A CRITICAL EVALUATION OF DESIGN OF DEEP TUBEWELLS IN THAKURGAON AREA

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN ENGINEERING (WATER RESOURCES)

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Certificate

This is to certify that this thesis work has been done by me and neither this thesis nor any part thereof has been submitted elsewhere for the award of any degree or diploma.

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ABSTRACT

The extensive development of groundwater resources for irrigation makes it imperative that hydrogeological properties of aquifers and performance of existing tubewells should be thoroughly studied. Efficient withdrawal of groundwater is dependent on tubewell performance which is turn depend on the design of tubewell fixtures to best suit the characteristics of water bearing formations, their construction and development. Keeping this in mind the performance of tubewells in the existing as well as the new project of the Thakurgaon tubewell project area has been studied.

Due to limited availability of relevant data it has not been possible to have a detail analysis of local aquifer material but attempts have been taken on the basis of analysis of such limited data to have a guide line for the design of screen slot openings and gravel pack material by Johnson's method. The design has then been compared with that made by C.K.C., the consultant of BWDB for the project. For comparison of design parameters three different sets of design parameters have been determined based on D_{90}, D_{50}, D_{40}, D_{10} etc. of entire project area, D_{90}, D_{50}, D_{40}, D_{10} etc. of individual borehole and D_{90}, D_{50}, D_{40}, D_{10}, etc. of the finest layer of a bore hole. Design parameters based on D_{90}, D_{50}, D_{40}, D_{10} etc. of the finest layer of aquifer material of four different installed tubewells have also been determined and compared. The performance

of the existing wells have been discussed in light of the well design parameters determined. The tubewells of the existing project seems to have correct screen lengths while the screen lengths for the tubewells of the new project is required to be increased to ensure minimum entrance velocity so as to keep the well loss value minimum and thus to make the well efficient with a longer life. Discussing the probable reasons of early failure of the defunct wells of the existing project it has been inferred that the use of higher capacity pumps and larger gravel packing materials might have caused early defunct of some wells with Nold type of screens in the existing project.

From the study of design parameters determined it may also be concluded that the use of standard and fixed slot opening size of 40/1000 inch may create problem in cases where the screen has been placed in finer layers, It is therefore important that proper sieve analysis of aquifer material be made before installing the well fixtures for proper selection of the layers to be screened.

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NOTATIONS

Symbols	Definition
A_o	Effective open area per foot length of the well screen.
b	Thickness of confined aquifer.
BA	Baliadangi.
BADC	Bangladesh Agricultural Development Corporation.
BG	Birganj
BRRI	Bangladesh Rice Research Institute
BWDB	Bangladesh Water Development Board
C	Well Loss Constant
CKC	Chuo Kaihatsu Corporation.
C_u	Coefficient of uniformity.
D_{10}	Size such that 10% of the sample which will be retained.
D_{15}	Size such that 15% of the sample which will be retained.
D_{40}	Size such that 40% of the sample which will be retained.
D_{50}	Size such that 50% of the sample which will be retained.
D_{60}	Size such that 60% of the sample which will be retained.
D_{70}	Size such that 70% of the sample which will be retained.
D_{85}	Size such that 85% of the sample which will be retained.
D_{90}	Size such that 90% of the sample which will be retained.
DTW	Deep Tubewell.

Notations (Contd...)

Symbols	Definition
EPWAPDA	East Pakistan Water And Power Development Authority.
H	Hagusta type of screens.
h_o	Saturated depth of an unconfined aquifer.
k	Coefficient of permeability.
$\log_e$	Logarithm to the base e.
$\log_{10}$	Logarithm to the base 10.
LLP	Low lift pump.
LWC	Lower well casing.
N	Nold type of screens.
PI	Pirganj
PVC	Polyvinyl Chloride
Q	Maximum discharge of the well.
r	Radial distance from well centre.
r_w	Radius of the well.
S	Storage coefficient
S_L	Optimum length of the screen.
SWL	Static water level
t	Time elapsed since discharge began
t_o	Time intercept on the zero drawdown axis.
t'	Time since pumping stopped.
T	Coefficient of transmissibility
T-62	Thakurgaon well No. 62
UWC	Upper well casing

Notations (Contd...)

Symbols	Definition
u	$r^2s/4Tt$
V_e	Entrance velocity at the screen
W(u)	The exponential integral known as "Well loss function".
Δh	Drawdown difference per log cycle of time
$\Delta h'$	Change in residual drawdown per log cycle of time
Δs	Drawdown difference per log cycle of time

CHAPTER 1

INTRODUCTION

1.1 General

Water is most vital for mankind. Without it the existence of mankind as well as all the living beings cannot be thought of. Hence, the regions with easy availability of surface water have always been inhabitated by mankind. With time the demand for water has increased and it is now found that surface water alone cannot meet the various demands in many regions.

With increase in population and having an agro-based economy, Bangladesh should increase her agricultural production. Although there has been some agricultural development in recent years yet Bangladesh needs to import large quantities of food-staff spending scarce and valuable foreign exchange. Under such a condition agricultural production must be increased at an accelerated rate to bring about self sufficiency in food grains. This can be achieved by assurance of more than one crop in most of the land cultivated. For this it is necessary to satisfy crop water requirement not only in winter months when there is almost no rainfall but also in monsoon when there is enough rainfall but not according to requirement. During rainy season irrigation demand can be met from surface water sources such as rivers, canals, ponds etc. by low lift pumps (LLP) if the local rainfall is not enough. But during the winter months the irrigation requirement shall have to be met in most of the cases from sources other than surface water.

Fortunately Bangladesh is underlain by water bearing formation in many places at various depths. So, groundwater can be considered to be a potential source of water supply for irrigation during winter months when surface water is not easily available. Intensive tubewell irrigation projects undertaken by different government and autonomous bodies show how the groundwater utilization specially for irrigation has increased in recent years to attain self sufficiency in food.

With increasing emphasis on tubewell irrigation, it is necessary to design, install and develop tubewells so that these can be most economically and efficiently utilized. It is therefore necessary that the wells should have not only high specific capacity but also a longer life.

Efficient and economical utilization of groundwater through wells depend on the design of wells to best suit the characteristics of the water bearing formations. Flow of groundwater into wells is influenced by the physical characteristics of the water bearing formations, the number and extent of these formations, the elements of well design and the methods used for constructing and developing the wells. Keeping this in mind the present topic has been selected. And as such the deep tubewells under Thakurgaon Tubewell Project are considered for the study, which is the biggest project in Bangladesh where irrigation is done by deep tubewells. It is expected that the study will help to identify the various problems associated with inefficient functioning of some of the tubewells of the project and to suggest how these problems can be taken care in our future projects.

1.2 Project Description

The project is located in the Thakurgaon district which lies in the north-west corner of Bangladesh. Preliminary studies in the late 1950s have shown that the area is underlain by a deep sand and gravel alluvium which constitutes a groundwater reservoir of exceptionally high potential for tubewell development. Again, there are no major rivers in the project area and the flow of existing stream is insignificant during dry season. Considering the inadequacy of surface water resources it was decided to use the available groundwater source by tubewell for irrigation. Thus the Thakurgaon tubewell project was concieved and implemented.

A total of 381 tubewells were installed in the Thakurgaon tubewell project during the period 1962-64(9). All the wells were sunk without casing by the reverse circulation method having a diameter of 22 inch. The boring depth depended on the subsoil conditions because workable and suitable soil layers had to be available for a filter length of at least 130 feet. On an average the boreholes were 280 feet deep. The aquifers chosen for water discharge were tapped with either Nold bridge-slotted screens or with Hagusta screens of 10 inches diameter(33) With the Nold screens, the residual space between the borehole wall and the tube was filled with filter gravel of 1 mm. to 4 mm. diameter. Hagusta type of screens were also provided with 1 mm. to 4 mm. diameter gravel packing although suitable bore spoil could have been used in parts for these screens which are already gravelled at the plant[33].

At the planning stage of the project, the operational life of the tubewells was anticipated to be around 20 years[9]. But from the records it has been found that many wells were becoming defunct much earlier than their anticipated life, while a large number of wells are giving discharge less than that obtained initially and in many cases even less than the design discharge.

BWDB have rehabilitated some of these defunct wells by the year 1981 and have a programme to rehabilitate 250 wells of the existing project[9]. Again, out of these newly sunked tubewells a few are already showing signs of getting defunct and infact one has already been defunct. Such early failure and lower discharge of tubewells causes not only tremendous financial losses but also sufferings to the farmers, causing great hazard to proper irrigation.

1.3 Importance of Present Study

BWDB is going to install another 710 deep tubewells to supply irrigation water in a new project area in the same region under the project heading "Tubewell Project (North Bangladesh) in Bangladesh"[9]. These tubewells in the new project area and rehabilitated ones in the Thakurgaon project area may face the same problems as those faced by many of the earlier tubewells in the existing Thakurgaon Project area. Hence, it is necessary to undertake a study to identify the probable causes of early failures of the defunct tubewells in the Thakurgaon area and to make recommendations as regards tubewells design procedure to be adopted in the proposed new area. This may help to obtain better performance of the tubewells of the proposed project and in any other project for ground water utilization by tubewell technology.

1.4 Objectives of the Study

The objectives of the study can be summarised as follows:

i. To study the performance of the existing tubewells for identifying the probable causes of early failure of some of the tubewells.

ii. To evaluate the aquifer characteristics of the project area.

iii. To examine how the design parameters selected for various components of tubewells fit with the aquifer characteristics and how this affects functioning of the tubewells.

iv. To make recommendations regarding tubewell design procedure for obtaining better service from them.

CHAPTER 2

DESIGN PRINCIPLES

2.1 Design of Tubewells

2.1.1 Introduction

Generally, wells are designed for the purpose of irrigation, drainage, sanitation, domestic and industrial works. The design of each type of well for each purpose requires particular attention, taking into account its purpose.

A water well for irrigation is designed to get the optimum quantity of water economically from a suitable geological formation. The design should ensure an efficient and economical well with a service life of more than a decade or a period of run of 50,000 to 70,000 hours[24,37]. Though conflicting design criteria have been enunciated from time to time by those working in the field of well design, a stage has now been reached when it is possible to design an optimum well for almost all the aquifer conditions.

A water well design involves selection of proper dimensions like the diameter of the well and that of the casing, length and location of the screen including slot size, shape and percent open area, design of gravel pack if necessary, selection of screen material etc. Screened wells in unconsolidated formations involve considerations of more design details when compared to wells in consolidated rock formations.

Generally, the aim of engineering design is to achieve the best possible combination of performance, useful life and reasonable cost.

The hydraulic and hydro-geological characteristics of aquifers vary greatly. Irrigation wells should be designed and constructed to take advantage of the natural conditions at a given location. When it is done, and the materials of construction are properly selected, an economical and efficient well structure of long life can be achieved. Irrigation wells are usually-designed to obtain the highest yield available from the aquifer, and the highest efficiency in terms of specific capacity. These factors bear directly upon operating costs. It is not good engineering to use inadequate sizes of well casing and well screen, or to choose materials of inferior quality, merely to cut first cost. This only saddles the owner with higher pumping and maintenance costs, as well as reduced useful life of the well. Any additional investment for a properly designed, efficient well will, in long run, usually produce maximum economy.

The well structure may be considered to consist of two main elements. One element is the part of the well that serves as a housing for the pumping equipment and as a vertical conduit through which water flows upward from the aquifer to the level where it enters the pump. This is commonly the cased portion of the well, although some of its length may be uncased where the well is constructed in consolidated rock materials. The other main element is the intake portion of the well. Since through this intake portion water enters the well from the aquifer, the design of this element requires careful consideration of the hydraulic factors that influence well performance. This applies particularly to a well that derives water from an unconsolidated water-bearing formation. In such a case, a well screen is employed, and it functions as the intake portion of the well structures.

A properly constructed well screen allow water to enter the well freely with optimum velocity, prevents sand from entering with the water, and serves as the structural retainer to support the loose formation material.

The aim of both screened wells and gravel packed wells is to draw clear water from the aquifer without excessive head loss and at the same time to keep the aquifer material out. For this proper development of well is necessary. ~~Development of well is necessary.~~ Development removes the finer material from the aquifer surrounding the well so that only coarser material is left adjacent to the screen. The aquifer material around the well becomes more uniform in grainsize and holds back the finer material of the aquifer further beyond, so that it cannot clog the screen. Of course, when the well is gravel packed, much of the same purpose has been accomplished, although development is still beneficial.

The choice of whether a well is to be provided with a screen or with a screen with gravel pack depends primarily upon the effective grain size D_{50} and the uniformity coefficient (D_{40}/D_{90}) of the aquifer material.

2.1.2 Well Diameter

Choice of proper well diameter is very important because it affects significantly the cost of the well. In deep tubewells, however, the well structure usually consists of two main elements. One element is the part of the well that serves as housing for the pumping equipment and as a vertical conduit through which water flows upward after entering into the well through screen.

The other element is the intake portion of the well where water enters the well from the aquifer. The design of this element requires careful consideration of the hydraulic factors that influence well performance.

The well diameter must be chosen so as to satisfy the following two requirements:

i. The housing-pipe must be large enough to accommodate the pump with proper clearance for installation and efficient operation.

ii. The diameter of the intake section of the well must be such as will assure good hydraulic efficiency of the well.

In choosing the size of the casing, the controlling factor is usually the size of the pump. The diameter of the well casing should be two size larger than nominal diameter of the pump to ensure adequate clearance and plumbness if it occurs. In no cases should it be chosen less than one nominal size larger than the pump bowls.

The well diameter may not be same throughout. In deep-wells, the-well diameter can be reduced at a depth below the lowest anticipated pump setting.

2.1.3 Well Depth

The expected depth of a well is usually determined from the log of a test holes, from logs of other nearby wells on the same aquifer or during the drilling of the production well. Generally, a well should penetrate to the bottom of the aquifer. This is desirable for the following two reasons:

i. More of the aquifer thickness can be utilized as the intake portion of the well, resulting in higher specific capacity.

ii. More drawdown can be made available permitting greater well yield.

Departure from the above rules may be made in the following two cases:

i. Sometimes the well screen is placed at the middle of the aquifer thickness, to make more efficient use of a given length of screen, in uniform artesian aquifer.

ii. When water of poor quality is found in the lower part of the aquifer.

2.1.4 Well Screens

A well screen is a strainer, which separates the ground-water from the granular material having pores filled with water. Generally all formations, except stable rock, require well screens. The yield of a well depends primarily on matching the characteristics of the water-bearing formations to the elements of the well screen. The well screen elements refer to the length of the screen, its diameter, total open area and size, and arrangement of the slot openings etc.

The following are the basic requirements for any well screen:

i. Resistance to corrosion and deterioration.

ii. Enough structural strength to prevent collapse.

iii. Suitability to prevent excessive movement of sand into the well.

iv. Minimum resistance of flow of water into the well.

The selection of well screens is usually a matter of engineering judgement and experience. The recommendations on safe limit of entrance velocity of the flow into the well from the surrounding aquifer vary considerably. A criterion proposed by Bennison (1947) is that a velocity of 3 to 7.5 cm/sec. through the individual openings of the screen will keep the sand movement and head losses to the minimum.(7) Linsely and Franzini(1964) observed that the entrance velocity should be kept below 15 cm/sec in order to minimise sand movement and head loss.(32) The variation in the two recommendations has been attributed to the differences in the particle size distribution of the aquifer materials investigated.

Walton (1962) made a study of several well failures due to partial clogging of the screen openings and recommended the values for screen entrance velocity given in Table 2.1.

In gravel packwells, the average of the permeabilities of the aquifer and the pack is used to determine the optimum screen entrance velocity.

To prevent the rapid clogging, the length of the well screen for a well is designed on the basis of the following equation (Walton, 1962):

$$S_L = \frac{Q}{7.48\ A_o V_e} \qquad (2.1)$$

where,

S_L = optimum length of the screen, in feet

Q = maximum expected discharge capacity of well, in gpm.

A_o = effective open area per foot length of the well screen, in sft.

V_e = entrance velocity at the screen, in fpm.

The design procedure for the length of the well screen is as follows:

The optimum entrance velocity at the well screen is determined. Then, from the aquifer test the expected capacity of the well is calculated. From the information on the open area of the well screen per foot, the effective open area is determined as provided by the manufacturer. After providing a factor of safety of 2 to 5, the length of the screen is designed using the equation (2.1).

2.1.4.1 Slot Opening

Choosing the right size of slot width is one of the important steps in modern well design. Over-sized slots will pump finer material (sand, silt and clay) indefinitely and it will be difficult to obtain clear water, while under-sized slots will provide more resistance to the flow of ground water, resulting in more head loss. The fine slots are also blocked by small sand and silt-particles in the long run which are carried upto the screen by suspension. The problem of clogging is reduced as the well screen openings are increased. Therefore, the well slot openings are used as wide as possible by matching the opening with the grain size distribution of the material surrounding the screen.

The slot size in gravel packed wells, with homogeneous aquifer should be equal to the D_{90} size of the pack material so that it can retain 90 percent of the gravel pack. This criterion is accepted by all authorities except U.S. Bureau of Reclamation. The latter recommended that the slot size should be half the D_{15} size of the pack material. The slot size obtained by this criterion is also almost equal to the D_{90} size of the pack material.[24]

In non-homogeneous formations, which occur more generally in nature, slot openings of different sections of the well screen are chosen according to the gradation of the materials of the different strata. Each section of screen is made with openings to fit the material of each individual stratum. If the D_{50} grain size of the coarsestaquifer is less than four times the D_{50} grain size of the finest aquifer, the slot size or the pack should be based on the finest aquifer. If the difference is more than four times, the slot size or the pack should be tailored to individual layers.

In addition to the above the following two rules are adopted in selecting the openings for a multiple slot screen:

i. If fine material overlies coarse material, it is required to extend not less than 0.60 meter of the screen with the slot size designed for the fine material down into the coarse stratum below.

ii. If fine material overlies coarse material, the slot size for the screen section to be installed in the coarse stratum should not be more than double the slot size for the overlying finer material. But if a gravel designed to match the same is provided, it is necessary to keep the slot size in this coarser material also in accordance with the pack designed for the upper finer aquifer so that if the finer gravel moves down it is retained on the slots.

Generally, horizontal slot openings give a better control of unconsolidated material than do vertical openings. The slots may be made in different ways, vertical or horizontal, continuous or intermittent. The width of the slot depends on the grain size distribution of the aquifer and varies in practice from values as low as 0.20 or 0.50 mm., depending on screen construction to as large as 2 to 5 mm. The square openings in the wire mesh and circular drilled holes in the wall of the pipe are easily plugged by particles of nearly the same size as the openings.

2.1.4.2 Percent Open Area

Water flows more freely through a screen with large open area than through one with limited open area. When the open area of the screen is large, the entrance velocity is low and the head loss at the screen is minimum. The open area of the screen should be so selected that the well loss is small, Corey (1949) observed that little or no increase in well efficiency results when the open area is greater than 15 percent of the total surface area of the screen.[18] Open area larger than about 15 percent affects the structural strength of the well screen. In actual practice sometimes larger open areas are found desirable in order to hold the screen entrace velocities within optimum limits.

When a screen is placed in an aquifer, sediment will settle around it and partially block the slot openings. Walton (1962) observed that on an average, about one-half of the open area of the screen is blocked by aquifer materials. Thus, it may be said that the effective open area averages about 50 percent of the actual open area of the screen. Therefore, screen should be designed keeping this factor in view.

2.1.4.3 Screen Diameter

The effect of the screen diameter on the aquifer loss is not very large, because in the well equation

$$Q = 2\pi k b \frac{h_o - h_w}{\ln(r_o/r_w)}$$

the logarithm of the well radius is used. The yield of a well is a function of the diameter of its intake portion, though the two are not directly proportional. Many cases are on record of costly large-diameter wells which were put down because of belief that "the bigger the well, the more the yield". It is true that the larger diameter well will yield some more, but the percentage of increase may be relatively small. An increase in well diameter increases yield slightly. Keeping the hydraulic properties of the aquifer as constant, doubling the diameter of the screen in a water-table well will increase the discharge only about 11 percent.[32,39] (Slichter, 1899 and Linsely, et. al. 1964). Ahrens (1958) showed that doubling the diameter of the well screen, in a confined well, will increase its yield by about seven percent.[3] The value of increase in yield in a confined well is less than a water-table well because for the same discharge rate the radius of influence is larger for the former.

However, the well diameter influences the well loss to a large extent, and has to be selected so that the total loss, i.e. the aquifer loss plus the well loss, is kept minimum in conjunction with the cost of the screen, the boring and the pumping costs required. If the well diameter selected is too large, the cost of installation would be high but the remaining costs would be low. If the well diameter selected is too small, the cost of installation would be low but the head loss would be high resulting in high running costs.

Screen diameter is selected to satisfy the essential basic principle that enough total area of the screen openings must be provided so that the entrance velocity of the water will not exceed the design standard. Screen diameter is a factor that can be varied after the length of the screen and size of the screen openings have been selected. Screen length depends upon the thickness of the water-bearing sand; screen openings depend upon the gradation of the aquifer material. To a large extent, the natural characteristics of the aquifer fix these dimensions, leaving the diameter as a factor that can be varied.

Laboratory tests and field experience show that if the screen entrance velocity is equal to or less than 3 cm/sec., friction losses in the screen openings will be negligible and the rate of incrustation and corrosion will be a minimum.[34]

The entrance velocity is calculated by dividing the expected or desired yield of the well by the total area of the openings in the screen. If the figure is greater than 3 cm/sec, the screen diameter should be increased to provide enough open area so that the entrance velocity is less than 3 cm/sec.[28,34] If, on the otherhand, the calculated entrance velocity is less than this figure, the screen diameter may be reduced somewhat to achieve economy.

2.1.5 Design of Gravel Pack

A gravel envelope or gravel pack is a layer of gravel placed around the well screen to prevent the movement of relatively coarse sand but to allow free passage of water into the well. Wells can be "Natural Gravel Packed" or "Artificially Gravel Packed". A naturally developed envelope can be produced by removing the fine sand and silt from the natural formation and transporting these fines through the well screen openings by surging and bailing. An artificial gravel envelope can be provided by keeping the bore of the well somewhat larger than the well screen, centering the screen in the hole and then filling the annular space around the screen with properly selected gravel designed to suit the aquifer gradation.

A properly designed gravel envelope should satisfy the following two main requirements:

i. It must be fine enough to prevent the passage of coarser particles from the formation material through its pores.

ii. It must be coarse enough so that the head required for the flow of water through it is minimum.

2.1.5.1 Formations Requiring Artificial Gravel Pack

Not all water bearing formations require artificial gravel packing. Generally, formations with an effective size of 0.25 mm. and a uniformity coefficient ($C_u = \frac{D_{40}}{D_{90}}$) of 2 or more can be safely developed without a gravel pack, provided there are few vertical changes in sizing in the formation. As the formation becomes coarser, the desirability of the gravel pack decreases; however, exceptions to the above are common.

Artificial gravel pack construction is recommended where the natural formation consists of fine uniform sands and/or where the formation is extensively laminated (consists of alternating fine, medium, or coarse layers that are thin and difficult to locate precisely). These conditions are frequently met in most deep tubewells. An artificial gravel pack may also be used for an aquifer containing fine materials, when it is desirable to use larger screen openings than are indicated by the sieve analysis. This often occurs when C_u is between 2 and 3 and the D_{60} size is less than 0.42 mm. In areas where incrustation is a problem it is desirable to use large screen openings.

The following are the advantages of the gravel packed wells:

i. Gravel packing increases the effective diameter of the well, thus increasing its specific yield.

ii. It increases the yield of a well due to low resistance against flow at the well screen.

iii. It reduces the incrustations. This is due to the large screen openings.

iv. When designed properly, gravel packs provide sand-free water, thus increasing the efficiency of the well and the pumping unit.

v. It provides higher structural strength for the well screen.

vi. It prevents the caving in of the formation material, thus reducing the danger of clogging of the well screen.

vii. It facilitates the removal of the well casing and screens in shallow wells.

Two types of gravel packings are in general use — the uniform-grain size pack and graded-grain size pack. The former has been widely accepted in recent years, specially when manufactured screens are used because the size of the openings can be controlled. In the case of a graded-pack, the formation material may invade a graded pack at the gravel formation interface, partly filling the pores and resulting in reduced permeability. With a well sorted (uniform) gravel pack, the fines of the formation can travel between the grains and be pulled into the well during development, thereby increasing the formation permeability while retaining the highly permeable nature of the pack. Lack of availability is the main draw-back in adopting uniform pack material in many cases. The most important physical property of uniform-grain-size material is the particle size as represented by the mean grain diameter which is the 50 percent grain size. The pack need not be of large grain size. The American Society of Agricultural Engineers has recommended that the maximum size of the particle in the gravel pack should be 6.4 mm.[34]

2.1.5.2 Design Criteria

To prevent the movement of formation material, a relationship between the aquifer grain size and the pack grain size has been determined on the basis of practical experience and laboratory experiments by various agencies concerned with water wells. All have agreed that different criteria are required for uniform aquifer material ($C_U \leqslant 2$) and for graded aquifer material ($C_U > 2$). The most widely used criteria are summarized below:

i. U.S. Bureau of Reclamation adopted the following criteria.

a. Uniform aquifers ($C_U \leqslant 2$)

$\frac{D_{50} \text{ of pack}}{D_{50} \text{ of aquifer}}$ should lie between 5 and 10.

The average slope of the filter material gradation curve should be the same as that of the aquifer material.

b. Graded aquifers ($C_U > 2$)

$\frac{D_{50} \text{ of pack}}{D_{50} \text{ of aquifer}}$ should lie between 12 and 58.

and $\frac{D_{85} \text{ of pack}}{D_{85} \text{ of aquifer}}$ should lie between 12 and 40.

ii. U.S. Department of Agriculture, after Kruse's model experiments, laid down the following criteria.

a. Uniform aquifers

$$\frac{D_{50} \text{ of pack}}{D_{50} \text{ of aquifer}} = 9.5$$

b. Graded aquifers

$$\frac{D_{50} \text{ of pack}}{D_{50} \text{ of aquifer}} = 13.5$$

iii. Johnson recommended as follows:

a. Uniform aquifers

$$\frac{D_{70} \text{ of pack}}{D_{70} \text{ of aquifer}} = 4$$

b. Graded aquifers

$$\frac{D_{70} \text{ of pack}}{D_{70} \text{ of aquifer}} = 6$$

iv. The Central Board of Irrigation and Power of India- recommended as follows:

a. Uniform aquifers

$$\frac{D_{50} \text{ of pack}}{D_{50} \text{ of aquifer}} \text{ should lie between 9 and 12.5}$$

b. Graded aquifers

$$\frac{D_{50} \text{ of pack}}{D_{50} \text{ of aquifer}} \text{ should like between 12 and 15.5.}$$

The Central Board of Irrigation and Power of India after an extensive experimental studies found that with an increase in Pack-Aquifer ratio the sand movement progressively increases whereas the headloss through the gravel pack shows an initial decline but increases at higher values of Pack-Aquifer ratio due to partial chocking of the gravel pack. Based on model studies conducted at the Irrigation Research Institute, Roorkee; the limiting pack-aquifer ratio has been proposed as given in Table 2.2 for stable filtering action in tubewells.

The results of model studies conducted at Ludhiana indicated the upper limits (Table 2.3) of Pack-Aquifer ratios in order to maintain a stable filtering action.

Ellithrope (1970) stated that in order to minimize the headloss through the gravel pack, the lower Pack-Aquifer ratio should be 4.0. Pack-Aquifer ratio exceeding 9.0 may allow the movement of sand and perhaps this value of 9.0 should be considered as a practical upper limit.[19] Smith (1954) reported that ratios of 4 to 5 were found satisfactory for the efficient design of wells with gravel packing.[38] However, wells having gravel-pack ratios of 7 to 10 were found inefficient because of sand pumping.[33] Smith further observed that still higher values of gravel-pack ratio (10 to 20) produced excessive sand pumping.

2.1.5.3 Design Procedure of Gravel Pack

For proper design of gravel pack in the field, the following procedure should be adopted:

i. To prepare the sieve-analysis curves of the material obtained from the well log and to determine the particle size distribution of different formations encountered by the well.

ii. To identify the formation depth in which the well screen is to be placed.

iii. From the plot of sieve analysis the D_{50}, D_{40}, and D_{90} sizes of the aquifer should be read and the C_u of each aquifer should be calculated from the ratios of D_{40} to D_{90} sizes and thus the type of the aquifer whether uniform or non-uniform will be determined.

iv. The D_{70} size of the aquifer should be multiplied by 4 for uniform aquifers ($C_u \leq 2$) and by 6 for non-uniform-aquifers ($C_u > 2$).

The products so obtained should be marked on 70 percent abscissa of the semi-logarithmic graph and a line approximately parallel to the central portion of the uniform aquifer gradation curve should be drawn through this point. For non-uniform aquifers, the corresponding gravel grading curve should have a uniformity coefficient of 2.

v. The procedure detailed in item (iv) above should be repeated for all the water-bearing aquifers and a common gravel size satisfying the requirements of all the aquifers should be adopted for use in the well.

vi. Aquifers of substantially finer grading than the major portion of the aquifer encountered, which require gravel of relatively very much smaller size than for remaining thickness, should be left untapped.

vii. Where the major portion of the total aquifers tapped consists of relatively fine material and comparatively smaller depths have coarser material, the size of gravel should be designed to suit the requirements of finer aquifers and this will automatically stabilize the coarser aquifers although it might result in a nominal reduction of discharge per unit drawdown of the well.

viii. The slot size in the well screen should be such that at least 90% of the pack material is not able to pass through it.

Apart from a stable pack-aquifer ratio the following considerations should also be kept in view while designing a gravel pack:

i. Non-uniform gravel packs are unsuitable for use as their placement by a shovel results in segregation of particles. With the present method of shovelling it is desirable to use uniform packs only.

ii. The pack material should be well rounded river gravel as the flat particles stick to the screen slots and reduce the open area.

iii. Six to nine inches (15.2 to 22.8 cm.) thick gravel packs should be used.

iv. The well after completion should be fully developed.

2.1.5.4 Gravel Pack Thickness

Since the design theory of gravel pack gradation is based on the mechanical retention of the formation particles, a pack thickness of only two or three grain diameters is what is actually needed to retain and control the formation sand. Laboratory tests made by Johnson, show that a gravel pack with a thickness of only a fraction of a centimeter successfully retains the formation particles regardless of the velocity of water tending to carry the particles through the gravel pack. However, it is impractical to place in a well a gravel pack of only a fraction of a centimeter thick and expect the material to completely surround the well screen. To ensure that an envelope of gravel will surround the entire screen, a thickness of 7.5 cm. is the minimum that is considered practical for installation in the field. Under most condition, the upper limit of gravel pack thickness should be about 20 cm. A thicker envelope does not materially increase the yield of the well. Thickness, in itself, does nothing to reduce the possibility of sand pumping because the controlling factor is the ratio of the grain size of the pack material to the formation material. Too thick a gravel pack requires higher capacity pump and thus increases the cost and time of installation, and can make final development of the well more difficult.

Walton recommended a thickness of gravel pack of 15 to 23 cm. U.S. Bureau of Reclamation suggested a range of 10 to 23 cm. Johnson recommended a thickness of 7.6 cm. with a maximum limit of 20 cm. U.P. Irrigation Research Institute determined after model experiments that the minimum thickness necessary to keep out sand movement is 12.5 cm. It is suggested that the gravel thickness should preferably be between 13 and 20 cm.

2.1.6 Alignment of Well

During drilling the well by any method, care should be taken to see that the hole remains straight and vertical and this must be checked before installation of the screens. A bore containing kinks and bends may create difficulties in installation and operation of the pump. It may cause undue wear on the pump shaft, bearings and casing and in a severe case might make it impossible to get the pump in or out. In case of deep well turbine pumps, for casing less than 35 cm. in diameter, the verticality should not deviate more than 15 cm. per 30 meter depth and the deviation should be in one direction and plane only.

If a suction air lift or submersible pump is installed, the alignment is not so important but it is still desirable to follow the above criterion. Normally a well should be tested for verticality after drilling is completed. However, in the case of gravel packed wells, verticality should be tested after installation of the well assembly but prior to commencement of gravel filling.

The alignment of a tubewell should be tested by use of a heavy plunger 6 mm. smaller in diameter than the inside diameter of the well casing. The plunger is suspended by a line running over a pulley at least 3 meter above the top of the casing. The plunger is lowered in steps of 3 meter and deviations of the line from the centre of the casing are observed. The drift at any depth is given by the deviation multiplied by the length of the line and divided by the height of the pulley above top of well casing.

If the eccentricity of a bore is seen to be more than that permitted, it can be corrected by loosening earth on one side of the pipe and forcing the pipe back by applying jacks on the other side. If the hole is badly eccentric, it may have to be rebored.

2.1.7 Well Development

Tubewells are developed to increase their specific capacity, prevent sanding and obtain maximum economic well life. Development means stabilization of the wells of a well adjacent to the sereen by a process which removes fine particles from the formation immediately surrounding the well screen, leaving coarser particles to contact and surround the screen. The basic principle in the development operation is to cause reversals of flow through the screen openings so that formation particles are loosened, the fines are drawn out, and the remaining coarser particles are rearranged. Development is necessary in all gravel packed wells and other screened wells except when the screen is formed of fine wire mesh or coir or other closely knit filters located in a highly permeable formation.

Development of wells bring the following benificial results :

(a) Corrects any damage to or clogging of the water bearing formation which occurs as a side effect from drilling. Every method of drilling plugs the pores of the water-bearing formation around the bore hole to some extent. In the direct rotary method, where drilling mud is used, a thin skin of relatively impervious material is plastered on the wall of the borehole and seals the same. In reverse circulation drilling water is lost into the formation due to excess fluid pressure that must be maintained in order to keep the hole open. In this process the silts, clays and fine sandy material picked up by the drilling water from the formation are deposited on the walls of the hole. Though this material is comparatively easier to remove than the mud cake formed in the rotary method, it has nevertheless to be completely removed. In case of drilling by pipe driving, a reduction of porosity is caused in the surrounding aquifer due to compaction and vibrations. The surrounding aquifer has therefore to be loosened.

(b) Increases the porosity and permeability of the water bearing formation in the vicinity of the well. Development pulls out and removes finer material from the aquifer thereby cleaning out, opening up and enlarging passages in the vicinity of the well screen so that water can enter the well more freely through the developed zone. This zone is coarsest at the screen or envelope surface and grades gradually back to the original aquifer material. The thickness of the developed zone, may vary from a few centimeters to a few decimeters. The efficiency of development for increasing the permeability of the surrounding aquifer is better achieved when the aquifer is non-uniform.

(c) Stabilizes the sand formation around a screened well so that the well will yield water free of sand. In a zone just outside the hole, development removes all particles smaller than the screen slot size and only the coarsest material is left in place. The effect of development is progressively diminished farther away and the aquifer material progressively grades back to the original form of the water bearing stratum. By creating this succession of graded zones, the formation is stabilized so that no further sand movement would take place. In case of gravel packed wells all particles which can pass through the pores of gravel pack are removed. It has been observed that fine particles resist movement due to the characteristic mechanism of bridging of the pores. They do not move from their position even on increasing the velocity of flow through the aquifer by over pumping.

Development creates an alternating movement of water from the well into the aquifer and back to break up bridges of fine particles in pores between larger particles. The loose particles are then transported into the well.

Development should be started slowly and gently and as development progresses the energy should be increased in steps to the full capacity of the equipment. Development can be started at the top of the screen and worked down or started at the bottom of the screen and worked up. Some advocate the use of the former procedure, particularly in the case of development by a surge block, probably in order to minimise the possibility of material coming in above the surge block, which may result in 'sand locking' of the block. However, the upper layers compacted as a result of development may have a tendency to bridging and cavities may form around the screen when the lower formations are being developed. By starting development at the bottom of the screen the compaction takes place as work progresses upwards so that the overlying material can move down wards without much possibility of bridging and should a bridge develop, the development action would usually break it up.

The methods commonly employed for well development are jetting, pumping, surging, use of compressed air, and use of dispersing agents (chemicals).

CHAPTER 3

DATA COLLECTION AND PRESENTATION

Availability of relevant data plays a very important role in any study such as one undertaken. It has been found that it is not a very easy job to collect the appropriate data and information which are required to evaluate the performance of the tubewells in the project area. For this, satisfactory progress could not be achieved in time. In fact no information regarding the grain size distribution of aquifer and packing materials of the wells in the existing project was available. The probable reasons of early failure of the defunct wells of the existing project could not therefore be identified on the basis of proper data. The reasons of failure has however been tried to be explained on the basis of data available relating to the tubewells of the new project. These data have been collected mainly from the offices of BWDB at Dhaka and Thakurgaon. Data have also been collected from various other sources such as the offices of the consultants and contractors involved in the project.

Data for specific capacities of the tubwells of the existing project just after their installation were collected from the office of the Director, Groundwater Data Processing and Research Circle, BWDB, Sir McDonald & Partners Ltd. and C.K.C. It was found that the data received from BWDB and C.K.C.

were comparable while those received from McDonald and Partners Ltd. were quite different. Under such circumstances the data obtained from Groundwater Data Processing and Research Circle and from C.K.C. were used in the study.

The following data were collected from the sources as mentioned earlier:

i. The location map of the existing and the new project of deep tubewells.

ii. The design and construction procedures of deep tubewells used for the rehabilitated wells and the wells in the new project.

iii. The recorded lithology of aquifer at different tubewell sites.

iv. The sieve analysis data of finest layers where strainers have been provided at different sites in the new project.

v. The sieve analysis data of gravel packing materials as used at different sites of the new project.

vi. The characteristic features of the well components such as strainer, Upper Well Casing (UWC), Lower Well Casing (LWC) etc. of the tubwells of the existing, the rehabilitated and the new project.

vii. The total length and diameter of boring, blind pipe, housing pipe and of strainers of all the existing tubwells, some of the rehabilitated wells of the existing project and some wells under the new project.

viii. Informations regarding static water level, specific capacity and discharge as observed in different wells of the existing project just after their installation i.e. in the year 1962 and 1964 and also for the period 1983-'84 along with their present status.

ix. Pumping test data of some production wells, test wells and observation wells.

The existing tubewell project and the new tubewell project lie approximately between 88°10' to 88°40' eastern longitude and 25°45' to 26°20' northern latitude and is situated in the north-west corner of Bangladesh (Fig. 3.1). Groundwater is the main source of irrigation in this part of the country. The existing project was planned to irrigate the high-lands and particularly the areas which were never subjected to flooding. Before implementation of the existing project in the study area only one crop in a year was produced depending on the monsoon water. The existing project was planned to irrigate 86,000 acres of land for producing three crops in a year. The new project in the same region has been planned to irrigate about 1,07,740 acres of land(13).

To study the performance of the deep tubewells and the aquifer characteristics of the Thakurgaon project area, the related informations and data were collected from the concerned offices and were analysed. A comparison of tubewell efficiency regarding the specific capacities were also included in the present study.

The drilling of wells in the existing project area started in the year 1962 and during the period 1962 to 1964, 381 wells were drilled and constructed to depths varying from 210 feet to 355 feet using two types of brass screens namely Hagusta (factory made gravel packed with about 1 inch thick cemented around the casing) and Nold (bridge-slotted steel pipe) types. The length of the screens varied from 98.4 feet to 155.8 feet although most of them were about 130 feet long with a diameter of 10 inches. The pump chambers were 14 inches in diameter and about 84.3 feet deep. During the year 1979-1980 some of the wells drilled in 1962-'64 were rehabilitated having a reduced well depth of 171 feet to 267 feet. In the rehabilitated well wire-wound strainers of stainless steel having 10 inch in daimeter were used. Depth of pump chambers was also reduced to a length ranging from 71 feet to 80 feet with their diameter same as before. As per data collected, the wells in the new project area are being drilled upto a depth of 171 feet to 267 feet which is the same as those of rehabilitated wells. These wells have wire-wound stainless steel strainers having 8 inch diameter and length mostly of 80 feet. At present the project authority are using a standard and more or less fixed design parameters and construction and development procedures for tubewells in the project. A brief information about design parameters and construction and development procedure is given below:

Design Parameters:

The design parameters for the deep tubewells of the new project and for the rehabilitated tubewells of the existin project are as follows as per CKC's design.

i.	Diameter of boreholes	= 20 inch.
ii.	Diameter of housing pipes	= 14 inch.
iii.	Diameter of blind pipes	= 8 inch.
iv.	Diameter of strainers	= 8 inch.
v.	Slot opening	= 40/1000 inch.
vi.	Strainer length	= 60 feet for wells having a capacity of 2 cusecs.
		= 90 feet for wells having a capacity of 3 cusecs.
vii.	Screen open area	= 24 square inches (+ 10%) per foot run of the strainer.
viii.	Material of housing pipes	= Mild steel.
ix.	Material of blind pipes	= Mild steel.
x.	Material of strainers	= Stainless steel.
xi.	Thickness of the gravel envelope	= 7 inches.

xii. Gradation of gravel pack material:

Standard sieve Number	Percent by weight retained by the screen
5	1
10	20-30
18	95

Tubewell Construction:

The wells are to be drilled by reverse circulation rotary method. The drilling shall be carried out in one continuous operation. During the drilling operation and until the packing of gravel pack material is completed, the concerned contractor is instructed to maintain the circulation of water at an adequate head over the static water level (SWL) and shall take such other precautions as are necessary to prevent caving or collapse of the borehole.

The borehole shall be drilled to a uniform diameter of 20 inch and shall be sufficiently straight and plumb to enable the assembled tubewell components to hang freely throughout the full length of the borehole. On the basis of the borehole log and sieve analyses the Engineer will instruct the Contractor about the lengths of upper and lower well casing, the length of the screen to be inserted and the setting of each section of casing and screen in the tubweell. The casing and the screen components shall be joined by the electric arc welding method using neutral couplings between stainless steel/mild steel sections. The end of each component section shall be suitably beveled and the weld deposited in accordance with adjacent section welded so that alignment is within the allowable limits. All welded joints shall have atleast equal strength of the component material. The contractor shall supply and install centralizers consisting of four opposing mild steel bands attached to the assembled components at an interval of 30 feet throughout the full length of the tubewell components or as directed by the Engineer. The effective diameter of the centralizers shall be 2 inch less than the nominal diameter of the borehole along the lower well casing and screened section. A bail plug 5 feet long and made of the same material as the 8 inches blind pipe having its bottom end securely sealed is installed at the bottom of the well.

The contractor shall make a record of the construction of each tubewell in an approved form and shall submit such records to the Engineer following completion of the tubewell.

Before placing the gravel pack material the full length of assembled tubewell components must hang freely in the borehole. The Contractor shall install the UWC so that the deviation of its axis from the vertical does not exceed 2 inches at any point between the top of the UWC and the top of the reducer fitting. Gravels are placed immediately after the completion of casing installation.

Well Development

The Contractor shall develop each tubewell first by high velocity water jetting and secondly by pumping. Development will not be deemed to be complete until the water discharged at 1.5 times the design capacity of the tubewell is clear and free of sand. The tubewell shall be cleaned to the bottom of the bail sump by using the suction type bailer between successive operations in the development process. The high velocity water jetting tool shall discharge at a rate of 100 mps horizontally from four opposing nozzles. Jetting will proceed throughout each section of screen beginning at the lower most and proceeding to the upper most section. Discharge shall be maintained from the tubewell during the jetting operation by means of a suction lift pump capable of pumping at a rate of not less than 500 gpm from a level of 25 feet. The second stage of development shall include pumping at a slowly increasing rate until 150% of the design capacity of the tubewell is reached. Intermittent surging and backwashing are also part of the pumping development procedure. The rated capacity or design discharge of each tubewell are then determined by the Engineer-in-Charge.

CHAPTER 4

DATA ANALYSIS, RESULTS AND DISCUSSIONS

4.1 General

Due to nonavailability of any soil report of the study area other than those carried out under test boring programme during 1981-'82, it has not been possible to have a detail analysis of local aquifer material. Yet attempts have been taken with such limited numbers of borehole data to have a guide line for the design of screen slot openings and gravel pack material by Johnson's method. This method as per comments of various groundwater experts is the most satisfactory method for efficient design of tubewells with gravel packing.

The design has then been compared with those made by C.K.C., the consultant of BWDB for Tubewell Project, North-Bangladesh. For comparison of design parameters three different sets of design parameters have been found based on D_{10}, D_{40}, D_{50}, D_{90} of aquifer material of entire project area, D_{10}, D_{40}, D_{50}, D_{90} of individual borehole and D_{10}, D_{40}, D_{50}, D_{90} of the finest layer in a individual borehole. Design parameters based on D_{10}, D_{40}, D_{50}, D_{90} of the finest layer of aquifer material of four different installed tubewells have also been determined and compared. The performance of the existing wells have also been discussed in light of the well design parameters calculated since the existing wells as well as the wells of the new project are in the same region.

4.2 Rehabilitated Wells and the Wells Under New Project

4.2.1 Comparison of Design Parameters

4.2.1.1 Screen Length

As per Johnson's design principle, the screen length of tubewells are found to be 110 feet and 75 feet for wells having capacities 3 cfs and 2 cfs respectively whereas as per C.K.C.'s design these lengths are 90 feet and 60 feet respectively. In selecting the screen length the optimum entrance velocity has been considered to be 6 fpm as calculated from the limited data available for determining the co-efficient of permeability of the aquifer material for the project area (Table 4.5). The same value has also been suggested by Johnson and most other ground water specialists. The optimum entrance velocity has been determined by C.K.C. to be as 0.032 mps. i.e. 6.30 fpm, (12) which is very close to that considered in the study. The consideration for accounting the blockage of slots by grains has however been quite different. In the present study the blockage has been considered 50% as per opinion by most of the experts whereas C.K.C. considered it as 35% and mainly because of this there has been a quite variation of screen length. As per C.K.C.'s consideration a screen length of 90 feet and 60 feet respectively have been suggested for 3 cfs and 2 cfs capacity wells. In the field however a screen length of 80 feet are being provided in most of the 3 cfs capacity wells.

Figure 4.1 shows the range of the specific capacities of Thakurgaon Project wells, as measured just after installation and plotted on the basis of specific capacity per foot of screen actually installed. The three curves relate to unit specific capacities for samples of 131 original Hagusta type screens, 237 original Nold type screens and 21 wire-wound screens installed as rehabilitated wells in the same study area. The figure shows a significant difference in unit specific capacities among the three types. The Hagusta type has a median unit specific capacity of 0.313 gpm/ft^2 while the Nold and the wire-wound screens have median specific capacities of 0.486 gpm/ft^2 and 0.852 gpm/ft^2 respectively. Therefore, to achieve the same drawdown of about 30 feet and hence the same pumping costs for a discharge of 3 cfs, the respective screen lengths would have to be 143 feet, 92 feet and 53 feet.

Again, since each piece of strainer is of 20 feet length, the layers which are less than 20 feet in length but feasible for screening cannot be screened. For this difficulty, wells are installed to deeper depth for getting layers greater than 20 feet for screening. This causes substantial increase in the cost of well and well sinking. To avoid such increase in cost, screens of length 10 feet are more preferable for economy of well construction. Now, since the wells are sunk with strainers of 80 feet i.e shorter than that required as per design consideration, the yield may decrease in course of time. Figure 4.1 -

shows good performance with strainer of 80 feet length but under this condition entrance velocity will be much higher than the standard entrance velocity. For this reason it is better to use strainers of 110-feet length for 3 cfs. capacity wells in the new project and the rehabilitated wells of the study area to ensure minimum entrance velocity so as to keep the well loss at a minimum value which will thus provide a smooth and efficient ~~well~~ with a longer life.

4.2.1.2 Slot Opening and Gravel Pack

There is no provision for grain size analysis of aquifer material before the fixture of the wells are installed in the field. The suitable aquifer to be screened are selected on the basis of eye estimation and experience. Because of this procedure no sieve analysis data or soil sample of the surrounding aquifer material of the existing wells and the rehabilitated wells were found. For installing the screens of the tubewells of the new project, the selection of aquifer layer to be screened is not entirely on the basis of eye estimation. The sieve analysis of the finest layer was performed whenever it was felt that eye estimation is not enough to form an idea about grain size. Some of these sieve analysis data have been collected and are shown in Fig. 4.2 to Fig. 4.5. The grain size analysis of gravel packing materials used for the wells in the new project were also collected as shown in Fig. 4.2. The grain size analysis of the gravel packing materials for the existing project were not available but from the information available it was found that their size range was from 1 mm. to 4 mm. This size range is approximately the same as that now in use in the new project. With the limited information regarding aquifer material and packing material analysis were made to see how the actual design fit with the result obtained from analyses. In light of this analysis the probable reasons of early failure of the defunct wells in the existing project and the rehabilitated wells were also pointed out.

The number of sites explored under the Test Boring Programme by the Bangladesh Water Development Board in 1983 does not permit to have a sufficiently detailed analysis of the aquifer material of the project area so as to specify slot opening and gravel pack design for each individual well. But C.K.C. has given a slot size and a gravel pack design based on an average condition of all borelog data.

The slot size of 0.75 mm. (30/1000 inch) as designed by C.K.C., the consultant of BWDB for Tubewell Project, North Bangladesh is based on the mean D_{10}, D_{40}, D_{50}, D_{90}, D_{70} size of aquifer material of all the boreholes of the Test Boring Programme in the entire area and is found to be much conservative in comparison with the value of 0.965 mm. (40/1000 inch) obtained by Johnson's method on the basis of same data. It may be pointed out here that screens having slot openings of 1.0 mm. (40/1000 inch) are actually being used in the new project as per recommendation of CKC.

It is necessary to mention here that the slot size and the gravel pack material need to be designed considering the gradation of the finest layer screened for an individual tubewell. From this view point it is found that though the slot opening as per design by CKC is conservative when compared with the slot opening obtained by Johnson method of design on the basis of same data yet it is relatively bigger as compared to the slot opening obtained on the basis of grain size distribution of the finest layer screened. For example Table 4.1 shows that slot opening obtained by Johnson's design principle vary quite appreciably depending on how grain size distribution data is used in the design. The table shows clearly that the slot opening obtained on the basis of mean size of all the layers of a borehole is quite bigger in all cases than that obtained on the basis of grain size distribution of the finest layer. In addition, the slot opening obtained on the basis of mean size of all the layers of different boreholes is also bigger than that obtained on the basis of gradation of finest layer. On the basis of grain size distribution of the finest layers on different boreholes the slot openings have been found to vary from 0.542 mm. (20/1000 inch) to 0.84 mm. (30/1000 inch) which are quite smaller than that actually used in the field.

Again, the gravel pack material size as per CKC's design ranges from 0.59 mm to 4.76 mm. Using Johnson's method the size ranges have been found to be 0.475 mm. to 3.55 mm. as shown in Table 4.1. Hence, Johnson's design principle gives relatively smaller gravel pack materials. Again if the finest layer of aquifer material screened is considered for the design of gravel packs, it is seen from the table that much smaller gravels are required. The size of gravel pack under this condition has been found to vary from 0.254 mm. to 2.10 mm. based on certain borehole data to as high as 0.44 mm to 2.39 mm. based on other similar data.

4.2.2 Probable Problems as per C.K.C. Design

The following discussion shows how the use of slot opening and gravel packs as recommended by CKC will affect the functioning of tubewells drilled in various locations with wide variations in aquifer material screened. As per CKC's design slot opening and gravel pack material size is based on some average characteristics of aquifer materials in the project area. Design based on this will probably be safe as long as the aquifer materials screened will be more or less of similar size range and distribution. Comparison of slot openings based on gradation of finest layers of different boreholes (Table 4.1) with slot opening based on average size distribution of aquifer material as used in CKC design clearly shows that in all cases slot opening-based on finest layer is much smaller than that based on average aquifer material consideration. It is true that the finest layer will not be screened in many cases as screens are not provided continuously for avoiding very fine layers. Even then chances are there that the slot size as recommended will be bigger than that required based on the finest layer screened. Study of tubewell characteristics of the new project has shown such examples and are discussed in the next article. Similarly, the comparison of the size of gravel packing materials based on gradation of finest layers of different borehole (Table 4.1) with those based on mean size distribution as used in CKC's design shows that in all cases the size of gravel packing materials based on finest layer are much smaller than those based on average aquifer material consideration. Under such circumstances there are chances of excessive sand pumping firstly from the finer layers which are screened. Due to such sand pumping more and more sand particles will be removed from these finer layers, and as a result the aquifer material and specially the gravel pack materials above this layer will be displaced from their position resulting in failure of the functioning of entire surrounding gravel pack material. Thus ultimately failure of the well will take place due to excessive sand pumping or sharp fall in efficiency of the well. It may be mentioned here that one of the rehabilitated well (DTW No.126) have already failed due to excessive sand pumping only after three years of rehabilitation. As per discussion above it will be quite logical to put forward the argument that most probably this failure was due to the use of relatively larger size of slot opening and gravel pack material.

4.2.3 Probable Problems which May Arise in the Newly Installed Wells of the Study-Area

Installation of 610 deep tubewells in the study area under the new project entitled 'Tubewell Project (North Bangladesh)' are now in progress. The procedure followed in selecting the aquifers to be screened for the tubewells are based mainly on the eye-estimation and experience of the person giving the decision. In most of the cases no analysis of aquifer material was made and fixtures were placed hurriedly to avoid cavity. Analysis of the relatively finer layers were however made in case of few tubewells. Four such tubewells have been studied and their future performance is discussed below:

From the fixture of DTW No. T-281 (Fig. 4.6) it is seen that strainers are installed at depths 97.02 feet to 135.41 feet and 159.87 feet to 178.89 feet. Most of the aquifers screened were selected on the basis of eye estimation and experience. The aquifer materials in depths 104 feet to 110 feet, 125 feet to 128 feet and 131 feet to 134 feet were however collected and sieve analysis was done as the materials in those layers were quite fine. C_u value for the aquifer material in depth

104 feet to 106 feet was found to be less than 2.00 and D_{70} size of aquifer material was found to be 0.210 mm. Based on this grain size characteristics the gravel pack design parameters and slot opening as shown in Fig. 4.2 have been found by Johnson's method. The slot opening size and the salient features of gravel pack design are also shown below:

D_{90} = 0.715 mm., D_{70} = 0.815 mm., D_{50}= 0.94 mm., D_{40} = 1.00 mm., D_{10} = 1.25 mm.; the slot opening=28/1000 inch. The installed tubewell have however a slot opening of 40/1000 inch and gravel pack material of following characteristics:

D_{90} = 1.18 mm., D_{70} = 1.68 mm., D_{50} = 2.26 mm., D_{40} = 2.60 mm., D_{10} = 3.77 mm. (Table 4.2).

From a comparison of the above data it is apparent that the slot opening used is relatively big for the aquifer materials at depth 104 feeteto 106 feet. Furthermore, the size of gravels used are also much larger than the designed gravel size for that layer. Hence, the use of such large slot opening and larger gravel pack materials, may cause the finer materials of the formation to be pumped out with water forming cavities at the said depth. As a result turbulance pockets might be created which might increase the sand movement with time. Such movement of the formation material will disturb the gravel pack material resulting in more sand pumping and sharp reduction in the functioning of the tubewell with ultimate failure.

In DTW No. BG-12, strainers are fixed at depths 93 feet to 131 feet and 233 feet to 263 feet (Fig. 4.7). The finest layer screened is at depth 116 feet to 125 feet. Soil sample was collected from this layer and sieve analysis was done. The C_u value was found to be about 2.00 and D_{70} value 0.337 mm. For this aquifer condition the design slot opening comes out to be 40/1000 inch and the gravel pack should have the following characteristics as shown in Fig. 4.3.

D_{90} = 1.05 mm., D_{70}= 1.35 mm., D_{50} = 1.71 mm., D_{40} = 1.93 mm., D_{10} = 2.80 mm.

The slot opening and the gravel pack material used in this case is more or less of the same size and gradation as used in DTW No. T-281 and also shown in Table 4.2. From a comparison of the various parameters shown above and in Table 4.2, it is apparent that the slot size used is exactly the same as the designed slot size, but the size of gravels used is much larger than the designed gravel size. This may cause the finer materials of the formation reach the strainer through the voids of the large gravels and might block the slot openings in course of time resulting in a decrease in the capacity of the well. Excessive sand pumping may also take place resulting in quick failure. Failure procedure will however also depend on the well development.

In DTW No. T-62, strainers are placed at depths 103.02 feet to 141.07 feet and 205.39 feet to 224.42 feet (Fig.4.8).

The layers screened at depth 140 feet to 143 feet and 206 feet to 215 feet are relatively fine and hence soil samples were collected from these layers and sieve analysis was done. The C_u value was found to be 2.00 and D_{70} value 0.35 mm. For this aquifer material the design slot opening comes out to be 42/1000 inch and the gravel pack design should have the following characteristics and as shown in Fig. 4.4.

D_{90} = 1.70 mm., D_{70} = 1.40 mm., D_{50} = 1.84 mm., D_{40} = 2.10 mm., D_{10} = 3.20 mm.

The slot opening and the gravel pack material used in this case are more or less of the same size and gradation as used in DTW No. T-281 (Table: 4.2). It is apparent from the above data that slot size used are almost equal to the designed slot- size. Furthermore, the gravel pack material used also satisfy the required design size. DTW No. T-62 as constructed, therefore, can be said to fit very well with the designed parameters. Hence, this well is supposed to run better than DTW No. T-281 and DTW No. BG-12 and it should run well throughout its anticipated life provided that there has been proper well development.

3. DTW at Plot No. 6595 has its strainers installed at depths 170.99 feet to 209.33 feet and 233.77 feet to 252.79 feet (Fig. 4.9). Formation samples from the layers at depth 179 feet to 182 feet was found relatively fine. The soil samples from these relatively finer layers were collected and sieve analysis was done. From the analysis C_u value was

found less than 2.00 and D_{70} value about 0.212 mm. As per this grain size distribution a gravel pack was designed having size distribution as shown in Fig. 4.5. From Fig. 4.5 it is evident that the gravel should have the following characteristics :

D_{90} = 0.76 mm., D_{70} = 0.85 mm., D_{50} = 0.96 mm.

D_{40} = 1.02 mm., D_{10} = 1.23 mm. ; the slot opening = 30/1000 inch. The gravel pack material and the slot opening used in this case is also same as those used in other wells. A comparison of the required gravel pack material and slot opening as per design principles used in this study for well No. T - 281 and the well at plot No.6595 shows that in both cases - the slot opening used is bigger than that required and gravel pack material is relatively of bigger size. Hence, the functioning of the tube-well at Plot No.6595 should be more or less same as DTW No. T-281 as discussed before.

4.2.4 Rehabilitation of Deep Tubewells Suggested by BRRI

A low cost technique for rehabilitation of deep tube-wells was developed and tested in BRRI. It was suggested there to install locally made or Indian made 15 cm. dia PVC strainers inside the existing 25 cm. dia Well. The gap between the PVC strainers and the existing well is to be packed with gravels. Typical constructional details of deep tubewells to be rehabilitate under such technique are shown in Figure 4-17. BRRI advocates that after proper development such a rehabilitated well gives about 80% of discharge of the original well and the cost involvement is only 1/10th of the cost of a new tubewell[40].

This technique was used to rehabilitate the deep tubewell No. 126, under a pilot study undertaken in 1984 and the well has since then been in operation and no further problem has been reported[40]. It may be mentioned here that the same tubewell was rehabilitated in 1979 by the method suggested by CKC and failed after three years of rehabilitation.

The technique suggested by BRRI seems to be an attracting one for rehabilitating the defunct wells, because this method will ensure about 80% of discharge of the original well with very little cost. In the field, however it is found that the defunct wells are being rehabilitated by the method suggested by CKC. With reference to the BRRI method the Geologist, PMEU of the Thakurgaon Tubewell Project, has remarked that the technique suggested by BRRI were not followed as the PVC strainers were less durable and that the yield will decrease to a large extent that of the original well in course of time.

4.3 Wells in the Existing Project.

4.3.1. Wells with Hagusta Type of Strainers

The 'Hagusta' type of strainers have factory made gravel packing, about 1 inch thick, cemented around the casing having slot openings 1 mm. to 2 mm. (40/1000 inch to 80/1000 inch)[1] Because of such cemented packing of gravels the effective slot opening and percent open area are much reduced and hence a relatively longer screen length as compared to screen length in the new project is needed.

Fig. 4.1 shows that the Hagusta type of wells has an average unit specific capacity of 0.313 gpm/ft^2, while the Nold type and the wire-wound type have average specific capacities of 0.486 gpm/ft^2 and 0.852 gpm/ft^2 respectively. Therefore, under a constant drawdown of about 30 feet and hence at the same pumping costs and for a discharge of 3 cfs., the respective screen lengths for the three types of screens would have to be 143 feet, 92 feet and 53 feet. Now, the screen length of 143 feet required for a 3 cfs capacity well with Hagusta type of strainer is quite-large as compared to the screen length necessary in case of Nold type used in the existing project and wire-wound type of strainers used in the new project. Most of the wells with Hagusta type of strainers in the existing project have however a screen ranging from 130 feet to 140 feet in length (Table 3.1). It can therefore be said that the strainer length as provided are almost the same as those required in this regard. As the strainers are provided with prepacked gravel packing by the manufacturer, the possibility of sand pumping specially due to failure of gravel packing surrounding the strainer is negligible. Secondly, because of prepacked gravel packing chance of strainer blockage is relatively less and hence the entrance velocity will not increase. Thus, the wells with Hagusta type of strainers are supposed to provide a better performance in all respect.

The pumping capacity of the pumps used for the wells are 4.7 cfs. although the designed well capacity is 3 cfs . Because of this higher capacity of pump the well discharge has been found more than design discharge. But as the Hagusta type of strainers are pre-packed as mentioned before there has not been any sand pumping except in one well even though water entered the screens of the wells with relatively higher velocity because of higher pumping rate. The higher rate of pumping may however cause blockage in the packing material resulting in the reduction of well discharge. Failure of wells due to reduction of well discharge has been observed in about thirteen number of wells which is about ten percent of total wells of this type.

As per very recent report about ten more wells have started sand pumping very recently. This may be due to failure of the effectiveness of the prepacked gravel packing whose life has already expired as per specification.

4.3.2 Wells with Nold Type of Strainers

The 'Nold' type of strainers are bridge-slotted steel pipe and installed with gravel packing in the conventional manner. It has already been pointed out that under a constant drawdown of about 30 feet i.e. under same pumping lift as has been considered for other two types, and for a discharge of 3 cfs, a screen length of about 92 feet is required. In the field it is found that most of the screens provided in these wells are of length ranging from 130 feet to 140 feet. The strainer length as provided are therefore much larger than those actually required as per field performance. The gravel size provided have been found to be oversized as per design based on the data available from wells of the new project.

The wells are running with pumps having a capacity of 4.7 cfs. even though the design discharge is 3 cfs. and are discharging more than the design discharge. Because of higher pumping rate and use of oversized gravel packing materials the wells may eventually suffer from sand pumping resulting in well failure. It may be mentioned here that about 75 numbers of wells with this type of strainers have already failed mainly because of excessive sand pumping and 39 others are reported to have started sand puping. The percentage failures of wells with Nold type of strainers are much higher compared to that of Hagusta type of wells. The reason of higher failure rate in nold type of wells as per our discussion seems to be mainly because of lesser effectiveness of gravel packing under higher pumping rate.

4.4 Hydraulic Characteristics of the Aquifer Material of the Study Area

Pumping test data obtained from the study of test wells along with their observation wells and a pumping well with its observation wells, conducted by the Ground Water Circle of BWDB during the year 1976 and 1977, and the production wells, rehabilitated by the Soiltech, Construction firm engaged by BWDB during the year 1980, were used to determine the values of transmissibility, T for the aquifer material at different locations of the study area. The values of coefficient of transmissibility were determined by theis method, Jacob's method and Theis recovery method by using data from the test wells with their observation wells and a production well along with its observation wells. Table 4.4 shows the variation in the values of transmissibility obtained by using these three methods. From the table it is apparent that there is not much variation in T values obtained by different methods in most of the cases. The variation in T values however is quite large from one location to other between the piezometers. Such variations in T values may be due to their differences in distances from the test wells as their differences in depth. This variation of T values should be considered in the design of the tubewell for efficient and economic design.

4.5 Specific Capacity and Well Losses of Some Rehabilitated Wells

Table 4.5 shows well loss values of eight production wells rehabilitated during the year 1979-80. Well loss values depend on many factors such as well design, its installation and development etc. Study of the well loss constants as shown in Table 4.5 shows that during multiple step drawdown test large well development took place in some of the wells as indicated by negative C values, while clogging of the pores adjacent to the screen as indicated by increase in C values also took place in some other wells. This shows that well development was not properly done. Increase of C values may also be due to faulty design of wells. Table also shows that well loss varies from about 2% to about 40% of total drawdown at the well. High percentage of well loss indicates unsatisfactory performance of tubewells. This will generally cause increase in pumping cost. High values of well loss may be due to improper verticality of the well fixtures resulting high friction of flow through the riser. The high values of well loss may also be due to the partial clogging of screen beyond the accepted limit due to insufficient development of the well. Another cause for such high values of well loss may be due to the use of shorter screen length than that required as per design consideration. The use of shorter screen length creates generally an excessive entrance velocity to the well. The well loss values of these wells may increase more with time due to the clogging of screen. Hence, to ensure minimum well loss it is necessary to increase the screen length of the tubewells of the rehabilitated well, as well as of the wells of the new project. Proper development is also an important factor for reducing the well loss. To minimise well loss care should also be taken to keep the well components vertical during construction.

The specific capacity calculated for the already mentioned eight production wells have been found to vary from 55 gpm/feet to 103 gpm/feet (Table 4.5). Generally, higher specific capacity indicates higher coefficient of transmissibility. Table 4.5 also shows a comparison between the values of T and specific capacity. Higher T values are seen corresponding to higher specific capacity values except in one case which may be due to some other unknown reasons.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

From the study of data relating to the tubewells and aquifer characteristics of both the existing and the new project in Thakurgaon area, the following conclusions are drawn:

1. The uniformity coefficient of the aquifer material as found from the sieve analysis of the materials of the finest layers screened for four tubewells in the new project is around 2.00. The analysis of the bore-logs' data of the test boring programme shows a wide variation in the values of uniformity coefficient from one aquifer to another in the same location as well as from one tubewell location to another. This variation of uniformity coefficient should be properly taken care in tubewell design consideration.

2. The maximum and minimum values of effective grain size (D_{50}) of the aquifer material are around 0.93 mm. and 0.20 mm. with most of the values ranging from 0.50 mm. to 0.25 mm.

3. Wire-wound screens are more economical for North Bangladesh conditions than either the Hagusta or Nold screens which require relatively longer screen length.

4. The slot opening size of 40/1000 inch of the wire-wound strainers which are now being used in the new project and in the rehabilitated wells in the existing project may create problem when the screen is placed in finer aquifer having D_{50} less than 0.20 mm.

5. Screen lengths for the tubewells of the new project should be around 110 feet and 80 feet respectively for wells having capacities of 3 cfs. and 2 cfs. for better efficiency and durability.

6. To reduce the cost of well and well sinking, the length of each piece of strainers should be 10 feet and 5 feet instead of 20 feet presently in use.

7. It is necessary to have sieve analysis of the aquifer material to correctly select the aquifer layers to be screened. The present practice of selecting the aquifer layers to be screened from visual observation of the aquifer material may not give good result always.

8. The grain size distribution of the relatively finer layers that are to be screened should be properly determined to fix the slot opening of the screen and the size distribution of gravel pack material.

9. Wells of the existing project with both the Hagusta and Nold type of strainers seems to have correct screen length but the gravels used for Nold type of strainers are oversized.

10. For the use of larger gravels as gravel packing material and higher capacity pumps, wells with Nold type of strainers faced earlier failure due to sand pumping. Wells with Hagusta type of strainers did not face such failure.

11. The gravel pack material recommended by C.K.C. for the wells in the new project and the rehabilitated wells may not be ideal for all places. Different-gravel pack should be used in different places depending upon the size of aquifer material to be screened.

12. The coefficient of transmissibility 'T' of the study area is found to vary from 1.21×10^5 gpd/ft. to 1.43×10^6 gpd/ft.

13. Pumping tests of the production wells of the project area should be done for at least 72 hours. This principle has not been followed in many of the pumping tests.

14. The wide fluctuations in the values of well loss constant 'C' indicates insufficient development of the wells.

15. Lower percentage of well loss values are the indication of better performance of tubewells. This results from proper development and construction of tubewells.

Under such condition the coefficient of transmissibility of the aquifer as well as the specific capacity of pumping wells are found to be higher in comparison to those with higher percentage of well loss values.

16. Multiple step drawdown tests should be done for atleast four steps to get a clear variation in the values of well loss constants.

17. The specific capacities of the wells studied are found to vary within a range of 55 gpm/ft. to 103 gpm/ft. This is based on pumping test data collected just after their installation.

18. The specific capacity is dependent on well loss as well as aquifer loss. The specific capacity of a well extracting water from a relatively more permeable aquifer may be low due to excessive well loss due to faulty construction and insufficient development.

19. Specific capacities of some tubewells have decreased with time. The decrease in specific capacities may be mainly due to improper development of the wells. While in some tubewells they have been found to increase with time indicating further development with time.

5.2 Recommendations for Future Study

The following recommendations are made for future study of the Thakurgaon tubewell project:

1. Similar study in future by using data collected systematically for the new project and rehabilitated wells of the existing project will help to give more specific recommendation. The Project authority may be requested to collect relevant data for this type of study.

2. Laboratory study may be taken upto see how a variation in gravel pack design or a variation in selection of screen slot opening as designed under various condition shown in Table 4.1, affect the performance of a well.

3. Laboratory study may also be taken upto see how a fine layer screened by a slot size as per design of most of the layers screened affect the performance of a well.

4. Laboratory study may also be taken upto see how a higher capacity pump affect the performance of a well.

5. A study may be taken upto observe the effect of withdrawal of ground water on the hydrogeologic condition in the Thakurgaon tubewell project area.

6. A study may also be taken upto observe the effect of mutual interference of tubewells if any for the installation of such a large number of wells under the two projects in the Thakurgaon area.

7. A study may be taken upto predict the rate of natural recharge to asses the quantity of groundwater that may be safely withdrawal from the aquifer system without causing any groundwater mining.

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APPENDICES

APPENDIX - A

SAMPLE CALCULATIONS

SAMPLE CALCULATIONS

Analysis of test pumping data for the production well No. 304

Determination of coefficient of transmissibility (*T*) (from Recovery data) :

From equation, $T = \frac{264Q}{\Delta h'}$ and Fig. 4.11.

$$T = \frac{264 \times 4 \times 449}{2.46}$$

$$= 1.927 \times 10^5 \text{ gpd/ft.}$$

Determination of well loss :

From equation $C = \frac{\Delta s_i/\Delta Q_i - \Delta s_{i-1}/\Delta Q_{i-1}}{\Delta Q_{i-1} + \Delta Q_i}$ and Fig. 4.13

$$C_1 = \frac{6.36/1 - 17.83/3}{1 + 3} = 0.105 \text{ Sec}^2/\text{ft}^5 = 39.86 \text{ sec}^2/\text{mt}^5.$$

$$C_2 = \frac{1.95/0.5 - 6.36/1}{0.5 + 1} = -1.64 \text{ sec}^2/\text{ft}^5 = -622.61 \text{ sec}^2/\text{mt}^5$$

∴ Average C = 39.86 sec^2/mt^5

∴ Well loss for a discharge of 3 cfs.

$$= 0.105 \times (3)^2$$

$$= 0.945 \text{ ft.}$$

Determination of coefficient of transmissibility (T) of Test Well No. 129.

By Theis's method

From equation, $T = \frac{114.6Q}{h_o - h} W(u)$ and Fig. 4.14

$$T = \frac{114.6 \times 1593.95 \times 10}{13.0}$$

$$= 1.405 \times 10^5 \text{ gpd/ft.}$$

By Jacob's method

From equation, $T = \frac{264\ Q}{\Delta s}$ and Fig. 4.15

$$T = \frac{264 \times 1593.95}{2.385}$$

$$= 1.764 \times 10^5 \text{ gpd/ft.}$$

By Theis's Recovery method

From equation, $T = \frac{264\ Q}{\Delta h'}$ and Fig. 4.16

$$T = \frac{264 \times 1593.95}{3.30}$$

$$= 1.28 \times 10^5 \text{ gpd/ft.}$$

Determination of coefficient of permeability (K) and permissible screen entrance velocity (Ve)

For Production (Rehabilitated) Well No.12

From equation, $K = \frac{T}{1.2D}$ and Table 4.5

$$K = \frac{2.148 \times 10^5}{1.2 \times 80.83 \times 3.28 \times 7.48}$$

or, K = 90.26 mt/day

Then, from Table 2.1, For, K = 90.26 mt/day, Ve = 3.21 cm/sec.

Design of Deep tubewells

Determination of screen length (S_L)

From Equation, $S_L = \frac{Q}{7.48 \; A_o Ve}$

For, A_o = 0.165 mt^2/mt = 0.5412 ft^2/ft

Ve = 3 cm/sec = 6 ft/min. with 50% blackage consideration.

& Q = 3 cfs, 2 cfs.

S_L(for 3 cfs) $= \frac{3 \times 449}{7.48 \times 0.5412 \times 0.5 \times 6}$

= 110 ft.

S_L(for 2 cfs) $= \frac{2 \times 449}{7.48 \times 0.5412 \times 0.5 \times 6}$

= 80 ft.

APPENDIX- B

FIGURES

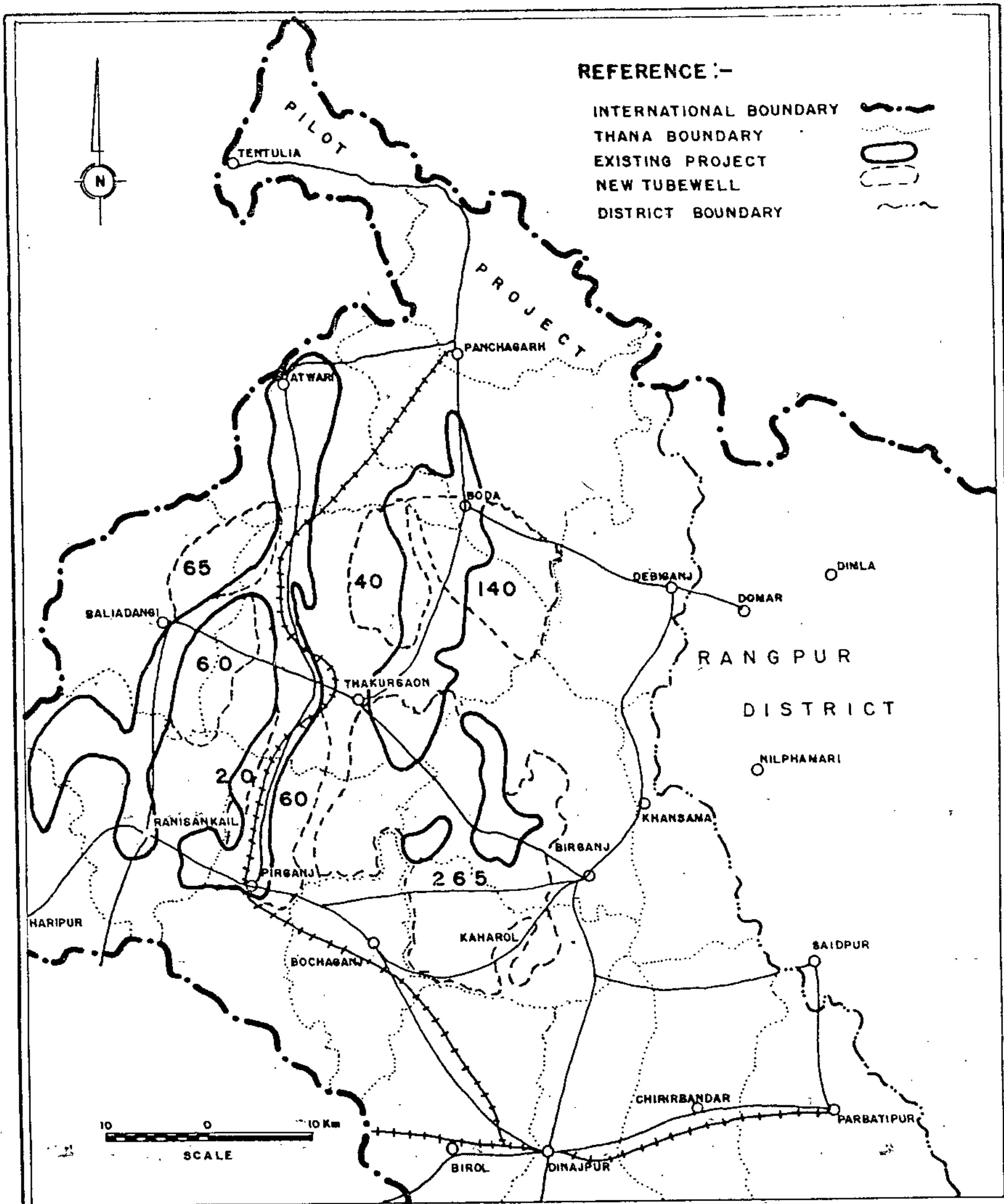


FIG. NO. 3·1 TUBEWELL PROJECT LOCATION MAP.

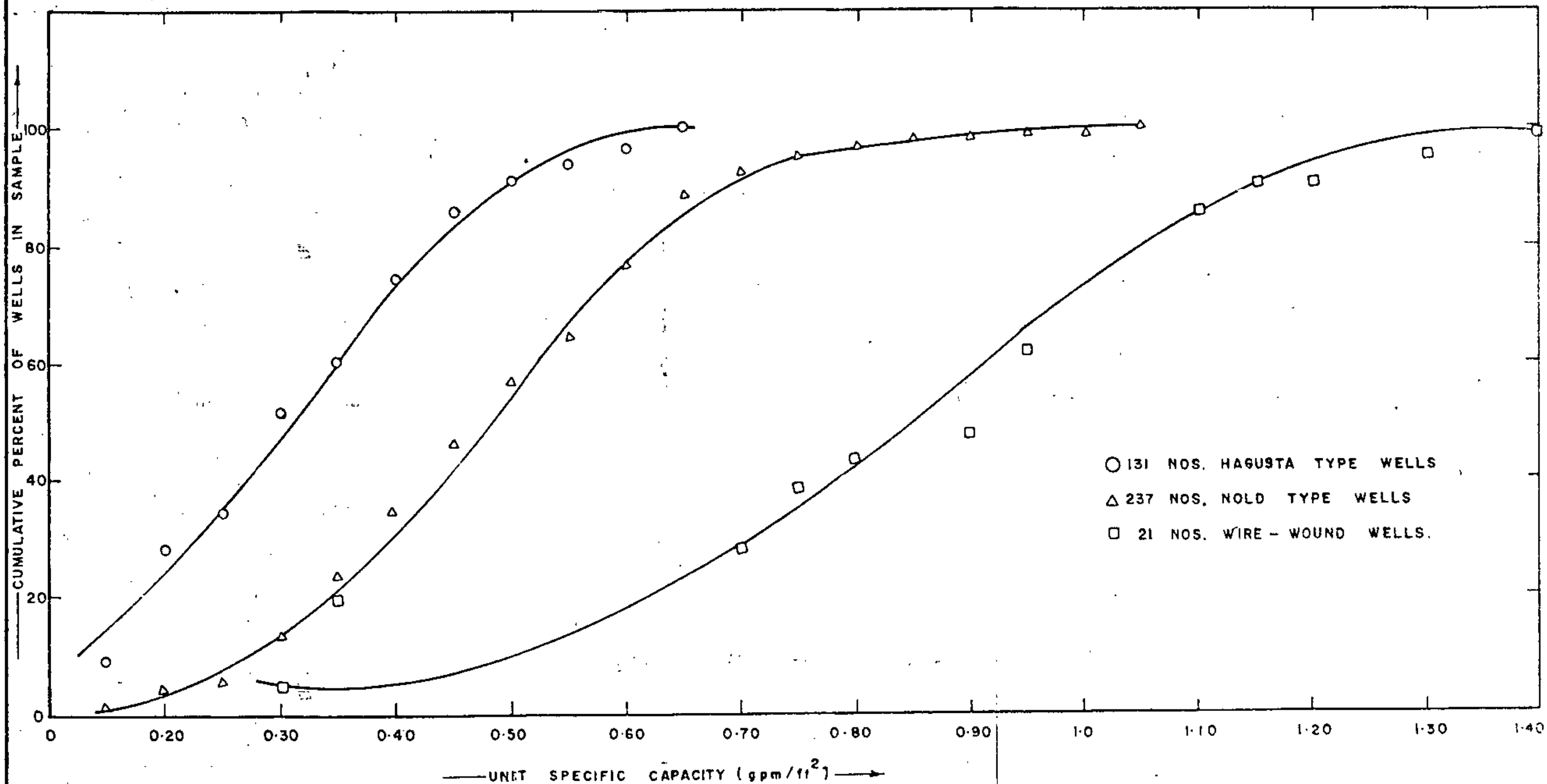


FIG. 4·1 WELL SCREEN PERFORMANCES.

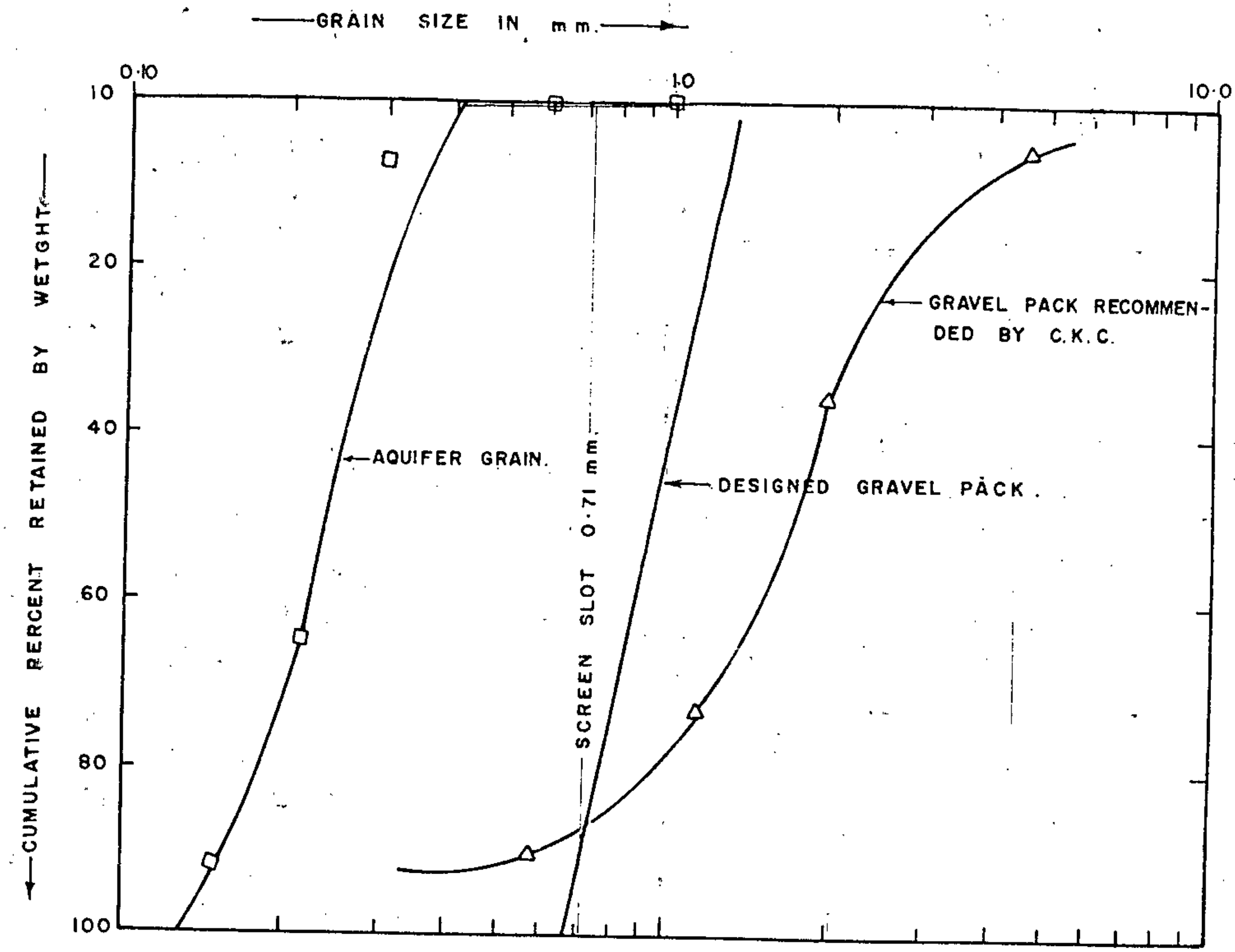


FIG. 4·2 GRAIN SIZE DISTRIBUTION (AT DEPTH 104' TO 107') WITH CORRESPONDING GRAVEL PACK AND SEREEN SLOT DESIGN AT WELL NO. T-281.

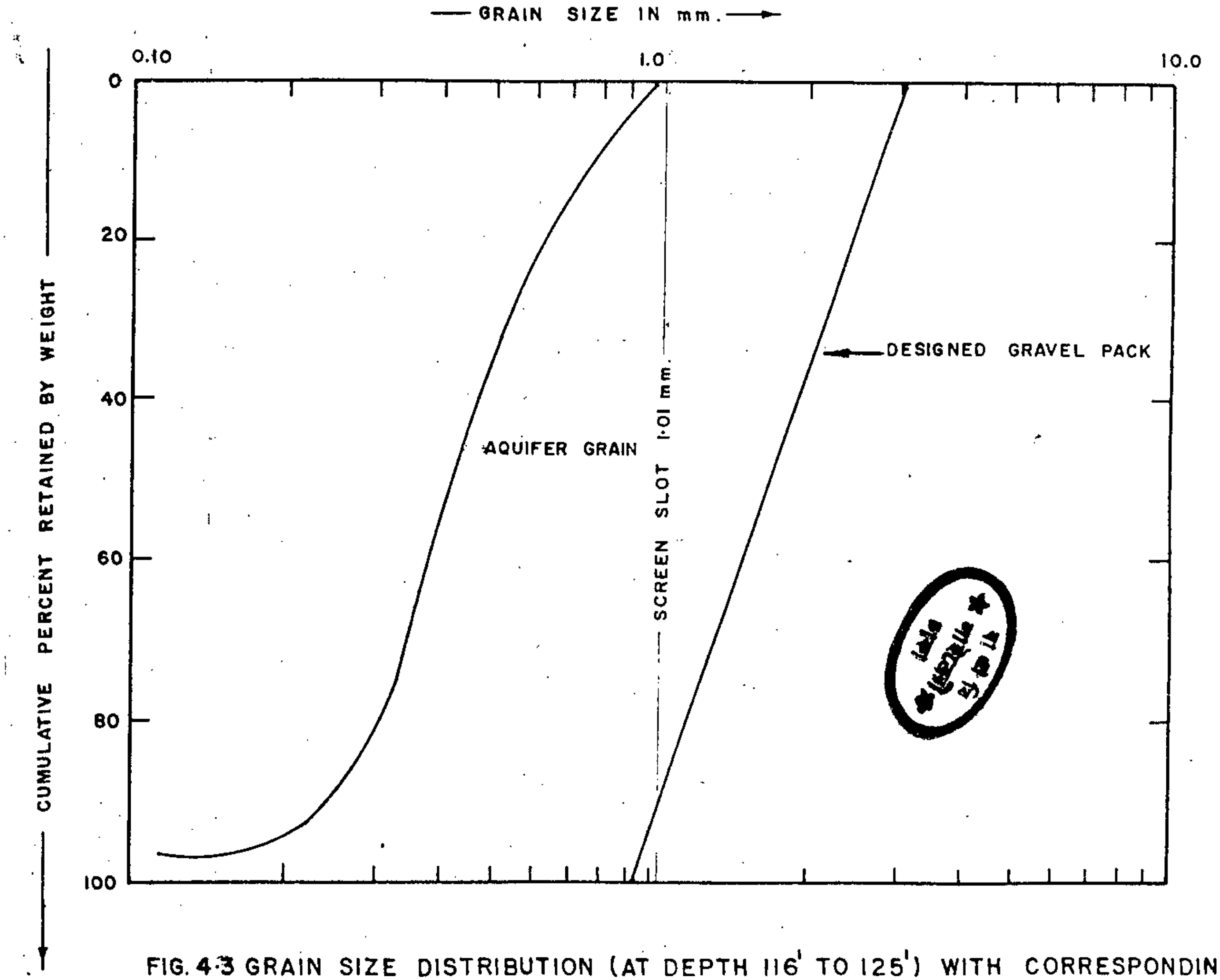


FIG. 4·3 GRAIN SIZE DISTRIBUTION (AT DEPTH 116' TO 125') WITH CORRESPONDING GRAVEL PACK AND SCREEN SLOT DESIGN AT WELL NO. BG-12

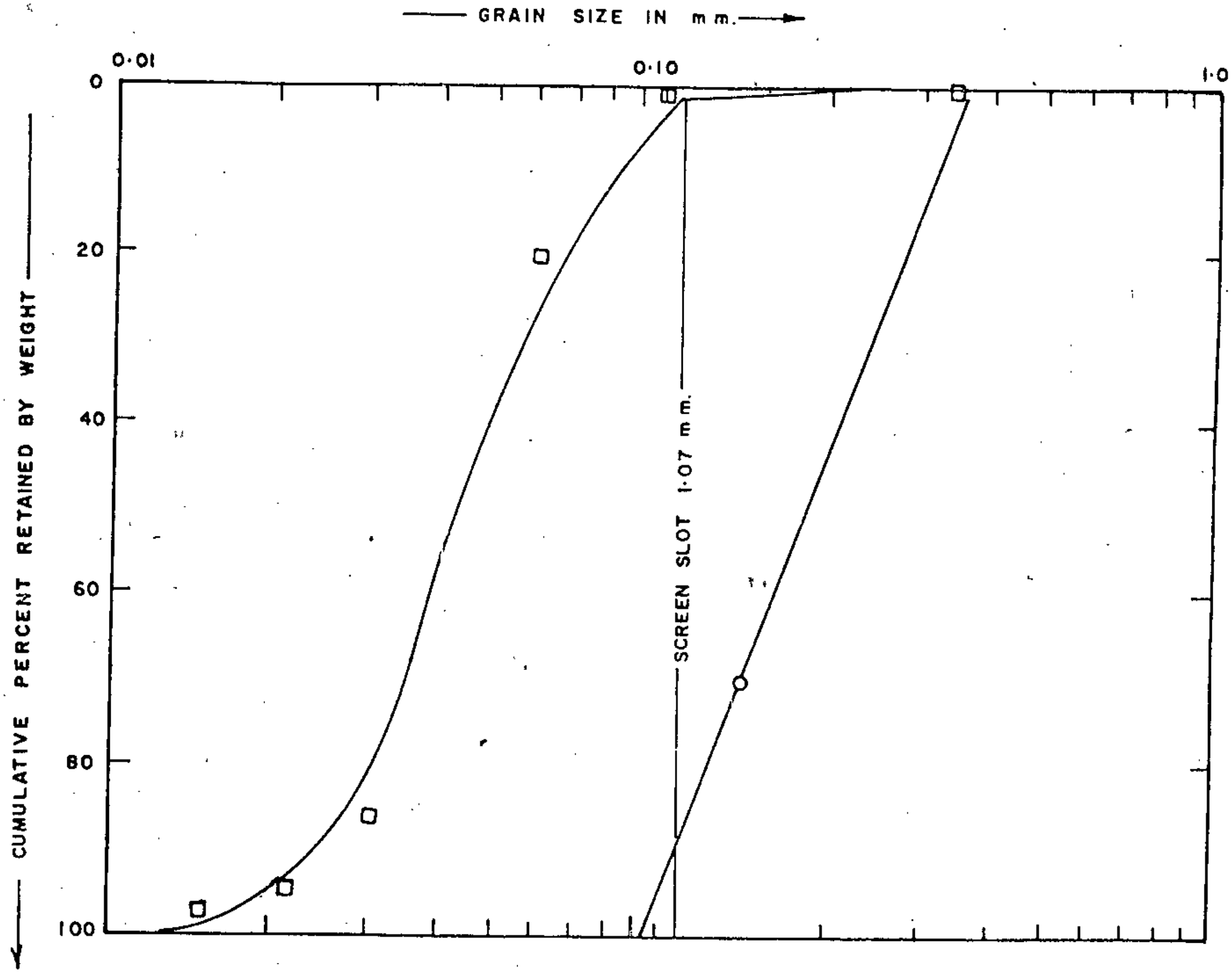


FIG. 4·4 GRAIN SIZE DISTRIBUTION (AT DEPTH 206' TO 215') WITH CORRESPONDING GRAVEL PACK AND SCREEN SLOT DESIGN AT WELL NO. T-62

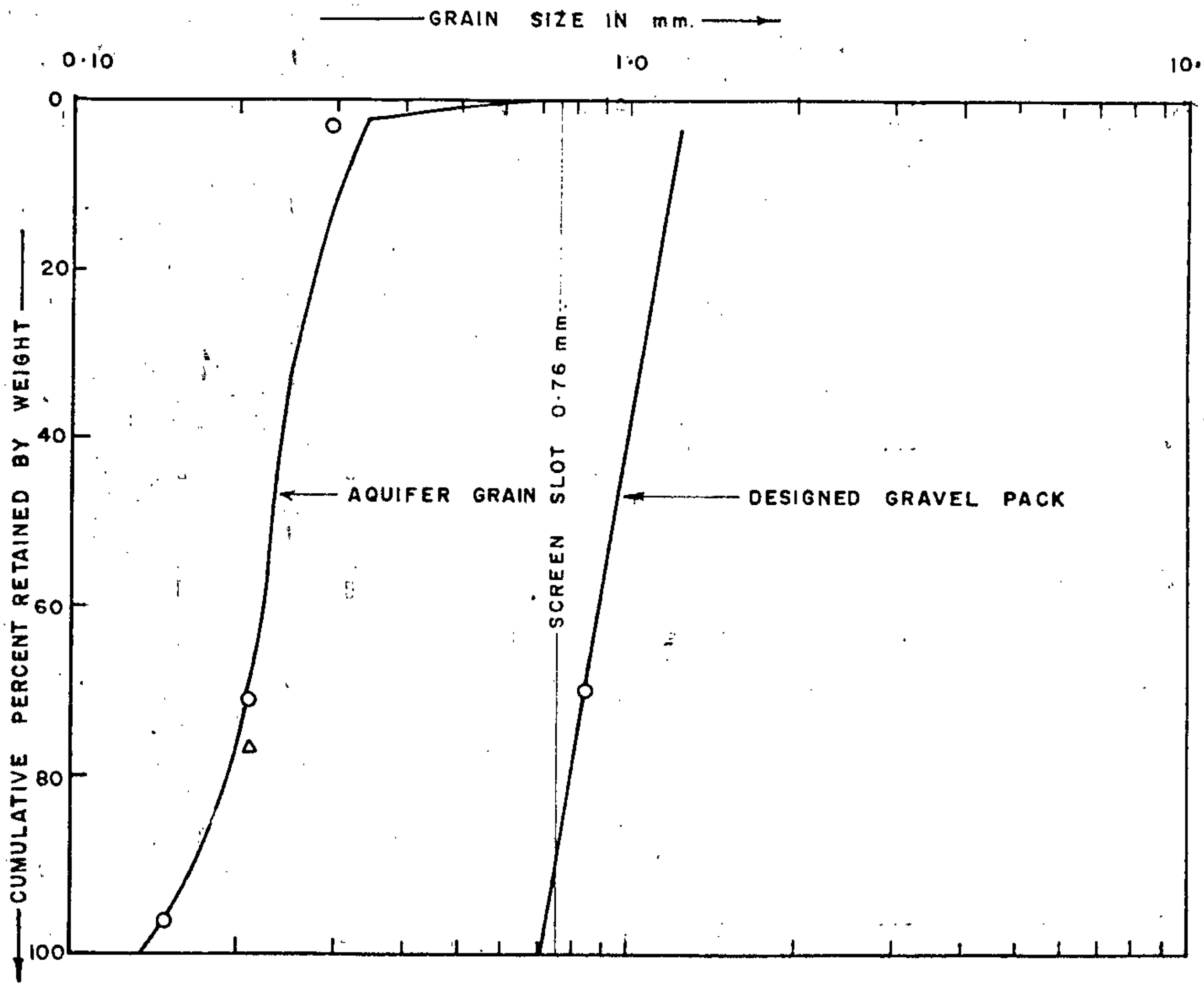
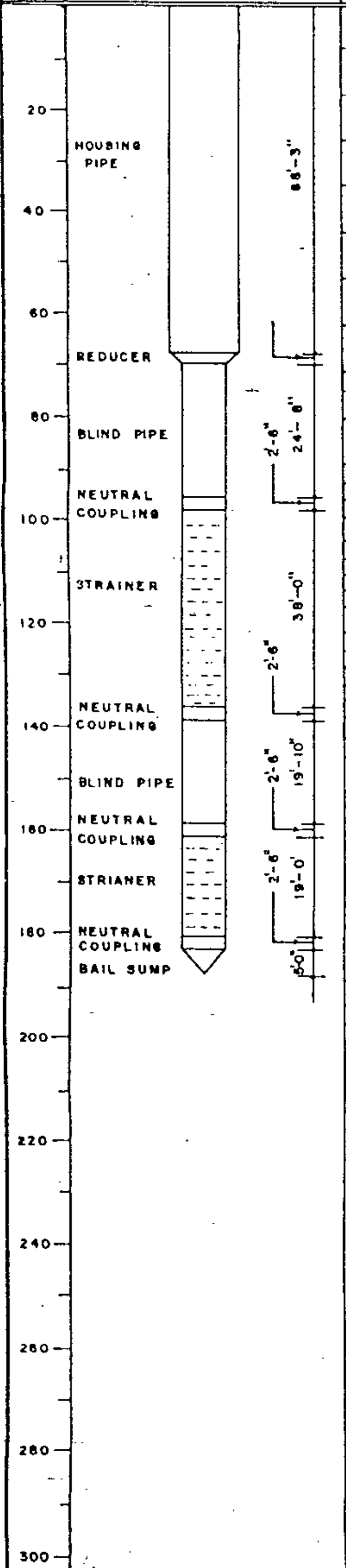


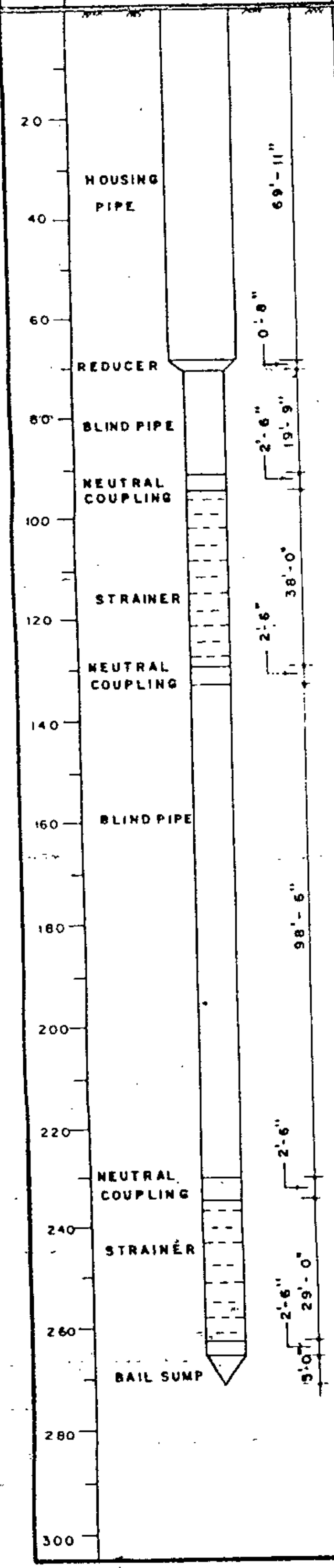
FIG.4·5 GRAIN SIZE DISTRIBUTION (AT DEPTH 179' TO 182') WITH CORRESPONDING GRAVEL PACK AND SCREEN SLOT DESIGN OF WELL AT PLOT NO. 6595



DEPTH (FT)	FORMATION DECRIPTION
0 – 8	Brown silty top soil
8 – 17	Light brown fine SAND
17 – 26	Grey med. SAND
26 – 35	Grey med. to coarse SAND
35 – 44	Grey fine SAND with mica.
44 – 53	Grey med. to coarse SAND
53 – 62	Grey fine SAND
62 – 71	Grey coarse to med. SAND
71 – 74	Light brown coarse to med. SAND
74 – 80	Grey coarse to med. SAND with clay
80 – 89	Grey coarse SAND with trace of pebbles
89 – 92	Brown med. to fine SAND
92 – 95	Brown fine SAND
95 – 98	Brown fine to med. SAND
98 – 104	Brown med. to fine SAND
104 – 107	Grey med. to fine SAND
107 – 110	Brown fine SAND
110 – 113	Grey med. SAND with pebbles
113 – 116	Light brown coarse to med. SAND
116 – 122	Light brown fine to med. SAND
122 – 125	Brown med. to coarse SAND with clay
125 – 128	Brown med. to fine SAND
128 – 131	Brown coarse to med. SAND
131 – 134	Brown fine SAND
134 – 140	Brown coarse SAND with pebbles
140 – 143	Brown fine SAND clay
143 – 152	Brown med. to coarse SAND with pebbles
152 – 161	Brown coarse SAND with pebbles
161 – 167	Brow fine SAND
167 – 173	Brown med. SAND
173 – 180	Brown fine SAND
180 – 182	Brown fine to med. SAND
182 – 188	Brown coarse SAND with pebbles
188 – 193	Grey fine to med. SAND
193 – 197	1'-0" clay & 2'-0" brown med. SAND
197 – 200	Grey fine to med. SAND.

UNION P : SALANDAR PLOT NO.- 4056
UPAZILA : THAKURGAON MOUZA : SALANDAR
DIST : THAKURGAON DTW NO. T - 281
DATE OF DRILLING. 11.1.86

FIG. 4.6 WELL FIXTURE WITH BORELOG DATA OF WELL NO-T-281.

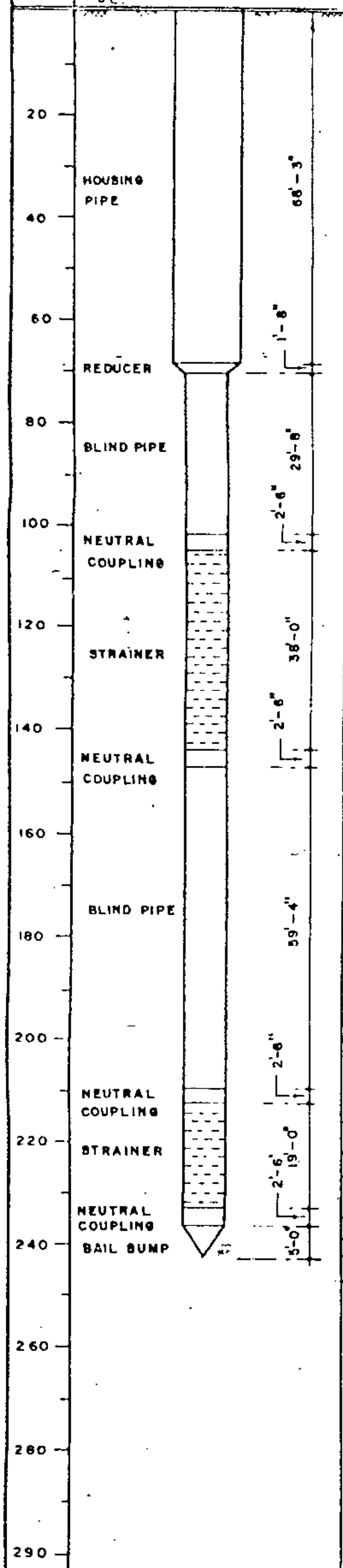


DEPTH(Ft)	FOMATION DESCRIPTION
0' - 8'	silty Top soil brown
8' - 17'	F to M SAND some silt brown
17'- 28'	F to M SAND brown
28'- 35'	M SAND brown
35'- 44'	M to C SAND brown
44'- 55'	F to M SAND brown
55'- 60'	CLAY black
60'- 80'	F to M SAND brown
80'- 89'	M SAND Grey brown
89'- 107'	M SAND Grey
107'- 132'	M to c SAND Grey
132'- 140'	M to C SAND Grey
140'- 143'	silty CLAY black
143'- 148'	CLAY Grey
148'- 152'	M to C SAND Grey
152'- 158'	F SAND Grey brown
158'- 161'	M SAND brown
161'- 164'	M SAND Grey brown
164'- 169'	M SAND Grey
169'- 174'	CLAY black
174'- 179'	F SAND Grey
179'- 188'	M SAND Grey
188 -202	M to C SAND Grey
202'-204'	M to F SAND Grey brown
204- 206'	CLAY black
206'- 215'	M SAND Grey brown
215'- 221	M to F SAND brown
221'- 224'	clayey SAND stone black
224'- 227'	F to M silt pubbirs grey
227'- 233'	M SAND Grey brown
233'- 242'	C SAND Grey
242'- 251'	C to M SAND Grey
251'- 266'	C SAND Some pebbles grey
266'- 269'	CLAY silty black
269'- 272'	M SAND & SILT Layer brown
272'- 278'	M to C SAND, Grey
278'- 287'	SILT Grey brown.

UNION P. : SATOIR DTW NO.- BG - 12
UPAZILA : BIRGANJ PLOT NO: - 766
DIST. : DINAJPUR MOUZA : PRANAGAR
DATE OF DRILLING : 18.11.85

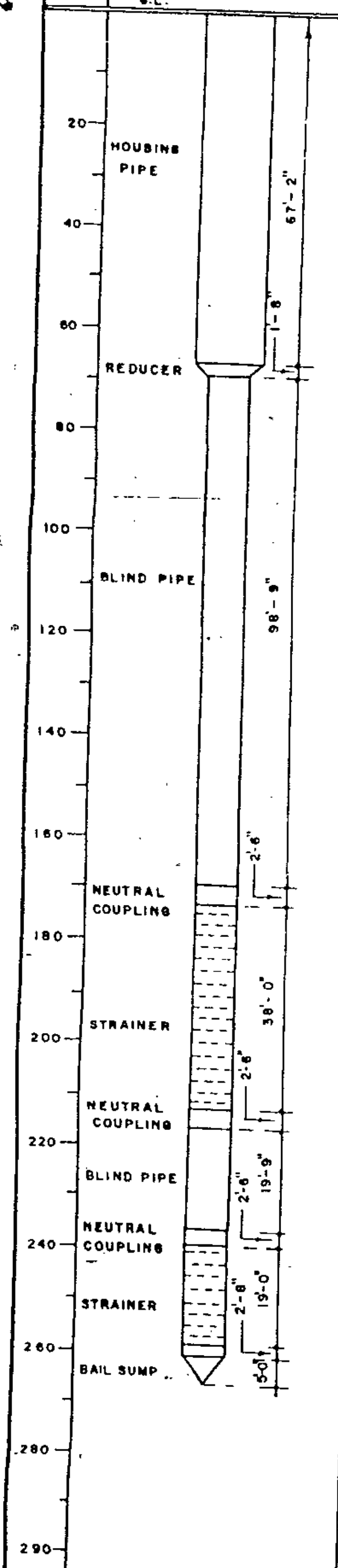
FIG. 4.7 WELL FIXTURE WITH BORE LOG DATA OF WELL NO. BG-12

UNION P. : CHILARANG DTW. NO. - T-62
UPAZILA : THAKURGAON PLOT NO. - 4120
DIST. : THAKURGAON MOUZA - VELAJAN
DATE OF DRILLING : 20.11.85



DEPTH (FT.)	FORMATION DESCRIPTION
0' – 5'	Brown sandy top soil
5' – 8'	Grey CLAY with silt
8' – 11'	Light grey fine SAND
11' – 14'	Light grey silty CLAY
14' – 23'	Light grey fine SAND with mica
23' – 28'	Light grey fine to med. SAND
28' – 38'	Light grey med. to coarse SAND
38' – 44'	Light grey coarse SAND
44' – 56'	Light grey med. to coarse SAND
56' – 66'	Light grey coarse to med. SAND with stone
66' – 78'	Light grey fine to med. SAND
78' – 86'	Grey fine to med. SAND
86' – 89'	Grey med. to fine SAND
89' – 92'	Grey plastic CLAY
92' – 98'	Grey med. SAND
98' – 107'	Grey coarse to med. SAND
107' – 122'	Grey coarse SAND with stone
122' – 134'	Grey coarse to med. SAND
134' – 140'	Grey med. SAND with stone
140' – 143'	Grey med. to fine SAND
143' – 146'	Brown fine SAND
146' – 149'	Grey coarse SAND with stone
149' – 152'	Brown med. to fine SAND
152' – 158'	Grey coarse to med. SAND
158' – 161'	Brown coarse SAND with gravel
161' – 170'	Light brown fine SAND
170' – 179'	Light brown very fine SAND with silt.
179' – 188'	Light brown very fine SAND.
188' – 191'	Light brown med. to course SAND
191' – 197'	Brown coarse SAND with gravels
197' – 215'	Brown med. SAND
215' – 221'	Brown coarse SAND
221' – 225'	Light grey med. to coarse SAND
225' – 233'	Brown med. SAND
233' – 239'	Brown coarse to med. SAND
239' – 242'	Grey coarse to med. SAND
242' – 247'	Brown med. SAND

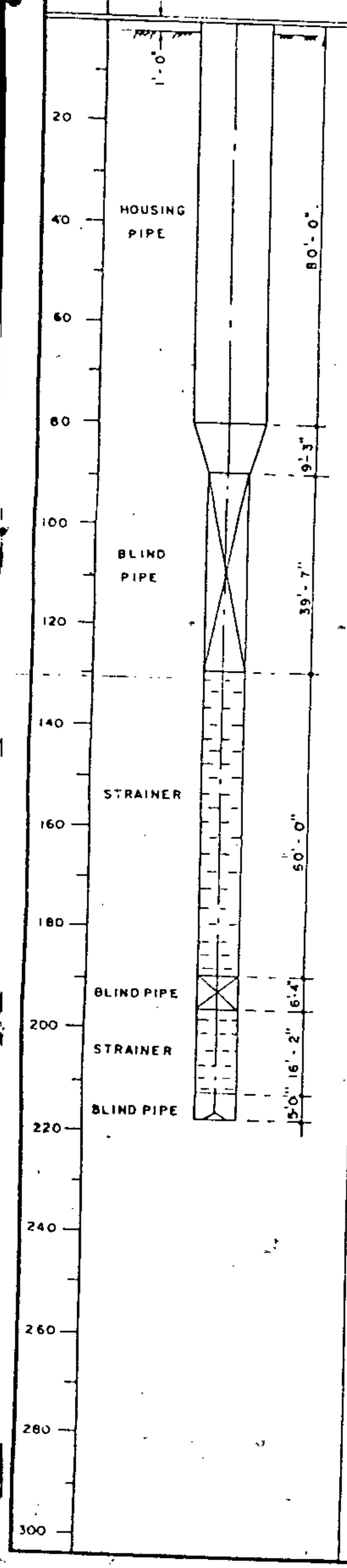
FIG 4.8 WELL FIXTURE WITH BORELOG DATA OF WELL NO-T-62



DEPTH (FT)	FOMATION DESCRIPTION
0 – 6	Brown silty top soil
6 – 17	Light brown very fine SAND
17 – 26	Grery very fine SAND
26 – 35	Light brown med. to fine SAND
35 – 44	Light brown fine SAND
44 – 53	Brown fine to med. SAND
53 – 62	Light brown med. to fine SAND
62 – 71	Brown very fine SAND
71 – 80	Light brown med. to fine SAND
80 – 91	Grey fine to med. SAND
91 – 97	Grey coarse to med. SAND with gravel
97 – 101	Grey fine to coarse SAND.
101 – 103	Grey fine to coarse SAND with gravels
103 – 109	Miceous fine SAND
109 – 113	Grery very fine SAND
113 – 118	Grey med. to fine SAND
118 – 124	Brownish grey coarse to med. SAND
124 – 128	Grey very fine SAND
128 – 134	Grey very fine to med. SAND
134 – 138	Light brown coarse to med. SAND
138 – 142	Light brown fine to med. SAND
142 – 146	White med. to fine SAND
146 – 148	Brownish grey fine SAND
148 – 152	Light brown med. to fine SAND
152 – 160	Light brown coarse SAND
160 – 163	Light brown coarse SAND with gravels
163 – 167	Brownish grey coarse SAND
167 – 170	Light brown med. to coarse SAND
170 – 178	Grey coarse SAND with pebbles
178 – 184	Grey med. to coarse SAND
184 – 188	Grey coarse SAND with gravels
188 – 194	Grey coarse to med. SAND
194 – 202	Grey coarse SAND with gravels
202 – 208	Grey coarse to med. SAND
208 – 212	Light brown coarse to med. SAND
212 – 218	Brownish grey coarse to med. SAND
218 – 227	Light brown med. to coarse SAND
227 – 233	Light brown coarse SAND with gravels
233 – 248	Grey coarse SAND
248 – 268	Greenish grey coarse SAND with pebbles
268 – 278	Brown coarse to med. SAND.

UNION P. : CHILARANG
UPAZILA : THAKURGAON   PLOT NO.- 6595
DIST :- THAKURGAON   MOUZA: VELAJAN
DATE OF DRILLING :- 8.1.86

FIG. 4.9 WELL FIXTURE WITH BORELOG DATA OF WELL AT PLOT NO-6595



DEPTH (FT)	FORMATION DESCRIPTION
0'- 12'	Top soil & brown med. to fine SAND
12'- 20'	Grey med. to course SAND with gravel
20'- 28'	DO
28'- 36'	Lt. brown med. to course SAND .
36'- 44'	Grey med. SAND .
44'- 52'	Do.
52'- 60'	Do.
60'- 68'	Lt. brown med. SAND .
68'- 76'	Do.
76'- 84'	Do.
84'- 92'	Do.
92'- 100'	Grey med. to fine SAND .
100'- 108'	Lt. brown med. to fine SAND .
108'- 116'	Grey med. to fine SAND .
116'- 124'	Grey med. to fine SAND with silt .
124'- 132'	Do.
132'- 140'	Grey med. to course SAND .
140'- 148	Lt. brown med. to course SAND .
148'- 156'	Do.
156'- 164'	Do.
164'- 172'	Lt. brown med to course SAND with gravel
172'- 180'	Do.
180'- 188'	Lt. brown med. to course SAND .
188'- 196'	Grey fine SAND with silt Grey med. SAND.
196'- 204'	Grey course SAND with gravel.
204'- 212'	Lt. brown course SAND with gravel .
212'- 220'	Lt. brown med. SAND .

P.S. : BALIADANGI VILL : BHANUR

DIST. : DINAJPUR WELL NO.- 304

DATE OF DRILLING : 7.4.80

FIG. 4.10 WELL FIXTURE WITH BORELOG DATA OF PRODUCTION WELL NO- 304.

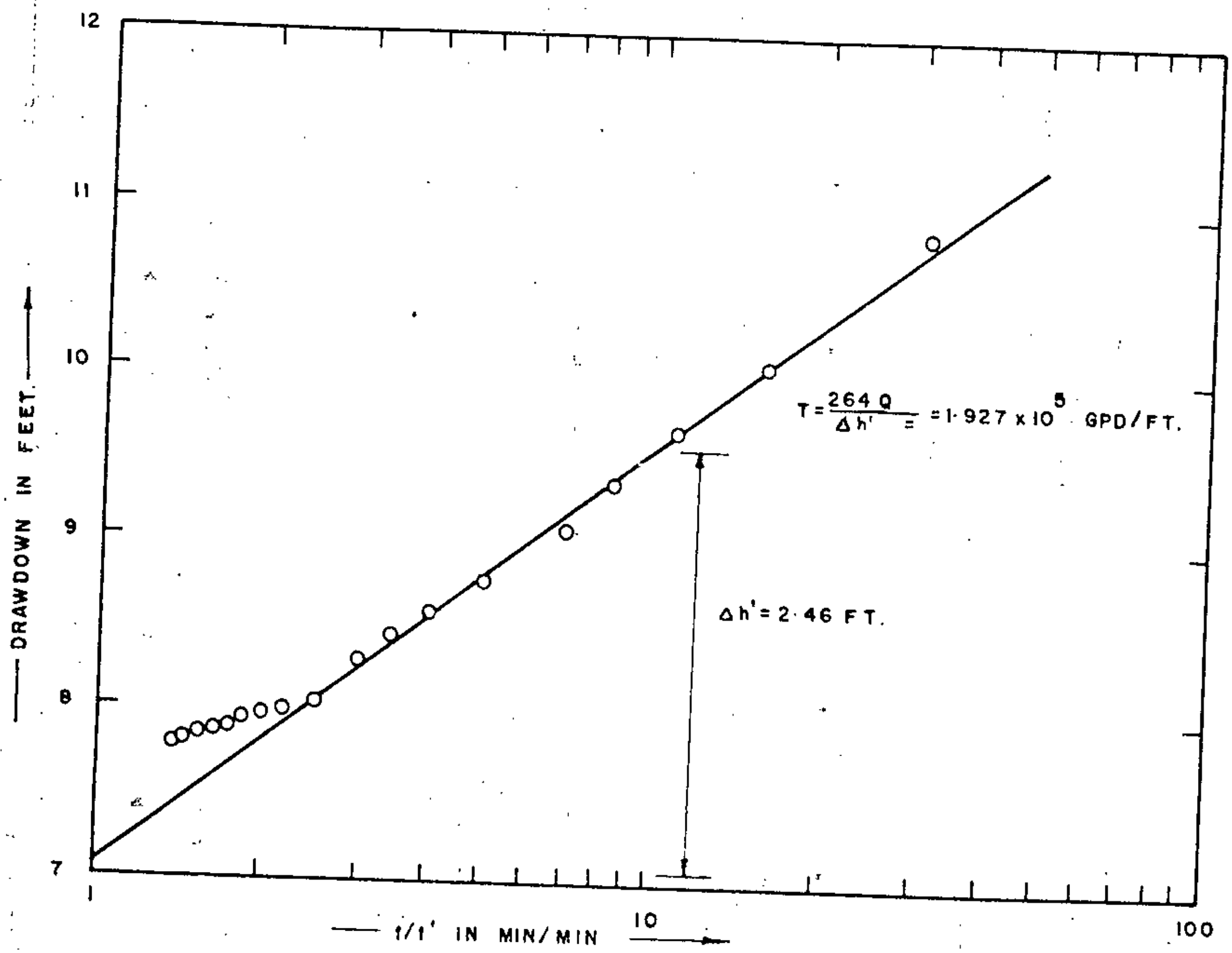


FIG. 4·11 DETERMINATION OF COEFFICIENT OF TRANSMISSIBILTY FROM TIME RECOVERY DATA FOR PRODUCTION WELL NO. 304

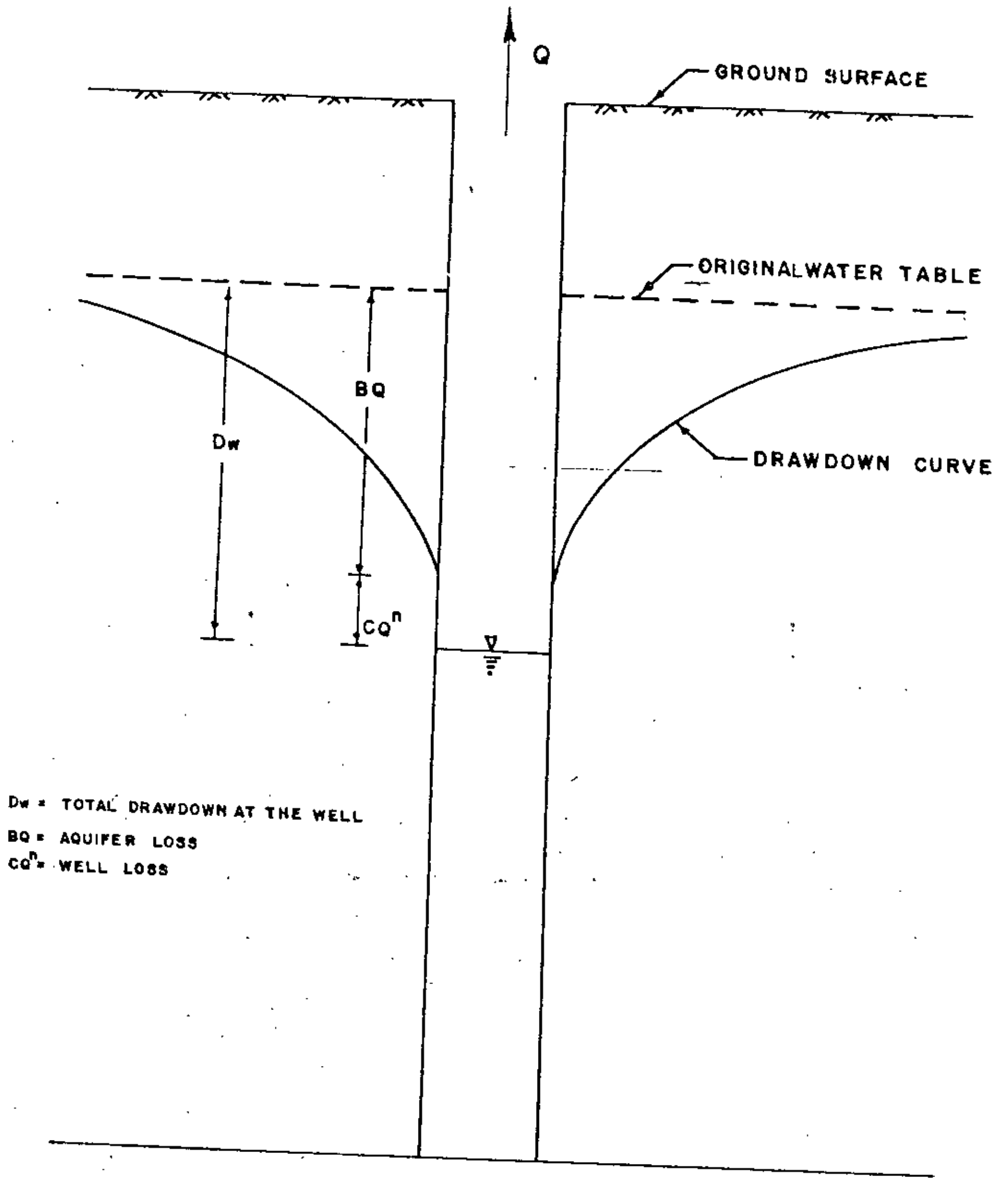


FIG. 4·12 WELL LOSS

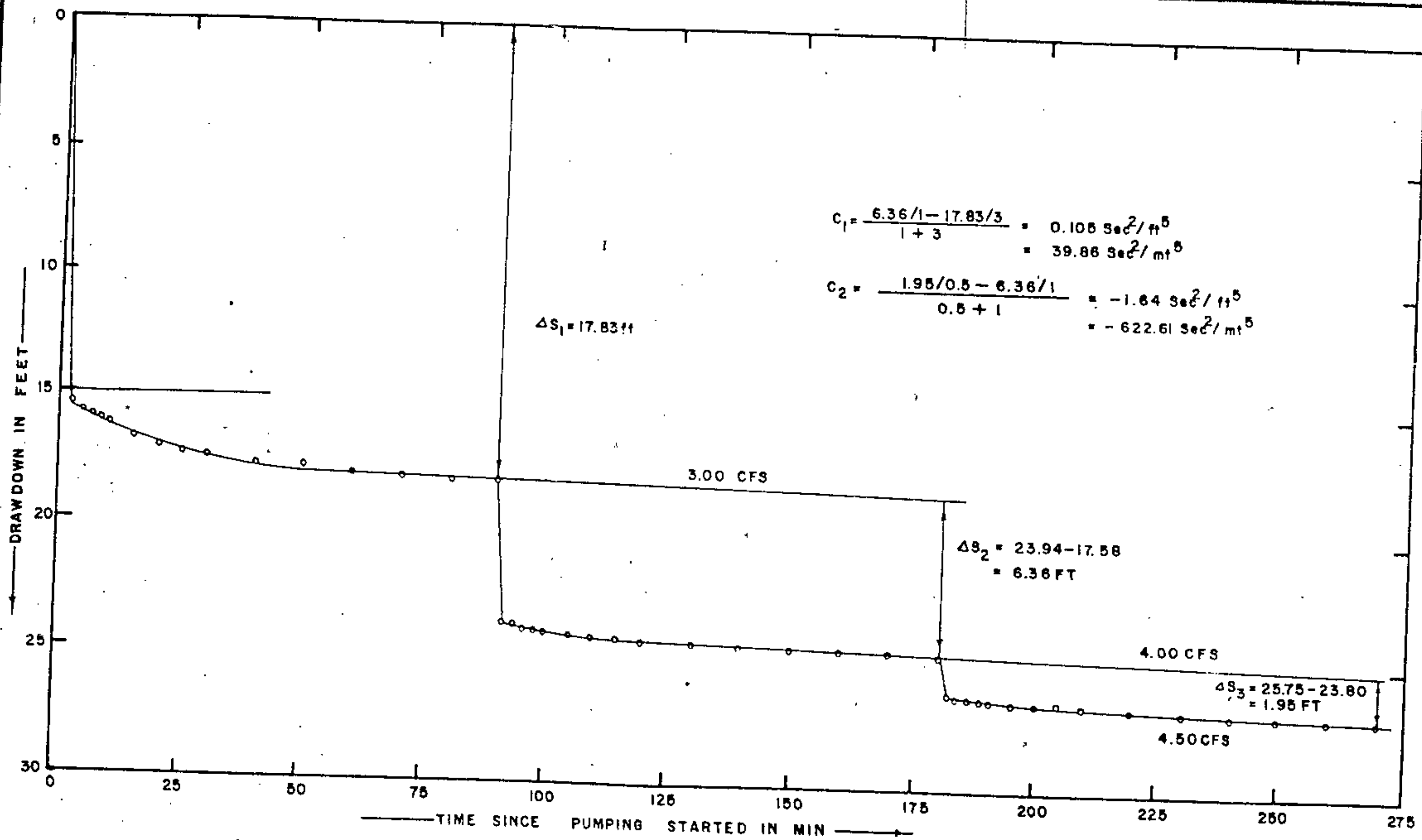


FIG. 4.13 DETERMINATION OF WELL LOSS CONSTANT FROM MULTIPLE STEP DRAWDOWN TEST DATA FOR PRODUCTION WELL NO— 304.

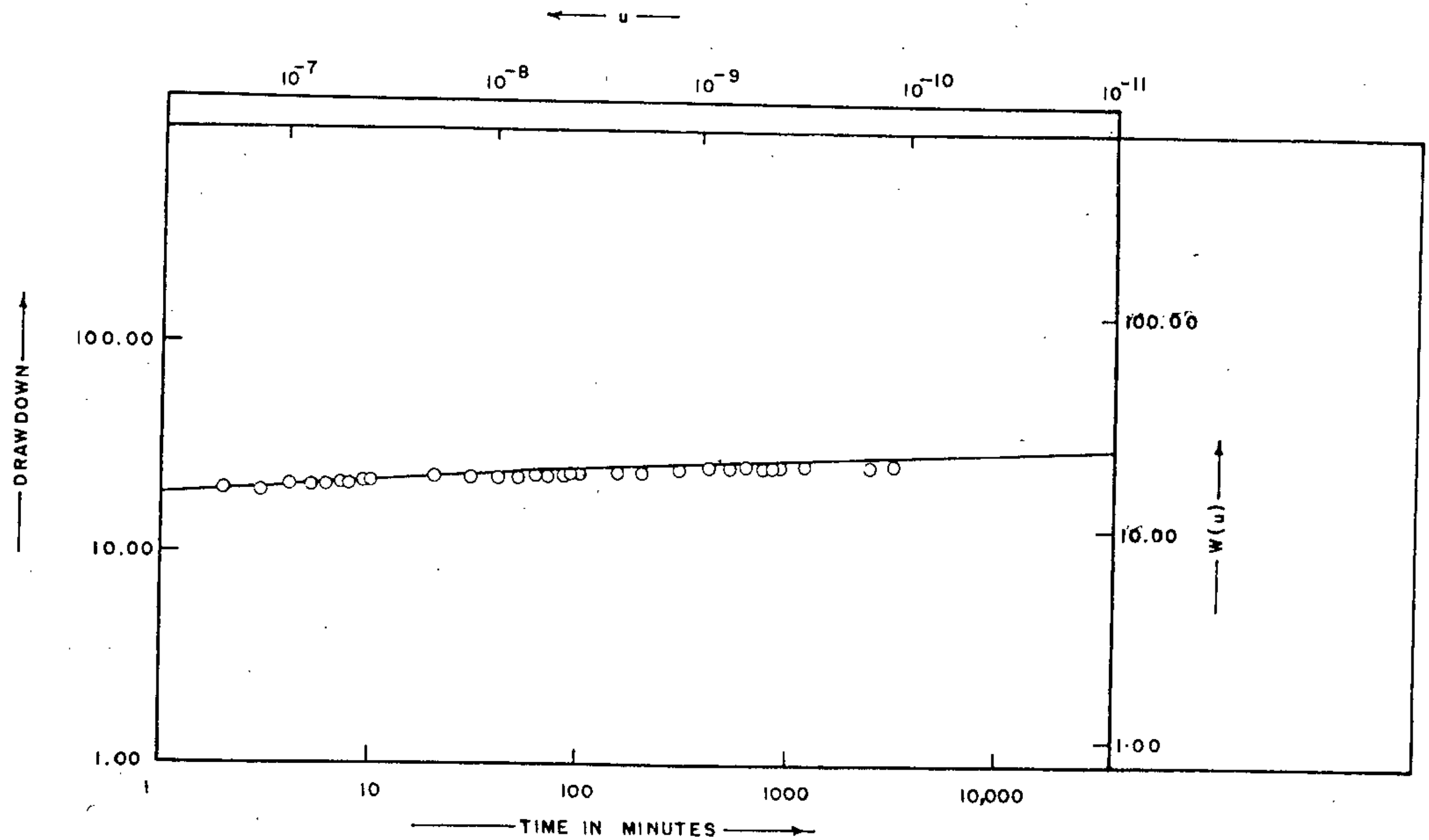


FIG. 4·14 DETERMINATION OF COEFFICIENT OF TRANSMISSIBILITY OF TEST WELL NO - 129 WITH THEIS METHOD

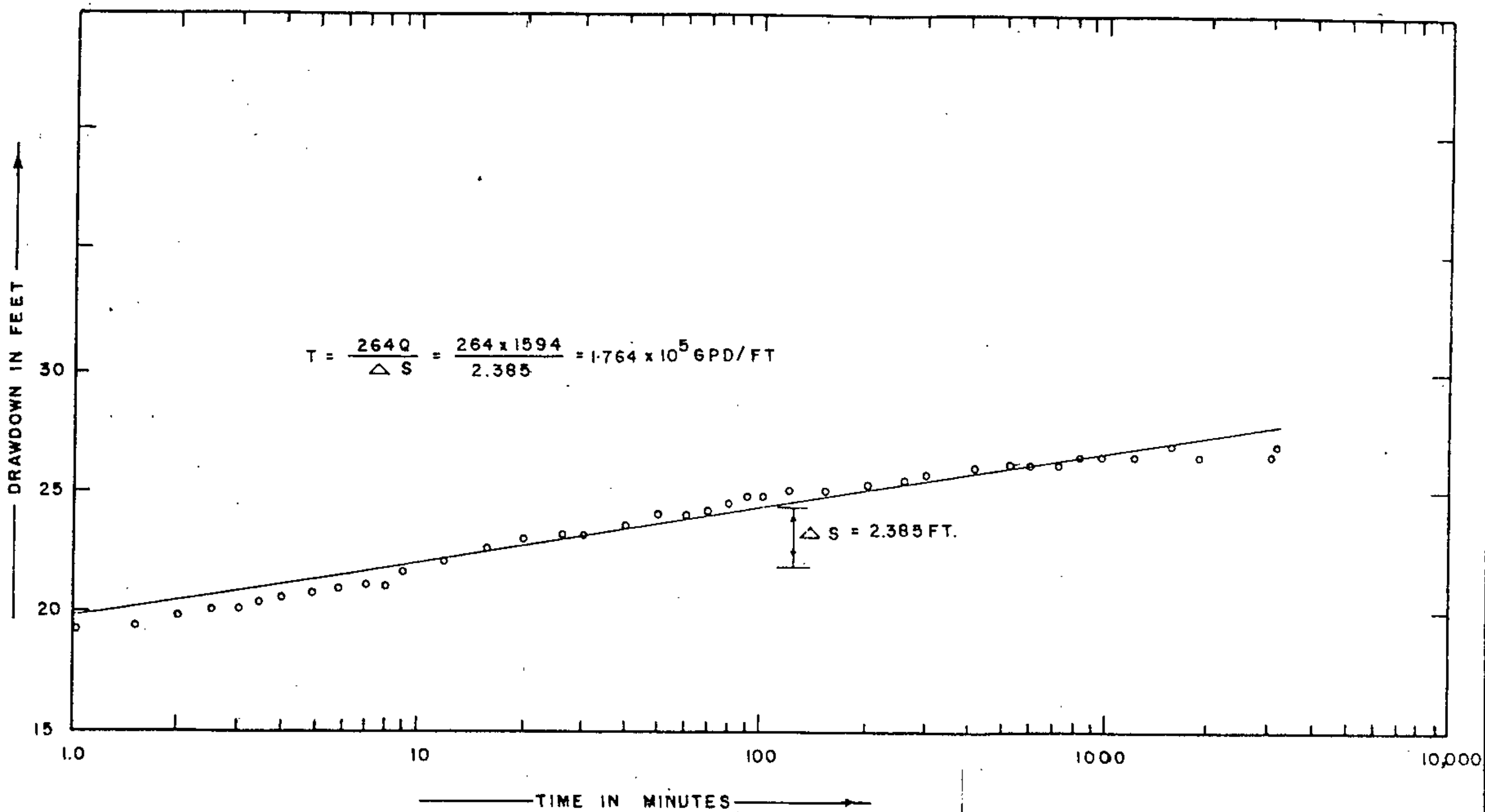


FIG. 4·15 DETERMINATION OF COEFFICIENT OF TRANSMISSIBILITY OF TEST WELL NO – 129 WITH JACOB METHOD

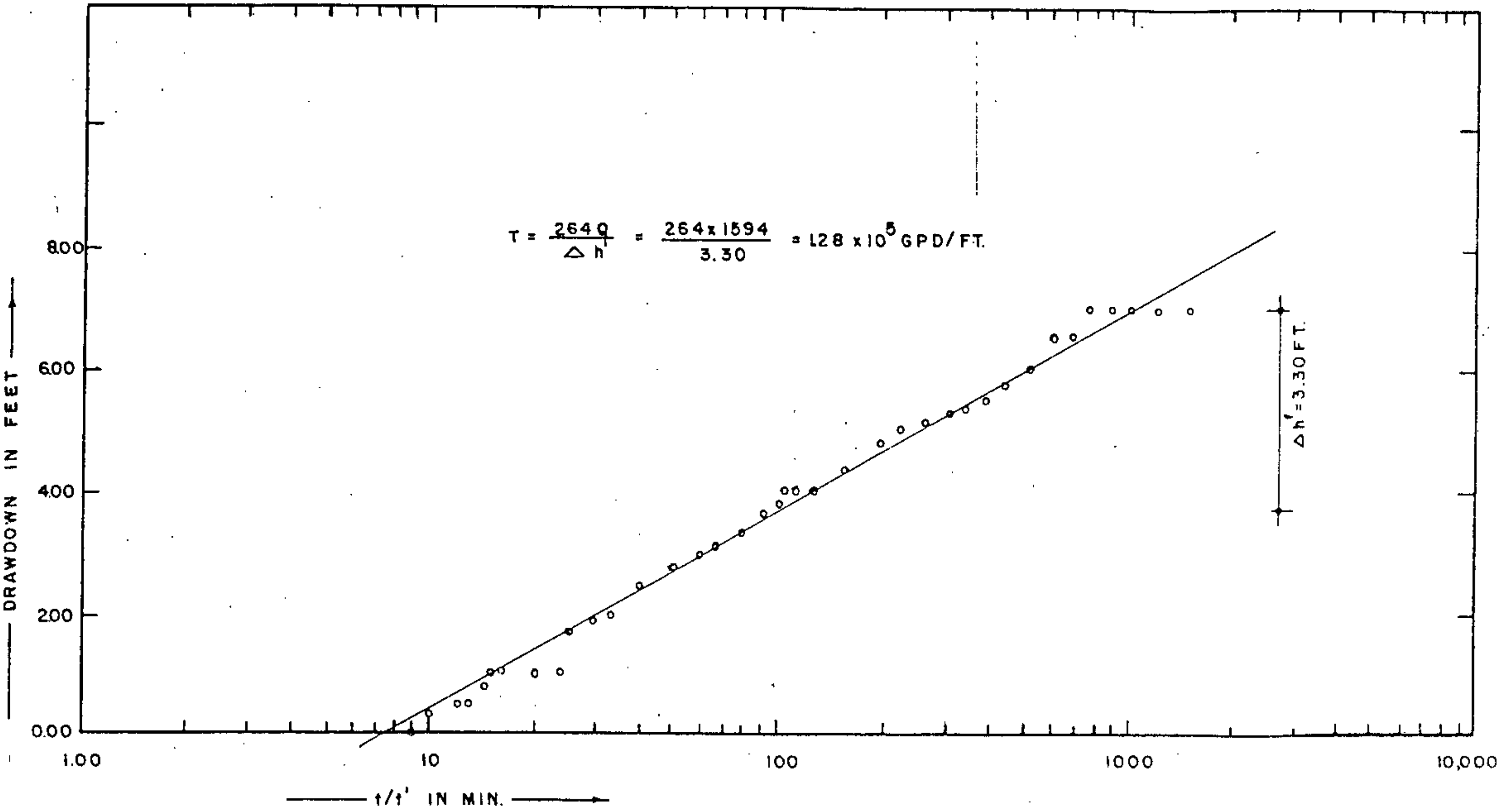


FIG. 4.16 DETERMINATION OF COEFFICIENT OF TRANSMISSIBILITY OF TEST WELL NO — 129 WITH THEIS RECOVERY METHOD

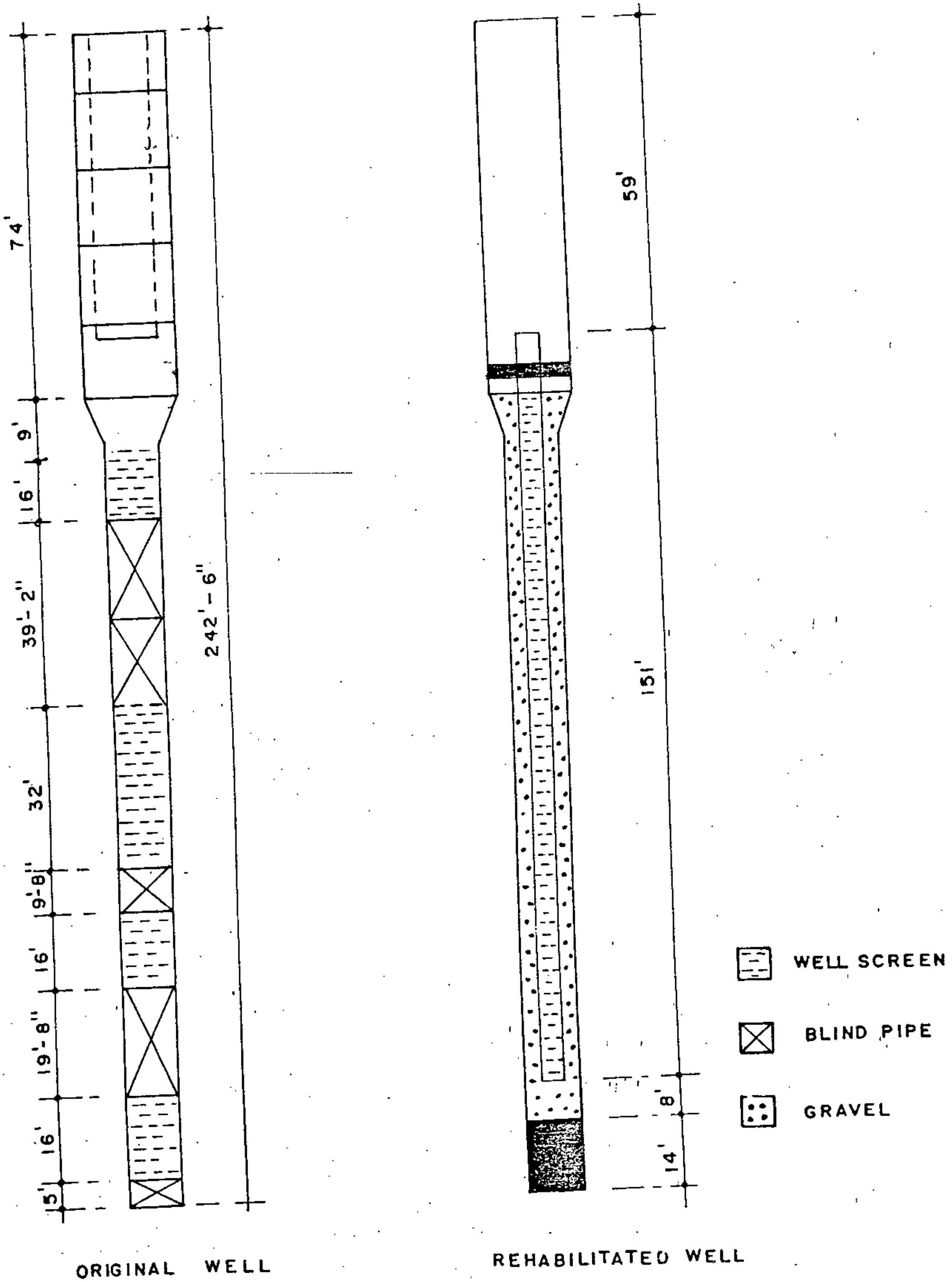


FIG. 4-17. SCHEMATIC DIAGRAM OF THE ORIGINAL AND REHABILITATED WELL.

APPENDIX- C

TABLES

TABLE 2.1

PERMISSIBLE SCREEN ENTRANCE VELOCITIES

Coefficient of permeability, (m/day)	Optimum screen velocity, (cm/sec.)
> 250	6.10
250	5.60
200	5.10
150	4.30
100	3.50
50	2.00
20	1.50
< 20	1.00

TABLE 2.2

RECOMMENDED PACK-AQUIFER RATIOS FOR STABLE FILTERING ACTION IN TUBEWELLS

(After the model study conducted by the Irrigation Research Institute, Roorkee)

Sl. No.	Type of material		Pack-aquifer ratio - 50% basis		
	Aquifer type	Gravel pack	Range within which both sand movement and resistance are minimum	Maximum upper limit after which the visible failure takes place	Recommended range of stable pack-aquifer ratio
a	Uniform	Uniform	9 to 13	29	9 to 13
b	Non-uniform	Uniform	11 to 16	33	11 to 16
c	Uniform	Non-uniform	12 to 18	35	12 to 18
d	Non-uniform	Non-uniform	15 to 22	42	15 to 22

TABLE 2.3

RECOMMENDED PACK-AQUIFER RATIOS FOR STABLE FILTERING ACTION IN TUBEWELLS
(After the model study conducted at Ludhiana)

Sl. No.	Type of material		Limiting pack-aquifer ratio
	Aquifer type	Gravel pack	
a	Uniform	Uniform	8
b	Non-uniform	Uniform	12

TABLE 3.1

TUBEWELL DATA SUMMARY OF THAKURGAON TUBEWELL PROJECT

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/83*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
1	T	2-2-62	337.8	90.5	1.3	85.3	155.8	4.9	43.02	-	0.276	-	15.45	3.25	-	H	Failing	Pumping some sand
2	T	9-2-62	319.7	90.5	1.3	75.4	147.6	4.9	-	-	-	-	-	2.65	-	H	Good	Rehabilitated Reported good condition
3	T	14-5-63	329.2	84.3	1.0	68.9	170.1	4.9	65.26	-	0.384	-	-	4.04	-	N	Failed	Severe sand pumping
4	BA	26-1-62	269.0	90.4	1.5	49.2	123.0	4.9	25.14	28.80 38.67*	0.204	-	20.00	2.78	2.33	H	Good	Rehabilitated 1980 Pumping some sand
5	BA	2-2-62	327.9	90.5	1.3	100.0	131.2	4.9	32.39	-	0.247	10.50	10.46	2.85	1.38	H	Good	Rehabilitated 1980
6	BA	16-2-62	313.4	90.5	1.3	85.3	131.2	4.9	33.84	12.60	0.258	-	10.96	3.00	2.26	H	Good	Reported low yield
7	BA	14-2-62	272.2	87.2	1.3	64.0	114.8	4.9	38.19	31.60	0.333	-	9.77	3.42	1.84	H	Good	Reported pumping sand
8	BA	12-2-62	293.6	87.6	1.0	85.3	114.8	4.9	49.79	-	0.434	-	11.64	3.38	1.41	H	Unconformed	Power failure
9	BA	16-2-62	285.4	87.6	1.0	77.1	114.8	4.9	74.45	-	0.648	12.73	14.99	4.22	3.21	H	Unconfirmed	Power line stolen
10	BA	2-3-62	264.8	84.3	1.0	64.6	110.0	4.9	51.24	30.10	0.466	-	13.64	3.46	2.65	N	Failed	Severe sand pumping
11	BA	13-3-62	263.6	85.9	1.0	51.8	120.0	4.9	61.39	24.50	0.512	9.84	13.99	4.04	3.11	N	Failed	Severe sand pumping
12	BA	19-2-62	265.1	90.9	1.0	53.5	114.8	4.9	75.90	-	0.661	12.17	11.15	4.04	-	H	Unconfirmed	Rehabilitated 1980. Power line stolen Not yet commissioned
13	BA	5-3-62	294.8	87.6	1.0	71.30	130.0	4.9	80.73	-	0.621	11.44	-	4.22	3.43	N	Failing	Pumping sand
14	BA	26-2-62	260.8	82.7	1.0	73.8	98.4	4.9	28.52	77.10 66.23*	0.29	-	9.74	2.76	2.08	N	Good	
15	BA	1-3-62	215.3	84.6	1.0	14.8	110.0	4.9	72.03	27.50	0.655	12.46	-	4.38	3.07	N	Good	Reported low yield
16	BA	6-3-62	280.4	87.6	1.0	56.9	130.0	4.9	51.24	29.40	0.394	12.14	-	3.25	2.26	N	Good	Rehabilitated 1980
17	BA	28-3-62	246.9	94.6	1.0	16.4	130.0	4.9	58.01	-	0.446	-	-	4.37	3.07	N	Failing	Pumping sand & gravel
18	BA	16-3-62	268.9	85.1	1.0	57.9	120.0	4.9	48.34	-	0.403	10.46	-	3.38	1.94	N	Failing	Pumping sand & gravel
19	BA	14-3-62	269.7	84.3	1.0	49.5	130.0	4.9	45.93	27.80 46.41*	0.353	11.91	15.58	3.38	2.47	N	Good	Reported low yield
20	BA	26-2-62	270.9	91.5	1.0	53.5	120.0	4.9	55.11	-	0.459	13.35	-	4.22	2.54	N	Good	
21	BA	20-3-62	288.9	84.3	1.0	78.7	120.0	4.9	73.48	-	0.612	10.59	-	4.38	2.86	N	Unconfirmed	Power line stolen
22	BA	26-3-62	290.3	80.7	1.0	23.0	180.7	4.9	20.30	-	0.112	-	-	1.90	-	N		Original DTW not commissioned due to low yield

T = Thakurgaon, BA = Baliadangi, N = Nold well screen, H= Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) CWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
23	BA	29-3-62	280.3	88.7	1.0	45.6	140.1	4.9	48.83	-	0.349	-	14.60	3.70	2.19	N	Unconfirmed	Power line stolen
24	BA	18-3-62	269.8	84.3	1.0	49.5	130.1	4.9	82.67	-	0.635	11.41	-	4.22	3.35	N	Unconfirmed	Power line stolen
25	BA	24-3-62	247.3	90.2	1.0	31.2	120.0	4.9	33.84	-	0.282	-	12.43	3.25	1.94	N	Unconfirmed	Power line stolen
26	T	6-3-62	259.9	87.6	1.0	46.4	120.0	4.9	46.41	-	0.387	9.84	-	4.22	2.65	N	Failing	Pumping sand & gravel
27	T	6-3-62	251.4	87.6	1.0	27.9	130.0	4.9	42.06	-	0.324	10.33	-	3.24	1.59	N	Failing	Electrical component failure Reported pumping sand
28	T	2-3-62	272.7	87.6	1.0	49.2	130.0	4.9	42.54	40.10	0.327	10.66	11.22	3.24	1.91	N	Failed	Severe sand pumping and casing subsidence
29	T	8-2-62	262.4	85.6	1.3	55.8	114.8	4.9	36.74	51.00 41.09*	0.320	-	15.07	3.08	2.19	H	Good	
30	T	16-2-62	272.2	84.3	1.0	42.6	139.4	4.9	53.18	-	0.381	11.48	-	4.04	3.28	H	Good	
31	T	12-2-62	250.9	90.5	1.3	31.2	123.0	4.9	45.93	38.00	0.373	14.04	14.44	3.38	1.91	H	Good	
32	T	14-2-62	242.8	90.9	1.0	14.8	131.2	4.9	39.16	45.80	0.298	13.97	14.37	3.25	2.47	H	Unconfirmed	Motor failure
33	T	16-2-62	273.9	90.9	1.0	62.3	114.8	4.9	36.74	43.80 56.08*	0.320	17.71	16.20	3.25	1.91	H	Good	
34	T	15-2-62	272.3	90.9	1.0	52.5	123.0	4.9	31.42	-	0.255	-	-	2.78	1.77	H	Good	
35	T	3-3-62	259.2	90.9	1.0	39.4	123.0	4.9	18.85	-	0.153	-	-	1.32	-	H		Original DTW not commissioned due to low yield
36	T	18-2-62	288.9	84.3	1.0	78.7	120.0	4.9	23.69	-	0.197	-	14.76	2.07	2.33	N	Failing	Pumping sand & gravel
37	T	18-2-62	259.2	90.9	1.0	39.4	123.0	4.9	25.14	27.90	0.204	12.97	-	1.96	1.48	H	Unconfirmed	Electrical component failure
38	T	20-2-62	260.8	90.9	1.0	41.0	123.0	4.9	21.27	34.40 42.06*	0.173	11.25	13.56	1.86	1.94	H	Good	
39	T	26-2-62	278.8	87.6	1.0	67.2	118.1	4.9	47.86	28.10	0.405	-	16.09	3.38	2.54	N	Failing	Reported low yield
40	T	26-2-62	224.3	82.3	1.0	8.2	127.9	4.9	36.74	-	0.287	13.71	-	2.81	1.77	N	Good	
41	T	28-2-62	259.2	87.6	1.0	35.6	130.1	4.9	36.72	29.30 34.32*	0.282	10.10	6.89	4.04	2.54	N	Good	Rehabilitated 1980
42	T	28-2-62	257.5	85.3	1.0	46.3	120.0	4.9	49.79	-	0.415	9.74	-	4.48	2.86	N	Good	

BA = Baliadangi, T = Thakurgaon, N = Nold well screen, H = Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs.) 1962	1984	Screen type	Operating condition (1984)	Remarks
43	T	4-3-62	229.6	85.3	1.0	28.4	110.0	4.9	65.26	-	0.593	10.27	-	4.22	2.72	N	Failing	Power failure. Pumping sand & gravel
44	T	13-3-62	268.2	84.3	1.0	47.9	130.1	4.9	73.48	-	0.565	8.72	-	4.72	3.57	N	Failed	Severe sand pumping
45	T	12-3-62	269.5	84.3	1.0	49.2	130.1	4.9	89.09	-	0.685	9.74	14.51	4.38	2.54	N	Unconfirmed	Rehabilitated 1981 Elect.component failure
46	T	15-3-63	278.8	84.3	1.0	48.5	140.1	4.9	59.91	41.70 55.11*	0.428	12.79	13.35	4.04	2.40	N	Good	Rehabilitated 1981
47	T	19-6-62	269.2	84.3	1.0	59.0	120.0	4.9	66.71	38.10	0.556	6.40	-	4.72	2.93	N	Good	
48	T	22-6-62	279.3	84.3	1.0	59.00	130.1	4.0	49.76	18.70	0.382	-	-	3.87	1.91	N	Good	Rehabilitated 1981
49	T	16-3-62	249.6	84.3	1.0	39.4	120.0	4.9	32.87	41.30	0.274	-	-	2.78	1.59	N	Good	
50	T	17-3-62	210.2	84.3	1.0	0	120.0	4.9	52.69	-	0.439	-	-	4.04	-	N	Failing	Power failure. Pumping sand & gravel
51	T	8-6-62	272.8	84.3	1.0	52.5	130.1	4.9	36.74	64.78*	0.282	14.01	15.55	4.22	2.93	N	Failing	Pumping sand & gravel
52	T	20-3-62	267.3	82.5	1.0	78.9	100.0	4.9	31.91	-	0.319	-	13.91	2.87	-	N	Failed	Abandoned due to severe sand pumping
53	T	17-3-62	280.6	85.6	1.0	59.0	130.1	4.9	35.29	41.09*	0.271	-	15.09	3.23	2.26	N	Good	
54	T	23-3-62	270.6	83.8	1.0	50.8	130.1	4.9	35.29	43.99*	0.271	-	14.00	3.08	1.91	N	Good	
55	T	22-3-62	250.2	85.3	1.0	59.0	100.0	4.9	59.94	-	0.599	-	16.27	4.04	-	N	Unconfirmed	Power failure. Pumping some sand
56	T	19-3-62	269.0	84.3	1.0	48.7	130.1	4.9	42.06	29.00*	0.323	-	13.86	3.38	2.01	N	Good	
57	T	20-3-62	227.9	84.3	1.0	27.7	110.0	4.9	52.69	-	0.479	-	16.60	4.04	-	N	Unconfirmed	Power failure
58	T	22-3-62	269.5	84.3	1.0	49.2	130.1	4.9	61.39	-	0.472	-	13.87	4.22	-	N	Unconfirmed	Motor failure
59	T	24-3-62	263.2	84.8	1.0	52.5	120.0	4.9	43.02	58.49*	0.359	10.04	14.56	3.38	3.43	N	Good	
60	T	25-3-62	258.2	89.1	1.0	13.1	150.1	4.9	55.11	-	0.367	-	16.76	4.22	2.93	N	Unconfirmed	Fuses removed
61	T	15-6-62	255.8	85.6	1.0	44.3	120.0	4.9	48.34	-	0.403	-	14.14	3.70	-	N	Unconfirmed	Power line stolen
62	B	3-4-62	229.6	85.3	1.0	23.6	114.8	4.9	14.50	-	0.126	7.31	-	*1.00	-	H		Original DTW not commi-ssioned due to low yiel
63	B	3-3-62	229.9	84.3	1.0	19.7	120.0	4.9	54.63	71.06*	0.455	-	14.76	4.47	3.07	N	Good	

T = Thakurgaon, B = Boda, N = Nold well screen, H = Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs.) 1962	1984	Screen type	Operating condition (1984)	Remarks
64	B	2-4-62	220.0	84.3	1.0	9.8	120.0	4.9	44.96	-	0.375	-	13.19	4.48	2.19	N	Unconfirmed	Power line stolen
65	B	29-3-62	224.7	78.7	1.0	0	140.1	4.9	63.33	63.33*	0.452	-	14.79	4.39	3.14	N	Good	
66	B	6-4-62	278.8	84.3	1.0	65.6	123.0	4.9	-	-	-	-	8.99	3.23	-	H	Unconfirmed	Rehabilitated 1980 Not yet commissioned
67	B	12-4-62	267.3	84.3	1.0	54.1	123.0	4.9	12.08	-	0.098	-	-	*1.56	-	H		Original DTW not commissioned due to low yield
68	B	16-4-62	254.2	84.3	1.0	41.0	123.0	4.9	9.67	-	0.079	-	-	*1.09	-	H		Original DTW not commissioned due to low yield
69	B	14-4-62	249.3	84.3	1.0	36.1	123.0	4.9	38.19	55.59*	0.310	-	17.25	3.87	2.26	H	Good	
70	B	19-4-62	259.1	84.3	1.0	45.9	123.0	4.9	49.79	65.26*	0.405	-	12.86	3.87	2.93	H	Failing	Pumping sand & gravel
71	B	24-4-62	259.1	87.6	1.0	42.6	123.0	4.9	21.75	-	0.177	-	-	2.76	-	H	Unconfirmed	Power line stolen
72	A	30-3-62	259.7	84.3	1.0	39.4	130.1	4.9	36.74	-	0.282	-	-	2.84	-	N	Unconfirmed	Power line stolen
73	B	28-4-62	239.4	84.3	1.0	26.2	123.0	4.9	29.00	-	0.236	-	11.61	3.25	-	H	Unconfirmed	Power line stolen
74	A	1-4-62	279.3	84.3	1.0	59.0	130.1	4.9	61.39	-	0.472	-	-	4.38	-	N	Unconfirmed	Power line stolen
75	A	23-3-62	259.2	90.9	1.0	39.4	123.0	4.9	29.00	-	0.236	-	15.32	3.39	-	H	Unconfirmed	Power line stolen
76	A	6-2-63	277.7	84.3	1.0	57.4	130.1	4.9	57.04	-	0.438	-	-	3.87	-	N	Unconformed	Rehabilitated 1980. No access to pumping house
77	A	18-4-62	239.4	84.3	1.0	26.2	123.0	4.9	17.40	-	0.141	-	-	2.03	-	H	Unconfirmed	Power line stolen
78	A	11-5-62	280.4	84.3	1.0	67.2	123.0	4.9	9.19	-	0.075	-	-	**0.75	-	H		Original DTW not commissioned due to low yield
79	A	19-5-62	269.0	84.3	1.0	55.8	123.0	4.9	30.94	-	0.252	-	-	3.13	-	H	Unconfirmed	Power line stolen
80	A	3-4-62	301.8	84.3	1.0	72.2	139.4	4.9	25.62	-	0.184	-	-	2.46	1.77	H	Good	
81	T	6-4-62	275.5	84.3	1.0	45.9	139.4	4.9	37.71	-	0.271	13.05	13.51	2.72	-	H	Unconfirmed	Power line stolen
82	A	4-4-62	228.0	84.3	1.0	23.0	114.8	4.9	14.99	-	0.131	-	-	*1.41	-	H		Original DTW not commissioned due to low yield
83	A	17-4-62	269.0	84.3	1.0	55.8	123.0	4.9	10.15	-	0.083	-	-	***0.68	-	H		Original DTW not commissioned due to low yield
84	T	12-4-62	269.0	84.3	1.0	39.4	139.4	4.9	27.56	-	0.198	-	12.56	*1.91	-	H	Failing	Pumping sand

B = Boda, A= Atwari, T = Thakurgaon, N= Nold well screen, H= Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
85	T	16-4-62	278.8	84.3	1.0	65.6	123.0	4.9	22.24	24.17*	0.181	-	14.40	2.10	1.62	H	Failing	Pumping sand
86	T	13-4-62	229.6	84.3	1.0	16.4	123.0	4.9	40.61	-	0.330	-	13.38	3.08	-	H	Unconfirmed	Motor failure
87	T	9-2-63	259.4	84.3	1.0	49.2	120.0	4.9	34.81	33.84*	0.290	-	16.17	2.90	2.01	N	Good	
88	T	12-2-63	249.8	84.3	1.0	29.5	130.1	4.9	58.01	-	0.446	-	-	4.38	-	N	Unconfirmed	Motor failure
89	T	7-5-62	229.6	84.3	1.0	16.4	123.0	4.9	36.74	41.30 47.86*	0.299	-	14.04	3.23	1.08	H	Good	
90	T	1-5-62	246.0	87.6	1.0	29.5	123.0	4.9	55.59	-	0.452	-	-	4.22	2.93	H	Good	
91	T	26-4-62	242.7	84.3	1.0	29.5	123.0	4.9	24.65	23.60	0.200	-	16.14	2.64	1.41	H	Good	
92	A	6-6-62	239.5	84.3	1.0	19.2	130.1	4.9	37.71	37.32*	0.290	-	17.12	4.48	2.58	N	Good	Rehabilitated 1980
93	A	3-6-62	259.4	84.3	1.0	49.2	120.0	4.9	58.01	63.81*	0.483	-	12.64	4.38	3.07	N	Good	Pumping some sand
94	T	27-4-62	279.3	84.3	1.0	59.0	130.1	4.9	44.96	-	0.346	-	11.45	3.39	-	N	Good	
95	T	10-3-63	272.8	84.3	1.0	52.5	130.1	4.9	64.78	14.70	0.498	-	11.00	4.38	-	N	Unconfirmed	Rehabilitated 1980. Elec.equipment failure
96	T	30-4-62	269.0	84.3	1.0	55.8	123.0	4.9	13.05	-	0.106	-	-	*1.30	-	H		Original DTW not commissioned due to low yield
97	T	7-5-62	265.7	84.3	1.0	52.5	123.0	4.9	24.17	-	0.197	-	-	2.18	1.59	H	Good	
98	T	3-3-62	292.1	84.3	1.0	71.8	130.1	4.9	66.71	50.5	0.513	10.50	15.35	4.38	2.86	N	Failing	Pumping sand
99	T	19-2-63	269.5	84.3	1.0	49.2	130.1	4.9	44.47	-	0.342	-	-	3.39	-	N	Unconfirmed	Power line stolen
100	T	21-2-63	272.8	84.3	1.0	52.5	130.1	4.9	44.47	-	0.342	-	-	3.24	-	N	Unconfirmed	Power line stolen
101	T	23-4-63	279.3	84.3	1.0	59.0	130.1	4.9	-	-	-	-	-	4.22	-	N	Unconfirmed	Rehabilitated 1980 Power line stolen
102	T	14-2-63	276.1	84.3	1.0	55.8	130.1	4.9	146.96	-	1.129	-	15.78	4.38	2.58	N	Unconfirmed	Power line stolen
103	T	12-4-62	259.1	84.3	1.0	54.1	114.8	4.9	32.39	21.00	0.282	-	-	3.00	1.48	H	Good	Pumping some find sand
104	T	17-4-62	236.2	84.3	1.0	31.2	114.8	4.9	49.79	30.10	0.434	-	13.33	3.87	2.19	H	Failing	Reported low yield
105	T	15-4-62	249.3	84.3	1.0	36.1	123.0	4.9	31.91	26.90	0.259	13.74	14.78	3.00	1.73	H	Unconfirmed	Fuses removed
106	T	13-3-62	250.9	84.3	1.0	45.9	114.8	4.9	29.00	-	0.253	-	-	3.08	2.01	H	Good	
107	T	5-4-62	282.1	84.3	1.0	52.5	139.4	4.9	35.29	37.22*	0.253	-	13.28	2.87	1.84	H	Failed	Severe sand pumping

T = Thakurgaon, A = Atwari, H= Hagusta well screen, N = Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
108	T	23-4-62	246.0	84.3	1.0	32.8	123.0	4.9	55.11	-	0.448	-	14.14	4.22	-	H	Unconfirmed	Fuses removed
109	T	25-4-62	264.0	85.9	1.0	49.2	123.0	4.9	13.54	-	0.110	10.82	-	*1.03	-	H		Original DTW not commissioned due to low yield
110	T	15-4-62	295.2	87.6	1.0	78.7	123.0	4.9	29.00	-	0.236	-	-	2.67	1.69	H	Good	
111	T	17-4-62	277.1	85.9	1.0	70.5	114.8	4.9	20.30	-	0.177	-	-	2.07	1.38	H	Good	
112	T	23-4-62	278.8	84.3	1.0	65.6	123.0	4.9	55.11	53.60 60.91*	0.448	-	15.51	4.22	2.93	H	Good	
113	T	25-1-63	266.2	84.3	1.0	45.9	130.1	4.9	52.21	-	0.401	-	11.68	4.38	-	N	Failed	Abandoned due to severe sand pumping
114	T	23-1-63	275.6	84.3	1.0	45.3	140.1	4.9	52.69	-	0.376	-	-	4.38	1.41	N	Good	
115	T	4-2-63	259.7	84.3	1.0	39.4	130.1	4.9	73.97	-	0.568	-	-	4.04	-	N	Good	Severe sand pumping
116	T	18-1-63	246.5	84.3	1.0	26.2	130.1	4.9	62.36	55.11*	0.479	-	12.37	4.22	2.93	N	Good	
117	T	21-1-63	275.8	84.3	1.0	65.6	120.0	4.9	45.93	31.42*	0.383	-	13.61	4.22	1.94	N	Good	
118	T	18-1-63	239.1	84.3	1.0	28.9	120.0	4.9	37.71	20.00 37.71*	0.314	-	12.82	2.87	1.59	N	Good	
119	T	7-6-62	229.5	84.6	1.0	39.0	100.0	4.9	55.11	20.10	0.511	-	12.60	4.22	-	N	Failed	Severe sand pumping
120	T	16-6-62	246.0	84.3	1.0	35.8	120.0	4.9	52.21	30.50 41.09*	0.435	-	14.00	4.04	2.65	N	Good	
121	T	16-6-62	269.3	84.3	1.0	49.0	130.1	4.9	70.10	-	0.539	-	-	4.48	2.86	N	Failing	Pumping sand & gravel
122	T	3-6-62	287.5	84.3	1.0	67.2	130.1	4.9	52.66	29.80	0.405	5.12	16.01	3.08	2.26	N	Good	Rehabilitated 1979
123	T	20.-6-62	284.3	84.3	1.0	64.0	130.1	4.9	48.32	29.80	0.371	6.92	-	3.70	2.40	N	Good	Rehabilitated 1979
124	T	23-6-62	354.8	84.3	1.0	134.5	130.1	4.9	92.82	-	0.713	-	-	4.48	3.50	N	Good	Pumping some find sand
125	T	15-3-62	279.3	84.3	1.0	59.0	130.1	4.9	90.40	-	0.695	-	-	4.38	2.72	N	Good	Pumping some fine sand
126	T	25-6-62	285.1	84.3	1.0	74.8	120.0	4.9	71.55	29.70	0.596	-	-	4.22	-	N	Failing	Rehabilitated 1979 Severe sand pumping
127	T	27-7-62	289.2	84.3	1.0	68.9	130.1	4.9	71.55	60.60 80.73*	0.550	3.15	9.35	4.49	3.78	N	Good	Rehabilitated 1979
128	T	23-4-63	282.8	84.3	1.0	52.5	140.1	4.9	51.24	41.70 49.79*	0.366	-	10.35	4.20	2.40	N	Good	
129	T	27-6-62	285.4	85.0	1.0	74.5	120.0	4.9	72.03	-	0.600	-	-	4.38	3.50	N	Good	

T = Thakurgaon, H = Hagusta well screen, N = Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Descharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
130	T	19-7-62	276.1	84.3	1.0	55.8	130.1	4.9	60.91	53.40	0.468	-	9.35	4.48	-	N	Failed	Severe sand pumping
131	T	31-3-63	266.2	84.3	1.0	45.9	130.1	4.9	18.85	-	0.145	-	16.89	1.96	1.48	N	Good	
132	BG	29-6-62	316.2	84.3	1.0	95.9	130.1	4.9	55.11	-	0.424	-	11.41	4.42	-	N	Failed	Severe sand pumping
133	BG	1-7-62	299.8	84.3	1.0	79.5	130.1	4.9	78.80	-	0.606	-	9.94	4.48	-	N	Unconfirmed	Rehabilitated 1979 Power line stolen
134	BG	13-7-62	295.7	84.3	1.0	75.4	130.1	4.9	80.73	-	0.621	-	10.46	4.22	-	N	Unconfirmed	Low voltage power
135	BG	10-7-62	275.6	84.3	1.0	55.3	130.1	4.9	55.59	-	0.427	-	13.51	4.38	2.93	N	Unconfirmed	Rehabilitated 1979 Low voltage power
136	BG	5-7-62	348.4	84.3	1.0	118.1	140.1	4.9	40.12	-	0.286	-	-	4.48	2.58	N	Good	Rehabilitated 1979
137	BG	4-7-62	312.6	84.3	1.0	82.3	140.1	4.9	24.65	-	0.176	-	-	3.75	-	N	Failed	Rehabilitated 1979
138	T	10-4-63	262.9	84.3	1.0	62.6	130.1	4.9	71.06	48.50 69.61*	0.546	10.82	14.43	4.22	2.86	N	Good	Rehabilitated 1979
139	T	8-4-63	256.4	84.3	1.0	36.1	130.1	4.9	54.63	58.01*	0.420	-	12.76	4.04	2.86	N	Good	Pumping some sand
140	T	4-4-63	269.5	84.3	1.0	49.2	130.1	4.9	72.03	54.20	0.554	-	-	4.22	-	N	Failed	Severe sand pumping
141	PG	6-4-63	279.5	84.3	1.0	49.2	140.1	4.9	79.76	59.20	0.569	-	9.58	4.04	3.57	N	Unconfirmed	Transformer failure
142	T	28-3-63	262.9	84.3	1.0	42.6	130.1	4.9	51.24	-	0.394	-	-	4.22	2.86	N	Good	Pumping some sand
143	T	26-3-63	289.2	84.3	1.0	68.9	130.1	4.9	82.18	-	0.632	-	-	4.22	3.53	N	Good	
144	BG	25-2-63	294.1	84.3	1.0	73.8	130.1	4.9	61.29	-	0.472	-	12.56	4.22	3.57	N	Unconfirmed	Low voltage power
145	BG	23-3-63	276.1	84.3	1.0	55.8	130.1	4.9	66.71	-	0.513	-	13.12	4.22	3.43	N	Good	Pumping some fine sand
146	BG	6-3-63	279.3	84.3	1.0	59.9	130.1	4.9	68.65	-	0.528	-	-	4.22	3.57	N	Unconfirmed	Power line stolen
147	BG	1-3-63	271.1	84.3	1.0	50.8	130.1	4.9	72.03	-	0.554	-	-	4.04	-	N	Unconfirmed	Power line stolen
148	BG	8-3-63	267.5	84.3	1.0	47.2	130.1	4.9	56.56	-	0.435	-	-	4.04	3.07	N	Good	
149	BG	11-3-63	269.5	84.3	1.0	49.2	130.1	4.9	42.54	-	0.327	-	-	4.38	2.33	N	Unconfirmed	Elec.component failure
150	BG	5-3-63	282.6	84.3	1.0	62.3	130.1	4.9	65.26	-	0.502	-	-	4.38	-	N	Unconfirmed	Power line stolen
151	BG	3-3-63	262.9	84.3	1.0	42.6	130.1	4.9	87.02	-	0.669	-	-	4.22	-	N	Unconfirmed	Power line stolen
152	BG	17-3-63	279.3	84.3	1.0	59.0	130.1	4.9	51.24	-	0.394	-	-	3.87	1.70	N	Good	
153	BG	16-3-63	279.3	84.3	1.0	59.0	130.1	4.9	46.41	-	0.357	-	15.12	3.87	2.33	N	Unconfirmed	Elec.component failure

T = Thakurgaon, BG = Birganj, PG = Pirganj, N = Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) LWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84	Unit specific capacity (gpm/ft2)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
154	BG	14-3-63	282.6	84.3	1.0	62.3	130.1	4.9	53.18	-	0.409	-	-	4.38	3.00	N	Unconfirmed	No access to pumphouse
155	BG	19-3-63	279.3	84.3	1.0	59.0	130.1	4.9	42.54	-	0.327	-	-	3.87	1.91	N	Failing	Pumping sand & gravel
156	BG	24-2-63	354.8	84.3	1.0	134.5*	130.1	4.9	35.77	-	0.275	-	16.37	3.39	-	N	Unconfirmed	Power line stolen
157	BG	22-3-63	279.3	84.3	1.0	59.0	130.1	4.9	51.24	-	0.394	-	-	4.38	3.04	N	Good	
158	BG	2-3-63	297.4	84.3	1.0	77.1	130.1	4.9	39.16	52.21*	0.301	10.50	11.18	3.39	2.26	N	Failing	Pumping sand & gravel
159	BG	4-3-63	305.6	84.3	1.0	85.3	130.1	4.9	34.32	-	0.264	-	-	2.87	1.94	N	Good	
160	BG	5-3-63	202.8	84.3	1.0	6.6*	110.0	4.9	54.63	-	0.497	-	-	4.48	-	N	Failing	Pumping sand & gravel
161	BG	6-3-63	308.9	84.3	1.0	88.6	130.1	4.9	49.79	-	0.383	-	11.28	3.87	-	N	Failed	Lows of ground of well head
162	BG	9-3-63	236.7	84.3	1.0	16.4	130.1	4.9	44.47	-	0.342	-	-	4.22	1.94	N	Good	
163	T	13-2-64	291.9	84.3	1.0	70.5	131.2	4.9	44.47	-	0.339	-	-	4.04	2.40	N	Good	
164	BG	10-3-63	282.6	84.3	1.0	62.3	130.1	4.9	51.24	-	0.394	-	18.06	4.04	2.97	N	Good	
165	BG	14-3-63	253.1	84.3	1.0	32.8	130.1	4.9	54.63	-	0.420	-	16.43	4.04	2.72	N	Good	
166	BG	14-3-63	310.2	84.3	1.0	100.0	120.0	4.9	37.71	-	0.314	-	-	3.24	-	N	Failed	Loss of ground at well head
167	BG	16-3-63	266.2	84.3	1.0	45.9	130.1	4.9	35.77	-	0.275	-	14.99	3.55	-	N	Failing	Pumping sand
168	BG	15-3-63	239.7	84.3	1.0	29.5	120.0	4.9	63.33	-	0.487	-	-	4.22	3.00	N	Good	
169	BG	8-3-63	246.5	84.3	1.0	26.2	130.1	4.9	76.86	-	0.591	-	-	4.38	3.00	N	Good	Rehabilitated 1979
170	BG	18-3-63	256.4	84.3	1.0	36.1	130.1	4.9	42.54	-	0.327	14.07	-	3.87	1.55	N	Good	Pumping some sand
171	BG	17-3-63	256.4	84.3	1.0	36.1	130.1	4.9	34.32	29.00*	0.264	14.99	16.01	3.05	1.84	N	Good	
172	BG	17-3-63	256.4	84.3	1.0	36.1	130.1	4.9	34.32	37.71*	0.264	14.04	18.60	3.05	1.84	N	Good	
173	BG	21-3-63	226.9	84.3	1.0	6.6	130.1	4.9	68.65	-	0.528	-	-	4.22	2.75	N	Good	
174	BG	29-3-63	308.6	84.3	1.0	98.4	120.0	4.9	37.71	-	0.314	-	16.20	3.24	-	N	Failed	Loss of ground at well head
175	BG	27-3-63	276.1	84.3	1.0	55.8	130.1	4.9	42.54	-	0.327	-	-	3.87	2.12	N	Good	Pumping some sand
176	BG	26-3-63	277.7	84.3	1.0	57.4	130.1	4.9	47.86	-	0.368	-	-	4.04	-	N	Failed	Loss of ground at well head

T = Thakurgaon, BG = Birganj, N = Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks.
177	BG	31-3-63	276.1	84.3	1.0	55.8	130.1	4.9	42.54	-	0.327	-	-	3.87	1.73	N	Failing	Pumping sand & gravel
178	BG	3-4-63	236.7	84.3	1.0	16.4	130.1	4.9	42.54	-	0.327	-	-	3.70	2.83	N	Good	
179	BG	6-4-63	169.5	84.3	1.0	49.2	130.1	4.9	16.92	-	0.130	-	-	1.71	1.52	N	Good	
180	BG	5-4-63	246.5	84.3	1.0	26.2	130.1	4.9	37.71	-	0.290	--	-	3.24	1.34	N	Good	
181	T	29-4-63	256.4	84.3	1.0	36.1	130.1	4.9	60.91	-	0.468	-	13.74	4.38	2.65	N	Unconfirmed	Power line stolen
182	BG	8-3-63	262.9	84.3	1.0	42.6	130.1	4.9	44.47	-	0.342	-	13.78	4.04	1.94	N	Failing	Pumping sand & gravel
183	BG	8-4-63	276.1	84.3	1.0	55.8	130.1	4.9	35.29	-	0.271	-	15.38	3.87	2.15	N	Good	Rehabilitated 1979
184	BG	21-4-63	262.7	84.3	1.0	52.5	120.0	4.9	42.54	-	0.355	-	16.66	4.04	-	N	Failed	Loss of ground at well head
185	BG	19-4-63	289.2	84.3	1.0	68.9	130.1	4.9	58.01	-	0.446	-	-	4.22	-	N	Good	Rehabilitated 1979
186	BG	17-4-63	285.9	84.3	1.0	65.6	130.1	4.9	51.24	-	0.394	-	14.59	4.22	-	N	Unconfirmed	Rehabilitated 1980 Canal under repair
187	T	28-3-63	279.3	84.3	1.0	59.0	130.1	4.9	58.98	-	0.453	10.69	-	4.22	3.14	N	Good	Rehabilitated 1979
188	T	17-3-63	300.7	84.3	1.0	80.4	130.1	4.9	61.39	-	0.472	-	-	4.38	2.93	N	Good	Pumping some sand
189	T	26-3-63	282.6	84.3	1.0	62.3	130.1	4.9	62.85	-	0.483	12.40	-	4.38	2.19	N	Unconfirmed	Rehabilitated 1979 Canal under repair
190	T	31-3-63	279.3	84.3	1.0	59.0	130.1	4.9	89.92	-	0.691	-	9.94	4.22	-	N	Failed	Severe sand pumping
191	T	29-3-63	279.3	84.3	1.0	59.0	130.1	4.9	48.83	53.18*	0.375	-	13.25	4.04	3.14	N	Good	
192	T	5-4-63	279.3	84.3	1.0	59.0	130.1	4.9	47.38	-	0.364	-	-	4.04	2.44	N	Unconfirmed	Transformer failure
193	T	6-4-63	285.9	84.3	1.0	65.6	130.1	4.9	46.41	34.10	0.357	-	13.15	4.22	2.40	N	Unconfirmed	Transformer failure
194	T	10-4-63	279.3	84.3	1.0	59.0	130.1	4.9	42.54	32.80	0.327	-	-	4.04	3.53	N	Good	Low voltage power
195	T	18-4-63	84.3	84.3	1.0	72.2	120.0	4.9	53.18	37.30	0.443	-	-	4.04	2.19	N	Failing	Pumping sand & gravel
196	T	8-4-63	279.3	84.3	1.0	59.0	130.1	4.9	47.86	36.30	0.368	14.30	-	4.22	2.19	N	Good	
197	T	10.12-62	269.0	84.3	1.0	39.4	139.4	4.9	55.11	-	0.395	9.09	14.99	4.22	-	H	Unconfirmed	Elec.component failure
198	T	8-12-62	269.0	84.3	1.0	39.4	139.4	4.9	52.69	68.65*	0.378	10.33	15.38	4.04	3.21	H	Good	

T = Thakurgaon, BG = Birganj, N = Nold well screen, H= Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
199	T	5-12-62	262.4	84.3	1.0	32.8	139.4	4.9	76.38	18.85*	0.548	9.32	13.78	4.22	2.19	H	Moderate	Rehabilitated 1979 Yield reduction.
200	T	2-12-62	270.6	84.3	1.0	49.2	131.2	4.9	72.89	33.84*	0.556	9.18	12.60	4.22	2.33	H	Good	Rehabilitated 1970
201	T	8-8-62	230.1	84.3	1.0	9.8	130.1	4.9	54.63	-	0.420	-	15.48	4.04	2.86	N	Good	Rehabilitated 1979
202	T	8-8-62	269.5	84.3	1.0	49.2	130.1	4.9	60.91	-	0.468	-	-	4.72	3.07	N	Good	
203	T	13-8-62	279.3	84.3	1.0	59.0	130.1	4.9	83.63	59.46*	0.643	-	10.00	3.87	3.35	N	Good	Rehabilitated 1979 Pumping some fine sand
204	T	18-9-62	279.3	84.3	1.0	59.0	130.1	4.9	55.11	-	0.434	-	9.97	4.22	-	N	Failing	Motor failure, pumping sand
205	T	16-8-62	269.5	84.3	1.0	49.2	130.1	4.9	100.07	62.85*	0.769	-	12.04	4.48	3.00	N	Good	Rehabilitated 1979
206	T	10-9-62	279.3	84.3	1.0	59.0	130.1	4.9	83.15	87.02*	0.639	-	10.61	4.22	3.21	N	Good	Rehabilitated 1979
207	PG	14-9-62	279.3	84.3	1.0	59.0	130.1	4.9	75.90	67.20*	0.583	-	9.68	4.22	3.14	N	Failing	Pumping sand & gravel
208	PG	10-9-62	266.0	84.3	1.0	55.8	120.0	4.9	70.10	-	0.584	-	-	4.22	-	N	Failed	Severe sand pumping
209	T	21-9-62	279.3	84.3	1.0	59.0	130.1	4.9	61.39	50.24*	0.472	-	13.09	4.22	2.86	N	Failing	Pumping sand & gravel
210	T	12-11-62	269.2	84.3	1.0	59.0	120.0	4.9	77.83	-	0.649	-	-	4.22	2.79	N	Good	
211	PG	12-10-62	276.3	84.3	1.0	76.1	110.0	4.9	63.33	-	0.576	-	11.55	4.38	3.74	N	Unconfirmed	Motor failure
212	PG	15-11-62	269.1	84.3	1.0	68.9	110.0	4.9	86.05	69.13*	0.782	8.99	11.79	4.22	2.14	N	Good	Rehabilitated 1979
213	PG	7-11-62	279.1	84.3	1.0	68.9	120.0	4.9	70.10	-	0.584	-	-	4.22	-	N	Unconfirmed	Power line stolen
214	PG	1-11-62	276.3	84.3	1.0	76.1	110.0	4.9	69.61	-	0.633	-	8.40	4.22	-	N	Unconfirmed	Rehabilitated 1980 Not yet commissioned
215	PG	29-10-62	272.5	84.3	1.0	62.3	120.0	4.9	71.06	-	0.592	-	-	4.22	3.14	N	Good	Rehabilitated 1979 Pumping some fine sand
216	PG	24-10-62	259.7	84.3	1.0	39.4	130.1	4.9	68.65	76.86*	0.528	-	9.71	4.48	3.50	N	Good	
217	PG	17-11-62	265.6	84.3	1.0	75.4	100.0	4.9	58.49	-	0.585	9.74	10.76	4.22	3.50	N	Unconfirmed	Rehabilitated 1979 Power line damaged
218	PG	23-11-62	249.8	84.3	1.0	29.5	130.1	4.9	73.96	-	0.568	10.14	-	4.38	3.57	N	Good	Rehabilitated 1979
219	PG	23-10-62	278.9	84.3	1.0	78.7	110.0	4.9	100.07	83.15*	0.910	5.44	12.56	4.22	3.25	N	Good	Rehabilitated 1979
220	PG	16-10-62	269.2	84.3	1.0	59.0	120.0	4.9	89.43	-	0.795	7.74	-	4.38	2.93	N	Good	Rehabilitated 1979
221	PG	21-11-62	249.4	84.3	1.0	49.2	110.0	4.9	58.01	73.00*	0.527	5.94	8.72	4.38	3.57	N	Good	

T = Thakurgaon, PG = Pirganj, H = Hagusta well screen, N = Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
222	PG	3-11-62	269.5	84.3	1.0	49.2	130.1	4.9	119.89	102.00*	0.922	-	10.20	4.04	3.11	N	Good	Rehabilitated 1979
223	PG	19-10-62	262.7	84.3	1.0	52.5	120.0	4.9	78.31	-	0.653	-	-	4.38	3.35	N	Good	Rehabilitated 1979 Pumping some fine sand
224	PG	1-12-62	269.0	84.3	1.0	39.4	139.4	4.9	128.11	-	0.919	-	11.61	4.38	2.93	H	Failed	Severe sand pumping
225	PG	25-10-62	269.2	84.3	1.0	59.0	120.0	4.9	58.01	36.74*	0.483	-	10.92	4.22	2.72	N	Good	
226	PG	16-11-62	269.1	84.3	1.0	68.9	110.0	4.9	-	18.85*	-	-	12.96	4.38	1.87	N	Good	Rehabilitated 1980
227	PG	3-11-62	272.4	84.3	1.0	72.2	110.0	4.9	66.71	-	0.606	-	10.33	4.38	2.86	N	Failing	Pumping sand
228	PG	5-11-62	279.1	84.3	1.0	68.9	120.0	4.9	146.96	-	1.225	-	15.47	4.38	2.33	N	Unconfirmed	Rehabilitated 1979
229	PG	7-11-62	279.3	84.3	1.0	59.0	130.1	4.9	84.60	66.23*	0.650	-	10.59	4.38	3.43	N	Good	Rehabilitated 1979
230	PG	12-11-62	269.2	84.3	1.0	59.0	120.0	4.9	63.33	-	0.528	3.90	-	4.38	3.28	N	Good	Pumping some sand
231	RA	12-11-62	269.2	84.3	1.0	59.0	120.0	4.9	52.69	-	0.439	-	-	4.04	3.00	N	Good	
232	RA	14-11-62	269.2	84.3	1.0	59.0	120.0	4.9	68.65	-	0.572	-	13.33	4.38	3.21	N	Unconfirmed	Low voltage power
233	RA	16-11-62	269.2	84.3	1.0	59.0	120.0	4.9	90.40	-	0.753	-	-	4.38	2.65	N	Unconfirmed	Power line stolen
234	RA	8-12-62	269.5	84.3	1.0	49.2	130.1	4.9	69.13	-	0.531	-	14.40	4.22	3.57	N	Unconfirmed	Power line stolen
235	RA	28-11-62	84.3	84.3	1.0	27.9	140.1	4.9	72.03	-	0.514	8.99	-	4.38	3.21	N	Good	
236	RA	8-11-62	269.2	84.3	1.0	59.0	120.0	4.0	72.03	-	0.600	9.25	12.73	4.38	3.21	N	Unconfirmed	Power line stolen
237	RA	8-11-62	226.6	84.3	1.0	16.4	120.0	4.9	88.47	-	0.737	-	-	4.38	3.57	N	Unconfirmed	Power failure
238	RA	18-11-62	256.5	84.3	1.0	26.2	140.1	4.9	73.48	-	0.524	-	12.96	4.38	3.21	N	Unconfirmed	Power line stolen
239	PG	21-11-62	329.3	84.3	1.0	119.1	120.0	4.9	68.65	-	0.572	12.92	15.61	4.38	3.00	N	Failed	Power line stolen Severe sand pumping
240	PG	5-11-62	279.1	84.3	1.0	68.9	120.0	4.9	68.65	-	0.572	6.95	12.37	4.38	2.93	N	Unconfirmed	Rehabilitated 1979 Power line stolen
241	PG	5-11-62	269.5	84.3	1.0	49.2	130.1	4.9	68.65	-	0.528	-	11.48	4.22	3.43	N	Unconfirmed	Power line stolen
242	PG	20-11-62	269.0	84.3	1.0	39.4	139.4	4.9	64.29	-	0.461	9.54	13.78	4.22	3.00	H	Unconfirmed	Power line stolen
243	PG	22-11-62	278.8	84.3	1.0	49.2	139.4	4.9	73.48	-	0.527	-	11.15	4.38	3.00	H	Unconfirmed	Power line stolen
244	PG	28-11-62	269.0	84.3	1.0	39.4	139.4	4.9	88.95	-	0.639	6.79	13.61	4.72	3.85	H	Unconfirmed	Power line stolen

PG = Pirganj, RA = Ranisankail, N = Nold well screen, H = Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	UWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1982	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
245	PG	31-10-62	242.8	84.3	1.0	42.5	110.0	4.9	68.65	-	0.625	-	-	4.38	-	N	Failed	Loss of ground well head
246	PG	15-2-63	262.7	84.3	1.0	52.5	120.0	4.9	85.57	-	0.713	-	-	4.22	-	N	Failed	Loss of ground well head
247	RA	16-1-63	273.9	84.3	1.0	60.7	123.0	4.9	60.91	-	0.495	-	-	4.04	2.26	H	Unconfirmed	Power line stolen
248	RA	6-12-62	256.4	84.3	1.0	36.1	130.1	4.9	60.91	62.36*	0.468	8.82	10.50	4.38	3.14	N	Good	Reported pumping sand
249	RA	4.12.62	243.3	84.3	1.0	23.0	130.1	4.9	82.18	-	0.632	12.89	-	4.22	2.65	N	Unconfirmed	No access to pump house
250	RA	8-12-62	295.9	84.3	1.0	85.3	120.0	4.9	80.73	-	0.673	8.95	-	4.38	-	N	Failed	Loss of ground at well head
251	RA	10-12-62	269.5	84.3	1.0	49.2	130.1	4.9	63.33	-	0.487	-	-	4.38	-	N	Failed	Severe sand pumping
252	RA	13-12-62	269.5	84.3	1.0	49.2	130.1	4.9	94.27	62.60	0.725	-	-	4.38	-	N	Failed	Severe sand pumping
253	RA	14-12-62	272.8	84.3	1.0	52.5	130.1	4.9	114.57	-	0.881	-	-	4.38	3.49	N	Unconfirmed	Rehabilitated 1980 Power failure
254	RA	19-12-62	243.3	84.3	1.0	23.0	130.1	4.9	90.88	-	0.698	-	-	4.55	2.12	N	Unconfirmed	Power line stolen
255	RA	17-12-62	248.2	84.3	1.0	27.9	130.1	4.9	100.55	36.20	0.773	-	15.58	4.22	3.28	N	Failed	Severe sand pumping
256	RA	21-12-62	241.6	84.3	1.0	21.3	130.1	4.9	81.70	-	0.628	-	-	4.38	2.40	N	Unconfirmed	Rehabilitated 1979. Power failure.Reported pumping some sand
257	RA	4-1-63	251.2	84.3	1.0	41.0	120.0	4.9	124.72	-	1.039	-	-	4.22	3.43	N	Unconfirmed	Power failure
258	RA	6-1-63	249.6	84.3	1.0	39.4	120.0	4.9	101.04	28.70	0.842	-	-	4.55	1.66	N	Failed	Severe sand pumping
259	RA	7-1-63	251.2	84.3	1.0	41.0	120.0	4.9	98.14	-	0.818	-	-	4.38	3.21	N	Unconfirmed	Power failure.Reported pumping some sand
260	RA	9-1-63	243.0	84.3	1.0	32.8	120.0	4.9	66.71	41.90	0.556	-	-	4.38	-	N	Unconfirmed	Rehabilitated Power failure
261	RA	13-1-63	307.0	84.3	1.0	96.8	120.0	4.9	55.11	62.60 60.91*	0.459	-	15.28	4.22	3.21	N	Good	
262	RA	7-2-63	267.4	85.9	1.0	65.6	110.0	4.9	72.03	26.59*	0.655	-	16.40	4.22	2.05	N	Good	Tested June 1983.Power line stolen 1984 survey
263	RA	9-2-63	310.5	84.3	1.0	90.2	130.1	4.9	83.63	-	0.643	-	-	4.38	-	N	Unconfirmed	Rehabilitated 1979 Power line stolen
264	RA	11-2-63	269.5	84.3	1.0	49.2	130.1	4.9	72.03	-	0.554	-	-	4.22	3.64	N	Good	

PG = Pirgang, RA = Ranisankail, H = Hagusta well screen, N = Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
265	RA	18-1-63	259.2	84.3	1.0	41.0	123.0	4.9	45.44	-	0.369	-	10.40	4.04	1.02	H	Failed	Low yield
266	RA	10-12-62	259.7	84.3	1.0	39.4	130.1	4.9	73.48	-	0.565	-	-	4.38	3.28	N	Failing	Pumping sand & gravel
267	RA	11-12-62	230.3	84.3	1.0	0	140.1	4.9	75.41	-	0.538	-	-	4.38	3.43	N	Unconfirmed	No access to pump house
268	RA	13-12-62	266.2	84.3	1.0	45.9	130.1	4.9	73.48	-	0.565	-	-	4.38	3.00	N	Unconfirmed	Power line stolen
269	RA	17-1-63	252.6	84.3	1.0	39.4	123.0	4.9	58.01	21.20	0.472	-	12.56	4.38	2.08	H	Failing	Reported pumping sand
270	RA	15-1-63	259.1	84.3	1.0	45.9	123.0	4.9	37.22	-	0.303	-	-	3.05	2.33	H	Unconfirmed	Power line stolen
271	RA	14-1-63	259.1	84.3	1.0	45.9	123.0	4.9	41.09	-	0.334	-	13.22	3.39	2.26	H	Unconfirmed	Power line stolen
272	RA	15-12-62	269.0	84.3	1.0	39.4	139.4	4.9	60.91	-	0.437	-	-	4.22	3.21	H	Unconfirmed	Power failure. Reported pumping some sand
273	RA	8-2-63	275.6	84.3	1.0	55.3	130.1	4.9	87.02	26.30	0.669	-	15.78	4.22	1.70	N	Failing	Reported pumping sand
274	RA	18-1-63	269.2	84.3	1.0	59.0	120.0	4.9	58.01	39.40	0.483	-	17.35	4.38	2.65	N	Unconfirmed	Power lile stolen
275	RA	8-1-63	239.7	84.3	1.0	29.5	120.0	4.9	56.56	-	0.471	-	16.99	4.48	*0.95	N	Yield Marginal	Power line stolen
276	RA	10-1-63	249.6	84.3	1.0	39.4	120.0	4.9	79.28	-	0.661	-	17.09	4.04	3.14	N	Unconfirmed	Power line stolen
277	RA	20-12-62	220.3	84.3	1.0	0	130.1	4.9	99.10	29.80	0.762	-	-	4.22	2.61	N	Failing	Reported pumping sand
278	RA	12-1-63	239.7	84.3	1.0	29.5	120.0	4.9	66.71	-	0.556	-	-	4.22	1.17	N	Yield Marginal	Power line stolen
279	RA	7-1-63	240.0	84.3	1.0	19.7	130.1	4.9	85.57	-	0.658	-	19.68	4.48	3.14	N	Unconfirmed	Power line stolen
280	RA	6-2-63	266.2	84.3	1.0	45.9	130.1	4.9	87.02	-	0.669	-	13.61	4.48	3.43	N	Unconfirmed	Power line stolen
281	RA	17-12-62	234.5	84.3	1.0	13.1	131.2	4.9	69.13	-	0.527	-	13.19	4.48	3.07	N	Unconfirmed	Elec.component failure
282	RA	18-12-62	221.4	84.3	1.0	0	131.2	4.9	34.81	-	0.265	-	13.84	*2.63	-	H	Good	Canal poor condition
283	RA	4-1-63	253.1	84.3	1.0	32.8	130.1	4.9	88.95	-	0.684	-	-	4.38	-	N	Good	Canal poor condition
284	HA	5-1-63	249.6	84.3	1.0	39.4	120.0	4.9	76.38	-	0.637	-	-	4.48	-	N	Unconfirmed	Elec.component failure
285	HA	22-1-63	252.6	84.3	1.0	39.4	123.0	4.9	47.38	-	0.385	-	-	3.70	-	H	Unconfirmed	No access to pump house
286	HA	21-1-63	249.3	84.3	1.0	36.1	123.0	4.9	44.96	-	0.366	-	12.96	3.39	-	H	Unconfirmed	Power line stolen
287	HA	24-1-63	249.3	84.3	1.0	36.1	123.0	4.9	41.09	-	0.334	-	-	3.39	-	H	Unconfirmed	Power line stolen

RA = Ranisankail, HA = Haripur, H = Hagusta well screen , N = Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Deischarge (cfs.) 1962	1984	Screen type	Operating condition (1984)	Remarks
288	HA	23-1-63	269.0	84.3	1.0	55.8	123.0	4.9	29.97	-	0.244	-	10.33	2.52	-	H	Unconfirmed	Power line stolen
289	HA	26-1-63	252.6	84.3	1.0	39.4	123.0	4.9	52.21	-	0.424	-	-	4.22	-	H	Unconfirmed	Power line stolen
290	HA	23-1-63	269.0	84.3	1.0	64.0	114.8	4.9	47.38	-	0.413	-	13.23	3.24	-	H	Unconfirmed	Power line stolen
291	HA	27-1-63	259.1	84.3	1.0	45.9	123.0	4.9	66.71	-	0.542	-	-	4.38	-	H	Unconfirmed	Power line stolen
292	HA	27-1-63	269.2	84.3	1.0	59.0	120.0	4.9	77.83	-	0.649	-	16.14	4.22	-	N	Unconfirmed	Power line stolen
293	HA	30-1-63	249.3	84.3	1.0	36.1	123.0	4.9	37.71	-	0.307	-	15.06	2.87	-	H	Unconfirmed	Power line stolen
294	HA	29-1-63	272.5	84.3	1.0	62.3	120.0	4.9	88.95	-	0.741	-	-	4.38	-	N	Unconfirmed	Power line stolen
295	HA	31-1-63	262.7	84.3	1.0	52.5	120.0	4.9	79.28	-	0.661	-	-	4.48	-	N	Unconfirmed	Power line stolen
296	HA	4-2-63	233.4	84.3	1.0	13.1	130.1	4.9	72.03	-	0.554	-	-	4.22	-	N	Unconfirmed	Power line stolen
297	HA	16-1-63	257.6	84.3	1.0	57.4	110.0	4.9	90.40	-	0.822	-	-	4.38	-	N	Unconfirmed	Power line stolen
298	RA	10-2-63	275.6	84.3	1.0	55.4	130.1	4.9	54.63	-	0.420	-	16.30	4.22	-	N	Unconfirmed	Power failure
299	BA	10-5-63	279.3	84.3	1.0	59.0	130.1	4.9	82.18	-	0.632	-	-	4.22	-	N	Failed	Severe sand pumping
300	BA	24-4-63	279.3	84.3	1.0	59.0	130.1	4.9	60.96	-	0.469	-	-	4.22	-	N	Unconfirmed	Power failure Reported pumping sand
301	RA	17-5-63	272.2	84.3	1.0	59.0	123.0	4.9	51.24	-	0.417	10.30	12.10	4.04	-	H	Unconfirmed	Power failure
302	BA	14-5-63	262.4	84.3	1.0	49.2	123.0	4.9	24.65	20.00	0.200	9.28	10.82	2.18	-	H	Unconfirmed	Power failure
303	BA	21-4-63	269.5	84.3	1.0	49.2	130.1	4.9	47.86	-	0.368	11.68	12.69	4.22	-	N	Unconfirmed	Motor failure
304	BA	12-5-63	272.8	84.3	1.0	52.5	130.1	4.9	75.41	54.44	0.580	9.25	12.82	4.04	3.04	N	Good	Rehabilitated 1980
305	BA	15-5-63	272.2	84.3	1.0	59.0	123.0	4.9	44.47	39.20	0.362	10.56	11.97	3.87	2.75	H	Unconfirmed	Power failure
306	BA	12-5-63	262.4	84.3	1.0	49.2	123.0	4.9	24.65	26.60	0.200	11.38	12.96	2.35	1.70	H	Unconfirmed	Power failure
307	BA	10-5-63	260.8	84.3	1.0	47.6	123.0	4.9	39.16	-	0.318	13.35	-	2.87	2.26	H	Unconfirmed	Power failure
308	BA	18-4.63	276.1	84.3	1.0	55.8	130.1	4.9	58.49	23.80	0.449	12.40	12.86	4.22	-	N	Unconfirmed	Rehabilitated 1980 Power line stolen
309	BA	18-4-63	269.5	84.3	1.0	49.4	130.1	4.9	73.48	-	0.565	9.74	14.01	4.38	3.81	N	Good	Rehabilitated
310	BA	20-4-63	279.3	84.3	1.0	59.0	130.1	4.9	73.48	-	0.565	13.15	11.22	4.38	-	N	Failed	Reported failed for sand pumping

HA = Haripur, RA= Ranisankail, BA= Baliadangi, N= Nold well screen, H= Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs) 1962	1984	Screen type	Operating condition (1984)	Remarks
311	RA	22-5-63	285.4	84.3	1.0	72.2	123.0	4.9	66.71	35.10	0.542	9.84	10.59	4.04	-	H	Unconfirmed	Elec.component failure
312	RA	23-5-63	272.2	84.3	1.0	59.0	123.0	4.9	72.03	-	0.586	13.61	-	4.22	3.46	H	Good	
313	RA	22-5-63	272.2	84.3	1.0	59.0	123.0	4.9	68.61	29.30 59.94*	0.558	11.74	12.56	4.22	3.35	H	Good	Rehabilitated 1980
314	T	9-5-63	272.2	84.3	1.0	59.0	123.0	4.9	13.54	-	0.110	15.78	-	*1.26	-	H		Original DTW not commissioned due to low yield
315	BA	12-5-63	269.0	84.3	1.0	47.6	131.2	4.9	58.01	-	0.442	11.94	12.60	4.38	3.18	H	Unconfirmed	Power line stolen
316	BA	15-5-63	270.6	84.3	1.0	49.2	131.2	4.9	34.32	-	0.262	12.89	-	3.24	2.08	H	Unconfirmed	Power line stolen
317	BA	27-5-63	290.3	84.3	1.0	68.9	131.2	4.9	52.69	-	0.402	11.55	-	4.22	2.72	H	Unconfirmed	Power line stolen
318	BA	29-5-63	270.6	84.3	1.0	49.2	131.2	4.9	63.33	-	0.483	13.19	-	4.38	-	H	Unconformed	Power lile stolen
319	T	11-8-63	290.3	84.3	1.0	68.9	131.2	4.9	21.27	-	0.162	13.12	-	2.02	1.70	H	Unconfirmed	Power line stolen.No access to pump house
320	T	11-2-64	267.3	84.3	1.0	45.9	131.2	4.9	34.32	-	0.262	11.78	-	3.70	-	H	Unconfirmed	Power line stolen
321	T	11-6-63	275.5	84.3	1.0	54.1	131.2	4.9	46.41	-	0.354	12.37	15.12	4.04	-	H	Unconfirmed	Rehabilitated 1980.Power line stolen.Canal under repair.
322	T	25-2-64	269.0	84.3	1.0	47.6	131.2	4.9	46.41	-	0.351	16.37	-	4.04	-	H	Unconfirmed	Power line stolen Canal under repair
323	T	24-2-64	280.4	84.3	1.0	59.0	131.2	4.9	58.01	-	0.442	15.94	-	4.04	-	H	Unconfirmed	Motor failure
324	T	23-2-64	280.4	84.3	1.0	49.2	131.2	4.9	47.86	-	0.365	15.48	17.15	4.04	-	H	Unconfirmed	Elec.component failure
325	T	22-2-64	265.7	84.3	1.0	44.3	131.2	4.9	37.71	-	0.287	12.96	15.89	4.04	-	H	Unconfirmed	Power line stolen
326	T	29-11-63	301.8	84.3	1.0	88.6	123.0	4.9	30.94	83.50 72.51*	0.252	8.76	14.01	2.93	2.01	H	Good	
327	PG	27-2-64	305.6	84.3	1.0	85.3	130.1	4.9	80.25	-	0.617	12.50	14.69	4.22	*5.16	N	Good	
328	PG	28-2-64	279.3	84.3	1.0	59.0	130.1	4.9	41.09	-	0.316	11.32	-	4.04	-	N	Failed	Loss of ground at well head
329	T	29-2-64	292.4	84.3	1.0	72.1	130.1	4.9	53.18	-	0.409	12.14	-	4.04	2.58	N	Good	
330	T	10-2-64	280.4	84.3	1.0	59.0	131.2	4.9	22.24	-	0.169	10.53	-	1.74	-	H	Unconfirmed	Power line stolen
331	T	8-2-64	269.5	84.3	1.0	49.2	130.1	4.9	29.00	-	0.223	11.02	-	2.78	-	N	Unconfirmed	Power line stolen

RA = Ranisankail, T = Thakurgaon, BA = Baliadangi, PG= Pirganj, N= Nold well screen, H=Hagusta well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs.) 1962	1984	Screen type	Operating condition (1984)	Remarks
332	T	5-2-64	280.4	84.3	1.0	50.0	131.2	4.9	47.86	-	0.365	12.07	-	4.04	2.30	H	Good	
333	T	22-11-63	288.6	84.3	1.0	75.4	123.0	4.9	48.83	-	0.397	9.45	--	4.38	2.54	H	Good	
334	T	1-11-63	255.9	87.6	1.0	39.4	123.0	4.9	52.69	35.70	0.428	6.13	13.12	3.87	-	H	Unconfirmed	Low-voltage power
335	T	5-11-63	246.0	84.3	1.0	32.8	123.0	4.9	56.56	--	0.460	6.30	-	4.48	-	H	Unconfirmed	No access to pump house
336	T	1-7-63	270.6	84.3	1.0	49.2	131.2	4.9	59.94	-	0.457	7.45	--	4.48	3.11	H	Good	
337	T	21-1-64	262.4	84.3	1.0	49.2	123.0	4.9	31.42	-	0.255	10.43	-	4.00	-	H	Unconfirmed	No access to pump house
338	T	15-1-64	295.7	84.3	1.0	75.4	130.1	4.9	73.96	-	0.568	10.79	15.12	*1.81	-	N	Unconfirmed	Rehabilitated 1980. Power failure
339	T	18-1-64	269.5	84.3	1.0	49.2	130.1	4.9	20.30	-	0.156	5.02	-	*1.81	-	N	Unconfirmed	Power line stolen
340	T	31-1-64	283.7	84.3	1.0	70.5	123.0	4.9	49.79	-	0.405	10.17	-	4.04	-	H	Failing	Pumping sand & gravel
341	T	24-1-64	272.2	84.3	1.0	59.0	123.0	4.9	22.24	-	0.181	3.31	-	2.07	-	H	Unconfirmed	Motor failure
342	A	28-1-64	280.4	84.3	1.0	59.0	131.2	4.9	49.79	-	0.379	12.99	12.66	4.04	-	H	Unconfirmed	Elec.component failure
343	A	12-1-64	274.4	84.3	1.0	54.1	130.1	4.9	24.17	-	0.186	7.71	13.61	2.00	-	N	Unconfirmed	Motor & transformer removed
344	A	9-1-64	276.1	84.3	1.0	55.8	130.1	4.9	25.62	-	0.197	7.02	-	2.21	-	N	Unconfirmed	Power line stolen
345	A	1-11-63	264.0	84.3	1.0	50.8	123.0	4.9	31.42	36.26*	0.255	8.59	14.43	2.63	1.52	H	Good	
346	A	22-1-64	262.4	84.3	1.0	49.2	123.0	4.9	22.24	-	0.181	4.79	10.69	2.07	-	H	Unconfirmed	Elec.component failure
347	T	19-1-64	265.7	84.3	1.0	52.5	123.0	4.9	14.50	-	0.118	4.56	-	1.32	2.58	H	Good	
348	A	15-1-64	272.2	84.3	1.0	59.0	123.0	4.9	13.54	-	0.110	7.02	-	1.32	-	H		Original DTW not commissioned due to low yield
349	A	12-1-64	272.2	84.3	1.0	59.0	123.0	4.9	22.72	-	0.185	5.58	-	2.07	-	H	Unconfirmed	Power line stolen
350	A	29-6-63	273.9	84.3	1.0	52.5	131.2	4.9	47.86	-	0.365	5.48	12.00	3.70	-	H	Unconfirmed	Power line stolen
351	A	19-11-63	272.2	84.3	1.0	59.0	123.0	4.9	47.86	-	0.387	6.46	-	4.48	2.79	H	Good	
352	A	15-11-63	272.2	84.3	1.0	59.0	123.0	4.9	32.39	-	0.263	5.74	11.51	2.87	-	H	Unconfirmed	Elec.component failure
353	T	3-3-64	279.5	84.3	1.0	49.2	140.1	4.9	41.09	-	0.293	15.91	-	3.24	-	N	Failed	Abandoned
354	A	9-1-64	269.0	84.3	1.0	55.8	123.0	4.9	20.79	-	0.169	4.92	-	1.81	-	H	Unconfirmed	Elec.component failure

T = Thakurgaon, A = Atwari, H= Hagusta well screen, N= Nold well screen

TABLE 3.1 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1962	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1962	1984	Discharge (cfs.) 1962	1984	Screen type	Operating condition (1984)	Remarks.
355	A	24-6-63	272.2	84.3	1.0	59.0	123.0	4.9	42.54	42.54*	0.346	4.76	12.89	4.00	2.79	H	Good	
356	A	6-1-64	262.4	84.3	1.0	49.2	123.0	4.9	19.81	-	0.161	4.23	9.94	1.81	-	H	Failed	Severe sand pumping
357	A	4-1-64	250.9	84.3	1.0	29.5	131.2	4.9	38.67	-	0.295	11.19	13.19	1.68	-	H	Unconfirmed	Low voltage power
358	A	25-6-63	273.9	84.3	1.0	52.5	131.2	4.9	54.63	45.70	0.416	5.74	12.89	4.48	-	H	Unconfirmed	Elec.component failure
359	A	6-1-64	280.4	84.3	1.0	59.0	131.2	4.9	24.17	46.41*	0.184	9.28	11.97	1.96	1.84	H	Good	
360	A	28-1-64	265.7	84.3	1.0	52.5	123.0	4.9	24.17	30.10	0.197	7.94	11.11	2.78	-	H	Unconfirmed	Low voltage power
361	A	4-1-64	267.3	84.3	1.0	45.9	131.2	4.9	26.59	57.80	0.203	7.15	11.15	2.07	-	H	Unconfirmed	Elec.component failure
362	A	22-12-63	265.7	84.3	1.0	52.5	123.0	4.9	21.27	30.00 43.02*	0.173	7.05	10.46	*1.49	2.05	H	Good	
363	A	21-12-63	280.4	84.3	1.0	59.0	131.2	4.9	34.32	-	0.262	10.56	12.23	3.39	-	H	Unconfirmed	Power line stolen
364	A	19-12-63	277.2	84.3	1.0	55.8	131.2	4.9	51.24	56.30 51.24*	0.391	6.46	10.56	*1.68	2.40	H	Good	
365	A	1-2-64	262.4	84.3	1.0	41.0	131.2	4.9	19.34	45.80	0.147	4.43	12.10	*1.68	-	H	Unconfirmed	Transformer failure
366	A	12-12-63	287.0	84.3	1.0	73.8	123.0	4.9	22.24	71.30	0.181	6.17	14.86	2.07	-	H	Unconfirmed	Transformer failure
367	A	11-12-63	282.1	84.3	1.0	68.9	123.0	4.9	22.24	-	0.181	6.33	12.27	2.18	-	H	Unconfirmed	Elec.component failure
368	A	4-12-63	272.2	84.3	1.0	59.0	123.0	4.9	35.29	29.50	0.287	8.40	11.61	4.04	1.52	H	Good	Elec.component failure
369	A	7-12-63	300.1	84.3	1.0	95.1	114.8	4.9	41.09	-	0.358	8.63	-	4.22	-	H	Unconfirmed	Power line stolen
370	A	14-12-63	296.8	84.3	1.0	83.6	123.0	4.9	42.06	-	0.342	8.63	9.05	4.22	-	H	Unconfirmed	Power line stolen
371	A	3-12-63	272.2	84.3	1.0	59.0	123.0	4.9	20.30	-	0.165	6.36	12.14	1.71	-	H	Unconfirmed	Power line stolen
372	A	29-11-63	272.2	84.3	1.0	59.0	123.0	4.9	37.71	-	0.307	8.00	10.00	3.70	-	H	Unconfirmed	Power line stolen
373	A	10-2-64	272.8	84.3	1.0	52.5	130.1	4.9	22.24	63.00 43.99*	0.171	10.04	11.51	2.00	1.94	N	Good	

A = Atwari, H = Hagusta well screen, N = Nold well screen

TABLE 3.2

TUBEWELL DATA SUMMARY OF SOME REHABILITATED WELLS OF THAKURGAON TUBEWELL PROJECT

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1979	1983/84	Unit specific capacity (gpm/ft)	SWL (ft.) 1979	1984	Discharge (cfs) 1979	1984	Screen type	Operating condition (1984)	Remarks
122	T	18-7-79	212.58	78.33	9.25	40.00	80.00	5.00	24.46	29.80	0.306	5.50	16.01	3.40	2.26	S	Good	Rehabilitated 1979
123	T	24-5-79	226.08	78.50	9.00	57.50	76.08	5.00	22.43	29.30	0.295	7.33	-	3.23	2.40	S	Good	Rehabilitated 1979
126	T	7-6-79	241.50	79.00	9.00	68.50	80.00	5.00	89.44	29.70	1.118	5.00	-	4.18	-	S	Failing	Rehabilitated 1979 Severe sand pumping
127	T	30-6-79	216.83	76.83	6.25	48.75	80.00	5.00	75.34	60.60 *80.73	0.942	3.50	9.35	4.18	3.78	S	Good	Rehabilitated 1979
133	BG	18-8-79	211.38	78.00	9.00	39.36	80.44	4.58	-	-	-	-	9.94	-	-	S	Unconfirmed	Rehabilitated 1979 Power line stolen
135	BG	28-10-79	179.25	77.00	9.00	0	88.67	4.58	-	-	-	-	13.51	-	2.93	S	Unconfirmed	Rehabilitated 1979 Low voltage power
136	BG	15-10-79	187.52	78.00	9.00	26.08	69.86	4.58	-	-	-	-	-	-	2.58	S	Good	Rehabilitated 1979
137	BG	7-10-79	254.50	78.33	9.00	92.51	69.66	5.00	24.36	-	0.350	7.58	-	2.21	-	S	Failed	Rehabilitated 1979 Severe sand pumping
138	T	20-6-79	241.25	77.25	9.00	48.33	101.67	5.00	68.87	48.50 *69.61	0.677	5.00	14.43	4.00	2.86	S	Good	Rehabilitated 1979
169	BG	15-9-79	195.75	77.33	9.25	21.67	82.67	4.83	-	-	-	-	-	-	3.00	S	Good	Rehabilitated 1979
183	BG	18-8-79	190.83	78.58	9.17	19.83	78.42	4.83	-	-	-	-	15.38	-	2.15	S	Good	Rehabilitated 1979
185	BG	7-9-79	245.33	78.33	9.25	72.09	80.66	5.00	58.16	-	0.721	8.00	-	3.23	-	S	Good	Rehabilitated 1979
186	BG	-	-	-	-	-	-	-	-	-	-	-	14.56	-	-	S	Unconfirmed	Rehabilitated 1979 Canal under repair
187	T	28-7-79	188.00	77.25	9.25	16.50	80.00	5.00	56.20	-	0.702	6.00	-	4.18	3.14	S	Good	Rehabilitated 1979
189	T	26-6-79	221.83	76.67	9.00	39.66	91.48	5.00	50.28	-	0.550	8.00	-	4.18	2.19	S	Unconfirmed	Rehabilitated 1979 Canal under repair
199	T	25-10-79	215.43	79.00	9.25	39.16	83.02	5.00	76.10	*18.85	0.917	9.00	13.78	4.35	2.19	S	Moderate	Rehabilitated 1979 Yield reduction
201	T	23-7-79	231.50	79.00	9.00	58.50	80.00	5.00	53.20	-	0.665	6.00	15.48	4.25	2.86	S	Good	Rehabilitated 1979
203	T	16-10-79	232.93	79.00	9.25	59.68	80.00	5.00	83.46	*59.46	1.043	7.00	10.00	4.35	3.35	S	Good	Rehabilitated 1979 Pumping some sand
205	T	-	266.17	79.00	9.25	72.34	100.58	5.00	96.77	*62.85	0.962	8.17	12.04	4.35	3.00	S	Good	Rehabilitated 1979

T = Thakurgaon, BG = Birganj

TABLE 3.2 (Continued)

DTW No.	Location	Date Drilled	Well Depth (ft.)	Components used (ft.) UWC (14")	Reducer (14"/10")	LWC (10")	Screen (10")	Bail plug (10")	Specific capacity (gpm/ft.) 1979	1983/84*	Unit specific capacity (gpm/ft²)	SWL (ft.) 1979	1984	Discharge (cfs) 1979	1984	Screen type	Operating condition (1984)	Remarks
206	T	5-9-79	220.96	79.17	9.25	45.87	81.67	5.00	80.18	*87.02	0.982	4.50	10.61	4.18	3.21	S	Good	Rehabilitated 1979
212	PG	21-7-79	207.50	79.00	9.25	33.00	81.25	5.00	83.15	*69.13	1.023	10.67	11.97	3.48	3.14	S	Good	Rehabilitated 1979
215	PG	2-8-79	216.43	78.17	9.25	43.01	81.00	5.00	62.10	-	0.767	7.67	-	3.28	3.14	S	Good	Rehabilitated 1979 Pumping some fine sand
217	PG	7-7-79	199.67	79.00	9.25	26.42	80.00	5.00	54.49	-	0.681	9.92	10.76	3.02	3.50	S	Unconfirmed	Rehabilitated 1979 Power line damaged
218	PG	9-7-79	199.67	79.00	9.25	26.42	80.00	5.00	71.27	-	0.891	6.67	-	3.48	3.57	S	Good	Rehabilitated 1979
219	PG	16-7-79	175.67	72.00	9.25	13.18	76.25	5.00	94.93	*83.15	1.245	13.83	12.56	3.40	3.25	S	Good	Rehabilitated 1979
220	PG	18-7-79	208.08	79.00	9.25	29.83	85.00	5.00	83.15	-	0.978	9.67	-	3.48	2.93	S	Good	Rehabilitated 1979
222	PG	5-7-79	188.33	70.67	9.25	26.41	80.00	5.00	113.38	*102.00	1.417	10.00	10.20	3.68	3.11	S	Good	Rehabilitated 1979
223	PG	14-7-79	218.08	71.00	9.25	52.83	80.00	5.00	74.34	-	0.929	10.83	-	3.33	3.35	S	Good	Rehabilitated 1979 Pumping some fine sand
228	PG	14-5-79	288.50	80.00	9.00	82.50	110.00	5.00	96.77	-	0.880	15.25	15.47	3.35	2.33	S	Unconfirmed	Rehabilitated 1979
229	PG	3-6-79	187.43	80.00	9.25	13.18	80.00	5.00	84.72	*66.23	1.059	13.50	10.59	3.50	3.43	S	Good	Rehabilitated 1979
240	PG	9-6-79	214.43	80.00	9.00	36.43	84.00	5.00	-	-	-	-	12.37	-	2.93	S	Unconfirmed	Rehabilitated 1979 Power line stolen
255	RA	24-6-79	170.75	74.00	3.75	0	88.00	5.00	95.53	36.20	1.085	9.25	15.58	3.56	3.28	S	Unconfirmed	Rehabilitated 1979 Power failure
263	RA	16-6-79	272.08	79.00	9.00	99.08	80.00	5.00	78.09	-	0.976	6.25	-	3.56	-	S	Unconfirmed	Rehabilitated 1979 Power line stolen
376	RA	29-6-77	198.00	79.00	9.00	0	105.00	5.00	100.22	-	0.954	4.50	-	3.78	2.19	S	-	-

T = Thakurgaon, PG = Pirganj, RA = Ranishankail.

TABLE 4.1

VARIATION IN THE DESIGN OF WELLS UNDER DIFFERENT CONSIDERATIONS

Borehole number	Considering the finest layers of the individual boreholes		Considering the mean of all the layers of a borehole to be screened	
	Slot opening (mm.)	Range of gravel pack design (mm.)	Slot opening (mm.)	Range of gravel pack design (mm.)
TH-1	0.84	0.73 to 3.15	1.02	0.90 to 3.55
TH-2	0.66	0.56 to 2.70	0.91	0.77 to 4.10
PI-1	0.772	0.665 to 2.90	1.02	0.90 to 3.60
PI-2	0.542	0.470 to 2.10	0.77	0.66 to 3.10
BI-1	0.542	0.475 to 1.80	0.77	0.63 to 4.40
BO-1	0.795	0.72 to 2.39	1.17	1.02 to 3.88
BO-2	0.72	0.62 to 2.65	1.02	0.89 to 3.83
KA-2	0.70	0.60 to 2.67	0.876	0.77 to 3.40
AT-1	-	-	1.025	0.91 to 3.90
Mean, $\bar{X}$	-	-	0.965	0.84 to 3.55

TABLE 4.2

DIFFERENCE BETWEEN THEORETICAL DESIGN AND ACTUAL CONSTRUCTION IN SOME NEWLY INSTALLED WELLS OF THE STUDY AREA

Sl. No.	DTW No.	D_{70} of formation material at depth (mm.)	Grain size distribution of gravel pack as per design (mm.)					Slot opening as per design (inch)	Approximate distribution of gravel pack used (mm.)					Slot opening used (inch)	Date of drilling
			D_{90}	D_{70}	D_{50}	D_{40}	D_{10}		D_{90}	D_{70}	D_{50}	D_{40}	D_{10}		
1.	BG-12	116Ft. to 125Ft. =0.337 mm. (C_u < 2.00)	1.05	1.35	1.71	1.93	2.80	40/1000	1.18	1.68	2.26	2.60	3.77	40/1000	17.11.85
2.	T-62	140Ft. to 143Ft. & 206Ft.to 215Ft. = 0.35 mm. (C_u=2.00)	1.07	1.40	1.84	2.10	3.20	42/1000	1.18	1.68	2.26	2.60	3.77	40/1000	20.11.85
3.	T-281	104Ft. to 106Ft. =0.201 mm. (C_u < 2.00)	0.715	0.815	0.94	1.00	1.25	28/1000	1.18	1.68	2.26	2.60	3.77	40/1000	10.1.86
4.	DTW at Plot No. 6595	167Ft. to 170Ft. & 179Ft.to 182Ft. = 0.212 mm. (C_u < 2.00)	0.76	0.85	0.96	1.02	1.23	30/1000	1.18	1.68	2.26	2.60	3.77	40/1000	8.1.86

TABLE 4.3

SCREEN INTERVALS FOR HYPOTHETICAL DTW CONSTRUCTED ON TEST BOREHOLES

Test Borehole	Screenable Zones Designed	
	For 2 cfs. capacity wells (75 Ft.)	For 3 cfs. capacity wells (110 Ft.)
TH-1	22 to 31 m. (9 m.) 40 to 55 m. (15 m.)	22 to 31 m. (9 m.) 40 to 55 m. (15 m.) 65 to 74 m. (9 m.)
TH-2	22 to 31 m. (9 m.) 41 to 56 m. (15 m.)	22 to 31 m. (9 m.) 44 to 56 m. (12 m.) 70 to 73 m. (3 m.) 79 to 88 m. (9 m.)
PI-1	34 to 46 m. (12 m.) 59 to 71 m. (12 m.)	34 to 46 m. (12 m.) 59 to 71 m. (12 m.) 80 to 89 m. (9 m.)
PI-2	35 to 47 m. (12 m.) 51 to 63 m. (12 m.)	35 to 47 m. (12 m.) 57 to 63 m. (12 m.) 70 to 79 m. (9 m.)
BI-1	25 to 43 m. (18 m.) 50 to 56 m. (6 m.)	24 to 48 m. (24 m.) 50 to 59 m. (9 m.)
BO-1	22 to 31 m. (9 m.) 34 to 49 m. (15 m.)	22 to 31 m. (9 m.) 34 to 49 m. (15 m.) 57 to 66 m. (9 m.)
BO-2	26 to 44 m. (18 m.) 47 to 53 m. (6 m.)	26 to 44 m. (18 m.) 47 to 53 m. (6 m.) 59 to 68 m. (9 m.)
KA-2	28 to 46 m. (18 m.) 70 to 76 m. (6 m.)	Not suitable for 3 cfs. capacity well.
AT-1	26 to 35 m. (9 m.) 44 to 59 m. (15 m.)	26 to 35 m. (9 m.) 44 to 59 m. (15 m.) 68 to 77 m. (9 m.)

TABLE 4.4

COEFFICIENT OF TRANSMISSIBILITY (T) AT DIFFERENT PLACES INSIDE THE STUDY AREA (BY DIFFERENT METHOD)

Serial No.	Location of the aquifer Test well No.	Coefficient of Transmissibility (T) (gpd/ft)		
		Theis's method	Jacob's method	Theis's recovery method
1	Test well No. 129	1.405×10^5	1.764×10^5	1.28×10^5
2	Observation well No.P-1 of Test well No. 129	1.21×10^5	1.27×10^5	1.33×10^5
3	Observation well No.P-2 of Test well No.129	6.54×10^5	1.40×10^6	9.27×10^5
4	Observation well No.P-3 of Test well No.129	1.36×10^5	1.688×10^5	1.63×10^5
5	Observation well No.P-4 of Test well No.129	1.357×10^5	2.11×10^5	1.42×10^5
6	Test well No. 157	1.347×10^5	2.513×10^5	1.29×10^5
7	Observation well No.P-1 of Test well No.157	2.07×10^5	3.33×10^5	2.024×10^5
8	Observation well No.P-2 of Test well No. 157	3.644×10^5	4.32×10^5	3.94×10^5
9	Observation well No.P-3 of Test well No.157	2.67×10^5	2.59×10^5	2.38×10^5
10	Observation well No.P-4 of Test well No.157	3.37×10^5	3.86×10^5	2.38×10^5
11	Test Well No. 261	1.385×10^5	2.96×10^5	-
12	Observation Well No.P-1 of Test well No. 261	5.72×10^5	5.97×10^5	5.44×10^5
13	Observation Well No.P-2 of Test well No.261	1.33×10^6	1.43×10^6	1.09×10^6
14	Observation Well No.P-3 of Test well No.161	6.43×10^5	6.28×10^5	5.93×10^5
15	Observation Well No.P-4 of Test well No.261	6.67×10^5	6.608×10^5	6.72×10^5

TABLE 4.4 (Contd...)

Serial No.	Location of the aquifer Test well No.	Coefficient of Transmissibility(T) (gpd/ft)		
		Thesis's method	Jacob's method	Theis's recovery method
16	Pumping No. 93	1.46×10^5	2.527×10^5	-
17	Observation well No.P-1 of Pumping well No.93	2.33×10^5	2.66×10^5	2.053×10^5
18	Observation Well No.P-2 of Pumping well No.93	2.104×10^5	2.404×10^5	2.143×10^5
19	Observation Well No.P-3 of Pumping well No.93	7.78×10^5	8.376×10^5	7.802×10^5
20	Observation Well No.P-4 of Pumping Well No.93	8.57×10^5	8.47×10^5	-

Table - 4.5

Values of Well loss constant (C), Specific Capacity, coefficient of Transmissibility (T), Coefficient of Permeability (K) and optimum screen velocity as observed in Different Rehabilitated Wells of Thakurgaon Project.

Sl. No.	DTW No.	Location	Value of 'C' (Sec^2/Mt^5) 1st step	2nd step	Average value of 'C' (sec^2/mt^5)	Well loss as percent of total loss at 3 CFS rate of pumping	Total draw-down (ft)	Specific capacity (gpm/ft.)	Coefficient of transmissibility 'T' (gpd/ft)	Strainer length (ft-in)	Coefficient of permeability (K' (mt/day)	optimum screen velocit (cm/sec
1	12	Baliadangi	+ 15.19	-960.48	+15.19	2.08	17.27	81.37	2.148×10^5	80'-10"	90.26	3.21
2	16	Baliadangi	+140.47	+253.38	+196.93	17.39	25.62	56.94	1.74×10^5	74'-7"	79.24	2.88
3	76	Atwari	+ 34.55	+447.97	+241.26	24.21	23.62	54.42	1.68×10^5	80'-0"	71.33	2.64
4	96	Thakurgaon	+ 31.51	-726.25	+ 31.51	3.66	20.39	68.40	2.528×10^5	84'-9"	101.32	3.50
5	253	Ranishankail	- 44.23	+ 63.40	+ 63.40	13.27	11.33	102.98	2.56×10^5	92'-4"	94.17	3.325
6	304	Baliadangi	+ 39.86	-622.61	+ 39.86	5.30	17.83	74.65	1.927×10^5	-	-	-
7	308	Baliadangi	-7.10	+382.67	+382.67	39.37	23.04	56.86	1.75×10^5	81'-8"	72.78	2.68
8	313	Ranishankail	+242.97	222.85	+242.97	36.09	15.96	81.34	1.976×10^5	98'-4"	68.26	2.55

Ve(average)=2.9

TABLE 4.6

GRAIN SIZE POPULATIONS OF THE BOREHOLES CARRIED OUT UNDER TEST BORING PROGRAMME IN 1983

Hole No.	Sample tested	Mean of predominant screenable material (mm.)					Finest layer among the screenable material(mm.)			
		Samples used	D_{10}	D_{40}	D_{50}	D_{90}	D_{10}	D_{40}	D_{50}	D_{90}
TH-1	4	4	0.66	0.39	0.34	0.10	0.54	0.31	0.27	0.08
TH-2	12	8	0.96	0.40	0.35	0.06	0.43	0.243	0.21	0.09
PI-1	10	10	0.64	0.37	0.33	0.11	0.52	0.30	0.26	0.05
PI-2	10	6	0.57	0.34	0.29	0.06	0.48	0.222	0.19	0.06
BI-1	10	6	0.85	0.37	0.39	0.06	0.29	0.182	0.16	0.07
BO-1	13	11	0.66	0.42	0.37	0.12	0.60	0.26	0.24	0.07
BO-2	10	6	0.86	0.41	0.36	0.10	0.36	0.263	0.23	0.075
KA-2	9	6	0.60	0.35	0.30	0.07	0.45	0.27	0.23	0.076
AT-1	10	7	0.65	0.40	0.35	0.10	0.39	0.306	0.27	0.18
Mean of the entire study area		88	0.69	0.38	0.33	0.10	-	-	-	-