URBAN DEVELOPMENT DIRECTORATE (UDD)

Ministry of Housing and Public Works

Government of the People's Republic of Bangladesh

Establishment of Monitoring Well and Field Investigation Report On HYDRO-GEOLOGICAL SURVEY UNDER PREPARATION OF PAYRA-KUAKATA COMPREHENSIVE PLAN FOCUSING ON ECO-TOURISM

Package No.: 2 (Two)

September, 2018

Submitted by

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1 Introduction

This report describes the establishment of a groundwater monitoring network in 7 upazilas of Patuakhali and Barguna districts (*Kalapara, Galachipa & Rangahali Upazila under Patuakhali Districts and Amtoli, Taltoli, Patharghata & Barguna Sadar under Barguna District)* under the hydrogeological study in the Payra-Kuakata comprehensive plan for Eco-Tourism development. Additionally, details of field investigations for water samplings, slug tests, and vertical electrical sounding (VES) has been described. The field investigation on water quality represent for Arsenic concentration the whole project area is free of Arsenic except the extreme western of Pathorghata Upazila and extreme southern part of Kalapara Upazila and for salinity of deep aquifer moderately intense in the western part of Pathorghata Upazila and an isolated zone at Barguna sadar Upazila.

Establishment of this monitoring network is the first step in a detail 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 locations. At each location, three (03) co-located wells (10 to 50 feet apart) have been installed at different depths. The deepest of each set is about 1000±100 feet deep, the intermediate one is about 300 feet deep and the shallowest one is about 100 feet deep.

Groundwater level as well as water quality in the study area will be monitored for about a year from now in each of these monitoring wells. The data that will be collected will be of outmost importance characterizing the hydrogeological condition in the study area. Detail methodology, locations, and lithological data collected during the drilling of these wells are discussed in the subsequent sections.

2 Methodology:

In order to establish the monitoring network in the field a field trip was carried out between 09 July and 14 August, 2018. A team consisting of 3 geologist and one team leader worked together in the field for the entire period. Three drilling teams were employed simultaneously to speed up the drilling and installation of the monitoring wells. Detail methodology for site selection, drilling, sampling, logging, and installation of the monitoring network is discussed in the subsequent sections.

2.1 Monitoring Well Installation

2.1.1 Site Selection:

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

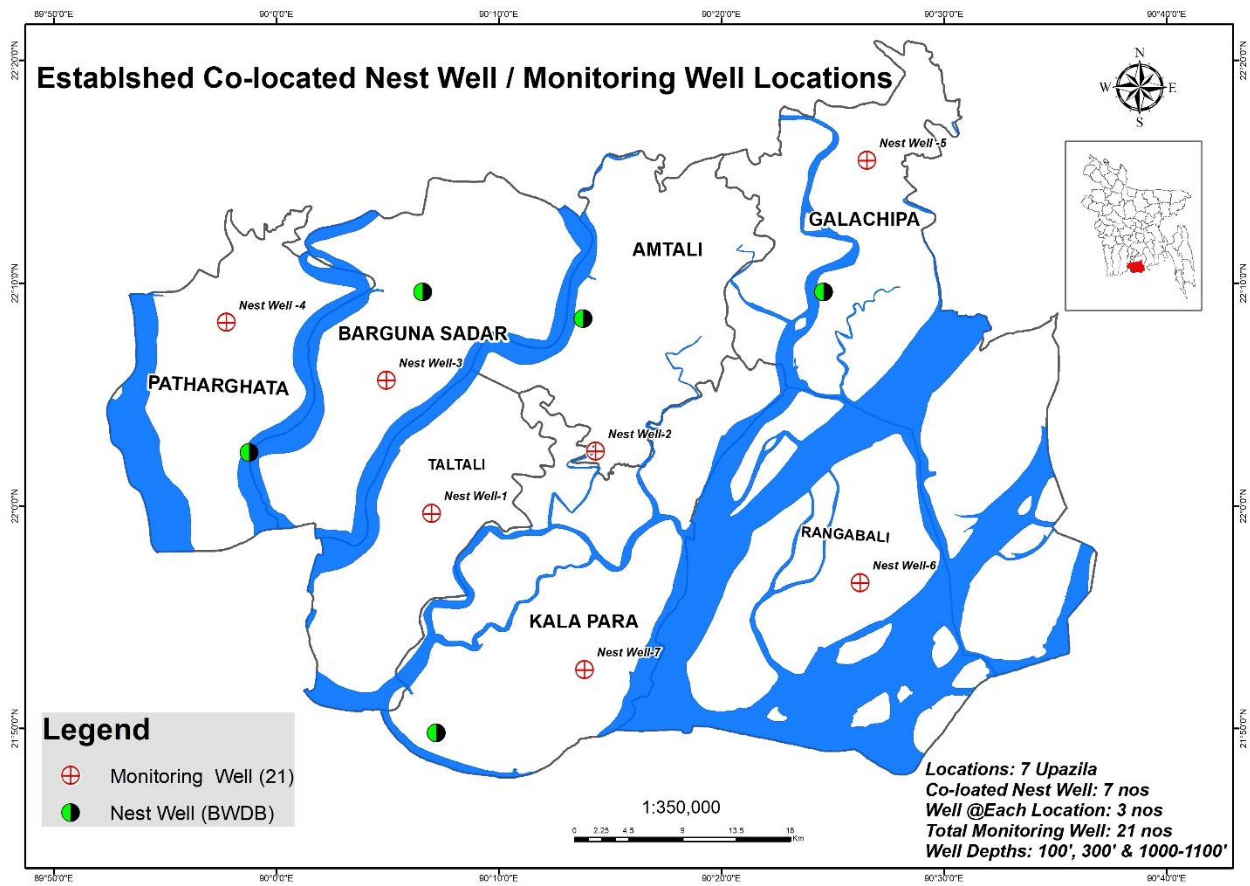

Figure 1: Location map of the monitoring nests

2.1.2 Drilling of Monitoring Wells:

Since the groundwater quality in the study area varies with depth, monitoring wells at multiple depth intervals is essential. A total of 21 monitoring wells have been installed at seven locations (one set of 3 wells in each Uapzila, Figure 2). At each location a cluster/nest[1] of three wells (one at around 1000±100 feet depth, one at around 300 feet depth and the other at around 100 feet depth, each well will be within 10-50 ft from the other) have been installed as shown in Figure-2.

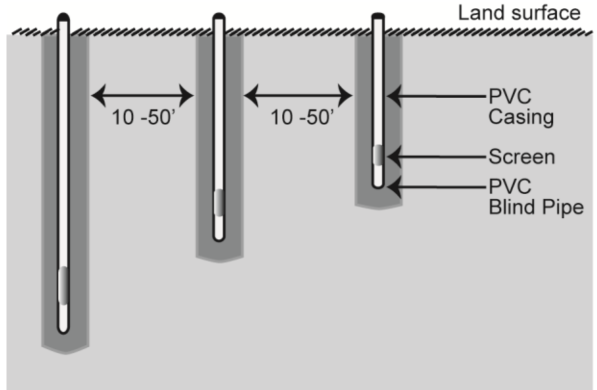

Figure 2: Cross Sectional View of Well Nest/Cluster

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 cuttings 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. For the deepest piezometer drilling was continued for at least 1000 feet, at some places where suitable layer could not be found around 1000 feet drilling was carried out for 1100 feet.

2.1.3 Lithological Sampling and Logging:

A well site Geologist was present at each site during drilling and he was responsible for logging the samples in standard format, collected every 10 feet interval. He logged the lithology in the log sheet provided by consultancy firm and preserved the samples for further laboratory test i.e. Grain size analysis. The drill cuttings were collected in bucket and preserved in polyethylene bag for further laboratory analysis. The samples were analyzed visually by an onsite geologist and a driller's log was prepared at the field. All the borelogs are presented in the appendix Table A-2.

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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.

2.1.4 Installation of Monitoring Wells

After the drilling was completed a monitoring well was installed at every drill hole. The deepest monitoring wells have 20 feet screen at the bottom of the well but above 5 to 15 feet blind pipes. The shallower monitoring wells have 10 feet screen above 5 to 10 feet blind pipe. Both the well casing and screen consists of PVC materials (Figure-4). After installing the pipes a gravel packing was done around the well screen. The well annulus was back filled by clays collected during the drilling.

Figure 3: Installation of Monitoring Well

2.1.5 Development of Monitoring Wells

After installation, each monitoring well was developed by both manual pumping for duration of several hours for the shallow wells to tens of hours for the deep well until the EC of the well water was stable and by an electrical compressor. A local hand pump was used for the manual pumping for well development.

2.1.6 Water Level Measurement and Sampling

After the successful development of the monitoring wells groundwater level 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 $P^{H,}$ Electrical conductivity (EC), Eh, TDS, and Arsenic (Figure-5 & 6). Water level will be measured automatically in hourly interval in the deep wells using automatic data loggers for a period of one year starting from Mid-September 2018. In the shallow wells water level will be measured bi-weekly using a water level meter for the same period.

Figure 4: Water Sampling and Field Test.

Figure 5: Water Sampling and Field test.

2.2 Water Sampling from Existing Wells

A total of 133 existing wells were sampled in 7 Upazilas. Before sampling each well was purged for 5-10 minutes. Samples were collected in 125 ml plastic bottles. Two samples were collected from each well, one sample was acidified and the other was non-acidified. Both samples were filtered before filling the sampling bottle. Each sample was given a sampling ID and sample bottle was labeled with ID. In addition to sample collection a number of onsite geochemical parameters were also measured in the field using field test kits. These parameters include $P^{H,}$ Electrical conductivity (EC), Eh, TDS, and Arsenic (Figure 7). Details of the sample locations and field parameters are given in Table A-3 in Appendix.

Figure 6: Water Sampling from Existing Well

2.3 Slug Test

Since pump test is 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-8).The temporal rate of this water level declination 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 7: 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 9 &10).

Figure 8: Slug test in the 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 9: Slug Test in Monitoring Well

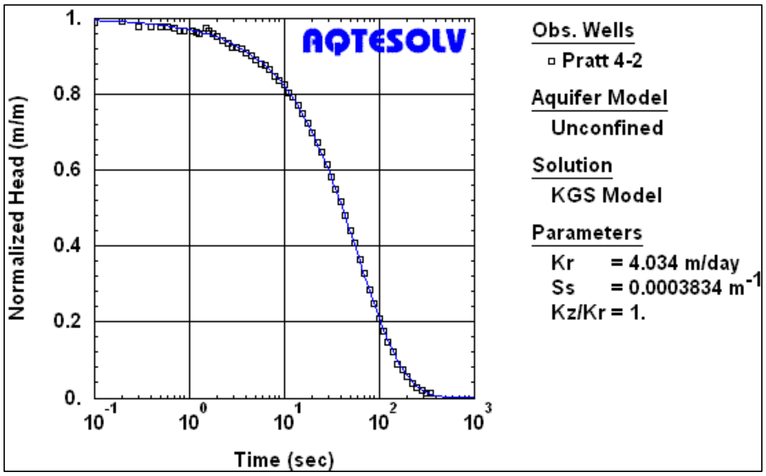

Figure 10: Estimation of aquifer properties from time-displacement data collected during an overdamped slug.

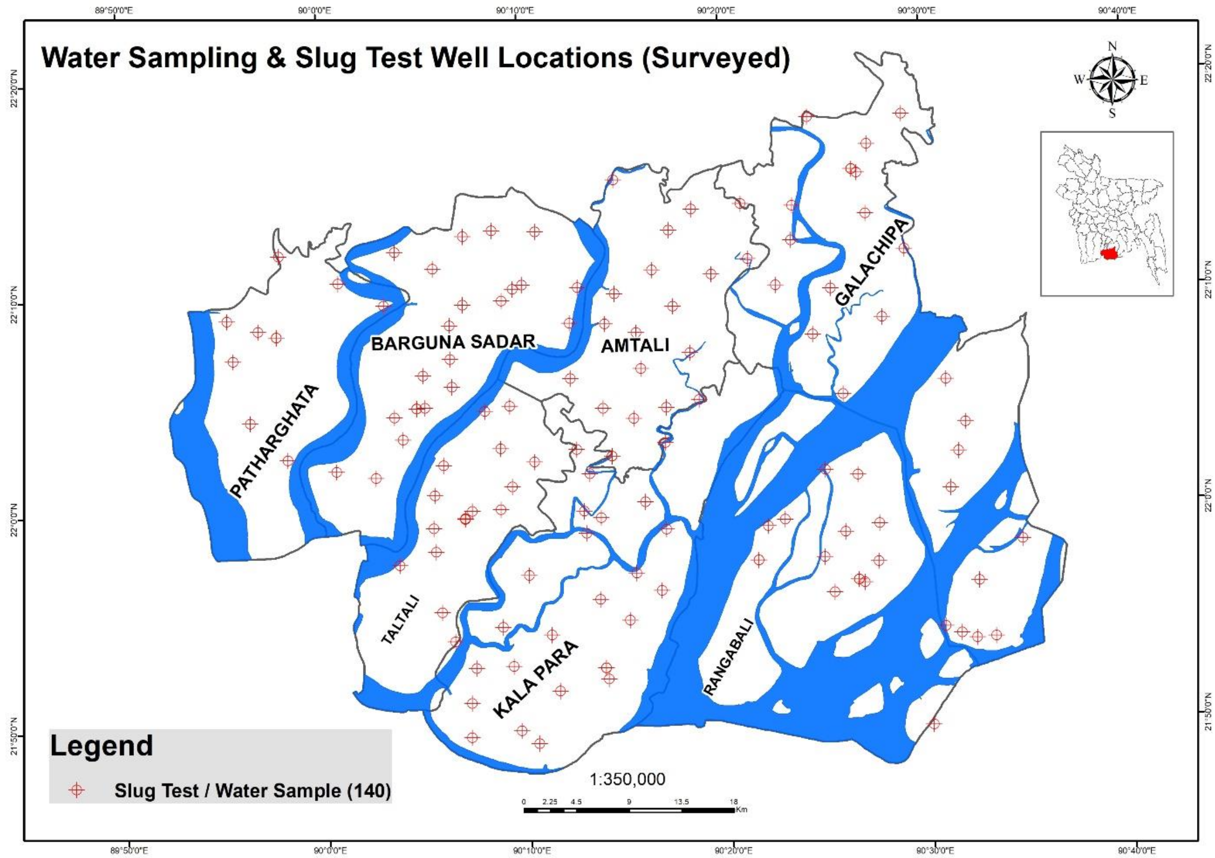

Figure 11: Water Sampling and Slug test Location Map

In addition to the 21 monitoring wells that will be installed under this study, slug test have been carried out in at least 132 locations in the existing hand tube wells throughout the study area.

2.4 Vertical Electrical Sounding

Boreholes provide direct information about the subsurface. However, drilling of 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 are between each borehole. Geophysical methods can be very useful in minimizing the data gap. In this study vertical electrical survey (VES) have been conducted in a total of 21 locations (3 at each upazila, Figure 13). Among these 21 points seven will be collocated with the nested monitoring wells and the other points will be distributed in between these nested wells.

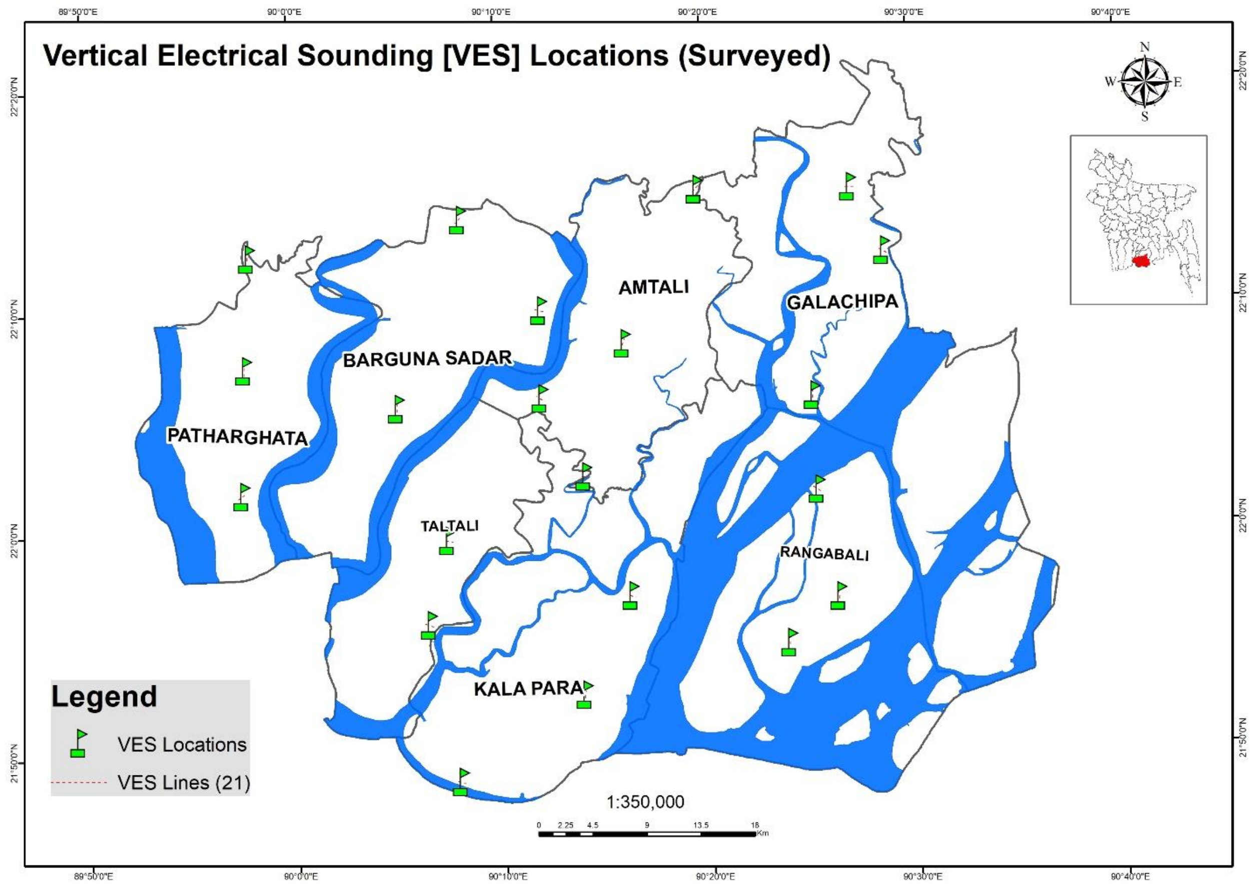

Figure 12: Location Map of VES

Procedure: The resistivity of a material is defined as the resistance in ohms between the opposite faces of a unit body of the material. The SI unit of resistivity is ohm-meter. A series of measurements of resistivity are made by increasing the electrode spacing in successive steps about a fixed point. This method of vertical exploration is known as the expanding electrode method, “Resistivity sounding” or “Depth probing” or vertical electrical sounding (VES). The apparent resistivity values obtained with increasing values of electrode separation are used to estimate the thickness and resistivity of the subsurface formations. VES mainly employed in groundwater exploration to determine the disposition of the aquifers.

Electrical resistivity methods rely on measuring subsurface variations of electrical current flow which is exhibited by an increase or decrease in electrical potential (voltage) between two electrodes. It is commonly used to map lateral and vertical changes in subsurface material.

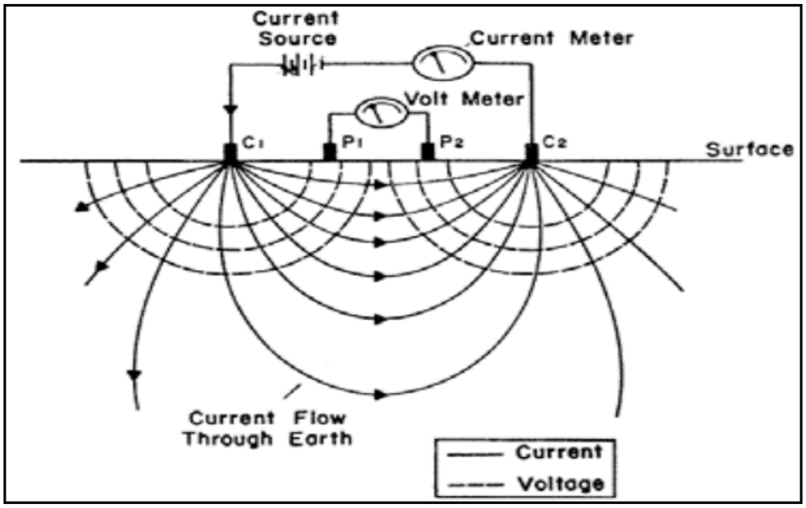

Figure 13: Basic Concept of Resistivity Measurement. [Source: Abstracted from Benson et al. (1988)]. Note: C1 and C2, P1 and P2 refer to the current and voltage/potential electrodes respectively.

According to the following formula which is based on Ohm's Law: $k\,(\Delta V/I) = \rho$ ……….. eq 1

Where ρ = Electrical resistivity

ΔV = Potential difference (voltage)

I = Applied current

k = Geometric factor

There are several standard combinations of electrode geometries which have been developed. The value of the geometric factor, k would depend on the particular electrode geometry used.

ASTM D6431-99 (2005) indicates that the most common electrode geometries used in engineering, environmental and ground-water studies are the Wenner, Schlumberger and dipole-dipole arrays. These arrays are shown in Figure 15.

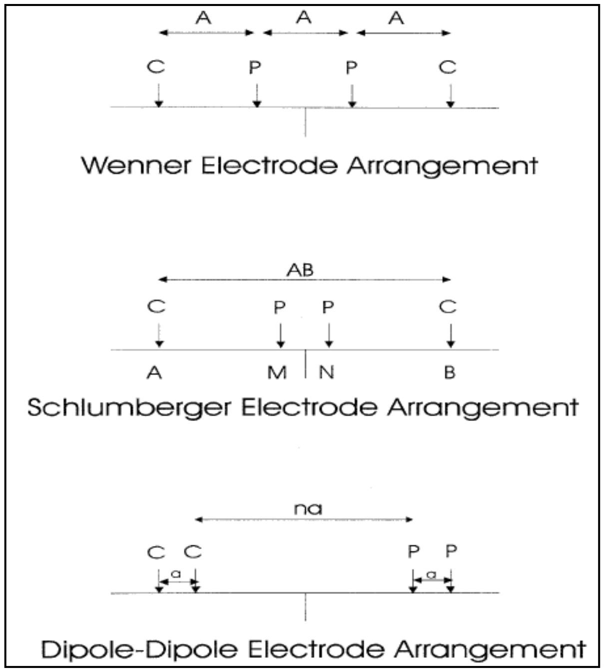

Figure 14: Standard Electrode Geometries. Source: Abstracted from ASTM D6431-99 (2005)

Wenner array mainly used for resistivity imaging/profiling and Schlumberger array provide better result in Vertical Electrical Sounding (VES). Dipole-Dipole array is used when survey line is very large with a view to getting greater depth of penetration. In this survey Wenner electrode configuration has been used.

The geometric factor (k) for Wenner array of equation1 is

$K = 2\pi a$

Where, 'a' is spacing between two electrodes.

Hence the equation become

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

Depth of Penetration: In homogeneous ground the depth of current penetration increases as the separation of the current electrodes is increased. Figure 3 shows the proportion of current flowing beneath a given depth Z as the ratios of electrode separation L to depth Z increases. When L=Z about 30% of the current flows below Z and when L=2Z about 50% of the current flows below Z. The current electrode separation must be chosen so that the ground is energized to the required depth, and should be at least equal to this depth (Figure 16).Fraction of current penetrating below a depth Z for a current electrode separation AB Proportion of current flowing below depth Z. For Wenner Configuration expected depth of penetration is about one third of the array length (AB/3).

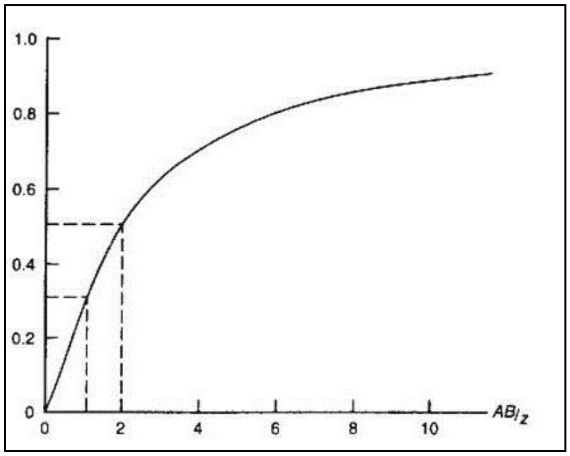

Figure 15: Fraction of current penetrating below a depth Z for a current electrode separation AB Proportion of current flowing below depth Z (Source: Telford, Second Edition)

Table: Standard specifications for McOHM resistivity meter (Model-2115)

Transmitter	
Output Voltage	400 V pp (Constant current)
Output Current	1, 2, 5,10,20, 50,100,200 mA (Constant current)
Operating Voltage	12 VDC
Receiver	
Input Impedance	1 M-ohm
Measurement Potential	±0.6 V ±6 V (Auto Range)
Resolution	20 micro V
S/N Ratio	90 dB (With 50/60 Hz.)
No of Stacking	1, 2, 4, 16, 64
Time of One Measurement	
Cycle	3.5 sec
Data memory	
Max No. of Files	128
Max No. of Data	2000
Max No. of Data Files	110
Interface	*RS-232C*
Power	DC 12 V Internal Rechargeable Battery, External 12 V Battery applicable
Operation Temperature Range	0-50^{0} C
Dimensions	(W) 206 X (H) 281 X (D) 200 mm
Weight	Approx. 7.5 Kg (Including Battery)

Interpretation Techniques of Data: When electrical resistivity measurements are conducted in the field, the values obtained are referred to as the apparent resistivity. These apparent resistivity values must be inverted in order to determine the true resistivity. The process of inversion entails comparing plots of apparent resistivity versus depth with master or theoretical curves. This process not only determines the true resistivity, but it also gives an estimate of the respective layer thickness. For the case studies outlined later, the inversion process was conducted using the computer program RES2DINV.The final model obtained through software is taken to be the layered geo-electric image of the subsurface. The field procedure of VES is given in Figure 17.

Figure 16: Resistivity Survey [Vertical Electrical Sounding (VES)]

Details of the locations and field data of VES are given in Table A-4 in the appendix.

3 Discussion

A total of 21 monitoring wells have been drilled and installed at seven locations. At each location, three (03) co-located wells (10 to 50 feet apart) have been installed at different depths. The deepest of each set is about 1000±100 feet deep, the intermediate one is about 300 feet deep and the shallowest one is about 100 feet deep.

The field investigation on water quality represent for Arsenic concentration the whole project area is free of Arsenic except the extreme western of Pathorghata Upazila and extreme southern part of Kalapara Upazila and for salinity of deep aquifer moderately intense in the western part of Pathorghata Upazila and an isolated zone at Barguna sadar Upazila.

The other investigation like grain size analysis, Major Anion, Cation, Trace element, VES data interpretation are going on in laboratory and it will take more than a month and will be included in the next phase of reporting.