CHAPTER 9

MASTER PLAN

Summary Report

CHAPTER 9 MASTER PLAN

9.1 Basic Policy

The National Policy for Safe Water Supply & Sanitation (1998) states that the removal of arsenic and the supply of the safe drinking water through alternative water sources in arsenic contaminated areas is one of its important short term goals. The purpose of this Master Plan is to supply safe drinking water to the residents of three districts, Chuadanga, Jhenaidah and Jessore, through the development of deep aquifers[1]. The Master Plan has been formulated in accordance with the National Policy.

According to UNICEF, groundwater had previously been the source of as much as 97% of Bangladesh's water supply. However, the rate has been declining since the 1990's due to an arsenic problem. The objective of the Master Plan is, therefore, to bring the safe water supply level back to 97%. The basic policy of the Master Plan is as follows.

(1) The Master Plan is targeted for the year-2010 and is divided into 3 stages: the short term (year-2003), the middle term (year-2005) and the long term (year-2010)[2].

(2) The Study Area is divided into rural areas and urban areas (Pourashava and urbanized areas).

(3) Measures against arsenic contamination in the rural area are planned at each arsenic contaminated zone based on the contamination map, which was prepared by the Study. The screening of all existing wells will be conducted for detailed planning.

(4) The urban area is divided into "supplied areas" and "unsupplied areas". The plan is mainly composed of the rehabilitation and expansion of existing water supply facilities in the supplied area. The plan in the unsupplied areas will be formulated based on the results of the screening.

(5) The groundwater in the deep aquifers will be the main water source. In the areas not supplied by the deep groundwater, alternative plans for water sources such as improved deep wells, arsenic removal devices, pond sand filtration, shallow dug wells, etc. will be applied.

(6) The target arsenic value for safe drinking water is set at less than 0.05 mg/l, which is Bangladesh's drinking water quality standard.

(7) A safe water quality level will be secured by monitoring the arsenic concentration of groundwater throughout the Master Plan period.

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[1] In this master plan the aquifer is divided into shallow (30-100m), middle (100-200m) and deep aquifers (200-300m).

[2] BAMWSP set the target year at 2013 when it started in 1998. In this project, the target year was set at year 2010 by the SW mission considering the BAMWSP's schedule and the urgency of tackling the arsenic problem. The study team also agreed with setting the target year of the project at 2010.

Table 9.2.1 Classification of Arsenic Contaminated Area

THANA	Urgent Area (As>0.1mg/l)			Semi-urgent Area (As>0.05mg/l)		
	Mouza	Area(Km^2)	Population	Mouza	Area(Km^2)	Population
CHUADANGA						
Alamdanga	4	11.8	4,874	18	59.6	38,327
Chuadanga	23	60.9	43,674	50	156.5	123,772
Damurhuda	3	11.8	8,235	10	54.3	40,651
Jibannagar	16	48.8	27,113	32	75.3	51,384
Sub-total	46	133.3	83,896	110	345.7	254,134
JHENAIDAH						
Harinakunda	---	---	---	5	8.8	4,872
Jhenaidah	2	1.6	982	29	51.7	31,400
Kaliganj	---	---	---	5	12.3	5,202
Kotchandpur	10	21.9	12,148	13	30.4	12,244
Maheshpur	20	46.6	29,865	58	164.1	98,977
Sub-total	32	70.1	42,995	110	267.3	152,695
JESSORE						
Chuagachha	49	94.4	86,857	45	99.4	61,875
Jessore	7	12.8	18,187	20	33.7	40,443
Jhikargachha	50	100.8	71,831	66	117.7	102,932
Keshabpur	61	100.7	83,999	61	115	92,419
Manirampur	45	69.3	54,203	77	167.2	131,977
Sharsha	29	89	68,002	28	74.9	50,572
Sub-total	241	467	383,079	297	607.9	480,218
Total	319	670.4	509,970	517	1220.9	887,047

Statistics of Arsenic Contaminated Area

Thana	14
Union	97
Mouza	836
Area(Km^2)	1,891
Pop (1991Census)	1,397,000
Pop (2001Estimated)	1,756,786

9.2 Zoning of Arsenic Contaminated Area

According to the arsenic analysis of 300 existing wells conducted in the dry and rainy seasons in the year 2000, the contaminated area, where arsenic concentrations exceed 0.05 mg/l in the groundwater from shallow layers (30 to 50 m depth), spreads over the western part of the Study Area. On the other hand, arsenic concentrations show less than 0.05 mg/l throughout the eastern part of the Study Area, though high concentration areas exceeding 0.05 mg/l are sporadically distributed. Comparing the rainy season with the dry season, arsenic concentrations slightly increase in the rainy season in several places. However, there are many cases to the contrary and no significant difference can be seen in the general situation. In order to identify the zones for the arsenic contamination measures, the arsenic concentration map was superimposed onto the mouza map produced by GIS, considering the difference between the rainy and dry seasons. As a result, the rural area, excluding pourashavas, was classified into "urgent areas" (As concentrations of more than 0.1 mg/l), "semi-urgent areas" (more than 0.05 mg/l and less than 0.1 mg/l) and "observation areas" (less than 0.05 mg/l) (see Figure 9.2.1)[3].

The urgent areas in the three districts total 670km^2. A population of about 0.5 million from 319 mouzas live in this highly contaminated area. In addition, the semi-urgent areas total 1,221 km^2, where about 0.89 million people from 517 mouzas live (see Table 9.2.1).

On the other hand, arsenic is also found in the groundwater of the production wells in several urban water supply systems as shown in Table 9.2.2. In Chuadanga, Jhenaidah and Mohespur, the arsenic concentration is slightly higher than the Bangladesh standard value. Approximately 0.25 million people supplied in these three pourashavas are directly exposed to the dangers of arsenic contamination. In addition, the people using shallow groundwater in the unsupplied areas of the pourashavas, are also at risk.

Table 9.2.2 Population (Coverage), Number of Wells and Arsenic Concentration

District	Pourashava	Population (Coverage)	Number of Production Wells	Highest Arsenic Concentration mg/l[4]
Chuadanga	Chuadanga	131,314(25%)	5	0.066
Jhenaidah	Jhenaidah	94,624(32%)	7	0.064
	Sailkupa	28,527(5%)	3	0.008
	Kaliganji	42,891(30%)	3	0.021
	Kotchandpur	40,000(30%)	3	0.015
	Moheshpur	24,433(8%)	2	0.072
Jessore	Jesoore	350,000(41%)	17	0.03

Based on the arsenic concentrations of groundwater, the urban area is divided into "supplied

3 The map was created at a measurement density of 1 point per 19km$^{2.}$ If the density increases, the map becomes more accurate and the area may subtly change. However, this can be later modified by the proposed screening in the Master Plan.

4 The highest values among the production wells（Analyzed by AAS from December 2000 to January 2001）

areas" and "unsupplied areas". The supplied areas are further subdivided into "contaminated production well areas" and "uncontaminated production well areas". The unsupplied areas are classified in accordance with the rural area. The zoning of the arsenic contaminated area is summarized as follows (see Table 9.2.3).

Table 9.2.3 Zoning of Arsenic Contaminated Area

<table>
<tr><th>Area</th><th colspan="2">Zoning of Contaminated Area (Arsenic concentration)</th></tr>
<tr><td rowspan="3">Rural Area</td><td colspan="2">Urgent Area (more than 0.1 mg/l)</td></tr>
<tr><td colspan="2">Semi-urgent Area (0.05 mg/l to 0.1 mg/l)</td></tr>
<tr><td colspan="2">Observation Area (less than 0.05 mg/l)</td></tr>
<tr><td rowspan="3">Urban Area
(Pourashava)</td><td rowspan="2">Supplied Area</td><td>Contaminated production well（more than 0.05 mg/l）</td></tr>
<tr><td>Uncontaminated production well (less than 0.05 mg/l)</td></tr>
<tr><td>Unsupplied Area</td><td>In accordance with Rural Area</td></tr>
</table>

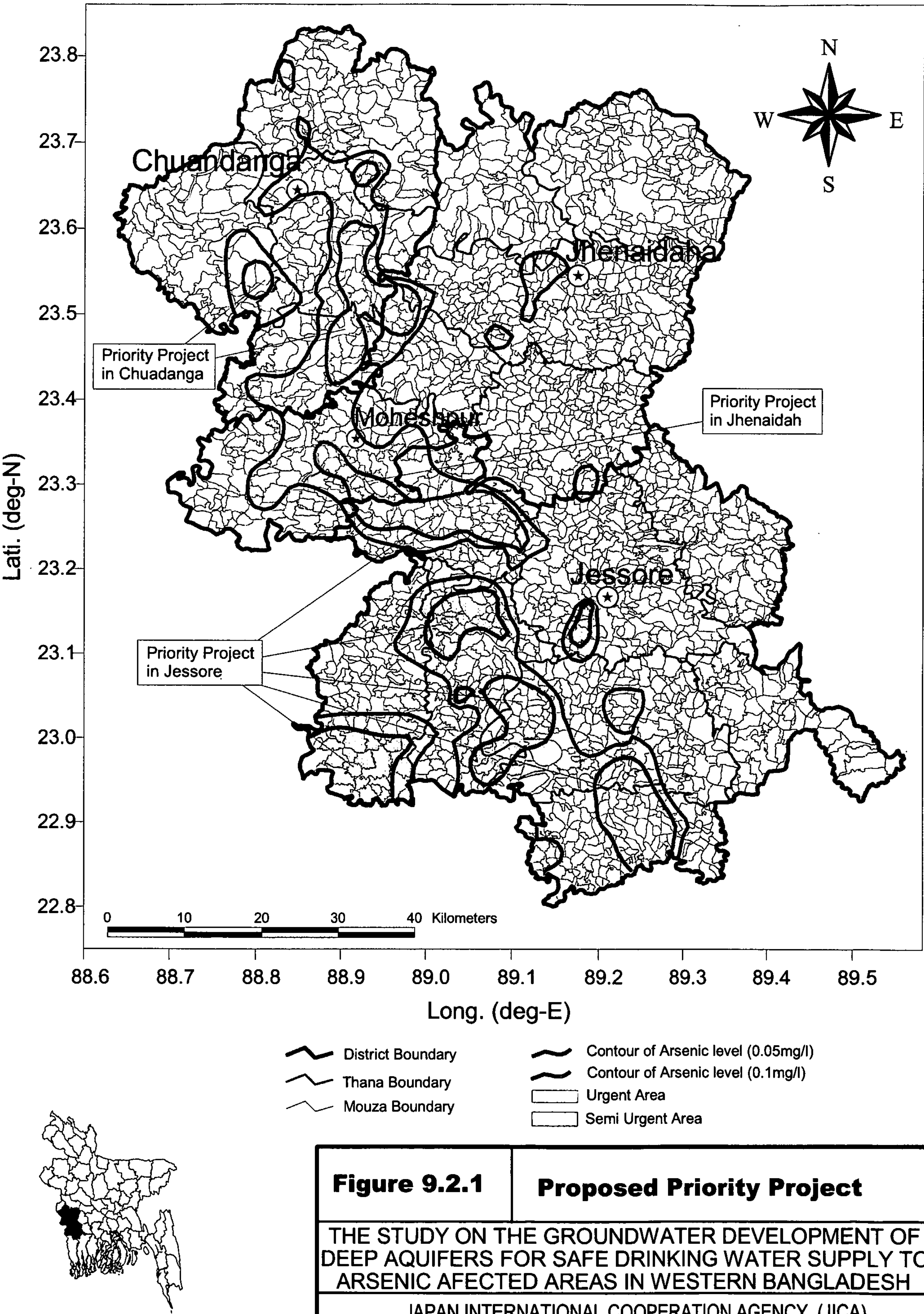


Figure 9.2.1	**Proposed Priority Project**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

9.3 Screening and Mapping

The National Screening Program has been carried out under the BAMWSP since October 1999 to understand the extent of the arsenic contamination of tube wells and to identify arsenic affected people having visible signs of arsenicosis in each village. The screening was carried out in 6 upazilas (Thanas) in Phase I and 40 upazilas in Phase II. In Phase III, the BAMASP will carry out screening in 147 upazilas throughout the country including 11 upazilas in the Study Area. However, the results of the screening have not yet been disclosed. Since the location of the contaminated tube wells and their arsenic concentrations are not presented on the map yet, the information necessary to design the facilities for countermeasures and their locations cannot be obtained at present.

The location and arsenic concentrations of each tube well were plotted on the map and the arsenic distribution of the village in the model rural area was created in the Study. This map could indicate visually the unsafe contaminated area as well as the safe uncontaminated area (see Chapter 6). If such a map is obtained throughout the contaminated area, urgent measures, such as utilization of the uncontaminated safe tube wells for the contaminated areas within the village, can be planned. Then, the permanent measures can be undertaken concretely. Accordingly, in the Master Plan, the screening and mapping of the arsenic contaminated zone are carried out based on the following procedure and methodology.

(1) Prepare screening survey sheet and mouza map[5]
(2) Explain to the mouza representative and the tube well owner
(3) Measure tube well location by GPS and plot it on map
(4) Investigate the well structure/conditions, users and arsenicosis patients
(5) Collect water samples and measure arsenic by field kit
(6) Measure field water quality
(7) Explain the screening results
(8) Mark contaminated wells with paint
(9) Take photograph
(10) Take water samples for AAS analysis in the laboratory（specified tube well）
(11) Prepare arsenic contamination map

[5] The mouza map is produced at a scale of 1/5,000-1/10,000 by using aerial photos and satellite images.

9.4 Arsenic Contamination Mechanism and Direction for Measures

The hydrogeological structure in the three districts shows that the sand and gravel layers lying at a depth from 10 to 300 m constitute good aquifers in Chuadanga and Jhenaidah Districts. The remarkable aquiclude or aquitard (impermeable or semi-permeable clayey layer) does not exist between the aquifers. On the other hand, a thick aquiclude separates the shallow-middle aquifers of up to 100 m in depth from the deep aquifers of 250 to 300 m in depth in the southern part of Jessore District. The deep aquifers are mainly composed of sand. Compared with the shallow and middle aquifers, the productivity of deep aquifers is less because of a low specific capacity. However, groundwater can be developed and utilized sufficiently for all water supply purposes.

According to arsenic concentration analyses of the deep groundwater, a slightly high arsenic concentration was detected in the deep observation wells in the northern part of the three districts. It slightly exceeds the Bangladesh standard value. However, compared with the shallow groundwater, the concentration is still low. On the other hand, the arsenic concentration was less than the detectable limit in the southern part of the three districts. In addition, no significant problems were found in general water quality.

An abundance of surface water such as rivers, lakes and ponds exists in the rainy season in the Study Area. However, most of them dry up in the dry season. It is difficult to secure a stable supply of surface water all year round. In addition, surface water is usually contaminated (by bacteria, nitrate, ammonia, etc,) because of the sewerage and livestock waste inflow. It is therefore very difficult to use surface water as the main water source. Accordingly, water supplies are to be secured through the development of deep groundwater by the Master Plan. A stable supply of arsenic-free deep groundwater is assured all year round. Although arsenic concentrations in the deep groundwater slightly exceed the standard value in the northern part, it is relatively easier to remove arsenic by aeration and filtration from deep groundwater than shallow groundwater.

In order to elucidate the geo-chemical arsenic contamination mechanism, various investigations and research are being conducted all over the world. However, the theory has not been established yet and further investigation and research are required in the future. According to the simulation of the regional groundwater flow mechanism, it is evident that the arsenic contaminated groundwater migrates to the shallow and middle aquifers from the contaminant source in the shallow clayey layer located within a few dozen meters depth. Migration occurs due to a declining of the groundwater head in the middle aquifer caused by the heavy pumping of irrigation tube wells. As far as regional groundwater flow, the groundwater head in the deep aquifer is higher than that of the middle aquifer. Accordingly, groundwater flows upward from the deep aquifer at all times and the contaminants never migrate downward to the deep aquifers.

Considering the above points, the arsenic contamination measures of the Master Plan are mainly to be taken by developing the groundwater of deep aquifers. On the other hand, the adaptability and feasibility of rainwater harvesters (RWH), pond sand filters (PSF), shallow dug wells (SDW), and the improved deep wells (IDW) that were developed by the Study depend on the geographical location, topographical and geological environment, availability of alternative water sources in both quantity and quality (conversion of the existing ponds etc), technical skills required for O&M, and willingness and affordability to pay for the cost in the target villages. Therefore, the alternative water source survey has been planned as a component of the Master Plan. Installation of RWHs, PSFs, IDWs and SDWs are to be planned based on the survey results.

Further examination of the efficiency and O&M of household/community-based arsenic removal devices (ARD), such as costs, replacement of adsorption agent, use of chemicals, disposal of sludge, monitoring of water quality, etc, is needed at present. Accordingly, installation and experimental operation of the adsorption based arsenic removal device and solar distillation combined with rainwater harvesting are planned as the components (model projects), respectively, in the Master Plan. The results of the projects will be utilized for dissemination of the ARD in the future.

9.5 Master Plan Framework

The Master Plan is divided into three stages: the short term (year-2003), the middle term (year-2005) and long term (year-2010). The Study Area’s three districts are divided into the rural and urban areas. They are subdivided into several zones by degree of contamination. The study, measures and research and development are planned by zone (see Figure 9.5.1).

9.5.1 Study

1) Short term measures

a. Screening of all wells

Before implementation of contamination measures, arsenic contamination of all tube wells in each mouza in the contaminated area is to be surveyed and the mouza contamination map is to be produced (Mapping). Referring to the BAMWSP screening results, the screening and mapping are to be carried out in all mouzas in the urgent and semi-urgent areas as a component of the Master Plan.

b. Survey on alternative water sources

Availability and applicability of alternative water sources, such as IDWs, PSFs, RWHs and SDWs are to be studied in the urgent and semi-urgent areas of the rural area. In parallel with the screening of all wells, a survey is to be conducted on the existing water sources to determine the type, quantity, water quality, dimensions of the facility (<u>well</u>: depth, diameter, material, pump /

pond: volume, purpose, possibility of diversion etc), the residents' willingness for O&M and its affordability.

c. Feasibility study

The feasibility of the priority projects proposed in the Master Plan is to be studied from technological, economical, financial and institutional points of view.

2) Midterm Measures

a. Hydrogeological survey

Additional hydrogeological surveys are to be conducted to understand in further detail the distribution and properties of the deep aquifers in the Study Area.

b. Groundwater utilization survey

A huge amount of groundwater is being extracted from the shallow and middle aquifers for irrigation purposes. In comparison, amount of groundwater used for drinking water is very small. In order to manage and conserve groundwater resources, groundwater utilization surveys are to be conducted for all the tube wells.

c. Database construction

Arsenic concentrations, water levels and water quality of the observation and monitoring wells, survey results of screening, hydrogeology and groundwater use will be added to the GIS database which was constructed by the Study.

3) Long term Measures

a. Comprehensive groundwater resource management study

Groundwater pumpage for agricultural use is much greater than for drinking use in the three districts. It has been increasing throughout the 1990's accompanied with diffusion of the pump. This resulted in a regional declining of groundwater levels and triggered arsenic contamination. In order to permanently ensure utilization of the arsenic-free deep groundwater resources, a comprehensive groundwater development and conservation plan will be examined based on the hydrogeological surveys, groundwater utilization surveys, database construction and monitoring that will be carried out in the short and middle terms.

9.5.2 Measures for Rural Area

1) Short term Measures

The development of deep aquifers as an arsenic contamination measure can be applied to four (4) thanas, which are located in *the urgent area* of southern Jessore District, because the arsenic concentration of the deep groundwater is less than the standard value according to the analysis of the observation wells and the hydrogeological structure. On the other hand, the arsenic concentration is slightly higher than the standard value in three (3) thanas in Jhenaidah District and four (4) thanas in Chuadanga District, both located in *the urgent area*. Monitoring will be carefully continued and a regional waterworks will be constructed in the middle term in this area. Therefore, in the short term, the ARD and the solar distillation combined with rainwater harvesting are planned for the public facilities.

IDWs, RWHs and SDWs are planned in the area where the above-mentioned measures are not to be implemented. In addition, in order to monitor the trend of arsenic concentrations, monitoring wells are to be constructed in *the observation area*.

a. Deep groundwater development for rural water supply in Keshabpur（Priority Project 1）

The shallow aquifers and the deep aquifers are clearly separated by a thick clayey layer lying at a depth from 100 to 200m in four (4) thanas in southern Jessore District of *the urgent area*. The shallow aquifers are highly contaminated, however, the deep aquifers are not contaminated, according to analysis results. The contaminated groundwater will not flow downward through this clay layer into the deep aquifer considering the thickness of the clay and the groundwater head. Accordingly, it is thought that arsenic-free water can be supplied by the development of the deep aquifers.

Sixty-one (61) mouzas, with a total population of 84,000, in Keshabpur are the most heavily affected by arsenic contamination among all the thanas in *the urgent area* as seen in Rajnagar Bankabarsi Village. Therefore, Keshabpur has been selected as a priority project. The project supplies arsenic-free groundwater through construction of deep wells at a depth of 300m, an elevated water tank, a pipeline and a public stand post. However, according to the feasibility assessment of O&M of the community, it can be changed to a deep well equipped with a hand pump.

b. Provision of arsenic-free water to socially vulnerable sectors (Priority Project 3)

ARD and RWH installation programs are planned for the contamination measures in *the urgent area* and *the semi-urgent area*, excluding Keshabpur. As these facilities must be operated and maintained by the residents at their own cost, the safety, usability and operational method must be disseminated in the long run. Therefore this program is planned as a dissemination activity for the vulnerable sector of the society, such as children and aged people, who have no capacity to implement immediate relief. The system is composed of a combined method using RWH and ARD of solar distillation. The system can be operated and maintained at minimum waste and a low cost.

c. Establishment of Thana Arsenic Mitigation Promotion Center (Priority Project 4)

Utilization of an ARD is one of the urgent contamination measures. Once the community agrees to share the O&M cost, an adsorption system is thought to be applicable. This project plans to construct a promotion center in the center of the thanas as a base for dissemination activities for the arsenic contamination measures in the long run. The center will be used to distribute the device and give technical support to the villages, where the O&M cost sharing is agreed. This will promote the sustainable arsenic contamination measures based on the villagers' own efforts. The promotion centers along with warehouses, where the adsorption system and adsorption media will be stored and displayed, are to be constructed in the DPHE thana offices.

d. Construction of alternative water sources

At least one type of alternative water source (IDW, PSF, RWH or SDW) is to be constructed at mouzas in the area not covered by the above-mentioned programs.

(1) IDWs are to be constructed in the southern area of Jessore District where this method is thought to be applicable considering the hydrogeological conditions.

(2) PSFs are to be constructed utilizing the ponds, which are applicable for drinking water all year round.

(3) RWHs are to be constructed at the official facilities in the mouzas.

(4) SDWs are to be protected from surface water infiltration.

e. Installation of monitoring well

Existing wells are to be selected and monitored at each mouza in *the observation area* and arsenic analysis is to be conducted once a year. The monitoring well is to be selected from the 300 existing wells surveyed in the Study.

2) Middle term and long term measures

Groundwater development of deep aquifers is to be carried out for 124 mouzas in Jikargacha Thana and another three thanas in the southern *urgent area*. In addition, the regional rural waterworks are to be planned for mid-long term measures in the northern *urgent area* and the entire *semi-urgent area*. Construction of alternative water sources is to continue at the selected mouzas.

a. Deep groundwater development for rural water supply in Jikargacha Thana etc.

A water supply system, consisting of a deep well (depth 300m), an elevated tank, a pipeline and a public stand post, is to be constructed at 124 mouzas in Jikargacha, Manirampur and Sharsha

Thanas in the southern *urgent area* to supply arsenic-free drinking water to the residents. The total population of the three (3) thanas is 194,000.

b. Regional Rural Waterworks

In order to supply arsenic safe drinking water to a wide area, the regional rural waterworks is planned for the northern *urgent area* and *semi-urgent area* as a core component of the Master Plan. In these areas, the water supply options are treatment of groundwater or surface water, or collection of rainwater. There are many restrictions in any case and the area for a sustainable O&M of the water supply system is limited. Therefore, the groundwater is treated in the urban area and transported to the rural area through the pipeline. The area to be supplied by the regional rural waterworks are four (4) thanas in Chuadanga, five (5) thanas in Jehnaidah and two (2) thanas in Jessore, with a total a population of 741,000 from 419 mouzas. In each mouza, a receiving water tank, pipeline and public stand post will be constructed. The water source is to be secured at the existing pourashava water supply systems and the thana water supply systems that will be constructed in the Master Plan.

c. Alternative water sources

Based on the screening survey, at least one of the alternative water sources (IDW, PSF, RWH or SDW) is to be implemented in the mouzas not covered by the regional rural waterworks.

9.5.3 Measures for Urban Areas

Pourashavas and thana centers are the urban areas of the three districts and they are classified into *the supplied* and *unsupplied areas* of the waterworks. Among the pourashavas, arsenic concentrations of the groundwater in the water supply systems in Chuadanga, Jhenaidah and Moheshpur exceed the Bangladesh standard. Therefore, urgent measures, including construction of arsenic removal plants, are necessary in these three pourashavas. The deep well water sources in Sailkupa, Kaliganj, Kotchadupur and Jessore are presently not contaminated, however, the water supply systems are to be rehabilitated and expanded in the middle term in order to increase coverage and to meet the future water demand.

Furthermore, temporary measures are to be adopted for *the unsupplied area* of the pourashavas as the arsenic contaminated shallow tube wells are being utilized for drinking purposes in this area. In addition, since the centers of each thana are growing and becoming urbanized, the water supply systems are to be constructed in the middle to long term in the centers as with the four pourashavas in Jhenaidah District. The water supply systems are also to be utilized as the water sources of the regional rural waterworks.

1) Short term Measures

a. Rehabilitation and Expansion of Three Urban Water Supply Systems（Priority Project 2）

The water supply systems of Chuadanga, Jhenaidah and Moheshpur are to be rehabilitated and expanded since the deep wells were contaminated. This program is to be implemented as a short-term measure. However, its long-term target is the water supply coverage of 50% by individual house connection and public stand posts, respectively, by the year-2010. The project is composed of the construction of arsenic removal plants, and the construction and rehabilitation of deep wells, elevated tanks, pipelines and public faucets.

b. Water Supply for Urban Outskirts

In three (3) pourashavas, the pipeline is to be expanded to *the unsupplied area* of the urban outskirts along the main road and public faucets are to be installed. Rickshaws will transport water to the remote area from the faucets. For emergencies, a water tank truck is to be stationed.

2) Mid to Long Term Measures

a. Rehabilitation and Expansion of Four Urban Water Supply Systems

The water supply systems of Sailkupa, Kaliganj and Kotchandupur in Jhenaidah district and Jessore are to be rehabilitated as a midterm measure. However, its long-term target is the water supply coverage of 50% by individual house connection and public faucets, respectively by year-2010. The project is composed of the construction of arsenic removal plants, and the construction and rehabilitation of deep wells, elevated tanks, pipelines and public faucets. The construction of elevated tanks, expansion of the pipelines, installation of the faucets are planned in Sailkupa, Kaliganj and Kotchandpur. In Jessore, the pipelines are to be expanded and the faucets are to be installed. In addition, a master meter and individual water meters are installed in all pourashava water supply systems.

b. Construction of Thana Water Supply Systems

Thana water supply systems are to be constructed in the growing centers of the thanas, i.e. Alamdanga, Damurufuda and Jibanagar in Chuadanga District, Harinakunda in Jhenaidah District, Chuagacha, Jikargacha, Keshabpur, Manirampur and Sharsha in Jessore District. The systems are to be composed of deep wells, arsenic removal plants, elevated tanks, a pipeline and public faucets. The systems will be connected to the regional rural waterworks.

9.5.4 Research& Development and Monitoring

In order to establish a methodology for arsenic contamination measures and apply it to other areas in Bangladesh, research and development is planned in the Master Man. In addition, monitoring will be conducted to verify the effect of the arsenic measures.

1) Short Term

a. **Start Monitoring**

b. **Research on Arsenic Contamination Mechanism**

c. **Utilization of Jhenaidah Laboratory（Accept samples, water analysis and training）**

d. **Observation of Water Quality and Water Levels**

2) Middle term

a. **Evaluation of Short Term Measures**

b. **Continuation of Monitoring**

c. **Elucidation of Arsenic Contamination Mechanism**

d. **Training of Water Chemists**

e. **Development of Safe Treatment Technology for Sludge**

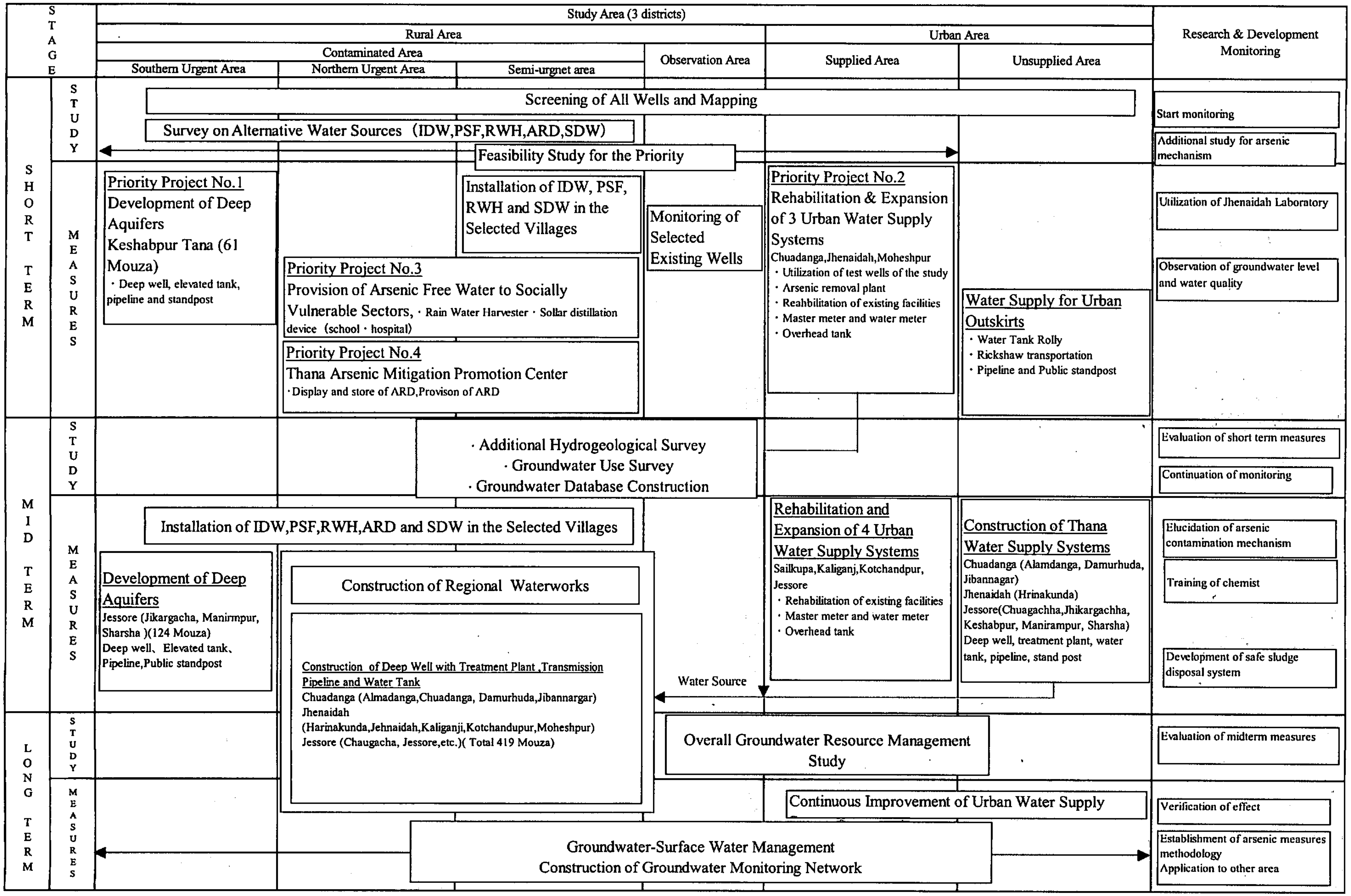
3) Long Term

a. **Evaluation of Midterm Measures**

b. **Verification of Effect of the Measures**

c. **Establishment of Methodology for Arsenic Contamination Measures (application to other area)**

Figure 9.5.1 MASTER PLAN FRAME WORK (Chuadanga, Jhenaidah, Jessore)



IDW: Improved Deep Well RWH: Rain Water Harvester SDW: Shallow Dug Well
PSF: Pond Sand Filter ARD: Arsenic Removal Device

9.6 Operation & Maintenance and Dissemination Activities

9.6.1 Operation & Maintenance Plan

The National Policy for Safe Water Supply & Sanitation (1998) states user’s participation in planning, development and operation and maintenance (O&M) through local government and community based organizations (CBO), phased cost sharing by the CBO and the introduction of an economic service price in water supply.

Considering this policy, O&M of the rural water supply systems in the Master Plan is to be carried out by the residents themselves under the concept of VLOM (Village Level Operation and Maintenance). The residents organize an O&M committee, elect the members, such as caretakers, and operate and manage the water supply systems by themselves. The residents share the cost of O&M. Periodical maintenance of the facility will be conducted by DPHE staff from thana offices more than once a year. The DPHE thana offices will be rearranged accordingly, the technical staff will be trained and the office will be equipped with the necessary equipment and materials.

On the other hand, pourashavas are carrying out O&M of the existing water supply systems. The proposed urban water supply systems in the Master Plan are also to be operated and maintained by the porurashavas. However, it is necessary to rearrange the organizations technically, financially and institutionally to upgrade the water supply service and improve its management.

9.6.2 Dissemination Activities

It is essential to use safe drinking water to prevent arsenic poisoning and water borne diseases due to arsenic and bacterial contamination. Most importantly, the correct information concerning arsenic issues must be given to the residents as an arsenic contamination measure. Therefore, in parallel with the implementation of various kinds of measures, dissemination activities including sanitary education are to be conducted as a component of the Master Plan. The staff from the DPHE thana offices and NGOs are to conduct educational activities and training on O&M of the alternative water supply facilities and ARDs installed in the villages. In addition, TRT (Trainer’s Training) is to be adopted to increase the capacity and ability of the organizations and their staffs (capacity building).

CHAPTER 10

PRIORITY PROJECTS

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10.1 Groundwater Development of Deep Aquifer in Keshabpur

10.1.1 Justification

Keshabpur Thana of Jessore District, which is located in the Master Plan Urgent Area, was selected as a priority project for the pre-feasibility study.

The aquifers in the southern part of Jessore District are clearly separated into a shallow aquifer and a deep aquifer by thick clayey layers lying at depth from approximately 100 to 200 m. According to the results of arsenic analysis, it is confirmed that the shallow aquifer is highly contaminated by arsenic while the deep aquifer is not contaminated[1]. Therefore, supply of arsenic free water by the development of deep aquifer is thought to be possible.

Keshabpur Thana consists of 61 Mouzas with a population of about 84,000,which is the highest number among all Thanas in the District. Since the area is deeply affected by arsenic contamination, it is significant to select this Thana as a priority project. A location map of the study area is given in Supporting Report 1, Figure 1.3.2 and the administration units and population of the Study Area are summarized in Table 11.1.1.

10.1.2 Outline of the Project

A pipeline water supply facility composed of a deep well, a generator, a power pump, a water tower, distributing pipes, and a communal faucet will be constructed in the 61 mouzas listed as urgent areas in Keshabpur, Jessore District to supply safe arsenic-free groundwater. Prior to the water supply facility construction, the following studies and activities will be carried out.

1) Screening

The screening of all existing wells in the project area is carried out. The purpose of screening is as follows.

(1) To verify the safety of the wells in terms of arsenic contamination and to notify the residents of the results.

(2) To prepare a map of arsenic contaminated areas, which will be reflected in the Water Supply Facility Plan.

(3) To grasp the actual harm suffered due to arsenic contamination

2) Public Education

Educational activities for the residents will be held on arsenic contamination, hygiene, O&M of

[1] Based on the results of arsenic analysis of the samples from the Improve deep wells and core boring hole (observation well) (April, 2001)

the water supply facility etc.

3) Capacity Building

Trainers and specialist who can support the project can be secured in Keshabpur by cultivating capable personnel through capacity building.

10.1.3 Water Supply Facility

1) Water Supply Area

As the total area of the 61 mouzas is 100.7km^2, the water supply area per mouza is 1.65km^2 (within a radius of 1.3km).

2) Water Supplied Population

As the total population of the 61 mouzas was 83,999 people (year 1992), the population per mouza was 1,377 people. The target year for the project is 2010 and the water-supplied population for each mouza will be 1,880 people.

3) Water Consumption

The water consumption is set at 35 lcd.

4) Water Supply Facility

Table 10.1.1 Summary of Water Supply Facility

Facility	Specifications	Per Mouza	Total
1. Production well	ϕ 150 mm	1	61
	Depth of 300 m, 24 m screen		
2. Pump	1 operating, 1 stand-by	2	122
	Lifting pipe, control panel included		
	1 operating, 1 stand-by		
3. Generator	RC, brick wall	2	122
4. Control office	Equipment room (4 m x 4 m), control room	1	61
	(4 m x 3 m), Total area of 28 m2		
	GI pipes, ϕ 50 mm		
	Capacity 15 m3, RC		
5. Water line	PVC pipes, ϕ 100 mm	100 m	6,100 m
6. Supply tower	Sluice valve	1	61
7.Distributing pipe	Sludge outlet	5,200 m	317,200
8.Incidental equipment of	Pipe terminal	1 set	m
distributing pipe	ϕ 13 mm		61 sets
9. Common faucet		104	
			6,344

10.1.4 Operation Cost

The project cost is summarized as follows.

Table 10.1.2 Project Costs

Unit cost: Taka

Item	Per mouza	61 Mouzas
1. Screening	45,360	2,766,960
2. Public education	115,200	7,027,200
3. Capacity building	388,800	1,555,200
4. Construction	10,048,320	612,947,520
Grand Total	10,234,375	624,296,880

10.1.5 Implementation of the Project

The project is carried out by DPHE. DPHE will organize a steering committee (PMU) with full-time members. The PMU will procure the consultant and the contractor and supervise the implementation of the project in liaison with DPHE's Jessore District office and the local office in Keshabpur.

(1) The residents of the mouzas should organize a village water committee and should manage the facility in a democratic way.
(2) The committee should be responsible for water charge collection and accounting.
(3) O&M of the facility should be entrusted to a local private business or a NGO.
(4) The DPHE should carry out periodical monitoring of water quality.

10.1.6 Operation and Maintenance Cost

The estimated O&M cost is summarized as follows:

Table 10.1.3 Operation and Maintenance Costs (Monthly cost per mouza)

Item	Price (Tk)
1. Generator fuel (1.51/h x 8h x 30 days x 50Tk/l)	18,000
2. Consumption articles such as engine oil	4,000
3. Repairs	3,000
4. Labor	18,000
5. Office supplies	1,000
6. Miscellaneous	1,000
Total	45,000
Charge per user (per month)	23.9
Unit cost / 1 m^3 of water	22.8

10.1.7 Water charge

1) Fixed-rate

A monthly charge of 23.9 Tk per person will be required. As the average number of people per household is 4.71, the monthly charge per household will be 112.6 Tk.

2) Charge based on volume of water consumed

The water charge for drinking and cooking only is 8.2 Tk/person/month and 38.6 Tk/month/household will be required

According to the social survey, the charge that the residents are willing to pay for arsenic free water is 16 to 75 Tk/household/month. As the charge based on a fixed-rate exceeds the residents' willingness to pay, a payment system based on water consumption should be adopted.

10.1.8 Alternative Plan for Water Supply

An alternative plan of hand pump wells is planned for comparison with the piped water supply plan.

1) Water Supply Facility

The water supply system is composed of the deep well with TARA hand pump and platform. Hand pump: TARA pump. This facility supplies 185 persons per hand pump at a water consumption rate of 35lpcd. As the estimated water supply population per mouza is 1,880 people, 10 wells are required for each mouza.

2) Construction Cost

The construction cost was estimated as follows.

Table 10.1.4 Construction Cost

Unit: Tk

Item	Per Well	Per Mouza
1. Production well	295,000	2,950,000
2. Hand pump	22,000	220,000
Subtotal	317,000	3,170,000
1. Construction (20%)	63,400	634,000
Total	380,400	3,804,000
2. Design supervision (20%)	76,100	761,000
Grand total	456,500	4,565,000

3) Maintenance Cost

The maintenance cost per mouza is estimated to be 6,890 Tk/month. The water charge is 3.7 Tk/person or 17.3 Tk/household.

4) Comparison with Piped Water Supply

The quantity of the water supplied is the same. However, the distance to the water source is less than 50 m in the piped system while it is less than 200 m in the hand pump system. The cost comparison is as follows.

Table 10.1.5 Cost Comparison

Unit: Tk

Water Supply Facility	Construction Cost (Per mouza)	Maintenance Cost (Monthly cost per mouza)
Power pump, pipeline	10,049,000	45,000
Hand pump well (10 locations)	4,565,000	6,890

If the plan is limited to a supply for drinking and cooking purposes only, the water consumption is 12lpcd. The number of wells required for each mouza is 4 and the construction and maintenance costs can be estimated at less than half of the above plan. However, in this case, the transport distance is within 320 m. The estimated construction and O&M cost are as follows.

Table 10.1.6 Construction Cost and OM Cost

Unit: Tk

Water Supply Facility	Construction Cost (Per mouza)	Maintenance Cost (Monthly cost per mouza)
Hand pump well (4 locations)	1,826,000	2,756

10.2 Urban water supply facilities improvement and expansion project

10.2.1 Background

There are seven urban water supply facilities in the study area. Among these, the existing wells of Chuadanga, Jhenaidah and Moheshpur have been polluted slightly by arsenic. The following matters have been concluded.

(1) The existing wells (about 100 to 150 m in depth) for the 3 Pourashava water supply facilities have been polluted by arsenic (0.05 to 0.1 mg/l). One of these wells (Cuadanga) showed 0.12 mg/l.

(2) In these 3 Pourashavas, about 250,000 residents are drinking polluted well water without any treatment.

(3) Arsenic concentrations can be lowered below the standard value with an arsenic removal device (ARP) of a similar treatment method constructed by 18 DTP (aeration + sand filtration type).

(4) If the treatment facilities are added to present water-supply facilities, the present amount of water demand is satisfied.

(5) Because the water supply coverage in 3 pourashavas is 8 to 32%, it is necessary to develop the new production well; And the coverage of a safe drinking water supply can be raised by enhancing the new distribution pipe and stand post to the unsupplied region where the shallow well is used now.

(6) It can possibly become an arsenic pollution measure in the local urban area and a model of the water-supply facilities improvement.

10.2.2 General condition of three pourashavas and content of plan

The general condition of the three pourashava water supply facilities is shown in Table 10.2.1. The coverage of Jhenaidah and Chuadanga is not widespread and the facilities are deteriorated. There is no elevated tank in Moheshpur and water is supplied directly from the well pump.

Therefore, it is necessary to construct the arsenic removal facilities but also rehabilitate and expand the present water supply facilities.

Table 10.2.1 General condition of three pourashava water supply facilities

Pourashava	Jhenaidah	Jhenaidah	Chuadanga
Population Served	94,624	25,490	152,000
Household	11,775	4,980	10,700
House Connection	2,320	375	2,541
Coverage (%)	31.6 %	8 %	18.7 %
Stand post (No.)	40	9	10
Production (m3/day)	3,000	863.65	3,000
Production well (No.)	7	2	6
Pipeline length (km)	55	8.67	42.5
Overhead Tank (No.)	3	0	3
WTP	0	0	0
Running Hand TW	785	550	700
Coverage (%)	24.89 %	92 %	14.0 %

WTP: Water Treatment Plant TW: Tube Well

10.2.3 Proposed Project

1) Water supply area and population served

The water-supply area is a pourashava community area. The population in the year-2005 and 2010 is estimated and presented in Table 10.2.2 (Growth rate: 1.8%). Coverage was presumed to be 100% in 2010 and 75% in 2005. The water is assumed to be supplied through an individual house connection at 50% and the public stand post at 50%.

Table 10.2.2 Population forecast

District	Pourashava	2001	2005	2010
Jhenaidah	Jhenaidah	97,000	105,000	115,000
	Mohespur	31,000	35,000	40,000
Chuadanga	Chuadanga	155,000	167,000	182,000
Total		285,001	309,005	339,010

2) Water demand forecast

The unit water demand is set as follows.

Table 10.2.3 Unit Water Demand

	Unit Water demand (L/c/d)
House Connection（13 people/house）	100 L/c/d
Stand Post(100 people/1 set)	35 L/c/d
loss of water (water leak and others)	30% of above mentioned

The water demand of each pourashava is calculated as follows.

Table 10.2.4 Water Demand Forecast

2000				2005		2010	
Population	Existing Production Capacity (m^3/d)	Operation Hours	Production Capacity (12hrs)	Population	Water Demand (m^3/d)	Population	Water Demand (m^3/d)
94,624	3,000	5	7,000	105,000	7,000	115,000	10,000
30,000	870	4	3,000	35,000	2,000	40,000	4,000
152,000	3,000	6	6,000	167,000	11,000	182,000	16,000
276,624	6,870		16,000	307,000	20,000	337,000	30,000

3) Water Supply Concept

The existing wells are rehabilitated and maintained to meet the future water demand. New wells will be constructed. After treatment, arsenic safe water is transmitted to an overhead tank, and then supplied to residents. The operation time is appropriate to be 12 hours/day.

4) Target Water Quality

The target arsenic concentration is set at 0.05 mg/l (the present Bangladesh drinking water standard).

5) Treatment Method

It is important that the treatment method allow operation and maintenance to be continued easily. According to the observation of aeration and sand filtration in Satkhira and Manikganj in the vicinity of the study area, decreasing arsenic concentrations below the water standard value 0.05 mg/l is thought to be possible. If chlorine and iron salt is added to this treatment method as an oxidizing agent and coagulant respectively, it is possible to decrease arsenic levels to less than 0.01 mg/l, which is the WHO guideline value. Therefore, the treatment method is assumed to be the aeration-sand filtration method in which treatment effects are already confirmed in this region.

6) Facility Plan

The facility plan of the 3 pourshavas is presented in Table 10.2.5.

Table 10.2.5 Number of the Facilities in the Project

Pourashava	Chuadanga				Jehnaidah				Moheshpur			
Facility	Total	Existing	2005	2010	Total	Existing	2005	2010	Total	Existing	2005	2010
1 Production Well (No.)	14	5	6	3	10	7	1	2	3	2	0	1
2 Well Pump (No.)	14	5	6	3	10	7	1	2	3	2	0	1
3 Pump House (No.)	14	5	6	3	10	7	1	2	3	2	0	1
4 Transmission Pipe (km)	14	0	11	3	10	0	8	2	3	0	2	1
5 Treatment Plant	2 Plant (５Unit)	0	1 Plant (3Unit)	1 Plant (2 Unit)	1 Plant (3Unit)	0	1 Plant (2Unit)	(1Unit)	1 Plant (1Unit)	0	1 Plant (1Unit)	0
6 Over Head Tank (No.)	7	3	2	2	5	3	1	1	2	0	1	1
7 Clean Water Transmission Pipe (km)	7	0	5	2	6.26	1.26	4	1	2	0	1	1
8 Transmission Pump (No.)	6	0	3	3	4	0	3	1	3	0	2	1
9 Pump House (No)	2	0	1	1	1	0	1	0	1	0	1	0
10 Reticulation Pipe (km)	110	43	68	0	107	59	48	0	20	9	11	0
11 Incidental Equipment												
12 House Connection (No.)	7,000	2,682	2,135	2,183	4,423	2,320	709	1,394	1,538	360	650	529
13 Stand Post (No.)	910	10	616	284	575	40	353	181	200	0	131	69

10.2.4 Estimated Construction Cost

The construction cost was calculated referring to the results of 18DTP of the Netherlands.

Table 10.2.6 Construction Cost for Target Year 2010

Unit: Lakh Taka

Item	Chuadanga	Jhenaidah	Moheshpur	Total
1) Direct Construction Cost	1,485.47	847.74	377.90	2,711.11
2) Land Acquisition and Compensation	74.27	42.39	18.90	135.56
3) Engineering Services	148.55	84.77	37.79	271.11
4) Administration Cost	222.82	127.16	56.69	406.67
5) Contingency	193.11	110.21	49.13	352.44
Total	2,124.22	1,212.27	540.40	3,876.89

10.2.5 Annual Operation and Maintenance Cost

The cost comprises all expenditures that are required to keep a system in operation and in good condition after it is placed on line. They include the expense for annual maintenance and repair costs, operation costs (e.g. salary, power, fuels, chemicals) and miscellaneous costs. The annual operation and maintenance cost is summarized in Table 10.2.7 below.

Table 10.2.7 Annual Operation and Maintenance Cost

Unit Lakh/year

District	Paurashava	2001	2005	2010
Jhenaidah	Jhenaidah	16.46	33.49	48.43
	Moheshpur	4.16	15.11	20.43
Chuadanga	Chuadanga	18.36	68.97	86.74
Total		38.98	117.56	155.61

Table 10.2.8 Annual Revenue

REVENUE

Unit Lakh/year

District	Paurashava	2001	2005	2010
Jhenaidah	Jhenaidah	13.92	17.91	26.10
	Moheshpur	2.16	5.68	8.28
Chuadanga	Chuadanga	16.092	28.76	41.93
Total		32.172	52.34	76.30

10.3 Provision of arsenic free water to socially vulnerable sectors by Rain Water Harvesting and Solar Distillation (RWH/SD) system

10.3.1 Objective and Justification

The arsenic mitigation program in the rural area shall be sustained by the rural people themselves by work and cost contribution for the supply of water. The unconditional provision of mitigation measures such as arsenic removal devices, without confirmation of willingness to share the operational and maintenance cost by the users, should be avoided to promote and sustain the program in the long run. Therefore, it is expected that extending the mitigation measure will be a long process, starting from awareness activities, etc. On the other hand, the vulnerable sector of the society, such as people in hospital and children in school, requires immediate relief as children and sick persons have no such capacity to implement the measure.

The mitigation measure for such groups of people shall be of very low or no operational and maintenance cost, as they do not have financial capacity. In this regard, rain water harvesting and a solar distillation system can serve as an ideal combination. Another objective is its impact on awareness building on arsenic mitigation, as hospital and school are the place where a large number of people will visit and benefit from it.

10.3.2 Project description

1) Basic concept

As discussed in detail in Chapter 7.2, solar distillation technology is the lowest costing option for operation and maintenance while its arsenic removal efficiency is nearly 100%. A drawback of the technology is its limited capacity to produce large volumes of water. On the other hand, rain water harvesting is the one of the proven technology for arsenic mitigation. A drawback is the shortage of rain in the long dry season. A combination of the two technologies can supplement the weak points of each technology, as solar distillation is most effective in dry season when clouds are at a minimum.

2) Project site

The sites for installation of the system are Thana health complexes and selected schools in the urgent and semi-urgent area for the arsenic mitigation program. A Thana health complex is the government hospital operational in each Thana center and provides wide medical services to the residents in the Thana. Health complexes that are currently fed by contaminated wells and do not have an alternative water supply shall be selected for the project. Schools for the project shall be selected from the most seriously affected area with no alternative water supply. The number of sites is assumed, at this stage, as 50. It is not possible to cover all schools in the area. Therefore, the schools will be selected to have a geographically uniform distribution so that an awareness impact can be made in all areas.

The Thana health complexes considered for the project are summarized in the table below.

Table 10.3.1 Number of Mouzas and Population

District	Thana	Urgent area		Semi-urgent area	
		Mouza	Population	Mouza	Population
CHUADANGA	Alamdanga	4	4874	18	38327
	Chuadanga	23	43674	50	123772
	Damurhuda	3	8235	10	40651
	Jibannagar	16	27113	32	51384
JHENAIDAH	Harinakunda	-	-	5	4872
	Jhenaidah	2	982	29	31400
	Kaliganji	-	-	5	5202
	Kotchandpur	10	12148	13	12244
	Maheshpur	20	29865	58	98977
JESSORE	Chaugachha	49	86857	45	61875
	Jessore	7	18187	20	40443
	Jhikargachha	50	71831	66	102932
	Manirampur	45	54203	77	131977
	Sharsha	29	68002	28	50572

3) System description

The system shall consist of

- A rain water collection system using the building roof of the school or hospital
- An initial rain water cut-off unit
- A rain water storage tank and sand filtration tank
- A groundwater pumping unit with solar cell power
- An oxidation and iron removal tank for groundwater
- A solar distillation unit (vacuum and multi-effect system)
- Necessary water piping for the water supply

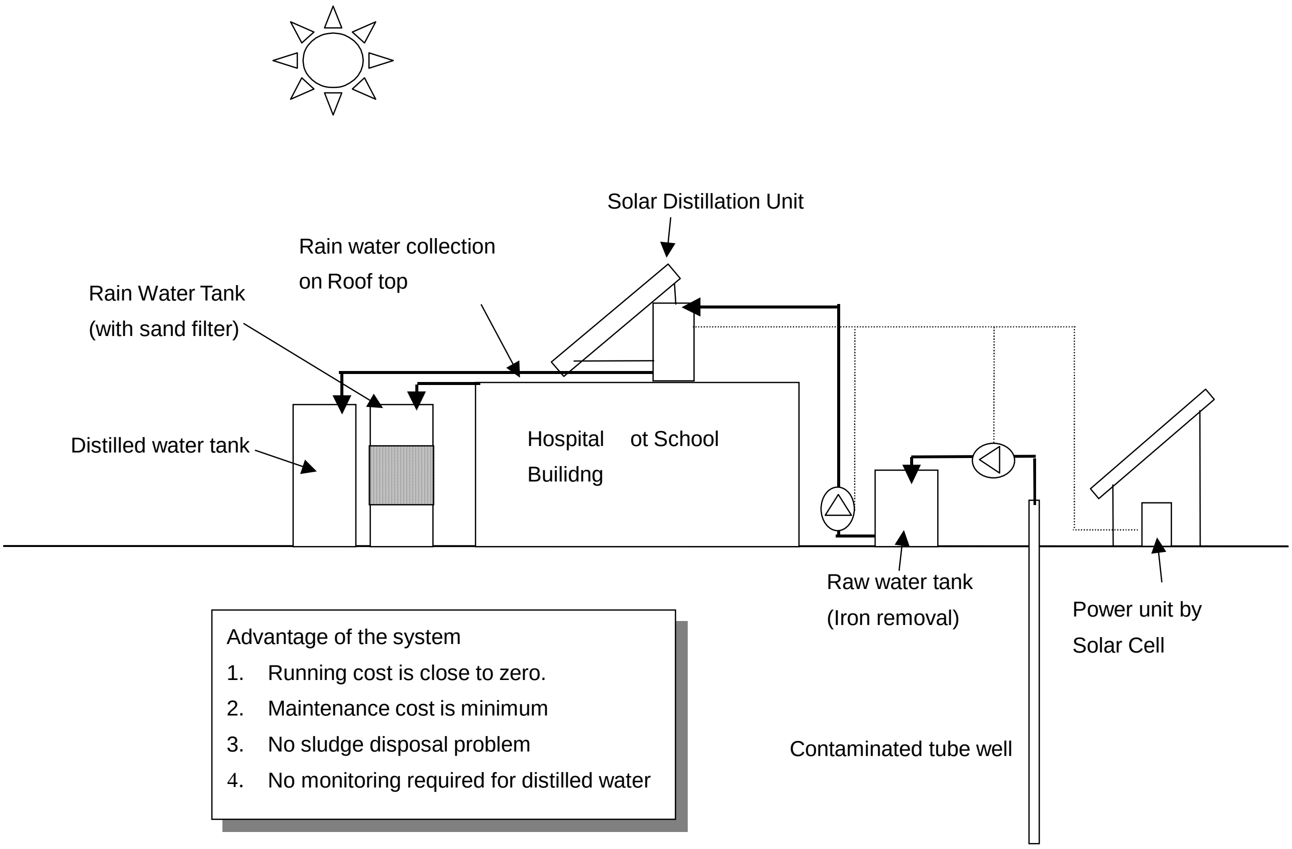

Figure 10.3.1 Conceptual view of Rain Water Collection + Solar Distillation in Hospital or School

10.3.3 Beneficiaries and Cost

1) Number of beneficiary

Because of the model project nature of the project, the beneficiaries are the ones who obtain the awareness and ideas about arsenic and arsenic free water by rain water collection and solar distillation. Assuming that the number of hospitals is 14 and that of schools is 36, the beneficiaries will be approximately 4,500 x 14 + 300 x 36 = 86,400 persons.

2) Cost estimate

The approximate cost of the project, assuming the number of locations as 50, was estimated at 3,582 Lakh Taka.

The annual operation and maintenance cost of the project is estimated at 30 Lakh Taka.

To implement the project, the feasibility study shall cover the site conditions, arsenic contamination in the areas, building roof conditions, details of the hospitals and the schools, water supply conditions, a detail design of the system, a cost estimate and O&M.

10.4 Establishment of Thana arsenic mitigation promotion center

10.4.1 Objective and Justification

Within the priority area, Thanas other than Keshabpur are not yet confirmed for safe development of deep aquifer. For such thanas, an immediate countermeasure available is an arsenic removal device (ARD). Community use of arsenic removal devices is recommended once a cost sharing arrangement is agreed on in the community. The promotion center will help such communities to start the arsenic removal and water supply operation by providing technical support as well as the removal device for initial operation.

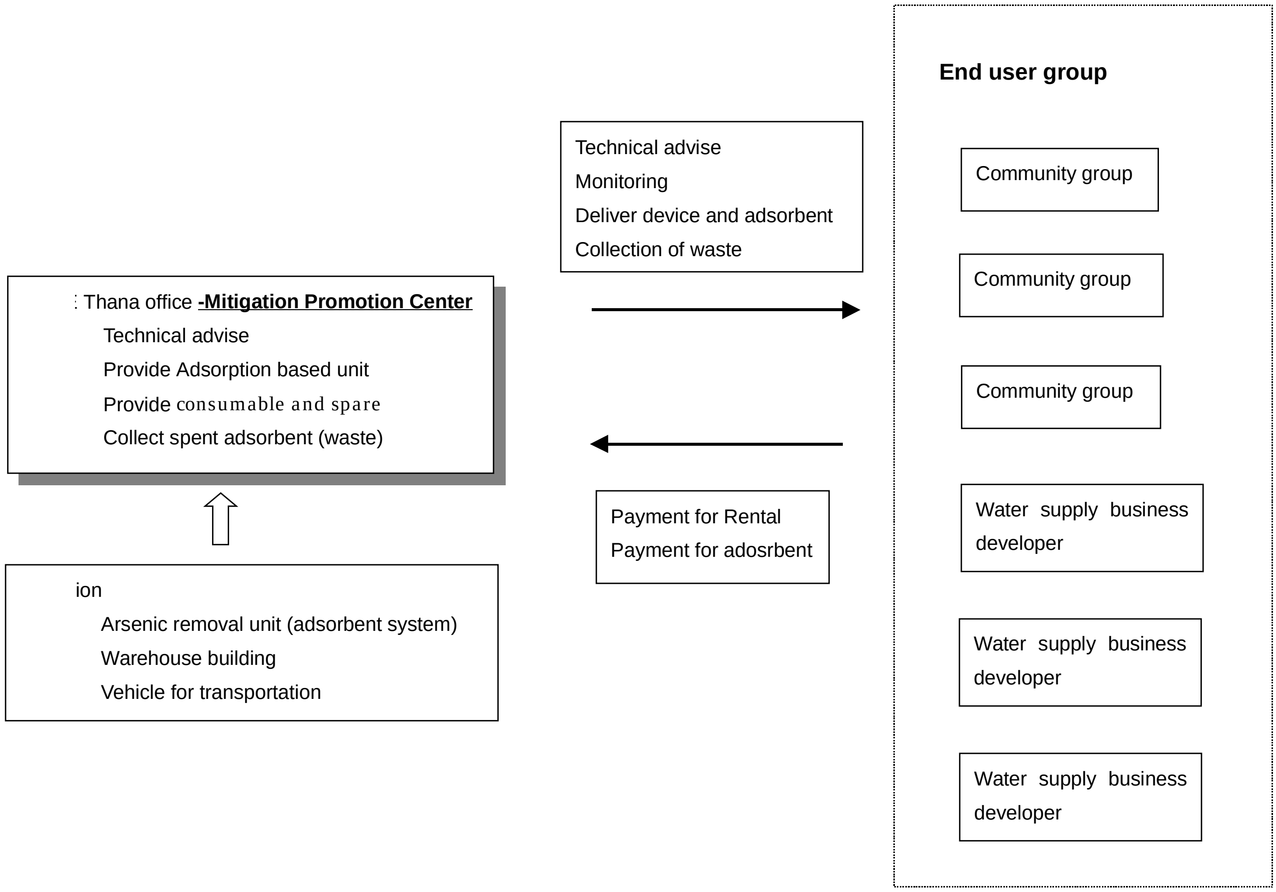

Figure 10.4.1 Concept of Mitigation Promotion Center

10.4.2 Project description

1) Basic concept

As discussed in detail at Chapter 7.2, an adsorption based arsenic removal device of community use is, at this stage, considered as a feasible option for immediate extension to the rural area. However, delivery of such a device without consent of the cost burden may fail in sustainable operation because it requires media replacement at some time interval.

On the other hand, communities or groups who have agreed on the cost burden need access to technical advice as well as arsenic removal devices to start mitigation work. The proposed center will function as such an access point for the community. The center will also provide technical advice to the community for rain water harvesting as well as passive sedimentation whenever the technology is applicable to the community site because it costs much less to the user.

Operational support for adsorption-based systems requires timely delivery of the replacement media as well as collection of waste or spent media to avoid secondary environmental contamination. Therefore, the proposed center will also function as a delivery and collection center of the media.

2) Project site

The site for the center is Thana DPHE in the urgent and semi-urgent area for the arsenic mitigation program.

3) Center description

The Center shall be consists of

- A technical adviser and water quality testing kit
- Social and health workers
- A warehouse for arsenic removal devices and adsorption media
- A warehouse for the storage of waste adsorption media
- A vehicle for transportation.

10.4.3 Beneficiaries and Cost

The communities' need for arsenic removal devices depends on awareness activities. At this stage, 2,000 units (with capacity of 100 person /unit) shall be sufficient to meet the need of the area.

1) Number of beneficiary

As one arsenic removal unit is assumed to provide arsenic free water to 100 persons, the total number of beneficiaries for the 2,000 units will be 200,000 persons.

2) Cost estimate

The initial construction and procurement cost of the project is estimated at 285 Lakh Taka. For operation of the center, an annual budget of 50 Lakh Taka is required.

To implement the project, the feasibility study shall cover site selection, arsenic contamination of the area and population, level of awareness for arsenic mitigation, details of the arsenic removal device, delivery and installation, monitoring and media replacement, cost and O&M.

10.5 Project Appraisal

This section analyzes the financial and economic feasibility of each priority project selected as the subjects of pre-F/S in the M/P.

The financial and economic appraisal of each project is carried out by analyzing its financial and economic internal rate of return (FIRR and EIRR) based on the net present value (NPV) method.

10.5.1 Project Appraisal of Rural Water Supply for Keshabpur by Groundwater from Deep Aquifers

The M/P recommends two options of rural water supply for Keshabpur by groundwater from deep aquifers. One is the piped water supply through public faucets, and the other is the water supply by hand pump (TARA) installation. The Study here made a preliminary appraisal of each project.

1) Piped water supply through public faucets

a. Operation Cost

Based on the project plan, construction of the rural water facility will be completed in two years including the detailed design of facilities and other preparatory works. The following table is the annual operation cost of the facility.

Table 10.5.1 Annual Operation Cost of the Facility

Unit: Tk/mouza/year

Item	Cost
Fuels for generator	216,000
Consumables (engine oil, etc.)	48,000
Maintenance and repair	36,000
Manpower cost	216,000
Office utensils	12,000
Miscellaneous expenses	12,000
Total	**540,000**

Remark: Cost of water quality monitoring is excluded from the operation cost above.

The Study assumed that no major replacement of water supply facility would occur during the project period while minor replacement of equipment and facility parts will be covered by the annual maintenance and repair expenses.

2) Estimation of Project Income

In accordance with the willingness-to-pay survey done by the Study Team, the water bill that rural users are willing to pay ranges from 16 to 75 Tk per household per month regardless of how much water they use. As the average number of family members per household is 4.71 according to our rural household survey, the per capita willingness-to-pay ranges from 3.39 to 18.75 Tk.

Even if applying the upper limit of willingness-to-pay of 18.75 Tk per capita, it cannot cover the annual operation and maintenance cost of the planned facilities using this flat rate billing system, as shown in Table 10.5.4 below.

Table 10.5.2 Estimation of the Water Bill to Cover O/M Cost of the Planned Facilities

(1) O/M cost	540,000 Tk/mouza/year	(1)
(2) Population supplied	1,880	(2)
(3) Per capita cost of O/M	**287Tk/year**	(1)/(2)
(4) Monthly WTP per capita	From 3.39 to 18.75Tk/month	WTP survey
(5) Annual WTP per capita	**From 40 to 225Tk/year**	(4) X 12 (months/year)

a. Appraisal of the project

To fully cover the project cost including initial investment, it is estimated that the required water-billing rate will be approximately 650 Tk per capita per year, which is far beyond the willingness-to-pay of the rural people.

All of these estimated figures indicated that the project would not be feasible in terms of the financial and economic evaluation of the project.

3) Water supply by hand (TARA) pump installation

As the alternative of the project mentioned in the former section, the Study recommends rural water supply by hand (TARA) pump installation.

a. O&M Cost

Table 10.5.3 O&M Cost of the Facilities

Item	Cost (TK/well/year)	Remark
Hand pump spare parts	550	Renewed annually
DPHE staff allowance	2,800	Well inspection
Patrol vehicle's fuel	1,750	DPHE vehicle
Hand pump cleaning	2,400	Every 3 years
Reserve for renewal of hand pump	770	Every 10 years
Total	**8,270**	

Reamrk: Replacement cost of hand pump is included in the above table. It is assumed that no other replacement cost will arise during the project period.

Because 4 hand pump wells are estimated to be necessary to meet the water demand for each mouza, the total O&M cost for each mouza is 33,080 Tk per year.

b. Estimation of Project Income

Considering that the willingness-to-pay of the rural people ranges from 3.39 to 18.75 Tk per capita per month or from 40.68 to 225 Tk per capita per year, the Study established several flat rates ranging from 40 to 225 Tk per capita per year. The project income is estimated as the result of multiplying the above flat rate of water bill by the population of each mouza, which is approximately 1,880.

c. Appraisal of the Project

Table 10.5.8 below shows the result of estimating the NPV and FIRR of the project by each flat rate of the water bill applied. The discount rate is set at 10% taking into account inflation and the commercial lending rate.

Table 10.5.4 Result of Estimating Key Financial Feasibility Indicators

Water Billing Rate (Tk/capita/year)	NPV (Taka)	FIRR (%)
40	-1,424,646	-20.5%
100	-794,549	-2.9%
150	-269,468	6.1%
170	-59,435	9.2%
200	255,614	13.5%

As shown in the table above, the project is financially feasible enough even by utilizing commercial lending in Bangladesh (which is between 12 and 13% in 2001/02) if the water bill is set at 200 Tk per capita per year. If the initial investment is granted by donors or the government, 100 Tk per capita per year will be enough to self-sustain the project in a financially feasible manner.

10.5.2 Project Appraisal of Piped Arsenic Free Water Supply in the Urban Area

The M/P recommends the project's piped arsenic-free water supply in the urban area of 7 pourashavas, Jessore Sadar, Jhenaidah, Sailkupa, Kaligonj, Kotchandpur, Moheshpur, and Chuadanga, by rehabilitation of the existing water supply facilities and development of new facilities.

1) Appraisal of the Project

A financial appraisal of the project here is made by analyzing the key financial feasibility indicators, i.e. net present value (NPV) and financial internal rate of return of the project after 15 years of the project period.

a. Project Cost and its Allocation

The O/M cost of the facilities shown below is estimated based on the estimation in Section 10.2.

Table 10.5.5 O&M Cost of the Facilities

Unit: Thousand Tk

	2002	2003	2004	2005	2006	2007	2008	2009	2010
O&M	114	114	182	290	290	290	321	355	393

Remark: The O&M cost is assumed to be fixed at 393 thousand Tk per year after 2010.

The Study assumed that no major replacement cost would arise during the 15 years of project period while minor replacement costs were included in the annual O&M cost.

b. Estimation of Project Income

The Study here estimated the income by two cases of water billing rates. One is to set a flat rate of 100 Tk per month per household connection, and the other is to set a meter rate of 5 Tk per cubic meter of water consumption plus the flat rate of 100 Tk per month per household connection, which is currently applied in Satkira. Meanwhile, the Study assumed that a water bill would not be collected from the users of public faucets because no such collection is found in the existing public faucets in Bangladesh.

On the other hand, in the case of applying the meter rate of 5 Tk per cubic meter of water use, the project income is estimated

c. Analysis of Key Financial/Economic Feasibility Indicators

Based on the currently applied water rate in Bangladesh, the Study estimated the NPV and IRR for several assumptions of flat rates ranging from 100 to 200 Tk/house connection/month. For comparison with these assumptions, the Study also estimated the same indicators in the case of combining the above flat rate of 100 Tk per household per month with the meter rate of 5 Tk per cubic meter of water consumption

The project will not be financially feasible if it is carried as an investment project with its own capital or commercial lending because NPV of the project is negative in all the cases above. However, if the construction cost is granted by the government or donors, the project can be financially feasible by applying a flat rate of 200 Tk per household per month or the combination of the flat and meter rates given above, taking into account the recent inflation rate of 1 to 2% in Bangladesh.

10.5.3 Preliminary Project Appraisal of Other Two Projects

1) Arsenic Free Water Supply to Socially Vulnerable Sectors by Rain Water Harvesting and Solar Distillation (RWH/SD) System

The Study estimated the financially feasible level of the cost covered by each beneficiary. The financially feasible level of IRR of the project is established at 10%, taking into account the current commercial lending rate in Bangladesh. According to the Study's estimation, the cost coverage of around 60 Tk per month per beneficiary is needed to self-sustain the project.

2) Project Appraisal of Thana Arsenic Mitigation Promotion Center

The Study estimated the financially feasible level of the cost covered by each beneficiary. The financially feasible level of IRR of the project is established at 10%, taking into account the current commercial lending rate in Bangladesh. According to the Study's estimation, the cost coverage of 150 to 200 Tk per month per beneficiary is needed to self-sustain the project.

10.6 Regional Rural Water Works

Groundwater in the deep aquifer in the northern *urgent area* is slightly contaminated with arsenic. The water supply options in this area and *semi-urgent area* are treatment of groundwater or surface water, or collection of rainwater. There are many restrictions in any case and the area for sustainable measures is limited. Therefore, the regional rural waterworks is planned. The groundwater is treated in the urban area and transported to the rural area through the pipeline.

10.6.1 Purpose and Design Criteria

1) Purpose

The purpose of the plan is to supply arsenic safe drinking water to the rural areas where deep aquifers are not suitable for development. The clean water is transported through the pipeline. The plan is the core of the middle term and long term measures of the master plan as mentioned in the previous chapter. The target areas for the plan are shown in the following table.

Table 10.6.1 Target Thana, Population and Water Demand

DISTRICT	Thana	Mouza	Population	Water Demand m^3/d	Supplied Water m^3/d
CHUADANGA	Alamdanga	22	43,201	1,512	1,210
	Chuadanga	73	167,446	5,861	4,688
	Damurhuda	13	48,886	1,711	1,369
	Jibannagar	48	78,497	2,747	2,198
	Sub total	156	338,030	11,831	9,465
JHENAIDAH	Harinakunda	5	4,872	171	136
	Jhenaidah	31	32,382	1,133	907
	Kaliganj	5	5,202	182	146
	Kotchandpur	23	24,392	854	683
	Moheshpur	78	128,842	4,509	3,608
	Sub total	142	195,690	6,849	5,479
JESSORE	Chuagacha	94	148,732	5,206	4,164
	Jessore	27	58,630	2,052	1,642
	Sub total	121	207,362	7,258	5,806
Total		419	741082	25,938	20,750

This plan assumes that 80% of the population of the target areas receives safe water through the regional rural water works. Each mouza shall bear the cost of construction of the receiving water tank and water charge. In addition, house connections or stand posts shall be constructed by the residents themselves when they are required.

2) Design Criteria

a. Target Year and Population served

The target year is 2010 and the population served is 80% of the projected population in 2010.

b. Unit Water Demand

It is assumed that the water works supplies 35 L/d/c for drinking and cooking purposes.

c. Water Source

The water source is secured at the existing wells of Pourashava Water Supply System (PWSS) (groundwater source: depth about 100 m) and newly constructed wells in Thana centers. The standard of the PWSS service is 12 hours operation. If the operation time is extended to nighttime, the amount of water required in the rural area can be produced from the existing wells. However, there are only seven PWSSs in this region. For instance, there is only one PWSS in Chuadanga Pourashava in Chuadanga District. Water may be supplied from one PWSS to the whole district technically. However, it is necessary to compare the cost depending on whether water is supplied for a large area or small area. As several growing Thana centers can be seen in the target area, this plan constructs new water supply facilities at Thana centers like Moheshpur and supplies water to the surrounding mouzas. Thus, Thana DPHE shall be responsible for O&M of the facility.

3) Pump Station

A water supply pumping station will be installed in the vicinity of the treatment plant of each Thana. A receiving well will be constructed in a Thana center such as Kaliganj, where the groundwater of existing wells is not contaminated with arsenic. A water supply pumping station will also be installed in close vicinity of the receiving well (It is necessary to examine the booster pumping method).

4) Mouza water receiving tank

The receiving water tank that is able to store a daily water use amount will be installed at each mouza (50-100 m^3). The tank is elevated at 10 m above ground level for flood protection. In addition, the ball tap is installed in order to stop water automatically when the tank is filled with water. The type of water tank and reticulation pipe should be decided in each Mouza.

5) Clean Water Transmission Pipe

The clean water transmission pipe is made of ductile cast-iron pipe. Reticulation pipe in the Mouza is PVC.

10.6.2 Water Supply Facilities Plan

A pipeline network of the regional rural waterworks plan is presented in Figure 10.6.1. A summary of the facilities are presented in Tables 10.6.2 and 10.6.3

Table 10.6.2 Designed Water Volume and Average Receiving Capacity

Distirct	Thana	Water Volume (m^3/d)	Receiving water capacity (average) m^3	Facility
CHUADANGA	Alamadanga	1,590	72	construction
	Chuadanga	6,162	84	existing
	Damuruhuda	1,799	138	construction
	Jibannagar	2,889	60	construction
	Subtotal	12,440		
JHENAIDAH	Harinakunda	179	36	construction
	Jhenaidah	1,192	38	existing
	Kaliganj	191	38	existing
	Kotchandupur	898	39	existing
	Moheshpur	4,741	61	existing
	Subtotal	7,201		
JESSORE	Chaugaccha	5,473	58	construction
	Jesoore	2,158	80	existing
	Subtotal	7,631		
TOTAL		27,272		

Table 10.6.3 Number of Facilities

Thana	Well	Elevated Tank	Raw Water Transmission Pipe（km）	Treatment Plant	Transmission Pump	Pump House	Clean Water Transmission Pipe(km)
Alamdanga	2	1	2	1	3	1	56
Chuadanga Sadar	0	0	0	0	3	1	80
Damuruhuda	2	1	2	1	3	1	53
Jibannagar	3	1	3	1	3	1	50
Subtotal	7	3	7	3	12	4	239
Harinakunda	2	1	2	1	3	1	40
Jhenaidah Sadar	0	0	0	0	3	1	38
Kaliganji	0	0	1	0	3	1	27
Kotchandpur	0	0	1	0	3	1	31
Moheshpur	0	0	0	0	3	1	92
Subtotal	2	1	4	1	15	5	228
Chaugaccha	5	2	5	2	3	1	114
Jesoore Sadar	0	0	2	0	3	1	27
Subtotal	5	2	7	2	11	2	141
Total	14	6	18	6	38	11	608

Note: It is necessary to construct the arsenic treatment plant in each Pourashava of Chuadanga, Jhenaidah and Moheshpur.

10.6.3 Preliminary Construction Cost Estimate

The preliminary construction cost was calculated by the same method as the PWSS referring to the results of 18DTP of the Netherlands, which had been executed recently. Table 10.6.4 shows the Preliminary Cost Estimate of the regional rural water works.

Table 10.6.4 Preliminary Construction Cost Estimate

District	Construction Cost in Tk. Lakh
Chuadanga	3,021.55
Jhenaidah	2,098.14
Jessore	1,797.87
Total	6,917.55

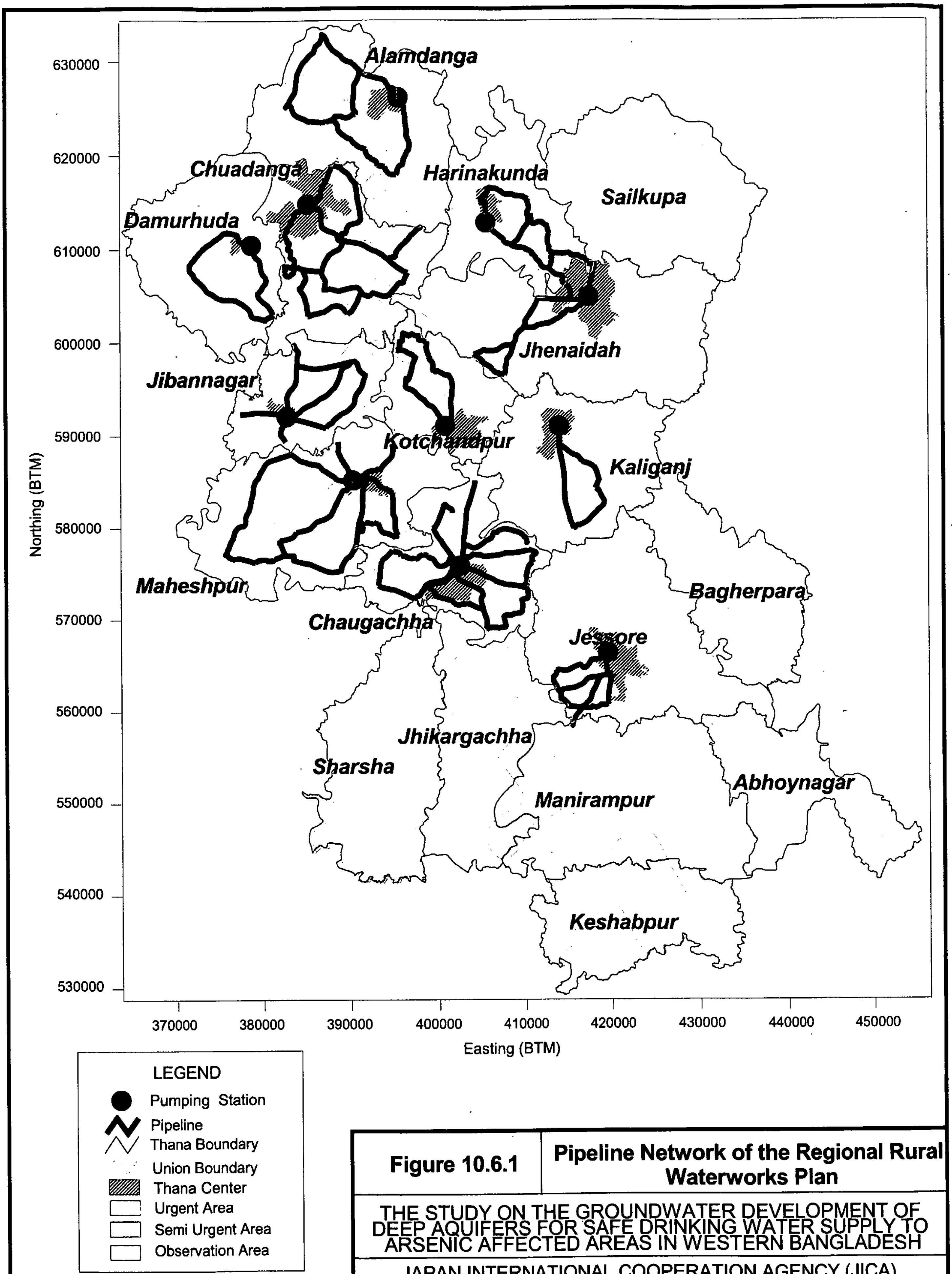

Figure 10.6.1	Pipeline Network of the Regional Rural Waterworks Plan

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)

CHAPTER 11

SUPPLEMENTARY SURVEY IN KESHABPUR AREA

CHAPTER 11 SUPPLEMENTARY SURVEY IN KESHABPUR AREA

A supplementary survey is performed for the formulation of the project in order to take countermeasures for arsenic contamination by using deep groundwater in the Keshabupur area, one of the four priority projects. The supplementary survey consists of a screening survey, mapping, well drilling and pumping test, social survey, water supply plan, facility design/estimation, and Project evaluation.

11.1 Screening Survey

11.1.1 Site Selection

Sixteen mouzas in Keshabpur Thana were selected from sixty proposed mouzas in the priority project based on the population, geographic environment, culture and characteristic of the villages.

Table 11.1.1 and Figure 11.1.1 show the mouzas list and location map of the supplementary survey area.

Table 11.1.1 List of 16 mouzas in keshabpur area on Supplementary Survey

NO.	UNION	MOUZA	AREA Km^2	POPULATION	DENSITY	CD
1	Keshabpur	Madhyakul	3.0448	2702→3485*	887.4	MD
2	Keshabpur	Ramchandrapur	1.9588	1303→1359	665.2	RH
3	Keshabpur	Habaspol	0.8185	799→1107	976.2	HB
4	Keshabpur	Byasdanga	1.2272	992→1118	808.3	BY
5	Keshabpur	Brahmakati	1.4967	1231→1448	822.5	BM
6	Keshabpur	Bhagati Narendrapur	3.1694	3096→4153	976.8	BN
7	Keshabpur	Maguradanga	1.3425	1142→1303	850.7	MG
8	Keshabpur	Khatiakhali	0.7047	648→895	919.5	KK
9	Keshabpur	Baliadanga	1.8232	1925→2907	1055.8	BL
10	Keshabpur	Kesabpur	0.4184	1000→1512	2390.1	KS
11	Keshabpur	Sabdia	1.1650	1013→1720	869.5	SB
12	Keshabpur	Altapol	5.0479	6022→8702	1193	AP
13	Keshabpur	Sujapur	1.4821	1117→1373	753.7	SP
14	Keshabpur	Bajitpur	0.7332	809→1142	1103.4	BJ
15	Keshabpur	Sarfabad	0.8016	549→519	684.9	SF
16	Panjia	Rajnagar Bankabarsi	2.4255	(1769→1941)	729.3	RB

*Population source: left; 1991, right; 2001
R. Bankabarsi: Estimation from household numbers

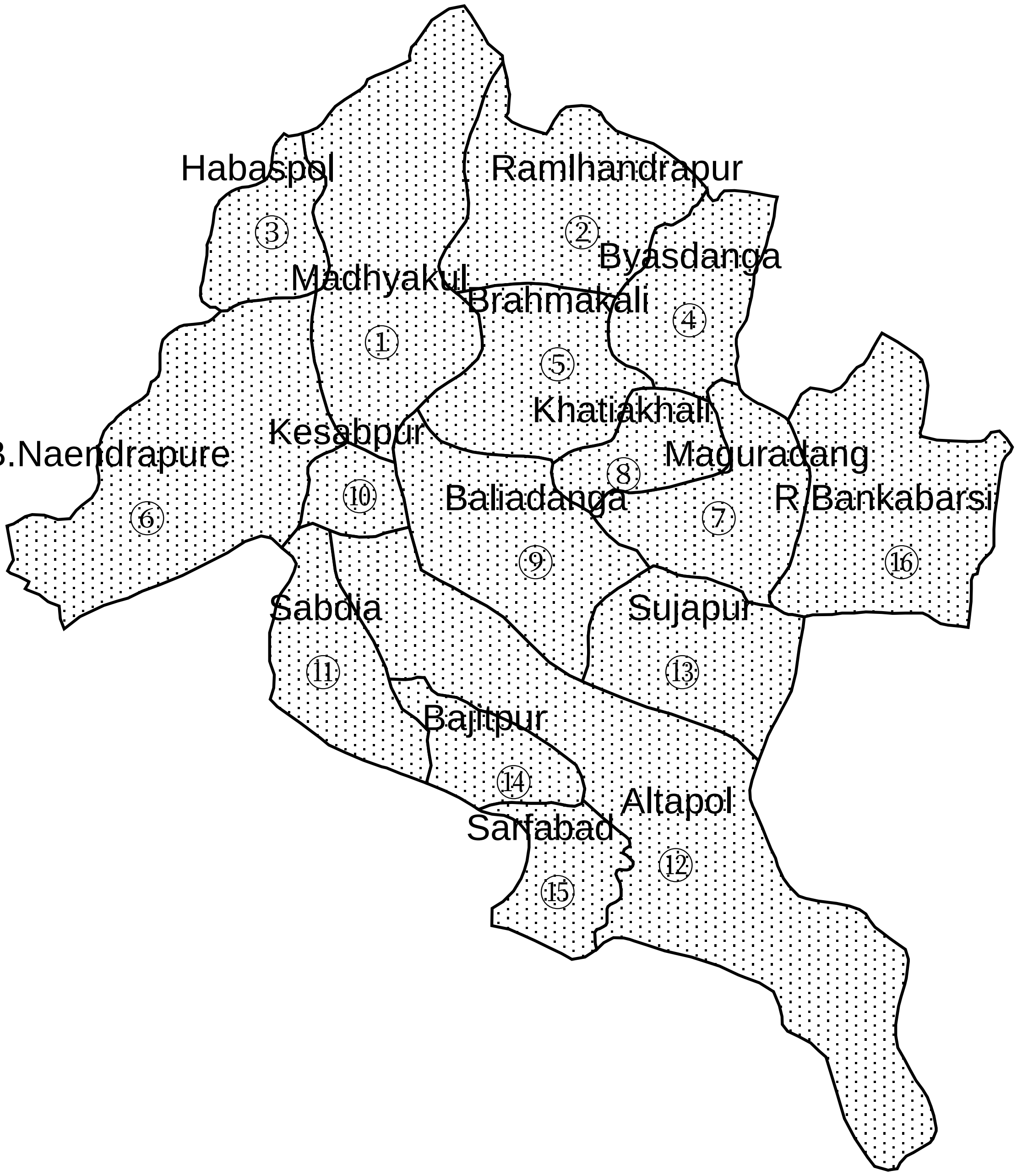

Figure 11.1.1 Location Map of 16 Mouzas

11.1.2 Survey Items and Method

The screening survey was conducted for all existing wells for domestic use in the 16 mouzas. Arsenic, pH, ORP and EC were measured at the site using field test kits. During the field screening survey in the 16 mouzas, groundwater samples from the existing wells were collected for arsenic analysis by the AAS in Jhenaidah Laboratory to compare FK and AAS. The number of samples was approximately more than 10% of the exisitng wells in the 16 mouzas. In the event that low arsenic concentrations by FK were found during the screening survey in the field, these groundwater samples were collected in addition to the 10% for the arsenic analysis by the

AAS in the laboratory.

11.1.3 Results

The results of the screening survey include the location map of wells, the survey sheets with items of well information and groundwater quality including As, pH, ORP, EC, and water temperature.

1) Number of Wells and Well Depth

In the screening survey, the number of wells surveyed in the 16 mouzas totaled to 3,037 (three thousands thirty seven) wells (Supplementary survey total: 2,963 wells +R.Bankabarsi mouza: 74wells).

Figure 11.1.2 shows well density to population (100 persons). Kesabpur has the highest well density to population. The surroundings of Keshbpur mousa also have a high well density. Figure 11.1.3 shows the well depth in the 16 mouza. Dozens of wells are from 40 to 60 m in depth in 16 mouzas, however B. Narendrapur, Sarfabad and Sabdia have many wells from 20 to 40 m in depth, in particular, the wells of this depth make up a large proportion (about 70%) of wells in B. Narendrapur.

2) Arsenic Analysis by Field Kit

a. Shallow Tube Wells

Figure 11.1.4 shows the arsenic concentration map at well points in the 16 mouza. Almost all of wells show values of more than 0.2 mg/l of arsenic. Arsenic concentrations show to be less than 0.1 mg/l at the western and southeastern edge of the survey area. Figure 11.1.5 shows an arsenic concentration contour map by FK. The arsenic concentrations of groundwater were measured at 3,037 exiting wells including R. Bankabalsi wells. On the whole, the high arsenic concentrations values (more than 0.5 mg/l) are distributed to most areas in the survey area. Especially, arsenic concentrations indicate less than 0.1 mg/l, including the values of less than 0.05 mg/l, in the western and southeastern edge of the survey area and a part of R.Bankabarsi. Figure 11.1.6 shows an arsenic concentration contour map by AAS. Sampling was carried out taking samples from 379 existing wells for measurement by AAS at the Laboratory. Most samples indicate values of 0.2 to 0.5 mg/l, although arsenic concentrations of less than 0.1 mg/l, including less than 0.05 mg/l, are seen in the west and southeast along the west boundary of the survey area. The distribution of arsenic concentrations by AAS is similar to that by FK.

b. Irrigation wells

Figure 11.1.7 shows an arsenic concentration contour map of 37 existing irrigation wells by FK. Arsenic concentrations have values of more than 0.2 mg/l in most areas. Arsenic concentrations show the values of less than 0.1 mg/l, including less than 0.05 mg/l, in the western and southeastern edge in the survey area. The results of irrigation wells correspond to the distribution of arsenic concentration in shallow tube wells.

3) Groundwater Quality

a. pH

The most frequent pH values show to be about 7.0 to 7.2 in most mouzas. On the other hand, the most frequent pH values indicate less than 6.8 in pH in Baliadanga.

b. Oxidation-Reduction Potential (Eh)

The most frequent Eh values shows to be about 50 to 150 mV in most mouzas.

c. Electric Conductivity (EC)

Figure 11.1.8 shows the contour map of EC values in the 16 mouzas. The most frequent EC values indicate less than 100 mS/m ranging in the direction of northwest to southeast in the west of the survey area. On the other hand, the most frequent EC values show to be more than 140 mS/m in the direction of northeast in the 16 mouzas.

d. Eh-pH-As Relationship

Figure 11.1.9 shows the relationship among Eh, pH and arsenic concentration in almost all wells. Most of the contaminated samples having more than 0.1 mg/l in arsenic concentration are plotted in a zone with 7 to 7.5 in pH and 50 to 120 mV in Eh.

4) Comparison of FK and AAS

Figure 11.1.10 shows the comparison of arsenic concentrations measured by the AAN
Field Kit and AAS by log-log plot. The results show that the field kit results tend to be relatively lower than AAS below 0.070 mg/l in arsenic concentration by AAS and relatively higher above the value. Concerning quality control, another QC sample group (travel-blank sample) also show good results, which are all below PQL (0.0005 mg/l).

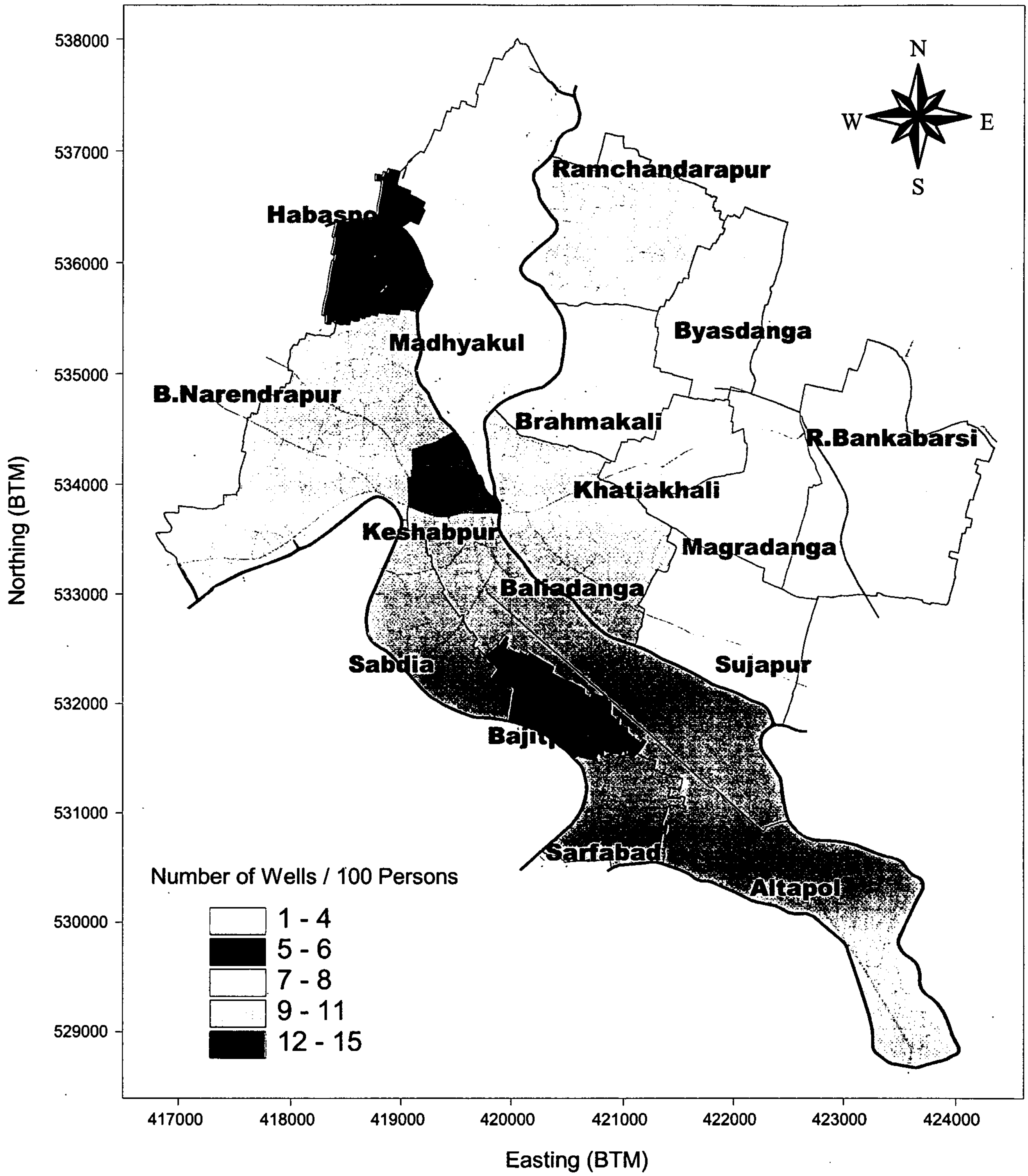

Figure 11.1.2	**Number of Wells / 100 Persons in the Study Area**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
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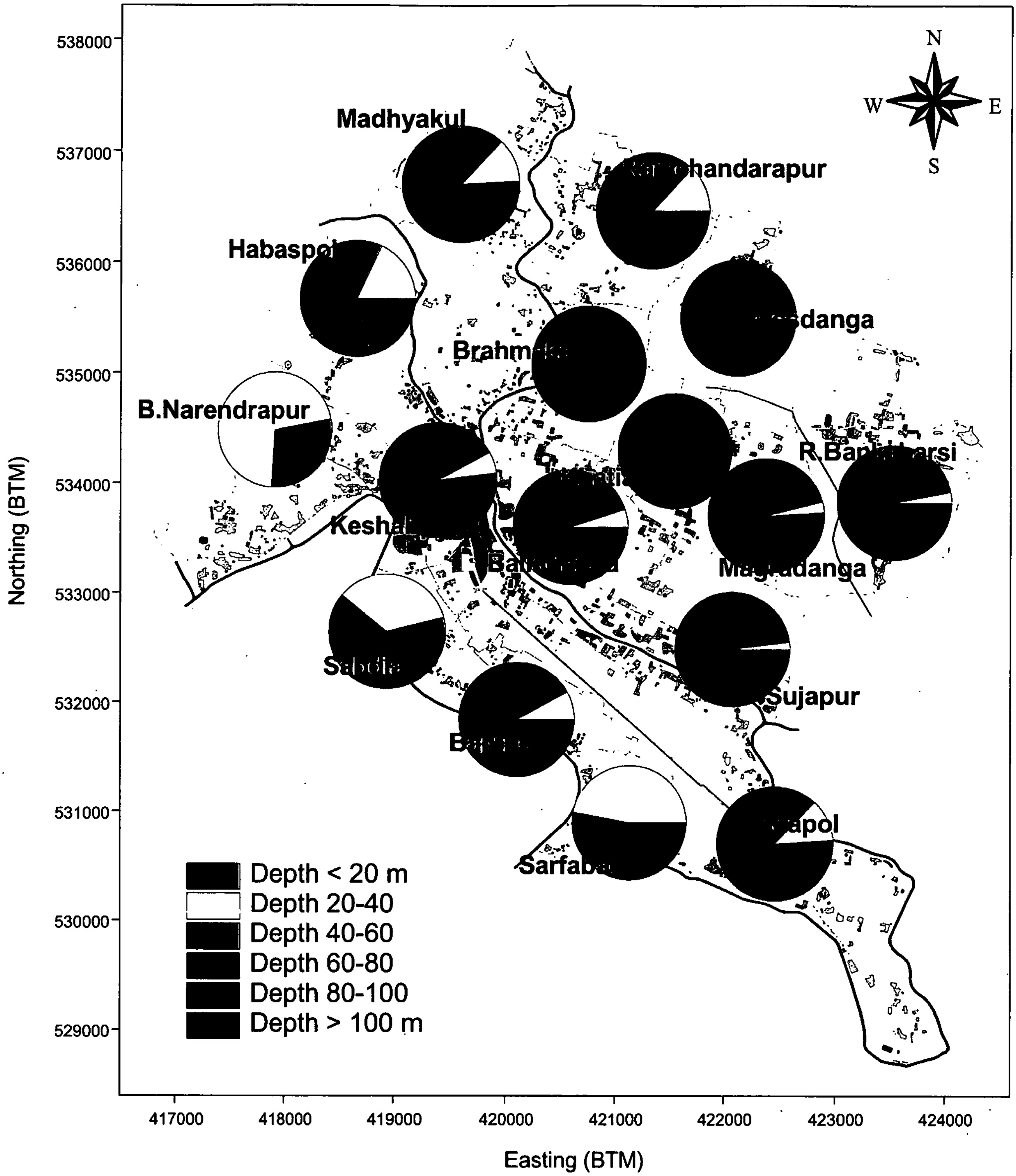

Figure 11.1.3	Well Depth Classification in the Study Area
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
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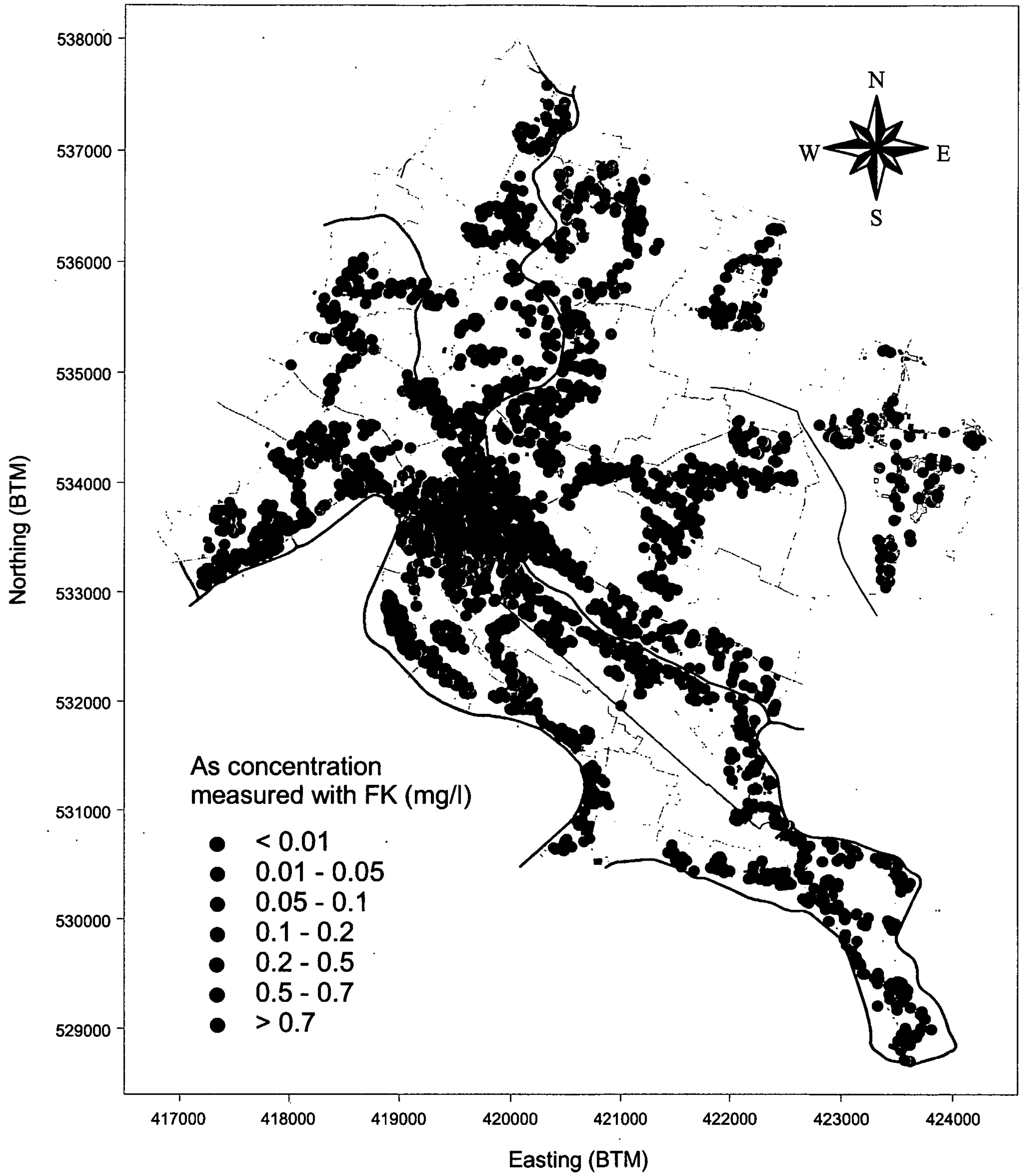

Figure 11.1.4	Arsenic Concentration Map at Well Points of Supplementary Survey
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
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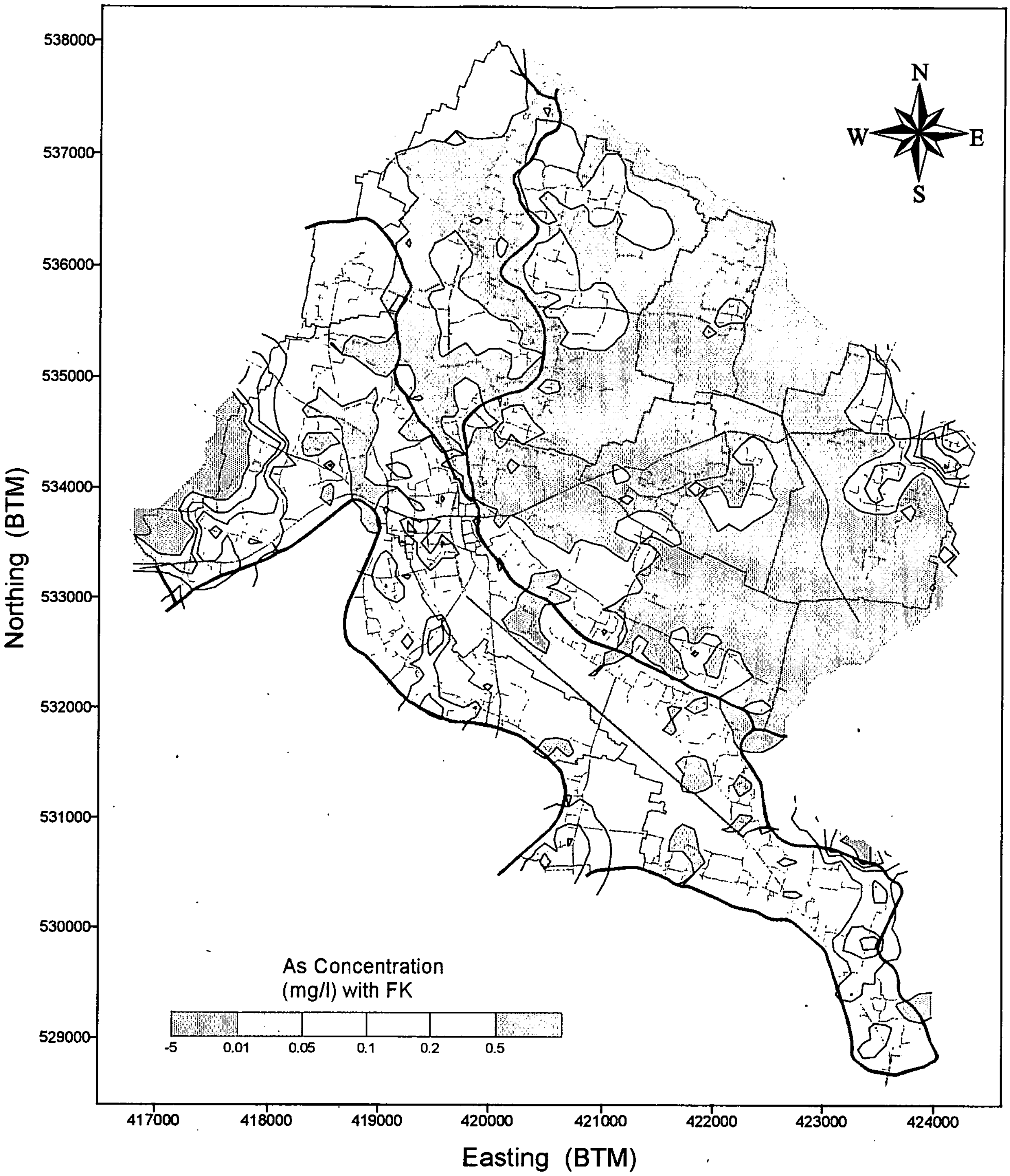

[The arsenic concentrations of groundwater were measured at 3037 existing wells with Field Kits during the supplementary survey Jan. to Feb. 2002.]

Figure 11.1.5	**Map of Arsenic Concentration Measured with Field Kits**
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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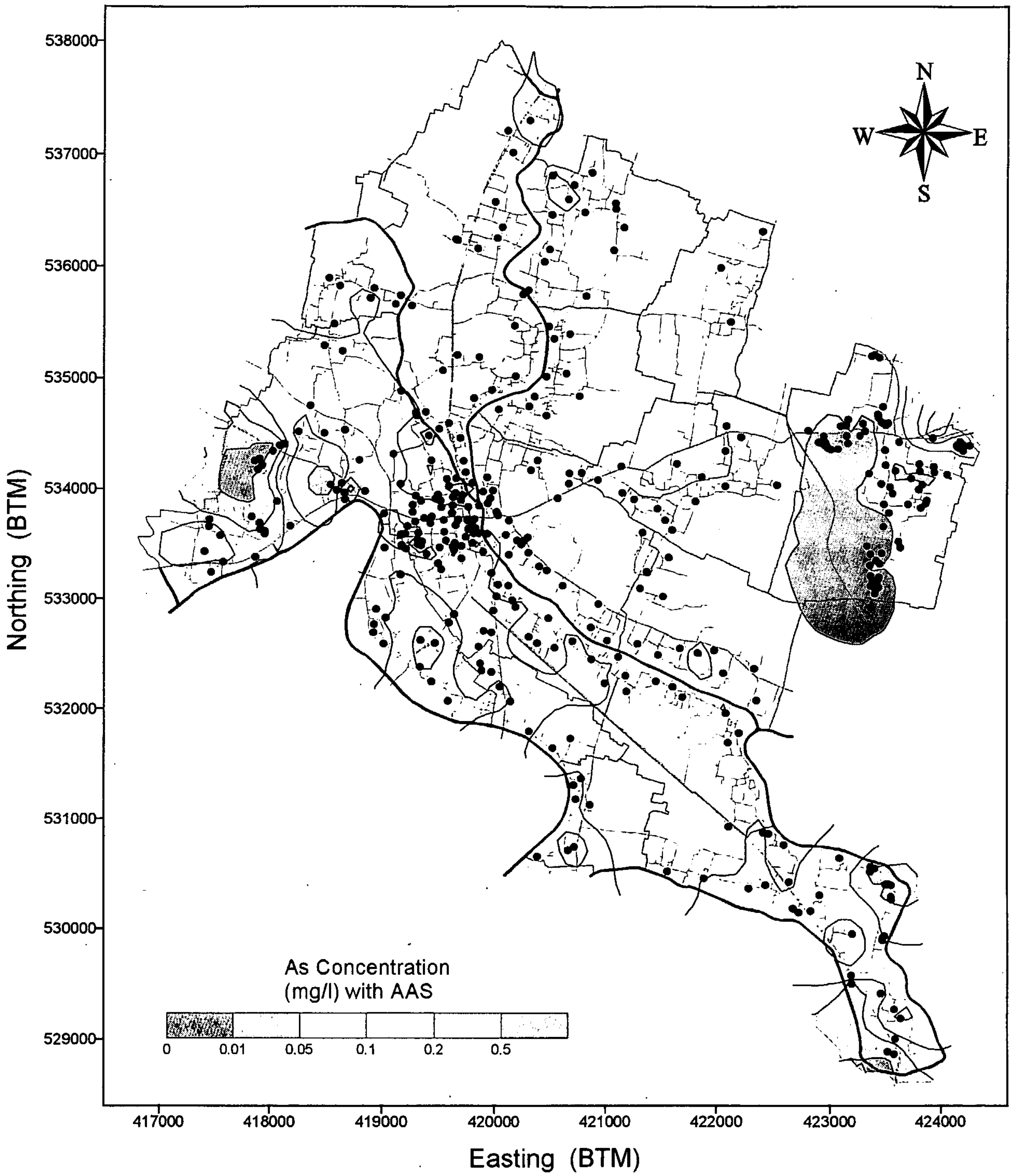

[The arsenic concentrations of groundwater were measured at 379 existing wells with AAS during the supplementary survey Jan. to Feb. 2002.]

● Location of Measured Existing Well

Figure 11.1.6	Map of Arsenic Concentration Measured with AAS
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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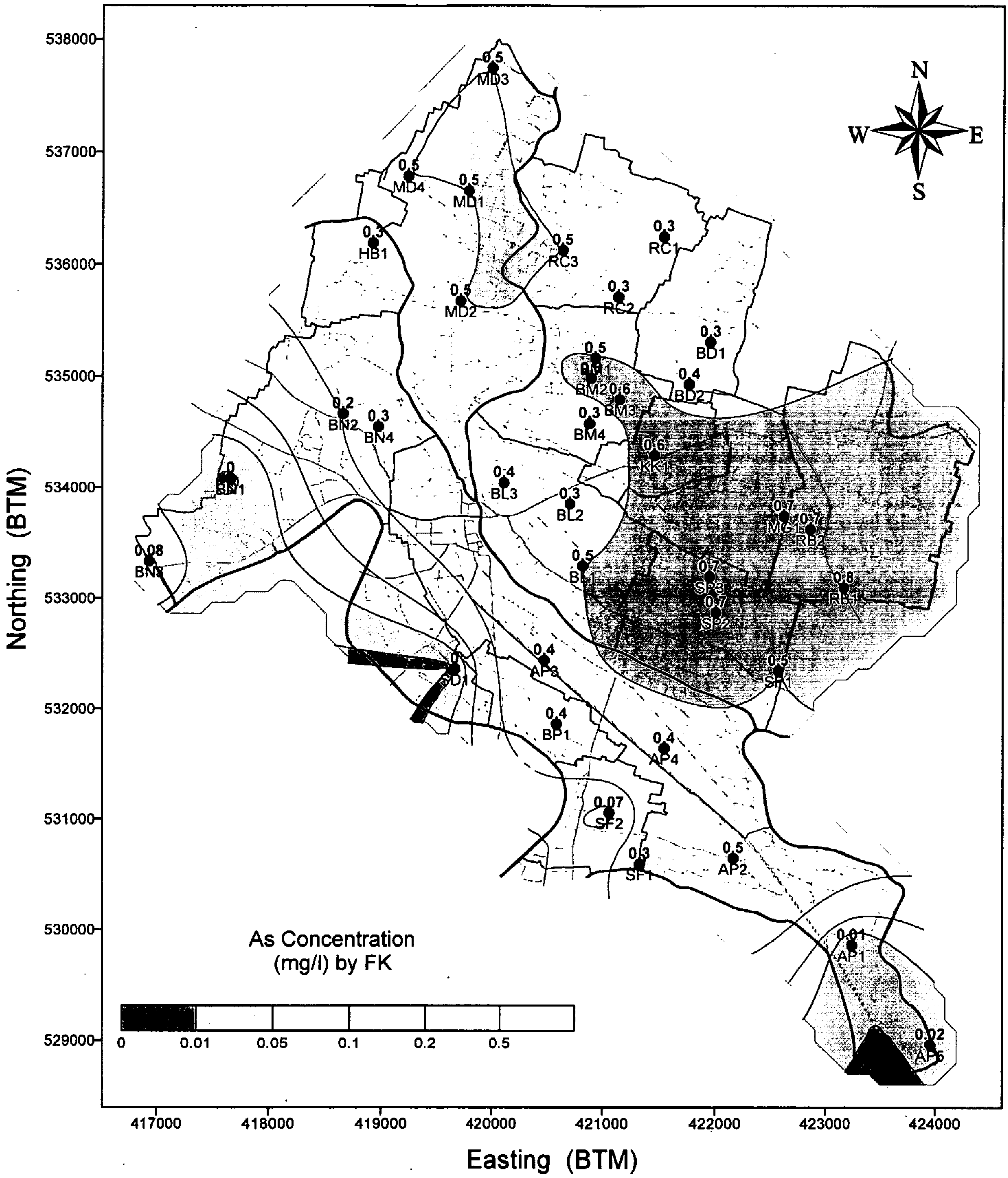

[The arsenic concentrations of groundwater were measured at 37 existing irrigation wells by the AAN Field Kit during the supplementary survey Jan. to Feb. 2002.]

0.05 ● MD2 — Existing Well with As Concentration (mg/l) by AAN Field Kit

Figure 11.1.7	Arsenic Concentration Map of the supplementary survey aera Jan. to Feb. 2002)
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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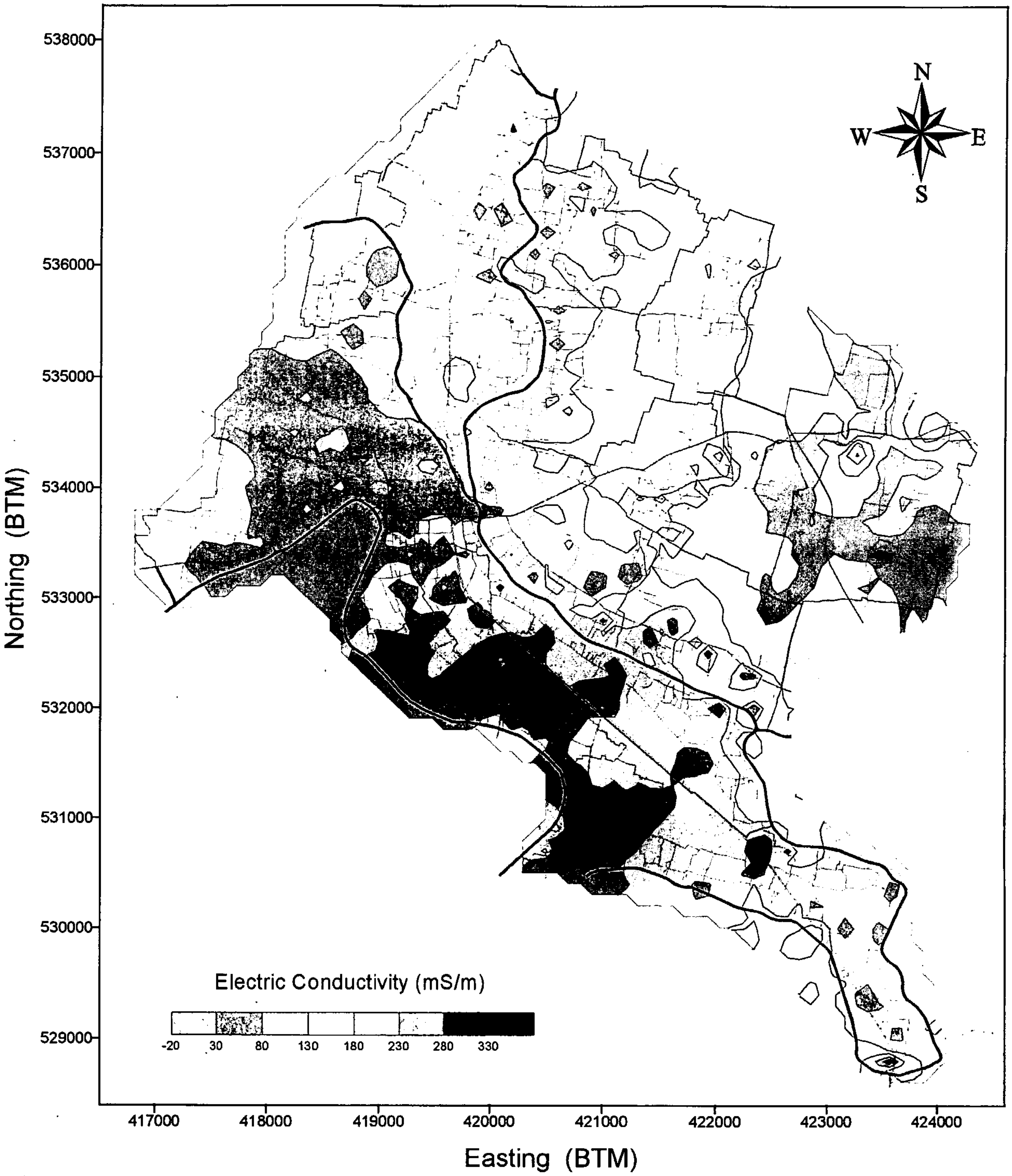

[Electric conductivity (EC) of groundwater was measured at 3037 existing wells with portable EC meters during the supplementary survey Jan. to Feb. 2002.]

Figure 11.1.8	**EC values measured at the existing wells**
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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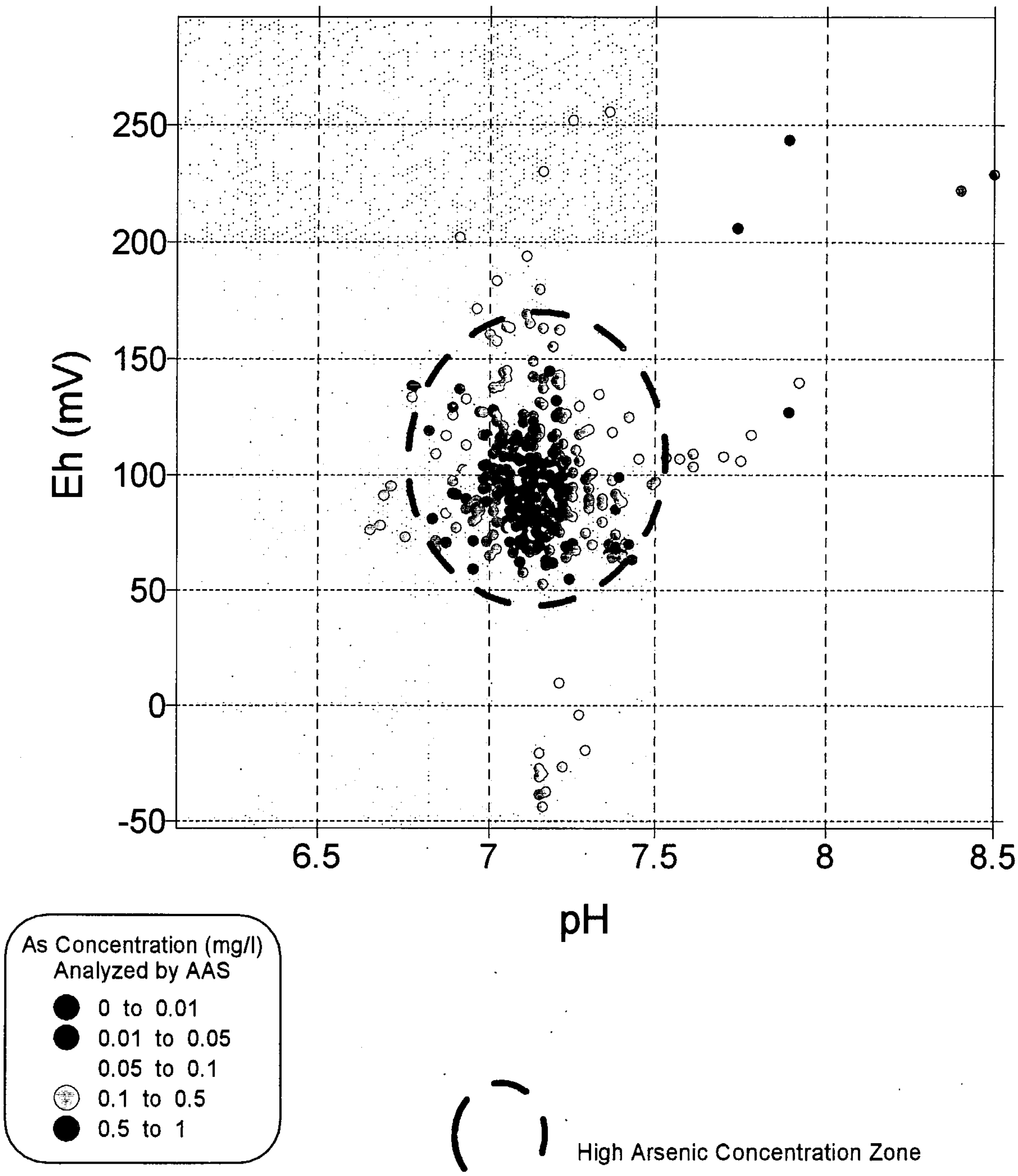

[The ORP and pH values were measured at existing wells from January to March 2002 by potable ORP meter and potable pH meter.
The arsenic concentrations were analyzed by the AAS in Jhenaidah Laboratory.

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 11.1.9	Eh-pH-As Relations of Existiog Wells of Supplementary Survey
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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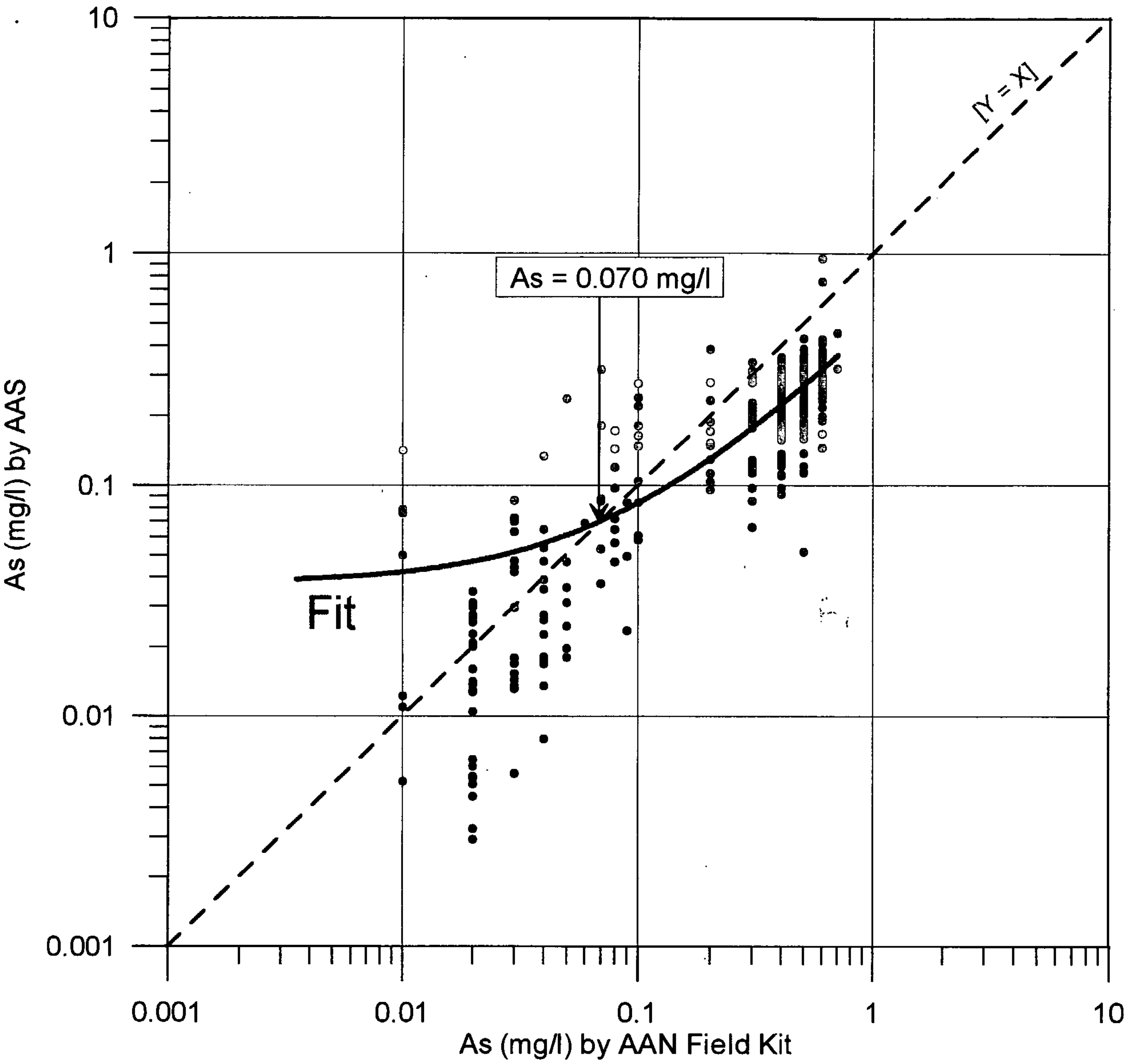


Fit Results

Fit : Linear
Equation Y = 0.4654463052 * X + 0.03759712448
Number of data points used = 349
Coef of determination, R-squared = 0.602472

(The arsenic concentrations were measured in Screening Survey in February to March 2002.)

Figure 11.1.10	**Comparison of As Concentrations Measured by FK and AAS by Log-Log Plot**

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)

11.2 Well Drilling and Pumping Test

11.2.1 Well Drilling

An observation well was drilled at Bramakati Mouza in order to confirm the hydrogeologic conditions and arsenic concentration of the deep aquifer (see Figures 11.2.1 and 11.2.2).

Since the shallow aquifer is contaminated by arsenic, the observation well targets the deep aquifer. The deep aquifer is separated from the shallow aquifer by an overlying thick clay layer in this area. Figure 11.2.3 shows the geologic columnar section with geophysical logs (resisitivity, natural gamma and SP) obtained at Bramakati site. The borehole encountered a coarse sand and gravel layer, which forms an aquifer, at a depth from 287 to 298 m. Based on the geophysical log and observation of the drill cuttings, a casing program was performed as presented in Figure 11.2.4.

11.2.2 Pumping Test

A step-drawdown test, continuous pumping test and recovery test were conducted after completion of the well and the well development. During the step-drawdown test and continuous test, groundwater samples for measuring arsenic level were collected. Water temperature, pH, ORP, and EC were also measured at each sampling time in the field.

The results of continuous pumping test at the observation well are summarized in Table 11.2.1 Figure 11.2.5 shows the results of the continuous pumping test at Js-OW-1 well. From the fitted line, the values of *T* and *S* are computed as 2.450 m^2/day and 5.87E-1, respectively.

During the pumping test, the arsenic level was measured by field kit. It detected 0.0 to 0.1 mg/l of arsenic, however, the result of more accurate analysis by AAS was less than the detectable limit.

Table 11.2.1 Resuls of Continuous Pumping Test in Brahmakati

District	Upazila/ Pourashav	Site Name (Site No.)	Well/Hole Type	Well/Obs. Hole No.	Drilling Depth (m)	Well Depth (m)	Screen Depth(s) (m)	Screen Length (m)
Jessore	Keshabpur	Brahmakati	Obs. Well (Production Well)	Js-OW-1	300	299	286.28-298.0	11.72

Continuous Pumping Test						Results of Analyses					
Date (dd/mm/yy)	Static Water Level (m)	Pumping Rate, Q (m^3/day)	Pumping Duration (hours)	Final Drawdown, (m)	Specific Capacity, S (m^2/day)	Data Used*	Cooper-Jacob Method T (m^2/day)	Cooper-Jacob Method k_{ap} (m/day)	Cooper-Jacob Method S	Recovery Method T (m^2/day)	Recovery Method k_{ap} (m/day)
10/03/02	6.385	93.8	48	18.810	5.0	P	2.45	0.2	5.87E-01	5.944	0.5

* P: Pumped Well/Hole Data

11.2.3 Hydrogeological Structure in Keshabpur area

1) A-B-C Profiles

Figure 11.2.6 shows the location map of geological profiles. Figures 11.2.7 and 11.2.8 show profiles ranging from north (direction of Jessore) to south (direction of Tala thana). The aquifers of three horizons are seen in the geological profiles. The upper aquifer is distributed from about 50 to 100 m in depth continuously. According to the results of the screening survey, almost all wells have taken groundwater from this horizon, which is contaminated by arsenic (more than Bangladesh Standard value). The middle aquifer is seen at about 220 m in depth, however this layer is not continuous and is recognized at the north of kesabpur mouza and several parts of Tala thana. The groundwater that is taken from this horizon has not been contaminated by arsenic (less than Bangladesh Standard value). The lower aquifer is distributed nearly 300 m deep in the surroundings of the well drilling site. It is not confirmed whether this layer is widely distributed or not. The groundwater that is taken from this horizon has not been contaminated by arsenic (less than Bangladesh Standard value). Figure 11.2.7 shows the possibility of the continuous distribution of this aquifer. This is probably because the layer's depth is gradually deeper than that of the well drilling site in the south direction.

2) D-E Profiles

Figure 11.2.9 shows the D-E profile ranging from north (direction of Jessore) to south (direction of Dumuria thana). Figure 11.2.9 runs parallel with Figures 11.2.7 and 11.2.8. The aquifers of the two horizons are seen in Figure 11.2.9. Both the upper and lower aquifers are continuous from north to south. The upper aquifer is distributed from about 20 to 70 m in depth. The thickness of the upper aquifer is about 50 m. This aquifer corresponds to the upper aquifer of A-B-C profiles and the groundwater of this aquifer is contaminated by arsenic (more than Bangladesh Standard value). The lower aquifer is underlain from about 150 to 250 m in depth. This aquifer corresponds to the middle aquifer of A-B-C profiles. The groundwater of this aquifer is not contaminated by arsenic either (less than Bangladesh Standard value).

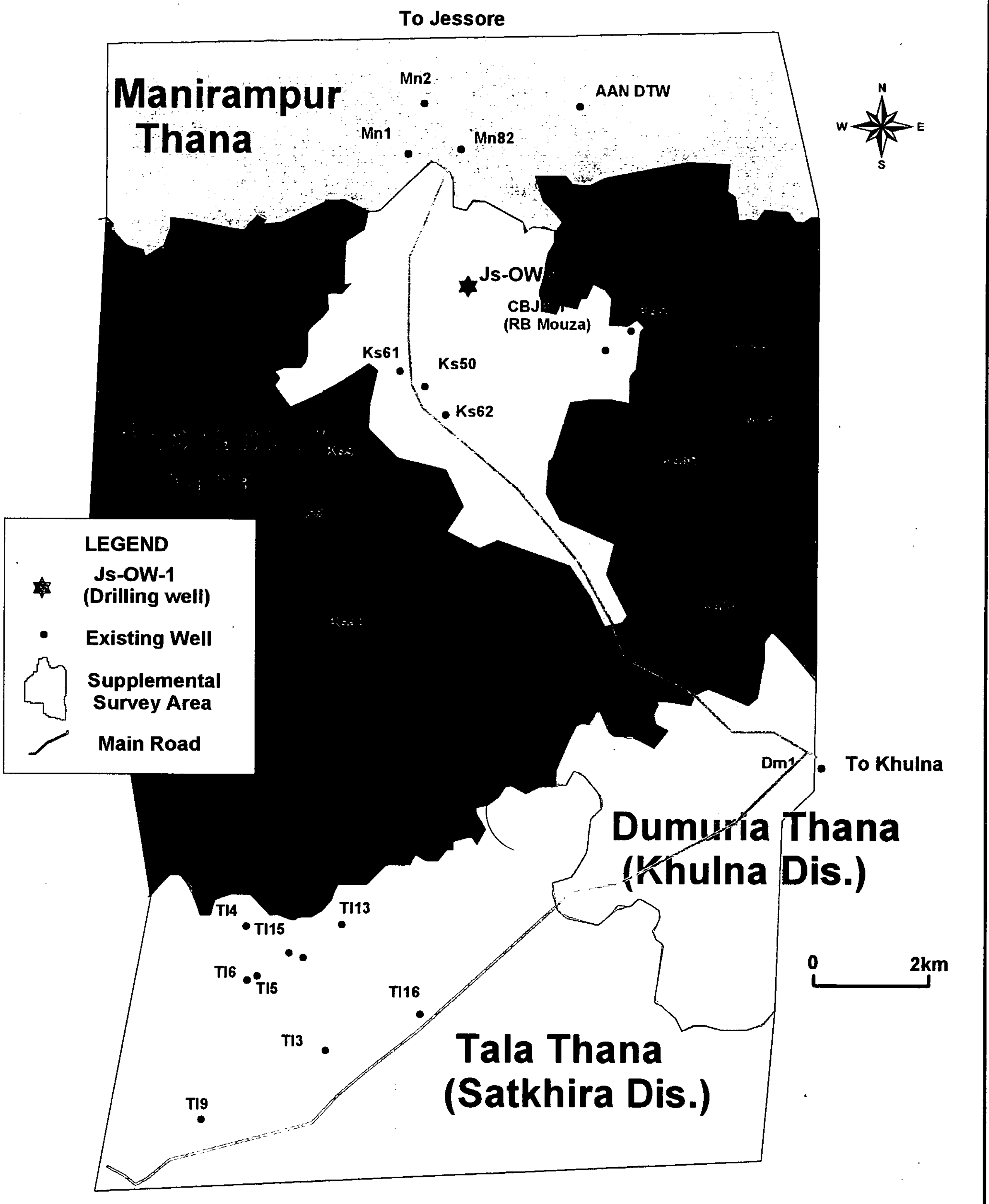


Figure 11.2.1	Location Map of Observation Well

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)

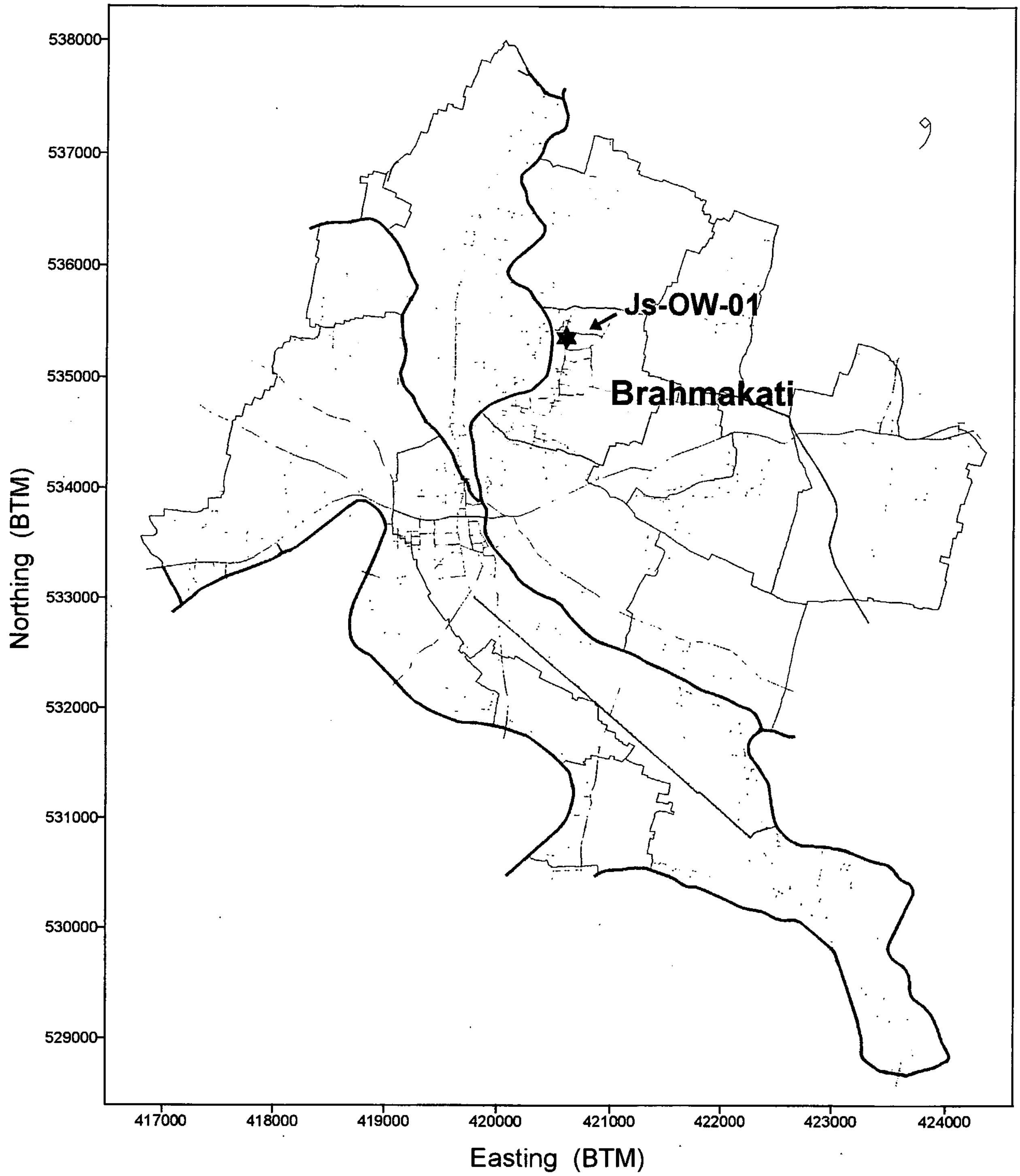
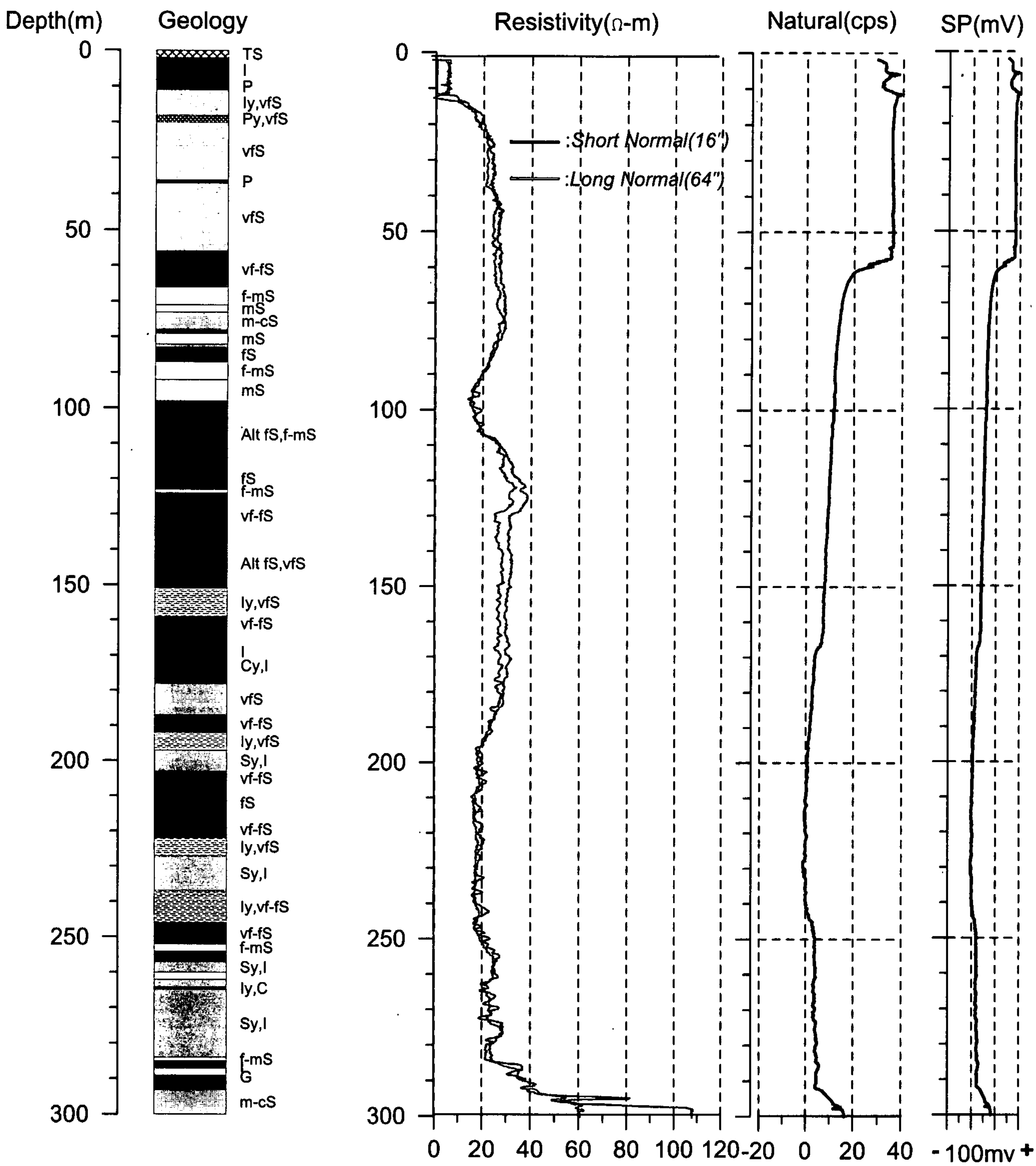


Figure 11.2.2	**Location Map of Observation Well**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



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

Figure 11.2.3 Columnar Section and Geophysical Logging at JS-OW-1 Site [Brahmakati, 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)

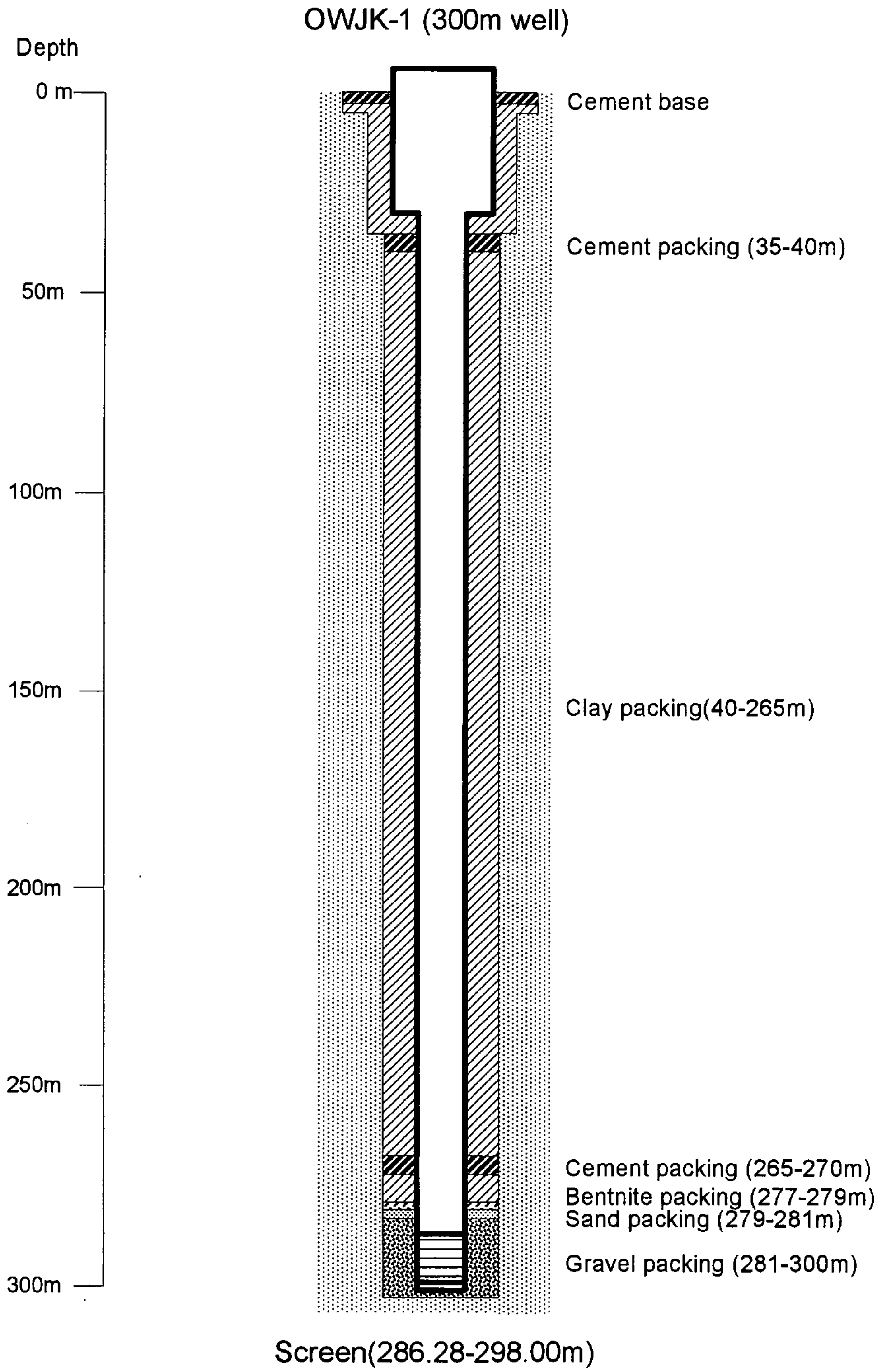
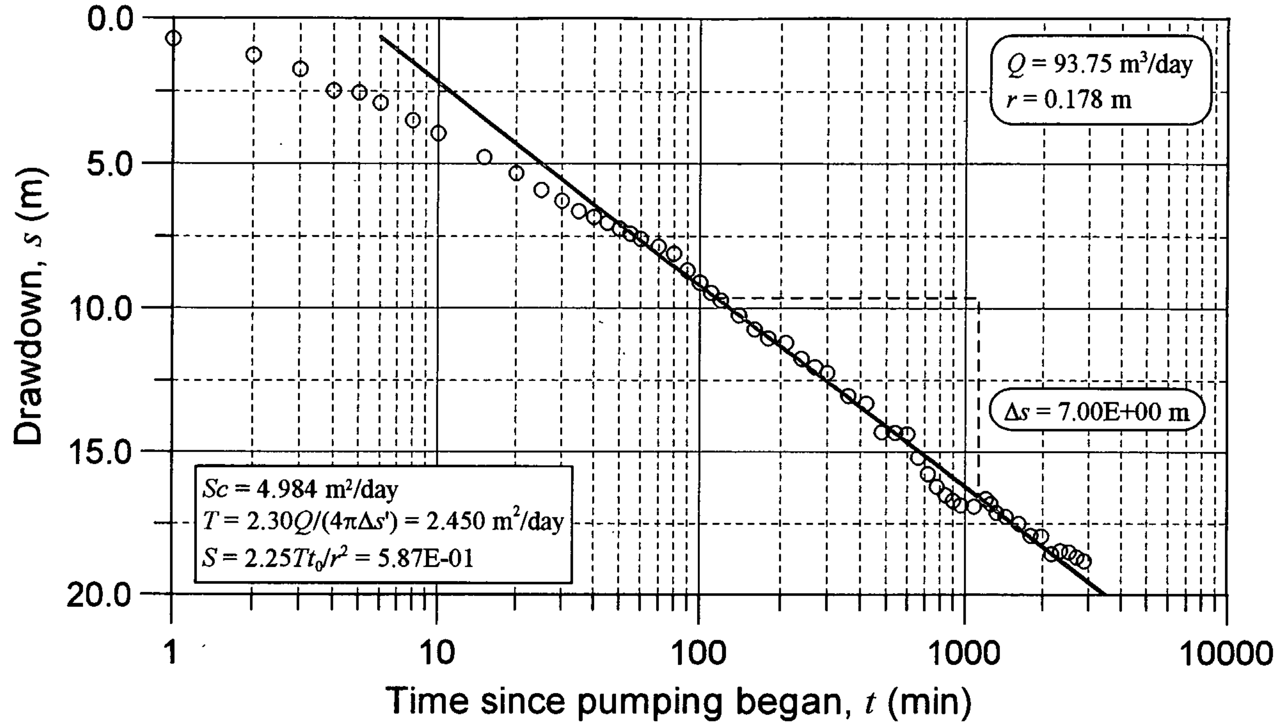
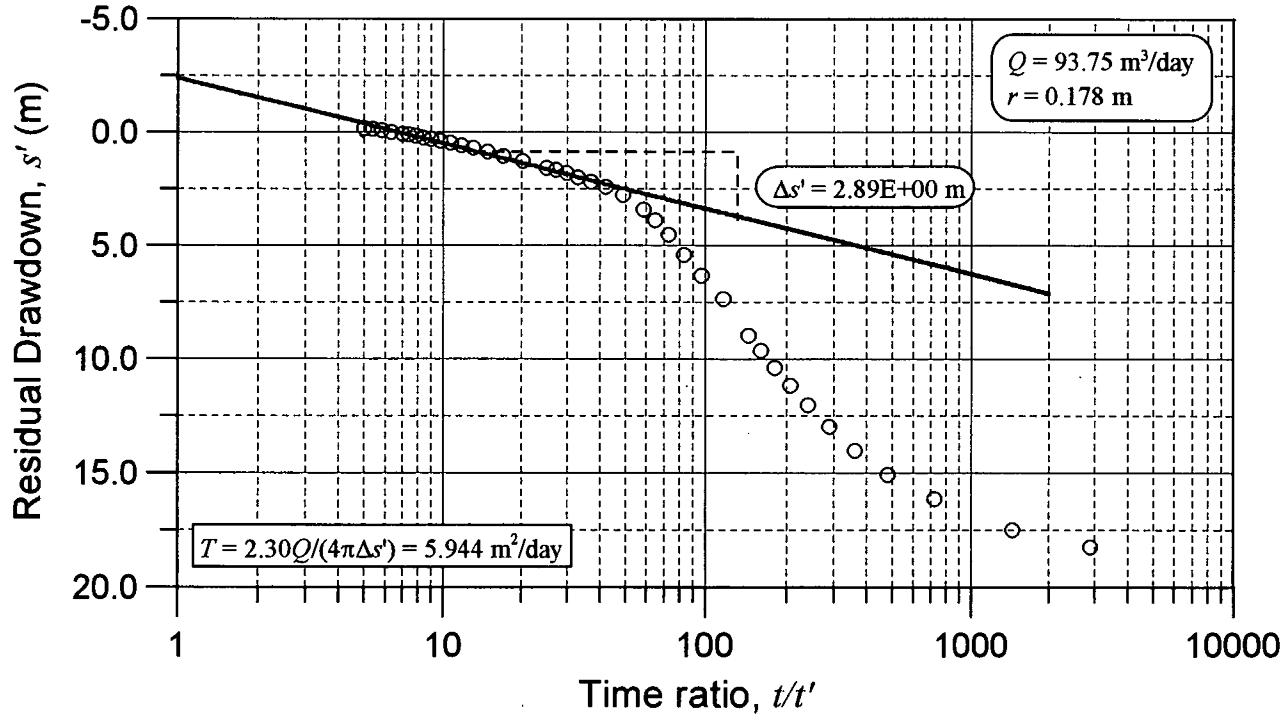


Figure 11.2.4	**Casing Program (Brahmakati)**
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	



(a) Continuous Pumping Test at Js-OW-1 Well



(b) Recovery Test at Js-OW-1 Well

Location:	Brahmakati, Keshabpur, Jessore
Site No.:	KSB-1
Well No.:	Ksb-1
Well Depth:	299.0 m
Well Diameter:	355.60 mm
Screen Depths:	286.28-298.0 m
Screen Length:	11.72 m
SWL:	GL- 6.385 m on 10-03-2002

Figure 11.2.5 **Results of Continuous Pumping Test and Recovery Test at Js-OW-1 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)

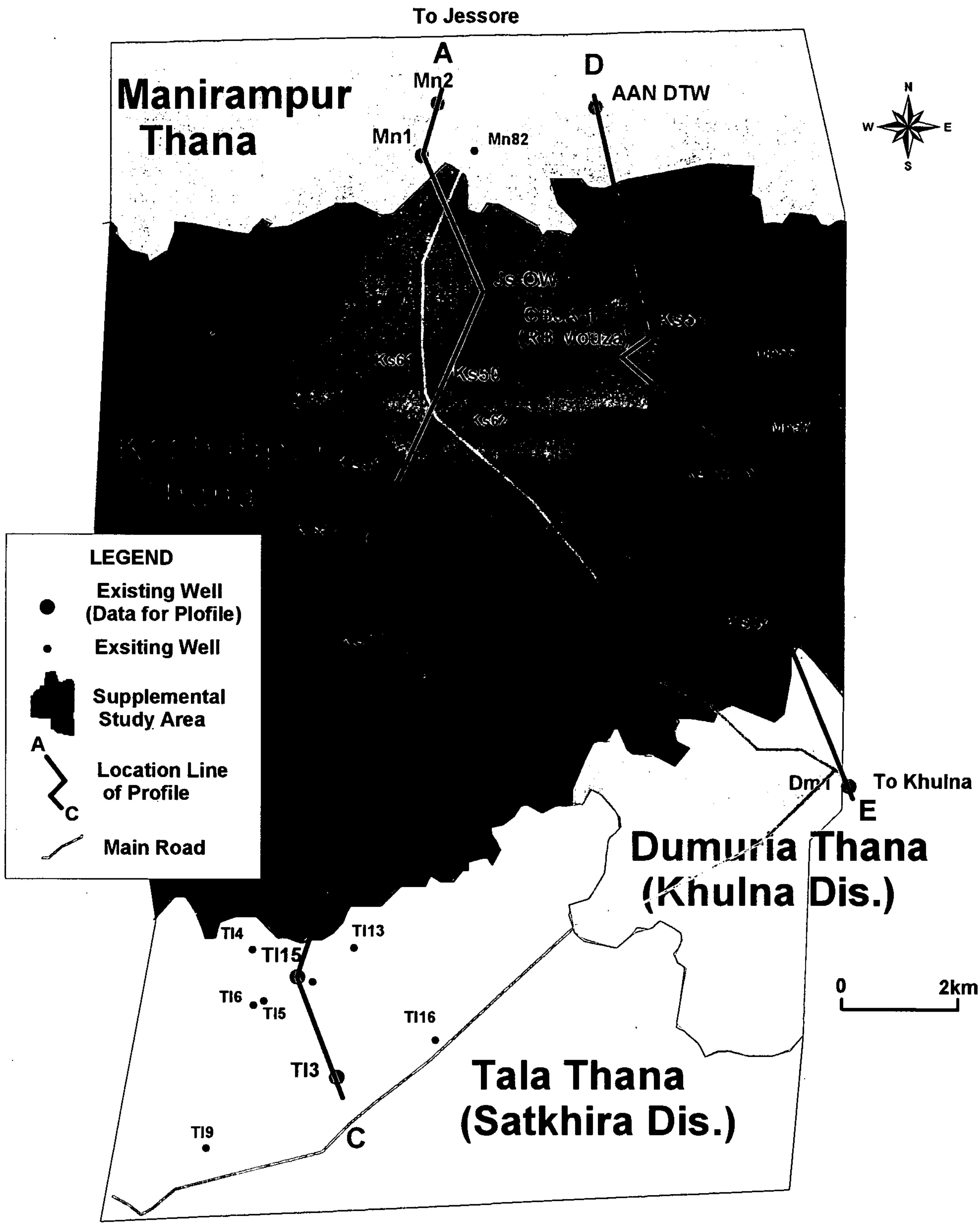


Figure 11.2.6	**Location Map of Geological Profile**

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)

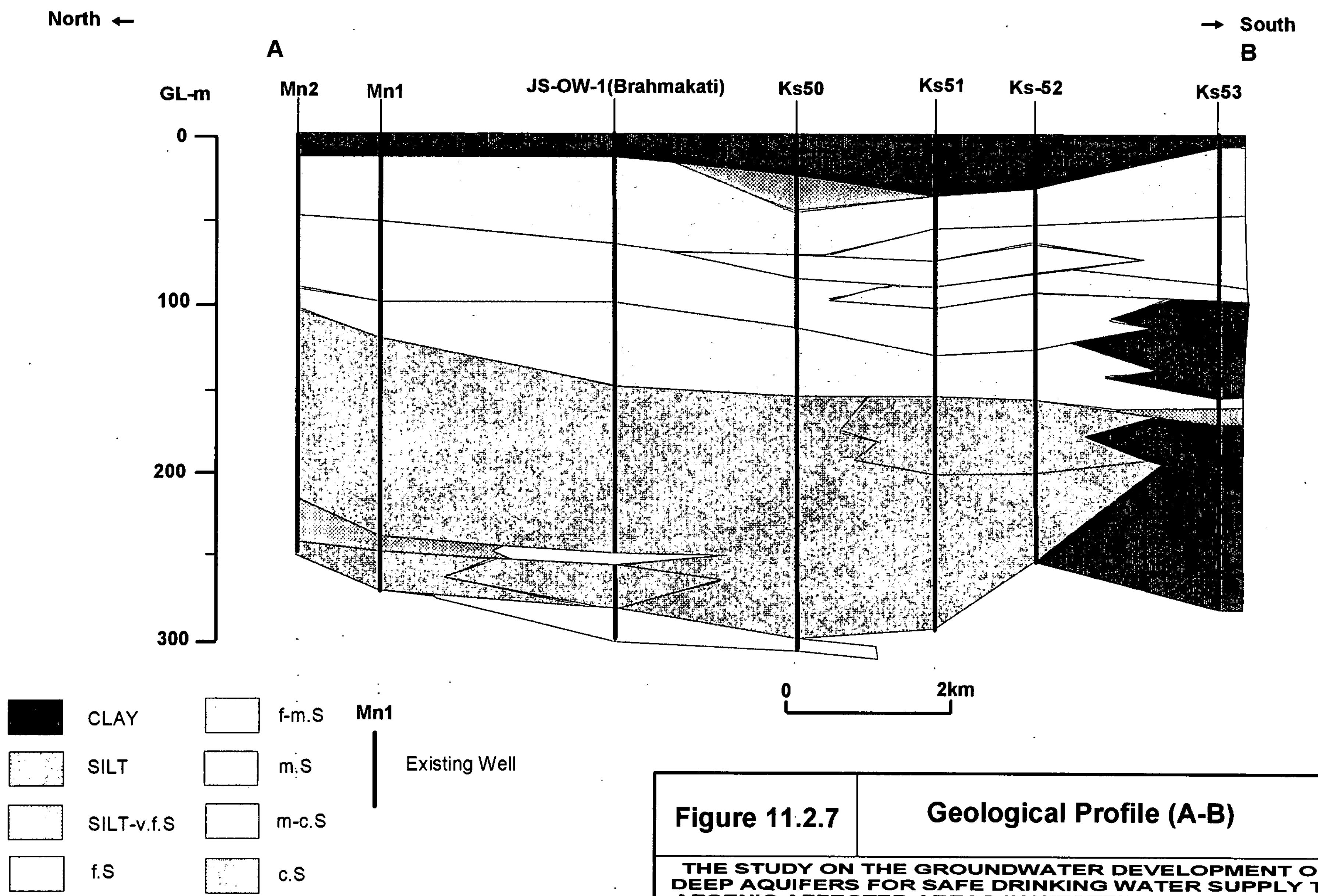


Figure 11.2.7	Geological Profile (A-B)
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

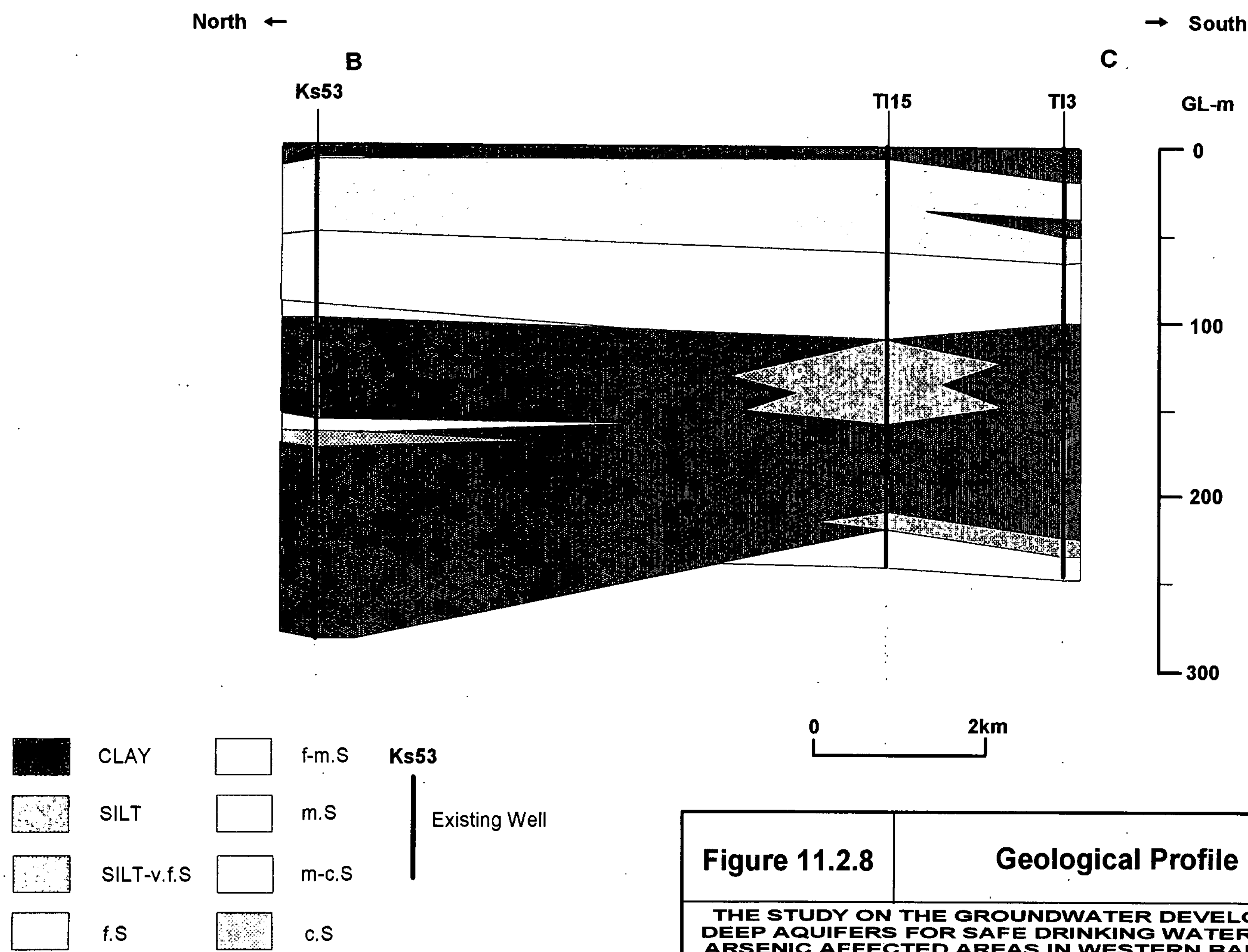


Figure 11.2.8	Geological Profile (B-C)

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)

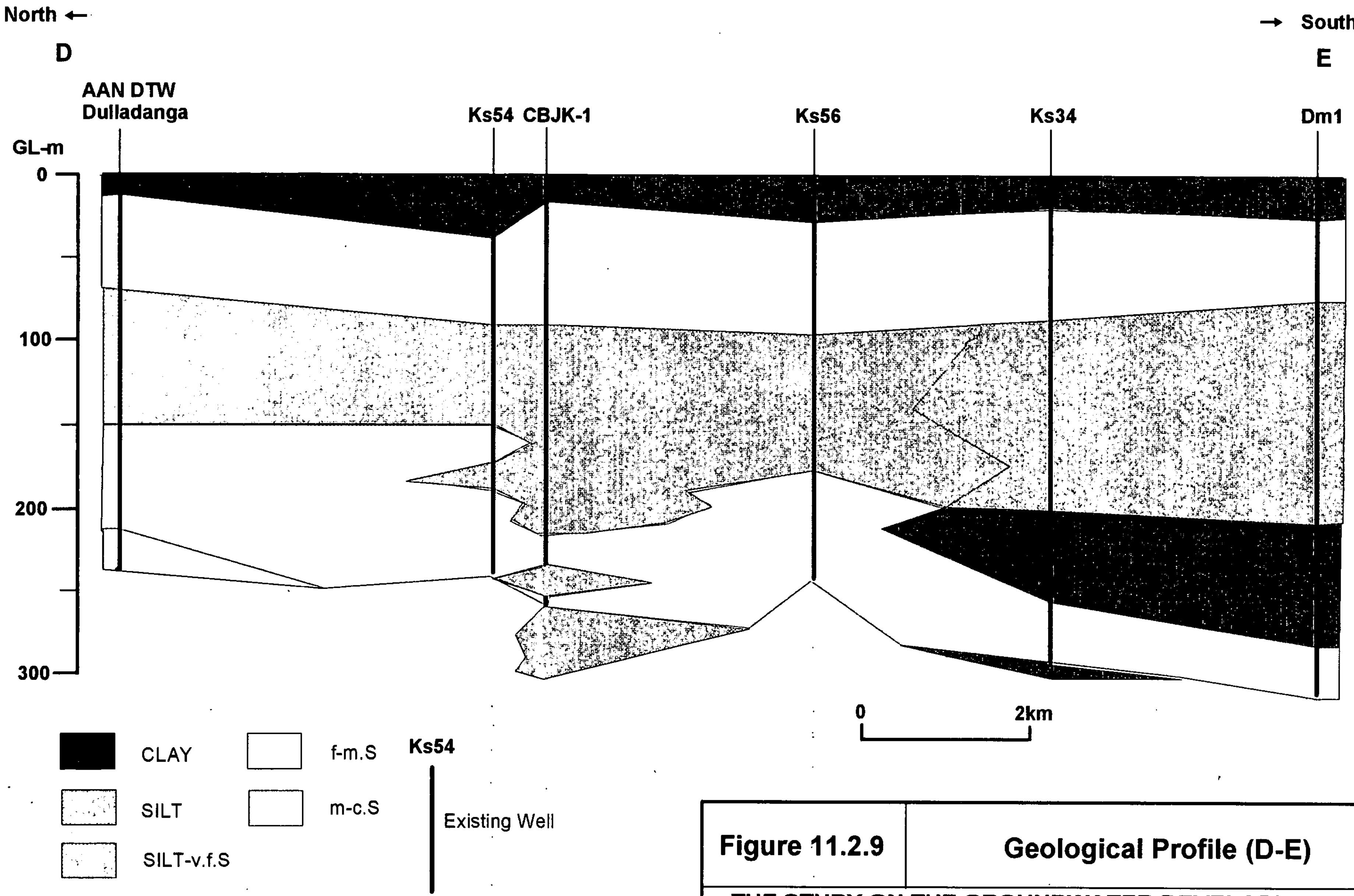


Figure 11.2.9	Geological Profile (D-E)
THE STUDY ON THE GROUNDWATER DEVELOPMENT OF DEEP AQUIFERS FOR SAFE DRINKING WATER SUPPLY TO ARSENIC AFFECTED AREAS IN WESTERN BANGLADESH	
JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)	

11.3 Results of Socio-economic Study

11.3.1 General Features of Mouzas

1) Demographic Characteristics of Mouzas

The target 16 Mouzas have an area of 29.05684km^2 where a total of 34,684 people reside. The number of households is 7,590. Islam is the most worshiped religion; 72.3% of the population is Muslim followed by Hindu (27.2%) and Christian (0.5%). The literacy rate varies by Mouza. More than 80% of residents are literate in Kesabpur on the one hand. Less than 50% of males and 20% of females are in Sabdia on the other hand.

2) Community Activities

Community leaders are generally selected by election or discussion among residents. In all 16 Mouzas, organized community meetings are held periodically. Community activities such as health programs and mutual assistance are widely conducted. In terms of the arsenic problem, some actions are taken by most of Mouza but they are not concrete and positive ones by residents themselves.

3) Economic Activities

Farming is the most important source of employment for individuals, followed by business (a kind of brokerage), transportation and aquaculture. Rice is the most widely cultivated agricultural product.

Aside from rice, jute, vegetables, pulse and wheat are grown. Public works projects have been conducted in 14 Mouzas in which local residents are hired.

4) Physical Infrastructure

Private toilets without septic tanks are commonly used for human waste treatment. The solid waste or garbage is mostly dumped in the garden. A health facility is accessible within a 2.30km distance, which is a 20 minute trip costing 5 Tk per trip. 14 Mouzas have primary schools while 5 Mouzas have secondary ones.

11.3.2 General Features of Households

1) Demography

The average household size is 5.53. A typical household consists of two male adults, two female adults, one male child and/or one female child.

2) Household Economy

The typical household in the 16 Mouzas has an annual income of 36,350 Taka. The major income source is salaried and self-employed work accounting for about 70% of the income. The household spends 34,157 Taka (including savings) annually. About 50% of the amount is spent on food.

3) Water Use

97.3% of households use well water for drinking. Pond water is used for cooking purposes by 70.5% of the households in the dry season and 66.1% in the wet season. The typical household consumes 45 liters per day for drinking and cooking purposes. At almost all households, women collect water. It takes normally 20 minutes to fetch water. Most of the residents think the quality of water they drink is good in terms of its taste, smell and clearness.

4) Arsenic Problems

91.1% of households have heard about arsenic poisoning. However only 51.0% of them have knowledge about its symptoms. The typical household's willingness to pay for arsenic safe water is 30 Taka per month. Residents would accept spending an additional 10 minutes for safe water.

5) Participation in Community Activity

The participation among households in the community-sponsored mutual assistance and health program is high while a lower percentage of households take part in group efforts to build or repair infrastructure and to clean up the environment.

11.3.3 Consideration on Sustainability of Improved Water Supply System

1) Ability to Pay for Improved Water Supply System

Villagers in Mouzas have the ability to pay 90.9 Taka per month per household (three percent of the monthly income of 3,029) for improved water supply systems.

2) Willingness to Pay for Improved Water Supply System

Even if villagers can afford to, they may still be unwilling to pay. As we discussed above, villagers' willingness to pay (WTP) for safe water is 30 Taka per month per household.

3) Factors Influencing Willingness to Pay

Villagers' incomes have a deep connection with their willingness to pay (WTP) for improved water supply systems. Also, villagers' knowledge about arsenic poisoning is not irrelevant to their willingness to pay for safe water. Further, the stronger the community cohesion is, the higher the villagers' willingness to pay is for improved water supply systems.

4) Conclusion and Recommendation

It becomes clear that the households with knowledge about arsenic poisoning would show a higher WTP than the ones without it. Likewise the households with strong cohesiveness with their community have a tendency to express more willingness to pay for safe water, compared with the ones with less feeling of community cohesion.

These results imply that by raising the villagers' level of knowledge of arsenic poisoning and/or cohesiveness with their own community, villagers would show a higher WTP.

Therefore, it seems reasonable to conclude that the activities to raise villagers' awareness about arsenic poisoning and/or consciousness of being a member of the community are necessary to satisfy the financial requirements for the operation and maintenance of water supply systems when they are to be introduced. As a result of these activities, the financial sustainability of the systems would be secured.

11.4 Water Supply Facilities Plan

11.4.1 Arsenic Mitigation Strategy

About ten years have passed since the arsenic pollution of underground water was confirmed in Bangladesh. The prospect of a solution still does not look up though various investigations are zealously done. BAMWSP promotes screening enthusiastically, and completes about 50% of screening. However, currently there have been no advancements made at all in securing an alternative water source due to the fund shortage.

Strategy to Solution

It is thought that it is necessary to execute the following measures.

1) The first stage

- **Screening of all existing wells.**

The arsenic safe wells should be specified, and joint use by nearby residents should be promoted.

- **Development of an alternative water source (for drinking and cooking).**

It is necessary to develop an arsenic safe water source if there is no safe well. This is done as follows.

(1) Rain water harvesting.
(2) Use of pond water (Pond sand Filter).
(3) Purification of conventional well water (iron removal device and activated aluminum filtration, etc.).
(4) Simple arsenic removal device (domestic use).

(5) Development of deep groundwater.

2) The second stage

The access distance to the arsenic safe water source becomes far in the first stage measures. If there is a public stand post for arsenic safe water near an existing well, the residents can select water without changing their lifestyle according to the purpose of water use. It is necessary to construct the following facilities to achieve such a situation.

- Overhead tank.
- Transmission pump (including generator).
- Distribution pipe (PVC).
- Public stand post.

In this case, who operates these facilities and who bears responsibility for the maintenance expense etc. becomes an important problem. This stage cannot be achieved without a solution to this problem.

3) The third stage

There is a region without an appropriate surface water source, and there is a region where the development of arsenic safe deep groundwater is impossible. For these regions, a water supply plan to supply arsenic safe water to a wide area is necessary. The following strategies are considered for this solution.

The water source is made by the existing urban water service or a newly constructed urban water service. The existing urban water service is in operation for several hours in the daytime and arsenic safe water is wasted by water leakage, etc. If water leakage is prevented, and the operation time is extended, drinking water necessary in the rural area can be sufficiently produced. It is necessary to do the following in order to supply arsenic safe water to the rural area.

- Rehabilitate the existing urban water service.
- Construct a water supply pump station to rural area.
- Construct a water transmission pipe and distribution pipe to rural area.
- Construct a receiving water tank in each village.
- Construct water service facilities in the villages.

Such a situation cannot be achieved if there is no solution to how to operate and maintain the system as well as the second stage.

There is no need to proceed through these three stages one by one in solving the arsenic problem. It can be said that working from the beginning to the 3rd stage is much better if one wants to solve the arsenic problem within ten years or so. Anyway, some maintenance expense is necessary. Do the local residents have the ability to pay? Do the local resident form the operation and maintenance organization? These are key to the success or failure.

11.4.2 Selection of water supply system

The selection of water supply facilities is generally based on the situation of the residential area. It is technically reasonable to develop a big water source and supply individual houses through a pipe connection. The cost of construction and the maintenance expense per person becomes cheap, too. On the other hand, when requesting a small water source in each individual small village, both the cost of construction and the maintenance expense become cheap in a sparsely populated, rural region. Based on this standard, it is judged that the level 1 hand pump system is reasonable in a rural area and the level 3 individual house connection system is reasonable in an urban area.

However, this project is for the development of deep, arsenic-safe groundwater in the region affected by arsenic. It is necessary to offer at least drinking water immediately. The water supply system must be examined from this viewpoint.

1) Water supply system in urban area

Though the water service plan has not arrived in this area at the design stage yet, there is a water service plan for an individual house connection water supply in the future. It is sure to be excluded from this project. However, it might still take 4 to 5 years by the time this plan is completed. It is not possible to leave this area for 4 to 5 years without an arsenic safe water source. In order to supply only arsenic safe drinking water by the hand pump system (level 1 system), it is necessary to dig a lot of wells in the regions where the density of population is high. It is impossible to request such a site in the urban area. Moreover, it is difficult to make them consistent with the Pourashava water service plan in the future even if the level 2 systems that supply water with pipes and stand posts are constructed.

The following water supply systems are available in such a region.

The population who relies on one well increases is high because the population density is high. An increase in well diameter corresponding to the population is inevitable. When the hand pump is installed, the well does not meet the demand because the pumping capacity of the hand pump is limited. A submerged motor pump is needed to match the amount of production to demand. In this case, a water storage tank is needed at the well site. It will be possible to meet the demand if the water tap (only for necessity) is installed in the water storage tank.

Therefore, the well where the conversion can be used as a water source of the Pourashava water service in the future is dug in this region. Set up the overhead tank (About 3 m in height) at the well site and set up the tap that corresponds to demand. That is, the system of the improved level 1 is assumed. A public stand post is necessary for the Pourashava water service in the future. The overhead tank set up will be used as a public stand post in the future.

2) Water supply system in rural area

If residents in a region can bear the cost of maintenance, drinking water is supplied to each home by piping with pressure by which the benefits of convenience and pleasantness can be enjoyed. (level 3 system). Attempts to construct such a water service system, which is partially requested in the rural region, have already been made in Bangladesh.

However, in the region where all existing wells have been polluted by arsenic, after all, planning such a water service invites the result of no safe water source for poor people who have no solvency. It is not possible to hope for the improvement of public health, which is the first purpose of the water service. The first step in solving the arsenic pollution problem is to secure an arsenic-safe water source (for drinking and cooking) within an allowable access distance.

In the master plan, from the well distribution situation in the rural region, it is judged that it is technically and economically advantageous for digging a lot of wells (level 1) to transport water from one well with a pipe, and to construct a public stand post which does not change present water fetching work (level 2). However, this selection is a matter that affects the willingness and the ability to pay as well as the maintenance cost that hangs on the user and should be decided by the residents.

As for willingness to pay, there were a lot of answers of 30 Taka per household for one month according to the social survey result, though there was one answer of 300 Taka, too. On the other hand, the maximum amount of the load is said to be generally up to 3% of the income. Based on that, the maximum amount of this local water service is 92 Taka/month/household.

It is not possible to improve public health if the cost of the water service is determined in consideration of low income people. The amount of the willingness to pay might double by campaigning for community participation, and level 2 facilities might be possible depending on the Mouza. However, the first step in solving the arsenic problem is to secure an arsenic safe water source at an appropriate access distance, and it is assumed that the level 1water service facilities will be planned. The improved level 1is assumed for a part of Kesabpur and Altapor.

11.5 Water Supply Facilities and Construction Cost

11.5.1 Water Supply Area

The total area of the 16 mouzas is 27.66km^2.

11.5.2 Water Supplied Population and Water Consumption

The total population of the 16 mouzas was 35,890 people (year 2001). The target year for the project is 2010 and based on Jessore District population statistics from 1981 to 1991 (according to P/R Chapter 8.4) there is a 1.74% increase/year.

And, the unit of water consumption is set at 35 lcd.

Table 11.5.1 Water Consumption for 16 Mouzas

Mouza	Area (Km^2)	Population		Water consumption (m^3/day)
		2001	2010	
Ramlhandrapur	1.9588	1,359	1,587	55.55
Byasdanga	1.2272	1,118	1,306	45.70
Brahmakati	1.4967	1,448	1,691	59.19
Khatiakhali	0.7047	895	1,045	36.59
Maguradanga	1.3425	1,303	1,522	53.26
Baliadanga	1.8232	2,907	3,395	118.83
Sujapur	1.4821	1,373	1,604	56.13
Altapol	5.0479	8,702	10,164	355.72
Sarfabad	0.8016	519	606	21.22
Bajitpur	0.7332	1,142	1,334	46.68
Sabdia	1.1650	1,720	2,009	70.31
Kesabpur	0.4184	1,512	1,766	61.81
Madhyakul	3.0448	3,485	4,070	142.46
Habaspol	0.8185	1,107	1,293	45.25
Bhagati Narendrapur	3.1694	4,153	4,851	169.77
Rajnagar Bankabarsi	2.4255	1,941	2,267	79.34
Total	27.6595	34,684	40,509	1,417.83
Average	***	2,168	2,532	88.61

11.5.3 Water Supply Facility

According to the result of the supplementary survey, 2 mouzas (Altapol and Keshabpur) may be divided into urban and rural areas. In the urban area, it is very difficult to construct several facilities because there is not enough land space. Therefore, the “improved level 1” facility will be planned in the urban area. The level 1 facility (hand pump) will be planned in the other area in the same mouzas and in the remaining 14 mouzas .

1) Improved Level 1 (Urban area)

The basic specification for the Improved Level 1 facility will be planned the same as the level 2 facility. But distribution pipes will not be constructed and pumped-up water goes directly to public faucets from the water tower. The facilities are designed the same as the lever 2 system. However, the height of the water tank will be 3 m.

2) Level 1 (the other area)

A water supply system with hand pumps will be planned.

Table 11.5.2 Required water supply system by Improved Level 1

Mouza	Level 1	Improved Level 1	
	Hand Pump	Motor Pump	Public Faucet
Ramlhandrapur	8	0	0
Byasdanga	7	0	0
Brahmakati	9	0	0
Khatiakhali	5	0	0
Maguradanga	8	0	0
Baliadanga	18	0	0
Sujapur	8	0	0
Altapol	28	2	18
Sarfabad	3	0	0
Bajitpur	7	0	0
Sabdia	10	0	0
Kesabpur	3	1	3
Madhyakul	22	0	0
Habaspol	6	0	0
Bhagati Narendrapur	26	0	0
Rajnagar Bankabarsi	12	0	0
Total	180	3	21

11.5.4 Total Project Cost

The project cost was estimated based on “Schedule of Rates, Public Works Department”(Ninth Edition, First Revision, November, 1997) and “Analysis of rate (ditto)”. The total project cost estimated is as follows

Table 11.5.3 Result of Project Cost Estimation

	Public education	Capacity building	Construction cost	Total
Total in 16 mouza	1,843,200	489,600	92,563,682	94,896,482

UNIT: TAKA

The operation and maintenance cost per household for improved level 1 is estimated as follows: The average in rural areas is 15.9 Tk (per month per household), and the average in urban areas is 104.7 Tk (per month per household)

11.5.5 Implementation of the Project

The implementation schedule is shown below:

Table 11.5.4 Project Impremantation Schedule

Month		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Consultant Service Agreement		●																											
Preparation Work			■	■																									
(1) Public Education							Arsenic Problem			Establishment of Organization			Utilization of Alternative Water Source			Hygiene						Management			Operation & Maintenance				
(2) Capacity Building					●						●									●							●		
(3) Water Supply Facility	Detailed Design					Detailed Design			Tender																				
	Construction										Well Drilling																		
												Facility Construction																	
											(Distribution Pipe Installation)																		

11.6 Issues on the Implementation of the Project

Based on the supplementary survey, it was revealed that most of the existing shallow tube wells, nearly 3,000 wells, in the 16 mouzas of Keshabpur are contaminated with arsenic. In addition, the observation borehole drilled at Brahmakati mouza showed that arsenic free groundwater of good quality and quantity exists in the deep aquifer at a depth of 300 m. It is possible to develop the deep aquifer and supply deep groundwater as an alternative water source to the arsenic affected areas in Keshabpur Thana. Considering the above conditions, a level 1 water supply system, which is composed of a deep well with hand pump, and an improved level 1 system (deep well, motorized pump and elevated tank with communal faucet without pipeline) were proposed.

In the implementation of this project, the following issues must be considered. The project will become feasible if these issues are solved.

11.6.1 Implementation Body

The main implementing body for the project is the DPHE. It is necessary to establish a Project Management Unit (PMU) in the DPHE and the full time staff must be assigned to it. At present, 4 mechanics are engaged in the supervision of the DPHE wells of 9 Unions under the sub-assistant engineer from DPHE Keshabpur Thana office. In addition to about 2,200 wells, 180 deep wells with hand pumps and 3 deep wells with motorized pumps, elevated tanks and communal faucets will be supervised by this office if the project is realized. As the DPHE Thana office guides and supervises the O&M organizations, which will be established in the mouzas, the office needs to strengthen its function and staff as well as establish the PMU.

11.6.2 Organization for O&M

The improved level 1 system requires the same O&M system as level 2, although the facility is constructed without pipeline. Therefore, O&M organizations for level 2 must be established in Keshabpur and Altapor mouza. According to the cost estimation, the O&M cost will become 105 Taka per month per household on average. It is not clear whether this amount is payable for the residents in the urban area because the questionnaire survey was only conducted in the rural area, although the willingness to pay in the urban area is expected to be higher than that of the rural area. It is therefore necessary to reach a consensus on this issue among the urban residents prior to the implementation of the project.

11.6.3 Dissemination activities

Compared with the level 2 system, O&M of the level 1 system is relatively easy. However, the water supply system is constructed as a public facility for arsenic mitigation. In this meaning, the facility must be sustainable and utilized effectively. Accordingly, the O&M of organizations, such as the Water Point Committee (WPC) will be established per hand pump and the caretaker will be assigned to engage in the O&M of the facility. In order to utilize deep groundwater as a measures for arsenic pollution and reduce the risk which is impending over the residents, a proper knowledge of arsenic, use of groundwater and hygiene practice need to be disseminated. As mentioned in the previous chapter (see Chapter 10), mobilization and participation of the residents in the project from the planning phase are necessary through the dissemination activities.

11.6.4 Monitoring

The water supply system will be constructed as a countermeasure for arsenic pollution. Therefore, periodical monitoring of water quality is a key issue. In order to monitor water quality properly, a monitoring system must be established. This system should enable measurement of arsenic, ORP, EC and so on by the field kits. The DPHE on the other hand should measure and analyze arsenic in the groundwater of each deep well at Jehnaidah laboratory using AAS. Technical training of the DPHE staff on the sampling of groundwater, testing by the field kit and so on are indispensable.

CHAPTER 12

CONCLUSIONS AND RECOMMENDATIONS

CHAPTER 12 CONCLUSIONS AND RECOMMENDATIONS

12.1 Conclusions

12.1.1 Arsenic Contamination

1) Existing Well

According to the analysis of groundwater of the existing wells (260 DPHE wells in the rural area: depth 40 to 45 m), the contaminated area with arsenic concentrations of more than 0.05 mg/l (Bangladesh standard) is extended in the western section of the Study Area. On the other hand, the contaminated area with arsenic concentrations of less than 0.01 mg/l (WHO guideline) is extended in the eastern section of the Study Area.

2) Production wells in Pourashava

Almost all production wells of the 7 pourashava, which consist of 40 wells in total with depths ranging from 100 to 120 m, show arsenic concentrations of less than 0.01 mg/l. However, arsenic concentrations of more than 0.05 mg/l but less than 0.1 mg/l were detected at 3 wells in Chuadanga, 2 wells in Moheshpur and 1 well in Jhenaidah.

3) Model Rural Area

Bara Dudpatila in Chuadanga, Krishna Chandrapur in Jhenaidah and Rajnagar Bankabarsi in Jessore were selected for the model rural area for the Study. As a result of the screening survey, 65% of the existing wells in Bara Dudpatila, 75% in Krishna Chandrapur and 98% in Rajnagar Bankabarsi showed arsenic concentrations of more than 0.05 mg/l. Particularly, 53% of the wells were seriously contaminated showing arsenic concentrations of more than 0.5 mg/l in Rajnagar Bankabarsi.

12.1.2 Arsenic Contamination by Depth

The arsenic contamination of groundwater by depth was measured at the observation wells that were constructed by the Study.

1) Chuadanga District

The observation wells constructed at different depths (*63 to 300 m*) in CH-1 site of Chuadanga pourashava show arsenic concentrations of 0.01 to 0.05 mg. However, at the *63 m* well, the arsenic content slightly exceeds 0.05 mg/l. The observation wells at different depths in CH-2 （*56.5 to 298.5 m*） show 0.05 to 0.22 mg/l of arsenic, the *56.5 m* well showing the highest. On the other hand, the deepest well (*298.5 m*) shows less than 0.01 mg/l of arsenic. In rural Bara Dudpatila, the *300 m* observation well (core boring hole) shows less than 0.01 mg/l. Arsenic concentrations fluctuate seasonally. It seems that the concentration rises in the rainy season.

2) Jhenaidah District

At the observation wells in JH-1 (*60 to 292.5 m*) and JH-2 (*60 to 301 m*) of Jhenaidah pourshava, both of the *60 m* wells show 0.05 to 0.08 mg/l of arsenic. Other wells show less than 0.05 mg/l. The deepest two wells (*300 m*) in JH-1 and JH-2 show arsenic concentrations of less than 0.01 mg/l . However, the *300 m* observation well (core boring hole) in rural Krishna Chandrapur shows 0.05 to 0.08 mg/l of arsenic and a tendency to increase seasonally.

3) Jessore District

Only the *120 m* observation well in JS-1 (*66 to 282 m*) shows 0.01 to 0.05 mg/l of arsenic in Jessore pourashava. Other observation wells show less than 0.01 mg/l. At the observation wells in JS-2 (66 to 261.8 m), the *114 m* well shows 0.05 to 0.1 mg/l. However other wells show less than 0.01 mg/l. In rural Rajnagar Bankabarsi, the *300 m* observation well (core boring hole) shows less than 0.01 mg/l of arsenic.

As mentioned above, the arsenic concentration is highest in the shallow groundwater at a depth of about 50 m. Arsenic concentrations show a tendency to decrease with depth. Groundwater at depths of 100 to 150 m shows slightly higher concentrations from 0.01 to 0.05 mg/l in the northern and central part of the Study Area, i.e. Chuadanga and Jhenaidah. On the other hand, the arsenic concentration at the same depth is less than 0.01 mg/l in the southern part of the Study Area, i.e. Jessore. Groundwater at a depth of about 300 m shows less than 0.01 mg/l except in the northern and central part of the Study Area. However, it shows less than 0.005 mg/l in the southern part of the Study Area.

12.1.3 Hydrogeologic Unit and Aquifer Capacity

1) Hydrogeologic Unit and Distribution

The underground geology up to the depth of 300 m can be divided into 5 formations, i.e. A, B, C, D and E according to the geological facies. These formations can be grouped into 3 units from a hydrogeological point of view.

The first aquifer (Shallow Aquifer: depth 20 to 100 m) is composed of mainly a sandy layer of A and B formations. The second aquifer (Middle Aquifer: depth 100 to 220 m) is composed of a sand and gravel layer of C formation. The third aquifer（Deep Aquifer: 220 to 300 m and more） is composed of a sand and silt layer of D and E formations. An aquiclude does not exist between the first and second aquifers. However, C formation changes its facies to clay and silt in the southern section of the Study Area, thereby the aquifer thickness becomes thin. Instead it changes to a thick aquiclude overlying the third aquifer.

2) Aquifer capacity, groundwater use and arsenic concentration

Many tube wells are drilled in the shallow portion of the first aquifer up to the depth of about 50 m. These tube wells are being utilized for drinking, domestic and irrigation (shallow irrigation well) purposes. In addition, the deep irrigation wells are drilled in the lower portion of the first aquifer and the pourashava production wells are drilled in the upper part of the second aquifer at a depth of about 100 m. These wells, particularly the irrigation wells, are extracting a huge amount of groundwater.

The first and second aquifers are high in quantity in terms of specific capacity and transmissivity. On the other hand, compared with the first and the second aquifers, the third aquifer has a low specific capacity and transmissivity and is not fully developed yet. Arsenic concentrations show to be high, particularly in the shallow portion of the first aquifer. However, concentrations show to still be low in the second and third aquifers.

12.1.4 Arsenic Contamination Mechanism

1) Arsenic Source

According to the core boring and its analysis at 6 sites in the Study Area, the presence of arsenic, the content of which is more than 30 mg/kg, was confirmed not only in the shallow bed at 10 to 20 m depth but also in the deep bed at 200 to 300 m depth. It is considered, however, that the arsenic in the shallow bed is “active” and elution in the shallow portion is mainly concerned with contamination of groundwater since the arsenic concentration is high in the shallow aquifer at a depth of 30 to 50 m and low in the deeper aquifers.

2) Dissolution of Arsenic in Groundwater

The groundwater of the Study Area is characterized by low oxidation-reduction potential (Eh) and high iron concentrations. Therefore, it is most likely that the dissociation of ferric oxyhydroxide and the release of iron and arsenic ion into the groundwater occur under reducing conditions. On the other hand, pyrite minerals were not found from the core samples obtained in the Study by naked eye observation. Therefore, the pyrite oxidation hypothesis is highly unlikely as the mechanism for the arsenic contamination. Very low concentrations of sulfate ion in most of the Study Area also support this idea.

3) Migration of Arsenic Contaminated Water

The dissolved arsenic migrates along with the movement of groundwater. Generally, the groundwater velocity is very slow if groundwater is not abstracted by human activities. However, once groundwater is pumped, the natural groundwater flow system is disturbed. Groundwater pumpage has increased since the 1980’s especially in the irrigation wells in the Study Area. The pumpage of the year 2000 is estimated to be 15.1 MCM, which is 4.5 times the pumpage in the year 1983. Such a huge amount of groundwater extraction caused a groundwater decline in the long term, particularly in the dry season. It is presumed that the steep decline of groundwater levels triggered the leakage and squeeze of pore water from the aquiclude, which is composed of fine sand and silt containing arsenic.

12.1.5 Safety of Deep Groundwater

The third aquifer (Deep Aquifer) is mainly composed of a sand layer of D and E formations. C formation that is overlying the third aquifer consists of thick clay and silt beds in the southern part of Jessore District. C formation, as the aquiclude, has the role of shutting out downward groundwater flow from the shallow aquifer to the deep aquifer as well as upward groundwater flow from the deep aquifer to the shallow aquifer. Therefore, it is unlikely that the arsenic contaminated groundwater of the shallow aquifer flows into the deep aquifer.

The results of groundwater simulation revealed that groundwater levels decline in the lower part of the first aquifer because of the heavy pumping of irrigation wells. Due to the decline, arsenic contaminated groundwater of the upper part of the first aquifer is pulled into the depression zone. Regionally, groundwater flows toward the lower part of the first aquifer from the upper and the second aquifer. However, the aquiclude prevents an upward groundwater flow from the deep aquifer in southern Jessore District. Moreover, the regional groundwater flow from the northern and southern part of the Study Area is prevented from flowing into the deep aquifer in southern Jessore District because of the presence of the aquiclude.

The deep groundwater in the southern part of Jessore District is free from arsenic and safe at present. However, groundwater levels will decline by a small amount of pumpage because the specific capacity and transmissivity is smaller than that of the shallow and the middle aquifers. Accordingly, the safety of the deep groundwater is assured unless a huge amount of groundwater is extracted by the irrigation wells, which may develop the deep aquifer in the future.

However, when the deep groundwater is eventually used, its safety as drinking water has to be examined first. The development of groundwater for drinking has to meet certain conditions such as;

(i) The areas in which development of deep groundwater is prioritized as a countermeasure of arsenic contamination have to be those having no other alternative water source but groundwater which is perennial.

(ii) The areas in which the clay layer divides the deep aquifer and shallow aquifer hydrogeologically have to be developed as a short-period countermeasure for arsenic contamination prior to the other areas which do not have the clay layer.

(iii) In the areas where the clay layer dividing the deep aquifer and shallow aquifer does not develop, hydrogeological and geological conditions in the shallow and deep portions and the condition of groundwater use have to be examined from a comprehensive standpoint and a middle to long development plan for groundwater has to be formulated.

(iv) Not only arsenic but also other general water quality has to be fit for drinking.

(v) Removing harmful substances has to be possible in view points of technology, economy and O&M when the water is contaminated with them.

(vi) The use of deep groundwater has to be limited only for drinking and prohibit using it for other purposes.

(vii) Monitoring of groundwater level and quality has to be regularly conducted when using the deep groundwater.

(viii) Study and investigation for the possibility of arsenic elution from the arsenic source layer in the deep portion have to be continued.

(ix) Backup systems for monitoring, water analysis, water source management and O&M of water supply facilities have to be established and expanded.

12.1.6 Technology for Arsenic Measures

The results of the field examination of technologies, arsenic removal devices (ARD), improved deep wells (IDW) and alternative water sources are presented as follows.

1) Arsenic Removal Devices (ARD)

Double buckets, aeration/passive sedimentation, activated alumina, basin-type solar distillation and vacuum-type solar distillation were examined in the model rural areas. According to the field results, the following three technologies are recommended.

a.Aeration/passive sedimentation

Arsenic can be removed together with iron by precipitation and sand filtration. The system requires no chemicals or consumables, and is easily operated and maintained at low initial cost and negligible running cost. However, arsenic removal efficiency depends on the raw water quality. It is not applicable to raw water of high EC and chloride. It is also not applicable to raw water of high Fe/As ratio and arsenic concentrations of more than 0.2 mg/l. If raw water quality meets the applicable standard, removal testing shall be conducted before installation of the device.

b. Solar distillation combined with rainwater harvesting

Solar distillation can remove arsenic perfectly. Since the system can be operated sufficiently in the dry season, it is effective to utilize it in combination with rainwater harvesters (RWH) in the rainy season. The system can remove not only arsenic but also other pollutants. It can be easily operated and maintained and the running cost is negligible. However, in order to produce a large amount of water, a large area and a high cost are required.

c. Adsorption based arsenic removal device

Arsenic is removed by adsorption media such as activated alumina and so on. Stable arsenic removal is assured in most case and operation and maintenance is easy. However, the frequency of media replacement depends on the raw water quality. It is necessary to monitor the sustainability of the removal effect. The waste site for the spent media is another problem.

2) Improved Deep Well (IDW)

The tube well is traditionally drilled by the manual “donkey “method in the Study Area. The bore hole is drilled at a small diameter so that the space between the casing and the bore wall can not be sealed. This causes leaking of arsenic contaminated groundwater from shallow aquifer to deep aquifer through the space along the casing. In the Study, the “donkey method” was improved by applying 3 kinds of sealing methods.

a. Type A: Cement sealing

The cement is injected in the space between the casing and the bore wall drilled using a large diameter drill bit. If the cement is injected carefully, effective sealing can be achieved at a required depth. The construction requires 10 to 20 days and it costs about 69,000 Taka.

b. Type B: Sealing material

Sealing material is attached to the upper part of the screen. The casing is inserted in the borehole. After that, the sealing material swells by absorbing water. It requires skill for smooth insertion. If the bore wall collapses, no sealing effect can be obtained. The construction requires 1 to 2 weeks and it costs about 48,000 Taka.

c. Type C: Metal basket

A metal petal basket is attached to the upper part of the screen. After the casing installation, cement is injected into the basket. The upper part of the basket works as a sealant. Insertion of the metal basket requires skill. Therefore, if the bore wall collapses, the sealing is not effective. The construction requires 10 to 30 days and it costs about 70,000 Taka.

Considering the easiness of construction work and effect of sealing, type A is suitable. However, all the sealing methods can be applied to a clayey layer that overlies the aquifer. If the clayey layer does not exist, they are not applicable. Therefore this technology depends on the geological conditions.

3) Other alternative water sources

Besides groundwater, there are water sources such as rain, rivers and ponds in the Study Area. In addition, shallow hand-dug wells that were utilized in the past time are also an alternative. According to the survey results, rainwater is not utilized well and most of the residents are not interested in rainwater utilization as it is only usable in the rainy season. Moreover, most of the river and pond water sources decrease or dry up in the dry season. Stable utilization of surface water sources is rather difficult all the year round. In addition, the pond water is often contaminated with bacteria, such as coliform bacillus. It is indispensable to install pond sand filter (PSF) to treat water and operate and maintain it properly. It is more than likely that the hand-dug wells are also contaminated.

Considering the above, it is necessary to conduct a detailed survey on the village water sources and dissemination activities on awareness of arsenic pollution and hygiene. Guidance on the construction, operation and maintenance of alternative water sources by the residents themselves is indispensable.

12.1.7 Socio-economic Study in the Model Rural Area

1) Socio-economical index

The size of the households in the model rural area is 3 to 5 persons. The main religion is Islam, although a small number of Hindus are living in the same village. The literacy rate is 65 to 85% and the average annual income is 25,000 Taka (Bara Dudpatila), 31,000 Taka (Krishna Chandrapur), 33,000 Taka (Rajnagar Bankabarsi), respectively.

2) Water use

Water fetching is a role of woman. The daily consumption of water is 45 lcd in the rainy season. It is used for drinking and domestic purposes. The willingness to pay for arsenic safe water is 30 Taka (Bara Dudpatila), 50 Taka (Rajnagar Bankabarsi) and 75 Taka (Krishna Chandrapur), respectively.

3) Awareness on the arsenic problems

The awareness level of the residents is low because they have little opportunity to watch TV and read newspaper due to the low literacy rate. However, there was a rise in awareness of the arsenic problem during the dissemination activity conducted in the Study. Particularly in Rajnagar Bankabarsi, many people switched from their usual tube wells to the new water source (improved deep well), although the time required for water-fetching increased.

12.1.8 Master Plan for Arsenic Measures

1) Purpose

The master plan aims to supply arsenic safe water to the residents of Chuadanga , Jhenaidah and Jessore Districts mainly by development of deep aquifers. The target year of the master plan is 2010. The master plan period is divided into 3 stages, i.e., short term (year-2003), middle term (year-2005) and long term (year-2010).

2) Area division

The rural area of the 3 districts is divided into *Urgent Areas* (more than 0.1 mg/l) and *Semi-urgent Areas* (more than 0.05 mg/l and less than 0.1 mg/l) based on the arsenic concentration. The urban area (7 pourashavas) is divided into *Supplied Areas* and *Un-supplied Areas*.

3) Contents

In the *Urgent Areas*, level 1 and/or level 2 water supply systems are constructed by development of deep aquifers. In the areas where deep groundwater development is difficult, regional rural water works are planned for the middle and long term. The water source of regional rural water works is groundwater extracted in the pourashava. It is transported to the rural area by pipeline. On the other hand, as a short term measures for the other *Urgent Areas* not covered by deep groundwater, installation of alternative water sources, such as ARD, RWH and PSF are promoted.

Arsenic measures in the urban area are promoted by the improvement and expansion of present pourashava water supply systems. However, an urgent project is planned for the 3 pourashavas where several production wells have already been contaminated more than the Bangladesh standard. The middle and long term improvement and expansion of the water supply are promoted in other pourashavas and thana growth centers considering connection to the regional rural water works.

4) Operation and Maintenance (O&M)

O&M of the water supply facilities constructed in the rural area is a responsibility of the residents. The residents form an O&M organization, elect caretakers, and operate and maintain the facility. The cost of O&M is shared by the residents. On the other hand, the pourashava operates and maintains the water supply system as in the past. However, it is improved technically, institutionally and financially in order to improve its management.

5) Dissemination activity

In order to carry out arsenic measures effectively, the residents have to be aware of correct knowledge and information on arsenic problems. Therefore, the dissemination activity including hygiene education is conducted in parallel with several kinds of arsenic measures in the master plan.

12.1.9 Priority Projects

Four priority projects were selected from the master plan. A pre-feasibility study was carried out. The cost was estimated on the basis of Bangladesh local prices.

1) Deep Groundwater Development in Keshabpur Thana

The project will supply arsenic safe deep groundwater to 61 mouza (population about 84,000) of Keshabpur thana located in the *Urgent Area* in the southern part of Jessore district. The water supply system is composed of a deep well (depth: 300 m), an elevated tank, pipeline and public faucets constructed in the center of the village. The project cost is estimated at 624 million Taka. The O&M cost is 23.9 Taka per month per person. The alternative water supply facility is the level 1 system, which is composed of a deep well with hand pump. In this alternative plan, the cost is estimated at 278 million Taka and the O&M cost is estimated at 3.7 Taka per montn per person.

2) Rehabilitation and Expansion of 3 Pourashava Water Supply Systems (PWSS)

Three pourashava water supply systems will be rehabilitated and expanded. Several production wells in the PWSS of Chuadanga, Jhenaidah and Moheshupur have already been contaminated with arsenic. The planned water consumption is 100 lcd for individual connection and 35 lcd for the public stand post. Deep wells, elevated tanks, treatment plants, pipeline and public stand posts are rehabilitated and/or newly constructed. The project cost is estimated at 388 million Taka. On the other hand, the water charge to meet the O&M cost will become 200 Taka per month per connection.

3) Provision of arsenic free water to socially vulnerable sectors by Rain Water Harvesting and Solar Distillation (RWH/SD) system

In order to provide measures for the vulnerable sector of the society, such as people in hospital and children in school, the arsenic removal system of solar distillation (SD) combined with the rainwater harvester (RWH) is installed in 14 hospitals and 16 schools. The project cost is estimated at 358 million Taka with an annual OM cost of 3 million Taka.

4) Establishment of Thana arsenic mitigation promotion center

Thana arsenic mitigation promotion centers are established in the DPHE Thana offices located in the *Urgent Areas* and *Semi-urgent Areas* not covered by the deep groundwater development plan. The centers exhibit and store the ARD and distribute 2000 sets of them upon request from the community. They also store adsorption media and keep spent media temporally. The project cost amounts to 208 million Taka.

According to the preliminary financial and economical evaluation, these projects are feasible.

12.1.10 Supplementary Survey in Keshabpur

In order to examine the details of the deep groundwater development project in Keshapur, mouza map preparation, screening of the existing wells, a social study and deep well drilling and pumping tests were conducted for 16 mouzas. Based on the survey, a water supply plan was proposed.

1) Screening survey

The number of the existing wells in the 16 mouzas totaled 3,037. There are 10 wells per person. The depth of the wells ranges from 40 m to 60 m. Arsenic was measured at 3000 wells by using the field kit. 379 samples out of 3,000 were measured by AAS. Almost all wells show arsenic concentrations of 0.2 to 0.5 mg/l. 99 % of the wells exceed the Bangladesh standard. Accordingly, it is confirmed that the area is actually located in an *Urgent Area* and measures are necessary.

2) Deep well drilling

Bramakati mouza was selected as a representative point of deep groundwater investigation. A borehole was drilled up to 300 m deep. Based on the geological and geophysical log, the screen was placed at a depth below 287 m. The casing was placed and the well was completed. According to the pumping test, a specific capacity of 9.48 m^2/day, transmissivity of 2.45 m^2/day, and storage coefficient of 5.87E-01 were obtained. Arsenic concentrations showed to be very low, less than 0.005 mg/l, and the safety of deep aquifer was confirmed.

3) Hydrogeological structure and groundwater development

According to the existing borehole data and the drilling records of newly constructed wells of the Study, the well depth is estimated at about 300 m in Keshabpur mouza and its northern part, 300 to 350 m in the southern part and 200 to 250 m in the vicinity of Rajinakgar Bankabarsi.

4) Social survey

Generally, the annual income per household in the 16 mouzas amounts to 36,350 Taka. On the other hand, household expenditure amounts to 34,157 Taka. About 50% is spent on food expenses. 97.3% of the households use groundwater for drinking purposes.

Villagers in mouzas have the ability to pay 90.9 Taka per month per household (three percent of the monthly income of 3,029) for improved water supply systems. However, they may still be unwilling to pay at present. Villagers' willingness to pay for safe water is 30 Taka per month per household.

The households with knowledge about arsenic poisoning show a higher willingness to pay than the ones without it. Likewise the households with strong cohesiveness with their community have a tendency to express more willingness to pay for safe water, compared with the ones with less feeling of community cohesion.

Therefore, it seems reasonable to conclude that the activities to raise villagers' awareness of arsenic poisoning and/or consciousness of being a member of the community are necessary to satisfy financial requirements for the operation and maintenance of water supply systems when they are to be introduced. As a result of these activities, the financial sustainability of the systems would be secured.

5) Water supply plan

A deep groundwater water supply plan for the 16 mouzas with a population of 35,890 is proposed. The planned water consumption is 35lcd. The improved level 1 water supply system which is composed of a deep well, motorized pump, elevated tank and communal faucets. Three sets of this system are constructed in the urbanized areas in Keshabpur and Altapol mouzas among the 16 mouzas. The level 1 system composed of a deep well with hand pump is constructed in the rural area (16 mouzas including Keshabpur and Altapol). The number of systems is 180 in total. The project cost amounts to approximately 95 million Taka with an O&M cost of 16 Taka per month per household for level 1and 105 Taka for the improved level 2.

6) Project evaluation

As a part of the priority project, deep groundwater development in Keshabpur, this project eliminates arsenic contamination risk for about 36,000 people. The water supply facilities constructed in the rural area will be sustainable from the points of the willingness to pay against O&M cost. Therefore, the project is thought to be feasible. However, the willingness to pay for the improved level 1 system must be studied further.

12.2 Recommendations

12.2.1 Groundwater development and management

Legal regulation of groundwater development and management has not yet been established in Bangladesh. The disordered development of deep groundwater must be avoided in the future. The government and responsible organizations should establish legal regulation that gives priority to the use of groundwater for drinking purposes. In addition, a monitoring and management system should be established in order to control groundwater use at present and in the future. Without policy, legal regulation and a management system, it is difficult to preserve this precious natural resource. It will be damaged soon. Deep groundwater resources cannot be remedied once they have been contaminated.

Accordingly, the best way to avoid secondary contamination must be investigated based on the hydrogeological studies at each site. It is important to monitor the shallow aquifer, not only the deep aquifer. Since the mechanism of arsenic contamination is not clarified yet, deep groundwater should be utilized carefully while monitoring groundwater levels and water quality at the same time.

The continuous utilization of deep groundwater in the future might cause an upward groundwater flow from deeper aquifers. The hydrogeologic conditions in the deeper aquifers are not known yet. Therefore, further study on deeper aquifers is required in the future.

12.2.2 Investigation of deep aquifer

One important finding obtained in this Study is the presence of arsenic in the deep stratum. According to the monitoring in the Study, arsenic contamination of the deep aquifer is not seen in almost the entire area although slight contamination is found in some areas. However, the possibility of contamination in the future cannot be denied. It is thought that the arsenic in the deep stratum is *inactive* at present. But there is a possibility of arsenic contamination in the future if the deep groundwater environment changes drastically.

Many scientists and researchers have studied about the mechanism of arsenic contamination in shallow groundwater. However, the study indicates the necessity of investigation and research of arsenic presented in the deep stratum. Investigation of deep geology is difficult compared with shallow geology and investigation requires high cost. Accordingly, the knowledge and experience obtained through the exploration of oil and gas reservoirs should be utilized for deeper aquifer studies. Establishing a strategy and methodology to solve this complicated arsenic problem is therefore strongly recommended.

12.2.3 Water supply plan for rural and urban

1) Early implementation of the project

The study proposed 4 priority projects as urgent measures against arsenic contamination. All these projects are proposing short term implementation considering the serious situation of arsenic contamination of the proposed area and the possibility and safety of deep groundwater development. Accordingly, the earliest possible implementation of these projects is strongly recommended.

2) Regional rural water works

Construction of the regional rural water works is also recommended in the middle and long term. This water works transports groundwater extracted at the pourshava production wells to the rural area through the pipeline. The area covered by the deep groundwater development project is excluded from the supplied area. Most of the pourashava water supply systems are operated in the daytime. If the operation time is extended, water production can be increased to meet the demand of the rural area. This system would solve the arsenic problem in a stroke.

3) Improvement of porashava water supply system

On the other hand, there are many problems in the pourashava water supply system. As pointed out in the main report, groundwater sources of these systems have not been contaminated yet. Arsenic concentrations are below the Bangladesh standard except at several production wells in Chuadanga, Moheshpur and Jhenaidah. The service time can be extended if the leakage stops by rehabilitation of the facilities and improvement of technical management. The water charge must be changed from the flat rate to a volume specific rate thereby reducing wastage of arsenic safe water, and expansion could be realized to meet future water demand.

4) Training of water supply engineers

As seen in the history of water supply in Bangladesh, groundwater has been a main water source from the beginning. Therefore, engineers in the field of pipeline and treatment plant construction, operation and maintenance are few. It is urgently needed to cultivate and train the engineers. It is recommended that DPHE engineers not only participate in the training program abroad but also be trained through OJT in cooperation with the organizations under the WASA. It is also recommended that the WASA staff be dispatched to the DPHE.

12.2.4 Dissemination activity on the arsenic problem

Sanitary water was secured in the past. However, the arsenic problem drastically changed this situation. Arsenic poisoning is not acute but chronic, thereby correct understanding is necessary. According to the social study, the households with knowledge about arsenic poisoning show a higher willingness to pay for the water supply facility.

Discussions were held in the model rural areas and target mouzas for the supplementary survey during the social study. However, actions such as the establishment of committees, public information activities and so on were not undertaken after that, although many villages still request advice from local government organizations and NGOs. This implies that appropriate organization to give advice to the communities does not exist. There are quite a few NGOs engaged in the arsenic problems in the Study Area. It is recommended that a campaign of "*water and hygiene*" and "*arsenic problems*" be promoted in the long run in coordination with these organizations.

12.2.5 Arsenic analysis laboratory

An arsenic analysis laboratory was set up at the DPHE Jhenaidah office and started operation in November 2000. The laboratory is equipped with a state-of-the-art Atomic Absorption Spectrometry (AAS) unit with a continuous hydride vapor generator and auto-sampler. The laboratory is also accommodated with a water distillation unit and ion exchange filter for pure water production, an in-line UPS and a back-up power generator for stable electricity supply. The laboratory has the capacity to analyze up to 1,000 samples per month.

The technology transfer to the DPHE chemist for the operation and maintenance of the laboratory started in March 2001. In order to sustain the operation of the laboratory, a "*Business Plan*" proposing staffing, a budget, and an operation mechanism was prepared. It is strongly recommended that outside samples from communities, NGOs or other organizations be accepted on a fee collection basis. This mechanism will ensure the provision of the budget required for consumables, chemicals, and the utility cost to keep the laboratory running. Success of the laboratory is an essential pre-requisite for future expansion of the arsenic laboratory by DPHE. Therefore, strong support in all aspects at the central and divisional level is required.

12.2.6 Utilization of GIS

A GIS database was constructed in the Study to be utilized as an information tool for arsenic measures. The GIS database consists of natural, socio-economic and groundwater information. Particularly, groundwater information includes the tube well inventory of DPHE, groundwater levels, log records and water quality data of BWDB. These data are installed in the computer with software. Using irrigation pumpage and other data stored in the GIS database, groundwater computer simulation was performed.

In the supplementary study, a digital mouza map was prepared at a scale of 1:5,000 and stored in the GIS database. It is possible to examine arsenic projects on the GIS. It is strongly recommended that GIS be utilized not only for the rural area but also the urban area in order to prepare the water supply projects. It is also recommended that the data obtained at the observation wells (i.e. groundwater levels, water quality, arsenic contamination and so on) be updated in the future.