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Ministry of Housing and Public Works

Government of the People's Republic of Bangladesh

REPORT ON DRY SEASONAL DATA COLLECTION, ANALYSIS AND INTERPRETATION ALONG WITH SPATIAL DISTRIBUTION (GIS SHAPE FILE)

FOR THE PROJECT OF
HYDRO-GEOLOGICAL SURVEYS AND STUDIES

UNDER
PREPARATION OF DEVELOPMENT PLAN FOR MEHERPUR ZILLA

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Submitted by

Center for Geoservices and Research
Flat# D1, House # 64/1,
Lake Circus, Kalabagan, Dhaka-1205

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1 Disclaimer

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Managing Director

Center for Geoservices and Research

2 Acronyms

UDD	Urban Development Directorate
CGR	Center for Geoservices and Research
VES	Vertical Electrical Sounding
EC	Electrical Conductivity
TDS	Total Dissolved Solid
ASTM	American Society for Testing and Materials

3 Introduction

This report describes the collection of dry-season groundwater level data from seven (7) clustered, established monitoring wells in three upazilas of Meherpur District as part of the **hydrogeological surveys and studies** conducted under the Preparation of Development Plan for Meherpur Zilla project. Additionally, details of field investigations for insitu water quality test.

The establishment of these monitoring networks is the first step in a detailed hydrogeological investigation in the study area that will be carried out over the period of more than a year from now. A total of 21 monitoring wells have been drilled and installed at seven (07) locations. At each location, three (03) co-located wells (5 to 10 feet apart) have been installed at different depths. The deepest of each set is about 500 ± 100 feet deep, the intermediate one is about 300 feet deep, and the shallowest one is about 100 feet deep.

Groundwater levels in the study area will be monitored over an approximate one-year period, encompassing both the dry and wet seasons, to capture seasonal variations in aquifer response. As part of the dry-season dataset, groundwater level data were collected from 22 March 2025 to 27 May 2025. This dataset is critical for characterizing the hydrogeological conditions and understanding seasonal fluctuations within the aquifer system.

Field investigations reveal that arsenic concentrations throughout the project area exceed the World Health Organization (WHO) and Bangladesh Standards and Testing Institution (BSTI) permissible limit of 10 ppb. Elevated arsenic levels are present across nearly all types of aquifers, with particularly high concentrations (>35 ppb) observed in shallow and intermediate aquifers. In addition, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) values surpass the BSTI threshold in several locations, especially in shallow and intermediate wells. However, pH levels remain within acceptable limits across all aquifer types
(Source: CGR).

During the in-situ field testing, the CGR team collected groundwater samples for laboratory-based ionic analysis. The target ions include Na^{+}, Ca^{2+}, Mg^{2+}, K^{+}, Fe, Mn, HCO_3^{-}, Cl^{-}, SO_4^{2-}, and NO_3^{-}, which are currently being analyzed at the Dhaka Laboratory. In addition, CGR performed slug tests to evaluate aquifer hydraulic properties. Grain size distribution analysis was also conducted in the laboratory to estimate the hydraulic conductivity (K) of various wells. The findings from these investigations will be integrated into the forthcoming wet season data collection report.

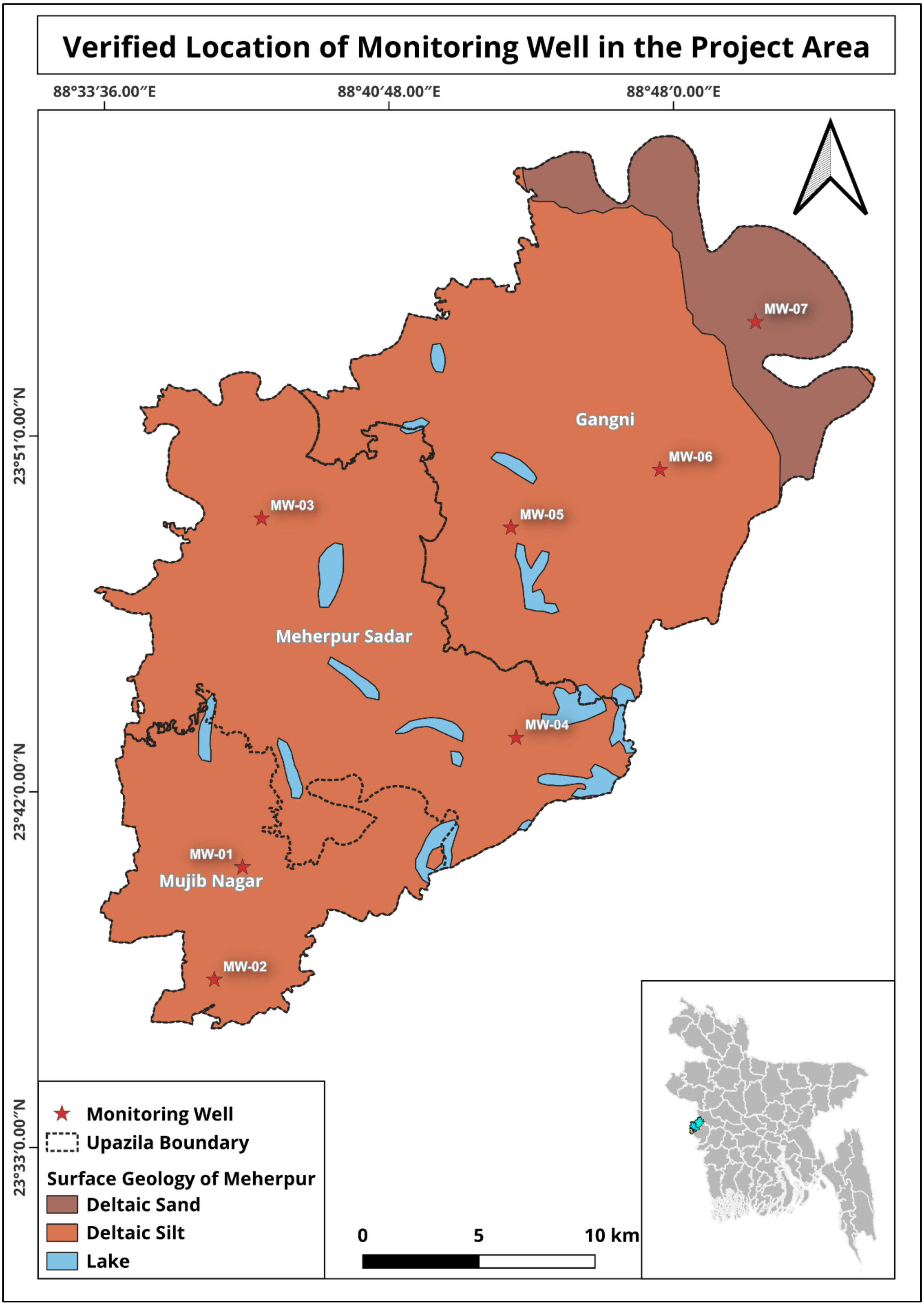
Detailed methodology, locations, and collected data analysis are discussed in the subsequent sections.

4 Methodology:

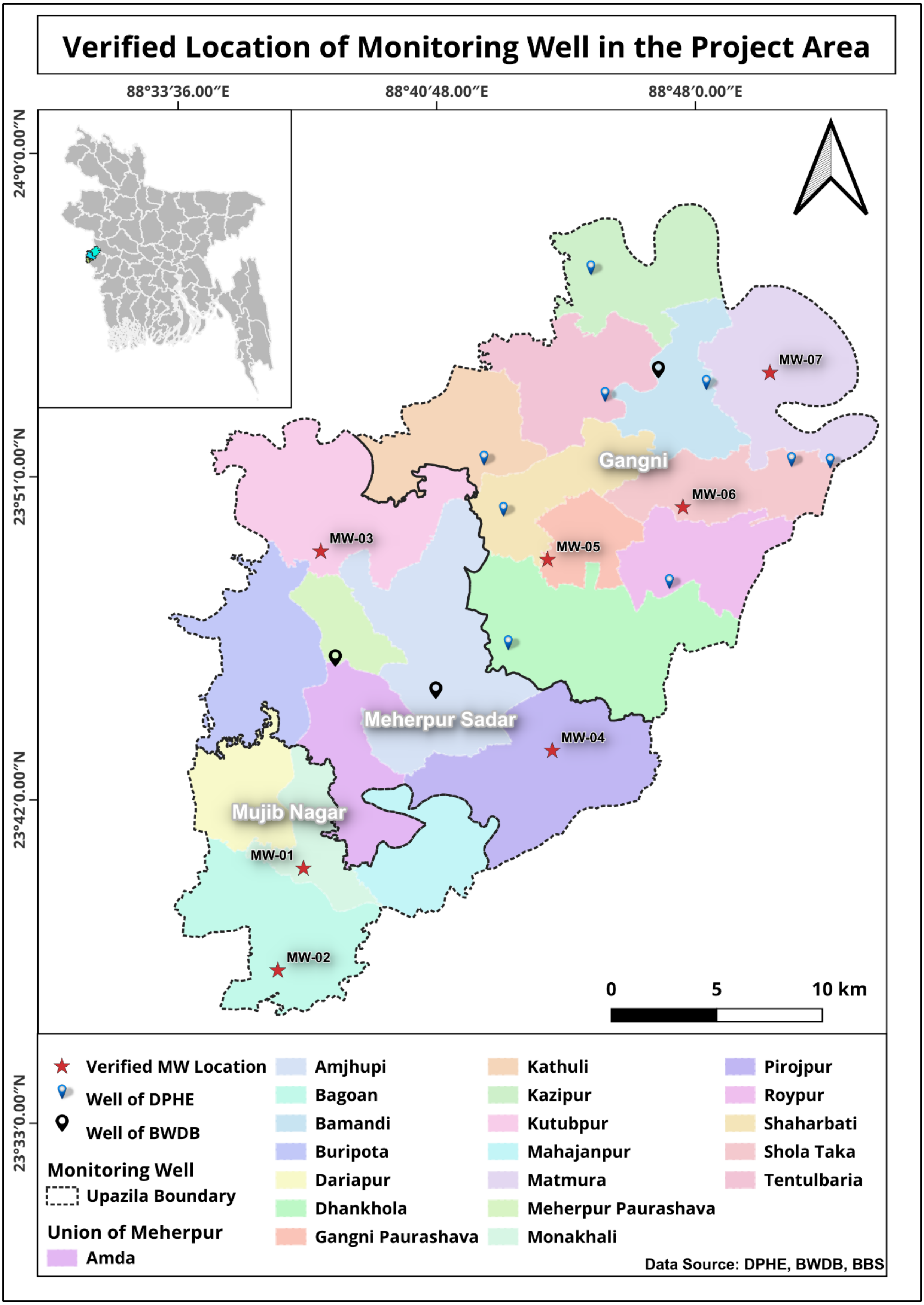
In order to establish the monitoring network in the field, a field trip was carried out between 20th February and 22 March 2025. A team consisting of one geologist and one civil engineer worked together in the field for the entire period. The drilling team was employed to drill and install monitoring wells one by one. The detailed methodology for site selection, drilling, sampling, logging, and installation of the monitoring network is discussed in the subsequent sections.

4.1 Site Selection:

Monitoring well locations were selected first based on Geological, Geomorphological, and hydrogeological variability, and the location of existing data in the study area. Later, the locations were verified by physical observation and shifted a bit based on local access and available space for the investigation as well as the permission of the landowners. All the locations are verified finally, and permission is also obtained from the landowners. Locations of the monitoring wells are shown in Figure 1 and in Table A-1 in the Appendix.



Map 1: Location map of the monitoring nests (Surface Geology Map)



Map 2: Location map of the monitoring nests (union based map)

4.2 Drilling of Monitoring Wells:

Since the groundwater quality in the study area varies in depth, monitoring wells at multiple depth intervals is essential. A total of 21 monitoring wells have been installed at seven (07) locations (one set of 3 wells, Map 1 and 2). At each location a cluster/nest[1] of three wells (one at around 500±120 feet depth, one at around 300±60 feet depth and the other at around 100 feet depth, each well will be within 5-10 ft from the other) have been installed as shown in Figure-2.

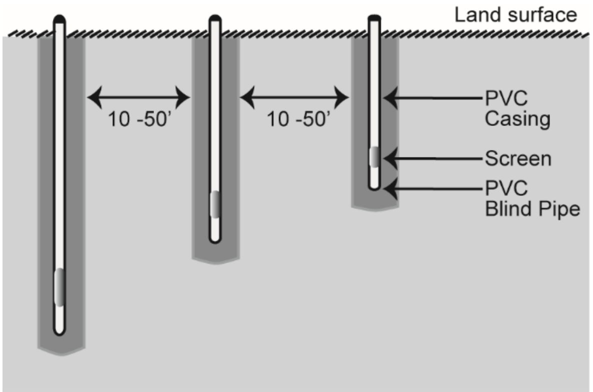


Figure 1: Cross Sectional View of Well Nest/Cluster

Reverse circulation conventional drilling method (Figure 3) was used for drilling the monitoring wells. In this method, drilling fluid enters the hole through the drill pipe and comes up to the surface with a mixture drill cutting through the annulus. Fluid was piped through the pipe using a high-speed mechanical pump. A mixture of water and cow dung was used as drilling fluids.

4.3 Lithological Sampling and Logging:

A well-site geologist was present at each site during drilling, responsible for logging the samples in a standard format and collecting samples at 10-foot intervals. He recorded the lithology on the log sheet provided by the consultancy firm, CGR, and preserved the samples for further laboratory testing, such as grain size analysis. The drill cuttings were collected in a bucket and stored in polyethylene bags for further laboratory analysis. The samples were visually analyzed by an onsite geologist, and a driller's log was prepared in the field.

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[1] **Nest well:** A cluster of wells where tubes or pipes are constructed in separate (10-50 feet distance to each other), individual boreholes that are drilled and completed at different depths.

Figure 2: Drilling Procedure of Monitoring well in Mujibnagar Upazila.

4.4 Installation of Monitoring Wells

After the drilling was completed, a monitoring well was installed at every drill hole. The deep and intermediate monitoring wells have 20 feet screens at the bottom of the well but above 10 to 30 feet blind pipes. The shallower monitoring wells have 10 feet screen above 10 feet blind pipe. Both the well casing and screen consist of PVC materials (Figure-3). After installing the pipes, gravel packing was done around the well screen. The well annulus was back filled with clays collected during the drilling.

Figure 3: Installation of Monitoring Well in Mujibnagar Upazila

4.5 Development of Monitoring Wells

After installation, each monitoring well was developed using both manual pumping and an electrical compressor. Manual pumping was performed for several hours for the shallow wells, while the electrical compressor was used for up to tens of hours for the deep and intermediate wells until the electrical conductivity (EC) of the well water stabilized. A local hand pump was used for manual pumping during well development.

4.6 Water Level Measurement, Water Sampling and Slug Test

The slug testing and water sampling campaign was conducted in two distinct phases. **Phase 1** focused on existing production wells and was carried out from 1 January 2025 to 8 January 2025. During this phase, slug tests were performed at 60 existing production wells, and water sampling along with in-situ water quality testing was conducted at 35 of these wells. **Phase 2** targeted the newly installed monitoring wells and took place from 18 May 2025 to 21 May 2025. In this phase, all field activities were conducted in the 21 newly established monitoring wells, providing comprehensive data for further hydrogeological analysis.

The description of water level measurement, water sampling and slug is given below:

4.6.1 Water Level Measurement, Water Sampling in Monitoring Well

After the successful development of the monitoring wells, groundwater levels at the monitoring wells were measured using an electronic groundwater level meter. Afterwards, the wells were pumped, and water samples were collected for laboratory analysis. During water sampling, a number of onsite geochemical parameters were also measured in the field using field test kits. These parameters include pH, electrical conductivity (EC), total dissolved solids (TDS), and arsenic (Figures 4).

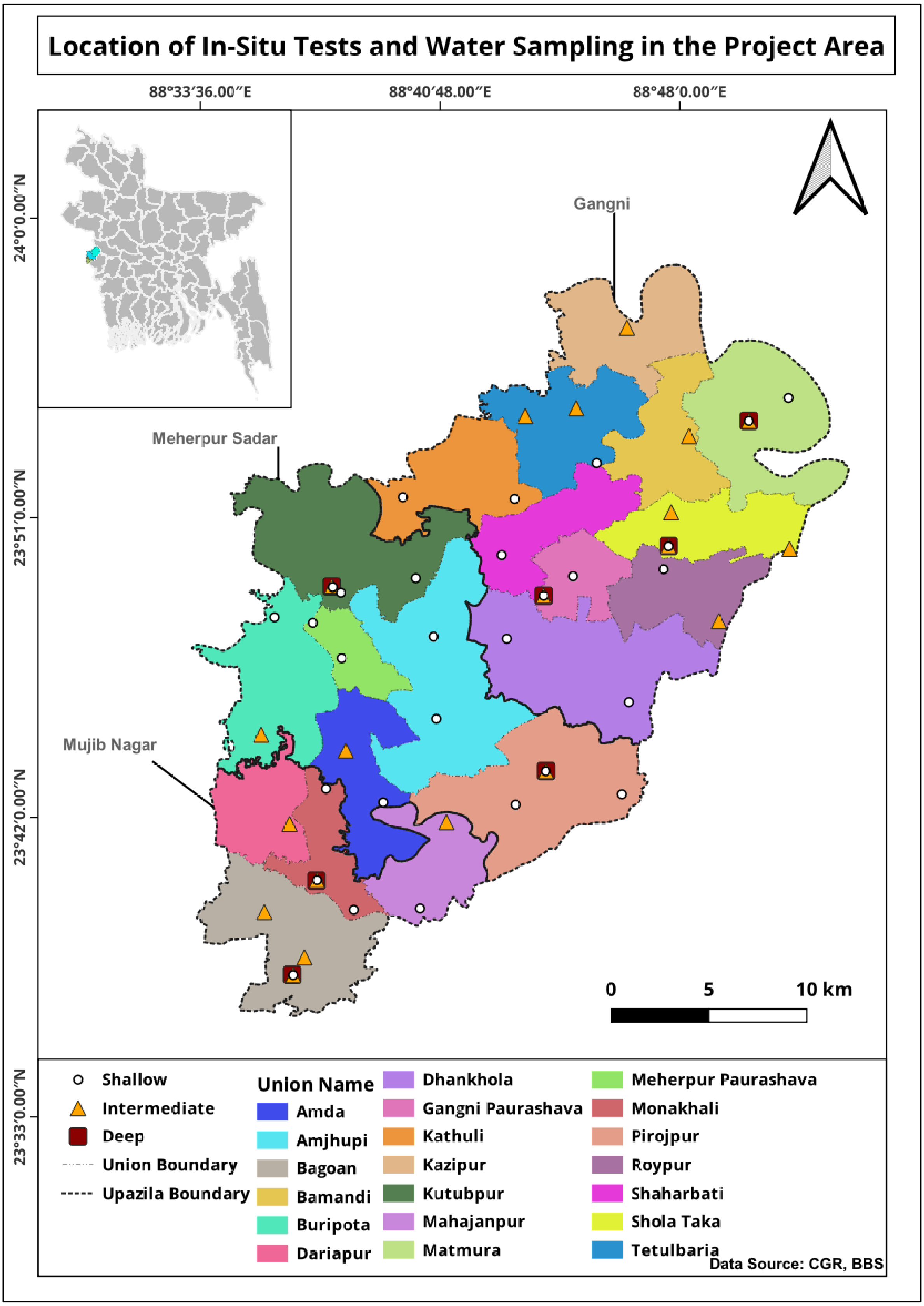
Water levels will be measured automatically at hourly intervals in the deep wells using automatic data loggers for a period of one year. In shallow and intermediate wells, water levels will be measured biweekly using a water level meter for the same period.

Figure 4: Water Sampling and Field Test.

4.6.2 Water Sampling from Existing Wells

A total of 35 existing wells were sampled in 3 Upazilas. Before sampling each well was purged for 5-10 minutes. Samples were collected in 100 ml plastic bottles. Two samples were collected from each well; one was acidified by Nitric acid (HNO_3), and the other was non-acidified. Both samples were filtered before filling the sampling bottle. Each sample was given a sample ID, and the sample bottle was labeled with ID. In addition to sample collection, several onsite geochemical parameters were measured in the field using field test kits. These parameters include pH, Electrical conductivity (EC), TDS, and Arsenic (Figure 5). Details of the sample locations and field parameters are given in Table A-3 in Appendix.

Figure 5: Water Sampling from Existing Well



Map 3: Location of In-situ Test and Water Sampling in the Project Area

4.6.3 Slug Test

Slug tests were conducted at a total of 81 locations across the study area, including 60 existing hand tube wells and 21 newly installed monitoring wells. (Map: 4). Since pump tests are very expensive, they are usually carried out at only a few locations, providing very sparse data on the aquifer properties. A cheap alternative of pump test is slug test. For high density coverage of hydraulic conductivity data slug test will be performed in a large number of wells throughout the study area. Slug test is a field method where a slug (usually a rod) is inserted in a well below the water table, which causes an instantaneous rise of water level in the well. Dissipation of the water level in the well is then recorded, usually by an automatic water level logger (Figure 6). The temporal rate of this water level declines provides information on the hydraulic conductivity and specific yield/storage of the aquifer surrounding the well. This is a quick but accurate method of estimating hydraulic conductivity in any small diameter tube wells.

Figure 6: Automatic data logger

A slug test is a controlled field experiment, performed by groundwater hydrologists to estimate the hydraulic properties of aquifers and aquitards, in which the water level in a control well is caused to change suddenly (rise or fall) and the subsequent water-level response (displacement or change from static) is measured through time in the control well and one or more surrounding observation wells (Figure 7 & 8).

Figure 7: Slug test in an existing well

Slug tests are frequently designated as rising-head or falling-head tests to describe water-level recovery in the control well following test initiation. Other terms sometimes used instead of slug test include baildown test, slug-in test and slug-out test. The goal of a slug test, as in any aquifer test, is to estimate hydraulic properties of an aquifer system such as hydraulic conductivity.

Figure 8: Slug Test in a Monitoring Well

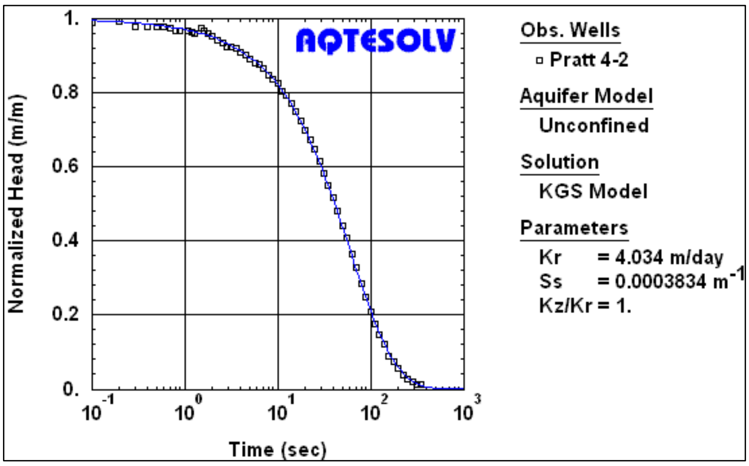
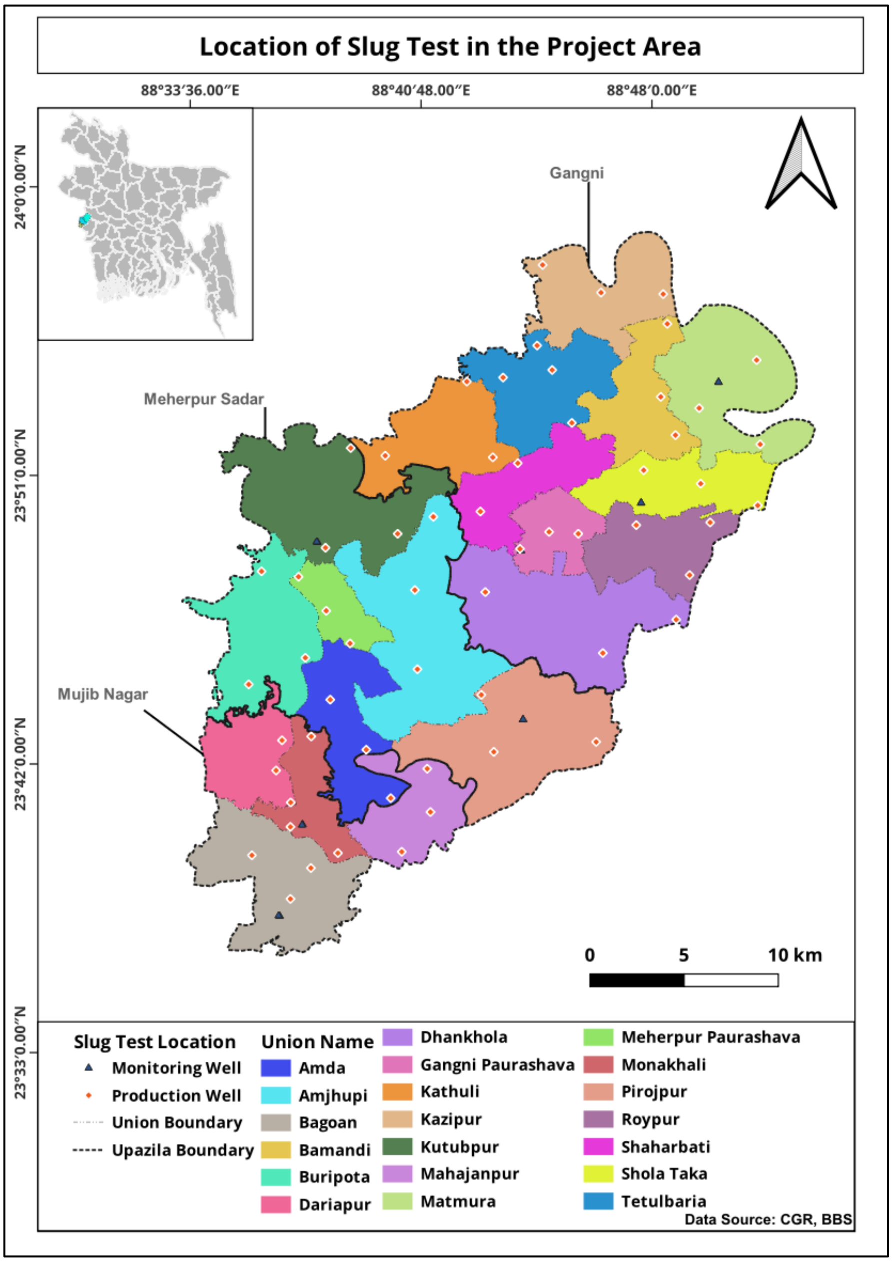


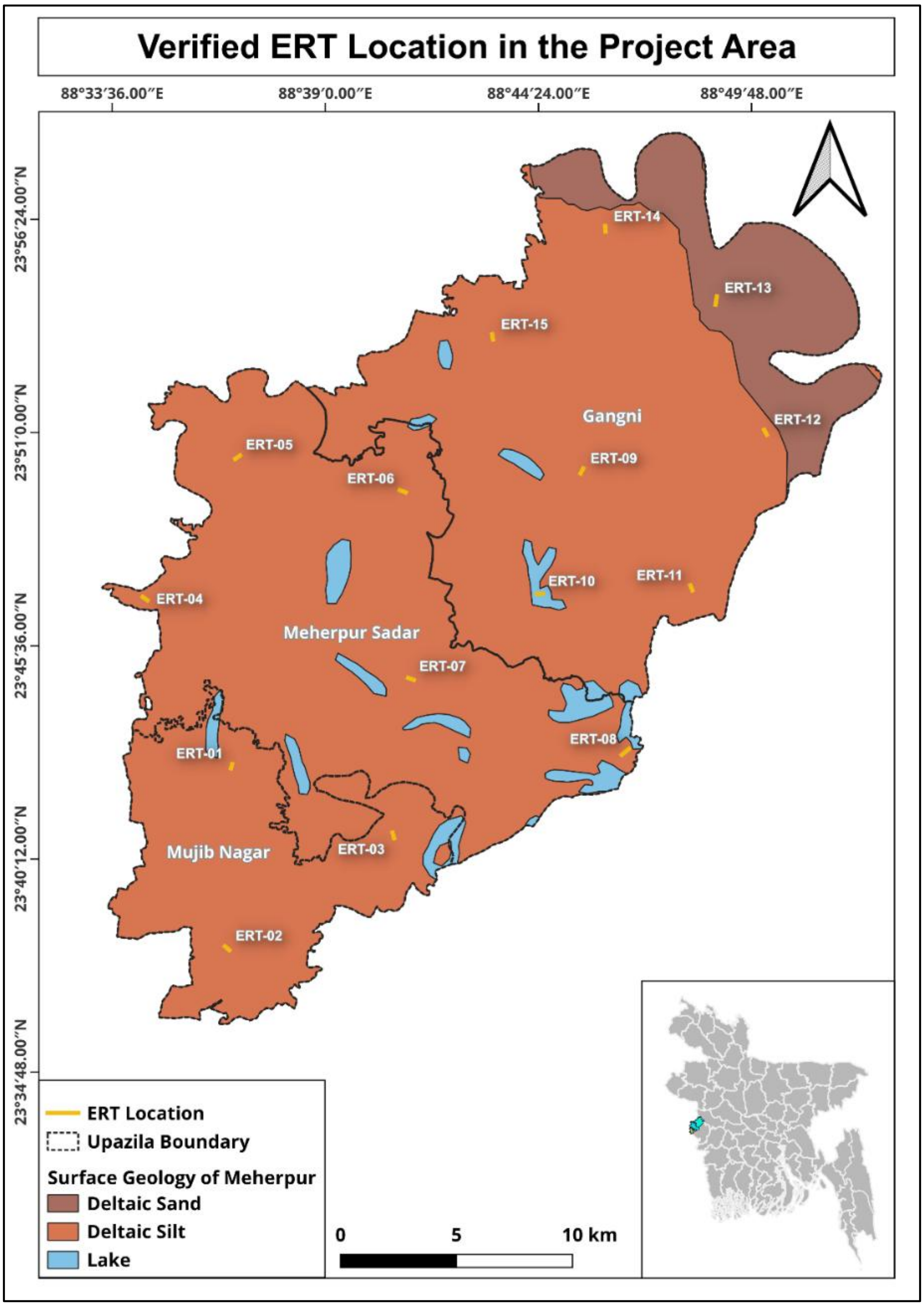
Figure 9: Estimation of aquifer properties from time-displacement data collected during an overdamped slug.



Map 4: Slug Test Location in Meherpur District (Source: BBS and CGR)

4.7 Electrical Resistivity Tomography

Boreholes provide direct information about the subsurface. However, drilling boreholes is expensive and their density in an area is usually low resulting in a spare point data about the subsurface geology. Interpolation of these sparse data for mapping subsurface geology/aquifers can be erroneous since usually there are data gaps over a large area between each borehole. Geophysical methods can be very useful in minimizing the data gap. In this study, Electrical Resistivity Tomography (ERT) surveys are planned to be conducted at 15 selected sites across three Upazilas (as shown in Map 5). The data acquisition will commence following the end of the rainy season to ensure optimal subsurface measurement conditions.



Map 5: Location Map of ERT (Data Source: BBS, CGR)

4.7.1 Methodology

Geo-electrical resistivity surveys have long been used for geo-engineering studies, and the method is found to be very successful. Geophysical methods are now widely used in solving complicated geological, hydrological, and environmental problems. Among all the geophysical methods, electrical and electromagnetic techniques are the most popular in groundwater exploration, geotechnical investigations, disaster science due to the close inter-relationship among electrical conductivity, hydrogeological properties of the aquifer such as porosity, clay content, mineralization of the groundwater, degree of water saturation, and lithology. Several case histories conducted in different parts of the world proved that the conventional direct current (DC) resistivity method is one of the most effective tools to decipher the underlying soil conditions in complicated geological settings.

4.7.2 Resistivity of Rocks

The resistivity of rocks varies considerably with lithology. The resistivity of rocks varies considerably with lithology. Sediments comprising aquifers are sands of various grain sizes. The electrical conductivity of these sediments depends on the salt concentration of the pore space water they contain. Clay and silt, rich in water-soluble minerals, have low resistivity even when their water content is low. The conductivity of sand and gravel is exclusively the consequence of their pore space water content, as they are composed of electrically non-conducting minerals. Consequently, sand and gravel show very high specific resistivity above groundwater level, and lower values below it. Resistivity is usually the most important property in determining the flow of electric current.

4.7.3 Resistivity Principles

In the resistivity method, artificially generated electric currents are introduced into the ground, and the resulting potential differences are measured at the surface. Generally, actual resistivity values are determined from apparent resistivity, which are computed from the measurements of current and potential differences between two pairs of electrodes placed on the ground surface. Two main types of procedures related to the resistivity survey are: vertical electrical sounding (VES) and constant separation traversing (CST). In groundwater exploration, vertical electrical sounding is widely used to identify the aquifer position, their lateral extent, variations in thickness, and water quality.

The resistivity of a material is defined as the resistance in ohms between the opposite faces of a unit cube of the material. For a conducting cylinder of resistance ΔR with a cross-sectional area ΔA and a length ΔL (Fig. 1), the resistivity of the cylinder can be expressed as:

$$\rho = \Delta R.\ \Delta A / \Delta L$$

The SI unit of resistivity is ohm-meter (Ω-m). The reciprocal of resistivity is termed as the conductivity and the SI unit of conductivity is ohm per meter or Siemens. The Ohm's law, which states that temperature remaining constant, the potential difference 'V' across a current bearing conductor is given by the product of the current 'I' and the resistance 'R' of the conductor.

$$V=IR \qquad (1)$$

Let the conductor be a plate of thickness 'L' and area of cross-section 'A', then

$$R= \rho L/A \qquad (2)$$

Where ρ is the resistivity of the plate

Putting equation (2) in equation (1) we get,

$$V = I\rho L/A,$$

$$\text{Or, } V= j\rho L \quad [j =I/A= \text{current density}] \qquad (3)$$

If 'L' is very small, the potential difference 'V' will also be small Δv, then the ratio –Δv/Δl is given by the potential gradient E

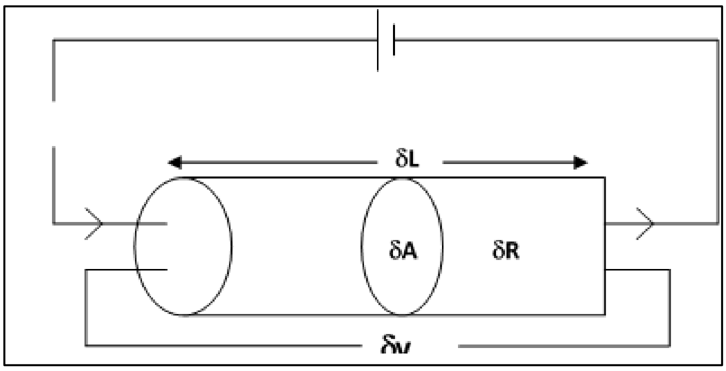


Figure 10 The parameters used in defining resistivity

Therefore, $-\Delta v/\Delta l = E= j\rho$ or

$$j = E/\rho = \sigma E \qquad (4)$$

Where, σ is the conductivity of the plate.

4.7.4 Resistivity of Homogeneous Isotropic Medium

The simplest approach to the theoretical study of earth resistivity measurements is to consider first the case of a completely homogeneous isotropic path. An equation giving the potential about a single point source of current on the spherical surface can be developed from ohm's law. In homogeneous isotropic ground where there is a point source of current below the ground surface, the current radiates equally in all directions. Hence the equipotential surfaces are spherical with center at source point. For two such equipotential surfaces very near to each other the potential difference would be $v_1 - v_2 = \Delta v$ between them.

If the radial distance between them is Δr, then potential gradient E at any point between them is

$$-\Delta v/\Delta r = E$$

The current density 'j' at any point on the equipotential surfaces would be

$$j = I/4\pi r^2$$

By ohms law,

$$J = I/4\pi r^2 = σE = - σ\ \Delta v/\Delta r$$

$$\text{Or, } \Delta v/\Delta r = - 1/σ.\ I/4\pi r^2$$

$$\therefore \Delta v = - 1/σ.\ I/4\pi r^2.\Delta r \qquad (5)$$

Now, integrating the equation (5) we get,

$$V = 1/σ.\ I/4\pi r + C$$

$$V = \rho I/4\pi r \qquad (6)$$

$$\text{When } \quad r = \infty \rightarrow C = 0.$$

If the point source of current is at the ground surface, then the current will flow hemispherically, then equation (6) can be expressed as

$$V = \rho I/2\pi r \qquad (7)$$

Potential functions are scalars and so, may be added arithmetically. If there are several sources of current rather than the single source assumed so far, the total potential at an observation point may be calculated by adding the potential contributions from each source independently. Thus, for n current sources distributed in a uniform medium, the potentials at an observation point, M will be-

$$V_M = \rho/2\pi\ [I_1/a_1 + I_2/a_2 + \text{----------------} + I_n/a_n] \qquad (8)$$

Where, I_n is the current from the n^{th} in a series of current electrodes and a_n is the distance from the n^{th} source to the point at which the potential is being observed.

Equation (8) is of practical importance in the determination of earth resistivities. The physical quantities measured in a field determination of resistivity are the current, I, flowing between two current electrodes; the difference in potential ΔV, between two measuring points and the distance between the various electrodes.

When there are two current electrodes (A&B) on ground surface and the distance between two current electrodes is finite (Figure 12), the potential at any nearby surface point will be affected by both current electrodes.

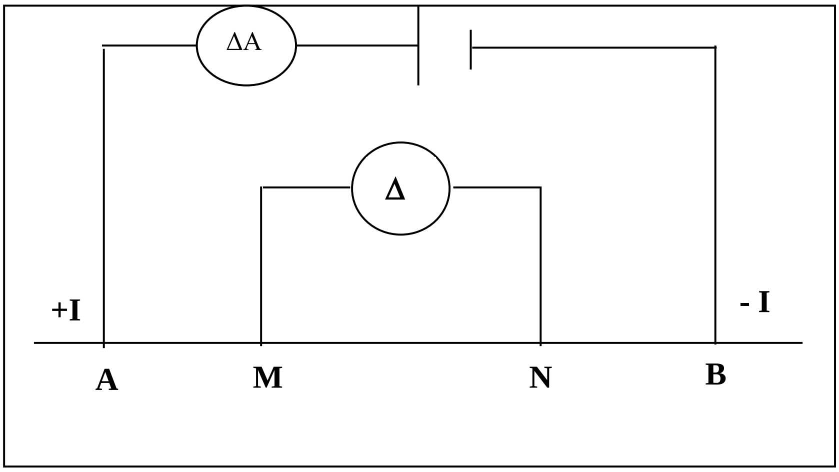


Figure 11 Generalized form of the electrode configuration used in resistivity measurements

The potential V_m at an internal potential electrode M_c is the sum of the potential contributions V_A and V_B from the current source at A and the sink at B.

$$V_M = V_A - V_B$$

From the equation (7) we get,

$$V_M = \rho I/2\pi\ (1/AM - 1/BM) \qquad (9)$$

Similarly,

$$V_N = \rho I/2\pi\ (1/AN - 1/BN) \qquad (10)$$

Absolute potentials are difficult to monitor so the potential difference ΔV between two electrodes 'M' and 'N' is measured:

$$\Delta V = V_M - V_N = \rho I/2\pi\ \{(1/AM - 1/BM) - (1/AN - 1/BN)\}$$

$$\text{Thus } \rho = 2\pi\ \Delta V/I\ \{(1/AM - 1/BM) - (1/AN - 1/BN)\} \qquad (11)$$

The equation (11) is applied for the ordinary four terminal arrays in measuring the earth resistivity in the field. Where the ground is uniform, the resistivity calculated from equation (11) should be constant and independent of both electrode spacing and surface location. When subsurface in homogeneities exist, the resistivity will vary with the relative positions of the electrodes. Any computed value is then known as the apparent resistivity (ρ_a) and will be a function of the form of the in homogeneity. Equation (11) is basic equation for calculating the apparent resistivity for any electrode configuration.

The arrangement of current and potential electrodes on or in the ground for the purpose of making an electrical survey is called electrode configuration. The current electrodes are generally placed on the outside of the potential electrodes.

Based on the position of current or potential electrodes and variation in distance between them, a variety of electrode configurations are possible of which some are mentioned below:

I. Wenner configuration
II. Schlumberger configuration
III. Dipole-dipole configuration

The choice of array and distance between the electrodes is very important for obtaining the best possible information of the subsurface geology of a given area. For ERT, Wenner configuration is preferred.

The Wenner configuration, in which potential difference is measured, is one of the simpler and most commonly used electrode arrays for determining resistivity. This is a symmetrical configuration consisting of four electrodes, the outer two electrodes are current electrodes and the inner two electrodes are potential electrodes. The distance between any two adjacent electrodes is called the array spacing and is equal and usually denoted by ‘a’ along a straight line (Figure 13).

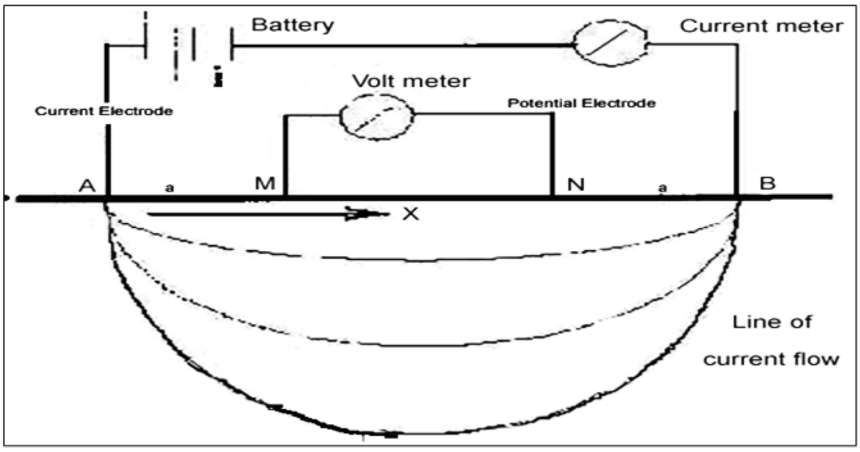


Figure 12 Wenner electrode configuration showing equal spacing

In spite of the simple geometry, this arrangement is quite often inconvenient for fieldwork. This arrangement has some disadvantages from a theoreticalpoint of view. For depth exploration using the Wenner configuration, the electrodes are expanded about a fixed center, increasing the spacing ‘a’ insteps. In case of lateral exploration of mapping, the spacing remains constant and all four electrodes are moved along the line, then along another line and so on.

The apparent resistivity with the Wenner array is given by-

$$\rho a = 2\pi a \ . \ \Delta V/I$$

Where,

ΔV = Potential difference in volts between V1 and V2;

I = Current in ampere;

a = Array spacing;

ρa = Apparent resistivity;

The geometric factor of Wenner configuration is $2\pi a$;

the resistivity of subsurface rock depends on this factor.

4.7.5 Basic Idea and Fundamentals of Resistivity Survey

Geo-electrical resistivity survey has long been used for ground water survey and the method is found to be very successful. As a preliminary step for the development of ground water, geo electrical resistivity survey proved to be very effective- (Bugg & Lloyed, 1976; Serres, 1969; Urish & Frohlich, 1990; Woobaidullah et al, 1996). In resistivity method, artificially generated electric currents are introduced into the ground and the resulting potential differences are measured at the surface. Generally actual resistivities are determined from apparent resistivities, which are computed from the measurements of current and potential differences between two pairs of electrodes placed in the ground surface. The procedure involves measuring a potential difference between two potential electrodes (M & N) resulting from an applied current through two other current electrodes (A & B) outside but in line with the potential electrodes. Thus, the measured current and potential differences yield an apparent resistivity over an unspecified depth. If the spacing between the electrodes is increased penetration of the electric field also increases and a different apparent resistivity is obtained. Two main type resistivity surveys are: Vertical Electrical Sounding and Constant Separation Traversing/ Profiling (CST).

Vertical Electrical Sounding sees the current and potential electrodes at the same relative spacing and the whole spread is progressively expanded about a fixed central point. Consequently, readings are taken as the current reaches progressively greater depths. In this case Schlumberger configuration is favored. Constant Separation Traversing is used to determine the lateral variations of resistivity. The current and potential electrodes are maintained at a fixed separation and progressively moved along a profile. In this case Wenner configuration is favored.

Electric Resistivity Tomography (ERT) is a robust and well-consolidated method for near-surface geophysics, with a wide spectrum of applications in the geological, engineering and environmental sciences. Technological advances (e.g., multi-channel arrays, innovative sensors) and novel tomographic algorithms for data inversion have rapidly transformed ERT into one of the most employed geophysical methods. In essence, the survey procedures are similar to CST, but with each increment in electrode spacing, the survey direction is reversed.

As for data processing, an inversion model is conducted. The least-squares method is used to calculate certain physical characteristics of the subsurface, the “model parameters”, from the apparent resistivity measurements. The “model parameters” are set by the way we slice and dice the subsurface into different regions. The method most commonly used in 2-D interpretation is a purely cell-based model where the subsurface is subdivided into rectangular cells. The positions of the cells are fixed and only the resistivity values of cells are allowed to vary during the inversion process. The model parameter is the resistivity of each cell.

4.7.6 ERT Data Acquisition

To define the subsurface resistivity condition Wenner configuration (WN) has been used. Four equally spaced electrodes are used in WN where two outer electrodes (A & B) acted as current electrodes (source) and two inner electrodes (M & N) acted as potential electrodes (Figure 14). The array spacing expands about the array midpoint while maintaining an equivalent spacing between each electrode (Keller, 1996). The resistivity measured by this configuration can be determined from the readings of current intensity (I) and the potential difference between M and N (ΔV) values as follows:

$$\rho A = k\frac{\Delta V}{I}$$

Where ρA is the apparent resistivity, k is the geometric factor as defined by the following expression:

$$k = \frac{2\pi}{(\frac{1}{AM} - \frac{1}{BN} - \frac{1}{AN} + \frac{1}{BN})}$$

The Wenner array employed in this study is one of the most commonly used arrangements, in the field.

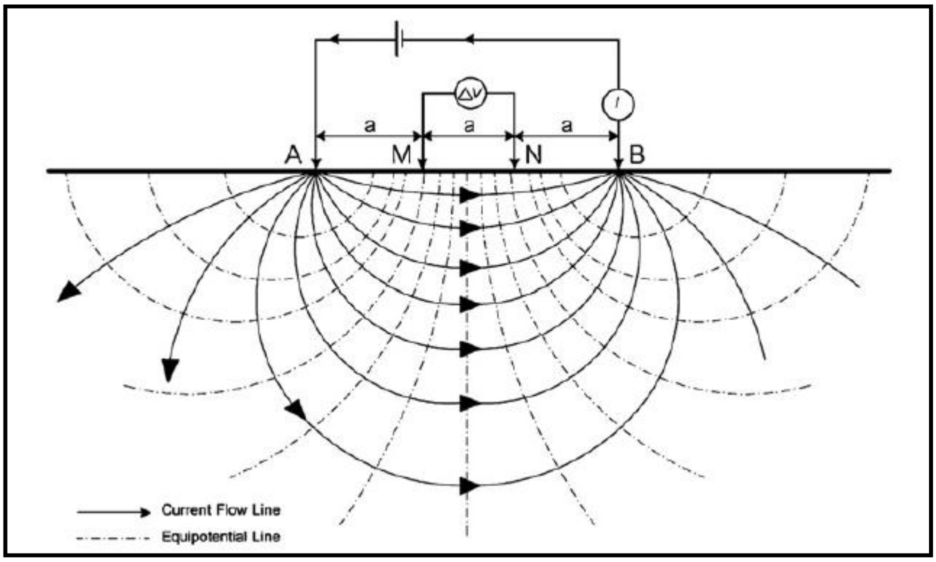


Figure 13 Wenner array ("a" is electrode spacing) and distribution of electric field underneath. (After Todd and Mays, 1980; Source: Wiwattanachang & Giao, 2011)

A spacing "a" separates the four electrodes equally. Wenner array's geometric coefficient is equal to 2a (Wiwattanachang & Giao, 2011). As a result, the apparent resistivity is determined as follows:

$$\rho A = 2\pi a \frac{\Delta V}{I}$$

Wenner configuration with a spread length of 90 m maximum is planned to execute where the electrode spacing was 3, 6, 9, 12 and 15 m respectively in all 20 sites in the investigated area.

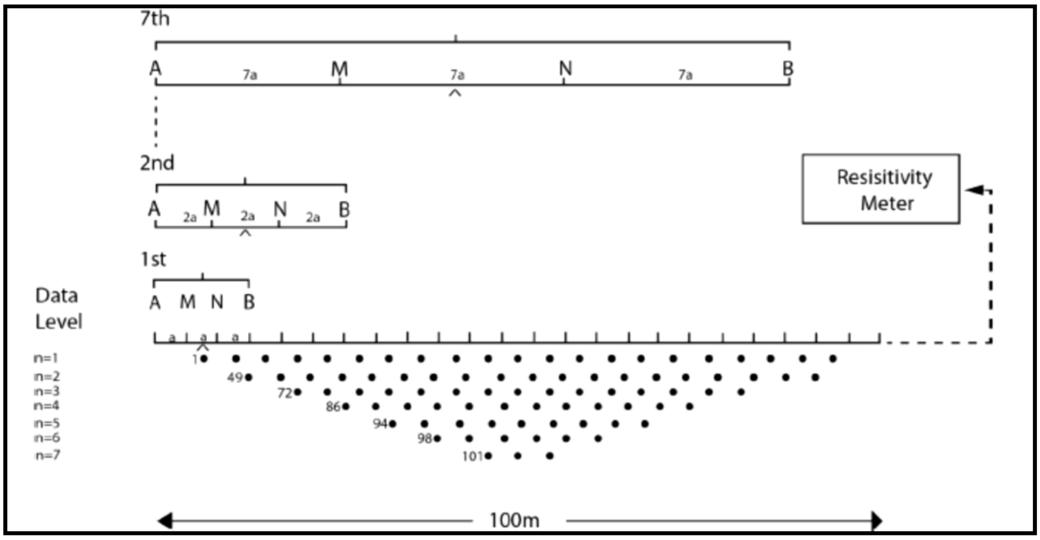


Figure 14: Measurement sequence for constructing a pseudo section.

4.7.7 ERT Data Processing

The measured data were converted into a suitable (.dat) format and therefore inverted using the smoothness-constrained least-squares inversion method in the Res2Dinv software (Loke and Barker, 1996; Sasaki 1992; deGroot-Hedlin and Constable 1990). The smoothness-constrained least-squares method is based on the following equation:

$$(\mathbf{J}^{\mathrm{T}}\mathbf{J} + u\mathbf{F})\,\mathbf{d} = \mathbf{J}^{\mathrm{T}}\mathbf{g}$$

Where, F = fxfxT + fzfzT; fx = horizontal flatness filter; fz = vertical flatness filter.

J = matrix of partial derivatives; u = damping factor; d = model perturbation vector; g = discrepancy vector.

5 Preliminary Results Based on Data Analysis

5.1 Groundwater Level

To date, groundwater level fluctuation data has been collected over an approximately two-month period during the dry season. An automated data logger was deployed in the deep monitoring well to record water level variations at daily and weekly intervals. Specifically, automated recordings were taken daily for Monitoring Well MW-06 and weekly for all other deep monitoring wells. Concurrently, manual water level measurements were conducted on a monthly basis in both shallow and intermediate monitoring wells.

5.1.1 Groundwater Level in Deep Aquifers

In the three aquifer zones, all aquifers exhibit minimal variation in groundwater levels over time. Between 22 March 2025 and 27 May 2025, the groundwater level in all deep wells fluctuated by more than 0.5 meters.

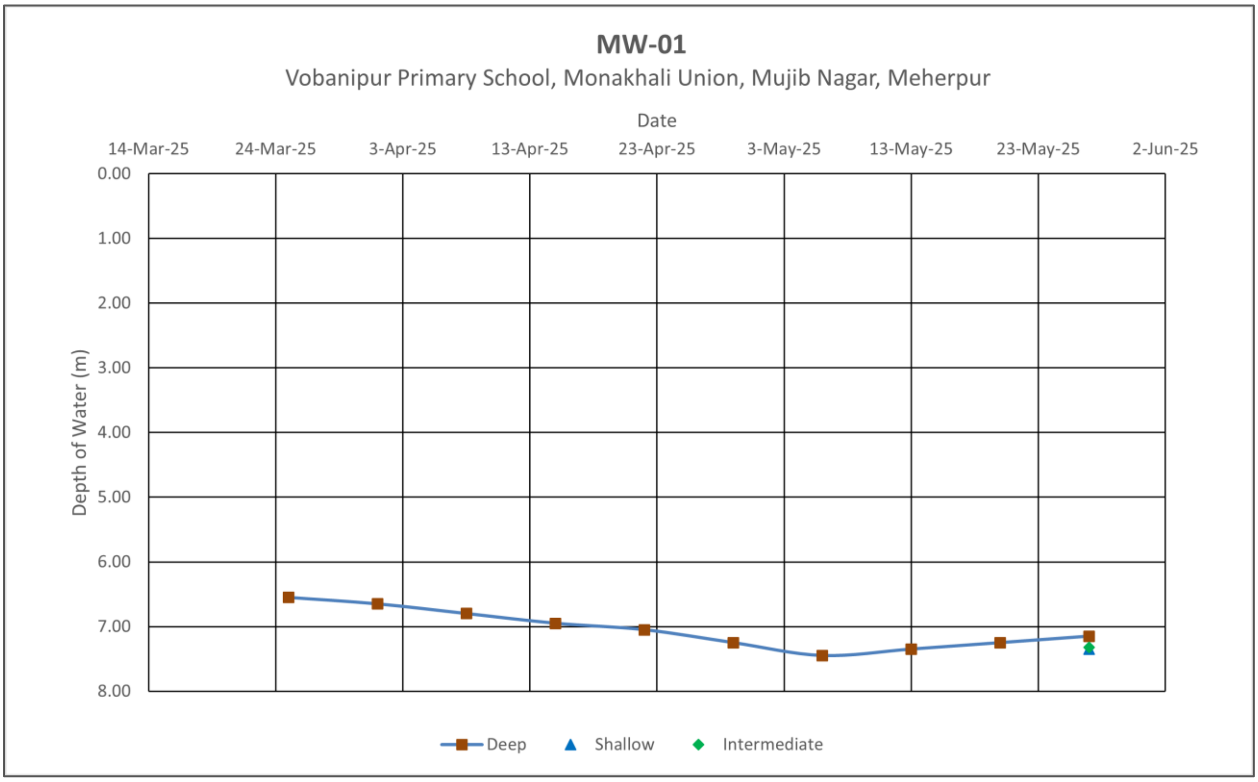


Figure 15: Ground Water Level in MW-01 Vobanipur Primary School, Monakhali Union, Mujib Nagar, Meherpur

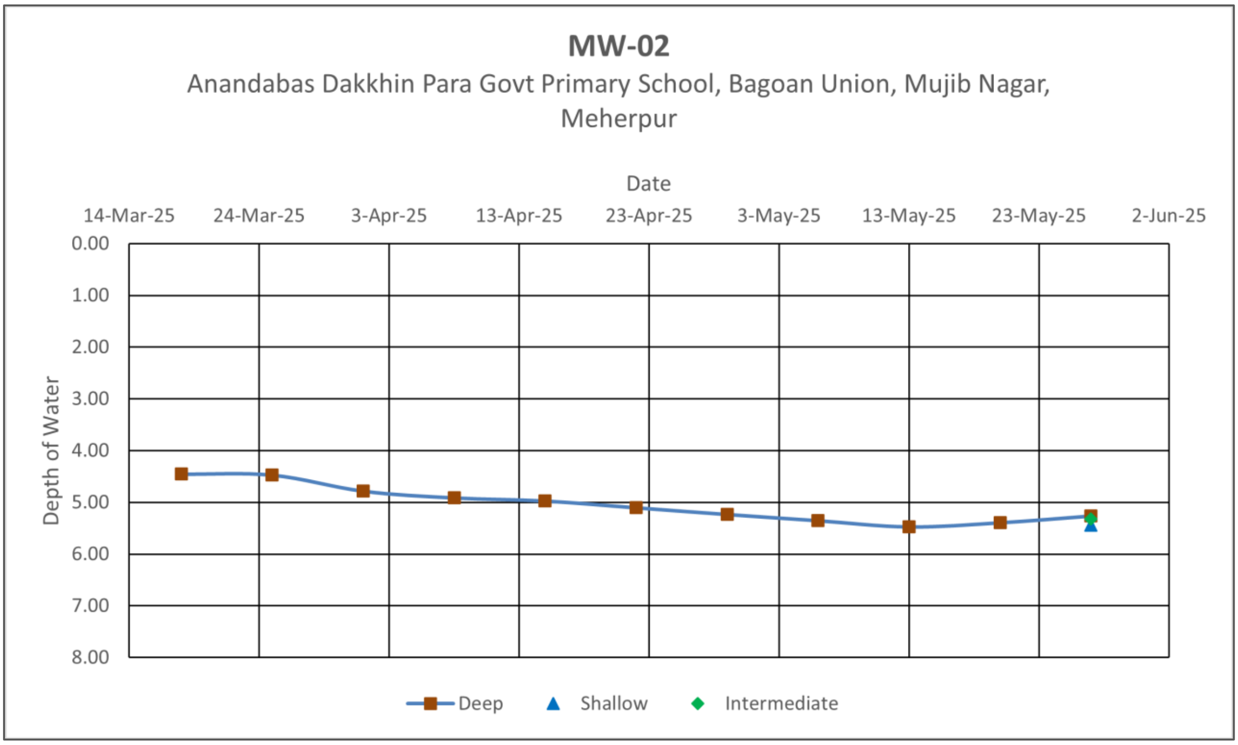


Figure 16: Ground Water Level in MW-02 Anandabas Dakkhin Para Govt Primary School, Bagoan Union, Mujib Nagar, Meherpur

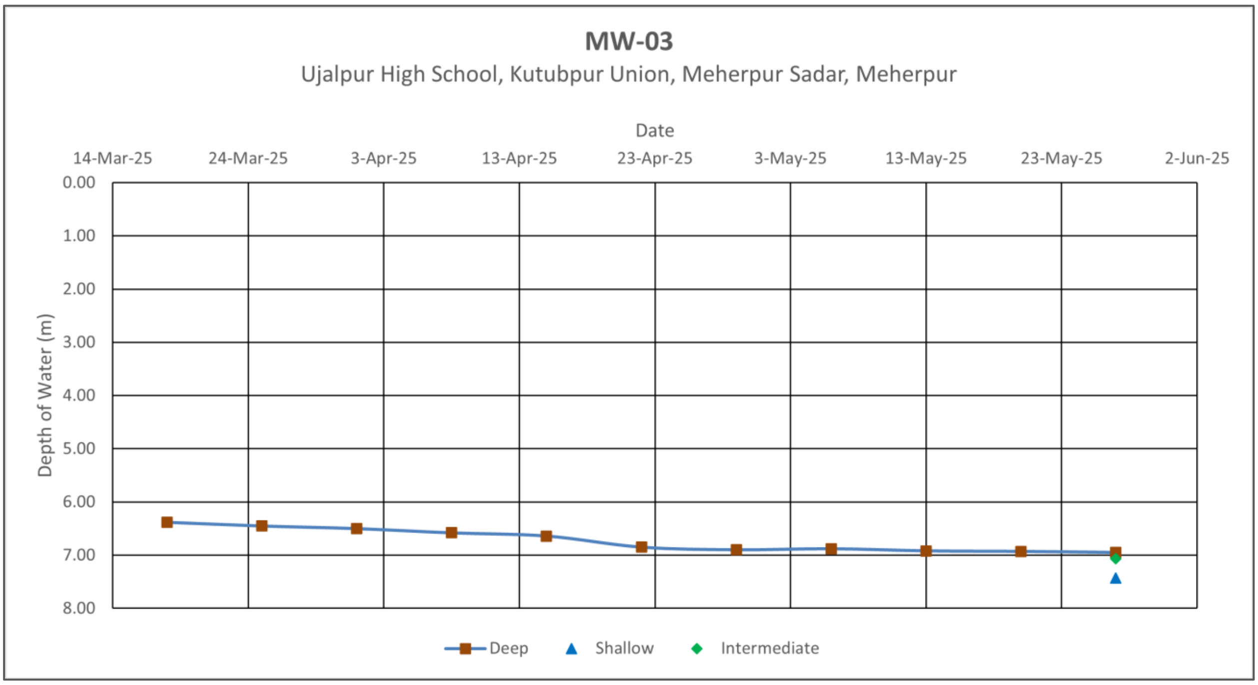


Figure 17: Ground Water Level in MW-03 Ujalpur High School, Kutubpur Union, Meherpur Sadar, Meherpur

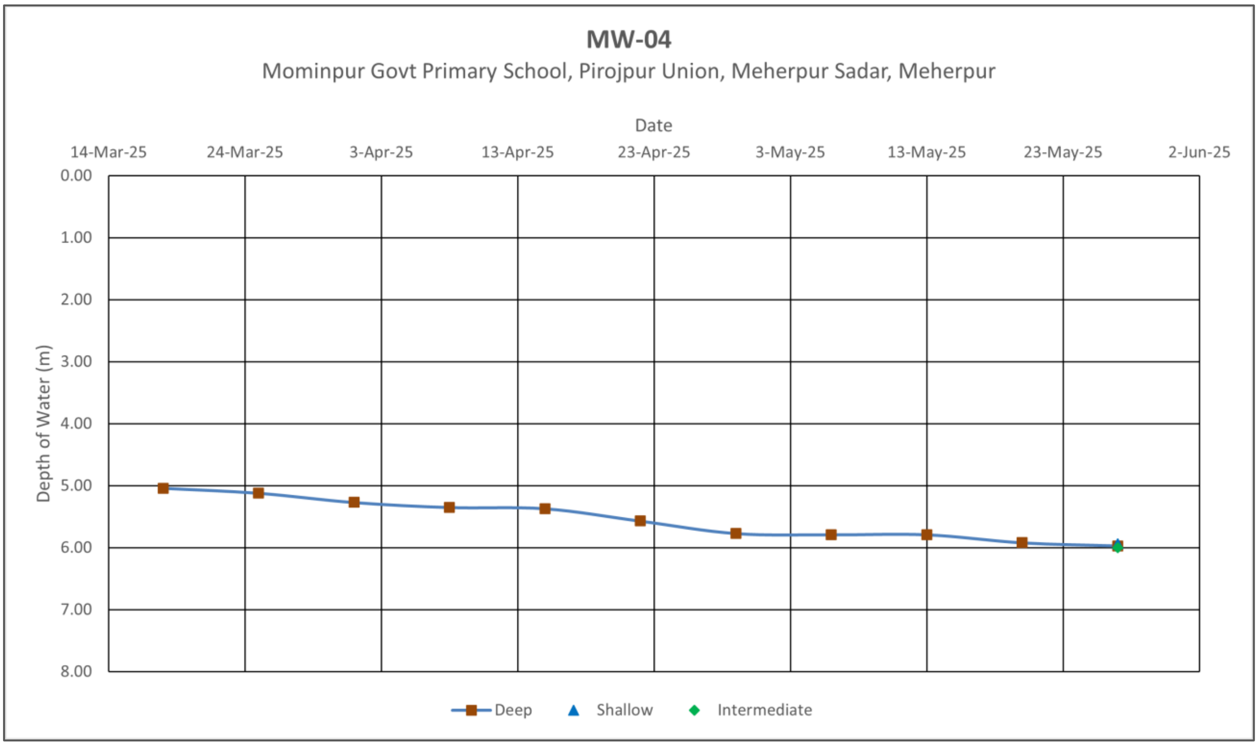


Figure 18: Ground Water Level in MW-04 Mominpur Govt Primary School, Pirojpur Union, Meherpur Sadar, Meherpur

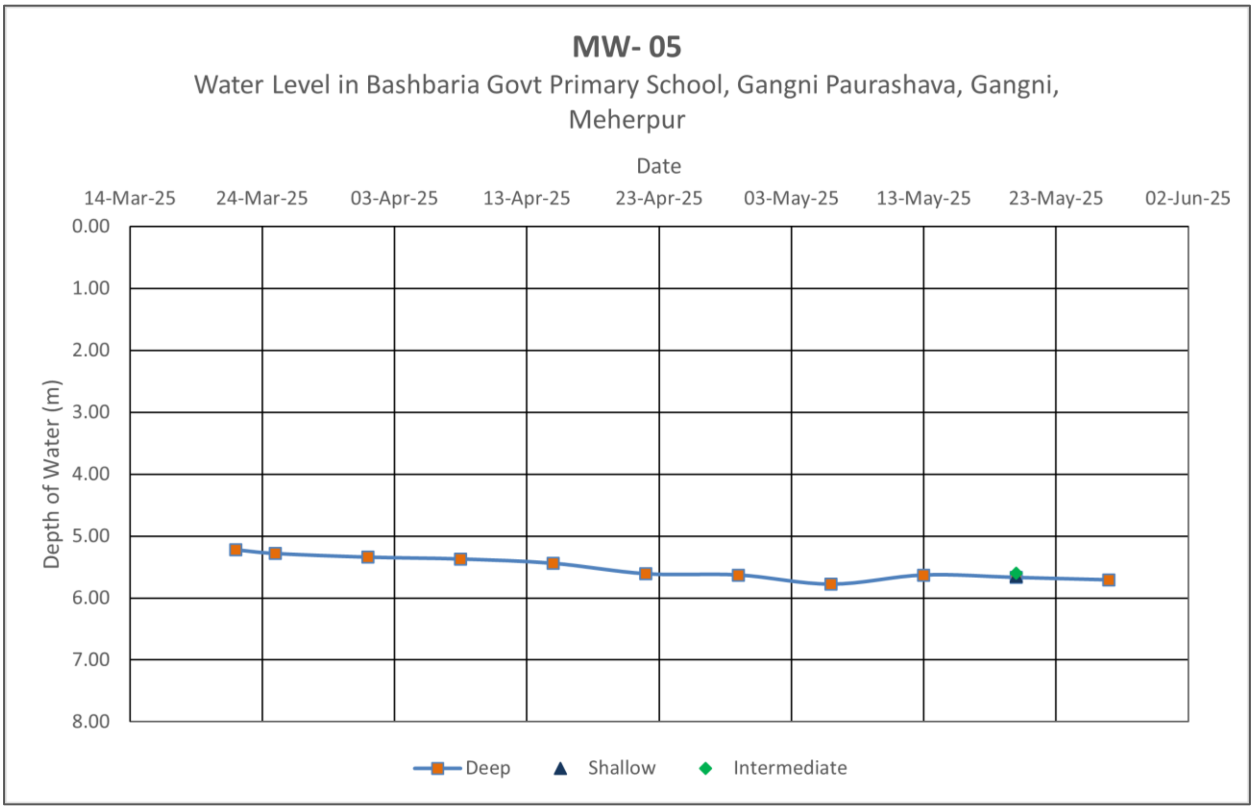


Figure 19: Ground Water Level in MW-05 Bashbaria Govt Primary School, Gangni Paurashava, Gangni, Meherpur

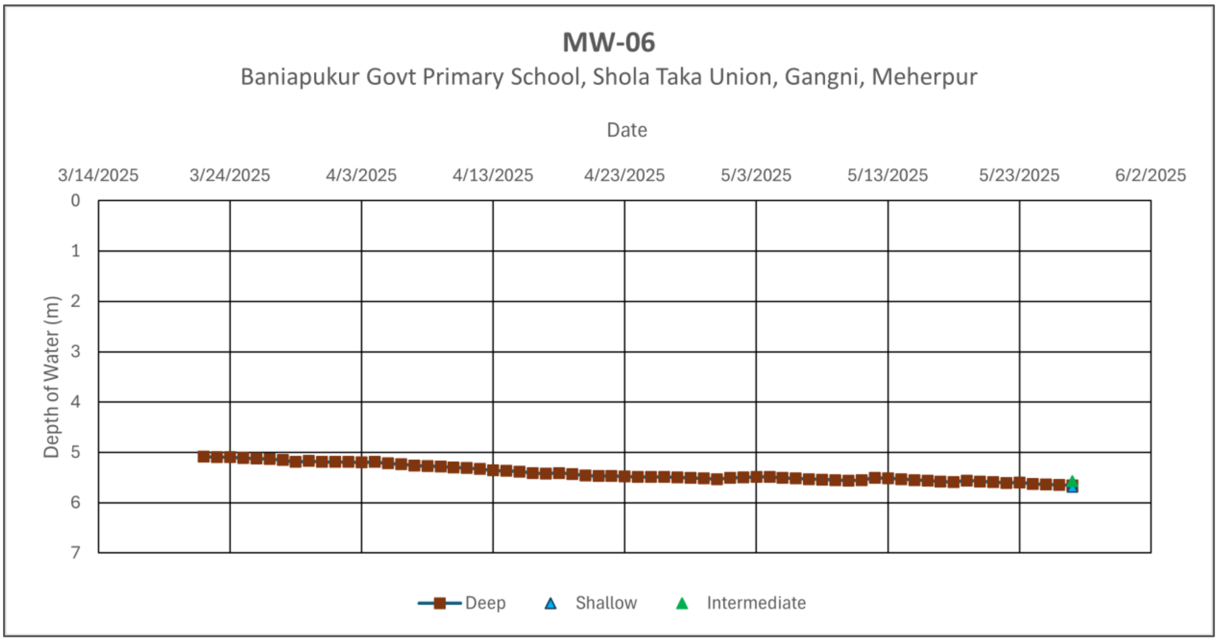


Figure 20: Ground Water Level in MW-06 Baniapukur Govt Primary School, Shola Taka Union, Gangni, Meherpur

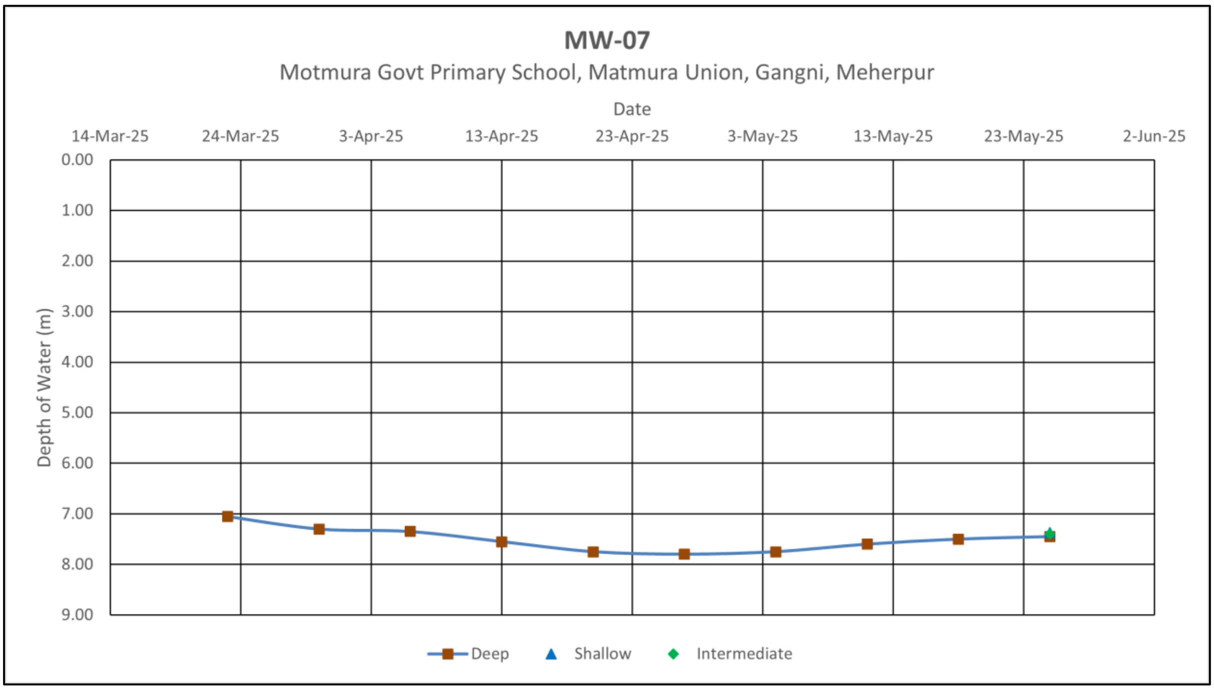


Figure 21: Ground Water Level in MW-07 Motmura Govt Primary School, Matmura Union, Gangni, Meherpur

Analysis of groundwater level data from monitoring wells MW-01, MW-02, and MW-03—located in Mujibnagar and the northern part of Gangni Upazila (Map 01)—indicates a general declining trend in water levels during the observation period. However, a noticeable rise in water levels toward the end of April is likely attributable to the onset of seasonal rainfall.

Given the geological setting of Meherpur District, it is plausible that minor fault zones or subsurface fractures exist within the study area. These features may serve as preferential pathways, facilitating localized recharge of the confined aquifer during periods of significant precipitation. Furthermore, if the confining layer is semi-permeable rather than strictly impermeable, vertical leakage from overlying unconfined or perched aquifers may occur. Such leakage, particularly during sustained rainfall events, can contribute to a delayed rise in groundwater levels within the confined system.

In contrast, monitoring wells MW-03, MW-04, MW-05, and MW-06—located in Meherpur Sadar and Gangni Upazila (Map 01)—exhibit a consistent decline in groundwater levels from March to May 2025, despite the occurrence of rainfall. This observation suggests that these wells may be hydraulically isolated from active recharge zones or are located in areas with limited vertical or lateral hydraulic connectivity to recharge sources.

5.1.2 Groundwater Level in Shallow and Intermediate Aquifer

Groundwater levels in the shallow and intermediate zones of the study area appear to correspond closely with those observed in the deep aquifer. However, as these measurements were collected using manual logging methods, data is available only for a single observation conducted at the end of May. Due to the limited temporal resolution of the dataset, no definitive interpretation or conclusions can be drawn regarding the hydrogeological behavior or interactions among the aquifer layers.

5.2 Dry Season Water Quality Data

In January 2025, CGR initiated in-situ testing at 35 existing production wells located across 18 unions and 2 municipalities (paurashavas) prior to the commencement of drilling for the installation of monitoring wells. The field investigations included measurements of electrical conductivity (EC), total dissolved solids (TDS), pH, and arsenic concentrations, as well as slug tests and water sampling for subsequent ion analysis at a laboratory in Dhaka.

Upon completion of the drilling campaign, CGR conducted the same suite of in-situ tests at 21 newly constructed monitoring wells in Meherpur district. In total, 56 wells (map: 03) were investigated, categorized as follows:

Table 1: Number of Wells for Water Sampling and Field Test

Type of Well	Number of Wells
Shallow	29
Intermediate	20
Deep	7
Total Well	56

This report presents the analytical results of EC, TDS, pH, and arsenic concentrations obtained from both the existing production wells and the newly developed monitoring wells.

5.2.1 Electrical Conductivity (EC) Distribution:

Electrical Conductivity (EC) reflects the sum of the contribution from all the dissolved ions; it is a good proxy measurement of salinity. Plots of lab measured TDS vs EC shows that EC = 1.4 x TDS. Both Bangladesh drinking water standard and WHO guideline value for TDS is set to a maximum of 1000 mg/L, which is equivalent to an EC value of 1400 µS/cm.

Spatial Variations: In the groundwater sample of the study area EC ranges from 561 µS/cm to 2000 µS/cm in shallow well, 465 µS/cm to 1507 µS/cm in intermediate well and 523 µS/cm to 736 µS/cm in deep well. Highest EC found in a shallow well at Meherpur Paurashava that is 2000 µS/cm and lowest EC found in an Intermediate well at Gangni Paurashava.

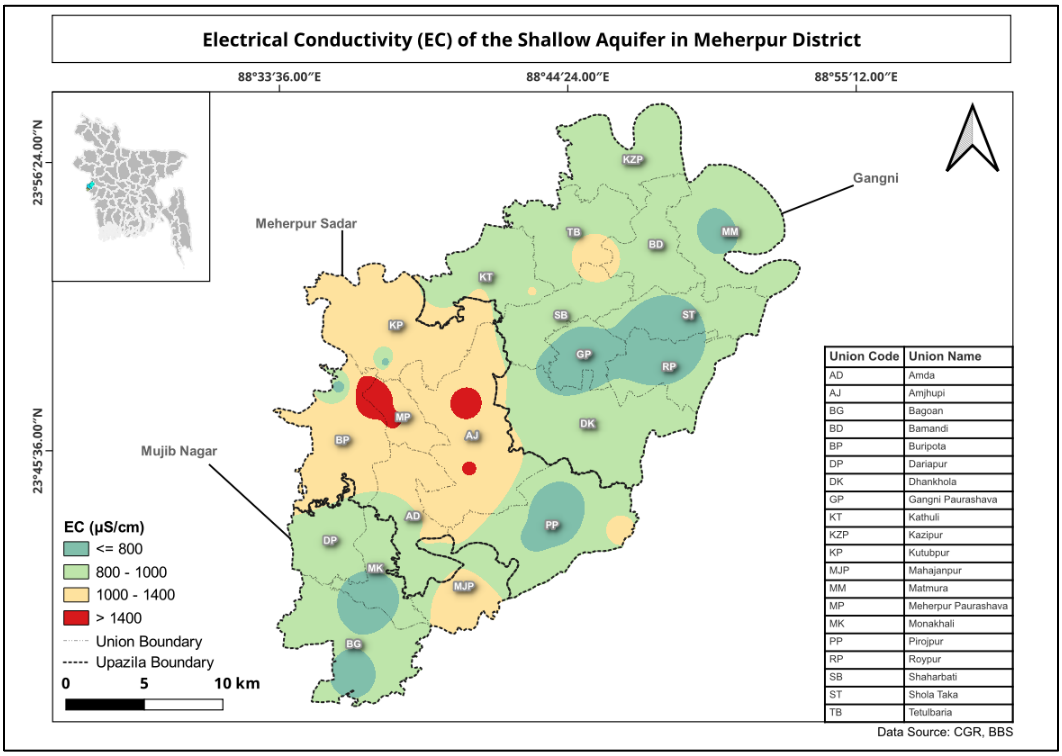


Figure 22: EC of the Shallow Aquifer in Meherpur District

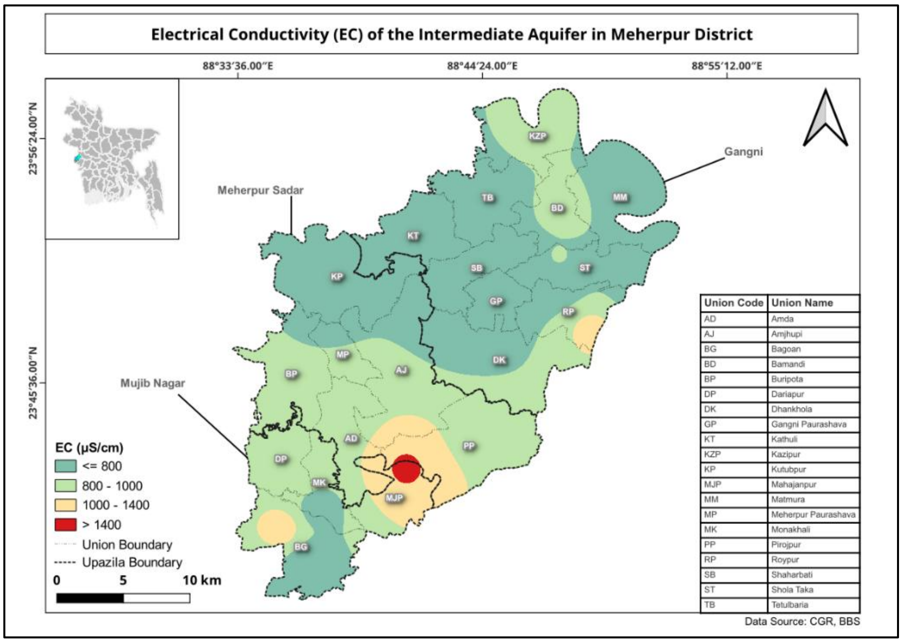


Figure 23: EC of the Intermediate Aquifer in Meherpur District

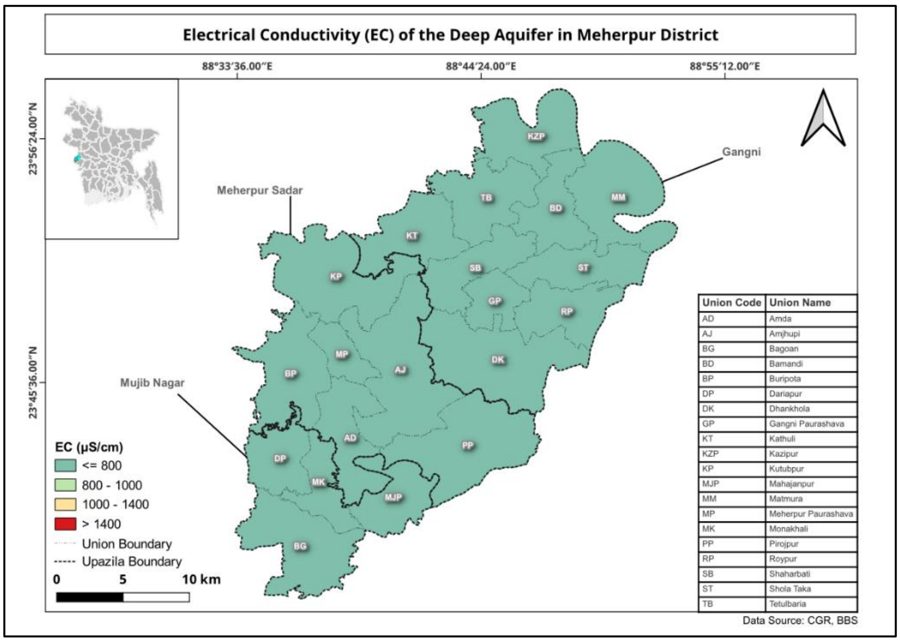


Figure 24: EC of the Deep Aquifer in Meherpur District

Based on the spatial distribution maps (Figure 22–24), it is evident that the shallow and intermediate aquifers exhibit higher electrical conductivity (EC) values compared to the deep aquifer. In many locations, EC values in the shallow and intermediate aquifers exceed 1000 µS/cm, occasionally surpassing 1400 µS/cm. Although laboratory confirmation is pending, the elevated EC observed in these aquifers may be attributed to the presence of ions such as calcium (Ca^{2+}), magnesium (Mg^{2+}), bicarbonate (HCO_3^-), sulfate (SO_4^{2-}), and nitrate (NO_3^-). Field observations indicate that the groundwater in these zones lacks a salty taste, suggesting that sodium (Na^+) and chloride (Cl^-) concentrations are likely low, and the water remains relatively fresh in Meherpur Sadar Upazila. The corresponding total dissolved solids (TDS) values are estimated to be in the range of 900–1,000 mg/L. In contrast, EC values in the deep aquifer predominantly remain below 800 µS/cm.

5.2.2 Total Dissolved Solids (TDS) Distribution:

In Bangladesh, the Bangladesh Standards and Testing Institution (BSTI) has set the maximum permissible limit for Total Dissolved Solids (TDS) in drinking water at 1000 ppm. In the present study, TDS levels were measured in groundwater samples collected from shallow, intermediate, and deep aquifers. The observed TDS concentrations ranged from 262 to 366 ppm in the deep aquifer, 238 to 1010 ppm in the shallow aquifer, and 233 to 950 ppm in the intermediate aquifer. These results indicate comparatively higher TDS concentrations in the intermediate aquifer. However, it is important to note that the data for the intermediate aquifer are limited, as only three wells were sampled from this depth.

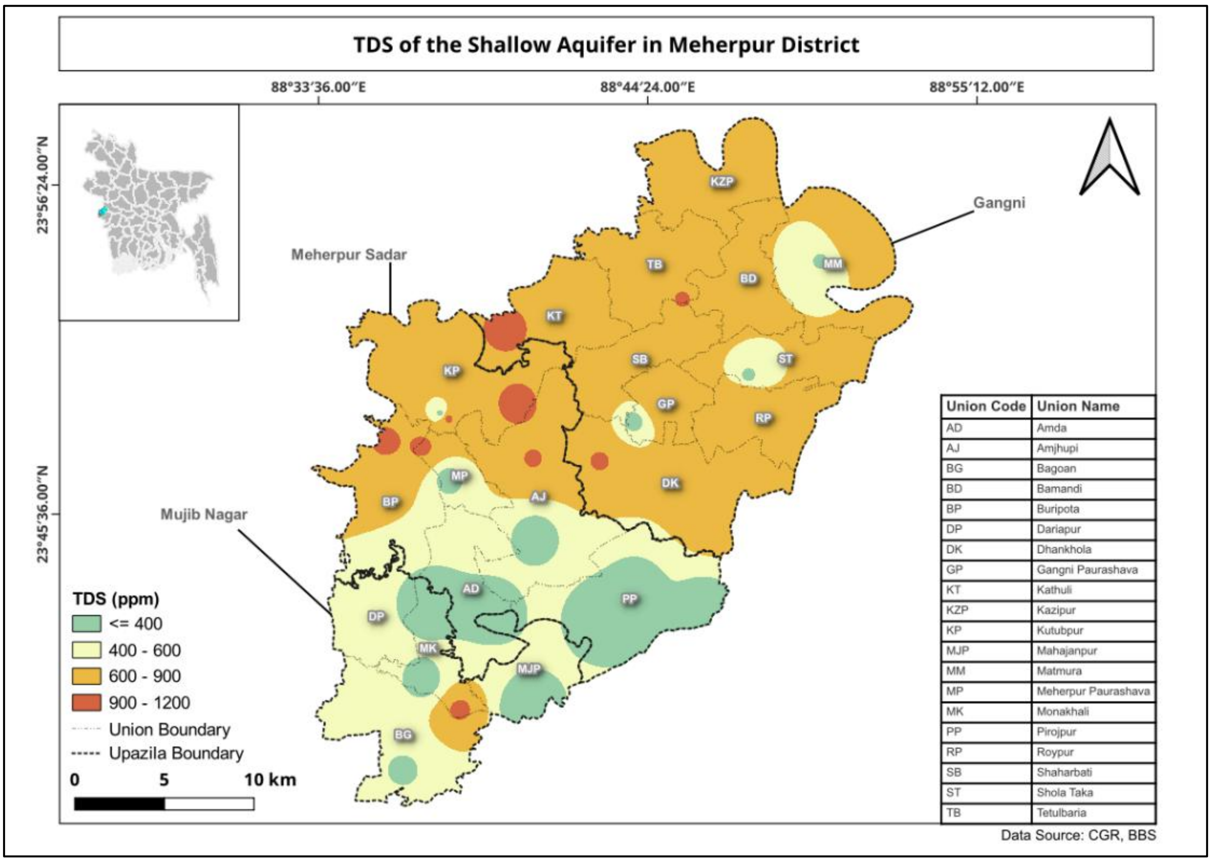


Figure 25: TDS of the Shallow Aquifer in Meherpur District

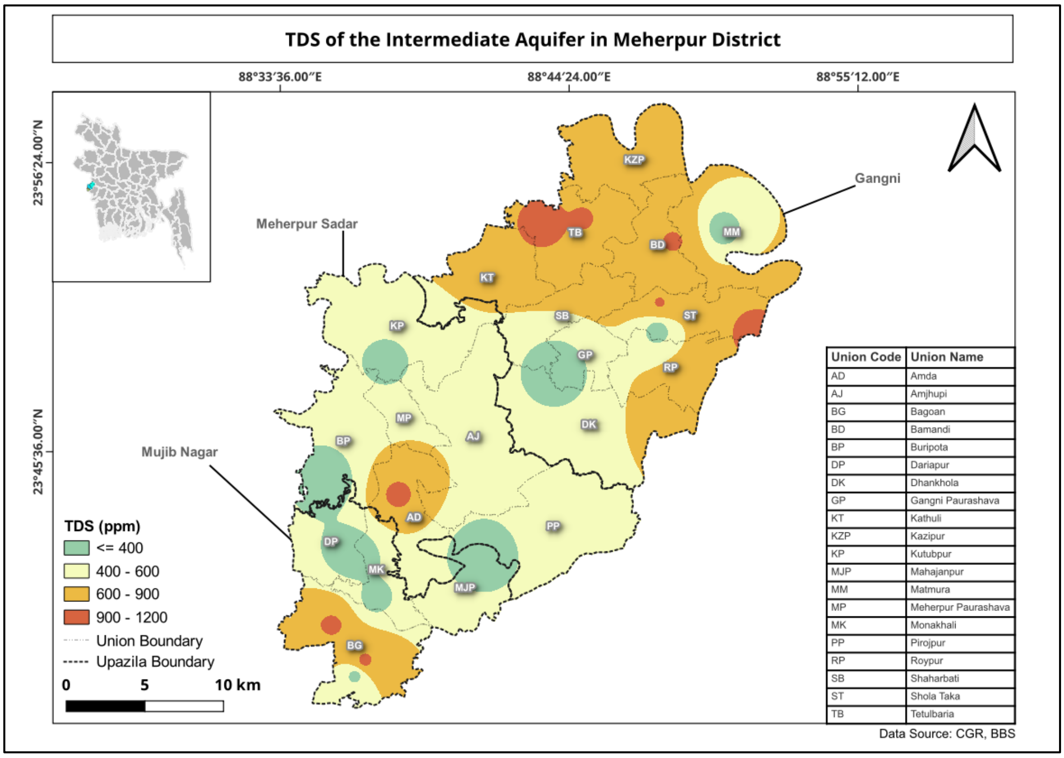


Figure 26: TDS of the Intermediate Aquifer in Meherpur District

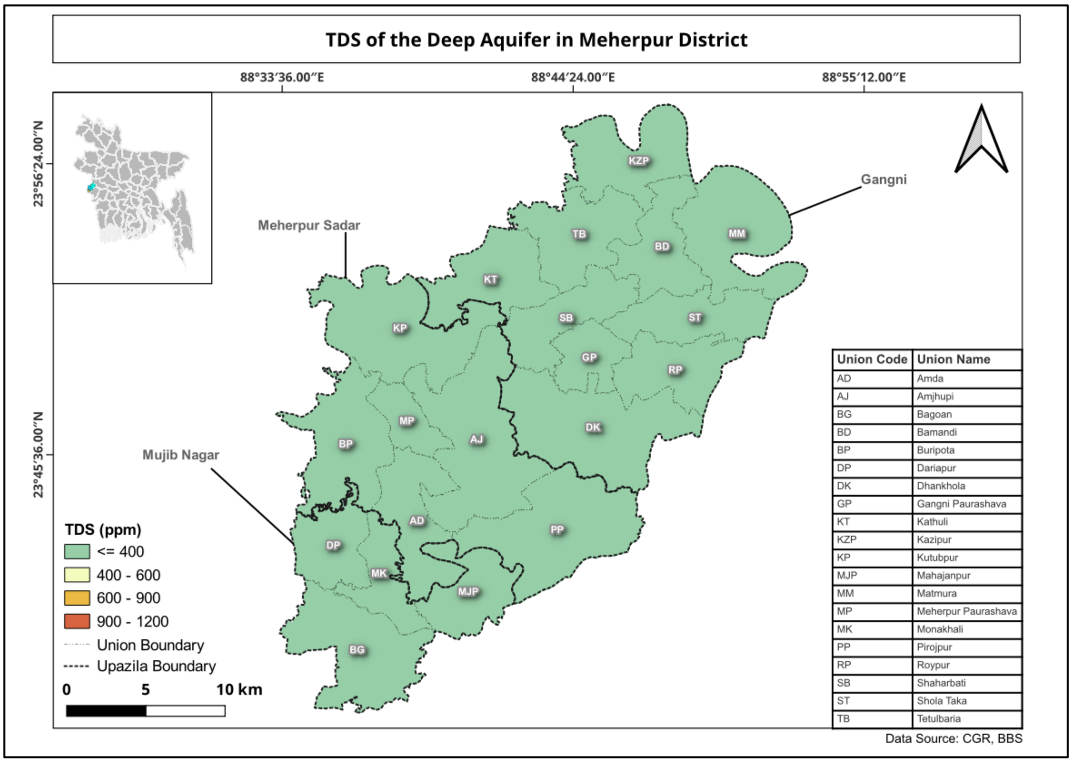


Figure 27: TDS of the Deep Aquifer in Meherpur District

The spatial distribution maps (Figure 25–27) indicate that total dissolved solids (TDS) concentrations are generally higher in the shallow and intermediate aquifers than in the deep aquifer. In the majority of sampled locations, TDS levels in the shallow and intermediate zones range between 600 and 900 ppm, with some areas recording values above 900 ppm. In contrast, TDS concentrations in the deep aquifer typically remain below 400 ppm.

5.2.3 Arsenic Distribution:

The Bangladesh Standards and Testing Institution (BSTI) has set the maximum allowable limit for arsenic in drinking water at 10 ppb (parts per billion). This standard reflects the country's current mitigation capabilities and resource constraints, despite being higher than the World Health Organization (WHO) guideline of 10 ppb.

In the groundwater sample of the study area, As ranges from 0 ppb to 50 ppb in shallow and intermediate well and from 5 ppb to 30 ppb in deep well.

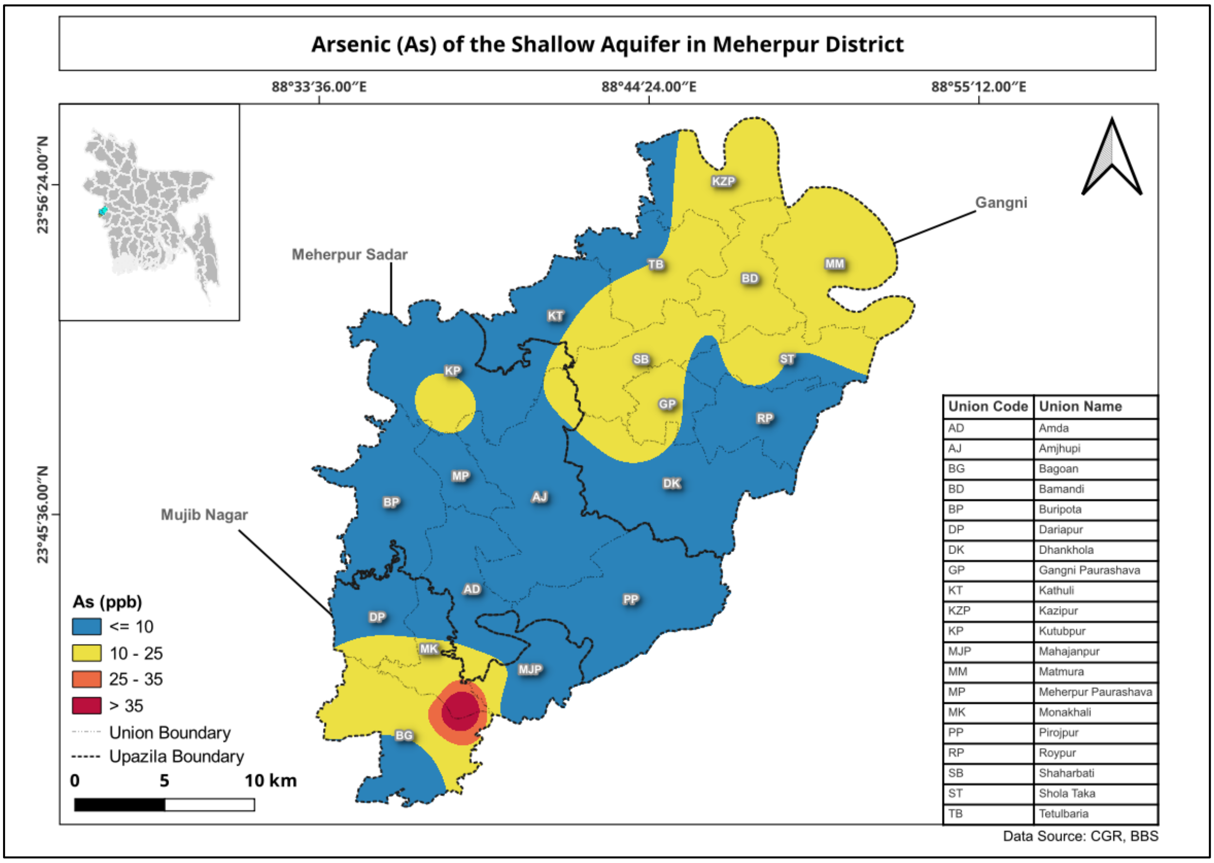
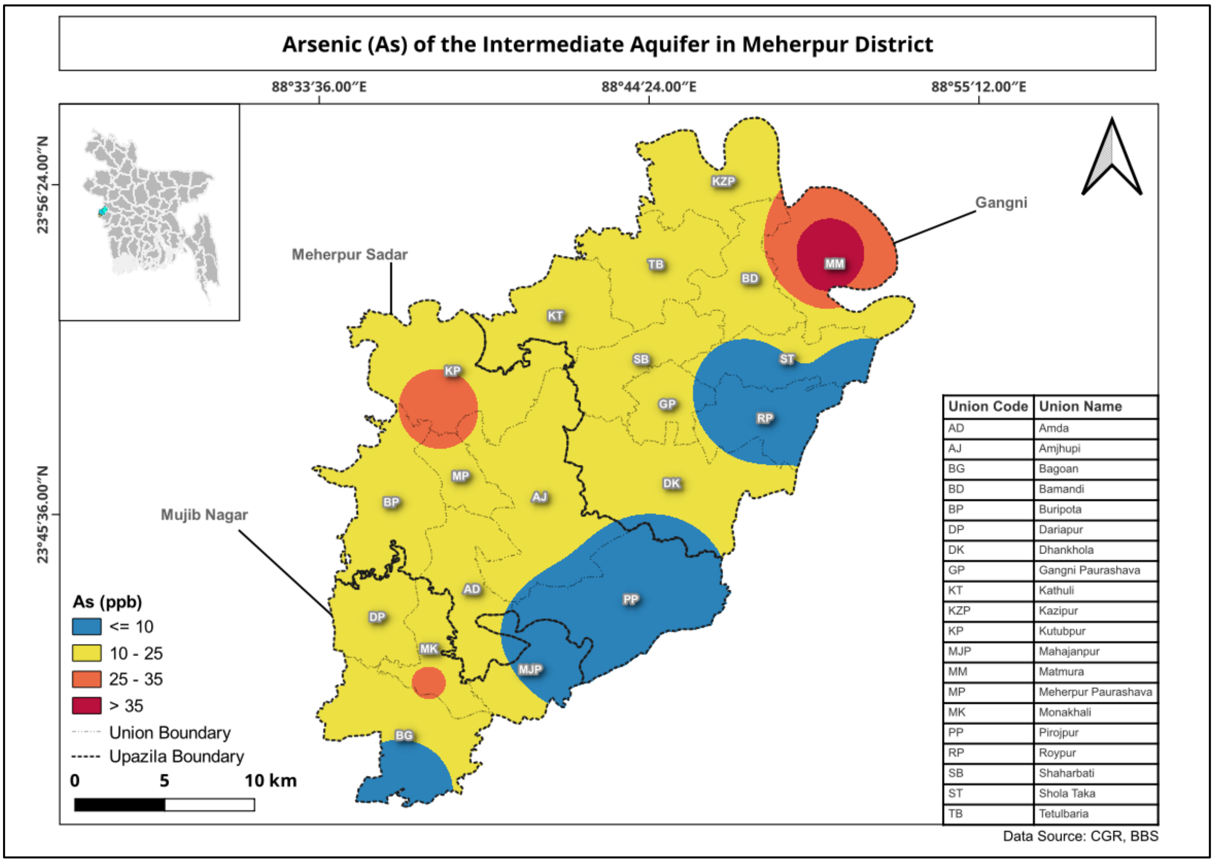
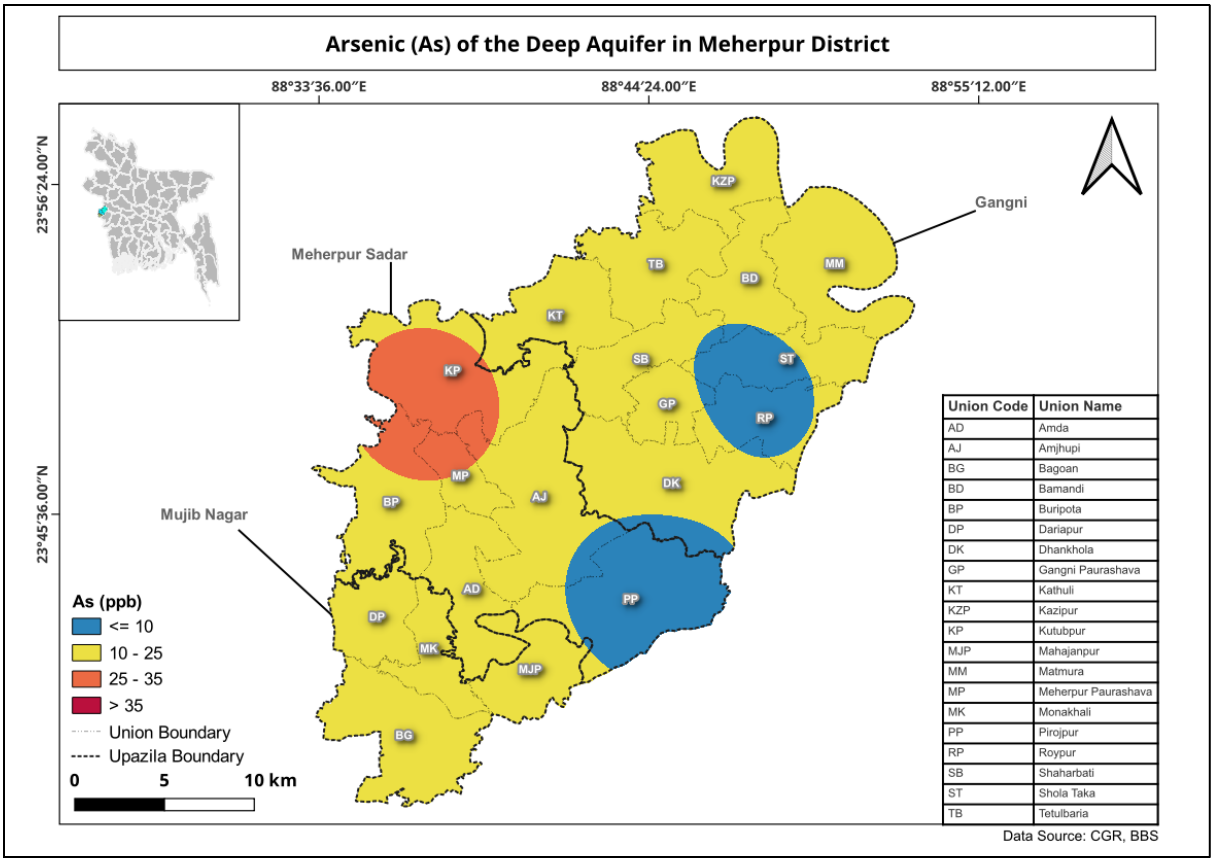


Figure 28: Arsenic (As) of the Shallow Aquifer in Meherpur District



Union Code	Union Name
AD	Amda
AJ	Amjhupi
BG	Bagoan
BD	Bamandi
BP	Buripota
DP	Dariapur
DK	Dhankhola
GP	Gangni Paurashava
KT	Kathuli
KZP	Kazipur
KP	Kutubpur
MJP	Mahajanpur
MM	Matmura
MP	Meherpur Paurashava
MK	Monakhali
PP	Pirojpur
RP	Roypur
SB	Shaharbati
ST	Shola Taka
TB	Tetulbaria

Figure 29: Arsenic (As) of the Intermediate Aquifer in Meherpur District



Union Code	Union Name
AD	Amda
AJ	Amjhupi
BG	Bagoan
BD	Bamandi
BP	Buripota
DP	Dariapur
DK	Dhankhola
GP	Gangni Paurashava
KT	Kathuli
KZP	Kazipur
KP	Kutubpur
MJP	Mahajanpur
MM	Matmura
MP	Meherpur Paurashava
MK	Monakhali
PP	Pirojpur
RP	Roypur
SB	Shaharbati
ST	Shola Taka
TB	Tetulbaria

Figure 30: Arsenic (As) of the Deep Aquifer in Meherpur District

The spatial distribution maps (Figure 28–30) indicate that Arsenic (As) concentrations are generally higher in the shallow and intermediate aquifers than in the deep aquifer. In shallow and Intermediate aquifers exceeds 35 ppb of arsenic. Generally, if your water has arsenic levels above 35 ppb (0.035 ppm), **young children, especially infants, should stop drinking it immediately**, because this level has been associated with health effects in children after very short-term exposures (2 weeks or less).

5.2.4 pH Distribution:

The Bangladesh Standards and Testing Institution (BSTI) has established the permissible pH range for drinking water between 6.5 and 8.5. In the current study, pH values ranging from 6.5 to 8. A pH below 6.5 indicates acidic conditions, which can result in the corrosion of pipes and promote the leaching of heavy metals, such as iron or lead, from plumbing systems.

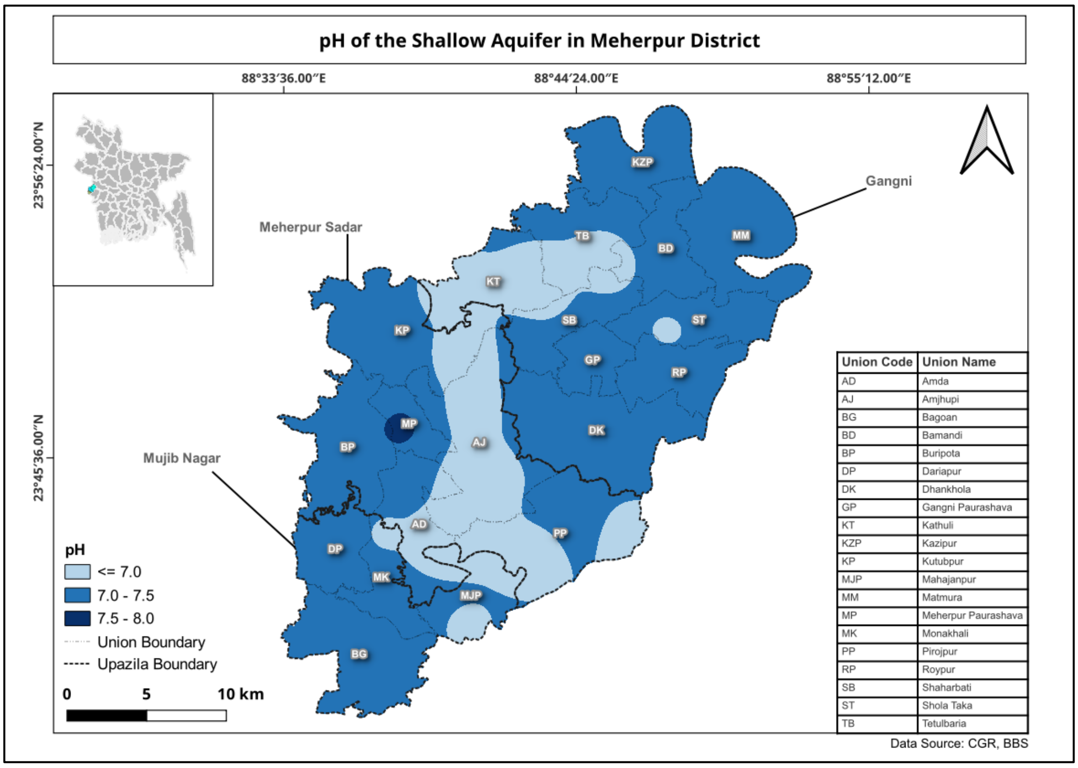


Figure 31: pH of the Shallow Aquifer in Meherpur District

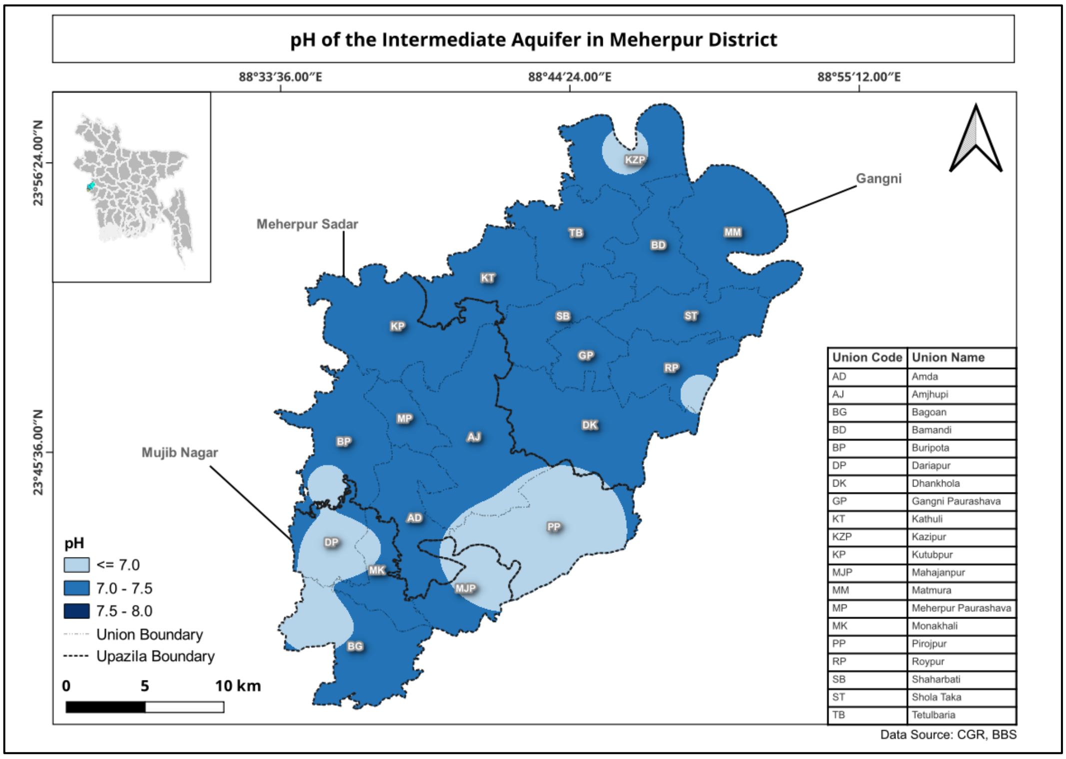


Figure 32: pH of the Intermediate Aquifer in Meherpur District

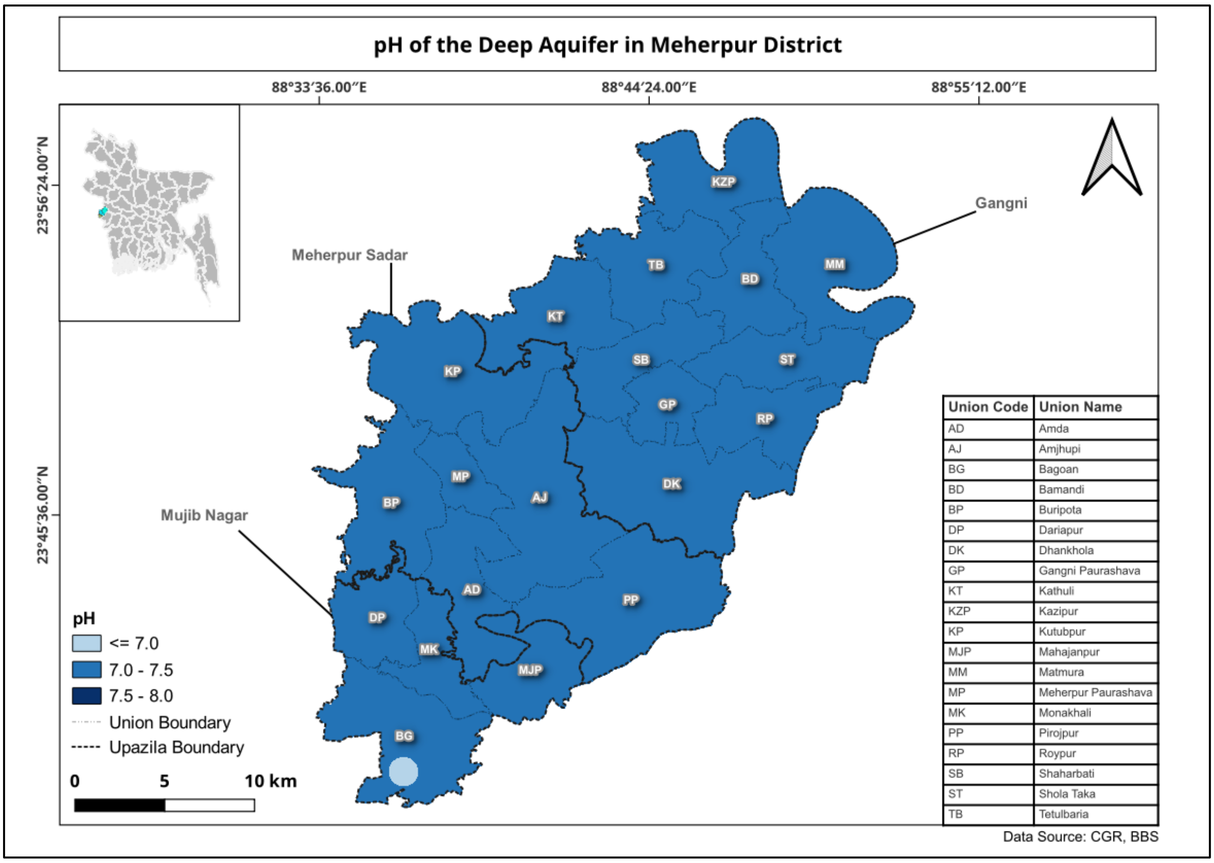


Figure 33: pH of the Deep Aquifer in Meherpur District

Based on the spatial distribution map 31-33, pH values in the shallow and intermediate aquifers of certain areas within Meherpur District range from 6.5 to 7.0, indicating slightly acidic to neutral conditions. In contrast, the deep aquifer consistently exhibits pH values between 7.0 and 7.5 across the entire district, which falls within the optimal range for drinking water quality.

6 Discussion

The initial phase of this hydrogeological investigation has successfully established a foundational monitoring network across Meherpur District, encompassing three upazilas and seven strategically selected locations. The installation of 21 monitoring wells—comprising shallow (~100 ft), intermediate (~300 ft), and deep (~500 ± 100 ft) wells at each site—provides a robust framework for evaluating vertical and lateral variations in groundwater levels and quality.

Dry-season groundwater level data collected from 22 March to 27 May 2025 represent a critical dataset for assessing baseline aquifer conditions in the absence of significant recharge. Preliminary results show both spatial and vertical variability in water level responses across the monitoring network. Notably, groundwater level trends in several wells indicate a gradual decline throughout the dry season, consistent with the expected seasonal drawdown in confined and semi-confined aquifers. However, isolated instances of water level recovery near the end of April suggest localized recharge events potentially facilitated by structural features such as minor faults or semi-permeable confining layers.

Water quality analyses indicate widespread exceedance of the WHO and BSTI arsenic thresholds, particularly in shallow and intermediate aquifers, where concentrations surpass 35 ppb in several instances. Elevated EC and TDS values observed in the shallow and intermediate aquifer zones suggest the presence of dissolved mineral content; however, these readings are not indicative of salinity-related issues, which are not prevalent in the Meherpur region. Instead, the elevated values may reflect geogenic influences or localized contamination from anthropogenic sources. In contrast, deep aquifers generally exhibit lower concentrations of dissolved constituents, indicating relatively better water quality, although ongoing monitoring is necessary to assess long-term trends. pH values across all aquifer depths remain within the acceptable range, suggesting stable acid–base conditions in the groundwater system.

In-situ field testing, supported by laboratory-based ionic analyses (including Na^+, Ca^{2+}, Mg^{2+}, K^+, Fe, Mn, HCO_3^-, Cl^-, SO_4^{2-}, and NO_3^-), is expected to yield further insights into groundwater chemistry and potential geogenic or anthropogenic influences. The concurrent slug tests and grain size distribution analyses conducted by CGR offer an initial understanding of aquifer hydraulic properties, including permeability and hydraulic conductivity, which are essential for groundwater flow modeling and sustainable management planning.

Given that this report focuses exclusively on dry-season data, it provides a crucial reference point for interpreting seasonal groundwater dynamics once wet-season data become available. Integration of both datasets will allow for a comprehensive understanding of recharge mechanisms, aquifer connectivity, and long-term groundwater sustainability in the region.

Continued monitoring over the full annual cycle, combined with laboratory results and aquifer property assessments, will significantly enhance the capacity to develop targeted groundwater management strategies and inform the broader development planning initiatives for Meherpur Zilla.

7 APPENDICES

7.1 APPENDIX: Table A-1: Location of Monitoring Well

Table A- 1: Location of the monitoring wells

MW No	Lat	Lng	Location	Well Type	Well Depth (ft)
MW-01S	23.668364	88.618485	Vobanipur Primary School, Monakhali Union, Mujib Nagar, Meherpur	Shallow	100
MW-01I	23.668334	88.618482		Inter	300
MW-01D	23.668061	88.618192		Deep	500
MW-02S	23.620756	88.606538	Anandabas Dakkhin Para Govt Primary School, Bagoan Union, Mujib Nagar, Meherpur	shallow	100
MW-02I	23.620741	88.606556		Inter	360
MW-02D	23.62092	88.605994		Deep	440
MW-03S	23.815158	88.626328	Ujalpur High School, Kutubpur Union, Meherpur Sadar, Meherpur	Shallow	100
MW-03I	23.815375	88.625838		Inter	300
MW-03D	23.815355	88.625874		Deep	390
MW-04S	23.722884	88.733103	Mominpur Govt Primary School, Pirojpur Union, Meherpur Sadar, Meherpur	shallow	100
MW-04I	23.722921	88.733171		Inter	300
MW-04D	23.723005	88.733194		Deep	500
MW-05S	23.810819	88.731965	Bashbaria Govt Primary School, Gangni Paurashava, Gangni, Meherpur	Shallow	100
MW-05I	23.810833	88.732028		Inter	300
MW-05D	23.810757	88.732004		Deep	455
MW-06S	23.835566	88.794543	Baniapukur Govt Primary School, Shola Taka Union, Gangni, Meherpur	Shallow	100
MW-06I	23.835622	88.794527		Inter	300
MW-06D	23.835708	88.794572		Deep	390
MW-07S	23.898399	88.834788	Motmura Govt Primary School, Matmura Union, Gangni, Meherpur	shallow	100
MW-07I	23.898398	88.834843		Inter	280
MW-07D	23.898397	88.834794		Deep	380

7.2 APPENDIX: Table A-2: Location of VES

Table A- 2: Location of VES

SlNo	lat	lng	Location Name	Upazila
ERT-01	23.709192	88.610437	Dariapur Playground, Dariapur, Mujibnagar	Mujib Nagar
ERT-02	23.632328	88.608547	Anandabash Playground behind Anandabash Girls High School, Bagoan, Mujibnagar	Mujib Nagar
ERT-03	23.679925	88.67875	Komorpur Secondary School, Mahajanpur, Mujibnagar	Mujib Nagar
ERT-04	23.77993	88.57395	Bajitpur Govt Primary School, Buripota, Meherpur Sadar	Meherpur Sadar
ERT-05	23.839616	88.612999	Tergharia Govt Primary School, Kutubpur, Meherpur Sadar	Meherpur Sadar
ERT-06	23.825234	88.68274	Shyampur Govt Primary School, Amjhupi, Meherpur Sadar	Gangni
ERT-07	23.746032	88.686194	Amjhupi Govt Health Complex Field, Amjhupi, Meherpur Sadar	Meherpur Sadar
ERT-08	23.715255	88.77673	Near Majhpara Sporting Club, Notun Dorbeshpur, Pirojpur Union, Meherpur Sadar	Meherpur Sadar
ERT-09	23.833839	88.75836	Opposite of CFM Secondary School, Gangni Paurashava, Gangni	Gangni
ERT-10	23.781947	88.740598	Near Nittyannandopur Playground, Dhankhola Union, Gangni	Gangni
ERT-11	23.784475	88.804593	Sanghat Chandamari High Schoo, Dhankhola Union, Gangnil	Gangni
ERT-12	23.850144	88.83589	Mikushis High School, Shola Taka Union, Gangni	Gangni
ERT-13	23.905773	88.815053	Near Motmura Eidgaon field, Matmura, Gangni	Gangni
ERT-14	23.936034	88.768265	Shahebnagar Govt Primary School, Kazipur Union, Gangni	Gangni
ERT-15	23.89041	88.720635	Near Tetulbaria Dayer Para Govt Primary Schoo, Tetulbaria Union, Gangni	Gangni

7.3 APPENDIX: Table A-3: Field Parameter of Water Sample

Table A- 3: Field Parameter of Water Sample

Water Sample ID	Upazilla	Union	Latitude	Longitude	pH	EC(uS/cm	TDS(ppm)	Arsenic ppb	Temperature ©	Type of Well	Depth of well (Feet)
MW-01S	Mujbnagar	Monakhali	23.668364	88.618485	7.19	619	313	20	27.8	Shallow	100
MW-01I	Mujbnagar	Monakhali	23.668334	88.618482	7.29	652	325	30	27.3	Inter	300
MW-01D	Mujbnagar	Monakhali	23.668061	88.618192	7.31	631	314	20	27.4	Deep	500
MW-02S	Mujbnagar	Bagoan	23.620756	88.606538	7.21	762	380	0	27.1	shallow	100
MW-02I	Mujbnagar	Bagoan	23.620741	88.606556	7.15	680	341	5	28.4	Inter	360
MW-02D	Mujbnagar	Bagoan	23.62092	88.605994	6.99	728	364	10	28	Deep	440
MW-03S	Meherpur Sadar	Kutubpur	23.815158	88.626328	7.25	694	343	20	28	Shallow	100
MW-03I	Meherpur Sadar	Kutubpur	23.815375	88.625838	7.45	725	363	30	27.7	Inter	300
MW-03D	Meherpur Sadar	Kutubpur	23.815355	88.625874	7.3	715	358	30	28	Deep	390
MW-04S	Meherpur Sadar	Pirojpur	23.722884	88.733103	7.25	561	281	5	26.5	shallow	100
MW-04I	Meherpur Sadar	Pirojpur	23.722921	88.733171	6.85	905	452	5	26	Inter	300
MW-04D	Meherpur Sadar	Pirojpur	23.723005	88.733194	7.27	736	366	5	26.9	Deep	500
MW-05S	Gangni	Gangni Paurashava	23.810819	88.731965	7.18	610	304	15	28.6	Shallow	100
MW-05I	Gangni	Gangni Paurashava	23.810833	88.732028	7.33	465	233	10	28.2	Inter	300
MW-05D	Gangni	Gangni Paurashava	23.810757	88.732004	7.31	523	262	15	28.3	Deep	455
MW-06S	Gangni	Shola Taka	23.835566	88.794543	6.95	701	351	15	27.8	Shallow	100
MW-06I	Gangni	Shola Taka	23.835622	88.794527	7.2	604	301	0	28.4	Inter	300
MW-06D	Gangni	Shola Taka	23.835708	88.794572	7.28	650	325	5	28.9	Deep	390
MW-07S	Gangni	Matmura	23.898399	88.834788	7.39	759	381	10	29.1	shallow	100
MW-07I	Gangni	Matmura	23.898398	88.834843	7.21	606	303	50	28.9	Inter	280
MW-07D	Gangni	Matmura	23.898397	88.834794	7.4	701	350	25	28.5	Deep	380
WQT-1	Mujibnagar	Bagoan	23.652351	88.592133	6.82	1175	960	10	26.7	Inter	160
WQT-2	Mujibnagar	Bagoan	23.62967	88.61218	7.14	671	970	10	21.6	Inter	100
WQT-3	Mujibnagar	Monakhali	23.65352	88.63687	7.07	802	980	50	26.6	Shallow	60
WQT-4	Mujibnagar	Monakhali	23.71415	88.623	6.98	818	244	0	25.3	Shallow	50

WQT-5	Mujibnagar	Dariyapur	23.69647	88.60473	6.87	985	237	10	26.3	Inter	160
WQT-6	Mujibnagar	Mohajonpur	23.65417	88.67006	6.97	1277	238	0	28.5	Shallow	70
WQT-7	Mujibnagar	Mohajonpur	23.69738	88.68331	6.88	1507	255	0	25.1	Inter	100
WQT-8	Meherpur Sadar	Amda	23.707255	88.651614	6.9	1004	273	0	21.1	Shallow	70
WQT-9	Meherpur Sadar	Amda	23.73329	88.63288	7.14	877	970	25	21.7	Inter	100
WQT-10	Meherpur Sadar	Pourosova	23.77949	88.6308	7.76	1425	276	0	19.2	Shallow	70
WQT-11	Meherpur Sadar	Pourosova	23.79721	88.61638	7.15	2000	980	0	27.6	Shallow	60
WQT-12	Meherpur Sadar	Buripota	23.74122	88.59048	6.98	809	261	10	21.3	Inter	160
WQT-13	Meherpur Sadar	Buripota	23.80002	88.59715	7.25	750	960	0	24.3	Shallow	60
WQT-14	Meherpur Sadar	Kutubpur	23.81229	88.63041	7.04	1326	970	10	24.1	Shallow	60
WQT-15	Meherpur Sadar	Kutubpur	23.81957	88.66794	6.76	1255	1010	10	18.6	Shallow	50
WQT-16	Meherpur Sadar	Amjhupi	23.79031	88.67689	6.73	1596	930	0	22.6	Shallow	60
WQT-17	Meherpur Sadar	Amjhupi	23.74912	88.67822	6.65	1430	252	0	23.1	Shallow	50
WQT-18	Meherpur Sadar	Pirojpur	23.706131	88.71795	6.87	775	244	0	26.7	Shallow	45
WQT-19	Meherpur Sadar	Baradi	23.711331	88.771158	6.87	1032	243	0	26.6	Shallow	50
WQT-20	Gangni	Dhankhola	23.75752	88.77465	7.02	937	890	0	27	Shallow	80
WQT-21	Gangni	Dhankhola	23.78925	88.71352	7.31	854	940	10	23.4	Shallow	90
WQT-22	Gangni	Raypur	23.798092	88.819782	6.96	1108	900	10	25.3	Inter	100
WQT-23	Gangni	Raypur	23.824077	88.792043	7.1	700	900	0	24	Shallow	70
WQT-24	Gangni	Pourosova	23.82054	88.74669	7.25	648	880	10	24.9	Shallow	70
WQT-25	Gangni	Saharbati	23.83114	88.71097	7.06	928	880	25	26.6	Shallow	65
WQT-26	Gangni	Saharbati	23.87723	88.75855	6.93	1074	910	10	27.2	Shallow	50
WQT-27	Gangni	Kathuli	23.859341	88.717427	6.87	1002	880	10	27.7	Shallow	80
WQT-28	Gangni	Kathuli	23.86018	88.66147	6.92	941	970	0	24.1	Shallow	65
WQT-29	Gangni	Tetulbaria	23.90084	88.72276	7.21	684	960	25	21.9	Inter	100
WQT-30	Gangni	Tetulbaria	23.90475	88.74831	7.07	742	910	10	23.9	Inter	100
WQT-31	Gangni	Kazipur	23.945	88.77371	6.96	869	900	25	27.2	Inter	100
WQT-32	Gangni	Bamandi	23.890789	88.804779	7.08	942	930	25	25.1	Inter	220
WQT-33	Gangni	Sholotaka	23.8526	88.7959	7.07	817	920	10	26.2	Inter	180
WQT-34	Gangni	Sholotaka	23.83431	88.8552	7.2	650	990	0	20.7	Inter	120
WQT-35	Gangni	Matmora	23.90991	88.85463	7.2	860	880	24.6	0	Shallow	70