CHAPTER 5

INVESTIGATION OF DEEP AQUIFERS

Summary Report

CHAPTER 5 INVESTIGATION OF DEEP AQUIFERS

5.1 Core Borings

5.1.1 Purpose

The core boring was performed to establish the basic subsurface stratigraphy. Focus was given particularly to the distribution of clay layers in the upper layer section and the thickness and continuity of clay layers in between the shallow and deep aquifers, as these are considered to significantly restrict arsenic contamination and groundwater flow. Facies, grain size, sedimentary structures, degree of consolidation, existence of particular minerals and fossils etc of the core samples were carefully observed. Undisturbed core samples were used for arsenic content tests and arsenic leaching tests to know the source of contamination as well as the potential of contamination.

5.1.2 Locations

The core boring was done at six (6) locations in the Study Area: three (3) sites in Pourashavas and three (3) sites in the model rural areas. In Chuadanga, Jhenaidah and Jessore Pourashavas, the core borings were performed at one of the drilling sites for deep observation wells by the study where the shallow groundwater is highly contaminated by arsenic. Figure 5.1.1 shows the core boring sites in the Study Area.

5.1.3 Methodology

At the six (6) sites, core boring was performed up to a depth of 300 m. The total length of core boring is 1,800 m. After the core observation, the samples for core analysis were carefully collected. The top depth, bottom depth and facies of the collected samples were recorded and sample numbers were systematically assigned.

5.1.4 Subsurface Geology

The identified statigraphic units were named as E formation to A formation in ascending order. Table 5.1.1 shows the characteristics of the subsurface geologic formations in the Study Area. Figure 5.1.2 shows the correlation of geologic units among the six (6) core boring sites.

These formations consist of many lamminated structures and occasionally biogenic sedimentary structures disturbed by bioturbation (Figures 5.1.3 and 5.1.4. And these formations include shell fragments, trace fossil, wooden fragments and blocks (Figures 5.1.5 to 5.1.8).

The geological features of each formation are described as follows. A more detailed description of each core boring sites is shown in Section 5.1.6.

1) E formation

E formation is the lowest geologic formation within a 300 m depth in the Study Area. It mainly consists of fine to medium sand in the northern part to the central part of the study area (Chuadanga, Damurhuda, Jhenaidah and Jessore). On the other hand, E formation in the southern part (Moheshpur and Keshabpur) mainly consists of silt and silt rich alternation of sand and silt layers. The thickness of E formation is more than 90 m.

2) D formation

D formation unconformably overlies E formation. The gap in sedimentary age between D and E formations may be long, because the boundary between E and D formations shows angular unconformity. D formation is divided into D2 and D1 members.

a. D2 member

It mainly consists of sandy layers (fine to medium sand or medium to coarse sand) with pebble in the northwest and in the south of the study area (Chuadanga, Damurhuda, Jessore and Keshabpur). In the northeastern part (Jhenaidah), it mainly consists of fine to medium sand. Alternating layers of silt and fine to medium sand are dominant in the western part (Moheshpur). Clay and silt blocks are partly found in the formation except in Jhenaidah. This member has a thickness of 1 to 16 m.

b. D1 member

It mainly consists of sandy layers (fine to medium sand or medium to coarse sand) with pebble in Chuadanga and Damurhuda. In Moheshpur, Jhenaidah, Jessore and Keshabpur the formation mainly consists of silt and alternating layers of silt and sand. Clay and silt blocks occur in this member. The thickness of D1 member ranges from 20 to 39 m.

3) C formation

C formation is characterized by a lot of pebble-sized gravel, which compose the inverse grading structure in some horizons. It mainly consists of sandy layers (fine to medium sand or medium to coarse sand) with a lot of pebble in Chuadanga, Damurhuda, Moheshpur, Jhenaidah and Jessore. It mainly consists of silt and alternation of silt and very fine sand layers in Keshabpur. C formation is intercalated by silt and fine sand except in Keshabpur. In Keshabpur, the formation is intercalated by very fine to fine sand layers and medium to coarse sand layers. The thickness of C formation ranges from 61 to 141 m.

From the bottom elevation, facies, and the continuity of distribution, it is presumed that C formation was deposited after the lowest stand of sea level during the last glacial maximum.

4) B formation

B formation is characterized by tube-shaped trace fossils in some horizons. It mainly consists of fine sand and medium sand in the Study Area. It is intercalated by silt, very fine sand and coarse sand. Parallel and cross laminae are found in some horizons. Biogenic sedimentary structures disturbed by bioturbation are found in the upper part of the formation in Moheshpur. The thickness of B formation ranges from 41 to 70 m.

It is presumed that B formation was deposited in a shallow sea palaeo-environment (shoreface) during the transgression time in late Pleistocene.

5) A formation

A formation is divided into two parts, i.e. A1 member and A2 member in descending order.

a. A2 member

It mainly consists of very fine sand and fine sand. The member is partly intercalated by clay and silt except in Jhenaidah where it is intercalated by medium sand and medium to coarse sand. Parallel and cross laminae are developed in some horizons. Clay and silt blocks are partly contained in the member. The thickness of the member ranges from 20 to 43 m.

It is presumed that A2 member was deposited with a palaeo-environment of sea (shoreface to offshore) during high sea level time in early Holocene.

b. A1 member

It mainly consists of clay and silt. It is intercalated by peat in Jessore and Keshabpur. Clay and silt blocks are partly contained in the layer except in Chuadanga and Keshabpur. The thickness of the member ranges from 5 to 20 m.

It is presumed that A1 member was deposited with a palaeo-environment of lake or marsh in middle to late Holocene.

5.1.5 Hydrogeological Classification

These geologic units are divided into three (3) aquifer units, according to permeability to estimate by facies up to 300 m in Study Area. The first (shallow) aquifer corresponds to A formation and B formation, which mainly consists of fine to medium sand. The second (middle) aquifer corresponds to C formation, which mainly consists of a sandy layer with gravel. The third (deep) aquifer corresponds to D formation and E formation, which consists of a sandy layer and silty layer. It is inferred that B formation has better permeability in shallow aquifers. It is inferred that C formation (equal middle aquifer) has very good permeability. It is inferred that D2 formation has better permeability in deep aquifers, but it is not so thick. The permeability of each drilling site is described in the results of the pumping test in Chapter 5.1.2.

The clear aquiclude is absent between the first aquifer and second aquifer. But the characteristics of groundwater flow are considered to be different, because of the different facies between each aquifer. The clear aquiclude (clay and silt) exists between the second aquifer and third aquifer except in the northern area (Chuadanga and Damurhuda).

The sedimentary facies and thickness of the first aquifer does not change in almost the entire area. The groundwater of this aquifer is mainly used for private and agricultural use. Particularly in A formation, the arsenic concentration is higher than in other aquifers (AAN *et al.* 1999).

The thickness of the aquifer increases towards the southern area in the second aquifer, which mainly consists of a gravel layer. But the facies of the aquifer suddenly changes in the south Jessore district area (between Jessore and Keshabpur). There is no function for the aquifer in Keshabpur, because there is no sandy layer in C formation. The groundwater of this aquifer is used for production wells in the Pourashava area (Chuadanga, Jhenaidah and Jessore).

The third aquifer is able to be a good aquifer in the northern and central area (Chuadanga, Damurhuda, Jhenaidah and Jessore), because the facies is a sandy layer. Particularly in Moheshpur, a good aquifer for groundwater use is not confirmed in D formation and E formation, because the facies is a muddy layer. There are no wells for groundwater use in Study Area.

The relationship between the subsurface geology and the aquifer classification is shown in Table 5.1.2. Although the absolute age of the sediment and groundwater was not analyzed in the study, the bottom of C formation can be presumed as an unconformity between so-called Diluvium and Alluvium based on the facies characteristics and available information such as Umitsu (1987).

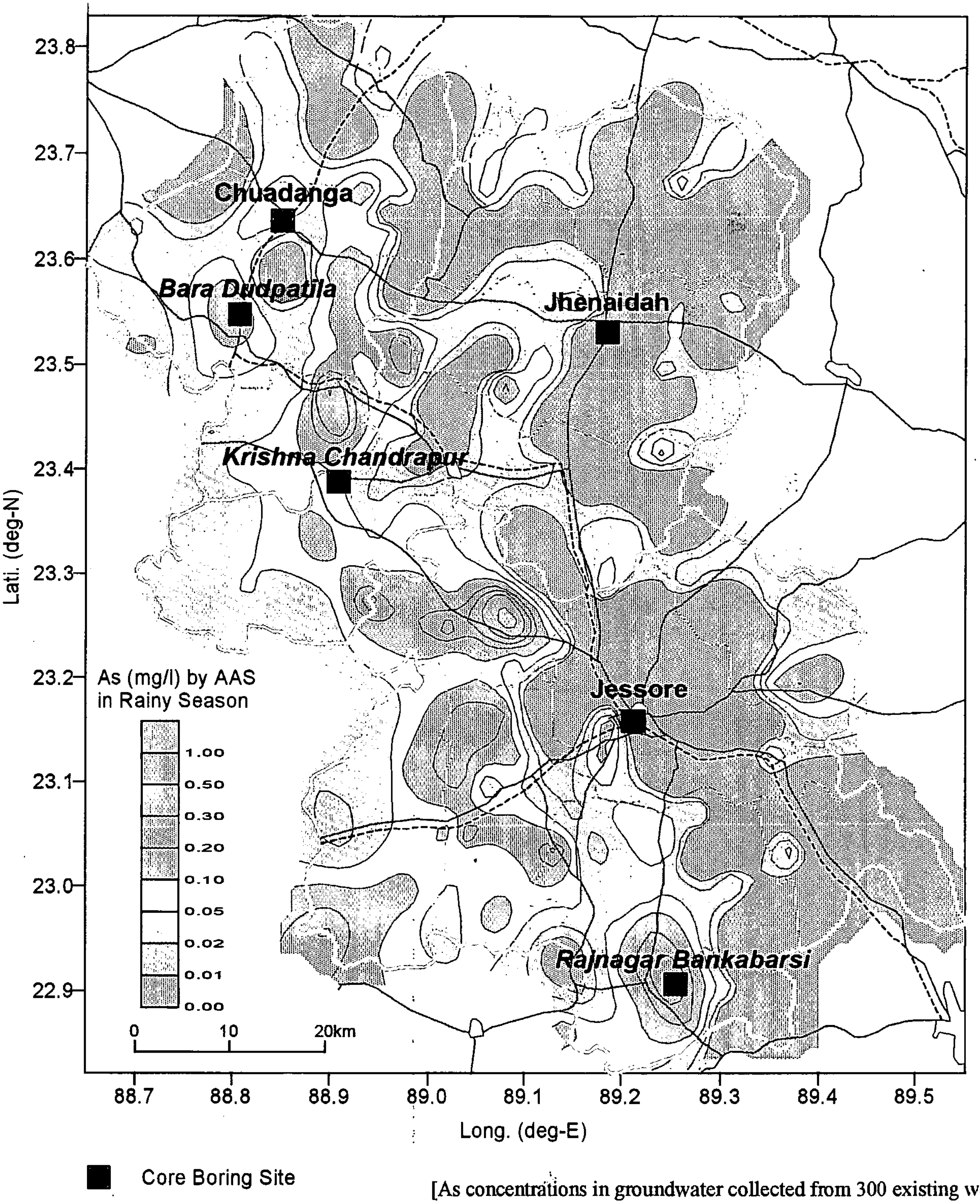
The definition of a "Deep Aquifer" has been confused in Bangladesh. The study team has hydrogeologically defined a "Deep Aquifer" as consisting D and E formations of Pleistocene sediment. The formations of a Deep Aquifer can be correlated with the Pleistocene Madhupur Formation (GSB, 2002). A Deep Aquifer occurs at depths below 160 to 220 m in the study area.

Table 5.1.2 Subsurface geology and aquifer classification

Geologic Age	JICA (2002)		BGS/DPHE (2001)
	Subsurface Geology	Aquifer Classification	
Holocene	A formation B formation	First Aquifer (Shallow Aquifer)	Upper shallow aquifer
Late Pleistocene	C formation	Second Aquifer (Middle Aquifer)	Lower shallow aquifer
	D formation	Third Aquifer (Deep Aquifer)	Deep aquifers
Plio-Pleistocene	E formation		

Table 5.1.1 Characterisitcs of Stratigraphy in Study Area

		facies(main)	facies(intercalated)	site	laminae	bioturbation	shell	trace fossil	woodden fragment	block	thickness (m)	color
Shallow	A1	clay, silt	peat (Js, Ks)	Ch				○			5 - 20	gray and olive brown
			clay (Mh)	Dm				○		○		grayish olive and dull yellow
			vf.s (Mh, Jh, Js, Ks)	Mh						○		grayish olive and olive yellow
				Jh						○		grayish olive, dark grayish yellow and olive black
				Js			○		○	○		olive gray and dark olive gray
				Ks					○			olive gray, yellowish brown and black
	A2	vf-f.s, f.s	clay, silt	Ch				○	○	○	20 - 43	gray, olive gray and grayish olive
			(Ch, Dm, Mh, Js, Ks)	Dm	○	○		○		○		gray
			m.s, m-c.s (Jh)	Mh	○	○				○		gray
				Jh	○				○	○		gray and grayish olive
				Js	○	○	○	○		○		gray, grayish olive and yellowish olive
				Ks		○			○	○		gray
	B	f.s, m.s	silt, vf.s, c.s	Ch	○			○	○	○	41 - 70	gray, olive gray and grayish olive
				Dm	○				○	○		gray
				Mh	○	○		○	○	○		gray
				Jh	○		○	○		○		gray
				Js	○			○	○	○		gray, grayish olive and yellowish brown
				Ks	○		○	○	○	○		gray
Middle	C	f-m.s, m-c.s, gravel	silt, f.s	Ch			○	○	○		61 - 141	gray, dark olive gray and grayish olive
		(Ch, Dm, Mh, Jh, Js)	(Ch, Dm, Mh, Jh, Js)	Dm	○				○			gray
				Mh	○			○		○		gray and olive gray
		silt, alt (Ks)	vf-f.s, m-c.s (Ks)	Jh	○				○	○		gray
				Js	○			○	○	○		gray and grayish olive
				Ks	○		○	○		○		gray, olive gray and dark olive gray
Deep	D1	f-m.s, m-c.s with pebble	vf-f.s(Ch)	Ch	○					○	20 - 39	gray
		(Ch, Dm)	silt, vf.s (Dm)	Dm	○			○	○	○		gray
		silt, alt (Mh, Jh, Js, Ks)	m-c.s with pebble (Jh)	Mh	○					○		gray, olive gray and grayish olive
			silt rich akternarion (Js)	Jh	○			○		○		gray, olive gray, greenish gray and grayish olive
				Js	○					○		gray
				Ks	○					○		olive gray
	D2	f-m.s, m-c.s with pebble	clay, silt (Ch, Jh, Js)	Ch	○					○	1 - 16	gray
		(Ch, Dm, Js, Ks)	vf.s (Ch, Dm, Mh, Ks)	Dm	○					○		gray
		f-m.s (Jh)	alternation (Ch, Dm)	Mh						○		gray
		alt (Mh)	m.s (Dm, Jh, Ks)	Jh	○							gray
				Js						○		gray and olive gray
				Ks						○		gray
	E	f-m.s (Ch,Dm,Jh,Js)	clay, silt, alt	Ch	○			○	○	○	90+	gray
		silt, silt rich alt (Mh,Ks)	(Ch,Dm,Jh,Js)	Dm	○				○	○		gray, olive gray and dark olive gray
			grabel (Ch)	Mh	○			○		○		gray and olive gray
				Jh	○				○	○		gray, olive gray and greenish gray
				Js	○					○		gray and greenish gray
				Ks	○							olive gray and dark olive gray



[As concentrations in groundwater collected from 300 existing wells in June to July 2000 were measured by AAS in Jhenaidah laboratory.]

Figure 5.1.1	Location of Core Boring Sites

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

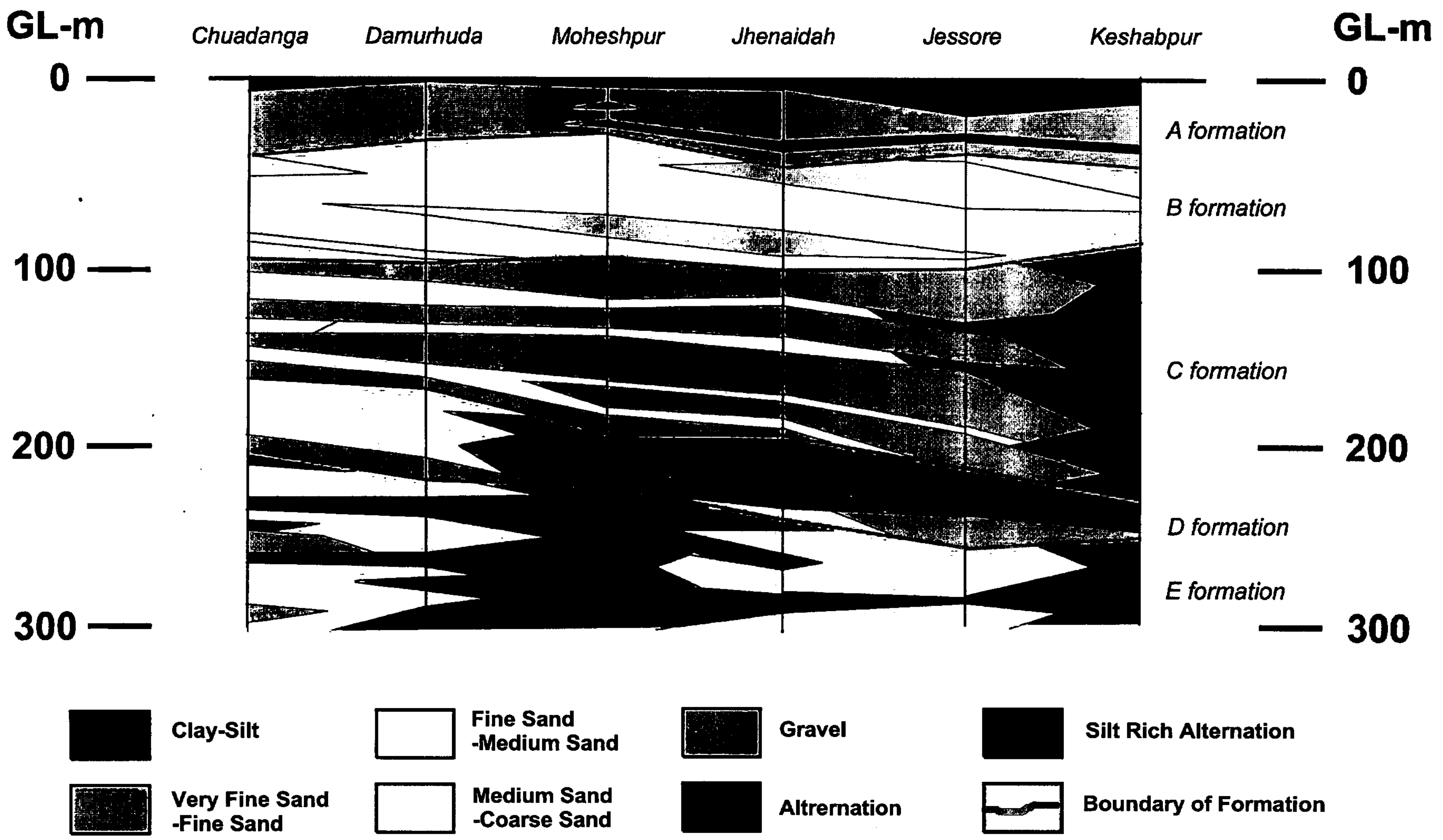


Figure 5.1.2 Correlation of Subsurface Geology Based on Core Boring

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

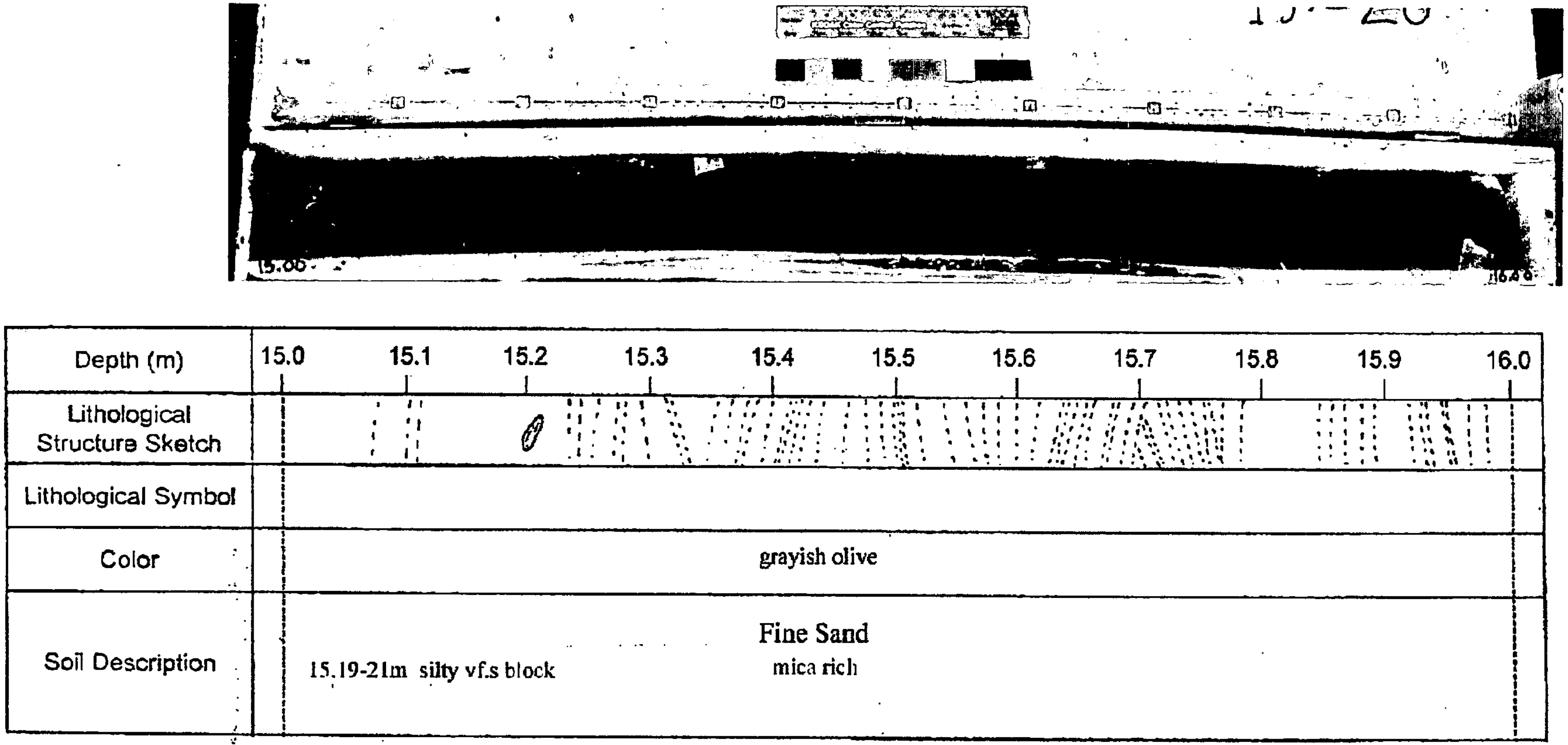


Figure 5.1.3	**Photograph and sketch of core sample with lamminated structure (Jhenaidah, JH-1, 15-16m)**

THE STUDY ON THE GROWNDWATER DEVELOPMENT OF DEEP AQUIFER FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WEST BANGLADESH

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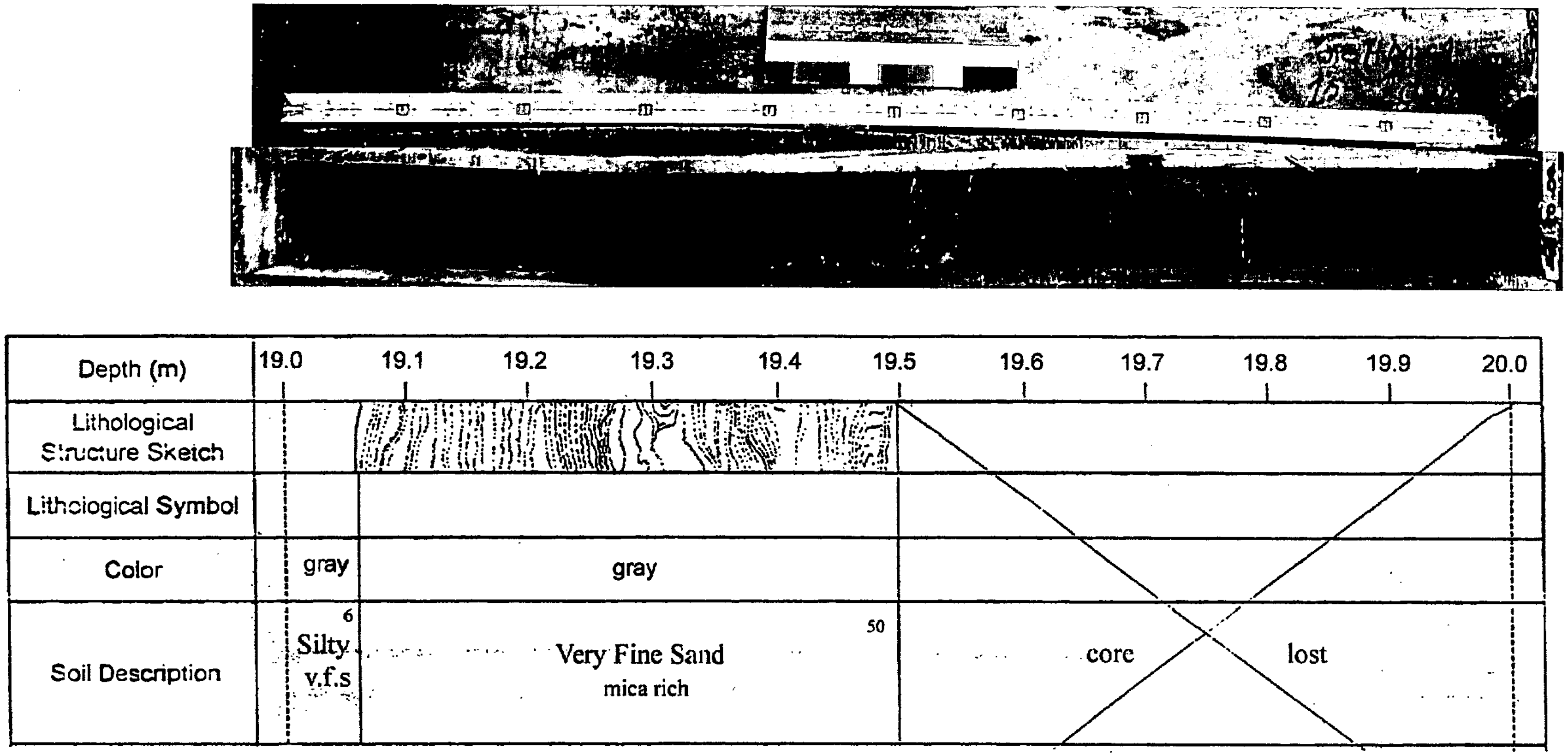

Figure 5.1.4

Photograph and sketch of core sample with biogenic disturbed sedimentary structure by bioturbation (Moheshpur, JH-KC, 19-20m)

THE STUDY ON THE GROWNDWATER DEVELOPMENT OF DEEP AQUIFER FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WEST BANGLADESH

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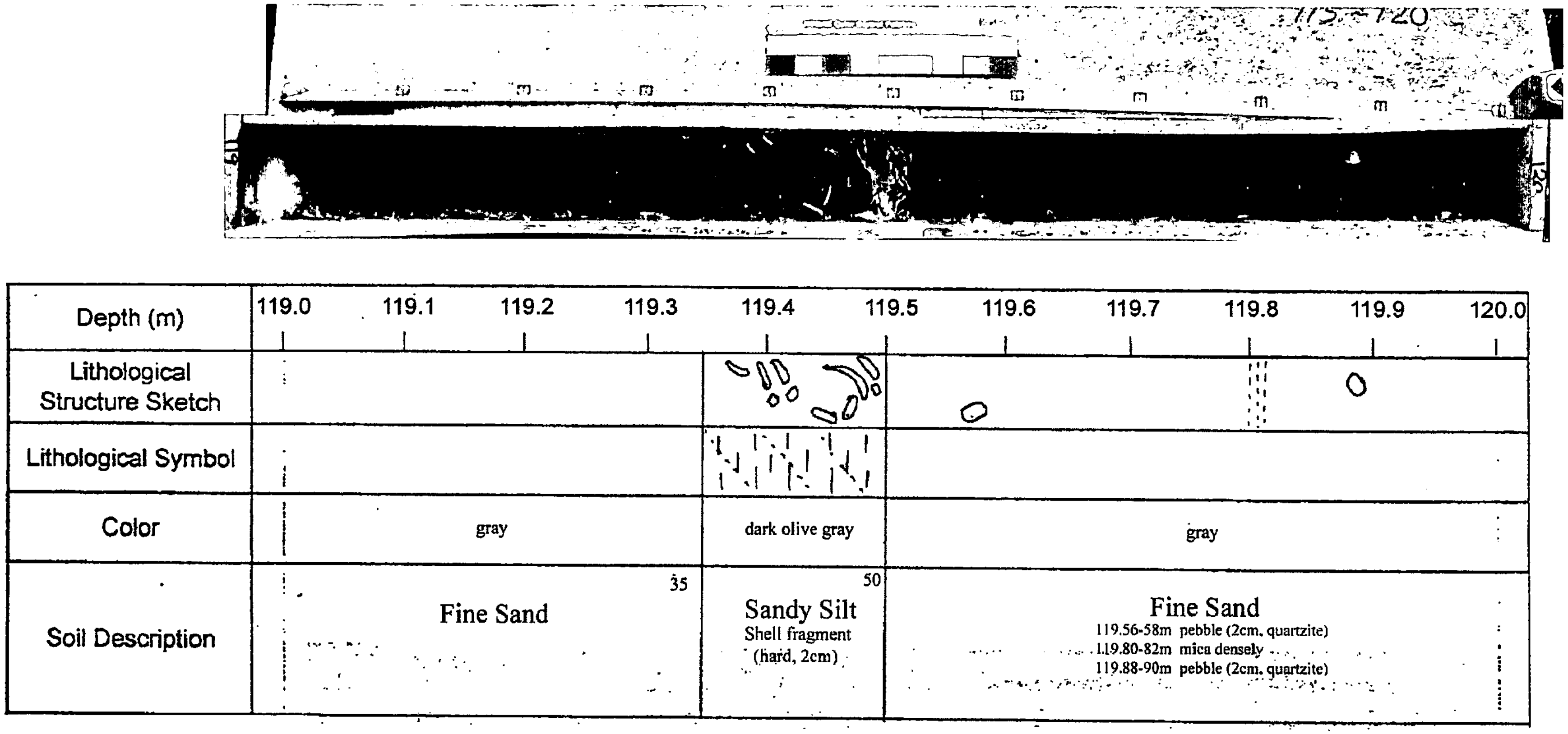

Depth (m)	119.0 – 119.35	119.35 – 119.5	119.5 – 120.0
Lithological Structure Sketch			
Lithological Symbol			
Color	gray	dark olive gray	gray
Soil Description	Fine Sand 35	50 Sandy Silt Shell fragment (hard, 2cm)	Fine Sand 119.56-58m pebble (2cm, quartzite) 119.80-82m mica densely 119.88-90m pebble (2cm, quartzite)

Figure 5.1.5	**Photograph and sketch of core sample with shell fragment (Chuadanga, CH-2, 119-120m)**

THE STUDY ON THE GROWNDWATER DEVELOPMENT OF DEEP AQUIFER FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WEST BANGLADESH

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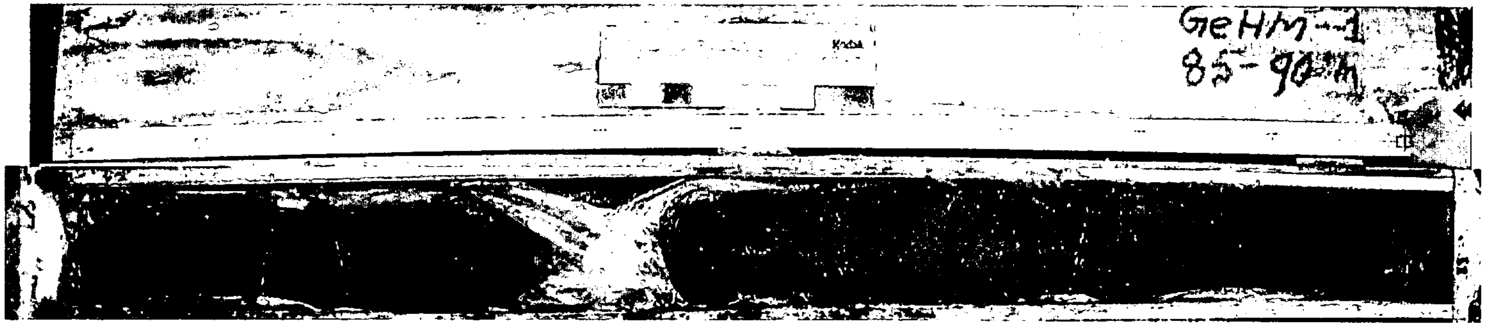


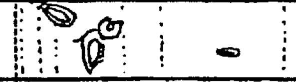
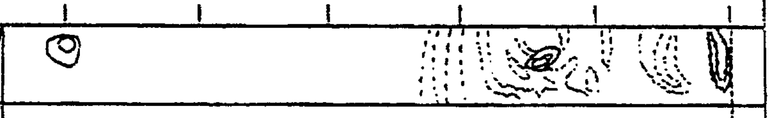
Depth (m)	87.0 87.1 87.2	87.3	87.4	87.5 87.6 87.7 87.8 87.9 88.0
Lithological Structure Sketch				
Lithological Symbol				
Color	gray	gray dark purprish gray		gray
Soil Description	21 Fine - Medium Sand mica rich trace fossil (ϕ 1cm)	35 Fine Sand with heavy mineral (dark purprish gray)	Core lost	45 Fine - Medium Sand mica rich 87.49-51m trace fossil (ϕ 1cm) 87.76-88.00m with heavy mineral (dark purprish gray) trace fossil (ϕ 1cm), bioturbation

Figure 5.1.6	Photograph and sketch of core sample with trace fossil (Moheshpur, JH-KC, 87-88m)

THE STUDY ON THE GROWNDWATER DEVELOPMENT OF DEEP AQUIFER FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WEST BANGLADESH

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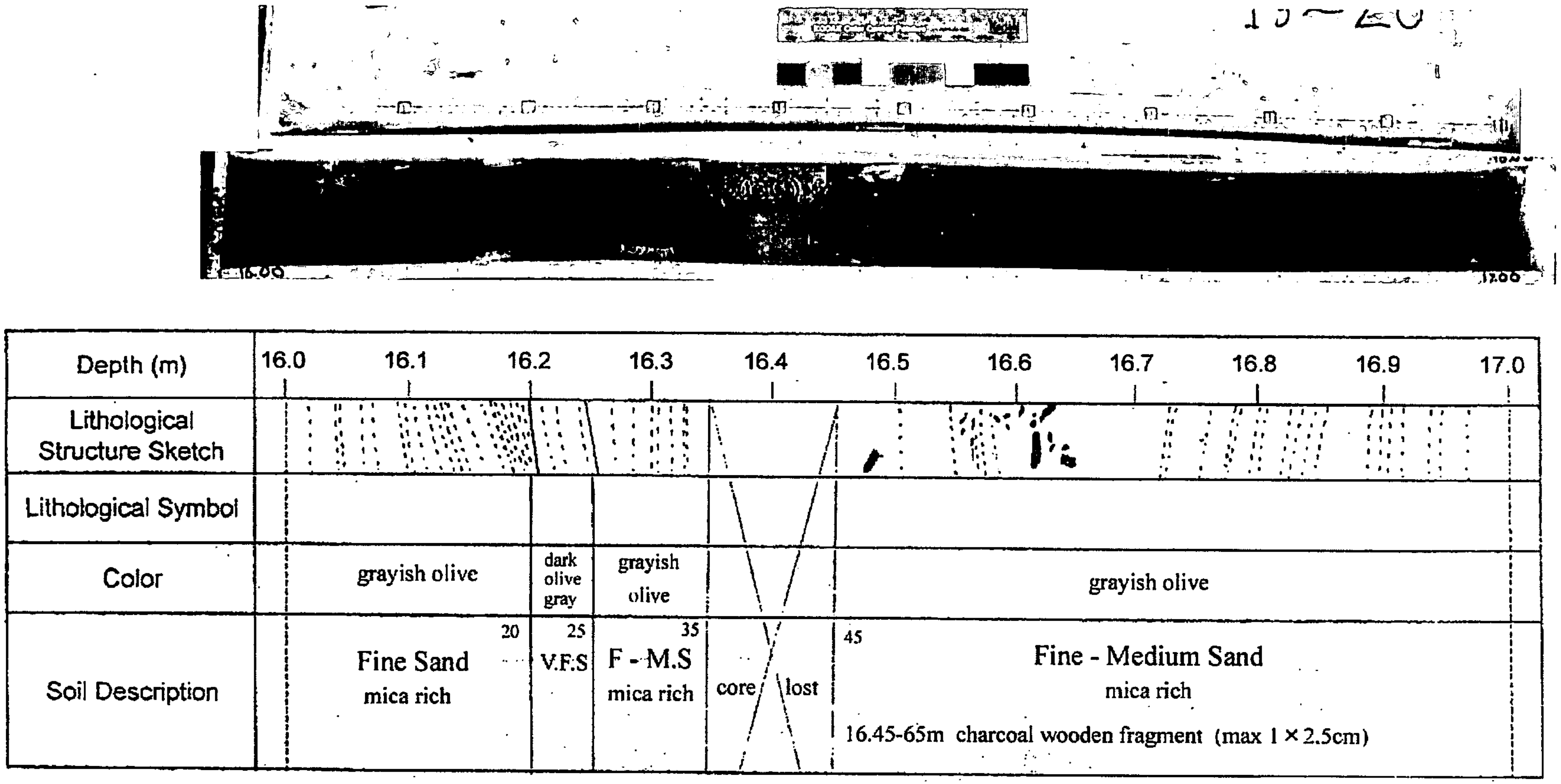

Figure 5.1.7

Photograph and sketch of core sample with Wooden fragment (Jhenaidah, JH-1, 16-17m)

THE STUDY ON THE GROWNDWATER DEVELOPMENT OF DEEP AQUIFER FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WEST BANGLADESH

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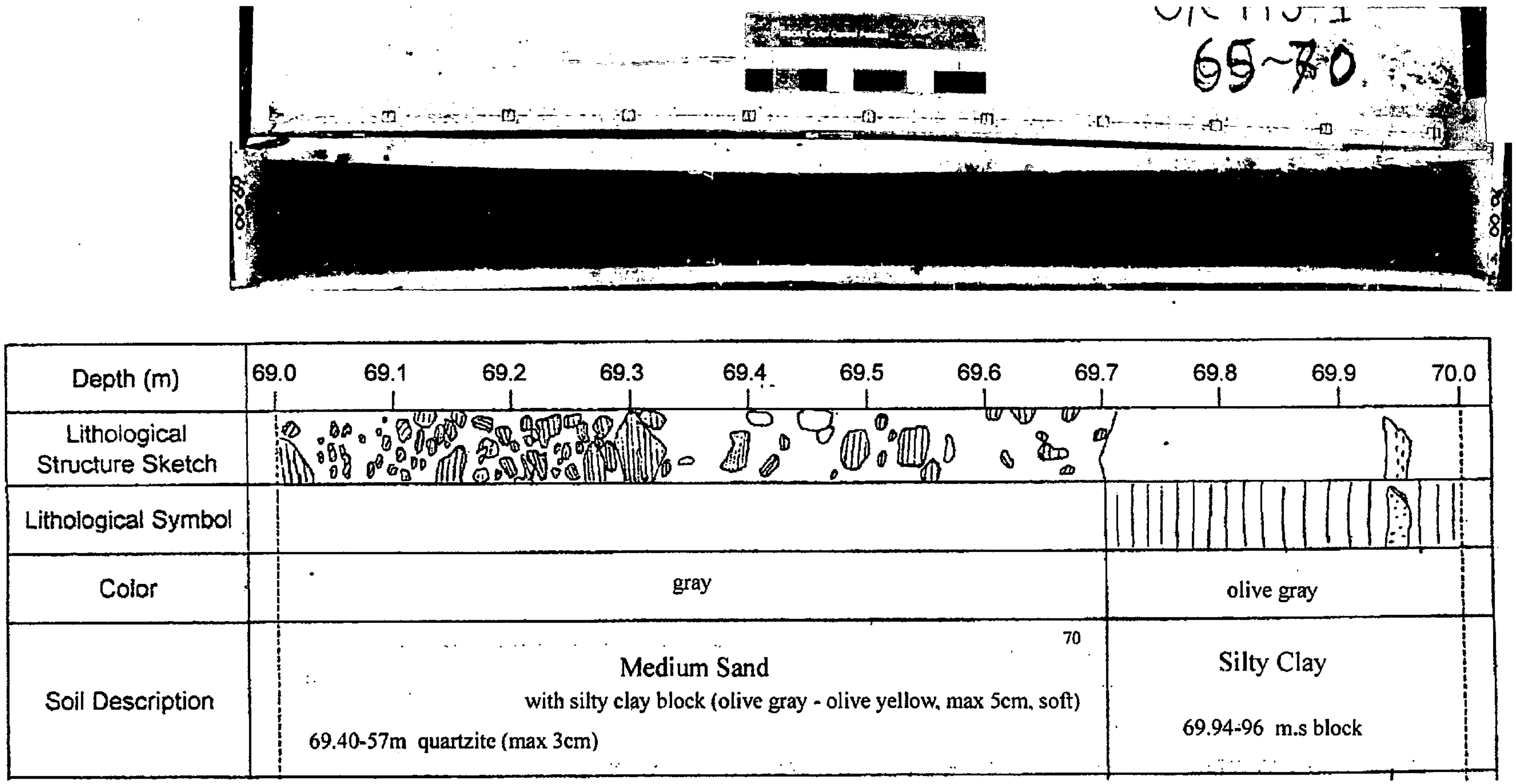

Figure 5.1.8	**Photograph and sketch of core sample with block (Jhenaidah, JH-1, 69-70m)**

THE STUDY ON THE GROWNDWATER DEVELOPMENT OF DEEP AQUIFER FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WEST BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

5.2 Drilling of Observation Wells/Holes

5.2.1 Purpose of Drilling

One of the main objectives of the Study is to reveal the development potential of deep groundwater in the Study Area up to a depth of around 300 m. To obtain hydrogeological information and geohydrologic parameters as well as to monitor groundwater level and groundwater quality of deep aquifers, drilling of deep wells at different places is very essential.

In the Study, a total of six (6) drilling sites were selected in Chuadanga, Jhenaidah and Jessore Pourashavas. It was planned that there were two (2) sites in each Pourashava area. At each site, a set of one deep observation well (300 m in depth) and four (4) groundwater level observation holes with different depths (50, 100, 150, and 300 m) was drilled. Figure 5.2.1 shows the schematic plans of the drilling program in a Pourashava area.

The drilling of observation wells/holes and subsequent pumping tests followed by groundwater monitoring can provide the following data/information:

(1) Geologic information by observing cutting samples
(2) Geophysical parameters such as borehole resistivity, SP, and gamma ray by borehole logging
(3) Drilling speed and hardness by drilling record
(4) Aquifer parameters such as transmissivity, apparent hydraulic conductivity, storage coefficient, leakance, etc. by continuous pumping test
(5) Well loss, aquifer loss, well efficiency, etc. by step-drawdown test.
(6) Vertical movement of groundwater by pumping test and groundwater level monitoring
(7) Groundwater level fluctuation by groundwater monitoring
(8) Changes in As concentration and other chemical parameters by water quality monitoring

5.2.2 Site Selection

Because it was planned that each observation deep well would be used as a production well in future, locations of existing production wells, existing water supply pipelines, land use, and future Pourashava development plans, etc. were taken into account for selecting the site. As a result, two (2) sites in each Pourashava area were determined as shown in Figures 5.2.2 to 5.2.4.

5.2.3 Drilling Configuration

As shown in Figure 5.2.1, a typical drilling configuration was prepared to construct the observation well and the observation holes. An observation well was located at the center and four (4) observation holes should be located 5 m away from the observation well in a cross shaped configuration.

Figure 5.2.5 shows the drilling site map of CH-1 site (Poshu Hat, Chuadanga). The distances between the observation well (Ch-1 well) and observation holes (Ch-1-1 to Ch-1-4 holes) range from 5.35 to 5.75 m. A benchmark (KBM) was set at the concrete base of the observation well. The heights of the measuring point, top of the casing pipe and concrete base of each observation well/holes were measured from the KBM by leveling survey.

The drilling site maps of CH-2 site (Girls College, Chuadanga), JH-1 site (Arabpur, Jhenaidah), JH-2 site (Hamdah, Jhenaidah), JS-1 site (Ghop, Jessore), and JS-2 site (Kharki) are shown in Figures 5.2.6 to 5.2.10.

In addition, the holes of the core boring drilled in the model rural areas were converted into observation holes.

5.2.4 Result of Drilling

The drilled deep observation wells/holes and their specifications are shown in Table 5.2.1.

1) Geology and Geophysical Logging

The results of geophysical logging with the geologic columnar section at the drilling sites are shown in Figures 5.2.11 to 5.2.19

2) Casing Program

The well/borehole depth and screen depth with the geologic columnar section and resistivity logs are in Figures 5.2.20 to 5.2.28. The detailed casing programs and well structures are shown in Figures 5.2.29 to 5.2.37.

Table 5.2.1 List of Drilled Observation Deep Wells/Holes and Their Specifications

District	Upazila/ Pourashava	Site Name (Site No.)	Well/Hole Type	Well/Obs. Hole No.	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Drillig Program	Casing Program	Gravel Pack (m)	Sand Pack (m)	Bentonite Seal (m)	Cement Seal (m)	Date of Drilling (CB:core boring)	Date of Well Con-struction & Completion	Distance from Production Well (m)	Level from KBM (m)	Remark
Chuadanga	Chuadanga Sadar	Poshu Hat (CH-1)	Obs. Well (Production Well)	Ch-1	300	274	212.5-215.75, 227.75-231 237-240.25, 246.25-249.5 255.5-258.75, 264.75-268	19.5	24in:0m-5.8m 20in:5.8m-36m 15in:36m-300m	14in:0m-35.5m 6in:35.5m-274m	207.5-300	202.5-207.5	201.5-202.5	38-45 165-170	13-22/Dec./2000	23/Dec./ 2000-1/ Jan./2001	-	+0.623	KBM=0m Ground Level(GL)-0.14～-0.165m
			Obs. Hole	Ch-1-1	65	63	54-60	6	12.25in:0m-2.8m 8.5in:2.8m-65m	3in:0m-63m	50-65	48-50	45-48	40-45	30/Jan./2001	30-31/Jan. /2001	5.75	+0.325	
			Obs. Hole	Ch-1-2	122	118	100-112	12	12.25in:0m-2.8m 8.5in:2.8m-122m	3in:0m-118m	95-122	93-95	91-93	40-45	28/Jan./2001	29-30/Jan. /2001	5.35	+0.354	
			Obs. Hole	Ch-1-3	170	168	150-162	12	12.25in:0m-2.8m 8.5in:2.8m-170m	3in:0m-168m	145-170	140-145	138-140	40-45	24-26/Jan./2001	26-27/Jan. /2001	5.55	+0.170	First 4 times measurement MP was +0.02 m from KBM
			Obs. Hole	Ch-1-4	300	300	228-231, 237-240 246-249, 255-258 264-267, 291-294	18	12.25in:0m-3m 8.5in:3m-300m	3in:0m-300m	223-300	218-223	216-218	39-45 165-170	30/Dec./2000- 19/Jan./2001	19-24/Jan. /2001	5.44	+0.325	
		Girls College (CH-2)	Obs. Well (Production Well)	Ch-2	303	298.5	270-283, 289-295.5	19.5	24in:0m-5.8m 20in:5.8m-38m 15in:38m-303m	14in:0m-36m 6in:36m-298.5m	265-303	260-265	259-260	232-237	CB:15/Dec./2000- 2/Jan./2001 Reaming:2-12/Feb./2001	13-16/Feb. /2001	-	+0.50	KBM=0m Ground Level(GL)-0.05m
			Obs. Hole	Ch-2-1	58	56.5	44.5-53.5	9	12.25in:0m-3m 8.5in:3m-58m	3in:0m-56.5m	43-58	41-43	40-41	31-36	2-3/Mar./2001	3/Mar. /2001	5.13	+0.501	
			Obs. Hole	Ch-2-2	111	109	97-106	9	12.25in:0m-3m 8.5in:3m-58m	3in:0m-111m	94-111	90-94	89-90	70-75	1-2/Mar./2001	2/Mar. /2001	5.37	+0.46	
			Obs. Hole	Ch-2-3	156	152.5	122.5-125.5, 140.5-149.5	12	12.25in:0m-3m 8.5in:3m-156m	3in:0m-152.5m	120-156	118-120	117-118	110-115	26-27/Feb./2001	27-28/Feb. /2001	5.26	+0.407	
			Obs. Hole	Ch-2-4	303	299.5	272.5-281.5, 290.5-296.5	15	12.25in:0m-3m 8.5in:3m-303m	3in:0m-299.5m	266.5-300	261-266.5	260-261	232-237	17-18/Feb./2001	18-25/Feb. /2001	5.64	+0.319	
	Damurhuda	Bara Dudpatila	Obs. Hole (Core Boring)	Ch-CB-2	302	300	264-276, 294-297	15	8.5in:0m-300m	3in:0m-300m	252-300	248-252	246-248	230-238	CB:8-18/Jan./2001 Reaming:21-23/Jan./2001	23-25/Jan. /2001	-	+0.35	
Jhenaidah	Jhenaidah Sadar	Arabpur (JH-1)	Obs. Well (Production Well)	Jh-1	296	292.5	251.5-254.75, 260.75-267.25 273.25-279.75, 285.75-289	19.5	24in:0m-6m 20in:6m-38m 15in:38m-296m	14in:0m-35.5m 6in:35.5m-292.5m	244-296	242-244	240-242	68-72 230-235	CB:30/Jan./2001- 11/Feb./2001 Reaming:11-21/Feb./2001	22/Feb.- 9/Mar. /2001	-	+0.710	KBM=0m Ground Level(GL)-0.131～-0.170m
			Obs. Hole	Jh-1-1	61	60	48-57	9	12.25in:0m-3m 8.5in:3m-61m	3in:0m-60m	46-61	43-45	41-43	30-34	6-7/Apr./2001	7-8/Apr. /2001	3.73	+0.545	
			Obs. Hole	Jh-1-2	125	123	108-120	12	12.25in:0m-3m 8.5in:3m-125m	3in:0m-123m	102-125	100-102	100-102	68-73	4-5/Apr./2001	5-6/Apr. /2001	7.04	+0.602	
			Obs. Hole	Jh-1-3	167	165	150-162	12	12.25in:0m-3m 8.5in:3m-167m	3in:0m-165m	146-167	144-146	142-144	68-72 133-138	1-2/Apr./2001	2-4/Apr. /2001	3.23	+0.548	
			Obs. Hole	Jh-1-4	285	282	261-267, 273-279	12	12.25in:0m-3m 8.5in:3m-285m	3in:0m-282m	256-285	254-256	252-254	68-72 230-235	26-29/Mar./2001	29-31/Mar. /2001	6.12	+0.403	
		Hamdah [Hospital Road] (JH-2)	Obs. Well (Production Well)	Jh-2	302	301	257.5-270.5, 279.5-282.75 294.75-298.0	19.5	24in:0m-5.20m 20in:5.20m-36m 15in:36m-302m	14in:0m-36m 6in:36m-301m	250-302	248-250	246-248	68-73 234-239	12-21/Apr./2001	22-29/ Apr./2001	-	+0.764	
			Obs. Hole	Jh-2-1	61	60	48-57	9	15in:0m-3m 12.25in:3m-61m	3in:0m-60m	45-61	43-45	41-43	28-32	27/May/2001	28/May /2001	5.42	+0.521	
			Obs. Hole	Jh-2-2	113	111	96-108	12	15in:0m-3m 12.25in:3m-113m	3in:0m-111m	91-113	89-91	87-89	68-73	24-26/May/2001	26-27/May /2001	5.21	+0.488	
			Obs. Hole	Jh-2-3	209	165	150-162	12	12.25in:0m-3m 8.50in:3m-209m	3in:0m-165m	145-168	143-145	141-143	68-73 129-134	30/Apr.-3/May/2001	14-15 /May/200	4.49	+0.360	
			Obs. Hole	Jh-2-4	275	273	258-270	12	15in:0m-3m 12.25in:3m-275m	3in:0m-273m	253-275	251-253	249-251	68-73 234-239	16-22/May/2001	22- 25/May	5.19	+0.404	
	Moheshpur	Krishna Chandrapur	Obs. Hole (Core Boring)	Jh-CB-2	301.9	300	267-270, 276-282, 288-297	18	12.25in:0m-3m 8.5in:3m-301.9m	3in:0m-300m	261-301.9	259-261	255-257	247-252	CB:13/Mar.-1/Apr./2001 Reaming:1-2/Apr./2001	3-6/Apr. /2001	-	+0.583	KBM=0m Ground Level(GL)-0.112m
Jessore	Jessore Sadar	Ghop [Rahman High School] (JS-1)	Obs. Well (Production Well)	Js-1	301	280.0	261-274	13	24in:0-5m 20in:5-39m 15in:39-301m	14in:0-30m 6in:30-280m	256-297	254-256	252-254	39-44 223-228	4-14/Jun./2001	14-24/Jun. /2001	-	+0.464	KBM=0m
			Obs. Hole	Js-1-1	69	66	54-63	9	15in:0-3m 12in:3-69m	3in:0-66m	50-69	48-50	47-48	39-44	6/Jul./2001	8-9/Jul. /2001	4.60	+0.548	
			Obs. Hole	Js-1-2	123	120	105-117	12	15in:0-3m 12in:3-123m	3in:0-120m	100-123	98-100	97-98	39-44 89-94	6-7/Jul./2001	7-8/Jul. /2001	5.03	+0.424	
			Obs. Hole	Js-1-3	171	168	153-165	12	15in:0-3m 12in:3-171m	3in:0-168m	148-171	146-148	144-146	39-44 129-134	3-4/Jul./2001	5-6/Jul. /2001	4.22	-0.024	
			Obs. Hole	Js-1-4	285	282	261-276	15	15in:0-3m 12in:3-285m	3in:0-282m	256-285	254-256	252-254	39-44 223-228	25-30/Jun./2001	30/Jun.- 3/Jul./2001	4.60	+0.334	
		Kharki (JS-2)	Obs. Well (Production Well)	Js-2	270	261.75	239.50-255.75	16.25	24in:0-12m 20in:12-40m 15in:40-270m	14in:0-35.5m 6in:35.5-261.75m	236-270	234-236	232-234	30-35 220-225	23/Jun.-10/Jul. /2001	11-15/Jul. /2001	-	+0.345	KBM=0m
			Obs. Hole	Js-2-1	70	66	54-63	9	12in:0-14m 9in:14-68m	3in:0-66m	51-70	49-51	47-49	30-35	27/Jul./2001	27/Jul. /2001	2.90	+0.292	
			Obs. Hole	Js-2-2	116	114	99-111	12	12in:0-14m 9in:14-116m	3in:0-114m	96-114	94-96	92-94	85-90	24/Jul./2001	25/Jul. /2001	3.20	+0.315	
			Obs. Hole	Js-2-3	247	162	147-159	12	24in:0-6m 20in:6-40m 15in:40-247m	3in:0-162m	144-165	142-144	141-142	30-35 134-139	CB:29/Apr.-28/May/2001 Reaming:29.May-3/Jun. /2001	14-23/Jun. /2001	3.98	+0.322	
			Obs. Hole	Js-2-4	260	255	240-252	12	11in:0-6m 9in:6-260m	3in:0-255	236-260	234-236	232-234	30-35 220-225	17-20/Jul./2001	21-23/Jul. /2001	3.15	+0.248	
	Keshabpur	Rajnagar Bankabarsi	Obs. Hole (Core Boring)	Js-CB-2	263	261	222-228, 231-234, 240-243 252-258	18	8.5in:0m-263m	3in:0m-261m	217-263	215-217	213-215	197-202	CB:11.-17/Apr./2001 Reaming:18-20/Apr./2001	21-24/Apr. /2001	-	+0.412	KBM=0m Ground Level(GL)-0.169m

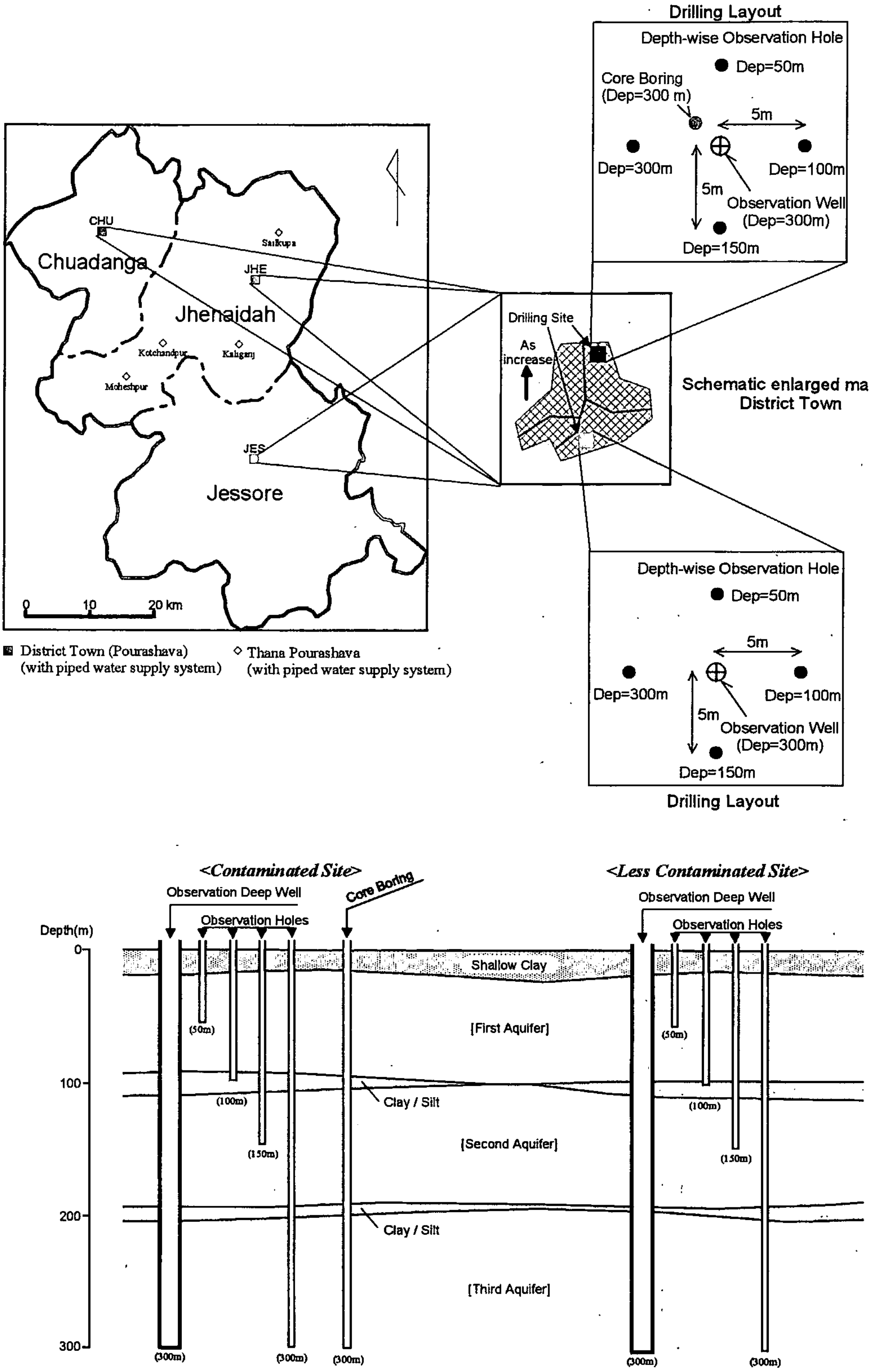

Figure 5.2.1 Schematic Drilling Plan of Observation Wells and Bore Holes

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

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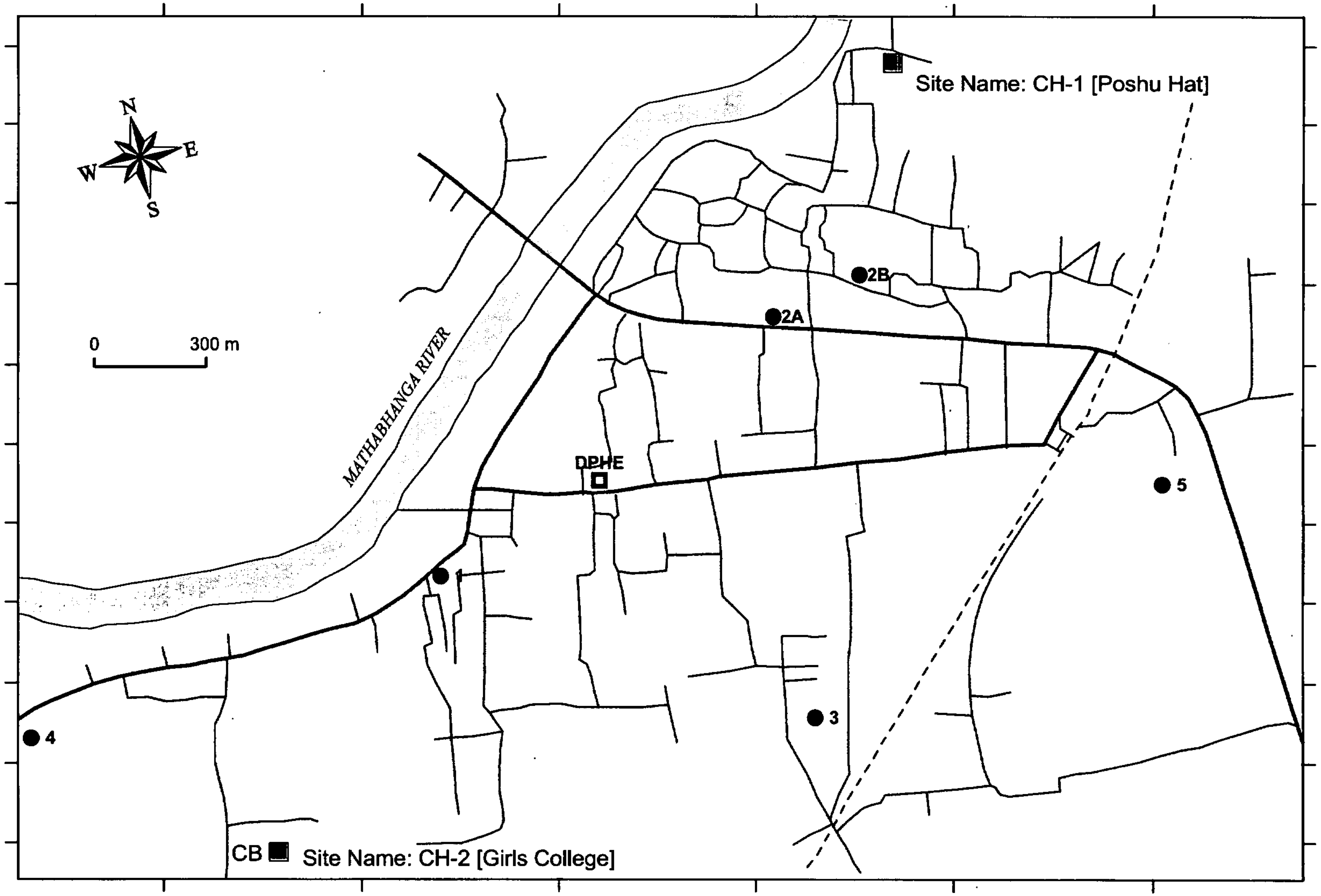

Figure 5.2.2

Location of Existing Production Wells and New Drilling Sites in Chuadanga Pourashava

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

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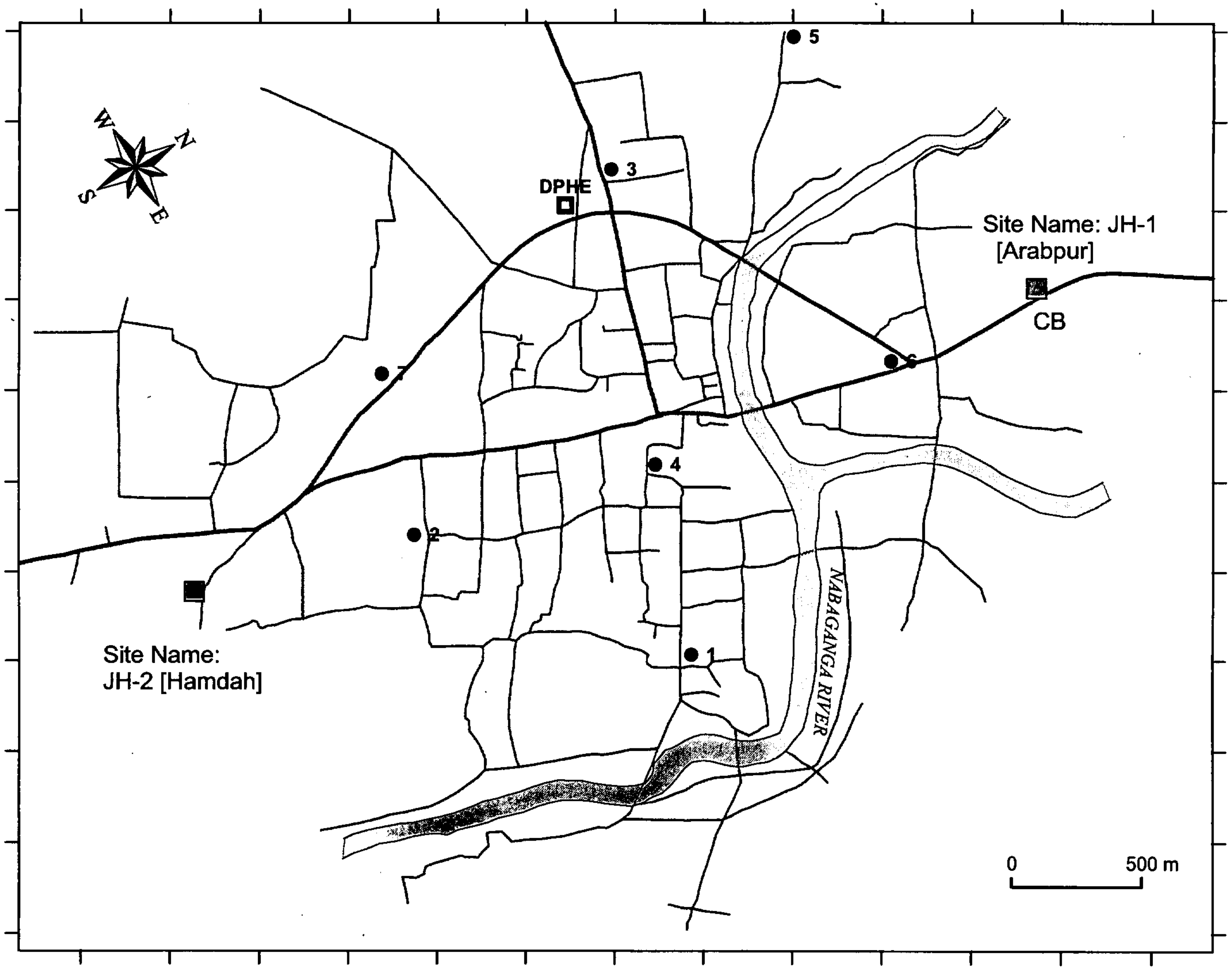
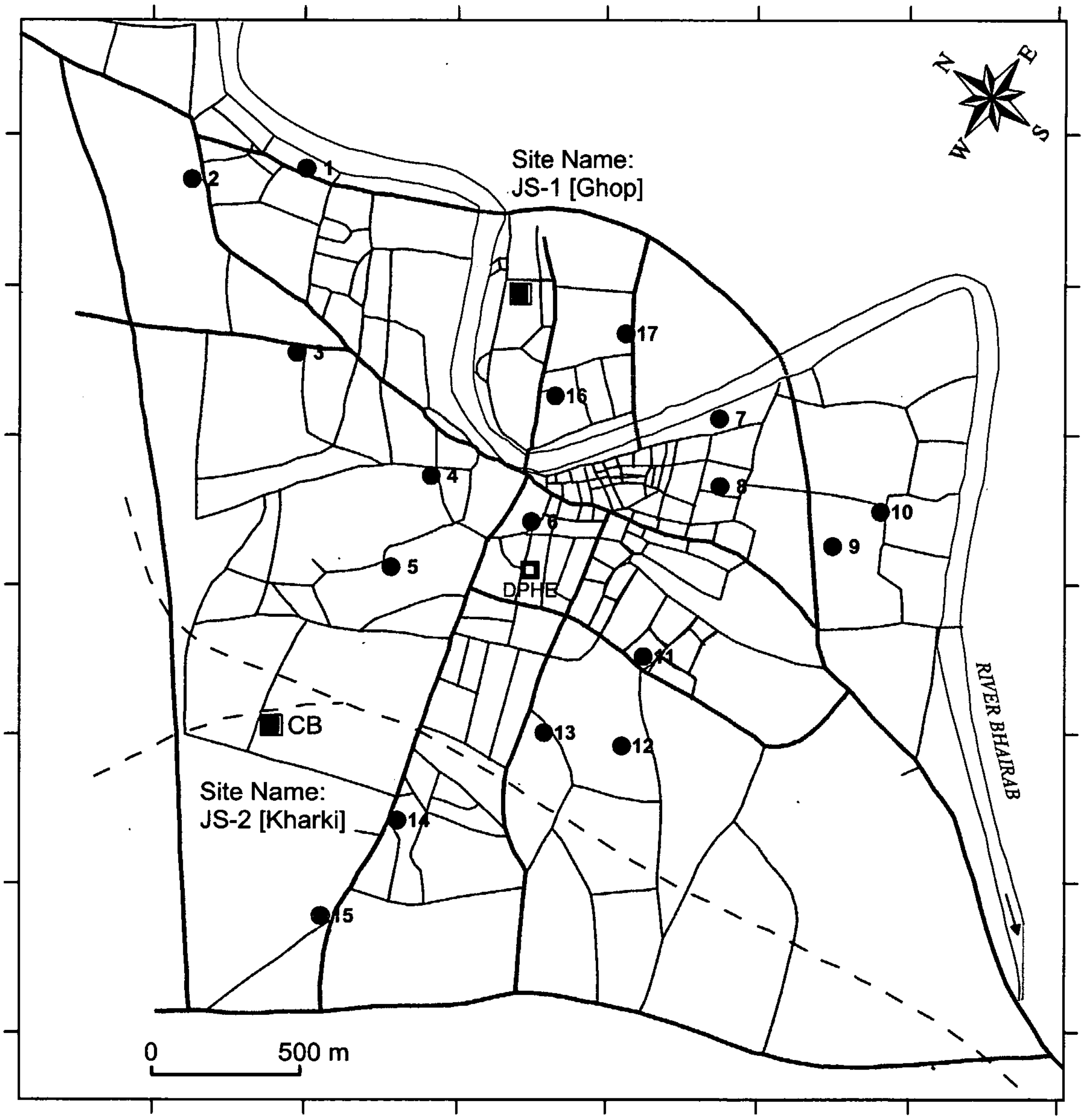


Figure 5.2.3 Location of Existing Production Wells and New Drilling Sites in Jhenaidah Pourashava

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



■ New Drilling Site by the Study (CB: with Core Boring)

● Existing Production Well

Figure 5.2.4 Location of Existing Production Wells and New Drilling Sites in Jessore Pourashava

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

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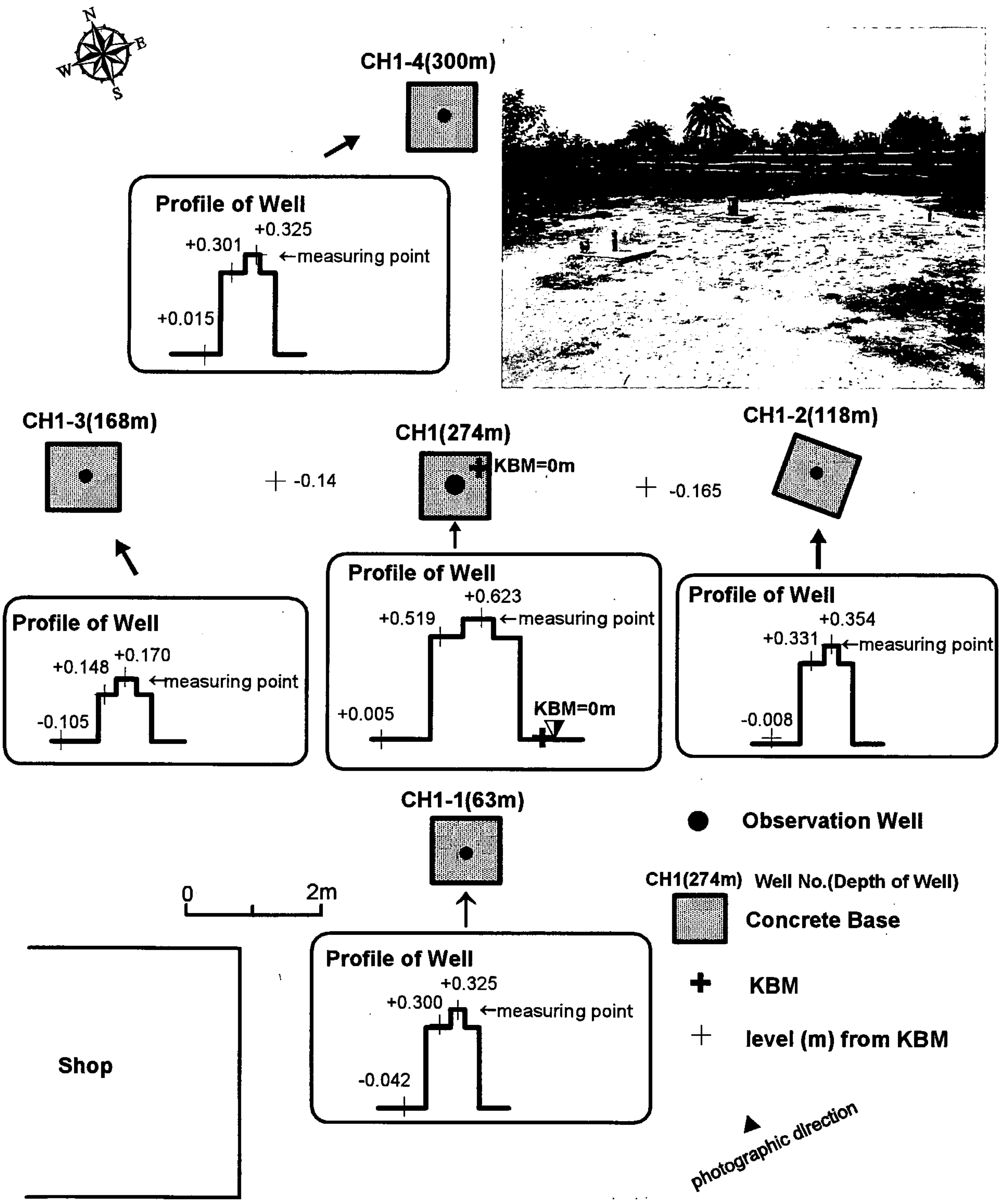


Figure 5.2.5	**Drilling Site Map of CH-1 (Poshu Hat, Chuadanga Pourashava)**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

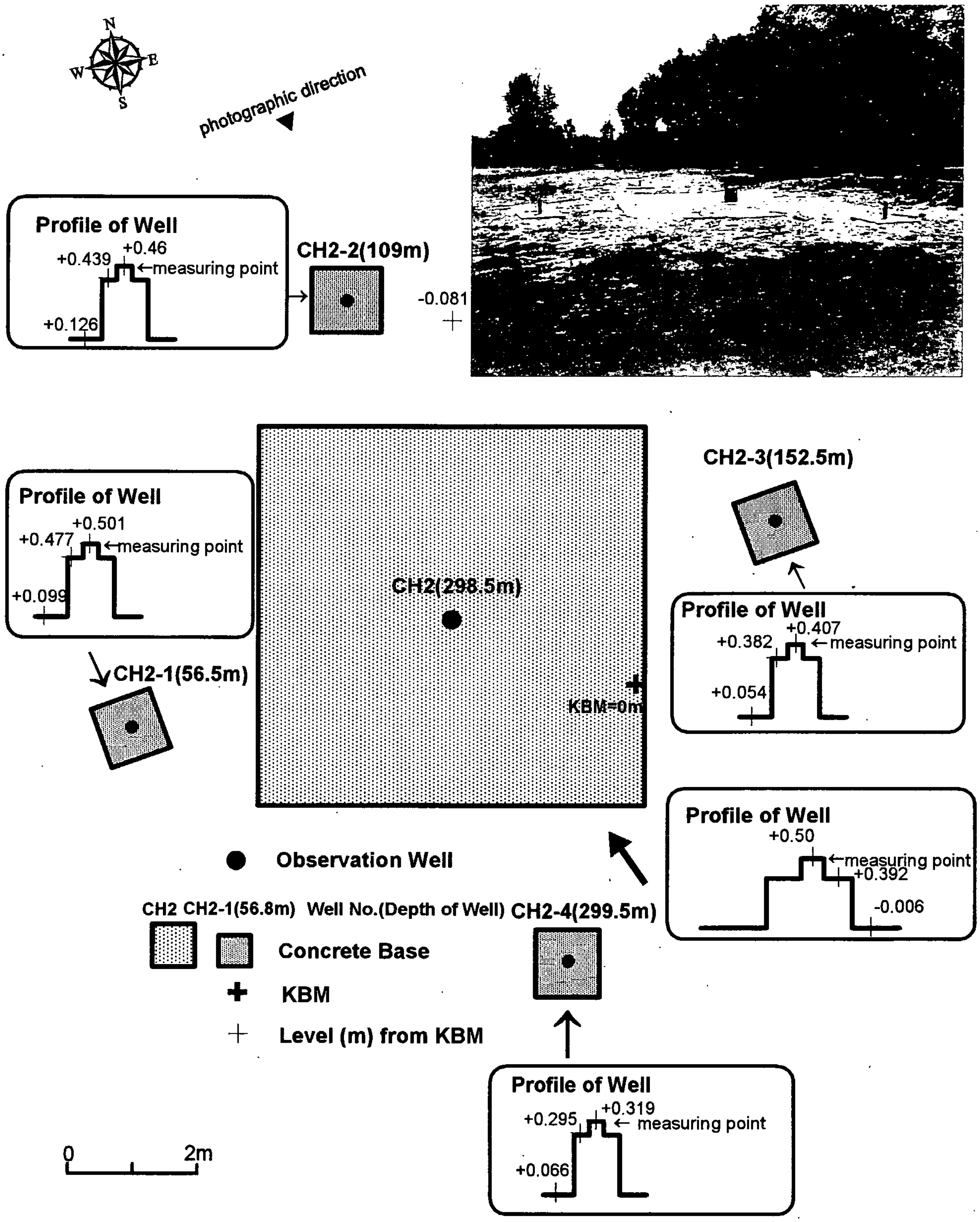


Figure 5.2.6	Drilling Site Map of CH-2 (Girls College, Chuadanga Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

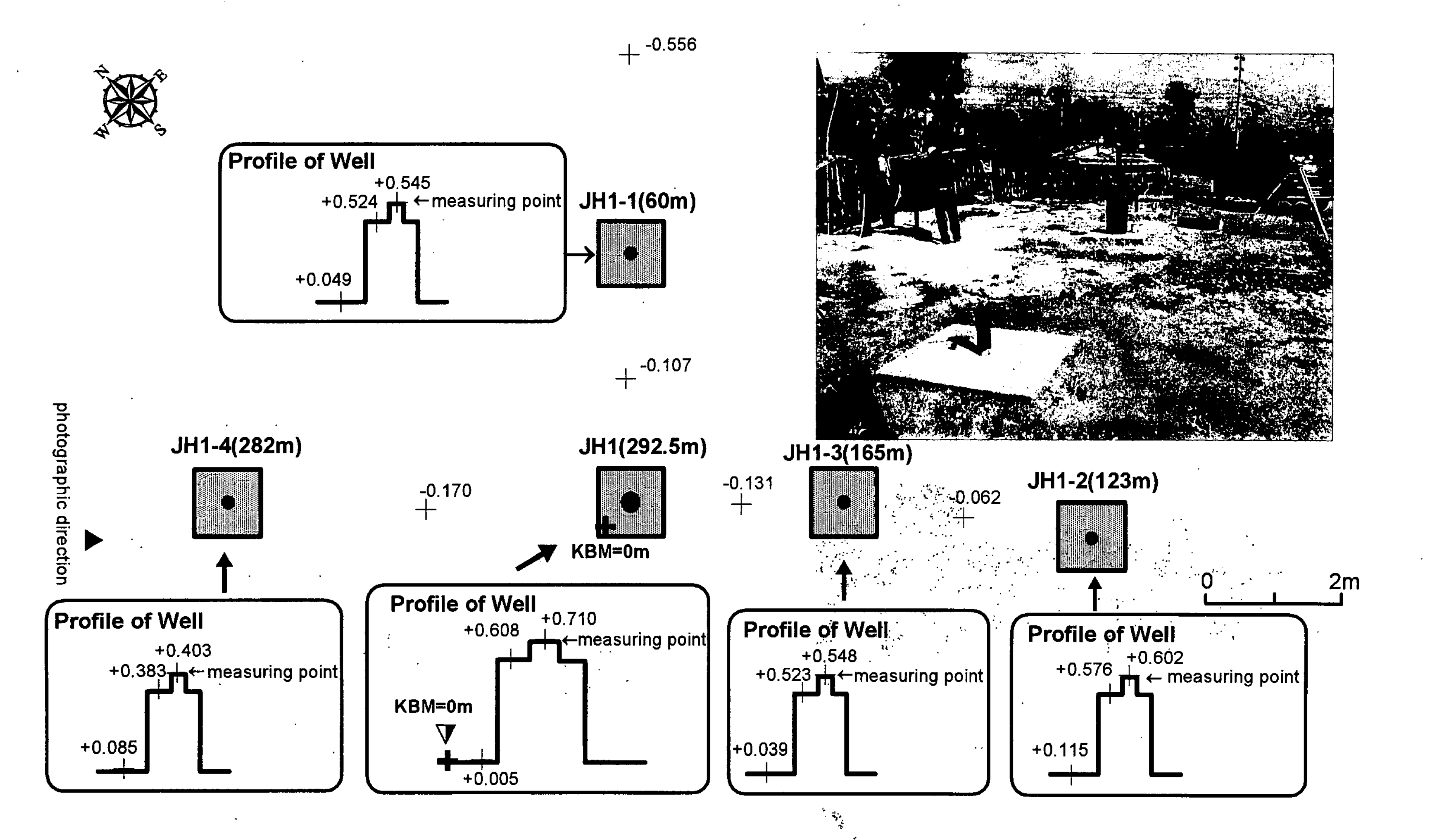


Figure 5.2.7

Drilling Site Map of JH-1 (Arabpur, Jhenaidah Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

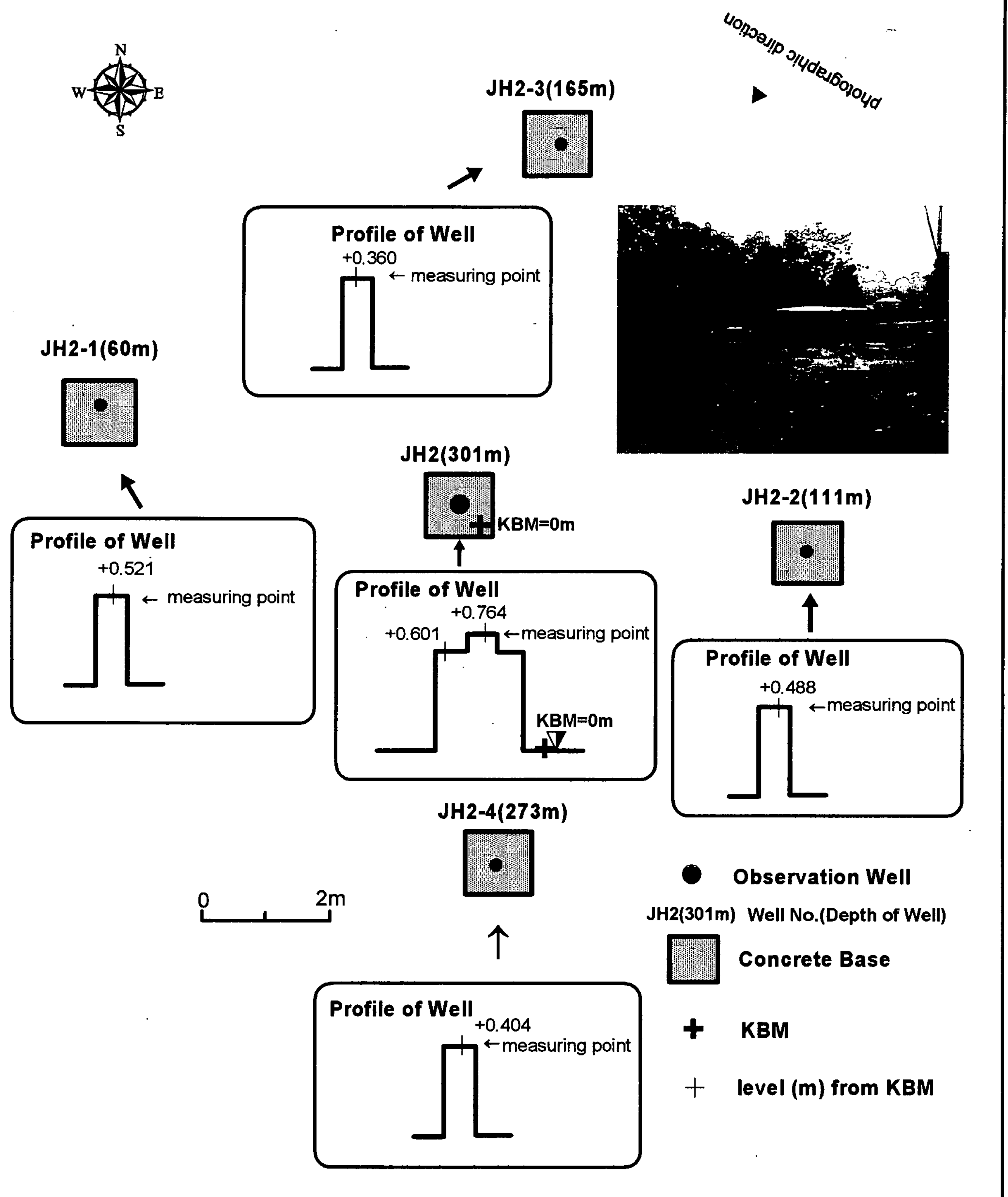


Figure 5.2.8	Drilling Site Map of JH-2 (Hamdah, Jhenaidah Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

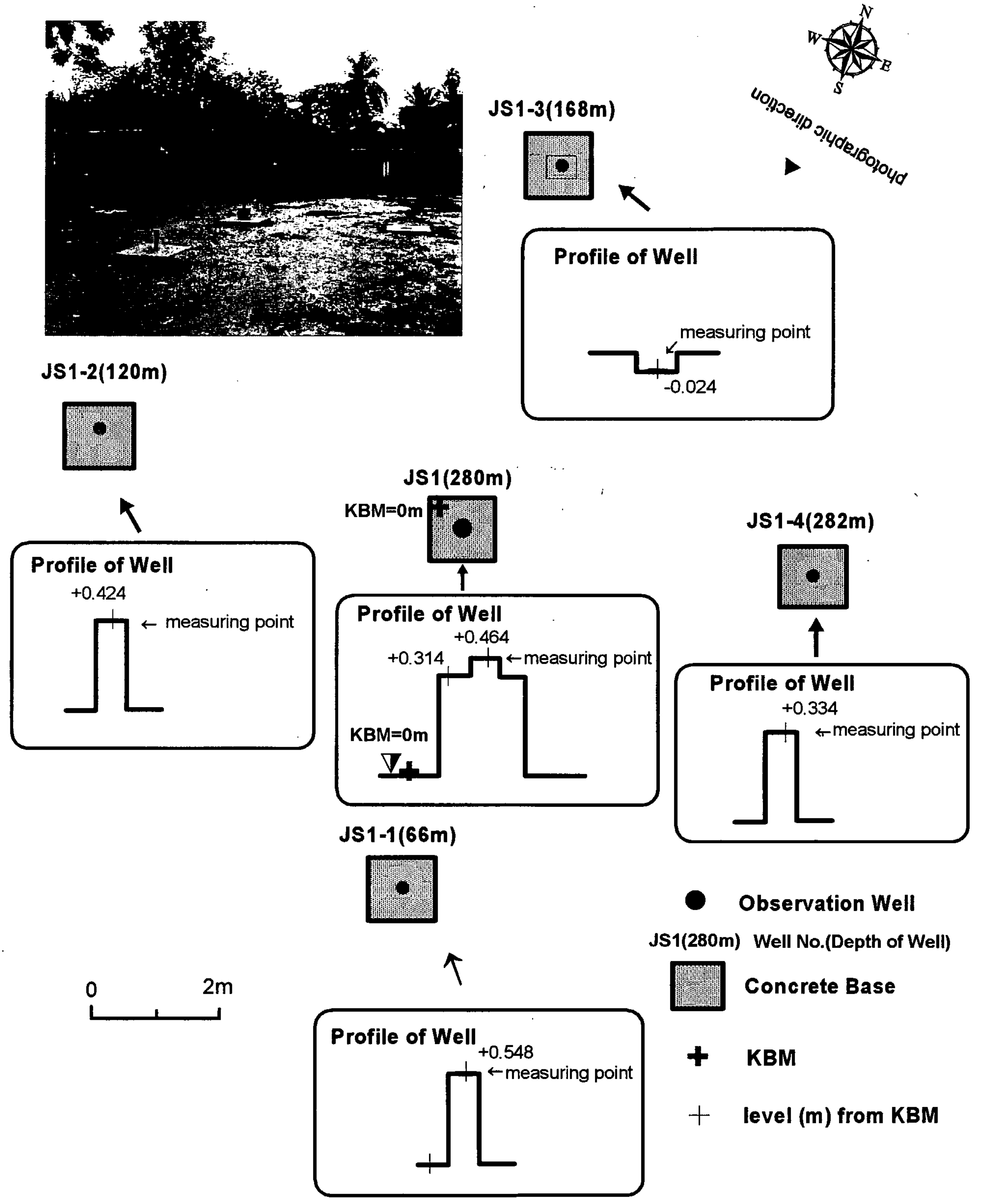


Figure 5.2.9	**Drilling Site Map of JS-1 (Ghop, Jessore Pourashava)**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

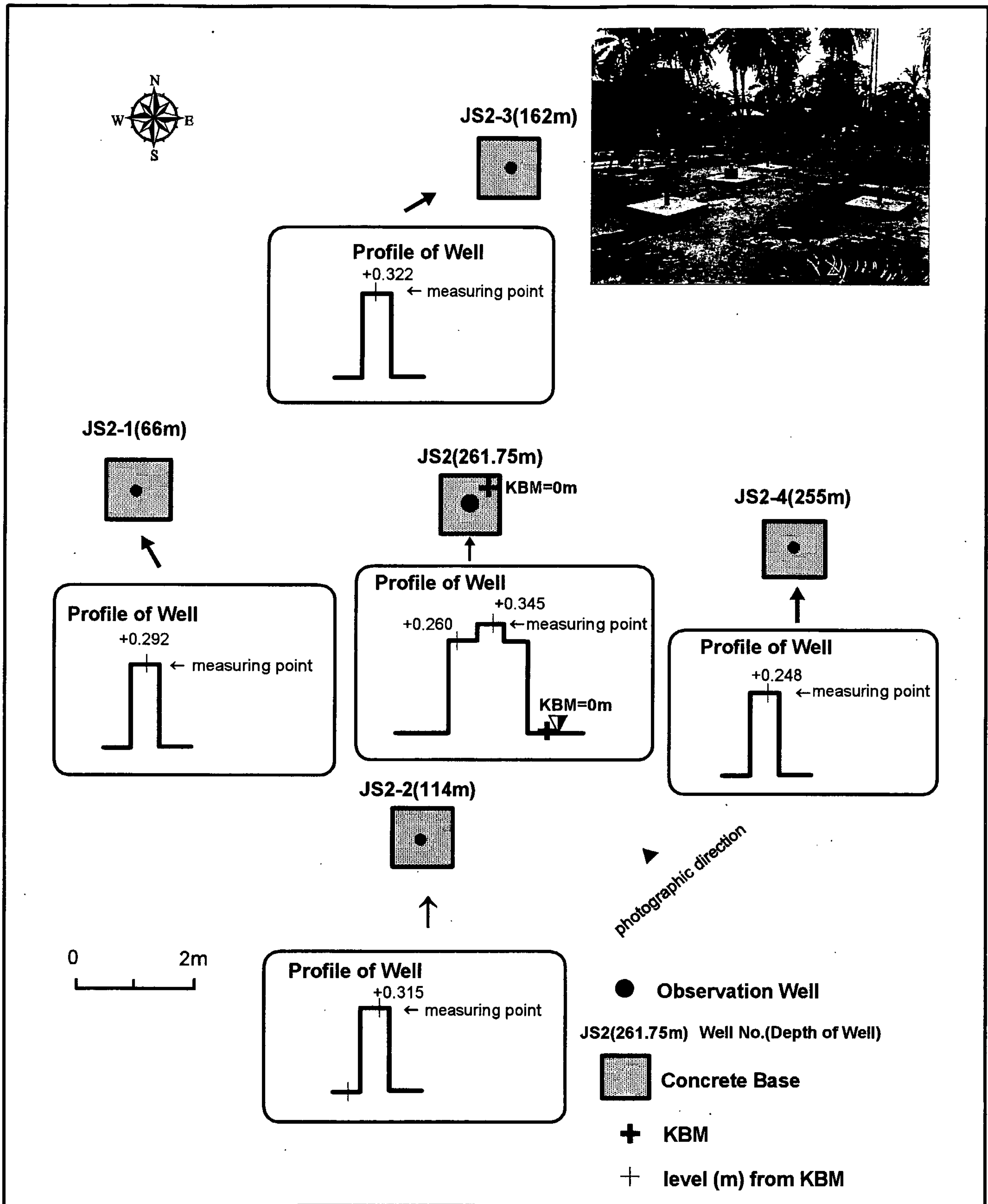
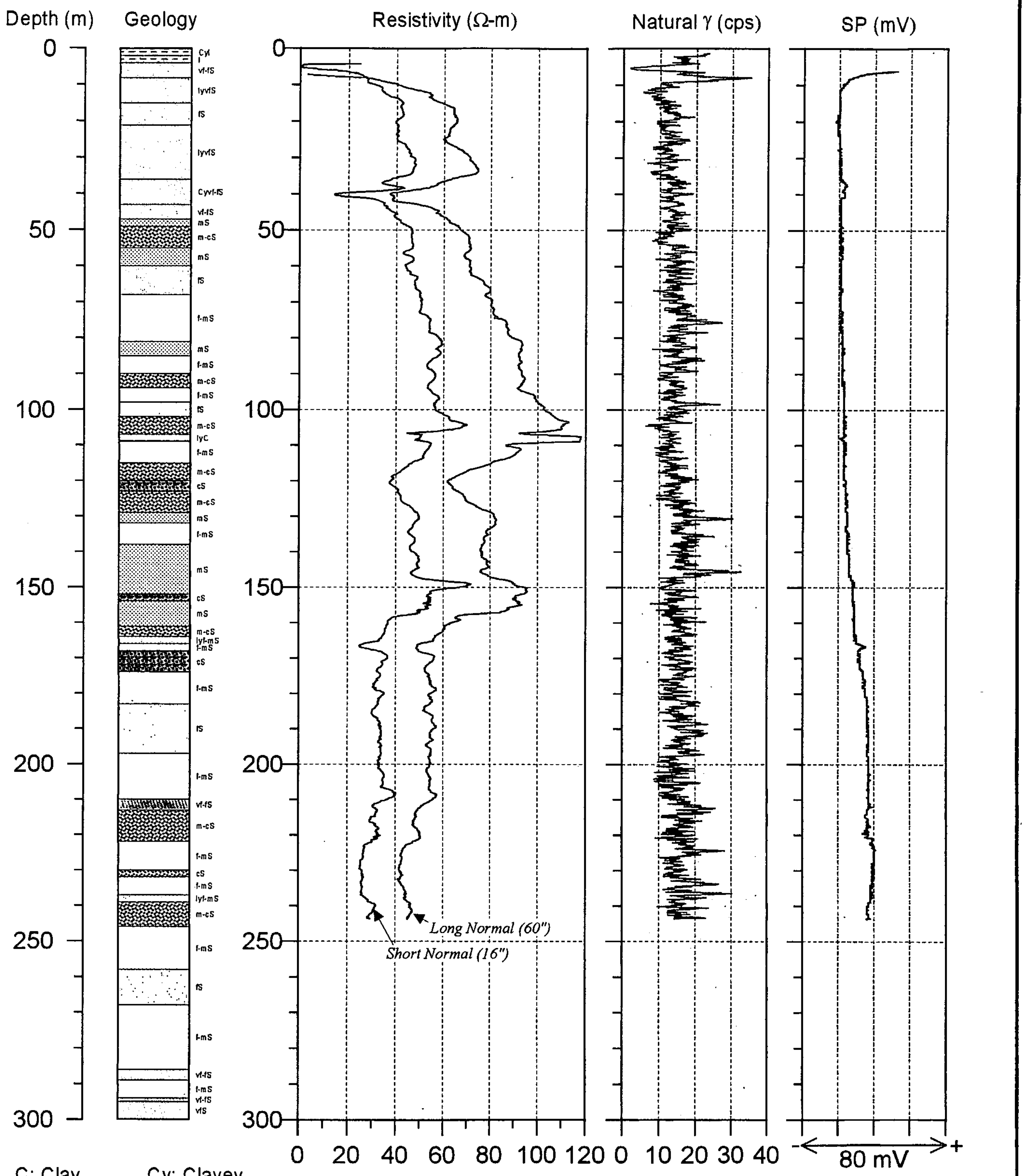


Figure 5.2.10 Drilling Site Map of JS-2 (Kharki, Jessore Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



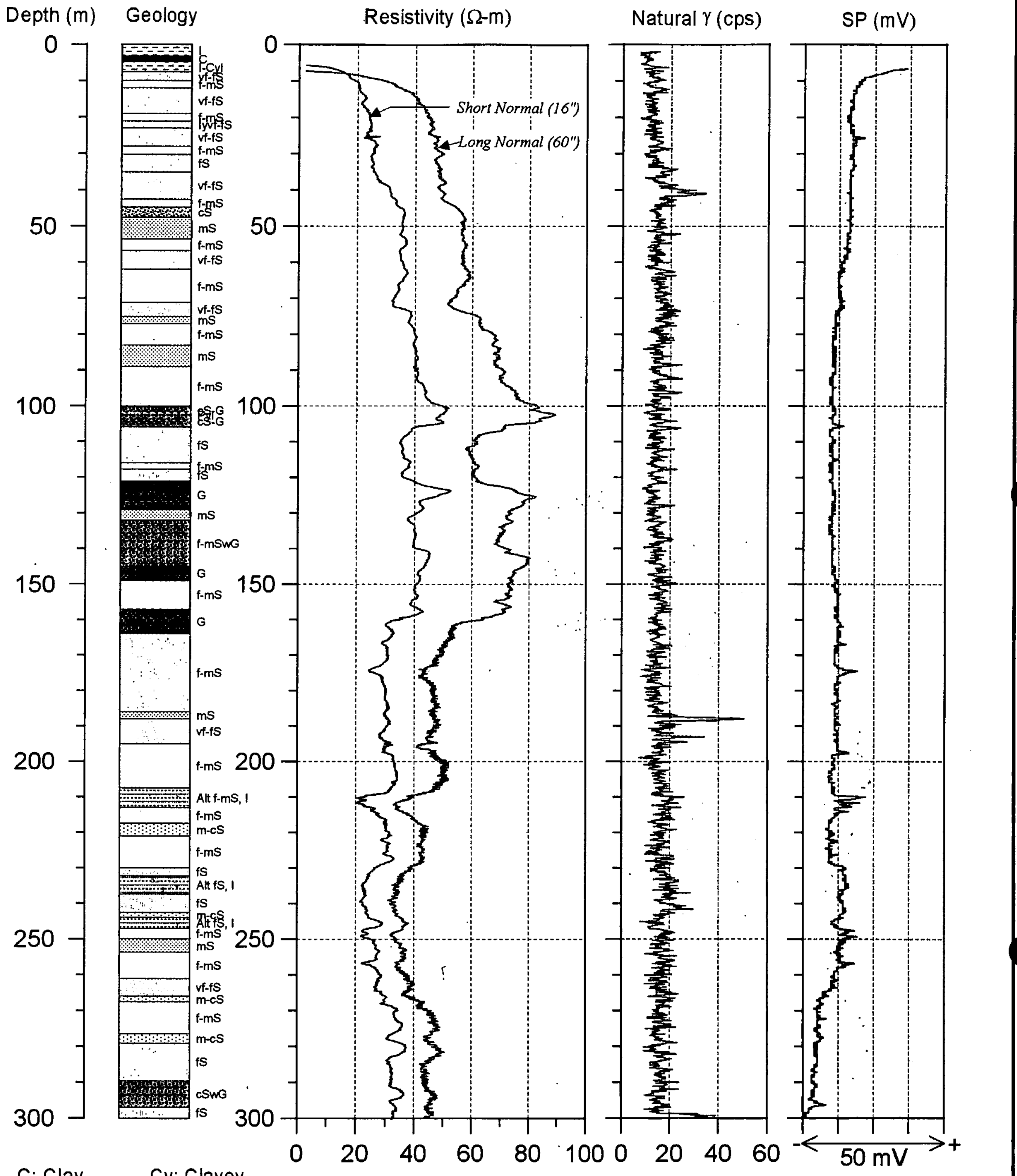
C: Clay
l: Silt
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.11 **Results of Geophysical Logging at CH-1 Site [Poshu Hat, Chuadanga Pourashava]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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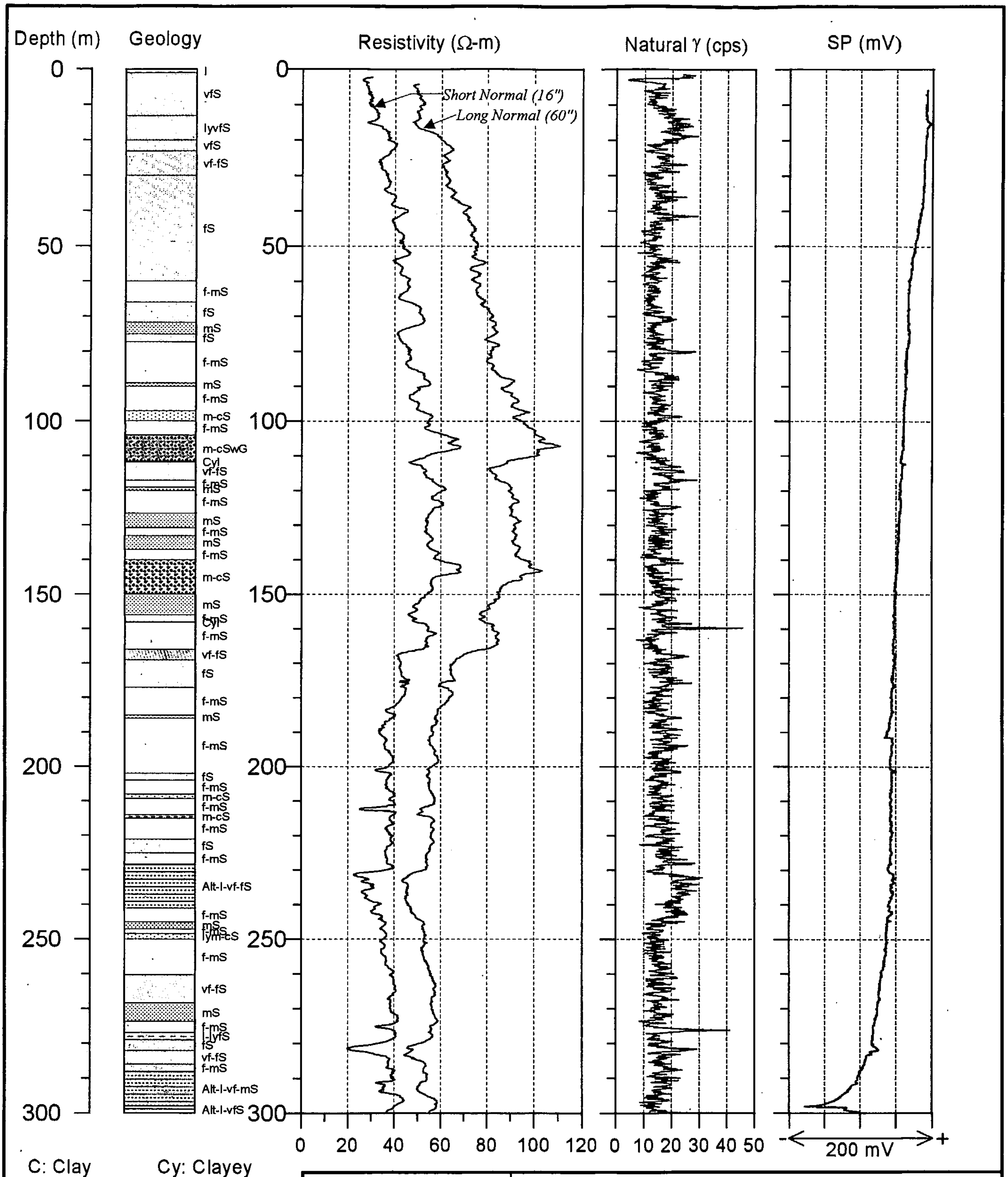
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.12 **Results of Geophysical Logging at CH-2 Site [Girls College, Chuadanga Pourashava]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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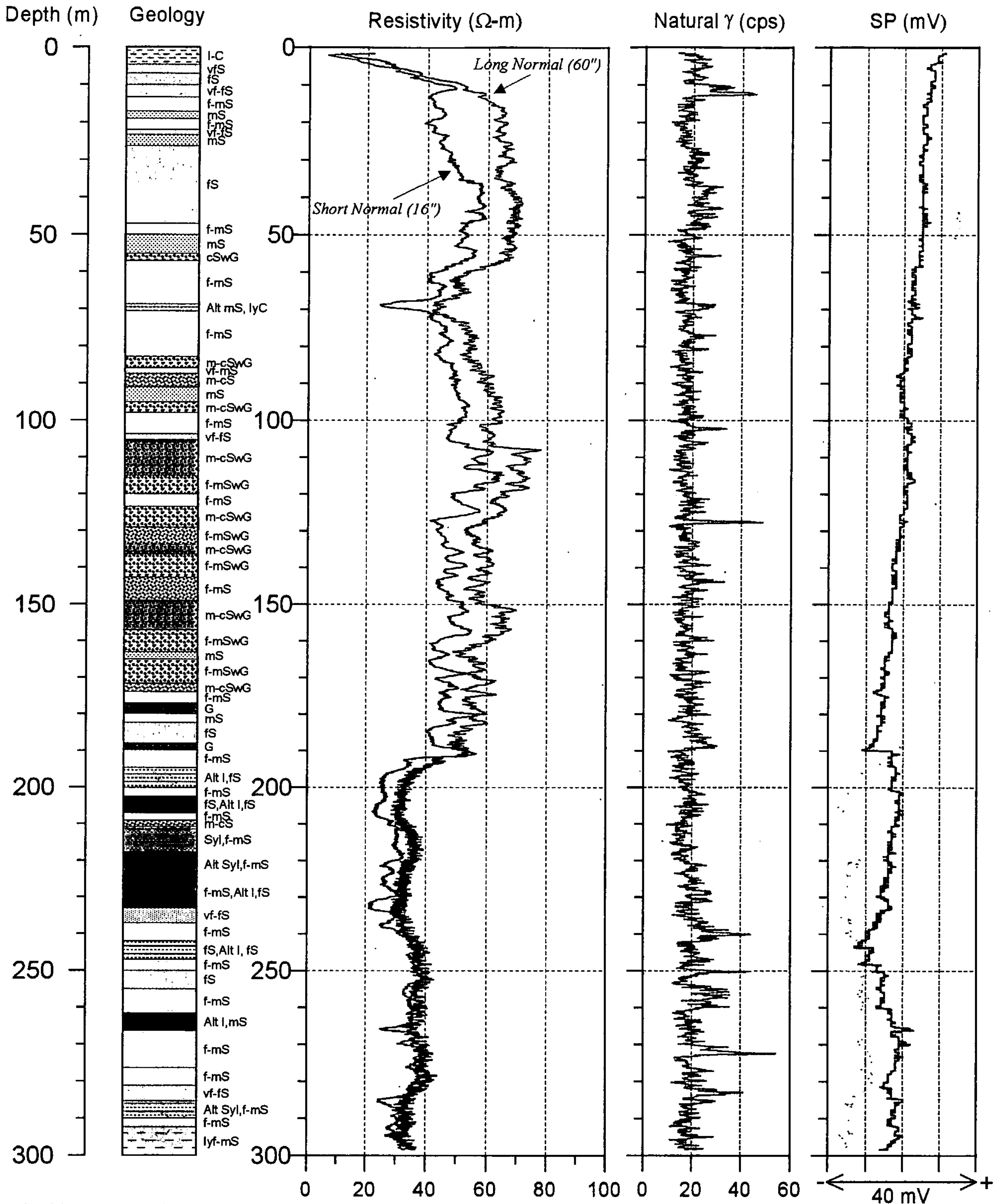
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.13 **Results of Geophysical Logging at CH-BD Site [Bara Dudpatila, Damurhuda]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



C: Clay
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f: fine
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c: coarse

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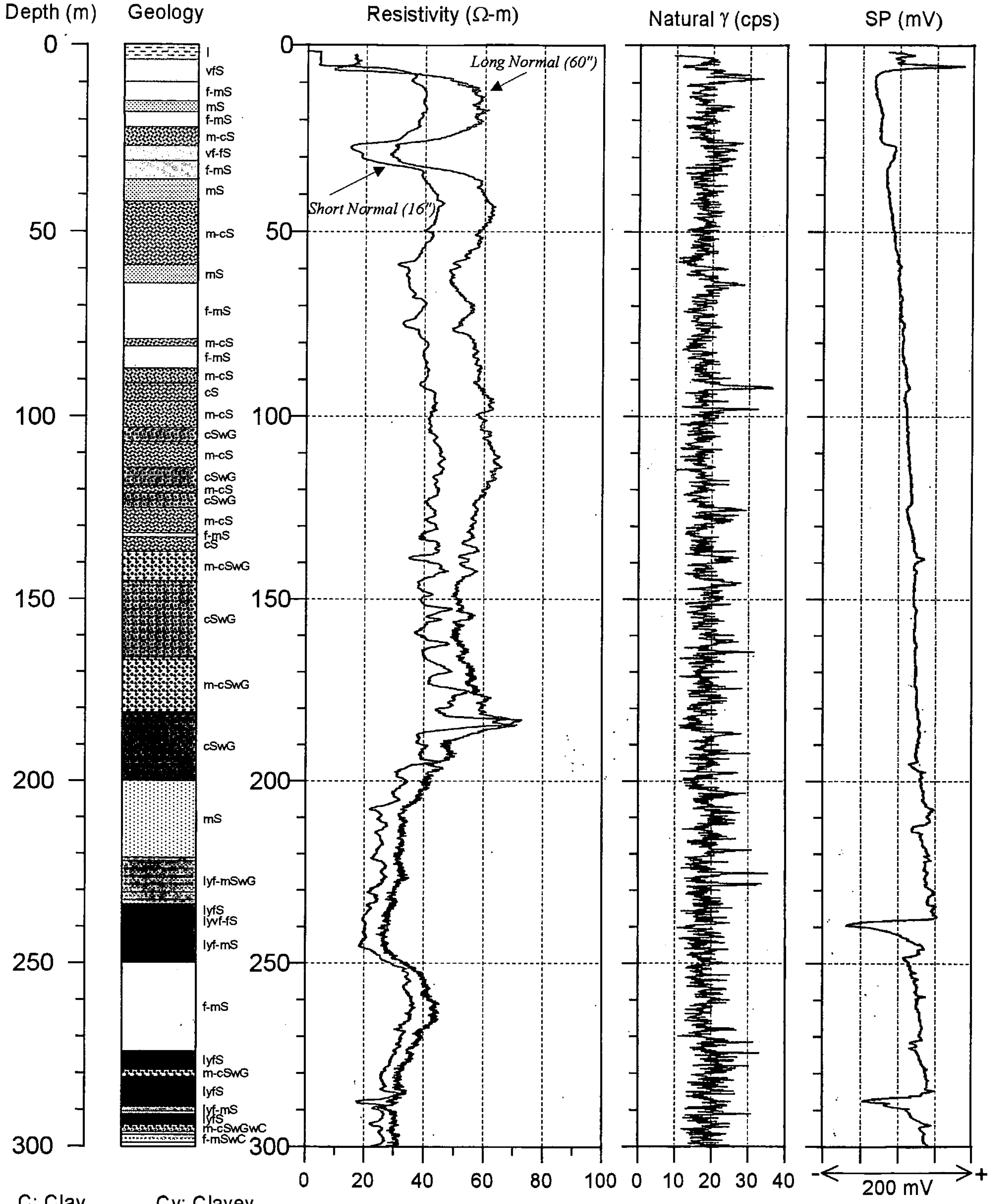
Sy: Sandy
w: with
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.14

Results of Geophysical Logging at JH-1 Site [Arabpur, Jhenaidah Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



C: Clay
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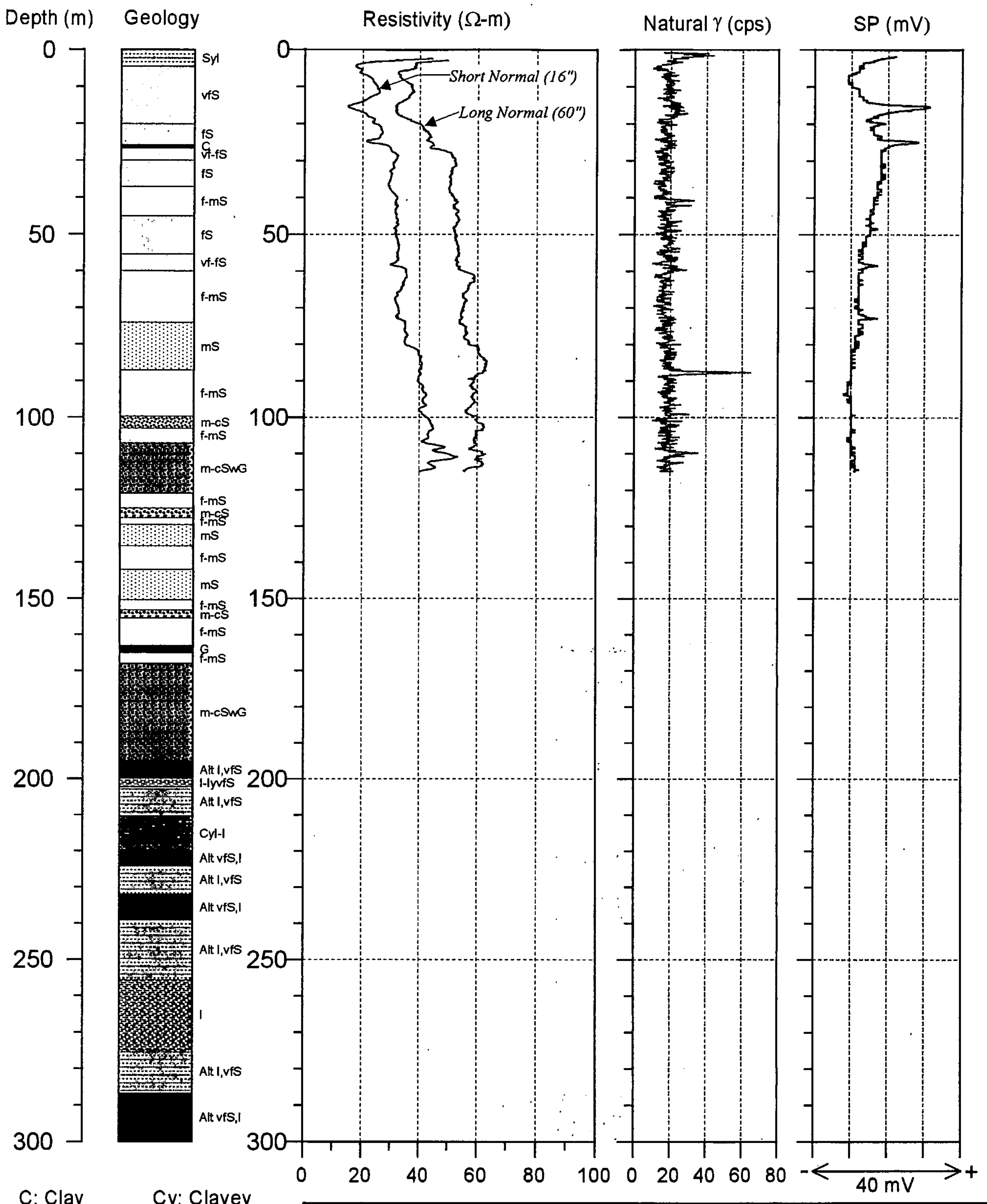
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.15 **Results of Geophysical Logging at JH-2 Site [Hamdah, Jhenaidah Pourashava]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



C: Clay
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S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

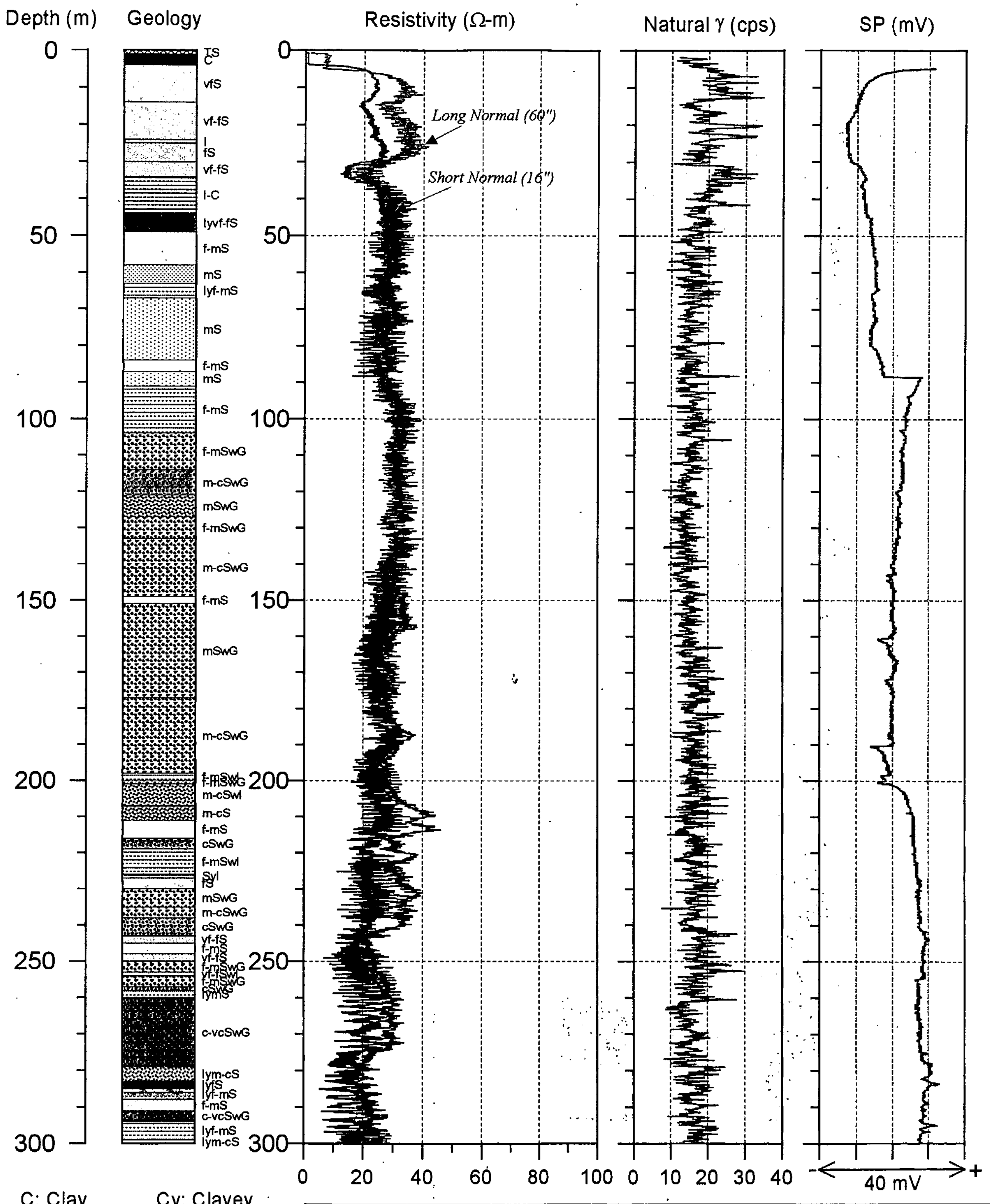
Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.16

Columnar Section and Geophysical Logging at JH-KC Site [Krishna Chandrapur, Moheshpur]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

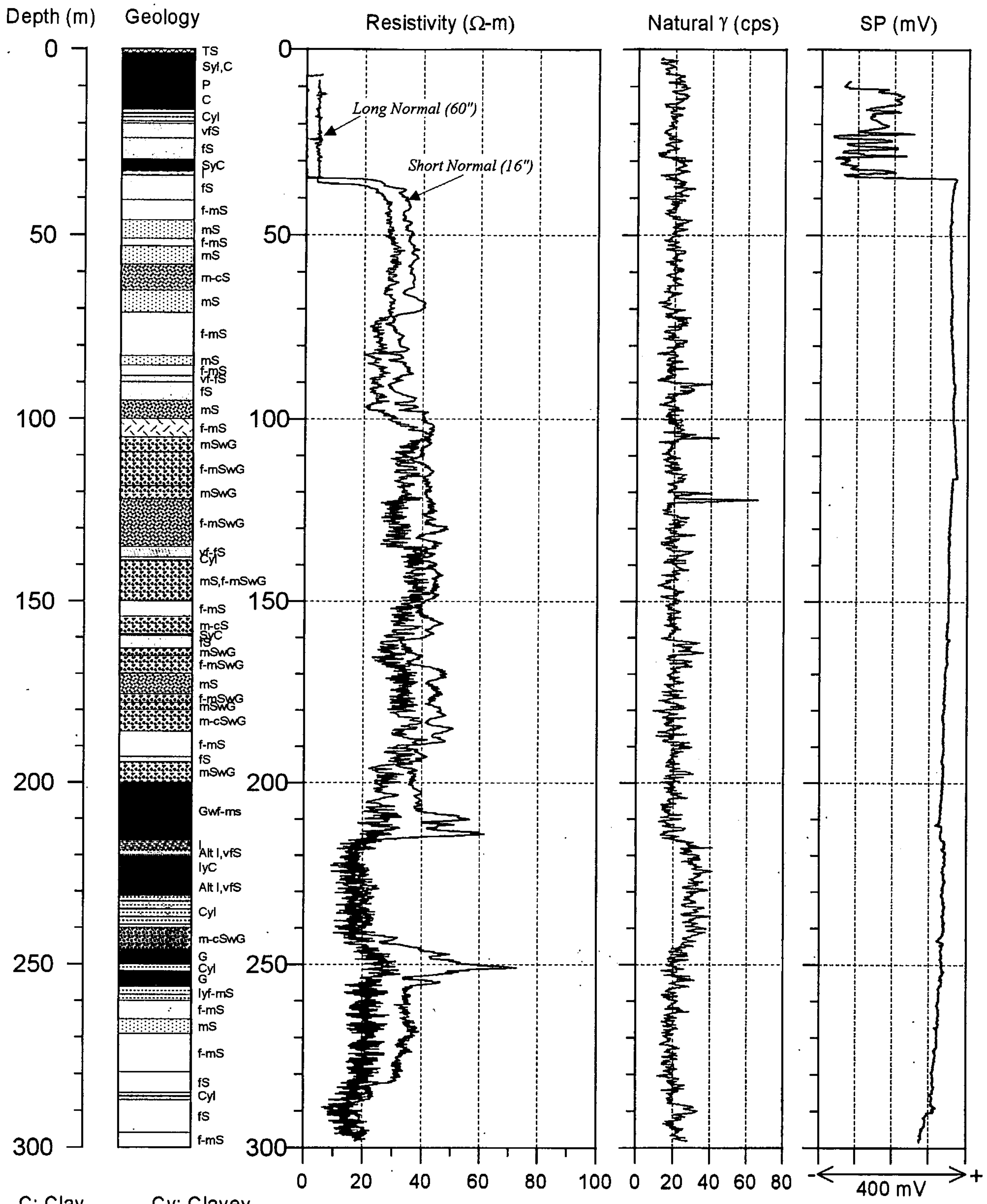


C: Clay	Cy: Clayey
l: Silt	ly: Silty
S: Sand	Sy: Sandy
G: Gravel	w: with
v: very	-: to
f: fine	Alt: Alternation
m: medium	P: Peat
c: coarse	TS: Top Soil

Figure 5.2.17 **Results of Geophysical Logging at JS-1 Site [Ghop, Jessore Pourashava]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



C: Clay
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c: coarse

Cy: Clayey
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Sy: Sandy
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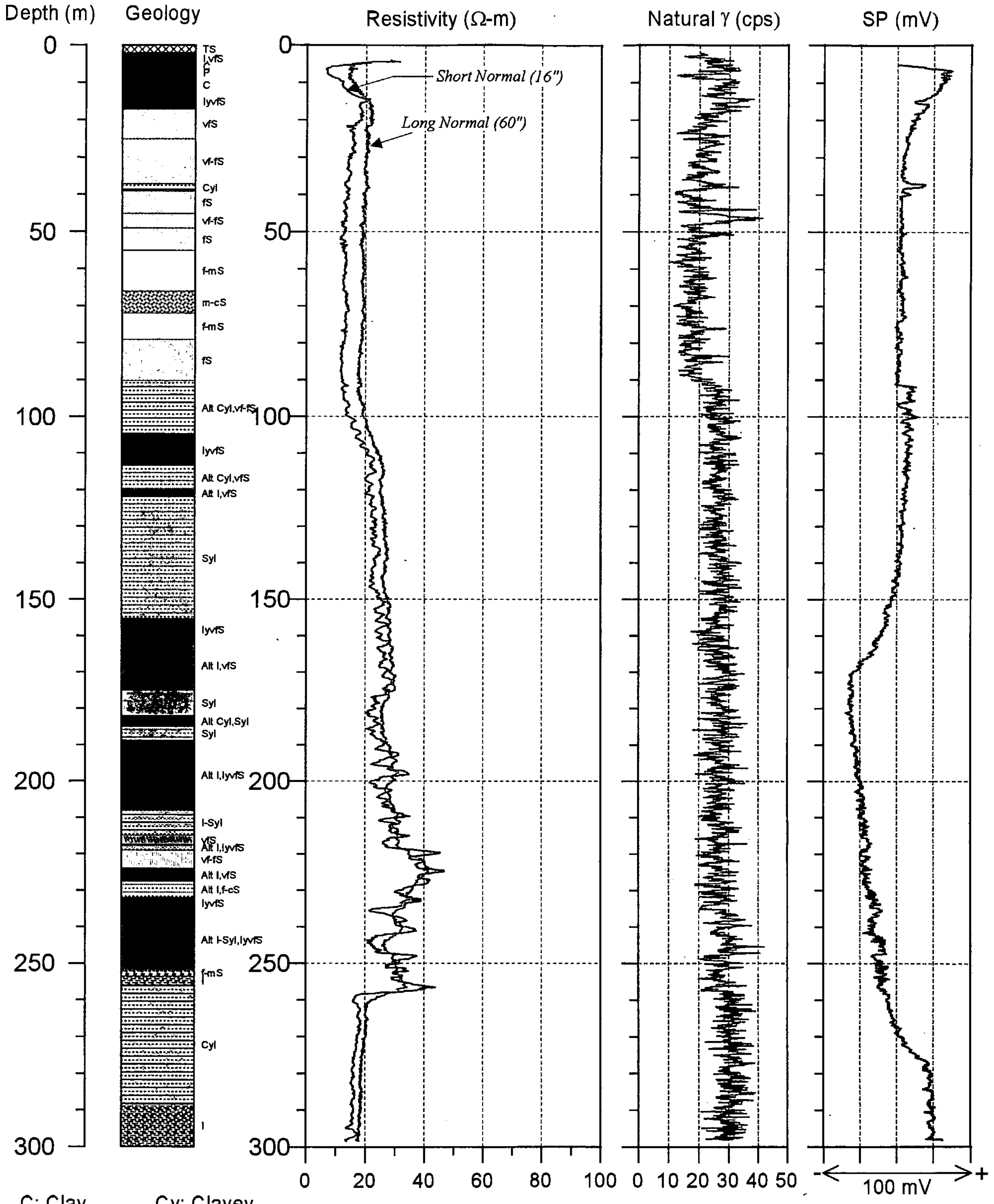
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.18 **Results of Geophysical Logging at JS-2 Site [Kharki, Jessore Pourashava]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



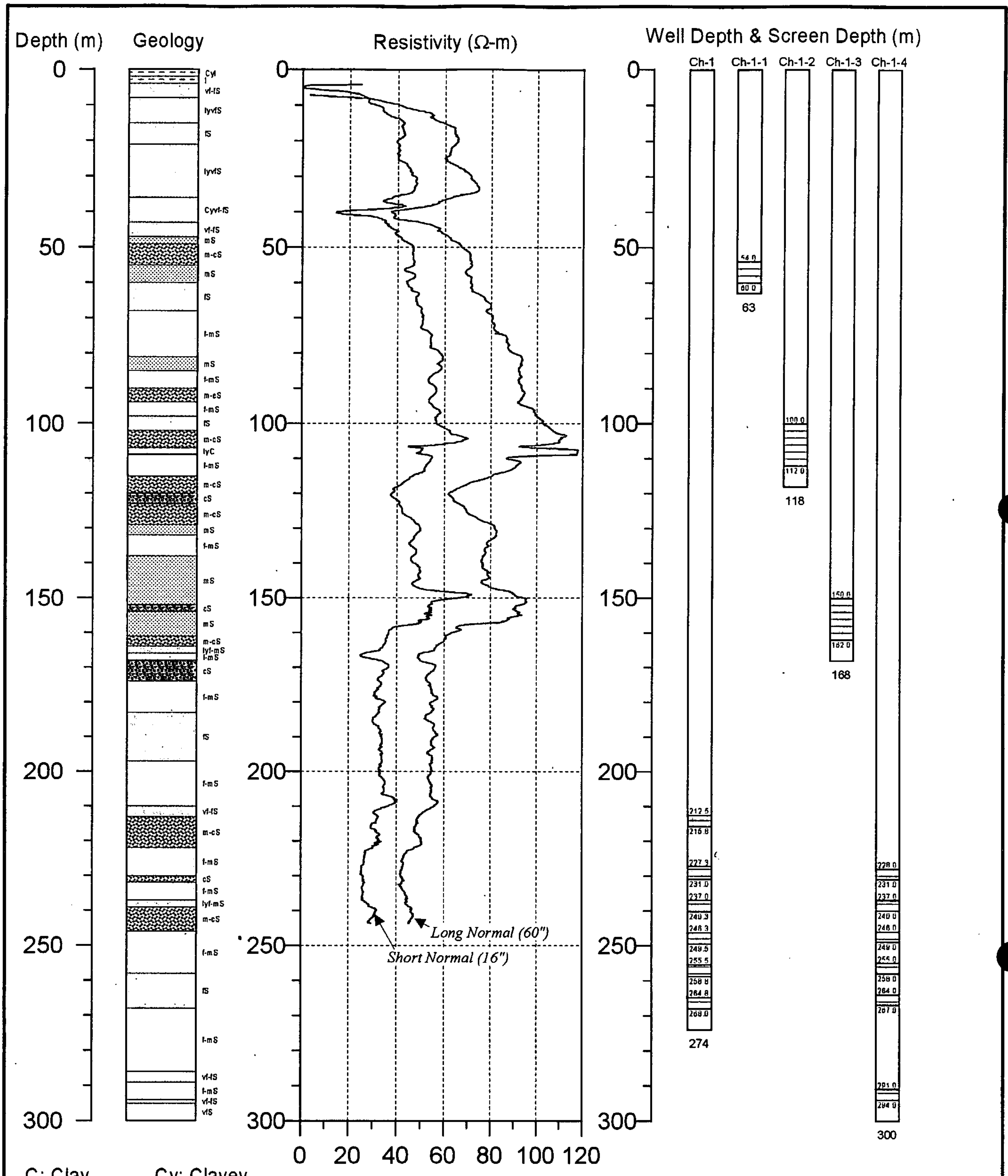
C: Clay
l: Silt
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.19 Results of Geophysical Logging at JS-RB Site [Rajnagar Bankabarsi, Keshabpur]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



C: Clay
I: Silt
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

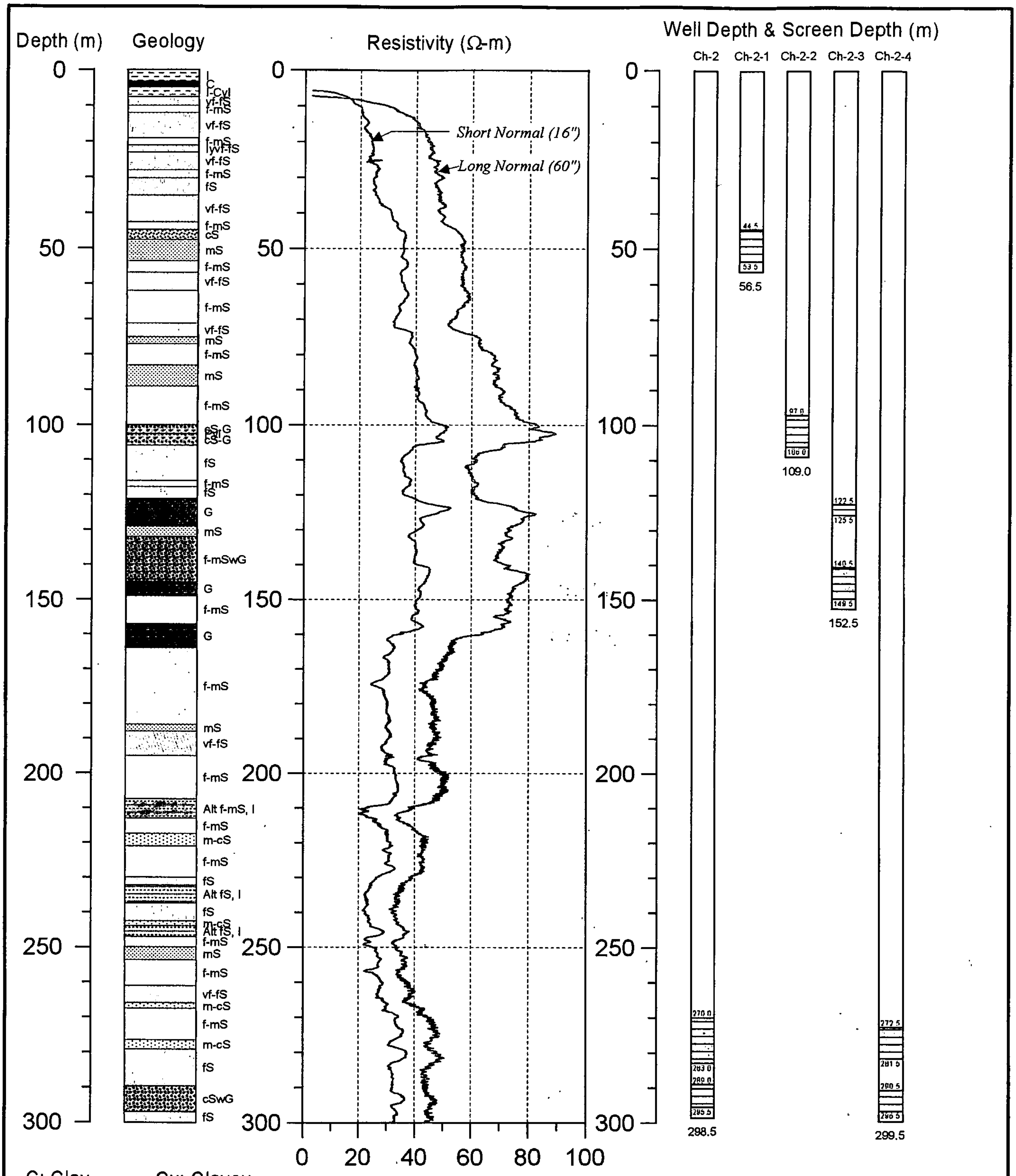
Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.20

Columnar Section and Geophysical Logging at CH-1 Site [Poshu Hat, Chuadanga Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



C: Clay
l: Silt
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.21

Columnar Section and Geophysical Logging at CH-2 Site [Girls College, Chuadanga Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

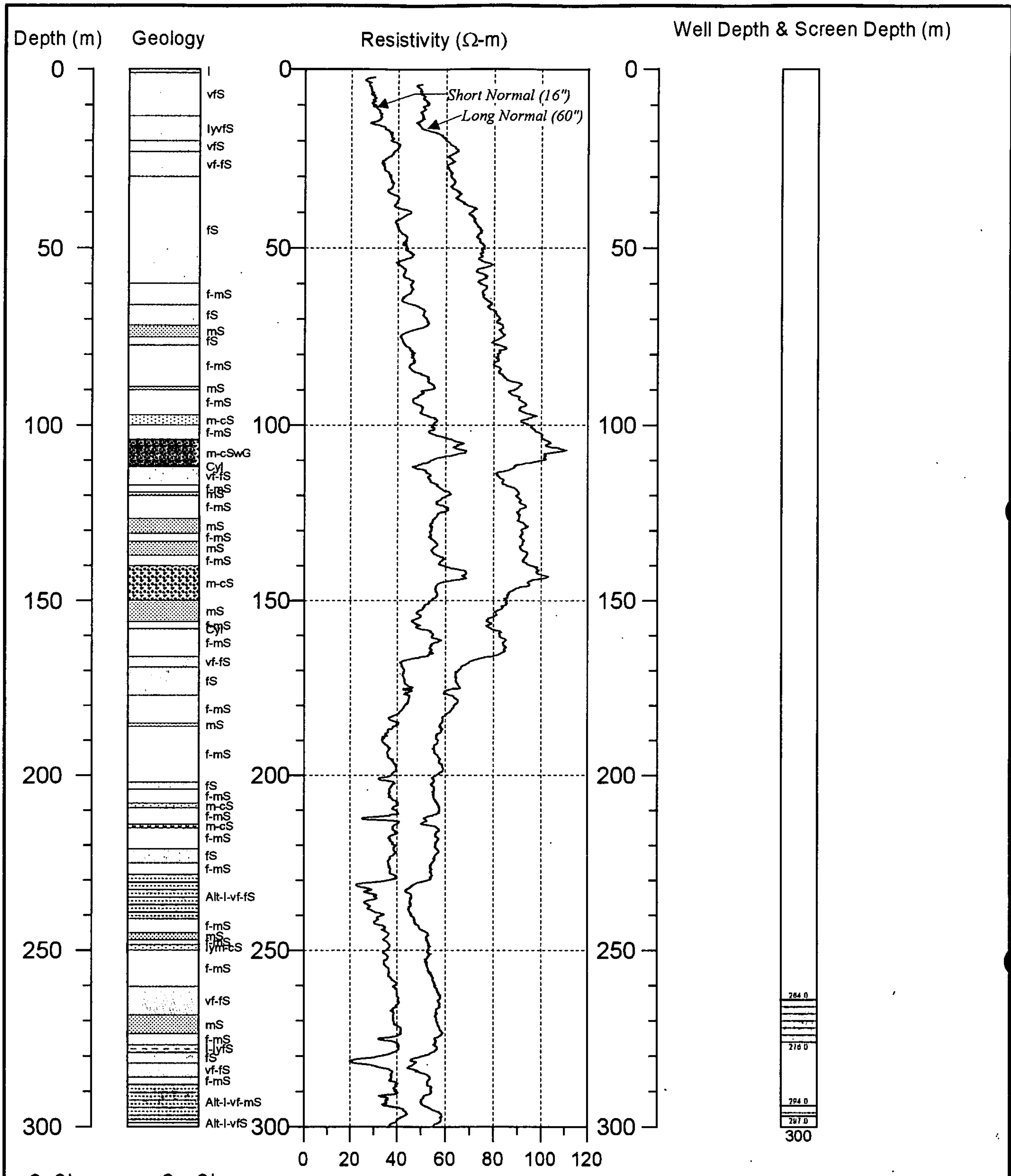


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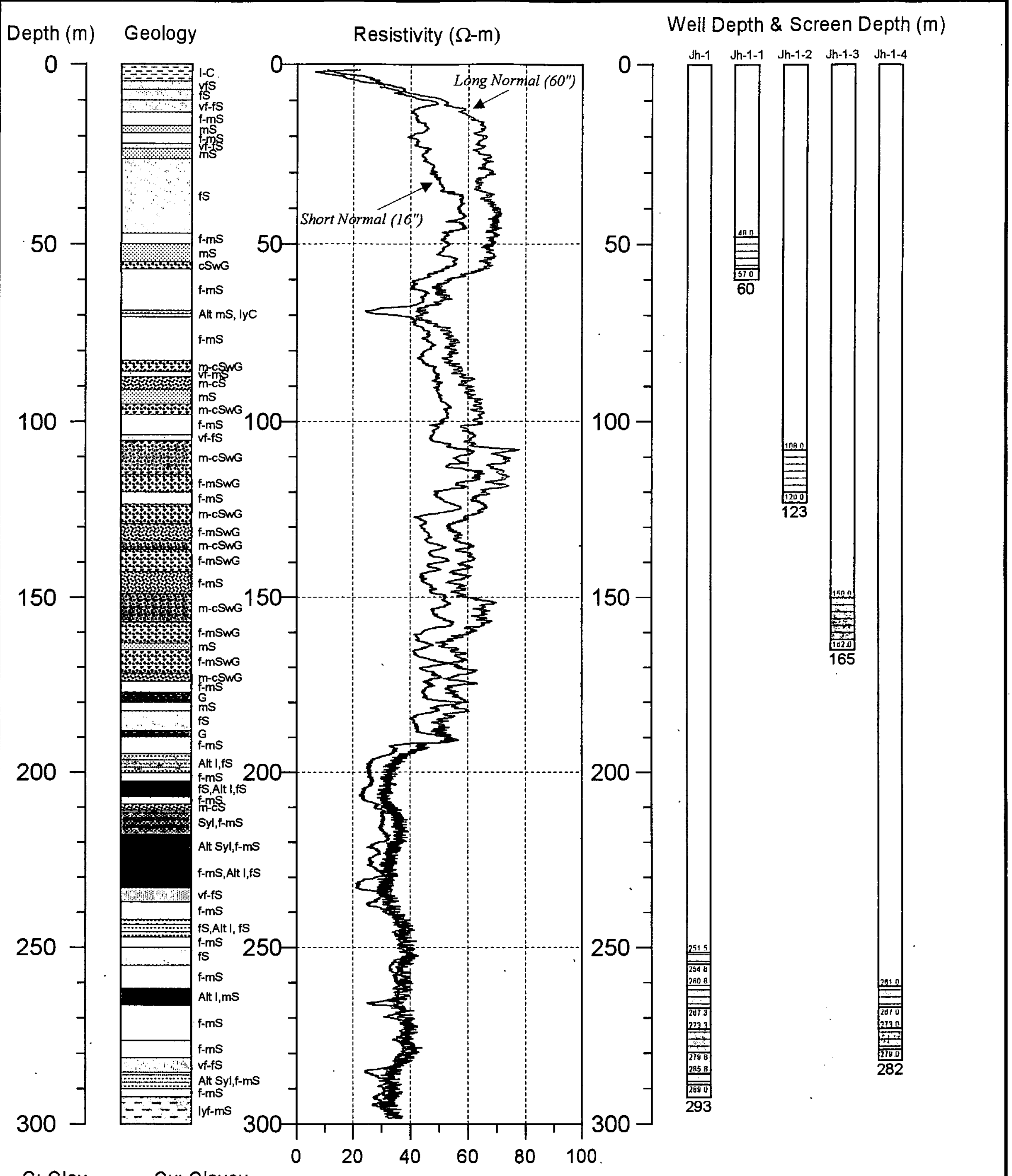
Figure 5.2.22 Columnar Section and Geophysical Logging at CH-BD Site [Bara Dudpatila, Damurhuda]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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Sy: Sandy
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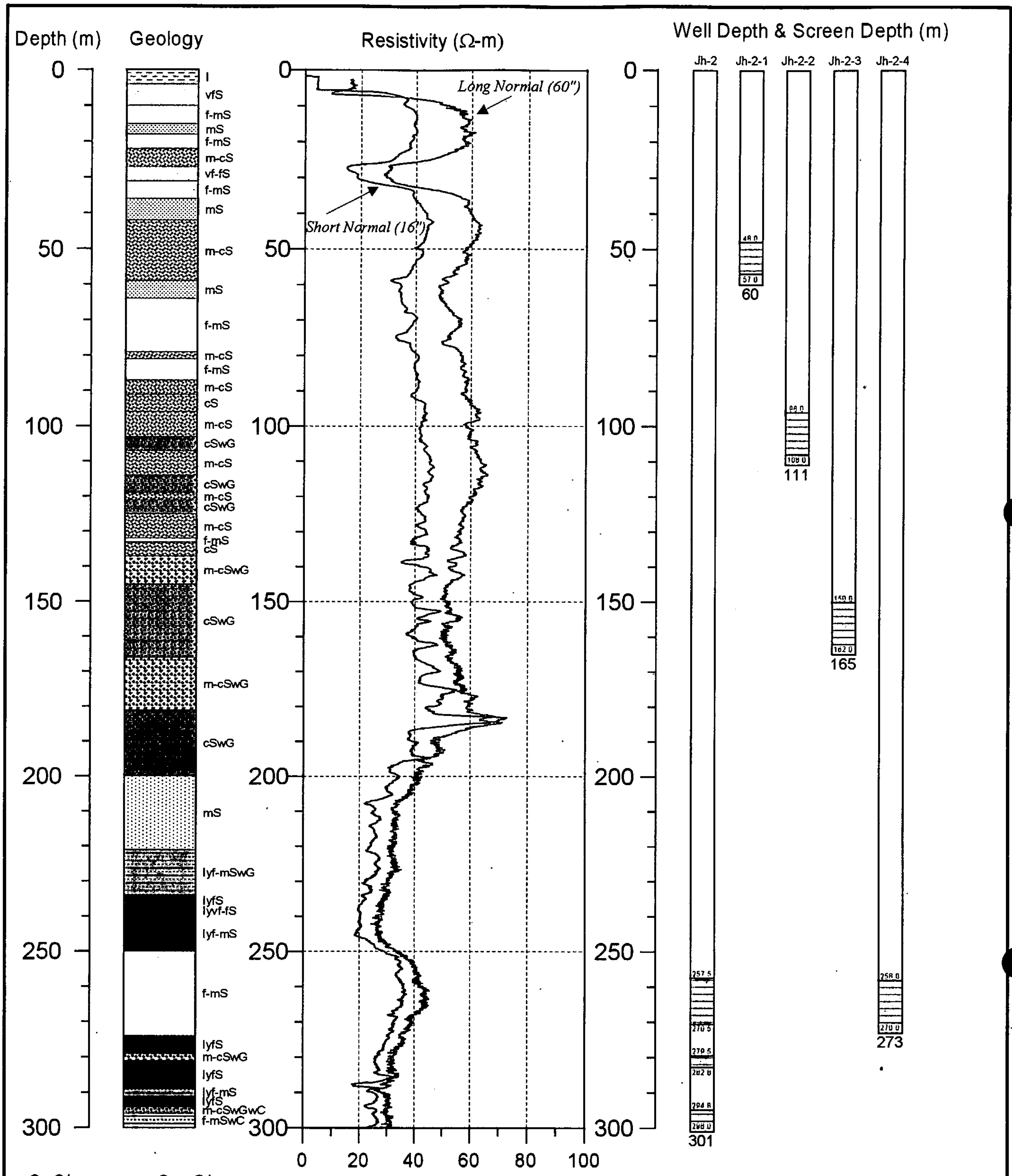
Alt: Alternation

Figure 5.2.23

Columnar Section and Geophysical Logging at JH-1 Site [Arabpur, Jhenaidah Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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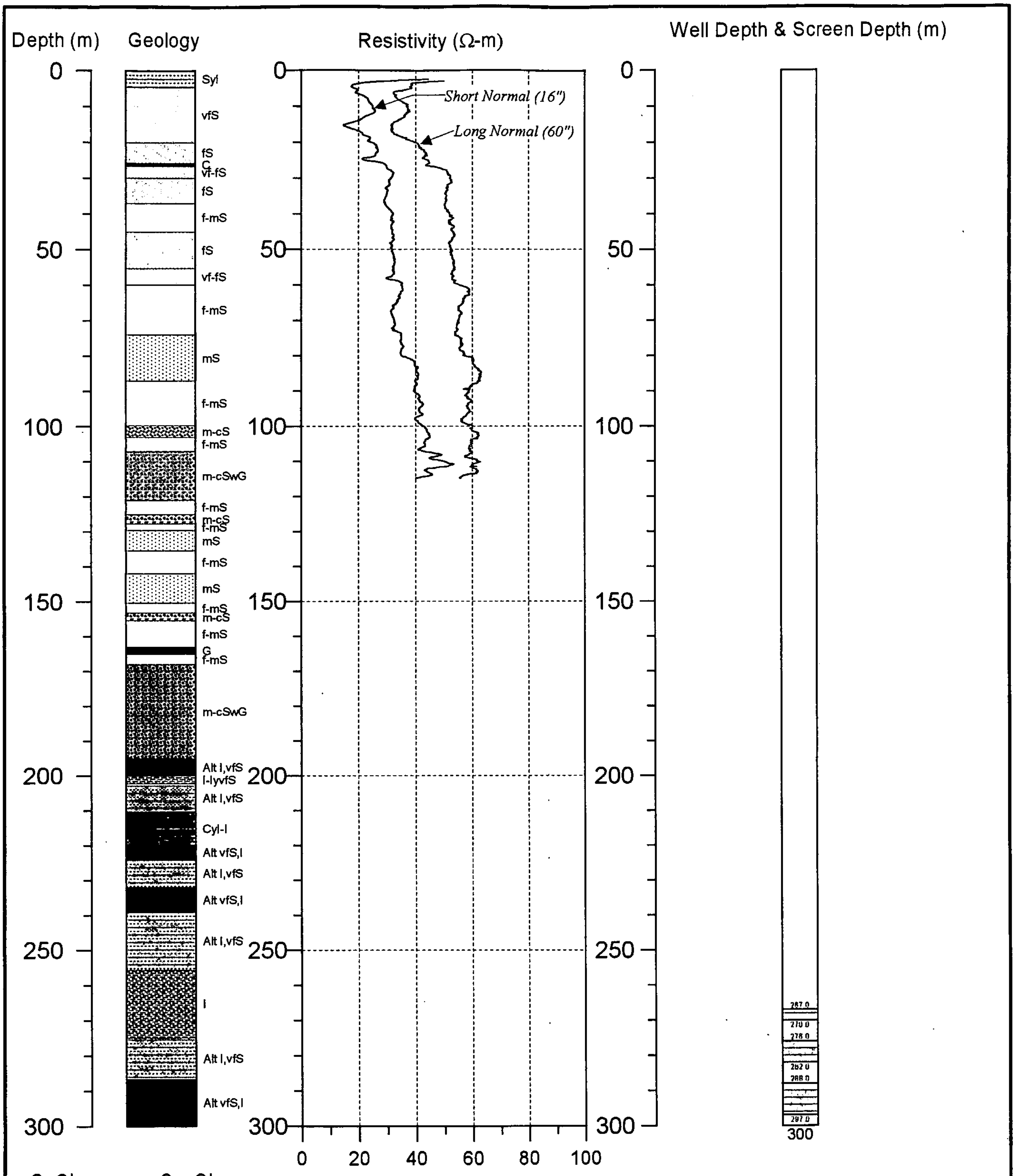
TS: Top Soil

Figure 5.2.24

Columnar Section and Geophysical Logging at JH-2 Site [Hamdah, Jhenaidah Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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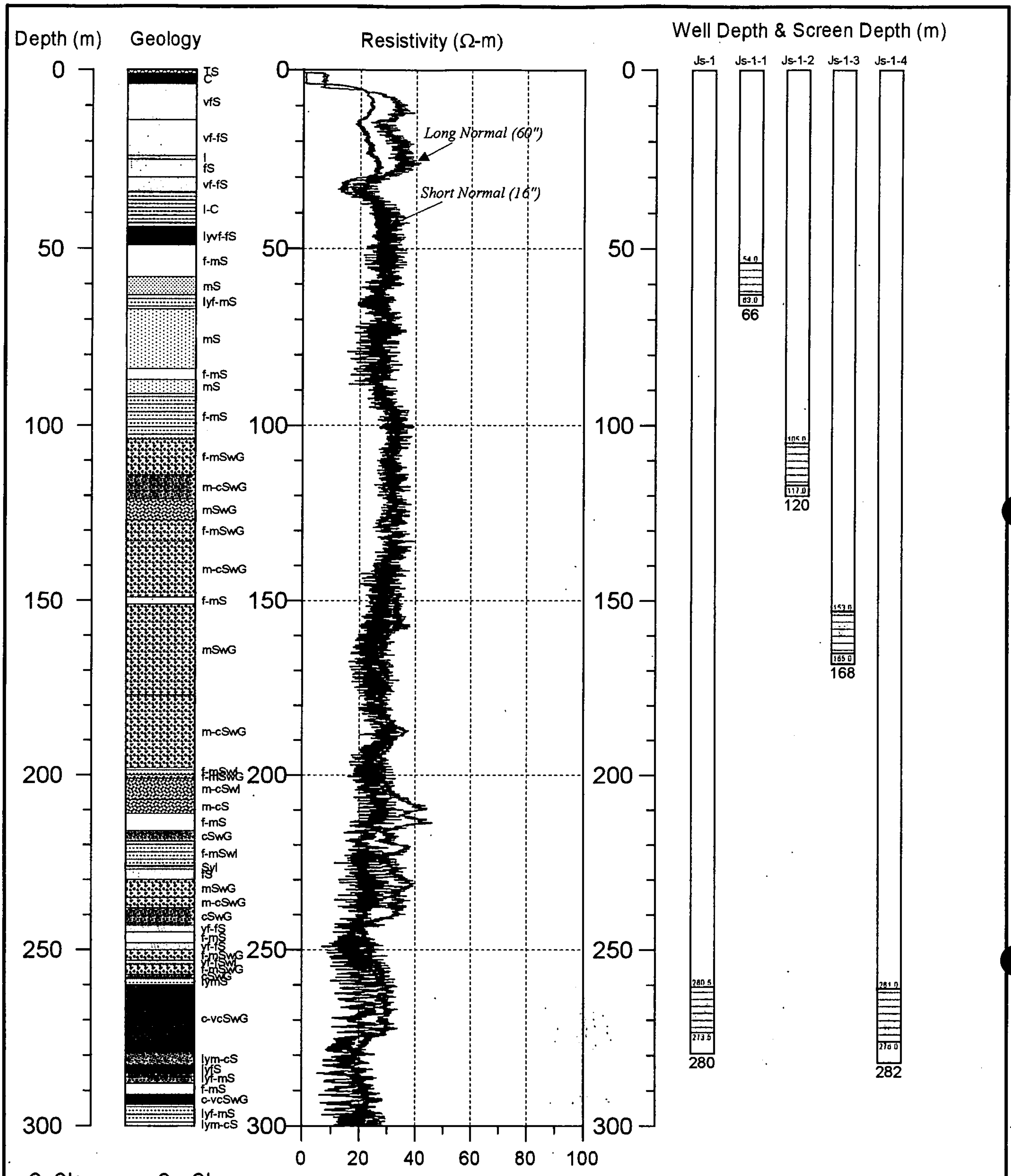
P: Peat
TS: Top Soil

Figure 5.2.25 Columnar Section and Geophysical Logging at JH-KC Site [Krishna Chandrapur, Moheshpur]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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ly: Silty
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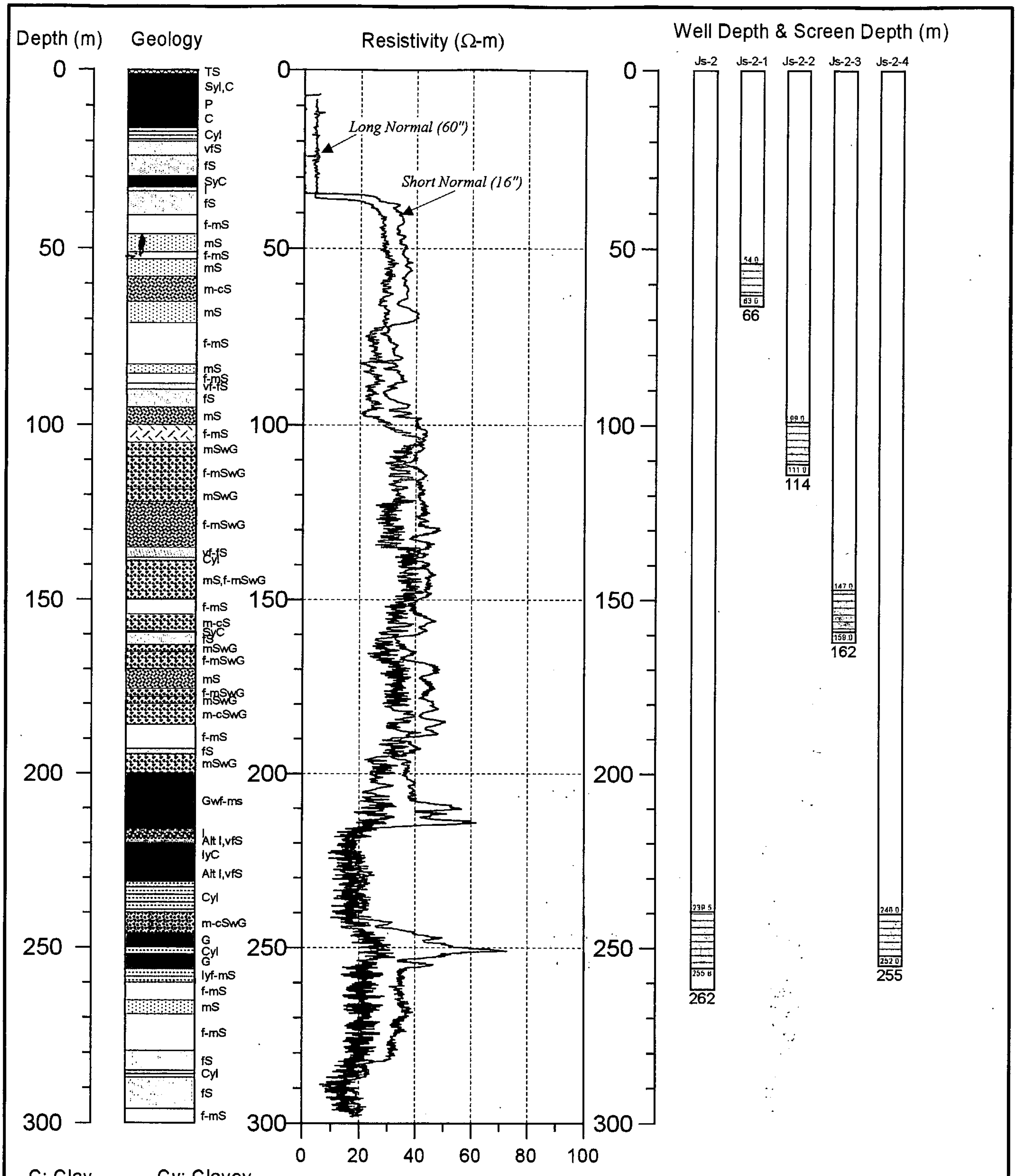
w: with
-: to
Alt: Alternation

Figure 5.2.26

Columnar Section and Geophysical Logging at JS-1 Site [Ghop, Jessore Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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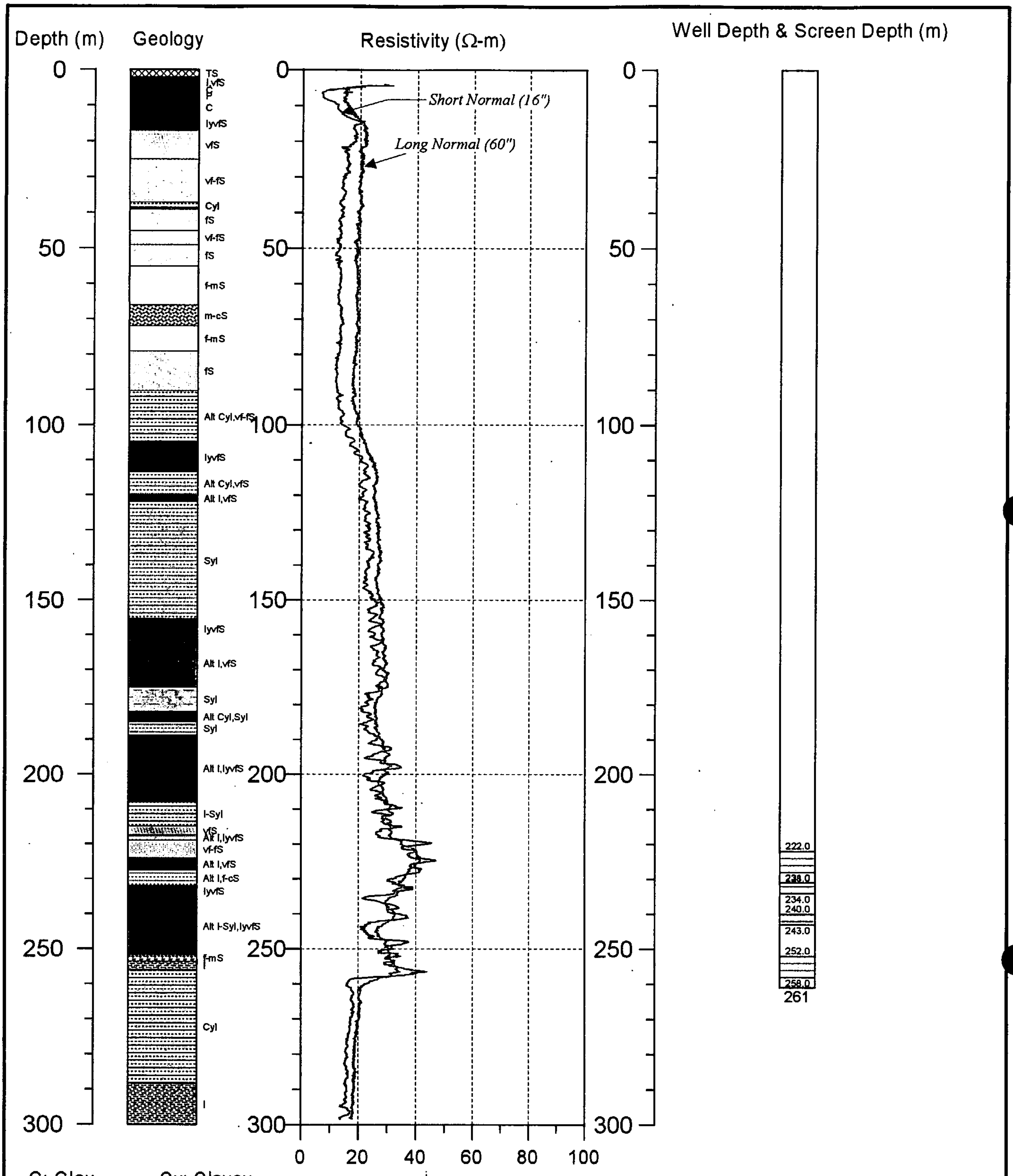
-: to
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.27

Columnar Section and Geophysical Logging at JS-2 Site [Kharki, Jessore Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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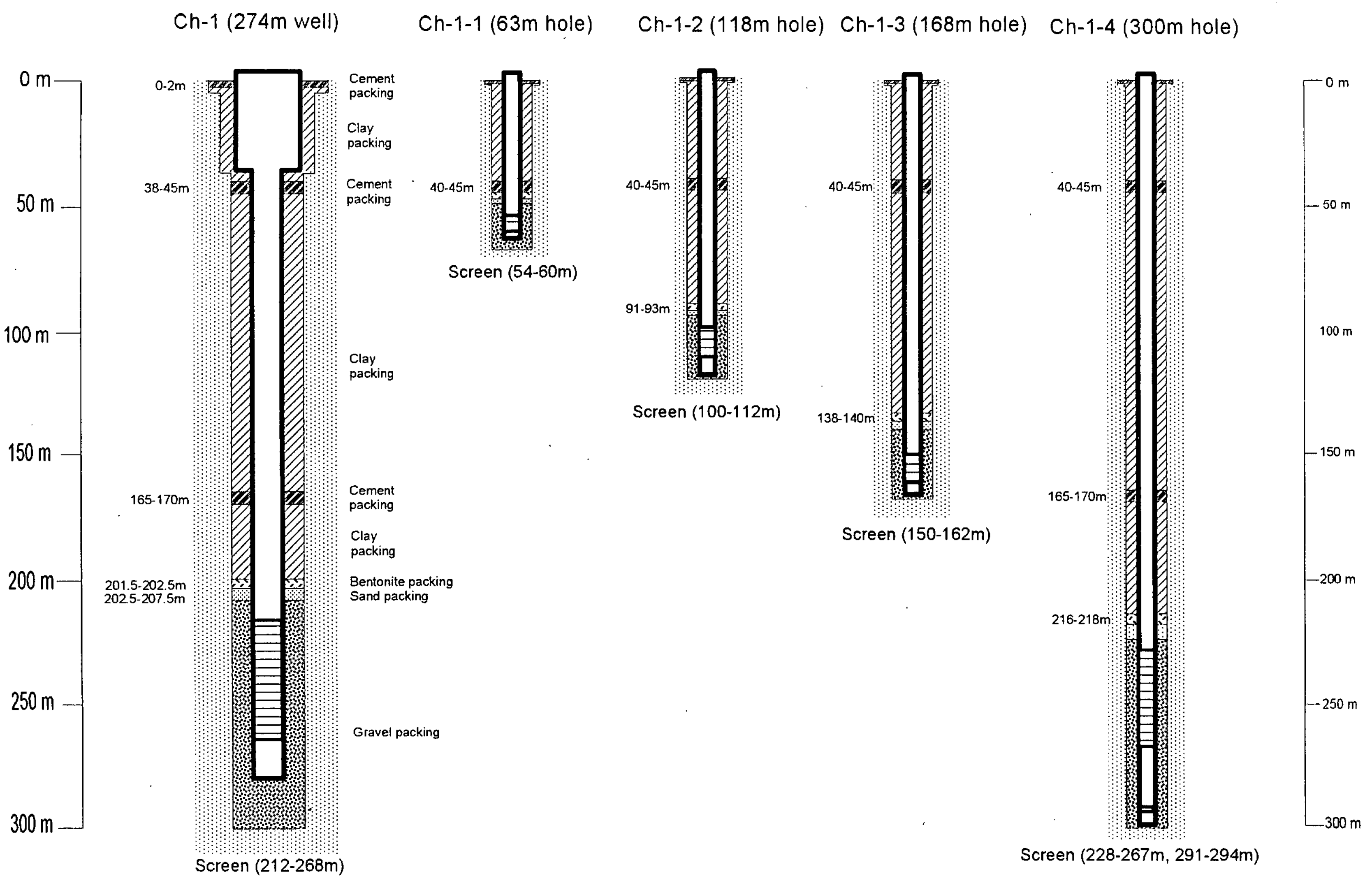
Alt: Alternation
P: Peat
TS: Top Soil

Figure 5.2.28 Columnar Section and Geophysical Logging at JS-RB Site [Rajnagar Bankabarsi, Keshabpur]



Legend

- Screen position
- ▨ Gravel packing
- ▨ Sand packing
- ▨ Bentonite packing
- ▨ Clay packing
- ▨ Cemet packing

Figure 5.2.29 Casing Program of Observation Deep Well & Holes at CH-1 Site (Poshu Hat, Chuadanga Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

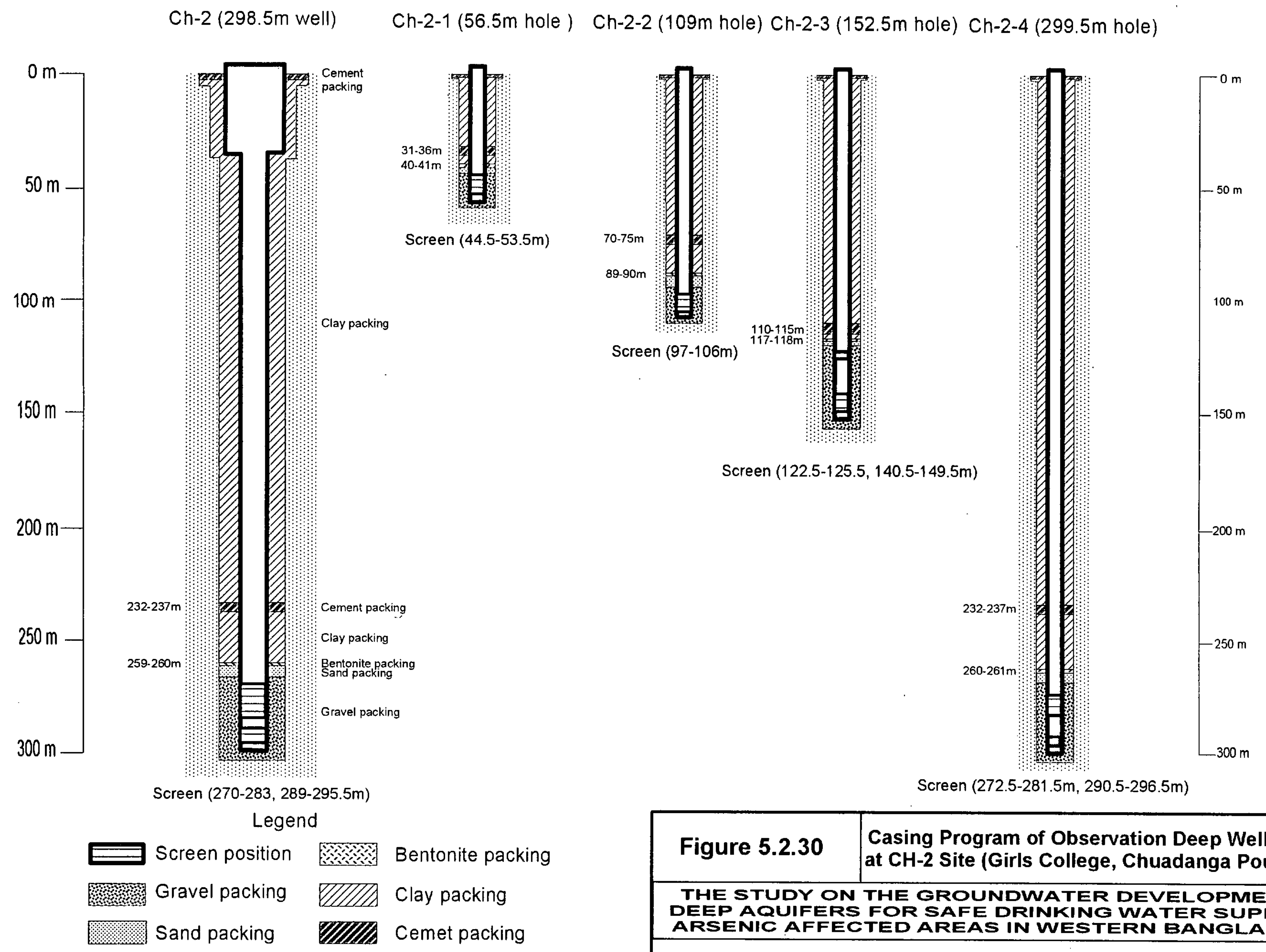


Figure 5.2.30 Casing Program of Observation Deep Well & Holes at CH-2 Site (Girls College, Chuadanga Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

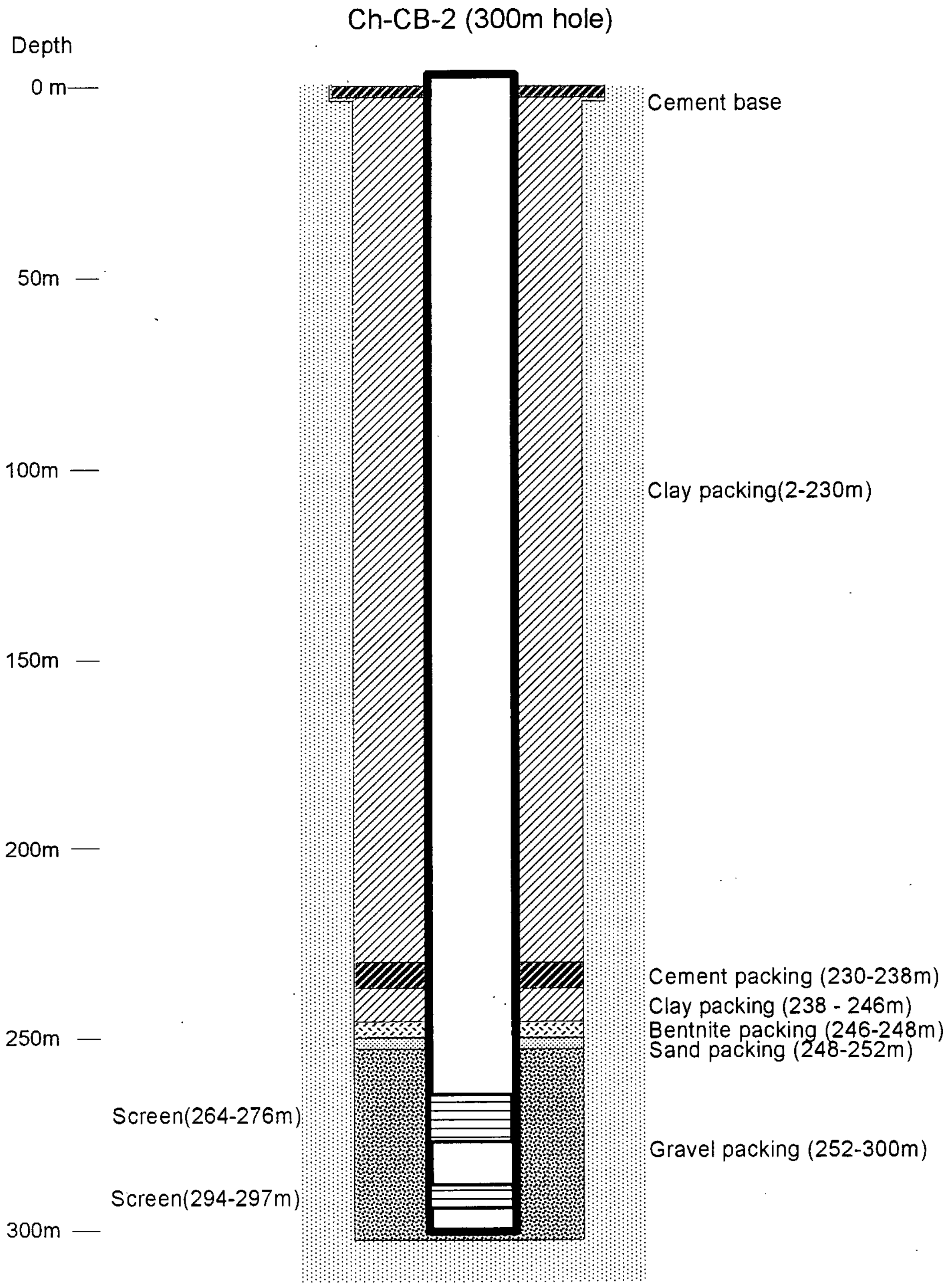


Figure 5.2.31 Casing Program of Observation Hole at CH-BD Site (Bara Dudpatila)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

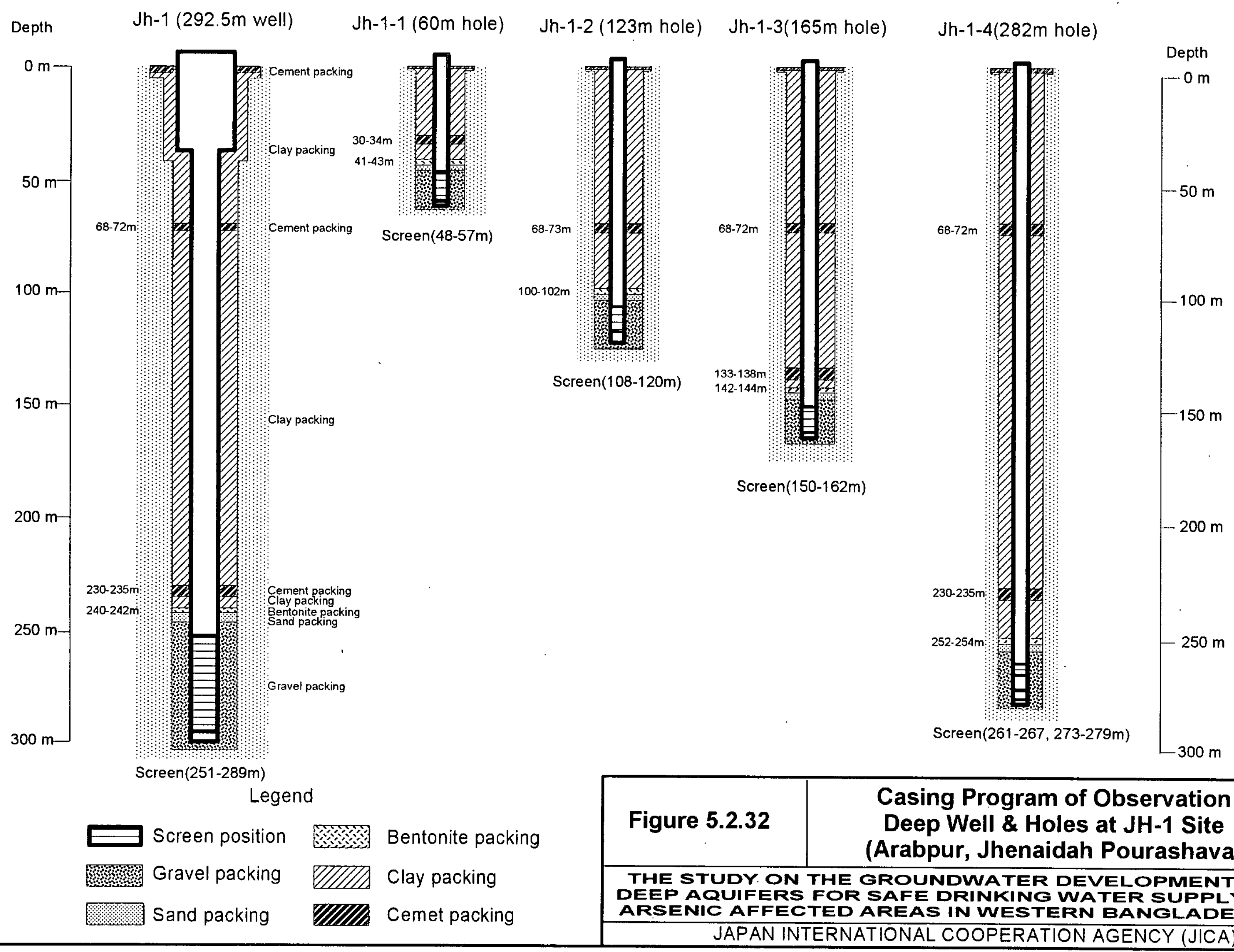


Figure 5.2.32

Casing Program of Observation Deep Well & Holes at JH-1 Site (Arabpur, Jhenaidah Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

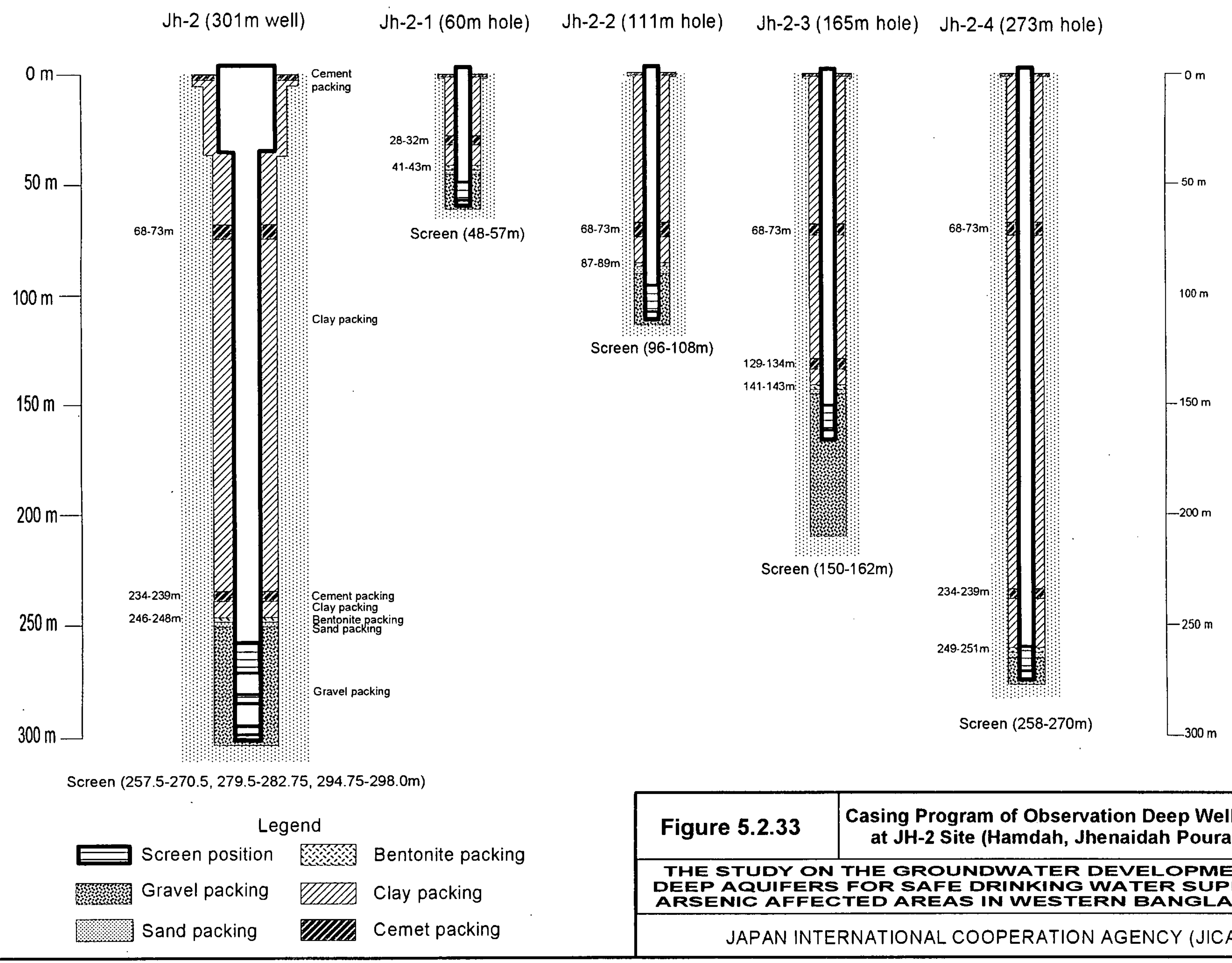


Figure 5.2.33 Casing Program of Observation Deep Well & Holes at JH-2 Site (Hamdah, Jhenaidah Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

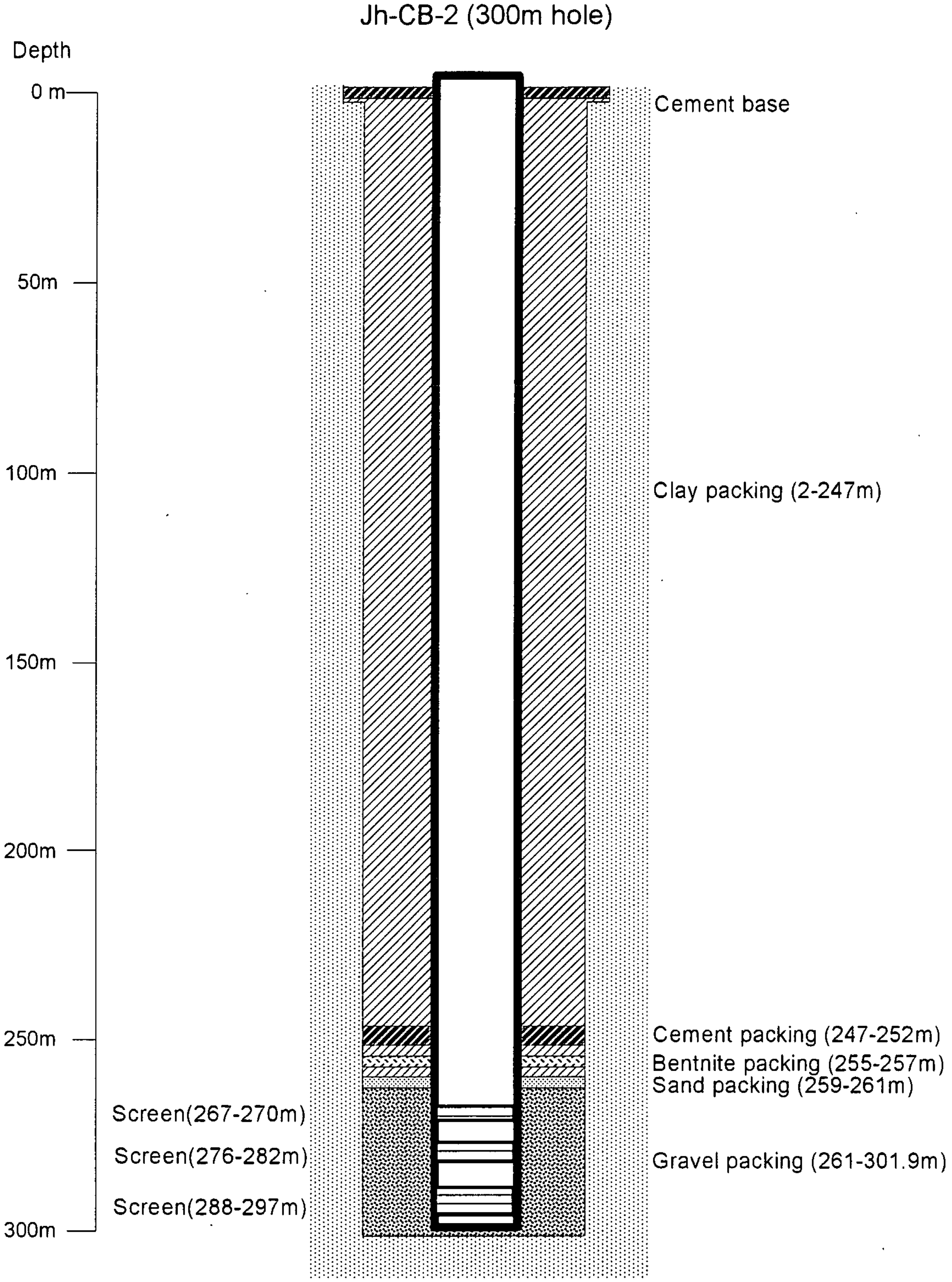


Figure 5.2.34	**Casing Program of Observation Hole at JH-KC Site (Krishna Chandrapur)**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

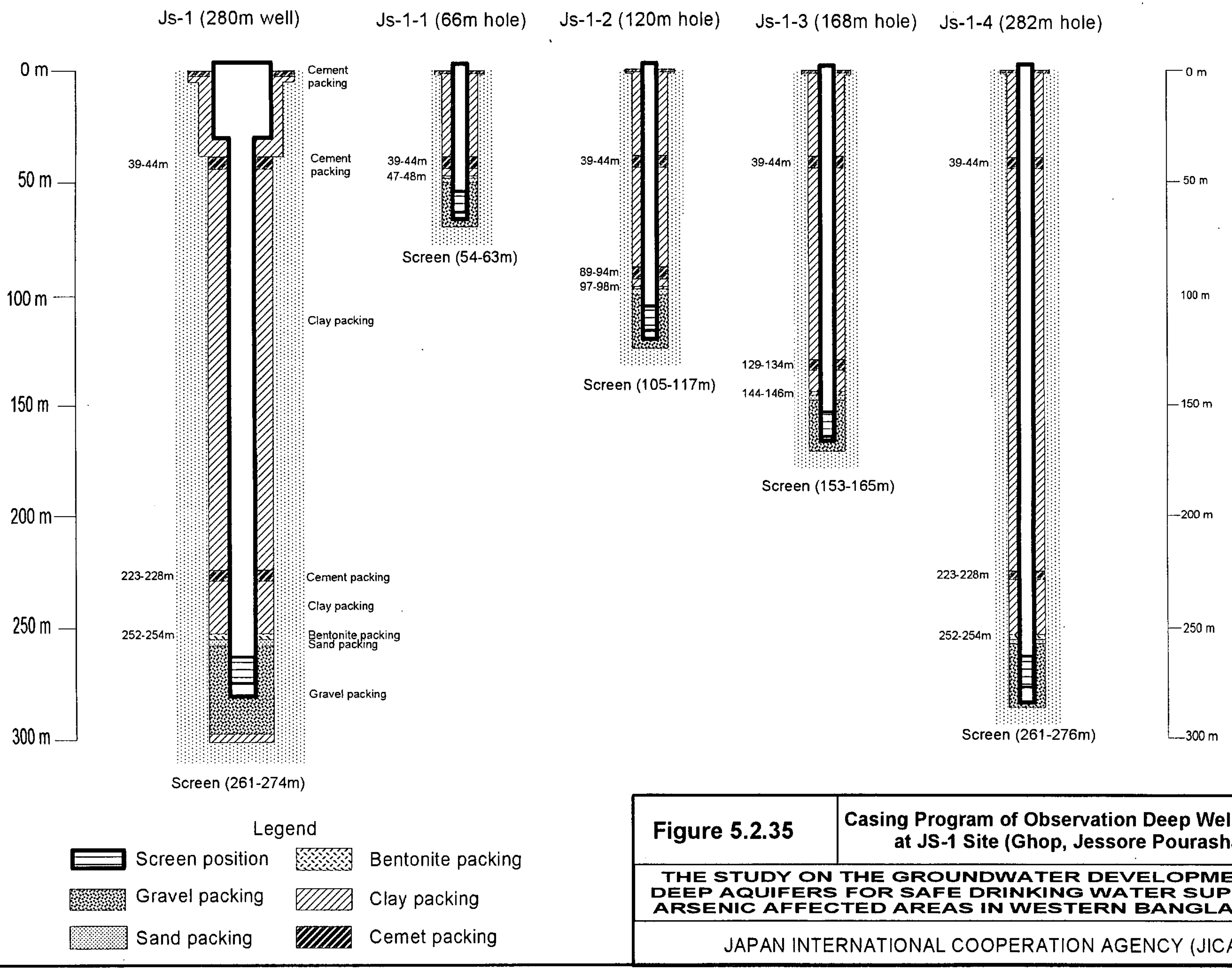


Figure 5.2.35 Casing Program of Observation Deep Well & Holes at JS-1 Site (Ghop, Jessore Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

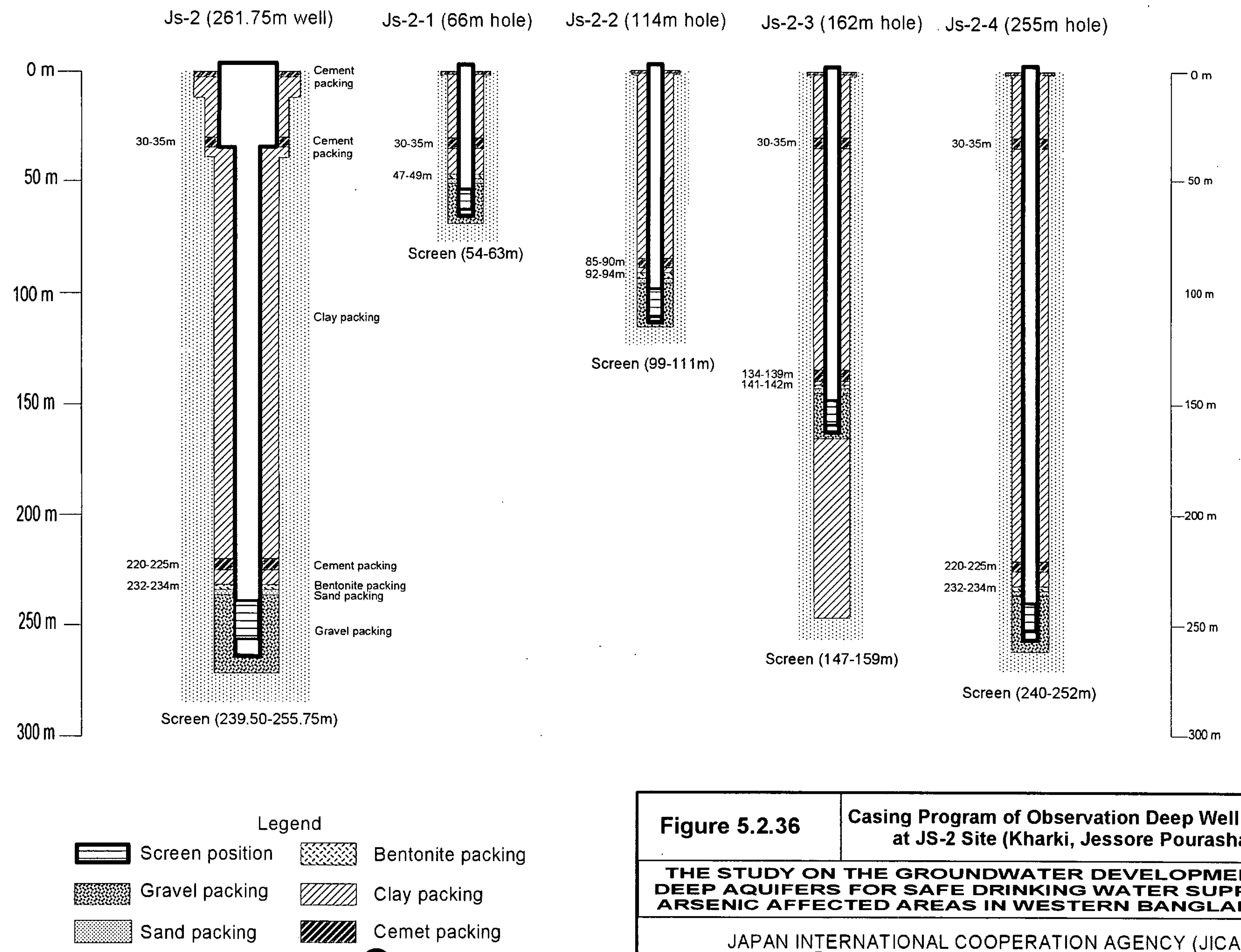


Figure 5.2.36 Casing Program of Observation Deep Well & Holes at JS-2 Site (Kharki, Jessore Pourashava)

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

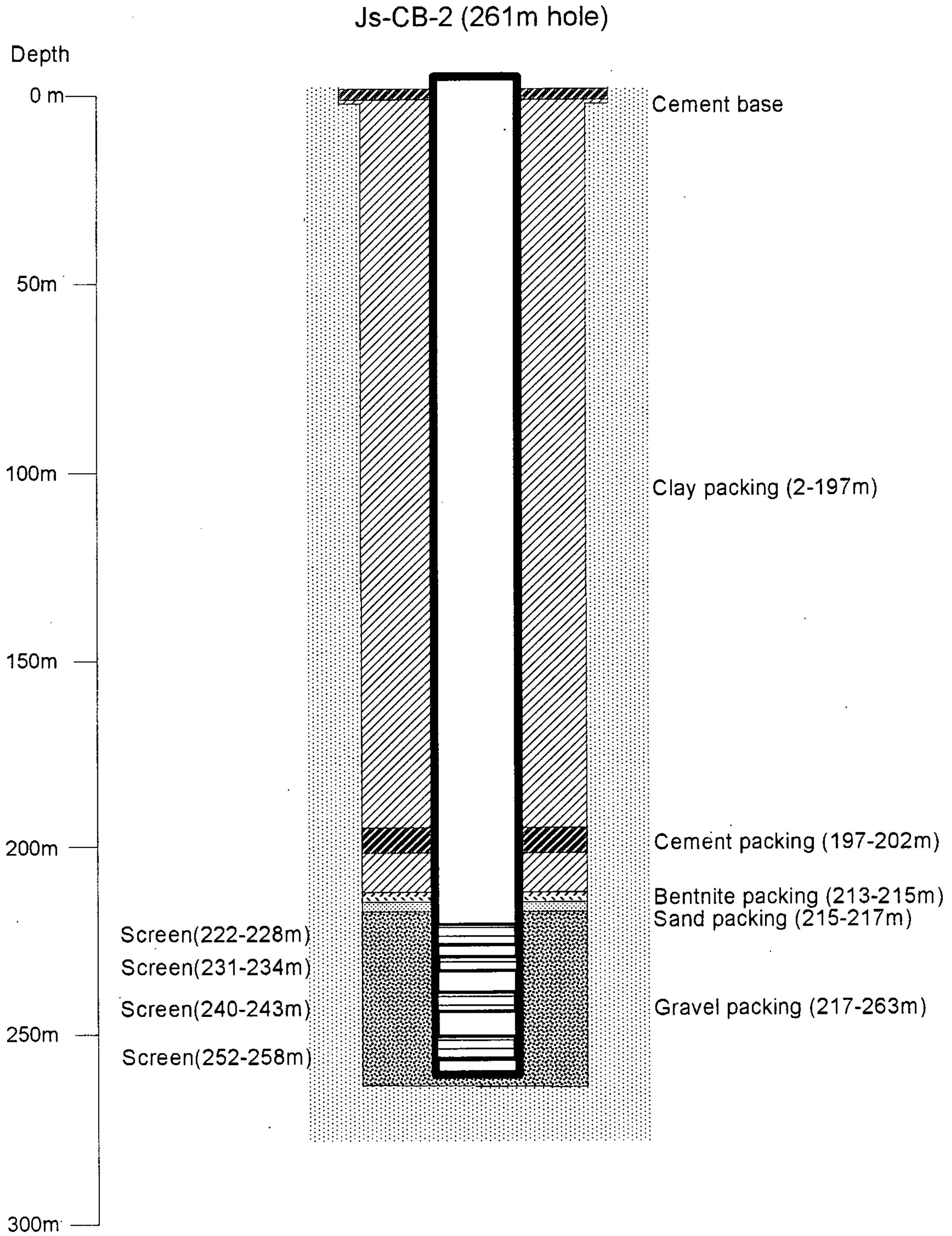


Figure 5.2.37	**Casing Program of Observation Hole at JS-RB Site (Ranjnagar Bankabarsi)**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

5.3 Pumping Test

5.3.1 Purpose of Pumping Test

The pumping test was performed at newly constructed observation wells/holes. One of the main objectives of the pumping test is to obtain aquifer parameters such as transmissivity and the storage coefficient of the deep aquifers in the Study Area. In addition, the well loss coefficient and aquifer loss coefficient were obtained by the step-drawdown pumping test. The results can help design a suitable operation plan for the future-production well.

During the pumping test, arsenic levels as well as other water quality parameters were monitored in the field and in the laboratory. The results of the water quality measurements can provide important information on changes in water quality by pumping. Further, the result of the measurements could provide useful information on the mechanism of groundwater contamination by arsenic and movement of contaminated water.

5.3.2 Methodology

For the deep observation wells, three (3) kinds of pumping tests viz. step-drawdown test, continuous pumping test and recovery test, were carried out. The changes in groundwater level were measured not only in the pumped well but also in the surrounding four (4) observation holes having different well depths.

For the observation holes, the continuous pumping test and recovery test were performed. The drawdown was measured in the pumped hole.

During the step-drawdown test and continuous pumping test, groundwater samples for measuring arsenic levels were collected. The following parameters were also measured at each sampling time in the field:

Water temperature, pH, ORP, EC
As (by Field Kit), Fe (by Pack Test Kit)

5.3.3 Results of Step-Drawdown Test

The results of the step-drawdown test at the deep observation wells are summarized in Table 5.3.1. The specific capacity value of each step was obtained from the test, and then the aquifer loss coefficient (*B*) and well loss coefficient (*C*) were computed. The well efficiency of each observation well was also calculated.

5.3.4 Results of Pumping Test at Observation Holes

The results of the continuous pumping test and recovery test at the observation holes are also summarized in Table 5.3.2. The values of transmissivity (*T*) and storage coefficient (*S*) were obtained by Cooper-Jacob method (Cooper and Jacob, 1946) from the drawdown test. In the recovery test, the value of transmissivity (*T*) was obtained by the recovery method using the residual drawdown curve on the semi-log plot.

Table 5.3.1 Results of Step-Drawdown Tests Performed at JICA Observation Deep Wells

District	Upazila/ Pourashava	Site Name (Site No.)	Well/Hole Type	Well/Obs. Hole No.	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Date (dd/mm/yy)	Static Water Level (m)	Step-1	Step-2	Step-3	Step-4	Step-5	Step-6	Step-7	Step-8	Step-9	Step-10	Step-11	Step-12	Aquifer Loss Coefficient B (d/m^2)	Well Loss Coefficient C (d^2/m^5)	Average Well Efficiency (%)	Remarks
											Q_1(m^3/d) s_1(m) Sc_1(m^2/d) Ew_1(%)	Q_2(m^3/d) s_2(m) Sc_2(m^2/d) Ew_2(%)	Q_3(m^3/d) s_3(m) Sc_3(m^2/d) Ew_3(%)	Q_4(m^3/d) s_4(m) Sc_4(m^2/d) Ew_4(%)	Q_5(m^3/d) s_5(m) Sc_5(m^2/d) Ew_5(%)	Q_6(m^3/d) s_6(m) Sc_6(m^2/d) Ew_6(%)	Q_7(m^3/d) s_7(m) Sc_7(m^2/d) Ew_7(%)	Q_8(m^3/d) s_8(m) Sc_8(m^2/d) Ew_8(%)	Q_9(m^3/d) s_9(m) Sc_9(m^2/d) Ew_9(%)	Q_{10}(m^3/d) s_{10}(m) Sc_{10}(m^2/d) Ew_{10}(%)	Q_{11}(m^3/d) s_{11}(m) Sc_{11}(m^2/d) Ew_{11}(%)	Q_{12}(m^3/d) s_{12}(m) Sc_{12}(m^2/d) Ew_{12}(%)				
Chuadanga	Chuadanga Sadar	Poshu Hat (CH-1)	Obs. Well (Production Well)	Ch-1	300	274	212.5-215.75, 227.75-231 237-240.25, 246.25-249.5 255.5-258.75, 264.75-268	19.5	21/02/01	5.610	1680.0 5.115 328.4 108.39	2400.0 10.302 233.0 76.88	3120.0 12.750 244.7 80.75	3600.0 14.745 244.2 80.57	4320.0 18.153 238.0 78.53	3388.3 14.745 229.8 75.83	2634.2 10.377 253.9 83.77	1901.0 7.368 258.0 85.14	1510.5 5.685 265.7 87.68	1144.4 4.232 270.4 89.23	- - - -	- - - -	3.30E-03	2.47E-07	84.68	
		Girls College (CH-2)	Obs. Well (Production Well)	Ch-2	303	298.5	270-283, 289-295.5	19.5	18/03/01	6.001	210.7 15.609 13.5 63.86	227.0 17.279 13.1 62.15	259.2 24.354 10.6 50.34	259.2 24.799 10.5 49.44	248.8 24.680 10.1 47.69	163.7 15.581 10.5 49.70	34.6 1.670 20.7 97.89	173.6 14.799 11.7 55.48	214.5 18.730 11.5 54.17	228.2 21.030 10.9 51.32	238.2 23.139 10.3 48.68	255.0 24.381 10.5 49.46	4.73E-02	1.88E-04	56.68	Carried out until 12th step.
Jhenaidah	Jhenaidah Sadar	Arabpur (JH-1)	Obs. Well (Production Well)	Jh-1	296	292.5	251.5-254.75, 260.75-267.25 273.25-279.75, 285.75-289	19.5	02/05/01	5.545	50.8 17.555 2.9 79.62	57.0 22.815 2.5 68.74	68.2 29.783 2.3 62.98	74.1 35.627 2.1 57.16	86.4 40.781 2.1 58.26	70.1 33.199 2.1 58.03	61.7 28.055 2.2 60.49	38.7 16.094 2.4 66.10	30.9 11.243 2.7 75.48	30.3 9.926 3.1 84.05	- - - -	- - - -	2.75E-01	2.49E-03	67.09	
		Hamdah (JH-2)	Obs. Well (Production Well)	Jh-2	302	301	257.5-270.5, 279.5-282.75 294.75-298.0	19.5	03/06/01	5.762	106.8 10.166 10.5 83.31	127.7 13.392 9.5 75.61	166.8 19.481 8.6 67.90	196.6 24.807 7.9 62.83	217.0 29.739 7.3 57.85	198.2 27.340 7.3 57.50	174.7 22.398 7.8 61.86	151.9 19.851 7.7 60.69	120.2 14.678 8.2 64.94	81.0 8.605 9.4 74.65	- - - -	- - - -	7.93E-02	2.67E-04	66.71	
Jessore	Jessore Sadar	Ghop (JS-1)	Obs. Well (Production Well)	Js-1	301	279.5	260.5-273.5	13.0	16/07/01	4.200	925.6 8.149 113.6 80.98	1800.0 18.650 96.5 68.82	1831.5 19.116 95.8 68.31	1892.6 20.199 93.7 66.81	1901.6 21.632 87.9 62.68	1664.3 19.232 86.5 61.70	1476.4 15.441 95.6 68.17	1338.2 12.459 107.4 76.58	1024.0 9.702 105.5 75.25	868.3 7.728 112.4 80.11	- - - -	- - - -	7.13E-03	2.04E-06	70.94	
		Kharki (JS-2)	Obs. Well (Production Well)	Js-2	270	261.75	239.50-255.75	16.25	02/08/01	2.369	111.9 7.144 15.7 110.26	135.5 9.712 14.0 98.24	175.2 13.878 12.6 88.89	192.8 16.641 11.6 81.58	228.5 21.562 10.6 74.62	206.4 20.141 10.2 72.14	188.5 18.659 10.1 71.12	161.3 15.862 10.2 71.60	126.8 12.120 10.5 73.65	84.8 7.827 10.8 76.31	- - - -	- - - -	7.04E-02	1.08E-04	81.84	

Q: Pumping Rate, s: Drawdown, Sc: Specific Capacity, Ew: Well Efficiency
One step = 120 minutes

Table 5.3.2 Results of Continuous Pumping Tests and Recovery Tests

District	Upazila/ Pourashava	Site Name (Site No.)	Well/Hole Type	Well/Obs. Hole No.	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Continuous Pumping Test						Results of Analyses						Remarks
									Date (dd/mm/yy)	Static Water Level (m)	Pumping Rate, Q (m^3/day)	Pumping Duration (hours)	Final Drawdown, s (m)	Specific Capacity, Sc (m^2/day)	Data Used*	Cooper-Jacob Method			Recovery Method		
																T (m^2/day)	k_{ap} (m/day)	S	T (m^2/day)	k_{ap} (m/day)	
Chuadanga	Chuadanga Sadar	Poshu Hat (CH-1)	Obs. Well (Production Well)	Ch-1	300	274	212.5-215.75, 227.75-231 237-240.25, 246.25-249.5 255.5-258.75, 264.75-268	19.5	22/02/01	6.258	4320.0	48	16.800	257.1	P	N.A.	N.A.	N.A.	17707	908.1	N.A. due to irregular fluctuations of ground-water level.
															O	16264	834.1	3.04E-08	14396	738.3	
			Obs. Hole	Ch-1-1	65	63	54-60	6	26/02/01	6.061	158.0	3	2.934	53.9	P	N.A.	N.A.	N.A.	2917	486.2	-do-
			Obs. Hole	Ch-1-2	122	118	100-112	12	26/02/01	6.057	153.1	3	6.111	25.1	P	N.A.	N.A.	N.A.	2564	213.7	-do-
			Obs. Hole	Ch-1-3	170	168	150-162	12	26/02/01	5.715	170.7	3	2.480	68.8	P	831.5	69.3	5.12E-62	8805	733.8	-do-
			Obs. Hole	Ch-1-4	300	300	228-231, 237-240 246-249, 255-258 264-267, 291-294	18	26/02/01	5.985	153.5	3	11.835	13.0	P	N.A.	N.A.	N.A.	298	16.5	N.A. due to irregular fluctuations of ground-water level.
		Girls College (CH-2)	Obs. Well (Production Well)	Ch-2	303	298.5	270-283, 289-295.5	19.5	19/03/01	6.012	239.3	48	22.838	10.5	P	77.07	3.95	7.73E-37	394	20.2	
															O	736.6	37.8	8.97E-02	735	37.7	
			Obs. Hole	Ch-2-1	58	56.5	44.5-53.5	9	16/03/01	6.105	170.7	3	2.886	59.1	P	302.2	33.6	7.48E-24	9583	1064.8	
			Obs. Hole	Ch-2-2	111	109	97-106	9	16/03/01	6.040	183.0	3	3.335	54.9	P	327.5	36.4	1.07E-28	4254	472.7	
			Obs. Hole	Ch-2-3	156	152.5	122.5-125.5, 140.5-149.5	12	17/03/01	6.000	190.8	3	3.777	50.5	P	530.5	44.2	1.51E-53	4101	341.8	
			Obs. Hole	Ch-2-4	303	299.5	272.5-281.5, 290.5-296.5	15	17/03/01	5.830	183.0	3	6.852	26.7	P	321.3	21.4	9.75E-62	2983	198.9	
	Damurhuda	Bara Dudpatila	Obs. Hole (Core Boring)	Ch-CB-2	302	300	264-276, 294-297	15	27/02/01	5.185	163.7	3	2.680	61.1	P	N.A.	N.A.	N.A.	2273	151.5	N.A. due to irregular fluctu-ations of groundwater level.
Jhenaidah	Jhenaidah Sadar	Arabpur (JH-1)	Obs. Well (Production Well)	Jh-1	296	292.5	251.5-254.75, 260.75-267.25 273.25-279.75, 285.75-289	19.5	18/04/01	5.412	80.73	48	31.928	2.5	P	6.92E-01	3.55E-02	2.24E-01	5.39E-01	2.76E-02	N.A. due to very small draw-down in Jh-1-4 hole.
															O	1439	73.8	4.32E-01	N.A.	N.A.	
			Obs. Hole	Jh-1-1	61	60	48-57	9	21/04/01	5.430	182.0	3	0.680	267.6	P	N.A.	N.A.	N.A.	134.7	15.0	N.A. due to quick stabilization of groundwater level.
			Obs. Hole	Jh-1-2	125	123	108-120	12	21/04/01	5.513	182.6	3	0.687	265.8	P	1963	163.6	2.63E-36	430.5	35.9	
			Obs. Hole	Jh-1-3	167	165	150-162	12	21/04/01	5.375	167.3	3	1.925	86.9	P	1853	154.4	very small	217.2	18.1	
			Obs. Hole	Jh-1-4	285	282	261-267, 273-279	12	21/04/01	5.862	146.2	3	9.798	14.9	P	336.4	28.0	very small	158.6	13.2	
		Hamdah [Hospital Road] (JH-2)	Obs. Well (Production Well)	Jh-2	302	301	257.5-270.5, 279.5-282.75 294.75-298.0	19.5	04/06/01	5.660	199.38	48	30.538	6.5	P	1.812	9.29E-02	1.33E-01	1.389	7.12E-02	
															O	1115	57.2	8.16E-02	909.8	46.7	
			Obs. Hole	Jh-2-1	61	60	48-57	9	07/06/01	5.205	157.7	3	3.945	40.0	P	288.3	32.0	1.90E-35	N.A.	N.A.	N.A. due to quick recovery of groundwater level.
			Obs. Hole	Jh-2-2	113	111	96-108	12	07/06/01	5.102	162.0	3	0.764	212.0	P	3391	282.6	2.06E-83	979.1	81.6	
			Obs. Hole	Jh-2-3	209	165	150-162	12	08/06/01	5.052	179.1	3	2.084	85.9	P	397.0	33.1	4.21E-20	1626	135.5	
			Obs. Hole	Jh-2-4	275	273	258-270	12	08/06/01	4.985	152.5	3	4.975	30.7	P	373.8	31.2	8.53E-63	2693	224.4	
	Moheshpur	Krishna Chandrapur	Obs. Hole (Core Boring)	Jh-CB-2	301.9	300	267-270, 276-282, 288-297	18	05/05/01	6.939	152.5	3	5.447	28.0	P	115.6	6.42	5.59E-19	185	10.3	
Jessore	Jessore Sadar	Ghop [Rahman High School] (JS-1)	Obs. Well (Production Well)	Js-1	301	279.5	260.5-273.5	13	17/07/01	4.159	1910.8	48	22.387	85.4	P	54.06	4.16	5.66E-03	2242	172.4	
															O	6643	511.0	2.95E-12	3986	306.6	
			Obs. Hole	Js-1-1	69	66	54-63	9	20/07/01	4.569	163.4	3	0.440	371.4	P	N.A.	N.A.	N.A.	N.A.	N.A.	N.A. due to irregular fluctu-ations of groundwater level.
			Obs. Hole	Js-1-2	123	120	105-117	12	20/07/01	4.439	166.2	3	0.671	247.7	P	N.A.	N.A.	N.A.	624.2	52.0	N.A. due to irregular fluctu-ations of groundwater level.
			Obs. Hole	Js-1-3	171	168	153-165	12	20/07/01	3.948	93.5	3	0.422	221.6	P	301.2	25.1	2.70E-03	N.A.	N.A.	N.A. due to irregular fluctu-ations of groundwater level.
			Obs. Hole	Js-1-4	285	282	261-276	15	20/07/01	4.050	158.2	3	1.530	103.4	P	N.A.	N.A.	N.A.	N.A.	N.A.	N.A. due to irregular fluctu-ations of groundwater level.
		Kharki (JS-2)	Obs. Well (Production Well)	Js-2	270	261.75	239.50-255.75	16.25	03/08/01	2.333	206.7	48	22.776	9.1	P	33.96	2.09	1.25E-17	2.052	1.26E-01	
															O	56.44	3.47	5.54E-03	41.24	2.5	
			Obs. Hole	Js-2-1	70	66	54-63	9	06/08/01	2.428	201.1	3	3.236	62.2	P	222.0	24.7	1.34E-05	3420	380.0	
			Obs. Hole	Js-2-2	116	114	99-111	12	06/08/01	2.588	192.2	3	0.804	239.1	P	321.6	26.8	2.83E-03	202.1	16.8	
			Obs. Hole	Js-2-3	247	162	147-159	12	06/08/01	2.557	127.3	3	22.724	5.6	P	2.121	0.177	8.73E-02	0.843	7.03E-02	
			Obs. Hole	Js-2-4	260	255	240-252	12	06/08/01	2.335	168.7	3	4.350	38.8	P	178.5	14.9	1.29E-22	252.3	21.0	
	Keshabpur	Rajnagar Bankabarsi	Obs. Hole (Core Boring)	Js-CB-2	263	261	222-228, 231-234, 240-243 252-258	18	09/05/01	5.130	56.6	3	2.974	19.0	P	48.80	2.71	8.30E-11	81.19	4.51	

* P: Pumped Well/Hole Data, O: Observation Hole Data (same aquifer).

5.4 Arsenic Concentration

5.4.1 Purpose

Arsenic concentrations of groundwater in the newly constructed observation wells/holes and improved deep wells were systematically monitored by the AAS in Jhenaidah laboratory, which was established in DPHE Jhenaidah office. After the construction of those wells/holes, the arsenic levels were measured during the pumping test. Then monthly monitoring of arsenic levels was carried out.

5.4.2 Methodology

1) Pumping Test

a. Observation Wells

At the observation wells, groundwater samples for arsenic analysis by AAS were collected in the step-drawdown test and the continuous pumping test. Prior to the pumping test, one groundwater sample was collected to know the initial arsenic level.

When the groundwater sample was collected, the following parameters were measured in the field:

Water Temperature, pH, ORP, EC, As (by Field Kit), and Fe (by pack test)

In the step-drawdown test, the samples were collected two (2) times in each step. In principle, the first sample was collected after 10 minutes and the second was collected after 100 minutes in each step. In the continuous pumping test, the samples were collected after 10 minutes, 1 hour, 3 hours, and then every 3 hours until 48 hours after pumping started.

b. Observation Holes

Before the pumping test, one (1) groundwater sample was collected to know the initial concentrations. During the discharge test, two (2) groundwater samples were collected for the AAS analysis. The first sample was collected after 30 minutes and the second was collected after 140 minutes after pumping started. The field groundwater quality parameters said above were measured at each sampling time.

2) Monthly Monitoring

a. Observation Wells/Holes

After the pumping test, the groundwater samples were collected at an interval of one (1) month. The monitoring was continued for at least a 6-month period.

At the time of sample collection, an engine pump was prepared to remove stagnant water in the well/hole. The pumping was done at least for one (1) hour. After removing the stagnant water, the groundwater sample was collected for arsenic analysis by AAS. At the time of sampling, the field groundwater quality parameters were measured. The monitoring was continued until December 2001.

In addition, groundwater levels in the observation have been monitored weekly since the wells/holes were constructed.

b. Improved Deep Wells

The arsenic concentrations of groundwater taken from the newly constructed improved deep wells were analyzed by AAS. During the pumping test, one (1) sample was collected and analyzed to understand the initial arsenic concentrations. After the pumping test, the arsenic level was monitored at least for 9 months.

5.4.3 Arsenic Concentrations during Pumping Test

1) Observation Well

a. Step-Drawdown Test

Figure 5.4.1 shows the changes in arsenic level, Eh, pH, and EC during the step-drawdown test at Ch-1 well. At the beginning of the pumping, the As concentration was 0.001mg/l. From 10 to 1,200 minutes, As concentrations ranged between 0.03 and 0.05mg/l. As levels increased when the discharge rate increased from the 1st step to the 2nd step. In the rest, although the As levels fluctuated in the range, there was no significant correlation with the discharge rate. The Eh value at the beginning was almost 0mV, however, it jumped up to about 150mV 10 minutes after pumping started. From the 1st step to the 2nd step, the Eh values tend to decrease. Then the values fluctuated around 150mV. The pH value at the beginning was 7.56, but it suddenly dropped in the 1st step to 7.01. Then the values varied within a range from 7.1 to 7.2. The values tended to slightly decrease over time. EC values showed some irregular fluctuations, however, the values tended to decrease over time.

Figure 5.4.2 shows the changes in arsenic level, Eh, pH, and EC during the step-drawdown test at Ch-2 well. Although the discharge pattern was disturbed by an unavoidable electricity failure, the arsenic levels tended to decrease over time from 0.0055 to 0.0010mg/l The Eh values varied within 150 to 200mV in most samples. The pH values tended to decrease when the discharge rate was high. EC values gradually decreased with time, but jumped up in the 12th step.

Figure 5.4.3 shows the changes in arsenic level, Eh, pH, and EC during the step-drawdown test at Jh-1 well. The arsenic concentration decreased from 0.014 to 0.011mg/l in the 1st to 2nd step, but it gradually increased from the latter part of the 2nd step to the 6th step. Eh and pH values tended to increase over time. On the other hand, EC values decreased with time.

Figure 5.4.4 shows the changes in arsenic level, Eh, pH, and EC during the step-drawdown test at Jh-2 well. Although the drawdown curve shows a symmetric pattern, the changes in As concentrations are complicated. As levels increased from 0.005 to 0.018mg/l in the 4th to 6th step, but suddenly dropped in the 8th step. Eh and EC values tended to decrease over time. On the other hand, the pH values tended to increase over time.

Figure 5.4.5 shows the changes in arsenic level, Eh, pH, and EC during the step-drawdown test at Js-1 well. Although the arsenic level irregularly oscillated, it tended to decrease over time from 0.0023mg/l in the 1st step to 0.0011mg/l in the 10th step. The Eh values increased in 1st step then stabilized at around 100mV. The pH values increased from 7.25in the 1st step to 7.58 in the 5th step. EC values stabilized between 82 and 84mS/m from the 3rd step.

Figure 5.4.6 shows the changes in arsenic level, Eh, pH, and EC during the step-drawdown test at Js-2 well. The As concentration was stable at around 0.002mg/l in the 1st and 2nd steps, but it fluctuated greatly from the 3rd step to the 6th step. Eh values tended to increase over time. The pH values clearly increased from 7.3 in the 2nd step to 7.65 in the 6th step. On the other hand, EC values slightly decreased over time.

b. Continuous Pumping Test

Figure 5.4.7 shows the changes in arsenic level, Eh, pH, and EC during the continuous pumping test at Ch-1 well. The As concentration fluctuated with a range from 0.035 to 0.045mg/l in the first 2,300 minutes, and then it decreased to 0.025mg/l. Eh values fluctuated greatly from 100 to 250mV. The pH and EC values fluctuated in the first 600 minutes, but after that they stabilized until the end of the pumping test.

Figure 5.4.8 shows the changes in arsenic level, Eh, pH, and EC during the continuous pumping test at Ch-2 well. At the beginning the As level was very low at 0.00005mg/l. Then it jumped up to 0.0015mg/l and stabilized with a very slight decrease. Eh values varied greatly in the first 1,000 minutes, and then stabilized over time. The pH values irregularly fluctuated between 6.92 and 7.08. EC values irregularly increased after 1,000 minutes.

Figure 5.4.9 shows the changes in arsenic level, Eh, pH, and EC during the continuous pumping test at Jh-1 well. At the beginning the As level was below 0.015mg/l. Then it rose and fluctuated between 0.023 and 0.027mg/l. Eh values were also lower than 100mV in the beginning. Then they rose up to 170mV and gradually decreased to 130mV. The pH values increased from 6.98 to 7.1 for the period from 0 to 2,000 minutes, and then slightly decreased. EC values irregularly fluctuated between 86.5 and 88.8mS/m.

Figure 5.4.10 shows the changes in arsenic level, Eh, pH, and EC during the continuous pumping test at Jh-2 well. The As levels increased over time from 0.005 to 0.016mg/l. On the other hand, the values of Eh and pH tended to decrease over time. Although EC values irregularly fluctuated, a slight increasing trend can be found after 1,000 minutes.

Figure 5.4.11 shows the changes in arsenic level, Eh, pH, and EC during the continuous pumping test at Js-1well. The As level increased from 0.0013 to 0.0023mg/l in the first 600 minutes. It decreased to 0.001 mg/l once, but gradually increased to 0.0019 mg/l at 2,880 minutes. Eh values ranged from 90 to 110mV. In the latter part of the test, the values stabilized. The pH values increased over time from 7.4 to 7.7. EC values slightly increased from 82 to 84mS/m for the period from 900 to 2,880 minutes.

Figure 5.4.12 shows the changes in arsenic level, Eh, pH, and EC during the continuous pumping test at Js-2well. The As level increased from 0.003 to 0.005mg/l during the period from 1,000 to 2,000 minutes. Then it suddenly dropped from 0.0043 to 0.0013mg/l in the period from 2,160 to 2,340 minutes. Eh values tended to increase over time. The pH values straightly increased from 7.2 to 7.58, but declined to 7.2 in the latter part of the test period. EC values irregularly increased in the beginning and in the latter part of the test.

2) Observation Holes

During the three (3) hour pumping period, As concentrations increased in all the observation holes in CH-1 site and CH-2 sites.

At JH-1 site in Jhenaidah Pourashava, the arsenic levels of Jh-1-2 and Jh-1-4 holes increased, however, the arsenic levels of Jh-1-1 and Jh-1-3 holes decreased. In JH-2 site, the level of Jh-1-1 hole slightly decreased. The levels of Jh-2-2 and Jh-2-4 slightly increased. The As levels in Jh-2-3 hole remain stable.

In Jessore Pourashava, the arsenic levels in all the observation holes in JS-1 and JS-2 sites decreased during the pumping.

5.4.4 Arsenic Concentrations during Monitoring

1) Monitoring Results of Observation Wells/Holes

a. CH-1 Site [Poshu Hat, Chuadanga Pourashava]

Figure 5.4.13 shows the results of the monitoring of groundwater level and arsenic concentrations at CH-1 site.

The groundwater levels were located between 3.5 and 6.5m below the benchmark (KBM). The lowest groundwater levels were recorded in the end of March 2001 and the highest levels were recorded in the middle of October 2001. Similar patterns of groundwater level change were observed at the well/holes. The piezometric head difference is generally within 0.5m.

For the arsenic levels, the shallowest observation hole (Ch-1-1) had the highest arsenic level from July to October 2001, exceeding the Bangladeshi standard value of 0.05mg/l in July 2001. The arsenic levels increased from June to July then started to decrease from August to December. It should be noted that the lower arsenic levels in April and May were caused by sampling method, because the pump used for that period had a small capacity to remove the stagnant water.

Figure 5.4.14 shows the results of groundwater level and groundwater quality monitoring at CH-1 site. Eh values of all the observation well/holes varied within a range from 40 to 120mV from June to December. The pH values ranged from 6.9 to 7.3. The EC values of Ch-1 well and Ch-1-4 hole were higher than those of shallow holes. From October to December 2001, the EC values tended to increase with depth.

b. CH-2 Site [Girls College, Chuadanga Pourashava]

Figure 5.4.15 shows the results of the monitoring of groundwater level and arsenic concentrations at CH-2 site.

The groundwater levels were located between 3.0 and 6.0m below the benchmark (KBM). The lowest groundwater levels were recorded in April 2001 and the highest levels were recorded in the middle of October 2001. Similar patterns of groundwater level change were observed at the well/holes. The piezometric head difference was generally within 0.5m.

For the arsenic levels, the shallowest observation hole (Ch-2-1) had the highest arsenic level during the monitoring period, ranging from 0.10 to 0.23mg/l. The arsenic levels of Ch-2-2 and Ch-2-3 holes also exceed the Bangladeshi standard value of 0.05mg/l. The levels in Ch-2 well and Ch-2-4 hole are much lower than the standard value, always showing less than 0.004mg/l.

The arsenic levels were higher from June to August at Ch-2-1 to Ch-2-3 holes then started to decrease from September to October. It should be noted that the lower arsenic levels in April were caused by the sampling method, because the pump used for that period had a small capacity to remove stagnant water.

Figure 5.4.16 shows the results of groundwater level and groundwater quality monitoring at CH-2 site. The Eh values generally ranged from 70 to 110mV at all the well/holes. However, the Eh value of Ch-1 well decreased below 50mV in September and October 2001. The pH values tended to decrease in the high groundwater level time. The values of Ch-1 well showed a different pattern from the others. The EC values tended to increase from October to December 2001 except in Ch-2-4 hole. The EC value of Ch-2-4 hole was higher than the others from September to December 2001.

c. CH-BD Site [Bara Dudpatila, Damurhuda Upazila]

Figure 5.4.17 shows the results of the monitoring of groundwater level and arsenic concentrations at CH-BD site.

The groundwater levels were located between 3.6 and 5.7m below the benchmark (KBM). The lowest groundwater level was recorded in the end of April 2001 and the highest level was recorded in the middle of October 2001. After that, the groundwater level continuously declined until January 2002.

The arsenic level in the observation hole always showed below 0.01mg/l. Once it rose up to 0.009mg/l, but the value declined below 0.003mg/l from March. In November the concentration elevated up to 0.0054mg/l, but it declined to 0.0015mg/l in December 2001.

Figure 5.4.18 shows the results of groundwater level and groundwater quality monitoring at CH-BD site. The Eh values ranged from 70 to 90mV from April to August. In September, the value decreased to below 0mV. The value jumped up to 107mV in October then gradually decreased to 55mV in December 2001. The pH value fluctuated from 6.9 to 7.4. From October to December it rose from 6.9 to 7.24. The EC value generally showed above 80 mS/m; however, it dropped below 50mS/m in April and September 2001.

d. JH-1 Site [Arabpur, Jhenaidah Pourashava]

Figure 5.4.19 shows the results of the monitoring of groundwater level and arsenic concentrations at JH-1 site.

The groundwater levels were located between 0.9 and 5.5m below the benchmark (KBM). The lowest groundwater levels were recorded in the end of April 2001 and the highest levels were recorded in early October 2001. Similar patterns of groundwater level change were observed at the well/holes. The piezometric head difference was generally within 0.1m.

For the arsenic levels, the shallowest observation hole (Jh-1-1) has the highest arsenic level from April to December 2001, exceeding the Bangladeshi standard value of 0.05mg/l in April and June 2001. The arsenic levels of Jh-1-1 to Jh-1-4 holes decreased from April to October. However, the values of Jh-1-2 to Jh-2-4 holes started to increase from November to December. The arsenic level of Jh-1 well was below 0.01mg/l from June to October. But it exceeded the WHO guideline value in November and December 2001.

Figure 5.4.20 shows the results of groundwater level and groundwater quality monitoring at JH-1 site. Eh values of all the observation well/holes decreased from April to June, and then almost stabilized. The Eh values of Jh-1-1 to Jh-1-4 holes generally show between 70 to 120mV. But the value in Jh-1 well was lower, ranging from 10 to 35mV. The pH values generally ranged from 6.8 to 7.4. The EC value of Jh-1-4 hole was relatively stable, ranging from 80 to 87mS/m. The rest varied from 40 to 90mS/m. In December 2001, the EC values of shallow holes from Jh-1-1 to Jh-1-3 were below 55mS/m, whereas the deep well/hole (Jh-1 well and Jh-1-4 hole) were more than 80mS/m.

e. JH-2 Site [Hamdah, Jhenaidah Pourashava]

Figure 5.4.21 shows the results of the monitoring of groundwater level and arsenic concentrations at JH-2 site.

The groundwater levels were located between 1.5 and 5.5m below the benchmark (KBM). The lowest groundwater levels were recorded in the end of May 2001 and the highest levels were recorded in the middle of September 2001. Similar patterns of groundwater level change were observed at the well/holes. The piezometric head difference was generally within 0.5m. It is noted that the groundwater levels of deep aquifers became lower than that of shallow aquifers.

For the arsenic levels, the shallowest observation hole (Jh-2-1) had the highest arsenic level among the well/holes. The levels exceeded the Bangladeshi standard value of 0.05mg/l most of the time. The second highest arsenic levels were recorded in Jh-2-2 hole, ranging from 0.01 to 0.05mg/l. The arsenic level of Jh-2-3 ranged between 0.01 and 0.02mg/l from June to September, but it declined below 0.01mg/l from October. The arsenic levels of Jh-2 well and Jh-2-4 hole showed below 0.01mg/l. The arsenic levels of Jh-2-1 and Jh-2-2 holes tended to decrease from July to November 2001.

Figure 5.4.22 shows the results of groundwater level and groundwater quality monitoring at JH-2 site. Eh values of all the observation well/holes decreased from June to August, and then almost stabilized except in Jh-2 well. The Eh value of Js-2 well continued to decrease until October. The Eh values of Jh-1-1 to Jh-1-4 holes generally showed between 60 to 100mV; But the value in Jh-2 well became lower from October, ranging from 15 to 60mV. The pH values generally range from 6.7 to 7.7. Jh-2 well has the highest value of pH, ranging from 7.15 to 7.7. The EC values showed almost stable during the monitoring period. It is noted that Jh-2 well had the lowest values of EC whereas Jh-2-4 hole, which tapped the same aquifer as Jh-2 well, had the highest EC values.

f. JH-KC Site [Krishna Chandrapur, Moheshpur Upazila]

Figure 5.4.23 shows the results of the monitoring of groundwater level and arsenic concentrations at JH-KC site.

The groundwater levels were located between 4.3 and 6.3m below the benchmark (KBM). The lowest groundwater level was recorded in early May 2001 and the highest level was recorded in early October 2001. After that, the groundwater level declined and reached 6 m in January 2002. The arsenic level was more than 0.05mg/l in April and from August to November 2001. In May the level dropped at below 0.01mg/l. The highest value of 0.10mg/l was recorded in November. The increasing trend of the arsenic level was identified from June to November. In December the level declined to 0.037mg/l.

Figure 5.4.24 shows the results of groundwater level and groundwater quality monitoring at JK-KC site. The Eh values ranged from 90 to 115mV from May to November. In December, the value decreased to below 40mV. The pH value was more than 8 in June 2001. Then it declined and ranged from 6.8 to 8.0 in June to December. The EC values were almost constant from May to December except in June. The values ranged from 88 to 94mS/m.

g. JS-1 Site [Ghop, Jessore Pourashava]

Figure 5.4.25 shows the results of the monitoring of groundwater level and arsenic concentrations at JS-1 site.

The groundwater levels were recorded from July 2001 to January 2002. For the period, the groundwater levels were located between 3.3 and 6.7m below the benchmark (KBM). The patterns of groundwater level change in the site were different from those in Jheiadah and Chuadanga. The lowest groundwater levels were recorded in the end of January 2002 and the highest levels were recorded in the middle of September 2001. From July to November, all the water levels rose in the early part of each month and declined in the latter. But from December 2001, all the groundwater levels continuously dropped and the lowering speed increased in January 2002. The piezometric head difference was generally within 0.6m from July to December 2001.

For the arsenic levels, they were relatively higher at all the well/holes in August 2001, and then they tended to decrease from September to December. In August, the level at Js-1-2 reached 0.033mg/l, but the rest of the samples showed below 0.01mg/l.

Figure 5.4.26 shows the results of groundwater level and groundwater quality monitoring at JS-1 site. Eh values of all the observation well/holes ranged from 20 to 110mV. The Eh value of Js-1-1 well gradually decreased with time from 104 to 91mV. The Eh values of Js-1-2 to Js-1-4 holes and Js-1 well ranged from 40 to 80mV in September to December 2001. The pH values of all the well/holes clearly decreased from July to September. Then the values slightly increased from September to December within a range from 6.8 to 7.2. The EC values of all the well/holes increased from July to August, and then decreased from September to November. The EC values in December tended to increase with depth. The values of Js-1-1 and Js-1-2 hole are about 60mS/m, whereas the values of Js-1-3, Js-1-4, and Js-1 well show between 80 and 90mS/m.

h. JS-2 Site [Kharki, Jessore Pourashava]

Figure 5.4.27 shows the results of the monitoring of groundwater level and arsenic concentrations at JS-2 site.

The groundwater levels were recorded from August 2001 to January 2002. For the period, the groundwater levels were located between 1.7 and 5.4m below the benchmark (KBM). The patterns of groundwater level change in the site were similar to JS-1 site and different from those in Jhenaidah and Chuadanga. The lowest groundwater levels were recorded in the end of January 2002 and the highest levels were recorded in the middle of September 2001. From August to November, all the water levels rose in the early part of each month and declined in the latter. But from December 2001, all the groundwater levels continuously dropped and the lowering speed increased in January 2002. The piezometric head difference was generally within 0.7m from July to December 2001. It should be noted that the groundwater levels of shallow aquifers are lower than that of deeper aquifers.

For the arsenic levels, the highest concentrations were recoded in the second shallowest hole of Js-2-2, ranging from 0.045 to 0.10mg/l. The arsenic levels of Js-2-1 hole were below 0.01mg/l. The second highest arsenic level was found at Js-2-3 hole, ranging from 0.003 to 0.03mg/l. The arsenic levels of Js-2 well and Js-2-4 hole were very low. There is no clear correlation between the groundwater level change and the arsenic level change.

Figure 5.4.28 shows the results of groundwater level and groundwater quality monitoring at JS-2 site. The Eh values generally ranged from 30 to 110mV. The pH values had a wide range of variation from 6.9 to 7.5 until September 2001, but the range became very small in November and December when the groundwater levels sharply declined. The EC values ranged from 55 to 105mS/m. The values were higher in deeper depths.

i. JS-RB Site [Rajnagar Bankabarsi, Keshabpur Upazila]

Figure 5.4.29 shows the results of the monitoring of groundwater level and arsenic concentrations at JS-RB site.

The groundwater levels were located between 2.7 and 4.7m below the benchmark (KBM) for the monitoring period from April 2001 to January 2002. The lowest groundwater level was recorded in the end of April and the highest level was recorded in the middle of October. The groundwater level gradually and smoothly increased from May to August. After reaching the highest value, the level gradually declined but it suddenly dropped to about 0.5m in January 2002.

The arsenic concentration was generally low. The highest level of 0.0023mg/l was recorded in June 2001. Then the concentrations gradually decreased and became below the detection level of 0.0005mg/l by AAS in November.

Figure 5.4.30 shows the results of groundwater level and groundwater quality monitoring at JK-KC site. The Eh value increased from 110mV in June to 160mV in September, then it decreased to 60mV in December 2001. The pH values were generally high, ranging from 7.6 to 7.9. The EC values ranged from 66 to 75mS/m. The values tended to increase from June to December 2001.

2) Monitoring Results of Improved Deep Wells

a. Bara Dudpatila Village [Damurhuda Upazila, Chuadanga District]

Figure 5.4.31 shows the monitoring results of arsenic measurement by AAS and groundwater quality parameters by field measurements in the improved deep wells constructed in Bara Dudpatila village.

The arsenic concentrations of the three (3) types of the wells ranged from 0.068 to 0.084mg/l in March 2001. The concentrations were almost stable from March to May, but started to increase from June to July. The highest value of the arsenic level at each well appeared from July to September. In Type-A well, the highest value of 0.11mg/l was recorded in August. In Type-B well, the highest value of 0.18mg/l was recorded in September. In Type-C well, the highest value of 0.14mg/l was recorded in July. The arsenic levels decreased from September to

December. The levels in December were lower than those in March 2001.

The Fe concentration measured by pack test kit had a wide range from 2 to 8mg/l in March, but the range gradually became smaller and the values ranged from 2 to 3mg/l from July to December.

The Eh values ranged from 130 to 280mV in March and April, but the values decreased from May. From June, the values in the three (3) wells showed almost the same value and slightly fluctuated below 100mV.

The changes in pH show similar patterns of fluctuation. The values increased from April to May, decreased from July to September, and increased from October to December.

The EC values were almost constant except for the March data. The values ranged from 45 to 50mS/m.

b. Krishna Chandrapur Village [Moheshpur Upazila, Jhenaidah District]

Figure 5.4.32 shows the monitoring results of arsenic measurement by AAS and groundwater quality parameters by field measurements in the improved deep wells constructed in Krishna Chandrapur village.

The arsenic concentrations of the three (3) types of the wells were just below the Bangladeshi standard value of 0.05mg/l after the construction. Then the values slightly declined from March to June. However, the arsenic concentrations exceeded the standard value from July in all the wells. Particularly the concentration in Type-A well rose from 0.018mg/l in June to 0.089mg/l in July. In August, the maximum level of 0.107mg/l was recorded. The values of the three wells were more than 0.05mg/l until September. From September to December the values tended to decrease. The arsenic concentrations in December became almost the same values as in March inn Type-B and Type-C wells. The value of Type-A well was still above the standard value, showing 0.06mg/l.

The Fe concentration measured by pack test kit had a wide range from 2 to 10mg/l from March to May, but the range became smaller from July. In October the concentrations slightly increased, but in December the values ranged from 2 to 4mg/l.

The Eh values ranged from 100 to 160mV from March to May, but the values decreased from May to June. From June to November, the values in the three (3) wells ranged from 80 to 120mV. In December, the values further lowered and the Eh value in Type-A well showed to be only 28mV.

The pH values ranged from 6.85 to 7.20. The changes in pH showed similar patterns of fluctuation. The values increased from March to July, and then decreased in August. The values again increased from September to December.

The EC values were slightly higher from March to June, but they slightly lowered and become almost constant after July, ranging from 88 to 92mS/m.

c. Rajnagar Bankabarsi Village [Keshabpur Upazila, Jessore District]

Figure 5.4.33 shows the monitoring results of arsenic measurement by AAS and groundwater quality parameters by field measurements in the improved deep wells constructed in Rajnagar Bankabarsi village.

The arsenic concentrations of the three (3) types of the wells were much lower than the WHO guideline value of 0.01mg/l. Slightly elevated concentrations up to 0.005mg/l were recorded in September and October 2001, the most results showing below 0.001mg/l. In November and December, all the levels were below the detection limit of AAS analysis.

The Fe concentration measured by pack test kit also showed very small values. From March 2001, most samples showed 0.2mg/l or less.

The Eh values generally ranged from 80 to 220mV. The values increased from November 2000 to March 2001. Then the values decreased from March to June. In October, all the three wells showed more than 160mV in Eh; the values dropped below 70mV in December.

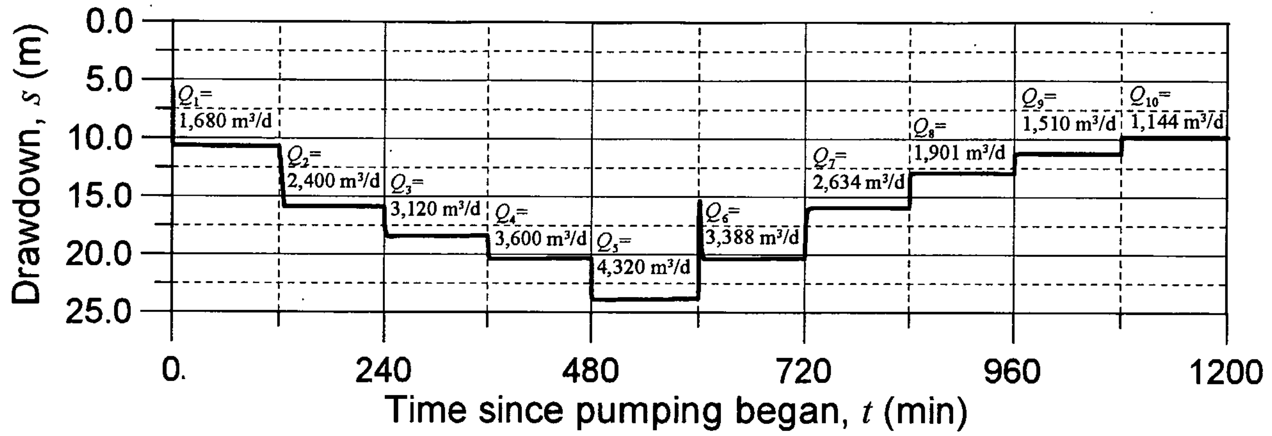
The pH values were relatively higher in the improved deep wells, ranging from 7.4 to 8.0. But the values clearly dropped from September to November, showing almost 7.0. The values again increased in December to 7.5 to 7.7.

The EC values generally showed a decreasing trend from 60mV in November 2000 to 50mV in December 2001. In August and September, some wells showed higher EC values up to 80mS/m.

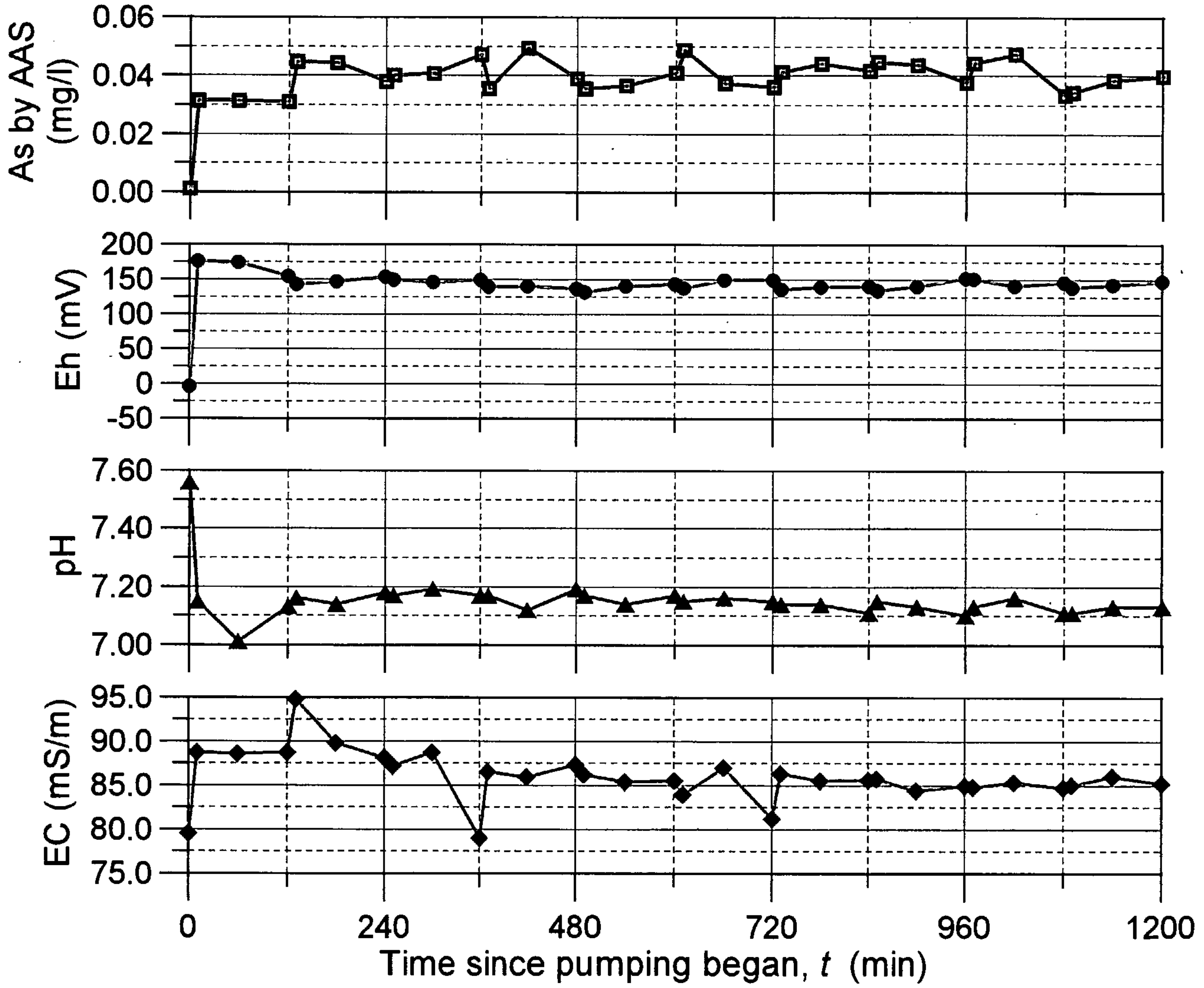
3) Eh-pH-As Relation

Based on the data of the monthly monitoring mentioned above, the Eh-pH-As relations were examined as shown in Figure 5.4.34. The used data were only obtained from the newly constructed observation wells/holes.

In the wells/holes, most samples have pH values within a range from 6.8 to 7.8. The Eh values range from -50 to 250mV. In the domain, the samples contaminated by arsenic were plotted in the area having 6.8 to 7.4 in pH and 70 to 250mV in Eh.



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

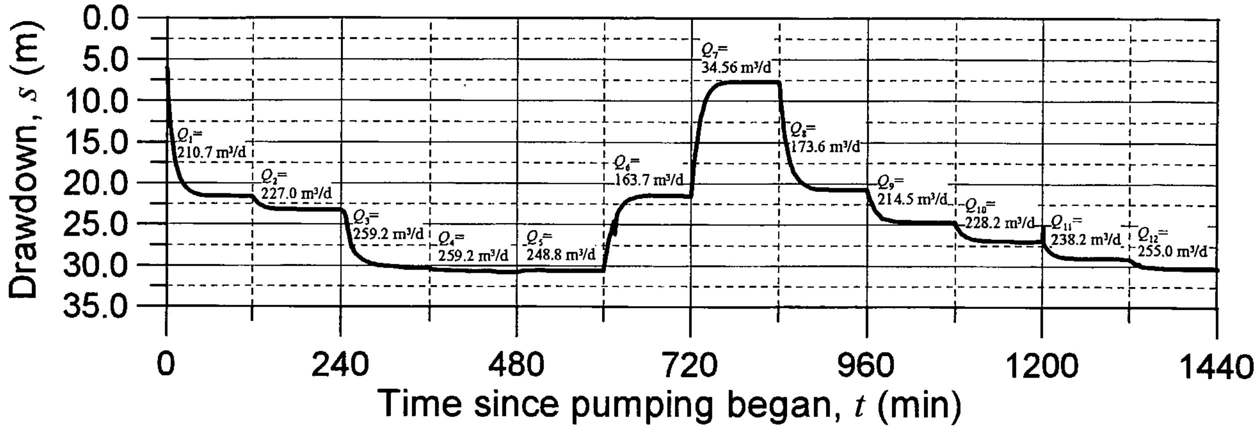
Location:	Poshu Hat, Chuadanga Pourashava
Site No.:	CH-1
Well No.:	Ch-1
Well Depth:	274 m
Well Diameter:	355.60 mm
Screen Depths:	212.5-268.0 m
Screen Length:	19.5 m
SWL:	GL- 5.610 m on 21-02-2001

Figure 5.4.1

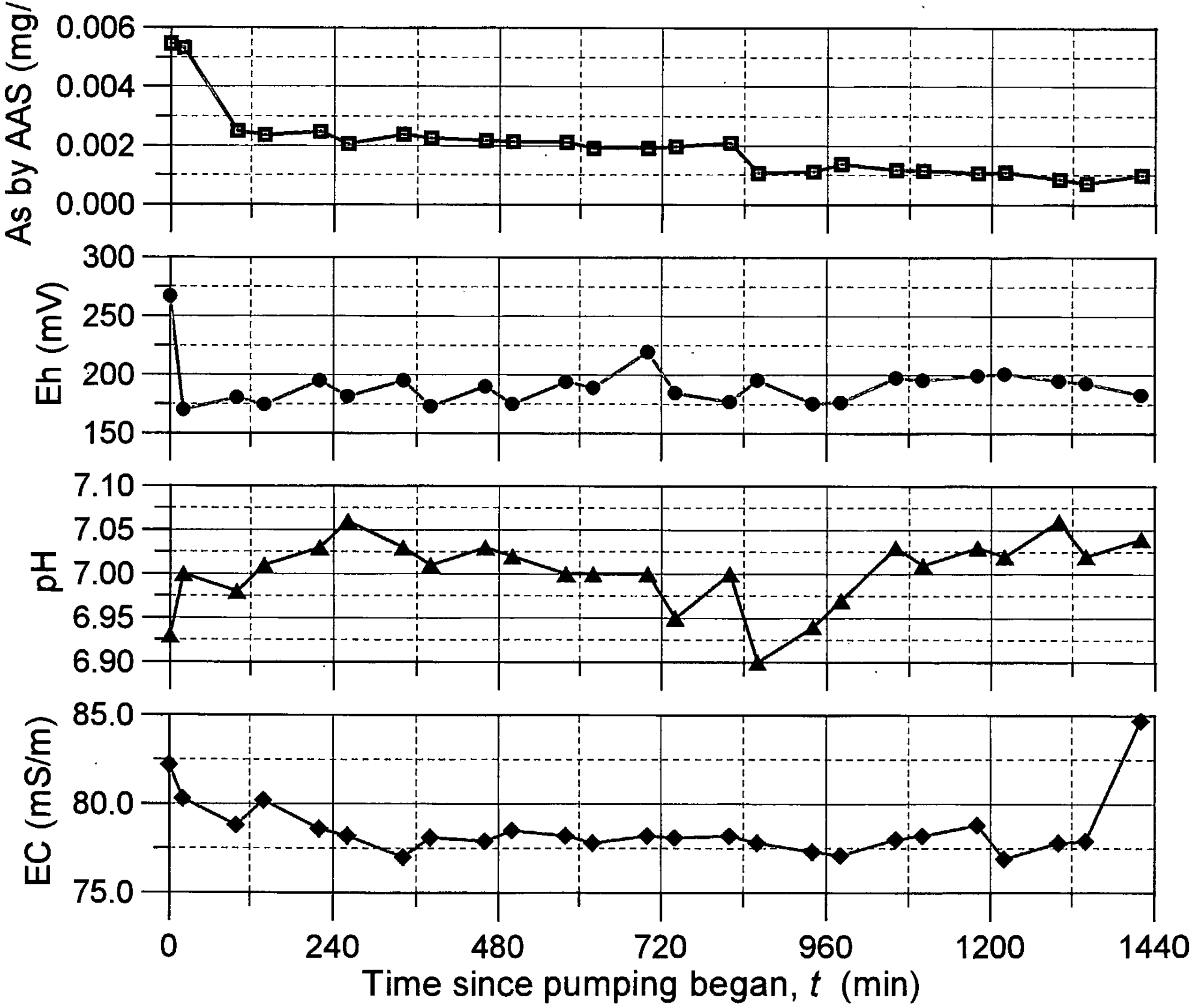
Changes in Water Quality during Step-Drawdown Test at CH-1 Site, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

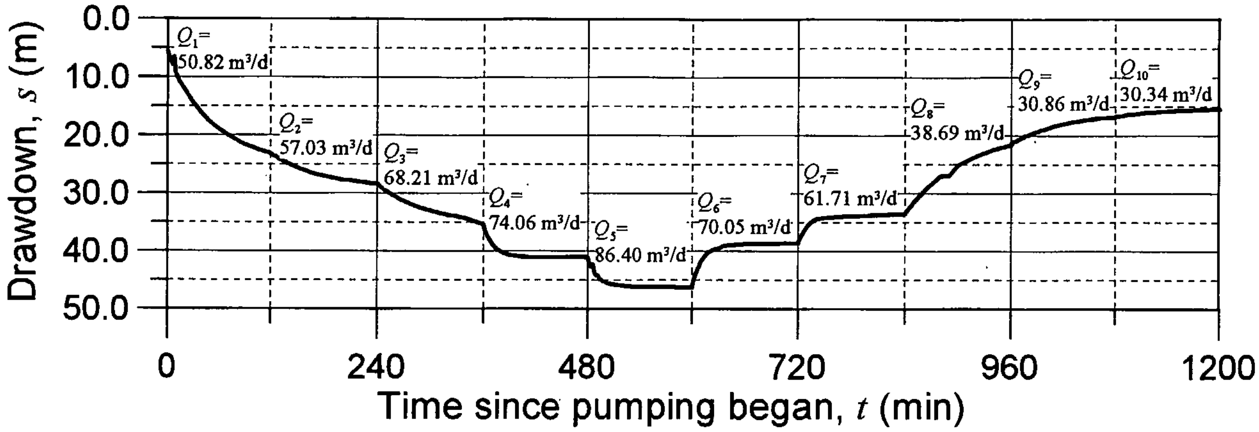
Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2
Well Depth:	298.5 m
Well Diameter:	355.60 mm
Screen Depths:	270-283, 289-295.5 m
Screen Length:	19.5 m
SWL:	GL- 6.001 m on 18-03-2001

Figure 5.4.2

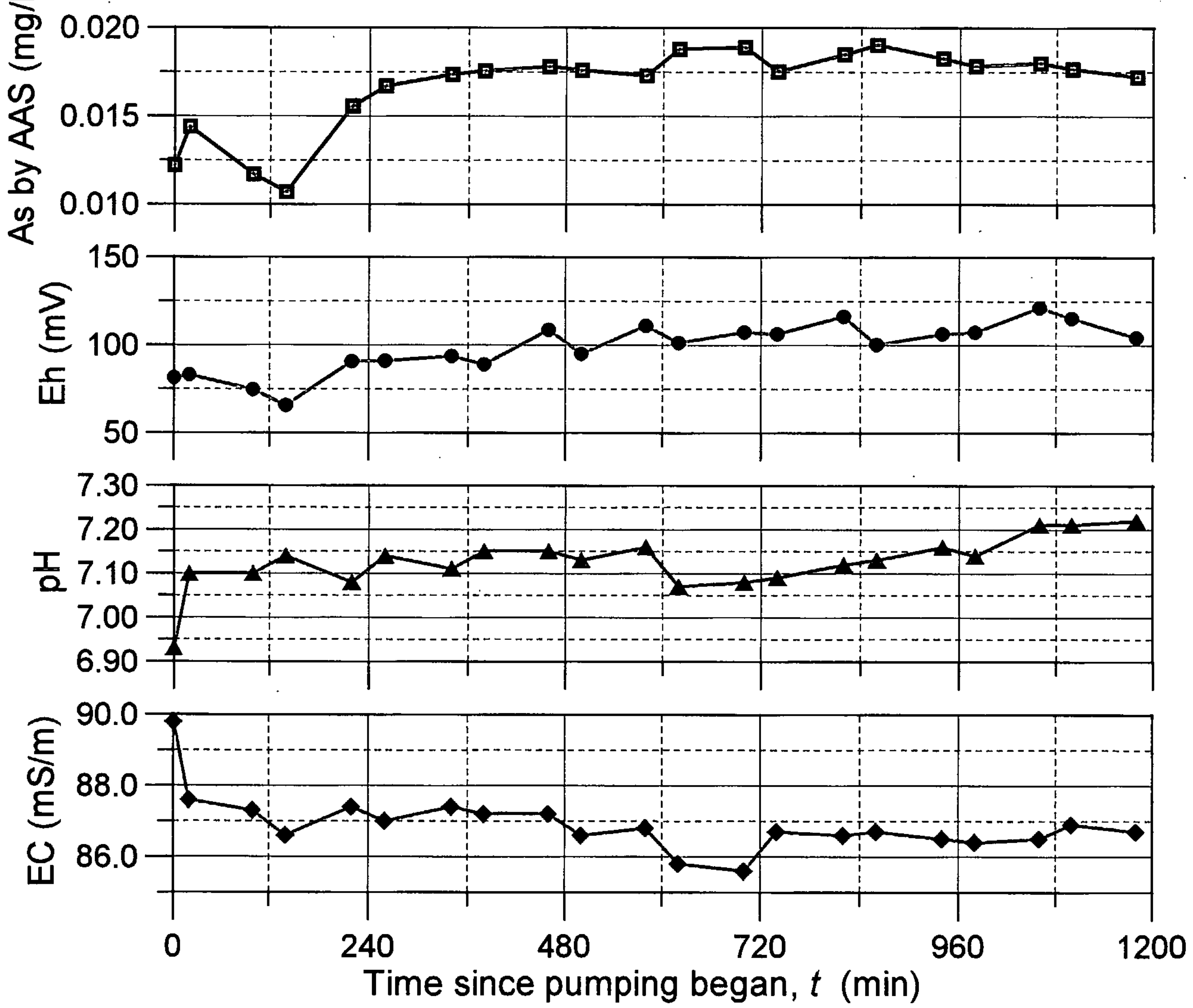
Changes in Water Quality during Step-Drawdown Test at CH-2 Site, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

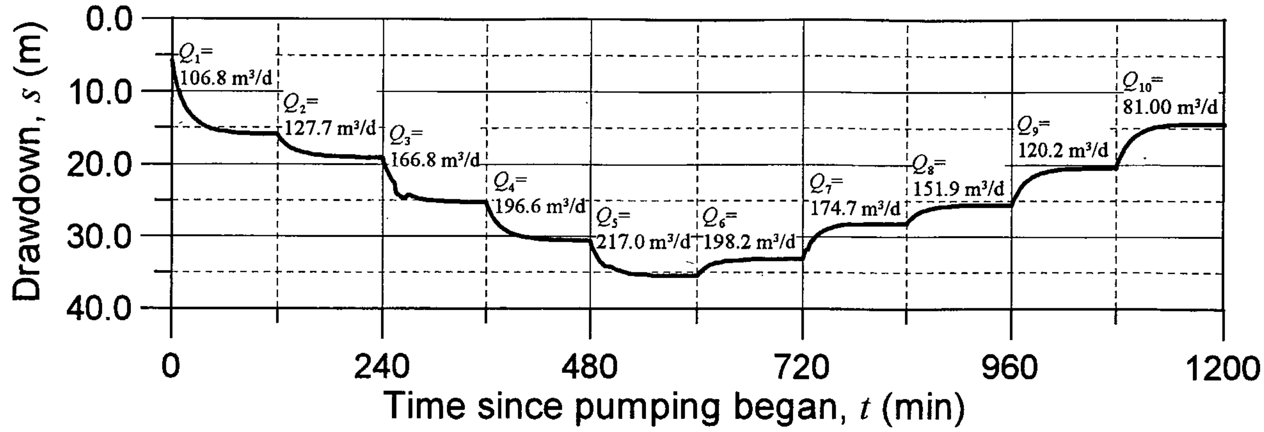
Location:	Arabpur, Jhenaidah Pourashava
Site No.:	JH-1
Well No.:	Jh-1
Well Depth:	292 m
Well Diameter:	355.60 mm
Screen Depths:	251.5-289.0 m
Screen Length:	19.5 m
SWL:	GL- 5.545 m on 02-05-2001

Figure 5.4.3

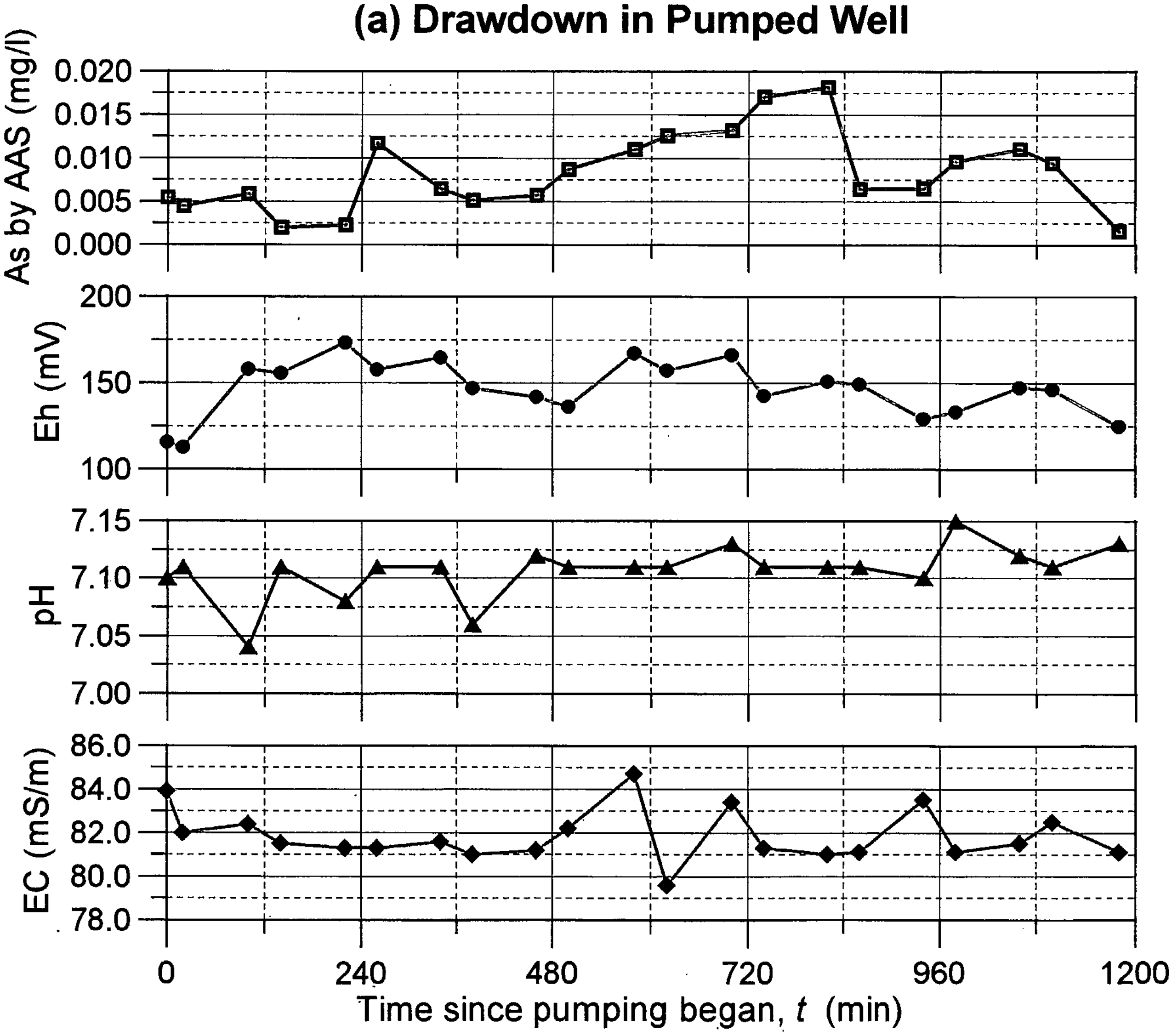
Changes in Water Quality during Step-Drawdown Test at JH-1 Site, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

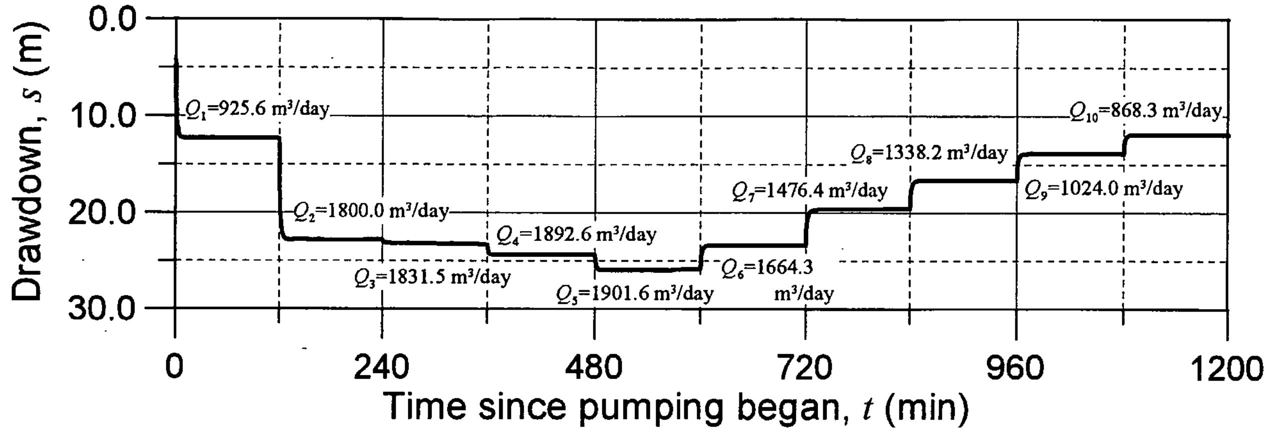
Location:	Hamdah, Jhenaidah Pourashava
Site No.:	JH-2
Well No.:	Jh-2
Well Depth:	301 m
Well Diameter:	355.60 mm
Screen Depths:	257.5-298.0 m
Screen Length:	19.5 m
SWL:	GL- 5.762 m on 03-06-2001

Figure 5.4.4

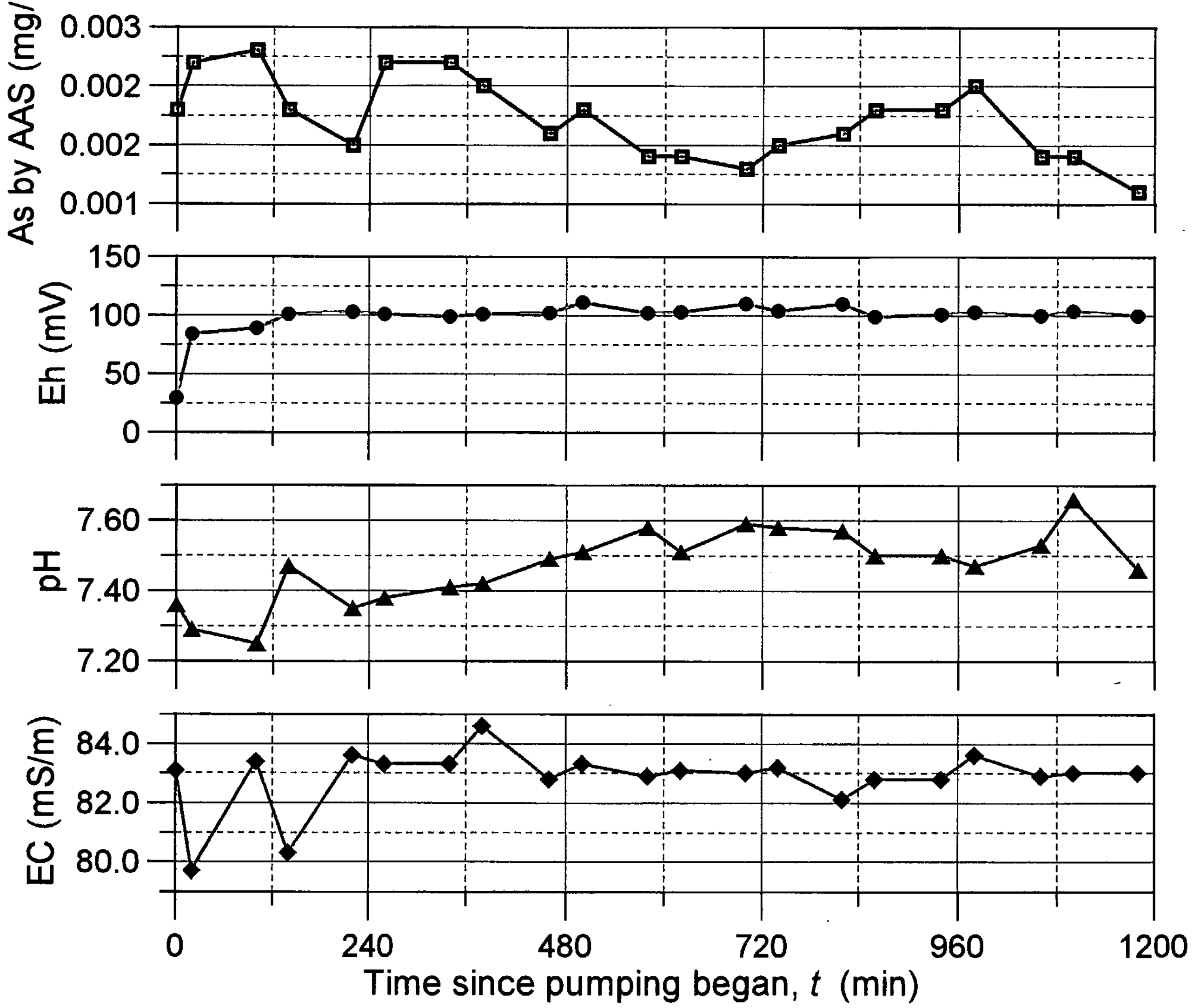
Changes in Water Quality during Step-Drawdown Test at JH-2 Site, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

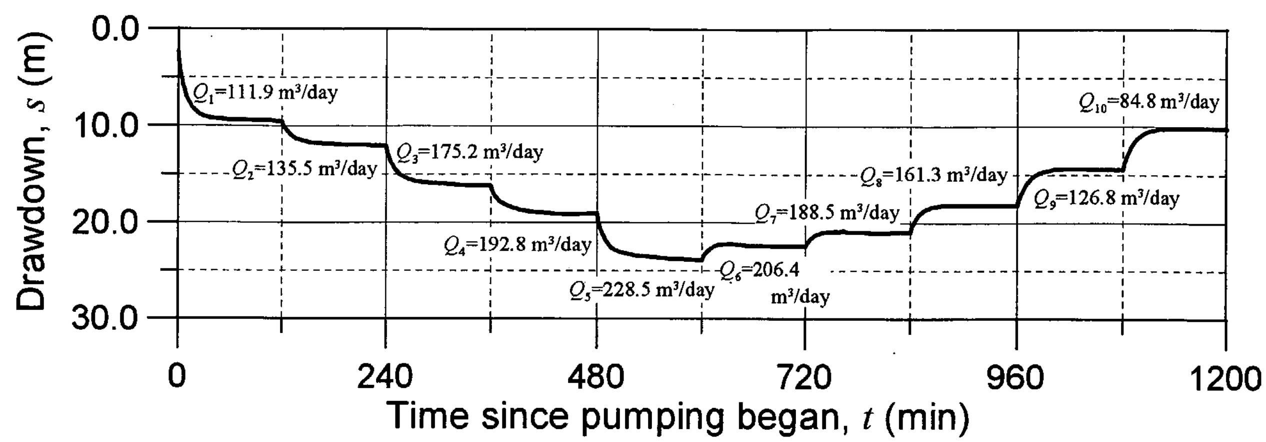
Location:	Ghop, Jessore Pourashava
Site No.:	JS-1
Well No.:	Js-1
Well Depth:	279.5 m
Well Diameter:	355.60 mm
Screen Depths:	260.5-273.5 m
Screen Length:	13.0 m
SWL:	GL- 4.200 m on 16-07-2001

Figure 5.4.5

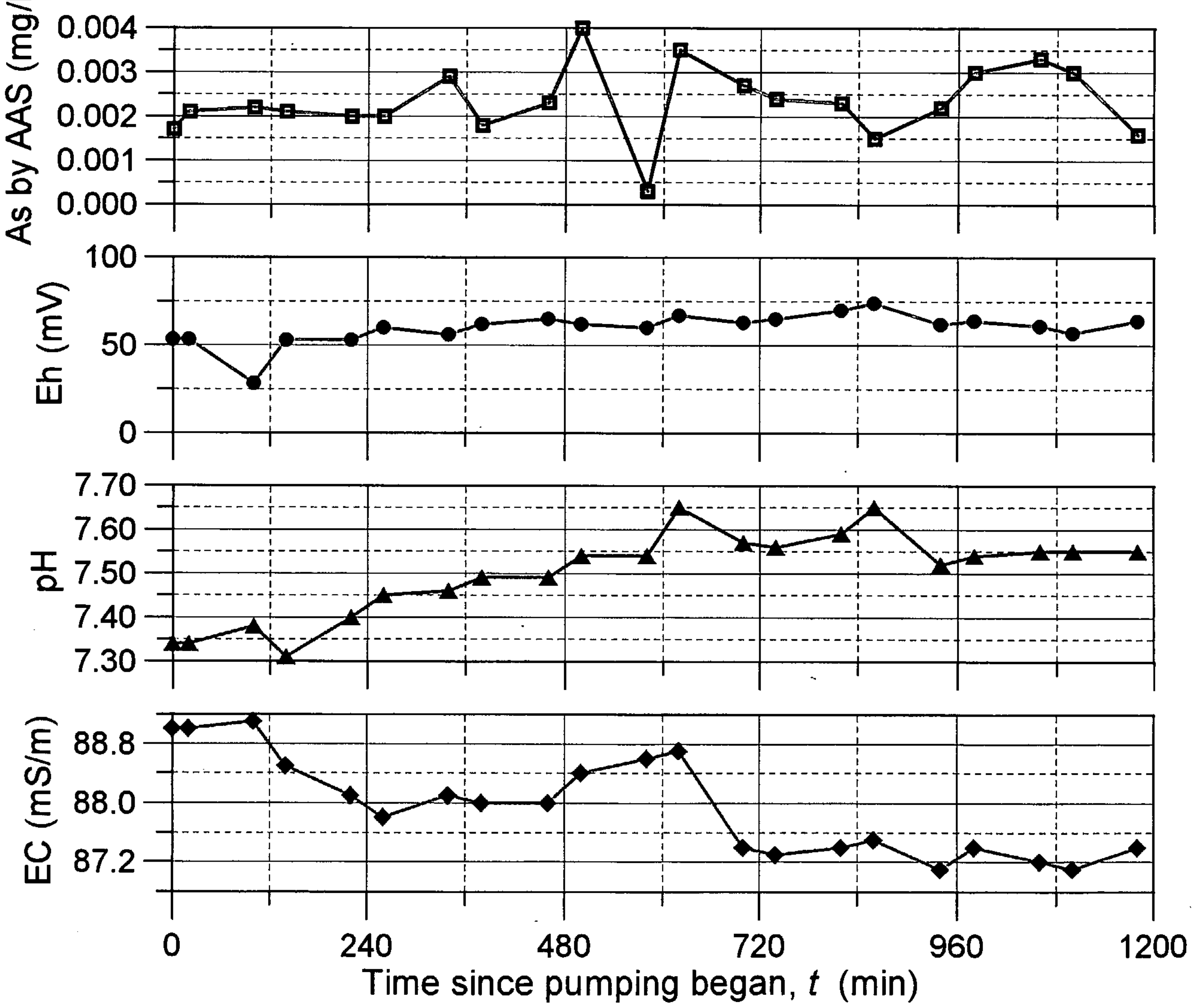
Changes in Water Quality during Step-Drawdown Test at JS-1 Site, Jessore

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



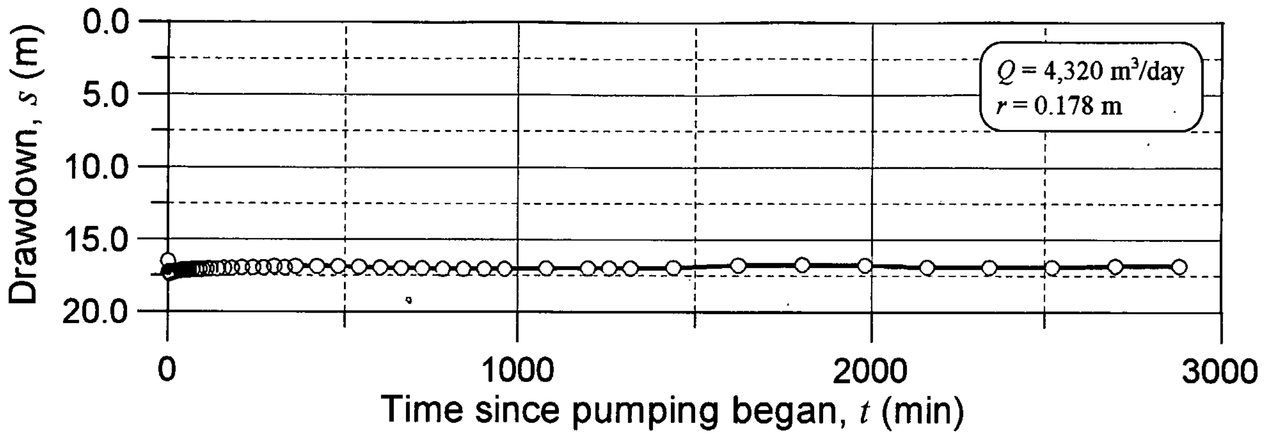
(b) Water Quality of Pumped Water

Location:	Kharki, Jessore Pourashava
Site No.:	JS-2
Well No.:	Js-2
Well Depth:	261.75 m
Well Diameter:	355.60 mm
Screen Depths:	239.50-255.75 m
Screen Length:	16.25 m
SWL:	GL- 2.369 m on 02-08-2001

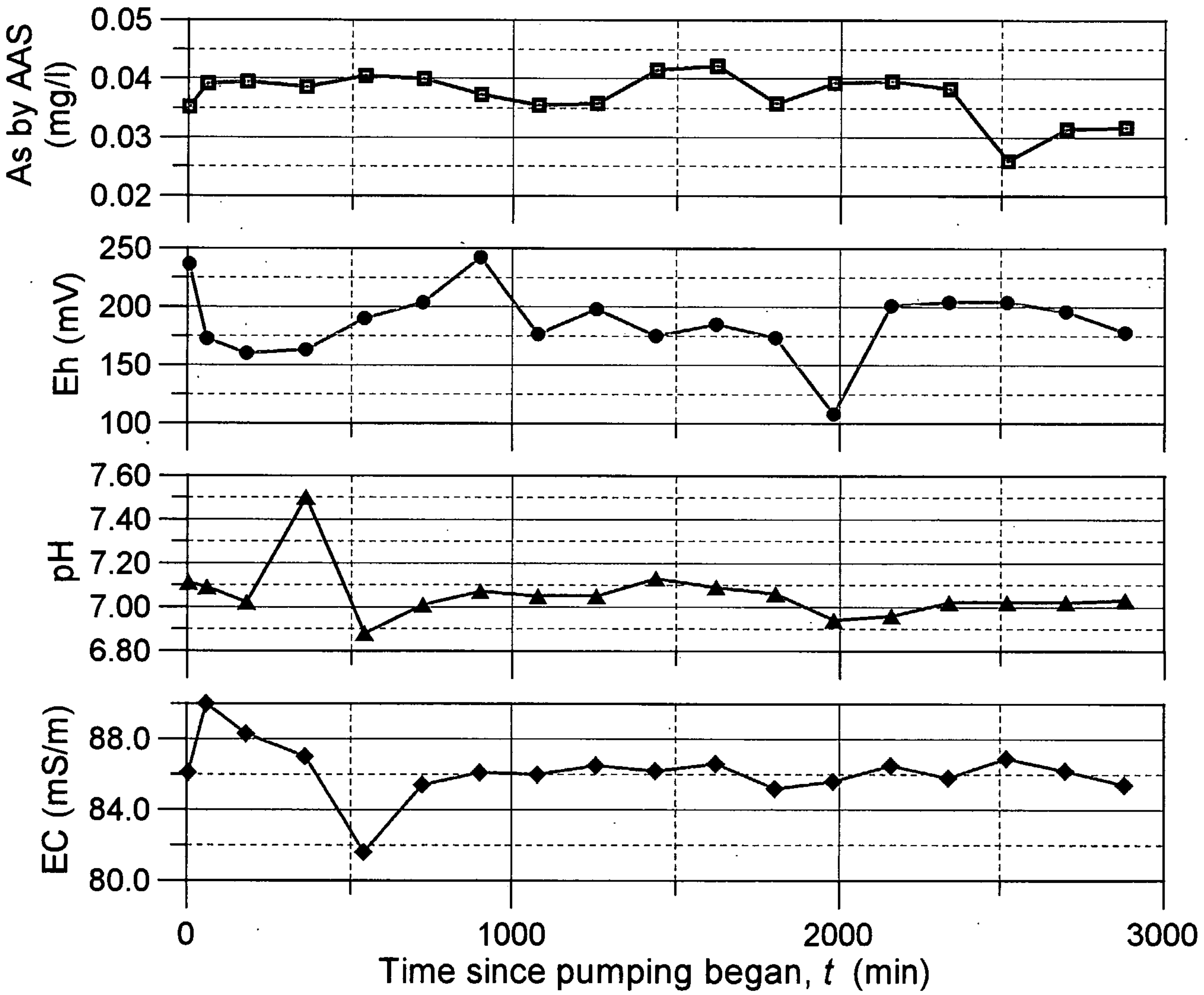
Figure 5.4.6	**Changes in Water Quality during Step-Drawdown Test at JS-2 Site, Jessore**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

Location:	Poshu Hat, Chuadanga Pourashava
Site No.:	CH-1
Well No.:	Ch-1
Well Depth:	274 m
Well Diameter:	355.60 mm
Screen Depths:	212.5-268.0 m
Screen Length:	19.5 m
SWL:	GL- 5.985 m on 22-02-2001

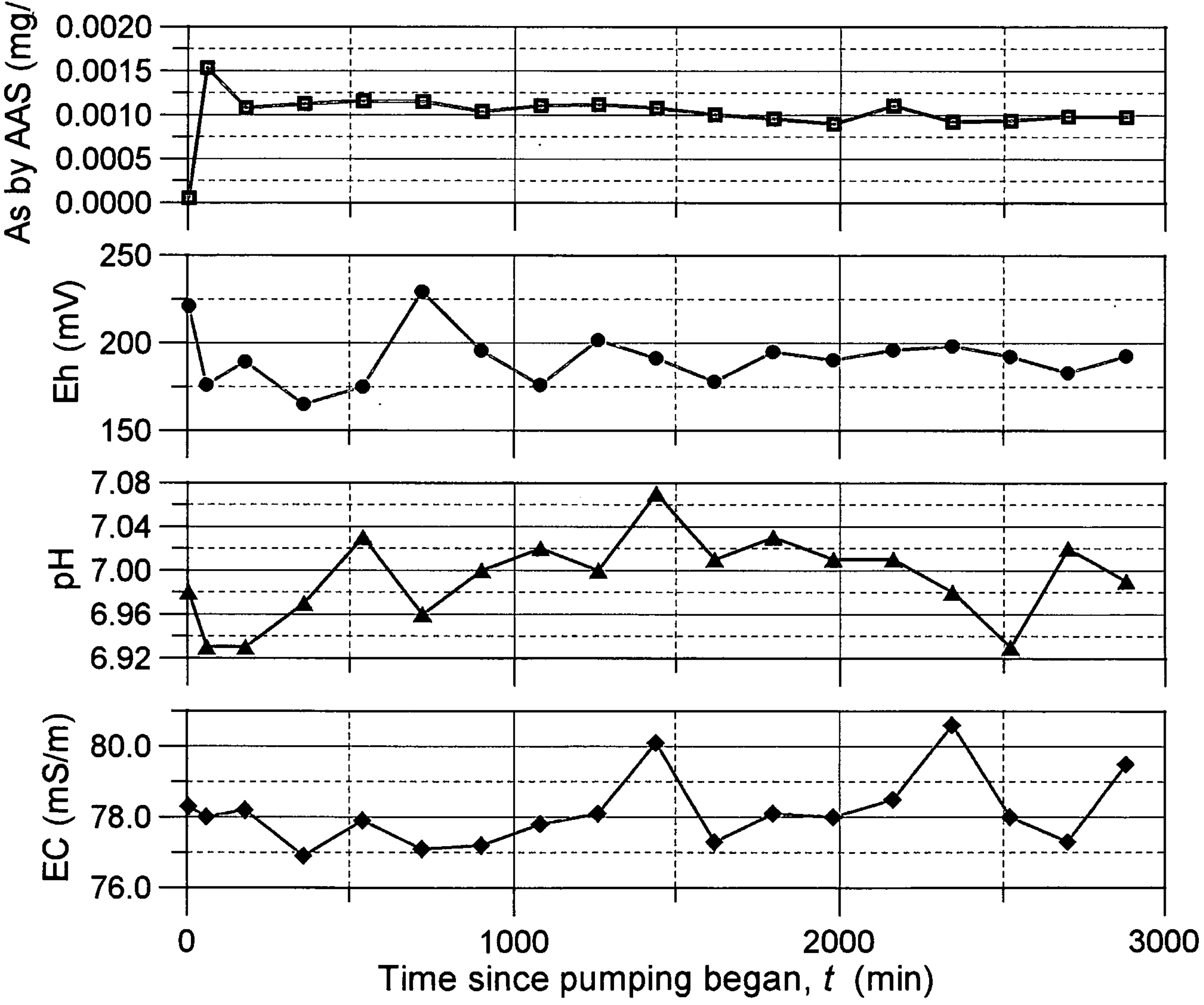
Figure 5.4.7

Changes in Water Quality during Continuous Pumping Test at CH-1 Site, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

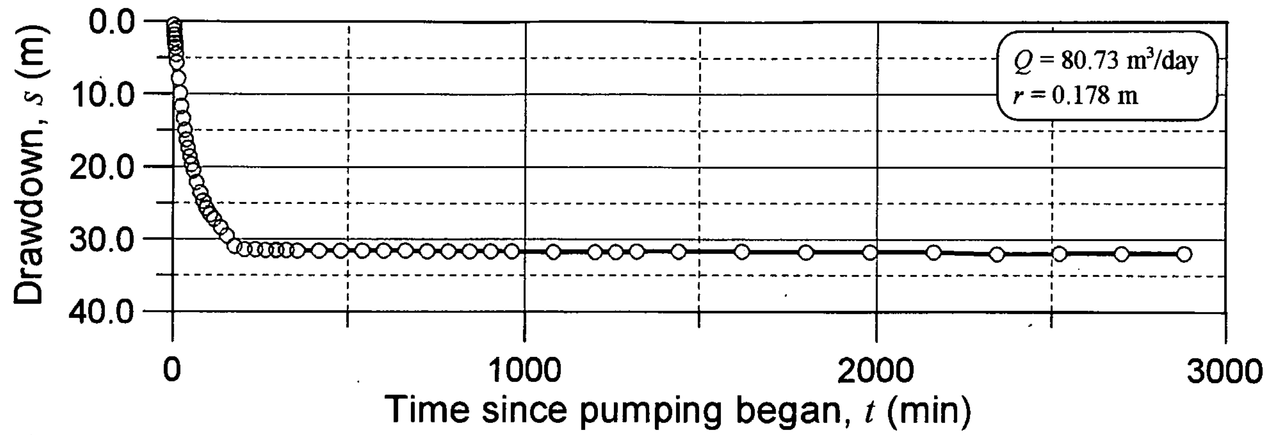
Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2
Well Depth:	298.5 m
Well Diameter:	355.60 mm
Screen Depths:	270-283, 289-295.5 m
Screen Length:	19.5 m
SWL:	GL- 6.012 m on 19-03-2001

Figure 5.4.8

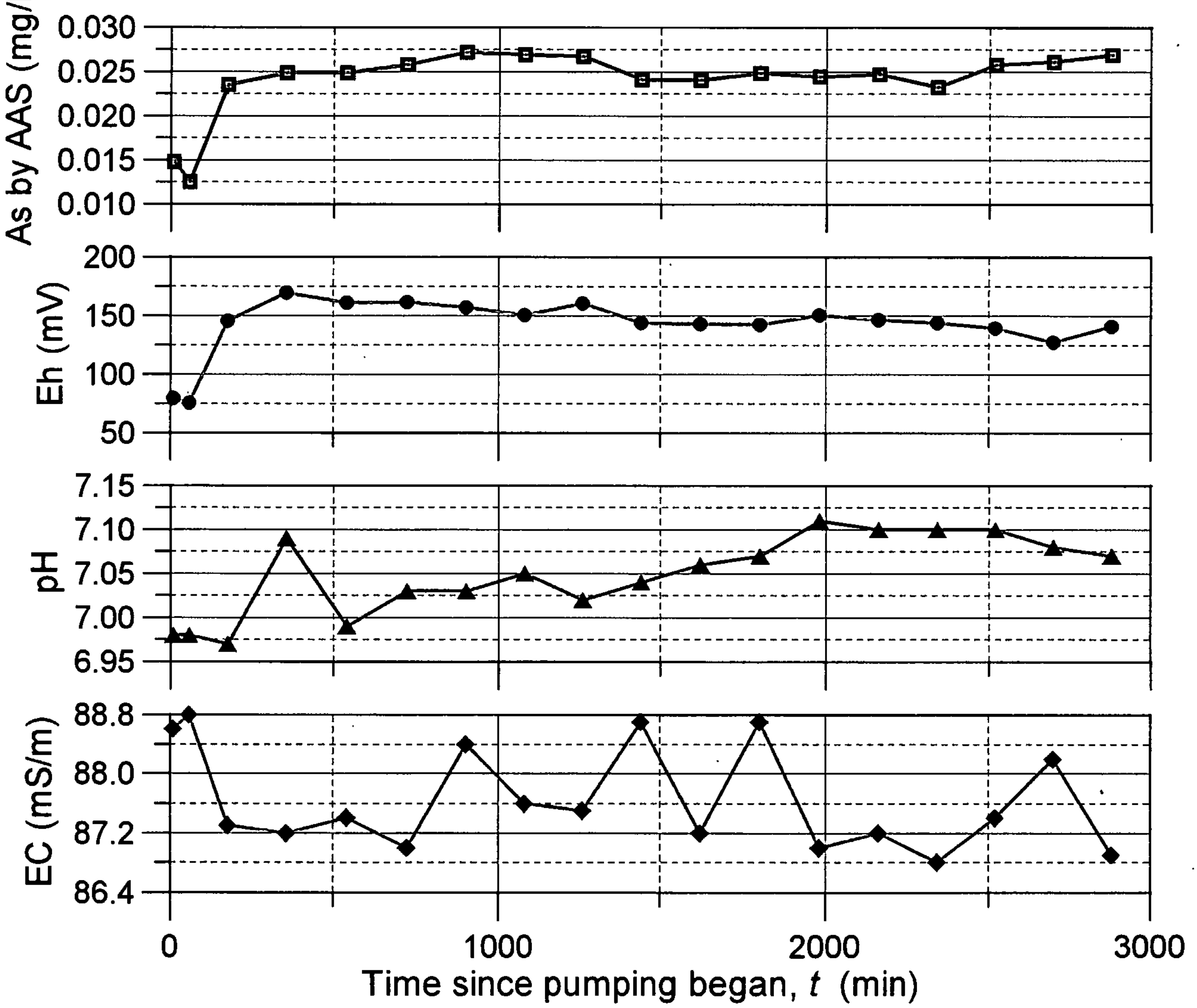
Changes in Water Quality during Continuous Pumping Test at CH-2 Site, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

Location:	Arabpur, Jhenaidah Pourashava
Site No.:	JH-1
Well No.:	Jh-1
Well Depth:	292.5 m
Well Diameter:	355.60 mm
Screen Depths:	251.5-289.0m
Screen Length:	19.5 m
SWL:	GL- 5.412 m on 18-04-2001

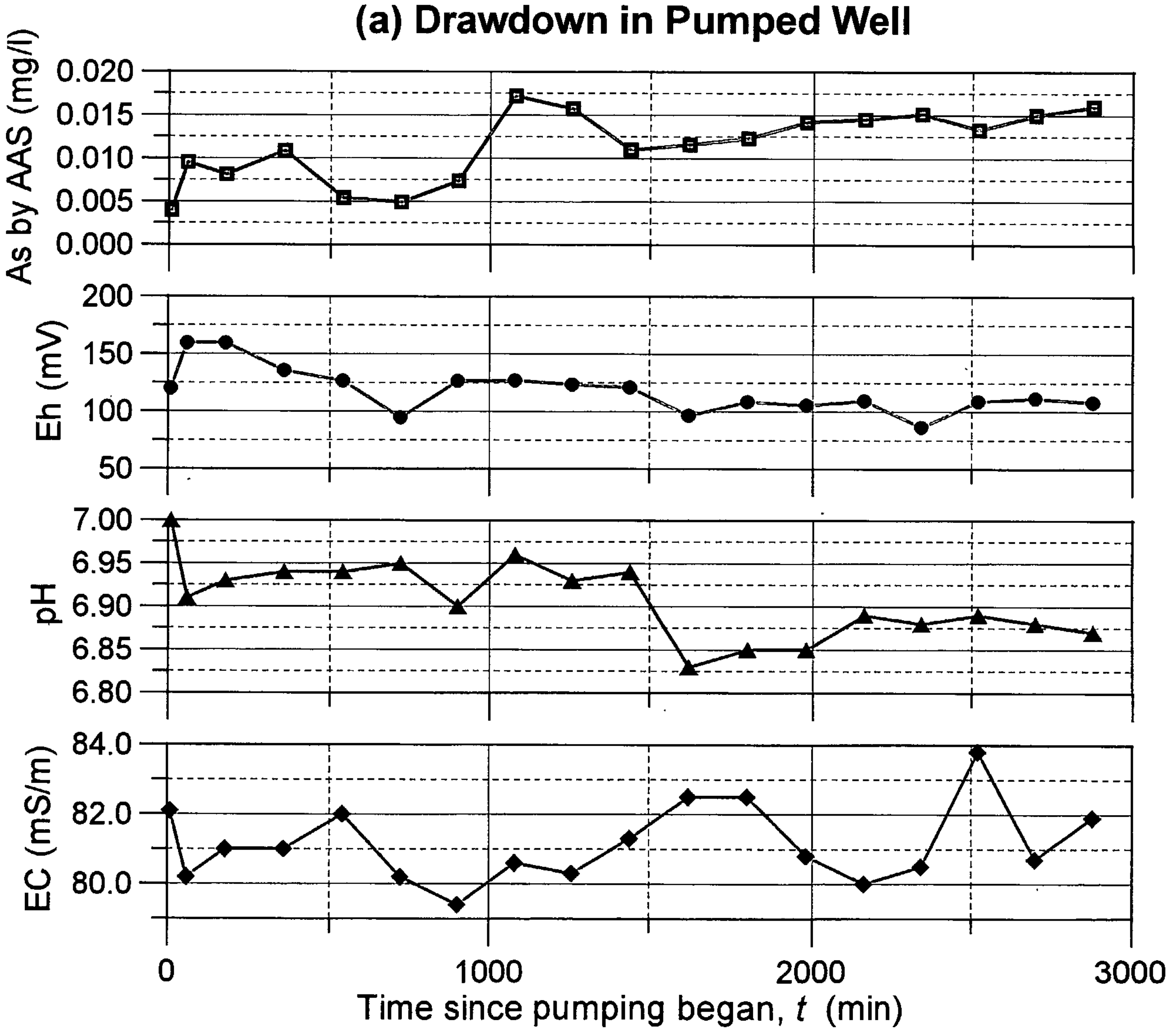
Figure 5.4.9

Changes in Water Quality during Continuous Pumping Test at JH-1 Site, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

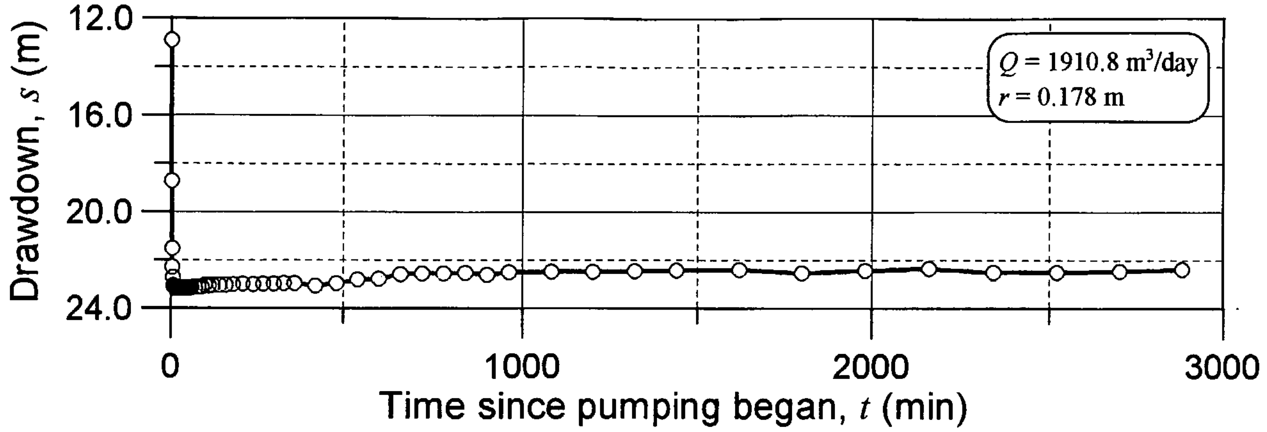
Location: Hamadh, Jhenaidah Pourashava
Site No.: JH-2
Well No.: Jh-2
Well Depth: 301.0 m
Well Diameter: 355.60 mm
Screen Depths: 257.5-298.0m
Screen Length: 19.5 m
SWL: GL- 5.660 m on 04-06-2001

Figure 5.4.10

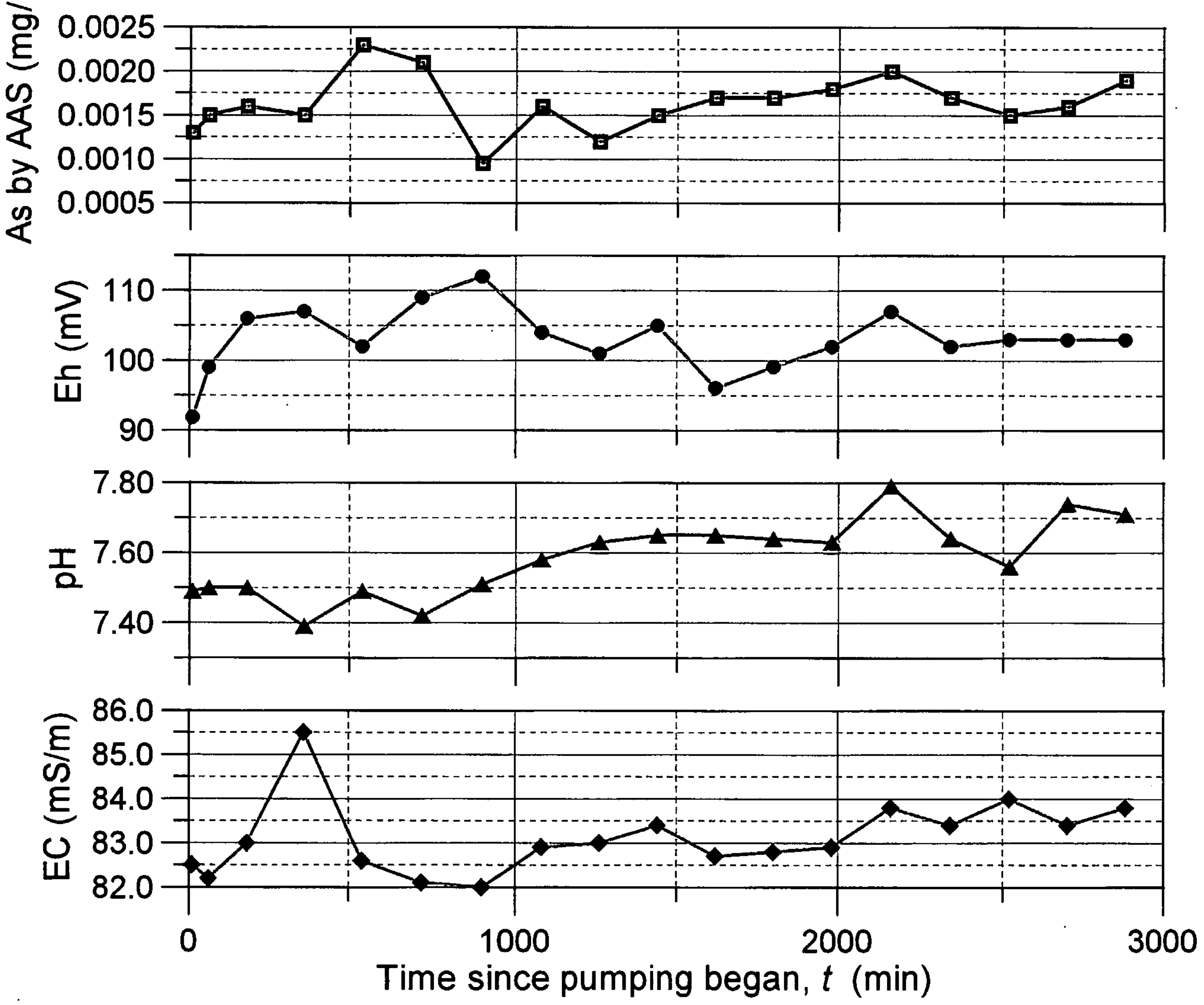
Changes in Water Quality during Continuous Pumping Test at JH-2 Site, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

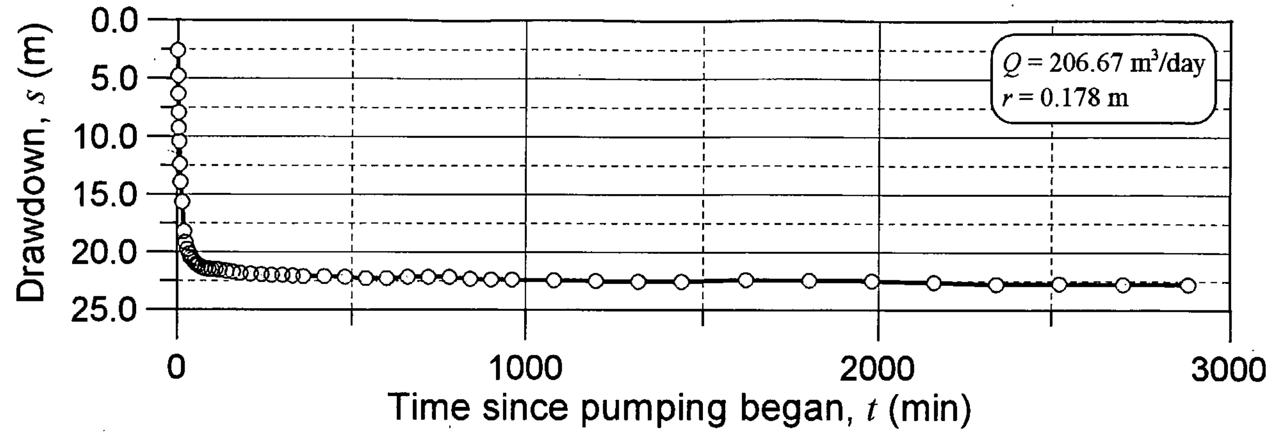
Location:	Ghop, Jessore Pourashava
Site No.:	JS-1
Well No.:	Js-1
Well Depth:	279.5 m
Well Diameter:	355.60 mm
Screen Depths:	260.5-273.5 m
Screen Length:	13.0 m
SWL:	GL- 4.159 m on 17-07-2001

Figure 5.4.11

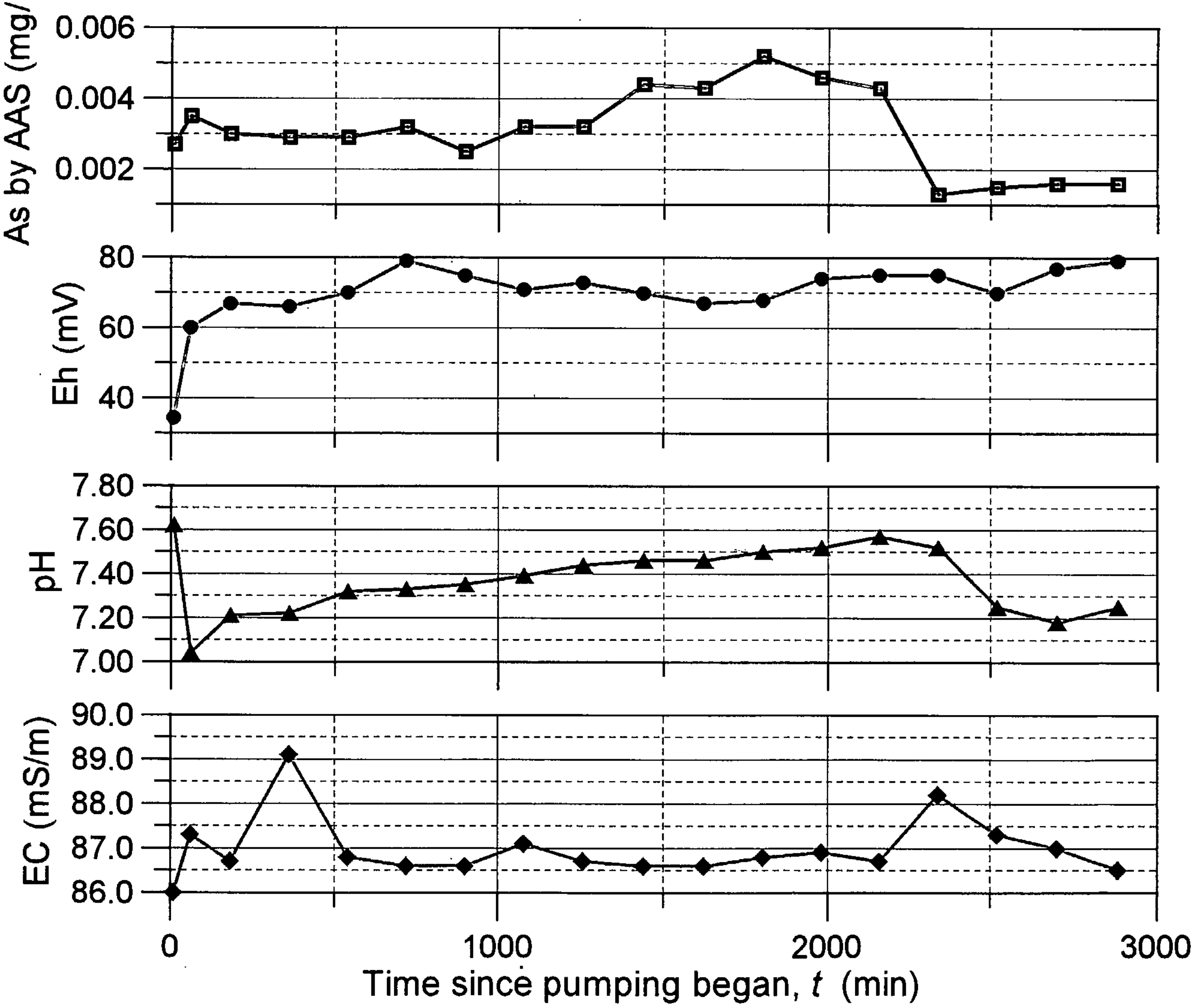
Changes in Water Quality during Continuous Pumping Test at JS-1 Site, Jessore

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Drawdown in Pumped Well



(b) Water Quality of Pumped Water

Location:	Kharki, Jessore Pourashava
Site No.:	JS-2
Well No.:	Js-2
Well Depth:.	261.75 m
Well Diameter:	355.60 mm
Screen Depths:	239.50-255.75 m
Screen Length:	16.25 m
SWL:	GL- 2.333 m on 03-08-2001

Figure 5.4.12

Changes in Water Quality during Continuous Pumping Test at JS-2 Site, Jessore

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

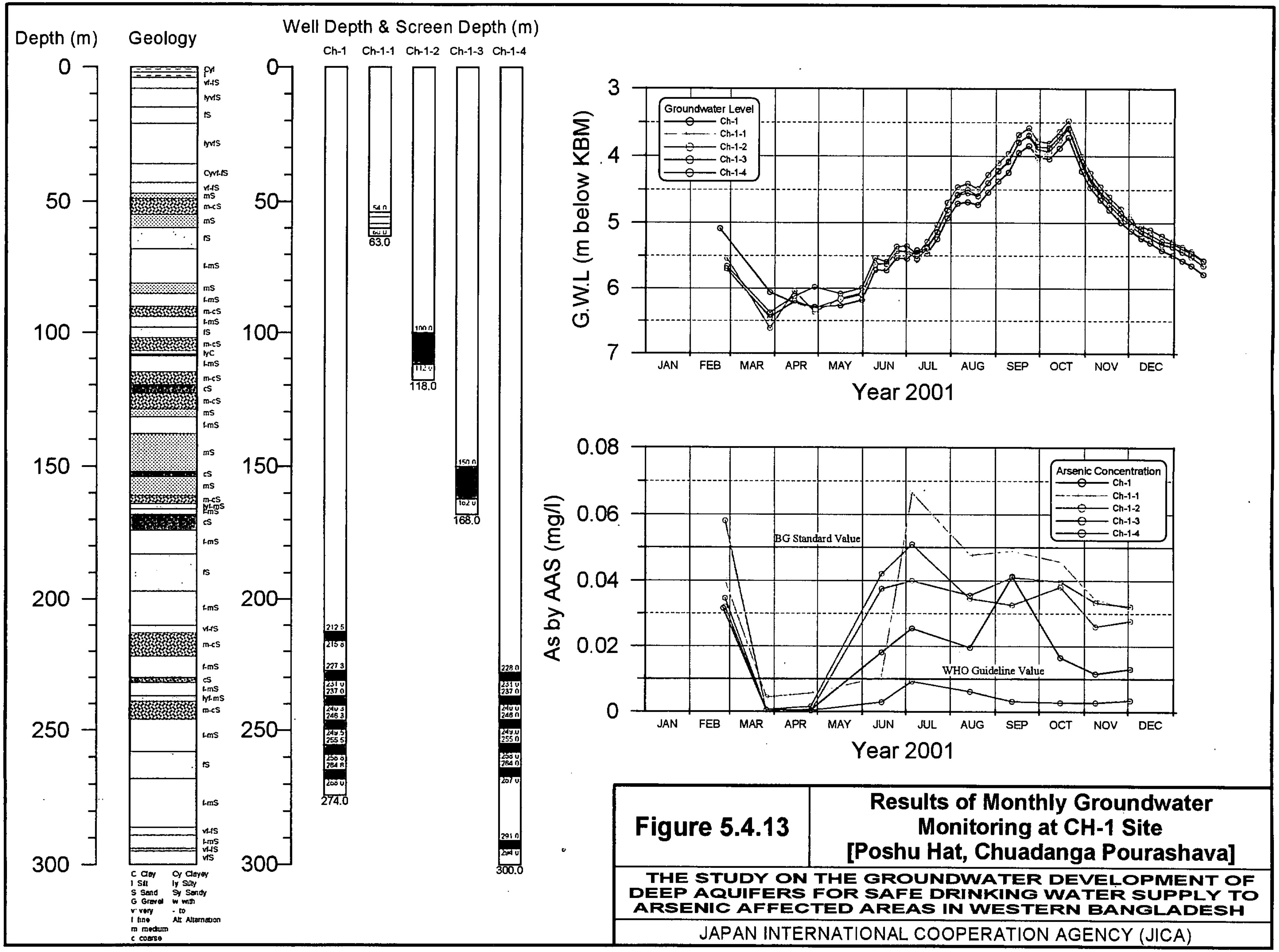
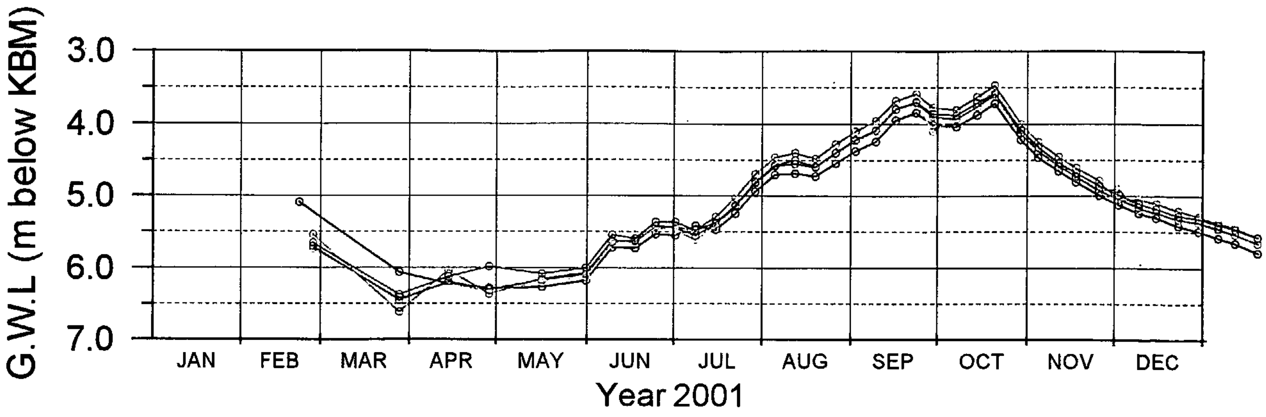


Figure 5.4.13

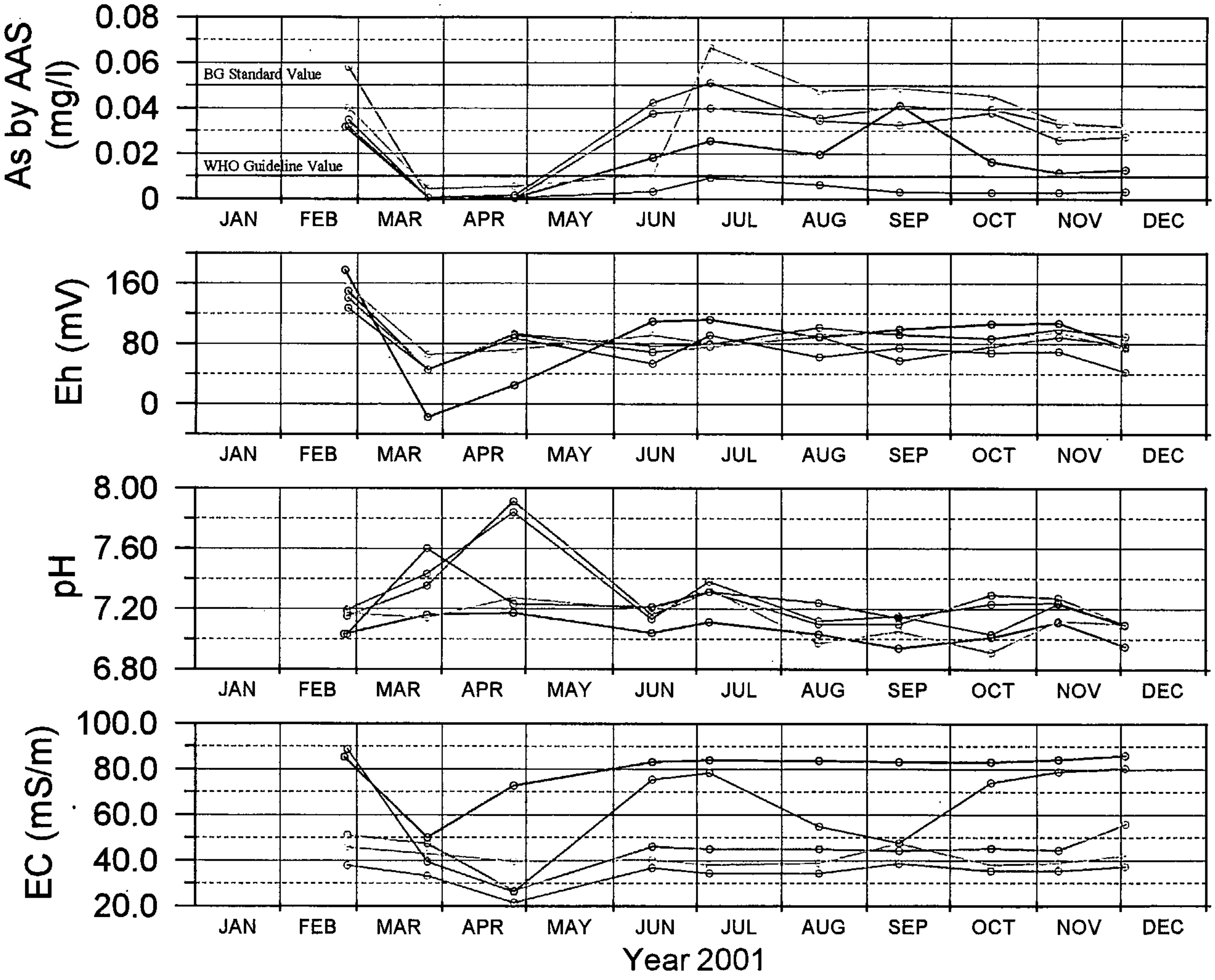
Results of Monthly Groundwater Monitoring at CH-1 Site [Poshu Hat, Chuadanga Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location:	Poshu Hat, Chuadanga Pourashava
Site No.:	CH-1

LEGEND
- Ch-1 (Depth = 274.0 m)
- Ch-1-1 (Depth = 63.0 m)
- Ch-1-2 (Depth = 118.0 m)
- Ch-1-3 (Depth = 168.0 m)
- Ch-1-4 (Depth = 300.0 m)

Figure 5.4.14

Changes in Groundwater Level and Groundwater Quality at CH-1 Site, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

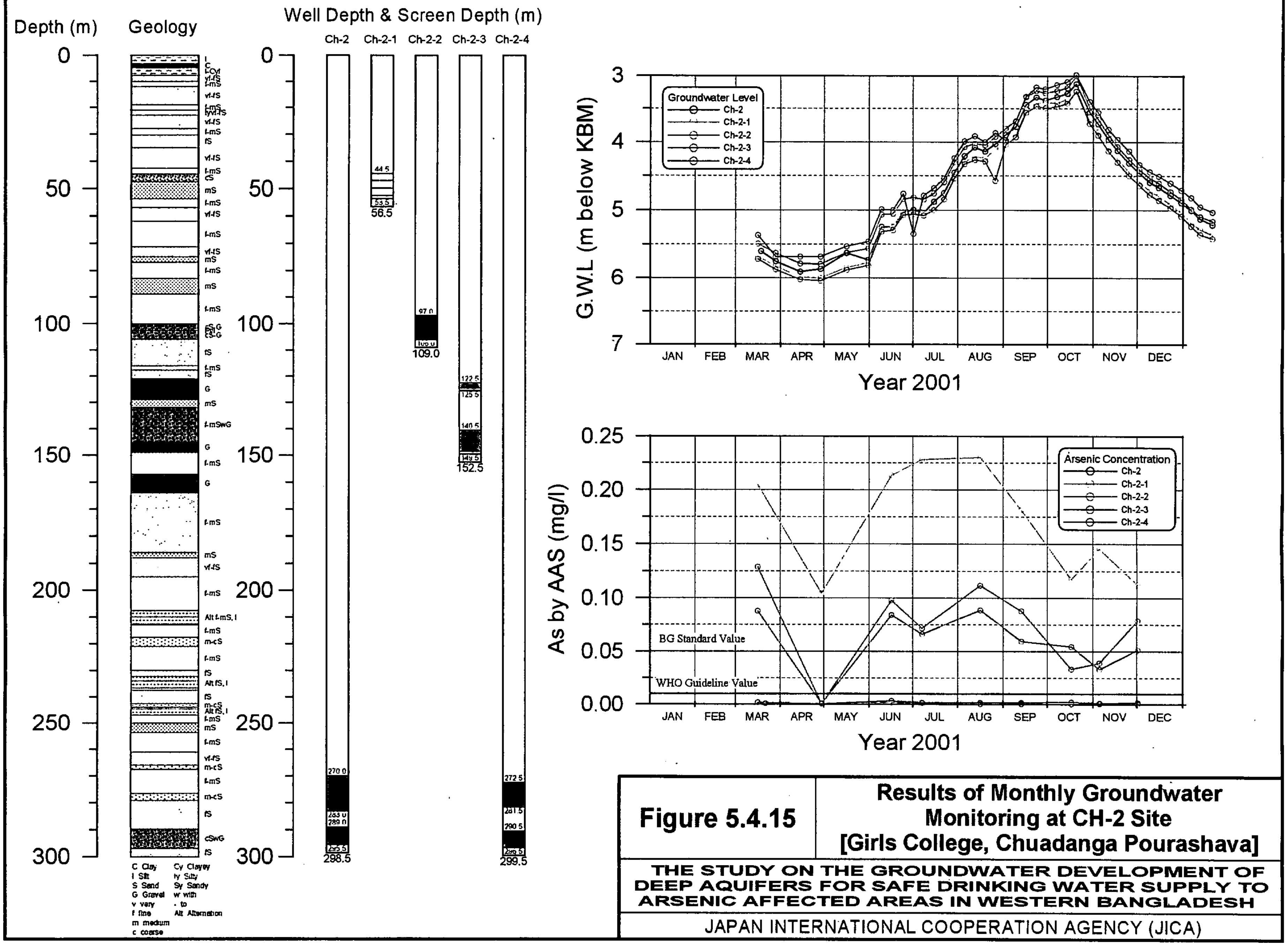
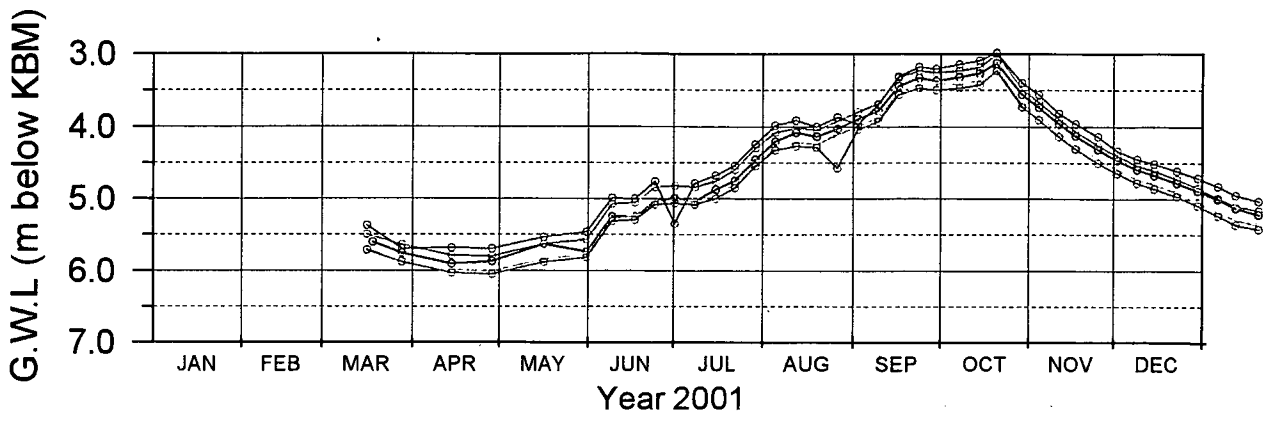


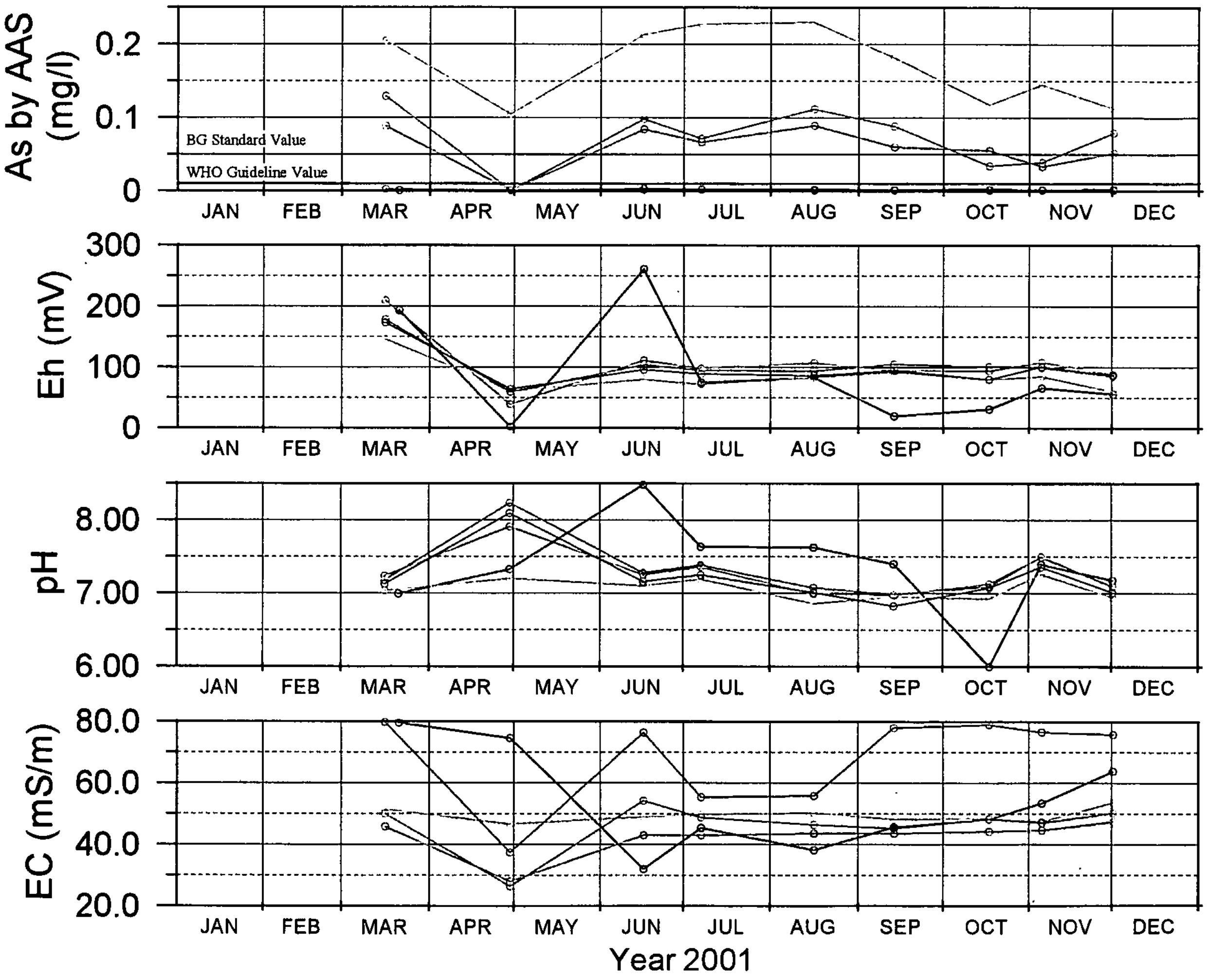
Figure 5.4.15	Results of Monthly Groundwater Monitoring at CH-2 Site [Girls College, Chuadanga Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location: Girls College, Chuadanga Pourashava
Site No.: CH-2

LEGEND
—○— Ch-2 (Depth = 298.5 m)
- - - Ch-2-1 (Depth = 56.5 m)
—○— Ch-2-2 (Depth = 109.0 m)
—○— Ch-2-3 (Depth = 152.5 m)
—○— Ch-2-4 (Depth = 299.5 m)

Figure 5.4.16

Changes in Groundwater Level and Groundwater Quality at CH-2 Site, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

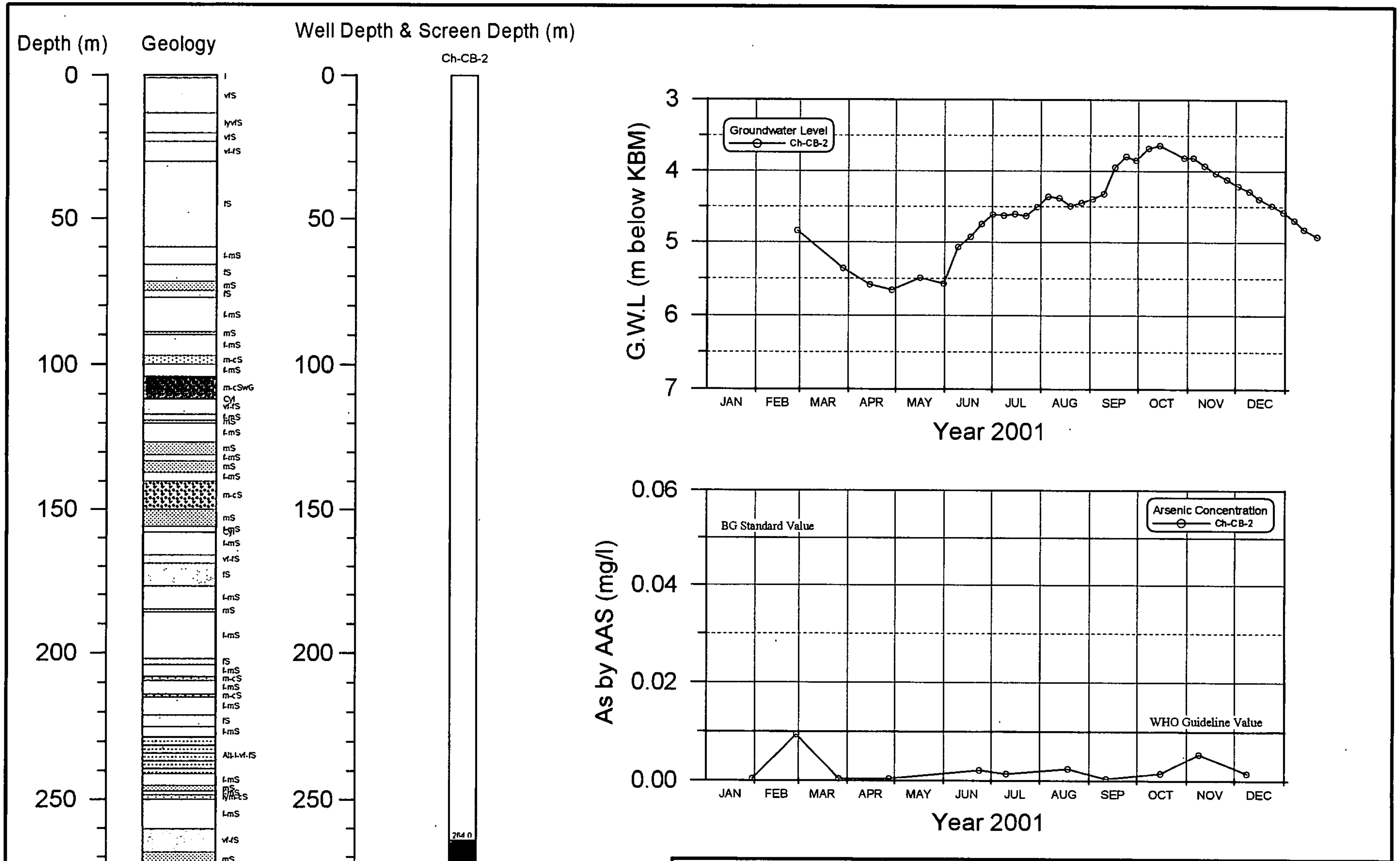
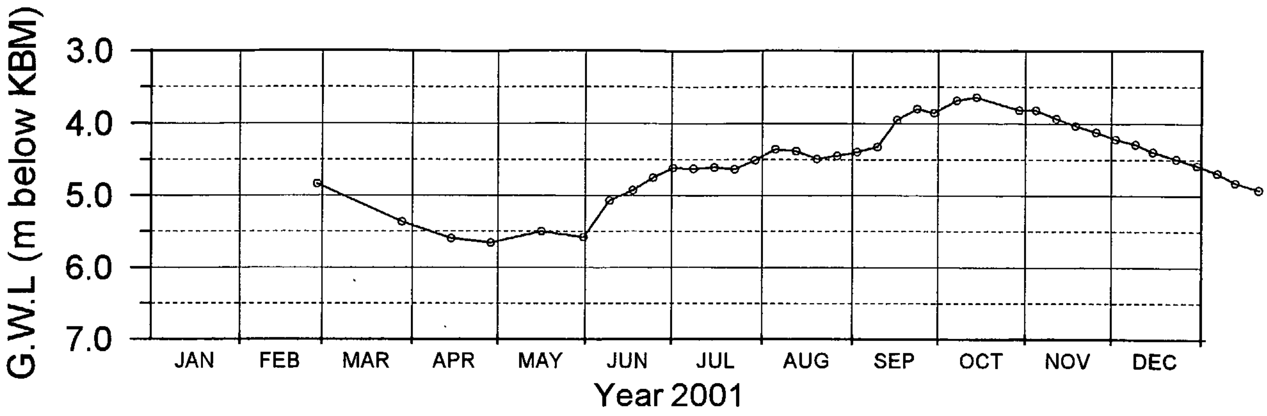


Figure 5.4.17

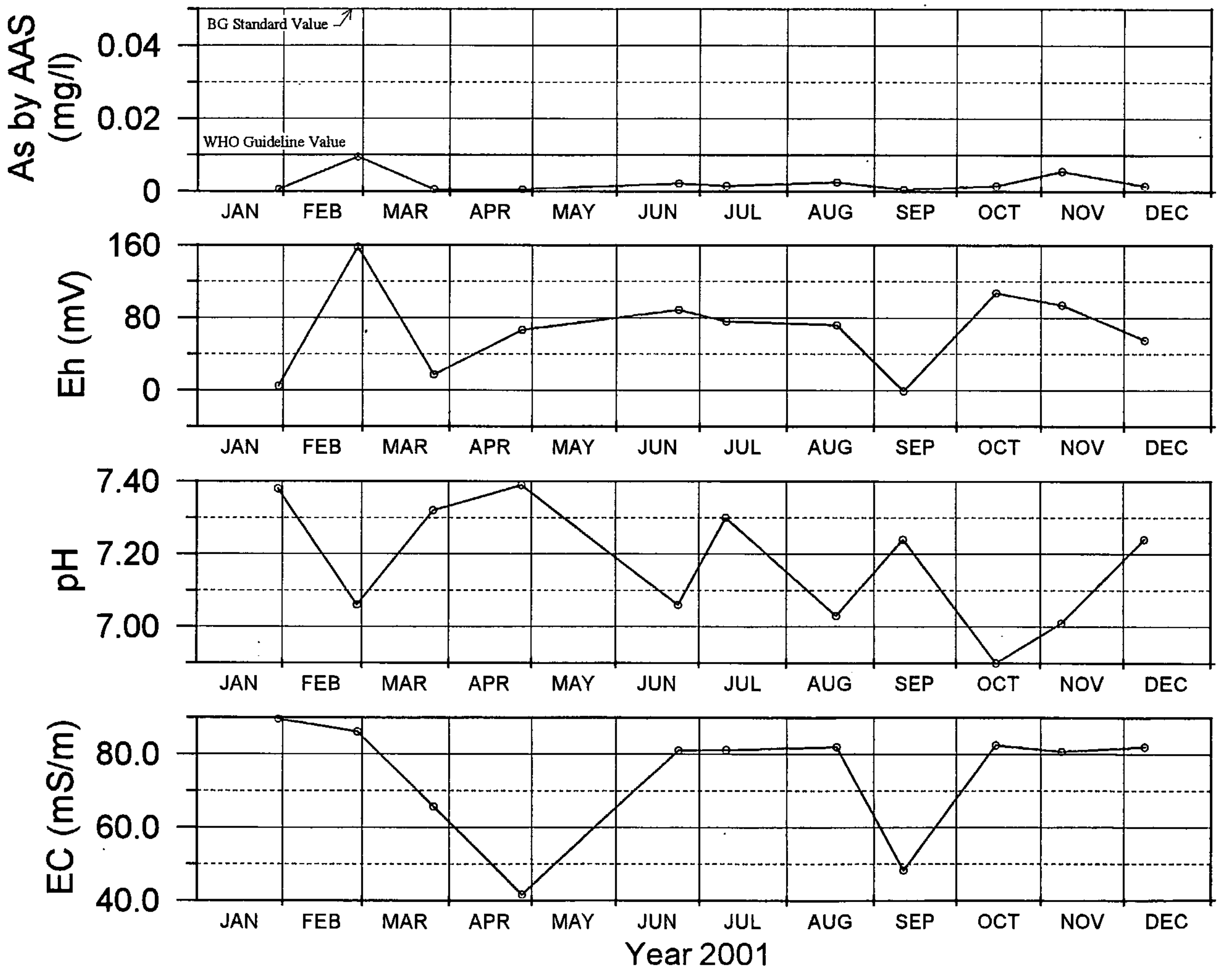
Results of Monthly Groundwater Monitoring at CH-BD Site [Bara Dudpatila, Damurhuda]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location:	Bara Dudpatila, Damurhuda Thana
Site No.:	CH-BD

LEGEND

—○— Ch-CB-2 (Depth = 300.0 m)

Figure 5.4.18

Changes in Groundwater Level and Groundwater Quality at CH-BD Site, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

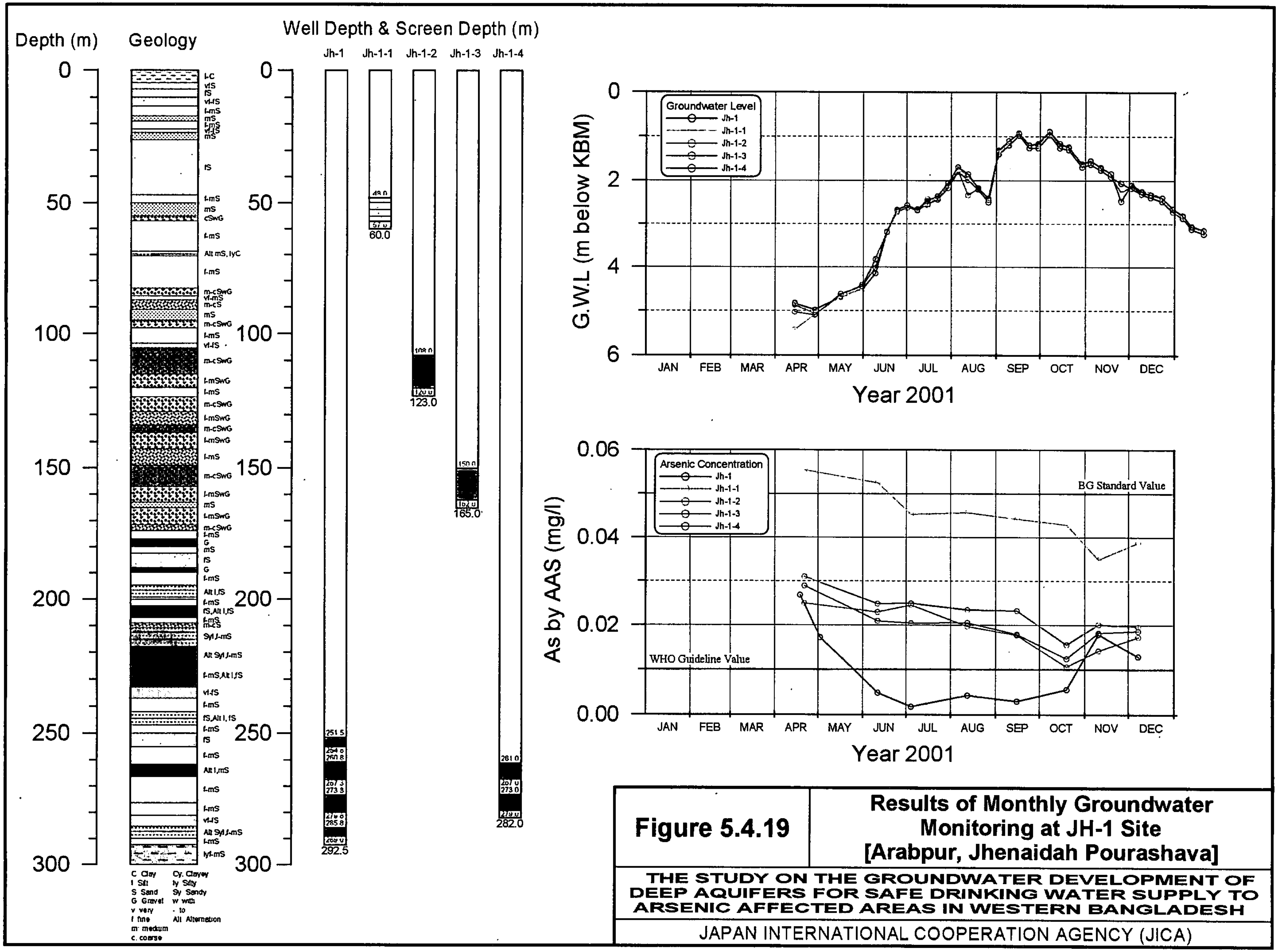
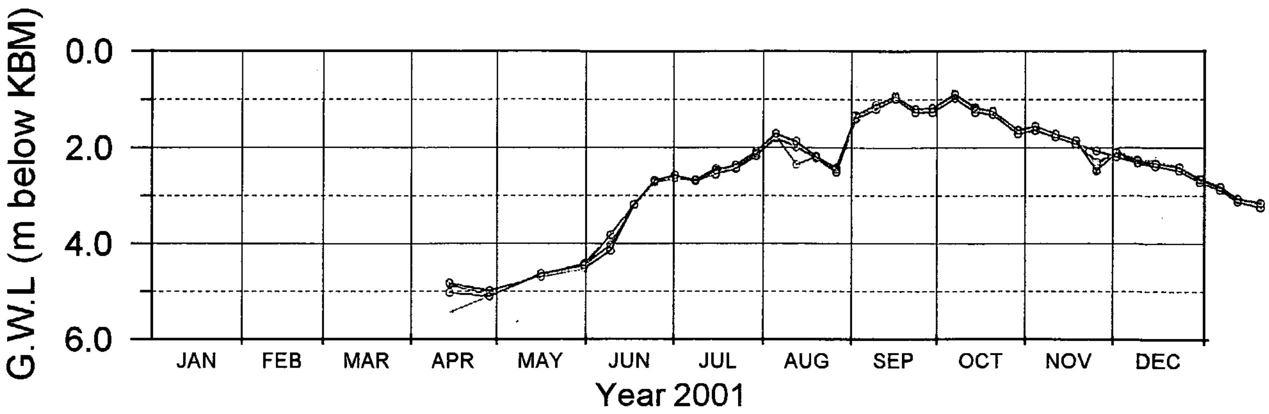


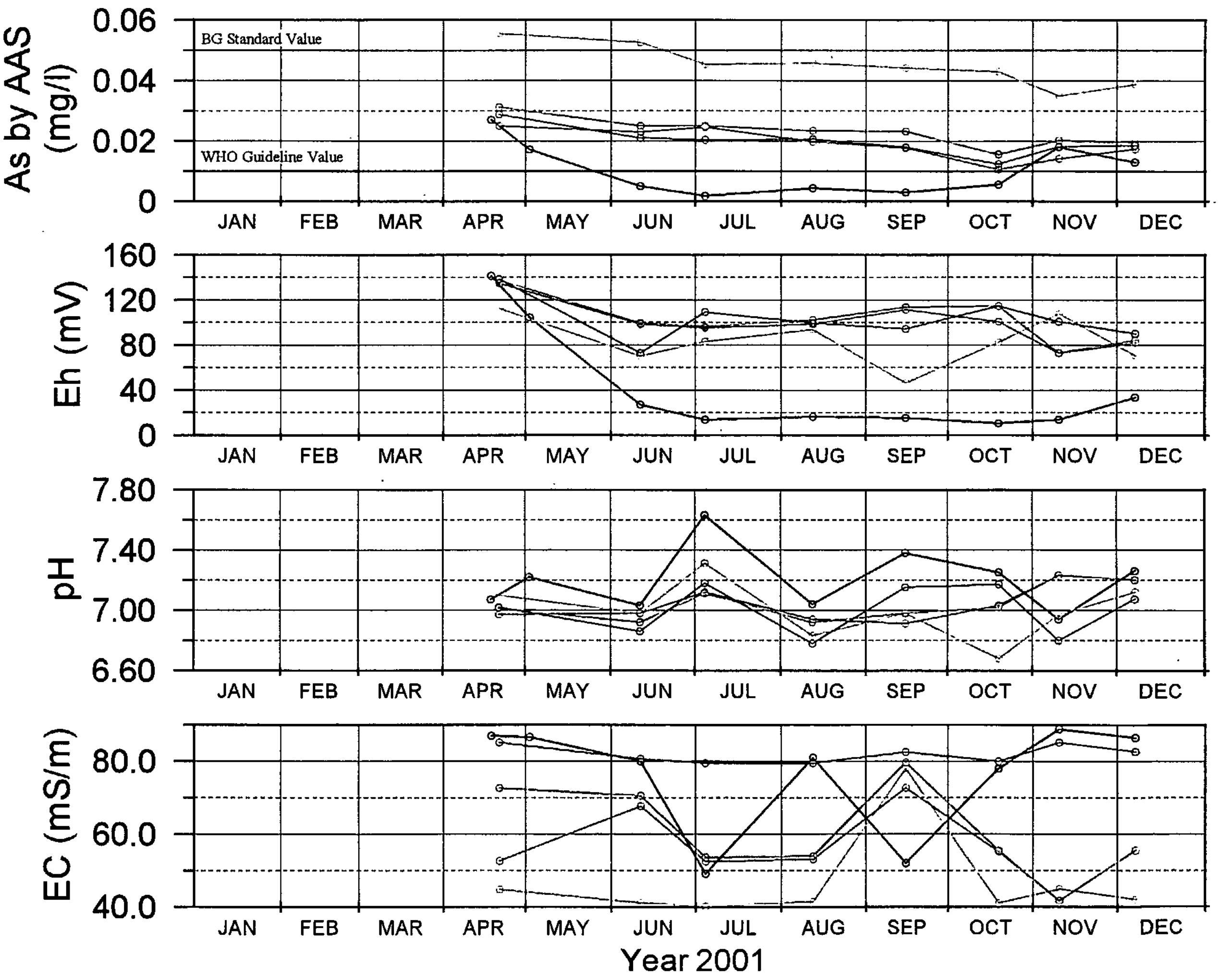
Figure 5.4.19	**Results of Monthly Groundwater Monitoring at JH-1 Site [Arabpur, Jhenaidah Pourashava]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location: Arabpur,
Jhenaidah Pourashava
Site No.: JH-1

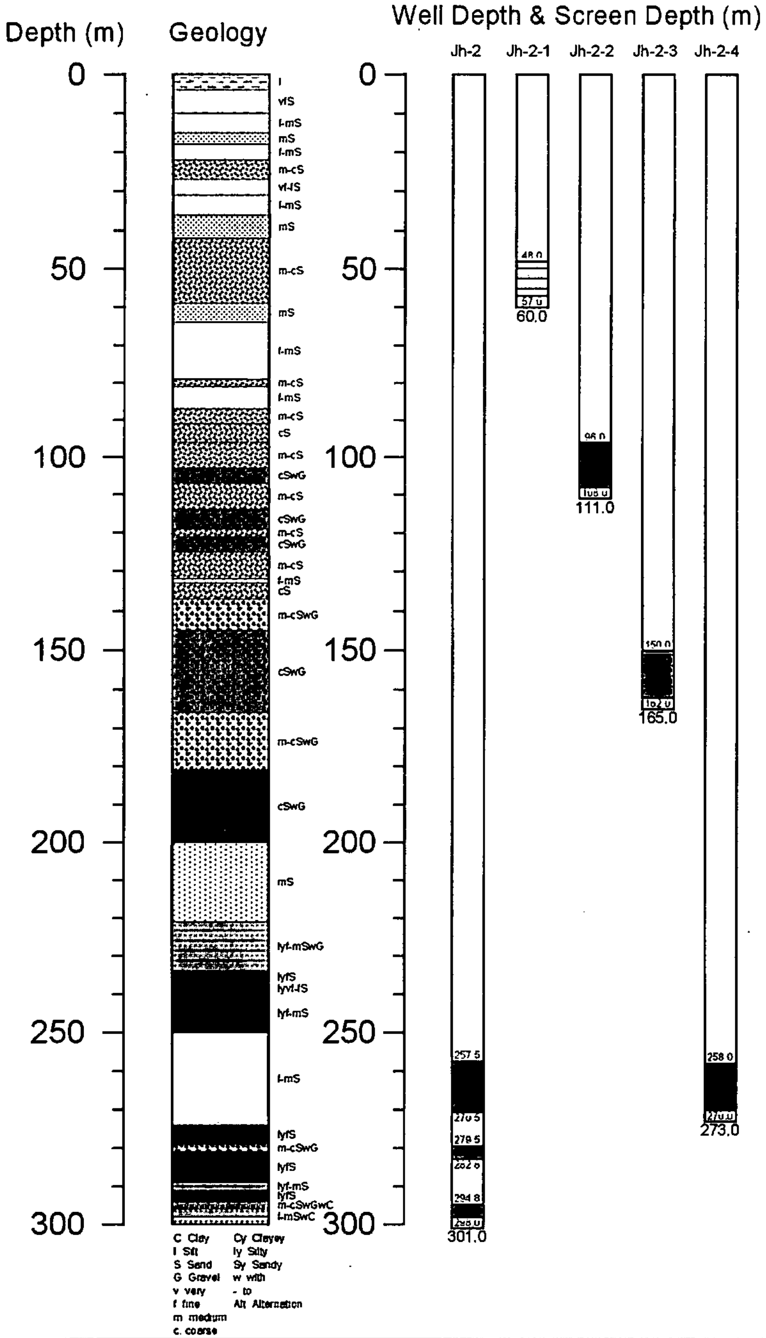
LEGEND
- Jh-1 (Depth = 292.5 m)
- Jh-1-1 (Depth = 60.0 m)
- Jh-1-2 (Depth = 123.0 m)
- Jh-1-3 (Depth = 165.0 m)
- Jh-1-4 (Depth = 282.0 m)

Figure 5.4.20

Changes in Groundwater Level and Groundwater Quality at JH-1 Site, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



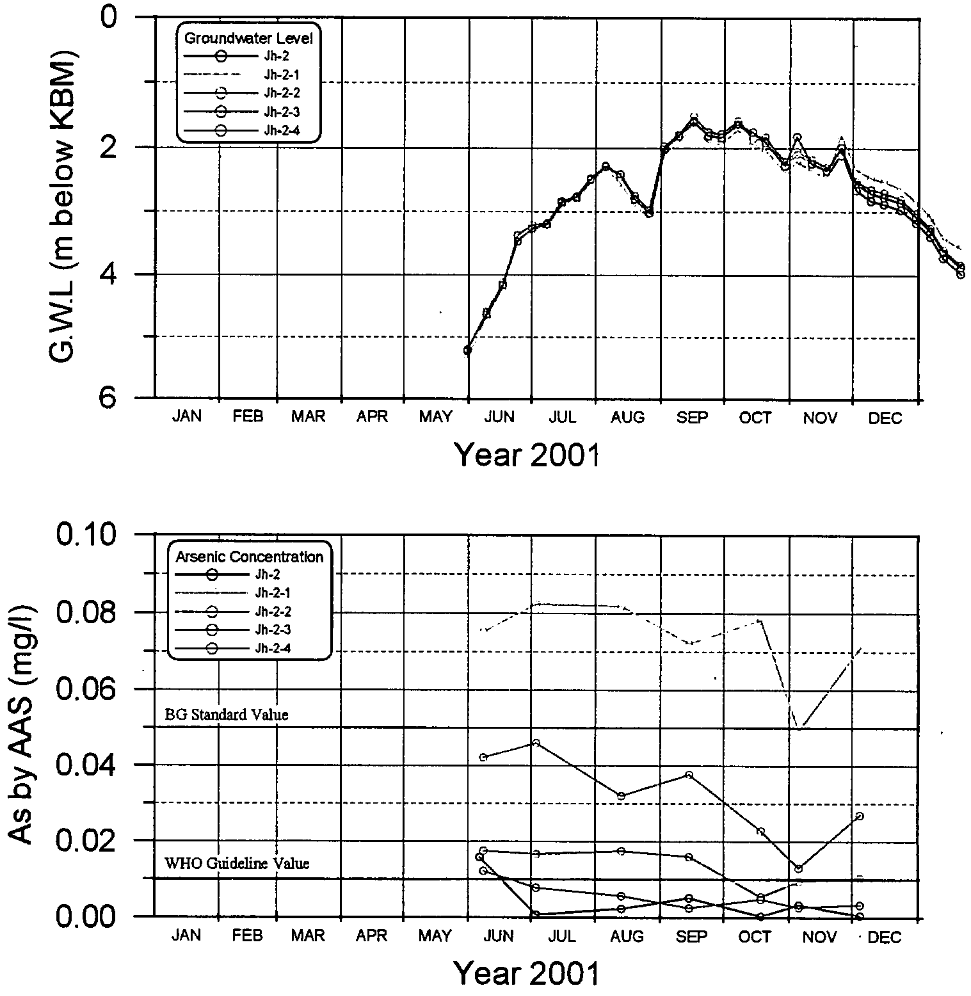
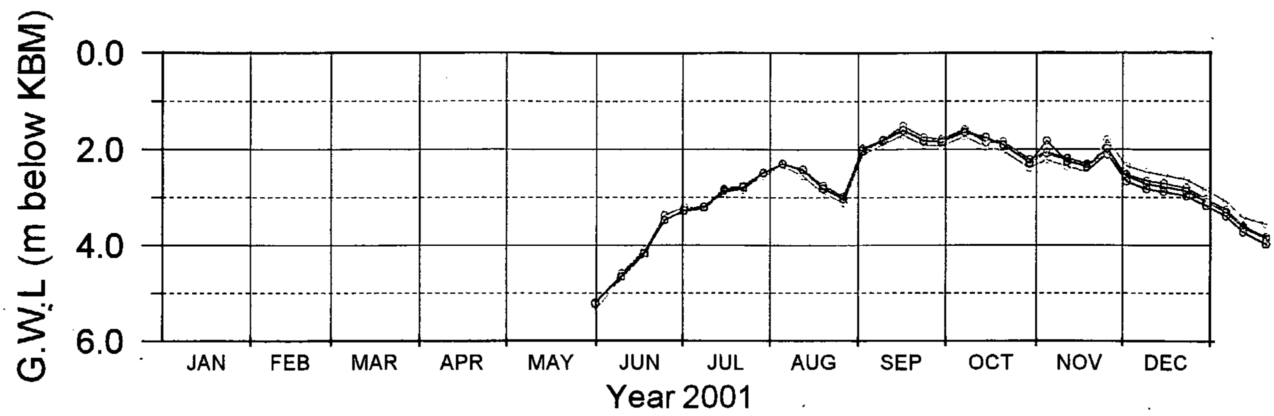


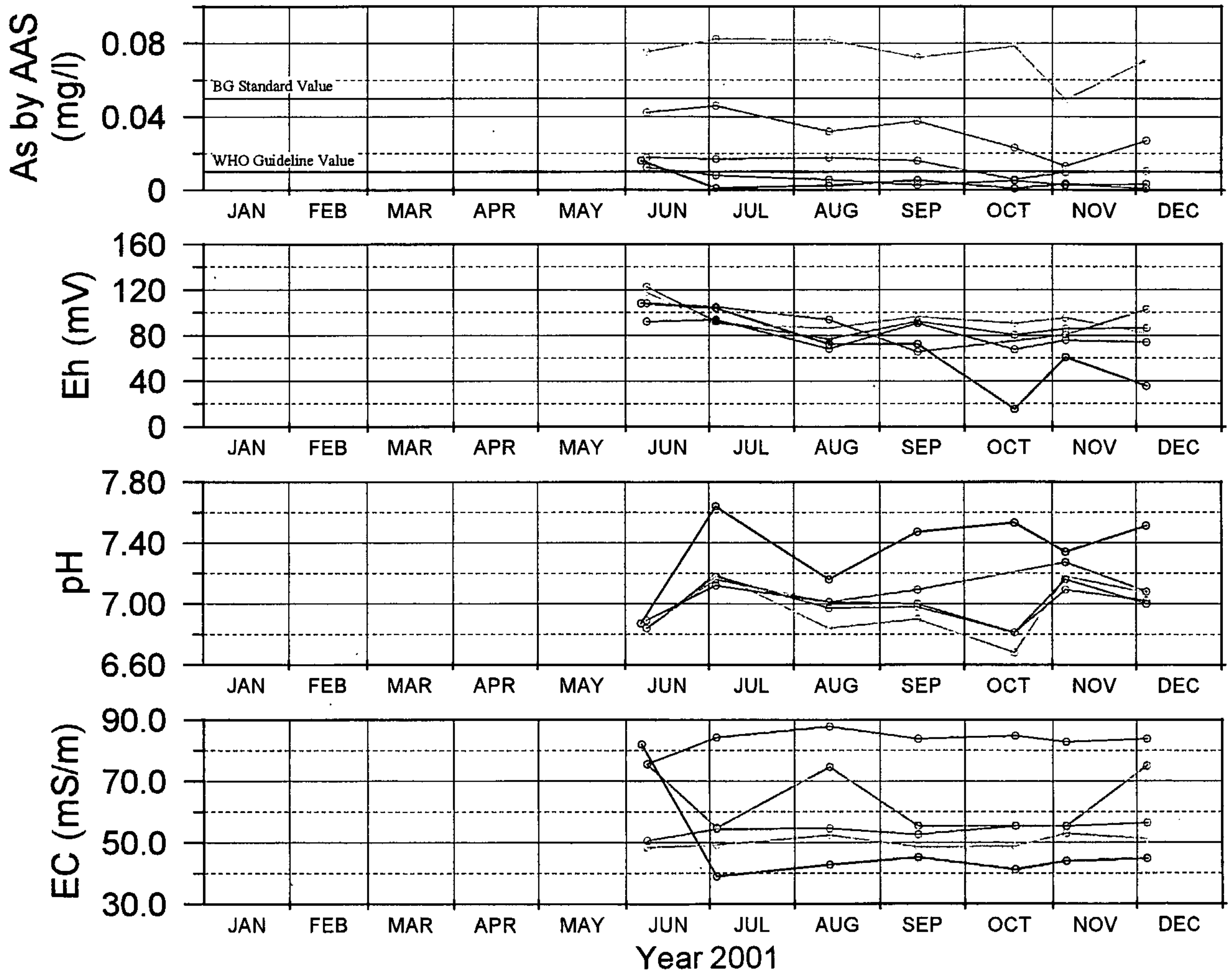
Figure 5.4.21	**Results of Monthly Groundwater Monitoring at JH-2 Site [Hamdah, Jhenaidah Pourashava]**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location: Hamdah, Jhenaidah Pourashava

Site No.: JH-2

LEGEND
- —⊖— Jh-2 (Depth = 301.0 m)
- - - - Jh-2-1 (Depth = 60.0 m)
- —⊖— Jh-2-2 (Depth = 111.0 m)
- —⊖— Jh-2-3 (Depth = 165.0 m)
- —⊖— Jh-2-4 (Depth = 273.0 m)

Figure 5.4.22

Changes in Groundwater Level and Groundwater Quality at JH-2 Site, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

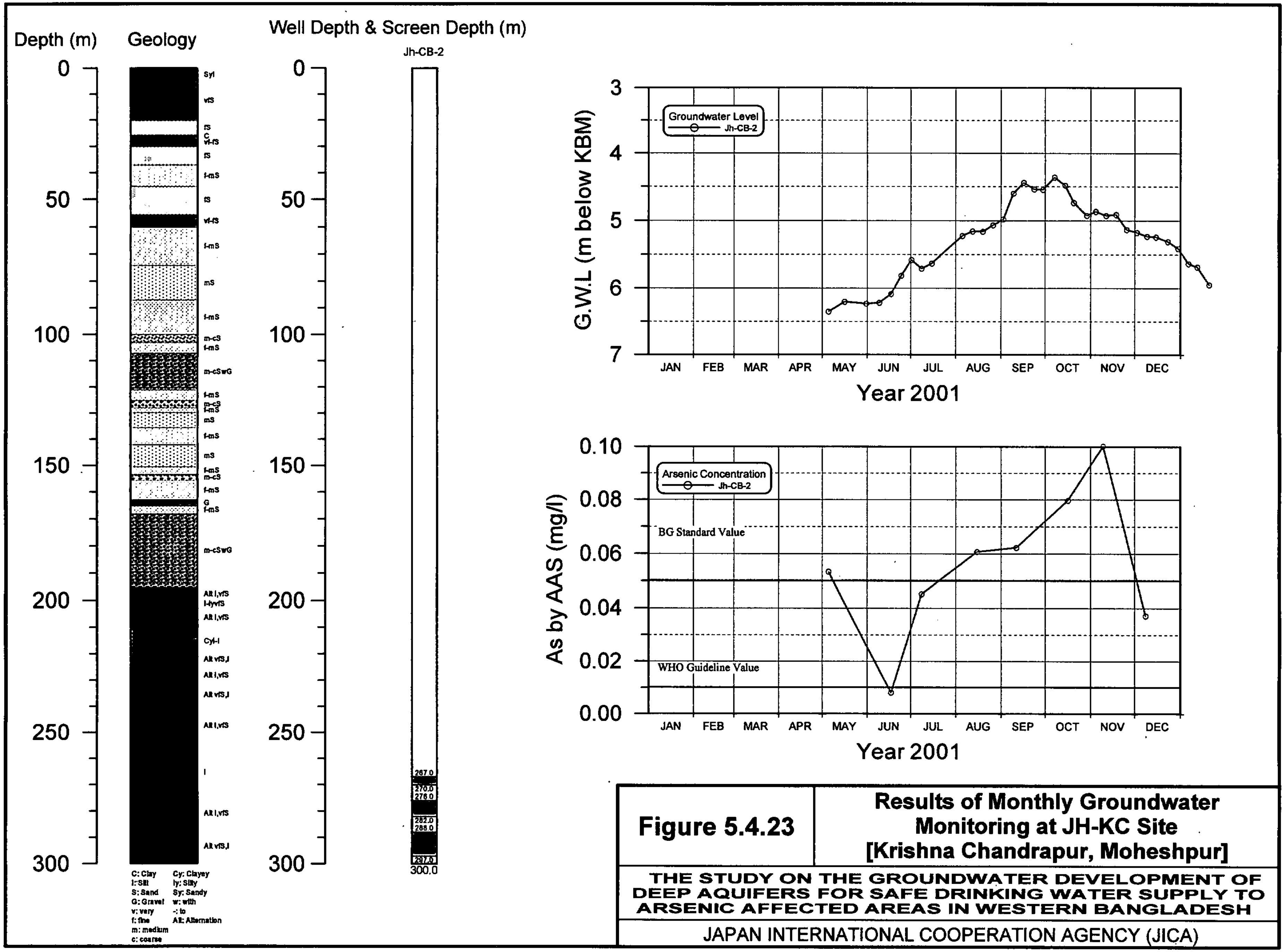
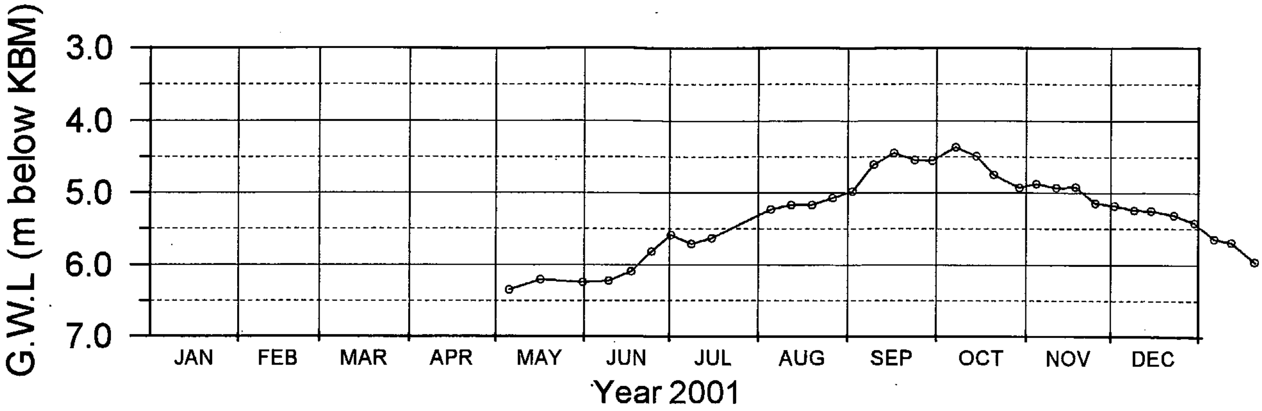


Figure 5.4.23

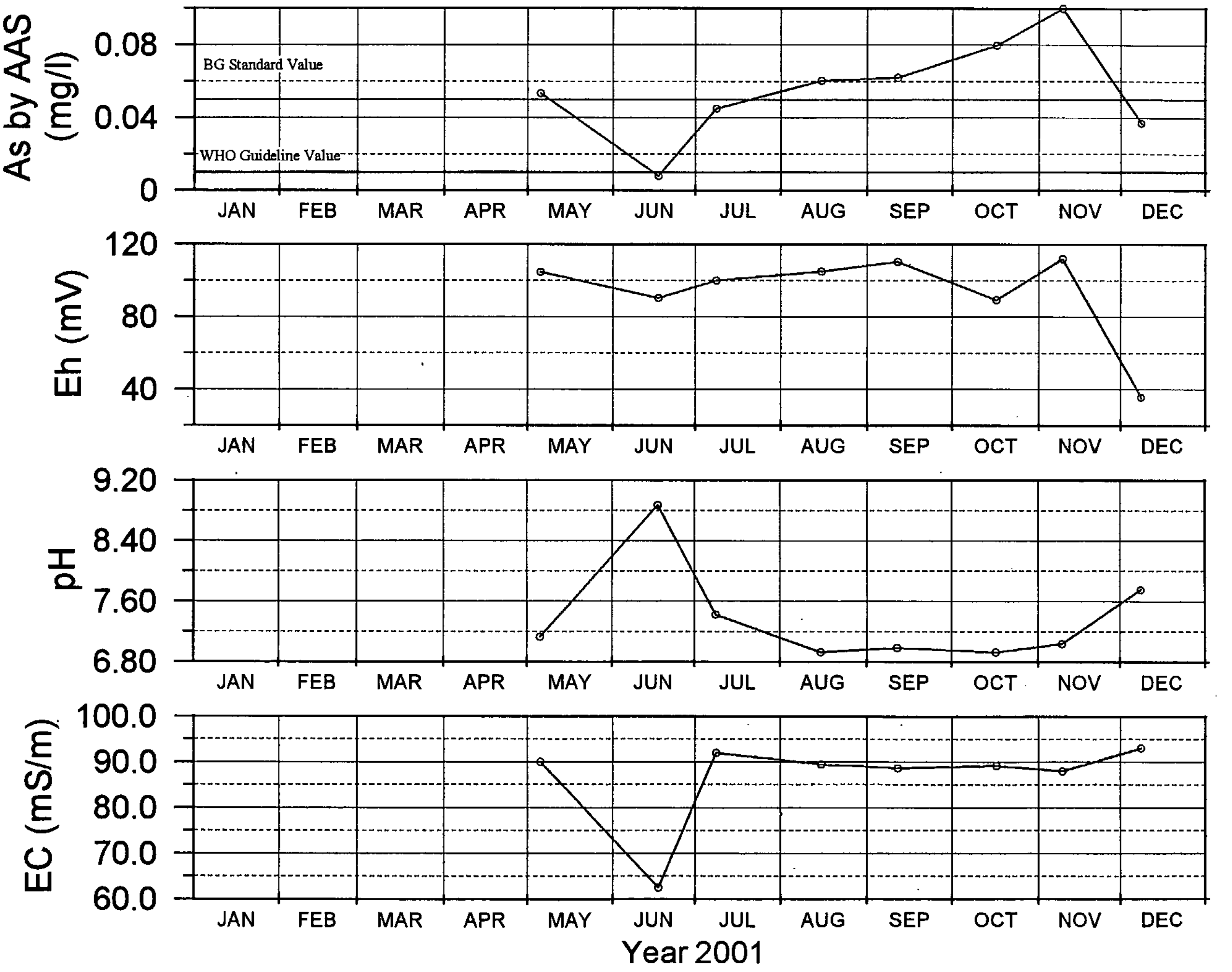
Results of Monthly Groundwater Monitoring at JH-KC Site [Krishna Chandrapur, Moheshpur]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location:	Krishna Chandrapur, Moheshpur Thana
Site No.:	JH-KC

LEGEND

—○— Jh-CB-2 (Depth = 300.0 m)

Figure 5.4.24

Changes in Groundwater Level and Groundwater Quality at JH-KC Site, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

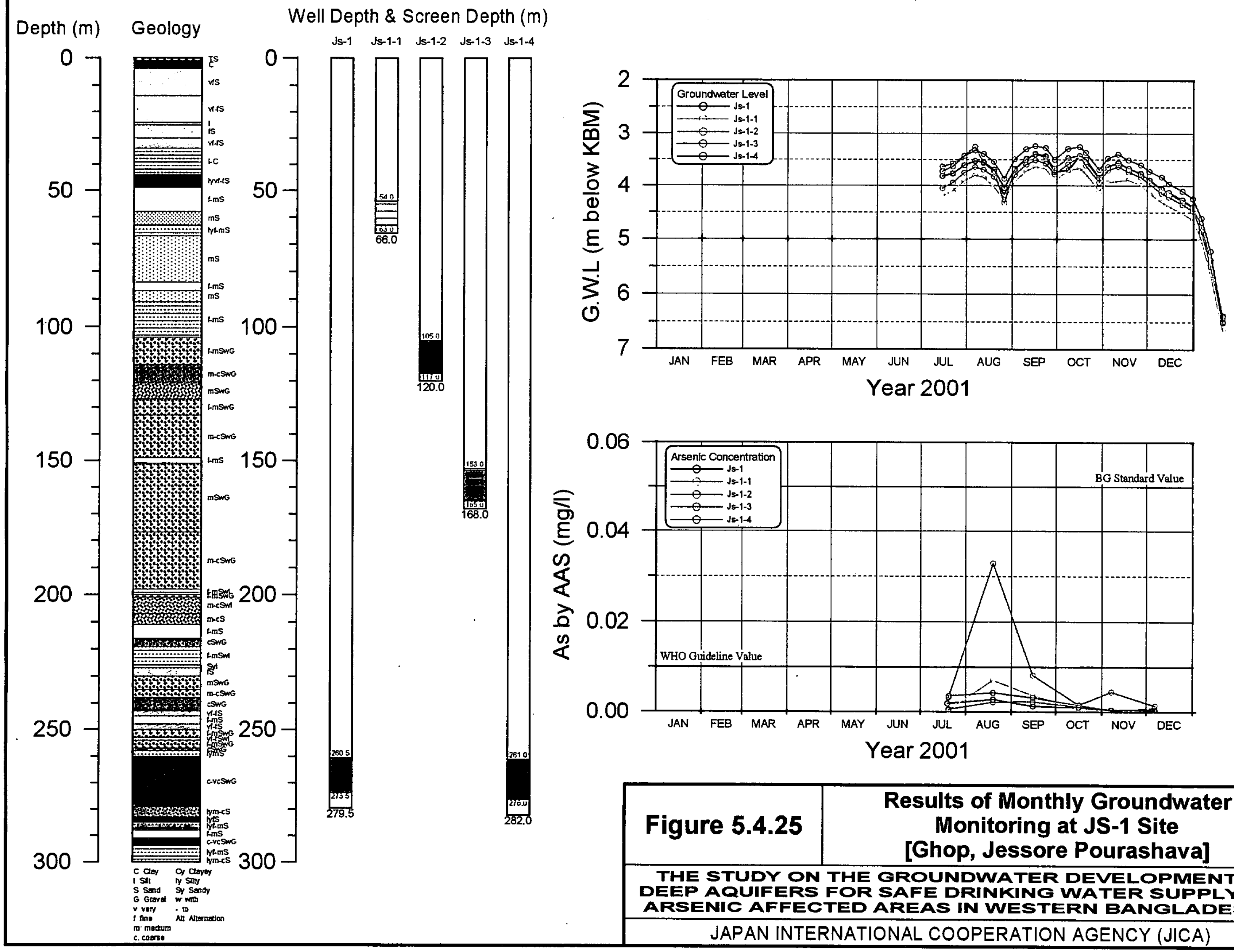
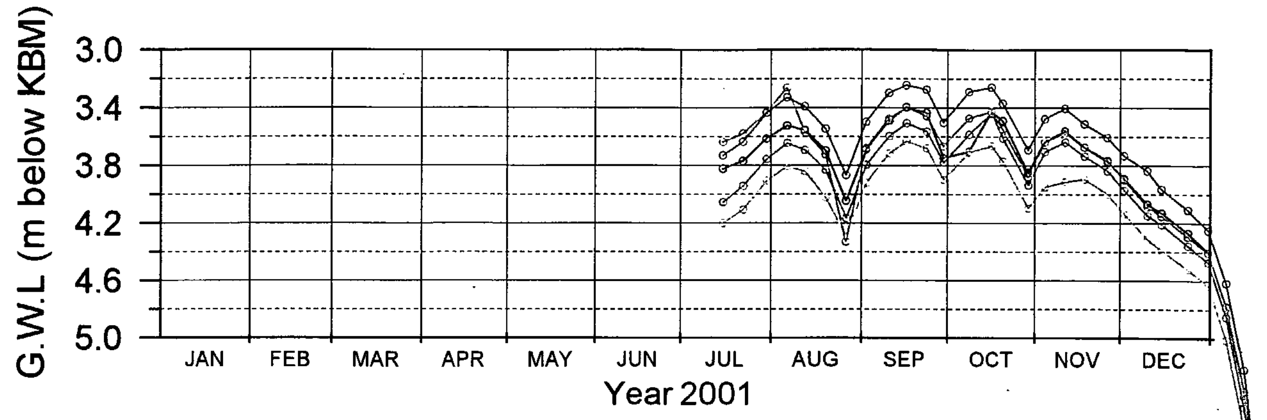


Figure 5.4.25

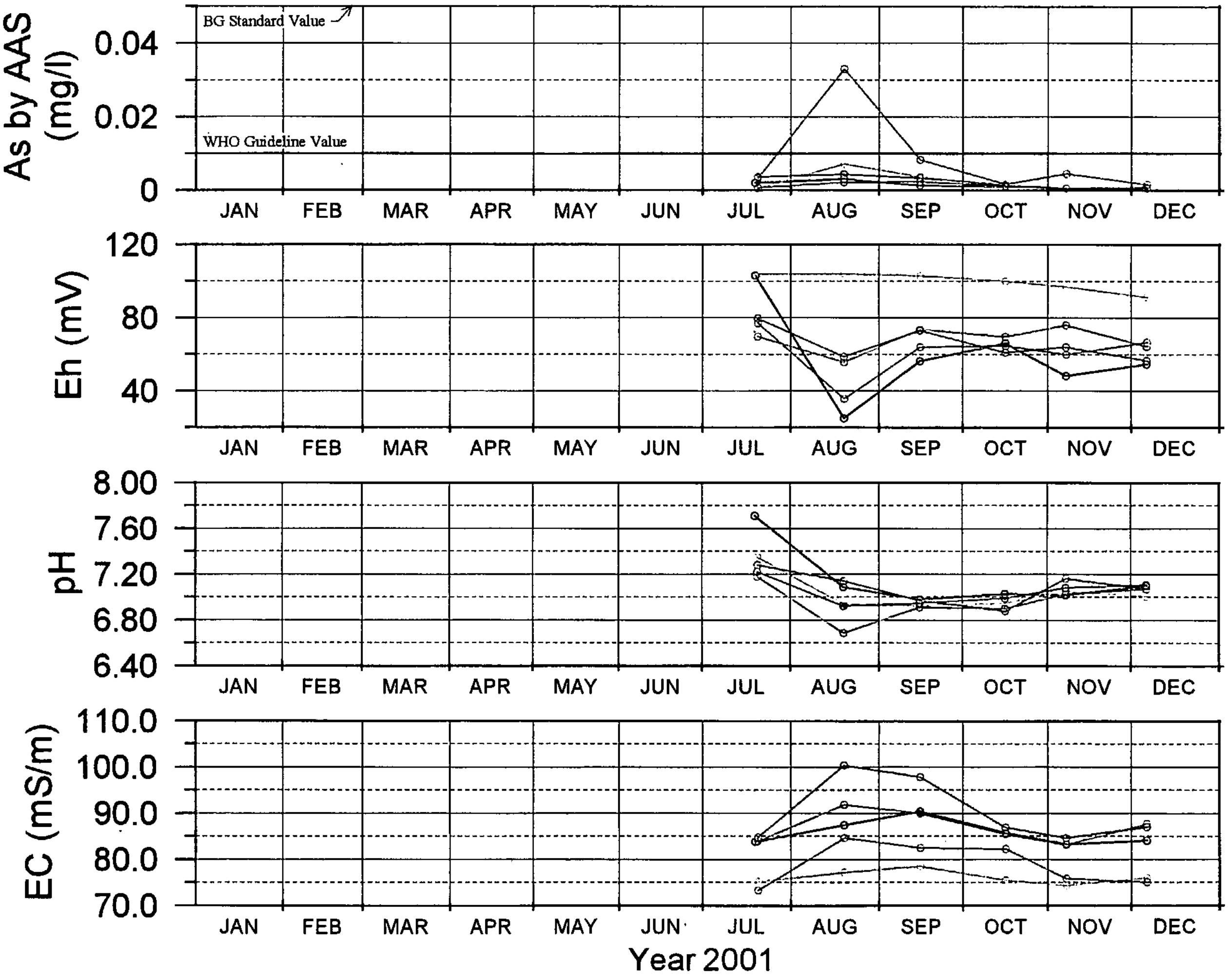
Results of Monthly Groundwater Monitoring at JS-1 Site [Ghop, Jessore Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location: Ghop, Jessore Pourashava
Site No.: JS-1

LEGEND
- Js-1 (Depth = 279.5 m)
- Js-1-1 (Depth = 66.0 m)
- Js-1-2 (Depth = 120.0 m)
- Js-1-3 (Depth = 168.0 m)
- Js-1-4 (Depth = 282.0 m)

Figure 5.4.26

Changes in Groundwater Level and Groundwater Quality at JS-1 Site, Jessore

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

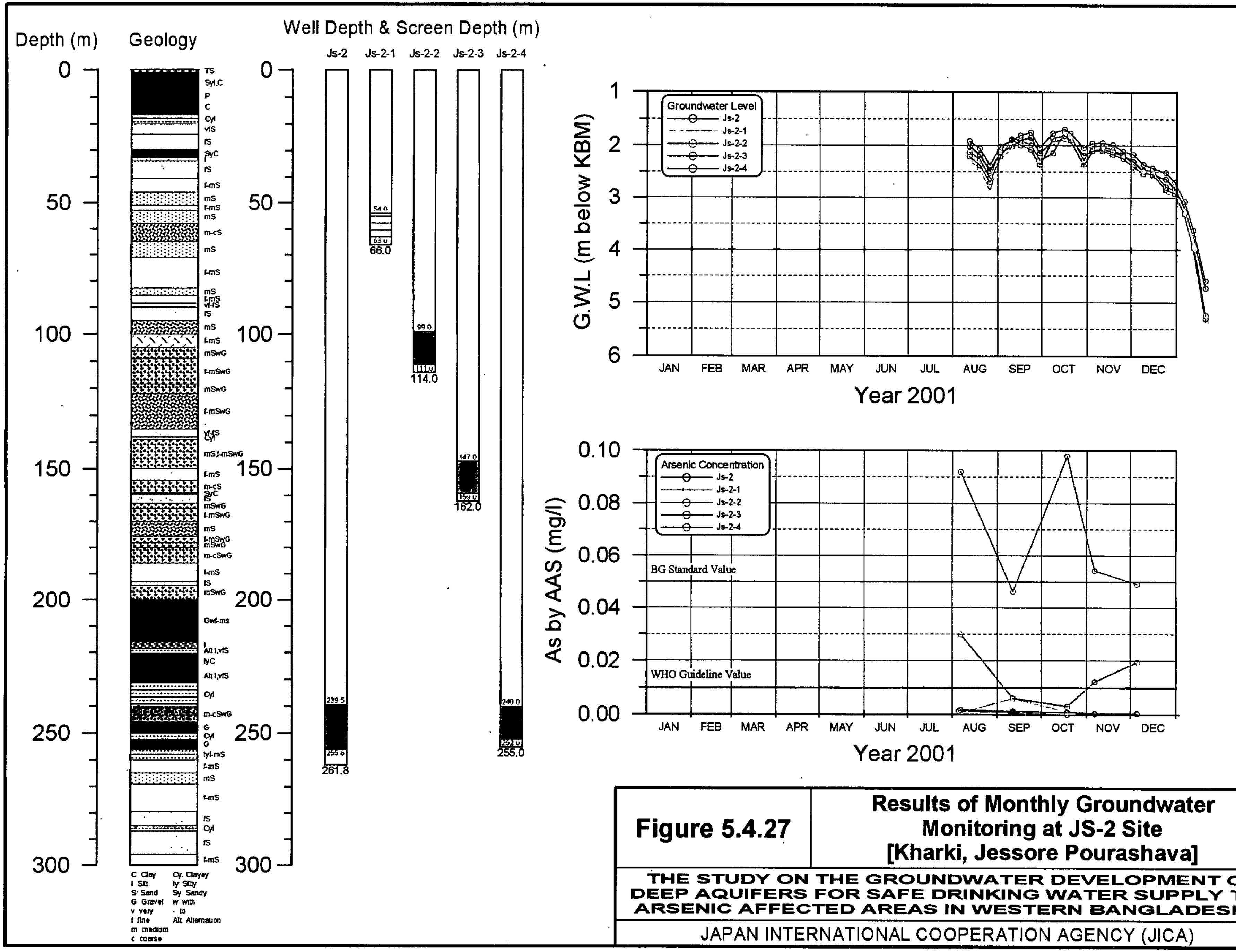
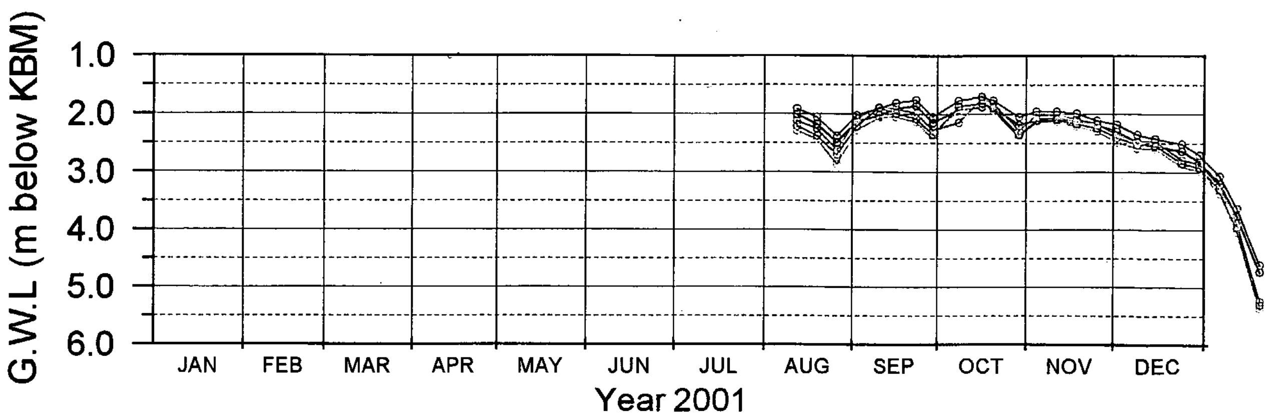


Figure 5.4.27

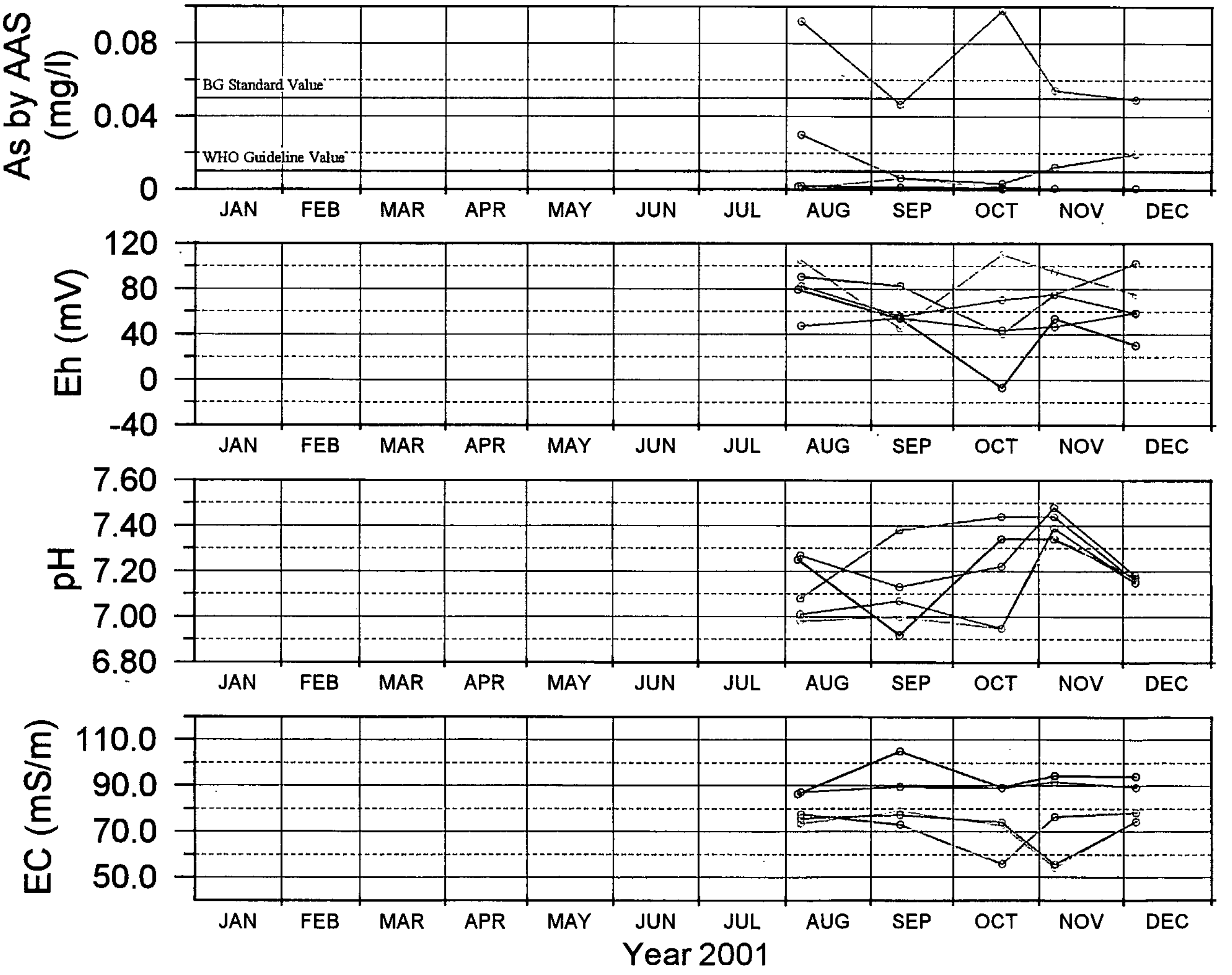
Results of Monthly Groundwater Monitoring at JS-2 Site [Kharki, Jessore Pourashava]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location: Kharki,
Jessore Pourashava
Site No.: JS-2

LEGEND
- Js-2 (Depth = 261.8 m)
- Js-2-1 (Depth = 66.0 m)
- Js-2-2 (Depth = 114.0 m)
- Js-2-3 (Depth = 162.0 m)
- Js-2-4 (Depth = 255.0 m)

Figure 5.4.28

Changes in Groundwater Level and Groundwater Quality at JS-2 Site, Jessore

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

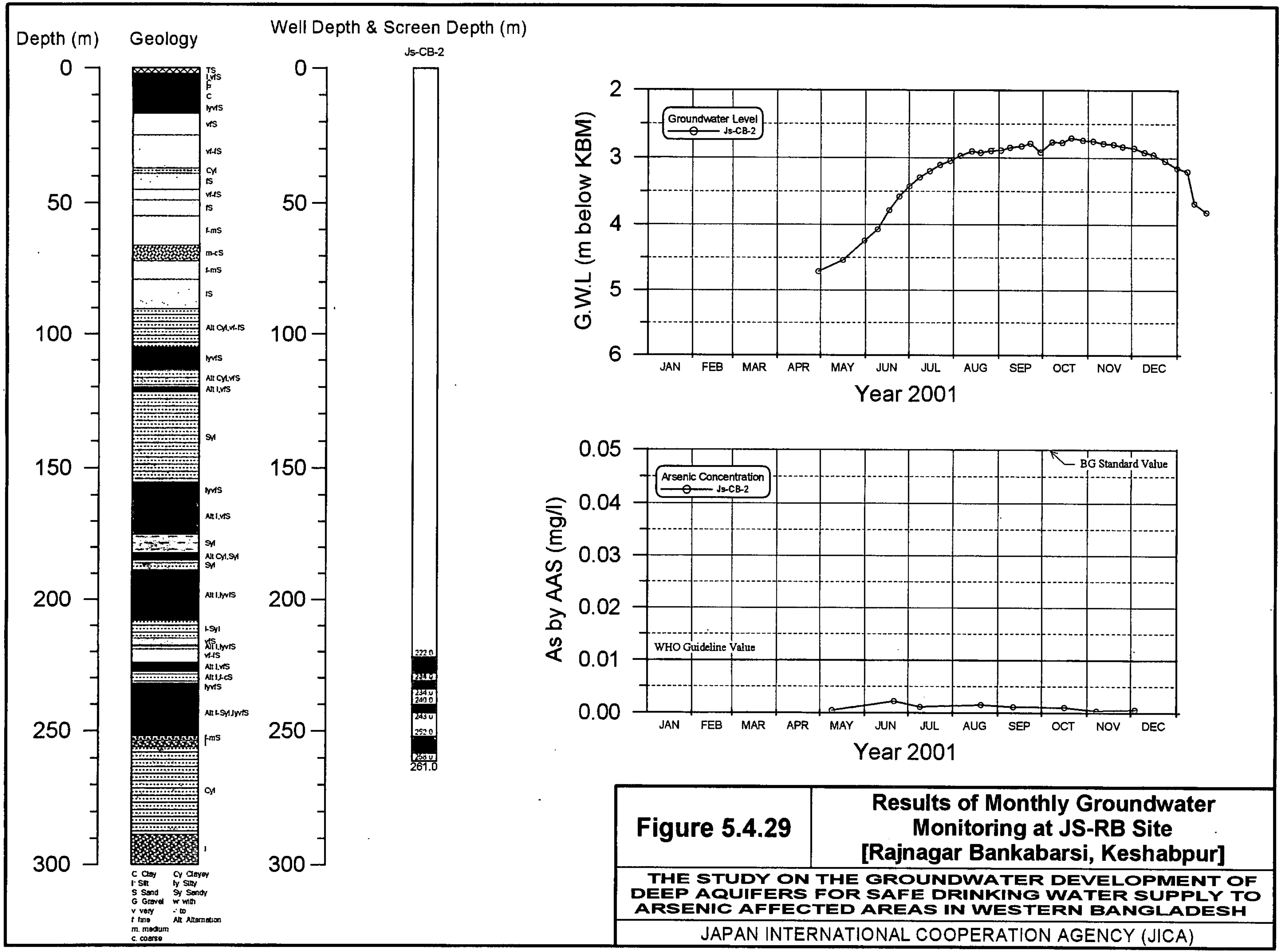
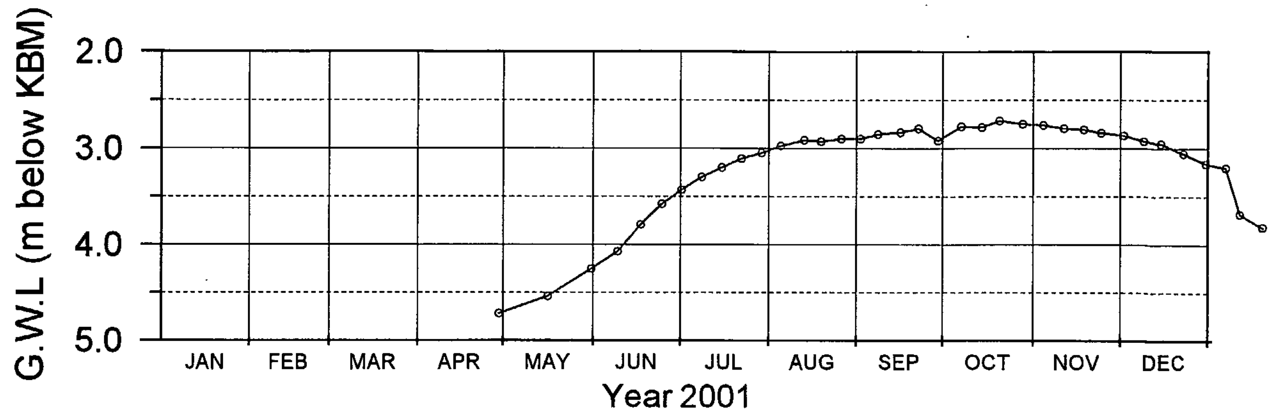


Figure 5.4.29

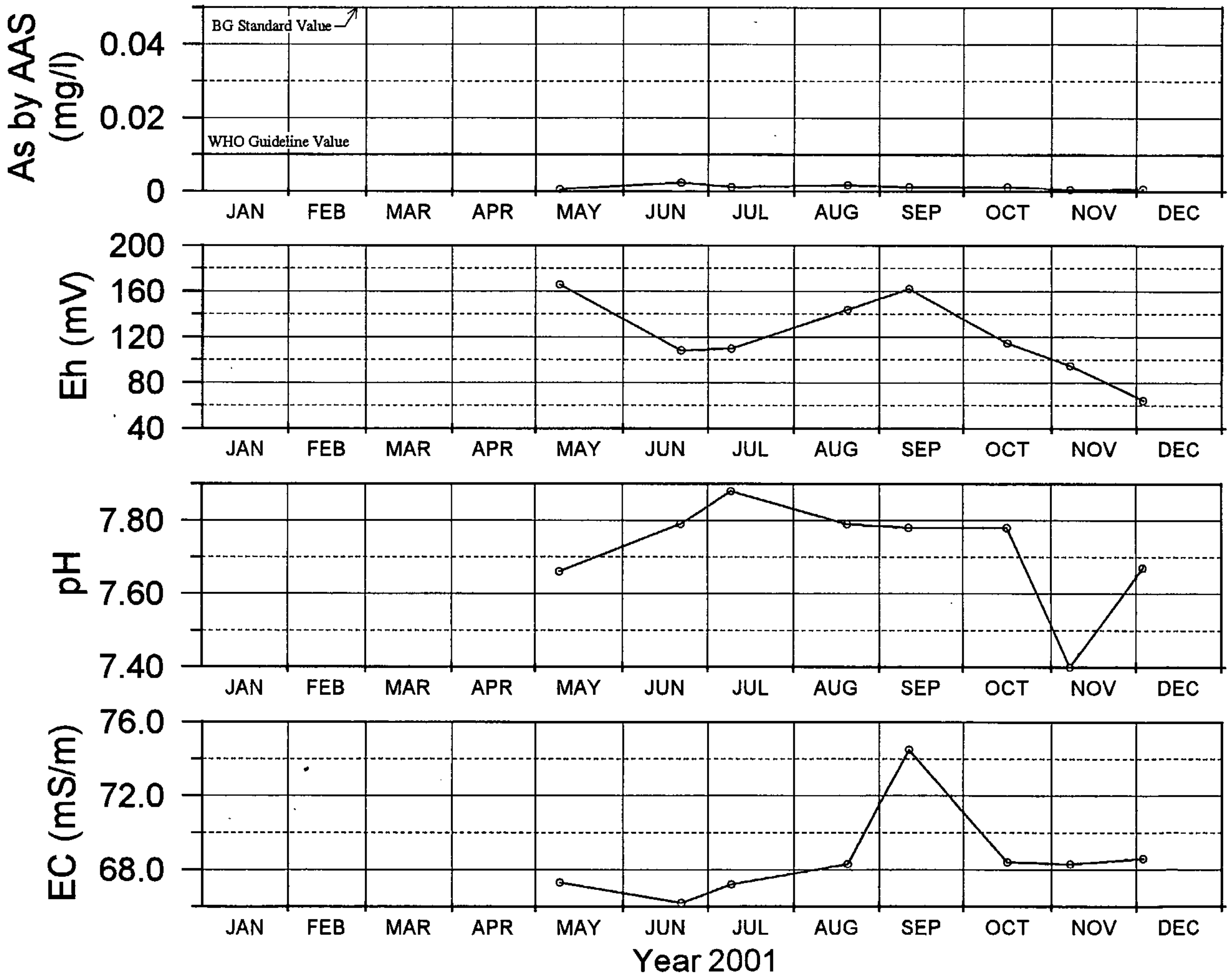
Results of Monthly Groundwater Monitoring at JS-RB Site [Rajnagar Bankabarsi, Keshabpur]

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Groundwater Level



(b) Groundwater Quality

Location:	Rajnagar Bankabarsi, Keshabpur Thana
Site No.:	JS-RB

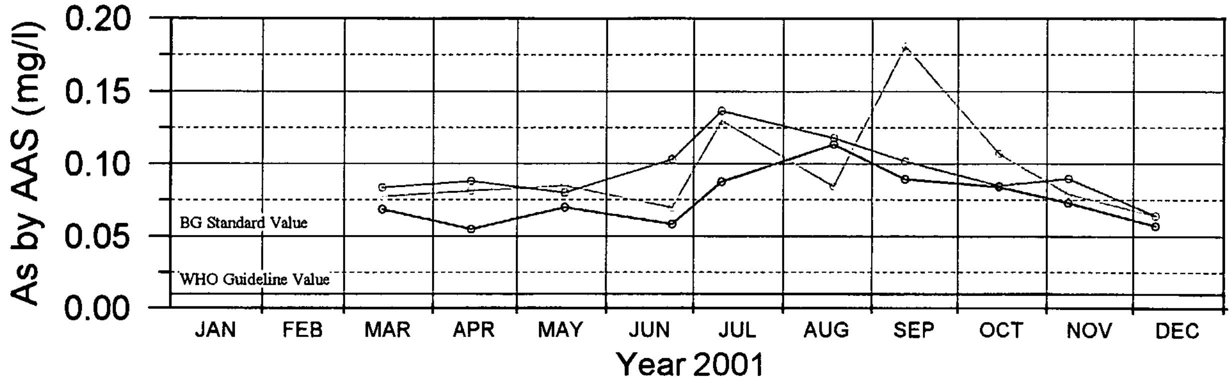
LEGEND

—○— Js-CB-2 (Depth = 261.0 m)

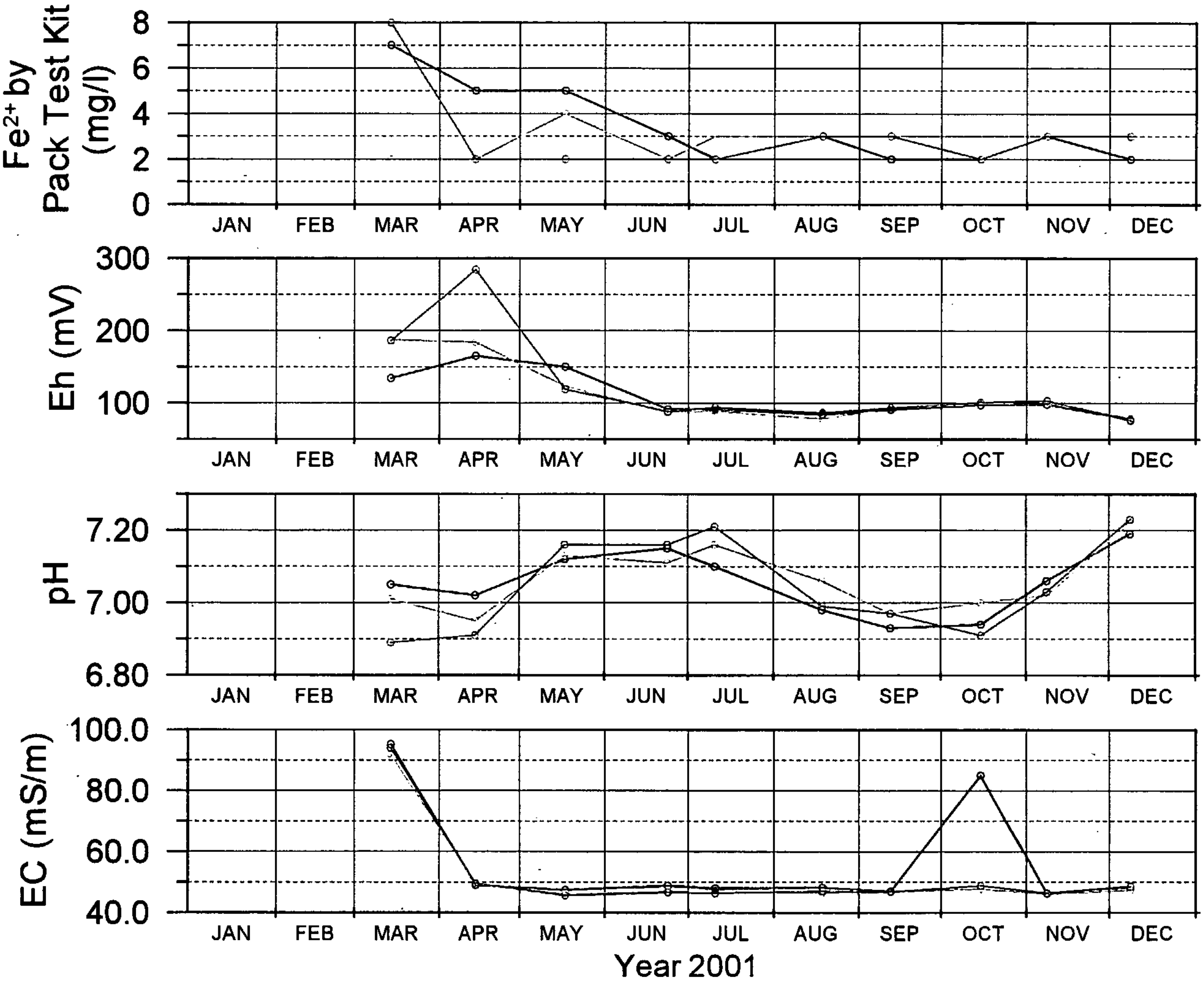
Figure 5.4.30 **Changes in Groundwater Level and Groundwater Quality at JS-RB Site, Jessore**

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Arsenic Concentration



(b) Groundwater Quality

Location:	Bara Dudpatila Village Damurhuda Thana Chuadanga District
Site No.:	BD-IDW

LEGEND

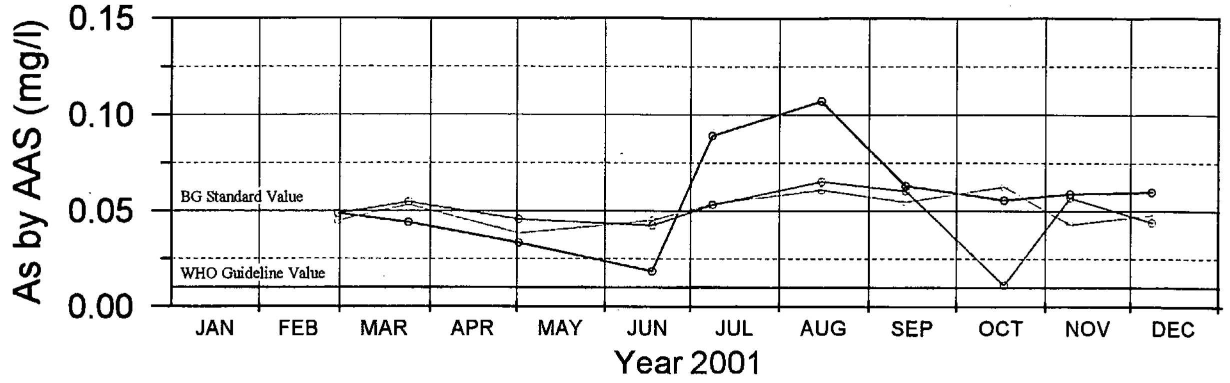
- ImCD-1 [Type-A] (Depth = 103.5 m)
- ImCD-2 [Type-B] (Depth = 105.0 m)
- ImCD-3 [Type-C] (Depth = 101.6 m)

Figure 5.4.31

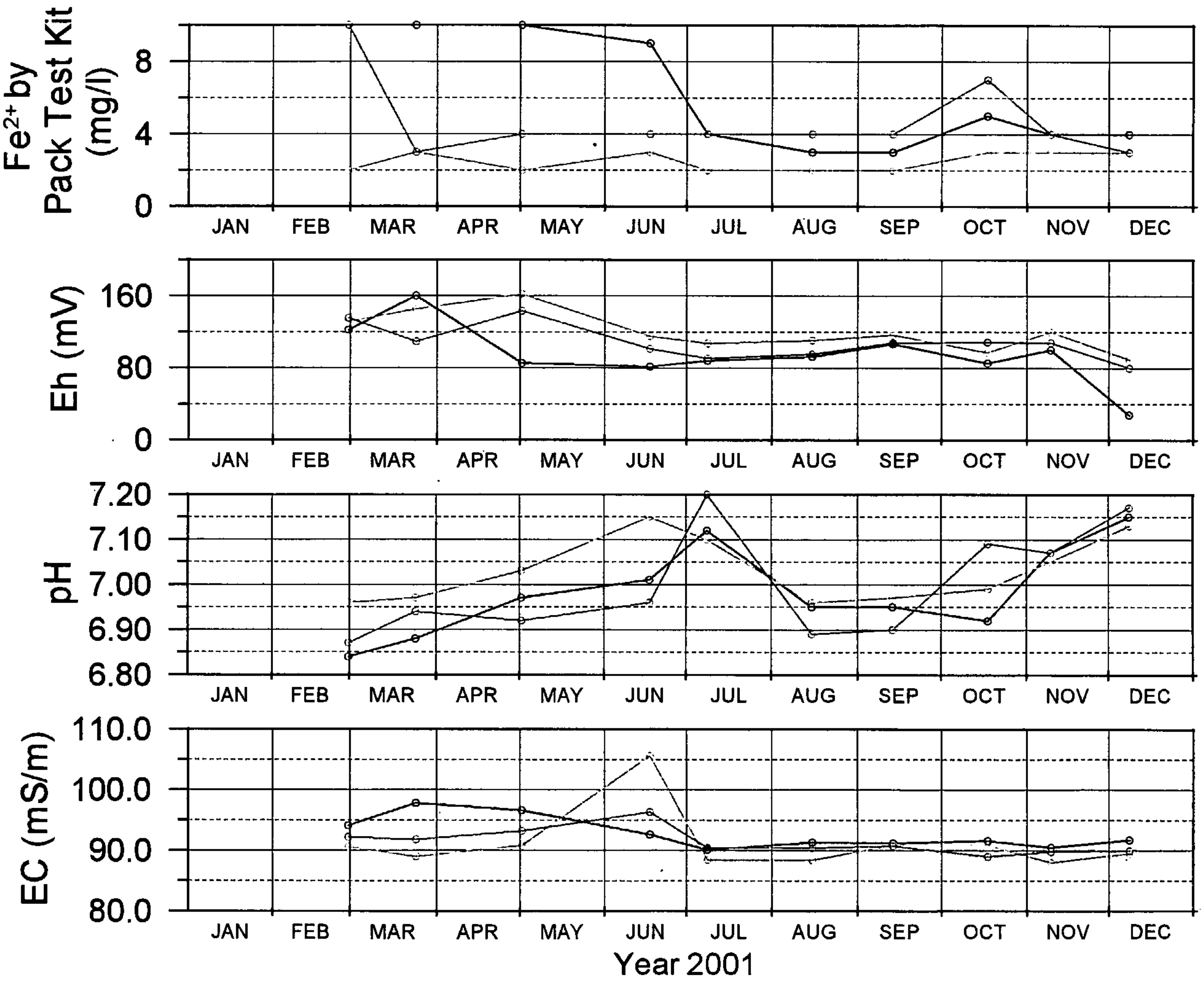
Monthly Monitoring Results of Improved Deep Wells in Bara Dudpatila Village, Chuadanga

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Arsenic Concentration



(b) Groundwater Quality

Location: Krishna Chandrapur Village
Moheshpur Thana
Jhenaidah District
Site No.: JH-KC

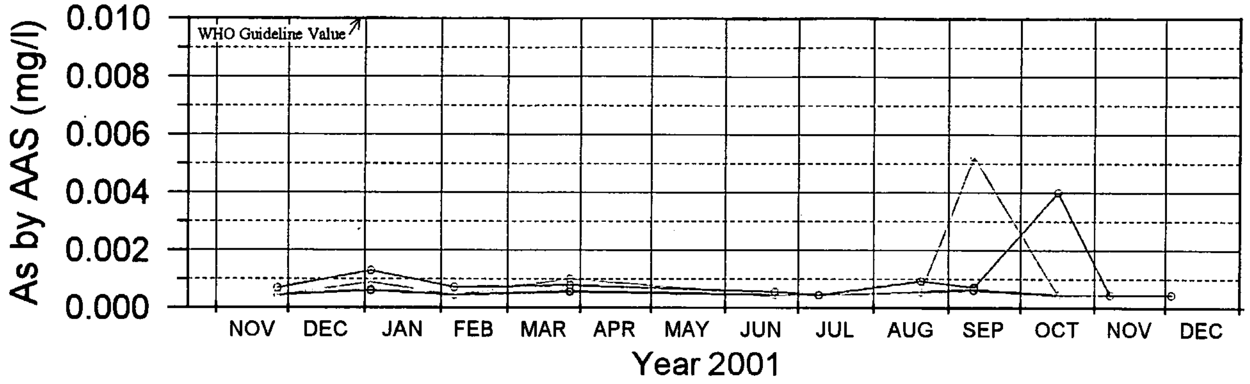
LEGEND
—o— ImHM-1 [Type-A] (Depth = 127.5 m)
– – ImHM-2 [Type-B] (Depth = 148.5 m)
—o— ImHM-3 [Type-C] (Depth = 147.0 m)

Figure 5.4.32

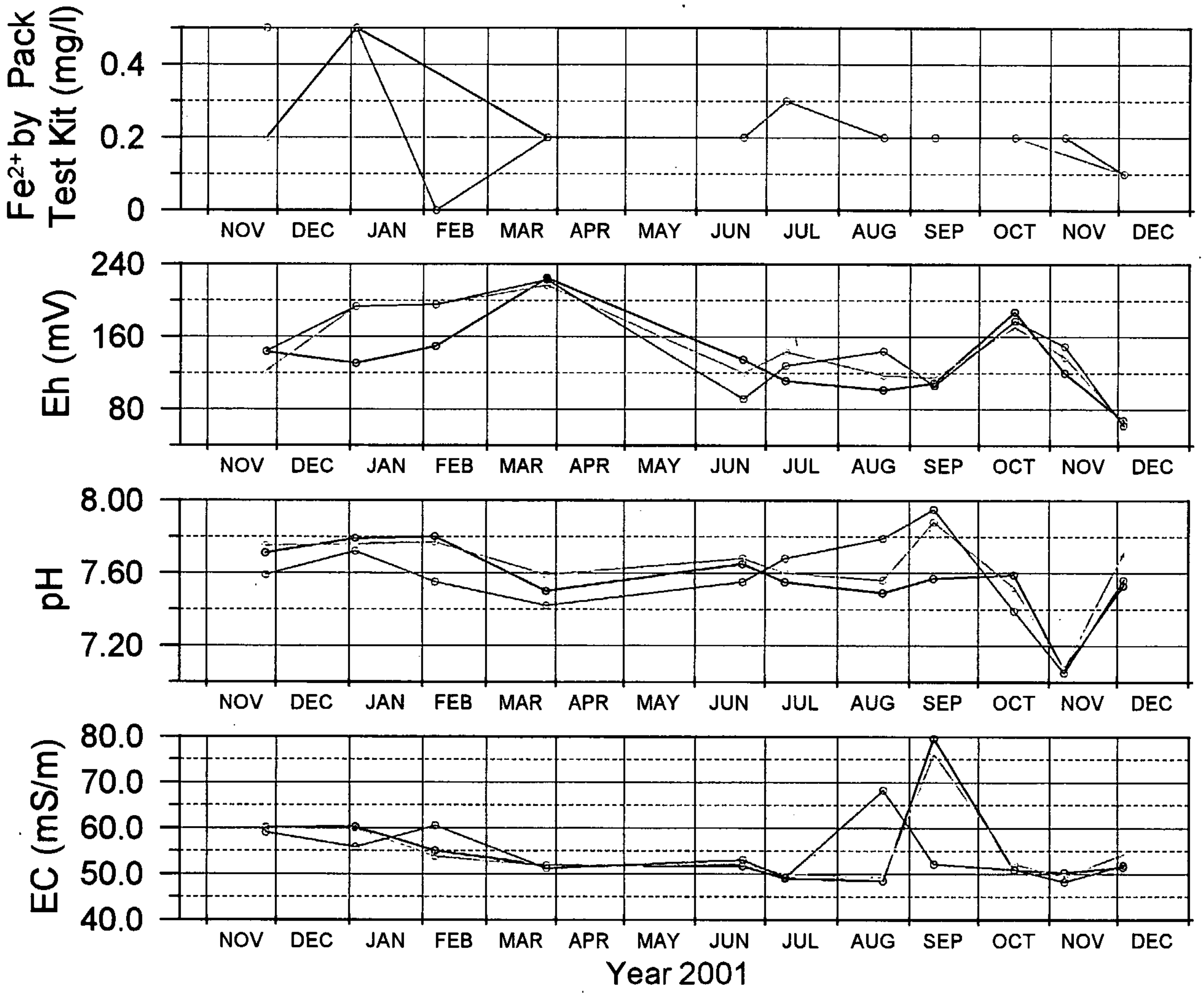
Monthly Monitoring Results of Improved Deep Wells in Krishna Chandrapur Village, Jhenaidah

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



(a) Arsenic Concentration



(b) Groundwater Quality

Location: Rajnagar Bankabarsi Village
Keshabpur Thana
Jessore District
Site No.: RB-IDW

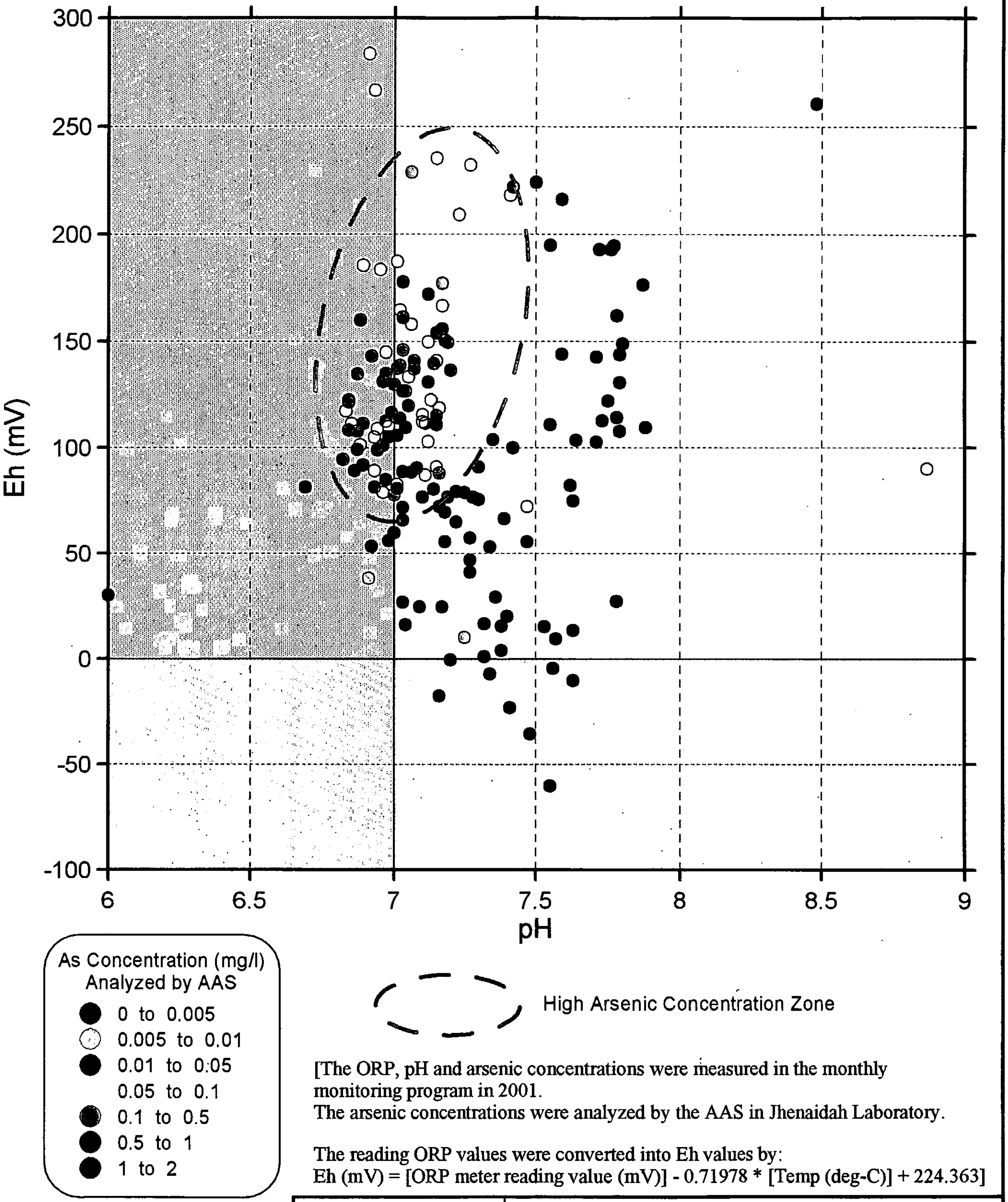
LEGEND
ImJK-1 [Type-A] (Depth = 217.8 m)
ImJK-2 [Type-B] (Depth = 212.2 m)
ImJK-3 [Type-C] (Depth = 214.6 m)

Figure 5.4.33

Monthly Monitoring Results of Improved Deep Wells in Rajnagar Bankabarsi Village, Jessore

THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



[The ORP, pH and arsenic concentrations were measured in the monthly monitoring program in 2001.
The arsenic concentrations were analyzed by the AAS in Jhenaidah Laboratory.

The reading ORP values were converted into Eh values by:
Eh (mV) = [ORP meter reading value (mV)] - 0.71978 * [Temp (deg-C)] + 224.363]

Figure 5.4.34 **Eh-pH-As Relations in Groundwater of JICA Observation Wells/Holes**