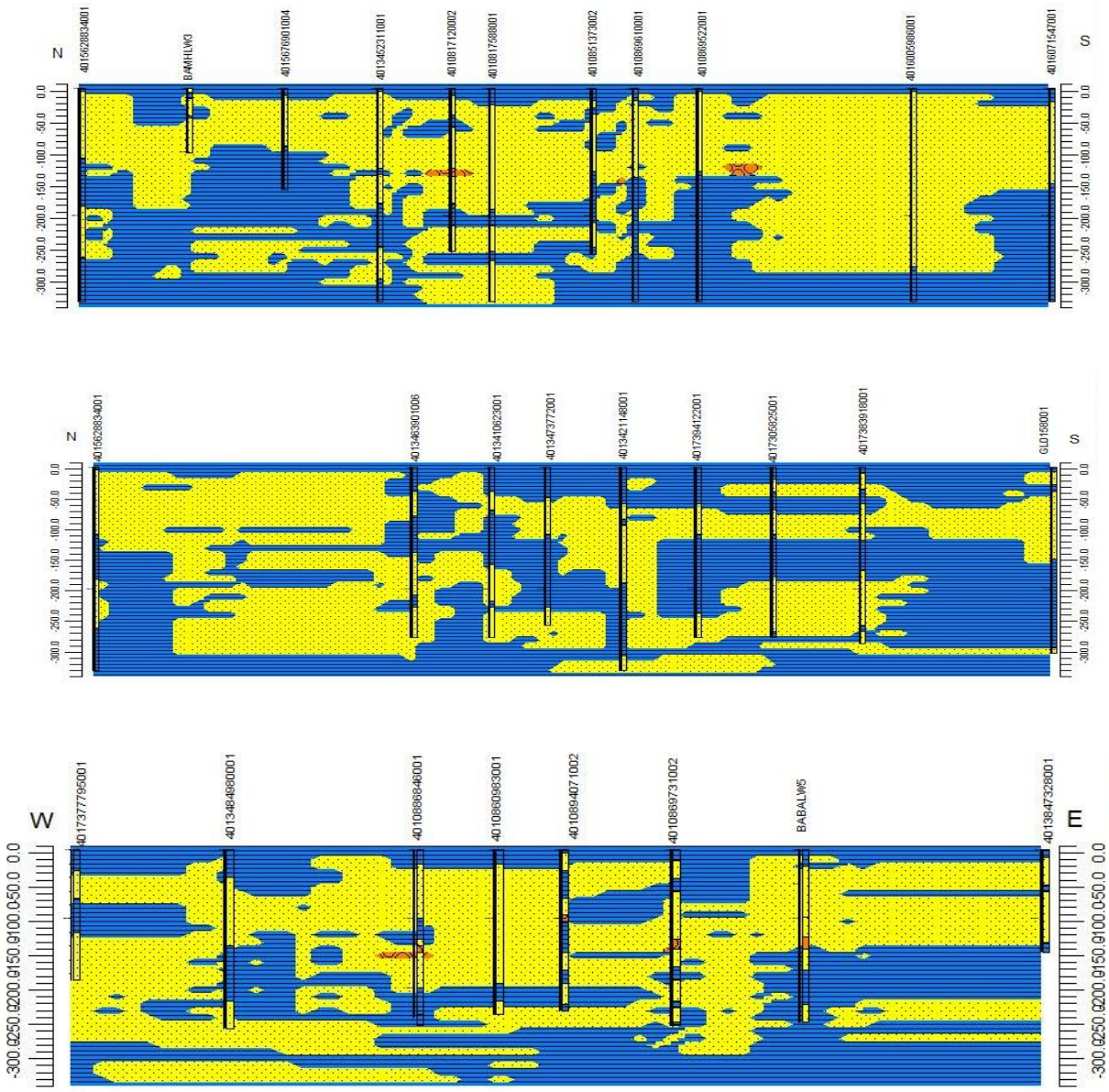
- Regionally extended Upper most clay and silty clay layer varies in thickness from 5 to 35m
- Predominantly by thick clay and silty-clay aquitards up to 300m depth
- Discontinuous sand bodies up to 100m thick occur within the clay and silty clay aquitards



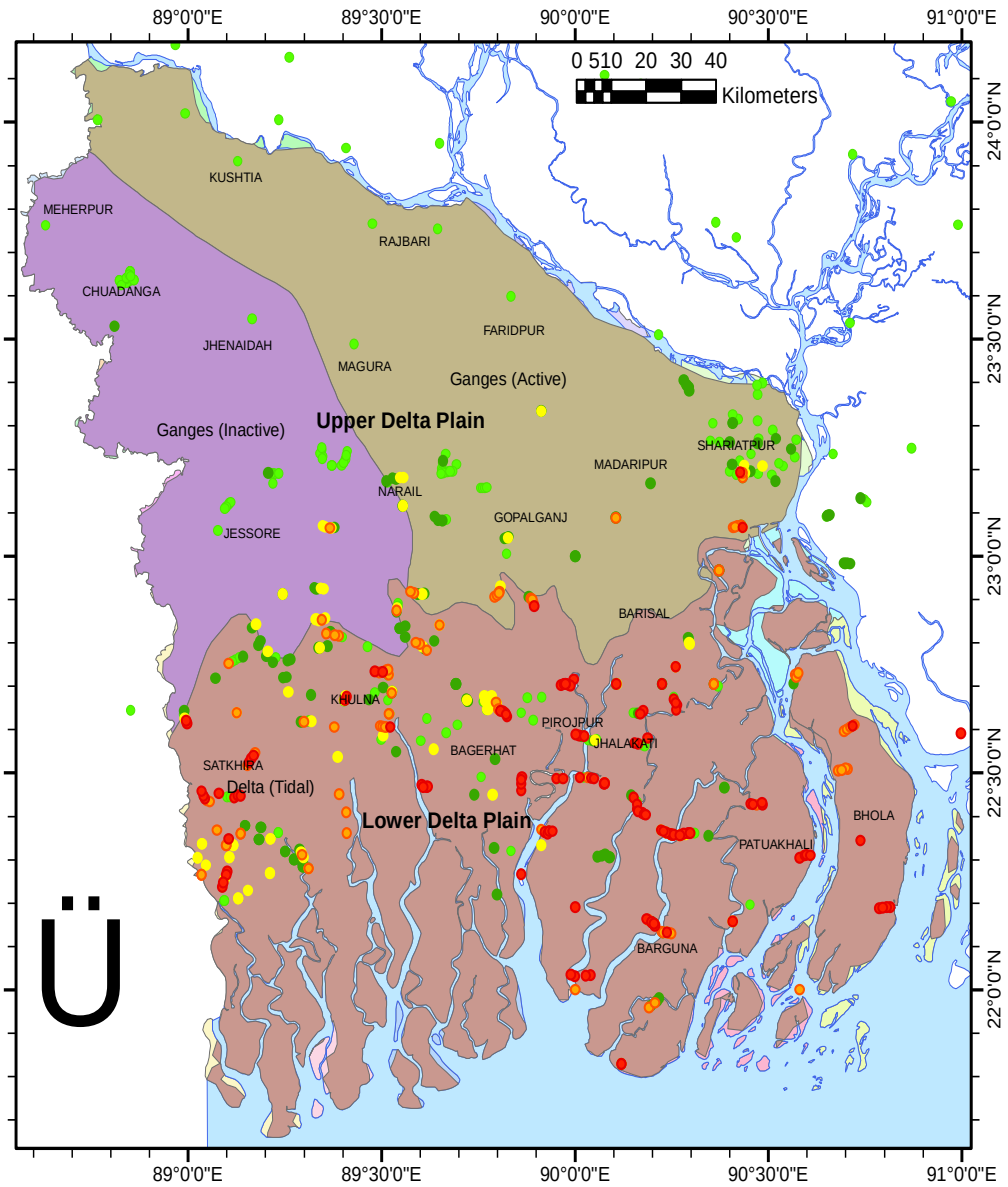
Barguna



Cross-sections of Bagerhat



Occurrence of Salt water in the study area



730 Laboratory measured Cl^- in groundwater for all depths (5m to 400m)

Data Sources:
BWDB 2013
MS Theses of DU, JU and RU
Different Research Projects of BAEC & IAEA

Legend

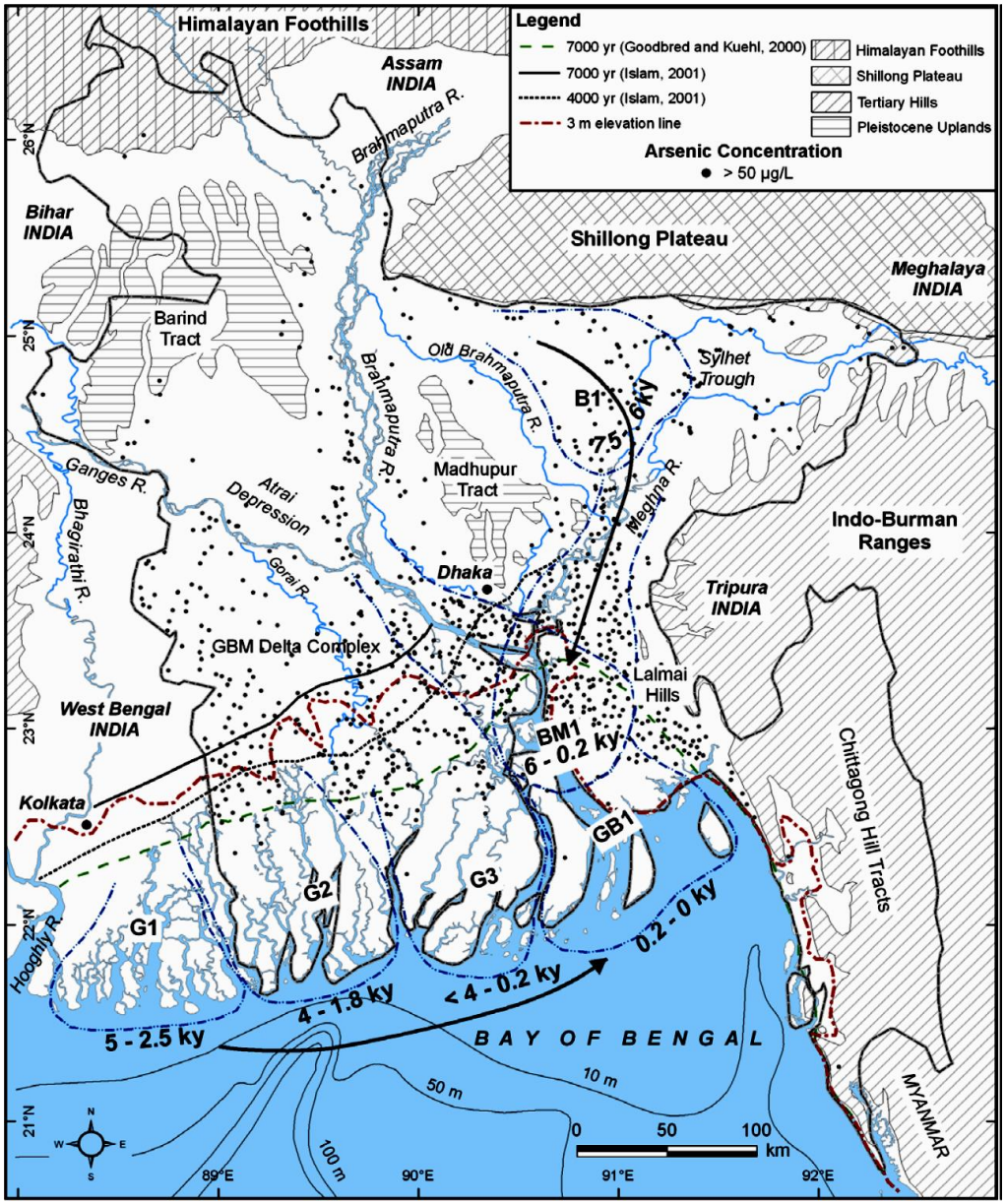
Cl_mg/L

- 10 - 150
- 150 - 600
- 600 - 1500
- 1500 - 3000
- >3000

Holocene Marine Transgression

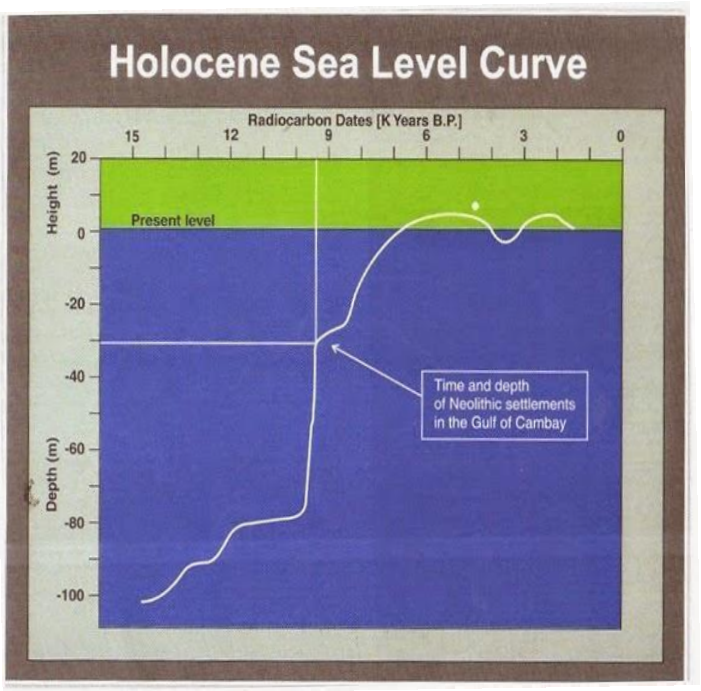
Maximum transgression was reached at about 100 km inland of the present shoreline at about 7000 cal years BP in the Sundarbans and Kuakata area
(Umitsu, 1993; Goodbred and Kuehl, 2000)

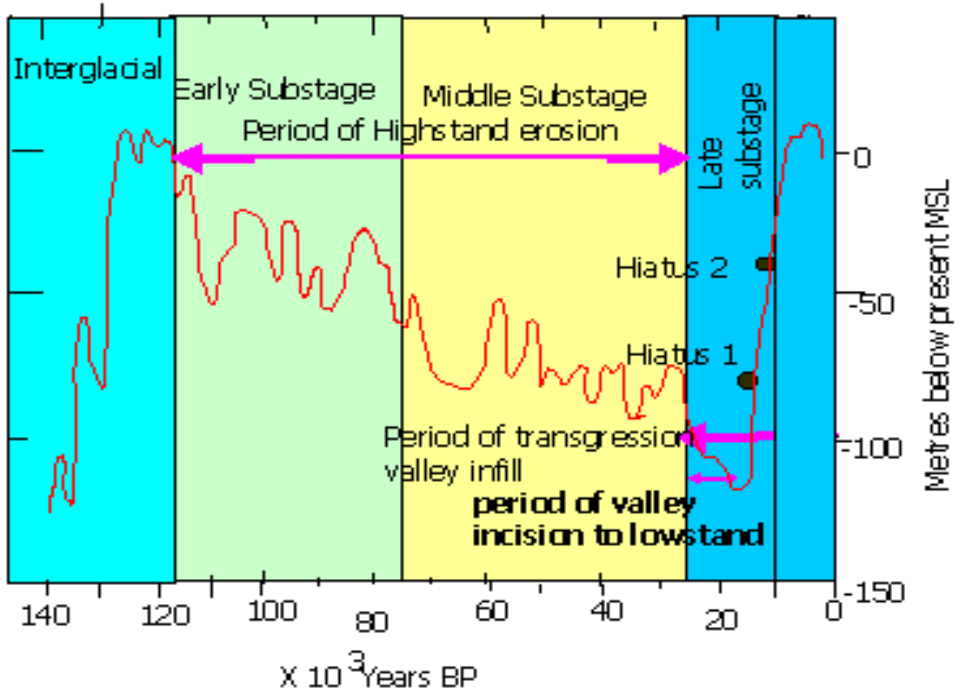
Most of the Delta lobes were developed in the Lower Delta plain area between 5000 to 200 years before present
(Allison et al. 2003)

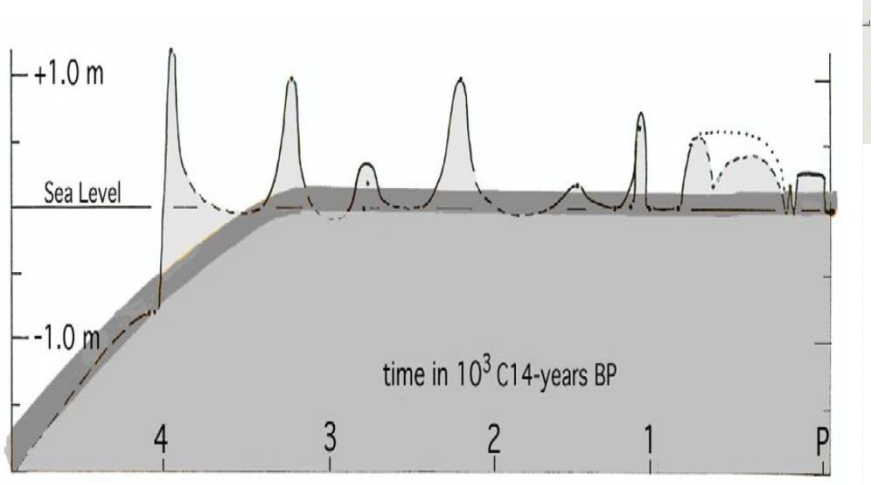


(Source: Shamsudduha and Ashraf Uddin, 2007)

Holocene Marine Transgression







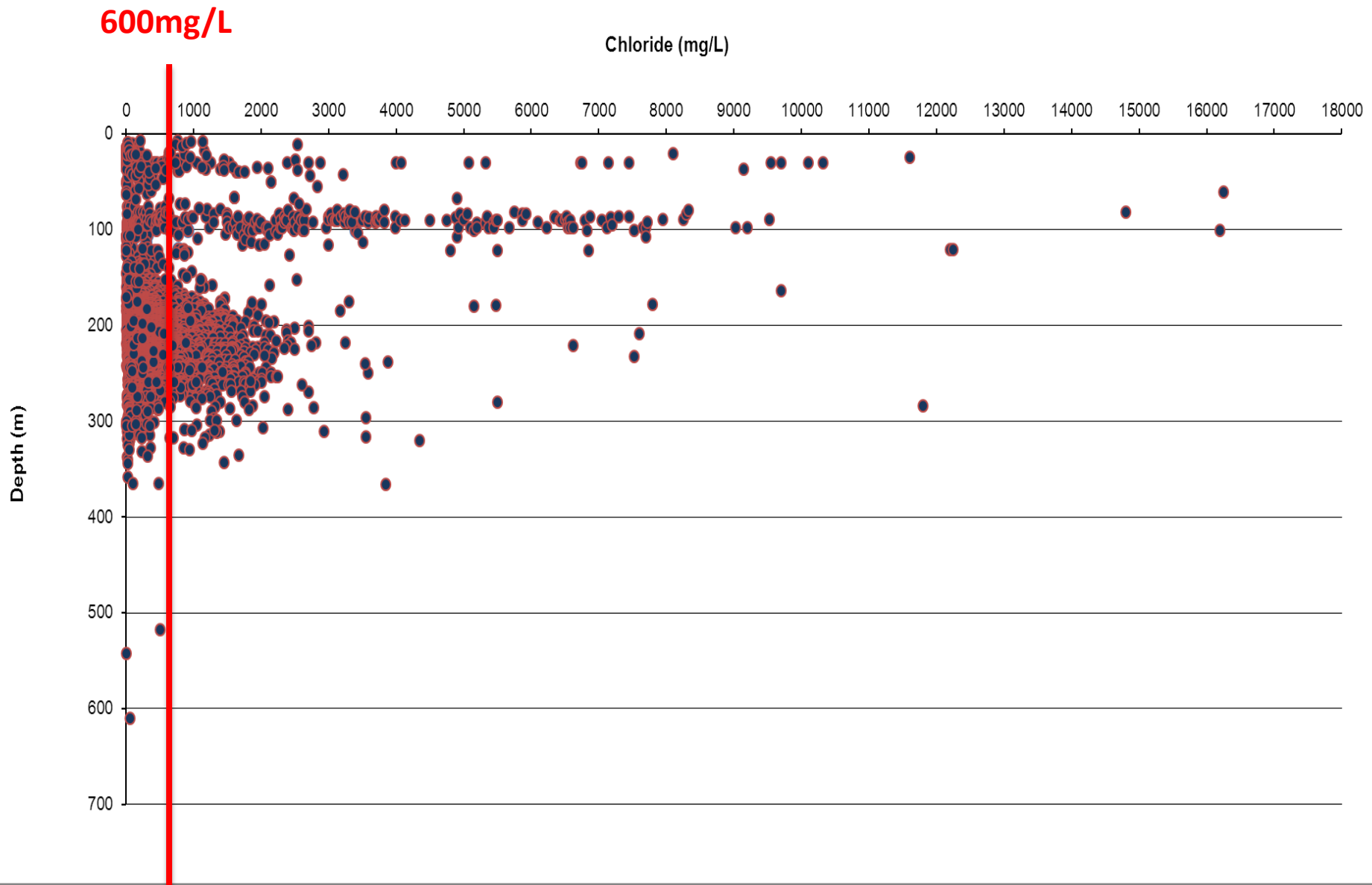
Sea Level Changes During Last Interglacial Transition (After Pirazzoli, 1991)

Paper 1: from Z. Geomorph. N.F., Suppl-Vol. 137, 91-102, 2005.

Sea level changes and crustal movements with special aspects on the Eastern Mediterranean

Nils-Axel Mörner
Paleogeophysics & Geodynamics, Stockholm University, Sweden

Laboratory measured chloride concentration in grounwater at different depths
(Data Source : BRAC WASH Program and others, 3257 data)



Present Drinking Water Supply Scenario in the Study area

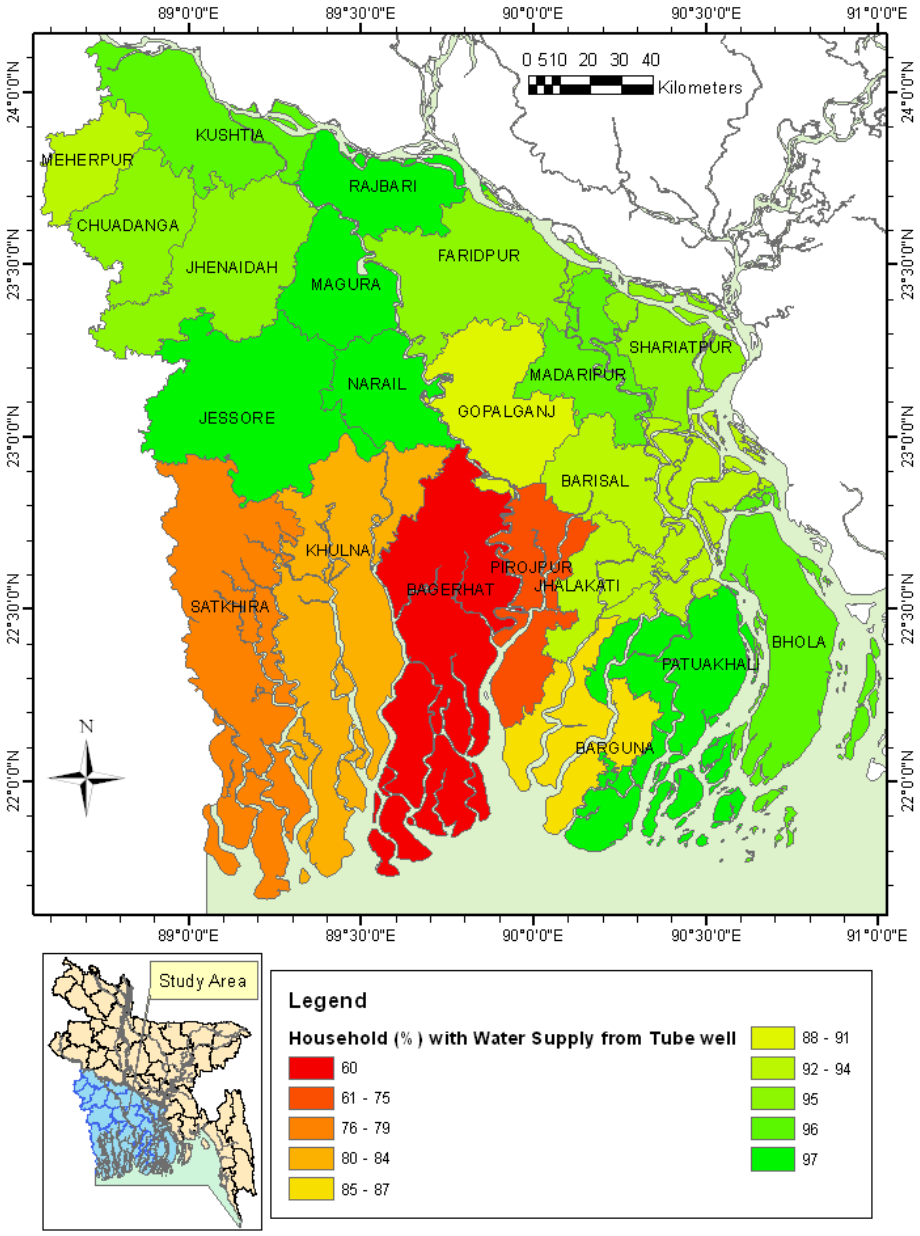
District	Number of Households	Source of Drinking Water (%)			Population	Population density [sq. km]
		Tap	Tube-Well	Other	Total	
Bagerhat	354223	6.4	59.9	33.7	1476090	1027
Barguna	215,842	1.8	86.6	11.6	892,781	488
Barisal	513673	1.6	93.8	4.5	2324310	835
Bhola	372723	0.3	96.2	3.4	1776795	522
Chuadanga	277464	3.0	94.8	2.2	1129015	962
Faridpur	420174	2.8	94.6	2.6	1912969	932
Gopalganj	249872	5.8	90.7	3.5	1172415	798
Jessore	656413	1.2	97.0	1.8	2764547	1060
Jhalokati	158139	0.6	93.8	5.6	682669	966
Jhenaidah	422332	2.4	95.2	2.4	1771304	902
Khulna	547347	2.0	83.7	14.3	2318527	1046
Kushtia	477289	1.5	95.9	2.6	1946838	1210
Madaripur	252149	1.0	95.8	3.3	1165952	1036
Magura	205902	1.3	96.5	2.2	918419	884
Meherpur	166312	3.0	93.8	3.3	655392	872
Narail	162607	1.2	96.6	2.2	721668	746
Patuakhali	346462	0.8	96.8	2.3	1535854	477
Pirojpur	256002	4.4	74.8	20.8	1113257	871
Rajbari	238153	0.8	96.6	2.6	1049778	961
Satkhira	469890	5.9	79.1	15.0	1985959	1044
Shariatpur	247880	0.7	95.4	4.0	1155824	984
					30,470,363	

Data Source: Population Census 2011 (BBS 2012)

People Affected by high Salinity

District	Number of Households	Source of Drinking Water (%)			Population
		Tap	Tube-Well	Other	Total
Bagerhat	354223	6.4	59.9	33.7	1476090
Pirojpur	256002	4.4	74.8	20.8	1113257
Satkhira	469890	5.9	79.1	15.0	1985959
Khulna	547347	2.0	83.7	14.3	2318527
Barguna	215,842	1.8	86.6	11.6	892,781
					77, 86614

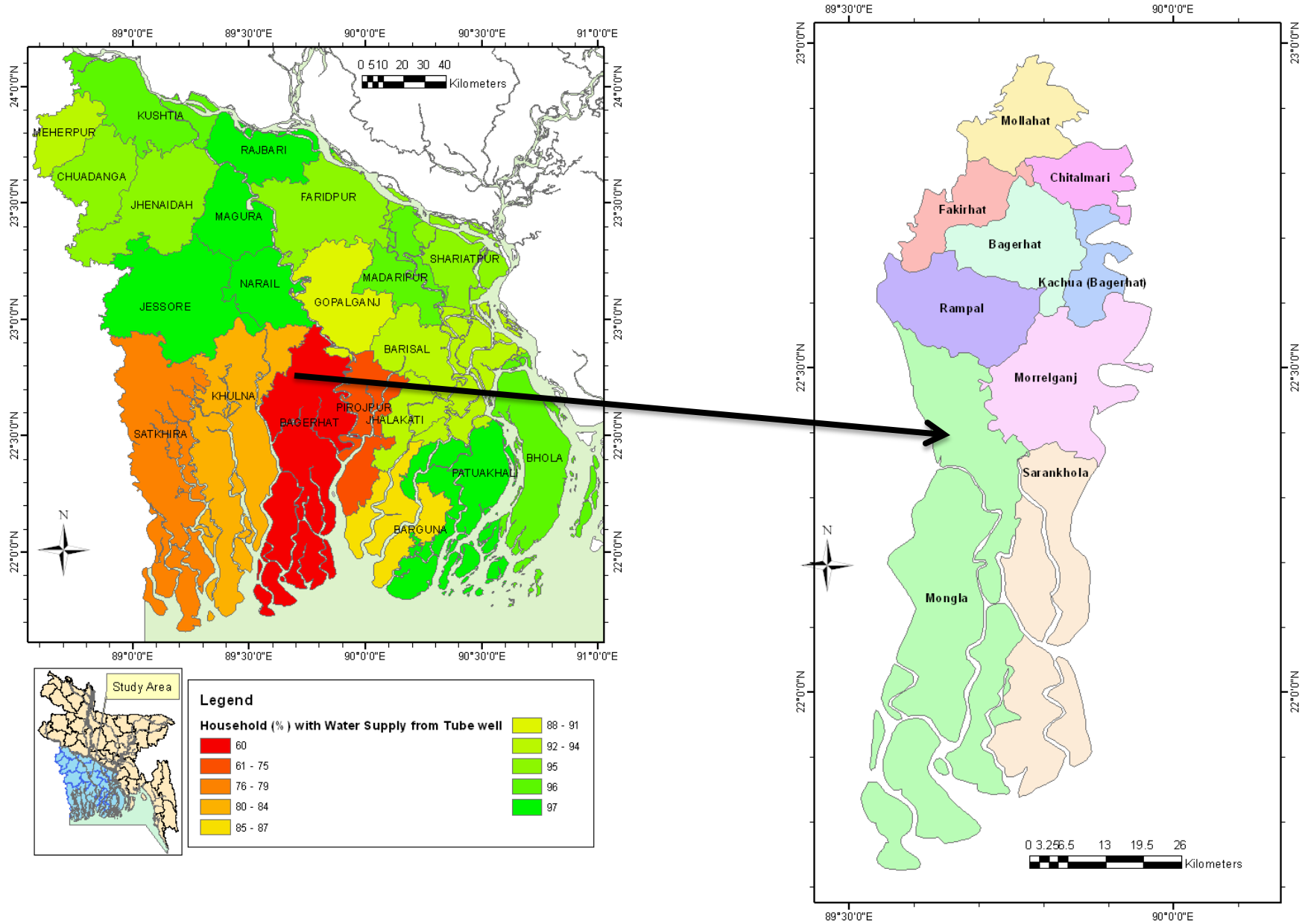
At least 7.79 million people in five districts are highly threatened by high salinity in drinking water



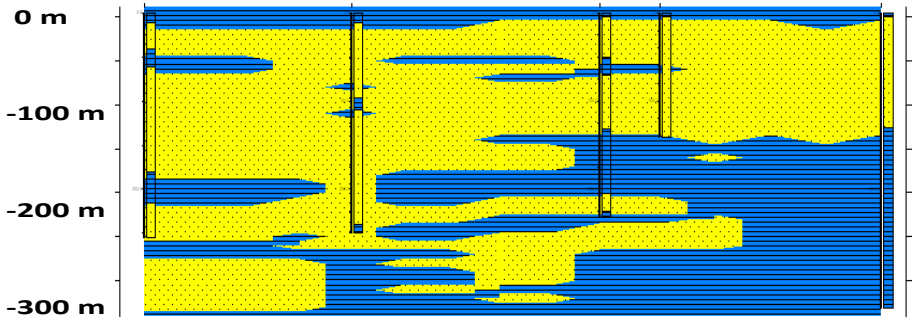
Technology in use for water supply

- Deep Tube well
- Shallow Tube Well
- Dug/Ring Well (DW)
- Pond Sand Filter (PSF)
- Rain Water Harvesting (RWH)
- Shallow Shrouded Tubewell (SST)
- Iron Removal Unit (IRU)
- Arsenic Removal Technology (ART)

Case study Bagerhat District



Bagerhat Sadar Upazila

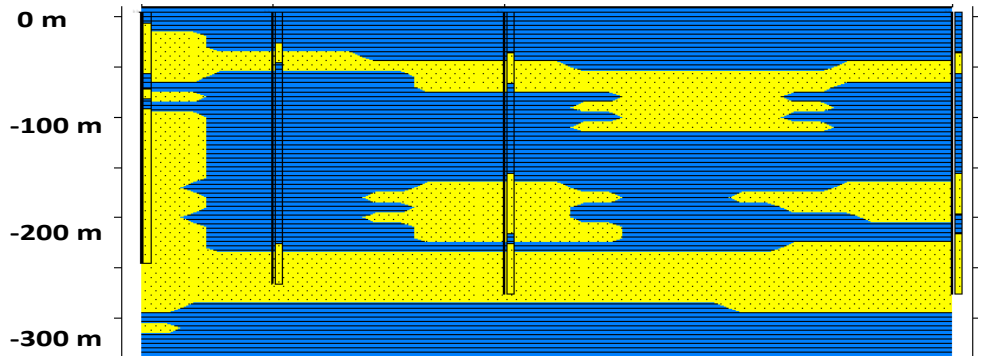


Union Name	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
				STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Barai Para	Yes	70	800	-	-	100%	-	-	-	-	-
Bemarta	Yes	65	800	-	-	75%	-	5%	-	20%	-
Bishnupur	Yes	65	800	-	-	95%	-	-	-	5%	-
Gota Para	Yes	65	800	-	-	75%	-	-	-	25%	-
Jatrapur	No.	75	800	-	-	100%	-	-	-	-	-
Kara Para	Yes	75	800	-	-	100%	-	-	-	-	-
Khanpur	No.	70	800	-	-	100%	-	-	-	-	-
Deuna	Yes	55	800	-	-	80%	-	-	-	20%	-
Rakhal Gachhi	No.	65	800	-	-	100%	-	-	-	-	-
Shat Gambuj	No.	65	800	-	-	100%	-	-	-	-	-
Paura shava	-	65	800	-	-	-	-	-	-	-	-

Chitalmari Upazila

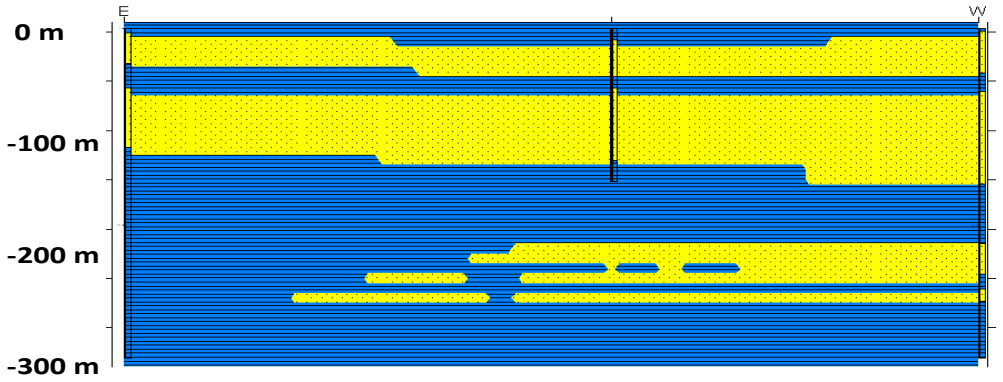
Union Name	% of Arsenic Contaminated Tube wells	Iron Problem (>5 ppm) Yes/No	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Bara Baria	77%	Yes	No.	77	850	-	-	25%	-	40%	2%	30%	3%
Char Baniari	95%	Yes	Yes	62	-	-	-	-	-	60%	2%	35%	3%
Chitalmari	78%	Yes	No.	107	850			30%		35%	2%	30%	3%
Hizla	84%	Yes	Yes	77	-			-		60%	2%	35%	3%
Kalatala	88%	Yes	Yes	77	-			-		35%	2%	60%	3%
Santoshpur	81%	Yes	Yes	72	-			-		55%	2%	40%	3%
Shibpur	68%	Yes	Yes	62	-			-		60%	2%	35%	3%

Fakirhat Upazila



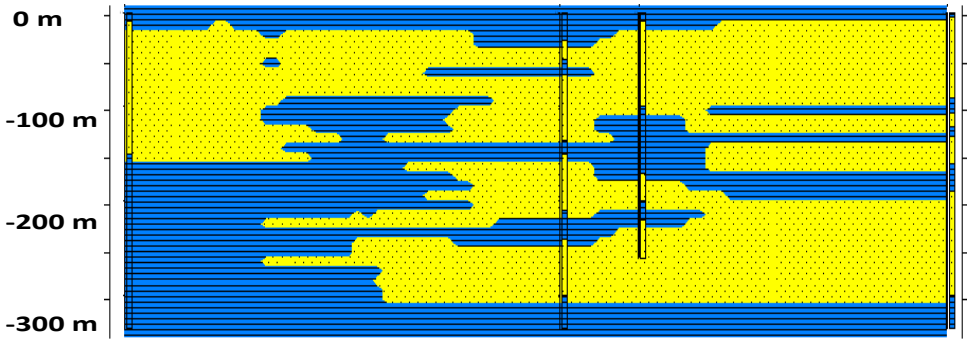
Union Name	% of Arsenic Contaminated Tube wells	Iron Problem (>5 ppm) Yes/No	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Bahirdia Mansa	71%	No.	Yes	140	900	-	-	60%	-	-	-	40%	-
Betaga	57%	No.	No.	150	900	-	-	95%	-	5%	-	-	-
Fakirhat	69%	No.	No.	160	900	-	-	95%	-	5%	-	-	-
Lakhpur	70%	No.	No.	140	900	-	-	95%	-	5%	-	-	-
Mulghar	90%	No.	No.	180	900	-	-	95%	-	5%	-	-	-
Naldha Maubhog	75%	No.	No.	170	900	-	-	80%	-	5%	-	15%	-
Piljanga	73%	No.	No.	150	900	-	-	95%	-	5%	-	-	-
Subhadia	48%	No.	No.	170	900	-	-	95%	-	5%	-	-	-

Kachua Upazila



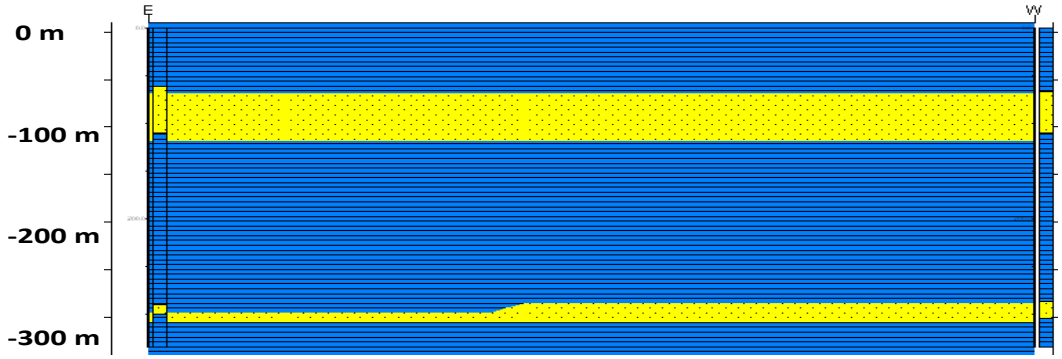
Union Name	% of Arsenic Contaminated Tube wells	Iron Problem (>5 ppm) Yes/No	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Badhal	60%	Yes	No.	88	-	22%	-	-	-	8%	2%	25%	43%
Dhopakhali	78%	Yes	No.	70	-	20%	-	-	-	10%	3%	20%	47%
Gazalia	58%	Yes	No.	75	-	18%	-	-	-	9%	5%	20%	48%
Gopalpur	24%	Yes	No.	73	-	16%	-	-	-	7%	2%	25%	50%
Kachua	25%	Yes	No.	90	-	22%	-	-	-	9%	6%	24%	39%
Maghia	38%	Yes	No.	74	-	20%	-	-	-	9%	5%	22%	44%
Rari Para	48%	Yes	No.	80	-	25%	-	-	-	8%	5%	20%	42%

Mollahat Upazila



Union Name	% of Arsenic Contaminated Tube wells	Iron Problem (>5 ppm) Yes/No	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Atjuri	59%	Yes	Yes	70	800	5%	-	80%	-	5%	5%	5%	-
Chunkhola	63%	Yes	Yes	65	800	5%	-	80%	-	5%	5%	5%	
Gangni	71%	Yes	Yes	76	750	10%	-	70%	-	10%	5%	5%	
Gaola	77%	Yes	Yes	62	850	5%	-	30%	-	5%	10%	50%	
Kodalia	70%	Yes	Yes	80	770	25%	-	30%	-	10%	10%	25%	
Kulia	56%	Yes	Yes	80	790	5%	-	80%	-	5%	5%	5%	
Udaypur	73%	Yes	Yes	92	800	10%	-	75%	-	5%	5%	5%	

Mongla Upazila



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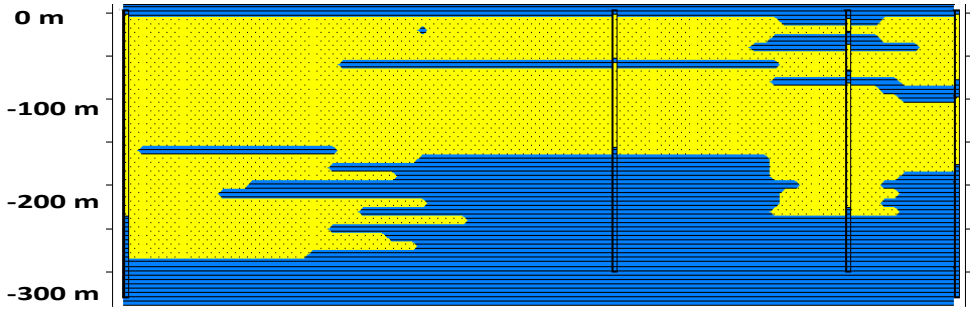
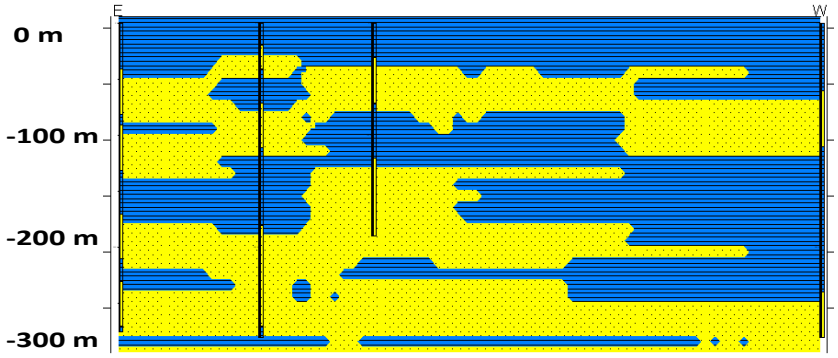
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Burirdanga	0.01	0.01	Yes	60	1000			5%	5%	-	-	85%	5%
Chandpi	0.00	0.00	Yes	70	-	-	-	-	-	-	-	100%	-
Chila	0.00	0.00	Yes	60	-	-	-	-	-	-	-	100%	-
Mithakhali	0.00	0.00	Yes	75	-	-	-	-	-	-	-	100%	-
Paurashava	0.00	0.00	Yes	70	-	-	-	-	-	-	-	100%	-
Sundarban	0.00	0.00	Yes	70	-	-	-	-	-	-	-	100%	-
Suniltala	0.00	0.00	Yes	70	-	-	-	-	-	-	-	100%	-

Morrelganj Upazila



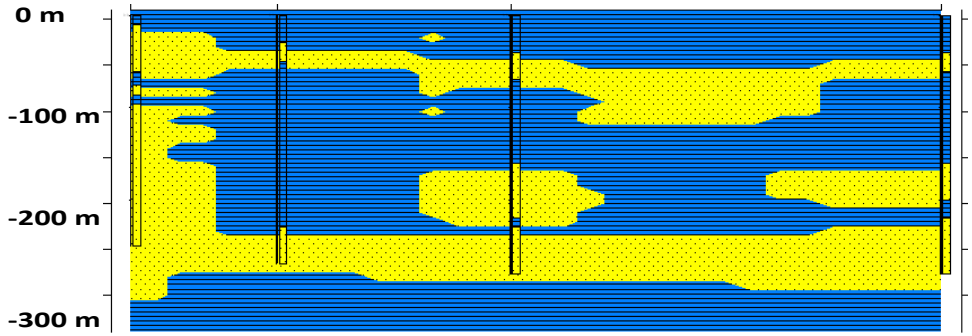
Union Name	% of Arsenic Contaminated Tube wells	Iron Problem (>5 ppm) Yes/No	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Baharbunia	22%	No.	No.	59	-	30%	-	-	-	20%	-	30%	20%
Balaibunia	17%	No.	No.	49	-	15%	-	-	-	10%	-	20%	55%
Banagram	59%	No.	No.	48	-	20%	-	-	-	15%	-	25%	40%
Baraikhali	20%	No.	No.	59	-	10%	-	-	-	5%	-	25%	60%
Chingrakhali	27%	No.	No.	48	-	10%	-	-	-	20%	-	10%	60%
Daibagnyahati	47%	No.	No.	58	-	20%	-	-	-	20%	-	20%	40%
Hogla Pasha	50%	No.	No.	54	-	30%	-	-	-	30%	-	20%	20%
Hoglabunia	39%	No.	No.	58	-	20%	-	-	-	30%	-	10%	40%
Jiudhara	25%	No.	No.	60	-	20%	-	-	-	35%	-	35%	10%
Khuolia	21%	No.	No.	51	-	20%	-	-	-	15%	-	25%	40%
Morrelganj	17%	No.	No.	58	-	10%	-	-	-	10%	-	20%	60%
Nishanbaria	15%	No.	No.	58	-	30%	-	-	-	20%	-	40%	10%
Panchakaran	28%	No.	No.	62	-	20%	-	-	-	30%	-	40%	10%
Putikhali	19%	No.	No.	59	-	20%	-	-	-	15%	-	50%	15%
Ramchandrapur	24%	No.	No.	57	-	10%	-	-	-	10%	-	20%	60%

Rampal Upazila



Union Name	% of Arsenic Contaminated Tube wells	Iron Problem (>5 ppm) Yes/No	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Baintala	0%	No.	No.	65	810	-	-	100%	-	-	-	-	-
Banshtali	0%	No.	No.	75	800	-	-	100%	-	-	-	-	-
Bhojpatia	30%	No.	Yes	82	-	5%	-	-	-	5%	-	85%	-
Gaurambha	0%	No.	No.	85	830	-	-	100%	-	-	-	-	-
Hurka	7%	No.	Yes	82	680	10%	-	30%	-	5%	-	50%	5%
Malliker Ber	80%	No.	Yes	85	-	-	-	-	-	20%	-	70%	10%
Perikhali	60%	No.	Yes	85	-	15%	-	-	-	10%	-	65%	10%
Rajnagar	35%	No.	Yes	70	650	5%	-	35%	-	5%	-	50%	5%
Rampal	0%	No.	No.	85	820	-	-	75%	-	-	-	20%	5%
Ujalkur	0%	No.	No.	70	830	-	-	95%	-	-	-	-	5%

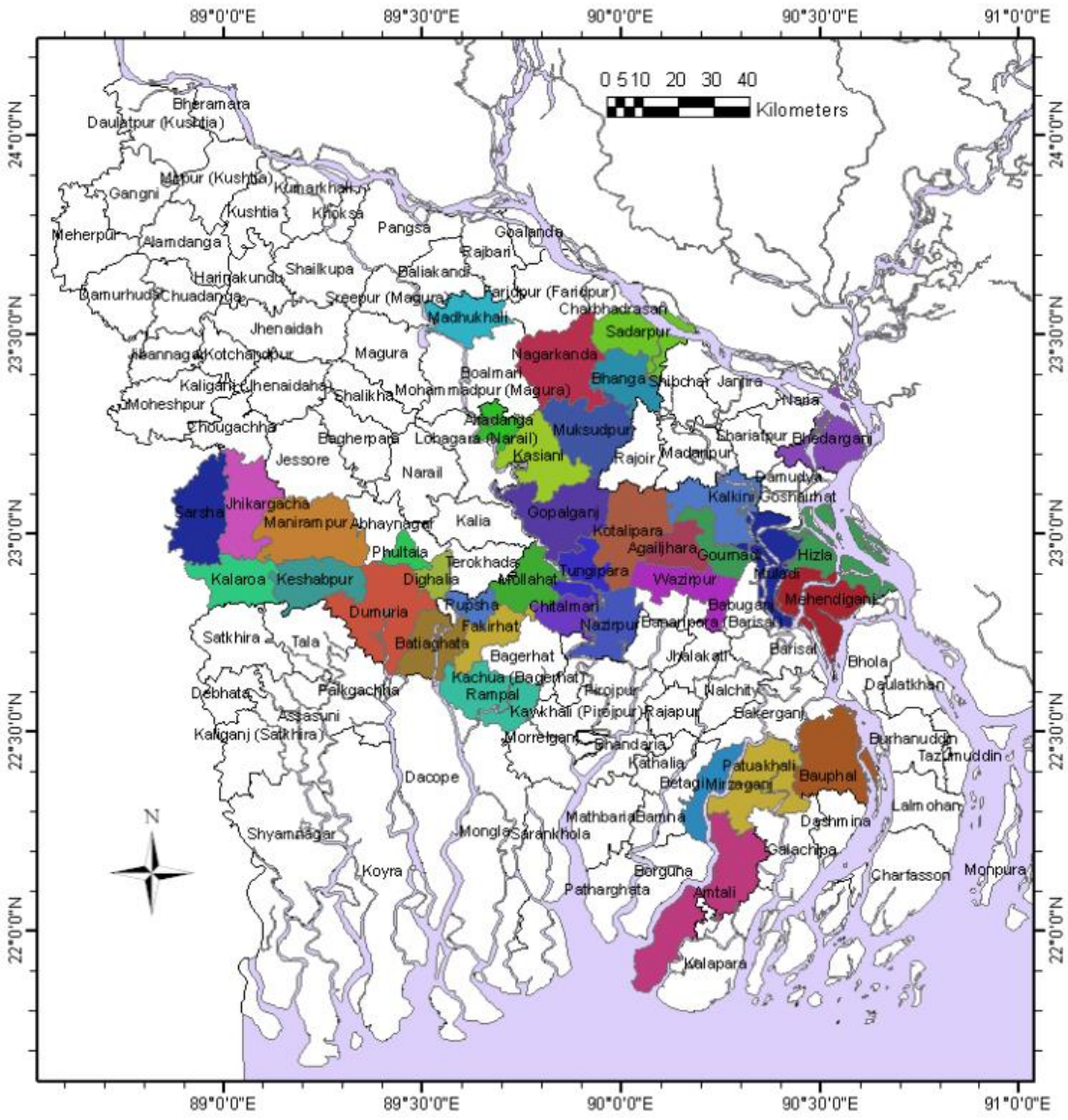
Sarankhola Upazila



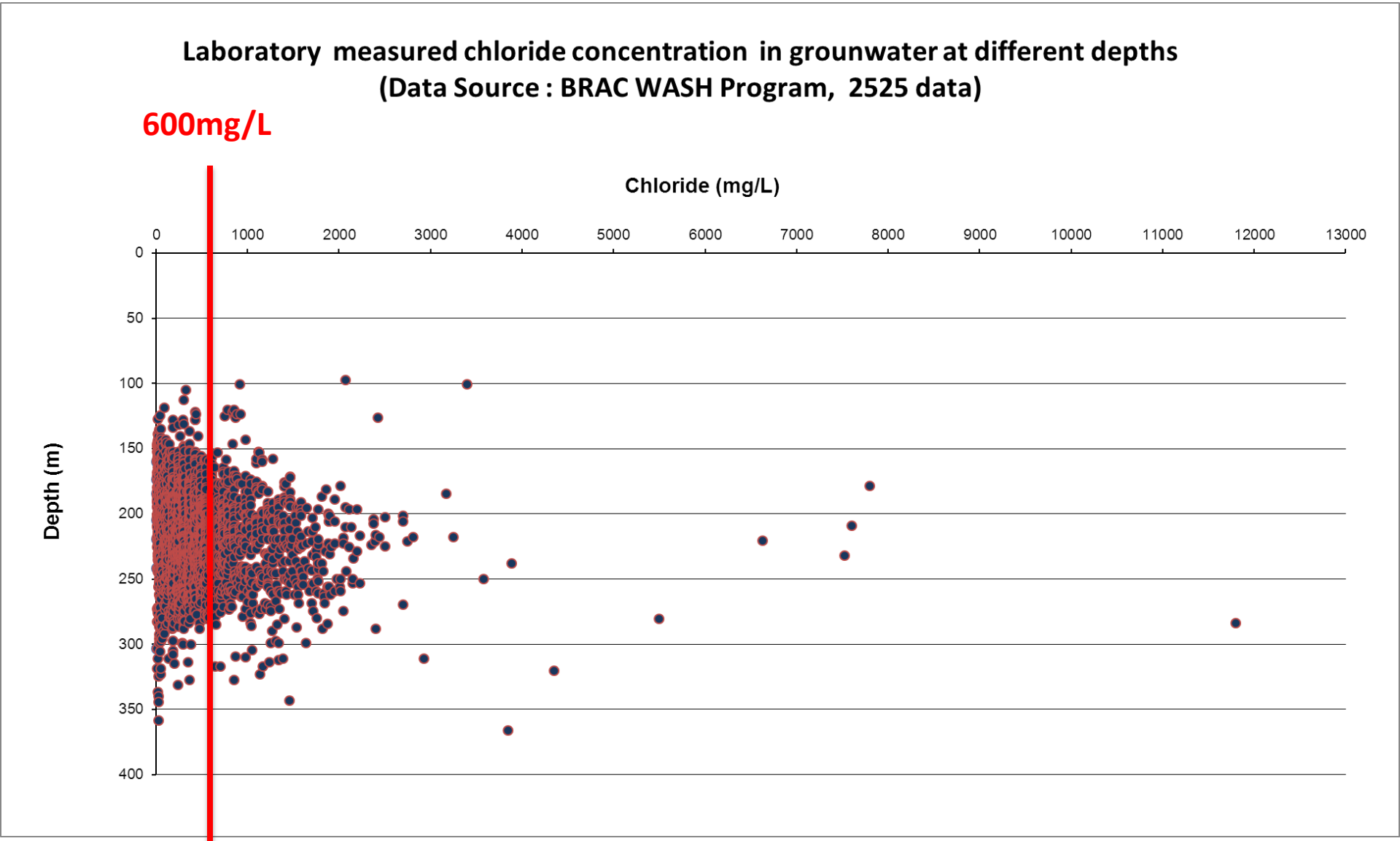
Union Name	% of Arsenic Contaminated Tube wells	Iron Problem (>5 ppm) Yes/No	Chloride Problem (>600 ppm) Yes/No	Average Depth of STWs in Feet	Average Depth of DTWs in Feet	Technology in Use (%)							
						STW (No. 6)	STW (T. Dev)	DTW (No. 6)	DTW (T. Dev)	PSF	Ring Well	Rain Water Harvesting	SST/ VSST
Dakshinkhali	16.25%	No.	Yes	50	-	5%	-	-	-	45%	-	30%	25%
Dhansagar	2.5%	No.	Yes	55	-	5%	-	-	-	35%	-	40%	20%
Khontakata	4.31%	No.	Yes	48	-	5%	-	-	-	65%	-	20%	10%
Royenda	16.25%	No.	Yes	55	-	10%	-	-	-	60%	-	20%	10%
Sharankhola Range	10.2%	No.	Yes	55	-	5%	-	-	-	65%	-	20%	10%

BRAC WASH Program Salinity data of Different Upazilas

Serial No	DIST_NAME	THANA_NAME	Chloride data
1	Bagerhat	Chitalmari	118
2	Bagerhat	Fakirhat	15
3	Bagerhat	Mollahat	132
4	Bagerhat	Rampal	13
5	Barguna	Amtali	5
6	Barisal	Agailjhara	32
7	Barisal	Gournadi	33
8	Barisal	Hizla	33
9	Barisal	Mehendiganj	18
10	Barisal	Muladi	50
11	Barisal	Wazirpur	17
12	Faridpur	Alfadanga	78
13	Faridpur	Bhanga	161
14	Faridpur	Madhukhali	24
15	Faridpur	Nagarkanda	148
16	Faridpur	Sadarpur	107
17	Gopalganj	Gopalganj	197
18	Gopalganj	Kasiani	111
19	Gopalganj	Kotalipara	147
20	Gopalganj	Muksudpur	134
21	Gopalganj	Tungipara	9
22	Jessore	Jhikargacha	99
23	Jessore	Keshabpur	124
24	Jessore	Manirampur	155
25	Jessore	Sarsha	50
26	Khulna	Batiaghata	43
27	Khulna	Dighalia	82
28	Khulna	Dumuria	61
29	Khulna	Phultala	20
30	Khulna	Rupsha	57
31	Madaripur	Kalkini	57
32	Patuakhali	Bauphal	11
33	Patuakhali	Mirzaganj	6
34	Patuakhali	Patuakhali	15
35	Pirojpur	Nazirpur	14
36	Satkhira	Kalaroa	105
37	Shariatpur	Bhedarganj	25
			2525



BRAC WASH Program Salinity data of Different Upazilas



Bangladesh Drinking Water Standard

The Environment Conservation Rules, 1997

[Bangla text of the Rules was published in the Bangladesh Gazette, Extra-ordinary Issue of 28-8-1997 and amended by Notification SRO 29-Law/2002 of 16 February 2002.]

Government of the People's Republic of Bangladesh
Ministry of Environment and Forest

NOTIFICATION

Date, 12 Bhadra 1404/27 August 1997

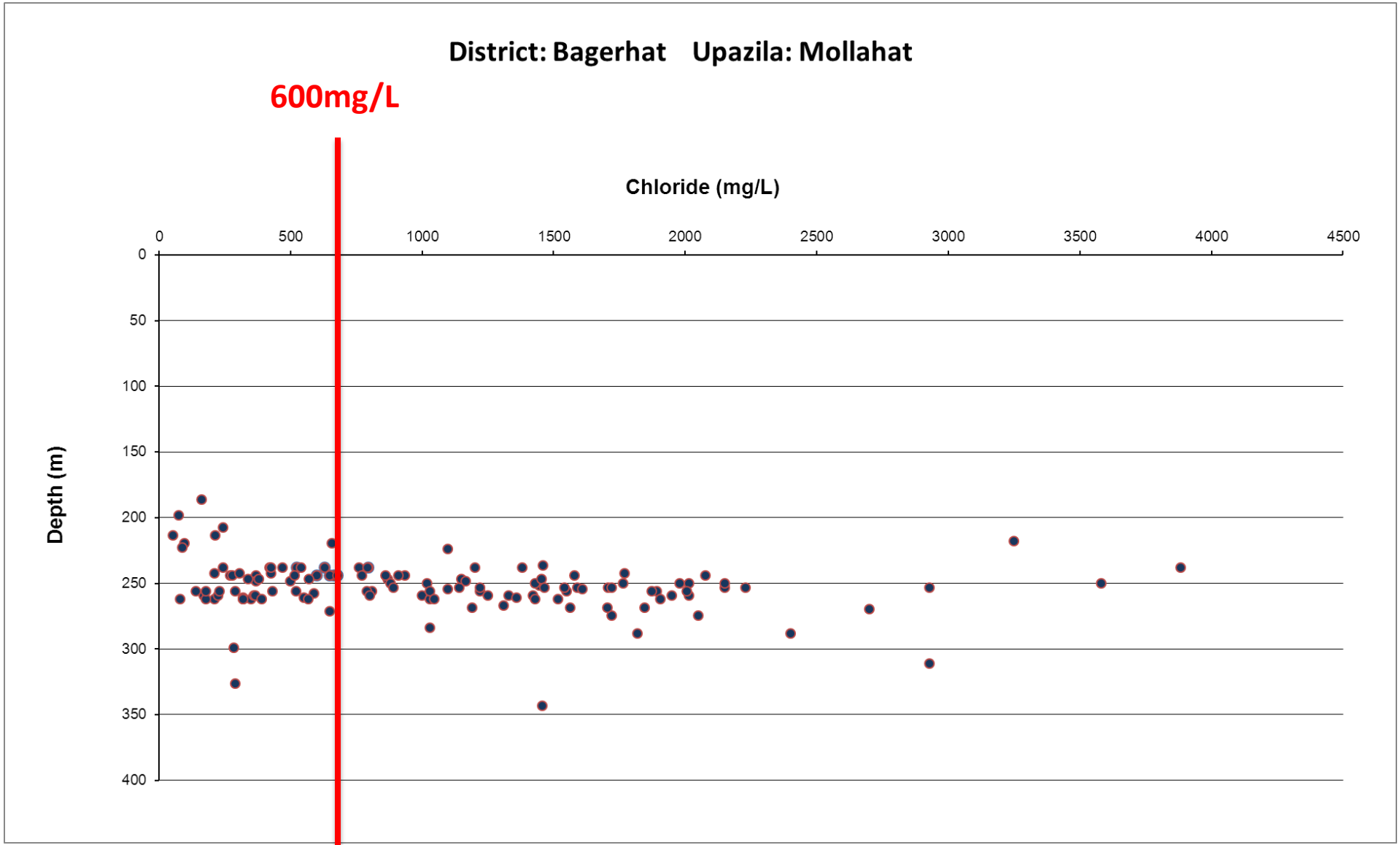
(B) Standards for drinking water

Sl. No.	Parameter	Unit	Standards
1	2	3	4
1.	Aluminum	mg/l	0.2
2.	Ammonia (NH_3)	„	0.5
3.	Arsenic	„	0.05
4.	Balium	„	0.01
5.	Benzene	„	0.01
6.	BOD_5 20°C	„	0.2
7.	Boron	„	1.0
8.	Cadmium	„	0.005
9.	Calcium	„	75
10.	Chloride	„	150 – 600*

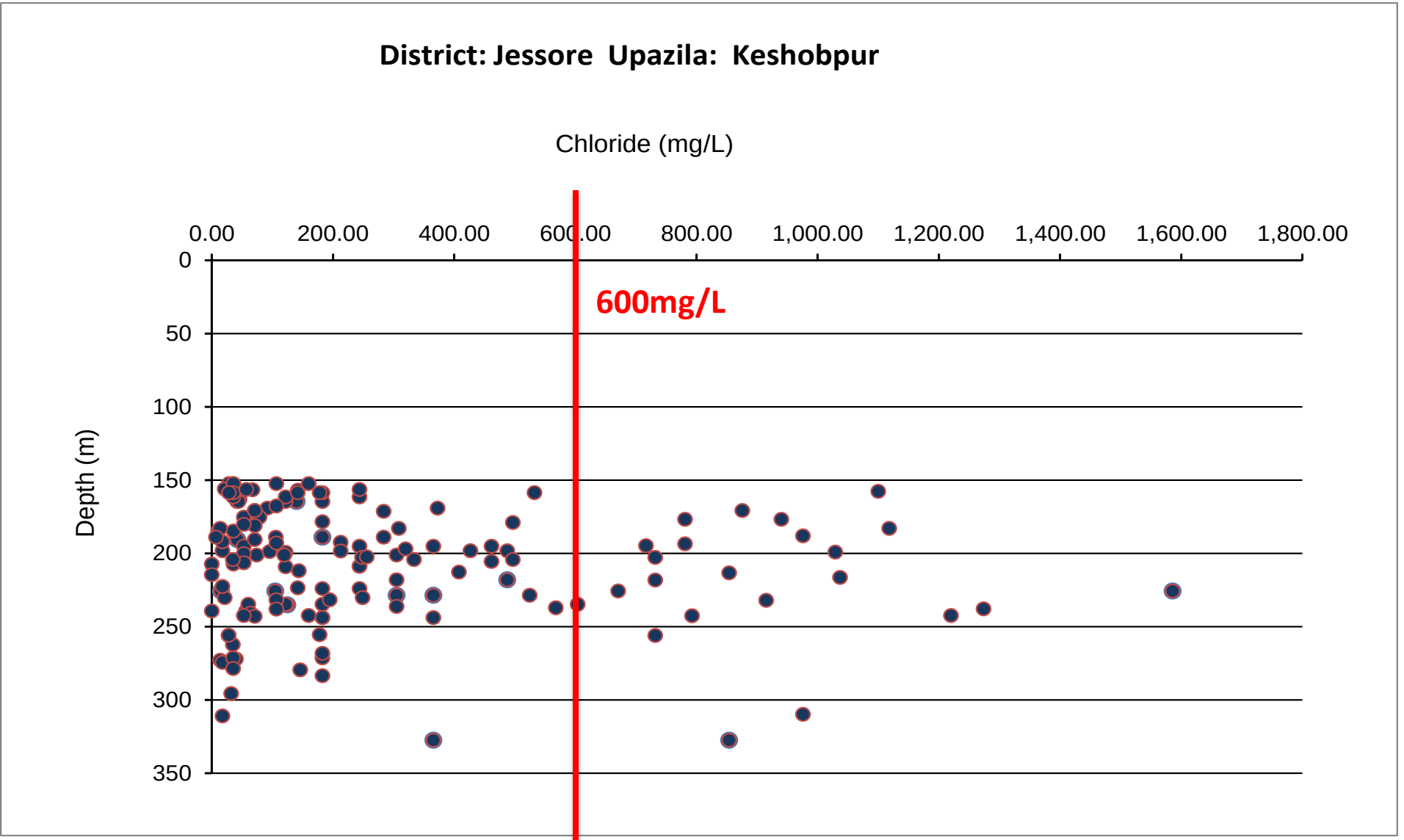
70% of Deep Tube wells maintained Bangladesh Drinking Water Standard For Chloride (150 to 600 mg/L)

- **792 (31%)** exceeded Bangladesh Standard of Drinking water for Chloride (150 to 600 mg/L)
- **360 (14%)** exceeded 1000 mg/L of Chloride
- **140 (5.5%)** exceeded 1500 mg/L of Chloride

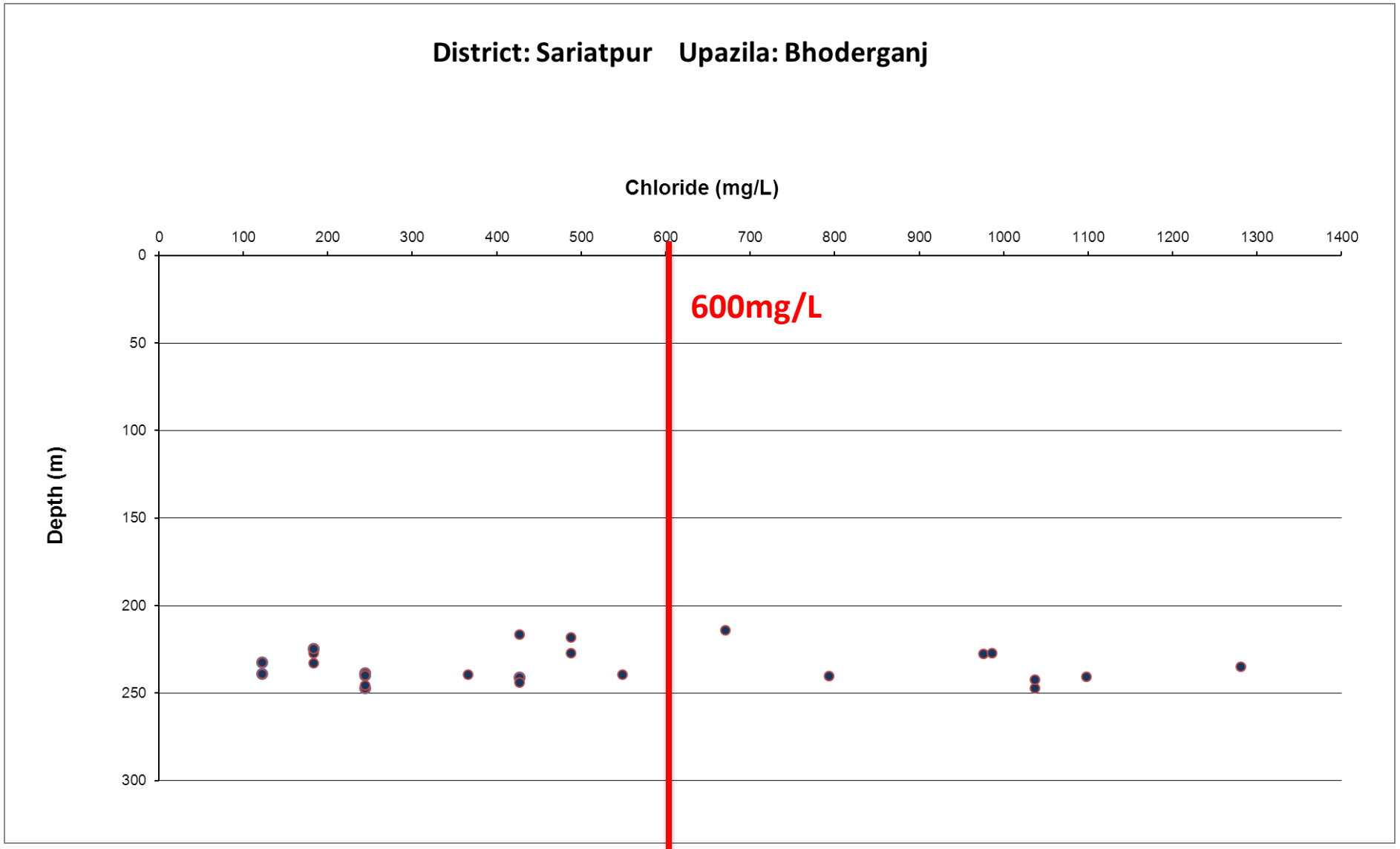
70% of Deep Tube wells maintained Bangladesh Drinking Water Standard For Chloride (150 to 600 mg/L)



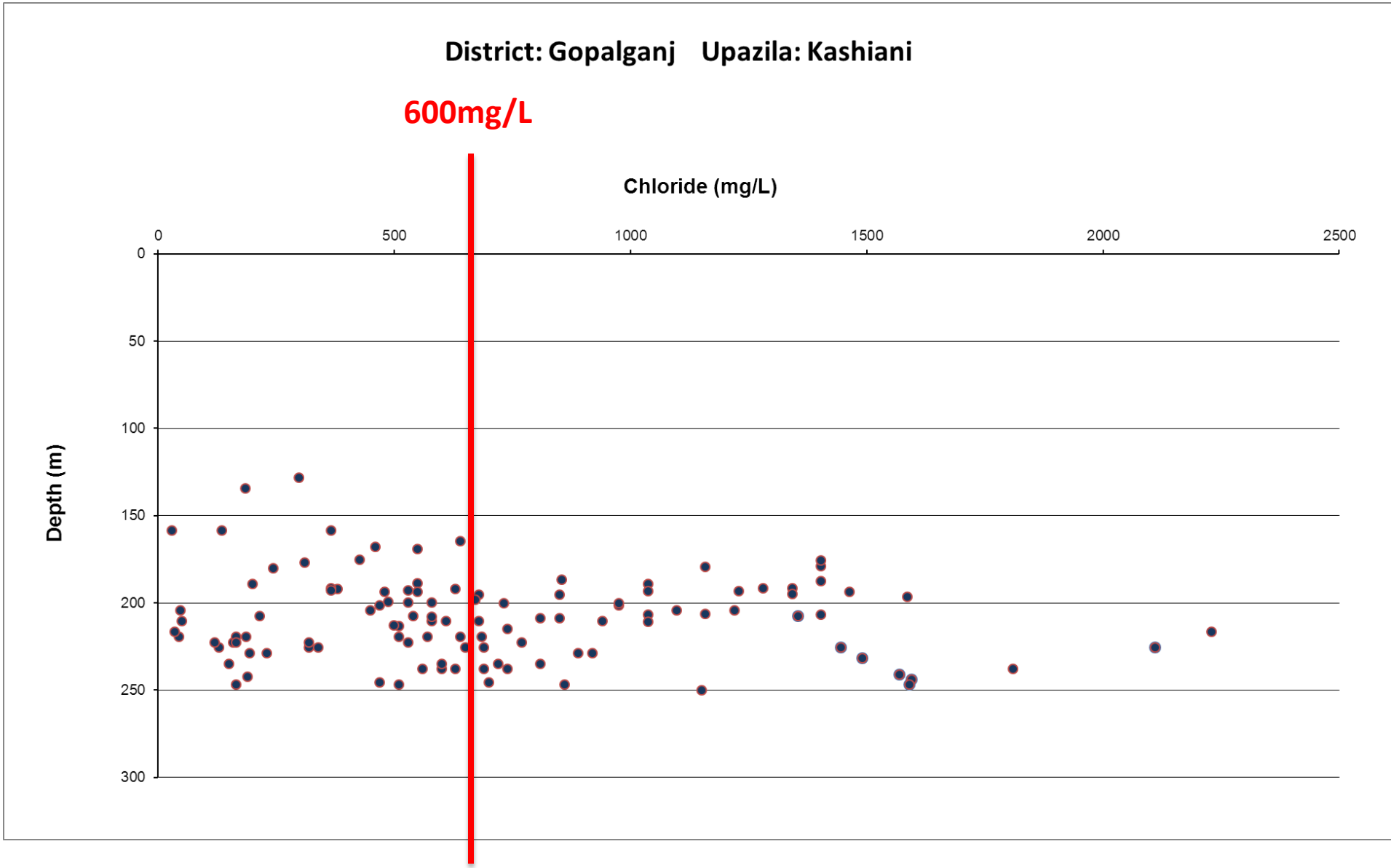
70% of Deep Tube wells maintained Bangladesh Drinking Water Standard For Chloride (150 to 600 mg/L)



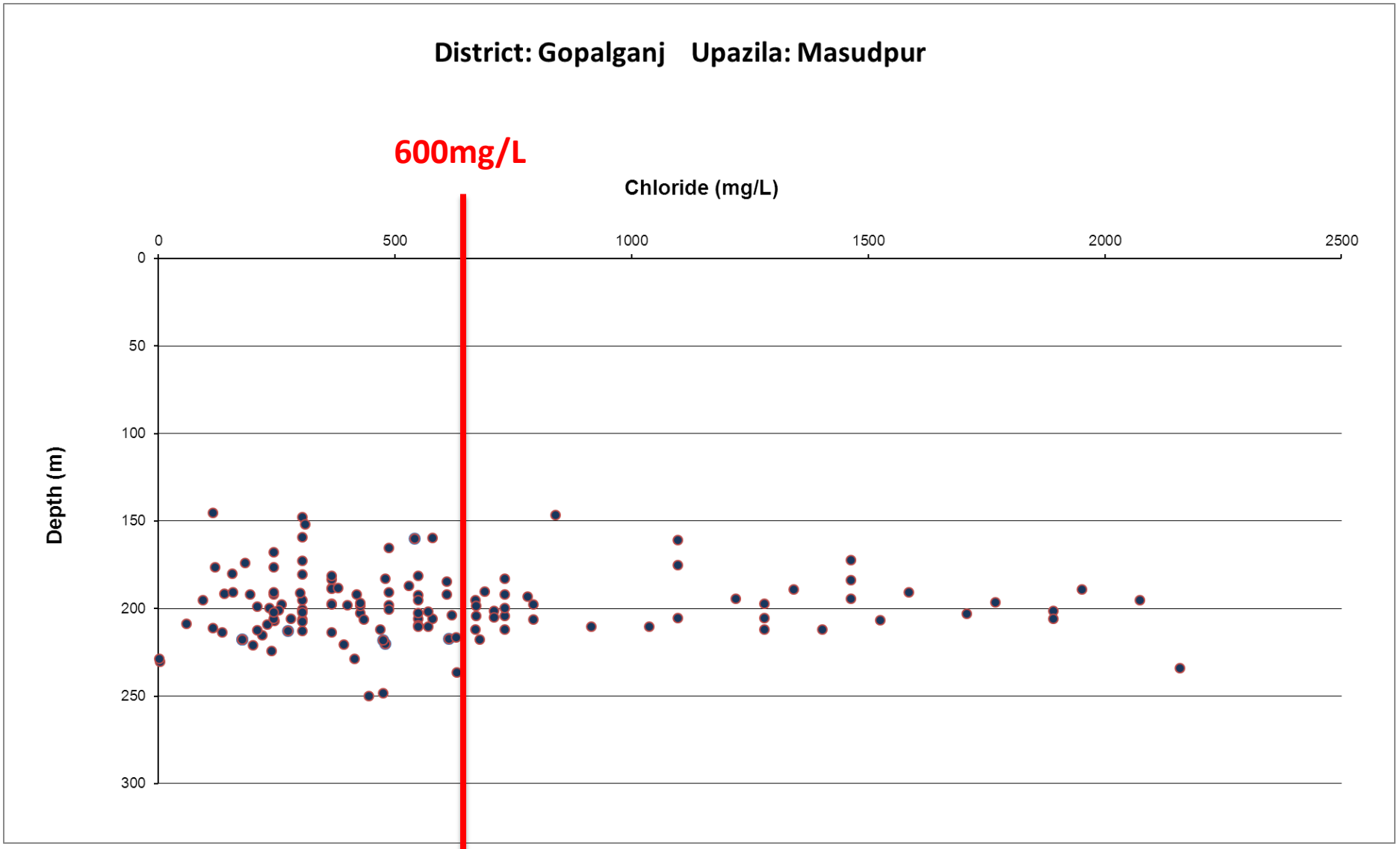
70% of Deep Tube wells maintained Bangladesh Drinking Water Standard For Chloride (150 to 600 mg/L)



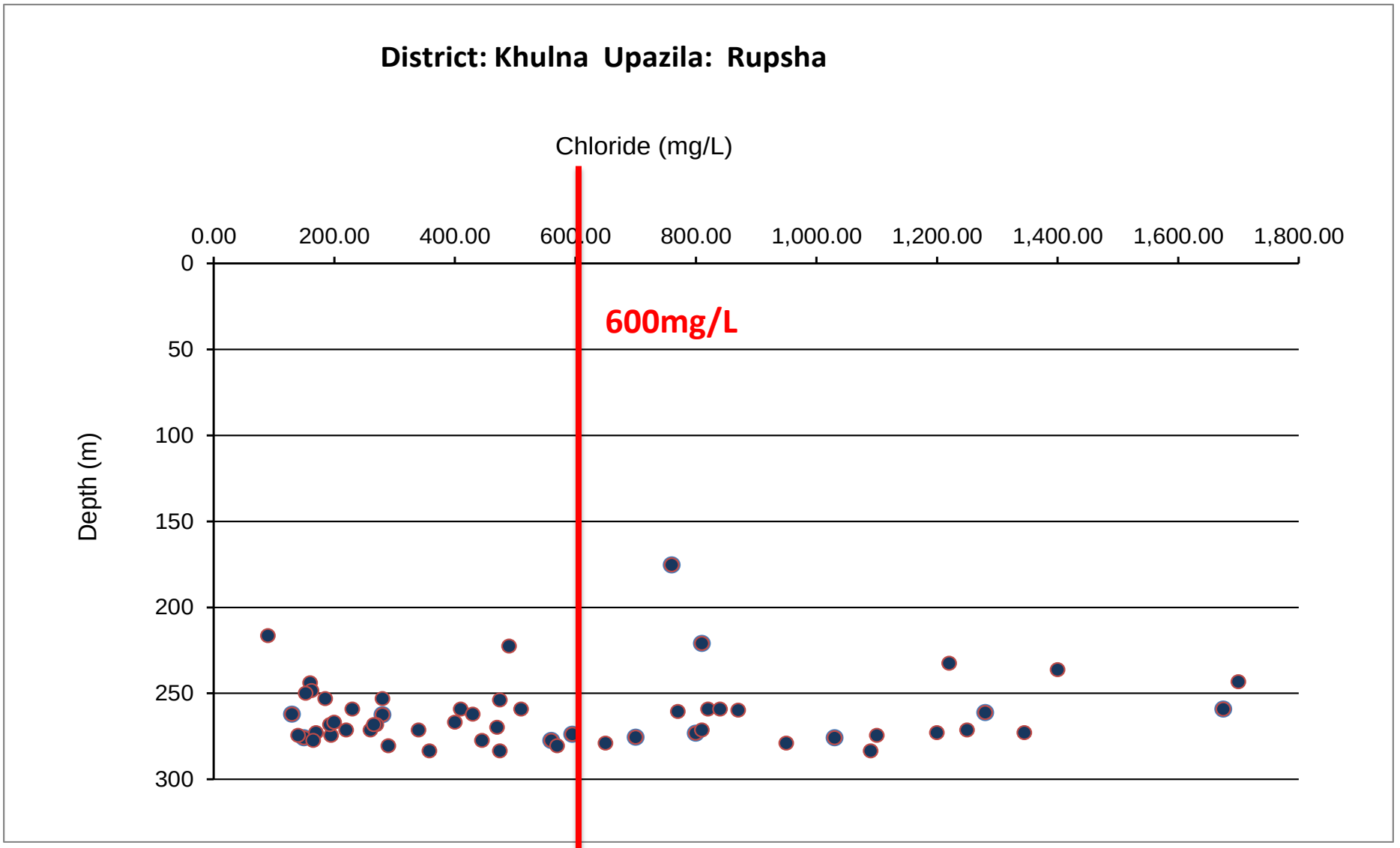
70% of Deep Tube wells maintained Bangladesh Drinking Water Standard For Chloride (150 to 600 mg/L)



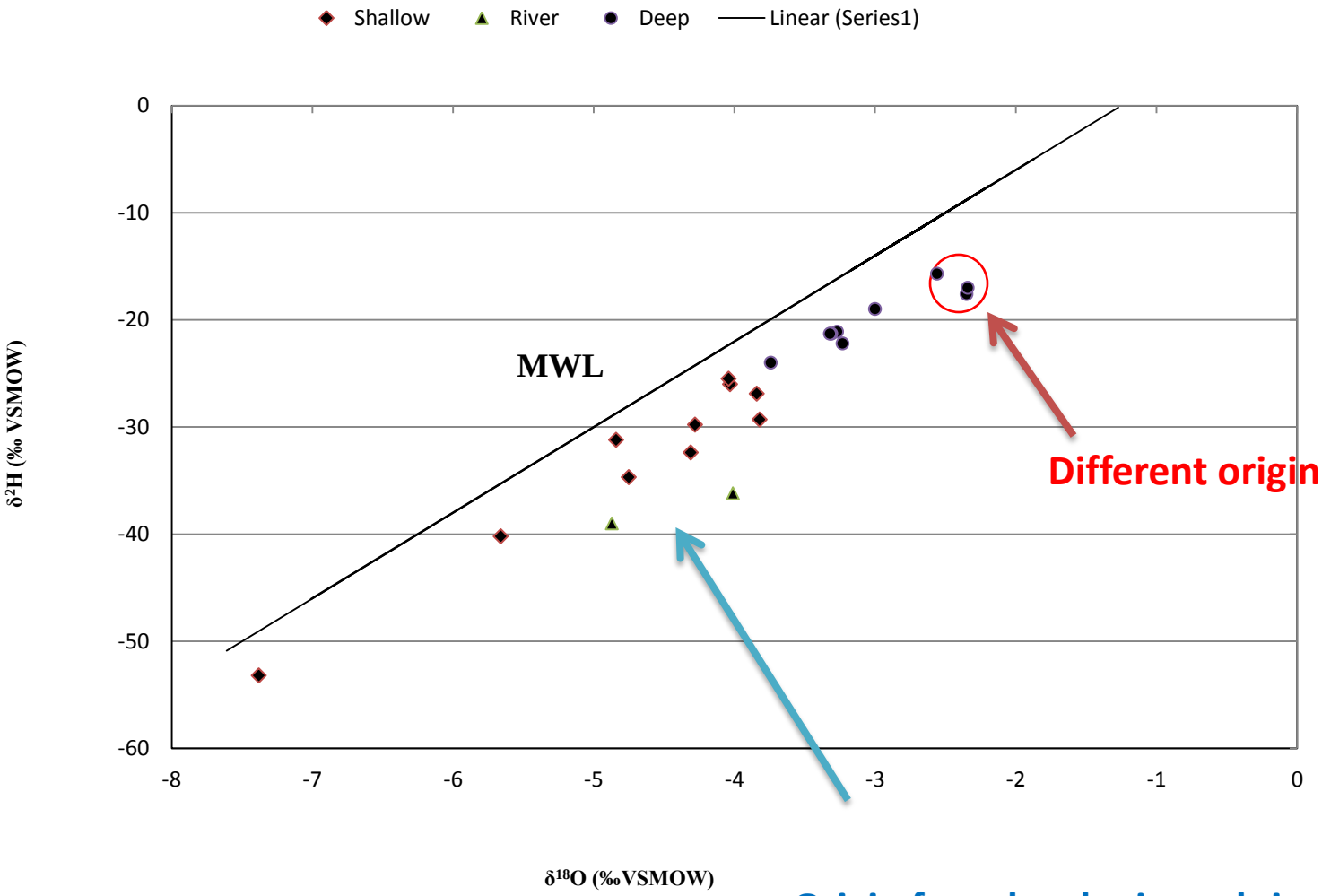
70% of Deep Tube wells maintained Bangladesh Drinking Water Standard For Chloride (150 to 600 mg/L)



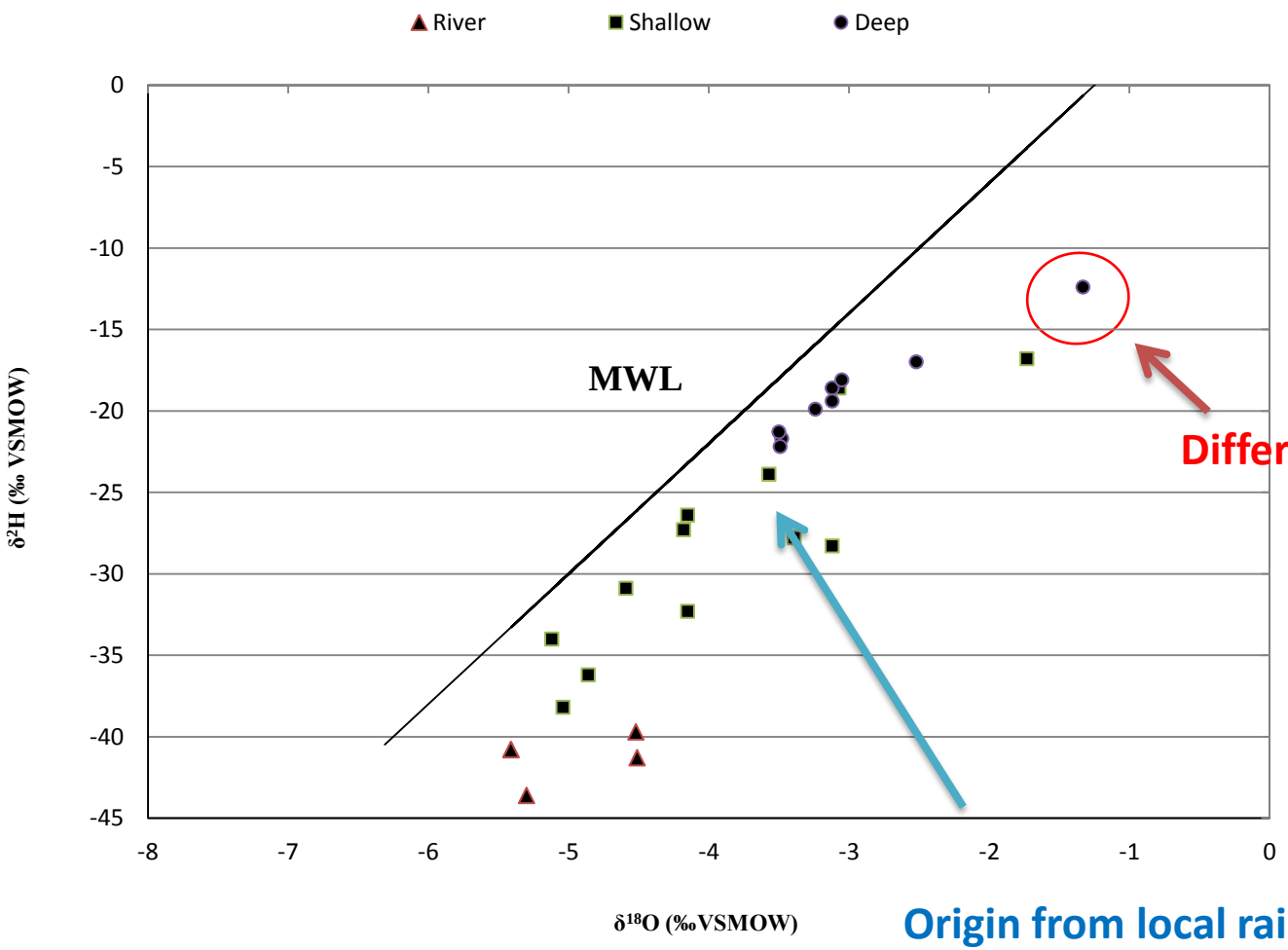
70% of Deep Tube wells maintained Bangladesh Drinking Water Standard For Chloride (150 to 600 mg/L)



Stable isotopic compositions of shallow, deep and river water of Bagerhat



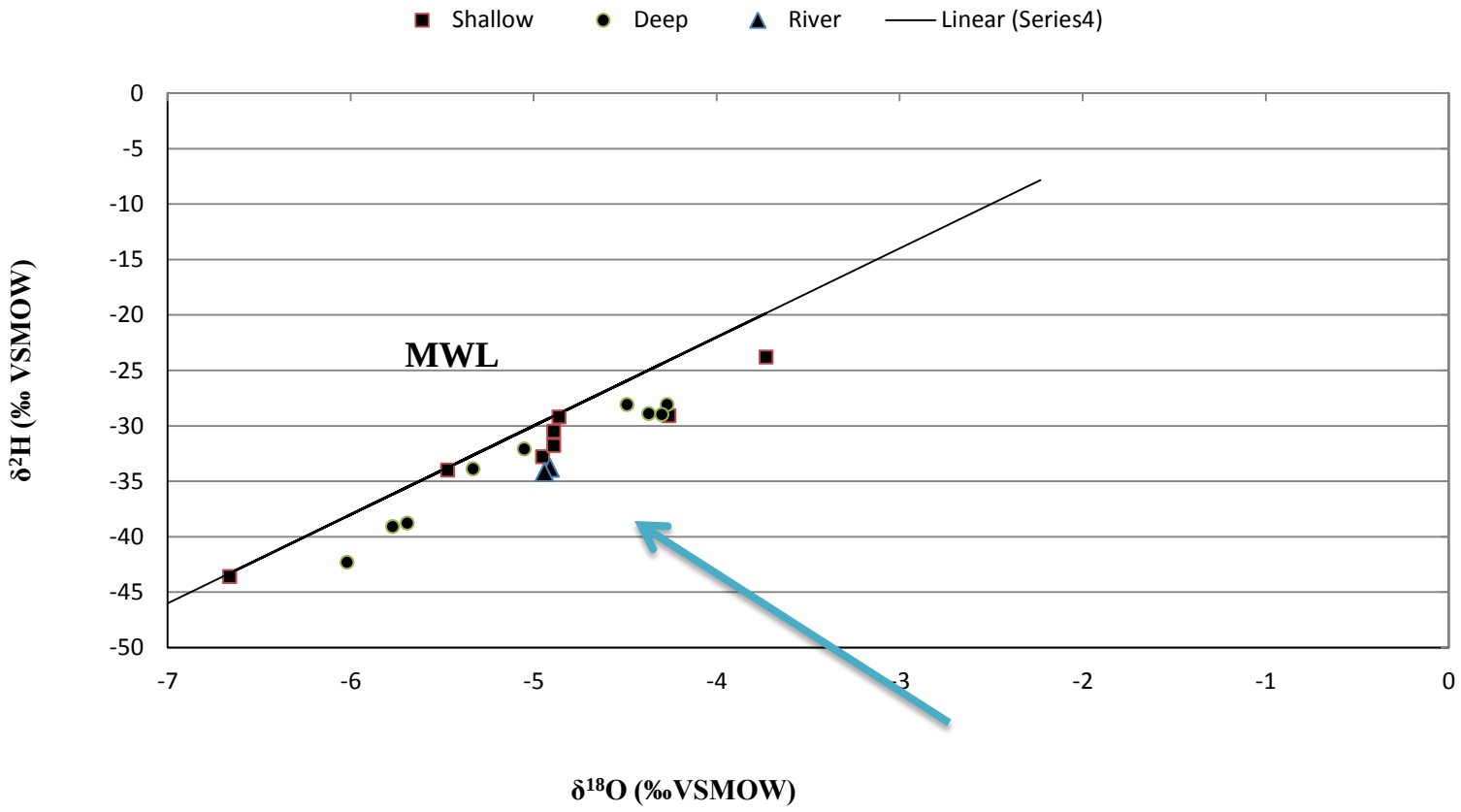
Stable isotopic compositions of shallow, deep and river water of Shaymnagar Upazila, Satkhira



Different origin

Origin from local rain and rivers

Stable isotopic compositions of shallow, deep and river water of Chuadanga



Origin from local rain and rivers

Findings from Stable Isotope data

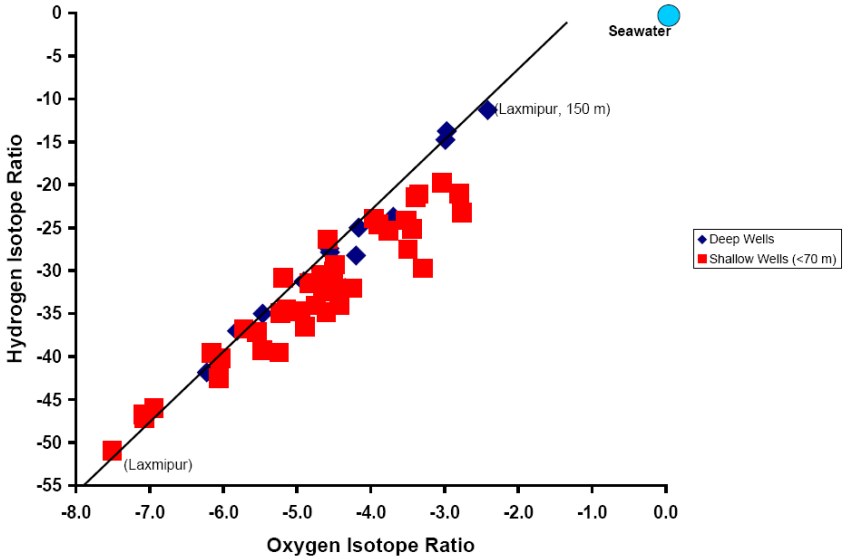
- **All samples plot on or slightly below the meteoric water line, indicating an origin from local rain and rivers, with or without some evaporation before infiltration.**

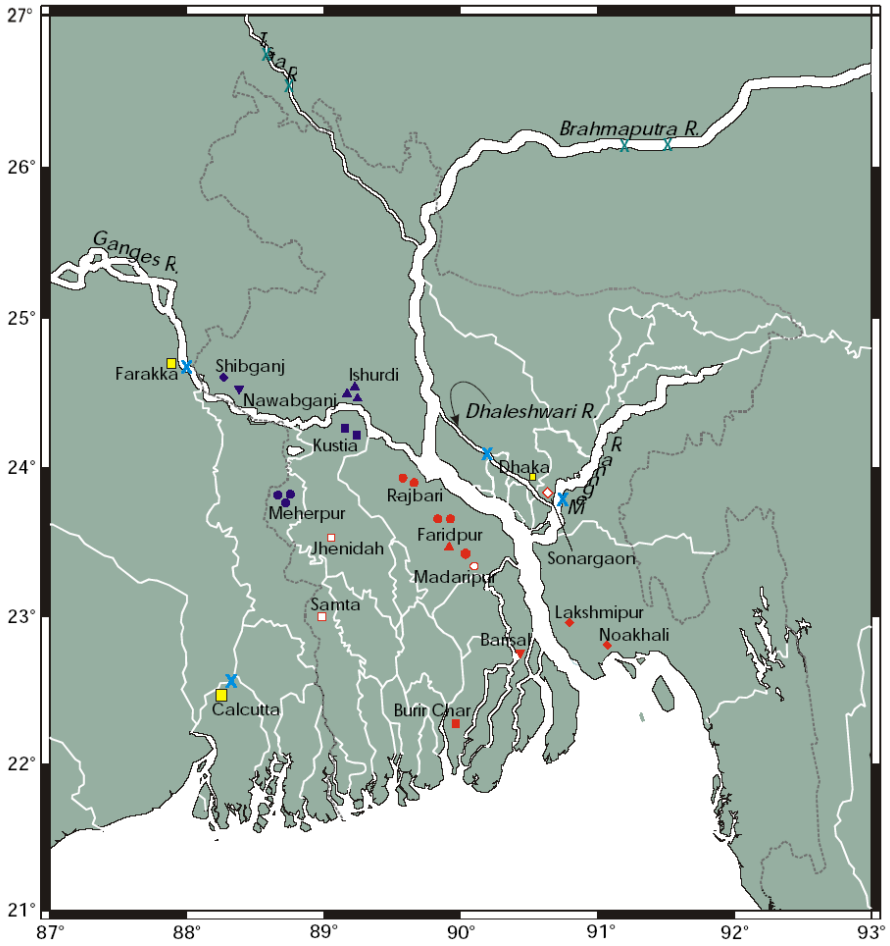
- **The large range and depth trends of isotopic values indicate processes like mixing with seawater, direct recharge from local rivers, and recharge under different climatic conditions.**

- **Deep groundwater samples (>150 m) from Bagerhat and Satkhira have high salinity, high isotopic values (~ -2 ‰ for oxygen) and plot below the meteoric water line indicate different origin**

Study of Isotope in Groundwater

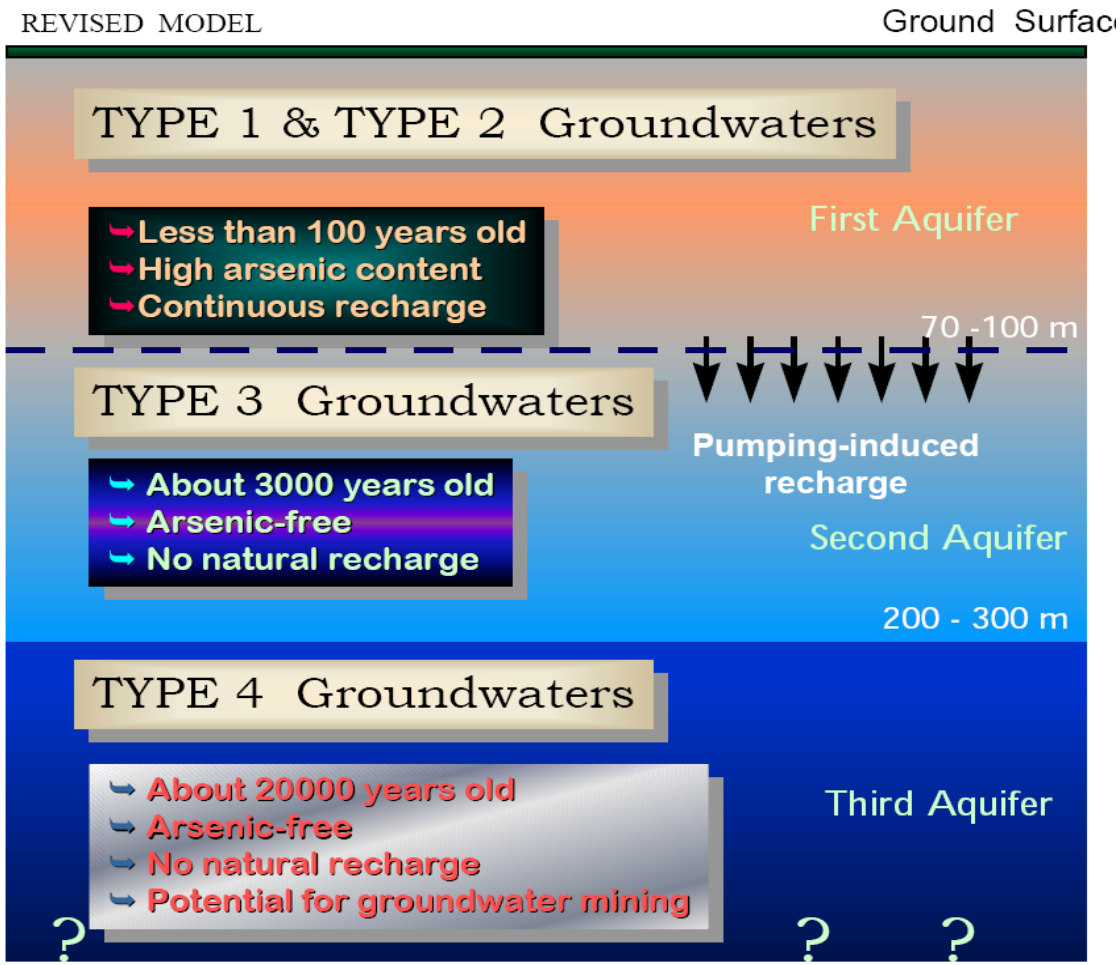
Aggarwal et al. 2000 studied
55 shallow and deep groundwater samples ranging in depth from 10 to 335 m





Source: Aggarwal et al. 2000

Age of Groundwater

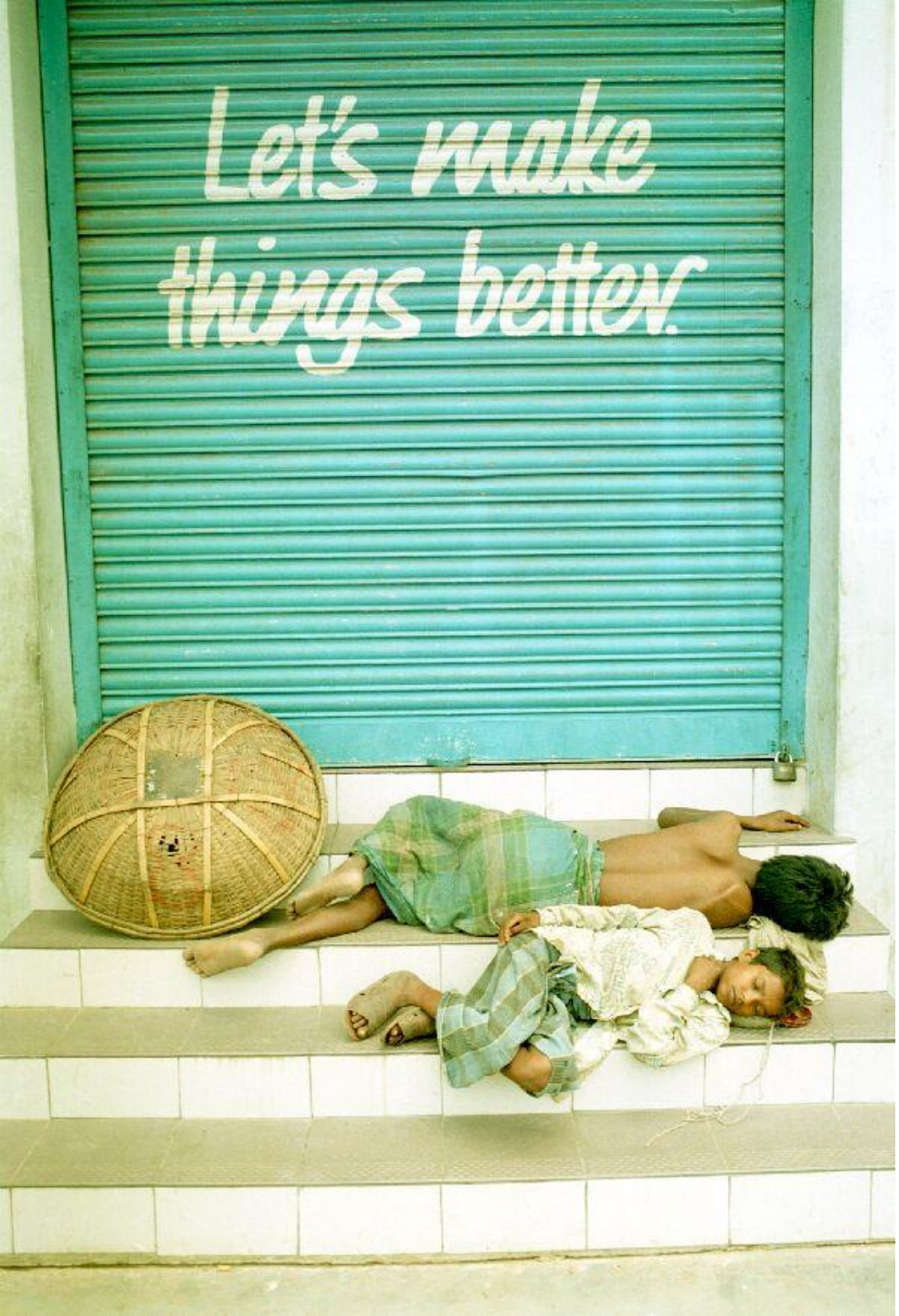


Type 4 of water was found at depths of approximately 300 m in the Barisal area and was dated to about 20000 years old

Source: Aggarwal et al. 2000

Conclusions

- The hydrogeology of coastal area is **complex**.
- **Marine regressions and transgressions** over the past thousands of years created an complex system of sedimentary deposits containing fresh and saline water.
- **Large scale abstraction of groundwater** in the last decades have impacted the system making it even more complex
- **Saline water of marine origin occur at different depths in the study area**
- **About 30% of DTW water exceeded Bangladesh Drinking Water Standard for Chloride 150 to 600 mg/L**
- **Age of brackish water in the Deep aquifer of coastal area could be several thousand years and may owe their origin to Holocene Marine Transgression**
- **Systematic monitoring of groundwater** is of key importance to understand the functioning of the the salinization processes



Thank You