CHAPTER 5

INVESTIGATION OF DEEP AQUIFERS

Main 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 at 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. Detailed observation of core samples can provide precise information on facies, grain size, sedimentary structures, degree of consolidation, existence of particular minerals and fossils, etc. that cannot be obtained by the cutting samples of normal well drillings. Moreover, one of the most important purposes of core boring is to collect undisturbed core samples for core analysis. To reveal the mechanism of groundwater contamination by arsenic, arsenic content testing and arsenic leaching testing are very essential to know the source of contamination as well as the potential of contamination.

For these reasons, the study team has paid special attentions to the core boring study. The drilling method and sampling method were carefully examined to collect as many reliable core samples as possible.

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 a deep observation well by the study where the shallow groundwater is highly contaminated with arsenic.

As mentioned in Chapter 6, the model rural areas were carefully selected not only from the viewpoints of the degree of arsenic contamination and the distribution of arsenicosis patients but also from the viewpoint of the hydrogeologic characteristics of the study area. In the selected three (3) villages, the core boring was performed in the highly contaminated area in each village based on the arsenic level survey of existing wells.

Figure 5.1.1 shows the core boring sites in the study area. Figures 5.1.2, 5.1.3, and 5.1.4 show the location of core boring sites in Chuadanga, Jhenaidah and Jessore Pourashavas. The detailed core boring points as well as the location of deep observation wells and observation holes at CH-2, JH-1, and JS-2 sites are shown in Figures 5.2.6, 5.2.7, and 5.2.10, respectively. The locations of core boring points in the model rural areas of Bara Dudpatila in Chuadanga District, Krishna Chandrapur in Jhenaidah district, and Rajnagar Bankabarsi in Jessore district are shown in Figures 5.1.5, 5.1.6, and 5.1.7.

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. The Study Team employed a drilling contractor from Thailand to carry out the core boring because there was no capable drilling contractor or drilling machine in Bangladesh. The actual drilling work started from December 2000 and it was completed in August 2001.

The specification of core boring is as follows:

Sampling Interval:	Continuous core sampling in clayey layers At least one sample at an interval of 5 m in sandy layers
Depth of Core Boring:	300 m
Drilling Method:	Rotary Drilling with Wire Line Method
Drilling Machine:	TBM-5 (having capacity to drill up to 500m depth)
Drilling Bit:	Diamond Tip Bit and Metal Tip Bit
Drilling Fluid:	Bentonite Fluid (Bentonite was imported from Thailand)
Sampler:	Denison Sampler (double core tube)
Drilling Diameter:	86 mm
Sample Diameter:	56 mm

The hydrogeologist and the drilling engineer of the study team supervised the core boring work at each site. The collected core samples were immediately wrapped in plastic sheet to prevent dry-up and secondary contamination. The wrapped samples were properly kept in wooden boxes.

The detailed core observation and the selection of core samples for arsenic analysis were done by the hydrogeologist of the study team. The hydrogeologist carefully cut the plastic cover and removed the mud cake adhered to the core samples with a clean spatula. The fresh surface of the core samples was carefully observed to describe facies, grain size, sedimentary structure, dominant minerals and fossils. The color of core samples was identified using the standard color chart. The result of the core sample observation was recorded on the core observation data sheet with a core sketch drawing at a scale of about 1/5. The individual core observation data sheet is presented in the Data Report. The geological log sheets are shown in Figures 5.6.1. to 5.6.6 in Section 5.6.

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. The remaining core samples were wrapped again in plastic sheet and kept in the wooden boxes. The wooden boxes are properly kept in the DPHE Jhenaidah Office and DPHE Jessore Office.

5.1.4 Subsurface Geology

Based on the 300 m deep core boring carried out at six (6) sites in the study area, viz. Chuadanga, Damurhuda, Moheshpur, Jhenaidah, Jessore and Keshabpur, five (5) stratigraphic units were identified. The identified statigraphic units were named from 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 5.1.8 shows the correlation of the geologic unit among the six (6) core boring sites.

These formations consist of many laminated structures and occasionally biogenic sedimentary structures disturbed by bioturbation (Figures 5.1.9 and 5.1.10). And these formations include shell fragments, trace fossils, wooden fragments and blocks (Figures 5.1.11 to 5.1.14).

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 depth of 300 m 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 formation is intercalated by clay, silt and an alternation of sand and clayey layers in the northern and central parts of the study area. Gravel layers often intercalate in Chuadanga. The formation consists of parallel and cross-laminated beds. Tube-shaped trace fossils (biogenic nest holes) are found in Chuadanga and Moheshpur. Wooden fragments are found at the sites in Chuadanga, Damurhuda, and Jhenaidah. The formation partly contains clay and silt blocks except in Keshabpur. The thickness of E formation is more than 90m.

2) D formation

D formation is divided into two parts, i.e. D1 member and D2 member in descending order.

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.

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.

In the southwestern area (Moheshpur, Jessore and Keshabpur), there is a possibility that the member is submarine fan deposits, because of the disordered sedimentary structure and muddy layers with gravel as typical turbidites facies.

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. Tube-shaped trace fossils are found in Damurhuda and Jhenaidah. Wooden fragments are contained in Damurhuda. 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 an 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. Shell fragments are found in Chuadanga and Keshabpur. Tube-shaped trace fossils are often found except in Damurhuda and Jhenaidah. Wooden fragments are contained in Chuadanga, Damurhuda, Jhenaidah and Jessore. Clay and silt blocks are found in the central to southern part of the study area. The thickness of C formation ranges from 61 to 141 m.

The formation is probably equivalent to the lowest unit by Umitsu (1987). From coarsening-upward in some horizons and intercalating of marsh deposits, it is presumed that C formation is deltaic deposit except in Keshabpur. 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 at some horizons. Biogenic sedimentary structures disturbed by bioturbation are found in the upper part of the formation in Moheshpur. A few shell fragments are found in Jhenaidah and Keshabpur. Tube-shaped trace fossils are contained at some horizons except in Damurhuda. Wooden fragments and some organic matters are partly contained in the formation except in Jhenaidah. Clay and silt blocks are partly found. The thickness of B formation ranges from 41 to 70 m.

The formation is probably equivalent to the lower unit by Umitsu (1987). From the type of laminae and tube-shaped trace fossil in some horizons, 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 at some horizons. Biogenic sedimentary structures disturbed by bioturbation are found in Damurhuda, Moheshpur, Jessore and Keshabpur. A few shell fragments are found in Jessore. Tube-shaped trace fossils are contained in Chuadanga, Damurhuda and Jessore. Wooden fragments are contained in Chuadanga, Jhenaidah and Keshabpur. Clay and silt blocks are partly contained in the member. The thickness of the member ranges from 20 to 43 m.

The formation is probably equivalent to the middle and upper unit by Umitsu (1987). From the facies, type of laminae and bioturbation, it is presumed that A2 member was deposited with a palaeo-environment of sea (shoreface to offshore) during a time of high sea level in early Holocene.

b. A1 member

It mainly consists of clay and silt. It is intercalated by peat in Jessore and Keshabpur. A few shell fragments are contained in the center area (Jessore). Tube-shaped trace fossils are contained in Chuadanga and Damurhuda. Wooden fragments are contained 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.

The formation is probably equivalent to the uppermost unit by Umitsu (1987). From the facies (especially peat), 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 aquifer corresponds to A formation and B formation, which mainly consists of fine to medium sand. The second aquifer corresponds to C formation, which mainly consists of a sandy layer with gravel. The third aquifer corresponds to D formation and E formation, which consists of a sandy layer and silty layer. The former two aquifers can be correlated with Shallow aquifers used by BGS and DPHE (2001) and the latter one aquifer corresponds to Deep Aquifer by BGS and DPHE (2001). It is inferred that B formation has better permeability in the shallow aquifer. It is inferred that C formation (equal middle aquifer) has very good permeability. It is inferred that D2 formation has better permeability in the deep aquifer, but it is not so thick. The permeability of each drilling site is described by the results of the pumping test in Chapter 5.1.2.

The clear aquiclude is absent between the first aquifer and second aquifer. But each characteristic of groundwater flow is considered to differ, 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 center area (Chuadanga, Damurhuda, Jhenaidah and Jessore), because the facies is a sandy layer. Particularly in Moheshpur, a good aquifer for groundwater use has not been confirmed in D formation and E formation, because the facies is muddy. There are not any 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 (Islam & Uddin, 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
Plio-Pleistocene	D formation	Third Aquifer (Deep Aquifer)	Deep aquifers
	E formation		

References

AAN, RGAG and DOEH NIPSOM (1999): Arsenic Contamination in Bangladesh –Interim report of the research at Samta village.

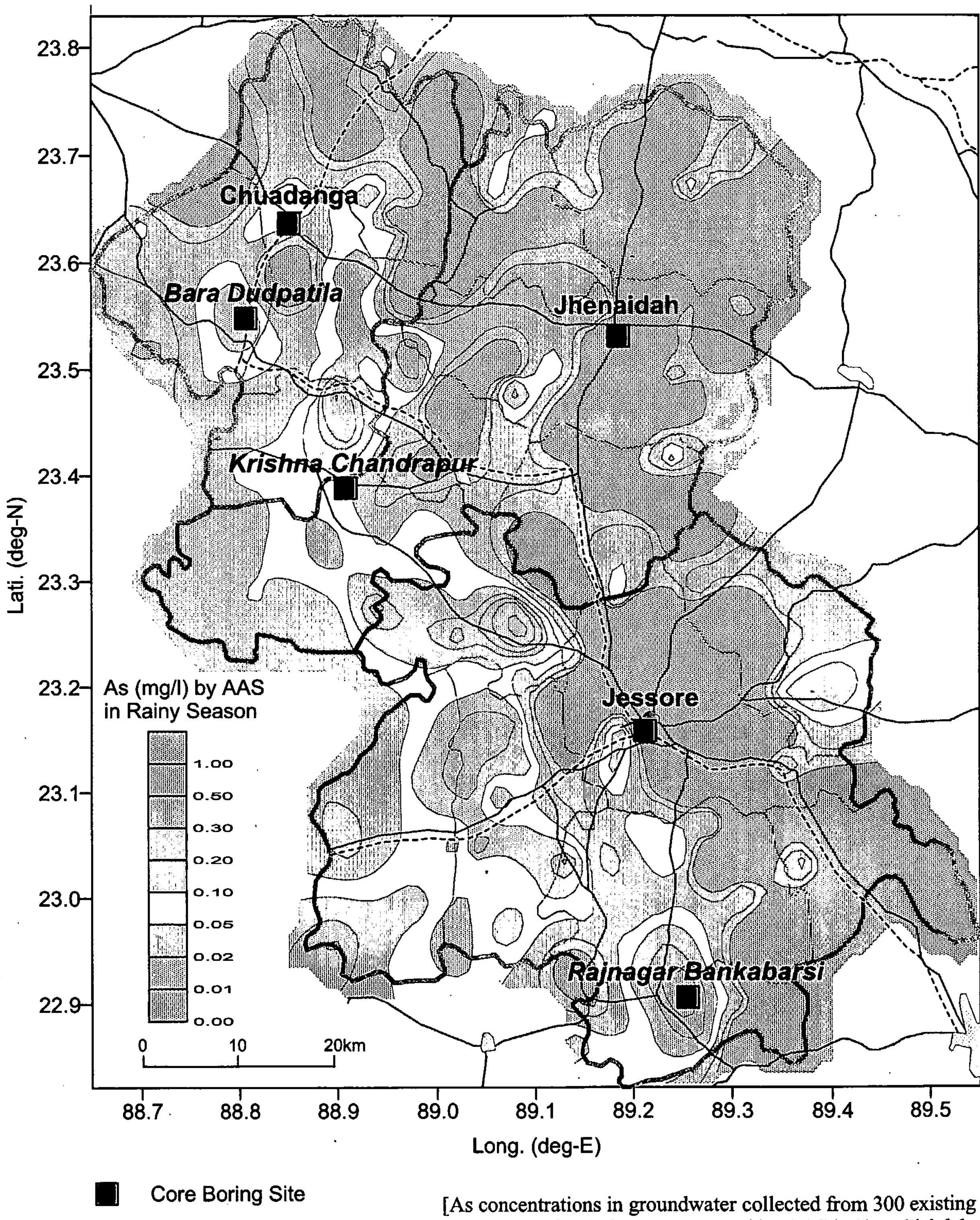
Umitsu M. (1987): Late Quaternary environmental and landform evolution in Bengal. Geog. Rev. Japan, Ser. B, 60, 164-178.

BGS/DPHE (2001): Arsenic contamination of groundwater in Bangladesh.

Islam M.N & Uddin.M.N. (2002): Hydrogeology and arsenic contamination in Bangladesh. Arsenic Mitigation in Bangladesh published by Ministry of Local Government Rural Development & Cooperatives. GOB.

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)	

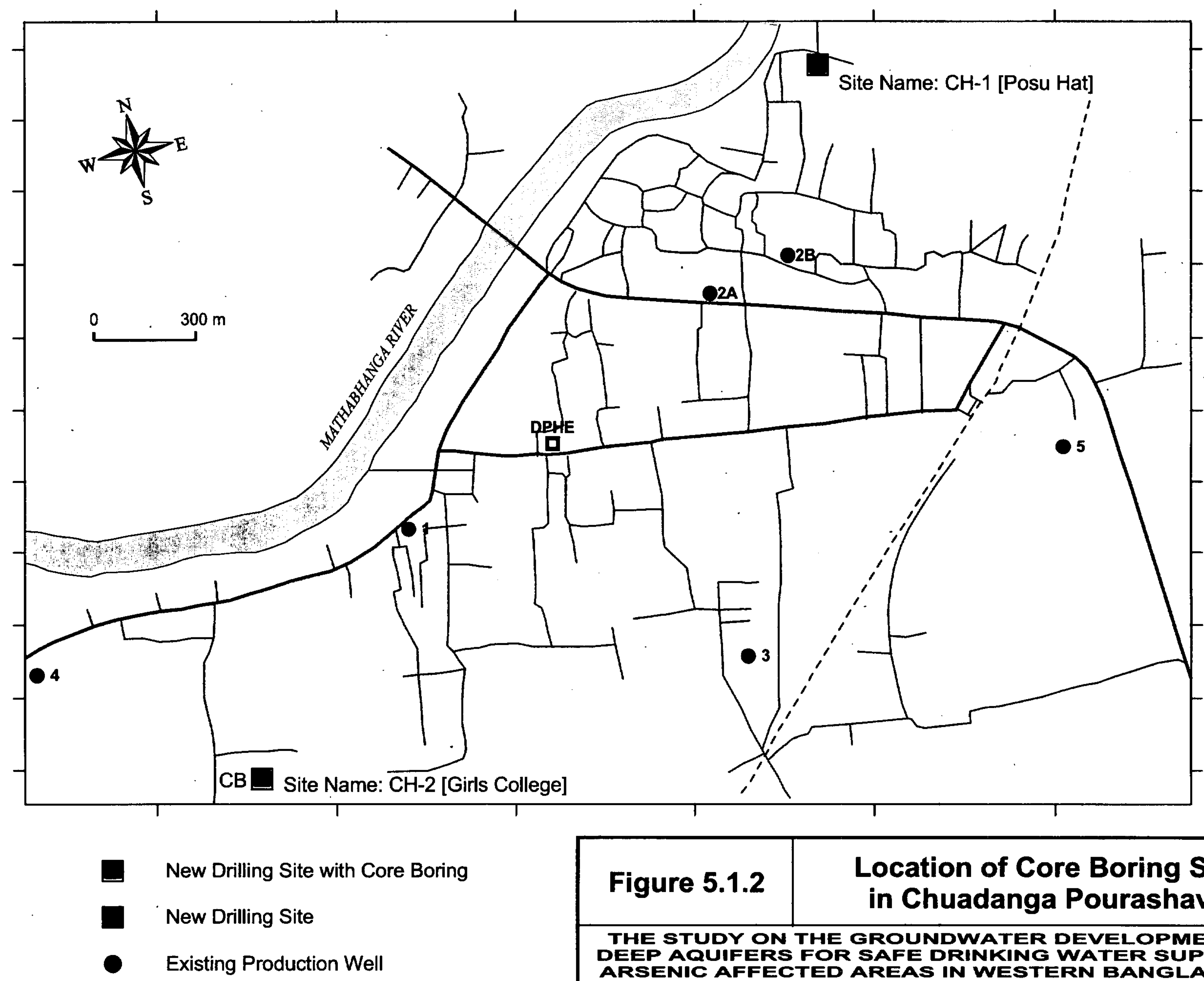


Figure 5.1.2	Location of Core Boring Site in Chuadanga Pourashava
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

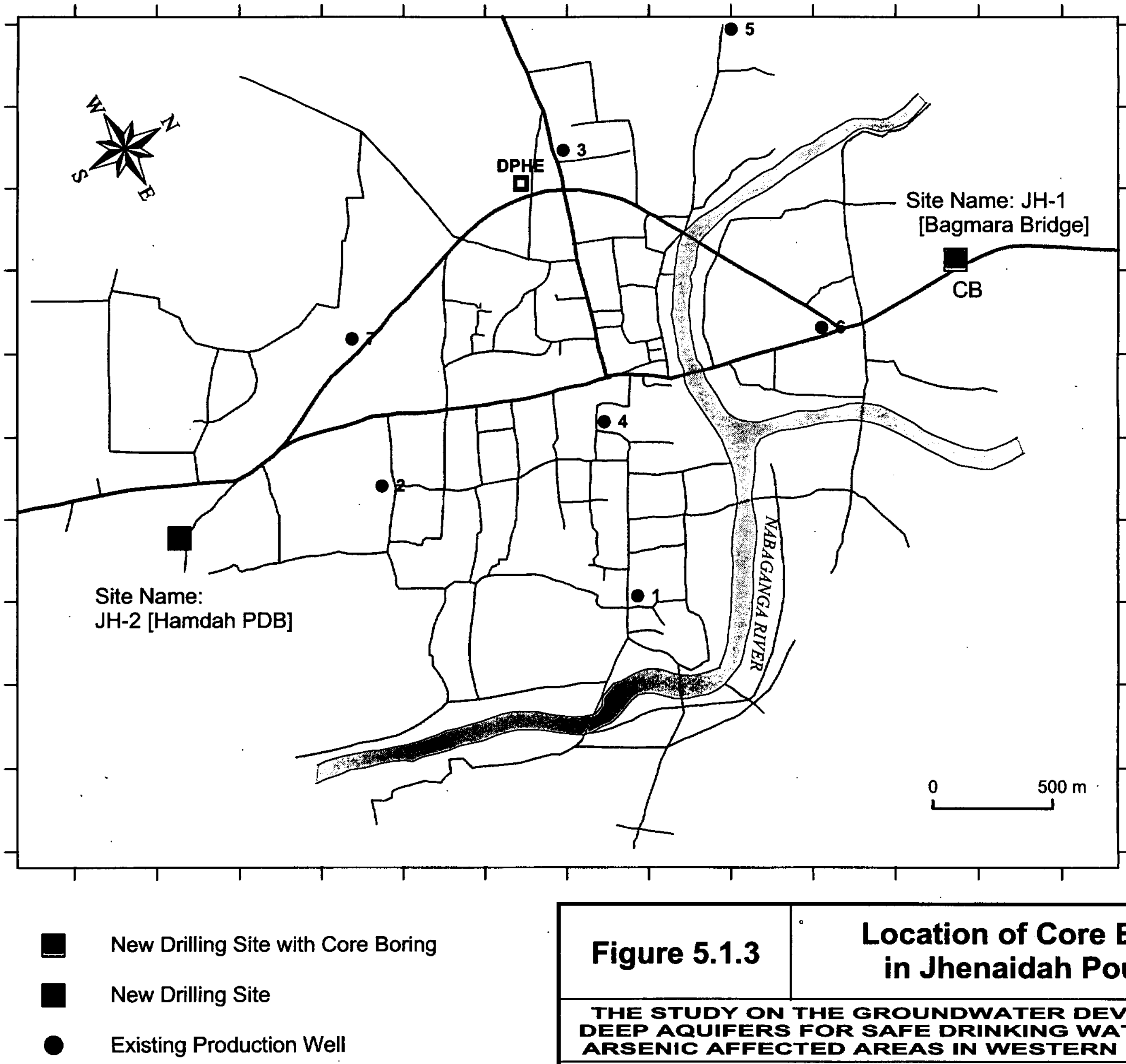


Figure 5.1.3	**Location of Core Boring Site in Jhenaidah Pourashava**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

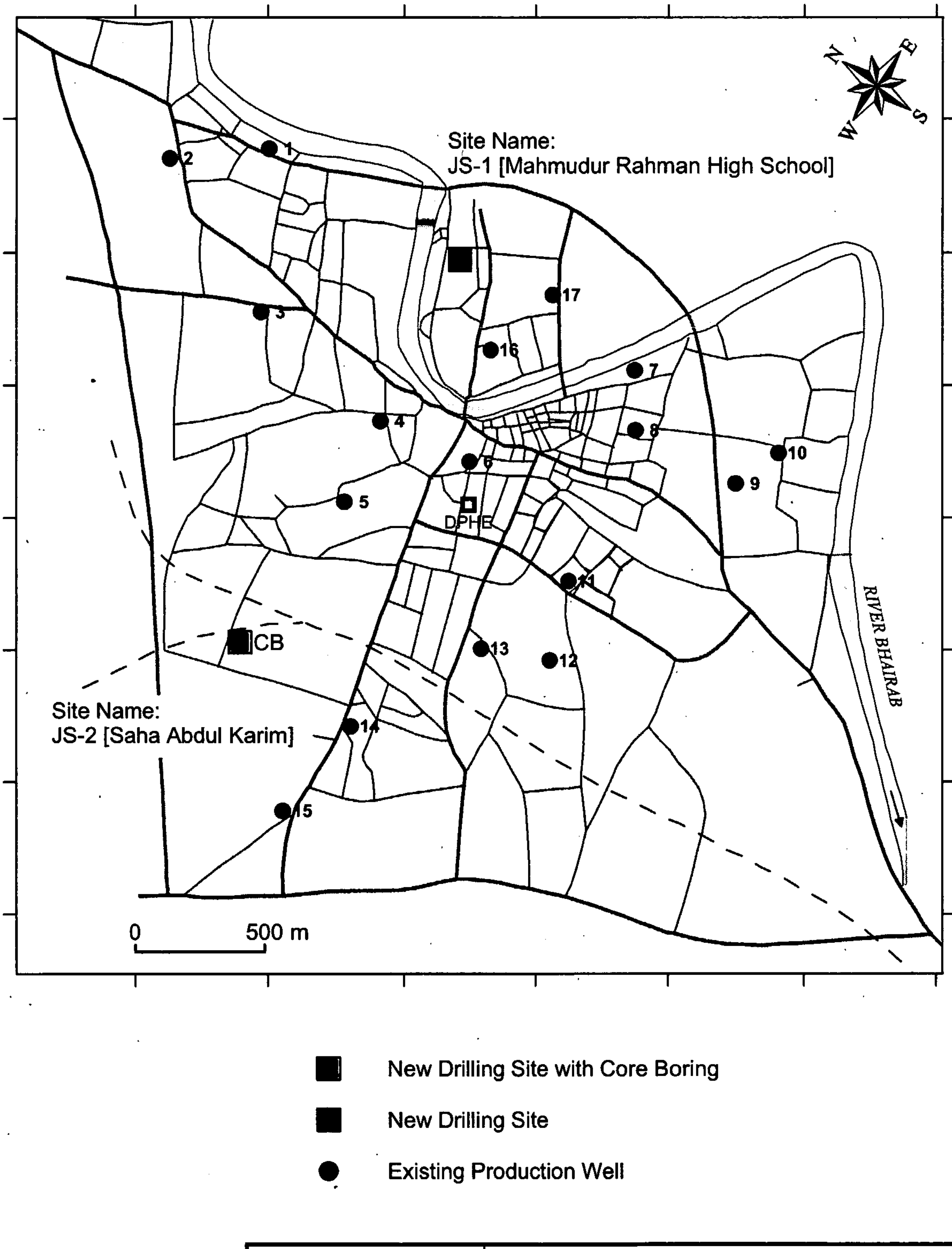


Figure 5.1.4	**Location of Core Boring Site in Jessore Pourashava**

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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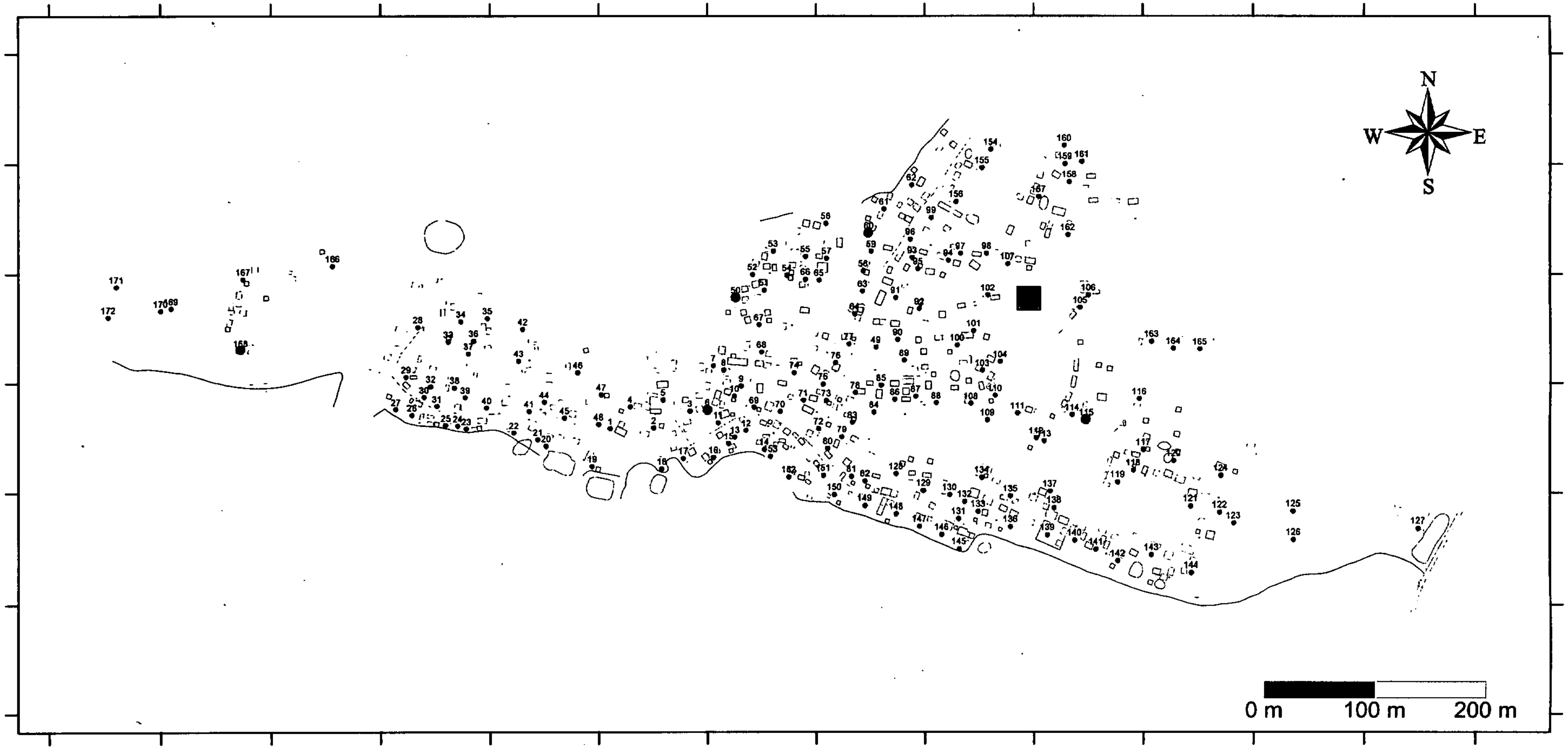


Core Boring Site (Ch-CB-2)

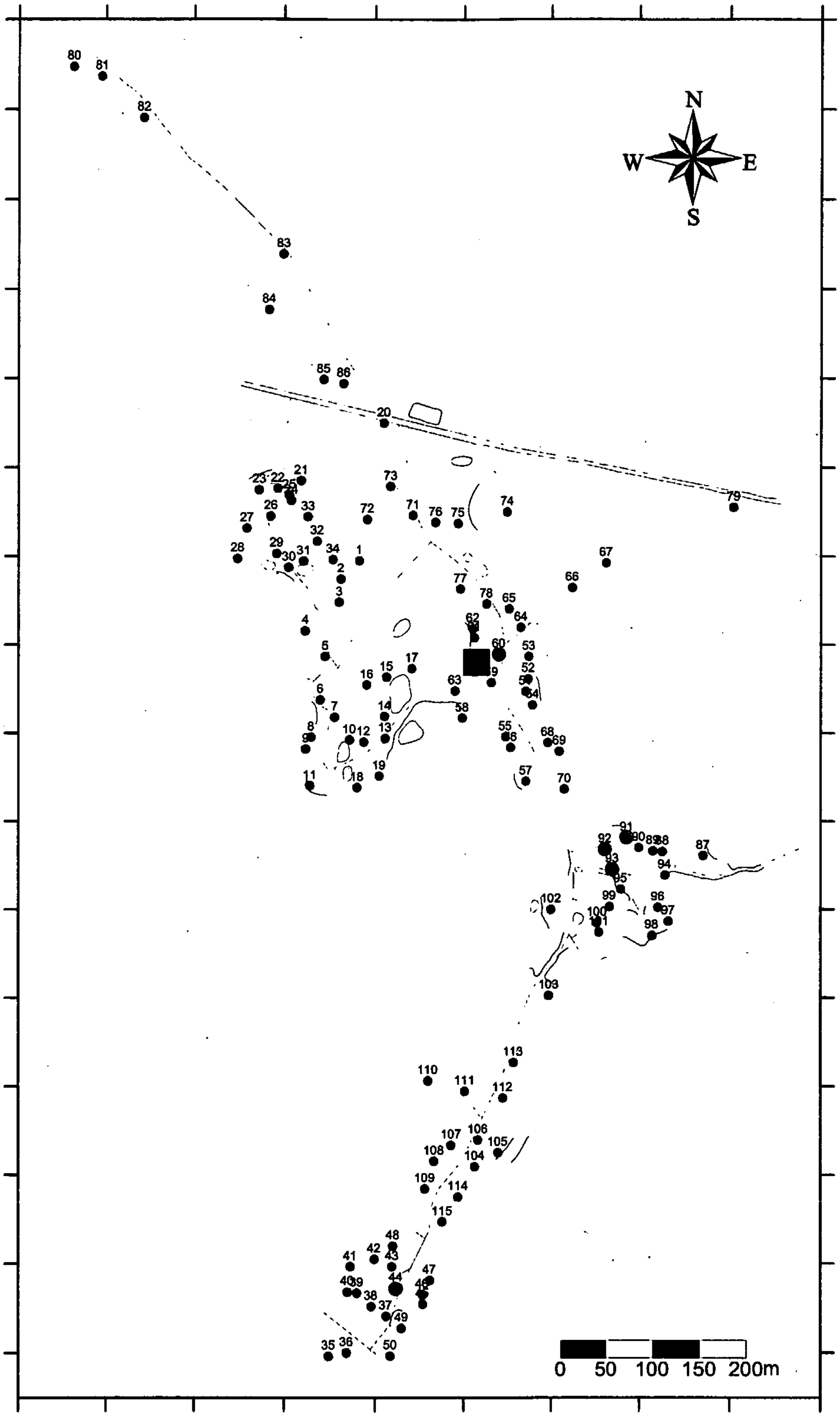
172 Existing Well with TW No.

Existing Well where General Water Quality Sample Collected

Figure 5.1.5	Location of Core Boring Site in Bara Dudpatila Village

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)



■ Core Boring Site (Jh-CB-2)

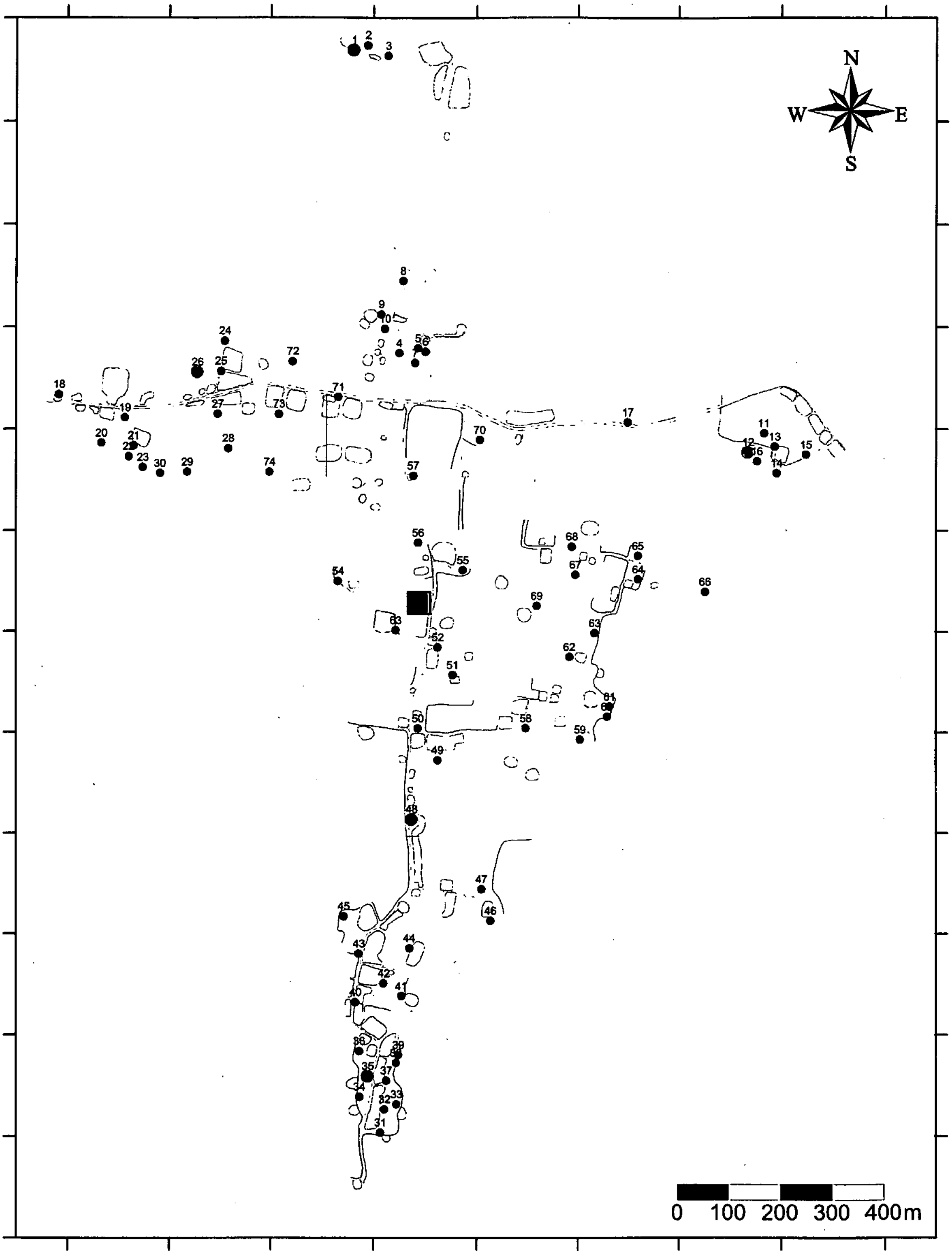
115 ● Existing Well with TW No.

● Existing Well where General Water Quality Sample Collected

Figure 5.1.6	Location of Core Boring Site in Krishna Chandrapur Village

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)



Core Boring Site (Js-CB-2)

74 Existing Well with TW No.

Existing Well where General Water Quality Sample Collected

Figure 5.1.7	Location of Core Boring Site in Rajnagar Bankabarsi Village
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)	

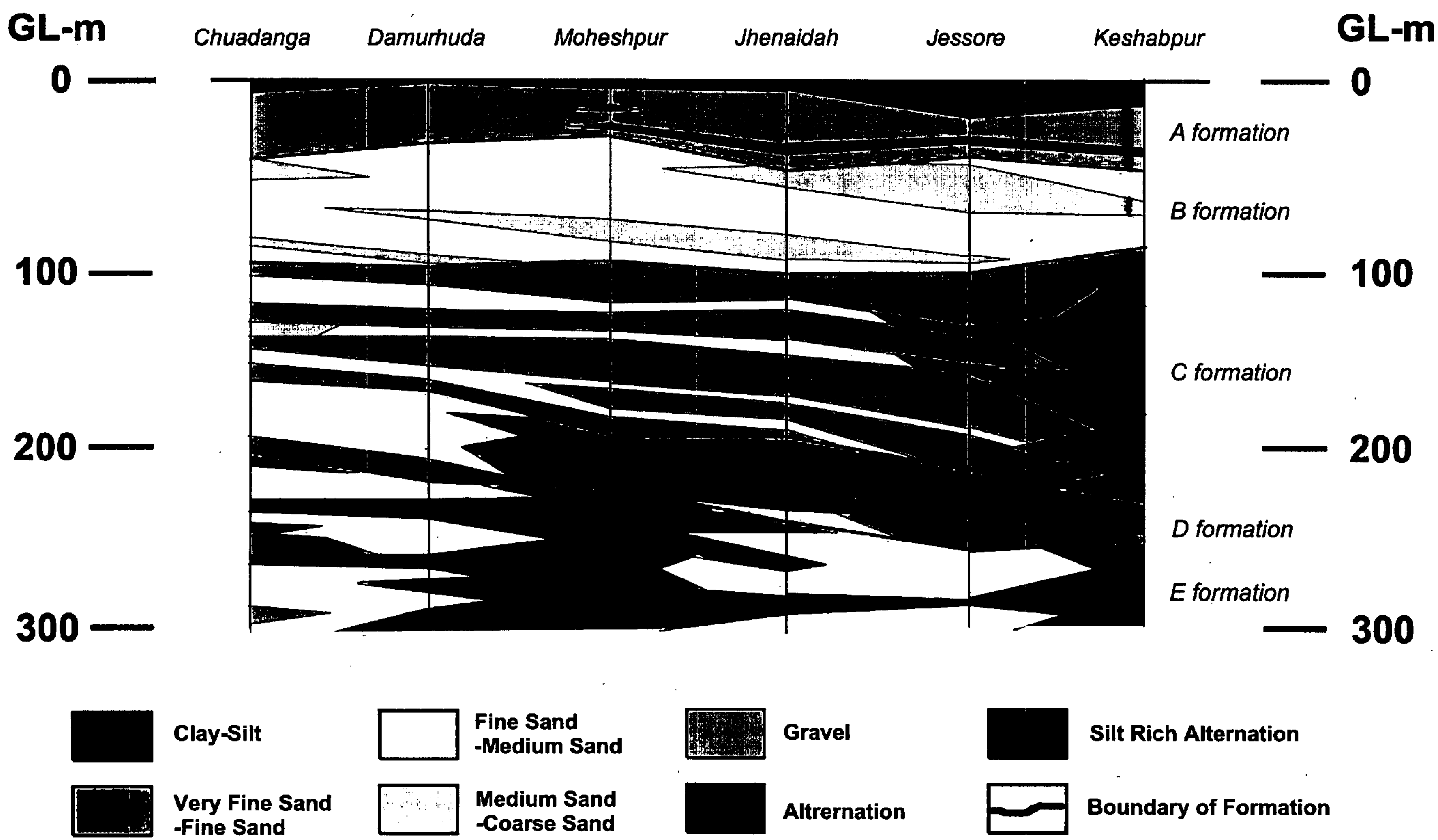
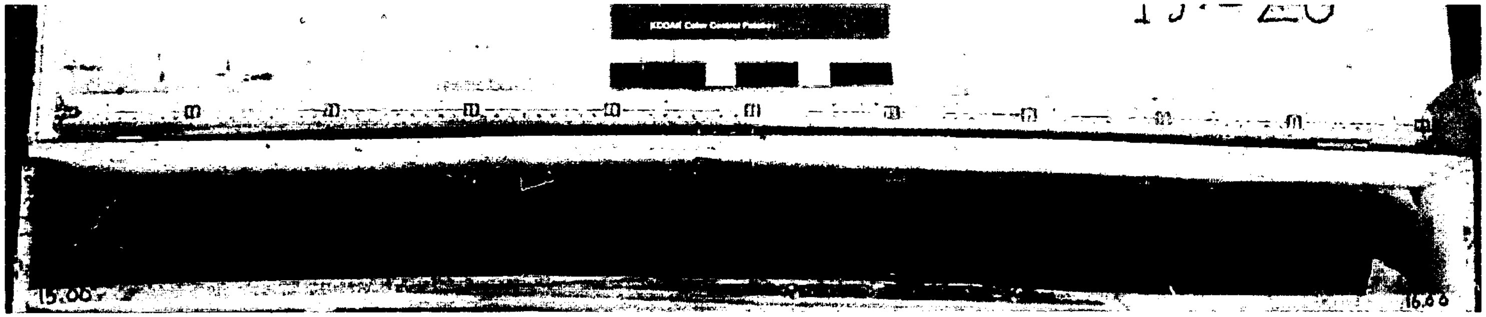


Figure 5.1.8 Correlation of Subsurface Geology Based on Core Boring

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)



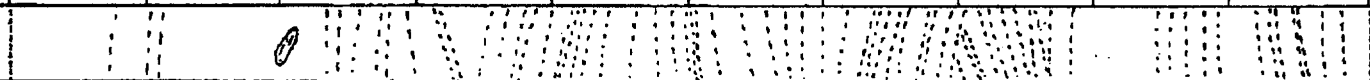
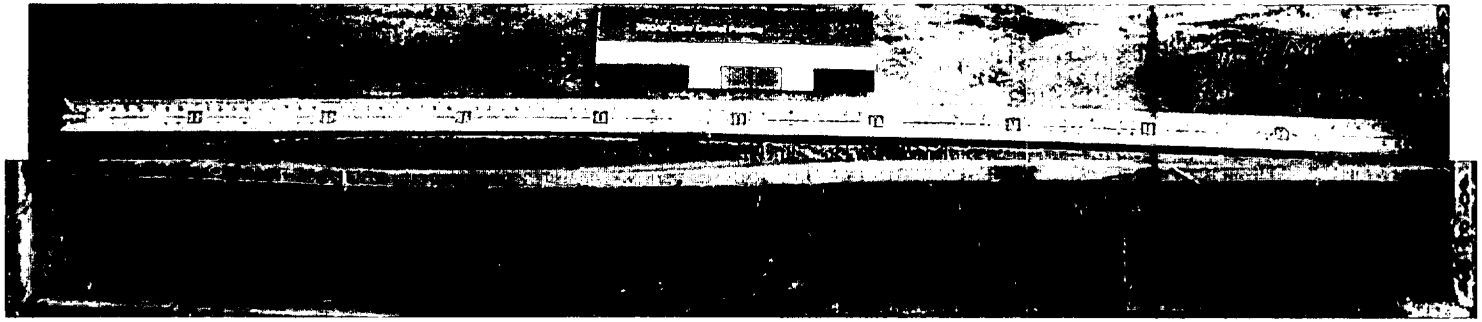
Depth (m)	15.0 – 16.0 (ticks at 15.0, 15.1, 15.2, 15.3, 15.4, 15.5, 15.6, 15.7, 15.8, 15.9, 16.0)
Lithological Structure Sketch	
Lithological Symbol	
Color	grayish olive
Soil Description	Fine Sand mica rich 15.19-21m silty vf.s block

Figure 5.1.9	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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



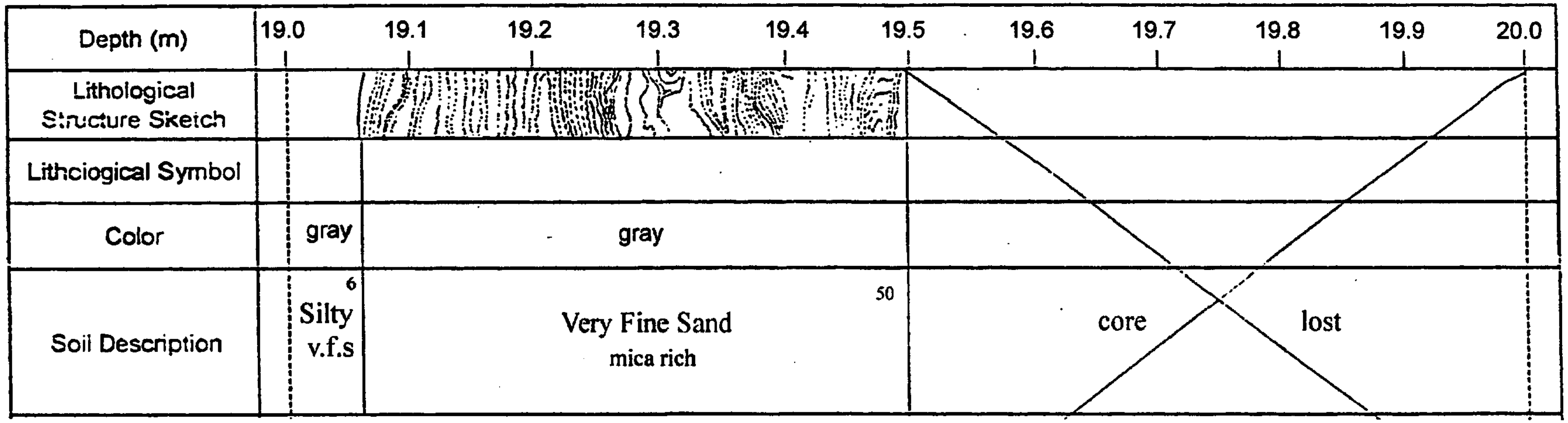
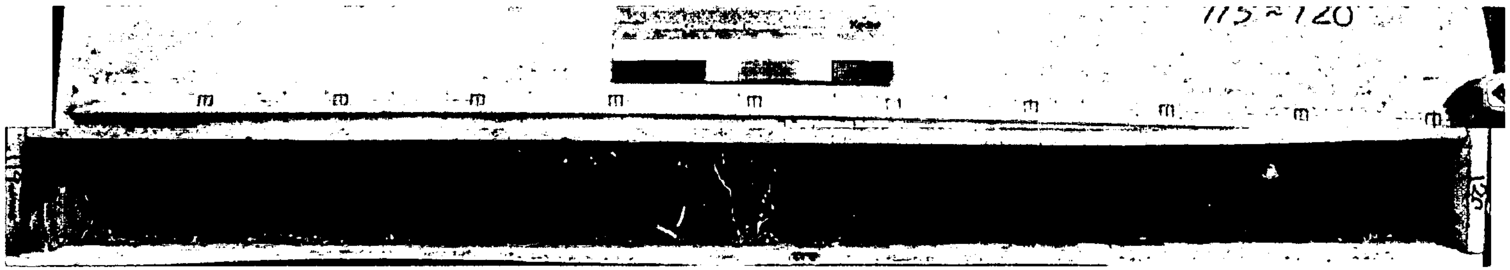


Figure 5.1.10	Photograph and sketch of core sample with biogenic disturbed sedimentary structure by bioturbation (Moheshpur, JH-KC, 19-20m)

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



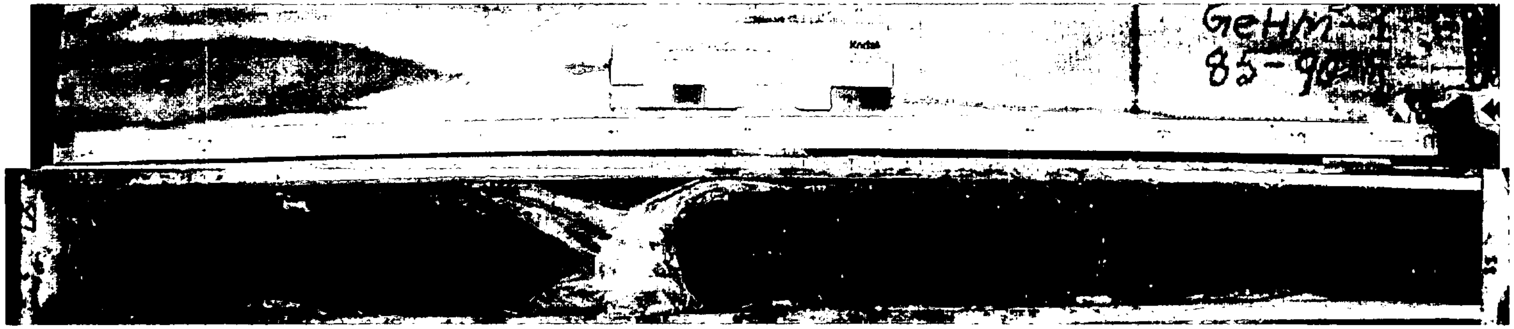
Depth (m)	119.0 – 119.35	119.35 – 119.5	119.5 – 120.0
Lithological Structure Sketch			
Lithological Symbol			
Color	gray	dark olive gray	gray
Soil Description	Fine Sand	Sandy Silt Shell fragment (hard, 2cm)	Fine Sand 119.56-58m pebble (2cm, quartzite) 119.80-82m mica densely 119.88-90m pebble (2cm, quartzite)

Depth scale: 119.0, 119.1, 119.2, 119.3, 119.4, 119.5, 119.6, 119.7, 119.8, 119.9, 120.0 (boundary marks at 35 and 50)

Figure 5.1.11 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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



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 5.1.12 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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

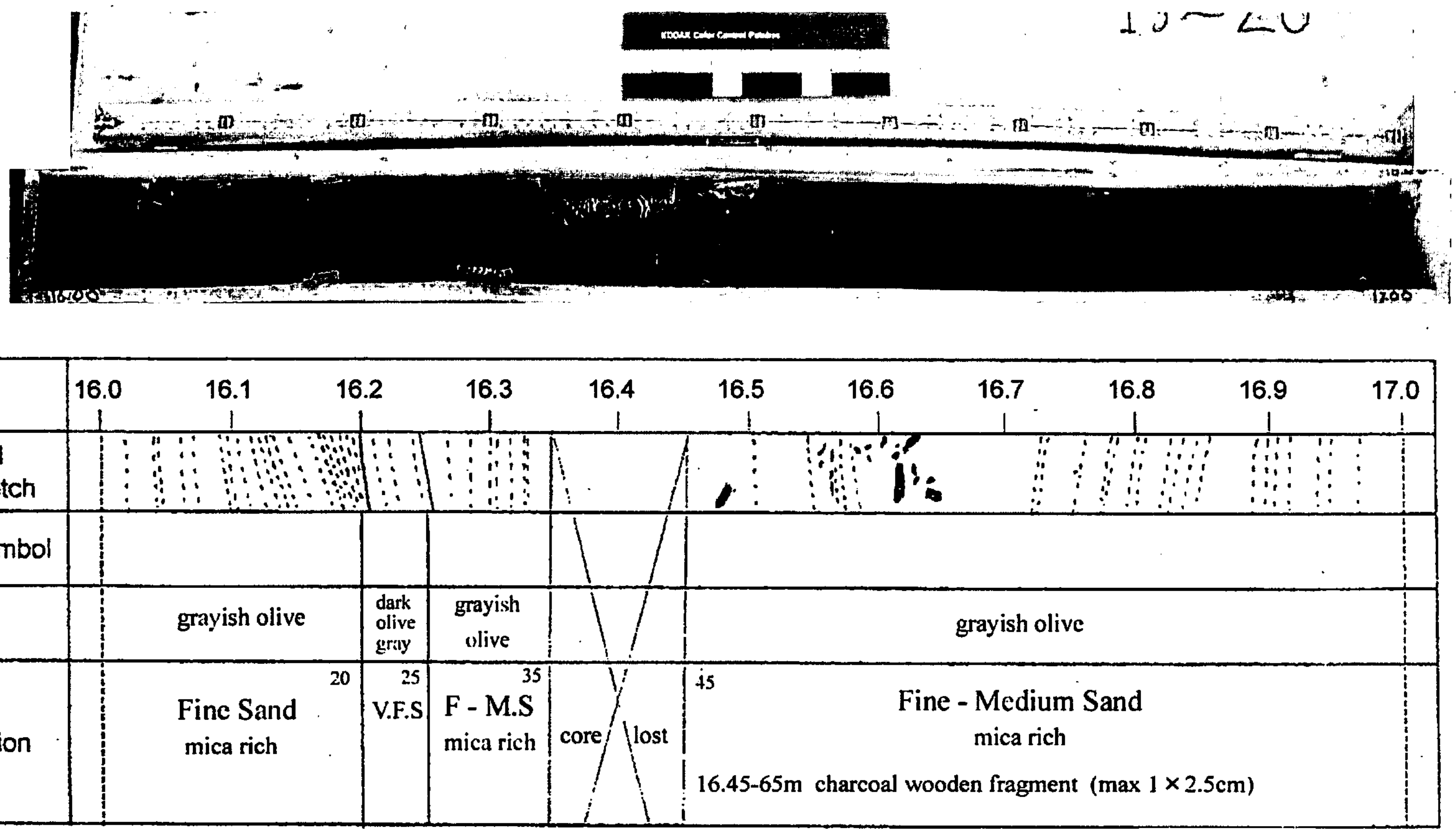
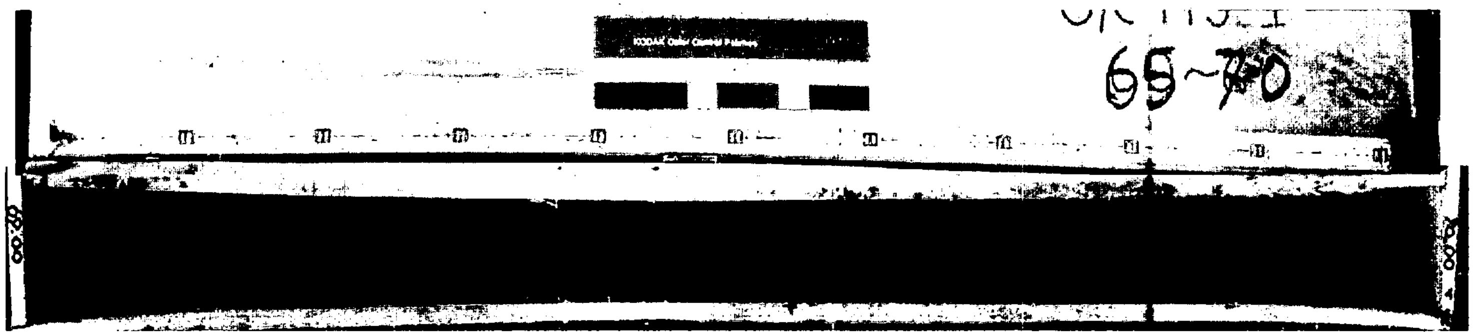


Figure 5.1.13	Photograph and sketch of core sample with Wooden fragment (Jhenaidah, JH-1, 16-17m)

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)



Depth (m)	69.0 – 69.7	69.7 – 70.0
Lithological Structure Sketch		
Lithological Symbol		
Color	gray	olive gray
Soil Description	70 Medium Sand with silty clay block (olive gray - olive yellow, max 5cm, soft) 69.40-57m quartzite (max 3cm)	Silty Clay 69.94-96 m.s block

Depth ticks: 69.0, 69.1, 69.2, 69.3, 69.4, 69.5, 69.6, 69.7, 69.8, 69.9, 70.0

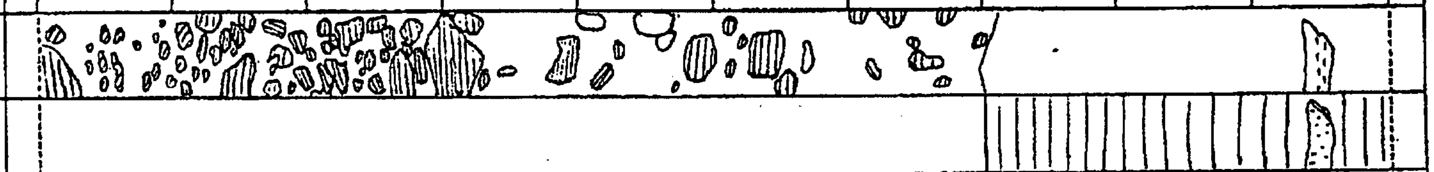


Figure 5.1.14	Photograph and sketch of core sample with block (Jhenaidah, JH-1, 69-70m)

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 around 300 m. To obtain hydrogeological information and geohydrologic parameters as well as to monitor groundwater level and groundwater quality of deep aquifers, the 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 deep observation 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. At JH-1 site in Arabpur of Jhenaidah, the configuration of observation holes was different from the original plan because the available land was limited. The distances from the observation well to observation holes at JS-2 site range from 2.90 to 3.98 m, which are shorter than that of other sites. This was because the drilling of observation holes at the initially planned points was unsuccessful due to the difficulty in trying to penetrate the thick gravel layer at a depth of about 200 m. The observation holes were re-drilled at slightly shifted points.

In addition, the holes of the core boring drilled in the model rural areas were converted into observation holes. The site maps of CH-BD site (Bara Dudpatila village, Chuadanga district), JH-KC site (Krishna Chandrapur village, Jhenaidah), and JS-RB site (Rajnagar Bankabarsi village, Jessore district) are shown in Figures 5.2.11, 5.2.12, and 5.2.13, respectively.

5.2.4 Result of Drilling

The drilling work was started in December 2000 from Chuadanga district and was completed by the end of July 2001 in Jessore district. The drilled observation deep wells/holes and their specifications are shown in Table 5.2.1.

1) Drilling Program

The observation deep wells and observation holes were drilled by TOP-500 machine and TBM-5 machine, which were brought from Thailand. The drilling machines have enough capacity to drill up to 500 m in depth.

For the deep observation wells, a shallow portion from the ground surface up to a depth about 6 m was drilled using a large diameter bit. The diameter of the drilled hole is 24 inches. Then the drilled diameter was reduced to 20 inches and drilled up to a depth about 40 m. Below this, bore holes having 15 inches in diameter were made up to a depth of about 300 m.

For the observation holes, a shallow portion up to a depth of about 3 m was drilled, 15 inches or 12.25 inches in diameter. Then the drilled diameter was reduced to 12.25 inches or 8.5 inches in general.

The boreholes drilled by the core boring in the model rural areas were enlarged to at least 8.5 inches by re-drilling to be able to install casing pipes and screen pipes.

2) Geology and Geophysical Logging

At the Pourashava drilling site with core boring and the core boring site in the model rural areas, the geologic columnar section was made based on the detailed core sample observation. At the Pourashava drilling site without core boring, the cutting samples taken from the deep observation well and the deepest observation hole were carefully observed to prepare the geologic columnar section. The cutting samples were collected at an interval of 1 m in depth.

After drilling the deepest well/borehole at the site, geophysical logging was carried out before installing casing pipes and screens. Resistivity values by short normal electrode configuration (16 inches) and long normal electrode configuration (60 inches), natural gamma ray, and spontaneous potential (SP) were measured by well logging equipment.

The results of geophysical logging with the geologic columnar section at the drilling sites are shown in Figures 5.2.14 to 5.2.22.

a. CH-1 Site [Poshu Hat, Chuadanga Pourashava] (see Figure 5.2.14)

The geologic columnar section was made based on the observation of cutting samples. The site is underlain by fine sediments in the shallow portion up to a depth of 47 m, that are identified as

A formation in the study area. Clayey silt and silt layers occur at depths from 0 to 4 m. Silty fine sand to sand layers are dominant at depths from 4 to 47 m. B formation at the site occurs at depths from 47 to 102 m, characterized by fine to medium sand layers with medium to coarse sand layers. C formation is composed mainly of medium to coarse sand layers with gravel. The formation has a thickness of 62 m. The bottom depth of C formation is 164 m and the boundary between C formation and D formation is clearly identified by the facies change. D formation is overlain by C formation, occurring at depths from 164 to 210 m. The facies of D formation is characterized by fine to medium sand layer. E formation occurs at depths from 210 to 300+ m at the site. There are three (3) layers of medium to coarse sand in the upper part at depths from 213 to 246 m. The lower part consists mainly of fine sand.

The resistivity logs show that the higher resistivity values are recorded in B and C formation, indicating that the sediments are coarse in grain size. The resistivity logs also show a clear difference between C and D formations: the resistivity of D and E formation is lower than C formation. The intensity of natural γ ranges from 10 to 20 cps, showing a slight increase of the intensity with depth. The SP log shows that the SP values slightly increase with depth below 150 m in depth.

It is noted that the geophysical logging was carried out only up to 245 m, because the medium to coarse sand layer at a depth of about 240 m would easily collapse.

b. CH-2 Site [Girls College, Chuadanga Pourashava] (see Figure 5.2.15)

The geologic columnar section was made based on the observation of core boring samples. A formation occurs at a depth from 0 to 42.62 m. There are silt and clay layers at the top of A formation with a thickness of 7.6 m. The rest of A formation mainly consists of fine sand layers with very fine sand and medium sand. B formation occurs at depths from 42.65 to 102.5 m. In the upper part of B formation a coarse sand layer and a medium sand layer exist at depths from 44.6 to 53.6 m. Below this coarse sediment, the main part of B formation consists of fine to medium sand. There is a coarse sand to gravel layer at the bottom of B formation. C formation occurs at depths from 102.5 to 164 m. At the top, there is a thin peaty silt layer with a thickness of 0.2 m. Gravelly layers are dominant in C formation, particularly at depths from 121 to 149 m and from 157 to 164 m. In contrast, D formation and E formation is mainly composed of fine sediments. D formation has a thickness of 43.5 m, mainly consisting of fine to medium sand. E formation occurs at a depth below 207.5 m. The upper part of E formation consists of alternation of fine sand and silt layers. Below a depth of 250 m, the facies of E formation gradually becomes coarser with depth. There is a coarse sand layer with gravel at depths from 289.6 to 297 m.

The general pattern of resistivity logs at this site is similar to that of CH-1 site. The resistivity values are higher in C formation corresponding to the occurrence of the coarse sediments. In contrast, the resistivity of D and E formations is low, particularly the resistivity values at silty layers in the upper part of E formation. The natural γ slightly increases with depth in general. In A formation the natural γ value ranges from 7 to 20 cps, but the value exceeds 30 cps at a very fine to fine sand layer in the lower part of A formation. The natural γ value of B and C formation range between 10 to 20 cps. In D formation, there is a peak reaching 50 cps in a very fine to sand layer. It is presumed that the content of mica in the layer affects the natural γ value. In the upper part of E formation the natural γ value is slightly higher than that of the lower part. The SP value tends to decrease with depth. There are some small peaks in the upper part of E formation. Below 270 m depth in E formation the value clearly decreased.

c. CH-BD Site [Bara Dudpatila, Damurhuda upazila] (see Figure 5.2.16)

The geologic columnar section was made based on the observation of core boring samples. A formation occurs at a depth from 0 to 35 m. There is only one (1) thin layer of silt at the top. The thickness is 1 m. Then the upper part of A formation is dominated by very fine sand layers and the lower part is mainly comprised of fine sand layer. B formation occurs at depths from 35 to 104 m. The upper part consists mainly of fine sand, however, the lower part consists of fine to medium sand with medium to coarse sand. C formation is rich in gravel, occurring at depths from 104 to 169 m. There are two distinguished gravelly layers: one is located in the upper part and the other is located in the lower part. D formation mainly consists of fine sand, distributed at depths from 169 to 221 m. There are three (3) thin medium to coarse sand layers. E formation occurs below 221 m in depth. There are two (2) thick alternating layers of silt and sand at depths from 228.3 to 241 m and 288 to 300 m. The facies in between the two layers is mainly very fine sand to fine sand. A relatively thick medium sand layer occurs at depths from 268.35 to 273.77 m.

The resistivity values increase with depth in A and B formations. The values in C formation are high particularly at gravelly layers. The values sharply drop in D formation and the lower values continue to E formation. The natural γ values are generally oscillating between 10 and 20 cps, however, there are some peaks at finer sediment layers. It is noted that the baseline values increase to 20 cps in the upper alternating layer of silt and sand in E formation, where the mica content seems to be higher than that in other layers. The SP values gradually decrease with depth.

d. JH-1 Site [Arabpur, Jhenaidah Pourashava] (see Figure 5.2.17)

The geologic columnar section was made based on the observation of core boring samples. A formation occurs at depths from 0 to 48 m. At the site, a clayey layer was found only in the upper most part at depths from 0 to 4.62 m. The rest mainly consists of fine sand. There are only two (2) medium sand layers from 17 to 19 m and 23.35 to 26.2 m in depth. B formation is distributed at depths from 47 to 105.35 m. There are two (2) coarse zones in grain size in the upper part and in the lower part of the formation. The middle zone mainly consists of fine to medium sand. There is an alternation of medium sand layers and silty clay layers at depths from 68.7 to 70.5 m. C formation occurs at depths from 105.35 to 194.6 m. Gravelly layers are dominant in the formation. D formation occurs at depths from 194.6 to 242 m. The facies of the formation is characterized by alternations of silt and sand layers. E formation occurs below a depth of 242 m. There are several alternating layers of sand and silt in fine to medium sand layers.

The resistivity curves show good agreement with the facies change. A, B, and C formations have relatively higher resistivity values. On the other hand, the values of D and E formations are clearly lower. The resistivity of the middle part of B formation where the alternating layer of medium sand and silty clay occurs is very low. Higher natural γ values are found in the upper part of A formation, the middle part of C formation, and E formation. There are many peaks of natural γ values in E formation. The SP values decrease with depth from A formation to C formation. There is a gap in SP values between C formation and D formation. The Sp values in D formation also decrease with depth, however, the SP values in E formation tend to increase with depth.

e. JH-2 Site [Hamdah, Jhenaidah Pourashava] (see Figure 5.2.18)

The geologic columnar section was made based on the observation of cutting samples. A formation occurs at depths from 0 to 42 m. There is a silt layer below ground surface with a thickness of 4 m. Then the facies becomes coarser with depth. A medium sand layer occurs at depths from 15 to 18 m and a medium to coarse sand layer occurs at depths from 22 to 27 m. The remaining parts of A formation consist of very fine to fine sand and fine to medium sand layers. B formation is overlain by A formation, occurring at depths from 42 to 103 m. Medium to coarse sand is dominant in the upper half of B formation. On the other hand, the lower half is mainly composed of fine to medium sand layers. C formation occurs at depths from 103 to 200 m. The formation mainly consists of medium to coarse sand occasionally with gravel in the upper part and gravel rich layers with medium to coarse sand in the lower part. D formation occurs at depths from 200 to 250 m. The upper part is a medium sand layer with a thickness of 21 m. The lower part mainly consists of silty fine to medium sand layers. E formation occurs below 250 m in depth. The upper part at a depth from 250 to 274 m consists of fine to medium sand layer. The lower part below 274 m mainly consists of silty fine sand layers. There are two thin layers of medium to coarse sand with gravel in the lower part.

The resistivity logs show good agreement with the facies changes. The resistivity values in A formation are high in the middle part and low in the upper and in the lower parts. The values in

B and C formations are generally high. D and E formations have relatively lower values of resistivity than that of C formation. In each formation, the resistivity values decrease with depth, indicating sedimentation cycle from fine sediments to coarse sediments in ascending order. The natural γ values generally ranges between 10 and 30 cps. In A formation, the natural γ values are high in the upper part and in the lower part where the grain size of the sediments is finer. In B formation, the values are less than 20 cps except in the middle portion of the formation. In C formation, there are several high peaks of natural γ values exceeding 30 cps. The range of variation of the natural γ values in D and E formations is greater than that of upper formations. The average values tend to decrease with depth in D and E formations, however, there are several high peaks exceeding 30 cps. The SP values increase with depth from A to C formations. In D and E formations, sharp drops of SP values are found in the lower part of each formation.

f. JH-KC Site [Krishna Chandrapur, Moheshpur upazila] (see Figure 5.2.19)

The geologic columnar section was made based on the observation of core boring samples. A formation occurs at depths from 0 to 30 m. The formation consists mainly of very fine sand. There are two (2) clayey layers in the formation. A sandy silt layer occurs at the top with a thickness of 4.64 m. Another thin clay layer is found at depth from 25.67 to 26.59 m. B formation occurs at depths from 30 to 99.78 m. The formation can be subdivided into the upper part and lower part. The upper part is comprised of a very fine to fine sand layer, a fine sand layer, a fine to medium sand layer, and a fine sand layer in ascending order. The lower part consists of fine to medium sand layers and a medium sand layer. C formation occurs at depths from 99.78 to 195 m. In the formation, thick gravelly layers are developed in the upper part and in the lower part. The middle part of the formation is composed of fine to medium sand layers and medium sand layers. D formation is composed of fine sediments in contrast to C formation. Alternating layers of silt and very fine sand are dominant. There is a clayey silt layer at depths from 210.33 to 220 m. E formation occurring below 224 m in depth also consists of fine sediments. Alternation of silt and very fine sand layers is dominant at depths from 224 to 255.52 m and 274.86 to 300 m. In between, there is a thick silt layer with a thickness of 19.34 m.

At the site, geophysical logging was carried out only up to a depth of 115 m, because the gravelly layer at depths from 107 to 121 m always collapsed and it was difficult to maintain the borehole. The resistivity values in A and B formation increase with depth. The natural γ values generally range between 15 and 25 cps. The top sandy silt layer has a maximum natural γ value of 40 cps. There is a sharp peak of natural γ value exceeding 60 cps in B formation. The SP values tend to increase with depth in A formation and decrease in B formation. There are two (2) clear peaks of SP values at fine sediments in A formation.

g. JS-1 Site [Ghop, Jessore Pourashava] (see Figure 5.2.20)

The geologic columnar section was made based on the observation of cutting samples. A formation occurs at depths from 0 to 44 m. The upper part of the formation consists mainly of very fine to fine sand layers. The lower part is composed of silt, clay and silty, very fine sands. There are three clayey layers in the formation, occurring at depths from 1 to 4 m, 24 to 25 m, and 34 to 44 m. B formation occurs at depths from 44 to 104 m. The facies of the formation is characterized by fine to medium sand in the upper part and in the lower part, and medium sand in the middle part. C formation occurs at depths from 104 to 219 m. The main facies is medium to coarse sand with gravel. D formation occurs at depths from 219 to 258 m. The upper part of the formation consists of finer sediments such as fine sand and fine to medium sand with silt layers. There is a thin sandy silt layer at depths from 226 to 227 m. The lower part shows gravelly facies. E formation occurs below a depth of 258 m. The upper part from 258 to 283 m mainly consists of gravelly layers. On the other hand, the lower part is composed of silty sand layers.

The resistivity values of A to C formations generally range from 20 to 40 Ω-m, which are smaller than that in Chuadanga and Jhenaidah. The resistivity values in D and E formations are smaller, ranging between 10 and 30 Ω-m. The natural γ values are higher in A formation, ranging between 10 to 35 cps. The values of B to E formations range from 10 to 20 cps in general. The upper part of E formation has higher natural γ values ranging from 15 to 30 cps. The SP values increase with depth from A formation to the middle part of B formation. The SP value suddenly increases at the boundary of the middle part and the lower part of B formation. Then the values decrease with depth in C formation. From the lower part of C formation, the SP values again increase and become almost stable in D and E formations.

h. JS-2 Site [Kharki, Jessore Pourashava] (see Figure 5.2.21)

The geologic columnar section was made based on the observation of core boring samples. A formation occurs at depths from 0 to 40.6 m. The facies of A formation is characterized by clay with peat in the upper part and very fine to fine sand in the lower part. The upper clayey layer has a thickness of 20 m in which a peat layer is found at depths from 8.4 to 10.9 m. There is another clayey layer at depths from 29.58 to 30.4 m. B formation occurs at depth from 40.6 to 105 m. The upper part is dominated by medium sand layers and the lower part consists mainly of fine to medium sand. C formation occurs at depths from 105 to 216 m. The formation mainly consists of gravelly layers, which are several intercalated fine sand layers. The size of gravel tends to increase with depth. There are two very thin clayey layers at depths of 138 and 159 m. The gravel layer at depths from 200 to 216 m unconformably overlies D formation. D formation occurs at depths from 216 to 256 m. The upper part consists of a clayey layer with a thickness of 24 m. The lower part mainly consists of clayey layers. E formation occurs below a depth of 256

m. The formation mainly consists of fine to medium sand layers. There is a medium sand layer and a clayey silt layer at depths from 265 to 269 m and from 285 to 287 m, respectively.

The resistivity logs indicate that the layers up to a depth of 30 m are affected by saline water because the resistivity values are very small. Below the clayey layers in the lower part of A formation, the resistivity values coincides the lithologic facies. Particularly, the gravelly layers at the bottom of C formation and D formation have more than 50 Ω-m in short normal logging. On the other hand, the clayey layers in the upper part of D formation have low resistivity below 20 Ω-m. The natural γ values generally range between 15 and 25 cps. The clayey formations in A formation and in the upper part of D formation have greater values in natural γ. The SP values in A formation where the layers are considered to be affected by saline water irregularly fluctuated. The SP values of B and C formations are almost stable. The values slightly decrease with depth in D and E formations.

i. JS-RB Site [Rajnagar Bankabarsi, Keshabpur upazila] (see Figure 5.2.22)

The geologic columnar section was made based on the observation of core boring samples. The lithologic facies at the site is quite different from other drilling sites. A formation occurs at depths from 0 to 49 m. The facies of A formation is clayey in the upper part and very fine to fine sand in the lower part. Clayey layers with a peat layer occur at depths from 5 to 13 m. The thickness of the peat layer is 1.84 m. B formation occurs at depths from 49 to 90.3 m. The formation consists mainly of fine sand and fine to medium sand layers. There is a medium to coarse sand layer at depths 66 to 72 m. C formation occurs at depths from 90.3 to 232 m. The layers up to a depth of 219 m are clayey. Fine to coarse sandy layers occur only in the lower part of C formation. D formation occurs at depths from 232 to 253.56 m. The formation mainly consists of silty, very fine sand and alternation of silt and very fine sand layers. There is a thin fine to medium sand layer with a thickness of 1.82 m. E formation occurs below a depth of 253.56 m. The formation consists of clayey silt and silt layers.

The resistivity logs indicate that A formation and B formation is affected by saline water, showing very low and smooth resistivity curves below 20 Ω-m. The resistivity values in C formation increase with depth, showing a good agreement with facies change. The resistivity of sandy layers in the lower part of C formation and D formation is about 40 Ω-m. The natural γ values in A formation take a wide range of variation from 10 to 40 cps. The clayey layers with peat have relatively higher natural γ values. Then the values tend to decrease with depth. However, the natural γ values at the bottom of A formation exceed 40 cps. The average values of natural γ in B formation is below 20 cps. The boundary of B and C formation is very clear from the natural γ values. The values in C formation range from 20 to 35 cps. The values in D and E formation range from 20 to 40 cps. The SP values from A formation to the middle of C formation decrease with depth. Then the values increase with depth up to a depth of 300 m.

3) Casing Program

The casing program is very important for observation wells and observation holes to define the target aquifers as well as to separate the target aquifer from other aquifers. The casing program was designed based on the observation of core samples, results of borehole geophysical logging, observation of cutting samples, and drilling records. The casing program was determined by the well supervisor and the hydrogeologists of the study team. The well/borehole depth and screen depth with the geologic columnar section and resistivity logs are in Figures 5.2.23 to 5.2.31. The detailed casing program and well structures are shown in Figures 5.2.32 to 5.2.40.

a. CH-1 Site [Poshu Hat, Chuadanga Pourashava] (see Figures 5.2.23 and 5.2.32)

For the observation well (Ch-1), the drilling was performed up to a depth of 300 m. The well depth was fixed at 27 m based on the decision made from the cutting samples and geophysical logging. The screen pipes were installed at depths from 212.5 to 268 m. The screen pipes were set at 6 portions in the depths. The total length of the screen is 19.5 m. After installing the casing pipes and screen pipes, gravel packing and cement packing etc. were made. At first, gravel packing was made from the bottom of the drilled hole up to a depth of 207.5 m. Above the gravel packing, sand packing and bentonite packing were made. Then clay was put up to a depth of 170 m. To prevent seepage from the upper aquifer, cement packing was made at depths from 170 to 165 m. Above the cement packing, the space between the drilled hole and casing pipes was filled with clay packing from 165 to 45 m in depth. The second cement packing was made at depths from 45 to 38 m. Then clay was filled from 38 to 2 m. Finally clay cement packing was made at depths from 2 to 0 m to prevent contamination from the ground surface.

Four observation holes were drilled around the observation well. The depths of the observation holes are 63 m for Ch-1-1 hole, 118 m for Ch-1-2 hole, 168 m for Ch-1-3 hole, and 300 m for Ch-1-4 hole. Screen pipes were installed at depths from 54 to 60 m in Ch-1-1 hole, 100 to 112 m in Ch-1-2 hole, 150 to 162 m in Ch-1-3 hole, and 228 to 294 m in Ch-1-4 hole. A single screen structure was employed in the holes of Ch-1-1 to Ch1-3. Screen pipes were set at six (6) portions in Ch-1-4 hole. The total length of screen is 6 m in Ch-1-1 hole, 12 m in Ch-1-2 and Ch-1-3 holes, and 18 m in Ch-1-4 hole. The screen portions were filled with gravel packing, then sand packing and bentonite packing were made. At each observation hole, cement packing was made at the surface portion and at depths from 40 to 45 m. In addition, another cement packing was made from 165 to 170 m in Ch-1-4 hole. The rest of the portions above the bentonite packing were filled with clay.

b. CH-2 Site [Girls College, Chuadanga Pourashava] (see Figures 5.2.24 and 5.2.33)

For the observation well (Ch-2), the drilling was performed up to a depth of 303 m, and then it was decided that the well depth would be 298.5 m. The screen pipes were installed at depths from 270 to 295.5 m. The screen pipes were set at 2 portions: from 270 to 283 m and from 289 to 295.5 m. The total length of the screen is 19.5 m. After installing the casing pipes and screen pipes, gravel packing and cement packing etc. were made.

Four observation holes were drilled around the observation well. The depths of the observation holes are 56.5 m for Ch-2-1 hole, 109 m for Ch-2-2 hole, 152.5 m for Ch-2-3 hole, and 299.5 m for Ch-2-4 hole. Screen pipes were installed at depths from 44.5 to 53.5 m in Ch-2-1 hole, 97 to 106 m in Ch-2-2 hole, 122.5 to 149.5 m in Ch-2-3 hole, and 272.5 to 296.5 m in Ch-2-4 hole. A single screen structure was employed in the holes of Ch-1-1 to Ch1-2 and a double screen structure was employed in Ch-2-3 and Ch-2-4 holes. The total length of the screen is 9 m in Ch-2-1 and Ch-2-2 holes, 12 m in Ch-2-3 hole, and 15 m in Ch-2-4 hole. The screen portions were filled with gravel packing, then sand packing and bentonite packing were made.

c. CH-BD Site [Bara Dudpatila, Damurhuda Upazila] (see Figures 5.2.25 and 5.2.34)

In Bara Dudpatila village, a core boring was drilled up to a depth of 300 m. After the core boring, the drilled hole was enlarged and screen pipes and casing pipes were installed to use the borehole as an observation hole.

The screen pipes were installed at depths from 264 to 276 m and 294 to 296 m. The total length of the screen is 15 m. The gravel packing was made from 252 to 300 m. Then, sand packing (250 to 252 m), bentonite packing (248 to 250 m), clay packing (236 to 248 m), and cement packing (230 to 236 m) were performed. Above the cement packing, clay was filled from 230 to 2 m in depth. Finally, surface cement packing was made.

d. JH-1 Site [Arabpur, Jhenaidah Pourashava] (see Figures 5.2.26 and 5.2.35)

For the observation well (Jh-1), the drilling was performed up to a depth of 296 m. The well depth was fixed at 292.5 m based on the decision made from the core observation and geophysical logging. The screen pipes were installed at depths from 251.5 to 289 m. The screen pipes were set at four (4) portions in the depths. The total length of the screen is 19.5 m. After installing the casing pipes and screen pipes, gravel packing and cement packing etc. were made. At first, gravel packing was made from the bottom of the drilled hole up to a depth of 244 m. Above the gravel packing, sand packing and bentonite packing were made. After the cement packing at depths from 230 to 235 m, clay was put up to a depth of 72 m. The second cement packing was made at depths from 68 to 72 m. Then clay was again filled from 68 to 2 m. Finally clay cement packing was made at depths from 2 to 0 m to prevent contamination from the ground surface.

Four observation holes were drilled around the observation well. The depths of the observation holes are 60 m for Jh-1-1 hole, 123 m for Jh-1-2 hole, 165 m for Jh-1-3 hole, and 282 m for Jh-1-4 hole. Screen pipes were installed at depth from 48 to 57 m in Jh-1-1 hole, 108 to 120 m in Jh-1-2 hole, 150 to 162 m in Jh-1-3 hole, and 261 to 279 m in Jh-1-4 hole. A single screen structure was employed in the holes of Jh-1-1 to Jh1-3. Screen pipes were set at two (2) portions in Jh-1-4 hole. The total length of the screen is 9 m in Jh-1-1 hole and 12 m in Jh-1-2, Jh-1-3 and Jh-1-4 holes. The screen portions were filled with gravel packing, then sand packing and bentonite packing were made. At each observation hole, cement packing was made at the surface portion and at depths from 30 to 34 m for Jh-1-1 hole and from 40 to 45 m for the rest. In addition, another cement packing was made from 133 to 138 m in Jh-1-3 hole and from 230 to 235 m in Jh-1-4 hole. The rest of the portions above the bentonite packing were filled with clay.

e. JH-2 Site [Hamdah, Jhenaidah Pourashava] (see Figures 5.2.27 and 5.2.36)

For the observation well (Jh-2), the drilling was performed up to a depth of 302 m. The well depth was fixed at 301 m based on the decision made from the observation of cutting samples and geophysical logging. The screen pipes were installed at depths from 257.5 to 298 m. The screen pipes were set at three (3) portions in the depths. The total length of the screen is 19.5 m. After installing the casing pipes and screen pipes, gravel packing and cement packing etc. were made. At first, gravel packing was made from the bottom of the drilled hole up to a depth of 250 m. Above the gravel packing, sand packing and bentonite packing were made. After the cement packing at depths from 234 to 239 m, clay was put up to a depth of 73 m. The second cement packing was made at depths from 68 to 73 m. Then clay was again filled from 68 to 2 m. Finally clay cement packing was made at depths from 2 to 0 m to prevent contamination from the ground surface.

Four observation holes were drilled around the observation well. The depths of the observation holes are 60 m for Jh-2-1 hole, 111 m for Jh-2-2 hole, 165 m for Jh-2-3 hole, and 273 m for Jh-2-4 hole. Screen pipes were installed at depth from 48 to 57 m in Jh-2-1 hole, 96 to 108 m in Jh-2-2 hole, 150 to 162 m in Jh-2-3 hole, and 258 to 270 m in Jh-2-4 hole. A single screen structure was employed in the holes of Jh-2-1 to Jh-2-4. The total length of the screen is 9 m in Jh-2-1 hole and 12 m in Jh-2-2, Jh-2-3 and Jh-2-4 holes. The screen portions were filled with gravel packing, then sand packing and bentonite packing were made. At each observation hole, cement packing was made at the surface portion and at depths from 28 to 32 m for Jh-2-1 hole and from 68 to 73 m for the rest. In addition, another cement packing was made from 129 to 134 m in Jh-2-3 hole and from 234 to 239 m in Jh-2-4 hole. The rest of the portions above the bentonite packing were filled with clay.

f. JH-KC Site [Krishna Chandrapur, Moheshpur Upazila] (see Figures 5.2.28 and 5.2.37)

In Krishna Chandrapur village, a core boring was drilled up to a depth of 300 m. After the core boring, the drilled hole was enlarged and screen pipes and casing pipes were installed to use the borehole as an observation hole.

The screen pipes were installed at depths from 267 to 270 m, 276 to 282 m, and 288 to 297 m. The total length of the screen is 18 m. The gravel packing was made from 261 to 301.9 m. Then, sand packing (259 to 261 m), bentonite packing (255 to 257 m), clay packing (252 to 255 m), and cement packing (247 to 252 m) were performed. Above the cement packing, clay was filled from 247 to 2 m in depth. Finally surface cement packing was made.

g. JS-1 Site [Ghop, Jessore Pourashava] (see Figures 5.2.29 and 5.2.38)

For the observation well (Js-1), the drilling was performed up to a depth of 301 m. The well depth was fixed at 280.5 m based on the decision made from the observation of cutting samples and geophysical logging. The screen pipes were installed at depths from 261 to 274 m. The screen pipes were set at only one (1) portion. The total length of the screen is 13 m. After installing the casing pipes and screen pipes, gravel packing and cement packing etc. were made. At first, gravel packing was made from the bottom of the drilled hole up to a depth of 256 m. Above the gravel packing, sand packing and bentonite packing were made. After the cement packing at depths from 223 to 228 m, clay was put up to a depth of 44 m. The second cement packing was made at depths from 39 to 44 m. Then clay was again filled from 39 to 2 m. Finally clay cement packing was made at depths from 2 to 0 m to prevent contamination from the ground surface.

Four observation holes were drilled around the observation well. The depths of the observation holes are 66 m for Js-1-1 hole, 120 m for Js-1-2 hole, 168 m for Js-1-3 hole, and 282 m for Js-1-4 hole. Screen pipes were installed at depth from 54 to 63 m in Js-1-1 hole, 105 to 117 m in Js-1-2 hole, 153 to 165 m in Js-1-3 hole, and 261 to 276 m in Js-1-4 hole. A single screen structure was employed in all the holes from Js-1-1 to Js-1-4. The total length of the screen is 9 m in Js-1-1 hole, 12 m in Js-1-2 and Js-1-3 holes, and 15 m in Js-1-4 holes. The screen portions were filled with gravel packing, then sand packing and bentonite packing were made. At each observation hole, cement packing was made at the surface portion and at depths from 39 to 44 m. In addition, another cement packing was made from 89 to 94 m in Js-1-2 hole, from 129 to 134 m in Js-1-3 hole, and from 223 to 228 m in Js-1-4 hole. The rest of the portions above the bentonite packing were filled with clay.

h. JS-2 Site [Kharki, Jessore Pourashava] (see Figures 5.2.30 and 5.2.39)

For the observation well (Js-2), the drilling was performed up to a depth of 270 m. The well depth was fixed at 261.75 m based on the decision made from the observation of core samples and geophysical logging. The screen pipes were installed at depths from 239.5 to 255.75 m. The screen pipes were set at only one (1) portion. The total length of the screen is 16.25 m. After installing the casing pipes and screen pipes, gravel packing and cement packing etc. were made. At first, gravel packing was made from the bottom of the drilled hole up to a depth of 236 m. Above the gravel packing, sand packing and bentonite packing were made. After the cement packing at depths from 220 to 225 m, clay was put up to a depth of 35 m. The second cement packing was made at depths from 30 to 35 m. Then clay was again filled from 30 to 2 m. Finally, clay cement packing was made at depths from 2 to 0 m to prevent contamination from the ground surface.

Four observation holes were drilled around the observation well. The depths of the observation holes are 66 m for Js-2-1 hole, 114 m for Js-2-2 hole, 162 m for Js-2-3 hole, and 255 m for Js-2-4 hole. Screen pipes were installed at depth from 54 to 63 m in Js-2-1 hole, 99 to 111 m in Js-2-2 hole, 147 to 159 m in Js-2-3 hole, and 240 to 252 m in Js-2-4 hole. A single screen structure was employed in all the holes from Js-2-1 to Js-2-4. The total length of the screen is 9 m in Js-2-1 hole and 12 m in Js-2-2, Js-2-3, and Js-2-4 holes. The screen portions were filled with gravel packing, then sand packing and bentonite packing were made. At each observation hole, cement packing was made at the surface portion and at depths from 30 to 35 m except Js-2-2 hole. In addition, another cement packing was made from 85 to 90 m in Js-2-2 hole, from 134 to 139 m in Js-2-3 hole, and from 220 to 225 m in Js-2-4 hole. The rest of the portions above the bentonite packing were filled with clay.

i. JS-RB Site [Rajnagar Bankabarsi, Keshabpur Upazila] (see Figures 5.2.31 and 5.2.40)

In Rajnagar Bankabarsi village, a core boring was drilled up to a depth of 300 m. After the core boring, the drilled hole was enlarged and screen pipes and casing pipes were installed to use the borehole as an observation hole.

The screen pipes were installed at depths from 222 to 228 m, 231 to 234 m, 240 to 243 m, and 252 to 258 m. The total length of the screen is 18 m. The gravel packing was made from 217 to 263 m. Then, sand packing (215 to 217 m), bentonite packing (213 to 215 m), clay packing (202 to 213 m), and cement packing (197 to 202 m) were performed. Above the cement packing, clay was filled from 202 to 2 m in depth. Finally surface cement packing was made.

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

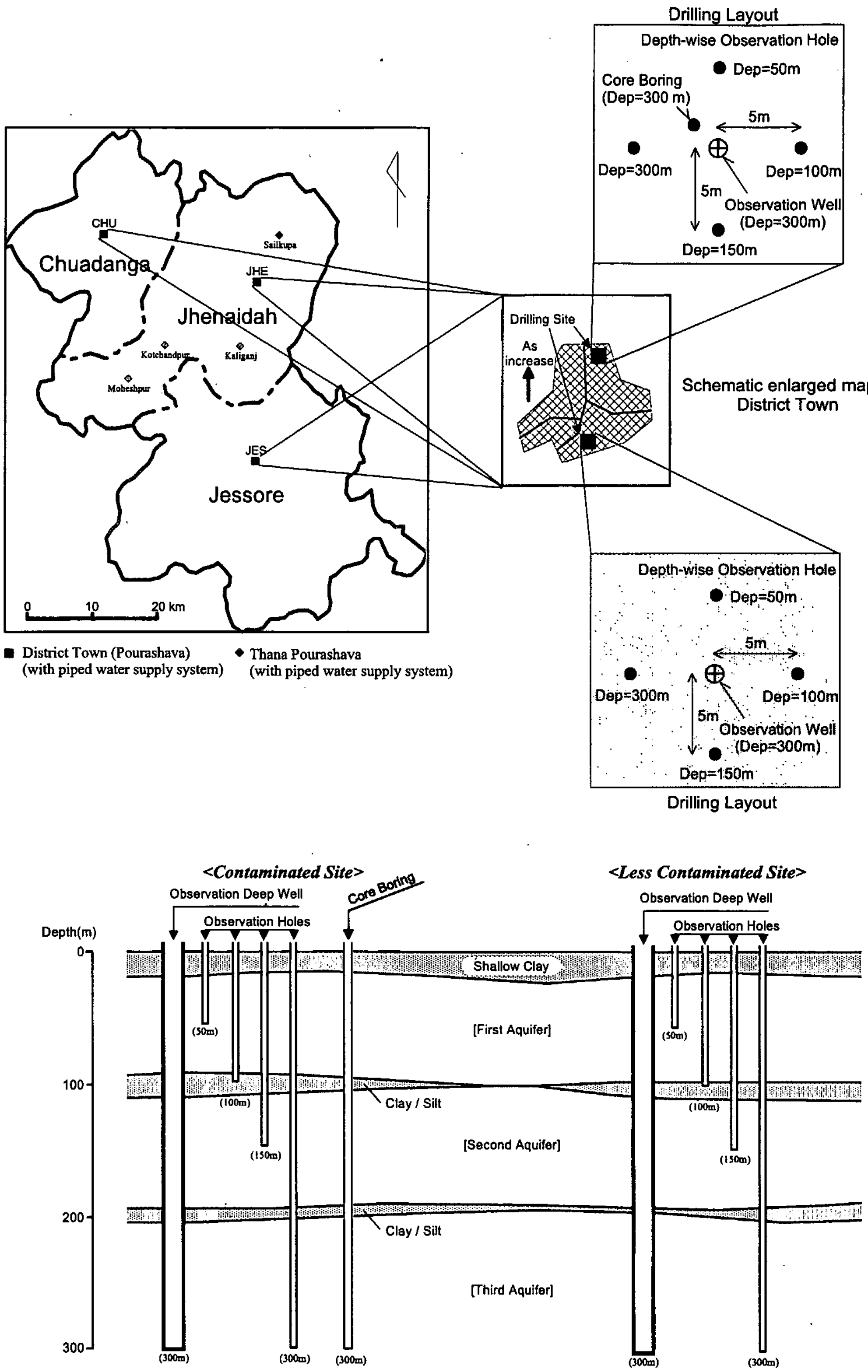


Figure 5.2.1	Schematic Drilling Plan of Observation Wells and Bore Holes

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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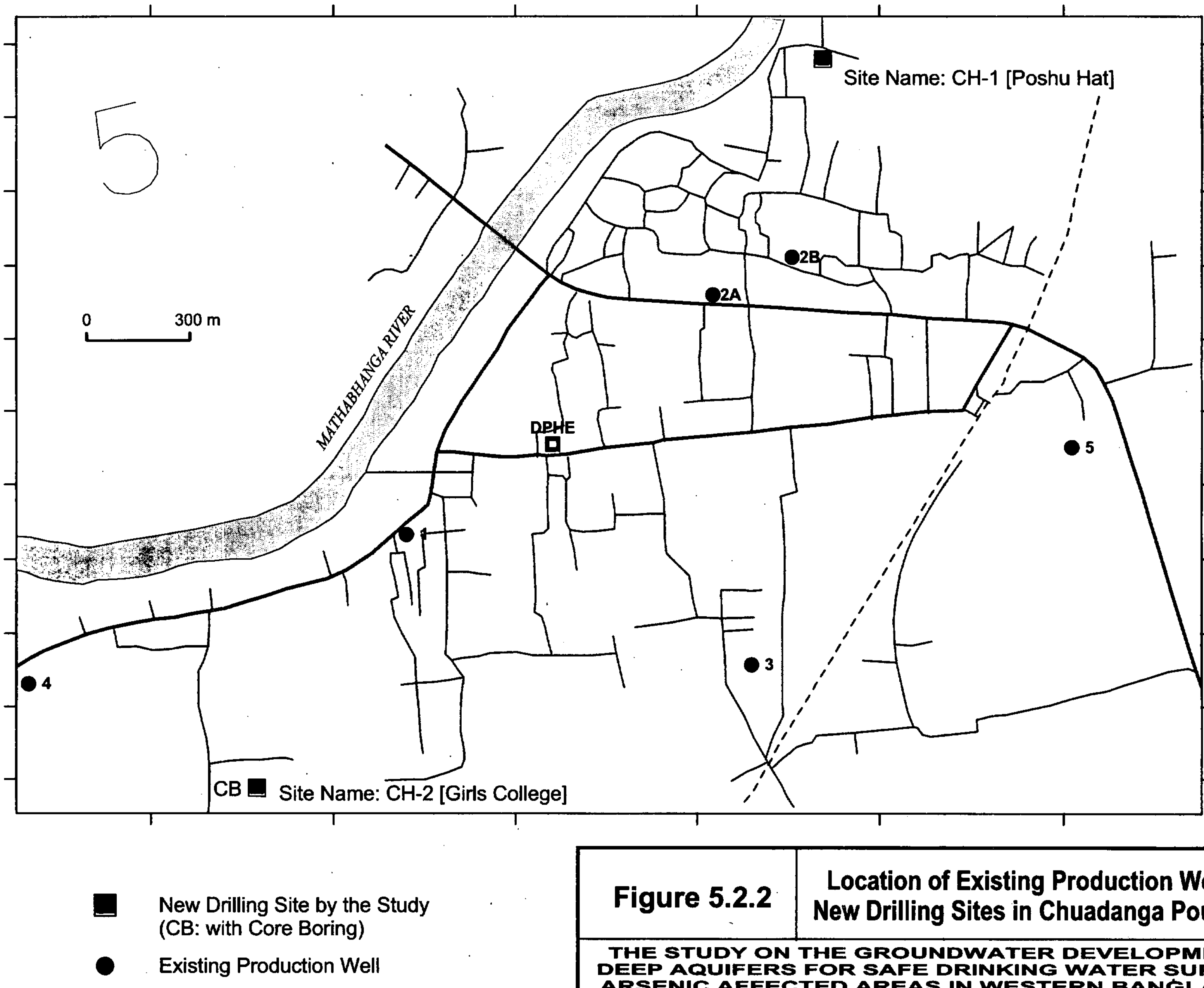


Figure 5.2.2	Location of Existing Production Wells and New Drilling Sites in Chuadanga Pourashava
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

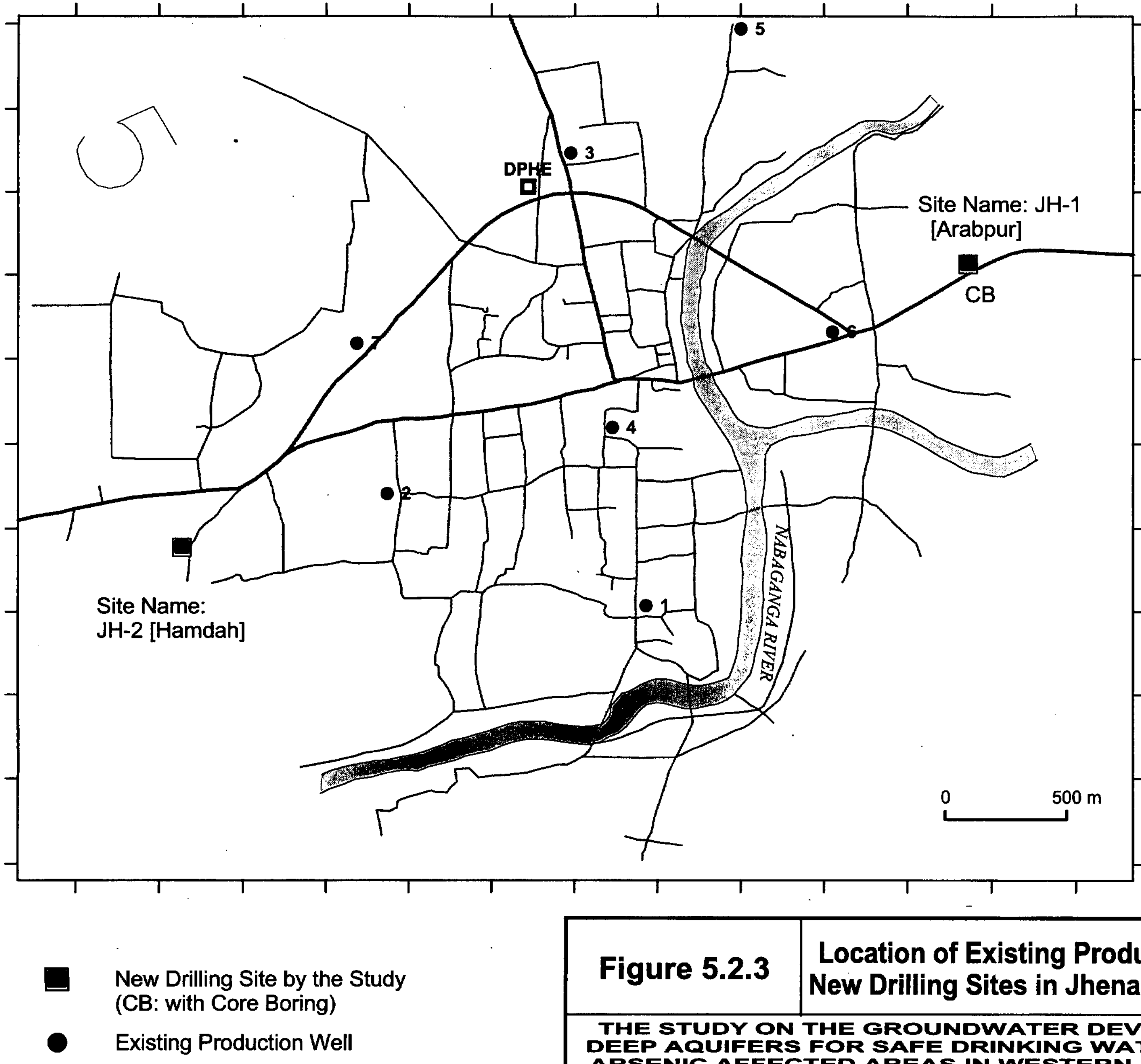
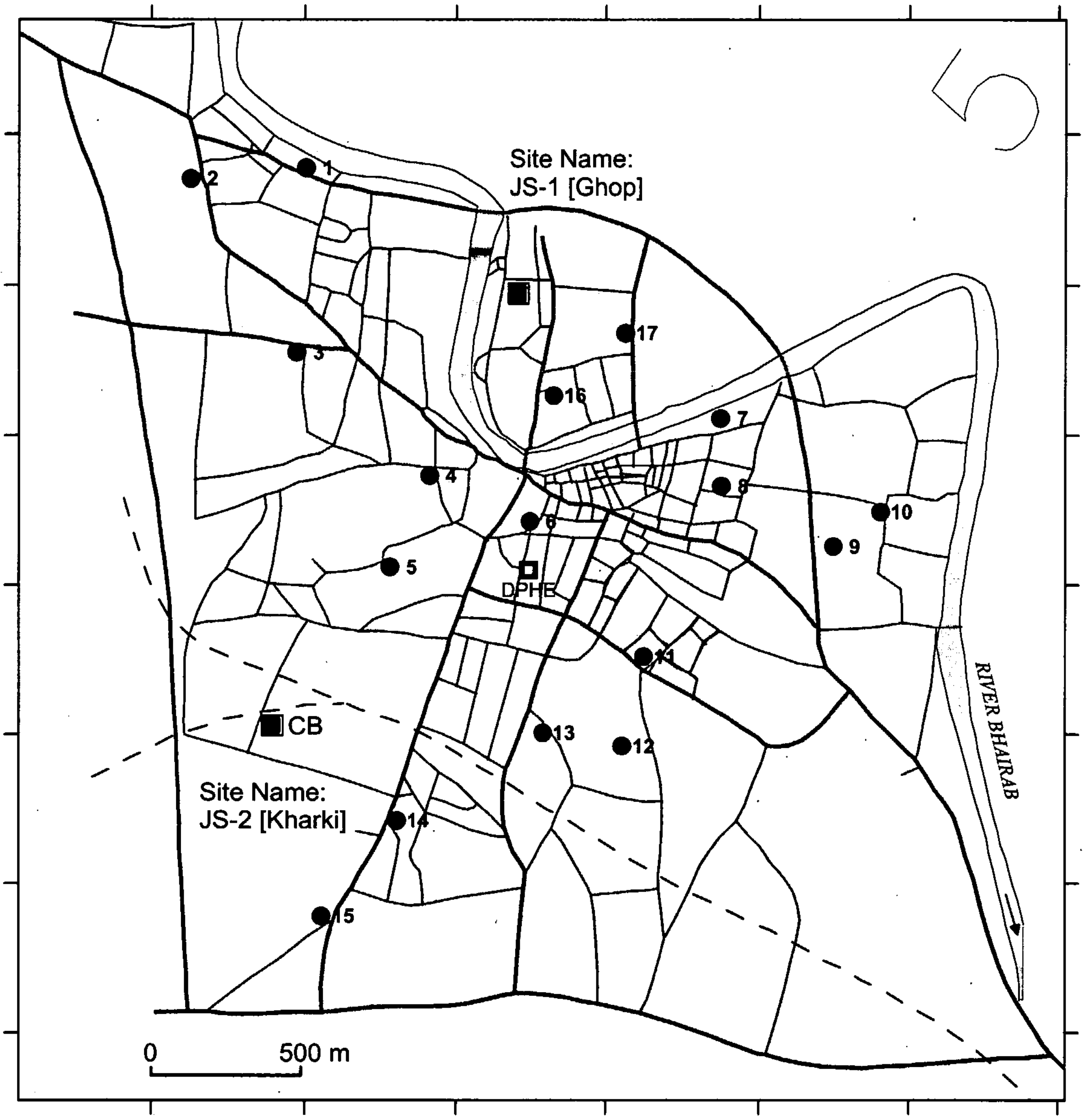


Figure 5.2.3 Location of Existing Production Wells and New Drilling Sites in Jhenaidah Pourashava

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

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

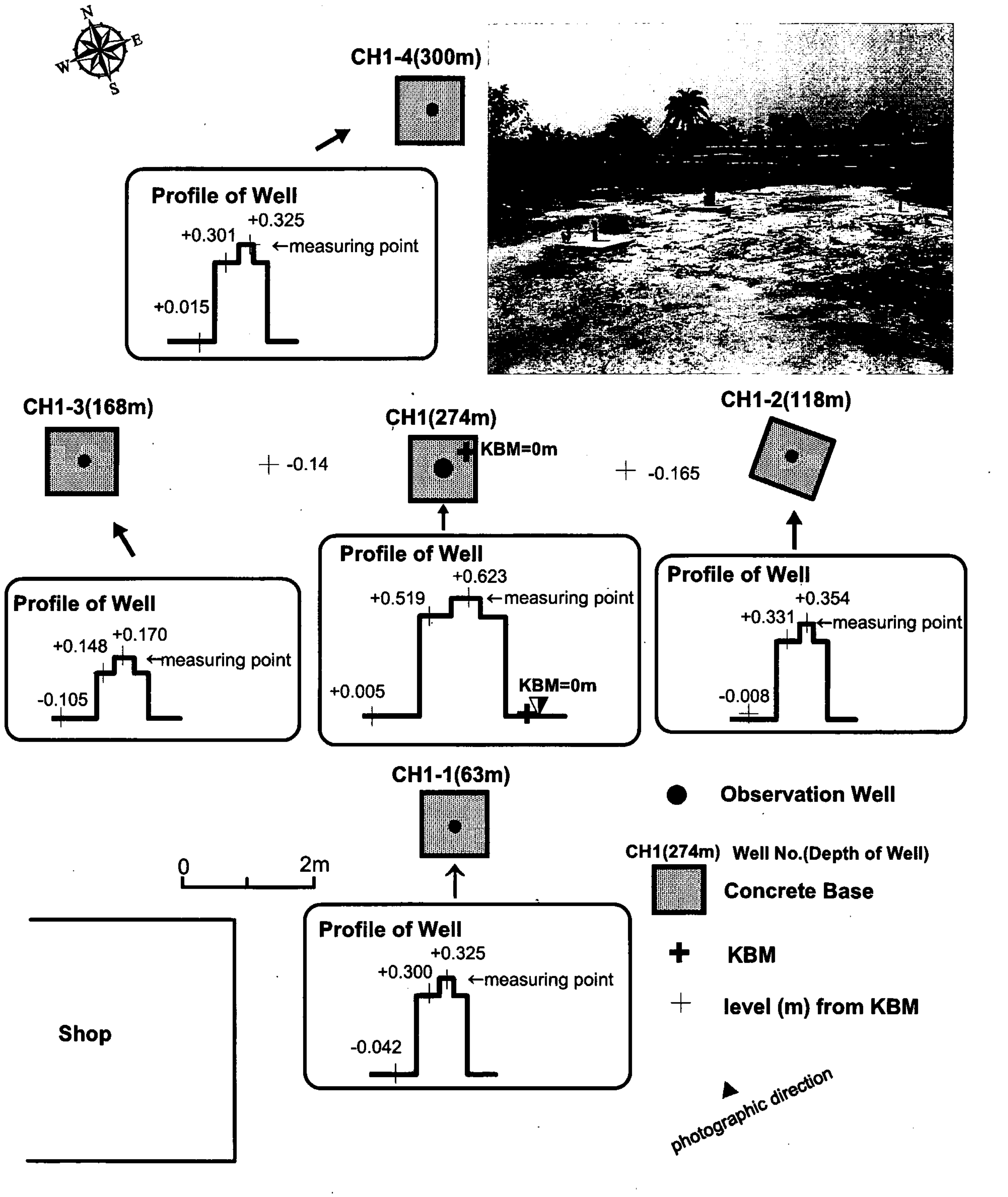


Figure 5.2.5	Drilling Site Map of CH-1 (Poshu Hat, Chuadanga Pourashava)
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

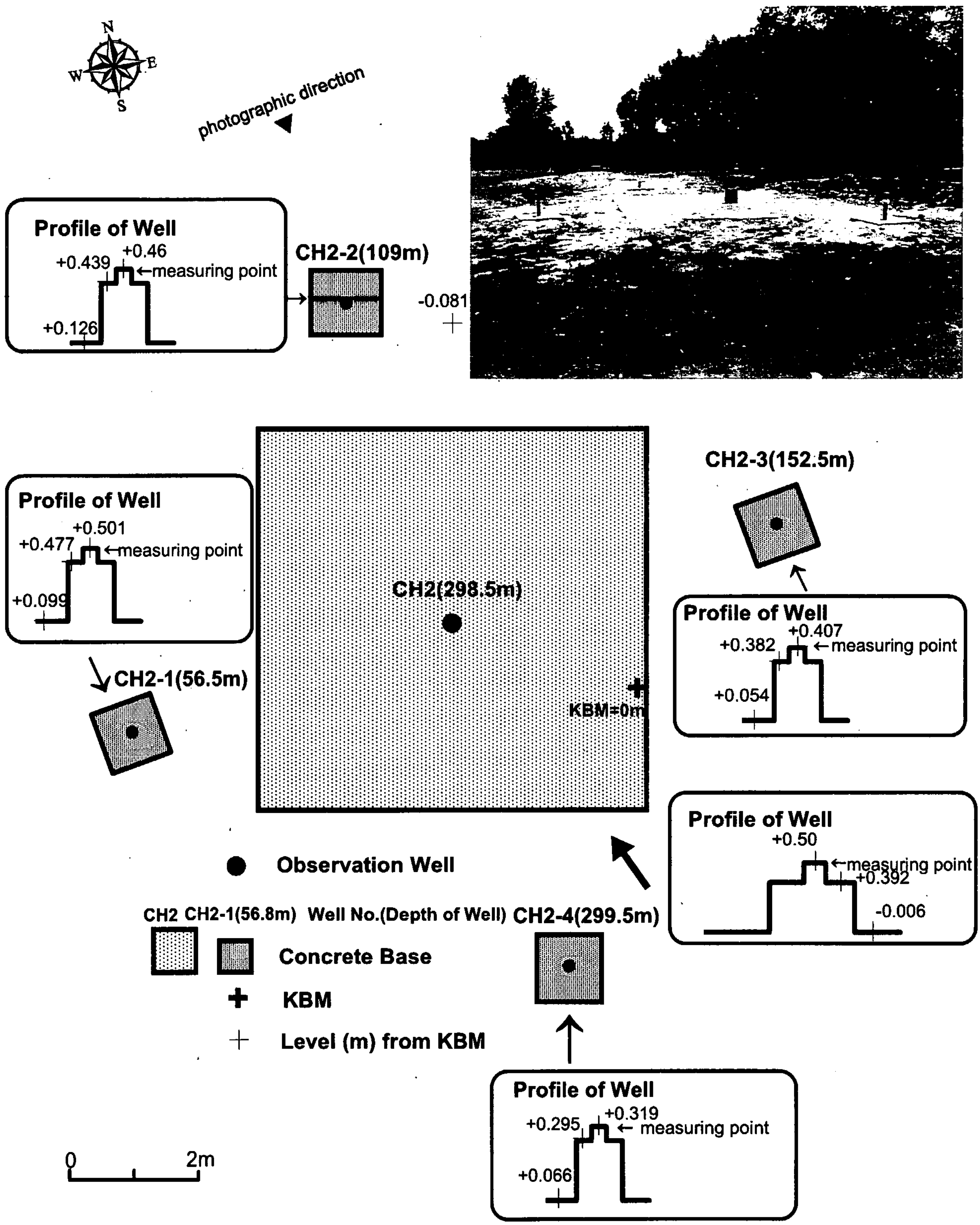
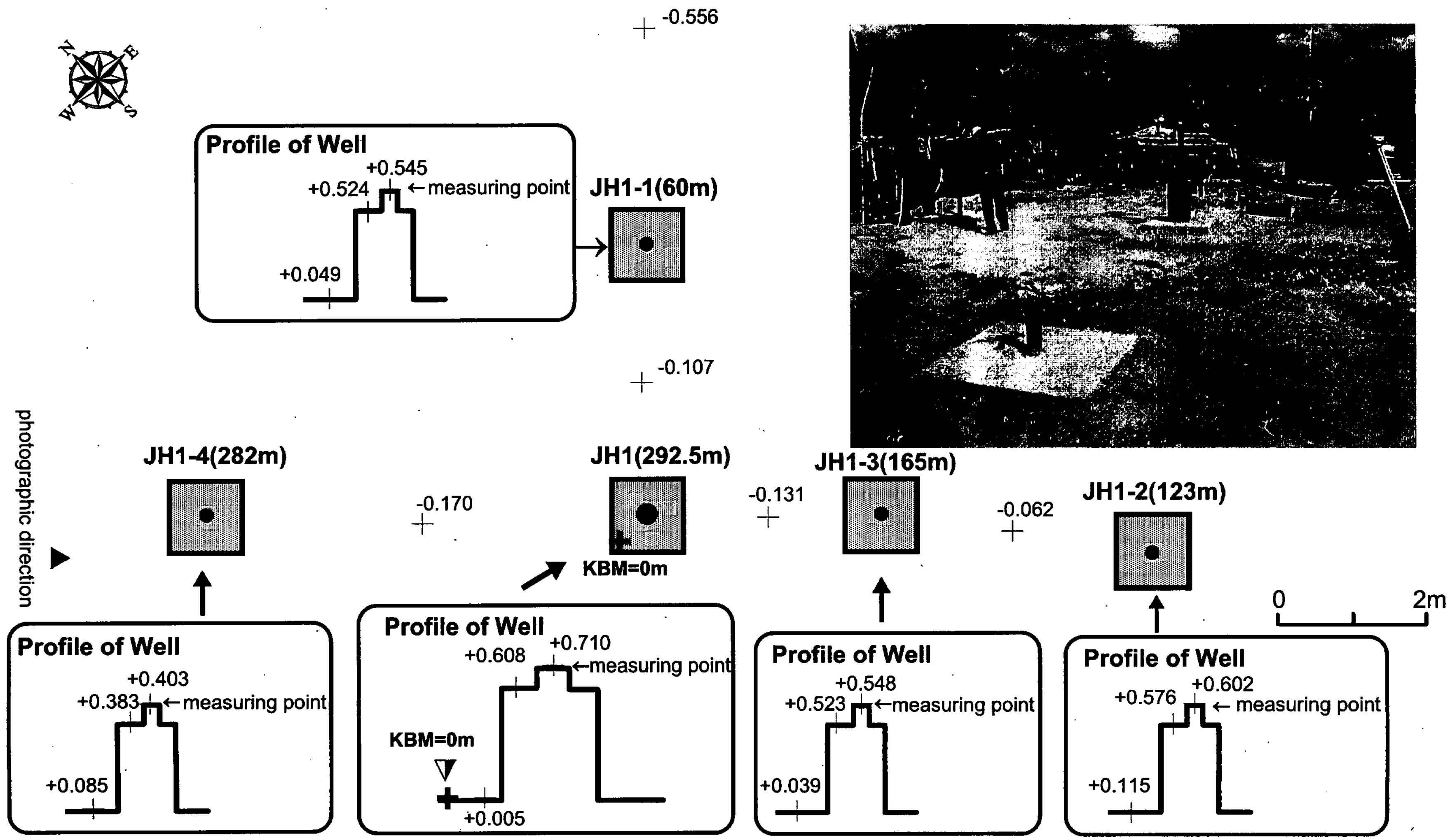


Figure 5.2.6	Drilling Site Map of CH-2 (Girls College, Chuadanga Pourashava)

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)



● Observation Well

JH1(292.5m) Well No.(Depth of Well)

Concrete Base

✚ KBM

+ Level (m) from KBM

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)

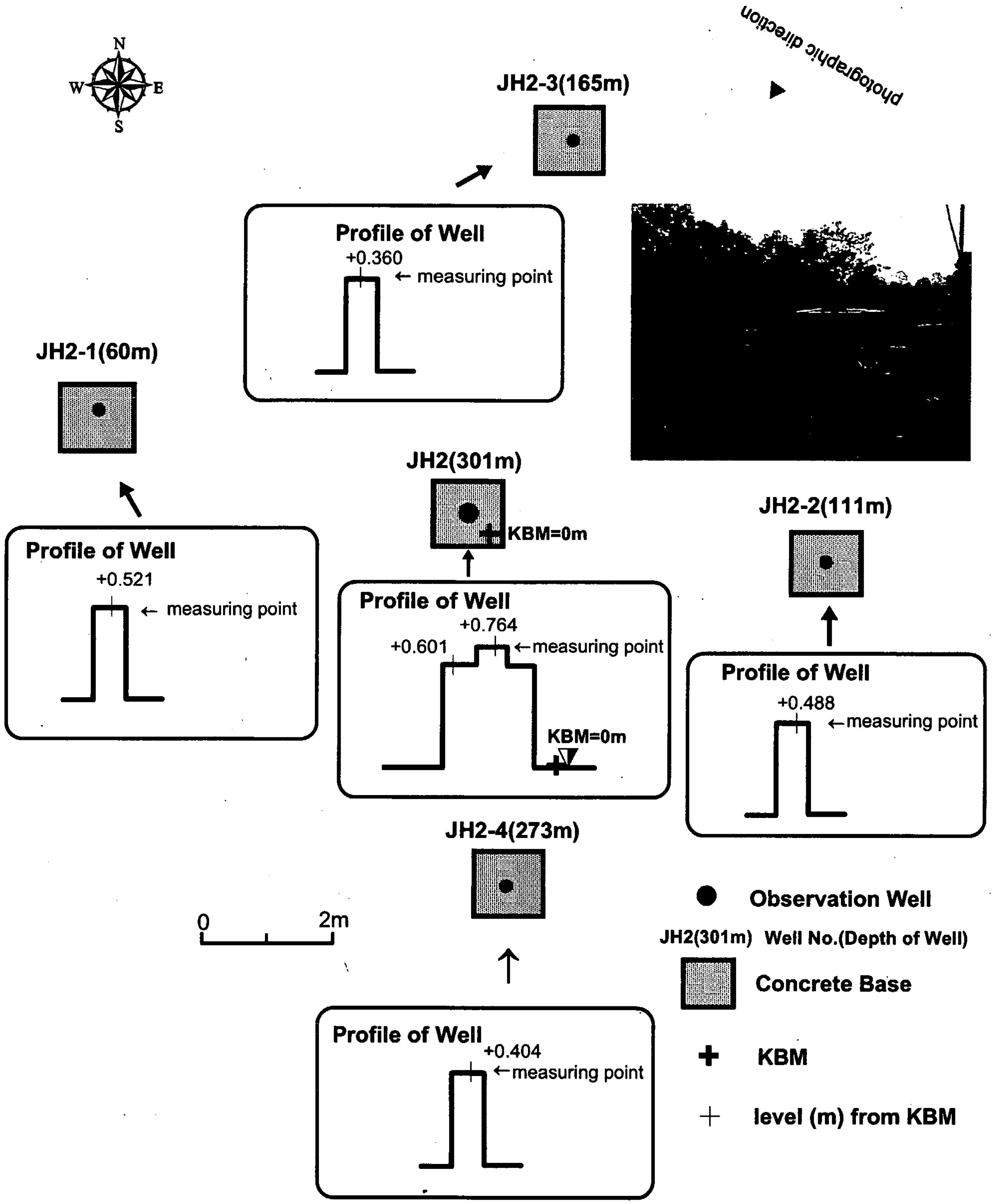


Figure 5.2.8	Drilling Site Map of JH-2 (Hamdah, Jhenaidah Pourashava)
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

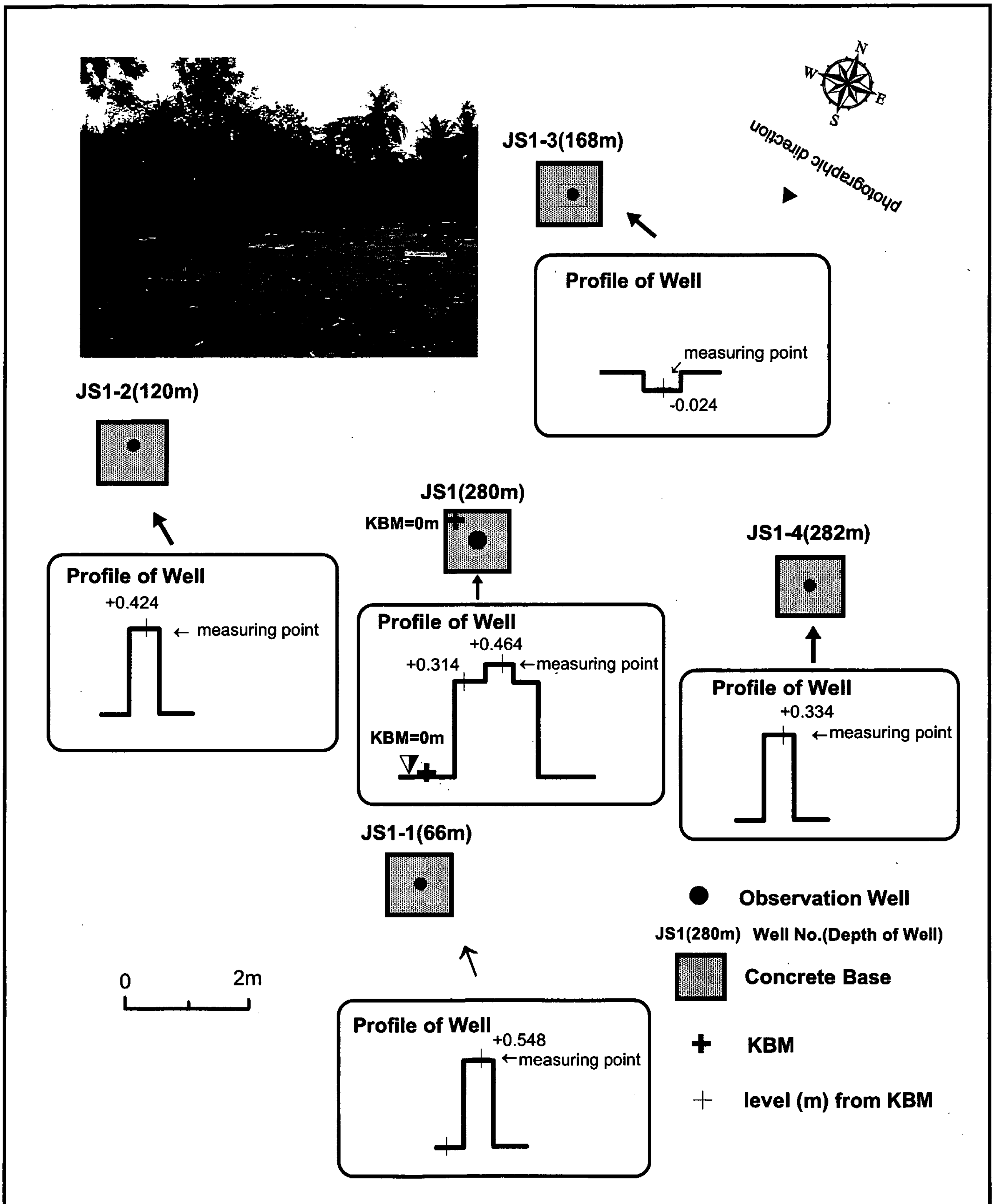


Figure 5.2.9	Drilling Site Map of JS-1 (Ghop, Jessore Pourashava)

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)

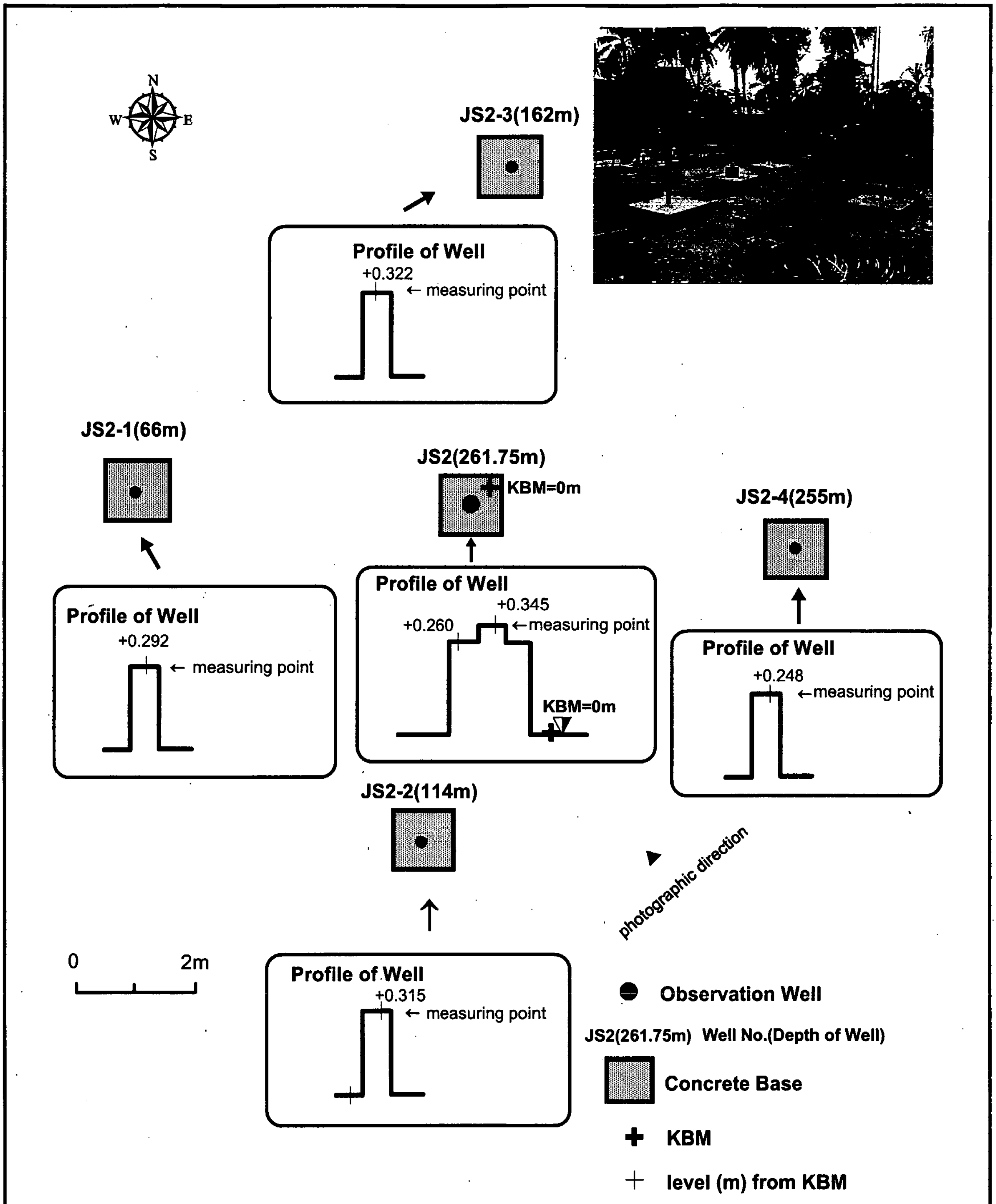


Figure 5.2.10	**Drilling Site Map of JS-2 (Kharki, Jessore Pourashava)**

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)

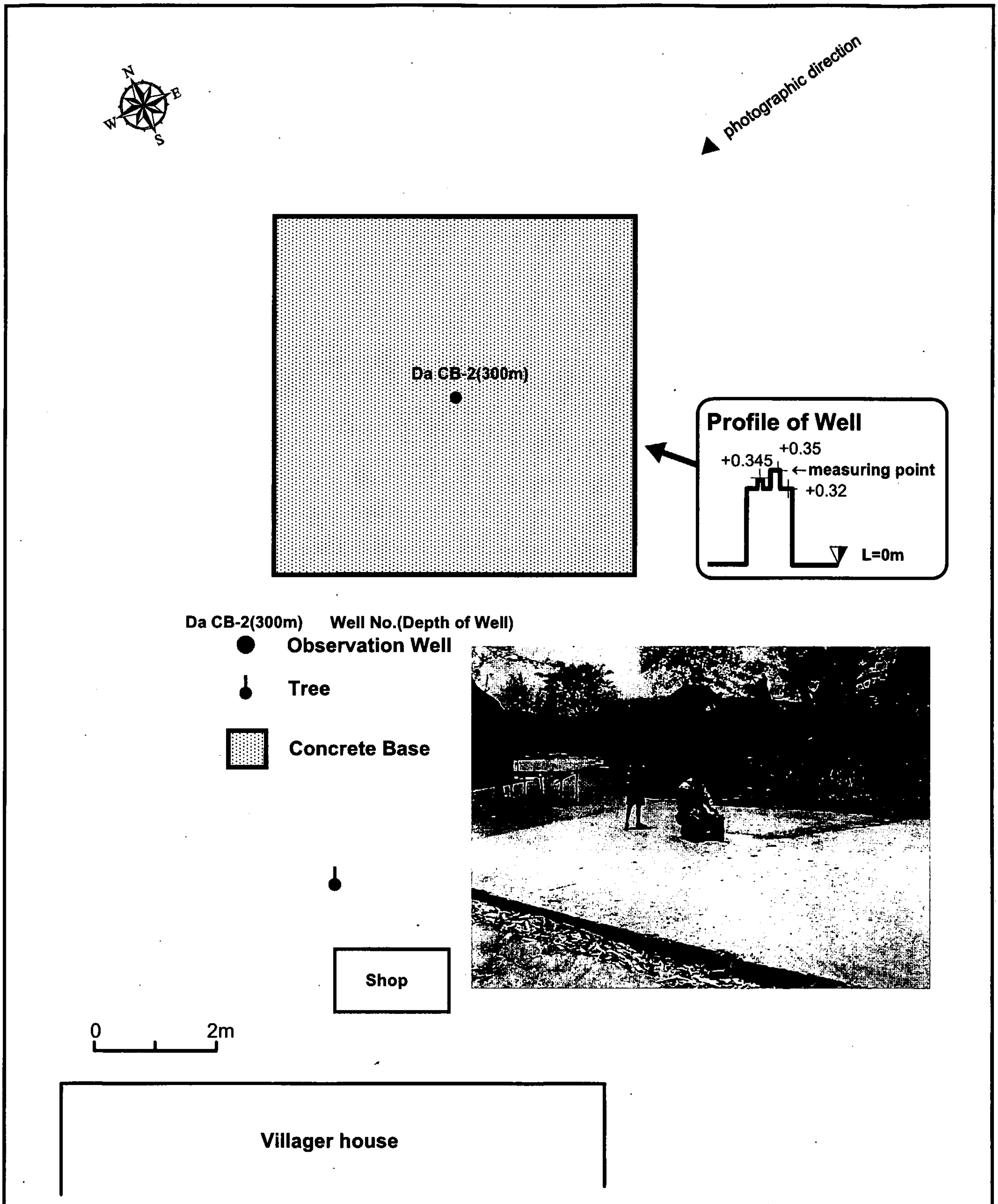


Figure 5.2.11	Drilling Site Map of CH-BD (Bara Dudpatila, Damurhuda Upazila)
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

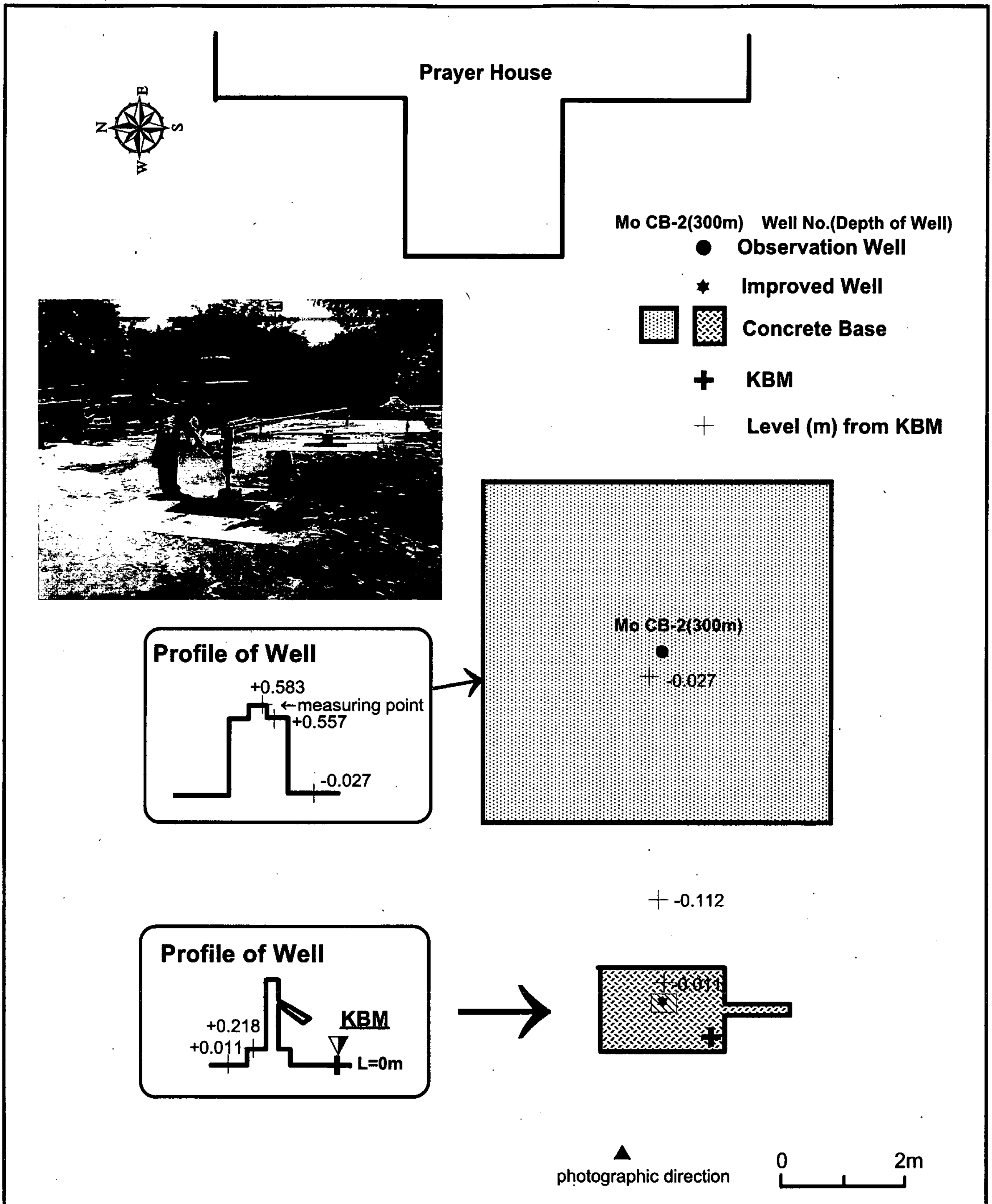


Figure 5.2.12	Drilling Site Map of JH-KC (Krishna Chandrapur, Moheshpur)
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

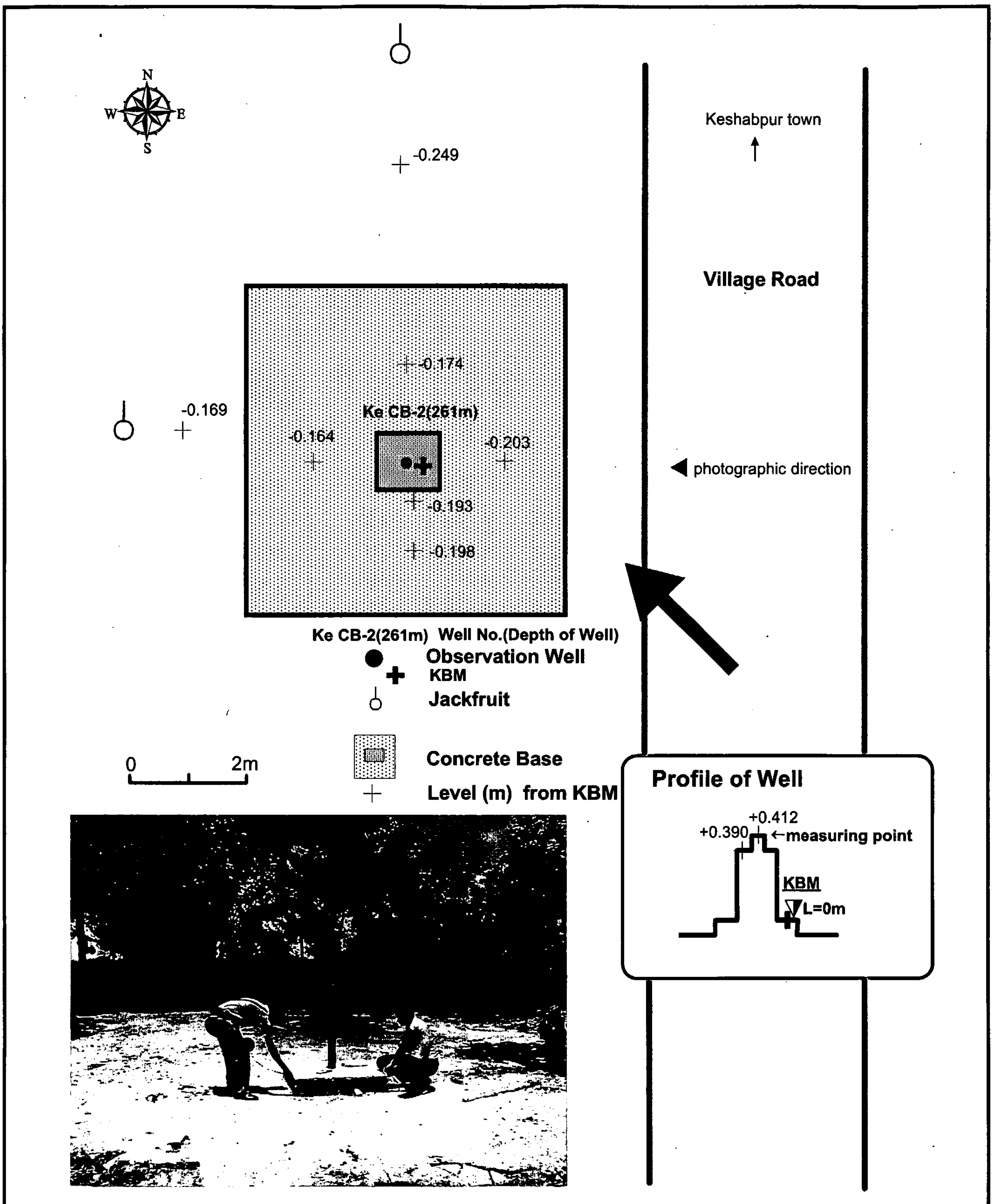
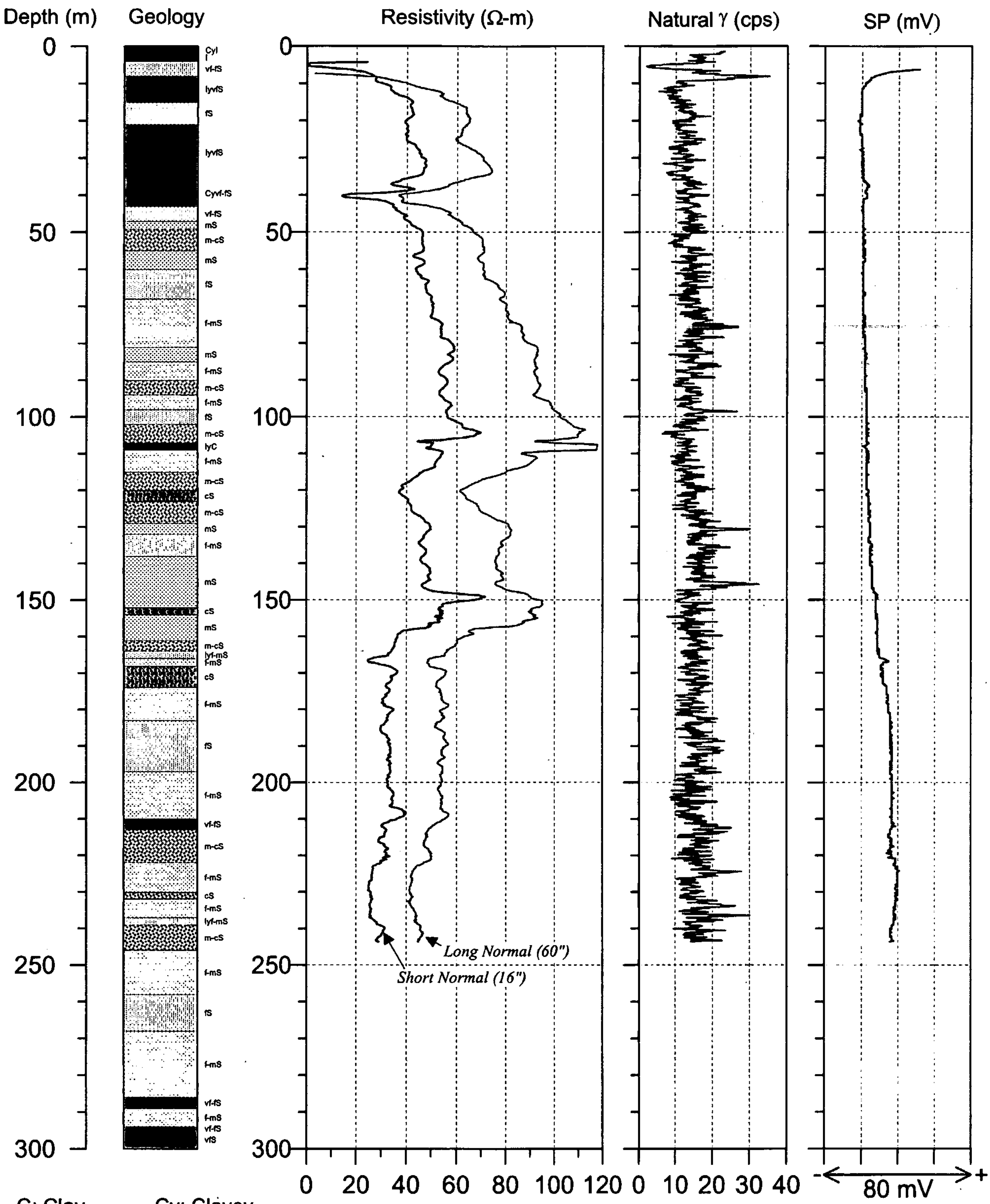


Figure 5.2.13	Drilling Site Map of JS-RB (Rajnagar Bankabarsi, Keshabpur)

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)



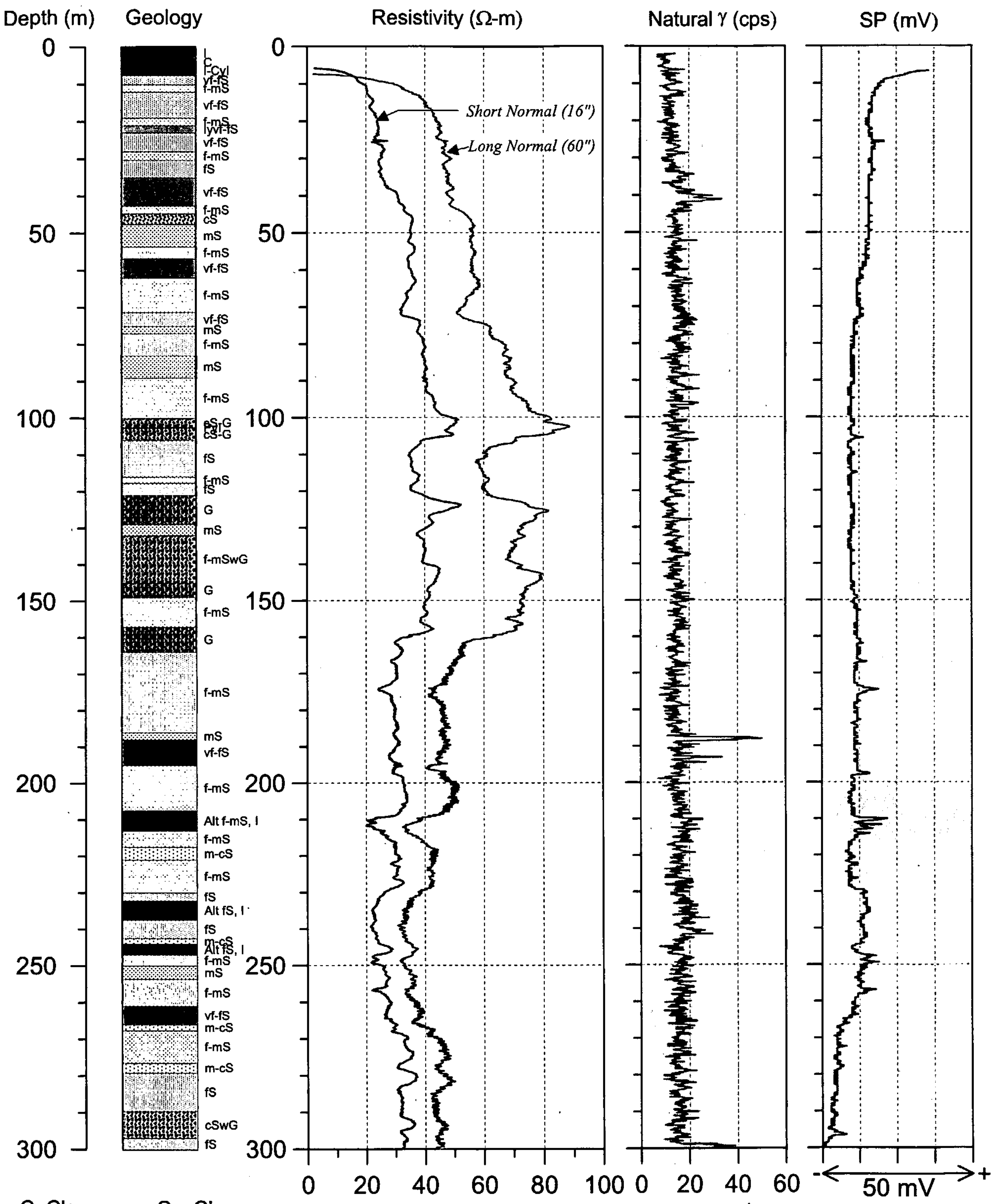
C: Clay
I: Silt
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

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

Figure 5.2.14 **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)

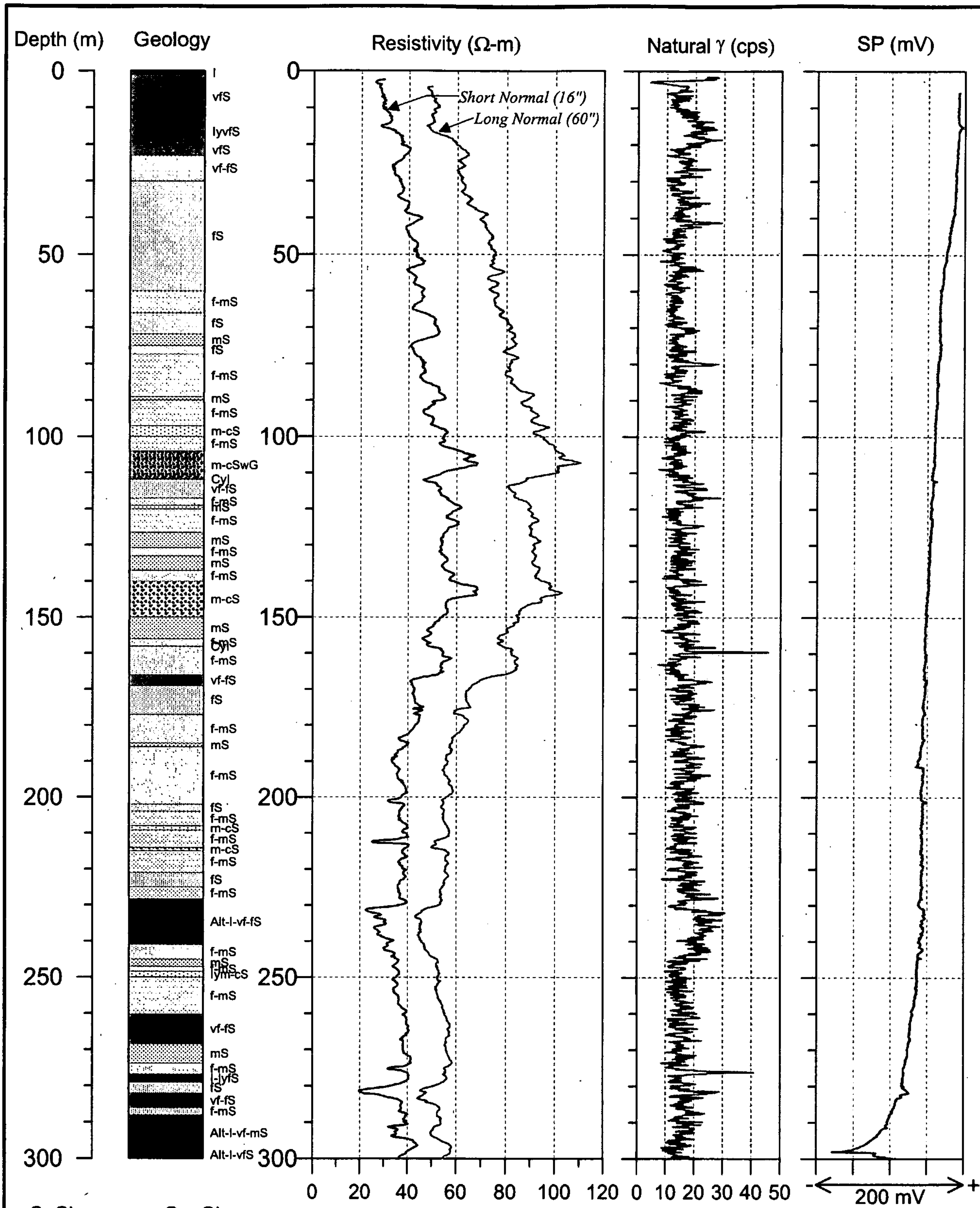


C: Clay	Cy: Clayey
I: Silt	Iy: Silty
S: Sand	Sy: Sandy
G: Gravel	w: with
v: very	-: to
f: fine	Alt: Alternation
m: medium	P: Peat
c: coarse	TS: Top Soil

Figure 5.2.15 **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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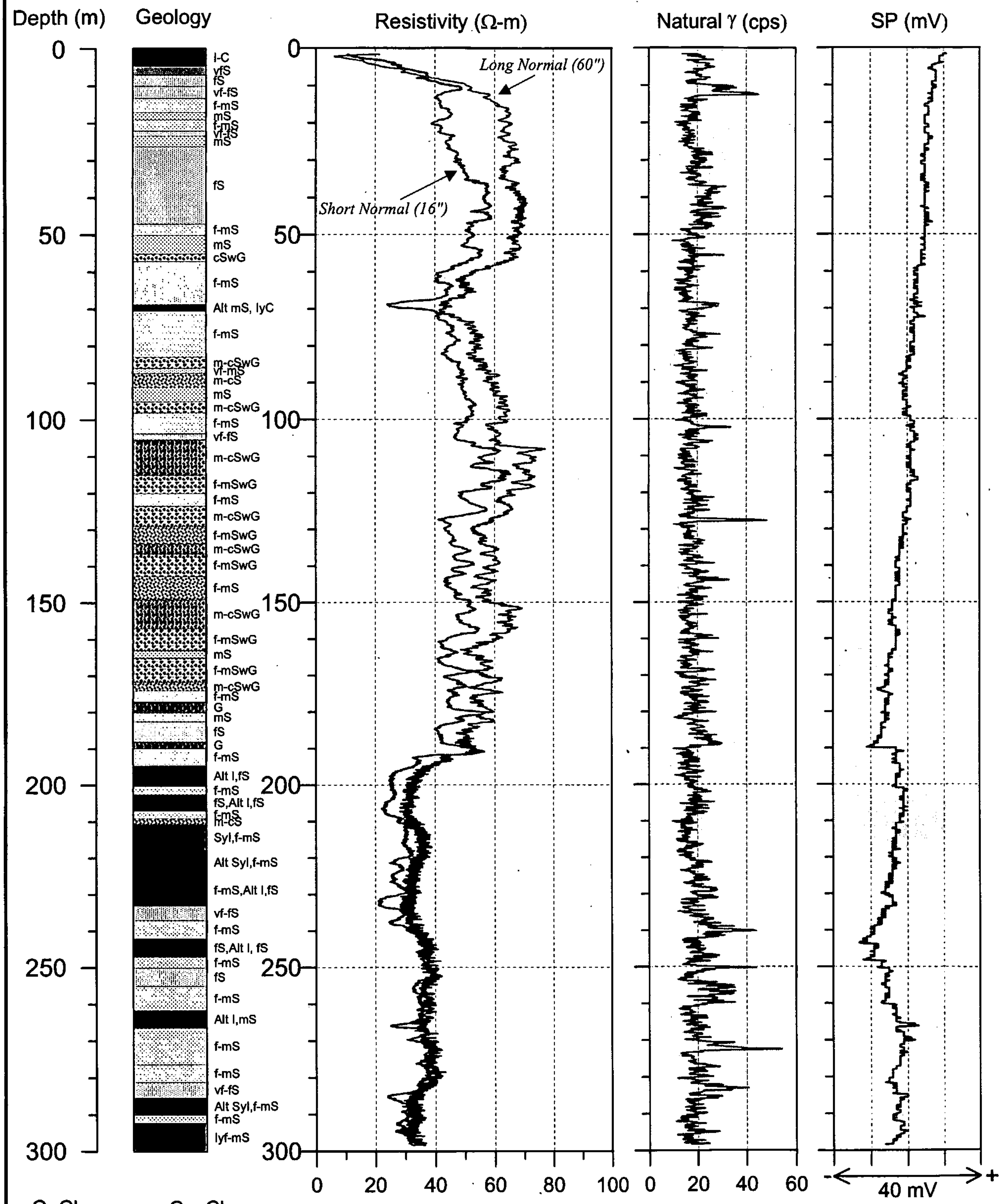
m: medium
c: coarse

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

Figure 5.2.16	**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)



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G: Gravel
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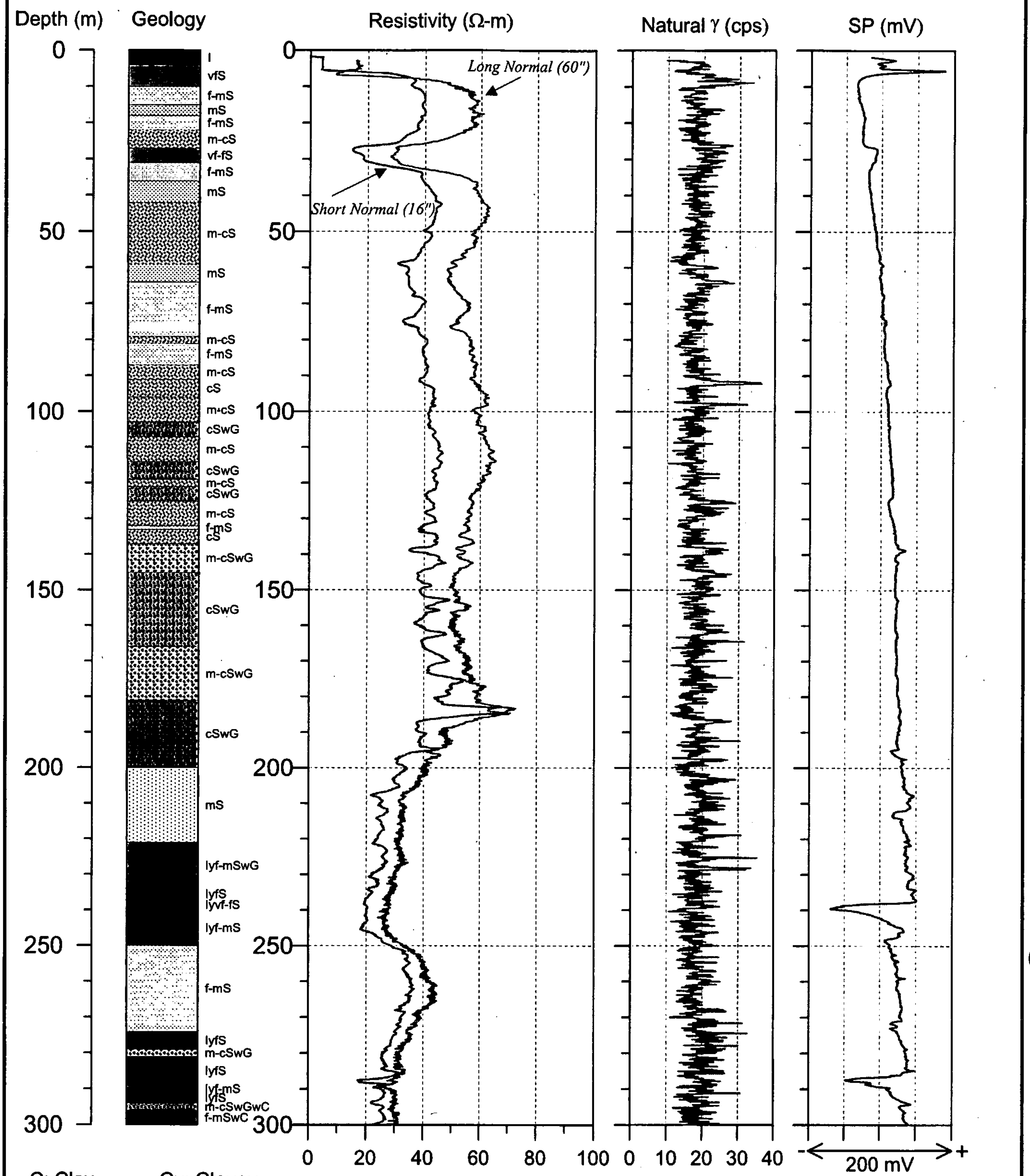
f: fine
m: medium
c: coarse

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

Figure 5.2.17	**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)

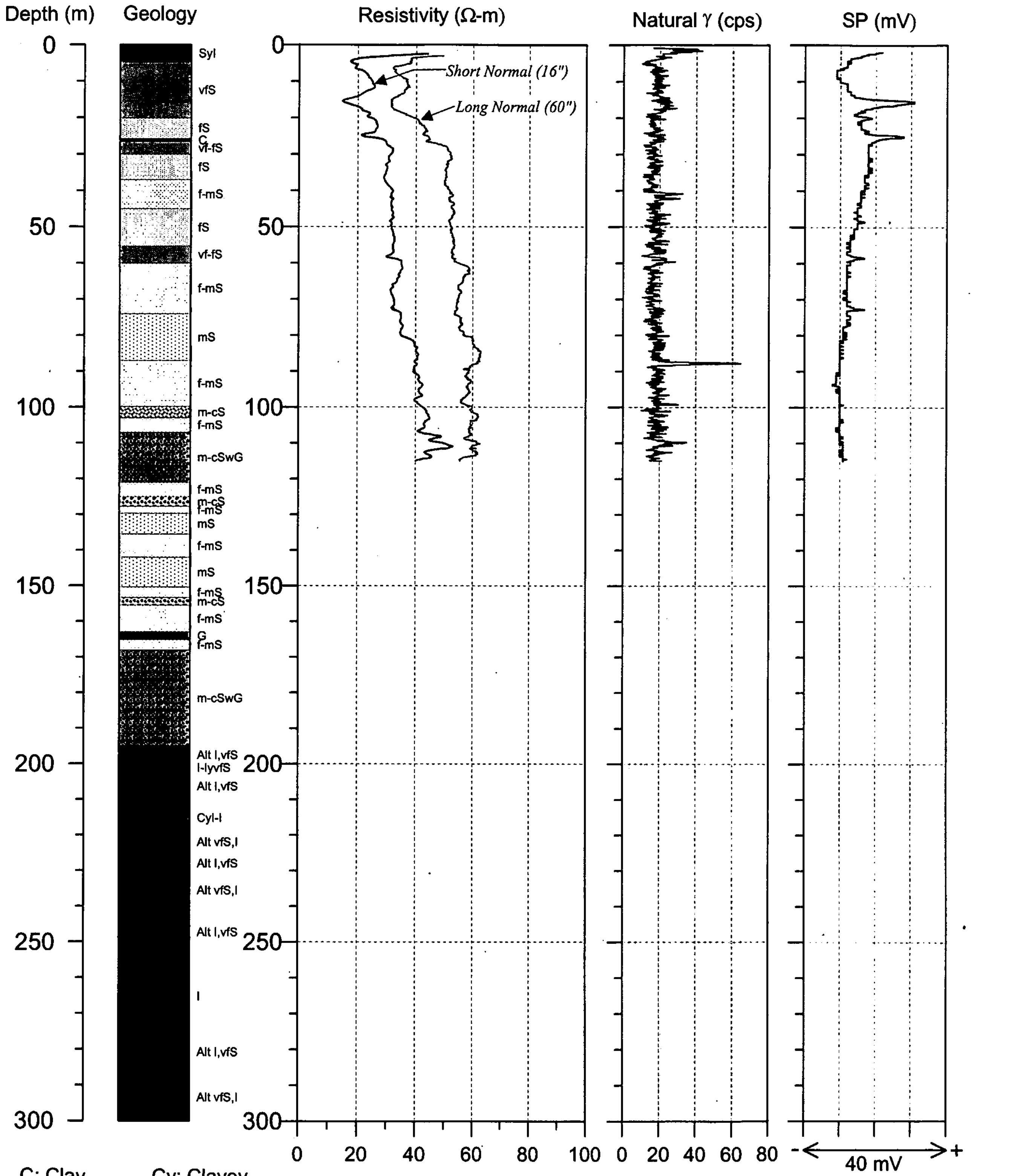


C: Clay	Cy: Clayey
I: Silt	ly: Silty
S: Sand	Sy: Sandy
G: Gravel	w: with
v: very	-: to
f: fine	Alt: Alternation
m: medium	P: Peat
c: coarse	TS: Top Soil

Figure 5.2.18 **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)



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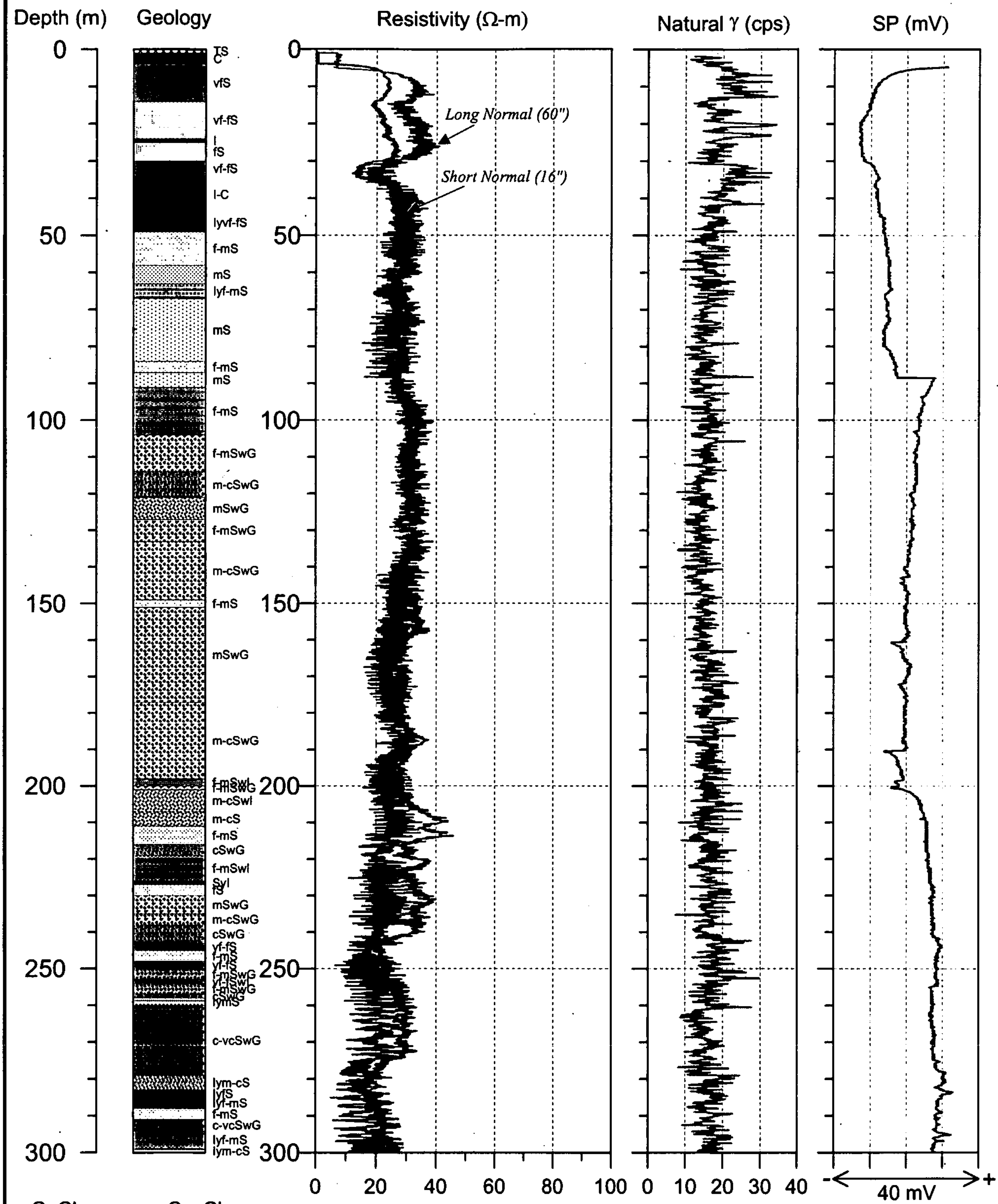
f: fine
m: medium
c: coarse

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

Figure 5.2.19	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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G: Gravel
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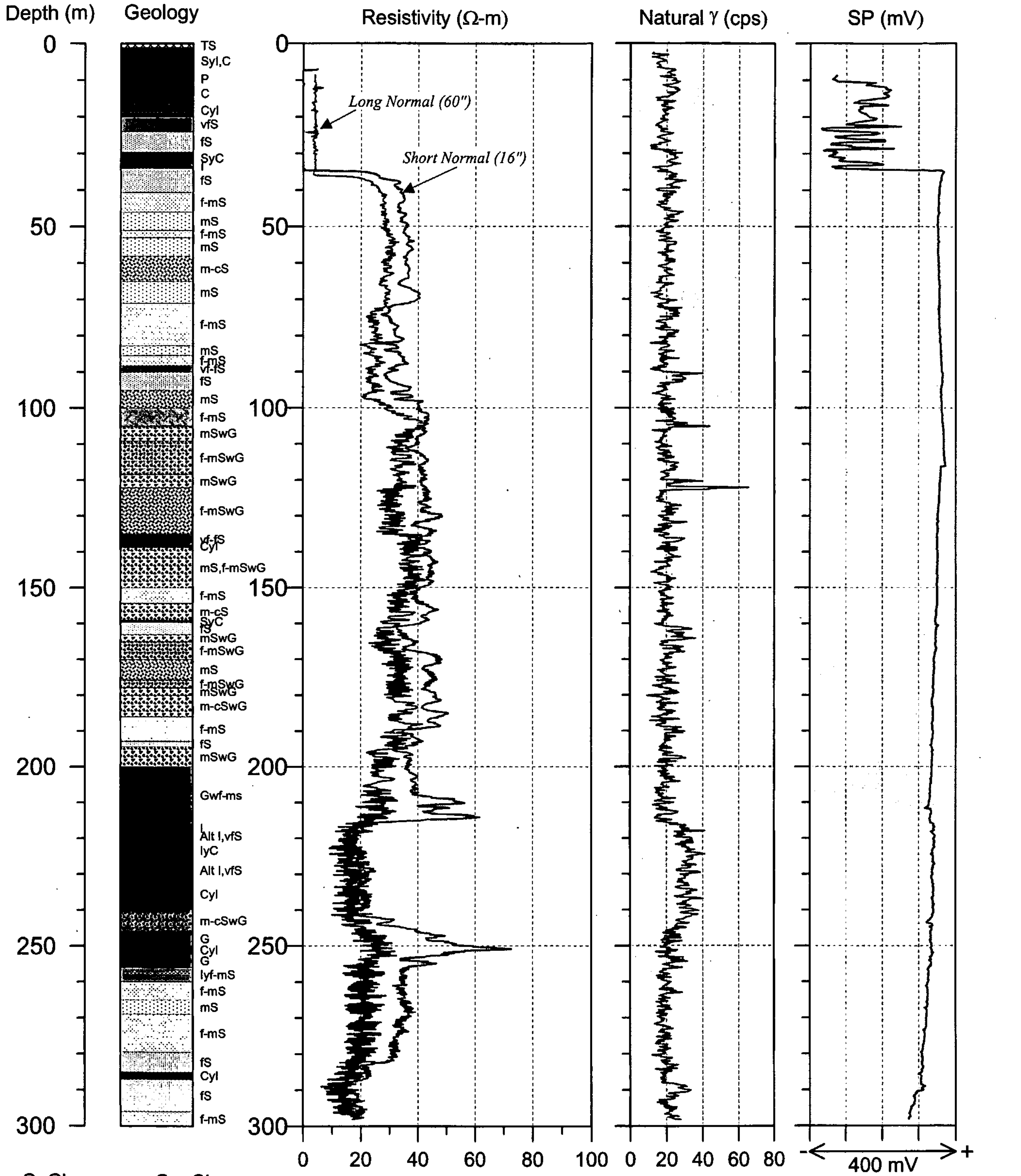
f: fine
m: medium
c: coarse

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

Figure 5.2.20	**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)



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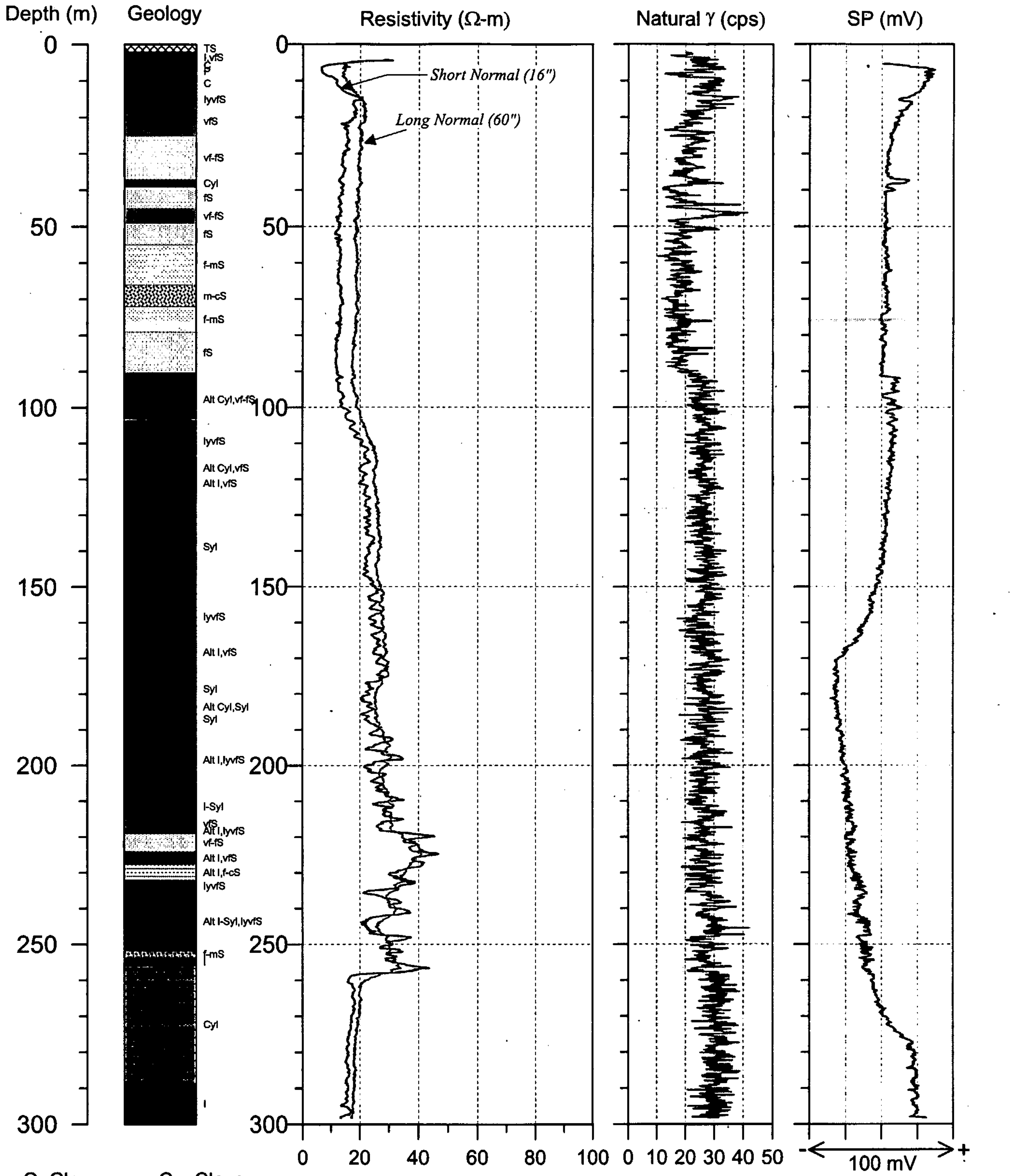
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

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

Figure 5.2.21	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
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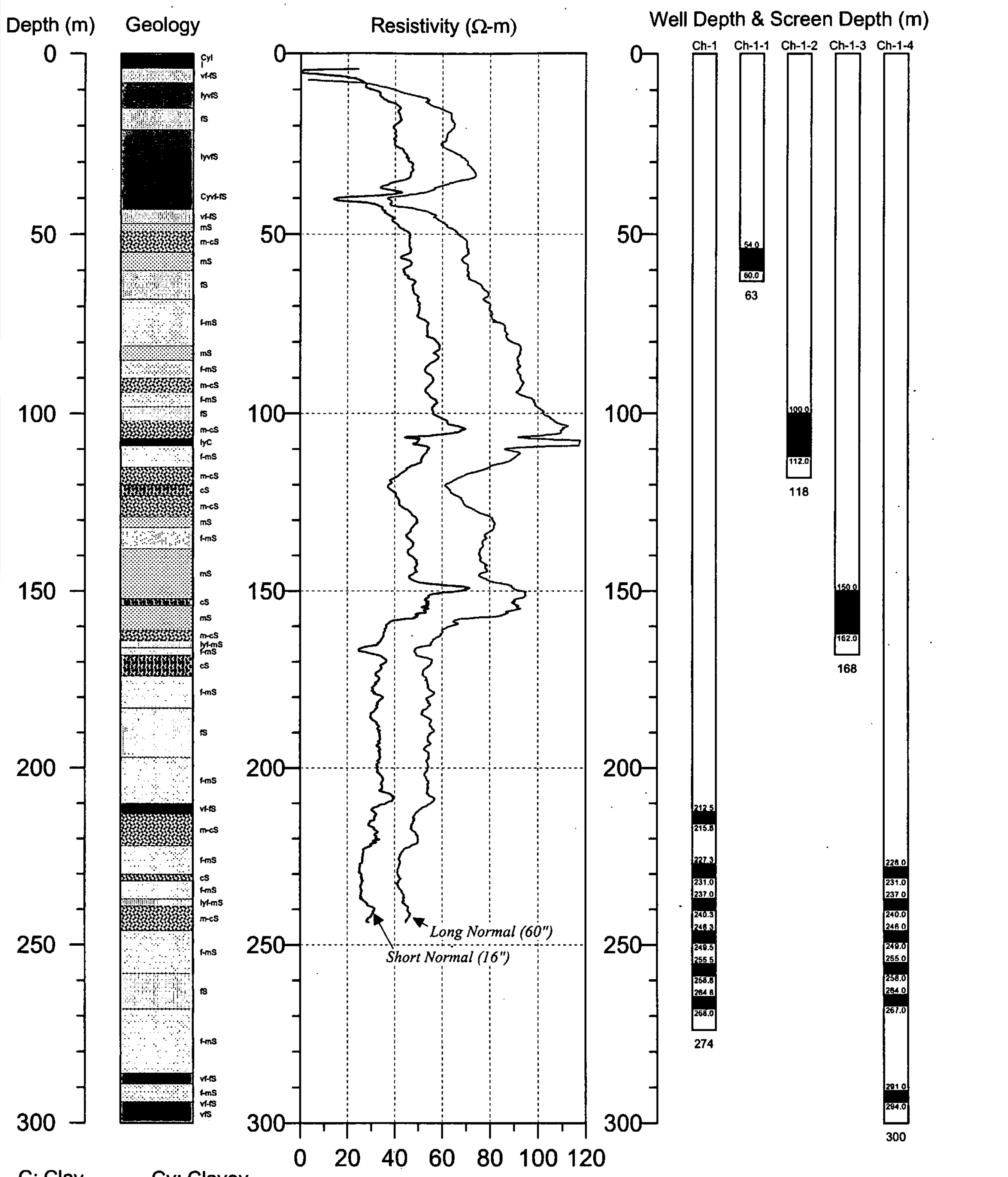
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

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

Figure 5.2.22	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)



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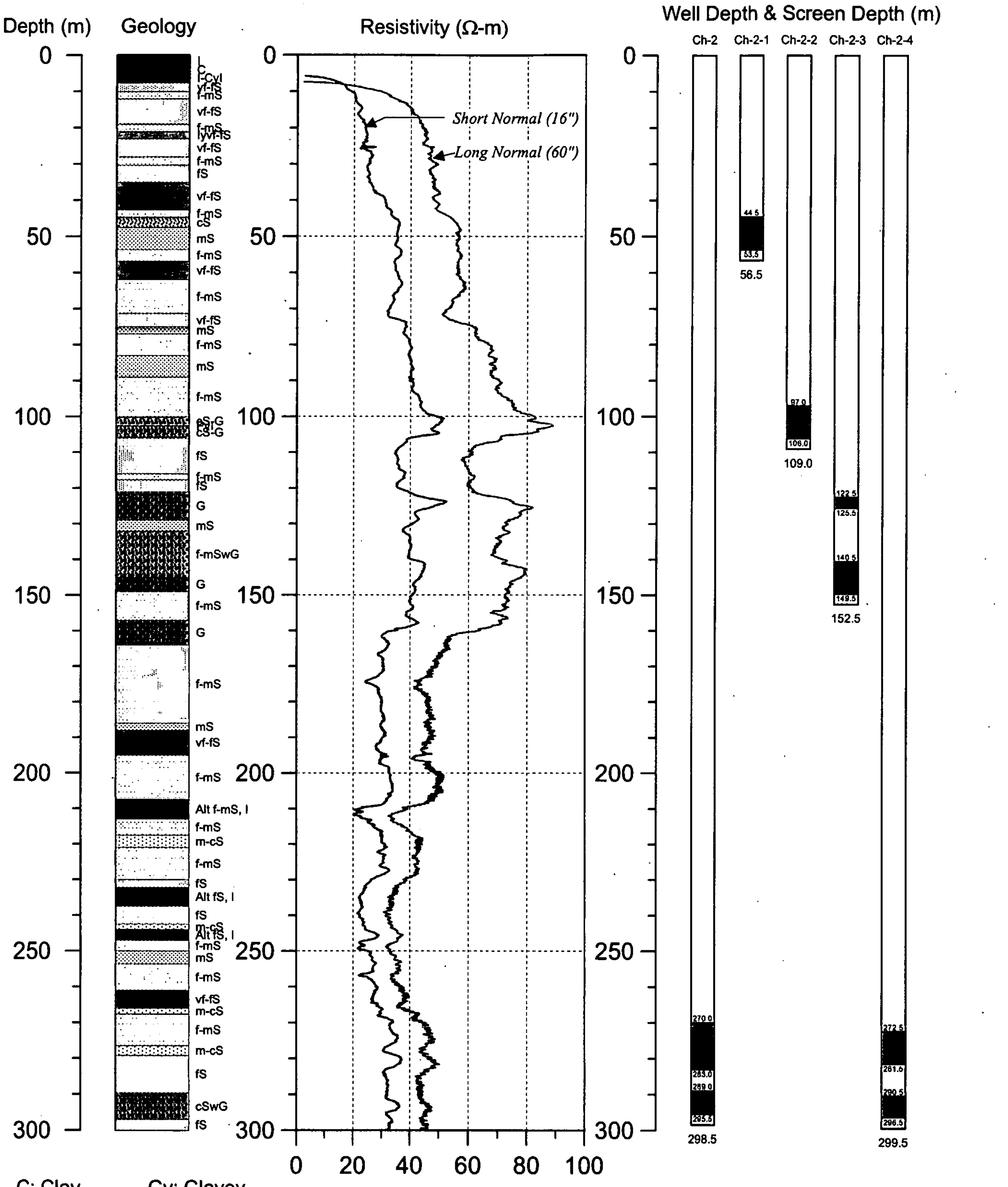
I: Silt
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

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

Figure 5.2.23	**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)	



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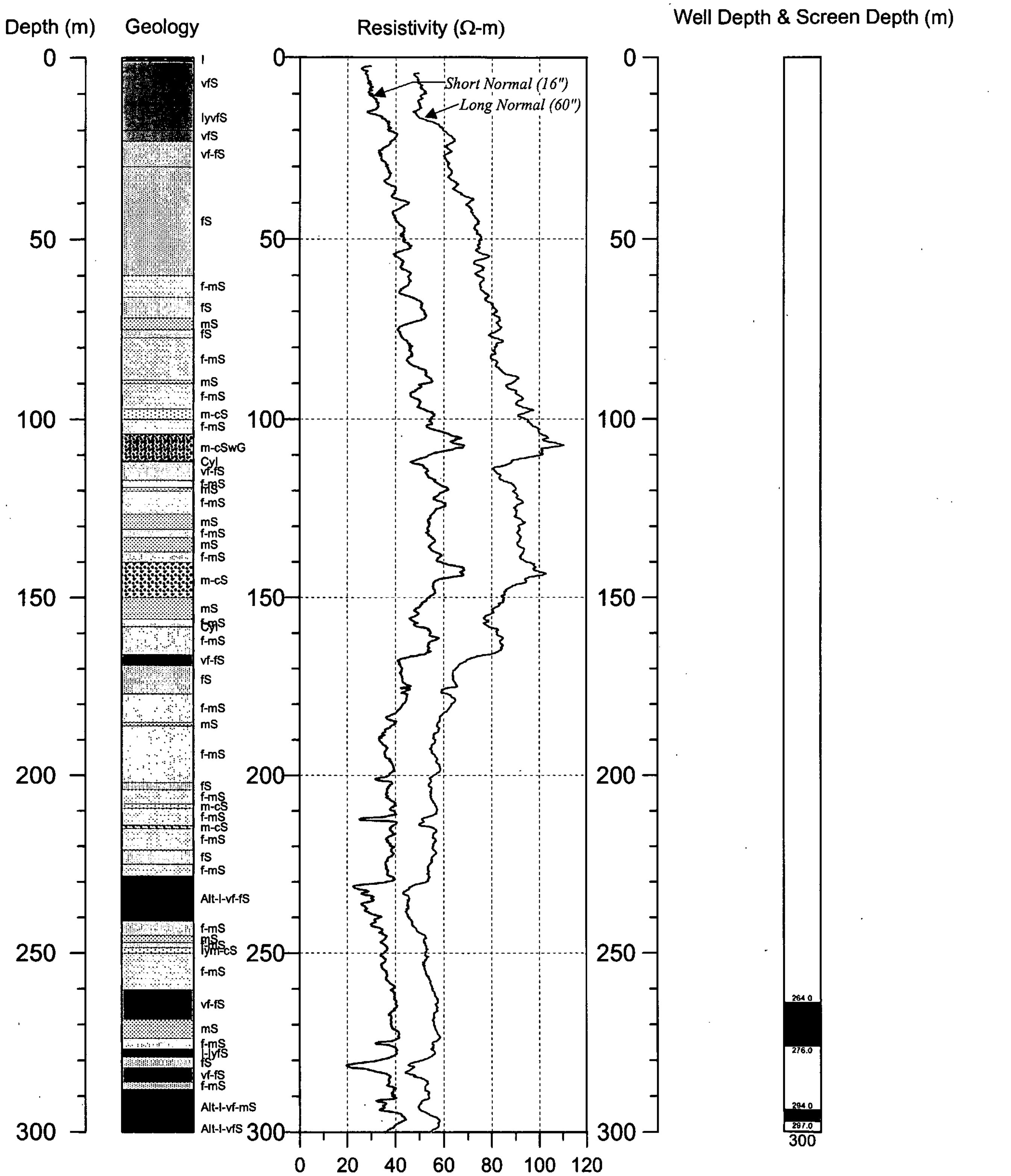
I: Silt
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

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

Figure 5.2.24 **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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S: Sand
G: Gravel
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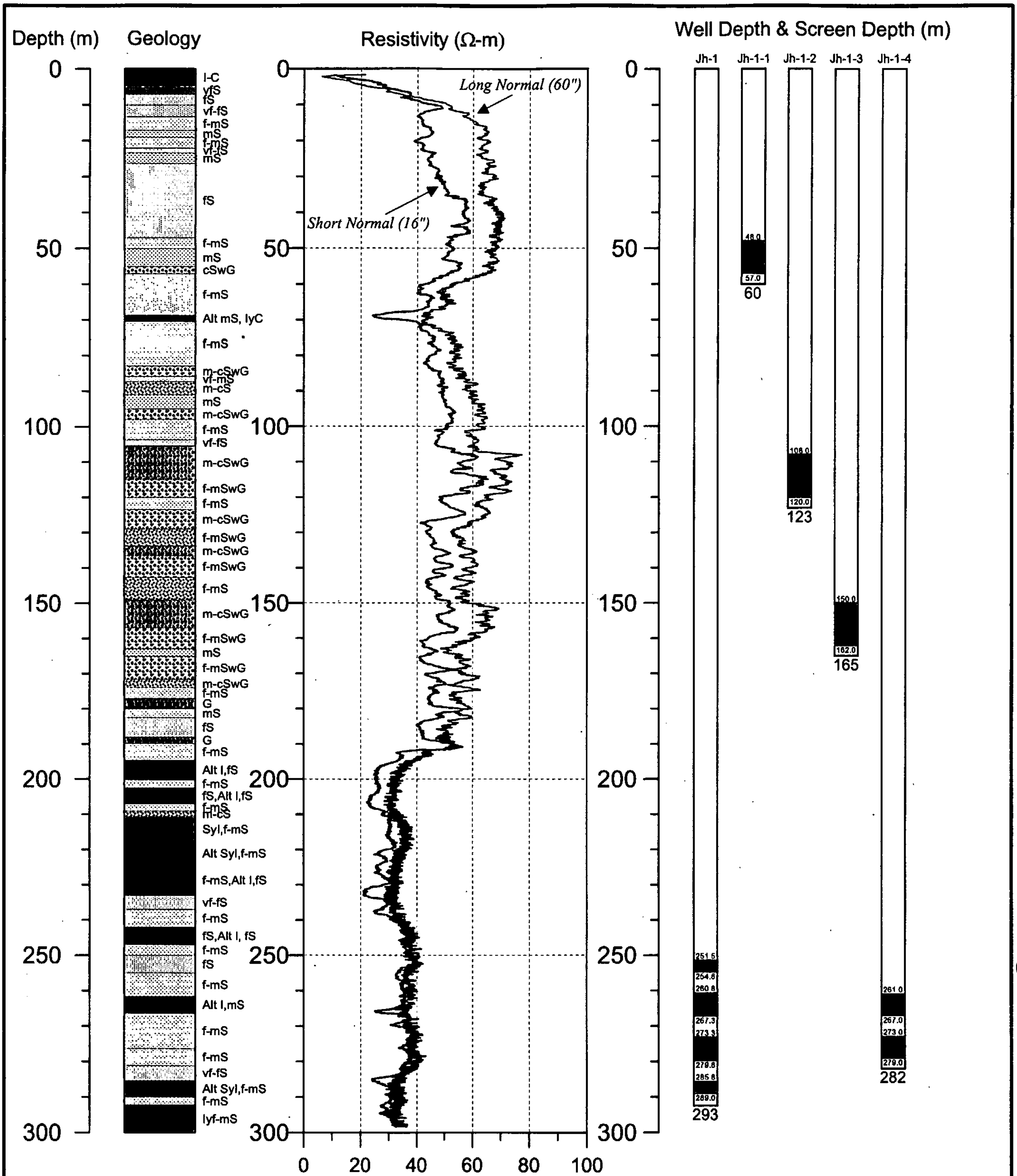
f: fine
m: medium
c: coarse

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

Figure 5.2.25	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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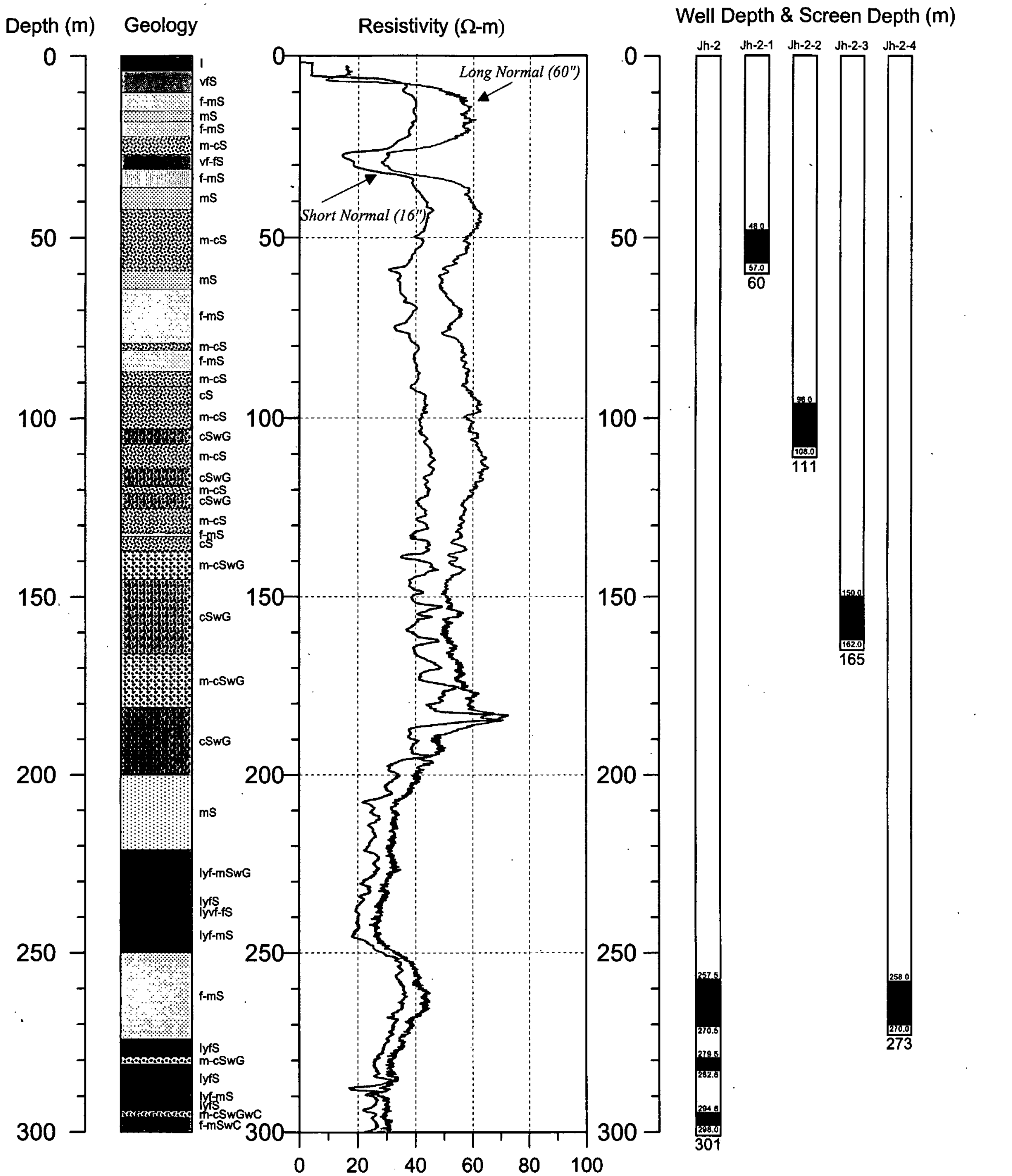
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation

Figure 5.2.26	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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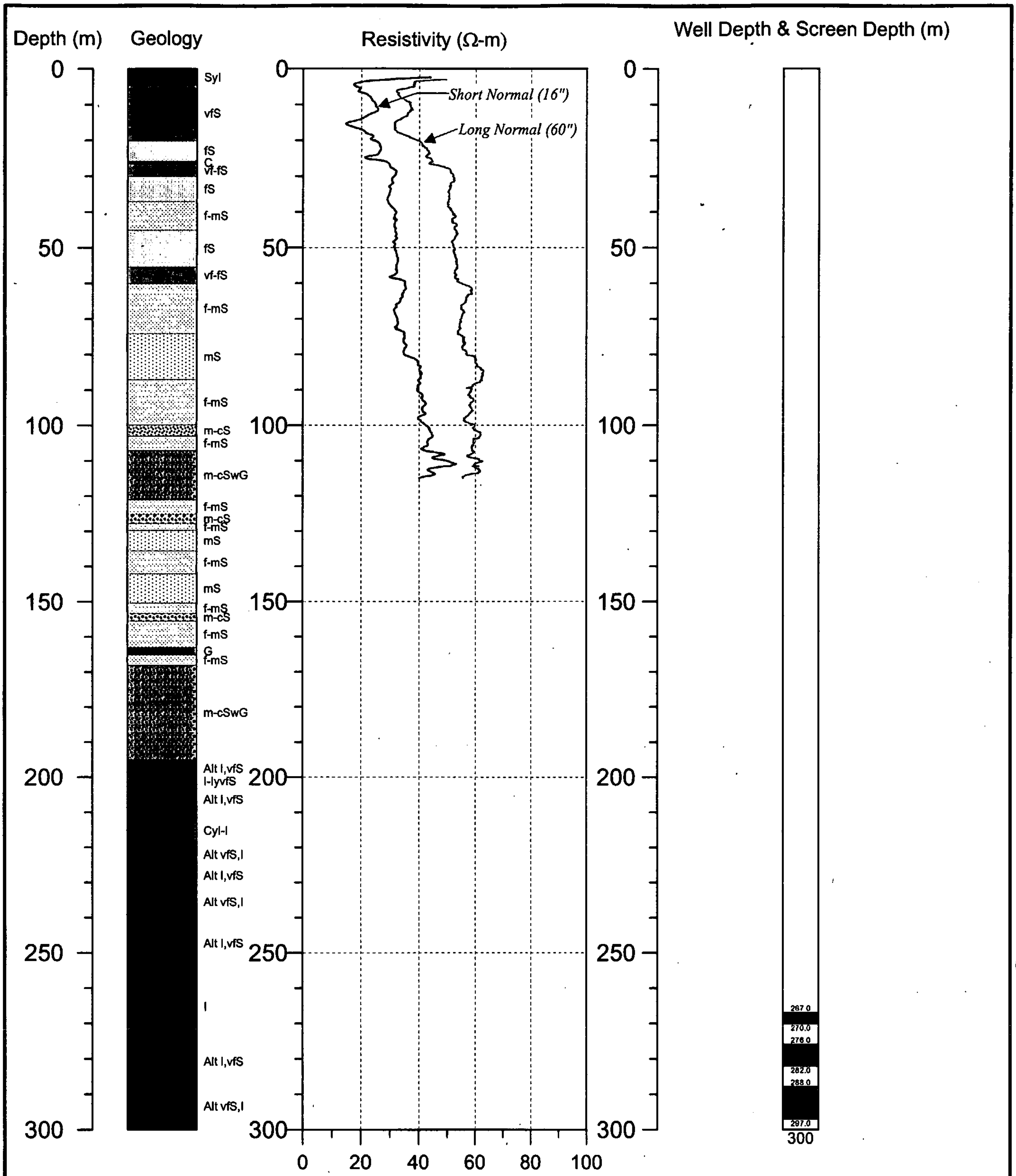
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

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

Figure 5.2.27	**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)



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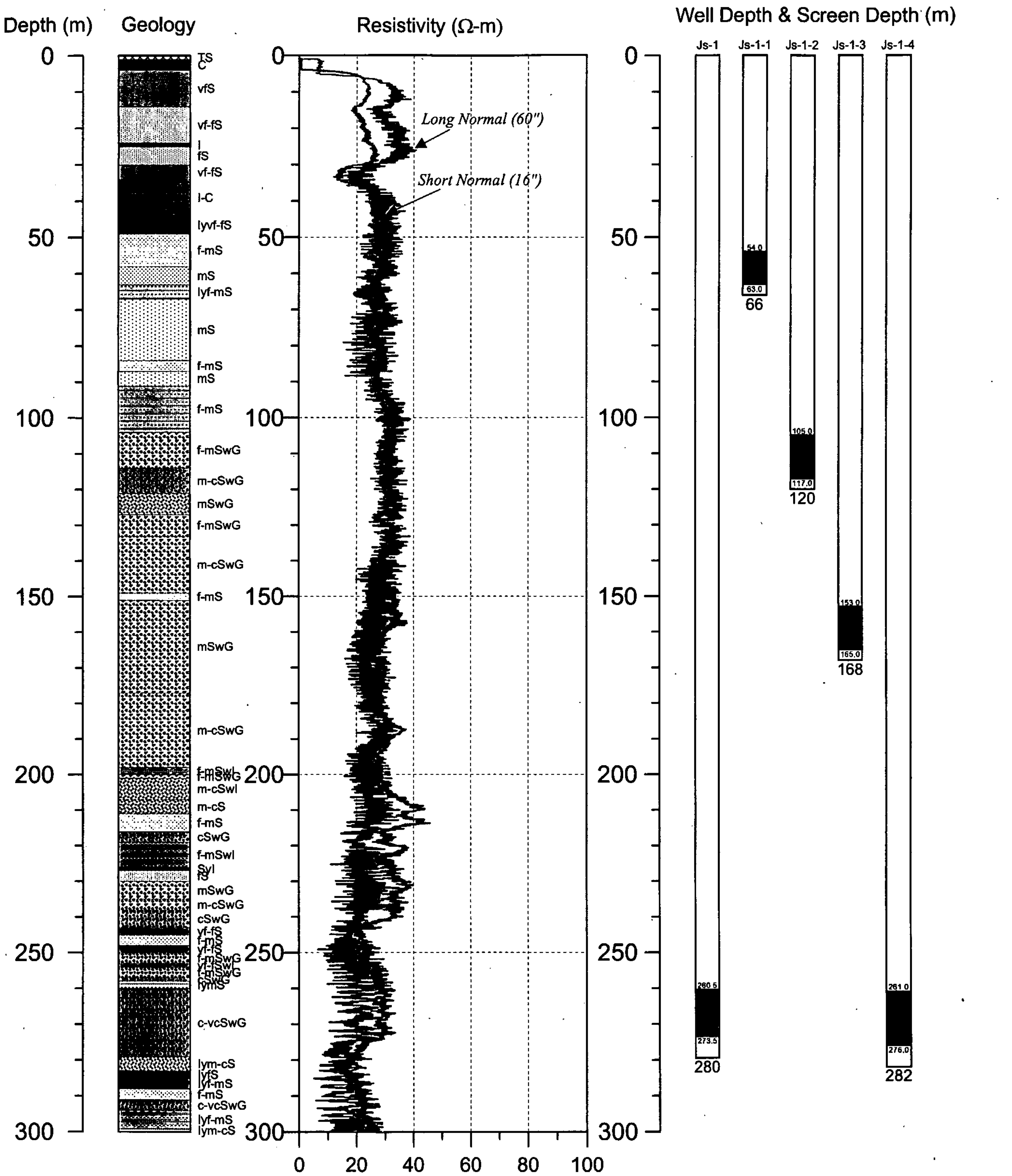
S: Sand	Sy: Sandy
G: Gravel	w: with
v: very	-: to
f: fine	Alt: Alternation
m: medium	P: Peat
c: coarse	TS: Top Soil

Figure 5.2.28 **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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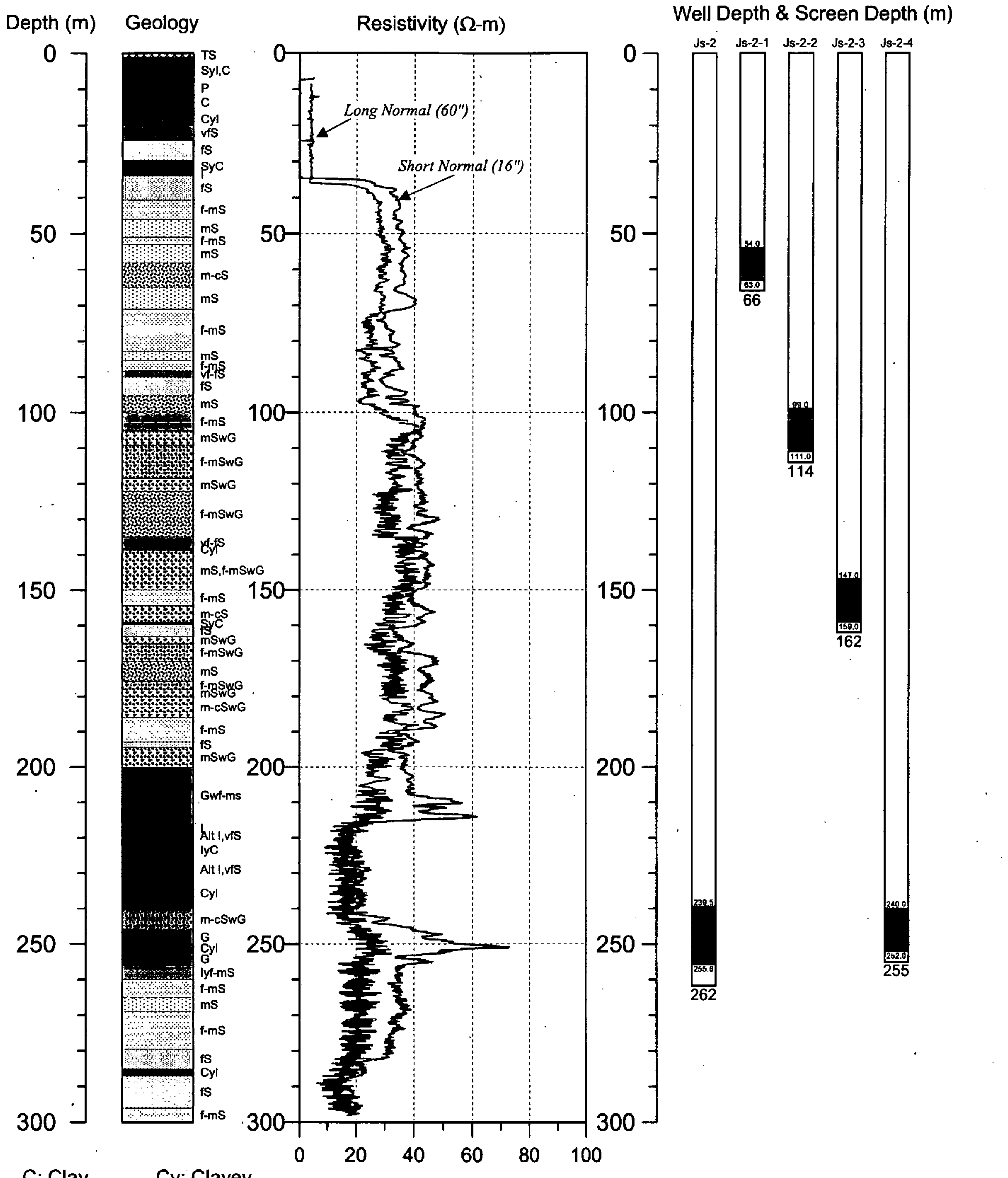
S: Sand
G: Gravel
v: very
f: fine
m: medium
c: coarse

Cy: Clayey
ly: Silty
Sy: Sandy
w: with
-: to
Alt: Alternation

Figure 5.2.29	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)



C: Clay
I: Silt
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G: Gravel
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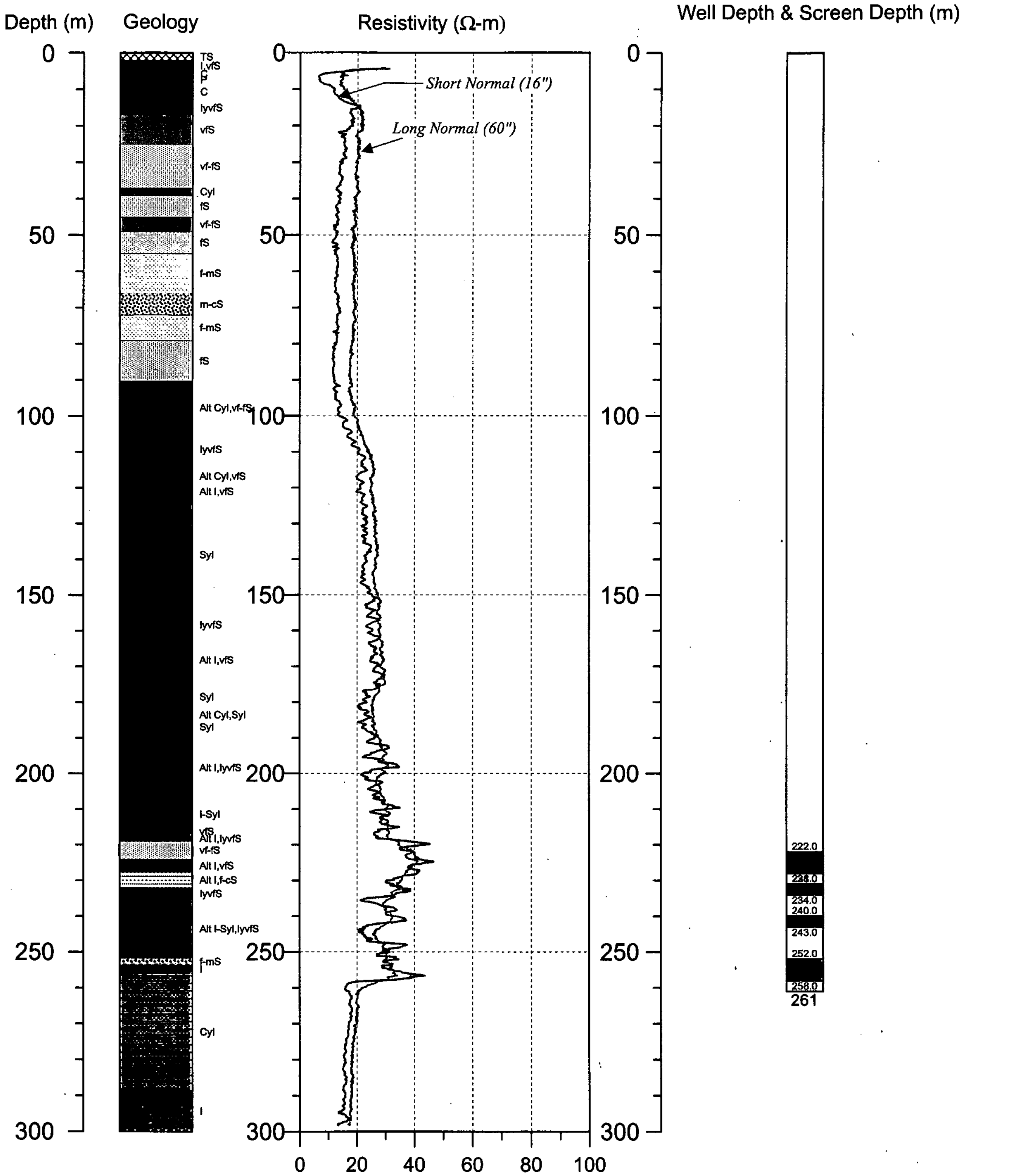
f: fine
m: medium
c: coarse

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

Figure 5.2.30	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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m: medium
c: coarse

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

Figure 5.2.31	Columnar Section and 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)

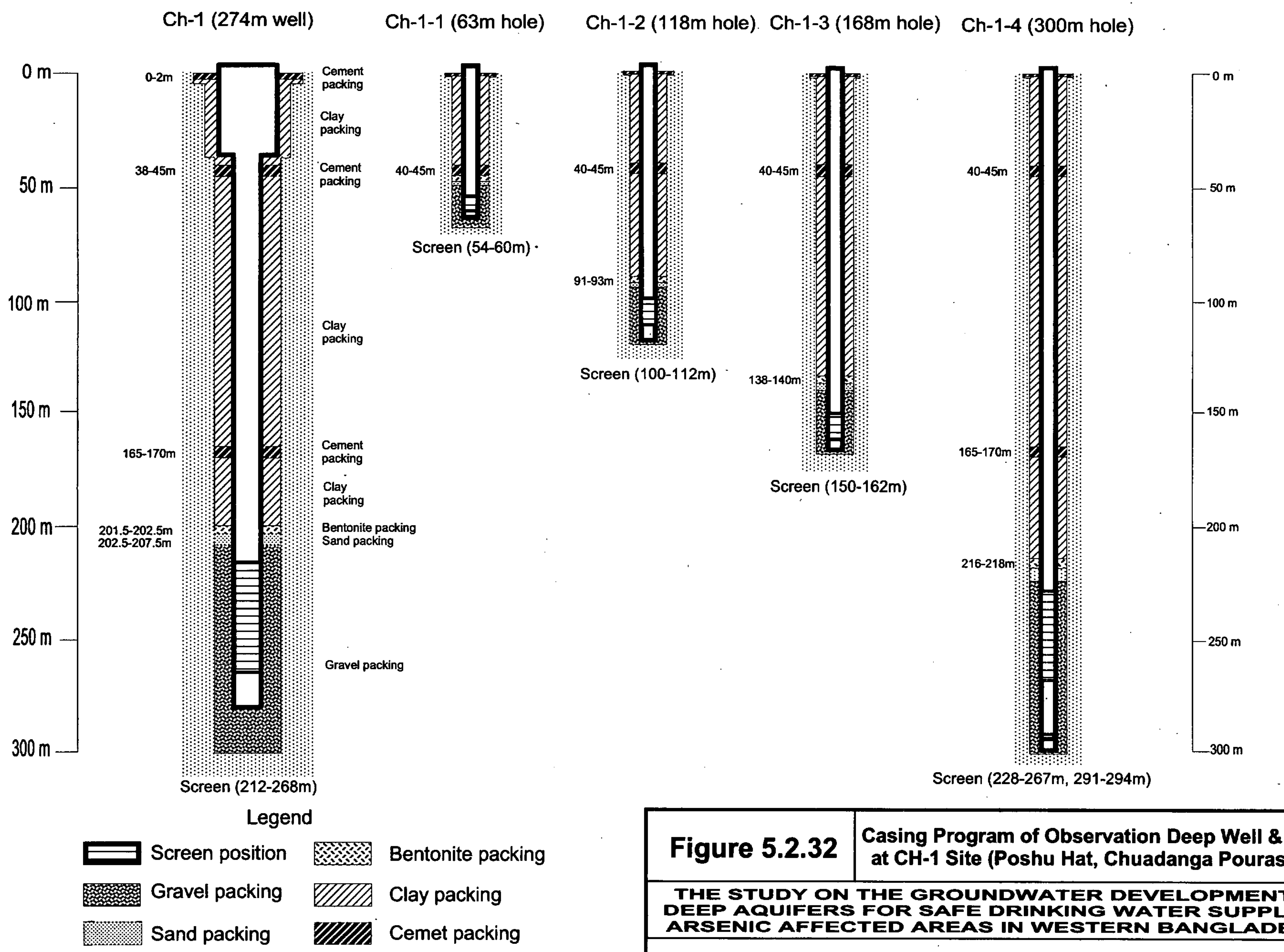

Figure 5.2.32	Casing Program of Observation Deep Well & Holes at CH-1 Site (Poshu Hat, Chuadanga Pourashava)
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

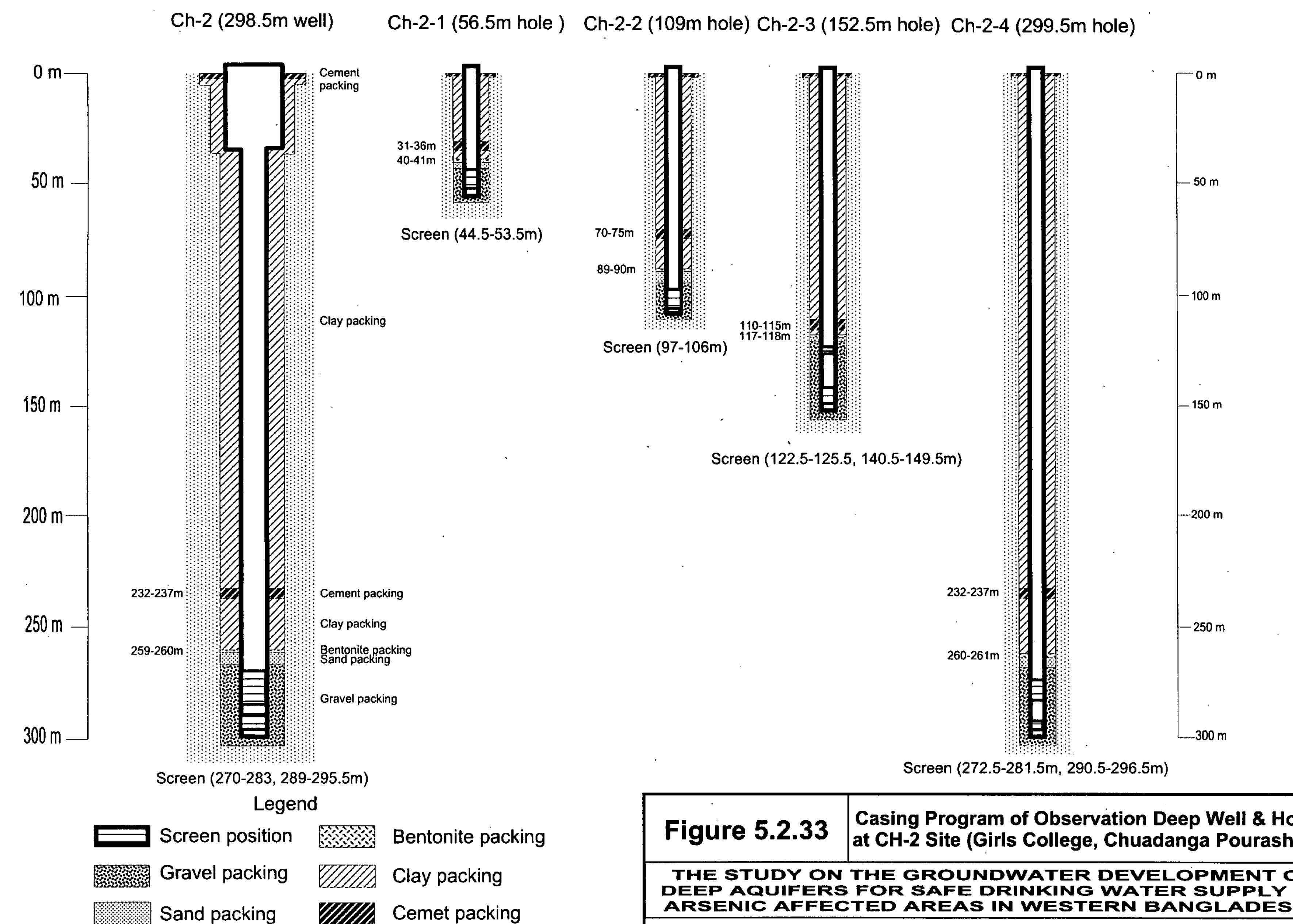

Figure 5.2.33 Casing Program of Observation Deep Well & Holes at CH-2 Site (Girls College, Chuadanga Pourashava)

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)

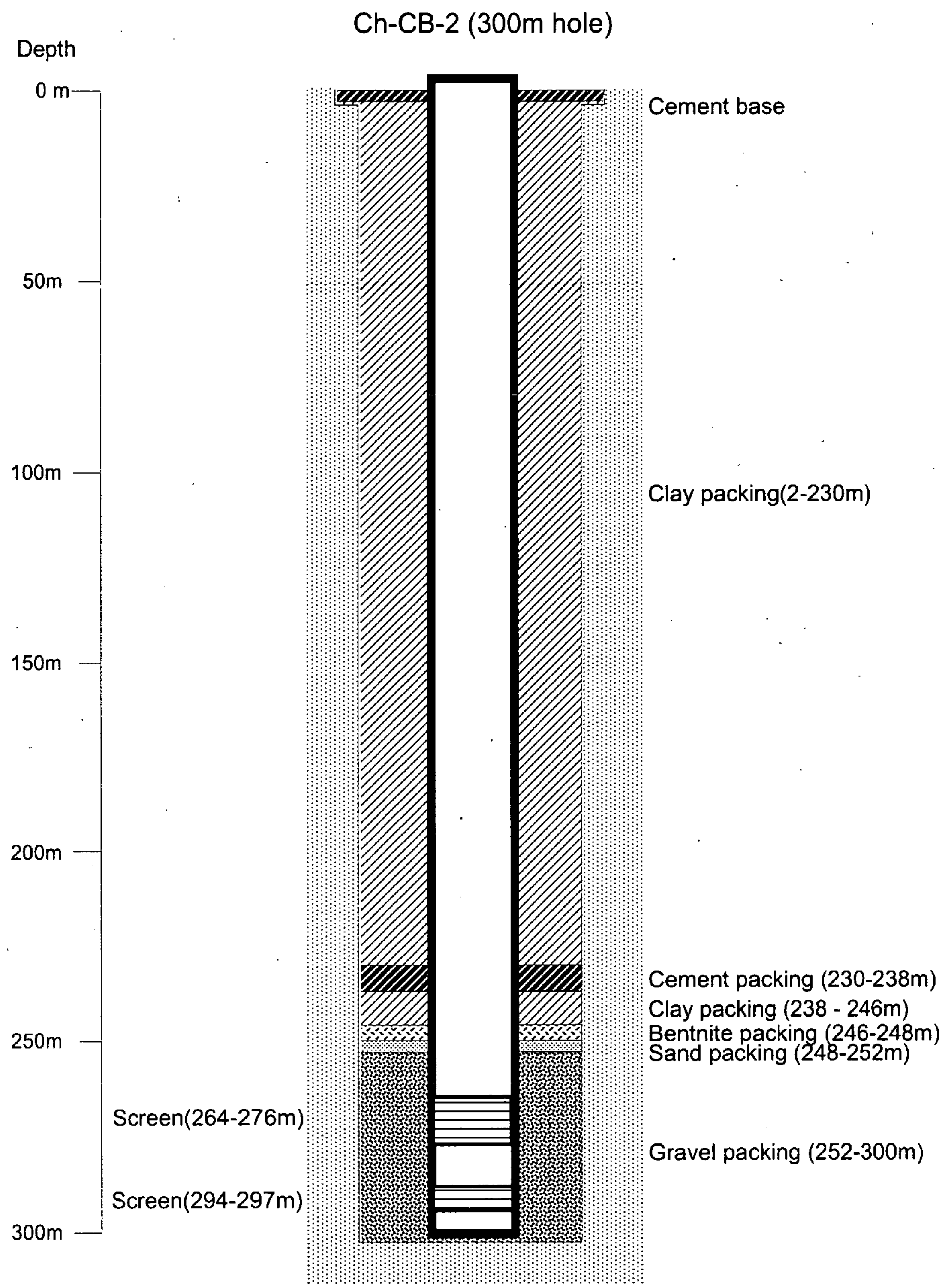

Figure 5.2.34	**Casing Program of Observation Hole at CH-BD Site (Bara Dudpatila)**

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)

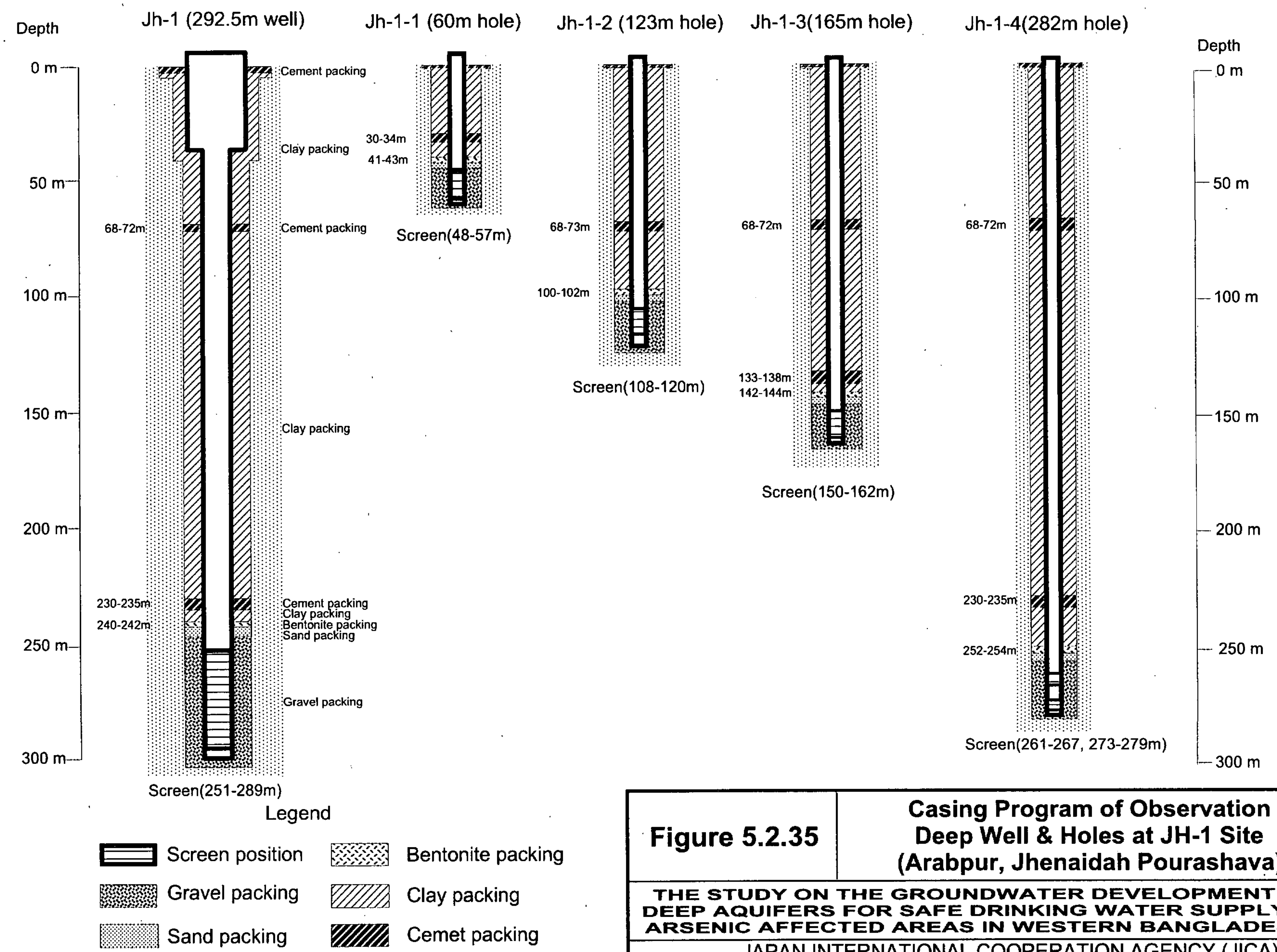

Figure 5.2.35 Casing Program of Observation Deep Well & Holes at JH-1 Site (Arabpur, Jhenaidah Pourashava)

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

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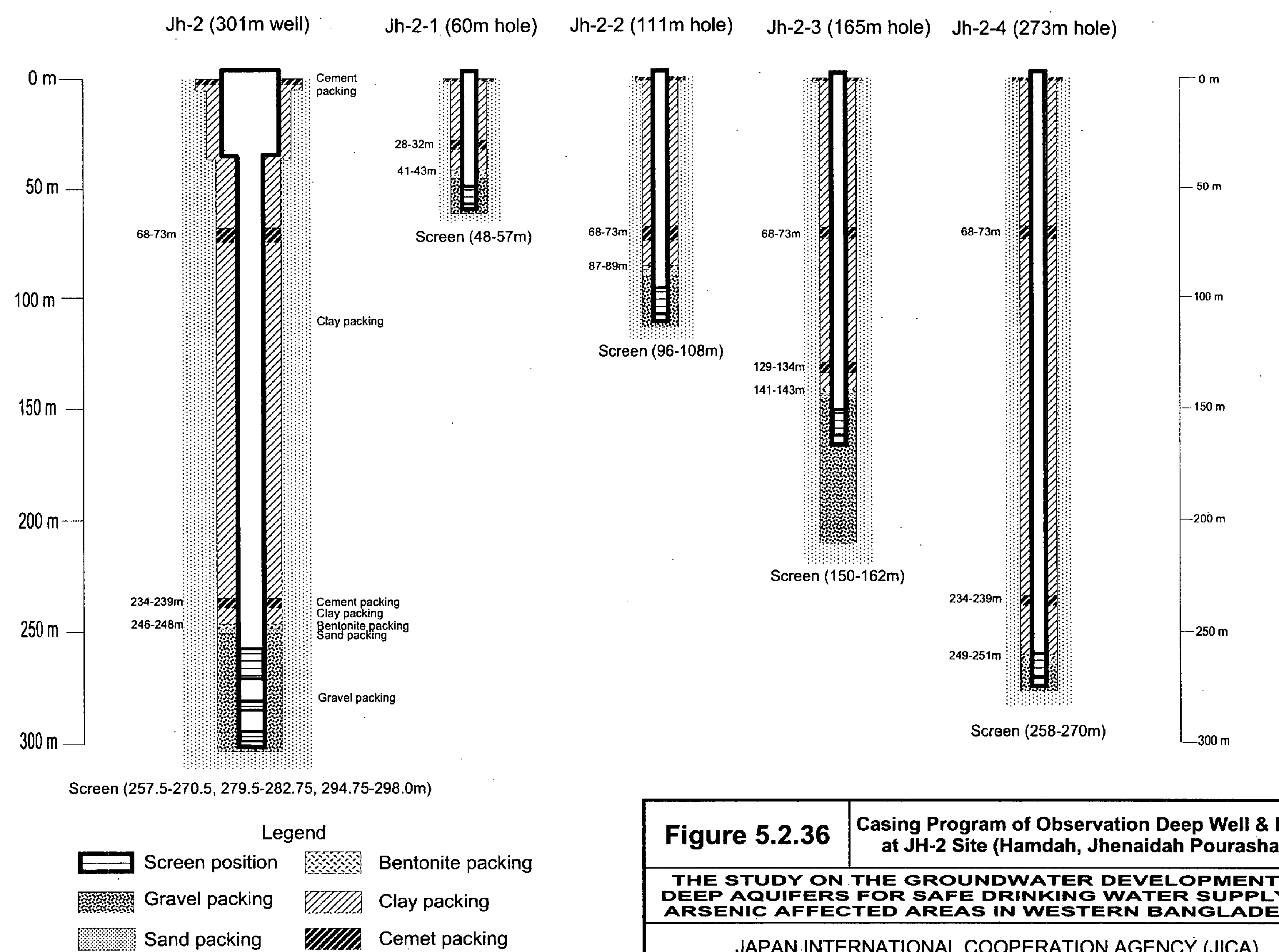

Figure 5.2.36	Casing Program of Observation Deep Well & Holes at JH-2 Site (Hamdah, Jhenaidah Pourashava)
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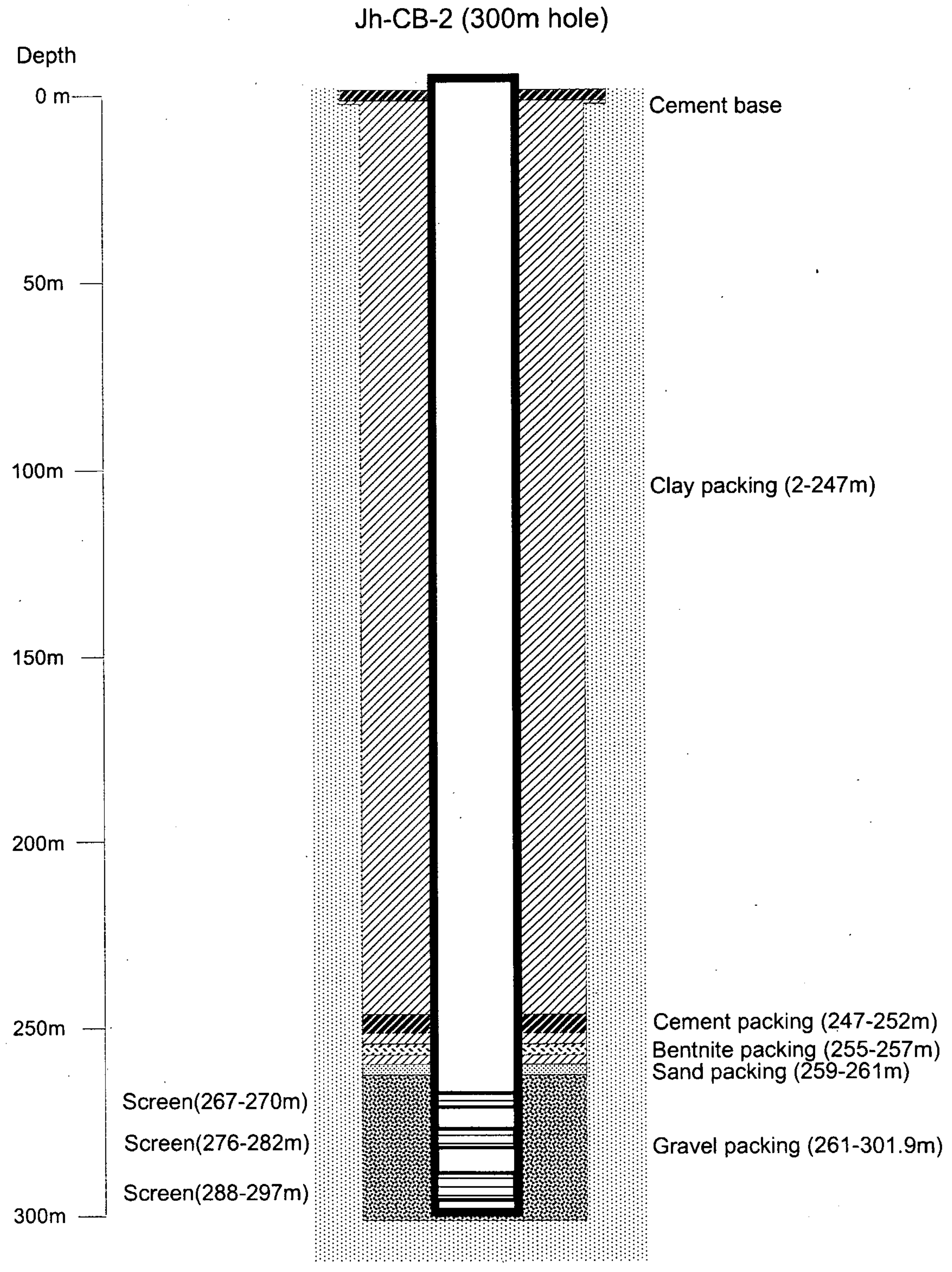

Figure 5.2.37	**Casing Program of Observation Hole at JH-KC Site (Krishna Chandrapur)**

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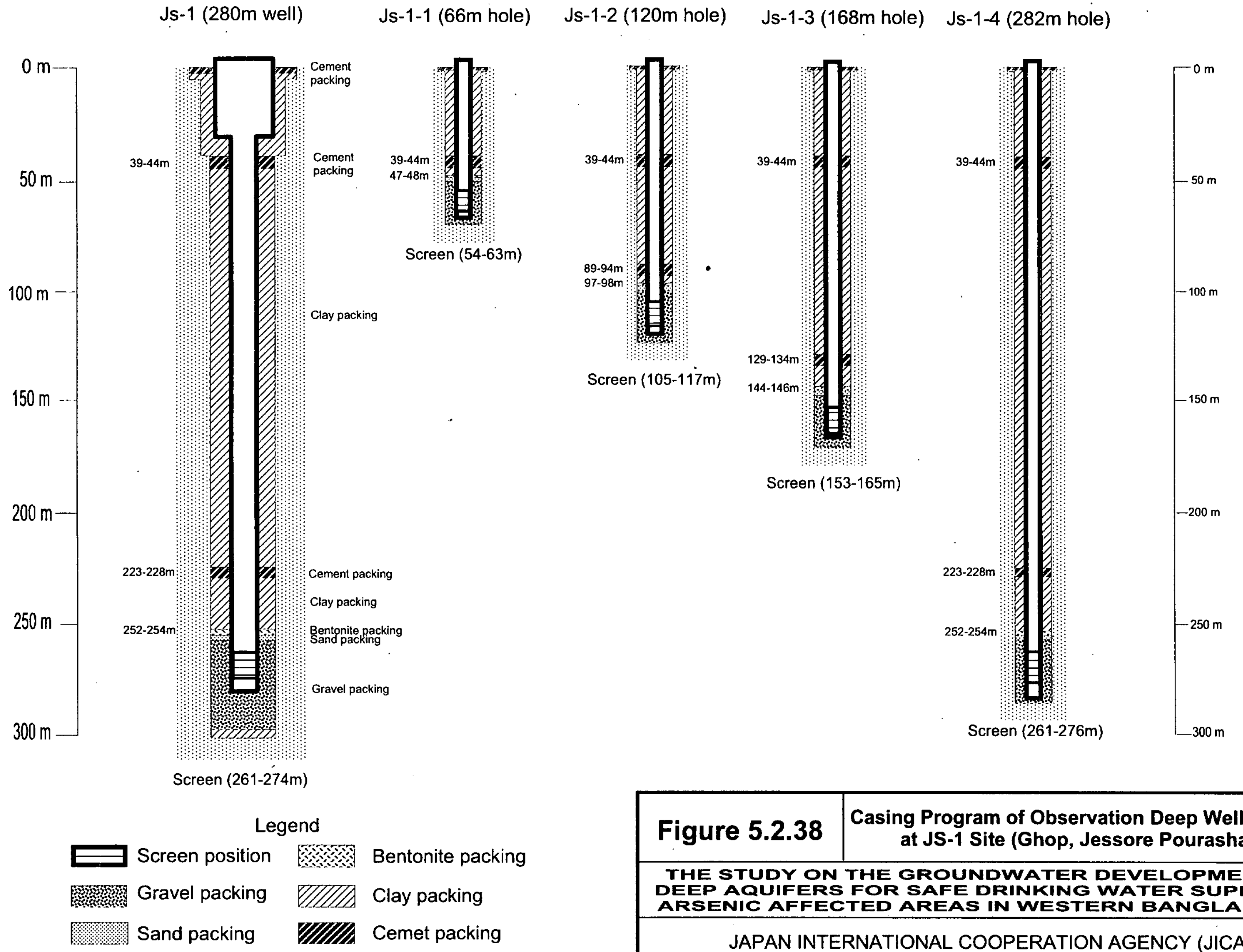

Figure 5.2.38	**Casing Program of Observation Deep Well & Holes at JS-1 Site (Ghop, Jessore Pourashava)**
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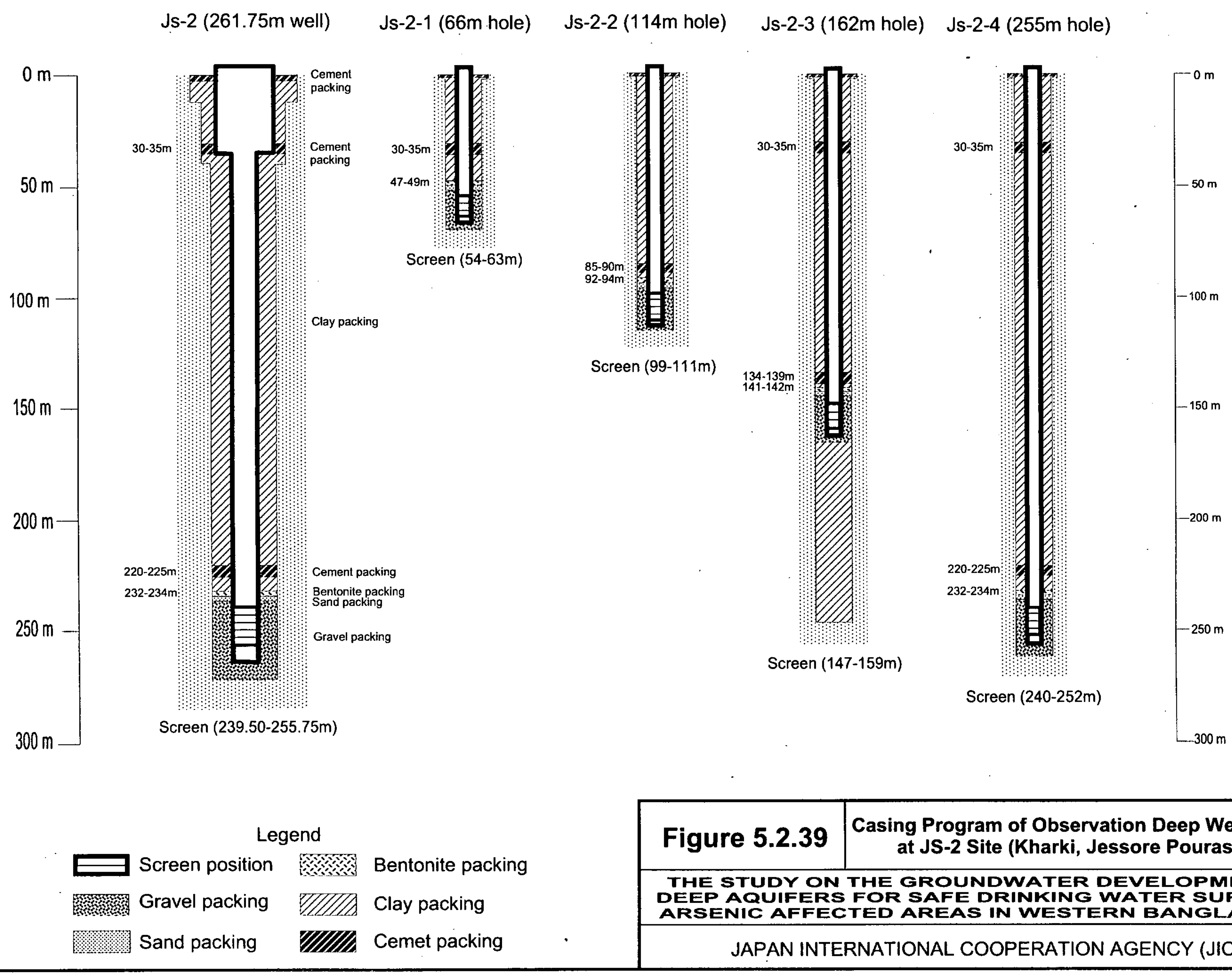

Figure 5.2.39	Casing Program of Observation Deep Well & Holes at JS-2 Site (Kharki, Jessore Pourashava)

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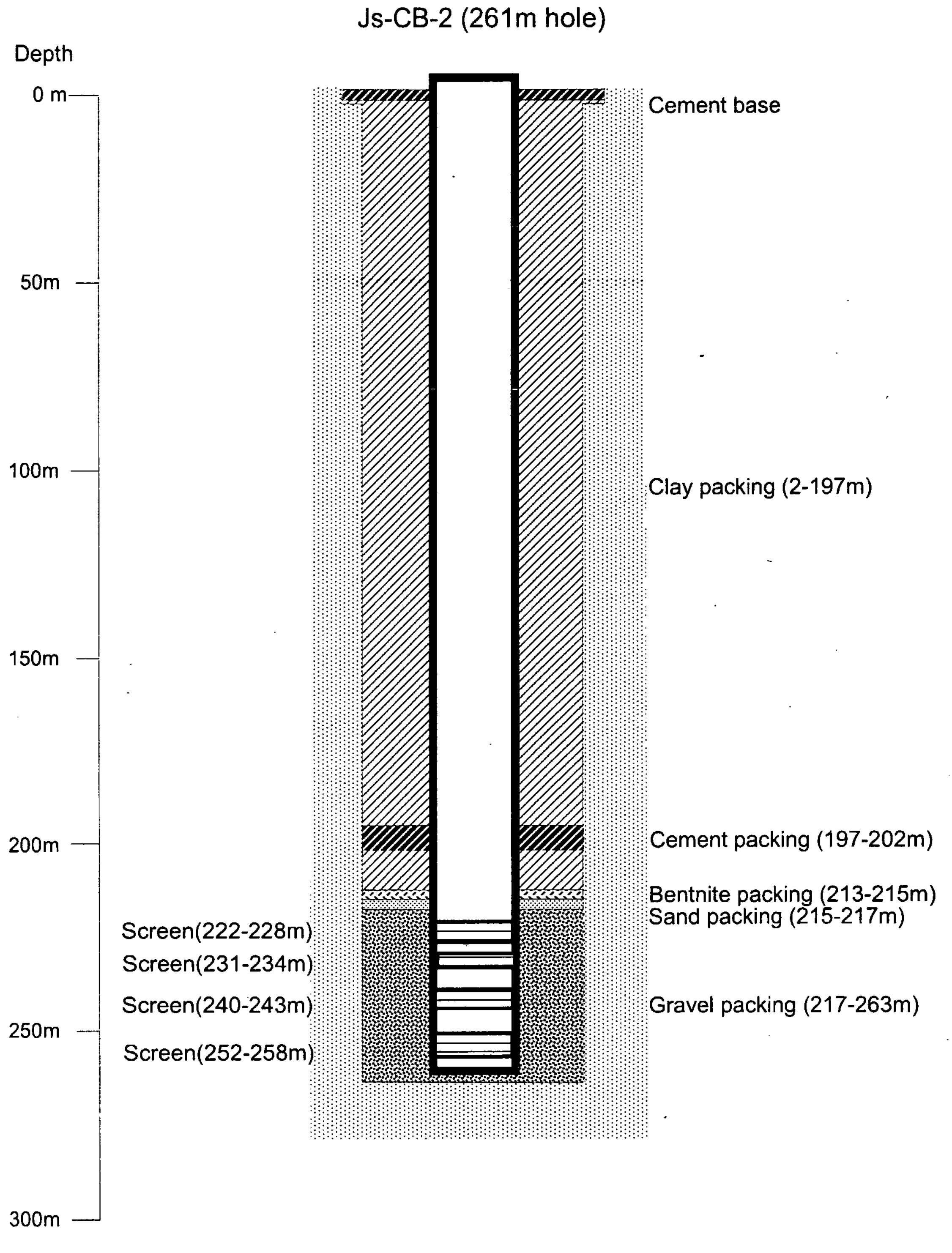

Figure 5.2.40	Casing Program of Observation Hole at JS-RB Site (Ranjnagar Bankabarsi)
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5.3 Pumping Test

5.3.1 Purpose of Pumping Test

A pumping test was performed at newly constructed observation wells/holes by the study. One of the main objectives of performing the pumping test is to obtain aquifer parameters such as transmissivity and the storage coefficient of the deep aquifers in the study area, because so far there are very limited data for evaluating aquifer characteristics not only of the deep aquifers but also of the shallow aquifers. The pumping test can also provide important information on the possibility and degree of vertical movement of groundwater at the site by measuring drawdowns in the pumped aquifer and other aquifers. If the decline in the groundwater level is generated in an upper aquifer when the groundwater of a lower aquifer is pumped, it is judged that groundwater of the upper aquifer is hydraulically connected with the lower aquifer and the shallow water moves downward towards the center of the piezometric head depression.

In addition, the well loss coefficient and aquifer loss coefficient can be obtained by the step-drawdown pumping test. The well efficiency can be evaluated from the results of step-drawdown test. The result of step-drawdown test can help design a suitable operation plan of the future-production well.

During the pumping test in the study, 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 the movement of contaminated water.

5.3.2 Methodology

The pumping test was performed at each observation well/hole after cleaning the well/hole. For the observation deep well, which can be used for a production well in future, the well development using an air-lift pump was performed to remove muddy water and mud cake in and around the borehole. The well development was continued until the pumped water became clean. Similarly, the well development of the observation holes was performed by the air-lift pump.

For the deep observation wells, three (3) kind of pumping tests viz. a 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, a continuous pumping test and a recovery test were performed. The drawdown was measured in the pumped hole.

1) Pumping Test at Observation Wells

a. Step-Drawdown Test

The step-drawdown test was conducted prior to the continuous pumping test. Ten (10) steps with pumping duration of two (2) hours for each step were conducted in each step-drawdown test. In the first five (5) steps, the pumping rate was step-wise increased. The total pumping time is 20 hours.

During the step-drawdown test, groundwater samples for measuring arsenic level were collected. 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)

b. Continuous Pumping Test

After the declined groundwater level by the step-drawdown test was fully recovered, the continuous pumping test was carried out. The duration of pumping is 48 hours. The pumping rate was decided based on the result of the step-drawdown test.

The changes in groundwater levels were measured at the pumped well and the four (4) observation holes.

During the continuous pumping test, groundwater samples for measuring arsenic level 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)

c. Recovery Test

The recovery test was started just after the continuous pumping test. The recovery of the groundwater level was measured as the residual drawdown. The duration of the recovery test is 12 hours.

The recoveries of the groundwater level were measured in the pumped well and the four (4) observation holes.

2) Pumping Test at Observation Holes

At each drilling site in Pourashava areas, 4 observation holes were constructed to investigate groundwater conditions and aquifer characteristics in aquifers of different depths. Although the diameter of observation holes is only three (3) inches, a small diameter submersible pump was inserted in the holes and then the drawdown test and recovery test were performed.

The durations of the drawdown test and the recovery test were three (3) hours and one (1) hour, respectively. During the drawdown test, groundwater samples for measuring arsenic level 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.

1) Ch-1 Well [CH-1 site, Poshu Hat, Chuadanga Pourashava]

Figure 5.3.1 shows the results of the step-drawdown test at Ch-1 well. The maximum pumping rate was 4,320 m^3/day, which caused a drawdown of 18.15 m. The values of specific capacity (*Sc*) range from 229.8 to 328.4 m^2/day. The aquifer loss coefficient (*B*) and well loss coefficient (*C*) are calculated as 3.30E-03day/m^2 and 2.47E-03day^2/m^5, respectively. The average well efficiency is computed as 84.68%. The Discharge - Drawdown graph (*Q* - *s* curve) shows that the curve during decreasing *Q* is similar to that of increasing *Q*.

2) Ch-2 Well [CH-2 site, Girls College, Chuadanga Pourashava]

Figure 5.3.2 shows the results of the step-drawdown test at Ch-2 well. The maximum pumping rate was 259.2 m^3/day, which caused a drawdown of 24.80 m. The values of specific capacity (*Sc*) range from 10.1 to 20.7 m^2/day. The aquifer loss coefficient (*B*) and well loss coefficient (*C*) are calculated as 4.73E-02 day/m^2 and 1.88E-04 day^2/m^5, respectively. The average well efficiency is computed as 56.68%. Although the test was affected by unavoidable electricity failure, the Discharge - Drawdown graph (*Q* - *s* curve) shows almost a straight line.

3) Jh-1 Well [JH-1 site, Arabpur, Jhenaidah Pourashava]

Figure 5.3.3 shows the results of the step-drawdown test at Jh-1 well. The maximum pumping rate was 86.4 m^3/day, which caused a drawdown of 40.78 m. The values of specific capacity (*Sc*) range from 2.1 to 3.1 m^2/day. The aquifer loss coefficient (*B*) and well loss coefficient (*C*) are calculated as 2.75E-01 day/m^2 and 2.49E-03 day^2/m^5, respectively. The average well efficiency is computed as 67.09%. The Discharge - Drawdown graph (*Q* - *s* curve) shows that the slope of the curve during decreasing *Q* is slightly gentler than that of increasing *Q*.

4) Jh-2 Well [JH-2 site, Hamdah, Jhenaidah Pourashava]

Figure 5.3.4 shows the results of the step-drawdown test at Jh-2 well. The maximum pumping rate was 217.0 m^3/day, which caused a drawdown of 29.74 m. The values of specific capacity (*Sc*) range from 7.3 to 10.5 m^2/day. The aquifer loss coefficient (*B*) and well loss coefficient (*C*) are calculated as 7.93E-02 day/m^2 and 2.67E-04 day^2/m^5, respectively. The average well efficiency is computed as 66.71%. The Discharge - Drawdown graph (*Q* - *s* curve) shows that the slope of the curve during decreasing *Q* is slightly gentler than that of increasing *Q*.

5) Js-1 Well [JS-1 site, Ghop, Jessore Pourashava]

Figure 5.3.5 shows the results of the step-drawdown test at Js-1 well. The maximum pumping rate was 1901.6 m^3/day, which caused a drawdown of 21.63 m. The values of specific capacity (*Sc*) range from 86.5 to 113.6 m^2/day. The aquifer loss coefficient (*B*) and well loss coefficient (*C*) are calculated as 7.13E-03 day/m^2 and 2.04E-06 day^2/m^5, respectively. The average well efficiency is computed as 70.94%. The Discharge - Drawdown graph (*Q* - *s* curve) shows that the slope of the curve during decreasing *Q* is almost the same as that of increasing *Q*.

6) Js-2 Well [JS-2 site, Kharki, Jessore Pourashava]

Figure 5.3.6 shows the results of the step-drawdown test at Js-2 well. The maximum pumping rate was 228.5 m^3/day, which caused a drawdown of 21.56 m. The values of specific capacity (*Sc*) range from 10.1 to 15.7 m^2/ day. The aquifer loss coefficient (*B*) and well loss coefficient (*C*) are calculated as 7.04E-02 day/m^2 and 1.08E-04 day^2/m^5, respectively. The average well efficiency is computed as 81.84%. The Discharge - Drawdown graph (*Q* - *s* curve) shows that the slope of the curve during decreasing *Q* is clearly gentler than that of increasing *Q*.

5.3.4 Results of Continuous Pumping Test

The results of the continuous pumping test at the deep observation wells are summarized in Table 5.3.2. The values of transmissivity (*T*) and storage coefficient (*S*) were obtained by the Cooper-Jacob method (Cooper and Jacob, 1946). For the analysis, two (2) kinds of drawdown data were used; one is the drawdown in the pumped well and the other is the drawdown in the deepest observation hole, which tapped the same aquifer from which the pumped well extracted the groundwater.

1) Ch-1 Well [CH-1 site, Poshu Hat, Chuadanga Pourashava]

Figure 5.3.7 shows the results of the continuous pumping test at Ch-1 well. The test was carried out with a constant discharge rate of 4,320 m^3/day. In the pumped well, the groundwater level irregularly fluctuated due to the surrounding pumpage at existing wells. The drawdown ranged from 16.7 to 17.4 m. Therefore, the values of transmissivity (*T*) and storage coefficient (*S*) cannot be computed.

In the deepest observation hole (Ch-1-4 hole), an almost straight drawdown curve appeared for a period from 10 to 2,500 minutes after pumping began. The maximum drawdown was 0.526 m. From the fitted line, the values of *T* and *S* are computed as 16,264 m^2/day and 3.04E-08, respectively.

In the other observation holes, slight drawdowns were observed for a period from 30 to 1,000 minutes after pumping started. The amounts of drawdowns are 7.4cm in Ch-1-1 hole, 6.8cm in Ch-1-2 hole, and 9.5cm in Ch-1-3 hole.

2) Ch-2 Well [CH-2 site, Girls College, Chuadanga Pourashava]

Figure 5.3.8 shows the results of continuous pumping test at Ch-2 well. The test was carried out with a constant discharge rate of 239.3 m^3/day. In the pumped well, the groundwater level declined at a relatively higher rate until 30 minutes after pumping started. After reaching a drawdown of 22 m, the declining rate decreased and the curve shows a straight line on the semi-log plot. The final drawdown was 22.838 m. From the fitted line, the values of T and S are computed as 16,264 m^2/day and 3.04E-08, respectively.

In the deepest observation hole (Ch-2-4 hole), an almost straight drawdown curve appeared for a period from 10 to 800 minutes after pumping began. The maximum drawdown was 0.143 m. After 800 minutes, the groundwater level started to fluctuate with a range of 5cm. If it is assumed that the decline of groundwater level was caused by the pumping from Ch-1 well, the values of T and S are computed as 736.6 m^2/day and 8.97E-02, respectively.

In the other observation holes, the groundwater levels declined about 10cm from 20 to 500 minutes after pumping started. However, the levels rose about 10cm from 500 to 1,300 minutes. It is noted that the patterns of groundwater level changes in Ch-2-1 to Ch-2-3 holes are almost the same, indicating that the fluctuations are caused not by the pumping from Ch-1 well but by the pumpage of other exiting wells.

3) Jh-1 Well [JH-1 site, Arabpur, Jhenaidah Pourashava]

Figure 5.3.9 shows the results of the continuous pumping test at Jh-1 well. The test was carried out with a constant discharge rate of 80.7 m^3/day. In the pumped well, the groundwater level declined at a relatively higher rate until 200 minutes after pumping started. After reaching a drawdown of 31 m, the declining rate decreased and the curve shows an almost horizontal straight line on the semi-log plot. The drawdown curve shows a leaky type of aquifer. The final drawdown was 31.928 m. From the fitted line from 10 to 200 minutes, the values of T and S are computed as 0.69 m^2/day and 2.24E-01, respectively.

In the observation holes, the groundwater levels irregularly fluctuated but the range of fluctuation was within 3cm. The groundwater level in Jh-1-4 hole tends to decline from 50 to 1,500 minutes. Although it is rather hard to identify whether the declining portion was caused by the pumping test, the values of T and S are computed as 1,439 m^2/day and 4.32E-01, respectively from the fitted line.

4) Jh-2 Well [JH-2 site, Hamdah, Jhenaidah Pourashava]

Figure 5.3.10 shows the results of the continuous pumping test at Jh-2 well. The test was carried out with a constant discharge rate of 199.38 m^3/day. In the pumped well, the groundwater level declined at a relatively higher rate until 50 minutes after pumping started. After reaching a drawdown of 30 m, the declining rate decreased and the curve shows an almost horizontal straight line on the semi-log plot. The drawdown curve shows a leaky type of aquifer. The final drawdown was 30.538 m. From the fitted line from 3 to 50 minutes, the values of T and S are computed as 1.81 m^2/day and 1.33E-01, respectively.

In the deepest observation hole (Jh-2-4), a slight drawdown can be identified from 5 to 150 minutes after pumping started. The maximum drawdown is 6.3cm. For this period, the groundwater levels in the other observation holes remain stable. From the fitted line, the values of T and S are computed as 1,115 m^2/day and 8.16E-02, respectively. After 150 minutes, groundwater levels in all the observation holes started to rise showing similar changing patterns.

5) Js-1 Well [JS-1 site, Ghop, Jessore Pourashava]

Figure 5.3.11 shows the results of the continuous pumping test at Js-1 well. The test was carried out with a constant discharge rate of 1910.8 m^3/day. In the pumped well, the groundwater level suddenly declined at 23 m within 10 minutes after pumping started. Then the drawdown curve shows to be almost flat. Compared with the groundwater levels in the observation holes, it is judged that the drawdown curve in the pumped well was affected by the pumpage of the surrounding wells. The maximum drawdown was 23.176 m. Although it is rather difficult to find a reliable straight portion on the semi-log plot, the values of T and S are computed as 54.1 m^2/day and 5.66E-03, respectively from the fitted line.

In the deepest observation holes, the groundwater levels in holes Js-1-1 to Js-1-3 have almost the same patterns of fluctuations. These groundwater levels started to rise after 100 minutes. In the Js-1-4 observation hole, the drawdown was identified until 100 minutes after pumping started. The maximum drawdown was 0.677 m. From the straight portion of the drawdown curve, the values of T and S are computed as 6,643 m^2/day and 2.95E-12, respectively.

6) Js-2 Well [JS-2 site, Kharki, Jessore Pourashava]

Figure 5.3.12 shows the results of the continuous pumping test at Js-2 well. The test was carried out with a constant discharge rate of 206.7 m^3/day. In the pumped well, the groundwater level declined at a relatively higher rate until 50 minutes after pumping started. Then the declining rate decreased and showed a straight portion until 2,880 minutes. The final drawdown was 22.776 m. From the fitted line, the values of T and S are computed as 34.0 m^2/day and 1.25E-17, respectively.

In the observation holes, a clear drawdown was observed in Js-2-4 hole, which tapped the same aquifer. However, no drawdown was observed in the rest. The maximum drawdown in Js-2-4 well was 1.152 m. From the straight portion of the drawdown curve, the values of *T* and *S* are computed as 56.4 m^2/day and 5.54E-03, respectively.

5.3.5 Results of Recovery Test

The results of the recovery test at the observation deep wells are also summarized in Table 5.3.2. The value of transmissivity (*T*) was obtained by the recovery method using the residual drawdown curve on the semi-log plot. For the analysis, two (2) kinds of residual drawdown data were used; one is the residual drawdown in the pumped well and the other is the residual drawdown in the deepest observation hole, which tapped the same aquifer from which the pumped well extracted the groundwater.

1) Ch-1 Well [CH-1 site, Poshu Hat, Chuadanga Pourashava]

Figure 5.3.13 shows the results of the recovery test at Ch-1 well. The test was carried out just after the 2,880 minute continuous pumping test with a constant discharge rate of 4,320 m^3/day. In the pumped well, the groundwater level was quickly recovered and the straight portion of the residual drawdown curve appeared at time ratios from 10 to 200. From the fitted line, the value of transmissivity (*T*) can be computed as 17,707 m^2/day.

In the observation holes, the groundwater level of Ch-1-4 hole gradually recovered. A straight portion of the residual drawdown curve was found at time ratios from 10 to 200. From the fitted line, the value of transmissivity (*T*) can be computed as 14,396 m^2/day.

The groundwater levels in the rest of the observation holes also gradually recovered. However, the groundwater levels including Ch-1-4 fluctuated in the latter part of the recovery test due to the influence of the existing wells' pumpage.

2) Ch-2 Well [CH-2 site, Girls College, Chuadanga Pourashava]

Figure 5.3.14 shows the results of recovery test at Ch-2 well. The test was carried out just after the 2,880 minute continuous pumping test with a constant discharge rate of 239.3 m^3/day. In the pumped well, the groundwater level was gradually recovered. The straight portion of the residual drawdown curve appeared at time ratios from 30 to 80. From the fitted line, the value of transmissivity (*T*) can be computed as 394.3 m^2/day.

In the observation holes, a clear recovery of the groundwater level was found in Ch-2-4 hole. A straight portion of the residual drawdown curve was found at time ratios from 70 to 1,000. From the fitted line, the value of transmissivity (*T*) can be computed as 735.3 m^2/day.

The groundwater levels in the rest of the observation holes did not show recovery. The groundwater levels including Ch-1-4 declined in the latter part of the recovery test due to the influence of the existing wells' pumpage.

3) Jh-1 Well [JH-1 site, Arabpur, Jhenaidah Pourashava]

Figure 5.3.15 shows the results of the recovery test at Jh-1 well. The test was carried out just after the 2,880 minute continuous pumping test with a constant discharge rate of 80.7 m^3/day. In the pumped well, the groundwater level was gradually recovered and the straight portion of the residual drawdown curve appeared at time ratios from 20 to 120. From the fitted line, the value of transmissivity (*T*) was computed as 0.54 m^2/day.

In the observation holes, since the groundwater level of Jh-1-4 hole hardly declined during the pumping, the residual drawdown curve was not obtained. Therefore, the value of transmissivity (*T*) cannot be computed.

The groundwater levels in the rest of the observation holes rose in the latter part of the recovery test. But the rise in groundwater levels was due to the influence of the surrounding pumpage at existing wells.

4) Jh-2 Well [JH-2 site, Hamdah, Jhenaidah Pourashava]

Figure 5.3.16 shows the results of the recovery test at Jh-2 well. The test was carried out just after the 2,880 minute continuous pumping test with a constant discharge rate of 199.4 m^3/day. In the pumped well, the groundwater level was gradually recovered and reached the static level at 60 minutes after pumping stopped. The straight portion of the residual drawdown curve appeared at time ratios from 60 to 500. From the fitted line, the value of transmissivity (*T*) was computed as 1.39 m^2/day.

In the observation holes, since the groundwater levels fluctuated during the continuous pumping test, the levels were already above the static levels measured before the continuous pumping test. Although the groundwater levels still rose in the recovery test period, the recovery of groundwater levels was identified in Jh-2-4 hole. The straight portion of the residual drawdown curve was found at time ratios from 25 to 500. From the fitted line, the value of transmissivity (*T*) was computed as 909.8 m^2/day.

The groundwater levels in the rest of the observation holes did not show clear recovery by the pumping test. The rise in groundwater levels was due to the influence of the surrounding pumpage at existing wells.

5) Js-1 Well [JS-1 site, Ghop, Jessore Pourashava]

Figure 5.3.17 shows the results of the recovery test at Js-1 well. The test was carried out just after the 2,880 minute continuous pumping test with a constant discharge rate of 1,910.8 m^3/day. In the pumped well, the groundwater level was quickly recovered within 3 minutes after pumping stopped and almost reached the static level. The straight portion of the residual drawdown curve appeared at time ratios from 200 to 500. From the fitted line, the value of transmissivity (*T*) was computed as 2,241.8 m^2/day.

In the observation holes, the groundwater level in Js-1-4 hole also quickly recovered for the most part. The straight portion of the residual drawdown curve was found at time ratios from 200 to 500. From the fitted line, the value of transmissivity (*T*) was computed as 3,985.6 m^2/day.

The groundwater levels in the rest of the observation holes did not show recovery because there were no drawdowns caused by the continuous pumping test. The water levels including Js-1-4 rose in the latter part of the recovery test due to the influence of surrounding groundwater use.

6) Js-2 Well [JS-2 site, Kharki, Jessore Pourashava]

Figure 5.3.18 shows the results of the recovery test at Js-2 well. The test was carried out just after the 2,880 minute continuous pumping test with a constant discharge rate of 206.7 m^3/day. In the pumped well, the groundwater level was gradually recovered and almost reached the static level at 70 minutes after pumping stopped. The straight portion of the residual drawdown curve appeared at time ratios from 80 to 700. From the fitted line, the value of transmissivity (*T*) was computed as 2.05 m^2/day.

In the observation holes, a clear recovery of groundwater level was found in Js-2-4 hole. The straight portion of the residual drawdown curve was found at time ratios from 80 to 700. From the fitted line, the value of transmissivity (*T*) was computed as 41.24 m^2/day.

The groundwater levels in the rest of the observation holes did not show recovery because there were no drawdowns caused by the continuous pumping test. The water levels of Js-2-1 to Js-2-3 holes rose in the latter part of the recovery test due to the influence of surrounding groundwater use.

5.3.6 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 the storage coefficient (*S*) were obtained by the 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.

1) CH-1 site [Poshu Hat, Chuadanga Pourashava]

Figure 5.3.19 shows the results of the pumping test carried out at Ch-1-1 hole (depth = 63 m). The drawdown test was carried out with a pumping rate of 158.0 m^3/day. The maximum drawdown of 3.274 m was obtained just after one (1) minute after pumping started. Then the water level gradually rose even though constant pumping continued due to the influence of surrounding groundwater use. From the final drawdown of 2.934 m, the value of specific capacity (*Sc*) was computed as 53.9 m^2/day. From the recovery test, the value of transmissivity (*T*) was computed as 2,917 m^2/day.

Figure 5.3.20 shows the results of the pumping test carried out at Ch-1-2 hole (depth = 118 m). The drawdown test was carried out with a pumping rate of 153.1 m^3/day. The maximum drawdown of 6.452 m was obtained just after two (2) minutes after pumping started. Then the water level gradually rose even though the constant pumping continued due to the influence of surrounding groundwater use. From the final drawdown of 6.111 m, the value of specific capacity (*Sc*) was computed as 25.1 m^2/day. From the recovery test, the value of transmissivity (*T*) was computed as 2,564 m^2/day.

Figure 5.3.21 shows the results of the pumping test carried out at Ch-1-3 hole (depth = 168 m). The drawdown test was carried out with a pumping rate of 170.7 m^3/day. From the final drawdown of 2.480 m, the value of specific capacity (*Sc*) was computed as 68.8 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 831.5 m^2/day and 5.12E-62, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 8,805 m^2/day.

Figure 5.3.22 shows the results of the pumping test carried out at Ch-1-4 hole (depth = 300 m). The drawdown test was carried out with a pumping rate of 153.5 m^3/day. The maximum drawdown of 12.737 m was obtained just after 5 minutes after pumping started. Then the water level gradually rose even though the constant pumping continued due to the influence of surrounding groundwater use. From the final drawdown of 11.835 m, the value of specific capacity (*Sc*) was computed as 13.0 m^2/day. From the recovery test, the value of transmissivity (*T*) was computed as 297.7 m^2/day.

2) CH-2 site [Girls College, Chuadanga Pourashava]

Figure 5.3.23 shows the results of the pumping test carried out at Ch-2-1 hole (depth = 56.5 m). The drawdown test was carried out with a pumping rate of 170.7 m^3/day. From the final drawdown of 2.886 m, the value of specific capacity (*Sc*) was computed as 59.1 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 302.2 m^2/day and 7.48E-24, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 9,583 m^2/day.

Figure 5.3.24 shows the results of the pumping test carried out at Ch-2-2 hole (depth = 109 m). The drawdown test was carried out with a pumping rate of 183.0 m^3/day. From the final drawdown of 3.335 m, the value of specific capacity (*Sc*) was computed as 54.9 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 327.5 m^2/day and 1.07E-28, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 4,254 m^2/day.

Figure 5.3.25 shows the results of the pumping test carried out at Ch-2-3 hole (depth = 152.5 m).

The drawdown test was carried out with a pumping rate of 190.8 m^3/day. From the final drawdown of 3.777 m, the value of specific capacity (*Sc*) was computed as 50.5 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 530.5 m^2/day and 1.51E-53, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 4,101 m^2/day.

Figure 5.3.26 shows the results of the pumping test carried out at Ch-2-4 hole (depth = 299.5 m). The drawdown test was carried out with a pumping rate of 183.0 m^3/day. From the final drawdown of 6.852 m, the value of specific capacity (*Sc*) was computed as 26.7 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 321.3 m^2/day and 9.75E-62, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 2,983 m^2/day.

3) JH-1 site [Arabpur, Jhenaidah Pourashava]

Figure 5.3.27 shows the results of the pumping test carried out at Jh-1-1 hole (depth = 60.0 m). The drawdown test was carried out with a pumping rate of 182.0 m^3/day. From the final drawdown of 0.680 m, the value of specific capacity (*Sc*) was computed as 267.6 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are not computed because of the quick stabilization of the groundwater level. From the recovery test, the value of transmissivity (*T*) was computed as 134.7 m^2/day.

Figure 5.3.28 shows the results of the pumping test carried out at Jh-1-2 hole (depth = 123.0 m). The drawdown test was carried out with a pumping rate of 182.6 m^3/day. From the final drawdown of 0.687 m, the value of specific capacity (*Sc*) was computed as 265.8 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 1,963 m^2/day and 2.63E-36, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 430.5 m^2/day.

Figure 5.3.29 shows the results of the pumping test carried out at Jh-1-3 hole (depth = 165.0 m). The drawdown test was carried out with a pumping rate of 167.3 m^3/day. From the final drawdown of 1.925 m, the value of specific capacity (*Sc*) was computed as 86.9 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 1,853 m^2/day and "very small", respectively. From the recovery test, the value of transmissivity (*T*) was computed as 217.2 m^2/day.

Figure 5.3.30 shows the results of the pumping test carried out at Jh-1-4 hole (depth = 282.0 m). The drawdown test was carried out with a pumping rate of 146.2 m^3/day. From the final drawdown of 9.798 m, the value of specific capacity (*Sc*) was computed as 14.9 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 336.4 m^2/day and "very small", respectively. From the recovery test, the value of transmissivity (*T*) was computed as 158.6 m^2/day.

4) JH-2 site [Hamdah, Jhenaidah Pourashava]

Figure 5.3.31 shows the results of the pumping test carried out at Jh-2-1 hole (depth = 60.0 m). The drawdown test was carried out with a pumping rate of 157.7 m^3/day. From the final drawdown of 3.945 m, the value of specific capacity (*Sc*) was computed as 40.0 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 288.3 m^2/day and 1.90E-35, respectively. From the recovery test, the value of transmissivity (*T*) was not computed due to the quick recovery of the groundwater level.

Figure 5.3.32 shows the results of the pumping test carried out at Jh-2-2 hole (depth = 111.0 m). The drawdown test was carried out with a pumping rate of 162.0 m^3/day. From the final drawdown of 0.764 m, the value of specific capacity (*Sc*) was computed as 212.0 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 3,391 m^2/day and 2.06E-83, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 979.1 m^2/day.

Figure 5.3.33 shows the results of the pumping test carried out at Jh-2-3 hole (depth = 165.0 m). The drawdown test was carried out with a pumping rate of 179.1 m^3/day. From the final drawdown of 2.084 m, the value of specific capacity (*Sc*) was computed as 85.9 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 397.0 m^2/day and 4.21E-20, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 1,626 m^2/day.

Figure 5.3.34 shows the results of the pumping test carried out at Jh-2-4 hole (depth = 273.0 m). The drawdown test was carried out with a pumping rate of 152.5 m^3/day. From the final drawdown of 4.975 m, the value of specific capacity (*Sc*) was computed as 30.7 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 373.8 m^2/day and 8.53E-63, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 2,693 m^2/day.

5) JS-1 site [Ghop, Jessore Pourashava]

Figure 5.3.35 shows the results of the pumping test carried out at Js-1-1 hole (depth = 66.0 m). The drawdown test was carried out with a pumping rate of 163.4 m^3/day. From the final drawdown of 0.440 m, the value of specific capacity (*Sc*) was computed as 371.4 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) cannot be computed because the groundwater level irregularly fluctuated during the test. From the recovery test, the value of transmissivity (*T*) was not computed due to the quick recovery of the groundwater level.

Figure 5.3.36 shows the results of the pumping test carried out at Js-1-2 hole (depth = 120.0 m). The drawdown test was carried out with a pumping rate of 166.2 m^3/day. From the final drawdown of 0.671 m, the value of specific capacity (*Sc*) was computed as 247.7 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) cannot be computed due to the irregular fluctuations of groundwater level caused by the surrounding groundwater usage. From the recovery test, the value of transmissivity (*T*) was computed as 624.2 m^2/day.

Figure 5.3.37 shows the results of the pumping test carried out at Js-1-3 hole (depth = 168.0 m). The drawdown test was carried out with a pumping rate of 93.5 m^3/day. From the final drawdown of 0.422 m, the value of specific capacity (*Sc*) was computed as 221.6 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 301.2 m^2/day and 2.70E-03, respectively. From the recovery test, the value of transmissivity (*T*) was not computed due to irregular fluctuations in the groundwater level caused by surrounding groundwater use.

Figure 5.3.38 shows the results of the pumping test carried out at Js-1-4 hole (depth = 282.0 m). The drawdown test was carried out with a pumping rate of 158.2 m^3/day. From the final drawdown of 1.530 m, the value of specific capacity (*Sc*) was computed as 103.4 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) cannot be computed because of irregular fluctuations of the groundwater level. From the recovery test, the value of transmissivity (*T*) was not computed due to irregular fluctuations in the groundwater level.

6) JS-2 site [Kharki, Jessore Pourashava]

Figure 5.3.39 shows the results of the pumping test carried out at Js-2-1 hole (depth = 66.0 m). The drawdown test was carried out with a pumping rate of 201.1 m^3/day. From the final drawdown of 3.236 m, the value of specific capacity (*Sc*) was computed as 62.2 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 222.0 m^2/day and 1.34E-15, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 3,420 m^2/day.

Figure 5.3.40 shows the results of the pumping test carried out at Js-2-2 hole (depth = 114.0 m). The drawdown test was carried out with a pumping rate of 192.2 m^3/day. From the final drawdown of 0.804 m, the value of specific capacity (*Sc*) was computed as 239.1 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 321.6 m^2/day and 2.83E-03, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 202.1 m^2/day.

Figure 5.3.41 shows the results of the pumping test carried out at Js-2-3 hole (depth = 162.0 m). The drawdown test was carried out with a pumping rate of 127.3 m^3/day. From the final drawdown of 22.724 m, the value of specific capacity (*Sc*) was computed as 5.6 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 2.12 m^2/day and 8.73E-02, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 0.84 m^2/day.

Figure 5.3.42 shows the results of the pumping test carried out at Js-2-4 hole (depth = 255.0 m). The drawdown test was carried out with a pumping rate of 168.7 m^3/day. From the final drawdown of 4.350 m, the value of specific capacity (*Sc*) was computed as 38.6 m^2/day. The values of transmissivity (*T*) and the storage coefficient (*S*) are computed as 178.5 m^2/day and 1.29E-22, respectively. From the recovery test, the value of transmissivity (*T*) was computed as 252.3 m^2/day.

References

Cooper, H. H., Jr. and Jacob, C. E., 1946, A generalized graphical method for evaluating formation constants and summarizing well-field history. Trans. Amer. Geophysical Union, 27, 526-534.

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

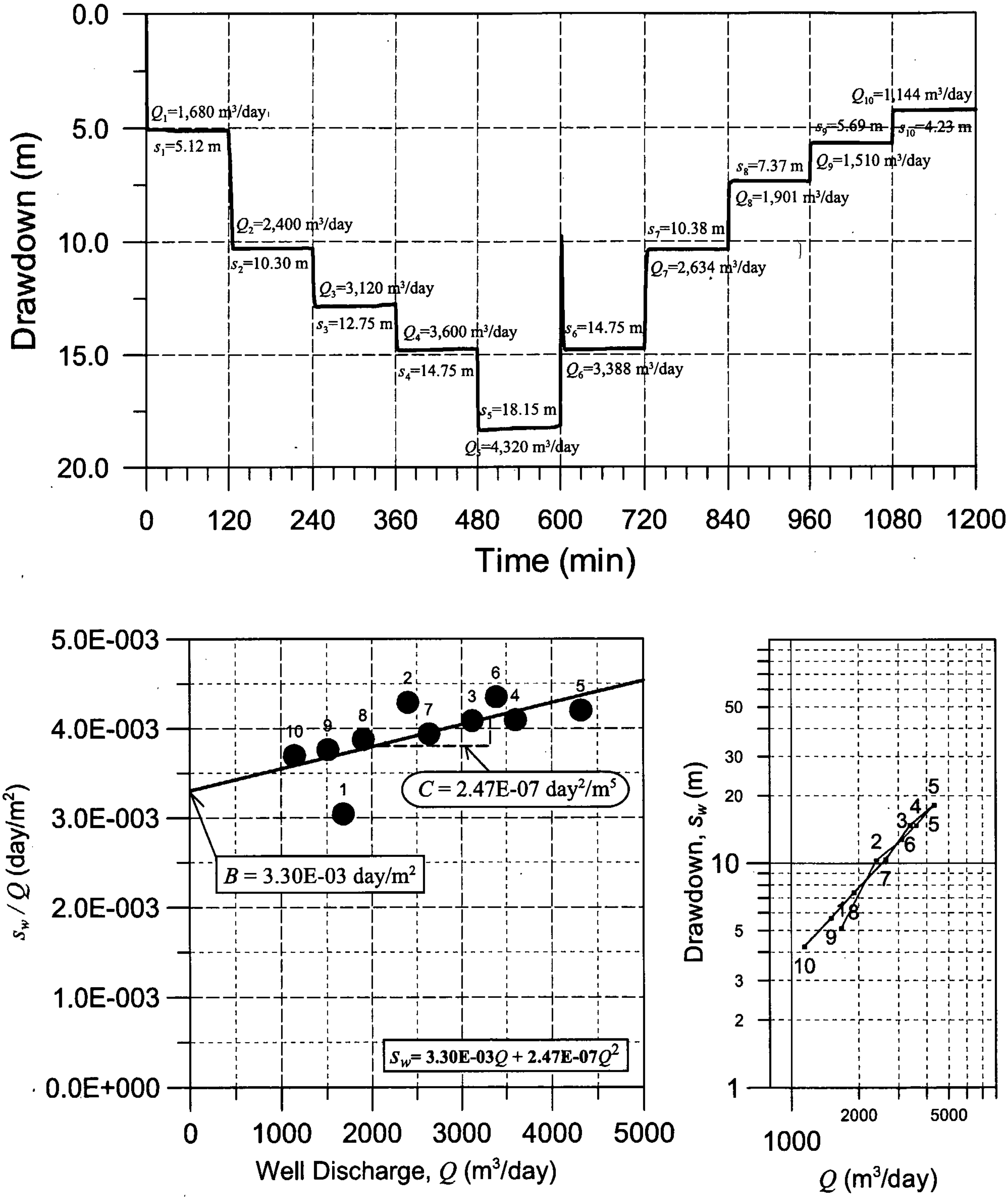
District	Upazila/ Pourashava	Site Name (Site No.)	Well/Hole Type	Well/Obs. Hole No.	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)	Date (dd/mm/yy)	Static Water Level (m)	Step-1 $Q_1(m^3/d)$ $s_1(m)$ $Sc_1(m^2/d)$ $Ew_1(\%)$	Step-2 $Q_2(m^3/d)$ $s_2(m)$ $Sc_2(m^2/d)$ $Ew_2(\%)$	Step-3 $Q_3(m^3/d)$ $s_3(m)$ $Sc_3(m^2/d)$ $Ew_3(\%)$	Step-4 $Q_4(m^3/d)$ $s_4(m)$ $Sc_4(m^2/d)$ $Ew_4(\%)$	Step-5 $Q_5(m^3/d)$ $s_5(m)$ $Sc_5(m^2/d)$ $Ew_5(\%)$	Step-6 $Q_6(m^3/d)$ $s_6(m)$ $Sc_6(m^2/d)$ $Ew_6(\%)$	Step-7 $Q_7(m^3/d)$ $s_7(m)$ $Sc_7(m^2/d)$ $Ew_7(\%)$	Step-8 $Q_8(m^3/d)$ $s_8(m)$ $Sc_8(m^2/d)$ $Ew_8(\%)$	Step-9 $Q_9(m^3/d)$ $s_9(m)$ $Sc_9(m^2/d)$ $Ew_9(\%)$	Step-10 $Q_{10}(m^3/d)$ $s_{10}(m)$ $Sc_{10}(m^2/d)$ $Ew_{10}(\%)$	Step-11 $Q_{11}(m^3/d)$ $s_{11}(m)$ $Sc_{11}(m^2/d)$ $Ew_{11}(\%)$	Step-12 $Q_{12}(m^3/d)$ $s_{12}(m)$ $Sc_{12}(m^2/d)$ $Ew_{12}(\%)$	Aquifer Loss Coefficient B (d/m^2)	Well Loss Coefficient C (d^2/m^5)	Average Well Efficiency (%)	Remarks
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	
Chuadanga	Chuadanga Sadar	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	
Jhenaidah	Jhenaidah Sadar	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	
Jessore	Jessore Sadar	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						Data Used*	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)		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 O	N.A. 16264	N.A. 834.1	N.A. 3.04E-08	17707 14396	908.1 738.3	N.A. due to irregular fluctuations of ground-water level.
			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 O	77.07 736.6	3.95 37.8	7.73E-37 8.97E-02	394 735	20.2 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 O	6.92E-01 1439	3.55E-02 73.8	2.24E-01 4.32E-01	5.39E-01 N.A.	2.76E-02 N.A.	N.A. due to very small draw-down in Jh-1-4 hole.
			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 O	1.812 1115	9.29E-02 57.2	1.33E-01 8.16E-02	1.389 909.8	7.12E-02 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 O	54.06 6643	4.16 511.0	5.66E-03 2.95E-12	2242 3986	172.4 306.6	
			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 O	33.96 56.44	2.09 3.47	1.25E-17 5.54E-03	2.052 41.24	1.26E-01 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).

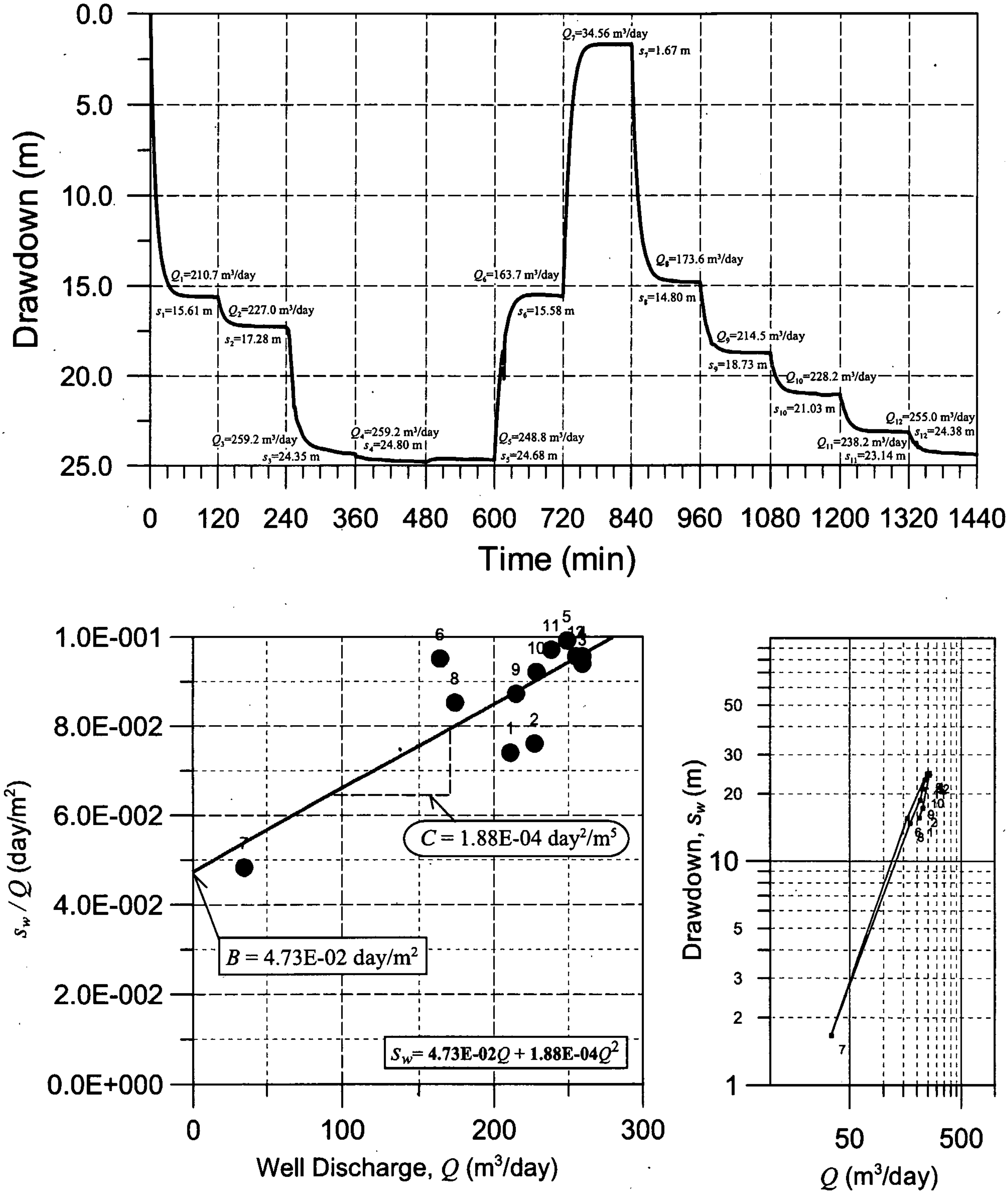


Location: Poshu Hat, Chuadanga Pourashava
Site No.: CH-1
Well No.: Ch-1
Well Depth: 274 m
Well Diameter: 355.60 mm
Screen Depths: 212.5-268.0 m
Screen Length: 19.5 m
SWL: GL- 5.61 m on 21-02-2001

Figure 5.3.1 **Results of Step-Drawdown Test at Ch-1 Observation Well**

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)

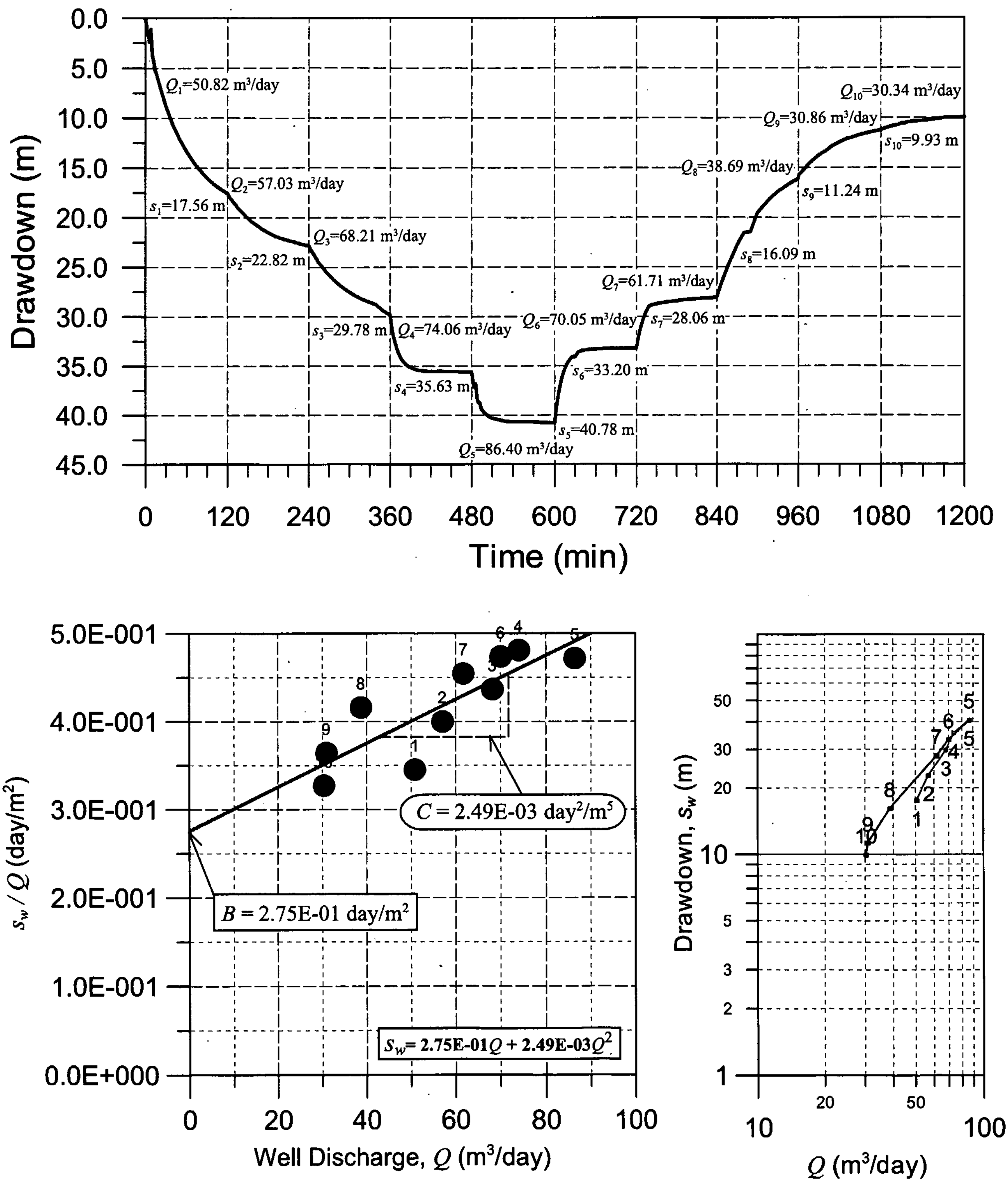


Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2
Well Depth:	298.5 m
Well Diameter:	355.60 mm
Screen Depths:	270-283, 289-295.5 m
Screen Length:	19.5 m
SWL:	GL- 6.001 m on 18-03-2001

Figure 5.3.2 **Results of Step-Drawdown Test at Ch-2 Observation Well**

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)

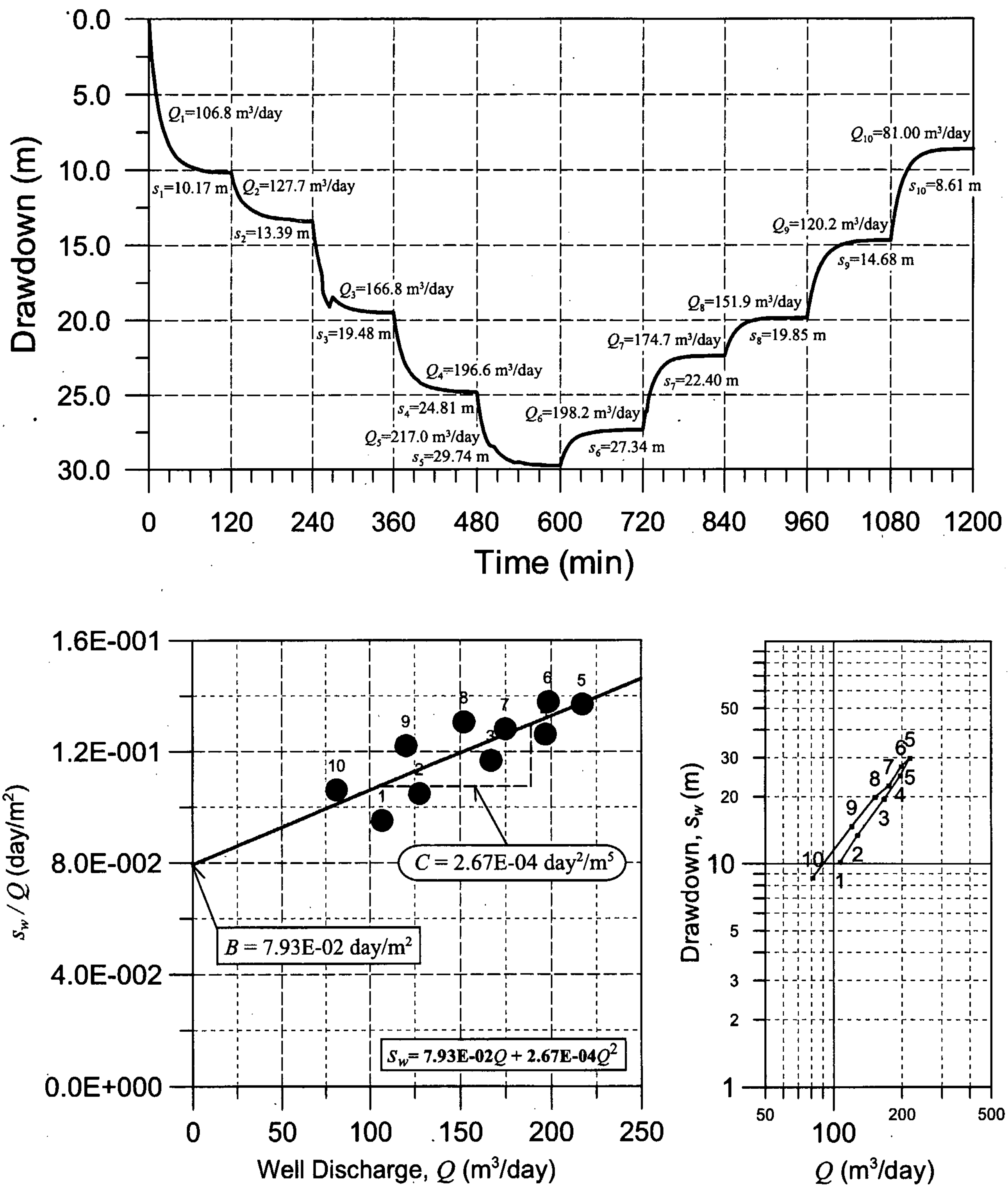


Location:	Arabpur, Jhenaidah Pourashava
Site No.:	JH-1
Well No.:	Jh-1
Well Depth:	292.5 m
Well Diameter:	355.60 mm
Screen Depths:	251.5-289.0 m
Screen Length:	19.5 m
SWL:	GL- 5.545 m on 02-05-2001

Figure 5.3.3 **Results of Step-Drawdown Test at Jh-1 Observation Well**

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)

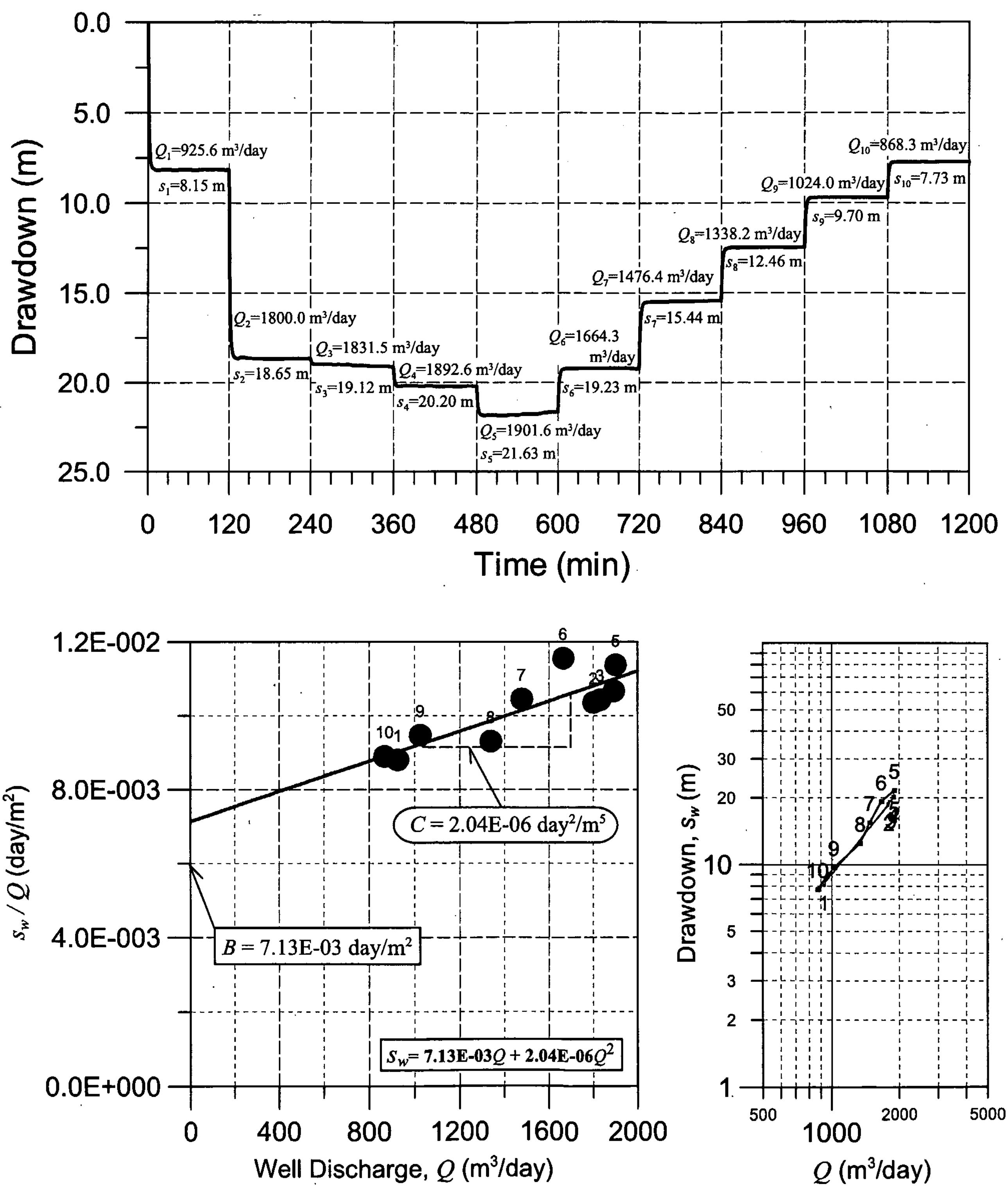


Location:	Hamdah, Jhenaidah Pourashava
Site No.:	JH-2
Well No.:	Jh-2
Well Depth:	301 m
Well Diameter:	355.60 mm
Screen Depths:	257.5-298.0 m
Screen Length:	19.5 m
SWL:	GL- 5.762 m on 03-06-2001

Figure 5.3.4 **Results of Step-Drawdown Test at Jh-2 Observation Well**

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)

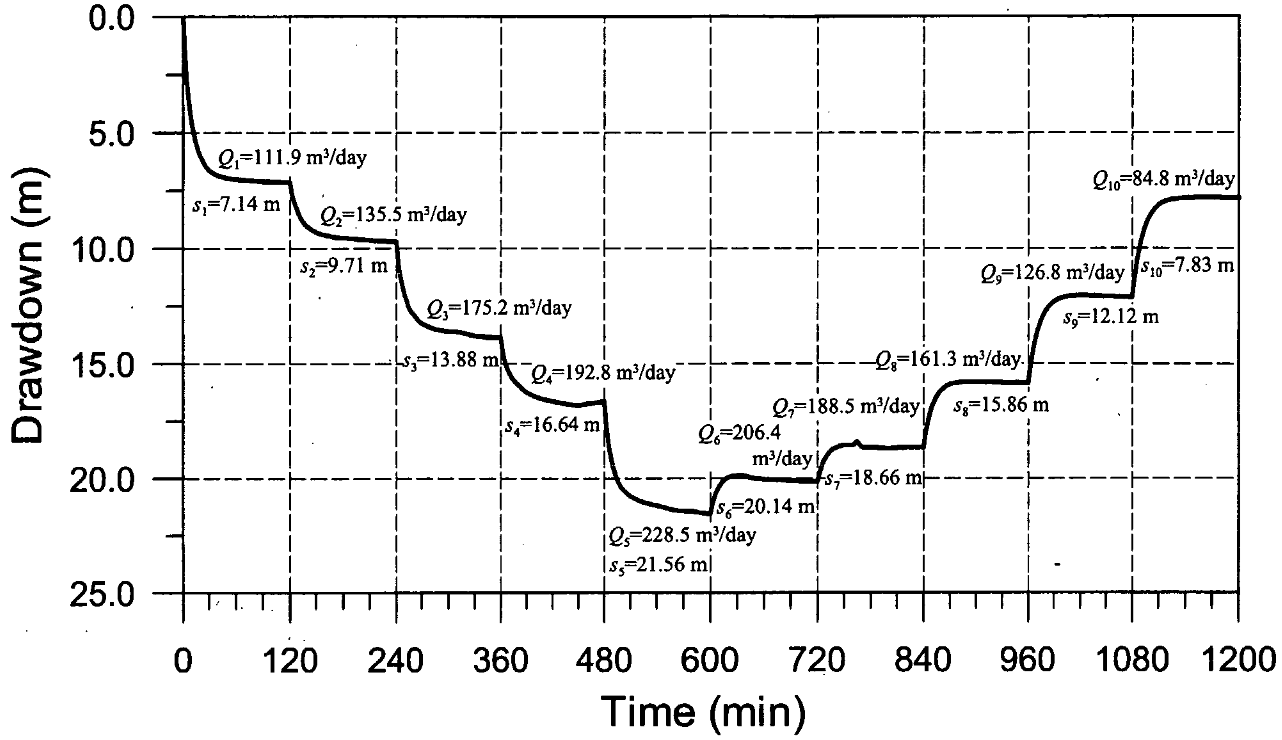


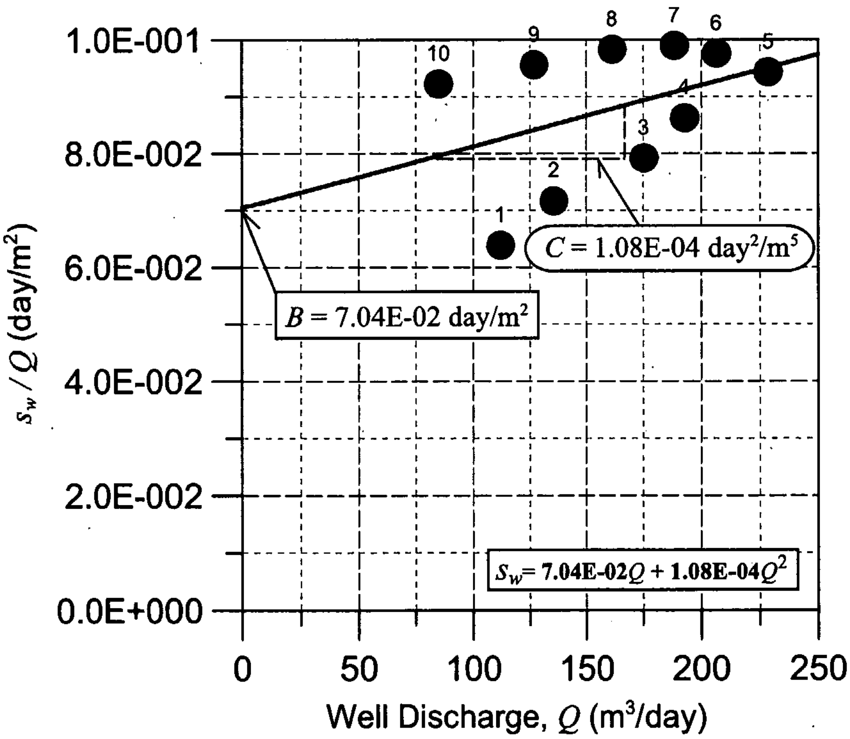
Location:	Ghop, Jessore Pourashava
Site No.:	JS-1
Well No.:	Js-1
Well Depth:	279.5 m
Well Diameter:	355.60 mm
Screen Depths:	260.5-273.5 m
Screen Length:	13.0 m
SWL:	GL- 4.200 m on 16-07-2001

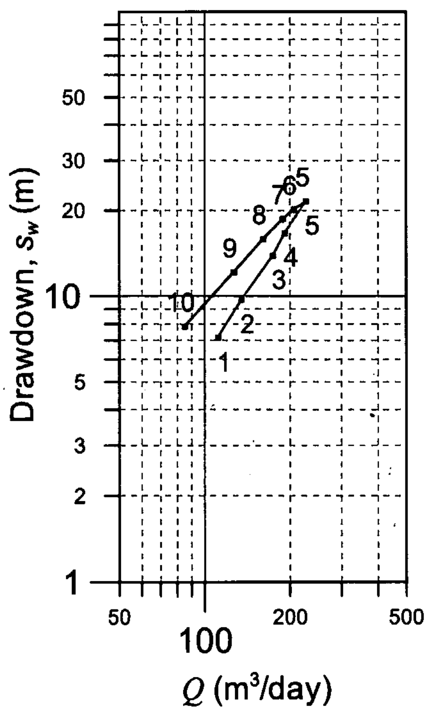
Figure 5.3.5 **Results of Step-Drawdown Test at Js-1 Observation Well**

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)





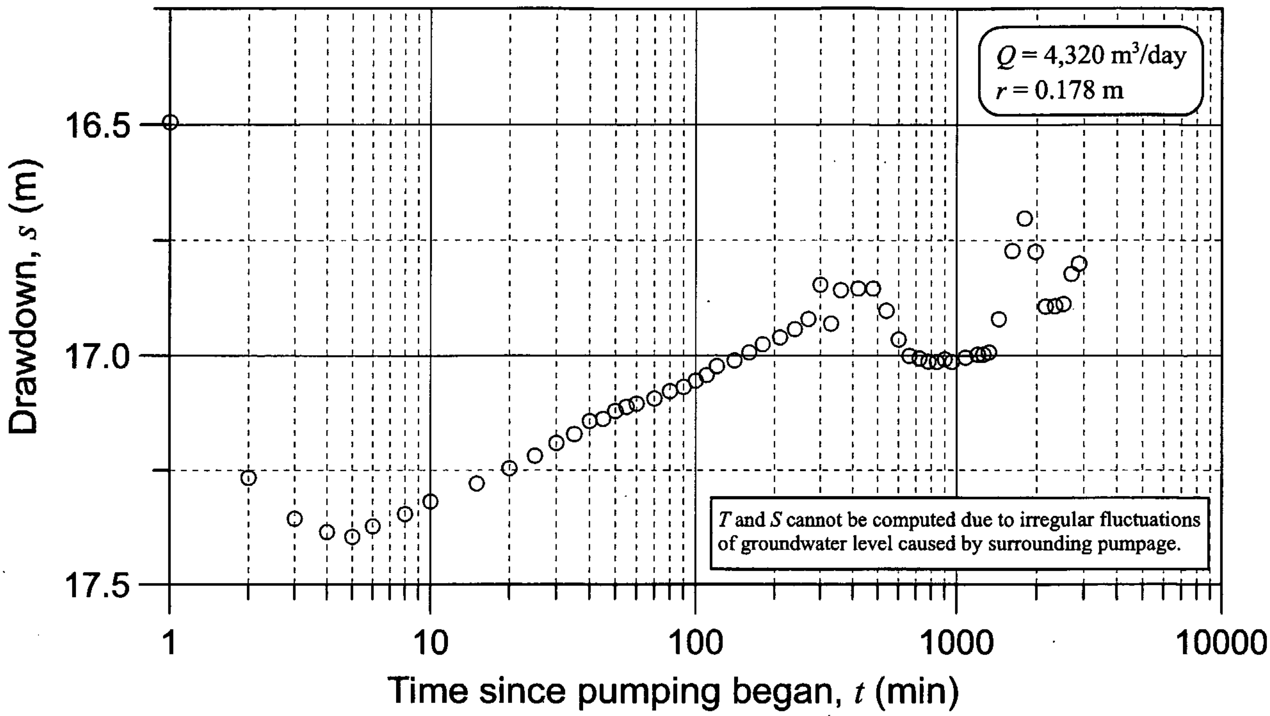


Location:	Kharki, Jessore Pourashava
Site No.:	JS-2
Well No.:	Js-2
Well Depth:	261.75 m
Well Diameter:	355.60 mm
Screen Depths:	239.50-255.75 m
Screen Length:	16.25 m
SWL:	GL- 2.369 m .on 02-08-2001

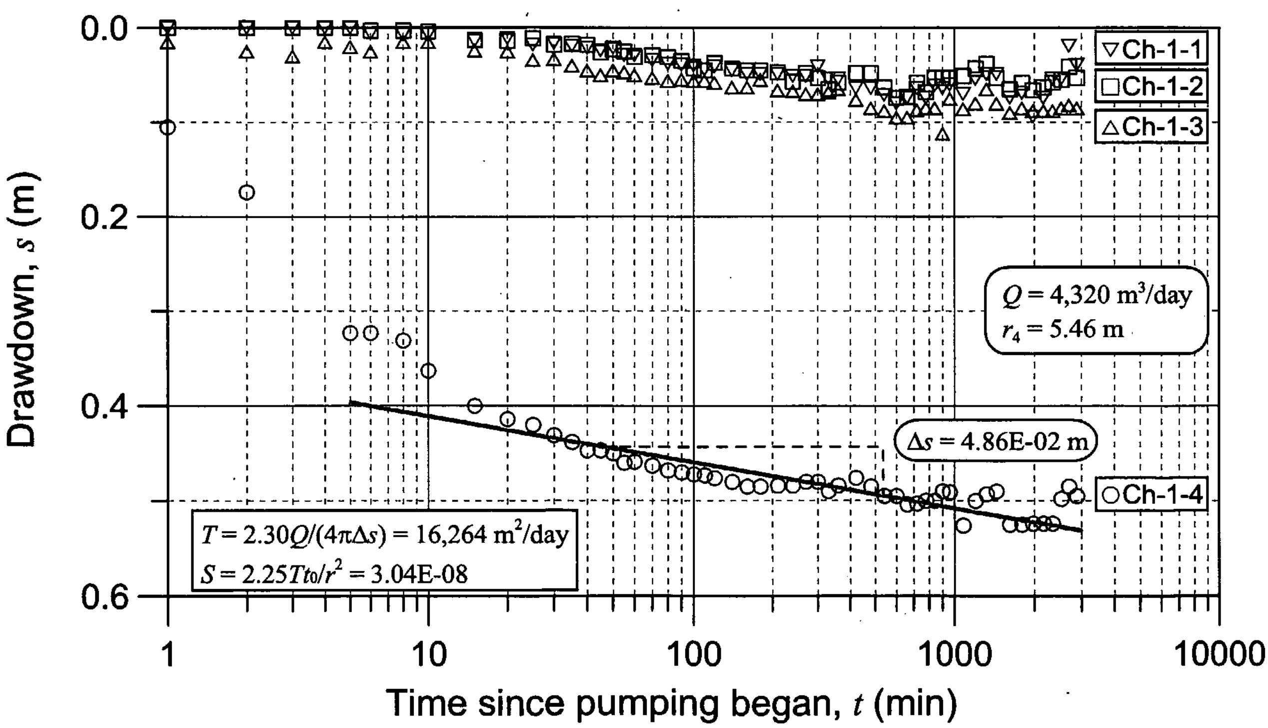
Figure 5.3.6 Results of Step-Drawdown Test at Js-2 Observation Well

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



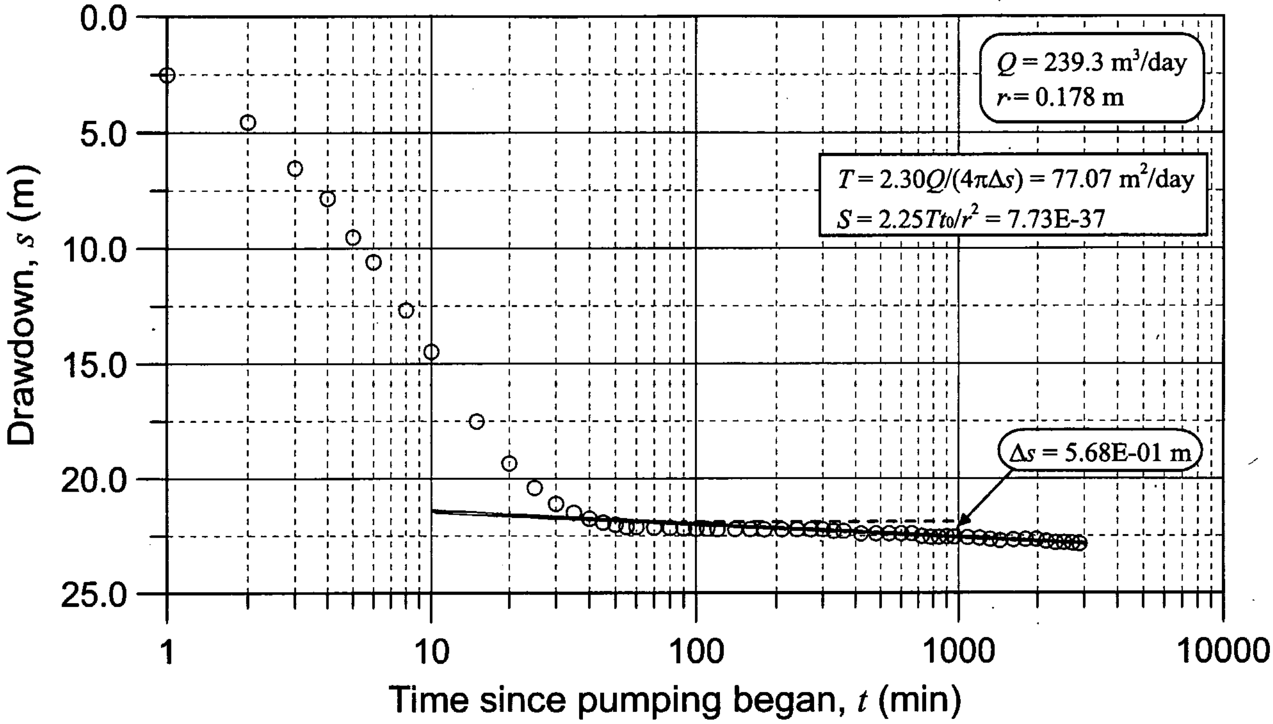
(b) Drawdown in Observation Holes

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- 6.258 m on 22-02-2001

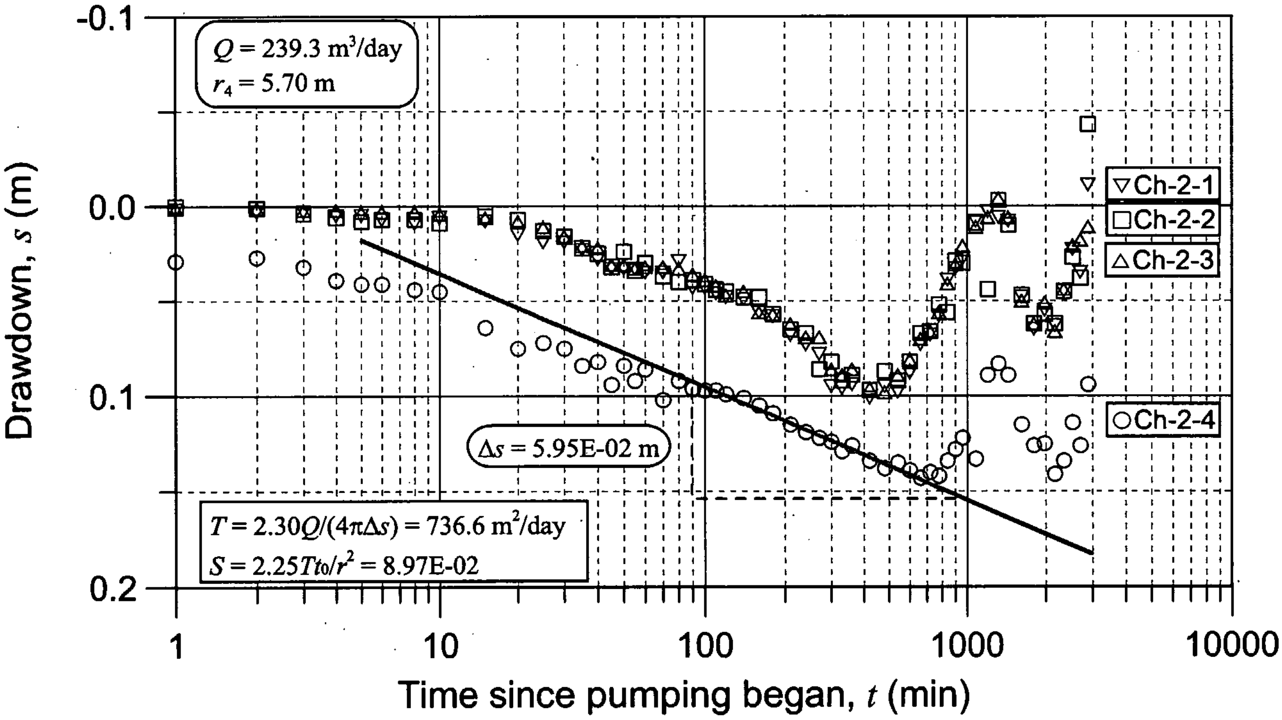
Figure 5.3.7 **Results of Continuous Pumping Test at CH-1 Site, Chuadanga**

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



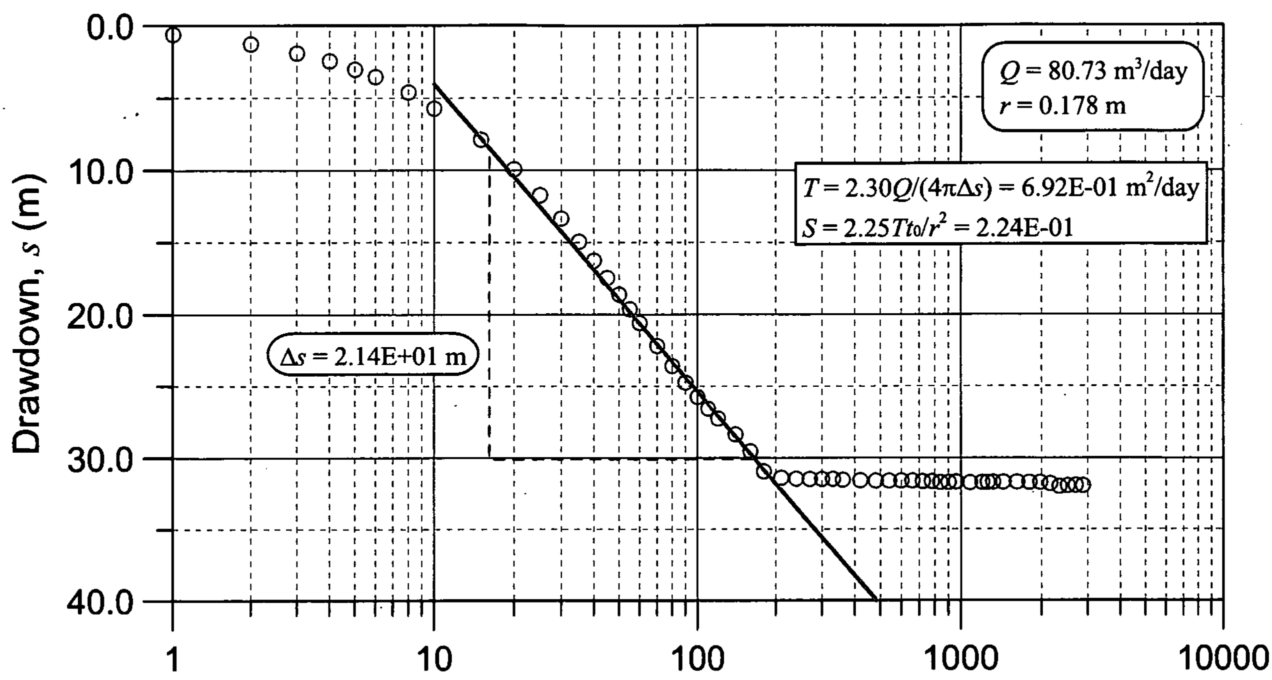
(b) Drawdown in Observation Holes

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

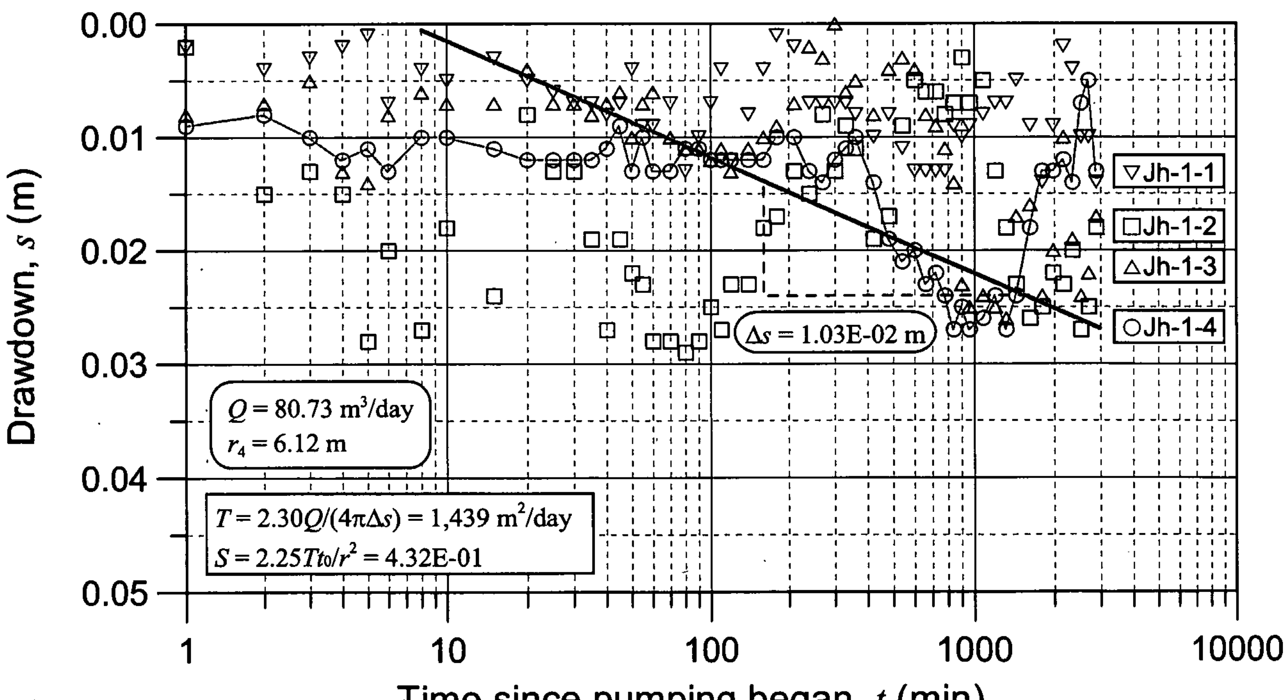
Figure 5.3.8 **Results of Continuous Pumping Test at CH-2 Site, Chuadanga**

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



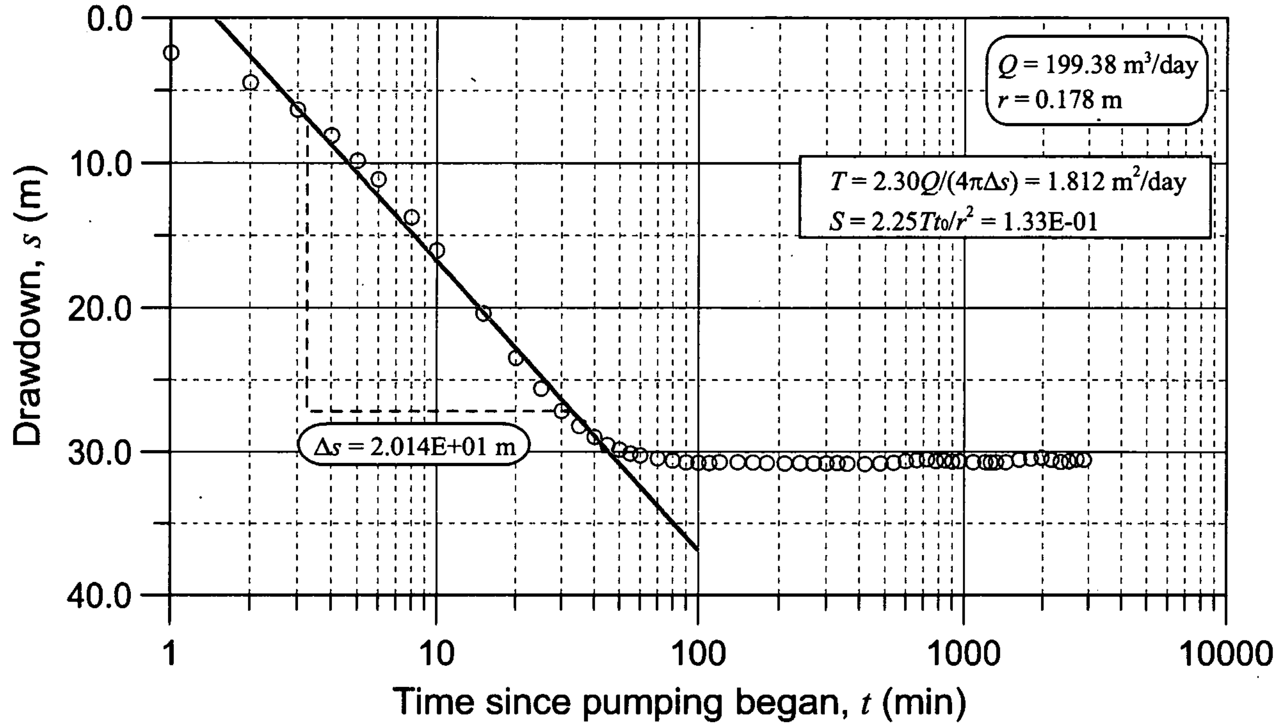
(b) Drawdown in Observation Holes

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

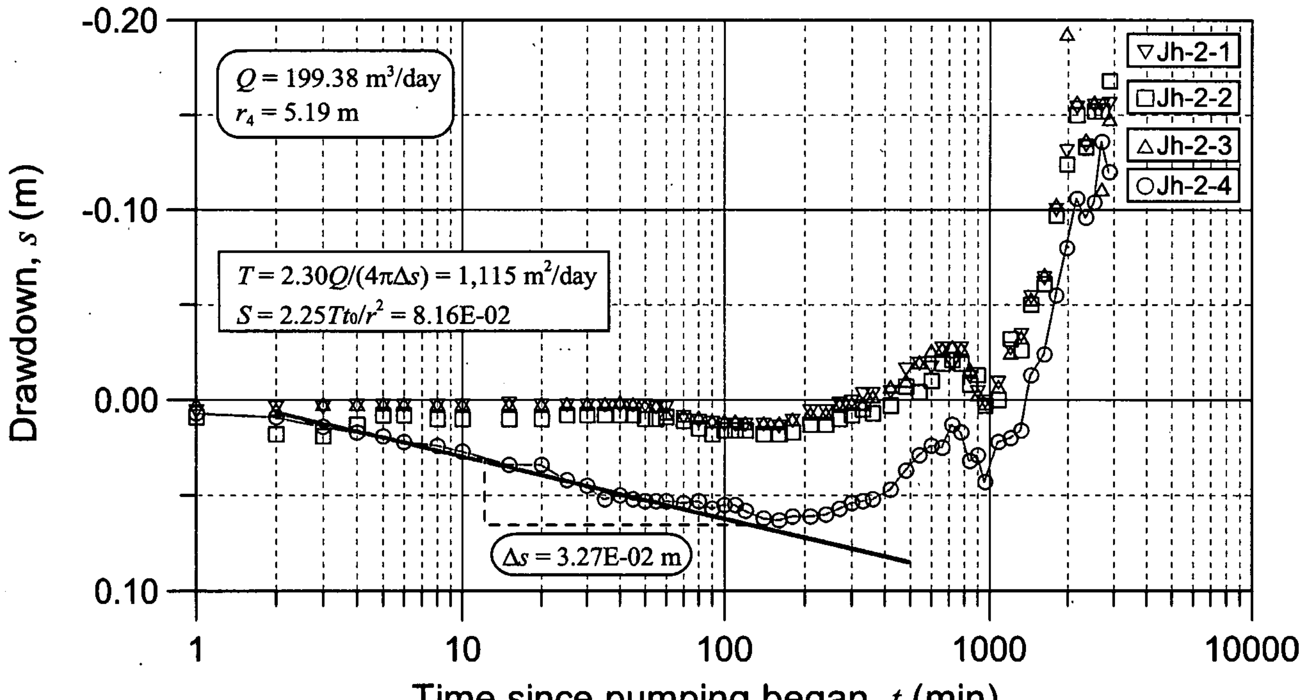
Figure 5.3.9 **Results of Continuous Pumping Test at JH-1 Site, Jhenaidah**

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



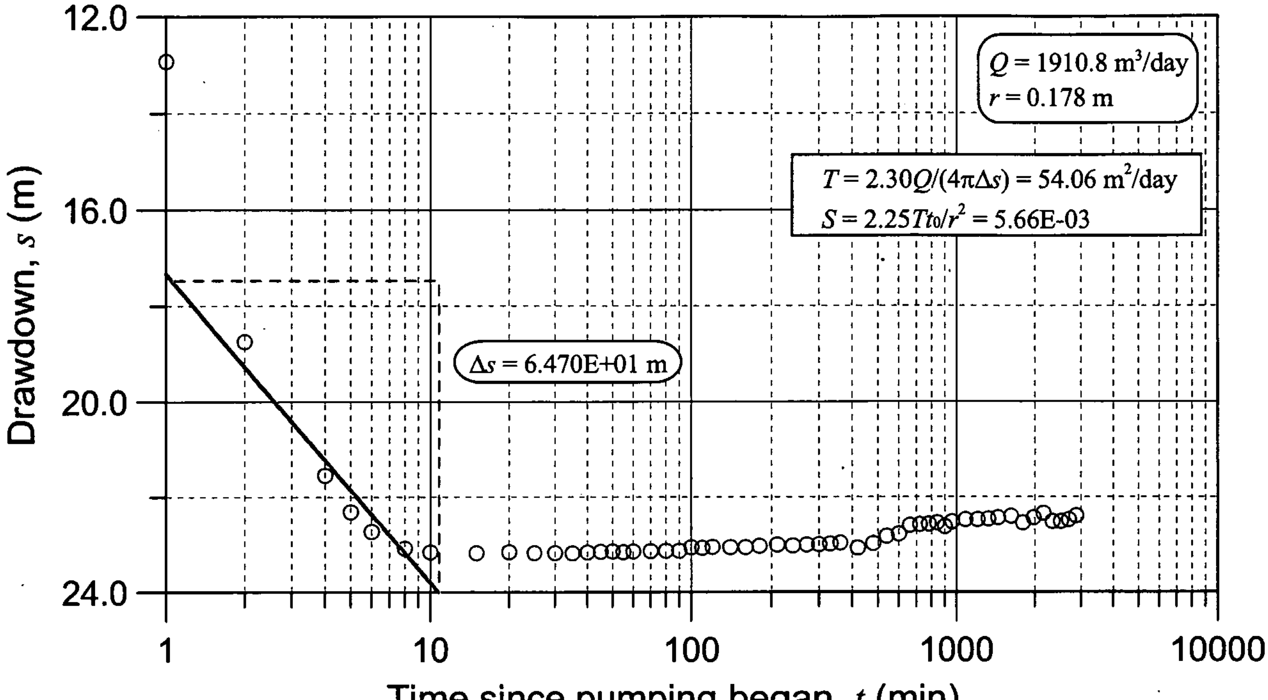
(b) Drawdown in Observation Holes

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

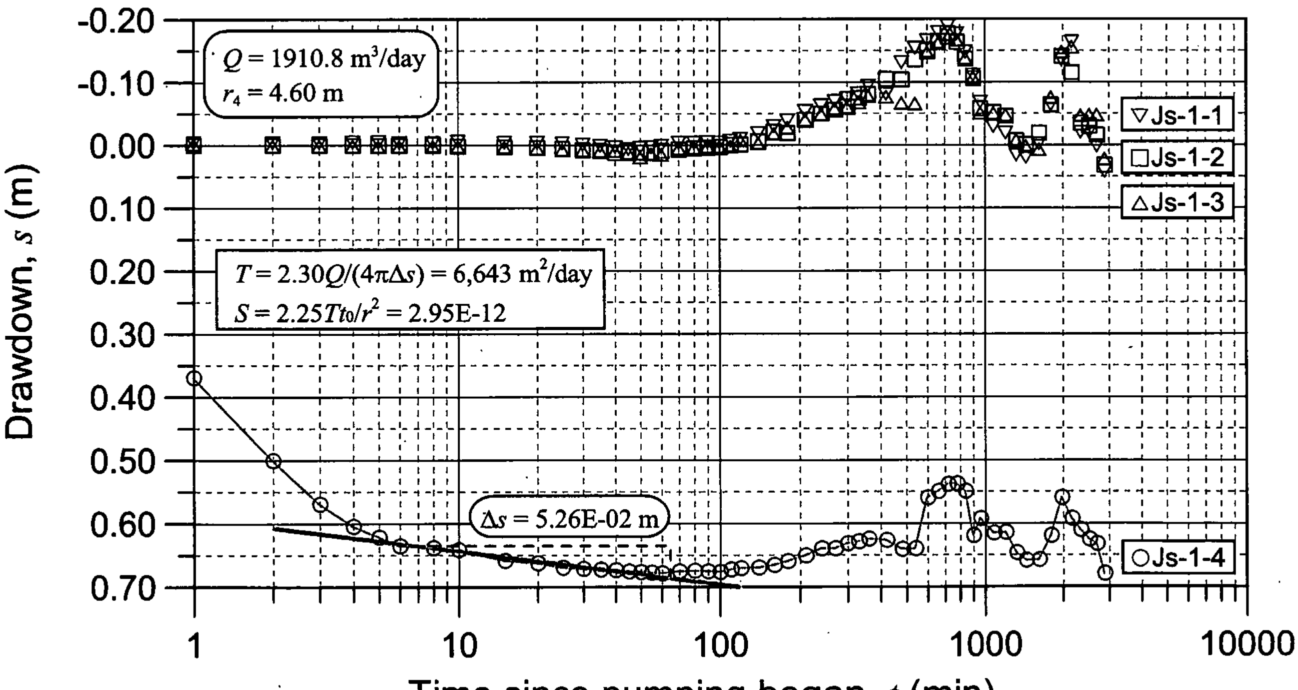
Figure 5.3.10 **Results of Continuous Pumping Test at JH-2 Site, Jhenaidah**

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



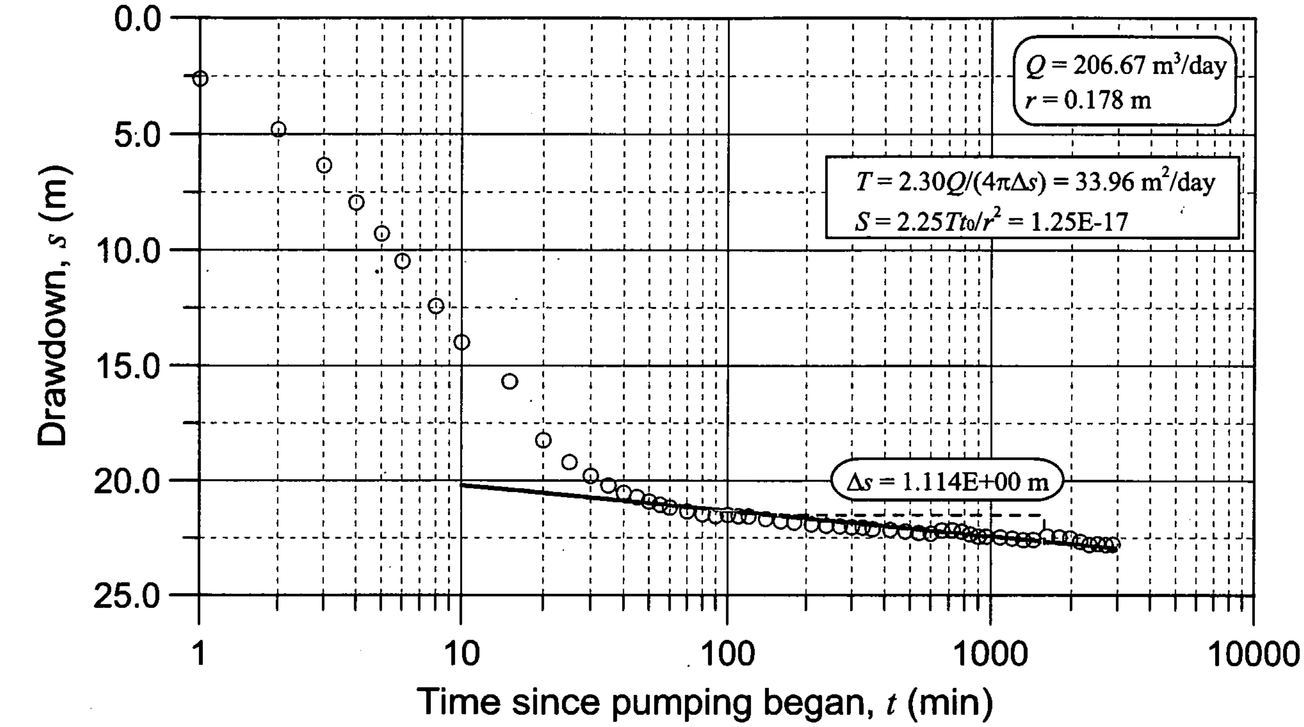
(b) Drawdown in Observation Holes

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

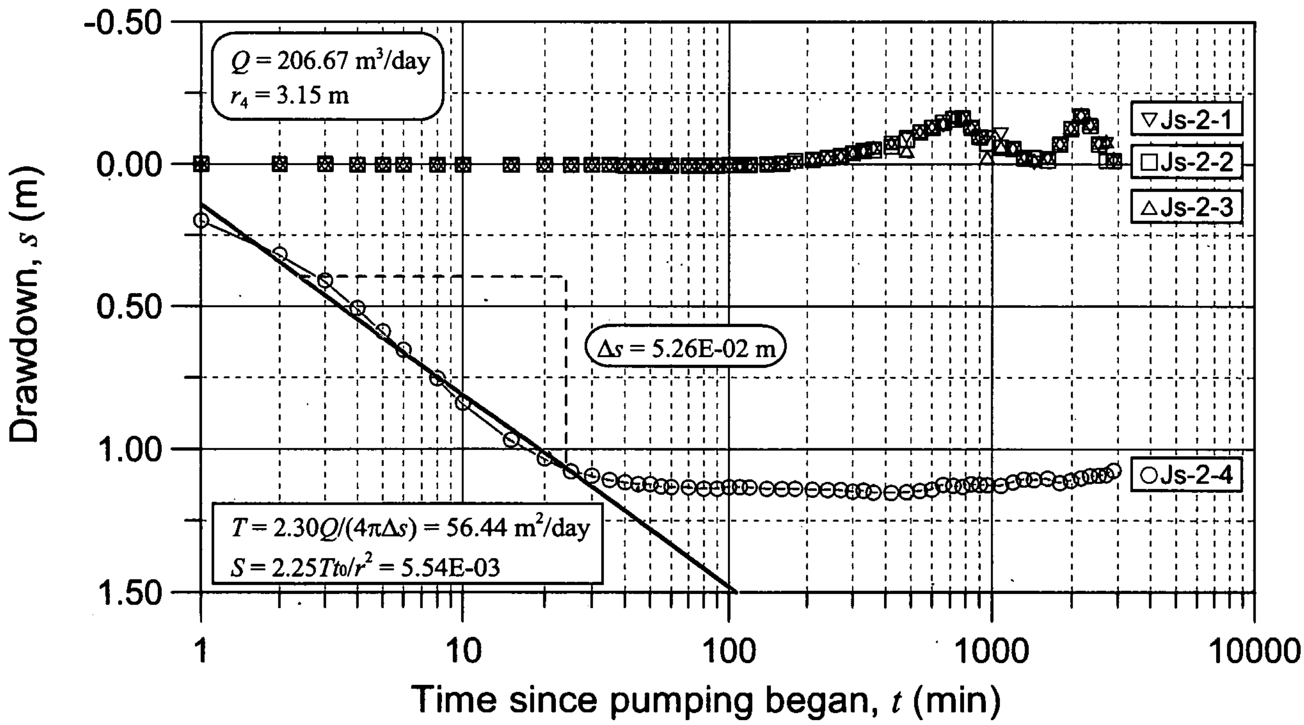
Figure 5.3.11 **Results of Continuous Pumping Test at JS-1 Site, Jessore**

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



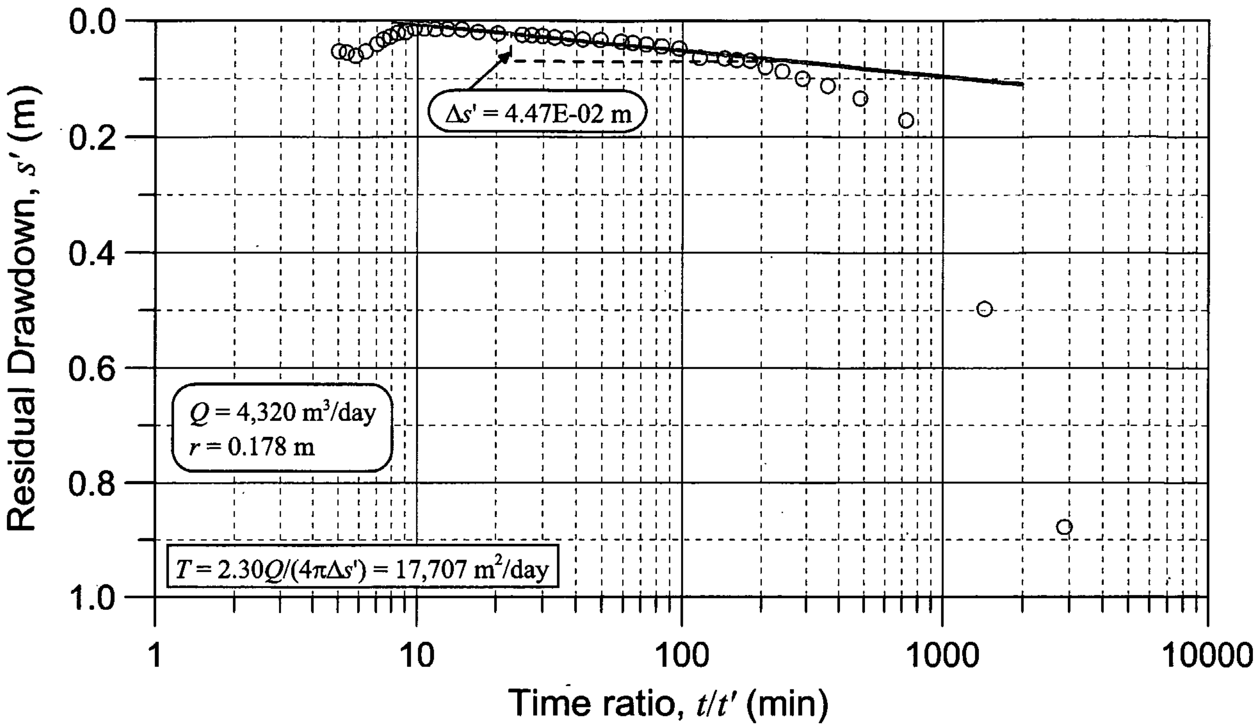
(b) Drawdown in Observation Holes

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

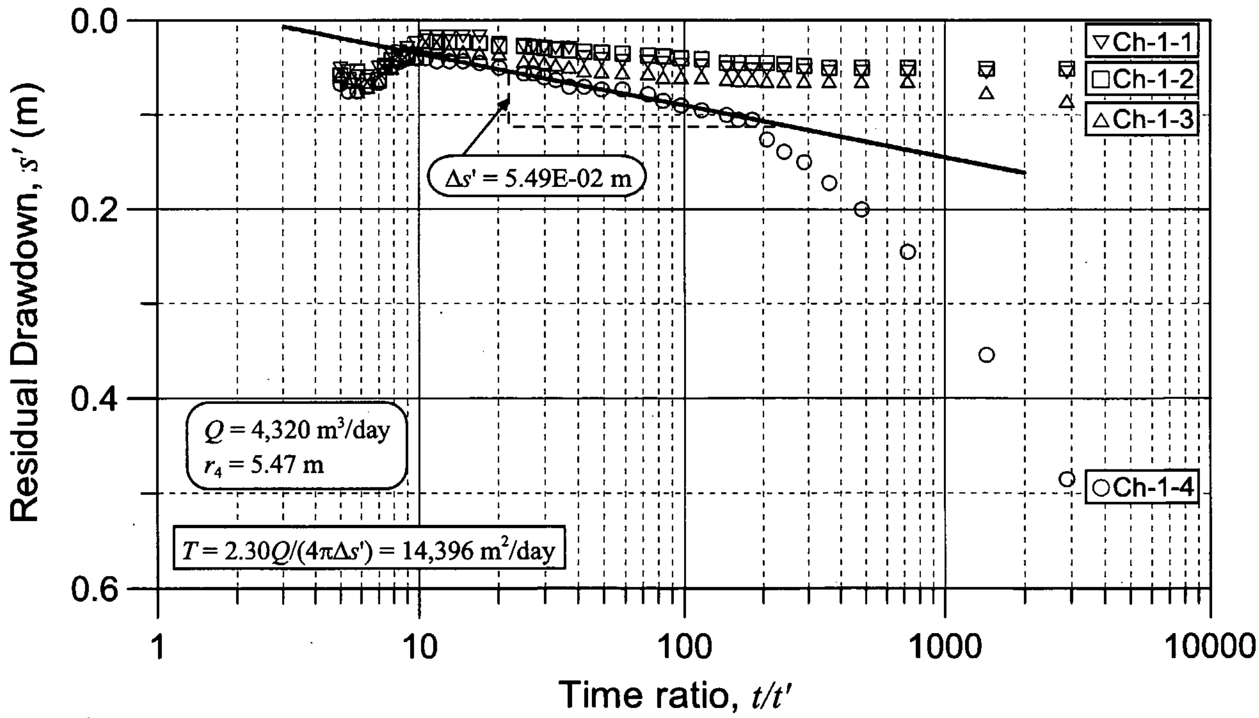
Figure 5.3.12 **Results of Continuous Pumping Test at JS-2 Site, Jessore**

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)



(a) Recovery in Pumped Well



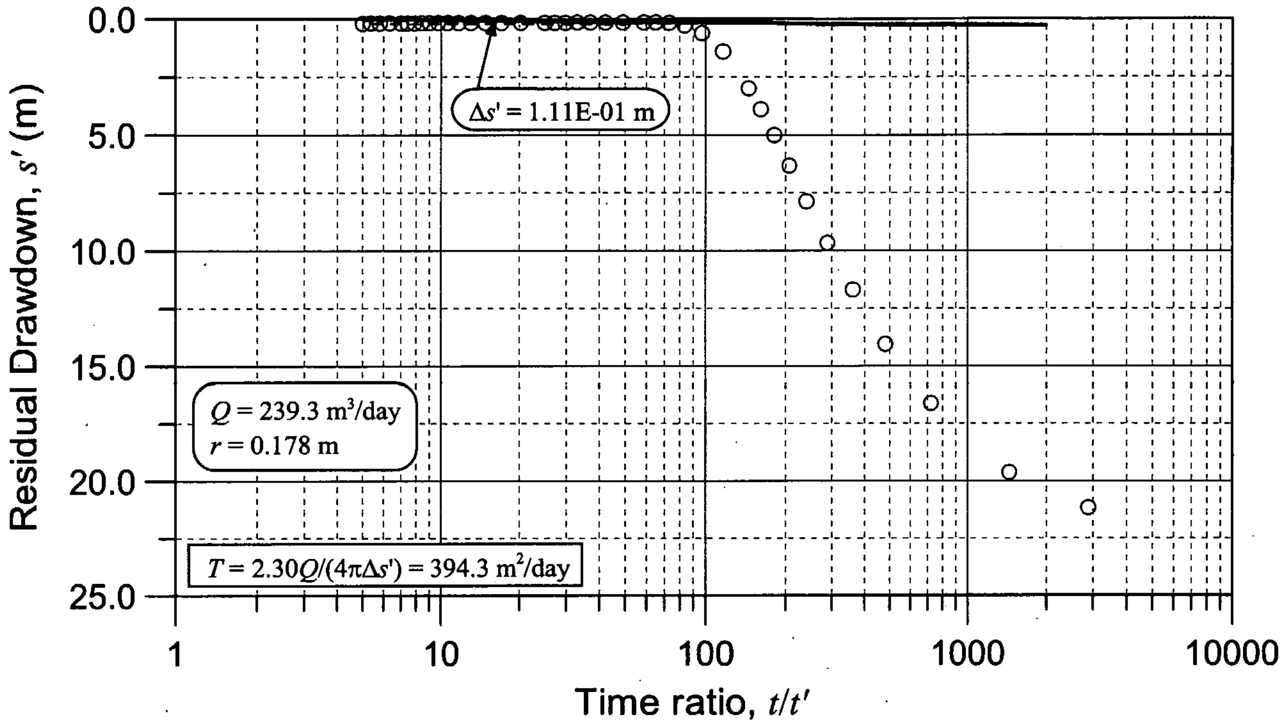
(b) Recovery in Observation Holes

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- 6.258 m on 22-02-2001

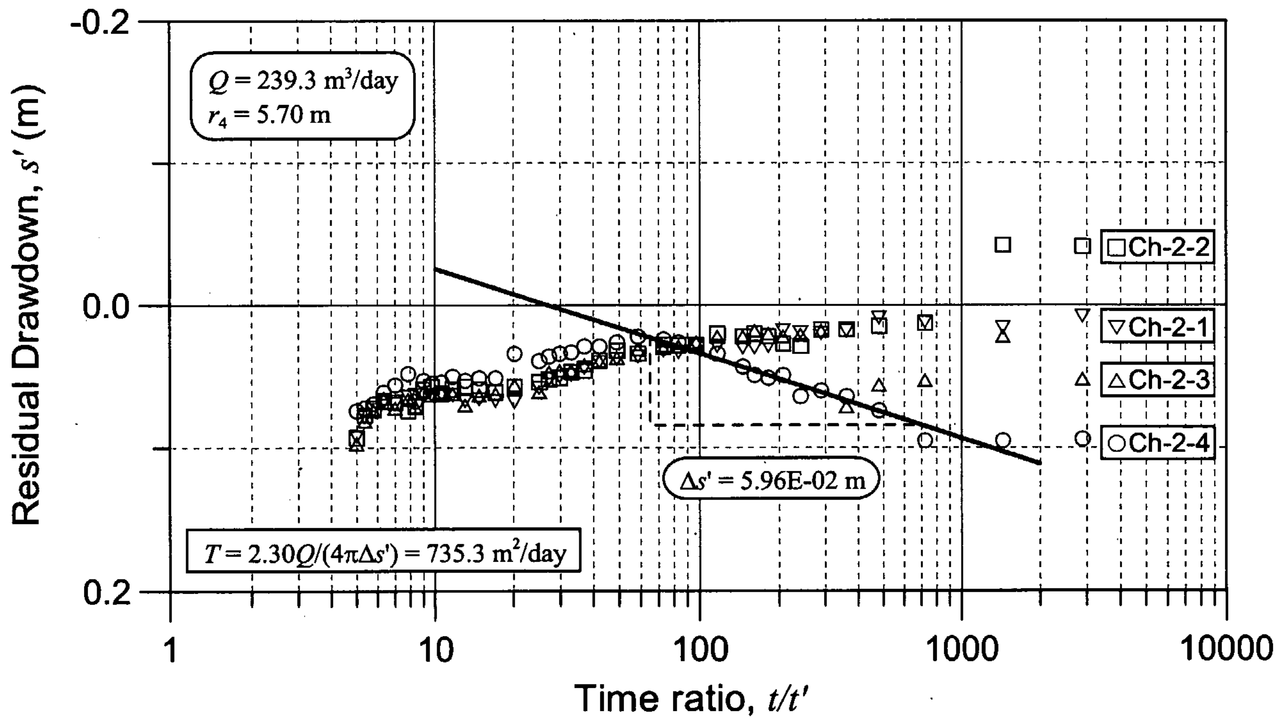
Figure 5.3.13 **Results of Recovery Test at CH-1 Site, Chuadanga**

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) Recovery in Pumped Well



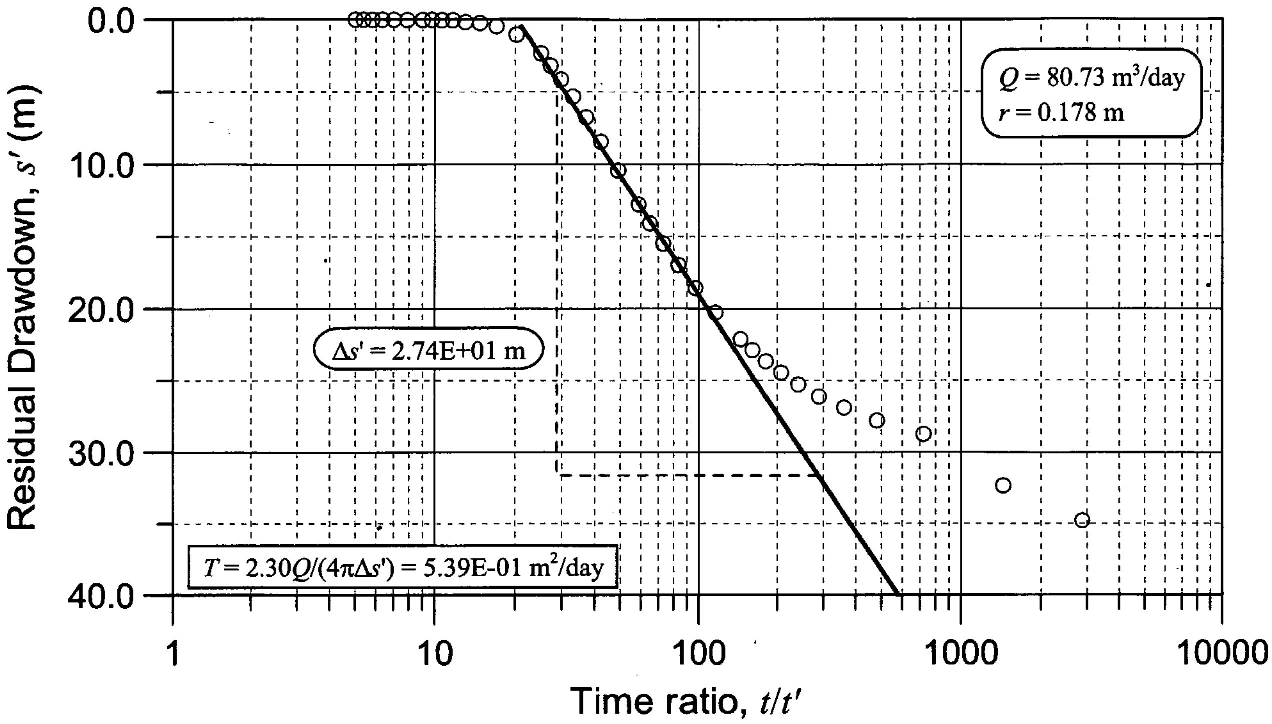
(b) Recovery in Observation Holes

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

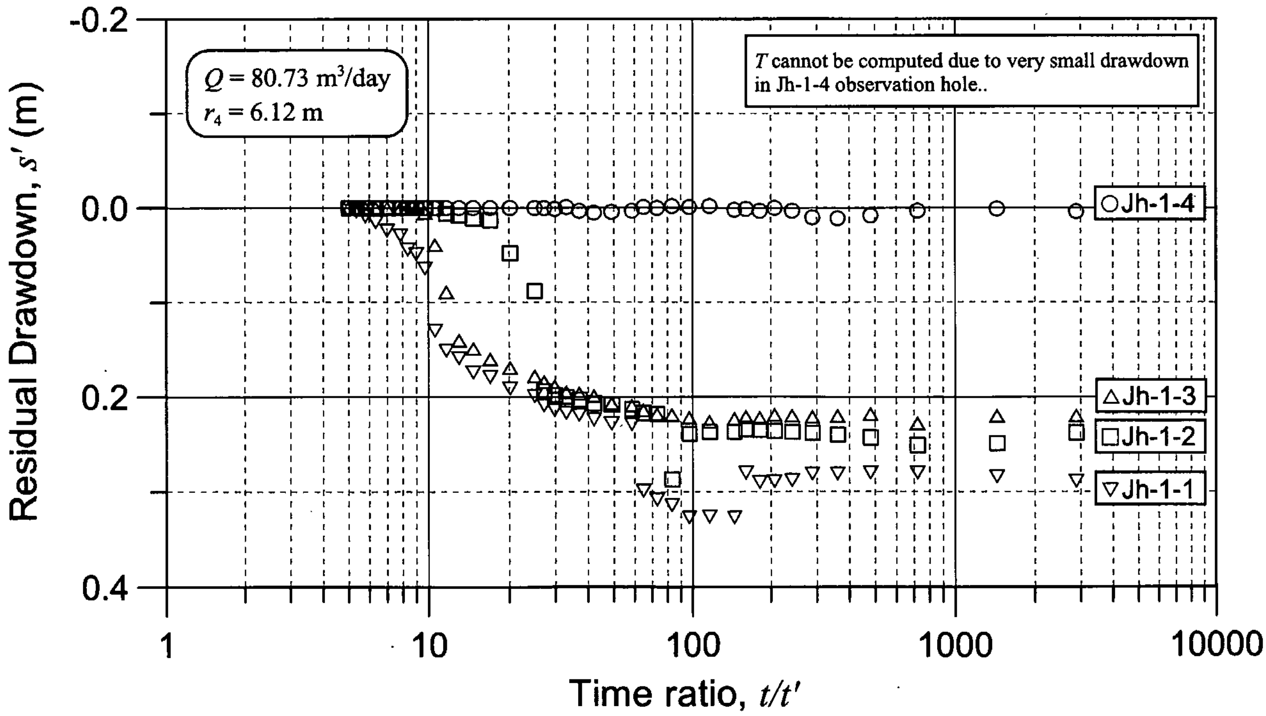
Figure 5.3.14 — **Results of Recovery Test at CH-2 Site, Chuadanga**

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) Recovery in Pumped Well



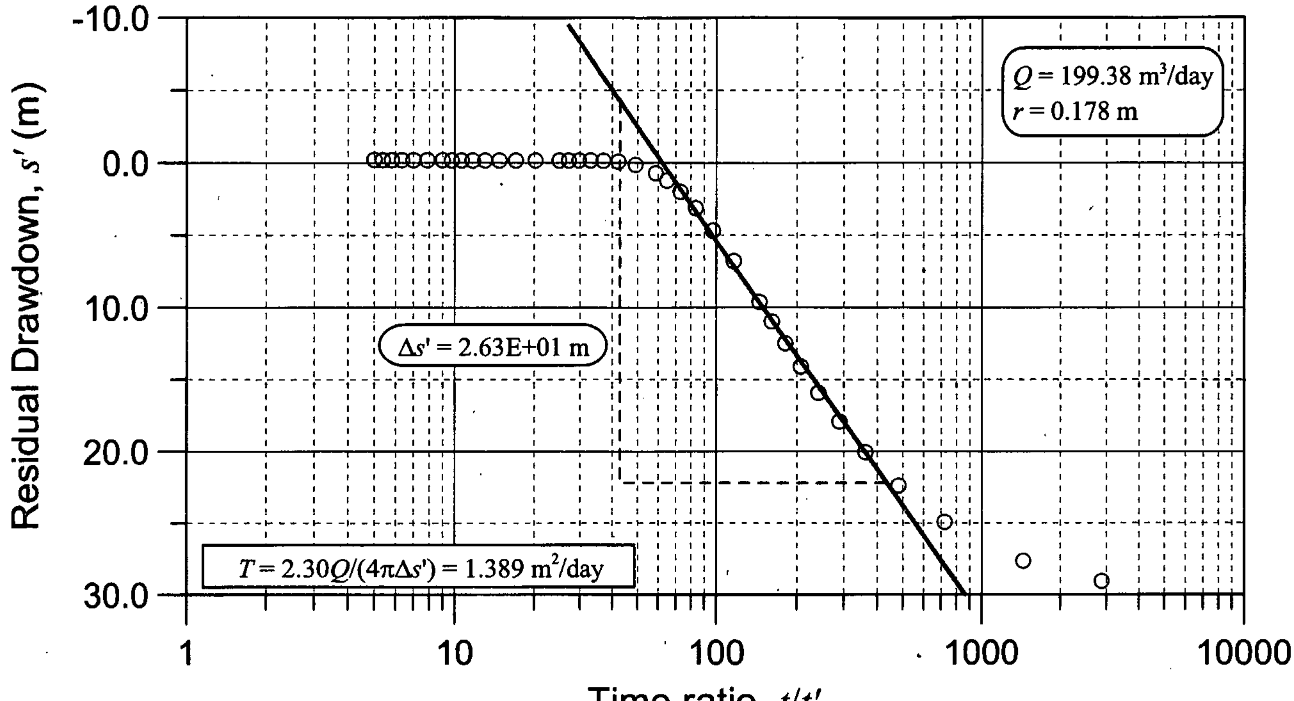
(b) Recovery in Observation Holes

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

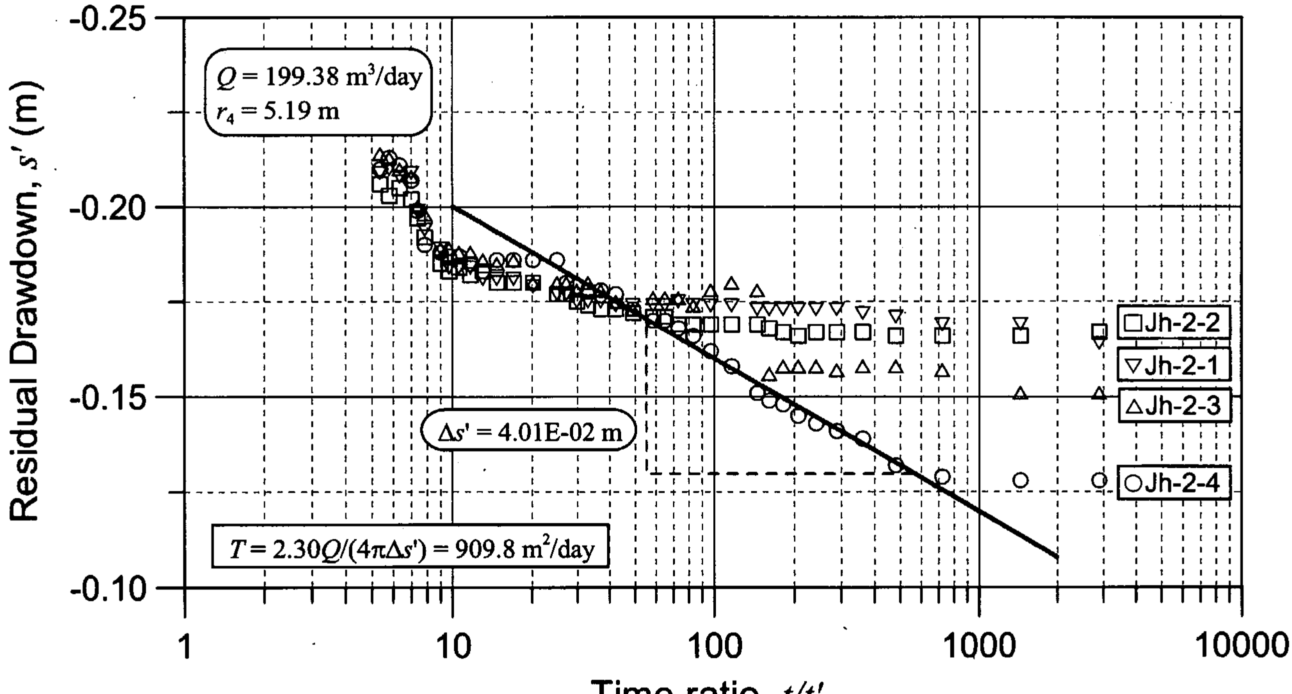
Figure 5.3.15 — **Results of Recovery Test at JH-1 Site, Jhenaidah**

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) Recovery in Pumped Well



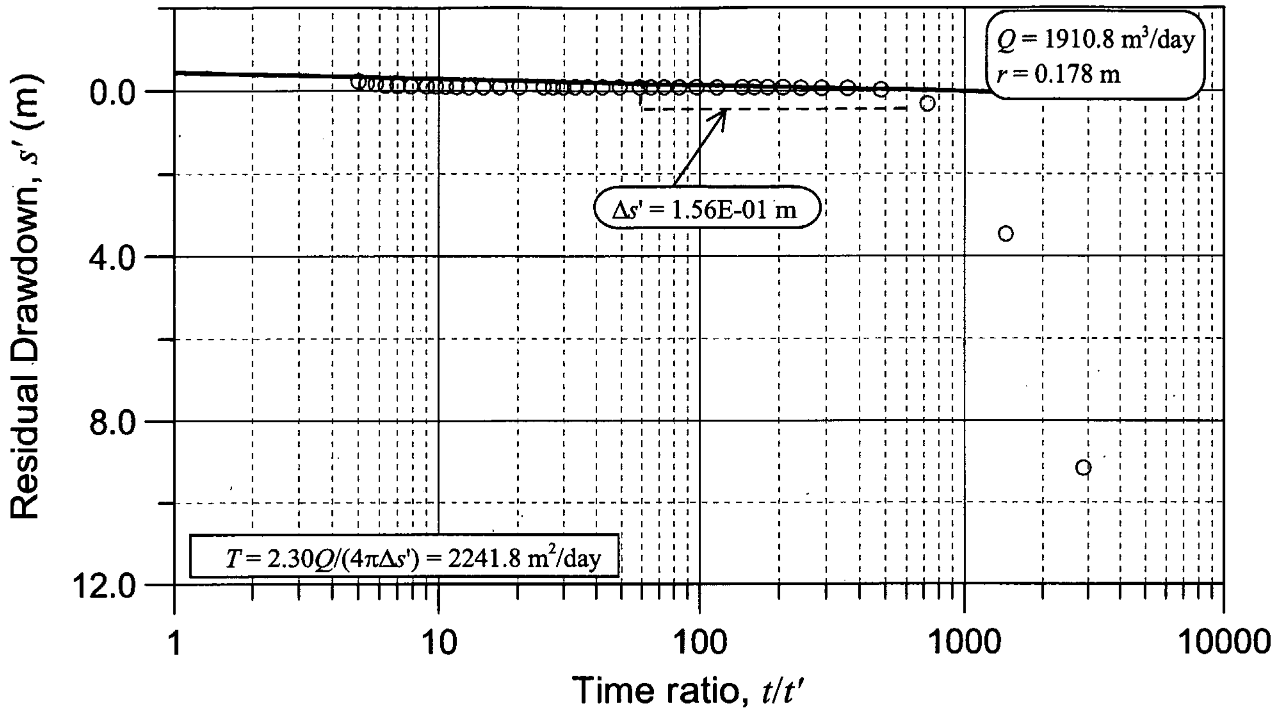
(b) Recovery in Observation Holes

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

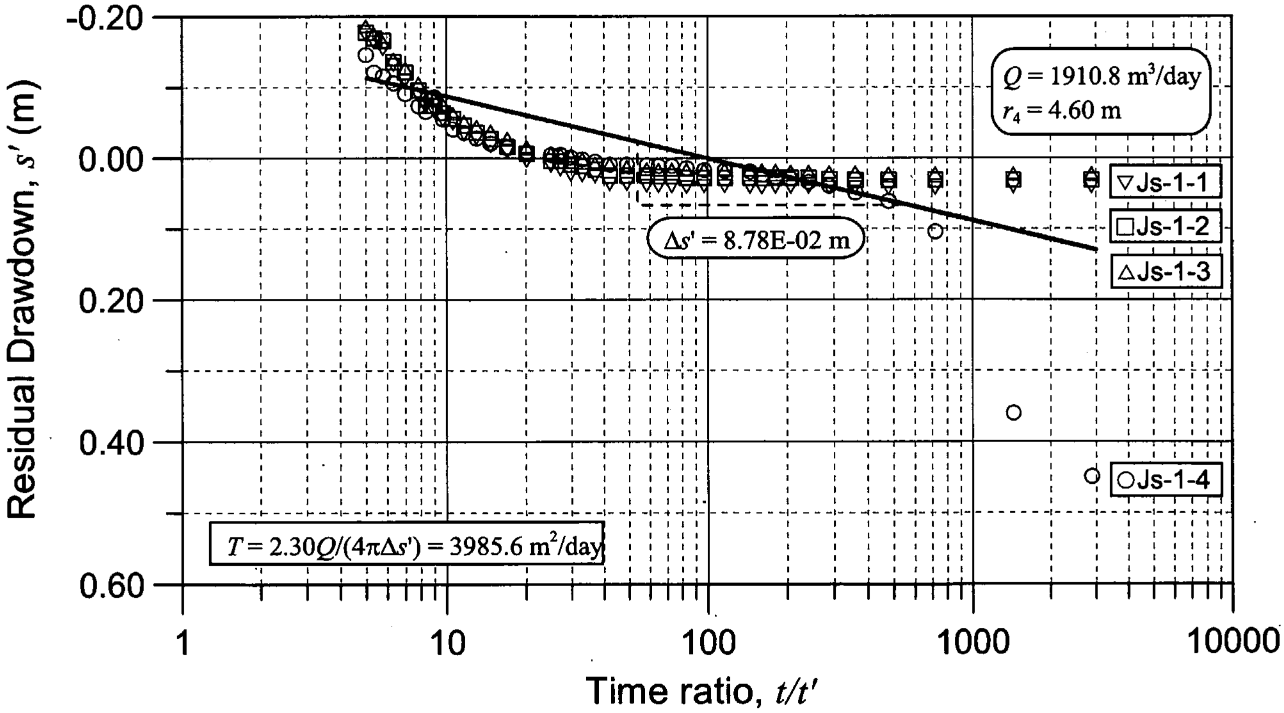
Figure 5.3.16 **Results of Recovery Test at JH-2 Site, Jhenaidah**

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) Recovery in Pumped Well



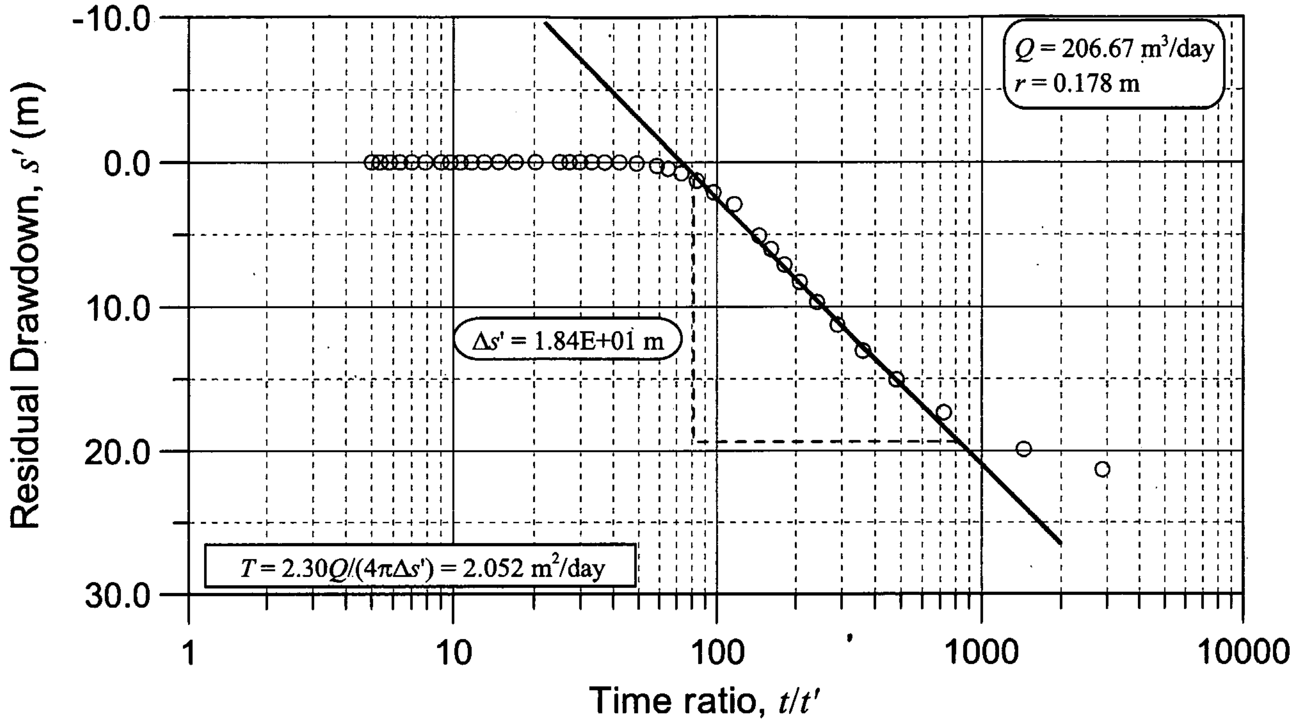
(b) Recovery in Observation Holes

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

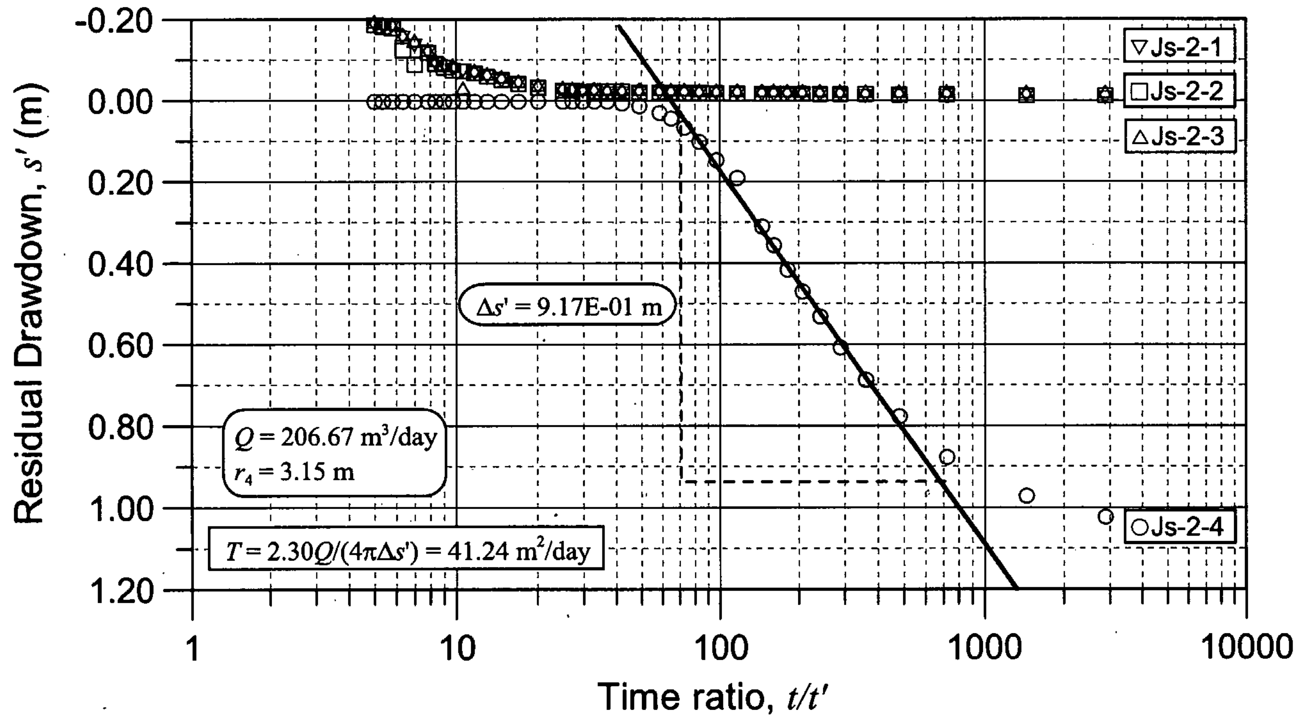
Figure 5.3.17 — **Results of Recovery Test at JS-1 Site, Jessore**

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) Recovery in Pumped Well



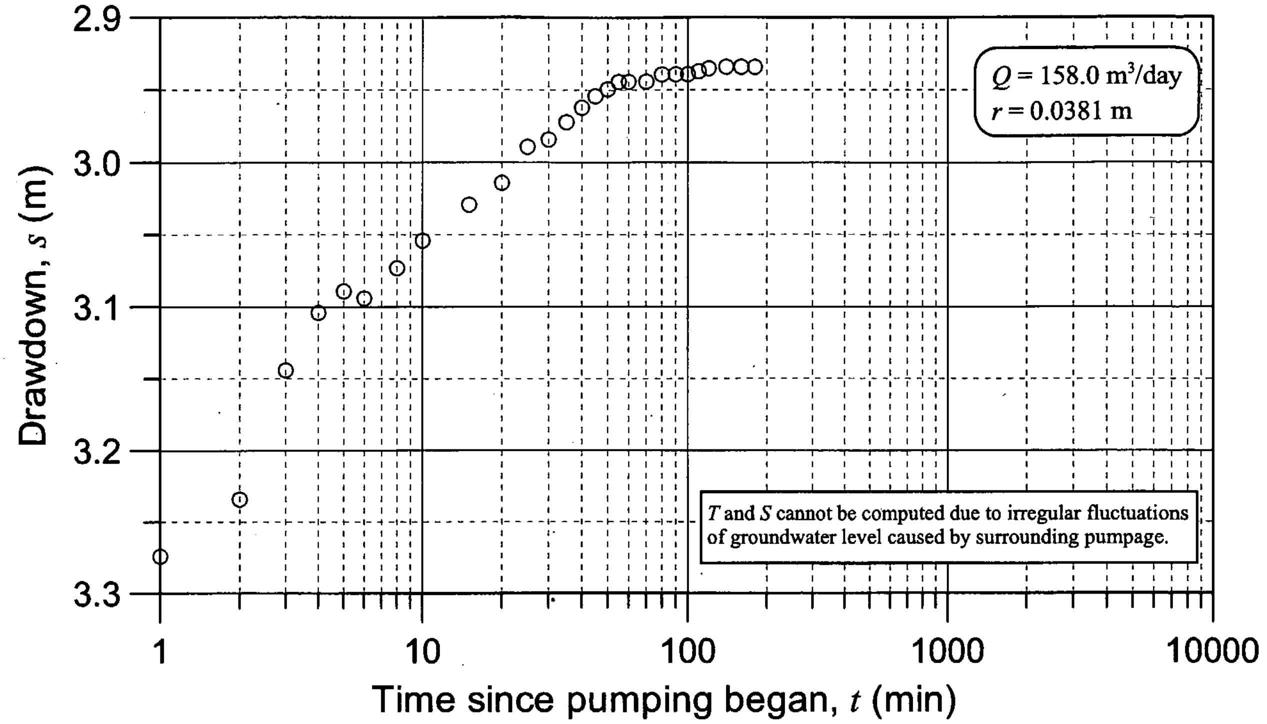
(b) Recovery in Observation Holes

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

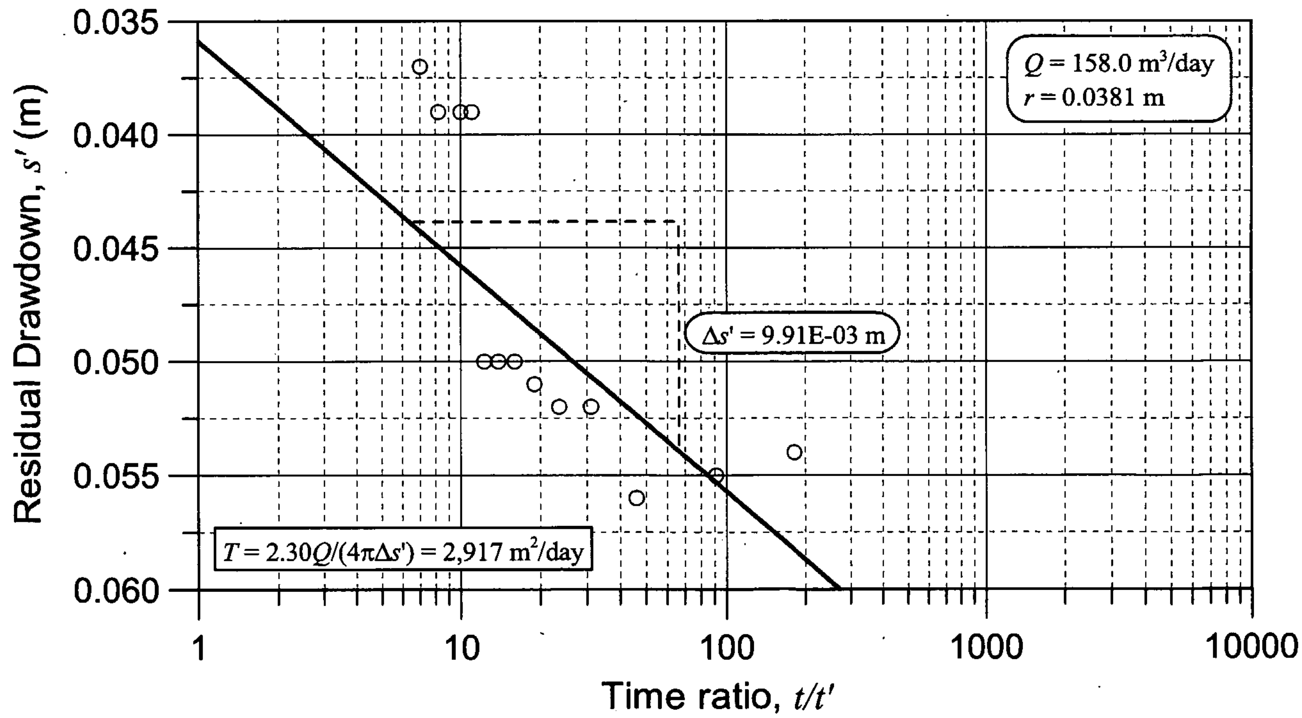
Figure 5.3.18	**Results of Recovery Test at JS-2 Site, Jessore**

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 Test at Ch-1-1



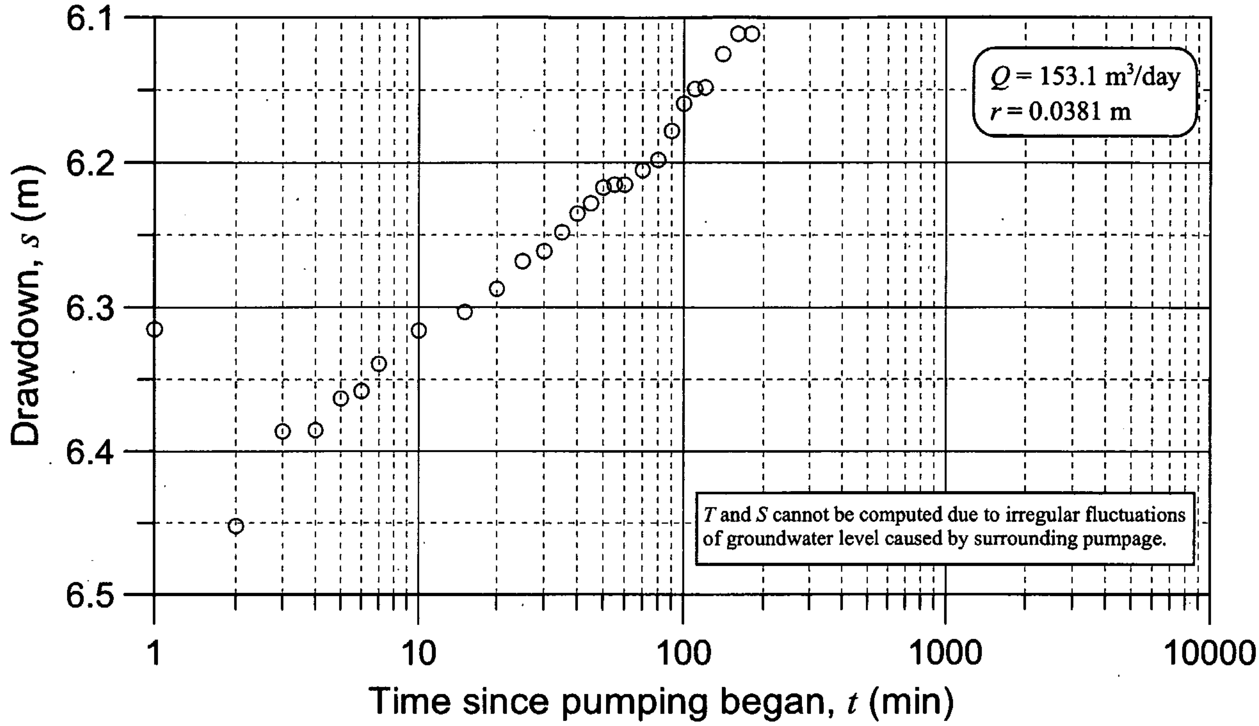
(b) Recovery Test at Ch-1-1

Location:	Poshu Hat, Chuadanga Pourashava
Site No.:	CH-1
Well No.:	Ch-1-1
Well Depth:	63.0 m
Well Diameter:	76.20 mm
Screen Depths:	54.0-60.0 m
Screen Length:	6.0 m
SWL:	GL- 6.061 m on 26-02-2001

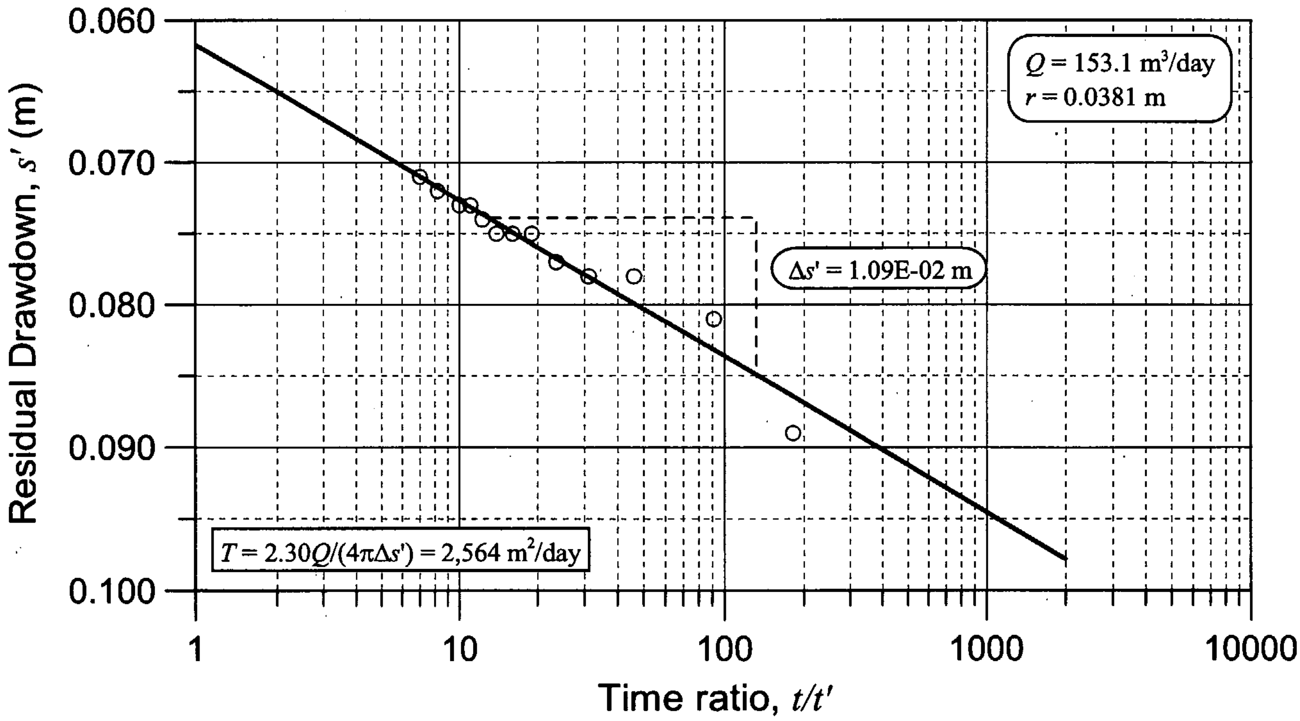
Figure 5.3.19 **Results of Simple Pumping Test at Ch-1-1 Observation Hole, Chuadanga**

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 Test at Ch-1-2



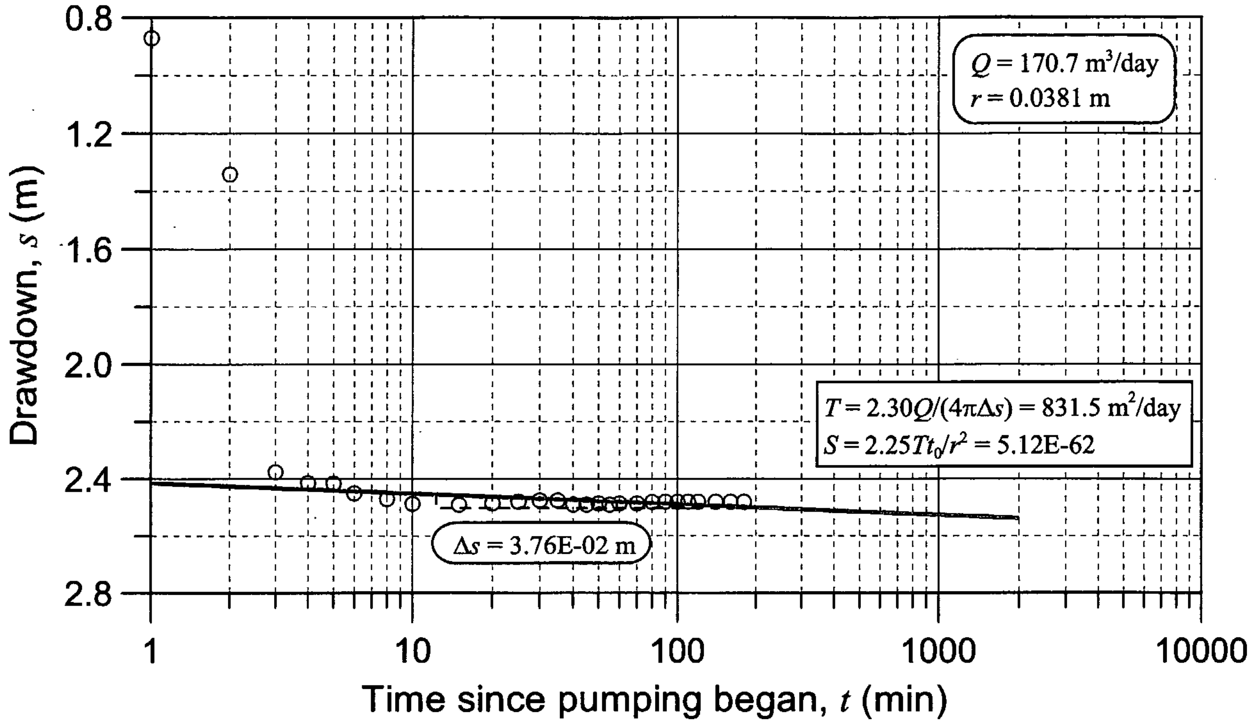
(b) Recovery Test at Ch-1-2

Location:	Posu Hat, Chuadanga Pourashava
Site No.:	CH-1
Well No.:	Ch-1-2
Well Depth:	118.0 m
Well Diameter:	76.20 mm
Screen Depths:	100-112 m
Screen Length:	20.0 m
SWL:	GL- 6.057 m on 26-02-2001

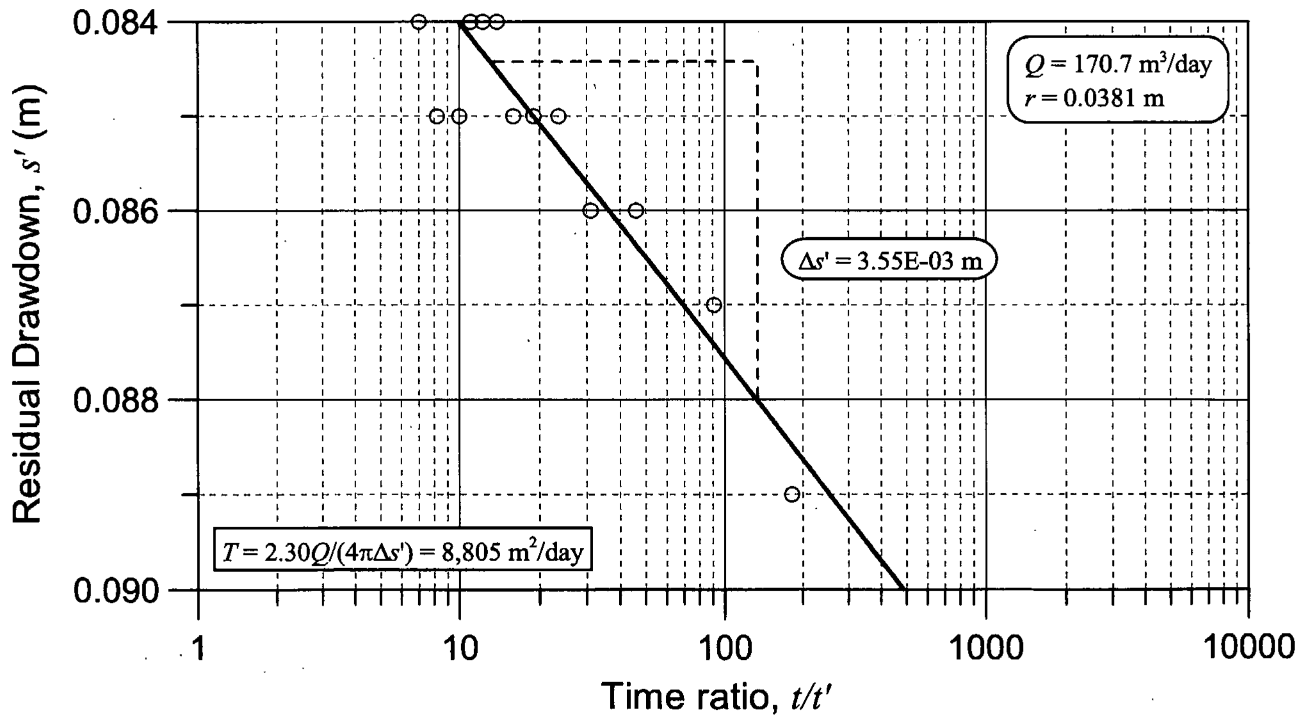
Figure 5.3.20 **Results of Simple Pumping Test at Ch-1-2 Observation Hole, Chuadanga**

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 Test at Ch-1-3



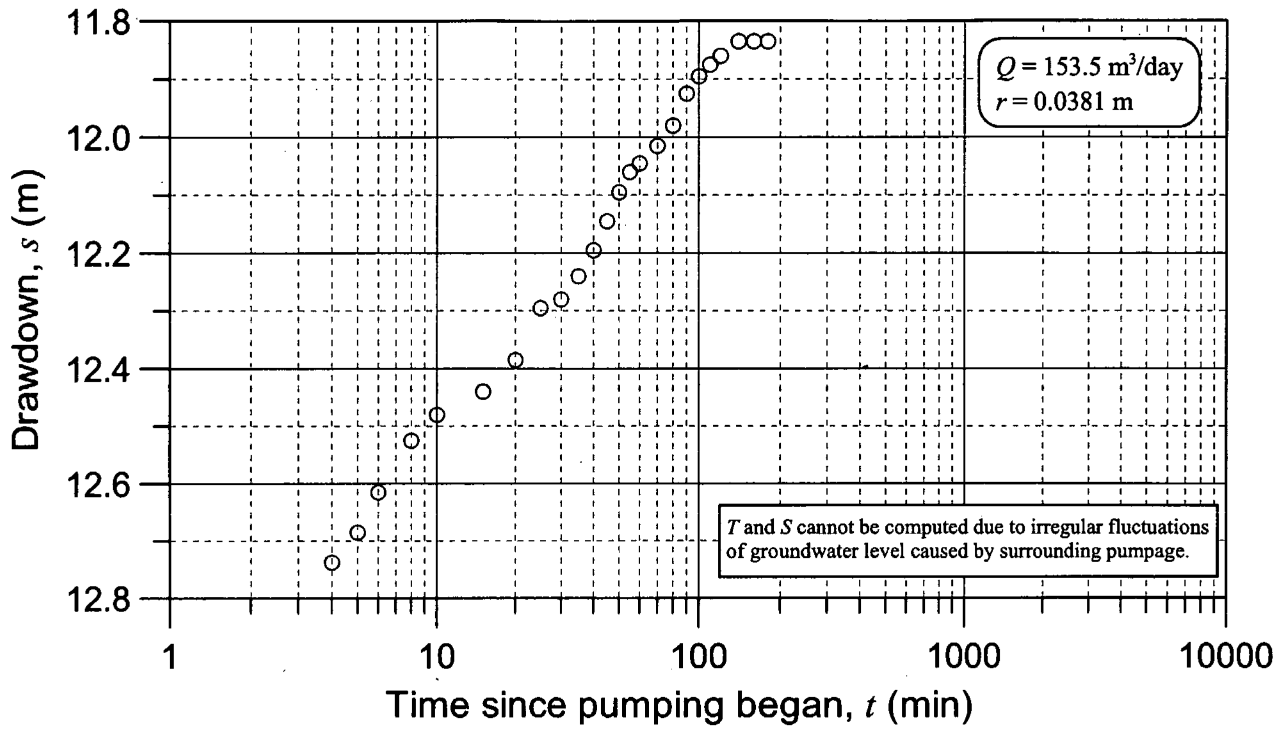
(b) Recovery Test at Ch-1-3

Location:	Posu Hat, Chuadanga Pourashava
Site No.:	CH-1
Well No.:	Ch-1-3
Well Depth:	168.0 m
Well Diameter:	76.20 mm
Screen Depths:	150-162 m
Screen Length:	12.0 m
SWL:	GL- 5.715 m on 26-02-2001

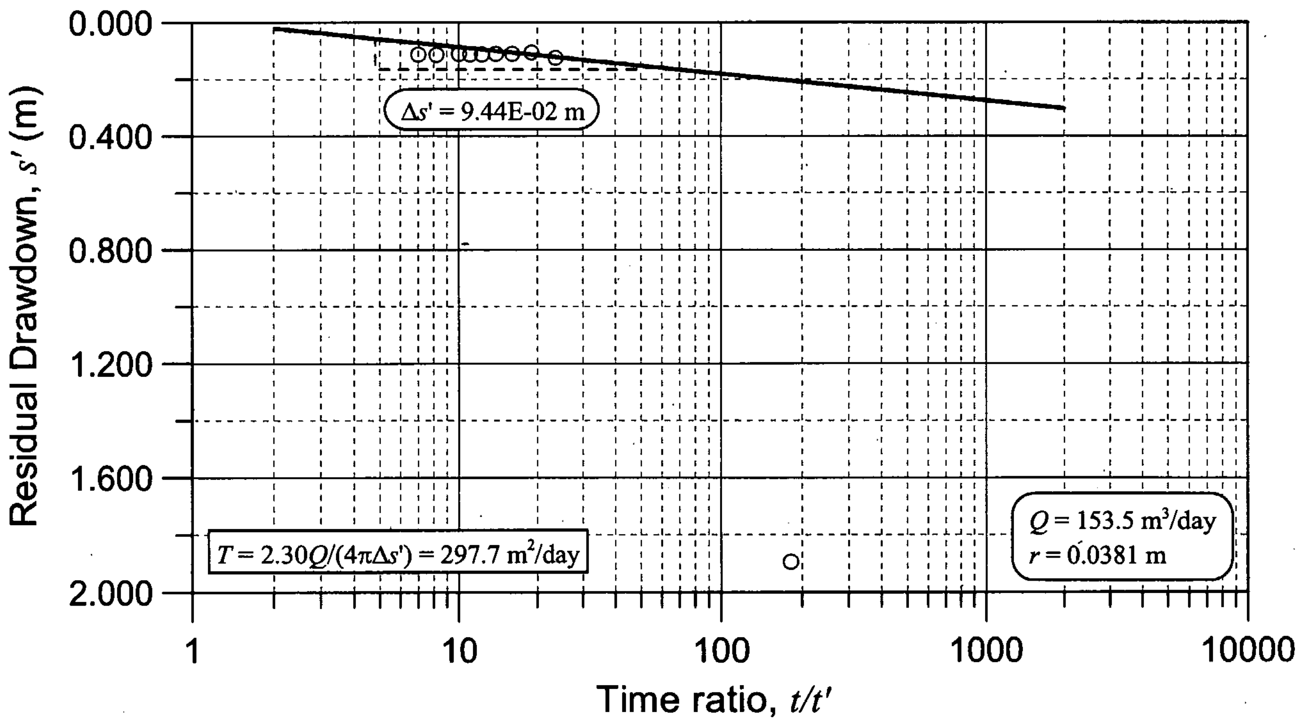
Figure 5.3.21 **Results of Simple Pumping Test at Ch-1-3 Observation Hole, Chuadanga**

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 Test at Ch-1-4



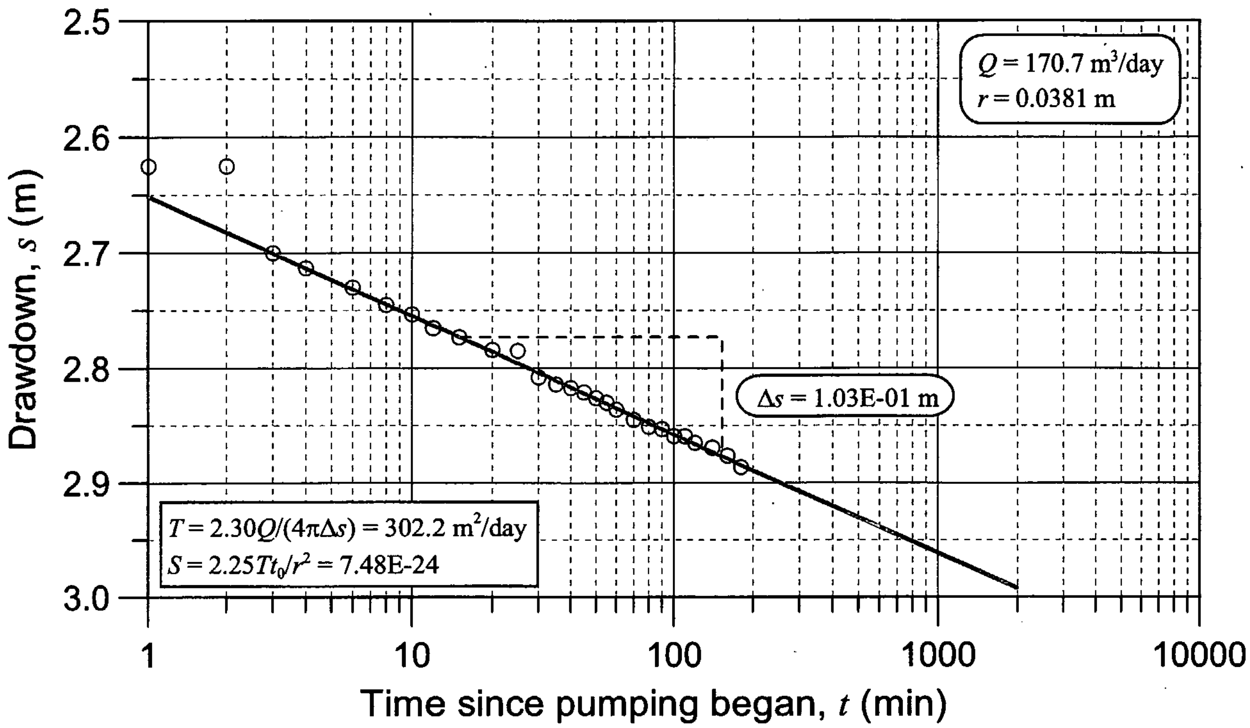
(b) Recovery Test at Ch-1-4

Location:	Poshu Hat, Chuadanga Pourashava
Site No.:	CH-1
Well No.:	Ch-1-4
Well Depth:	300.0 m
Well Diameter:	76.20 mm
Screen Depths:	228-294 m
Screen Length:	18.0 m
SWL:	GL- 5.985 m on 26-02-2001

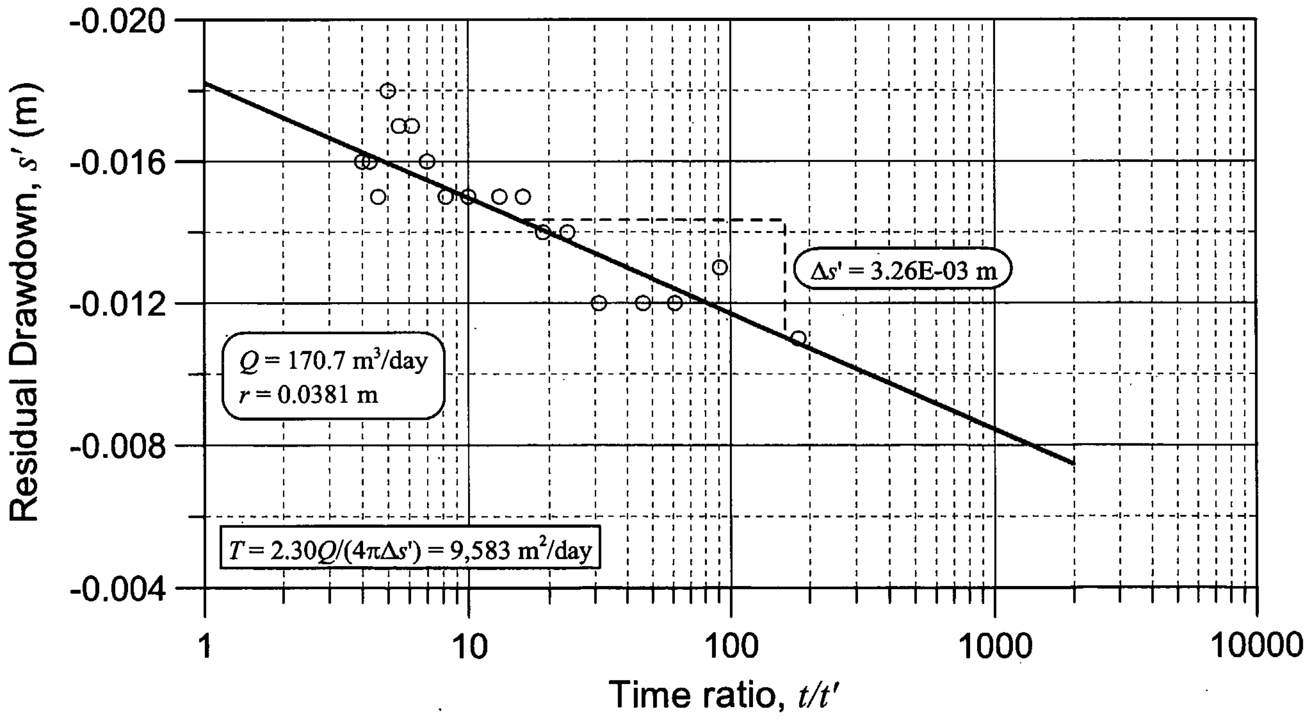
Figure 5.3.22 **Results of Simple Pumping Test at Ch-1-4 Observation Hole, Chuadanga**

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 Test at Ch-2-1



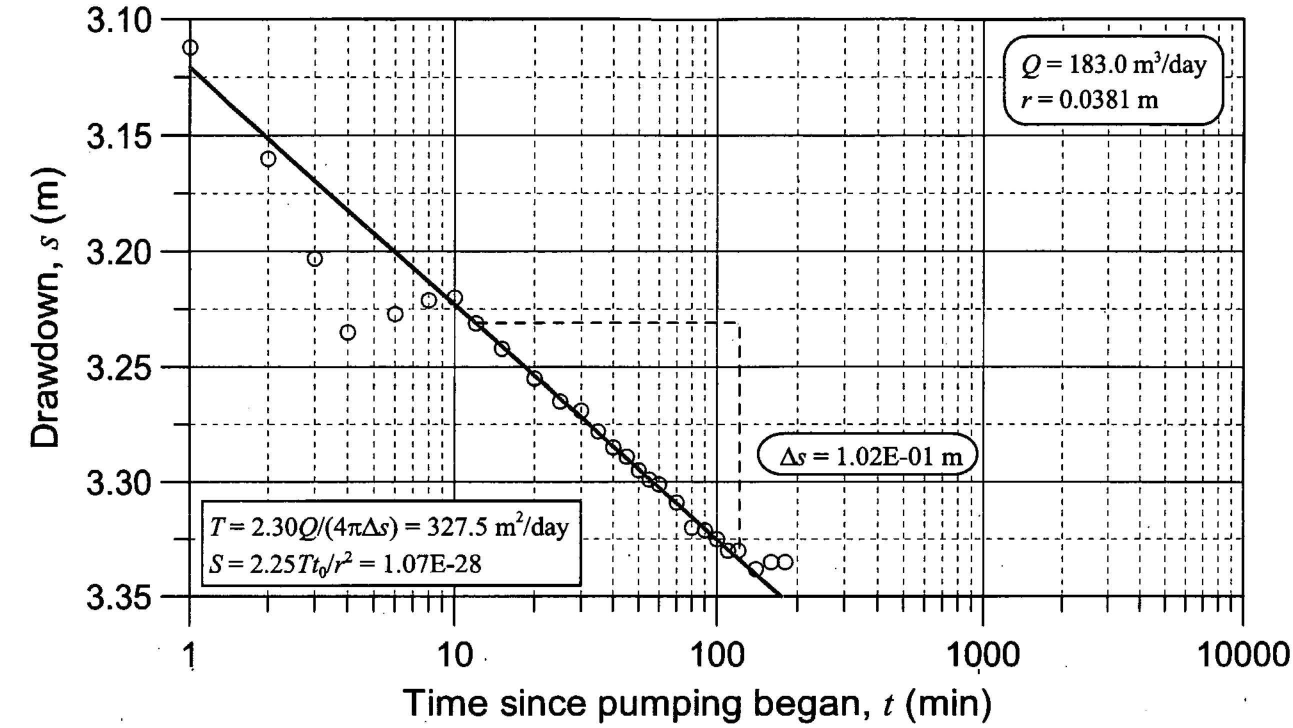
(b) Recovery Test at Ch-2-1

Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2-1
Well Depth:	56.5 m
Well Diameter:	76.20 mm
Screen Depths:	44.5-53.5 m
Screen Length:	9.0 m
SWL:	GL- 6.105 m on 16-03-2001

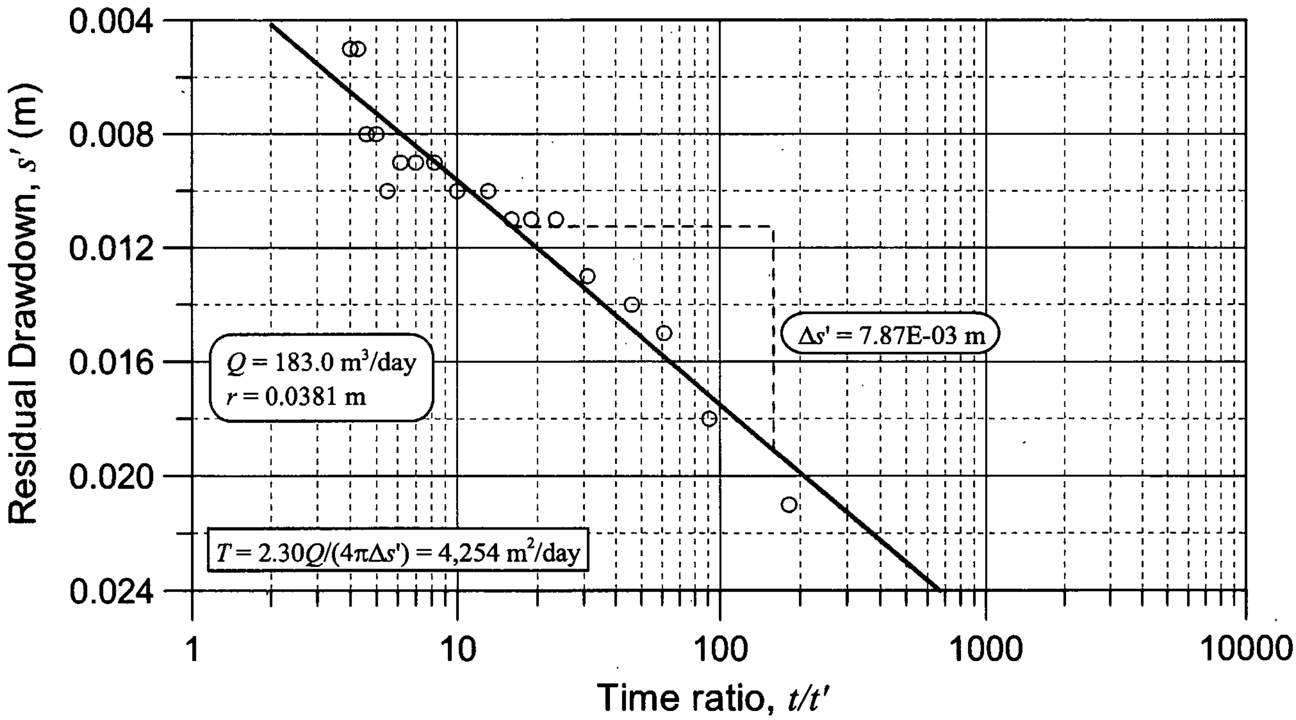
Figure 5.3.23 **Results of Simple Pumping Test at Ch-2-1 Observation Hole, Chuadanga**

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 Test at Ch-2-2



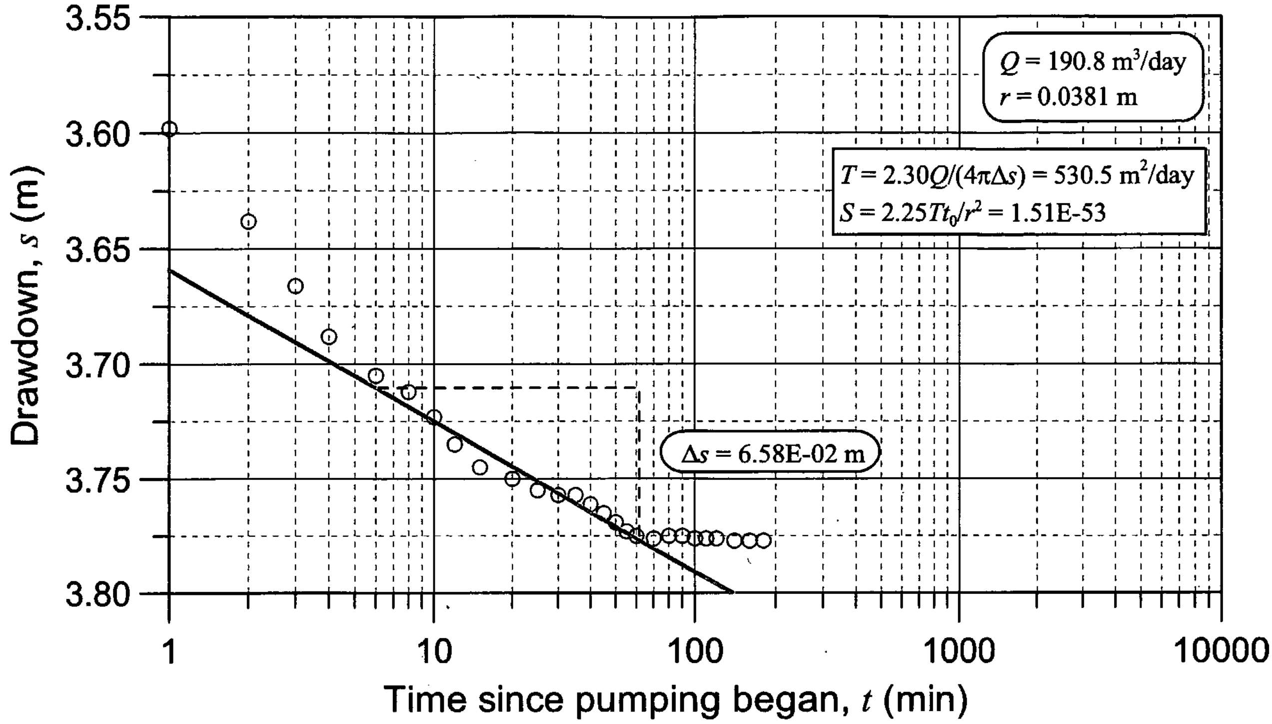
(b) Recovery Test at Ch-2-2

Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2-2
Well Depth:	109.0 m
Well Diameter:	76.20 mm
Screen Depths:	97.0-106.0 m
Screen Length:	9.0 m
SWL:	GL- 6.040 m on 16-03-2001

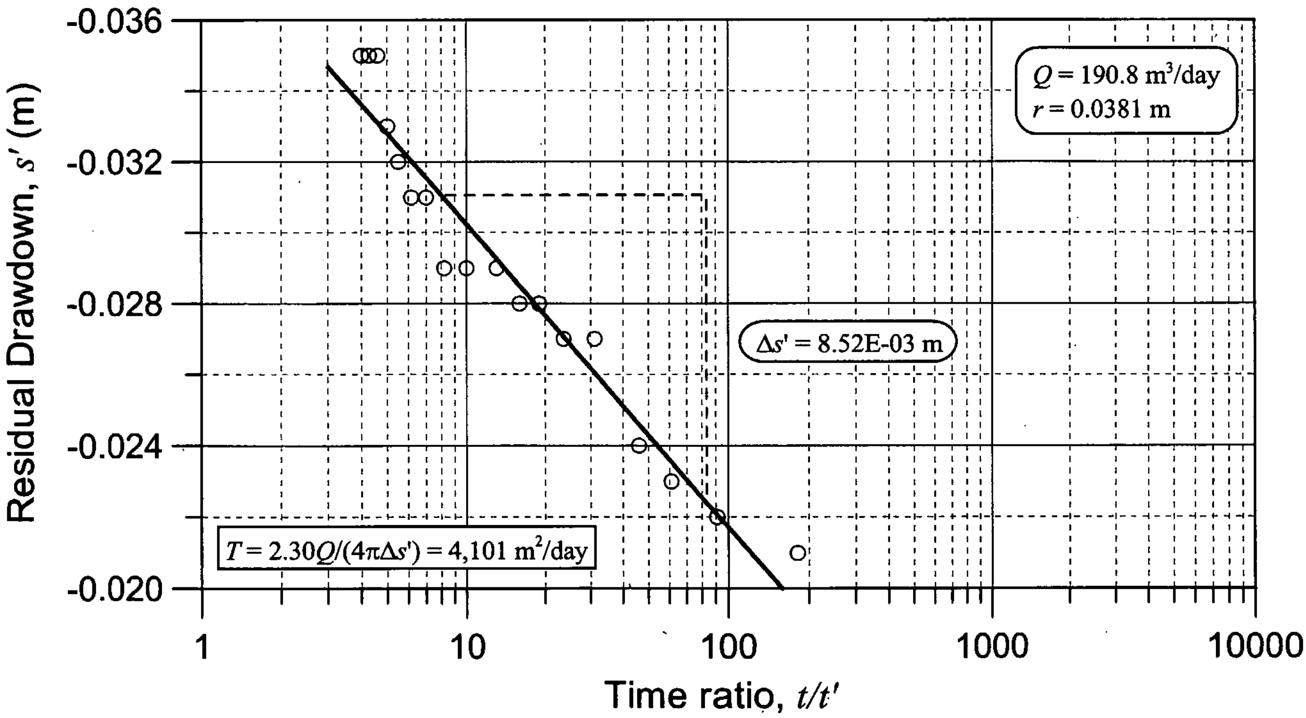
Figure 5.3.24 **Results of Simple Pumping Test at Ch-2-2 Observation Hole, Chuadanga**

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 Test at Ch-2-3



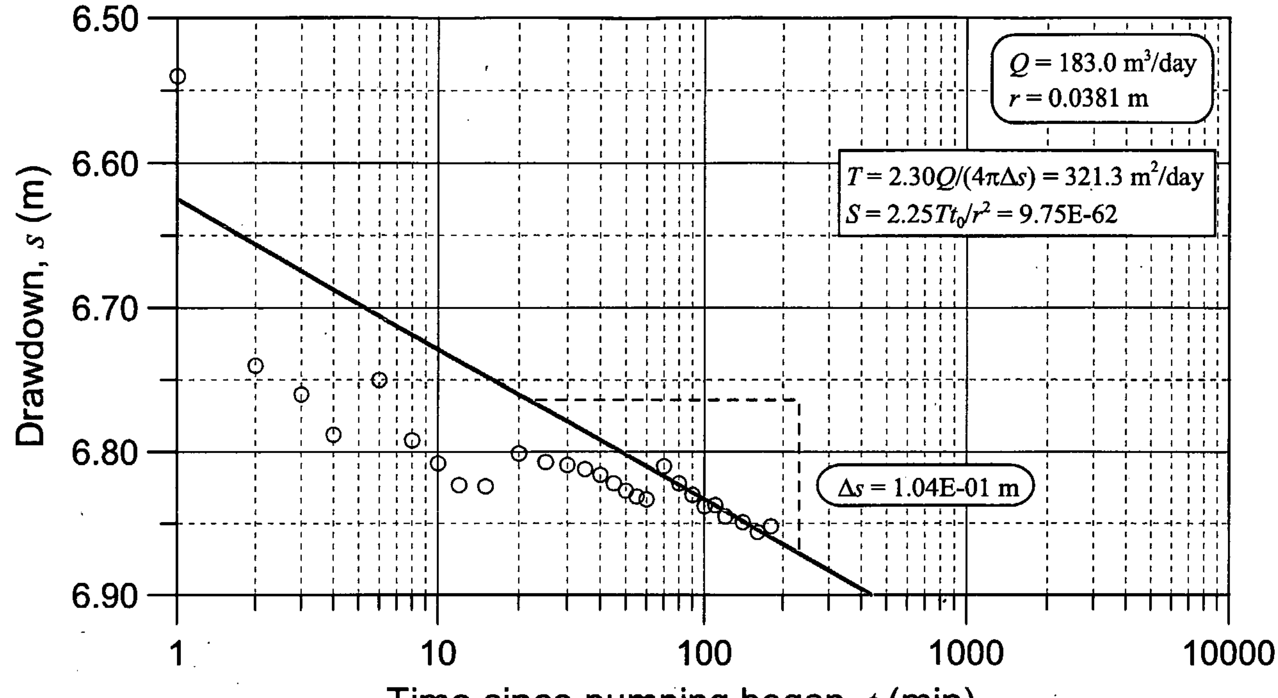
(b) Recovery Test at Ch-2-3

Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2-3
Well Depth:	152.5 m
Well Diameter:	76.20 mm
Screen Depths:	122.5-149.5 m
Screen Length:	12.0 m
SWL:	GL- 6.000 m on 17-03-2001

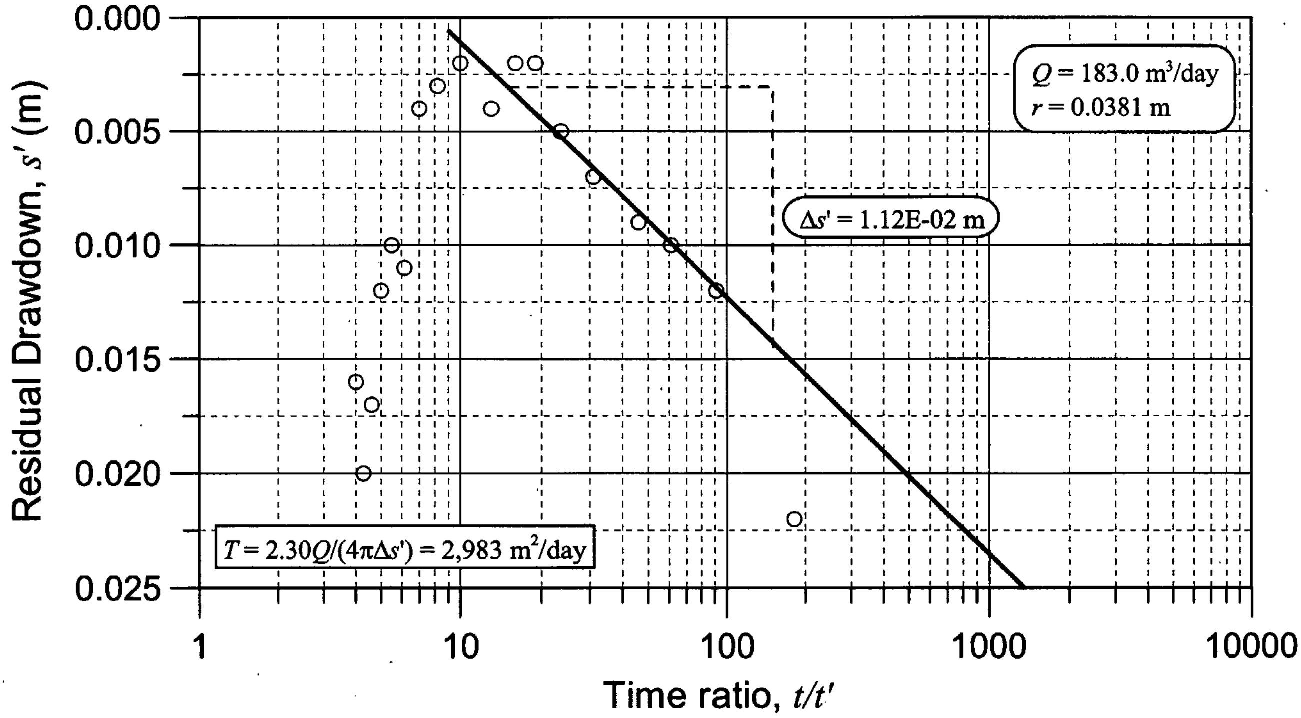
Figure 5.3.25 **Results of Simple Pumping Test at Ch-2-3 Observation Hole, Chuadanga**

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 Test at Ch-2-4



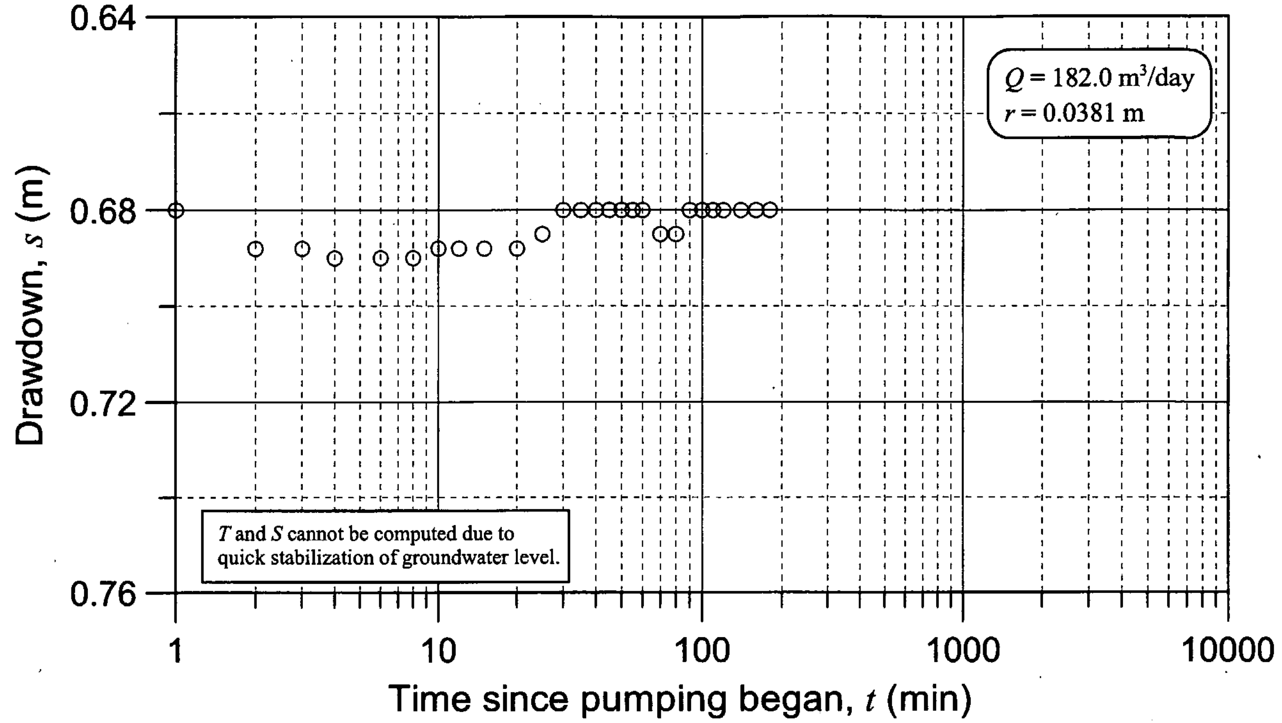
(b) Recovery Test at Ch-2-4

Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2-4
Well Depth:	299.5 m
Well Diameter:	76.20 mm
Screen Depths:	272.5-296.5 m
Screen Length:	15.0 m
SWL:	GL- 5.830 m on 17-03-2001

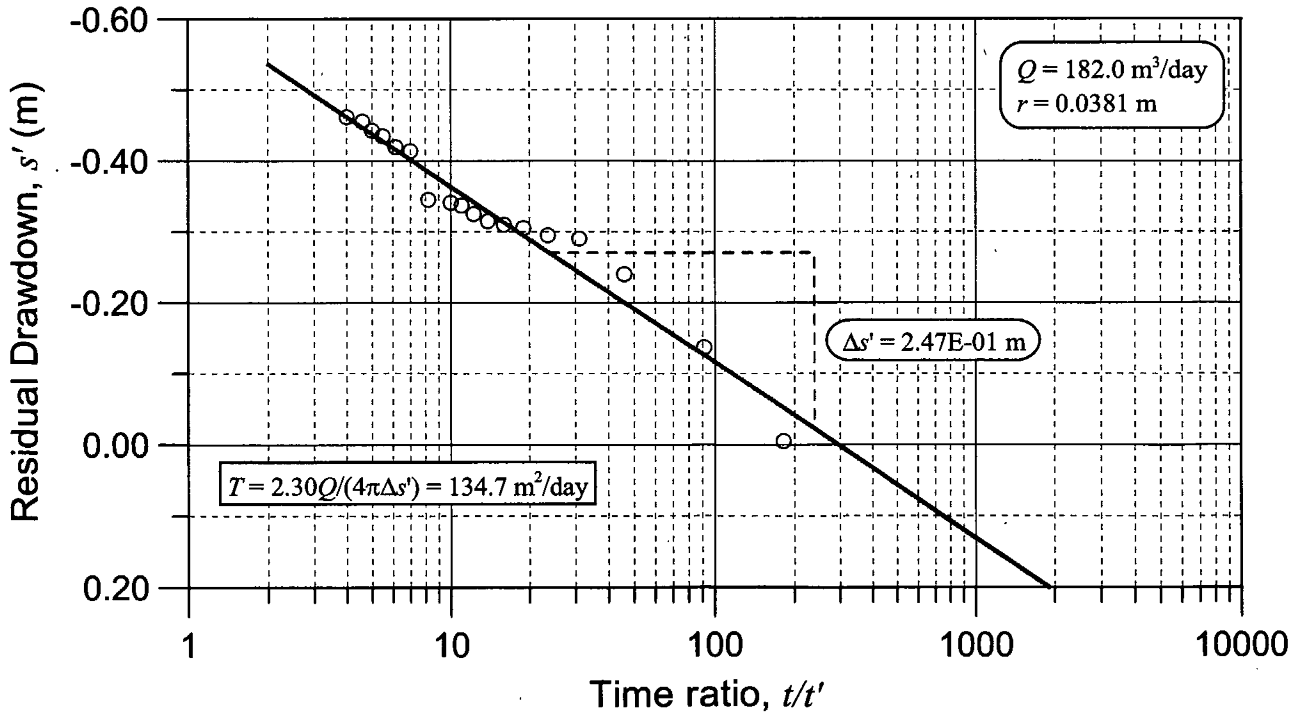
Figure 5.3.26 **Results of Simple Pumping Test at Ch-2-4 Observation Hole, Chuadanga**

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 Test at Jh-1-1



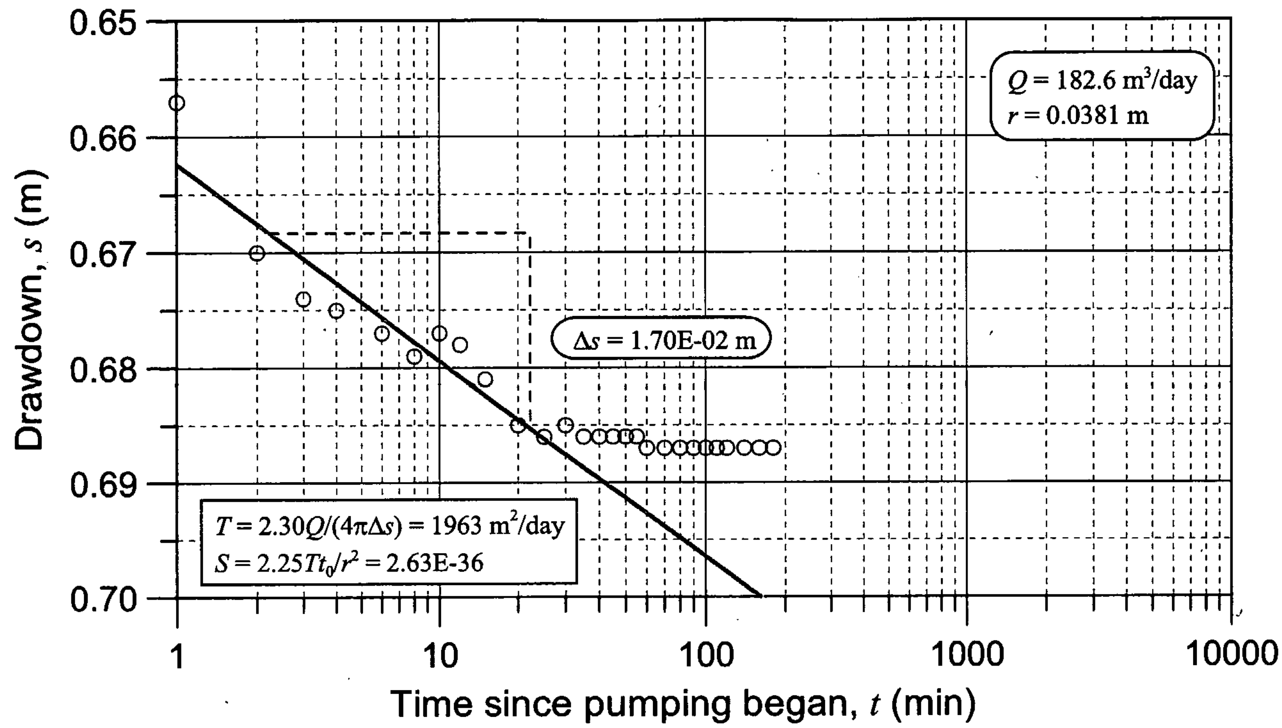
(b) Recovery Test at Jh-1-1

Location:	Arabpur, Jhenaidah Pourashava
Site No.:	JH-1
Well No.:	Jh-1-1
Well Depth:	60.0 m
Well Diameter:	76.20 mm
Screen Depths:	48.0-57.0 m
Screen Length:	9.0 m
SWL:	GL- 5.430 m on 21-04-2001

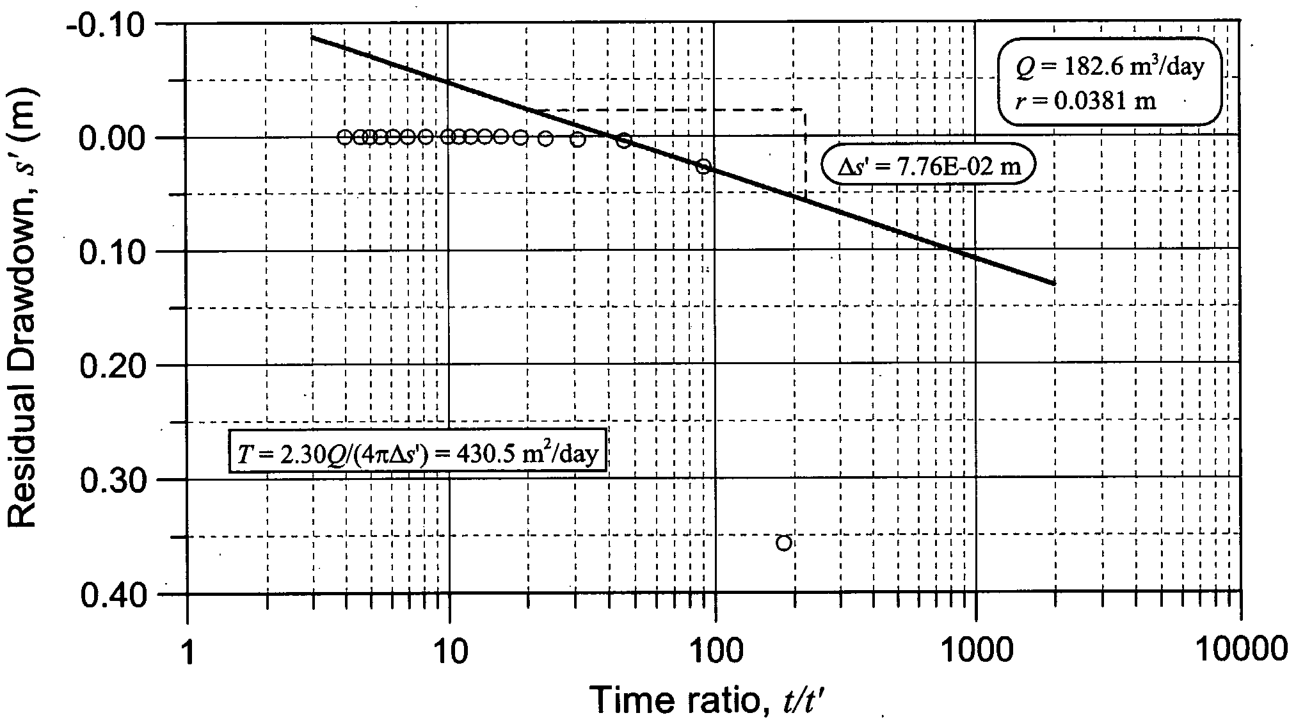
Figure 5.3.27	**Results of Simple Pumping Test at Jh-1-1 Observation Hole, Chuadanga**

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 Test at Jh-1-2



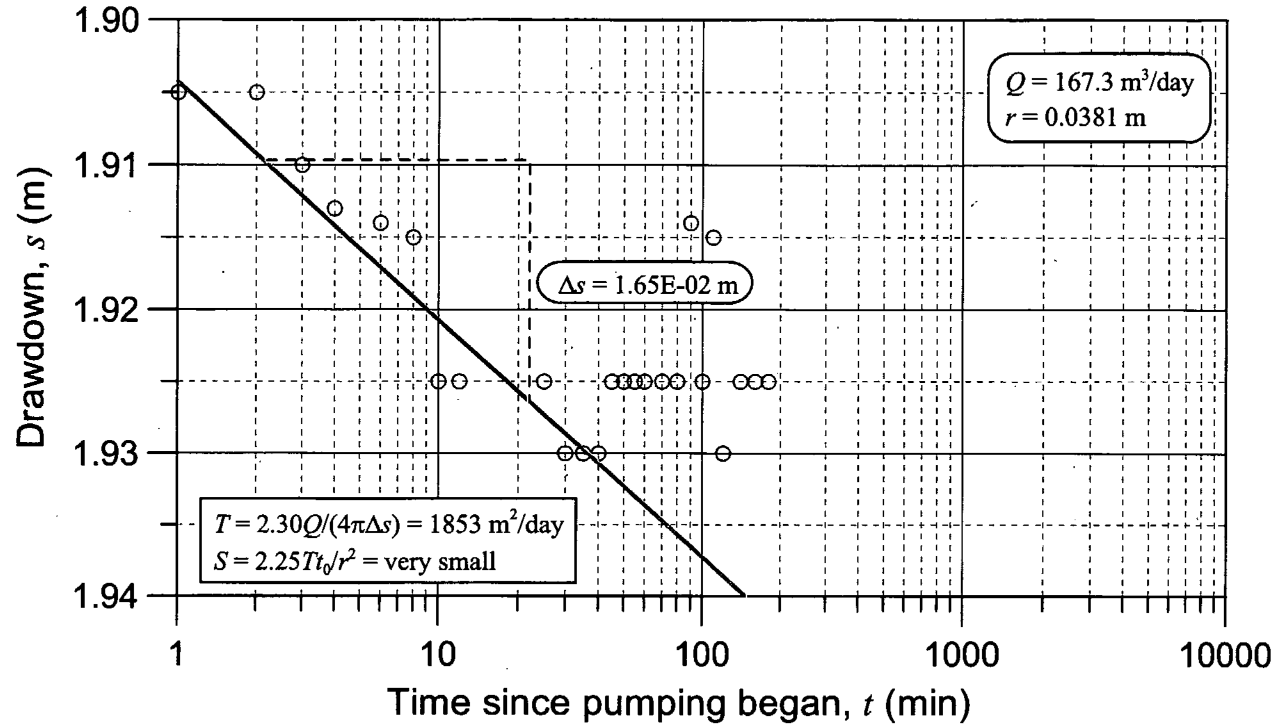
(b) Recovery Test at Jh-1-2

Location:	Arabpur, Jhenaidah Pourashava
Site No.:	JH-1
Well No.:	Jh-1-2
Well Depth:	123.0 m
Well Diameter:	76.20 mm
Screen Depths:	108.0-120.0 m
Screen Length:	12.0 m
SWL:	GL- 5.513 m on 21-04-2001

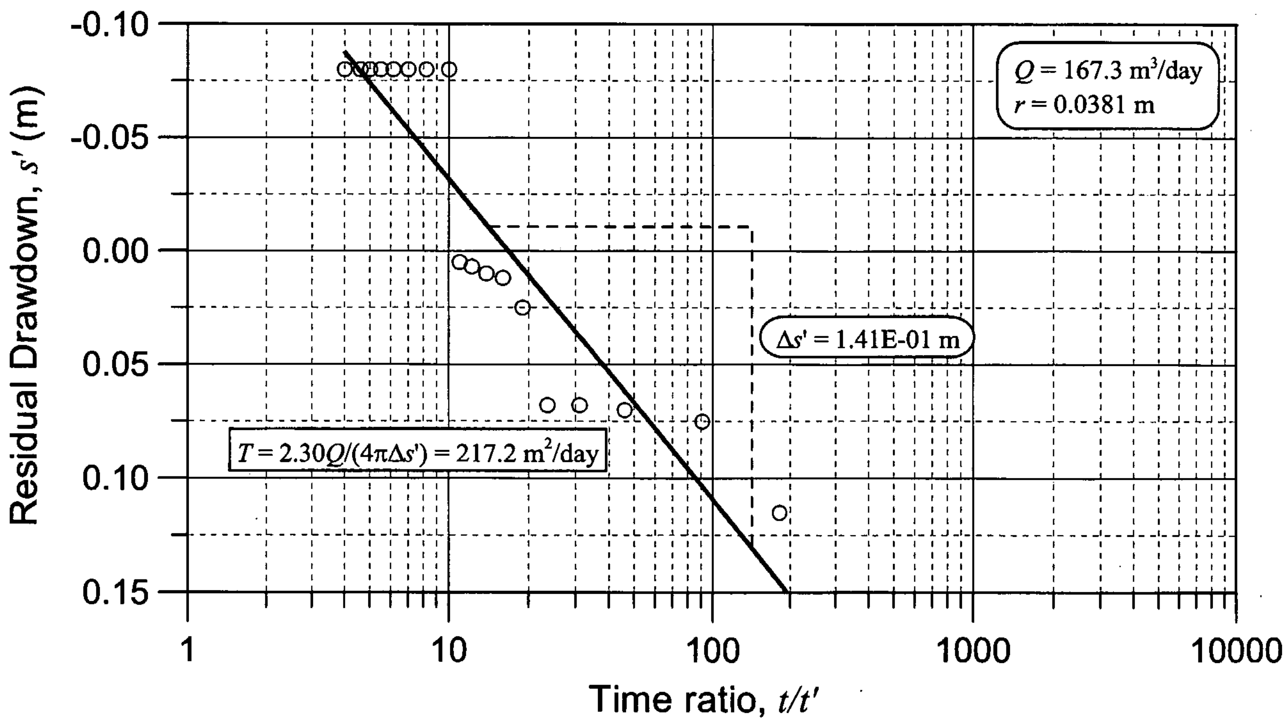
Figure 5.3.28 **Results of Simple Pumping Test at Jh-1-2 Observation Hole, Chuadanga**

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 Test at Jh-1-3



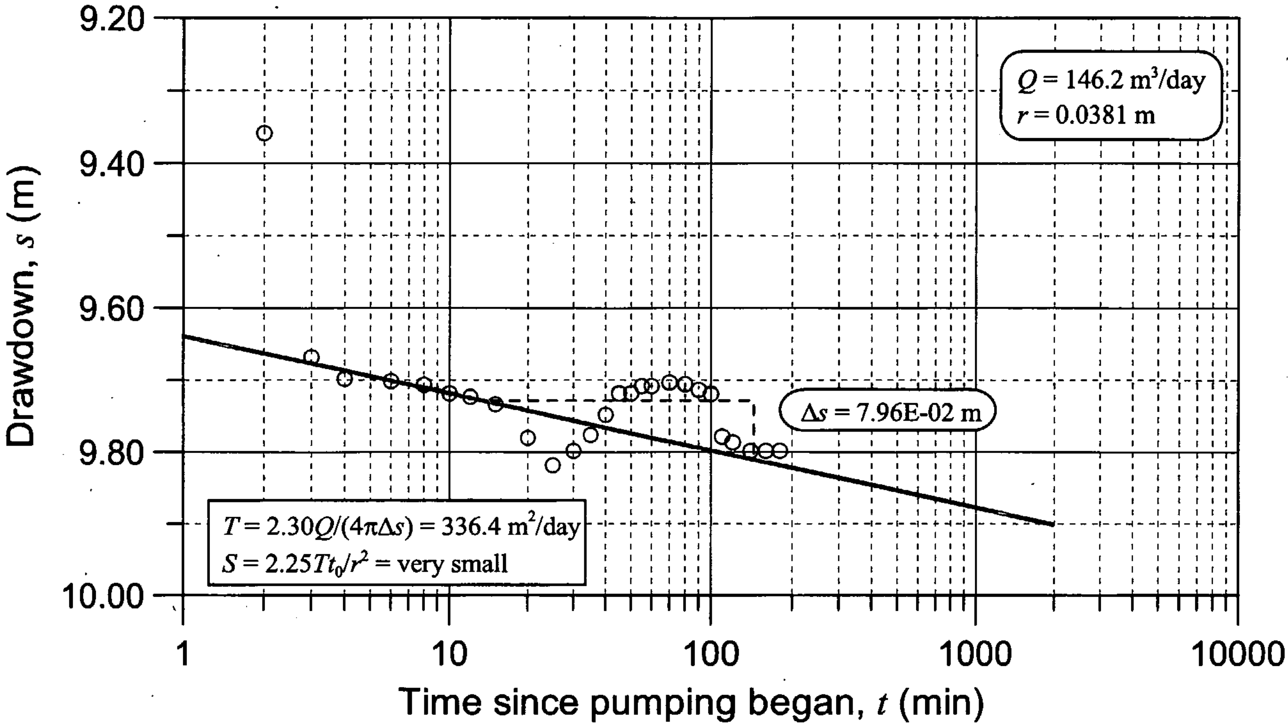
(b) Recovery Test at Jh-1-3

Location:	Arabpur, Jhenaidah Pourashava
Site No.:	JH-1
Well No.:	Jh-1-3
Well Depth:	165.0 m
Well Diameter:	76.20 mm
Screen Depths:	150.0-162.0 m
Screen Length:	12.0 m
SWL:	GL- 5.375 m on 21-04-2001

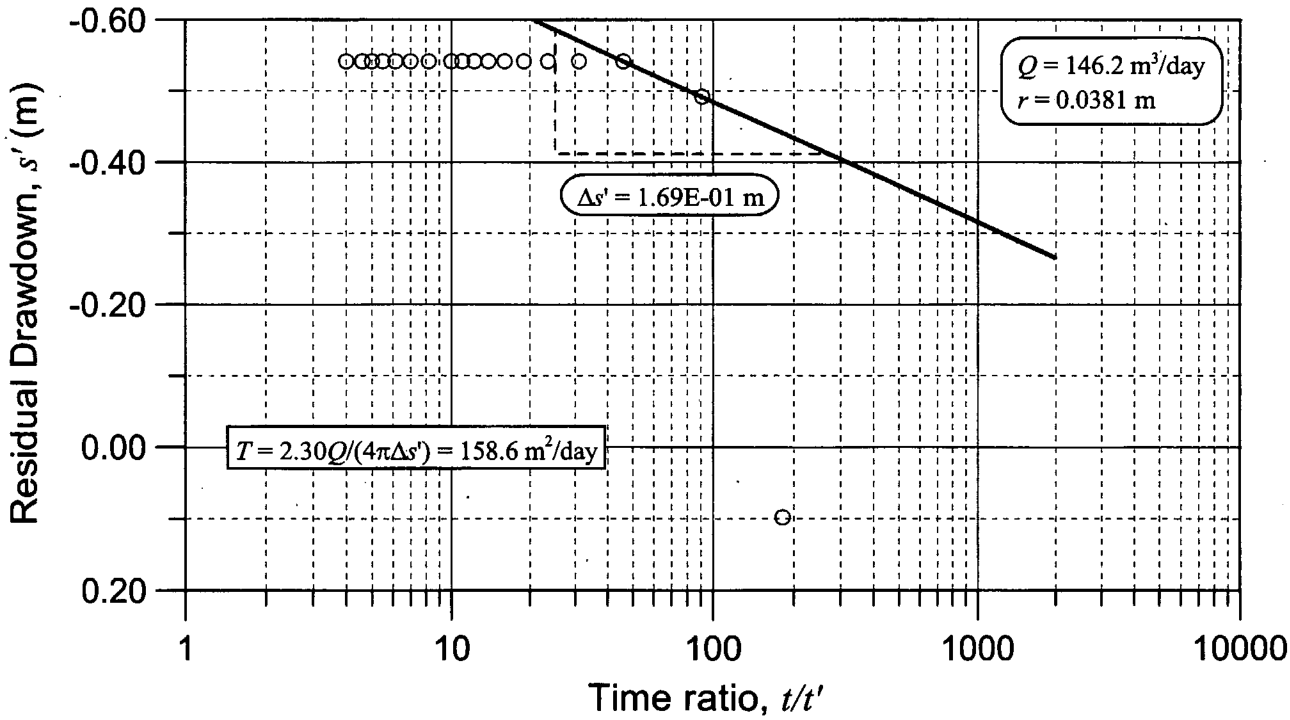
Figure 5.3.29 **Results of Simple Pumping Test at Jh-1-3 Observation Hole, Chuadanga**

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 Test at Jh-1-4



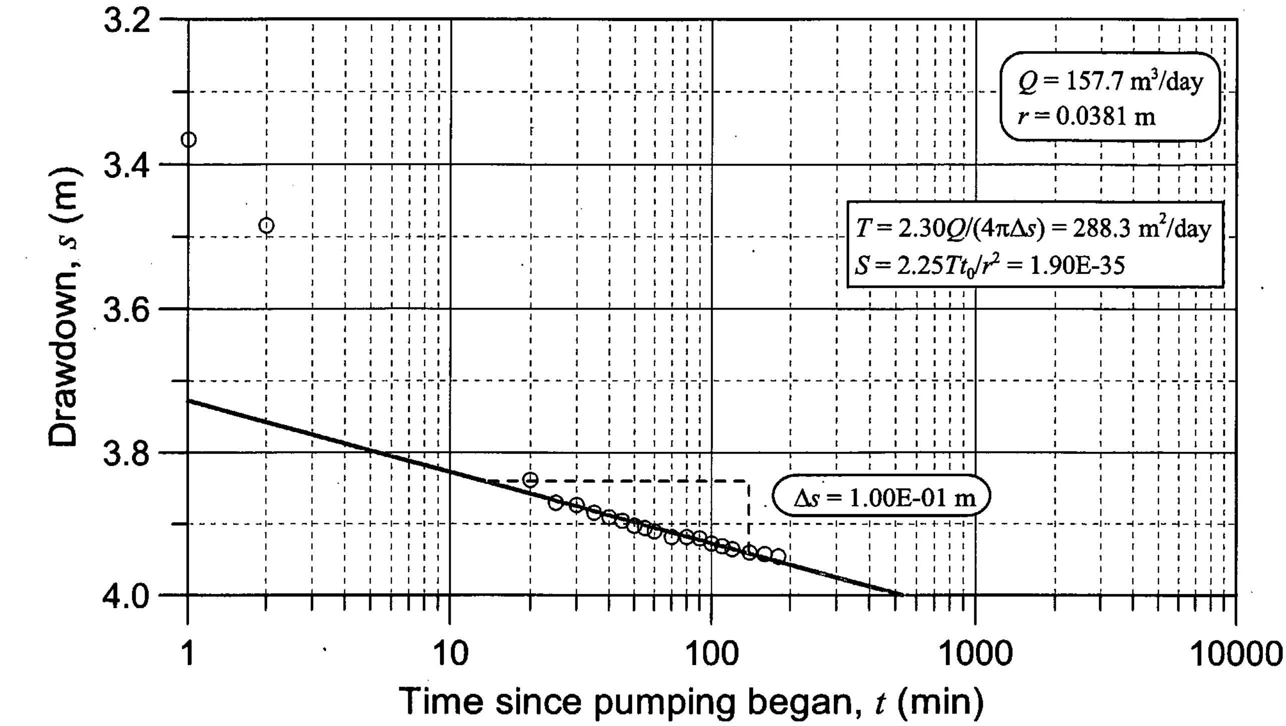
(b) Recovery Test at Jh-1-4

Location:	Arabpur, Jhenaidah Pourashava
Site No.:	JH-1
Well No.:	Jh-1-4
Well Depth:	282.0 m
Well Diameter:	76.20 mm
Screen Depths:	261-267, 273-279 m
Screen Length:	12.0 m
SWL:	GL- 5.862 m on 21-04-2001

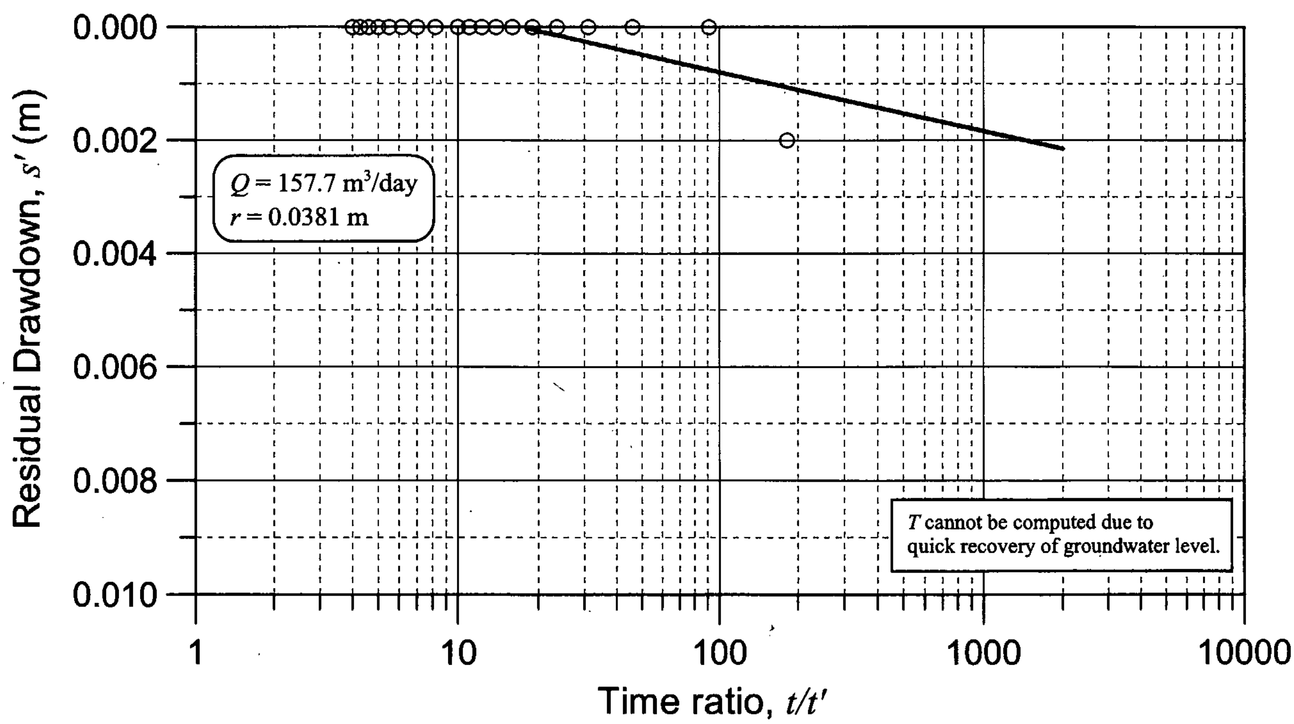
Figure 5.3.30 **Results of Simple Pumping Test at Jh-1-4 Observation Hole, Chuadanga**

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 Test at Jh-2-1



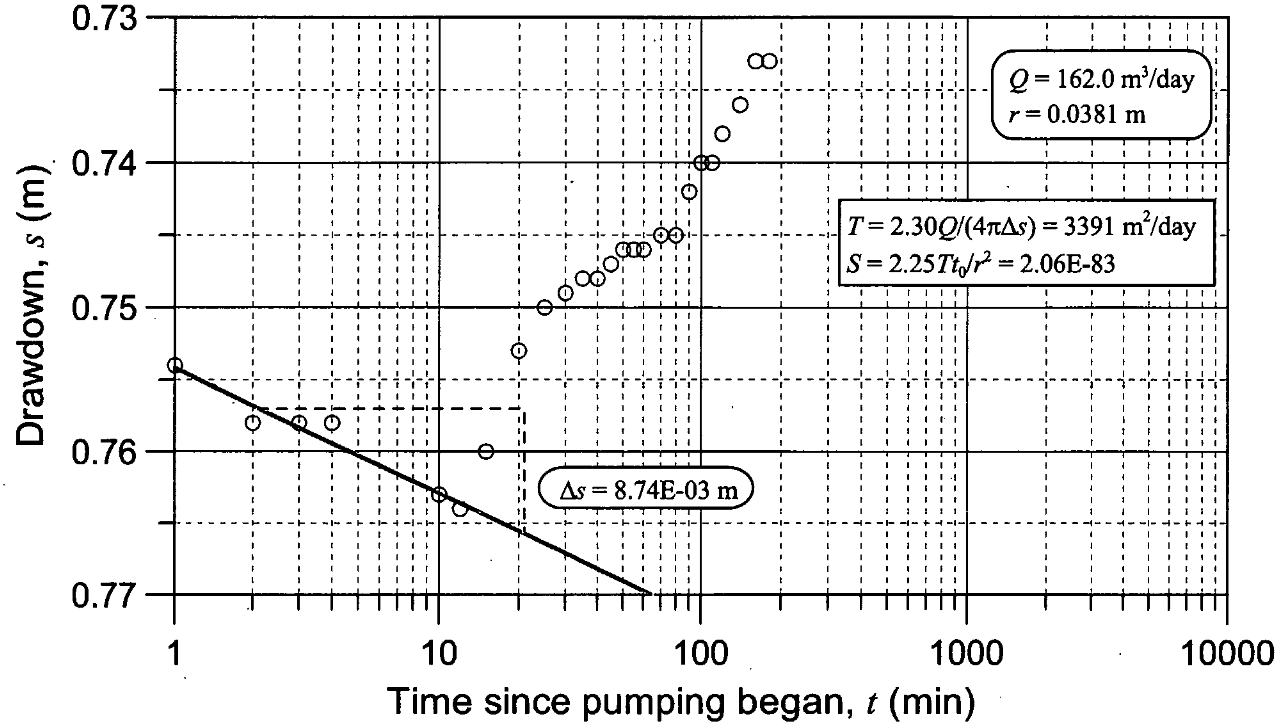
(b) Recovery Test at Jh-2-1

Location:	Hamdah, Jhenaidah Pourashava
Site No.:	JH-2
Well No.:	Jh-2-1
Well Depth:	60.0 m
Well Diameter:	76.20 mm
Screen Depths:	48.0-57.0 m
Screen Length:	9.0 m
SWL:	GL- 5.205 m on 07-06-2001

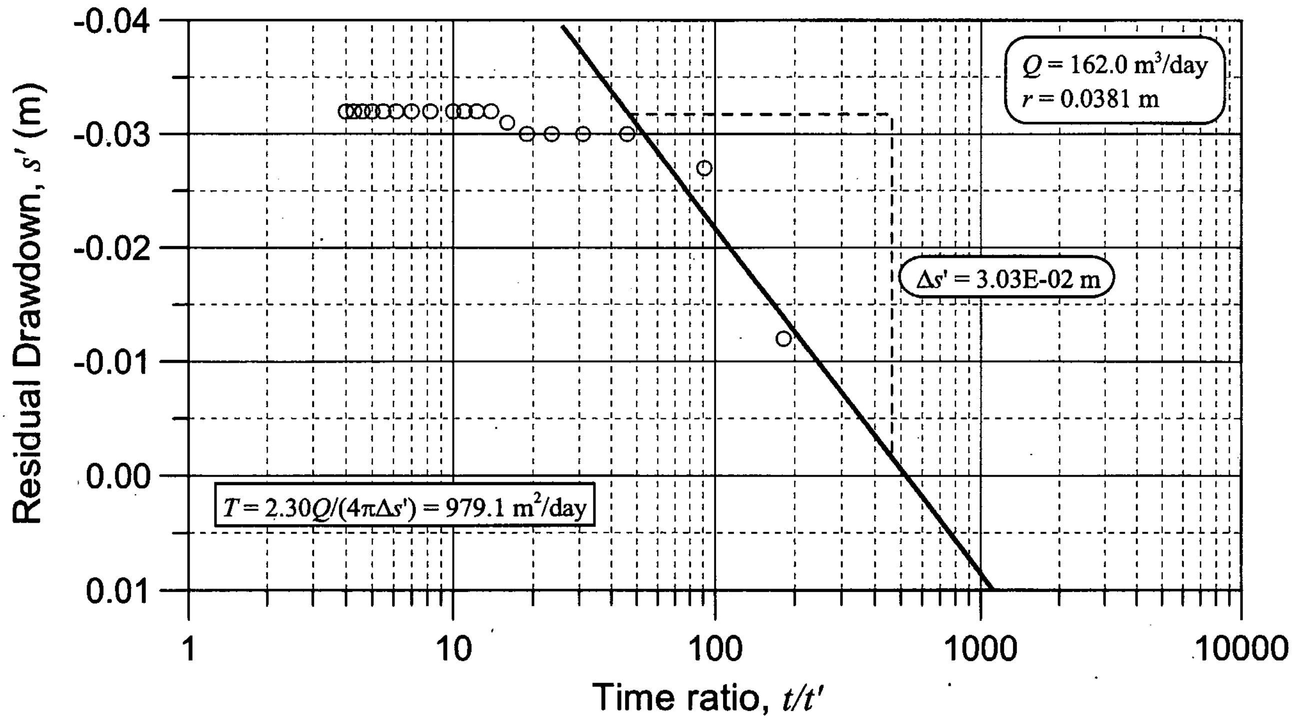
Figure 5.3.31 **Results of Simple Pumping Test at Jh-2-1 Observation Hole, Chuadanga**

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 Test at Jh-2-2



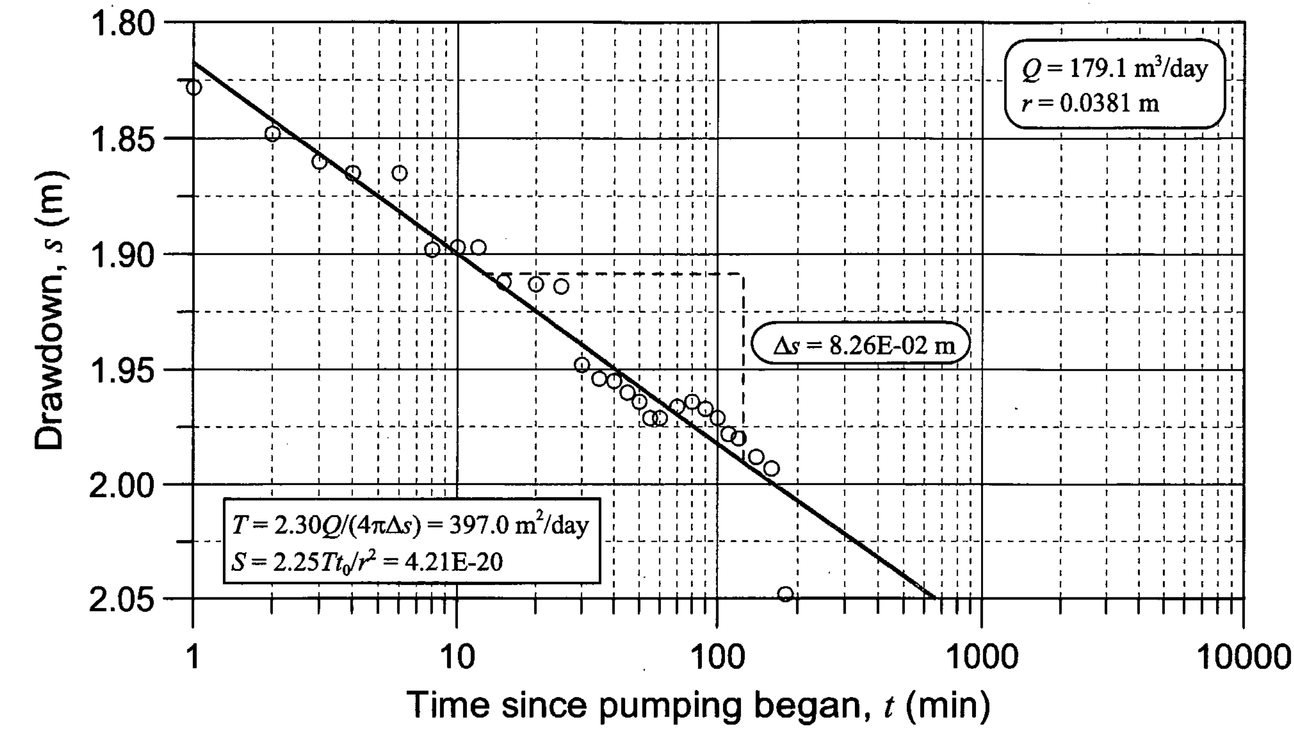
(b) Recovery Test at Jh-2-2

Location:	Hamdah, Jhenaidah Pourashava
Site No.:	JH-2
Well No.:	Jh-2-2
Well Depth:	111.0 m
Well Diameter:	76.20 mm
Screen Depths:	96.0-108.0 m
Screen Length:	12.0 m
SWL:	GL- 5.102 m on 07-06-2001

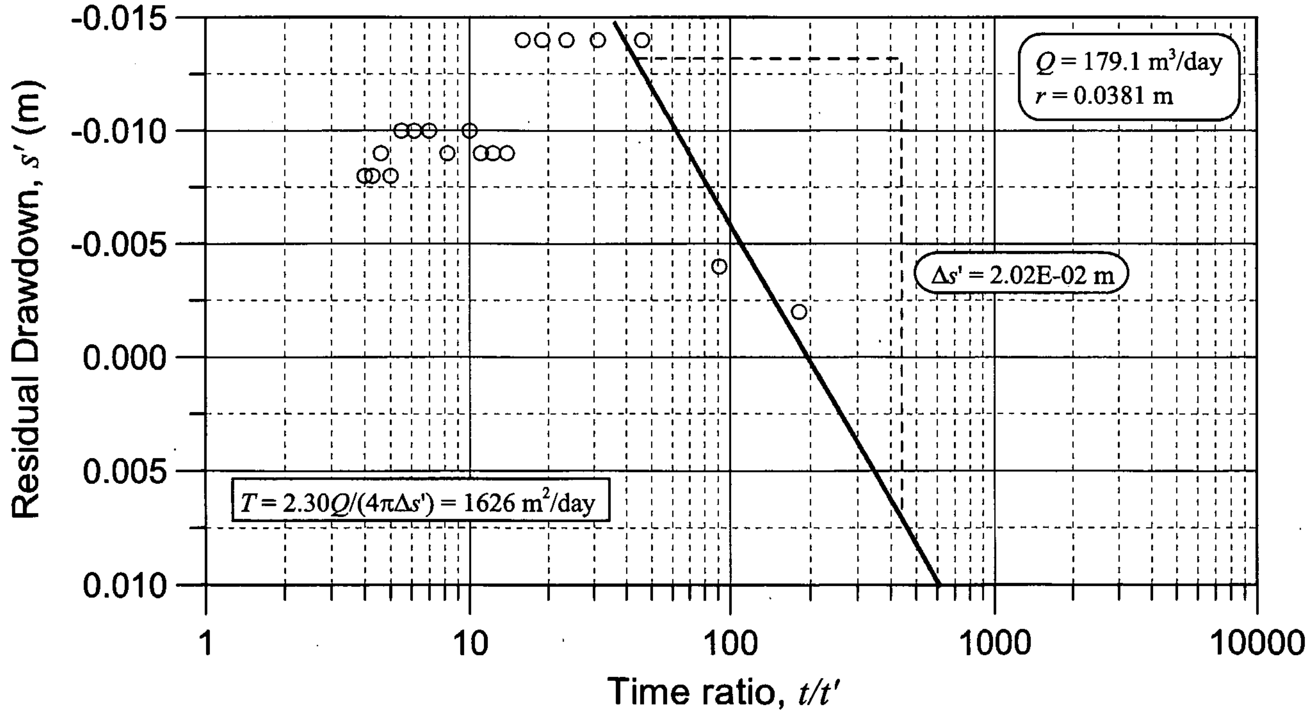
Figure 5.3.32 **Results of Simple Pumping Test at Jh-2-2 Observation Hole, Chuadanga**

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 Test at Jh-2-3



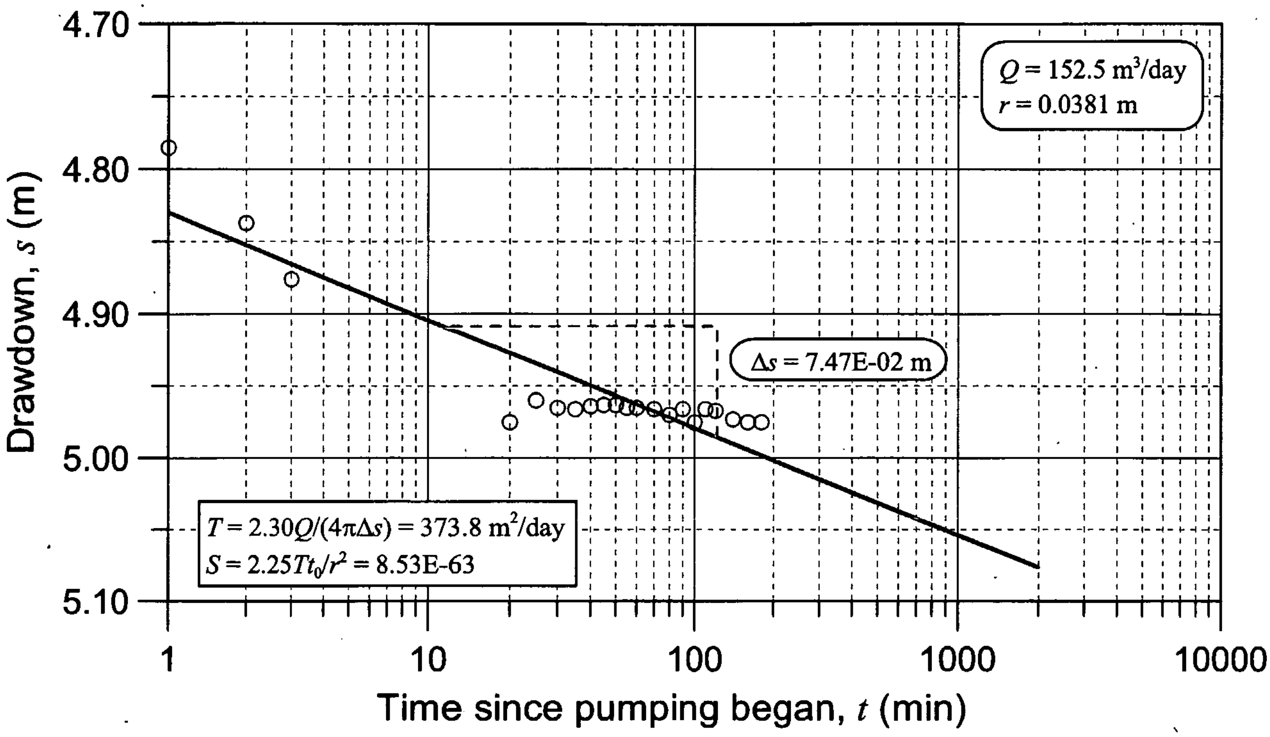
(b) Recovery Test at Jh-2-3

Location:	Hamdah, Jhenaidah Pourashava
Site No.:	JH-2
Well No.:	Jh-2-3
Well Depth:	165.0 m
Well Diameter:	76.20 mm
Screen Depths:	150.0-162.0 m
Screen Length:	12.0 m
SWL:	GL- 5.052 m on 08-06-2001

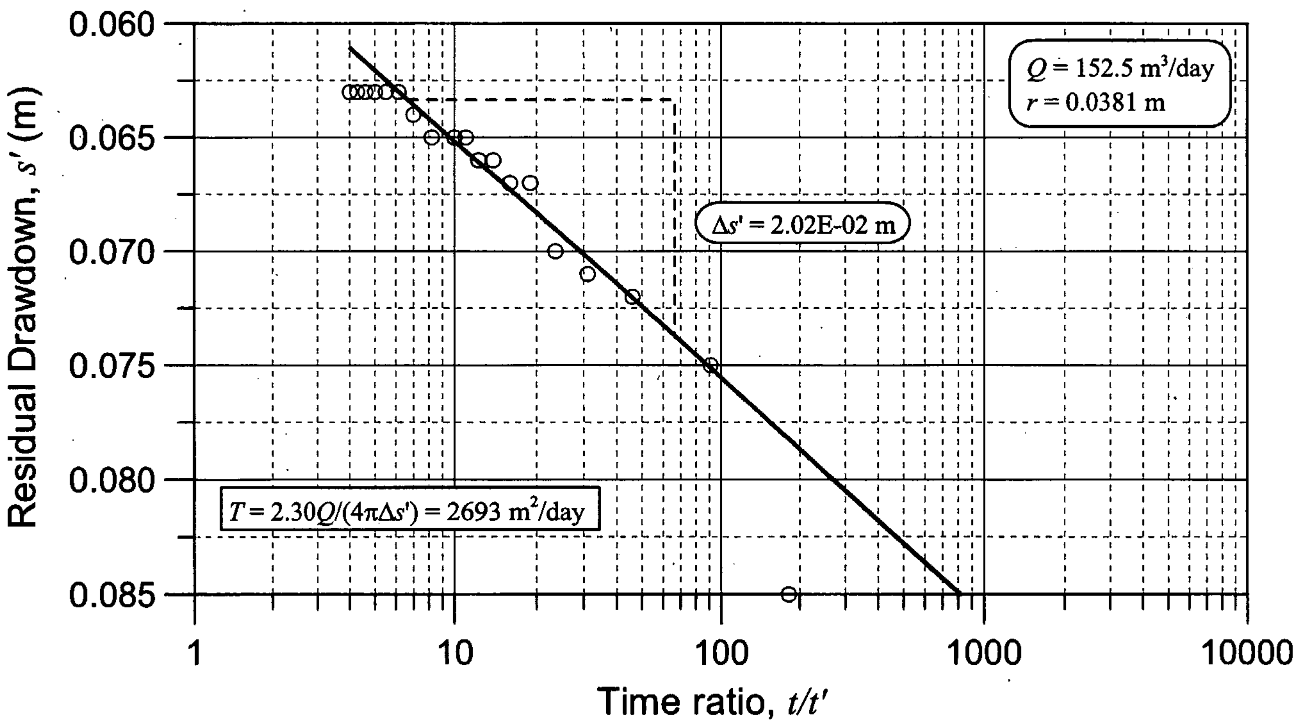
Figure 5.3.33 **Results of Simple Pumping Test at Jh-2-3 Observation Hole, Chuadanga**

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 Test at Jh-2-4



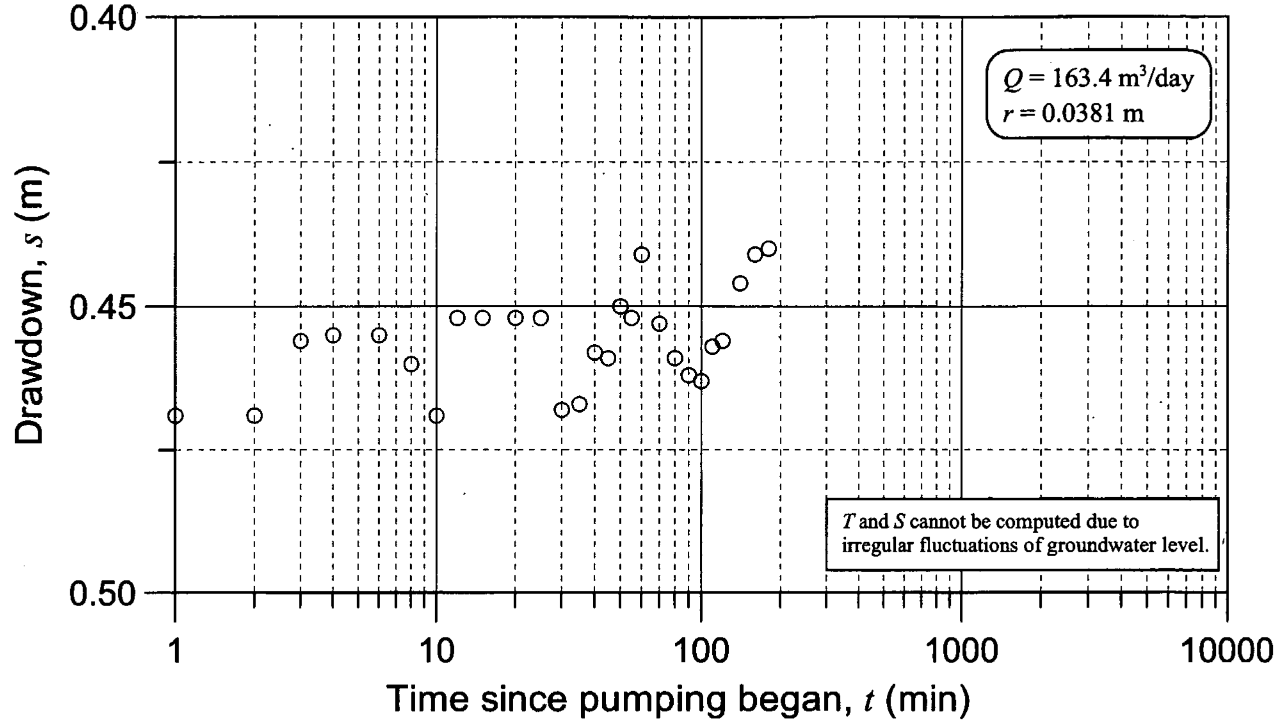
(b) Recovery Test at Jh-2-4

Location:	Hamdah, Jhenaidah Pourashava
Site No.:	JH-2
Well No.:	Jh-2-4
Well Depth:	273.0 m
Well Diameter:	76.20 mm
Screen Depths:	258.0-270.0 m
Screen Length:	12.0 m
SWL:	GL- 4.985 m on 08-06-2001

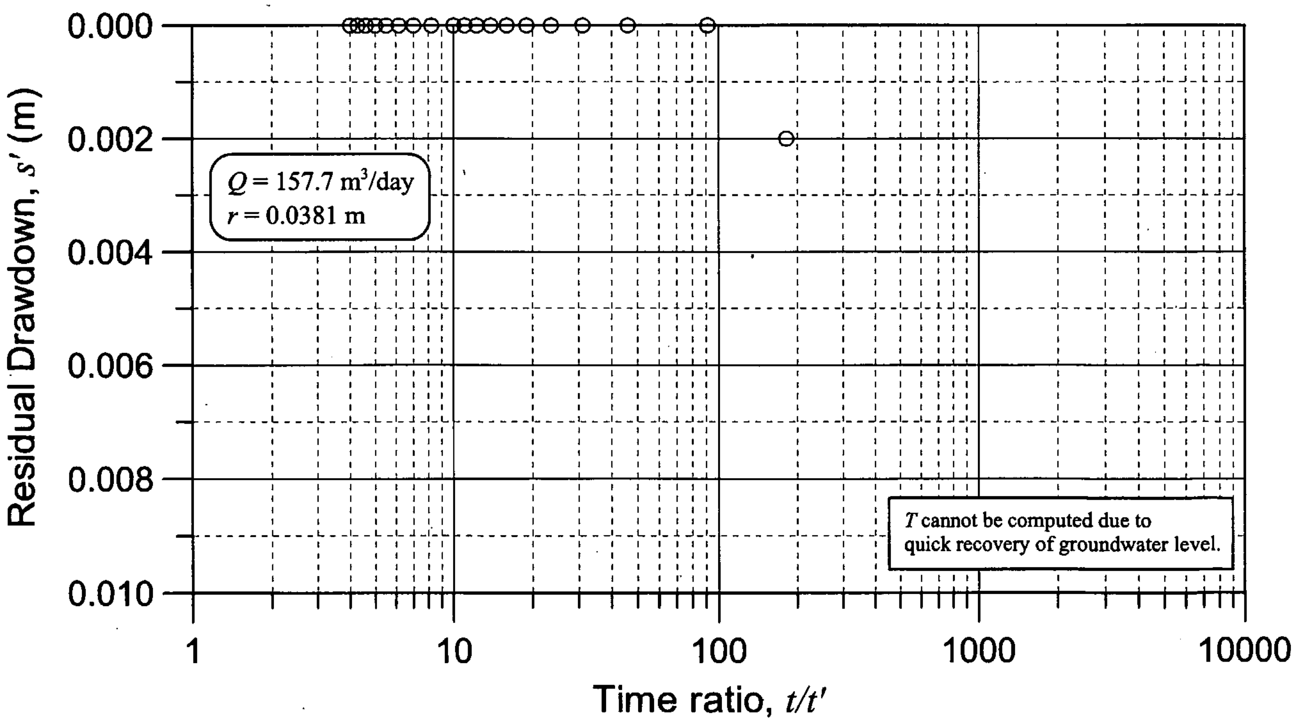
Figure 5.3.34 **Results of Simple Pumping Test at Jh-2-4 Observation Hole, Chuadanga**

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 Test at Js-1-1



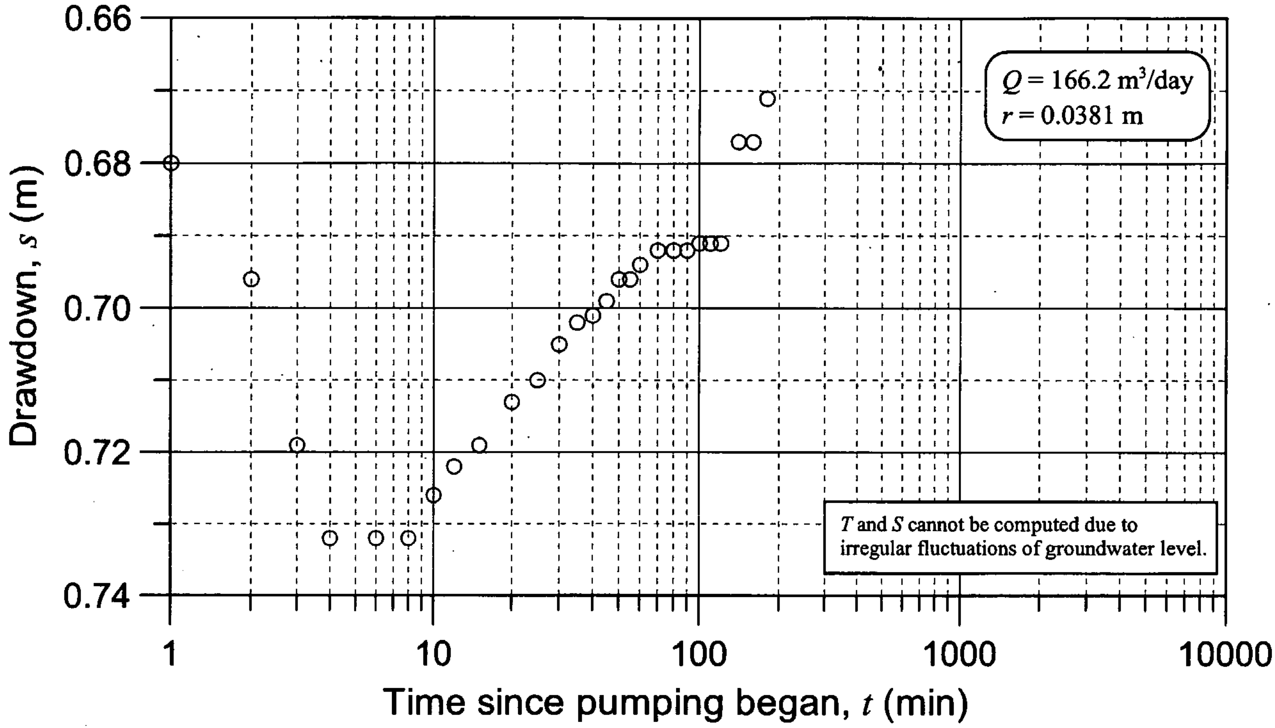
(b) Recovery Test at Js-1-1

Location:	Ghop, Jessore Pourashava
Site No.:	JS-1
Well No.:	Js-1-1
Well Depth:	66.0 m
Well Diameter:	76.20 mm
Screen Depths:	99.9-99.9 m
Screen Length:	9.9 m
SWL:	GL- 4.569 m on 20-07-2001

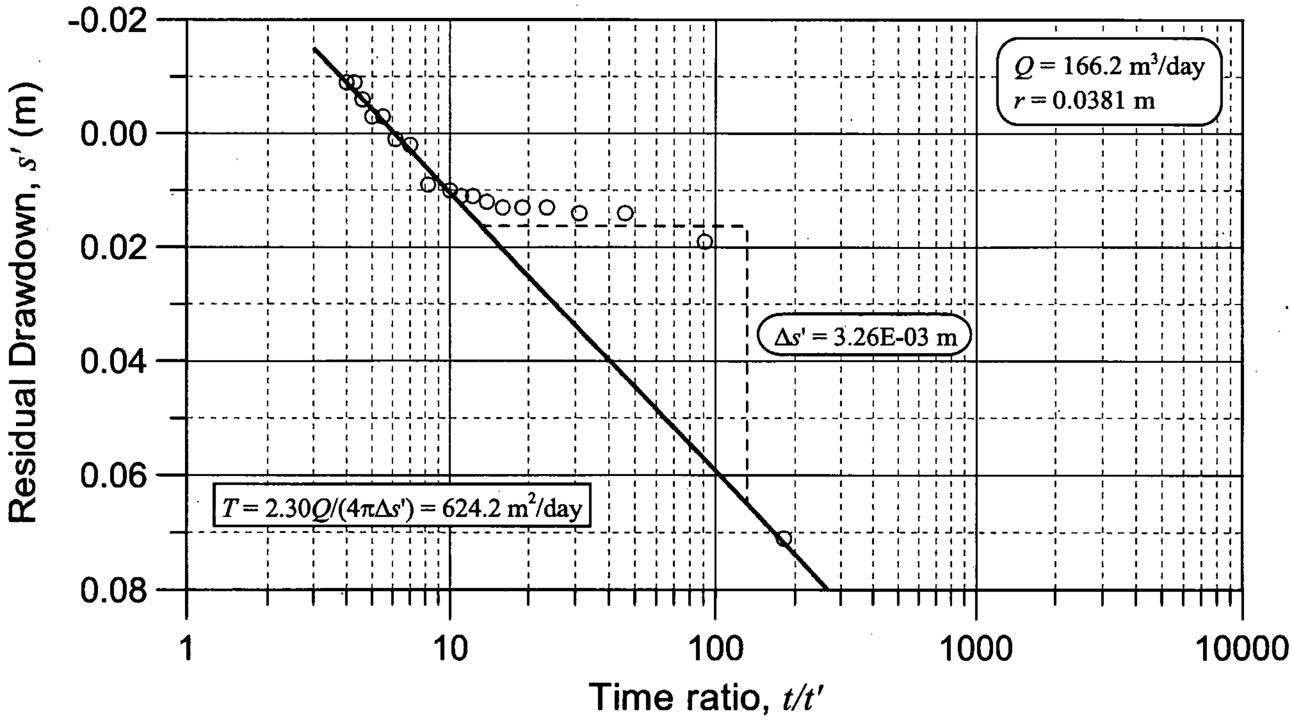
Figure 5.3.35 **Results of Simple Pumping Test at Js-1-1 Observation Hole, Jessore**

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 Test at Js-1-2



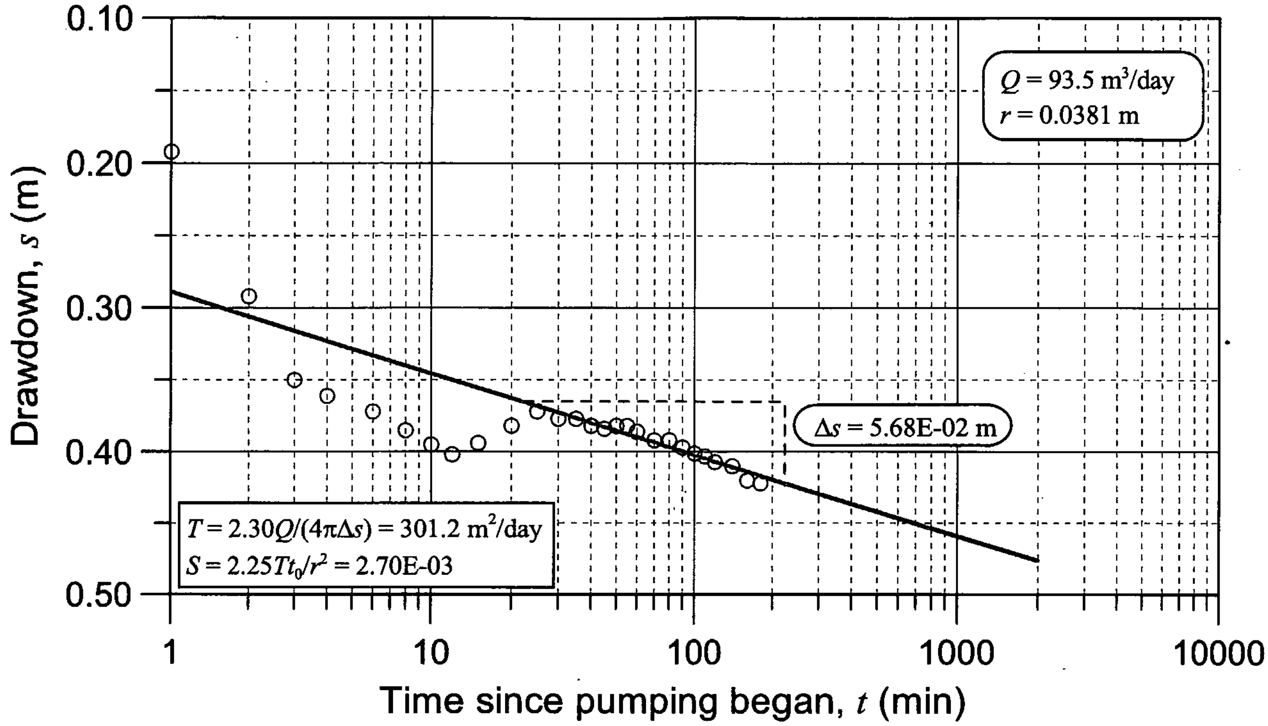
(b) Recovery Test at Js-1-2

Location:	Ghop, Jessore Pourashava
Site No.:	JS-1
Well No.:	Js-1-2
Well Depth:	120.0 m
Well Diameter:	76.20 mm
Screen Depths:	99.9-99.9 m
Screen Length:	9.9 m
SWL:	GL- 4.439 m on 20-07-2001

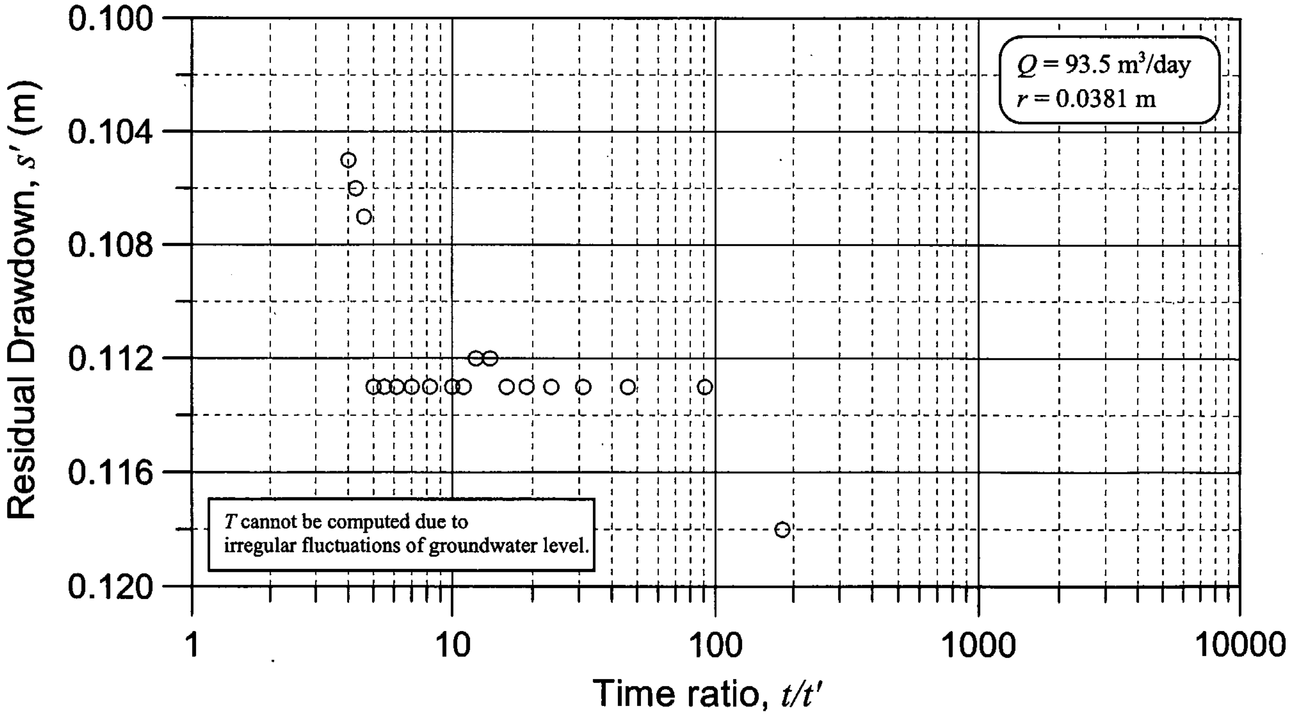
Figure 5.3.36 **Results of Simple Pumping Test at Js-1-2 Observation Hole, Jessore**

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 Test at Js-1-3



(b) Recovery Test at Js-1-3

Location:	Ghop, Jessore Pourashava
Site No.:	JS-1
Well No.:	Js-1-3
Well Depth:	168.0 m
Well Diameter:	76.20 mm
Screen Depths:	99.9-99.9 m
Screen Length:	9.9 m
SWL:	GL- 3.948 m on 20-07-2001

Figure 5.3.37	**Results of Simple Pumping Test at Js-1-3 Observation Hole, Jessore**

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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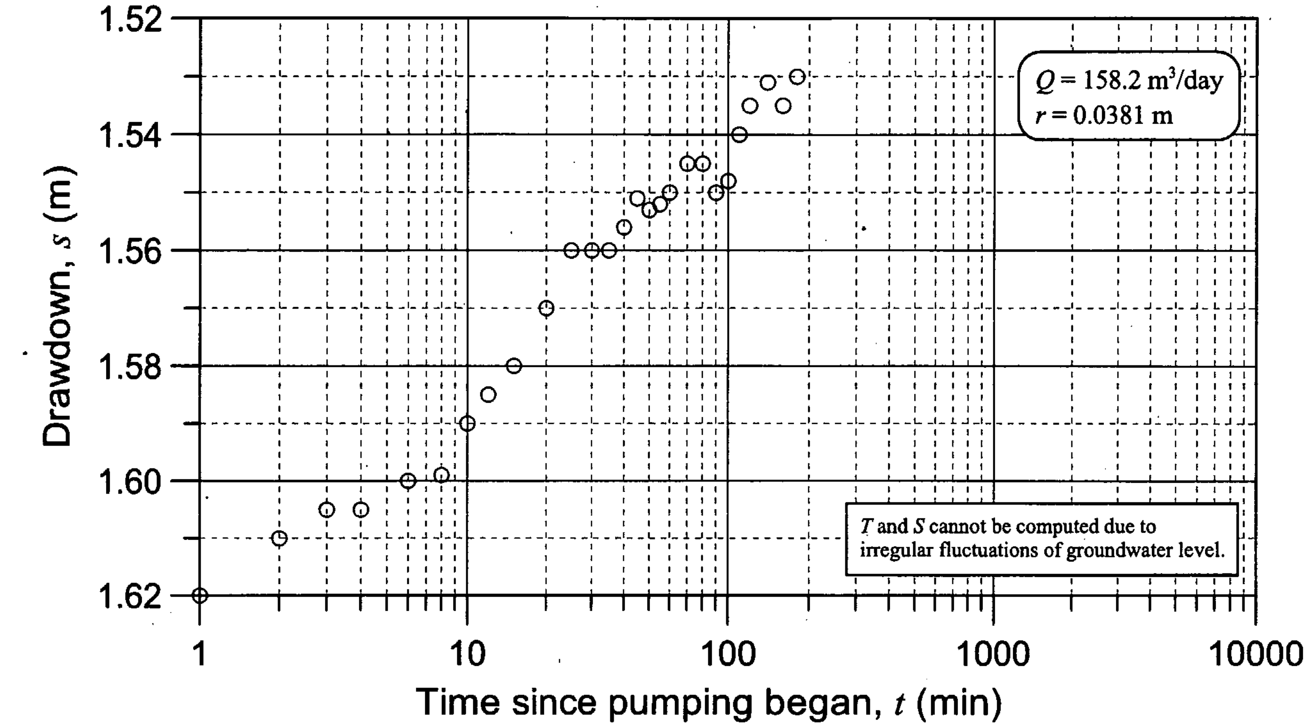
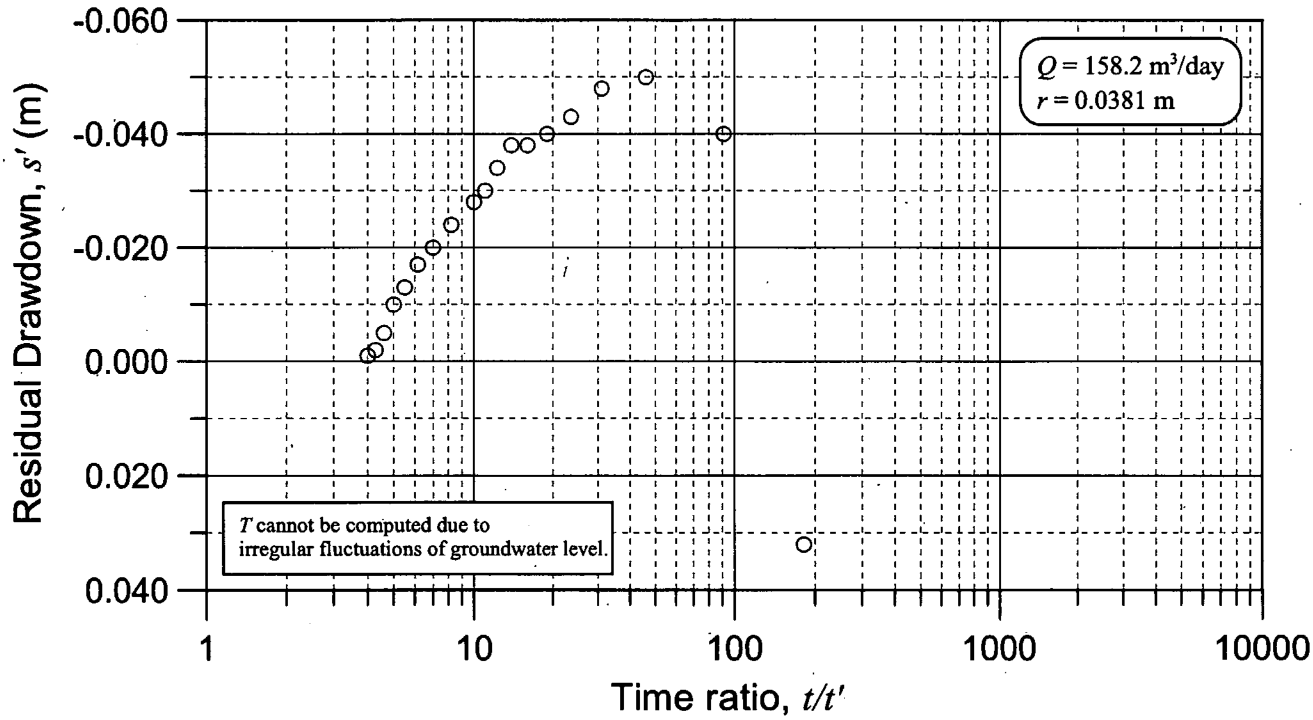


(a) Drawdown Test at Js-1-4



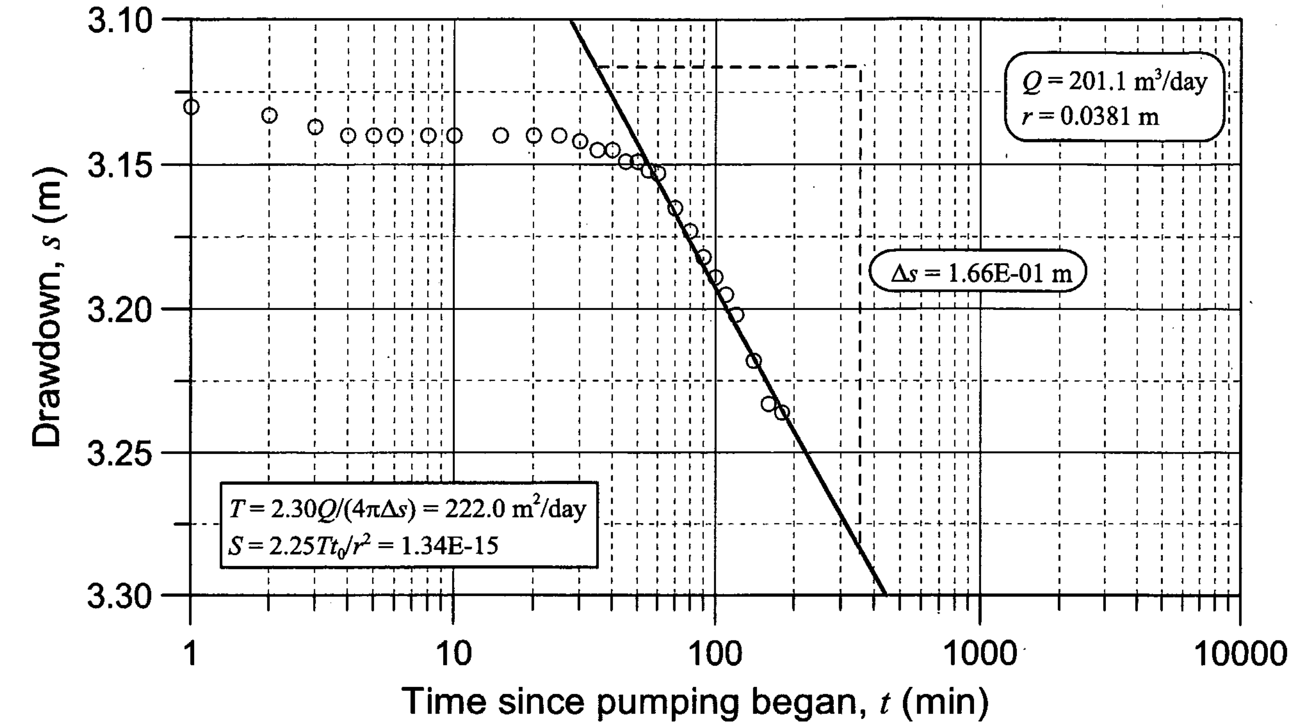
(b) Recovery Test at Js-1-4

Location:	Ghop, Jessore Pourashava
Site No.:	JS-1
Well No.:	Js-1-4
Well Depth:	282.0 m
Well Diameter:	76.20 mm
Screen Depths:	261.0-276.0 m
Screen Length:	15.0 m
SWL:	GL- 4.050 m on 20-07-2001

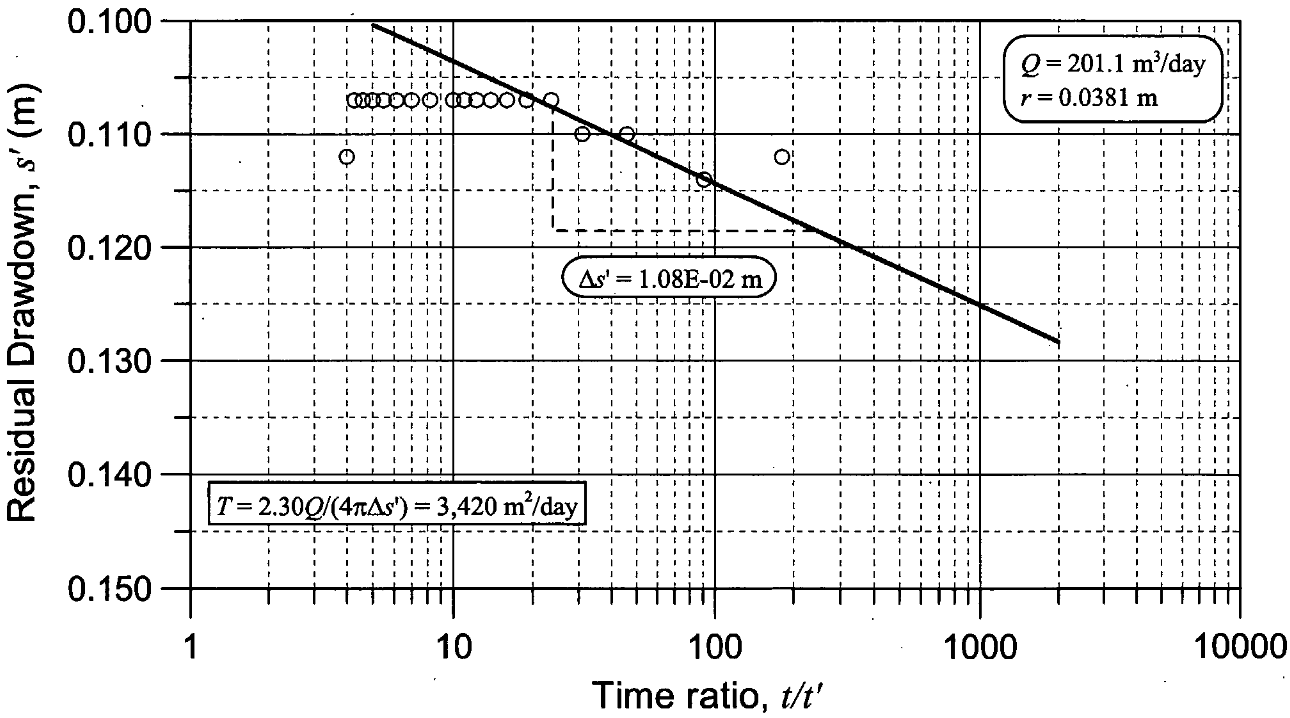
Figure 5.3.38 **Results of Simple Pumping Test at Js-1-4 Observation Hole, Jessore**

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 Test at Js-2-1



(b) Recovery Test at Js-2-1

Location:	Kharki, Jessore Pourashava
Site No.:	JS-2
Well No.:	Js-2-1
Well Depth:	66.0 m
Well Diameter:	76.20 mm
Screen Depths:	54.0-63.0 m
Screen Length:	9.0 m
SWL:	GL- 2.428 m on 06-08-2001

Figure 5.3.39 **Results of Simple Pumping Test at Js-2-1 Observation Hole, Jessore**

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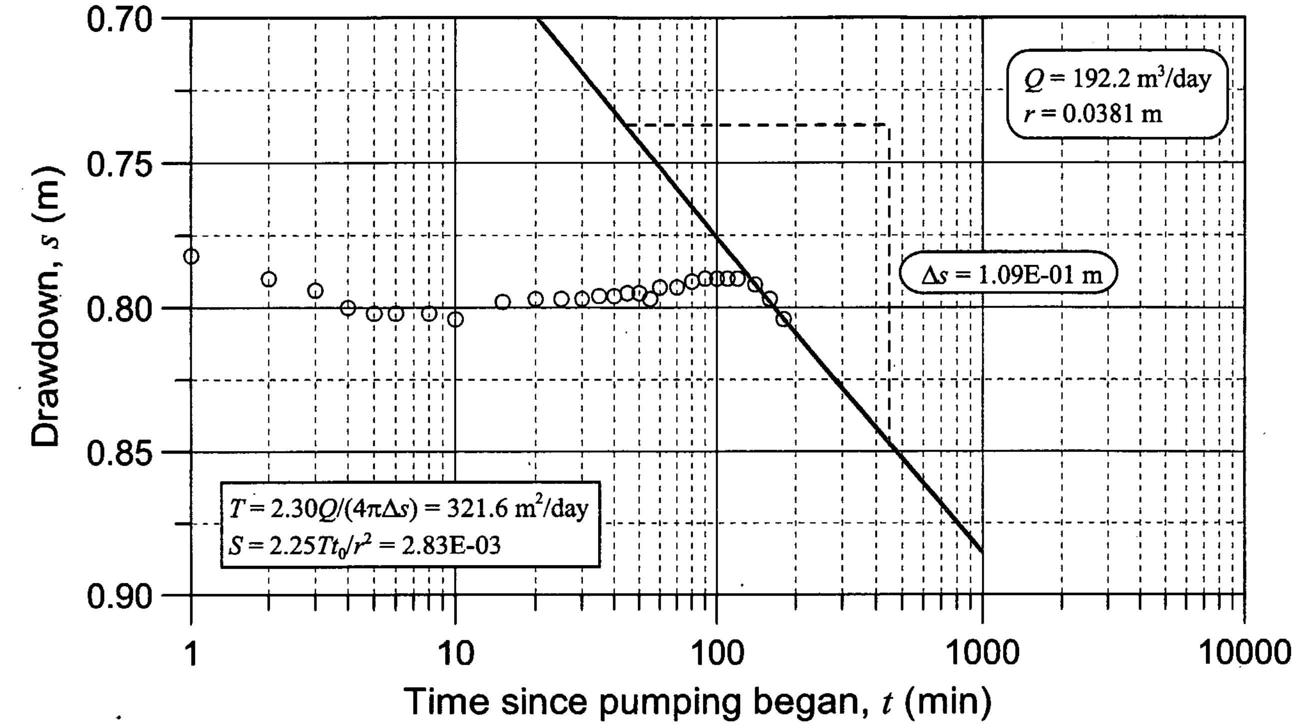
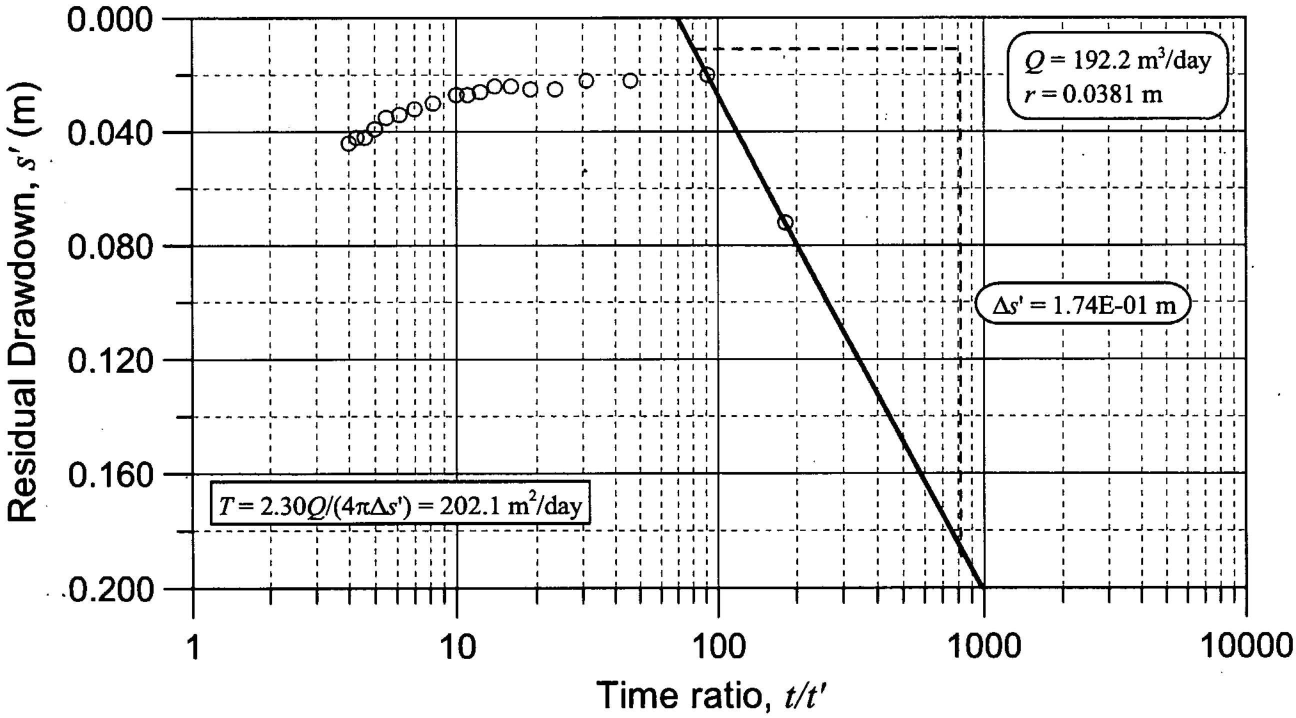


(a) Drawdown Test at Js-2-2



(b) Recovery Test at Js-2-2

Location:	Kharki, Jessore Pourashava
Site No.:	JS-2
Well No.:	Js-2-2
Well Depth:	114.0 m
Well Diameter:	76.20 mm
Screen Depths:	99.0-111.0 m
Screen Length:	12.0 m
SWL:	GL- 2.588 m on 06-08-2001

Figure 5.3.40 **Results of Simple Pumping Test at Js-2-2 Observation Hole, Jessore**

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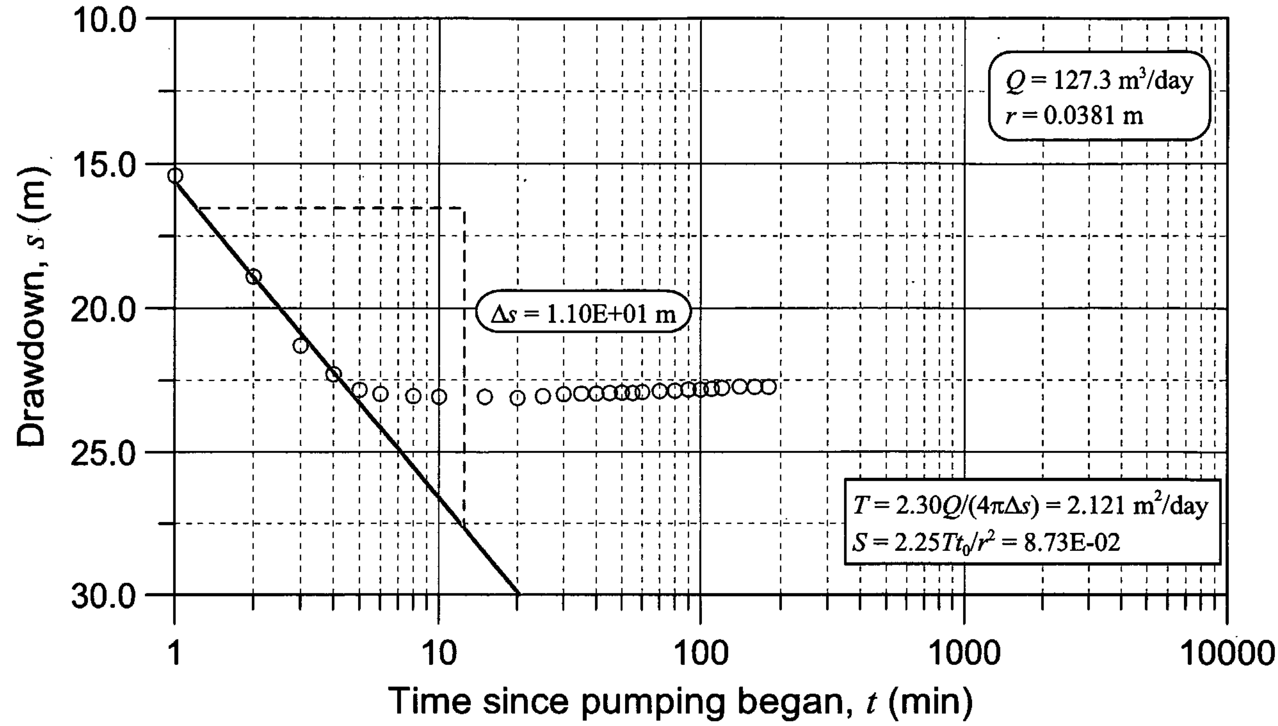
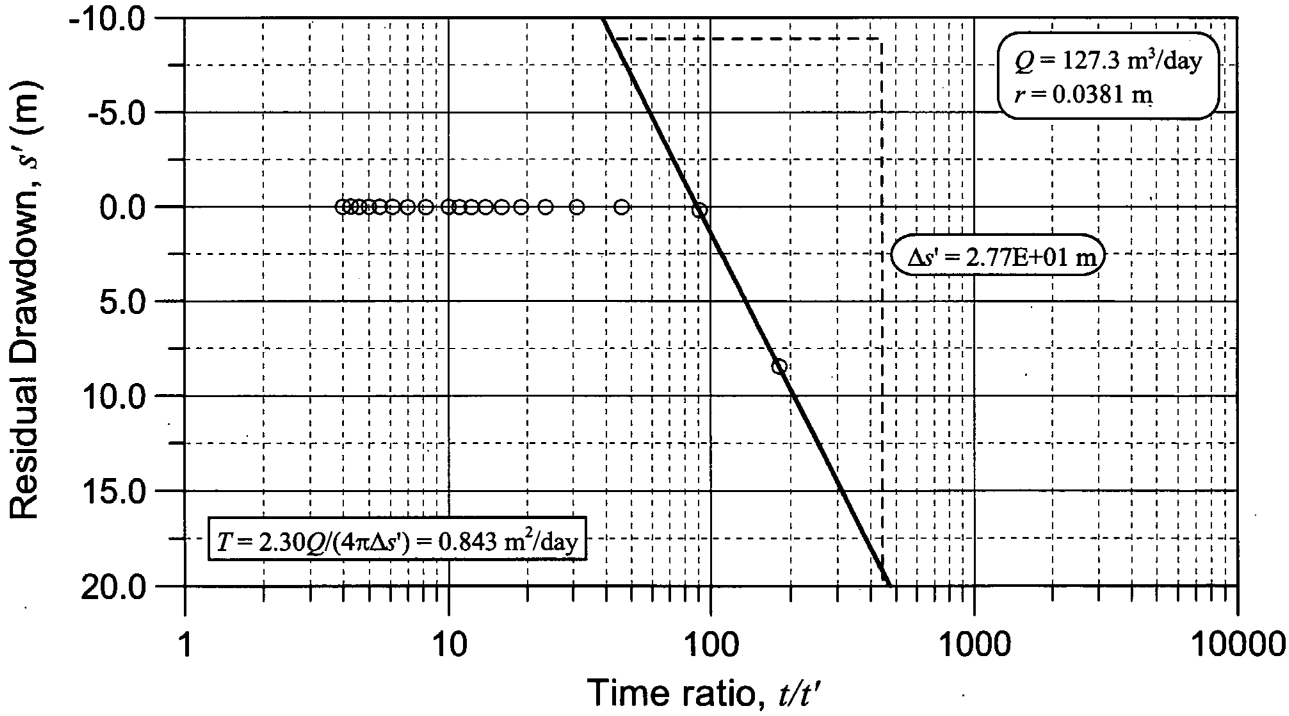


(a) Drawdown Test at Js-2-3



(b) Recovery Test at Js-2-3

Location:	Kharki, Jessore Pourashava
Site No.:	JS-2
Well No.:	Js-2-3
Well Depth:	162.0 m
Well Diameter:	76.20 mm
Screen Depths:	147.0-159.0 m
Screen Length:	12.0 m
SWL:	GL- 2.557 m on 06-08-2001

Figure 5.3.41 **Results of Simple Pumping Test at Js-2-3 Observation Hole, Jessore**

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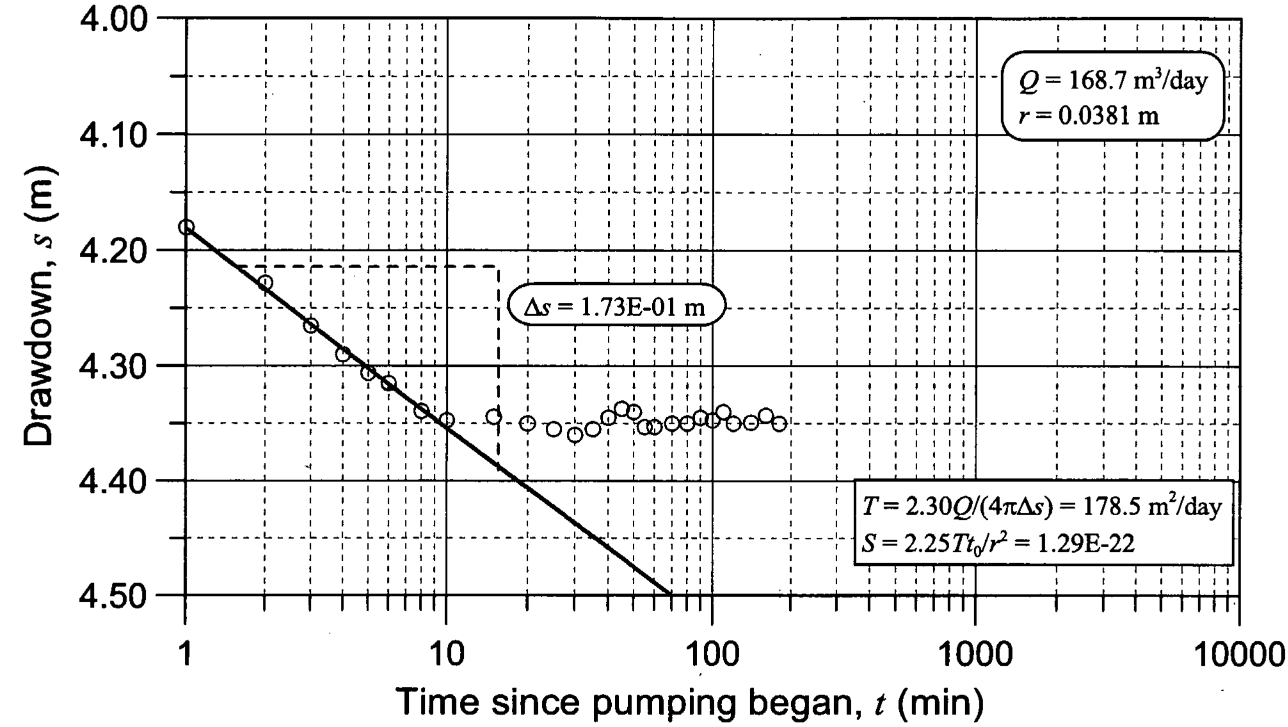
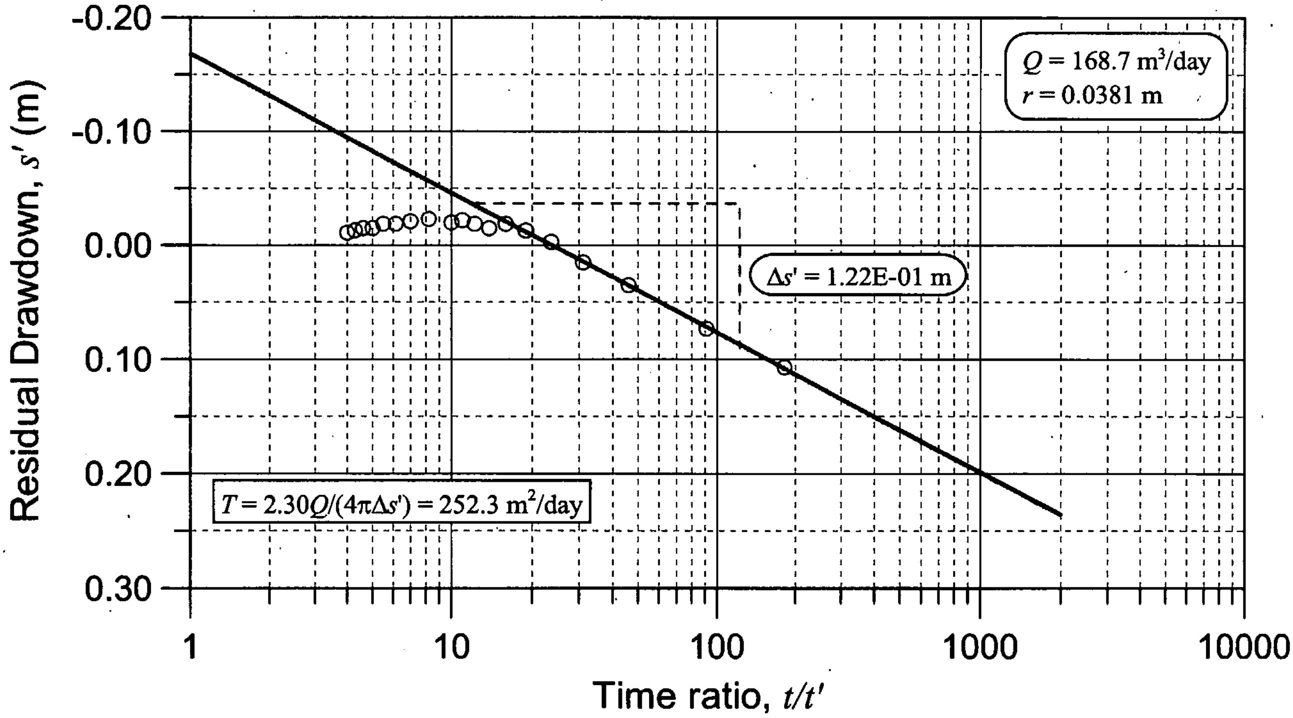


(a) Drawdown Test at Js-2-4



(b) Recovery Test at Js-2-4

Location:	Kharki, Jessore Pourashava
Site No.:	JS-2
Well No.:	Js-2-4
Well Depth:	255.0 m
Well Diameter:	76.20 mm
Screen Depths:	240.0-252.0 m
Screen Length:	12.0 m
SWL:	GL- 2.335 m on 06-08-2001

Figure 5.3.42 **Results of Simple Pumping Test at Js-2-4 Observation Hole, Jessore**

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5.4 Arsenic Concentration

5.4.1 Purpose

In Bangladesh, systematic measurements of arsenic concentrations by atomic absorption spectrophotometer (AAS) in groundwater have not been done particularly for deep groundwater. In the study area, the arsenic concentrations of some groundwater samples were analyzed by the spectrophotometer in DPHE Khulna Laboratory. However, regular monitoring of arsenic levels has not been done in the laboratory. Field kits have been widely used for screening purposes, however, the accuracy of field kit measurement is limited and the measurement cannot be used for precise monitoring of the arsenic level.

In the study, 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 the DPHE Jhenaidah office. After the construction of those wells/holes, the arsenic levels were measured during the pumping test. Then the 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, after 1 hour, after 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 for at least 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 for at least 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 0.001 mg/l. From 10 to 1,200 minutes, As concentrations ranged between 0.03 and 0.05 mg/l. The As level increased when the discharge rate increased from the 1st step to the 2nd step. In the rest, although the As levels fluctuated in range, there was no significant correlation with the discharge rate. The Eh value at the beginning was almost 0 mV, however, it jumped up about 150 mV 10 minutes after pumping started. From the 1st step to the 2nd step, the Eh values tend to decrease. Then the values fluctuated around 150 mV. The pH value at the beginning was 7.56, but suddenly dropped in the 1st step to 7.01. Then the values varied within a range from 7.1 to 7.2. The values tend to slightly decrease over time. EC values show some irregular fluctuations, however, the values tend 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 the unavoidable electricity failure, the arsenic levels tend to decrease over time from 0.0055 to 0.0010 mg/l The Eh values vary within 150 to 200 mV in most samples. The pH values tend to decrease when the discharge rate is high. EC values gradually decrease with time, but it 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 0.011 mg/l in 1st to 2nd step, but it gradually increased from latter part of the 2nd step to the 6th step. Eh and pH values tend 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. The As level increased from 0.005 to 0.018 mg/l in the 4th to the 6th step. But is suddenly dropped in the 8th step. Eh and EC values tend to decrease over time. On the other hand, the pH values tend 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 0.0023 mg/l in the 1st step to 0.0011 mg/l in the 10th step. The Eh values increased in the 1st step, and then stabilized at around 100 mV. The pH values increased from 7.25 in the 1st step to 7.58 in the 5th step. EC values stabilized between 82 and 84 mS/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 0.002 mg/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 0.045 mg/l from the beginning to 2,300 minutes, then it decreased to 0.025 mg/l. Eh values fluctuate greatly from 100 to 250 mV. 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 0.00005 mg/l. Then it jumped up to 0.0015 mg/l and stabilized with a very slight decrease. Eh values vary greatly in the first 1,000 minutes, 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 0.015 mg/l. Then it rose and fluctuated between 0.023 and 0.027 mg/l. Eh values were also lower than 100 mV in the beginning. Then it rose up to 170 mV and gradually decreased to 130 mV. The pH values increased from 6.98 to 7.1 for a period from 0 to 2,000 minutes, and then slightly decreased. EC values irregularly fluctuated between 86.5 and 88.8 mS/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 0.016 mg/l. On the other hand, the values of Eh and pH tend 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 0.0023 mg/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 110 mV. In the latter part of the test the values were stabilized. The pH values increased over time from 7.4 to 7.7. EC values slightly increased from 82 to 84 mS/m for a 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 0.005 mg/l for a period from 1,000 to 2,000 minutes. Then it suddenly dropped from 0.0043 to 0.0013 mg/l for a 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 pumping period of three (3) hours, 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 in Jh-1-2 and Jh-1-4 holes increased, however, the arsenic levels in Jh-1-1 and Jh-1-3 holes decreased. In JH-2 site, the level in Jh-1-1 hole slightly decreased. The levels in 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 6.5 m 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 0.5 m.

For the arsenic levels, the shallowest observation hole (Ch-1-1) has the highest arsenic level from July to October 2001, exceeding the Bangladeshi standard value of 0.05 mg/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 the 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 vary within a range from 40 to 120 mV from June to December. The pH values range from 6.9 to 7.3. The EC values of Ch-1 well and Ch-1-4 hole are 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 6.0 m 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 is generally within 0.5 m.

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

Figure 5.4.16 shows the results of groundwater level and groundwater quality monitoring at CH-2 site. The Eh values generally range from 70 to 110 mV at all the well/holes. However, the Eh value of Ch-1 well decreased below 50 mV in September and October 2001. The pH values tend to decrease in the high groundwater level time. The values of Ch-1 well show 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 in Ch-2-4 hole is 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 5.7 m 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 straightly declined to January 2002.

The arsenic level in the observation hole shows always below 0.01 mg/l. Once it rose up to 0.009 mg/l, but the value declined below 0.003 mg/l from March. In November the concentration elevated up to 0.0054 mg/l, but it declined to 0.0015 mg/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 range from 70 to 90 mV from April to August. In September, the value decreased to below 0 mV. The value jumped up to 107 mV in October then gradually decreased to 55 mV in December 2001. The pH values fluctuated from 6.9 to 7.4. From October to December it rose from 6.9 to 7.24. The EC value generally shows above 80 mS/m, however, it dropped below 50 mS/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 5.5 m 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 is generally within 0.1 m.

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 0.05 mg/l in April and June 2001. The arsenic levels in holes Jh-1-1 to Jh-1-4 decreased from April to October. However, the values in holes Jh-1-2 to Jh-2-4 started to increase from November to December. The arsenic level in Jh-1 well was below 0.01 mg/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 holes Jh-1-1 to Jh-1-4 generally show between 70 to 120 mV. But the value in Jh-1 well is lower, ranging from 10 to 35 mV. The pH values generally range from 6.8 to 7.4. The EC value of Jh-1-4 hole is relatively stable, ranging from 80 to 87 mS/m. The rest varied from 40 to 90 mS/m. In December 2001, the EC values of shallow holes from Jh-1-1 to Jh-1-3 are below 55 mS/m, whereas the deep well/hole (Jh-1 well and Jh-1-4 hole) are more than 80 mS/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 5.5 m 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 is generally within 0.5 m. 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 0.05 mg/l in most times. The second highest arsenic levels were recorded in Jh-2-2 hole, ranging from 0.01 to 0.05 mg/l. The arsenic level in Jh-2-3 ranged between 0.01 and 0.02 mg/l from June to September, but it declined below 0.01 mg/l from October. The arsenic levels in Jh-2 well and Jh-2-4 hole show below 0.01 mg/l. The arsenic levels in 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 holes Jh-1-1 to Jh-1-4 generally showed between 60 to 100 mV. But the value in Jh-2 well became lower from October, ranging from 15 to 60 mV. The pH values generally range from 6.7 to 7.7. Jh-2 well had the highest value of pH, ranging from 7.15 to 7.7. The EC values show to be almost stable during the monitoring period. It is noted that Jh-2 well has the lowest values of EC whereas Jh-2-4 hole, which tapped the same aquifer as Jh-2 well, has 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 concentration at JH-KC site.

The groundwater levels were located between 4.3 and 6.3 m 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 0.05 mg/l in April and from August to November 2001. In May the level dropped to below 0.01 mg/l. The highest value of 0.10 mg/l was recorded in November. The increasing trend of arsenic level was identified from June to November. In December the level declined to 0.037 mg/l.

Figure 5.4.24 shows the results of groundwater level and groundwater quality monitoring at JK-KC site. The Eh values range from 90 to 115 mV from May to November. In December, the value decreased to below 40 mV. 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 are almost constant from May to December except June. The values range from 88 to 94 mS/m.

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

Figure 5.4.25 shows the results of the monitoring of groundwater level and arsenic concentration 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 6.7 m below the benchmark (KBM). The patterns of groundwater level change in the site are 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 straightly dropped and the lowering speed increased in January 2002. The piezometric head difference is generally within 0.6 m from July to December 2001.

For the arsenic levels, they were relatively higher at all the well/holes in August 2001 then they tended to decrease from September to December. In August, the level at Js-1-2 reached 0.033 mg/l, but the rest of samples showed below 0.01 mg/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 110 mV. The Eh value of Js-1-1 well gradually decreased with time from 104 to 91 mV. The Eh values of holes Js-1-2 to Js-1-4 and Js-1 well range from 40 to 80 mV 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 holes are about 60 mS/m, whereas the values of Js-1-3, Js-1-4, and Js-1 wells show between 80 and 90 mS/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 5.4 m below the benchmark (KBM). The patterns of groundwater level change in the site are 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 straightly dropped and the lowering speed increased in January 2002. The piezometric head difference is generally within 0.7 m from July to December 2001. It should be noted that the groundwater levels of the shallow aquifer 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 0.10 mg/l. The arsenic levels of Js-2-1 hole were below 0.01 mg/l. The second highest arsenic level was found at Js-2-3 hole, ranging from 0.003 to 0.03 mg/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 110 mV. 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 105 mS/m. The values are higher at 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 concentration at JS-RB site.

The groundwater levels were located between 2.7 and 4.7 m 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 by about 0.5 m in January 2002.

The arsenic concentration was generally low. The highest level of 0.0023 mg/l was recorded in June 2001. Then the concentrations gradually decreased and became below the detection level of 0.0005 mg/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 110 mV in June to 160 mV in September, then it decreased to 60 mV in December 2001. The pH values are generally high, ranging from 7.6 to 7.9. The EC values ranged from 66 to 75 mS/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 0.084 mg/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 0.11 mg/l was recorded in August. In Type-B well, the highest value of 0.18 mg/l was recorded in September. In Type-C well, the highest value of 0.14 mg/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 8 mg/l in March, but the range gradually became smaller and the values ranged from 2 to 3 mg/l from July to December.

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

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 are almost constant except in the March data. The values ranged from 45 to 50 mS/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 0.05 mg/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 0.018 mg/l in June to 0.089 mg/l in July. In August, the maximum level of 0.107 mg/l was recorded. The values of the three wells were more than 0.05 mg/l until September. From September to December the values tended to decrease. The arsenic concentrations in December became almost the same as the values in March in Type-B and Type-C wells. The value of Type-A well was still above the standard value, showing 0.06 mg/l.

The Fe concentration measured by pack test kit had a wide range from 2 to 10 mg/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 4 mg/l.

The Eh values ranged from 100 to 160 mV 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 120 mV. In December, the values further decreased and the Eh value in Type-A well showed only 28 mV.

The pH values ranged from 6.85 to 7.20. The changes in pH show similar patterns of fluctuation. The values increased from March to July 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 decreased and became almost constant after July, ranging from 88 to 92 mS/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 0.01 mg/l. Slightly elevated concentrations up to 0.005 mg/l were recorded in September and October 2001, the most results showing below 0.001 mg/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 show 0.2 mg/l or less.

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

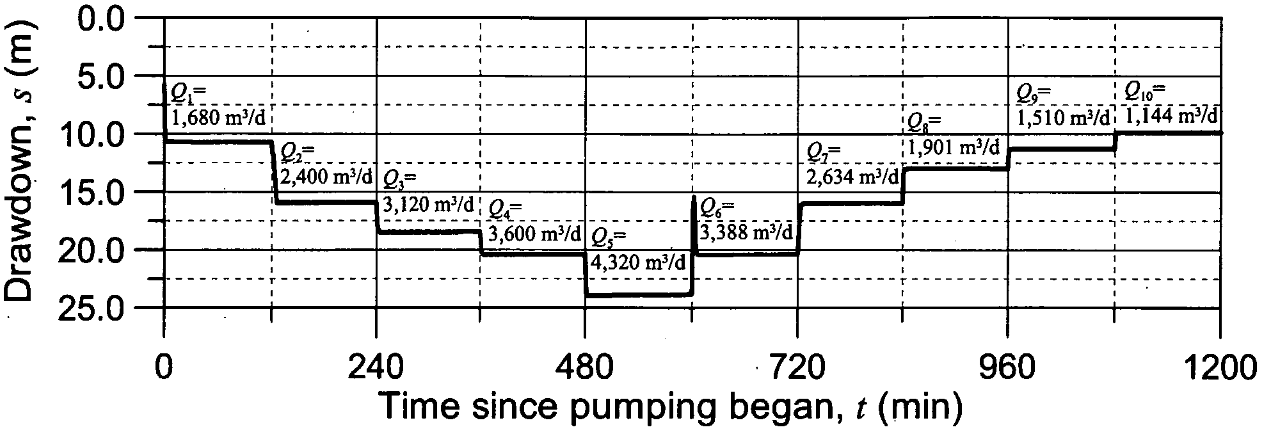
The pH values were relatively higher in the improved deep wells, ranging from 7.4 to 8.0. But the values clearly dropped from September to November, showing almost 7.0. The values again increased in December, being 7.5 to 7.7.

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

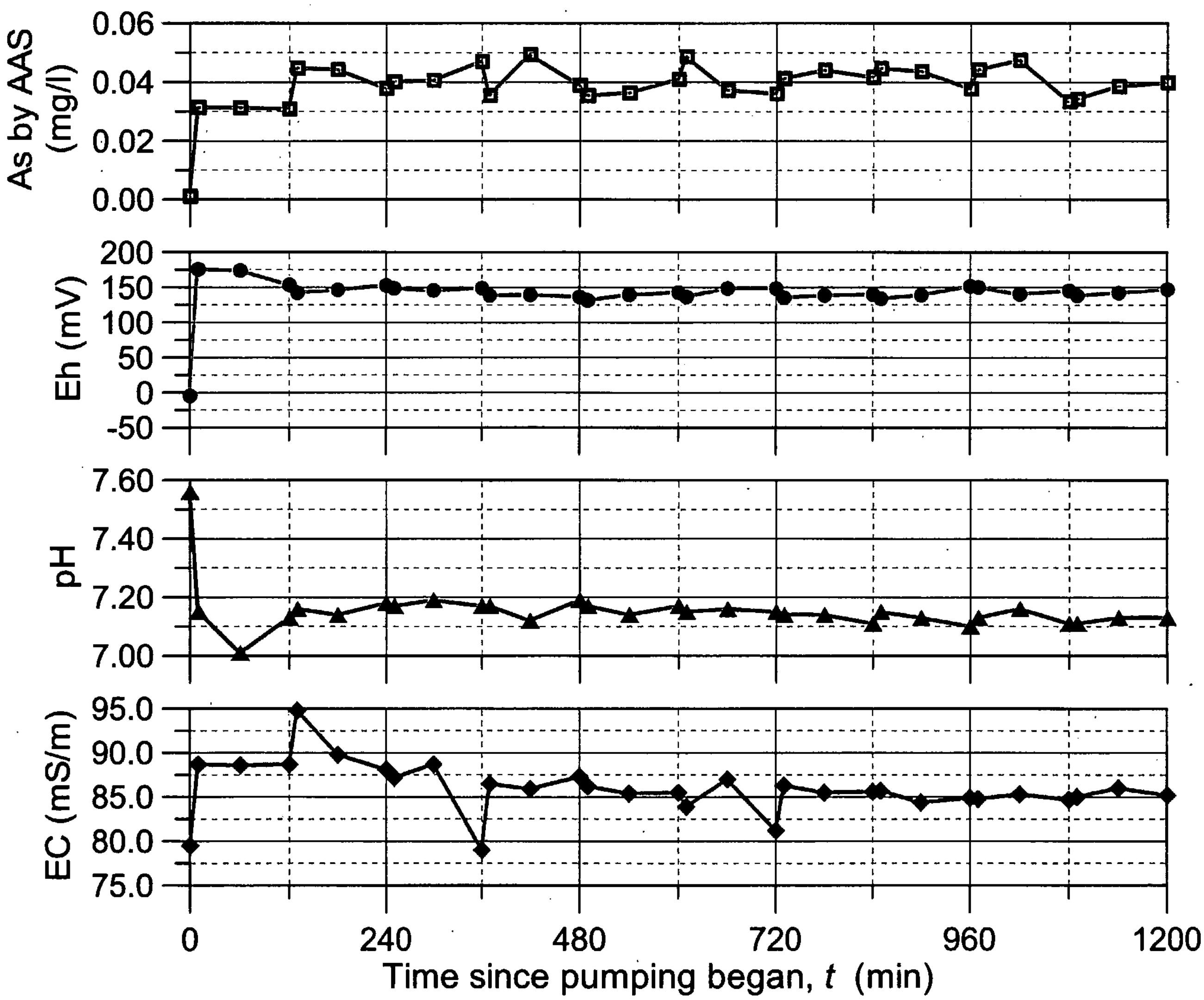
3) Eh-pH-As Relation

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 250 mV. In the domain, the samples contaminated by arsenic were plotted in the area having 6.8 to 7.4 in pH and 70 to 250 mV in Eh.



(a) Drawdown in Pumped Well



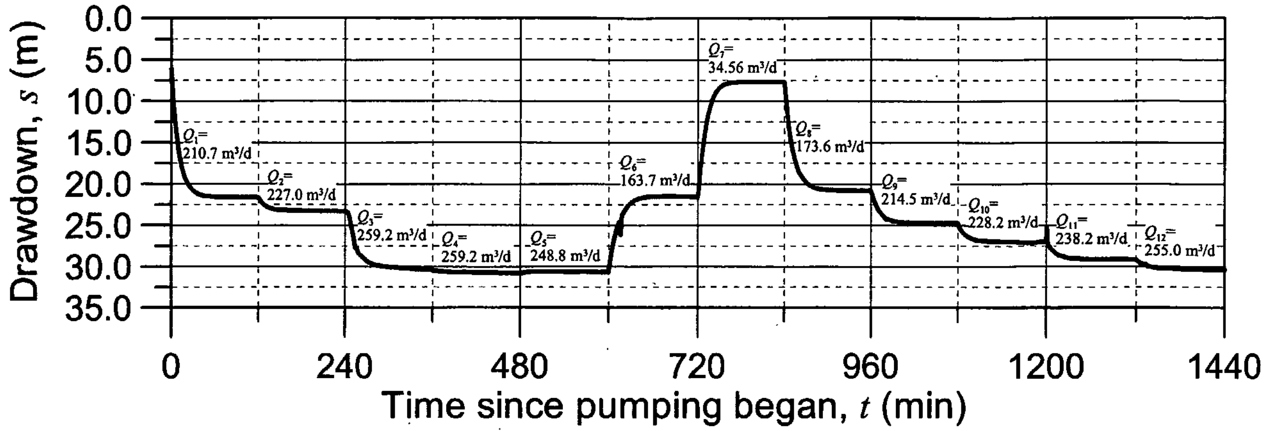
(b) Water Quality of Pumped Water

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

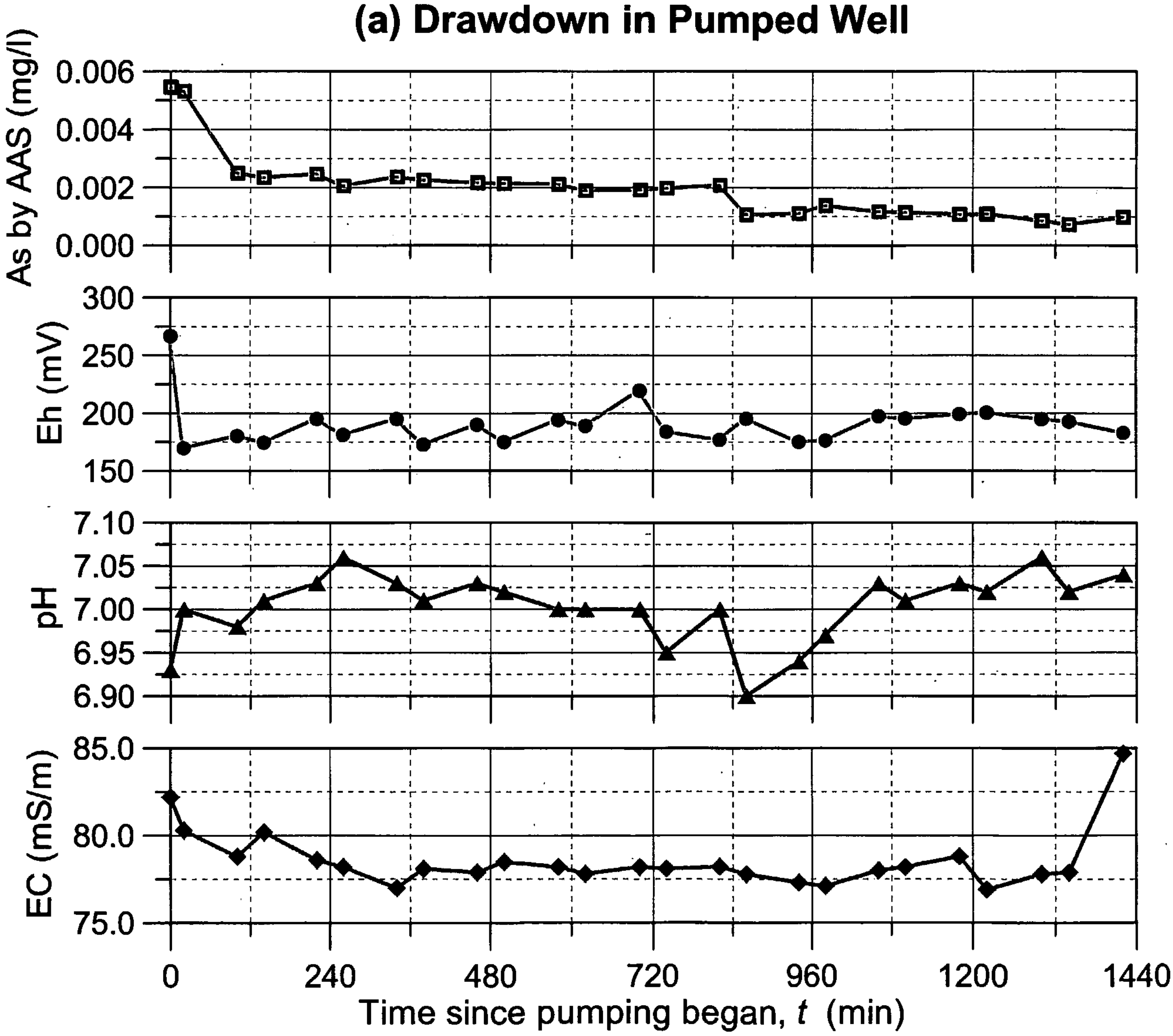
Figure 5.4.1 **Changes in Water Quality during Step-Drawdown Test at CH-1 Site, Chuadanga**

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



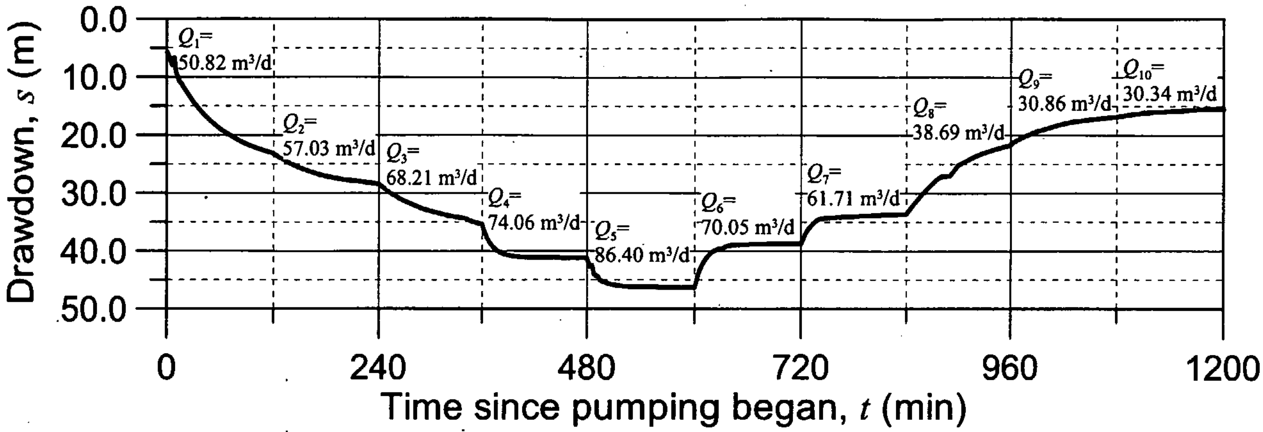
(b) Water Quality of Pumped Water

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

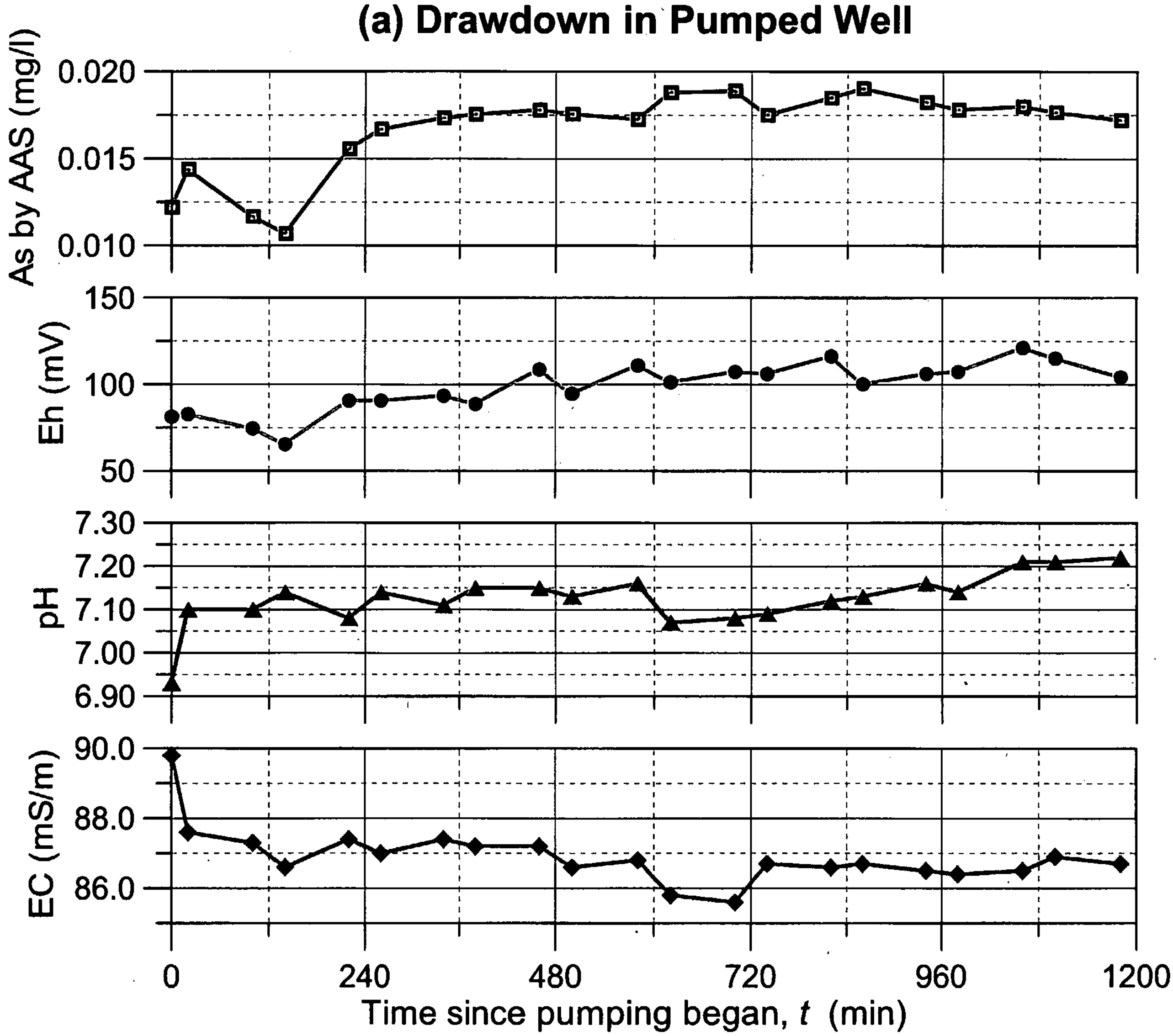
Figure 5.4.2 **Changes in Water Quality during Step-Drawdown Test at CH-2 Site, Chuadanga**

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



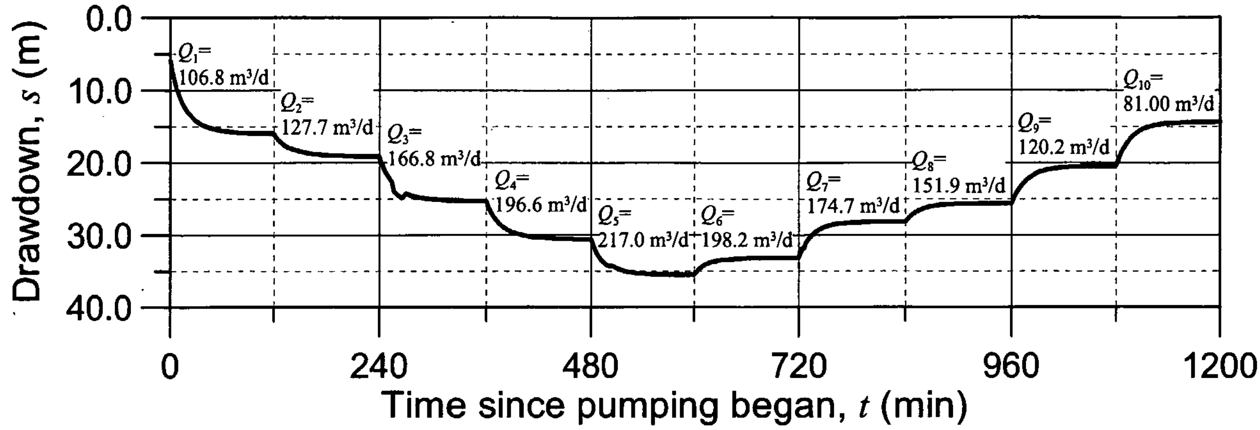
(b) Water Quality of Pumped Water

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

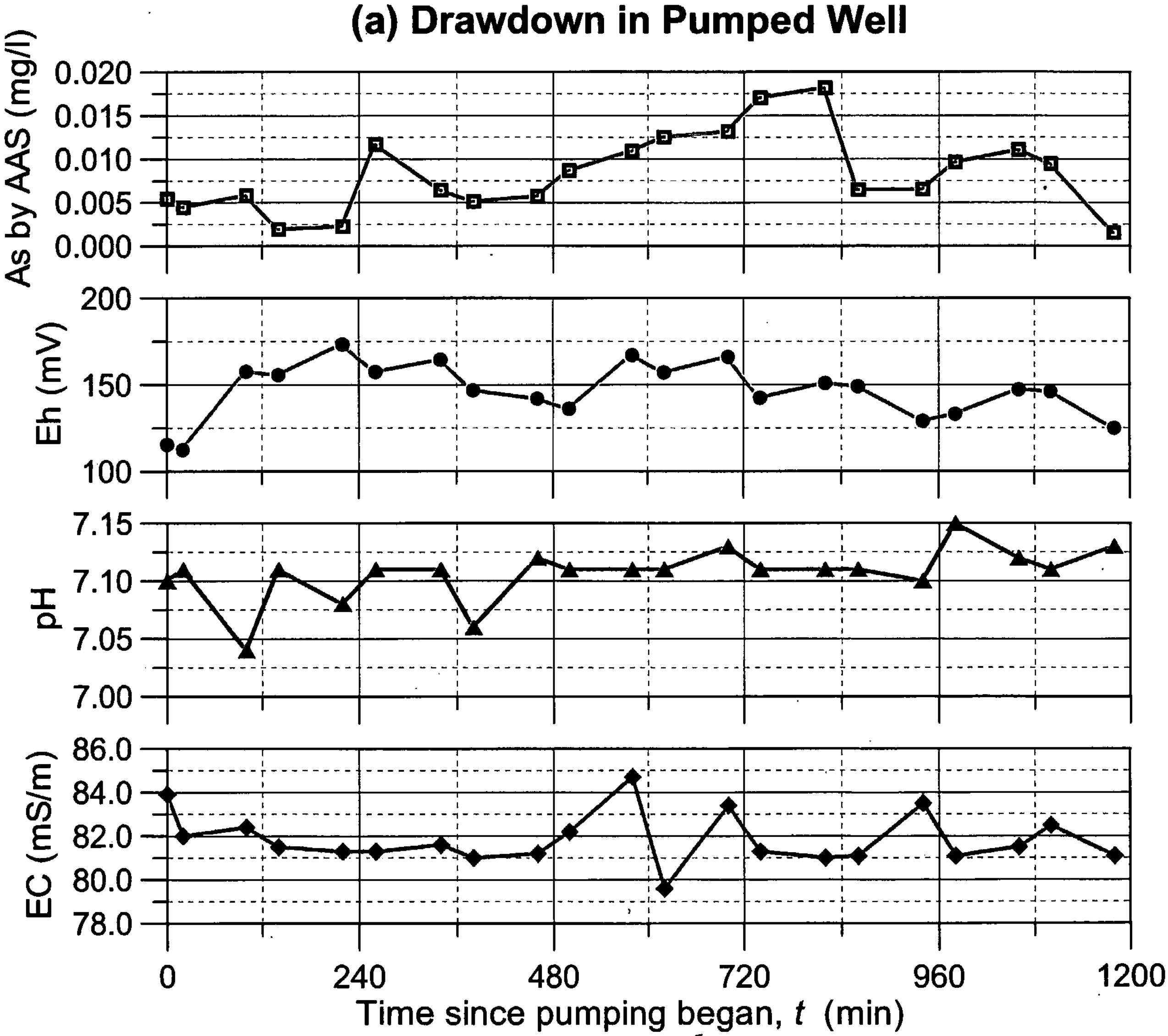
Figure 5.4.3 **Changes in Water Quality during Step-Drawdown Test at JH-1 Site, Jhenaidah**

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



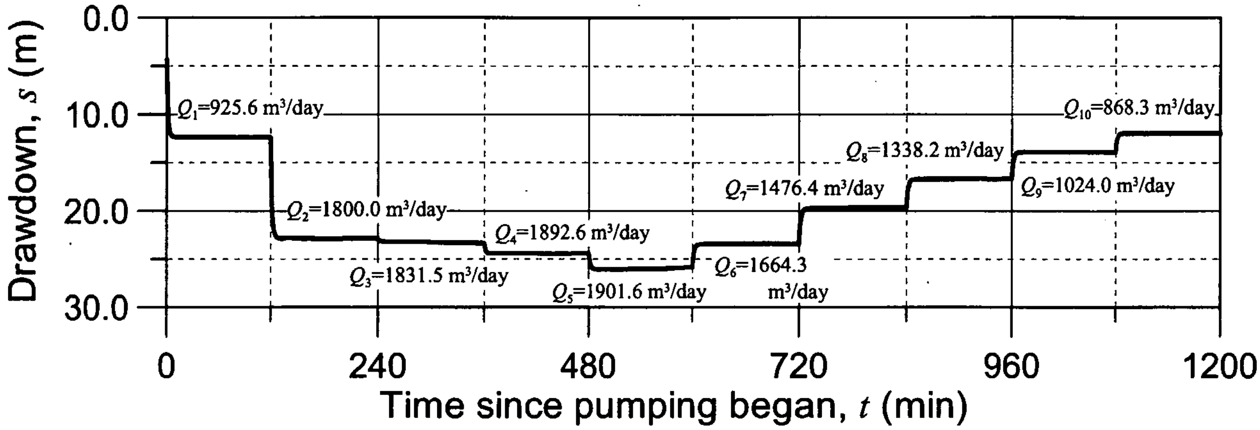
(b) Water Quality of Pumped Water

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

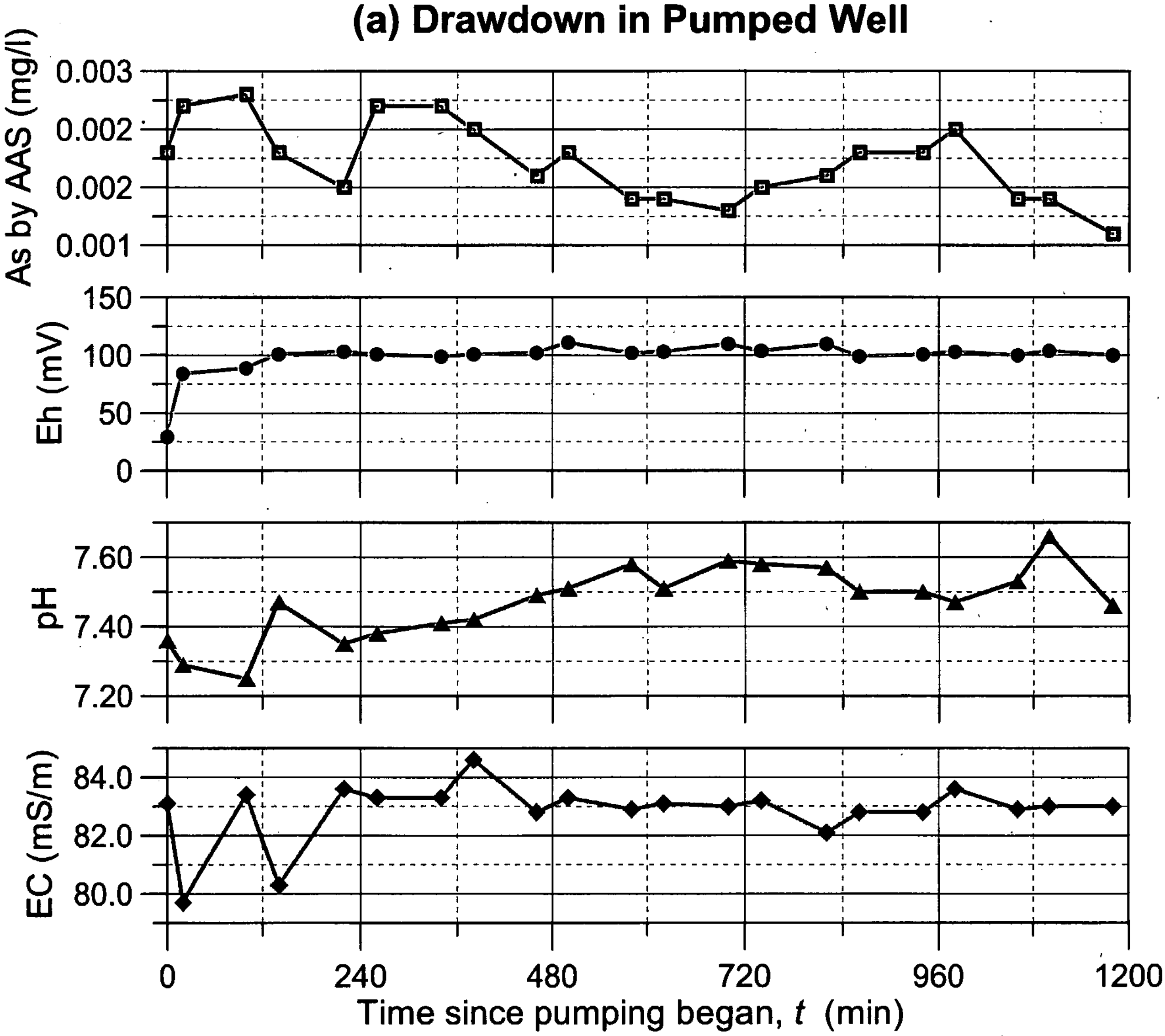
Figure 5.4.4 | **Changes in Water Quality during Step-Drawdown Test at JH-2 Site, Jhenaidah**

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



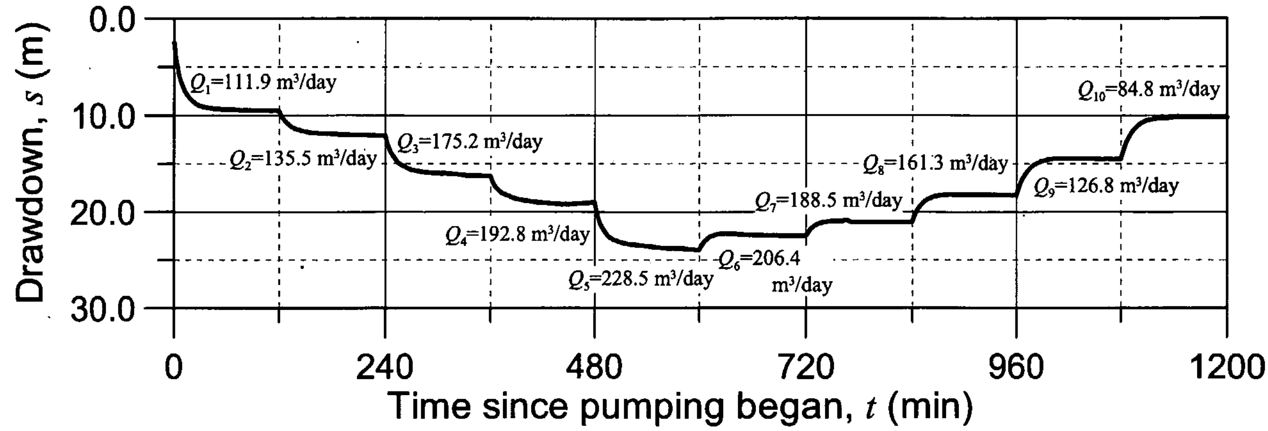
(b) Water Quality of Pumped Water

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

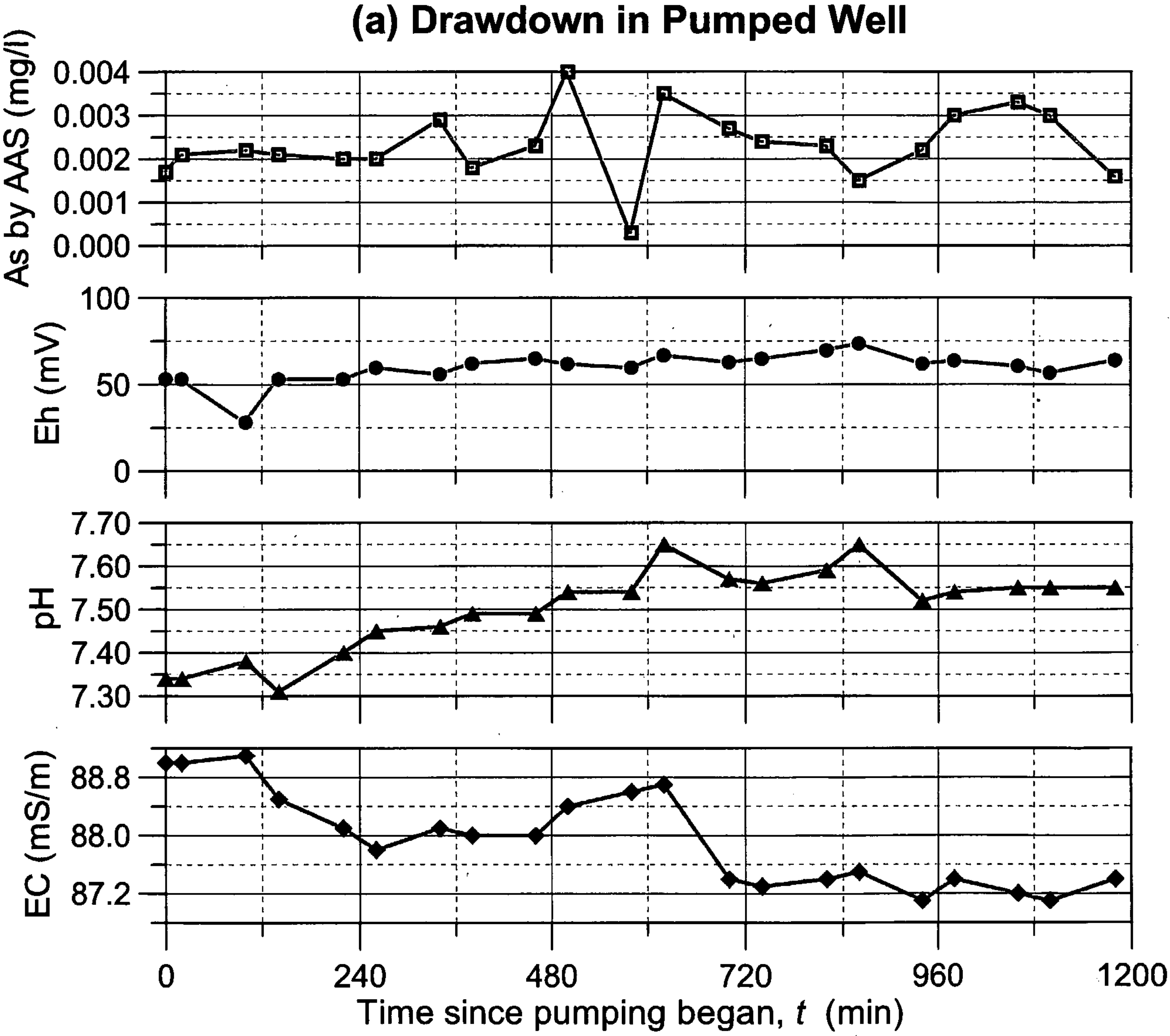
Figure 5.4.5 **Changes in Water Quality during Step-Drawdown Test at JS-1 Site, Jessore**

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



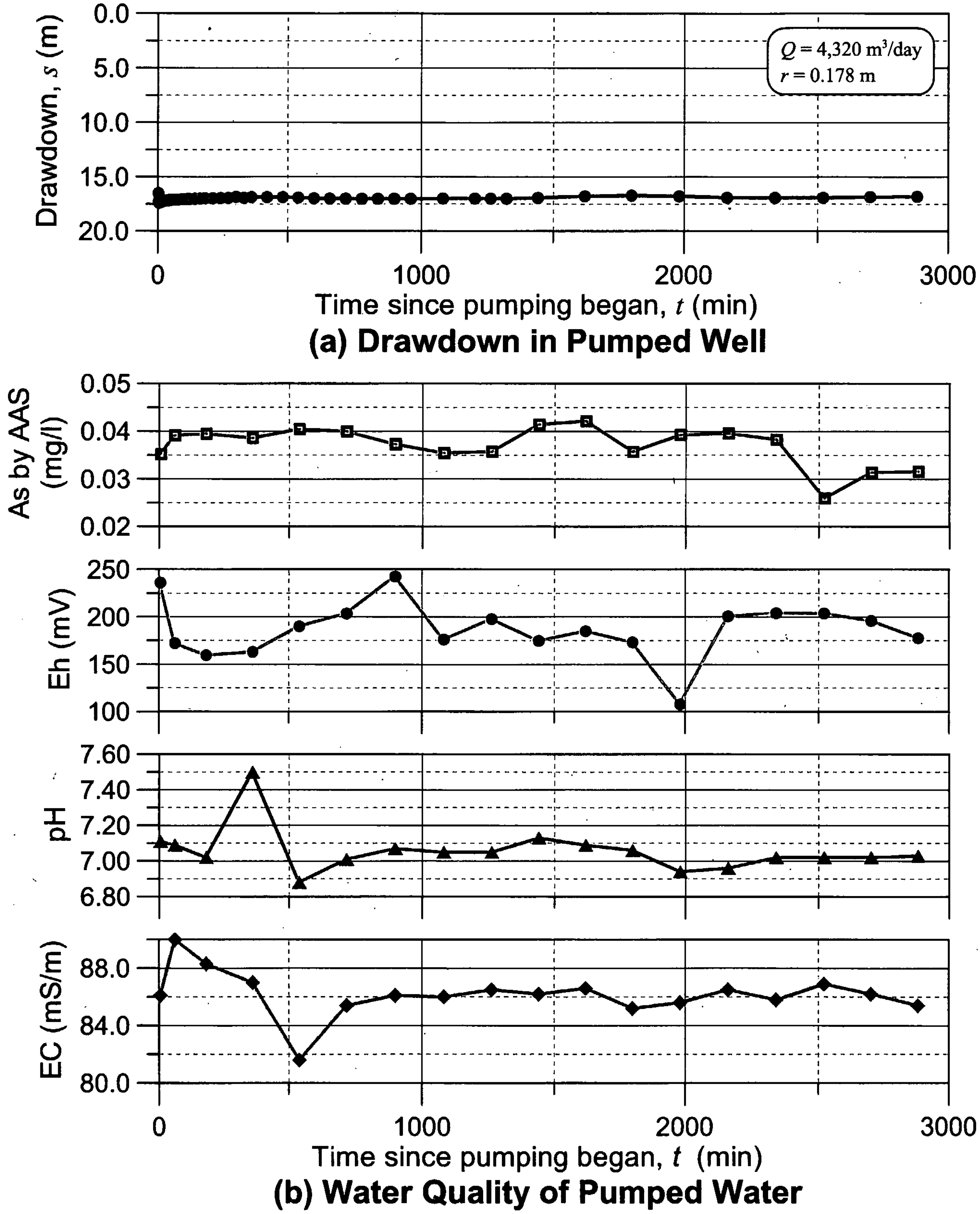
(b) Water Quality of Pumped Water

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)

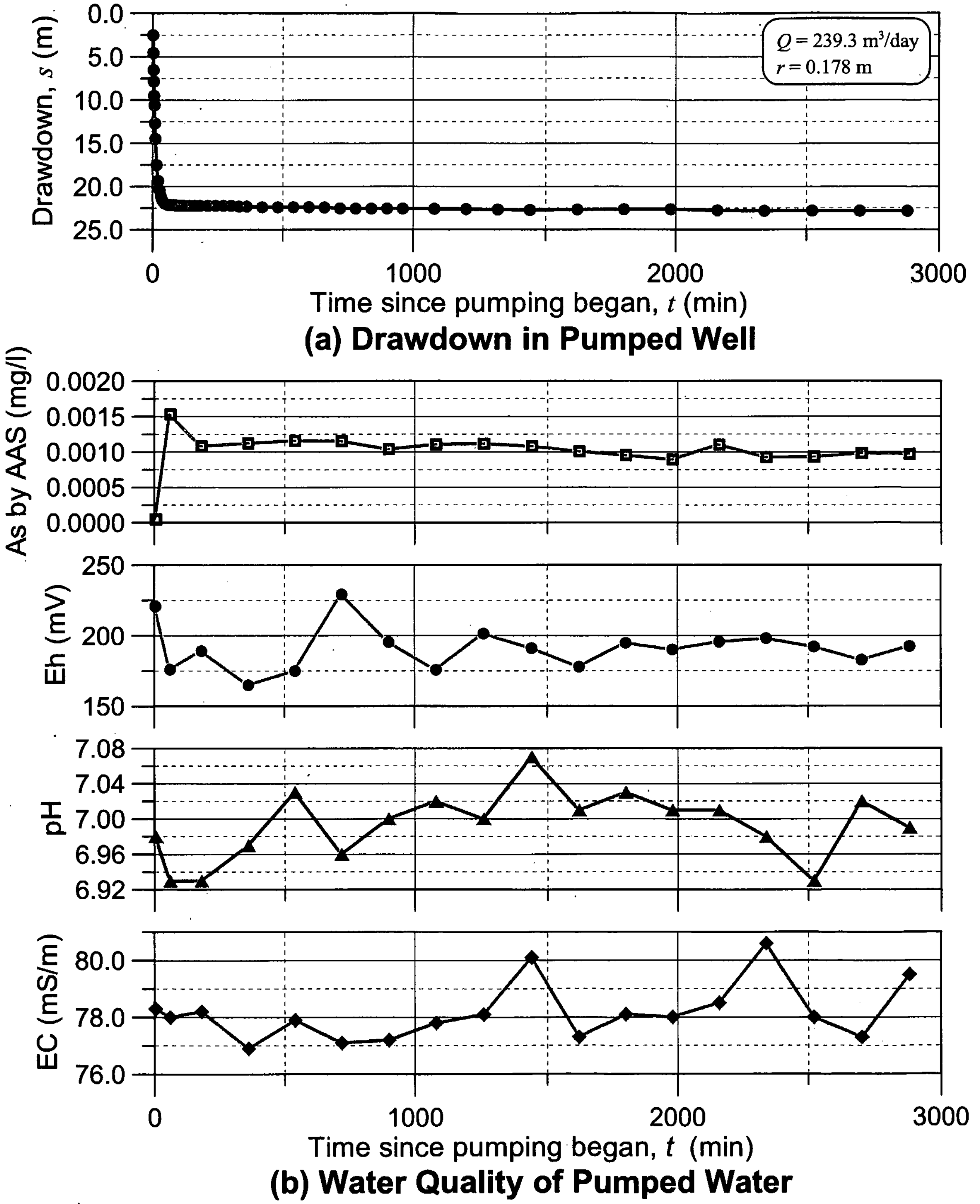


Location:	Poshu Hat, Chuadanga Pourashava
Site No.:	CH-1
Well No.:	Ch-1
Well Depth:	274 m
Well Diameter:	355.60 mm
Screen Depths:	212.5-268.0 m
Screen Length:	19.5 m
SWL:	GL- 5.985 m on 22-02-2001

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)

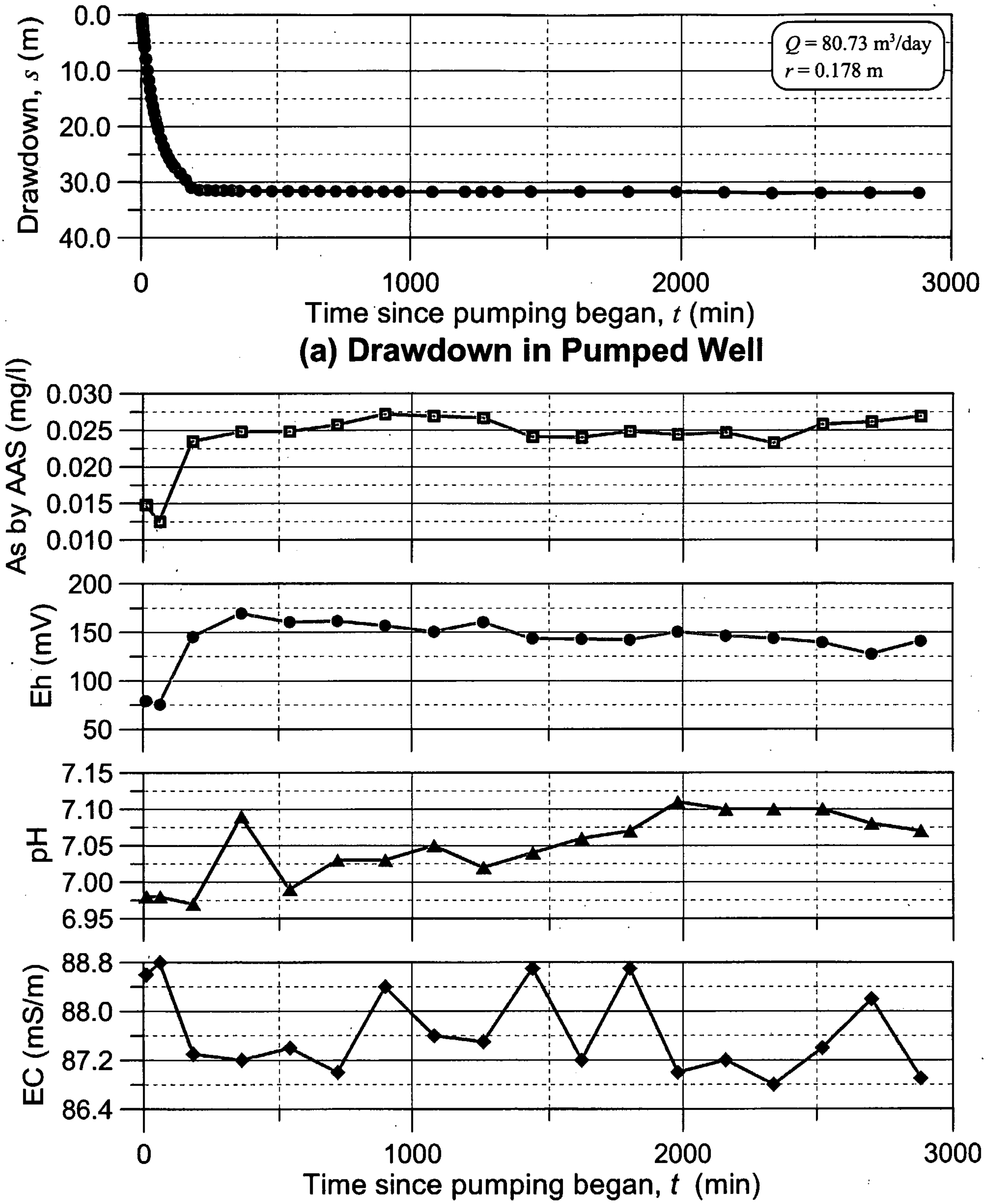


Location:	Girls College, Chuadanga Pourashava
Site No.:	CH-2
Well No.:	Ch-2
Well Depth:	298.5 m
Well Diameter:	355.60 mm
Screen Depths:	270-283, 289-295.5 m
Screen Length:	19.5 m
SWL:	GL- 6.012 m on 19-03-2001

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)



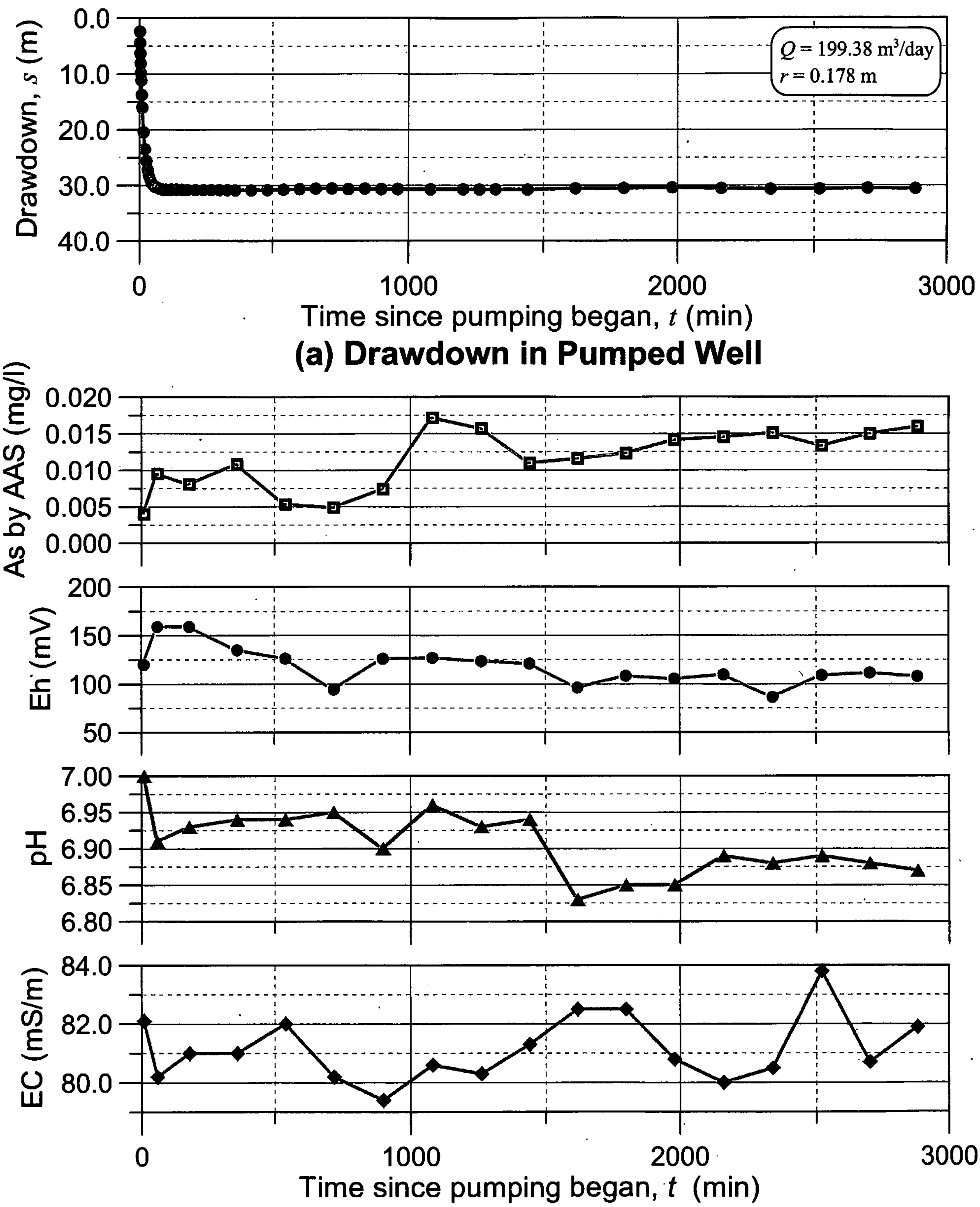
(b) Water Quality of Pumped Water

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)



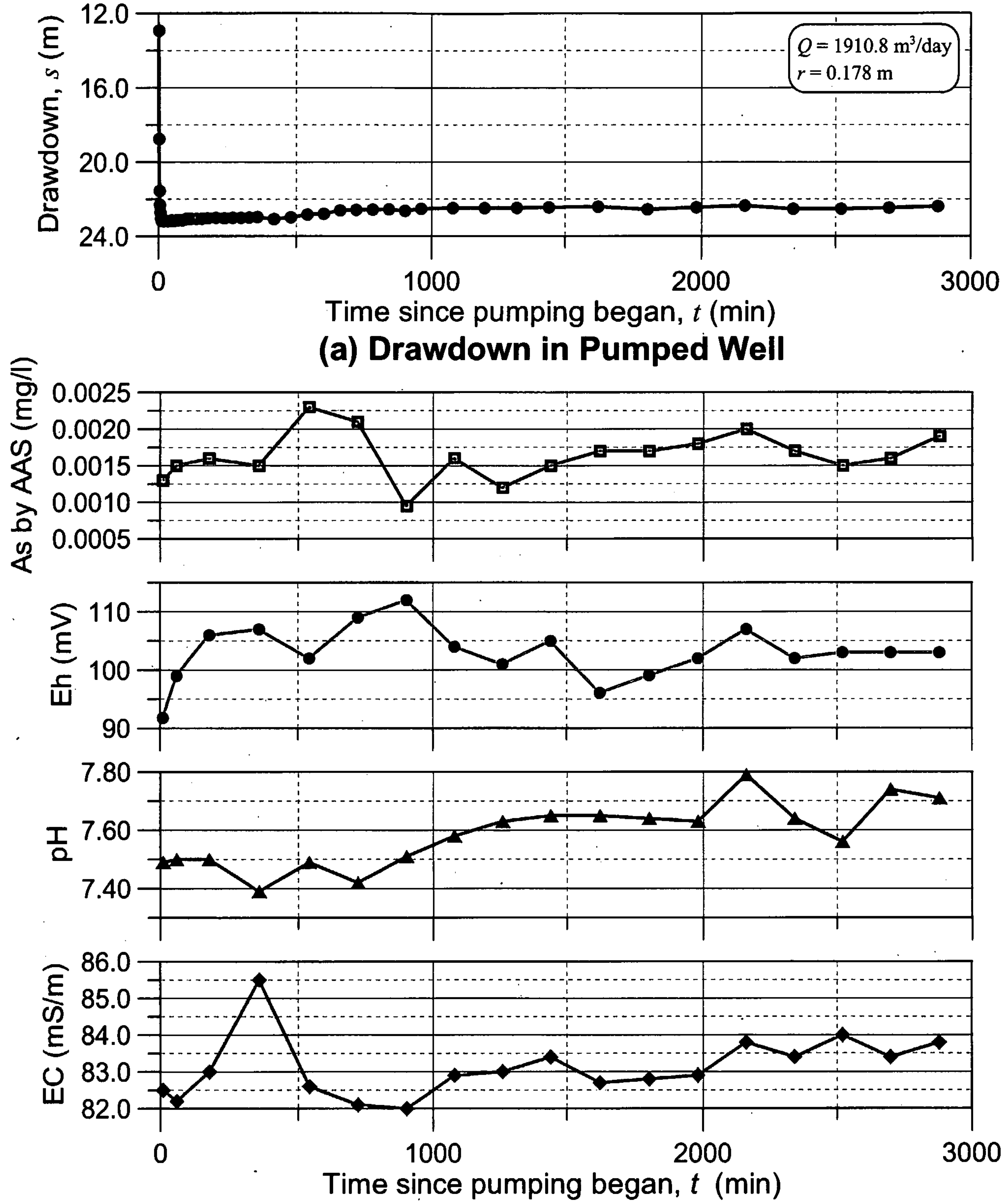
(b) Water Quality of Pumped Water

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)



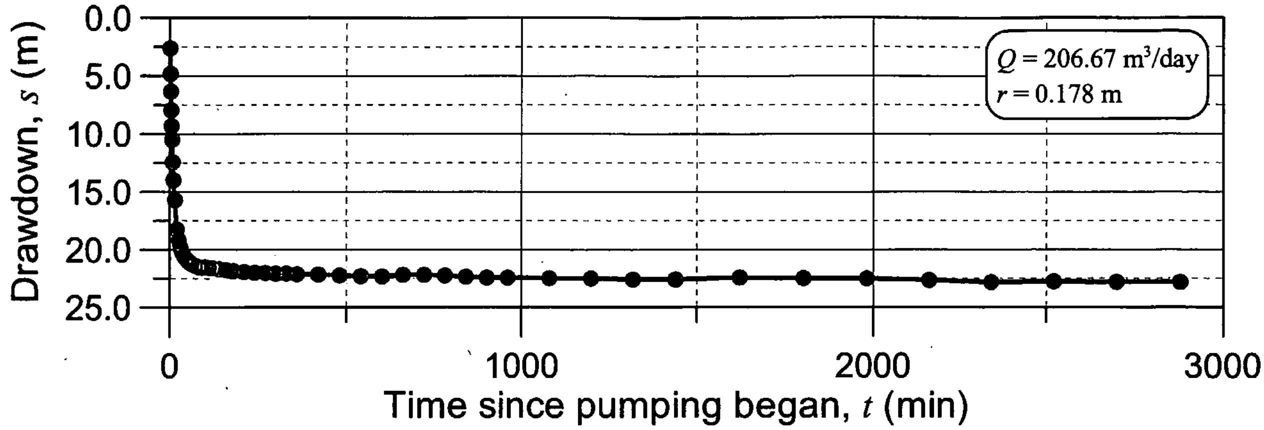
(b) Water Quality of Pumped Water

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

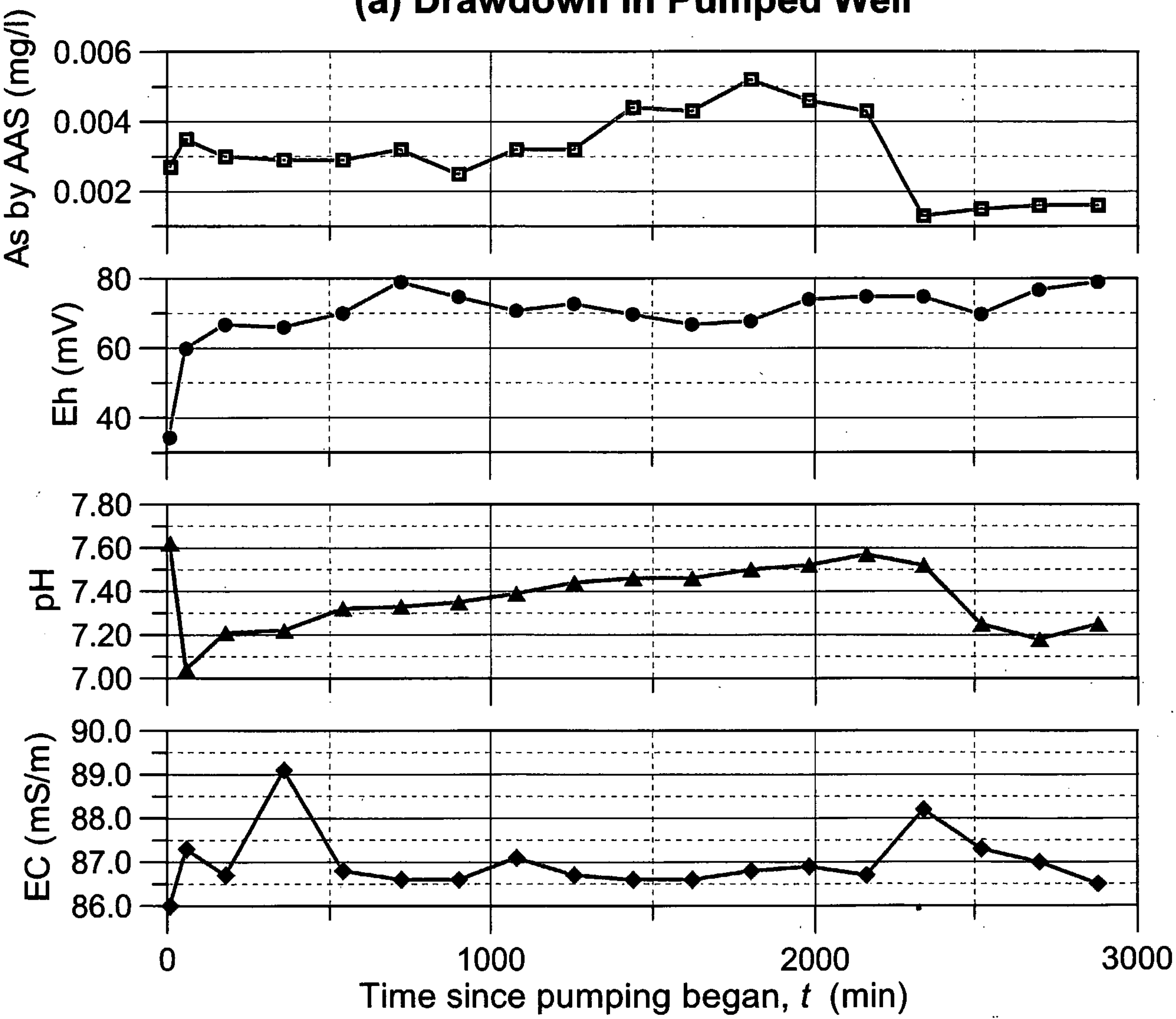
Figure 5.4.11 **Changes in Water Quality during Continuous Pumping Test at JS-1 Site, Jessore**

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)

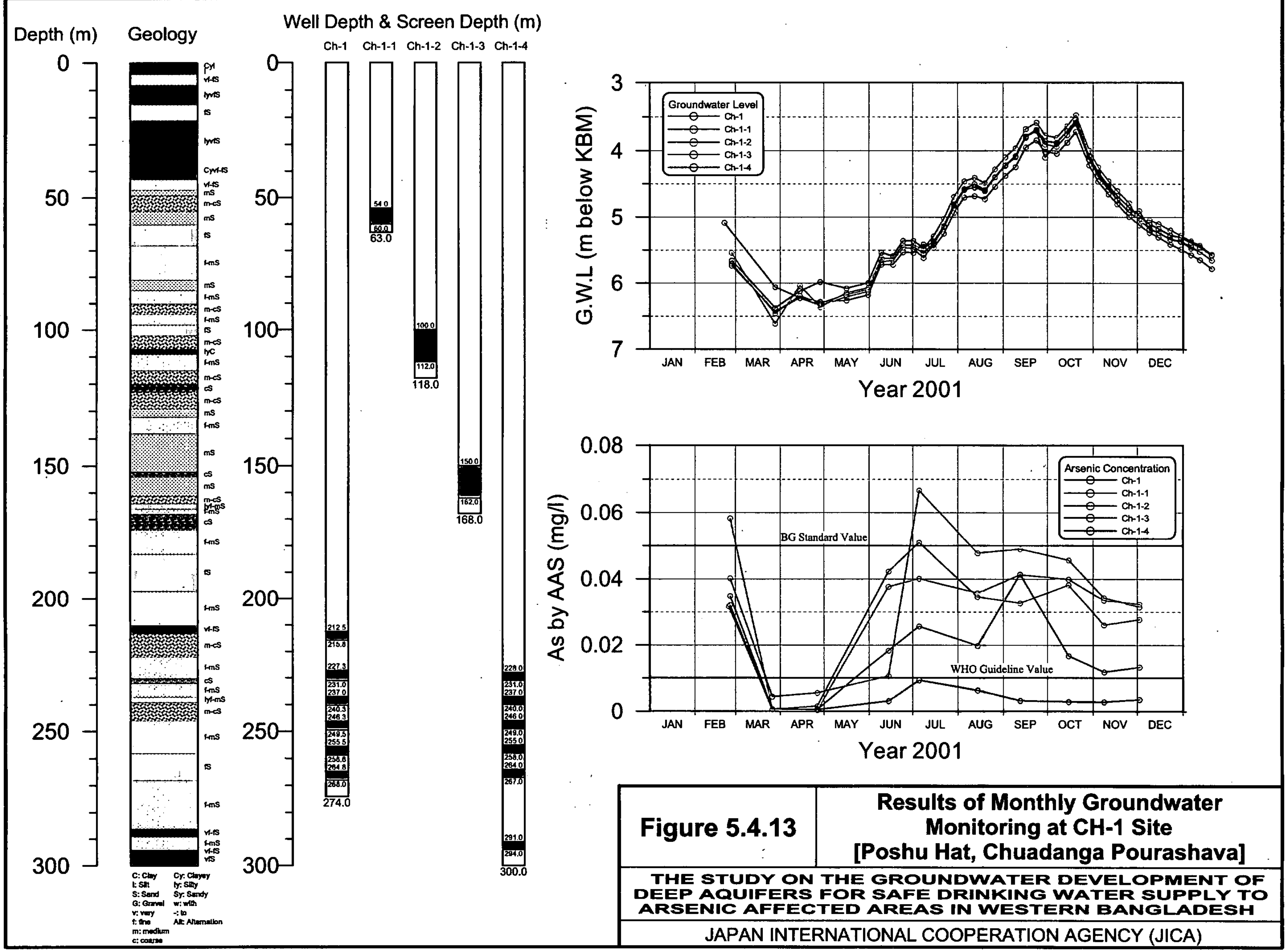
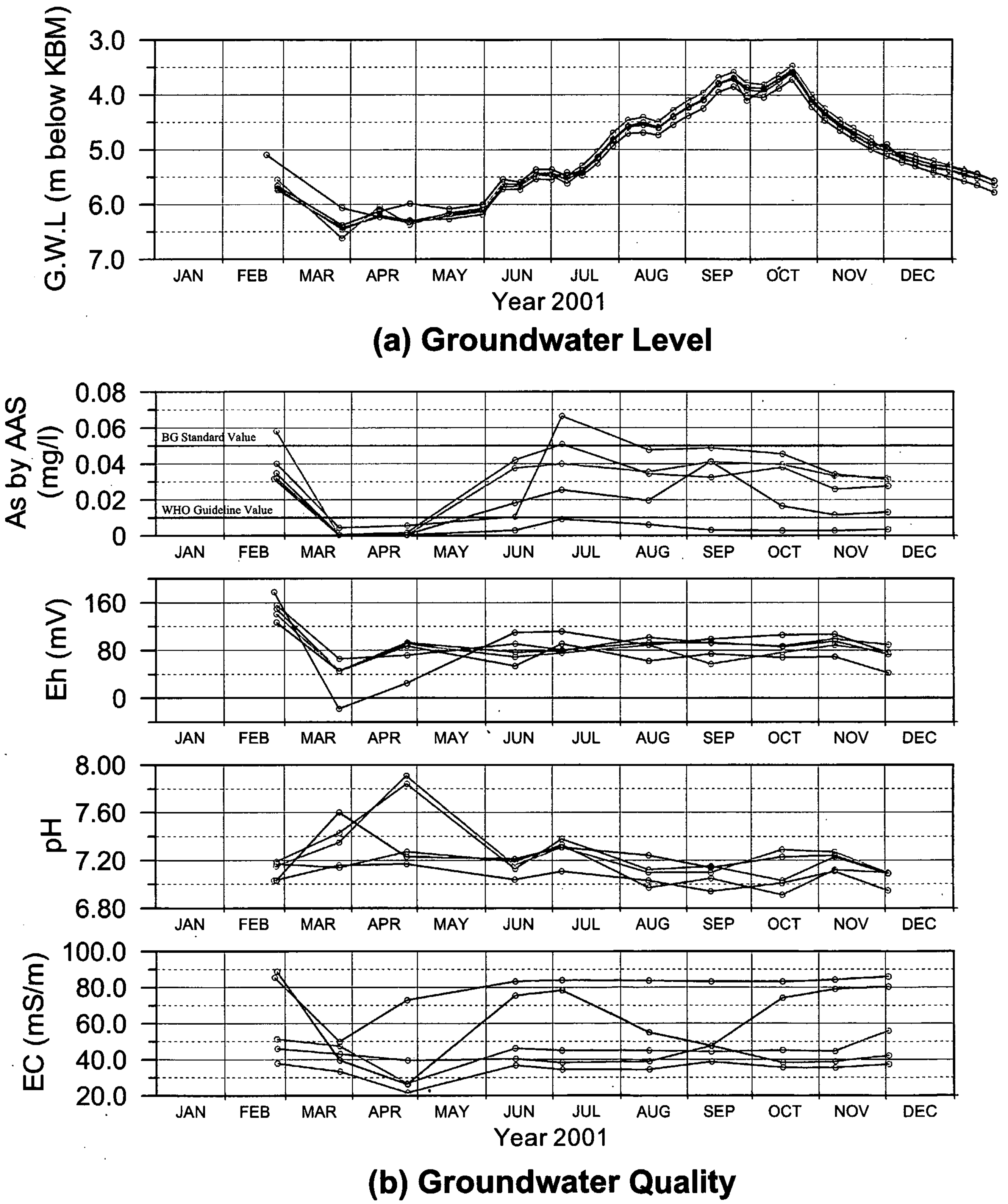


Figure 5.4.13	Results of Monthly Groundwater Monitoring at CH-1 Site [Poshu Hat, Chuadanga Pourashava]

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)



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)

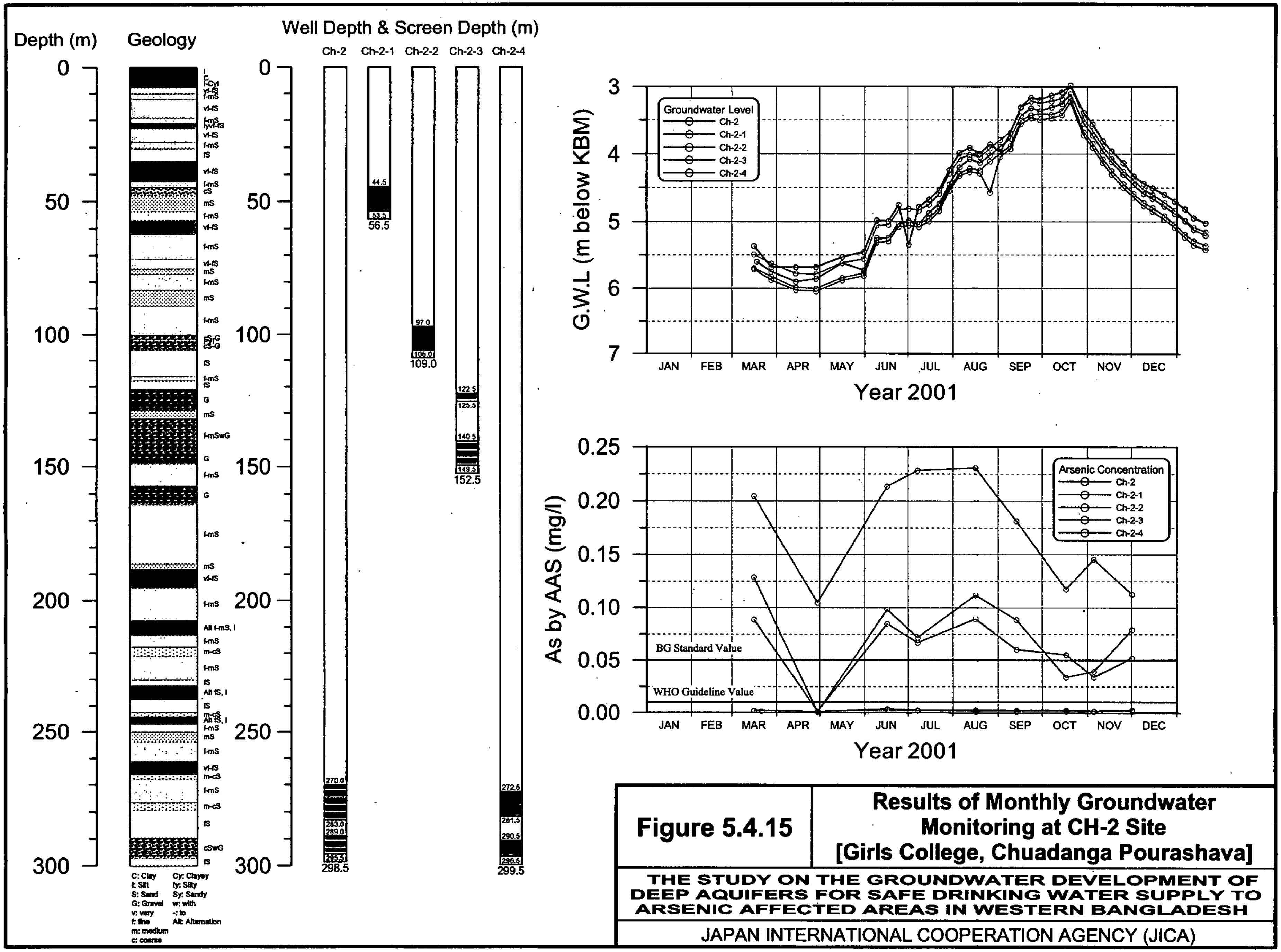
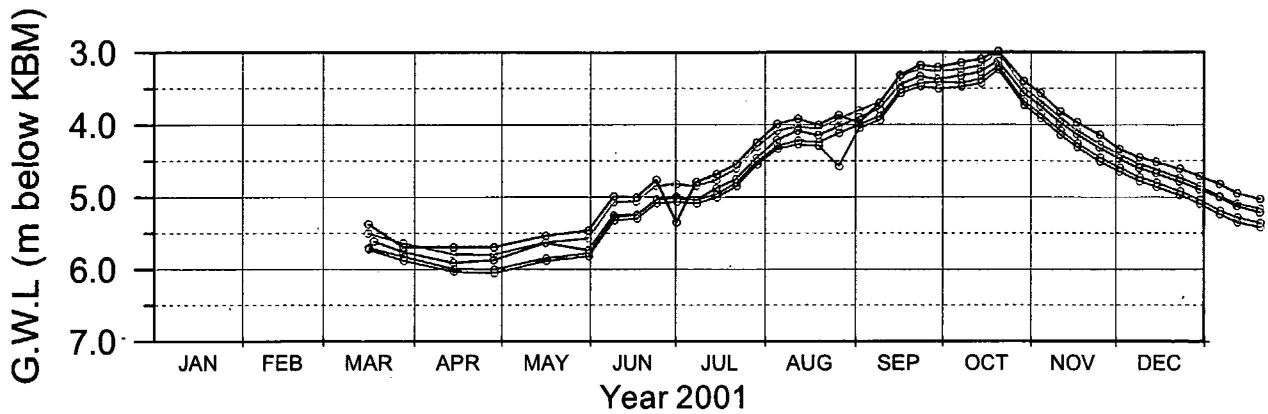


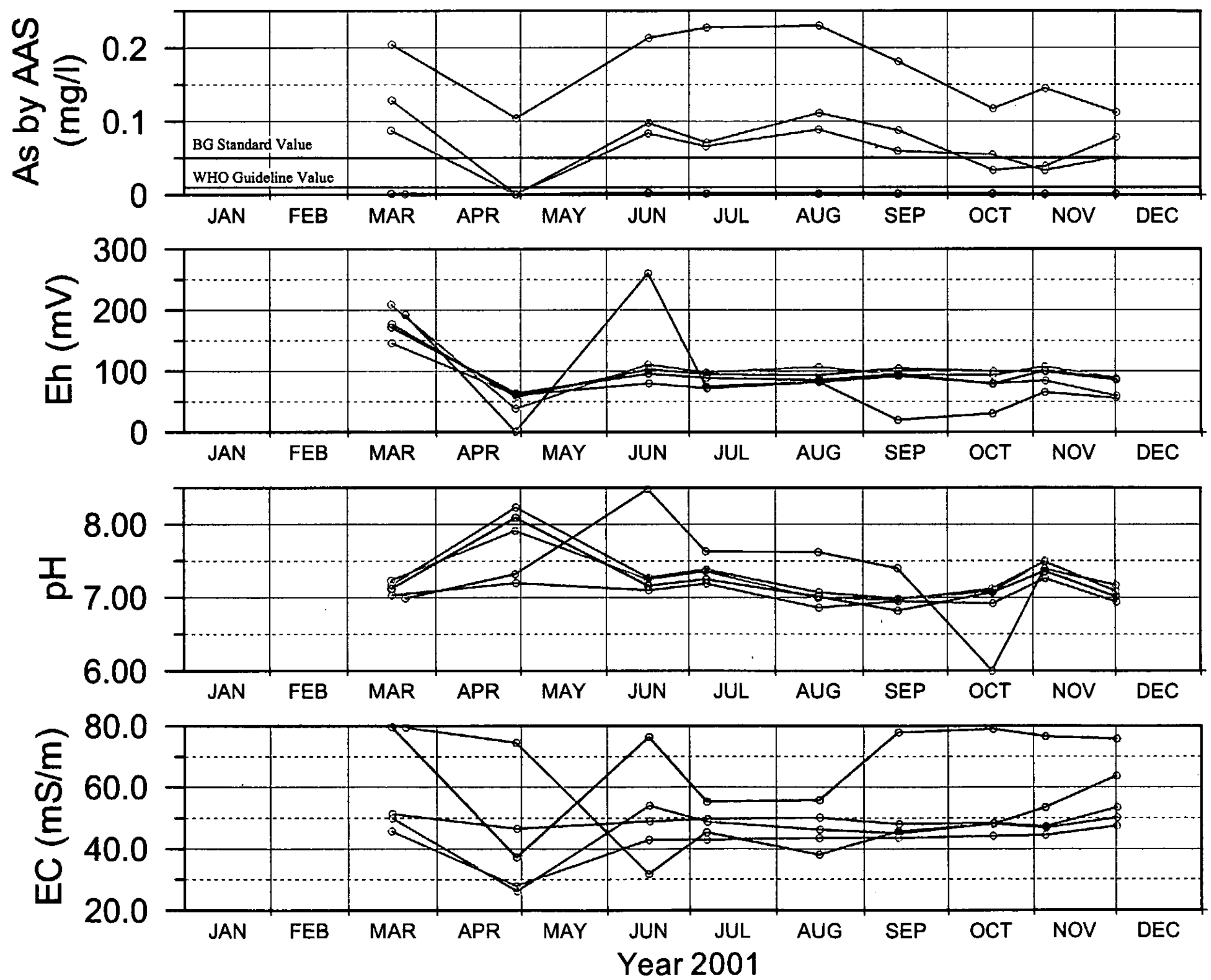
Figure 5.4.15	Results of Monthly Groundwater Monitoring at CH-2 Site [Girls College, Chuadanga Pourashava]

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)

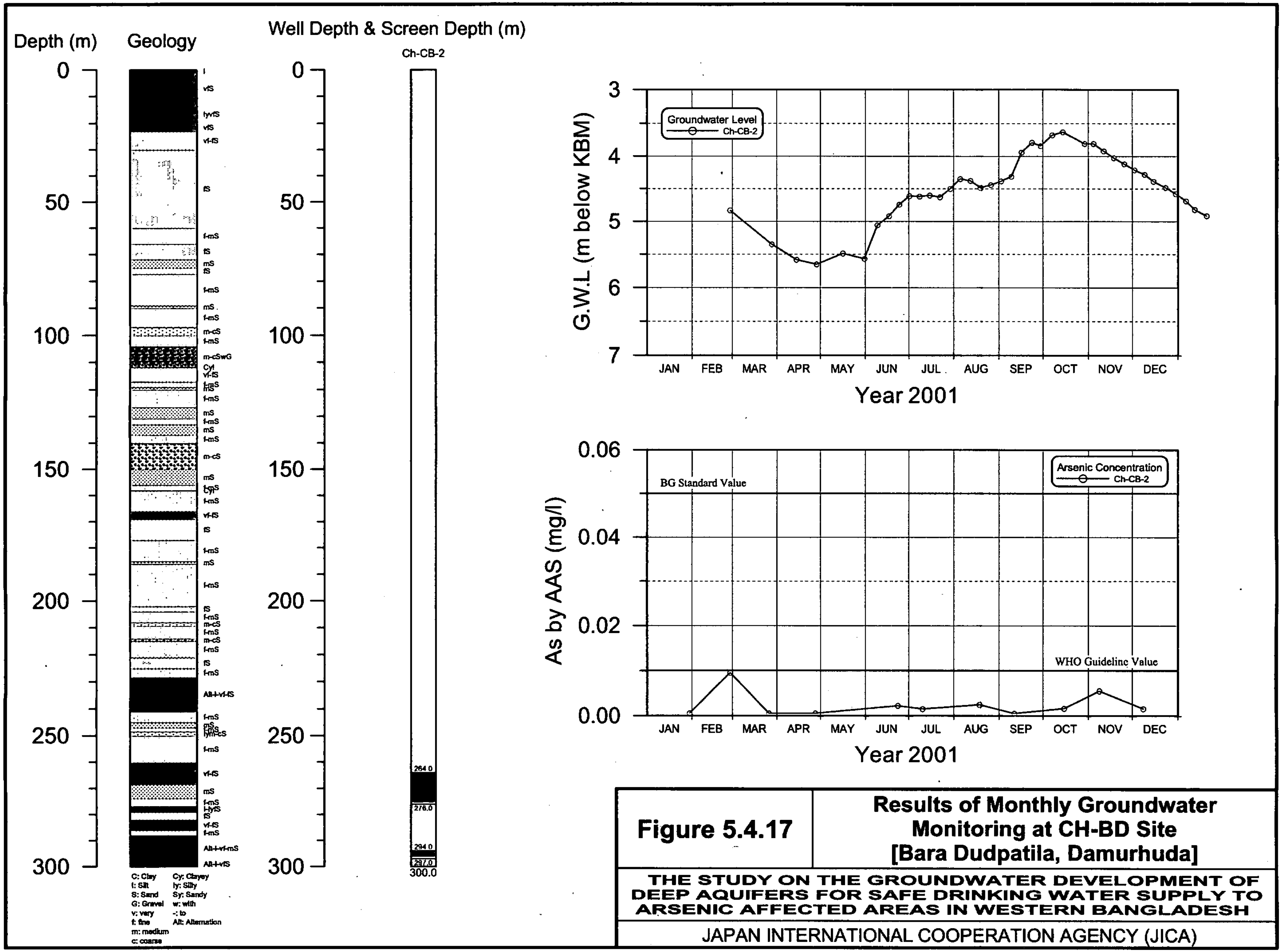
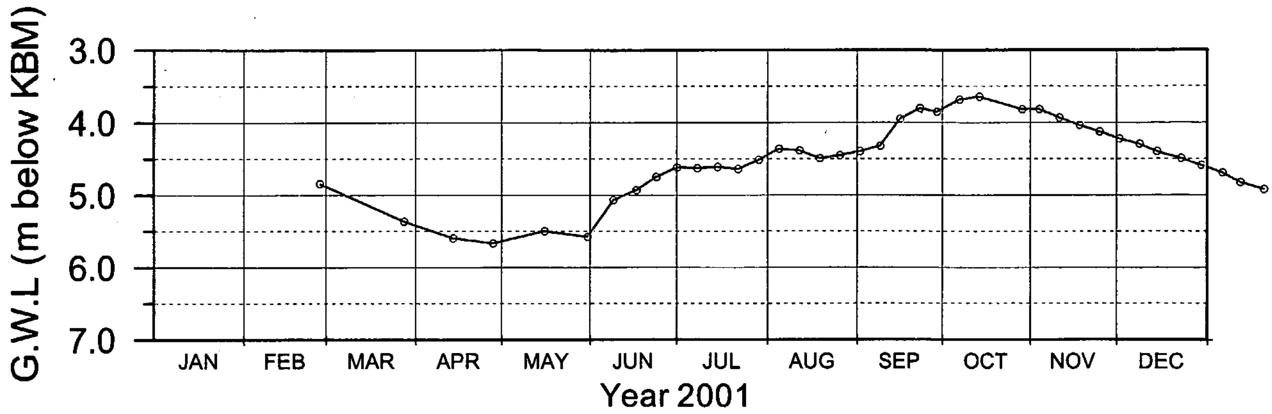


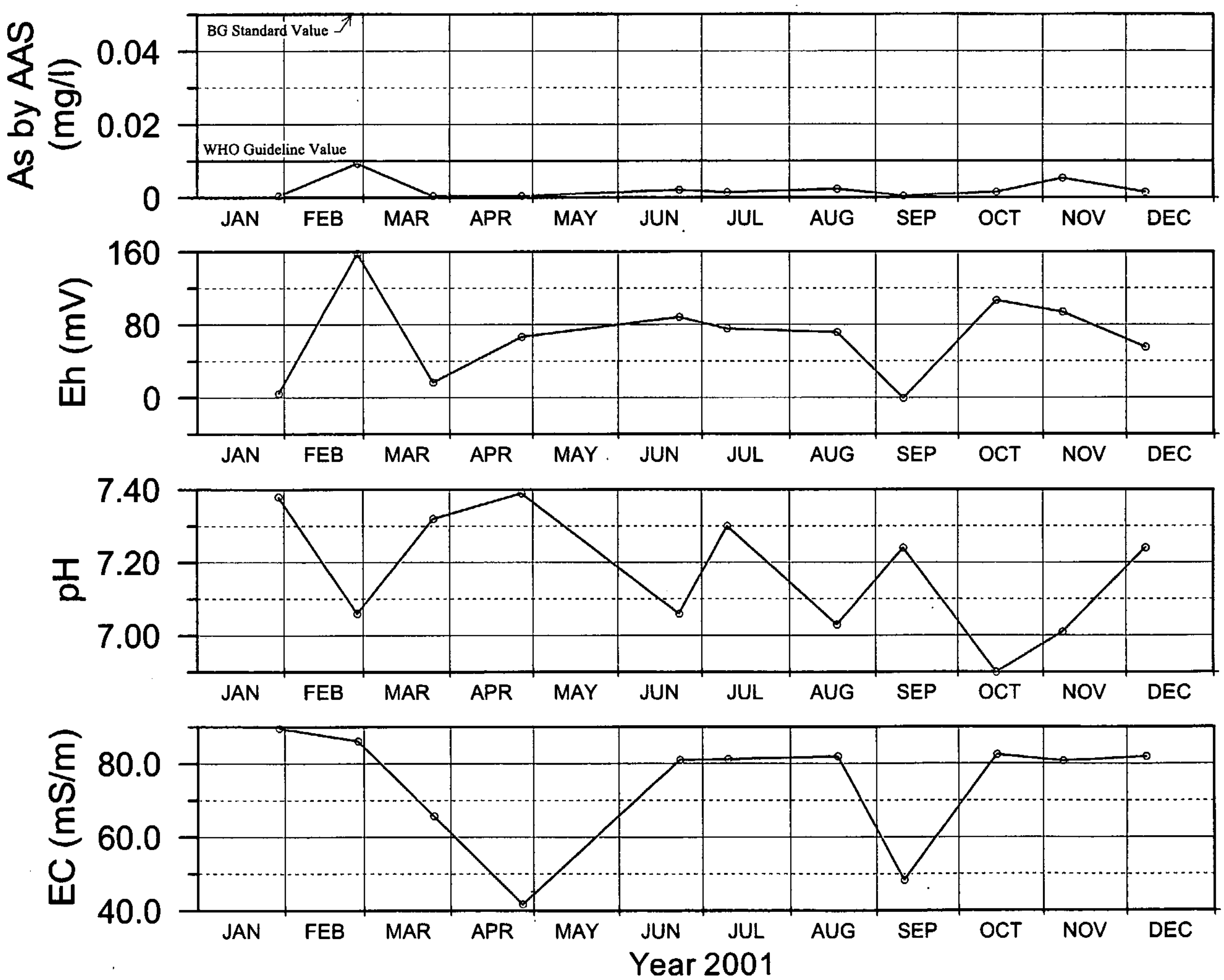
Figure 5.4.17	Results of Monthly Groundwater Monitoring at CH-BD Site [Bara Dudpatila, Damurhuda]

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)

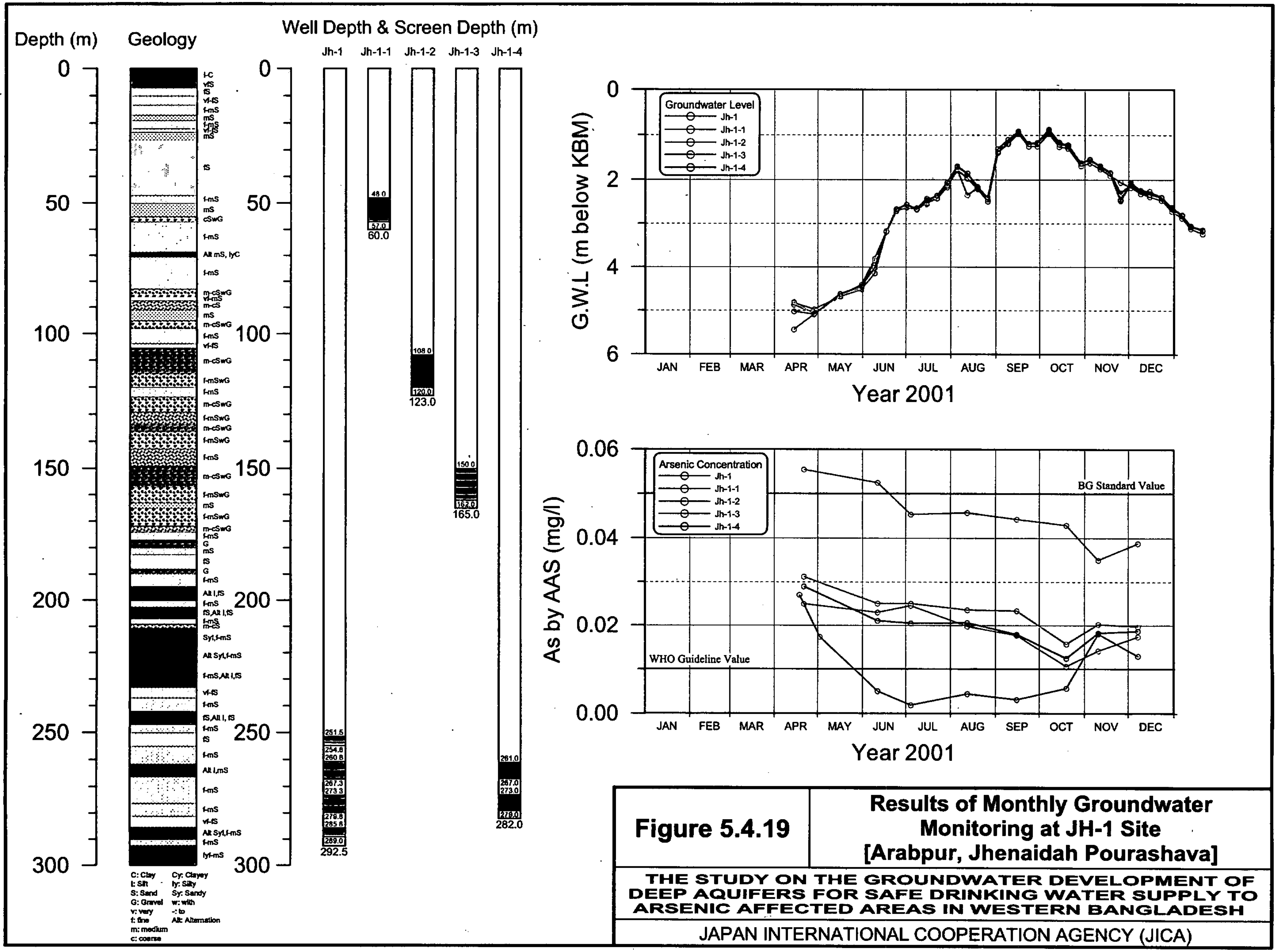
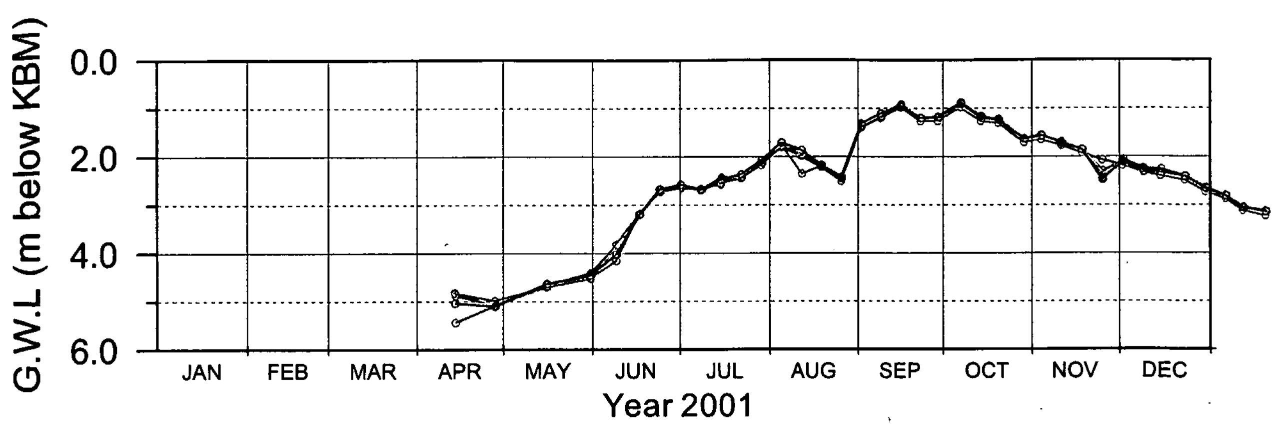


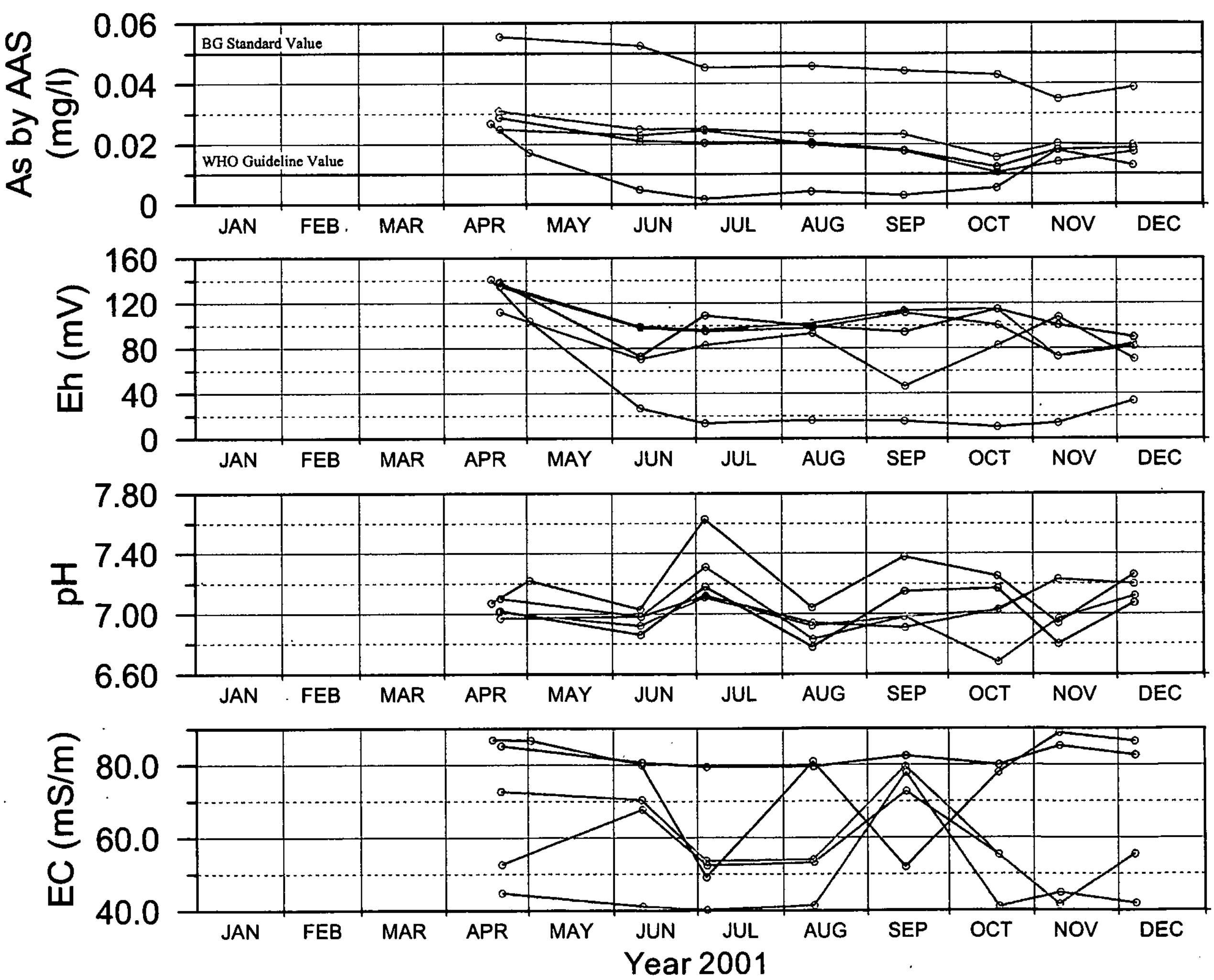
Figure 5.4.19	Results of Monthly Groundwater Monitoring at JH-1 Site [Arabpur, Jhenaidah Pourashava]

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)

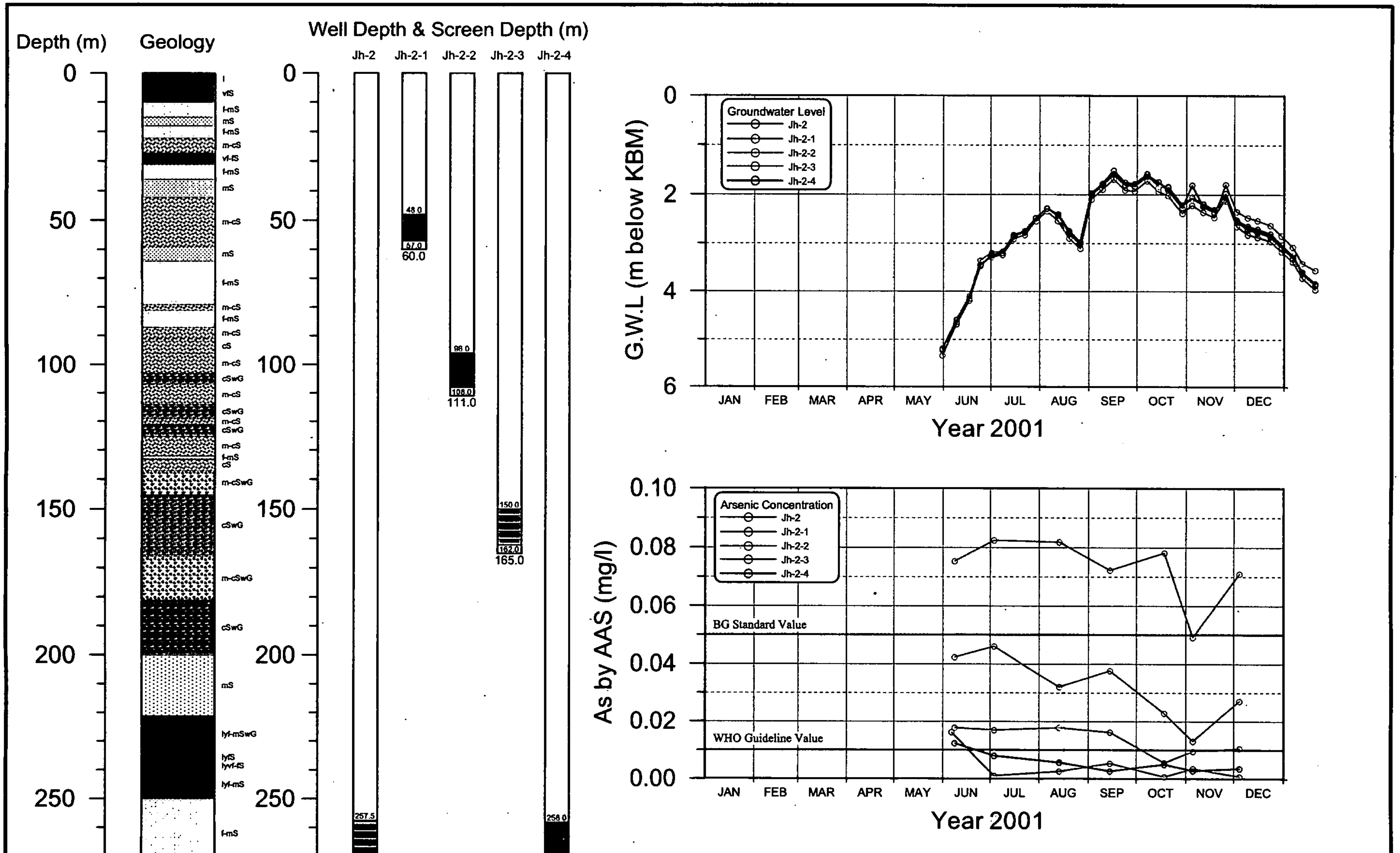
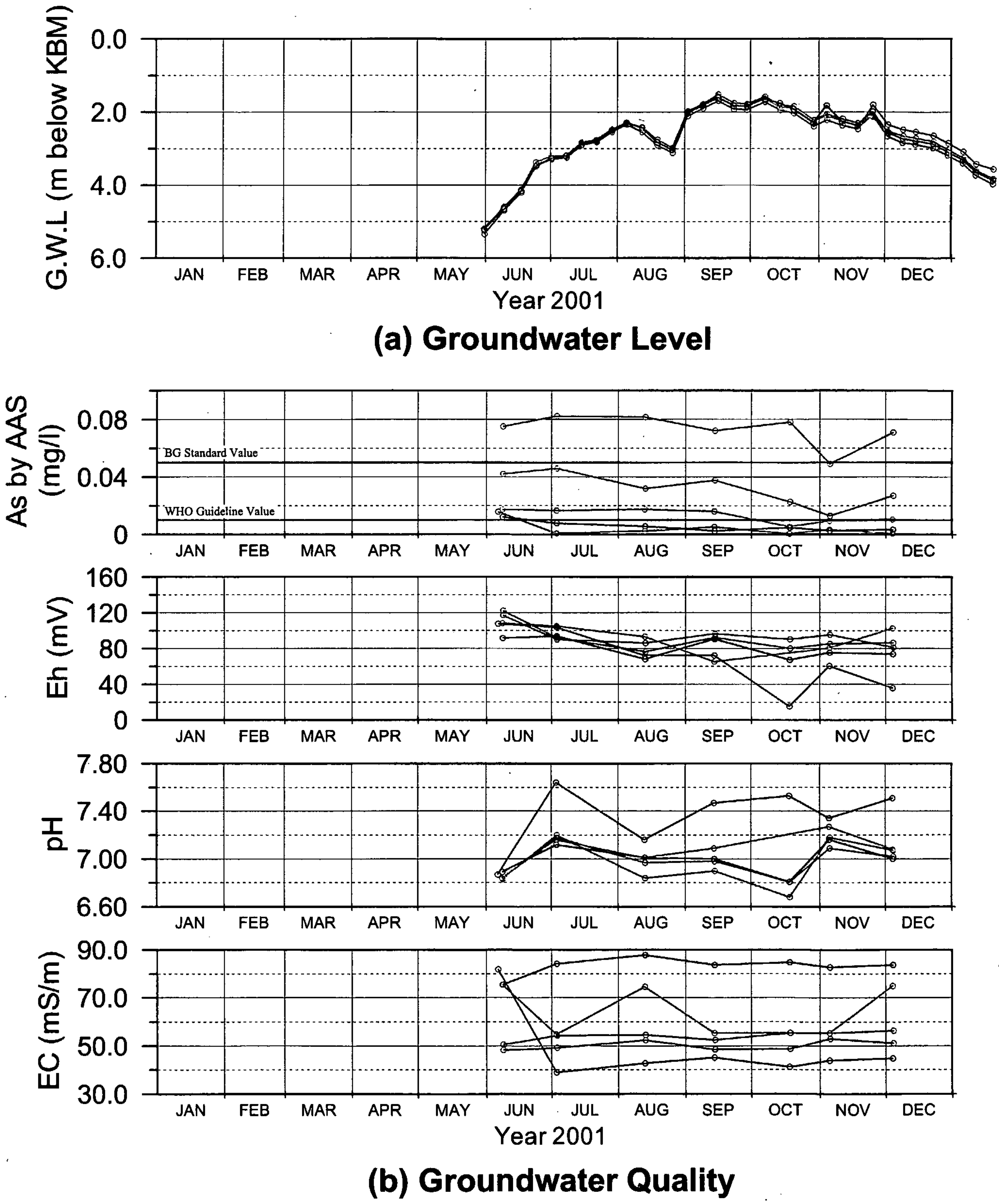


Figure 5.4.21

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)



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)

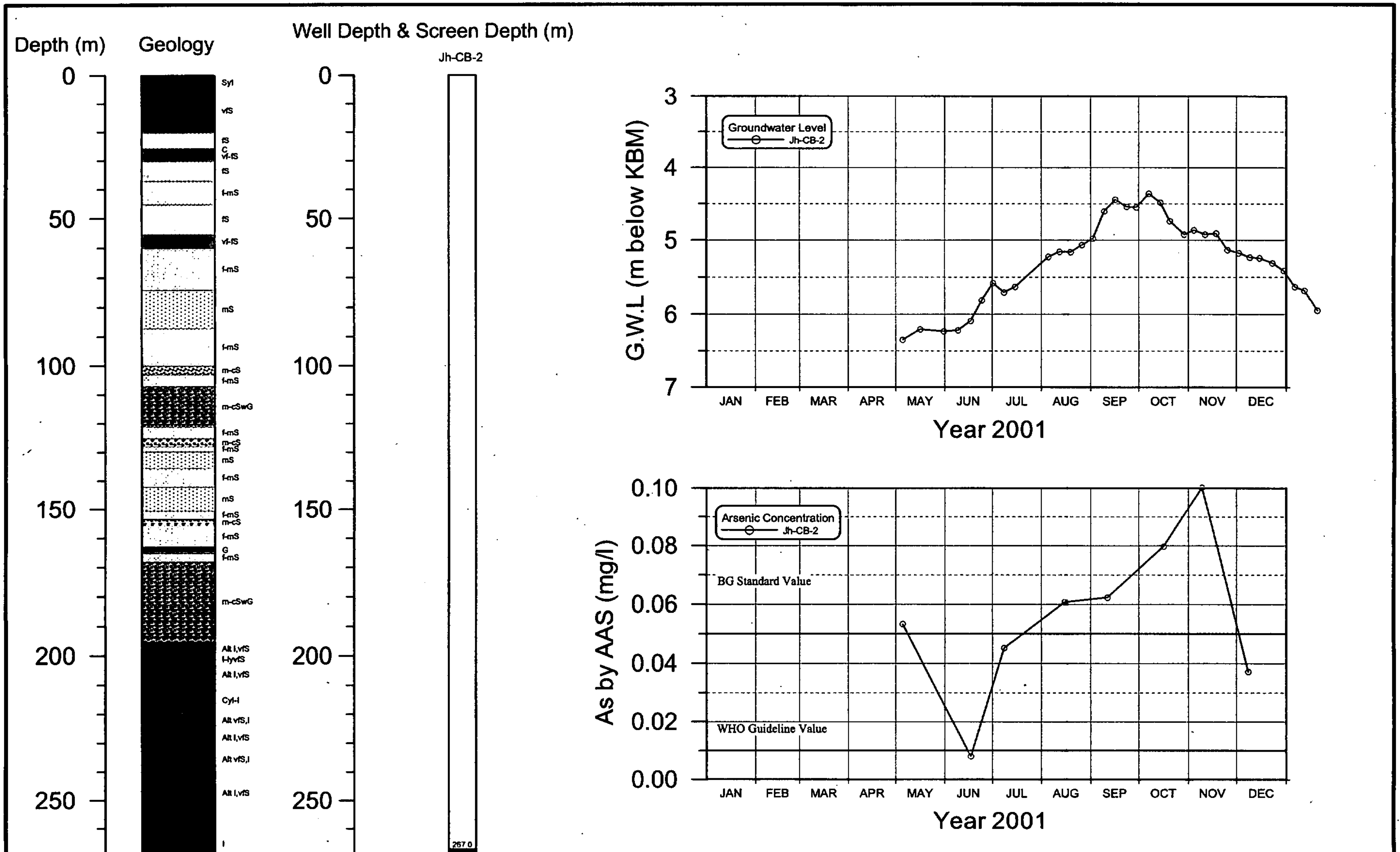
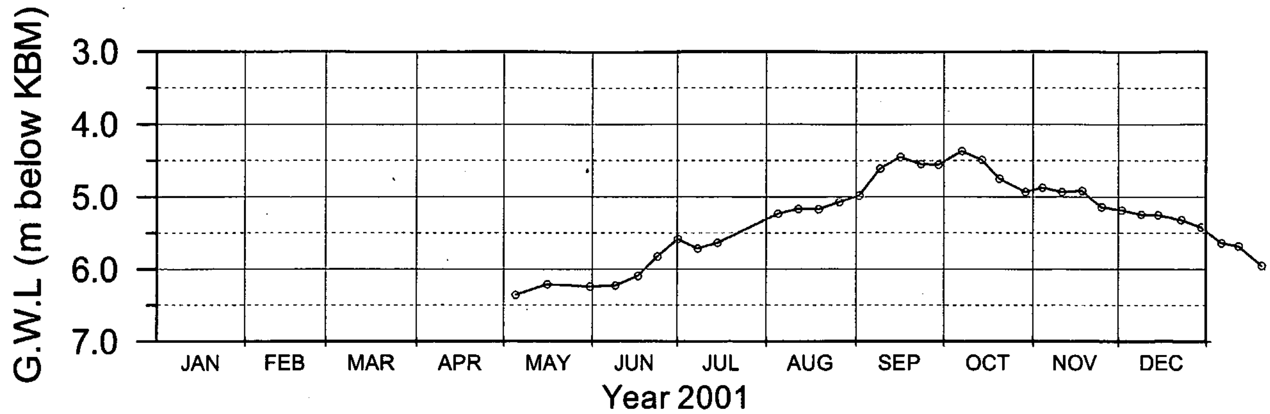


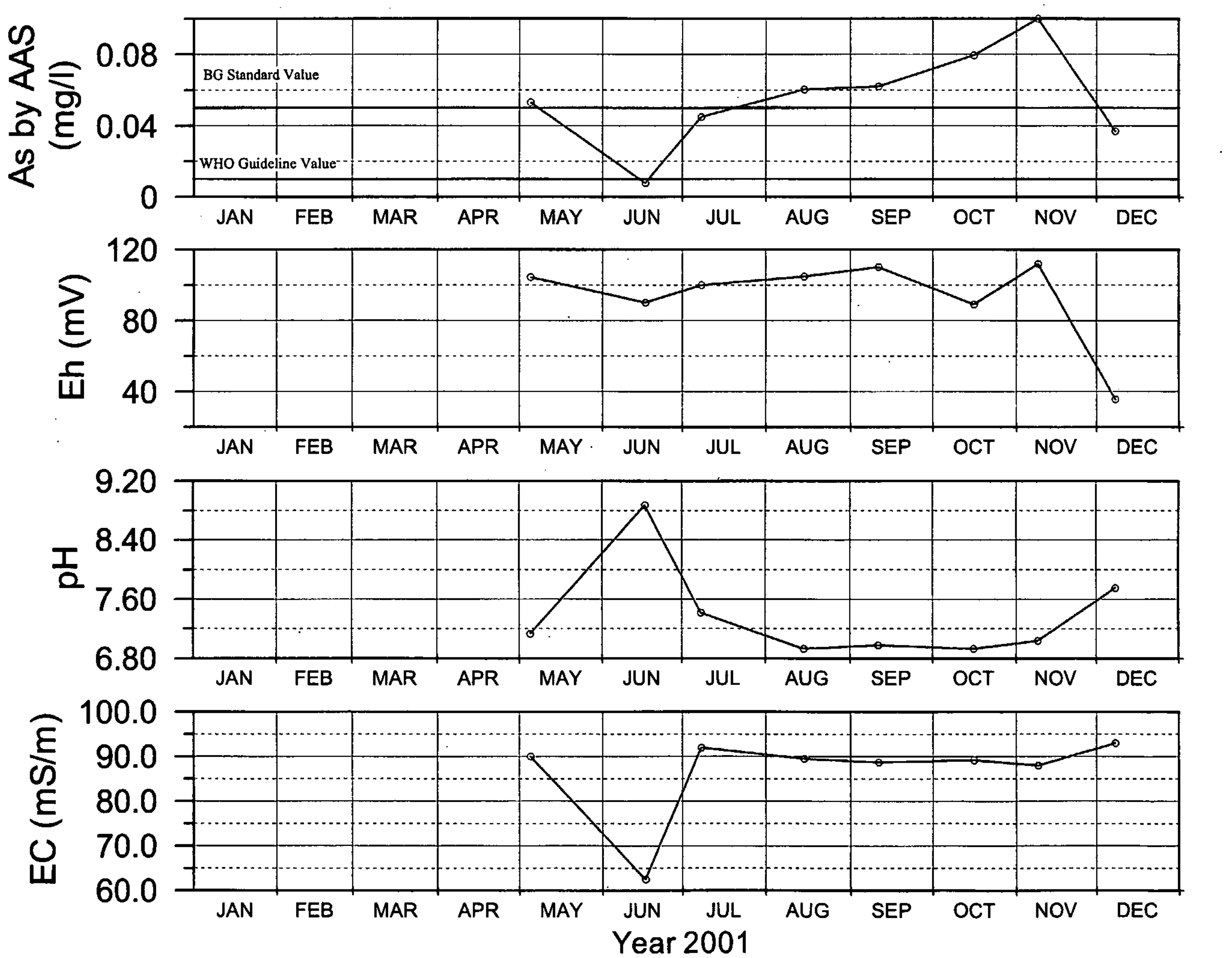
Figure 5.4.23 Results of Monthly Groundwater Monitoring at JH-KC Site [Krishna Chandrapur, Moheshpur]

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)

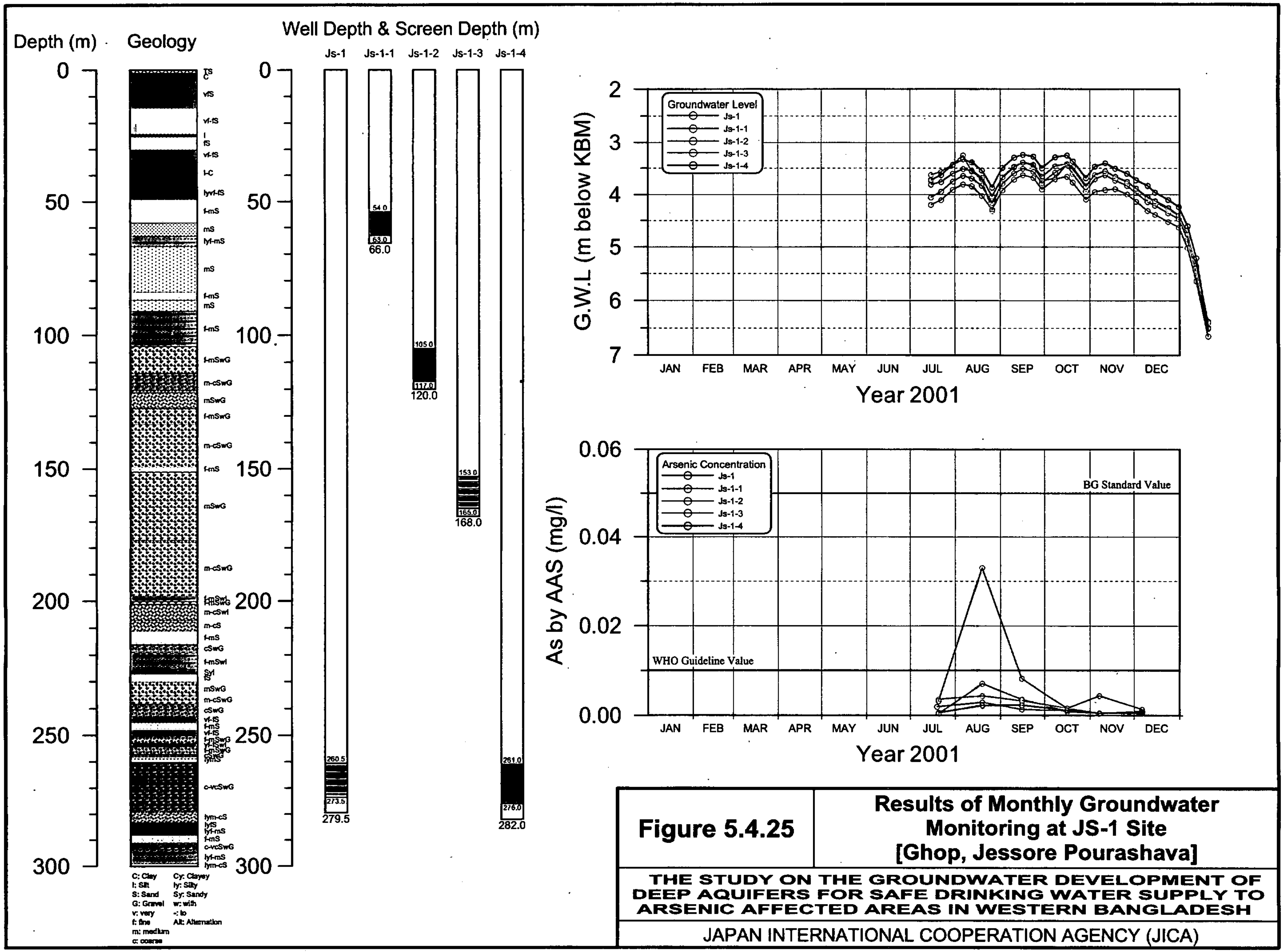
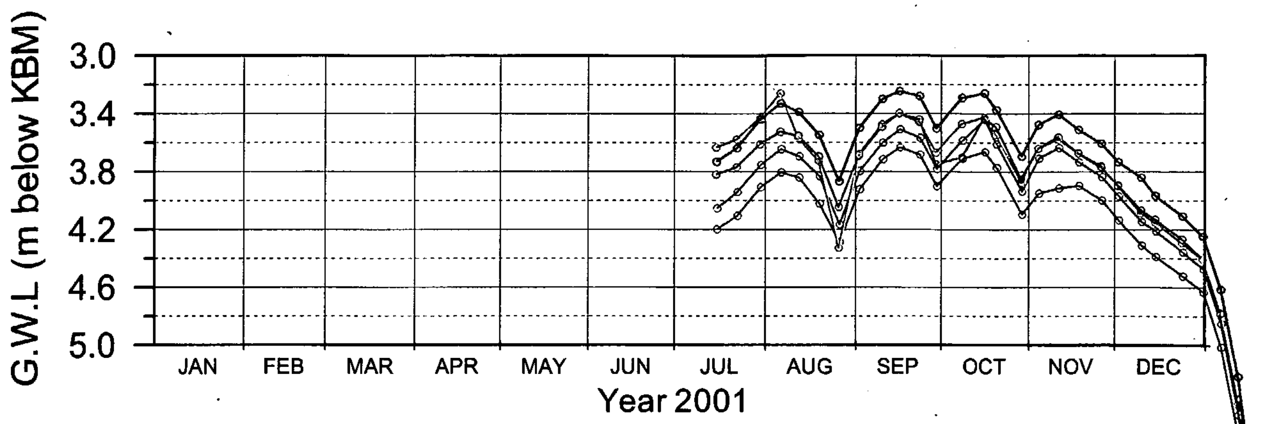


Figure 5.4.25

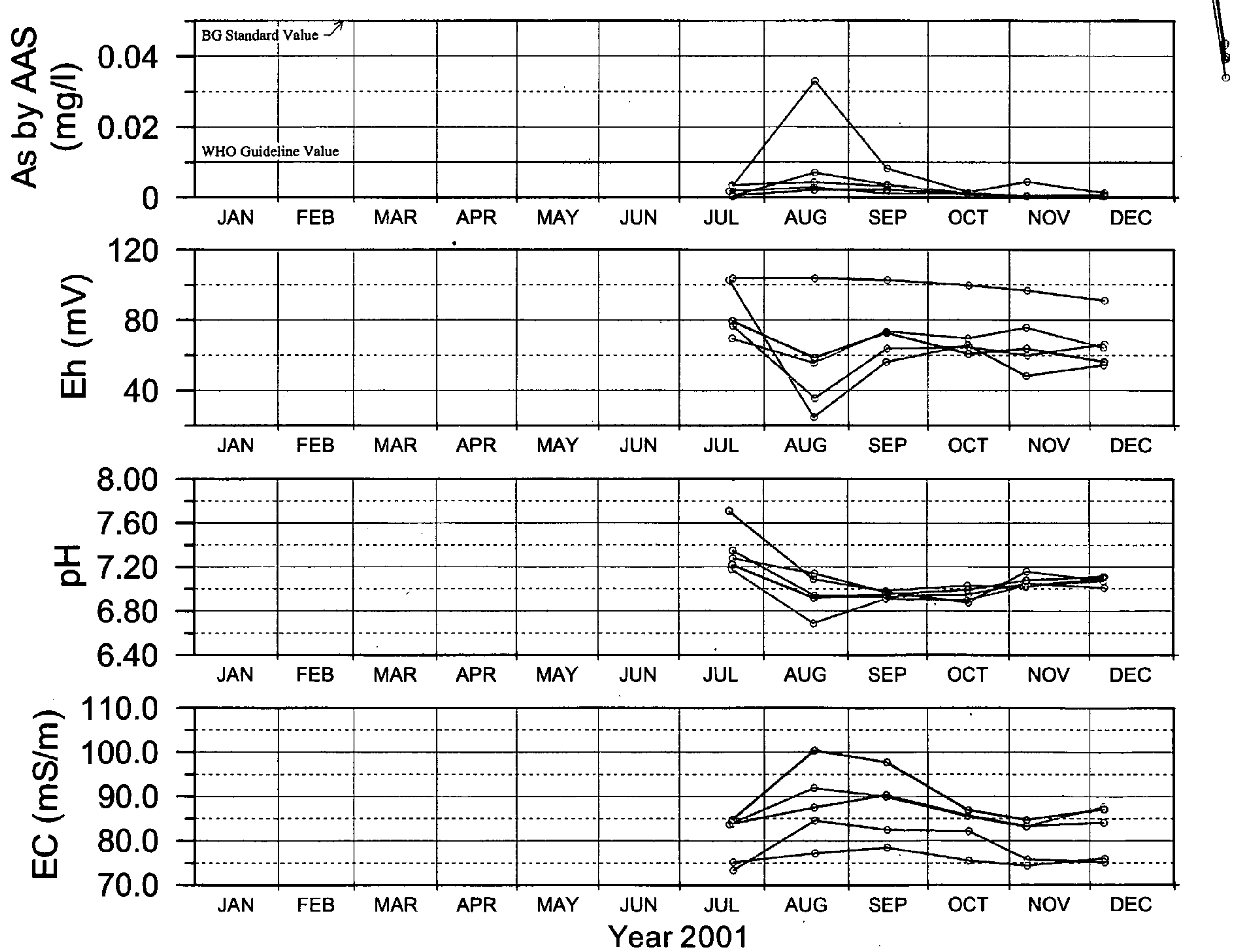
Results of Monthly Groundwater Monitoring at JS-1 Site [Ghop, Jessore Pourashava]

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)

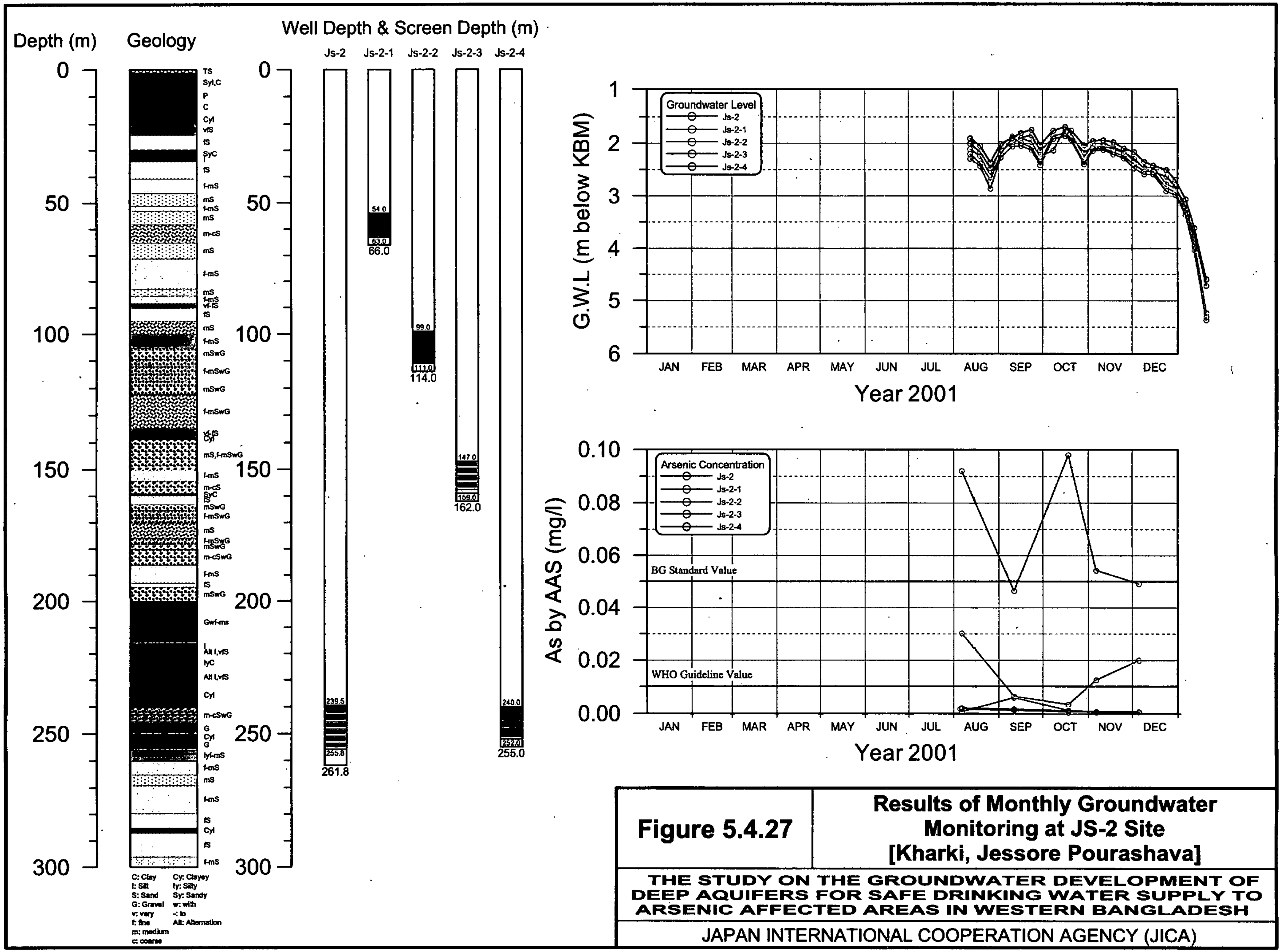
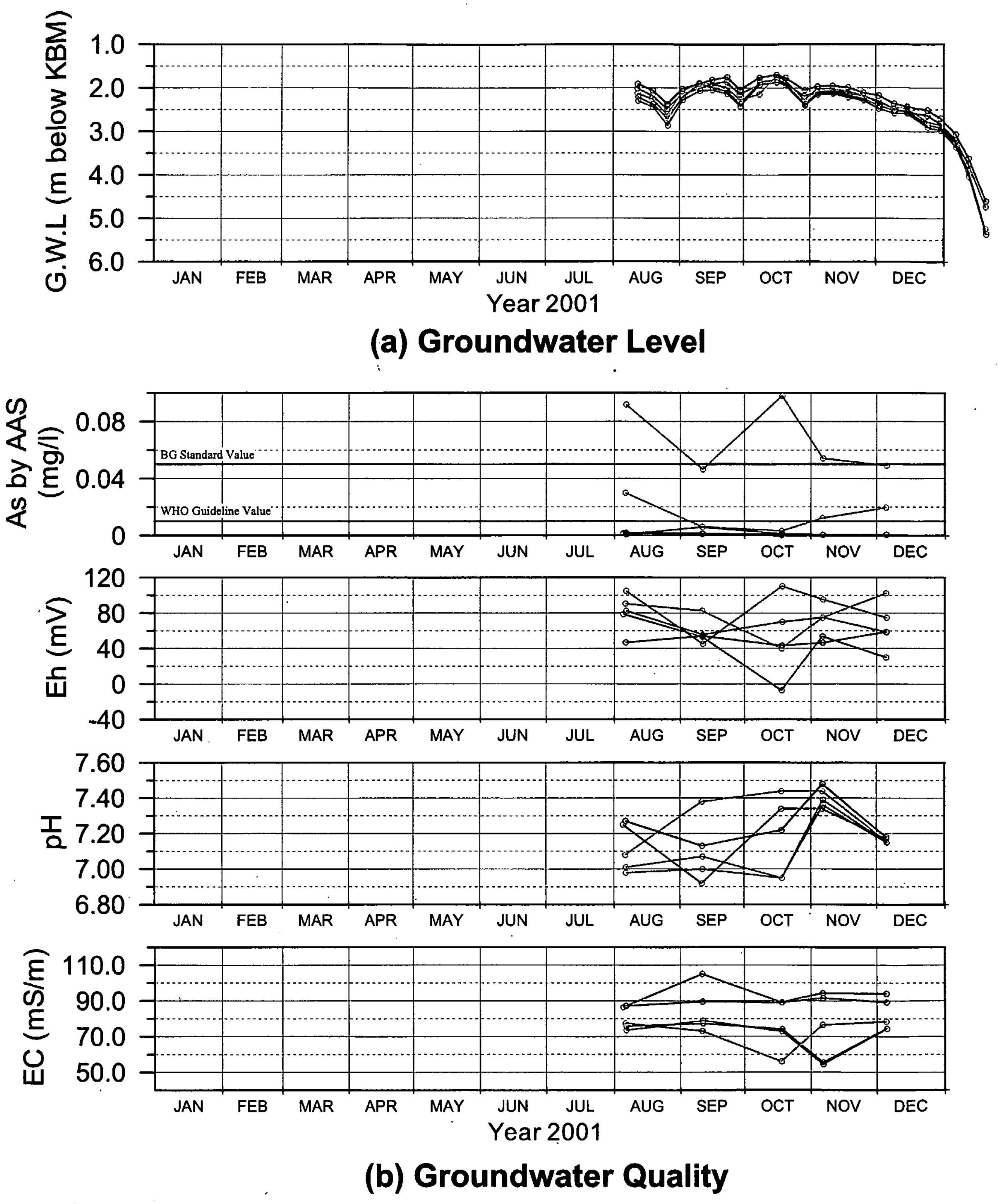


Figure 5.4.27	Results of Monthly Groundwater Monitoring at JS-2 Site [Kharki, Jessore Pourashava]
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



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)

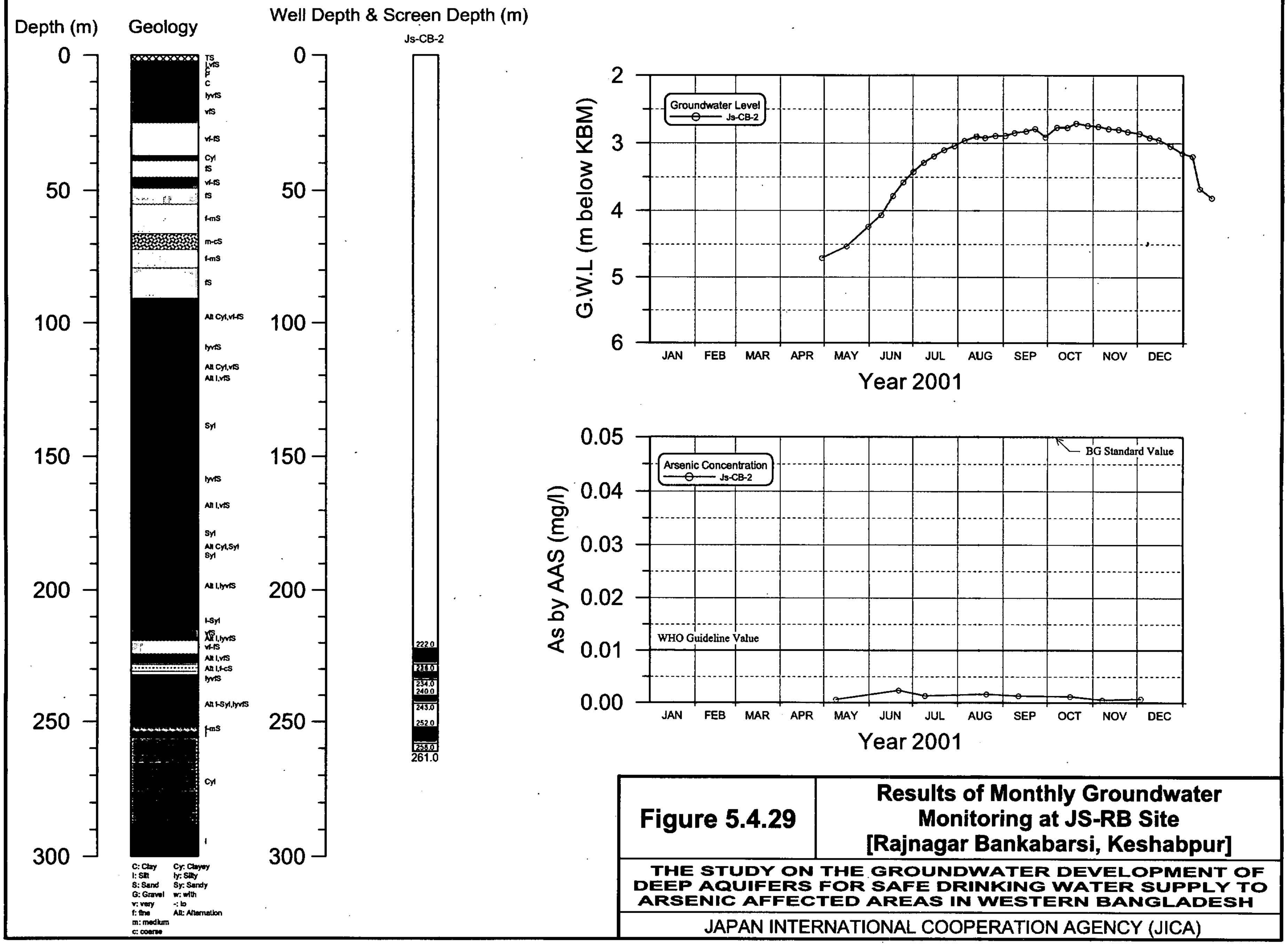
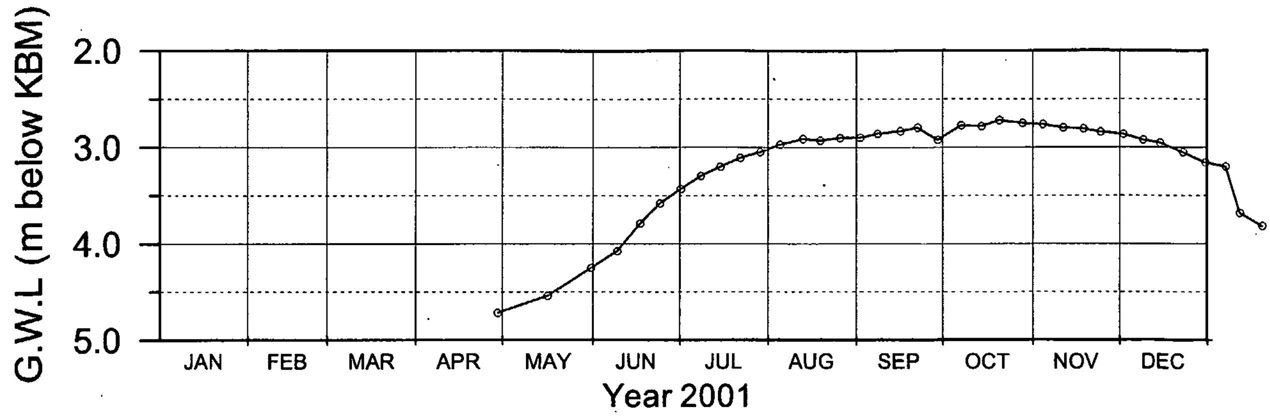


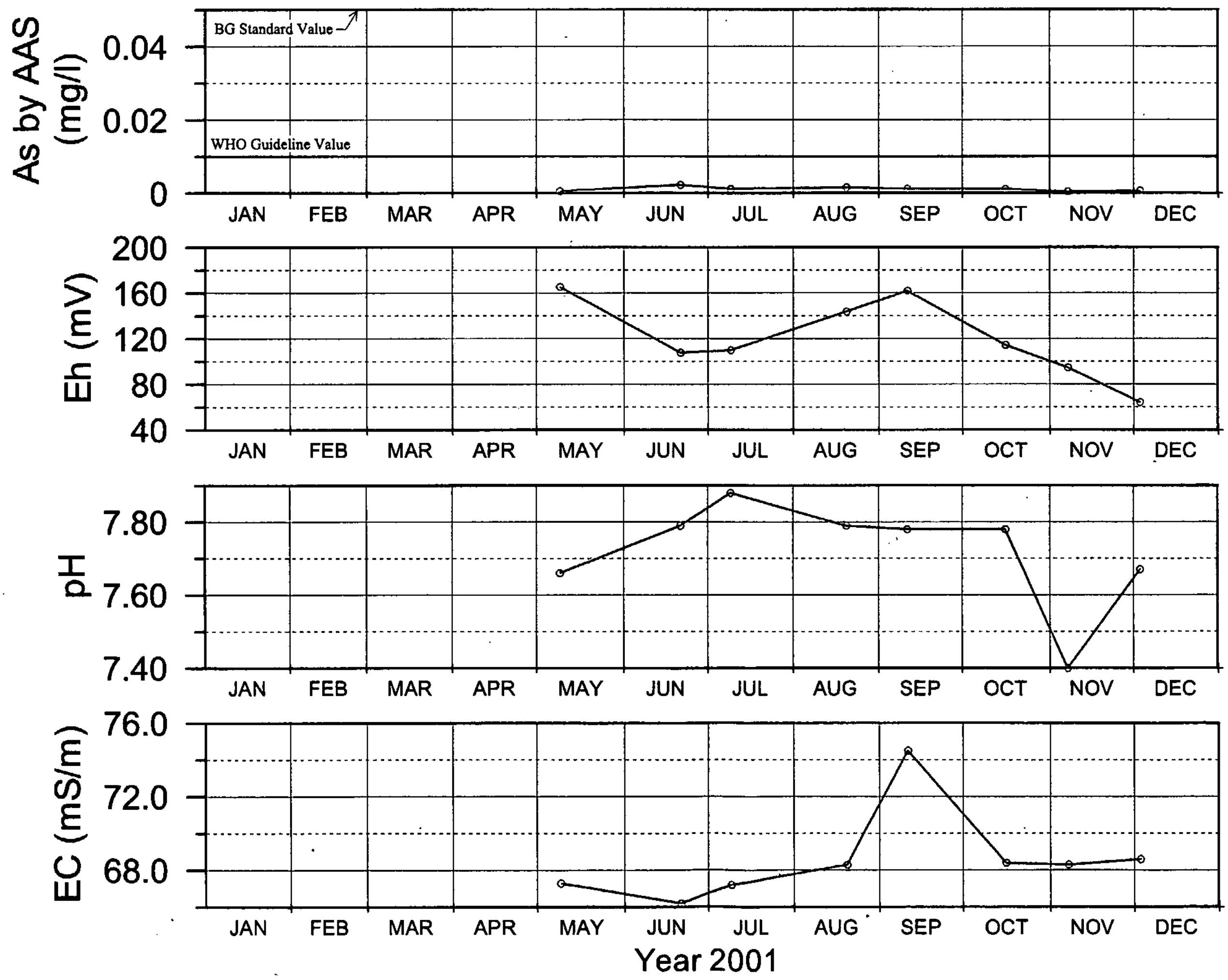
Figure 5.4.29	Results of Monthly Groundwater Monitoring at JS-RB Site [Rajnagar Bankabarsi, Keshabpur]

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

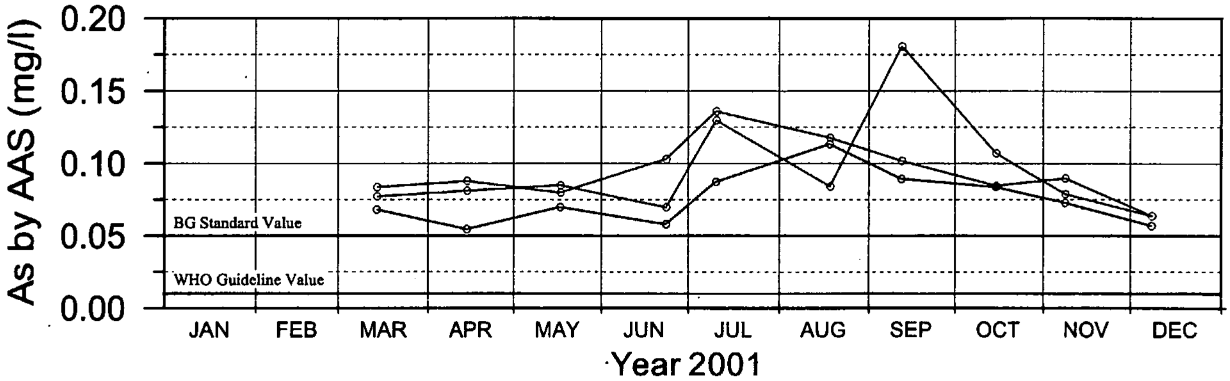
LEGEND

Js-CB-2 (Depth = 261.0 m)

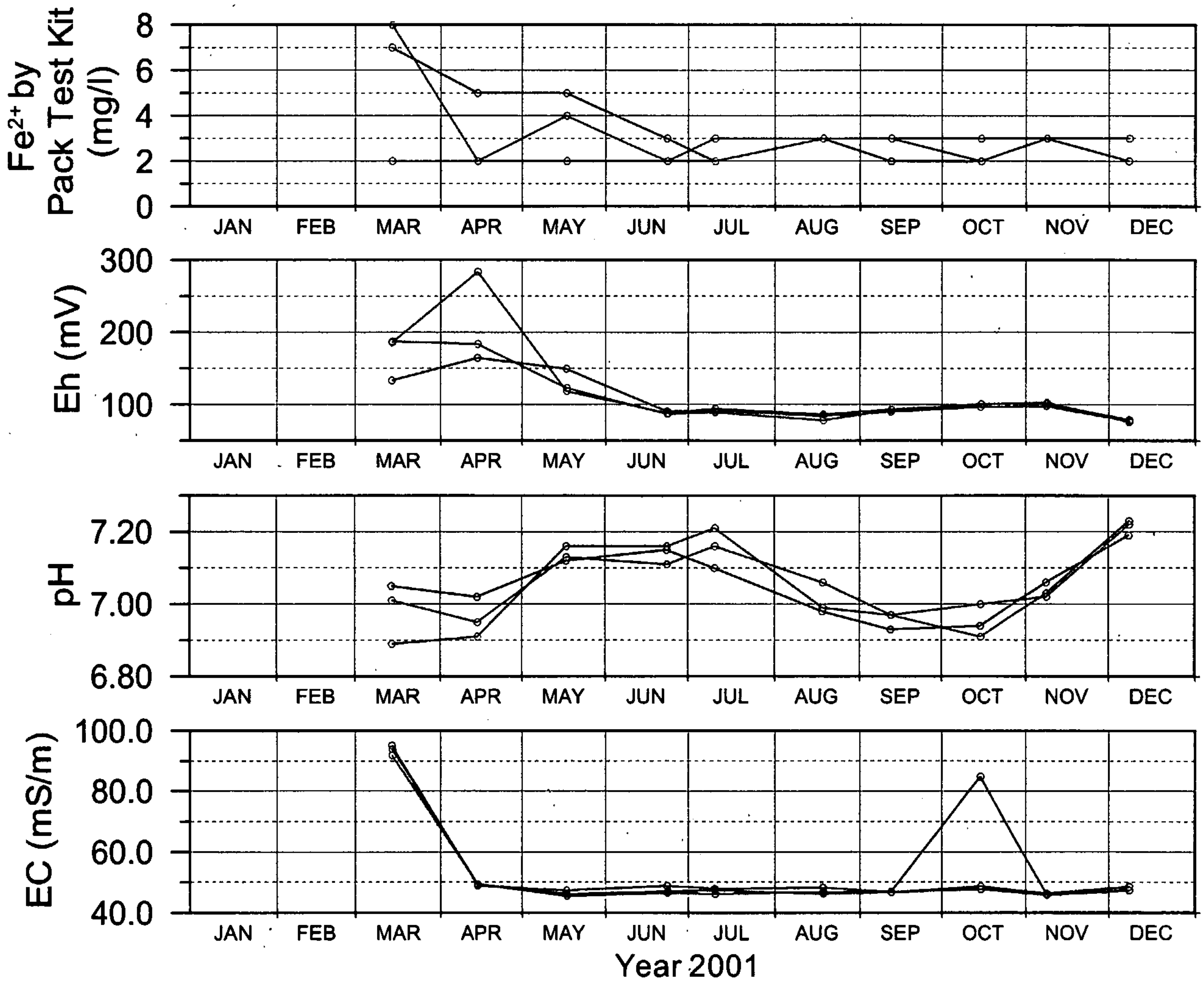
Figure 5.4.30	Changes in Groundwater Level and Groundwater Quality at JS-RB Site, Jessore

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

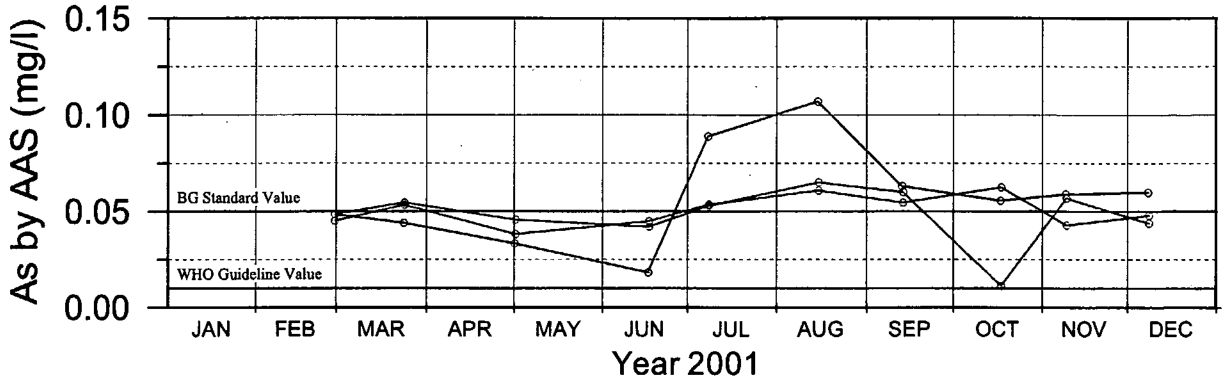
Location: Bara Dudpatila Village
Damurhuda Thana
Chuadanga District
Site No.: BD-IDW

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)

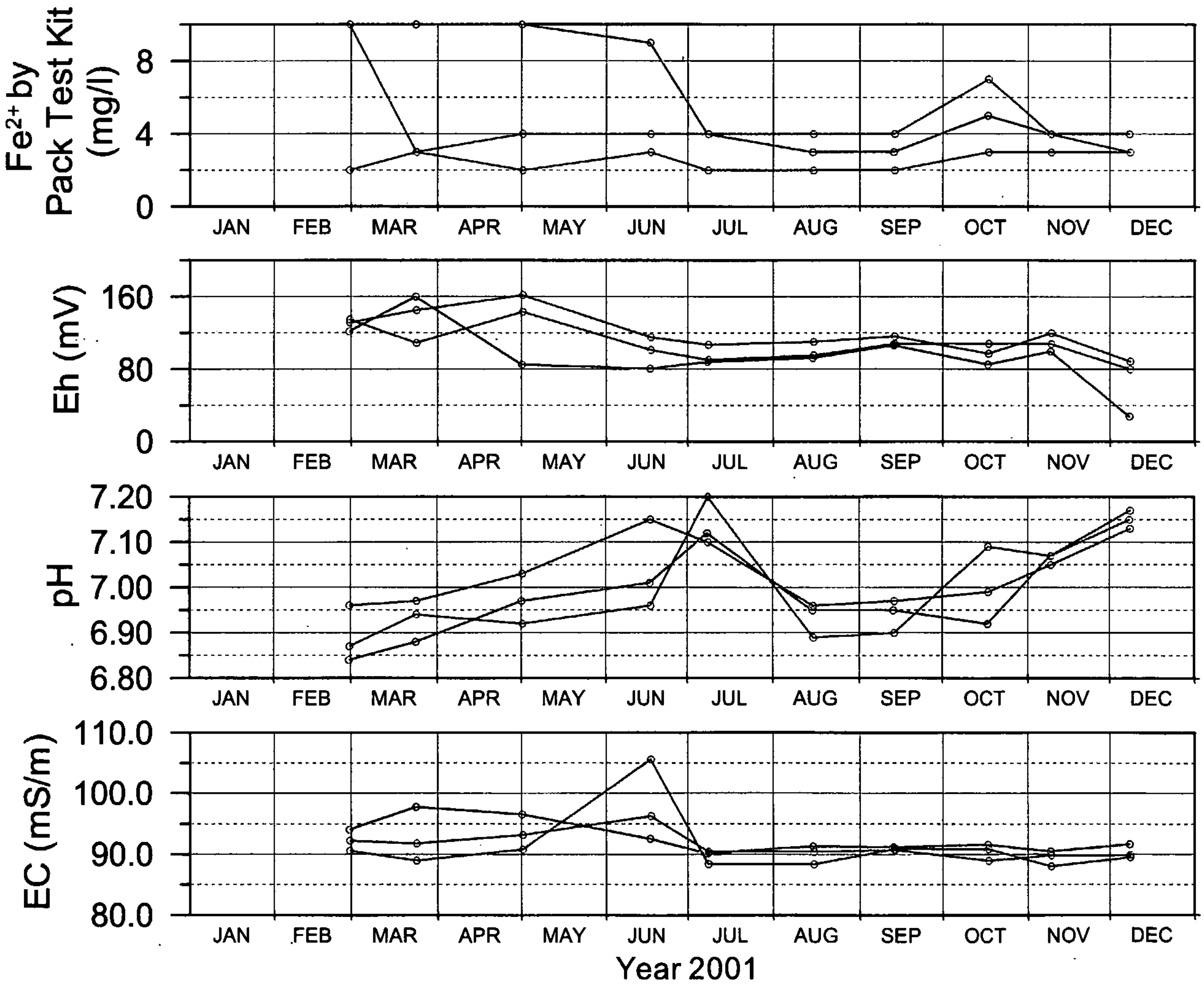
Figure 5.4.31 **Monthly Monitoring Results of Improved Deep Wells in Bara Dudpatila Village, Chuadanga**

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

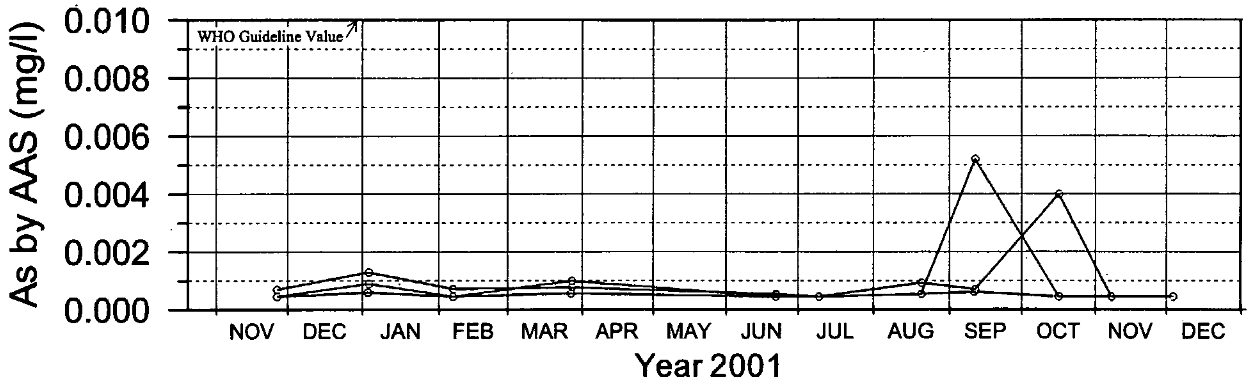
Location: Krishna Chandrapur Village
Moheshpur Thana
Jhenaidah District
Site No.: JH-KC

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

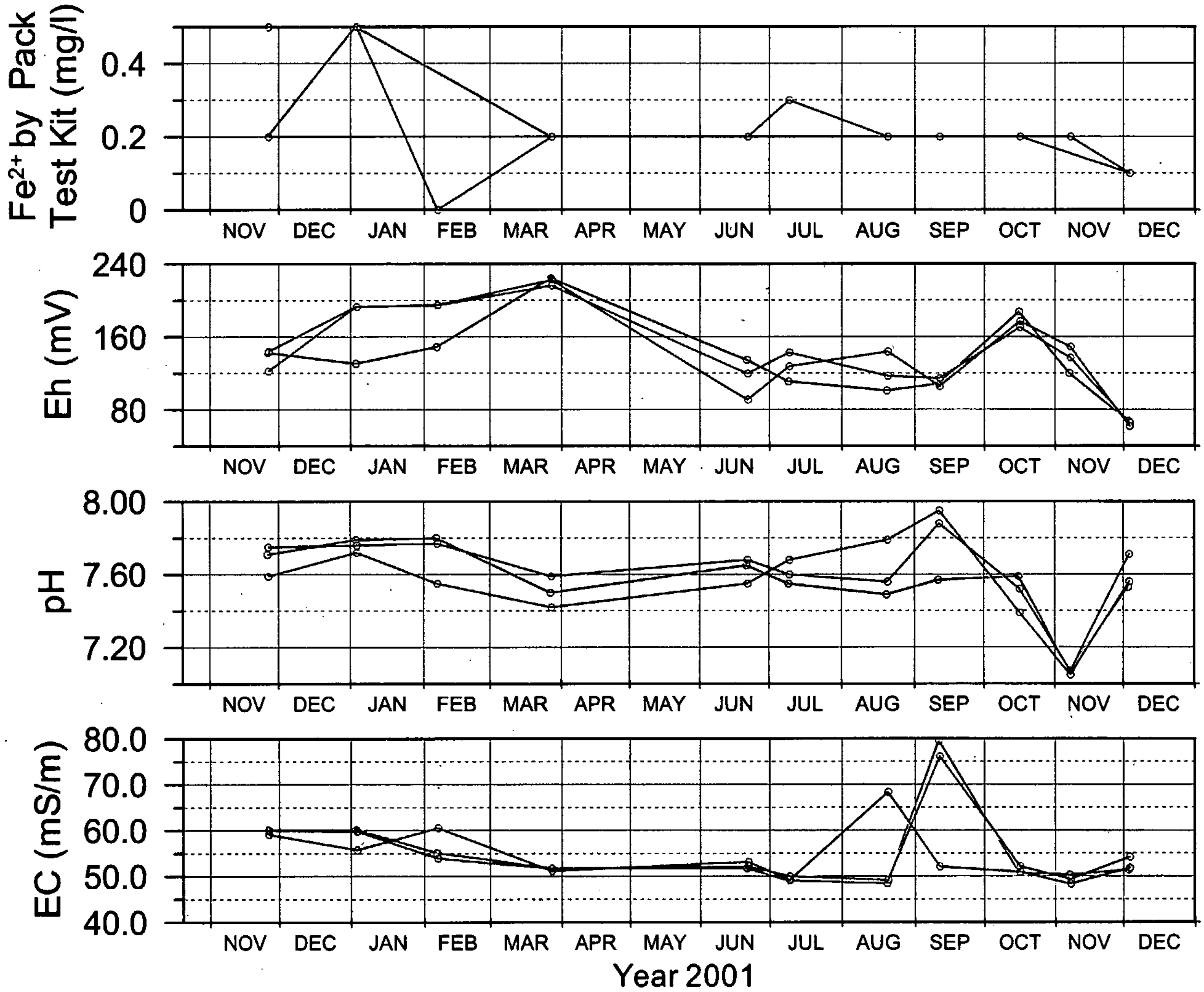
Figure 5.4.32	Monthly Monitoring Results of Improved Deep Wells in Krishna Chandrapur Village, Jhenaidah

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

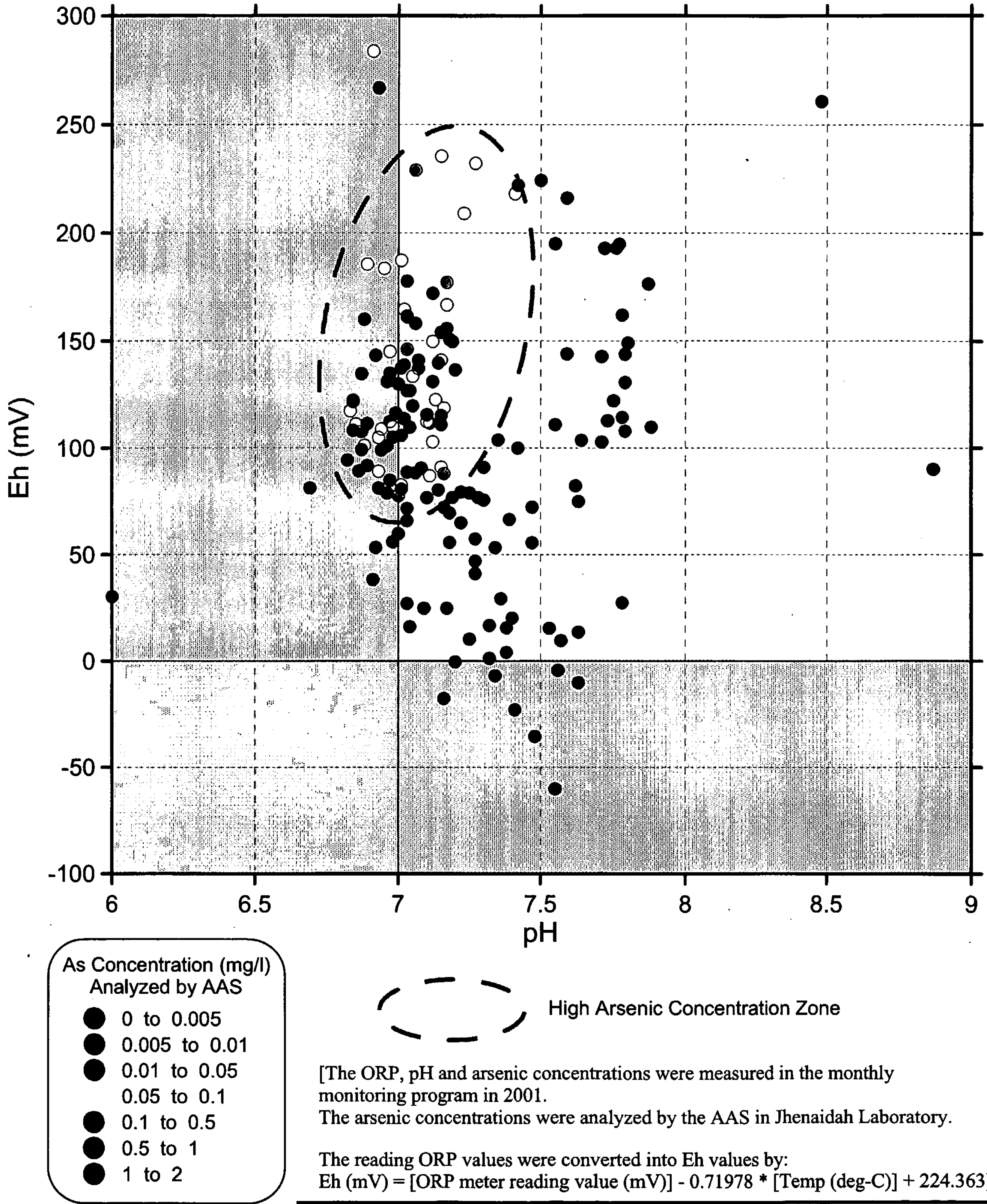
Location: Rajnagar Bankabarsi Village
Keshabpur Thana
Jessore District
Site No.: RB-IDW

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**

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)