People's Republic of Bangladesh
Ministry of Irrigation, Water Development
and Flood Control

Flood Plan Coordination Organisation

JAMALPUR PRIORITY PROJECT STUDY

Caisse Francaise de Developpement
and
Commission of the European Communities

FAP 3.1

FINAL FEASIBILITY REPORT

Annex 1 Ground Water

January 1993

Consortium

SOGREAH/ HALCROW/ LAHMEYER

in association with
Engineering & Planning Consultants Ltd.
AQUA Consultants and Associates Ltd.
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ANNEX 1

GROUND WATER

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GLOSSARY

BADC	-	Bangladesh Agricultural Development Corporation
BWDB	-	Bangladesh Water Development Board
CF	-	Controlled Flooding
DSSTW	-	Deep Set Shallow Tube Well
DTW	-	Deep Tube Well
FFP	-	Full Flood Protection
JPPS	-	Jamalpur Priority Project Study
LLP	-	Low Lift Pump
MOSTI	-	Manually Operated Shallow Tube Well for Irrigation
MPO	-	Master Plan Organization
NCR	-	North Central Region
NFP	-	No Flood Protection
NWP	-	National Water Plan
PFP	-	Partial Flood Protection
STW	-	Shallow Tube Well
Sy	-	Specific yield
Upazila	-	Upgraded thana as defined by the Local Government Ordinance of 1982

SUMMARY

The JPPS area is highly favourable for groundwater development for irrigation. Groundwater extraction by shallow tubewells dominates the present dry season irrigation and this is set to continue. The effect of flood protection on groundwater is to reduce recharge; the effect is variable depending upon conditions in each Thana but, generally, partial flood protection (PFP) has little effect, whereas, on average, full flood protection (FFP) would reduce recharge by 20%.

Thus FFP represents a worst-case option in terms of recharge. When compared with irrigation water requirements the FFP option would provide for a shortfall in some Thanas but only 10% in the whole project area. Given the very conservative nature of the recharge calculations, recharge should not be regarded as a constraint in project terms.

Calculations based on observed well performance show that virtually the whole of the irrigation water requirement can be obtained from shallow (STW) or deep set shallow tubewells (DSSTW), which are the favoured option in terms of groundwater development in Bangladesh.

The impact of the project on groundwater quality through the use of fertilizers and pesticides cannot be estimated at present. The situation, including the use of agrochemicals and water analysis, needs to be monitored, as discussed in Annex 3.

Conclusions

- An aquifer system is recognizable in the project area, which is typical of the alluvial areas of Bangladesh.
- The hydrogeological conditions are amongst the most favourable in the country for tubewell development.
- The typical groundwater level hydrograph can be identified from observation well behaviour; that is, a dry season recession followed by recharge to aquifer-full conditions in the wet season.
- There is no evidence of a groundwater quality problem with respect to irrigation.
- The MPO model which provides estimates of potential and usable recharge can be modified to provide equivalent values for partial and full flood protection (PFP and FFP) conditions.
- The proposed PFP has little effect but FFP would reduce potential recharge by up to 20%.

- The dominant current mode of groundwater extraction in the JPPS area is STW, which reflects the good aquifer conditions; there has been a steady increase in use of STW since 1985 but since their deregulation, the reliance on DTW has reduced.

- Preliminary estimates of total project area groundwater required (irrigation and potable) can be calculated and compared with values of usable recharge under NFP, PFP and FFP conditions.

- The FFP usable recharge is enough to meet demand in most Thanas but there are shortfalls in others; however in total the FFP recharge is within 10% of the currently estimated demand.

- The NFP and PFP project area recharge totals are in excess of demand in most Thanas and in the project area as a whole.

- Generally these results are encouraging in that the MPO methodology provides for very conservative estimates of recharge.

- The MPO (NWP-11 1991) estimates of the development potential for STW and DSSTW can be shown to be unreasonably conservative, in that the abstractions are consistently exceeded under present conditions, with no adverse effects.

- Revised estimates, based on observed tubewell performance, indicate that STW and DSSTW are capable of meeting virtually all the irrigation water requirements in the project area.

- Although intensification of agriculture may lead to increased use of agricultural chemicals, their use on a massive scale is constrained by cost.

- However, the current situation with respect to nitrate and pesticide residues in groundwater is unknown.

Recommendations

Groundwater Quantity

- Input parameters used in the calculations of water demand presented in this report should be re-examined and refined during the detailed design phase of the project. Two key parameters in this respect are irrigable area and water duty (the Mm^3 of water per ha. required).

- The revised groundwater potential values prepared for NCR by FAP 3 may be a catalyst for re-examination of the MPO model results, in terms of assumptions rather than methodology. This could lead to revised project area recharge estimates, and close liaison should be maintained with MPO to take into account any revisions.

Groundwater Quality

- As part of project implementation consideration of water quality issues is warranted, and some baseline NO_3 and pesticide data should be obtained if possible.
- The use of fertilizer and pesticides should be monitored, and periodic sampling and analysis incorporated into the routine water analyses undertaken by BADC, BWDB and other organizations.

1 INTRODUCTION

1.1 Background

A substantial proportion of the JPP study area is currently irrigated by groundwater and the potential exists for additional development. In order to assess the potential, it is required to consider groundwater resources in relation to the various tubewell technologies currently available. In particular it is necessary to consider the effects of potential changes to groundwater recharge due to flood protection measures under the various proposed land and water development options, and the recommended option.

1.2 Objectives

The objective of this annex is to provide a review of groundwater resource availability for a series of flood protection options and to provide recommendations as to how the available resources should be exploited.

Specific topics to be addressed include:

- existing use of groundwater and its effects in terms of changes in groundwater levels;
- recharge mechanisms, including an assessment of the significance of lateral recharge from rivers to groundwater;
- the effects of embanking the area on recharge under a variety flood protection options;
- an assessment of the total additional ground water requirement for irrigation;
- the impact of fertilizer and pesticide use on water quality.

1.3 Approach

This annex is based on a review of existing reports and data on the project area, together with field work to evaluate the current position with respect to groundwater utilization. The work was carried out as part of the following specialist inputs:

- Expatriate: Visit by Mr. E. Cooper, Principal Hydrogeologist, Sir William Halcrow and Partners, 19 January 1992 - 30 January, 1992;

- Local: Mr. M. M. A. Samad, counterpart Hydrogeologist, December 1991 - January 1992, inclusive.

A reference list of principal sources is provided at the end of this report;

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2 REVIEW OF HYDROGEOLOGICAL CONDITIONS

2.1 Geology

The area is located in the northern part of the Bengal Basin and is underlain by a great thickness of unconsolidated sediments deposited by the major river systems. Numerous accounts of the geology are available and an extensive reference list is given in UNDP (1982) and MPO/Harza (1984).

Only those units within 100-150 m of the surface are of relevance to this study in hydrogeological terms. They consist of a range of unconsolidated sediments from clay and silt to coarse sand in laterally extensive individual units. It is probable that the sediments at 150 m depth are no older than late Pleistocene. The rate of active sedimentation is rapid and successive annual floods bring down a large quantity of new material.

2.2 The Aquifer System

Hydrogeological studies for groundwater development projects have established that the following aquifer system is present within the project area:

- Upper Clay and Silt

  A unit up to 14 m thick which is characterized by high porosity but relatively low permeability. Its main importance is the extent to which it controls downward percolation of recharge to aquifer units below.

- Intermediate Layer

  This unit is 15-40 m thick and consists of fine-medium sand with some clays and is of high porosity and moderate permeability. It is a minor aquifer in project terms which can provide water to STW and MOSTI.

- Main Aquifer

  This unit is a fine to coarse sand of high porosity and high permeability. It is over 40 m thick and is capable of providing large quantities of groundwater to wells.

All these units are in hydraulic continuity and function as a semi-confined or semi-unconfined storage system. Hydraulic continuity also exists with surface water, particularly the main rivers. However, there is relatively little interchange of water between the ground and the main rivers, due to low hydraulic gradients; most natural groundwater movement is vertical, either downwards as infiltration of rainfall and flood-waters, or upwards, as capillary rise. The main rivers are thought to provide some recharge to a 2-3 km strip of land either side.

Groundwater development project pumping tests (UNDP, 1982) indicate that the transmissivity of the main aquifer is very high in the range 2500-3000 m^2/d. The storage coefficient values obtained from the tests were 1×10^{-3} to 4×10^{-3}, towards the semi-confined end of the range of values for the region. Specific capacity values for wells penetrating the Main Aquifer are correspondingly high, in the range 10-26 l/s/m (project data).

Groundwater observation wells monitored by BWDB and other organizations concerned with groundwater development show a pattern which is characteristic of other alluvial areas in Bangladesh. Hydrographs of 4 typical project area observation wells are shown in Figures 1.2.1 to 1.2.4 and the well locations are shown in Figure 1.2.5. Figure 1.2.5 also shows the maximum water level depletion at the end of the irrigation season in April 1991.

The characteristic pattern is:

- A variation in groundwater levels corresponding to the wet and dry seasons;

- Lowest water levels at the end of the dry season in April;

- A rapid rise following the onset of the rain, to field capacity (aquifer-full conditions) in the wet season;

- A dry season recession, to complete the cycle.

In most cases the lowest recorded water level is during April 1988, when the onset of the rain was unusually late. Hydrographs over a longer period often show a general trend of increasing maximum depths to groundwater, as a result of increased pumping for irrigation. However, aquifer-full conditions are always established during the wet season, so it is also a process of storage manipulation to increase recharge and is therefore a beneficial effect.

Maximum depths to groundwater and equivalent water table contours are shown on Figures 1.2.5 and 1.2.6. The data are for April 1991. The plots are indicative only and should be treated with caution. They probably represent an interaction of two controlling factors, a regional hydraulic gradient southward and local abstraction.

The natural groundwater quality is good and the BWDB 1985-88 data shown in Table 1.2.1 are probably typical. The groundwater is of the Sodium-Bicarbonate type with relatively low total dissolved solids and sometimes high iron. An anomalously high chloride level recorded in a Dewanganj observation well in 1985 may relate to a higher dry season salinity level in the Old Brahmaputra or a sampling error. There is no consistent indication of a salinity hazard in the project area.

2.3 Recharge Concepts

The usual method of evaluation of available groundwater resources which is adopted in Bangladesh is based on a calculation of recharge. Recharge is the process by which water infiltrates during the wet season and restores the groundwater levels to field capacity. It is usually expressed as a depth of water per unit area.

In the context of this study, the primary sources of natural recharge are taken to be direct rainfall and flood water; other potential sources such as groundwater inflows, are considered to be negligible (UNDP, 1982: MPO/Harza, 1986).

Recharge which occurs under natural conditions is referred to as Actual Recharge. However, if groundwater levels are artificially lowered by abstraction, the opportunity is created for increasing recharge to some maximum value. This value is a function of the soil conditions (which determine infiltration rate) and availability of water at the surface; the maximum value is referred to as Potential Recharge.

Determination of recharge has been an important component of numerous hydrogeological studies carried out in Bangladesh in recent years (UNDP/UNTCD, 1981, 1982; Karim, 1984; Sir M. MacDonald and Partners, 1984; MPO/Harza, 1986). In particular MPO/Harza (1986) calculated recharge based on distributed parameter models which have simulated the recharge process in individual catchments. This work represents the most rigorous estimate currently available.

The concepts of actual and potential recharge are shown in Figure 1.2.7 and the process involved in depleting storage so as to create higher recharge is shown in Figure 1.2.8.

Another important concept in understanding the recharge mechanism is depth-storage and its relationship with recharge. An underlying principle is depth-related specific yield. The main points are illustrated in Figure 1.2.9.

Using a lithological log obtained from drilling samples, a value of specific yield (Sy) can be estimated for each layer (Figure 1.2.9 (a)). Values of Sy ascribed to individual layers can be integrated to provide a depth-related cumulative value of Sy, (Figure 1.2.9 (b)), which, when multiplied by the depth, gives a depth-storage curve (Figure 1.2.9 (c)). This curve can be used to indicate:

- The amount of water in storage for any specified depth, and hence the available abstraction for a specified water level;

- The water-level equivalent of some specified value of recharge, and hence a depth to which groundwater levels must reduce in order to accept that value of recharge during the monsoon.

The importance of using depth-related Sy data in producing the storage curve, rather than an assumed constant value, is also illustrated in Figure 1.2.9. For a water level depth of, say, 10 m, the storage would be significantly overestimated by using an assumed constant 15% specific yield. Conversely, for a specified recharge value or storage available for abstraction, the depth to which regional water levels would fall would be under-estimated on the basis of the constant 15% assumption.

It is also important to recognize the necessity for accurate recording and interpretation of drilling samples to define lithologies, in order that the depth-specific yield relationship can be accurately determined.

The relationship is of particular value in assessment of the viability of the STW/DTW pumping options, given that the suction limit on STW's can be related to a value of storage, thus indicating the approximate quantity of water which can be abstracted using STW.

2.4 Recharge Calculations

The MPO/Harza modelling studies (MPO/Harza, 1986) to determine groundwater recharge were based on simulation of the surface water-groundwater system during the period 1964-1982 for individual river catchments at 10-day time steps. Finite difference models of representative catchments were developed and calibrated, and the same parameters were then used in the large scale models. The input data included soil and aquifer parameters, hydrometeorlogical data and agricultural factors.

In addition to providing estimates of potential and actual recharge as defined above, the master plan studies included determination of usable and available recharge. Usable recharge is taken as 75% of the mean annual potential recharge to allow for uncertainties (errors in calculation) of estimation, reduction in recharge due to flood alleviation etc.

Values of usable recharge under existing conditions for each Thana in the project area are shown in Table 1.2.2 together with average annual rainfall:

2.5 Tubewell Technologies

Groundwater is abstracted for irrigation in Bangladesh using a series of different pumping methods (or " Tubewell Technologies") as described below:

- Shallow Tubewells (STW)

  These are tubewells fitted with suction-mode pumps capable of abstracting 14 l/s (0.5 cusec) from pumping water levels up to 7.5 m below ground level.

- Deep Set Shallow Tubewells (DSSTW)

  These are similar to STW but the pump is set in a 1.2 m deep pit, thus extending the suction limit to 8.5 to 9.5 m.

- Deep Tubewells (DTW)

  These are tubewells fitted with force-mode pumps (usually shaft driven turbines) capable of producing 28-56 l/s (1-2 cusec) from pumping water levels of 20-25 m below ground level.

- Manually Operated Shallow Tubewells for Irrigation (MOSTI).

  These wells produce small quantities of irrigation water by use of a manually operated pump.

It is useful to note that the concepts of DTW and STW differ in terms of pumping mode and not the depth of the tubewell. Also, it is generally accepted that when all cost factors are taken into account, STW, or, when necessary, DSSTW, are the favoured pumping option. DTW are a viable option only when where hydrogeological conditions are such that the available groundwater resources cannot be abstracted by STW or DSSTW alone.

3 PROJECT GROUNDWATER DEVELOPMENT

3.1 Existing Development

Hydrogeological conditions in the project area are among the most favourable in Bangladesh for groundwater development. At present 30% of the total project area is irrigated, almost all of which comes from groundwater. The present state of groundwater development is shown in Table 1.3.1. Points to note are:

- The whole-Thana data were derived from the provisional 1991 census data on minor irrigation equipment;

- The project area data relate to that proportion of each Thana which falls in the project area and were collected during project field work from local BADC offices;

- The irrigated area figures are calculated based on the census data which show irrigated areas for each water source to be, on average, as follows:

STW	4.5 ha
DTW	22.0 ha
LLP	7.5 ha.

- Groundwater abstractions are based on the area irrigated divided by values of water duty derived from the census data for each Thana as follows:

Thana	WATER DUTY (ha/Mm^3)
Dewanganj	142
Islampur	147
Jamalpur	139
Madarganj	138
Melandaha	138
Sarishabari	138

  These figures are above-average for the NCR and probably reflect the more permeable soil conditions in this area.

- There is a greater use of DTW in the east of the project area, as the less favourable hydrogeological conditions of the Madhupur tract are approached; however the existence of DTW does not entirely relate to a requirement for additional pumping lift because prior to 1986 DTW were heavily subsidized. Trends in the growth of DTW and STW are shown in Tables 1.3.2 and 1.3.3.

These data have been derived from several sources including central and regional BADC offices together with published statistics. Minor inaccuracies inevitably exist with the thousands of tubewells involved. The data are subjectively estimated to be accurate to 5%. Points to note from these data are:

- The consistently high growth rate in numbers of STW;
- The slight decline in use of DTW in all parts of the project area, other than in Jamalpur Thana, where there has been a modest increase.
- The data include parts of the Thanas which are outside the project area; abstraction of statistics for earlier years which are exclusive to the project area would involve extensive time consuming research into BADC regional office statistics, which is not warranted.

In an area where the groundwater conditions are extremely favourable, and particularly if flood protection measures are to be instigated, there is no reason to anticipate that the growth rates for STW will decline until all suitable land is irrigated.

3.2 Future Development

3.2.1 The Effects of Flood Protection on Recharge

As part of the JPPS, consideration has been being given to a series of flood protection options ranging from full flood protection (FFP) by poldering, partial flood protection (PFP) through the concepts of controlled flooding and compartmentalisation, to no flood protection (NFP).

A particularly useful contribution to assessing the implications of the above proposals for groundwater recharge has been made as part of the hydrogeological studies carried out for FAP 3, the North Central Regional Study (MMP, 1991). Depth and duration of flooding are two of the input parameters to the MPO recharge model. Therefore in order to examine the effects of the main flood control options, the appropriate input data to the model were changed and the results are shown in Table 1.3.4.

The partial flood protection (PFP) option examined in this case involved reducing the period of inundation by 20 days at the beginning and at the end of the wet season, but maintaining average flood levels on each flood phase. Also, in each case, a deep percolation rate of 2-10 mm per day was used (MPO, medium category) as being applicable to the region. This may actually be low for the JPPS area.

The results show that the PFP option does not have a significant effect on recharge but that FFP causes substantial reductions averaging 19%. However, it can be shown that even the minimum values of FFP usable recharge come close to meeting the requirements for irrigation water in the project area.

3.2.2 Project Area Water Requirements

The irrigation water requirement for the FAP 3.1 project is the total water requirement less the existing use.

MMP (1991) have argued that an upper value for the irrigable part of the total land area in the NCR is 75% of the gross area in most Thanas; this is equivalent to a development target of 80% of all F0 to F3 land which is high but reasonable. Initial project area data indicate that 70% of the JPPS area is irrigable (67000 ha out of a total project area of 96000 ha) so this percentage has been used to derive a value of water required for each Thana.

The essence of the calculations shown is that they deal with a worst-case situation i.e. the FFP recharge and a possibly high estimate of irrigable area. The results in Tables 1.3.5 and 1.3.6 show that even in this worst case, the availability of groundwater is probably not a major constraint. Where shortfalls exist in the FFP case it should be remembered that the assumptions in the recharge computation are very conservative and a 25% reduction is made for uncertainties (i.e. usable recharge is 75% of potential). There is some variation between Thanas but in total, the FFP recharge provides 90% of the project area irrigation water requirement. In the case of no flood protection, or partial flood protection, there is enough groundwater to meet all irrigation and potable demands.

In terms of the calculations two main points are:

- Potable use, (Table 1.3.5) is taken from figures in MMP (1991), which related to the whole Thana, times the proportion of the Thana which falls in the JPPS area. The MMP (1991) determination is based on a predicted 2010 consumption using 50 l/h/d.

- The irrigation water requirement relates to 70% of the project area (i.e. the irrigable area) but potable use and recharge relate to the whole project area; it is a reasonable assumption that wells in the project area have access to all recharge occurring within it, even if the abstracted water is used to irrigate only 70% of it.

3.2.3 Development Strategy

This section deals with the type of wells to meet the water requirement for areas not yet under irrigation. Table 1.3.7 shows the total and existing irrigation water requirements for each of the six main Thanas in the project area. The balance is the potential demand on new wells.

The ability of individual tubewell technologies to abstract groundwater is called Resource Potential. Thus for the same set of hydrogeological conditions DTW's have a higher resource potential than STW because of their capability of accessing deeper groundwater.

However given the proven advantages of STW (or DSSTW) over other technologies an appropriate development strategy is to take as much of the project area irrigation water requirement as possible by STW.

MMP (1991) showed that it was possible to take the whole JPPS area irrigation water requirement by STW. This result is attributable to the favourable depth-storage conditions in the JPPS area, and the high specific capacity of wells.

An important point about the MMP (1991) work on groundwater conditions in the NCR, is that it is based on MPO (1986) methodologies but recalculations have been made using observed hydrogeological data taken during the period 1986 -1989 in response to pumping for irrigation. These observations show that MPO (1986) and NWP (1991) recommendations for development in the JPPS area (and in most of the NCR) are over conservative. A summary of the revised estimate is as follows:

- Current groundwater abstraction for irrigation is already in excess of NWP (1990) recommended development potential limits for STW in the JPPS area; whole-Thana data are shown in Table 1.3.8.

However, STW abstraction continues to operate successfully and did so in 1988 when the dry season was longer than usual. Clearly, it is necessary to revise these development potential limits.

- Revised development potential calculations were made by looking at abstraction in the 1988 irrigation season and its effects in terms of storage depletion. The calculations, for each Thana, provide a revised depth storage relationship and hence a revised effective storage coefficient. Then, in conjunction with known specific capacity values of wells a revised value of development potential for each technology can be calculated.

The result for the JPPS area (STW/DSSTW only) are shown in Table 1.3.9, in conjunction with the total groundwater requirement for irrigation.

The total irrigation water requirement is derived from Table 1.3.5; the development potential values are derived from MMP, 1991 (Table 1.3.4) by reducing the whole-Thana values of development potential in accordance with the percentage of the Thana which falls in the JPPS area.

The results indicate that virtually all of the water required to irrigate the project area can be abstracted by STW or DSSTW technology.

3.3 Water Quality Issues

Current and future agricultural activity, particularly if it is intensified, may have an effect on groundwater quality. In the developed world, agriculture is a primary cause of ground and surface water contamination. Particular issues are:

- Nitrate Fertilizer

  Over-use of fertilizer leads to an increase of Nitrate (NO_3) in groundwater which is regarded as a health hazard when present at more than 50 mg/l (as NO_3). Possible effects are 'blue-baby syndrome' (respiratory problems in nursing infants) and there is a possible link to stomach cancers.

- Pesticides

  Pesticides (taken here to include herbicides, insecticides, fungicides etc) and their residues, are rigidly controlled under international drinking water quality standards. For example EEC limits are 1 part in ten billion for any single pesticide and no more than 5 parts pesticides in total. The substances are said to be carcinogenic, though the physiological link is tenuous.

  The extent of the risk here is unclear. In the case of nitrate, the relationship between loading from fertilizer application (and animal/human sources) and NO_3 in groundwater is unknown for Bangladesh conditions. The same relationship for pesticides is not fully understood for any environment.

  In general the large volume of water and opportunity for dilution is favourable, as is the general cost constraint against the massive use of fertilizer and pesticides. It would seem sensible

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to instigate some level of monitoring (although monitoring for pesticides is very expensive) and if necessary, some simple codes of good agricultural practice could be established.

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TABLES

Table 1.2.1 **Groundwater Quality**

Stat No.	Location	Year	Ph	Ca mg/l	Mg mg/l	Na mg/l	Fe mg/l	Mn mg/l	CO_3 mg/l	HCO_3 mg/l	Cl mg/l	SO_4 mg/l	CO_2 mg/l	SiO_2 mg/l	TDS mg/l
W-4	Jamalpur WAPDA Colony	1985	7.10	6.50	3.30	80.96	6.80	NT	NT	152.43	14.91	58.79	4.44	-	330.00
		1988	-	37.07	6.07	59.02	2.05	NT	5.77	122.54	34.79	78.40	NT	5.80	298.00
H-43	Sarishabari Railway Station	1985	7.00	31.50	25.50	36.11	5.92	NT	11.73	188.30	43.73	26.97	0.90	-	300.00
		1988	-	76.65	31.64	49.13	42.25	NT	NT	86.68	268.38	24.50	NT	27.20	390.00
H-40	Dewanganj	1985	6.80	84.00	46.20	185.84	15.52	NT	2.05	118.76	347.90	63.68	2.97	-	810.00
		1988	-	30.56	19.74	19.94	1.33	NT	17.66	116.57	27.33	59.80	3.00	21.00	211.00

Legend: NT Not Tested
- Data not available

Table 1.2.2 Rainfall and Recharge Data

Thana	Rainfall (mm)	Potential Recharge (mm)	Useable Recharge (mm)
Dewanganj	2212	972	729
Islampur	2185	1054	791
Jamalpur	2249	694	521
Madarganj	2087	1034	776
Melandaha	2197	747	560
Sarishabari	2039	699	524

Table 1.3.1

Status of Minor Irrigation and Existing Development 1990/91

Thana	Gross Area (Km²)	Proj. Area (%)	Proj. Area (Km²)	Thana			Project Area			Irrigation Total					Abstractions Total				
	(approximate)			DTW (No)	STW (No)	LLP (No)	DTW (No)	STW (No)	LLP (No)	DTW (ha)	STW (ha)	LLP (ha)	G-Water (ha)	All (ha)	DTW (Mm³)	STW (Mm³)	LLP (Mm³)	G-Water (Mm³)	All (Mm³)
Dewanganj	266.18	35.93	95.64	10	647	-	9	379	-	198.00	1705.00	-	1903.00	1903.00	1.39	12.01	-	13.40	13.40
Islampur	343.15	42.61	146.21	50	1885	10	42	1173	10	924.00	5278.00	70.00	6202.00	6272.00	6.29	35.90	0.48	42.19	42.67
Jamalpur	481.37	14.63	70.42	397	1913	44	57	547	5	1254.00	2461.00	37.00	3715.00	3752.00	9.02	17.71	0.27	26.73	27.00
Madarganj	230.24	90.62	208.65	10	1998	-	9	1818	-	198.00	8181.00	-	8379.00	8379.00	1.43	59.28	-	60.71	60.71
Melandaha	239.72	100.00	239.72	88	3143	28	88	3143	28	1936.00	14143.00	210.00	16079.00	16289.00	14.03	102.49	1.52	116.52	118.04
Sarishabari	258.42	37.92	98.00	60	1783	20	8	632	11	176.00	2844.00	82.00	3020.00	3102.00	1.28	20.61	0.59	21.89	22.48
Total	1819.08	47.20	858.64	615	11369	102	213	7692	54	4686.00	34612.00	399.00	39298.00	39697.00	33.44	248.00	2.86	281.44	284.30

Legend: Proj. Project
- Data not available

Table 1.3.2 Growth of Shallow Tubewells, Jamalpur

Thana	Operating Number of Shallow Tubewells						
	1985	1986	1987	1988	1989	1990	1991
Jamalpur	1881	-	1389	1659	1909	2000	1913
Dewanganj	295	-	323	497	450	800	647
Islampur	1179	-	1084	1379	1681	1681	1885
Melandaha	2019	-	1546	1816	2186	2186	3143
Madarganj	1268	-	1146	1480	1768	1968	1998
Sarishabari	915	-	815	1255	1484	1484	1783
TOTAL	7557	-	6303	8086	9478	10119	11369
ANNUAL CHANGE %	-	-	-	28	26	7	12

Table 1.3.3 Growth of Deep Tubewells, Jamalpur

Thana	Operating Number of Deep Tubewell						
	1985	1986	1987	1988	1989	1990	1991
Jamalpur	302	352	348	354	387	387	397
Dewanganj	10	9	10	11	12	13	10
Islampur	42	45	42	47	43	44	50
Melandaha	107	108	106	107	103	105	88
Madarganj	4	4	4	4	8	8	10
Sarishabari	70	71	73	74	65	66	60
TOTAL	535	589	583	597	618	623	615
ANNUAL CHANGE %	-	10	-1	2	3	0.8	-1
Legend: - Data not available.							

Table 1.3.4 Recharge Data

Thana	Potential Recharge (mm)			Usable Recharge (mm)			% Reduction in Potential Recharge	
	NFP	PFP	FFP	NFP	PFP	FFP	PFP	FFP
Dewanganj	972	902	703	729	677	527	7	28
Islampur	1054	991	806	791	743	605	6	24
Jamalpur	694	675	618	521	506	464	3	11
Madarganj	1034	960	752	776	720	564	7	27
Melandaha	747	722	640	560	542	480	3	14
Sarishabari	699	681	630	524	511	473	3	10

Table 1.3.5 Project Water Requirements

Thana	Irrigable Area	Water Duty	Irrigation Water Requmt.	Potable use	Total G.W. Requmt.
	(ha)	(ha/Mm^3)	(Mm^3)	(Mm^3)	(Mm^3)
Dewanganj	7000	142	49	3	52
Islampur	11250	147	76	3	79
Jamalpur	4800	139	34	2	36
Madarganj	17700	138	128	5	133
Melandaha	18500	138	133	7	140
Sarishabari	8000	138	57	3	60

Source: Preliminary Project data.

Table 1.3.6 Water Requirements and Recharge

Thana	Total G.W. Requirement (Mm³)	Usable Recharge NFP (Mm³)	PFP (Mm³)	FFP (Mm³)
Dewanganj	52	70	65	51
Islampur	79	115	108	88
Jamalpur	36	36	35	32
Madarganj	133	162	150	118
Melandaha	140	134	130	115
Sarishabari	60	51	50	46
TOTAL	500	568	538	450

Table 1.3.7 Project Area Irrigation Water Requirement

Thana	Total Irrigation Water Requirement (Mm^3)	Current Irrigation By Ground Water (Mm^3)	By Low-Lift Pumps (Mm^3)	Total (Mm^3)	Balance (Mm^3)
Dewanganj	49	13.4	Nil	13	36
Islampur	76	42.19	0.48	43	33
Jamalpur	34	26.73	0.27	27	7
Madarganj	128	60.71	Nil	61	67
Melandaha	133	116.52	1.52	118	15
Sarishabari	57	21.87	0.59	22	35

Table 1.3.8 Current and MPO Recommended STW Abstraction

Thana	Actual 1989 STW Irrigation (Mm³) A	NWP-11 1991 Recommended (Usable Recharge, STW) (Mm³) B	Excess, A Over B (%)
Dewanganj	15.8	14.4	8
Islampur	41.8	47.4	-
Jamalpur	39.2	44.6	-
Madarganj	49.4	25.6	93
Melandaha	57.5	32.4	77
Sarishabari	42.3	42.0	-

Table 1.3.9 Development Potential

Thana	Total Irrigation Water Requirement (Mm³)	Development Potential (Amount Extractable by Technology Shown)	
		STW (Mm³)	DSSTW (Mm³)
Dewanganj	49	71	109
Islampur	76	76	115
Jamalpur	34	24	38
Madarganj	128	161	161
Melandaha	133	134	134
Sarishabari	57	50	51

FIGURES

FIGURE 1.2.1

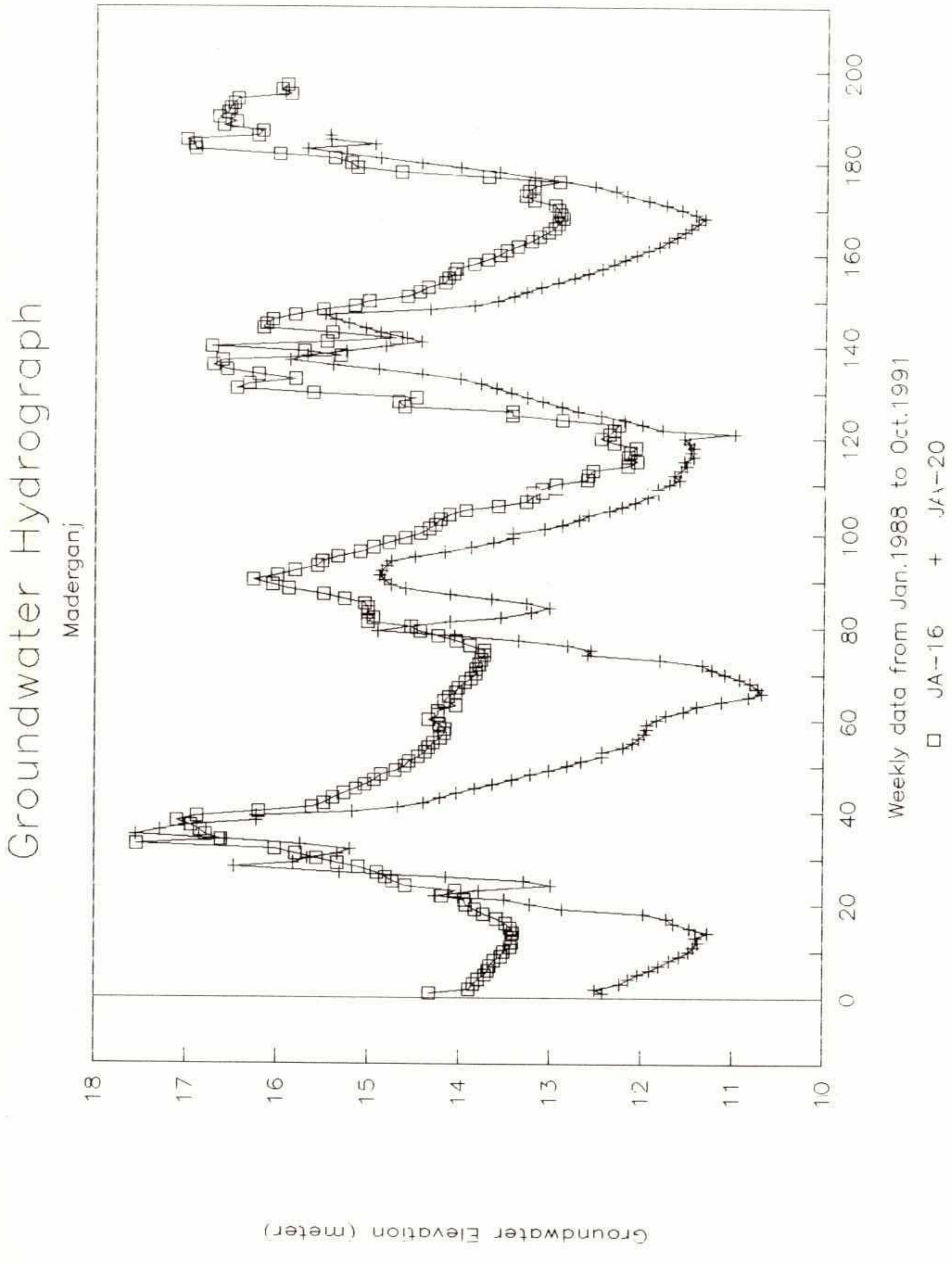

Groundwater Hydrograph
Madarganj
Weekly data from Jan.1988 to Oct.1991
JA-16
JA-20
Groundwater Elevation (meter)
10
11
12
13
14
15
16
17
18
0
20
40
60
80
100
120
140
160
180
200

FIGURE 1.2.2

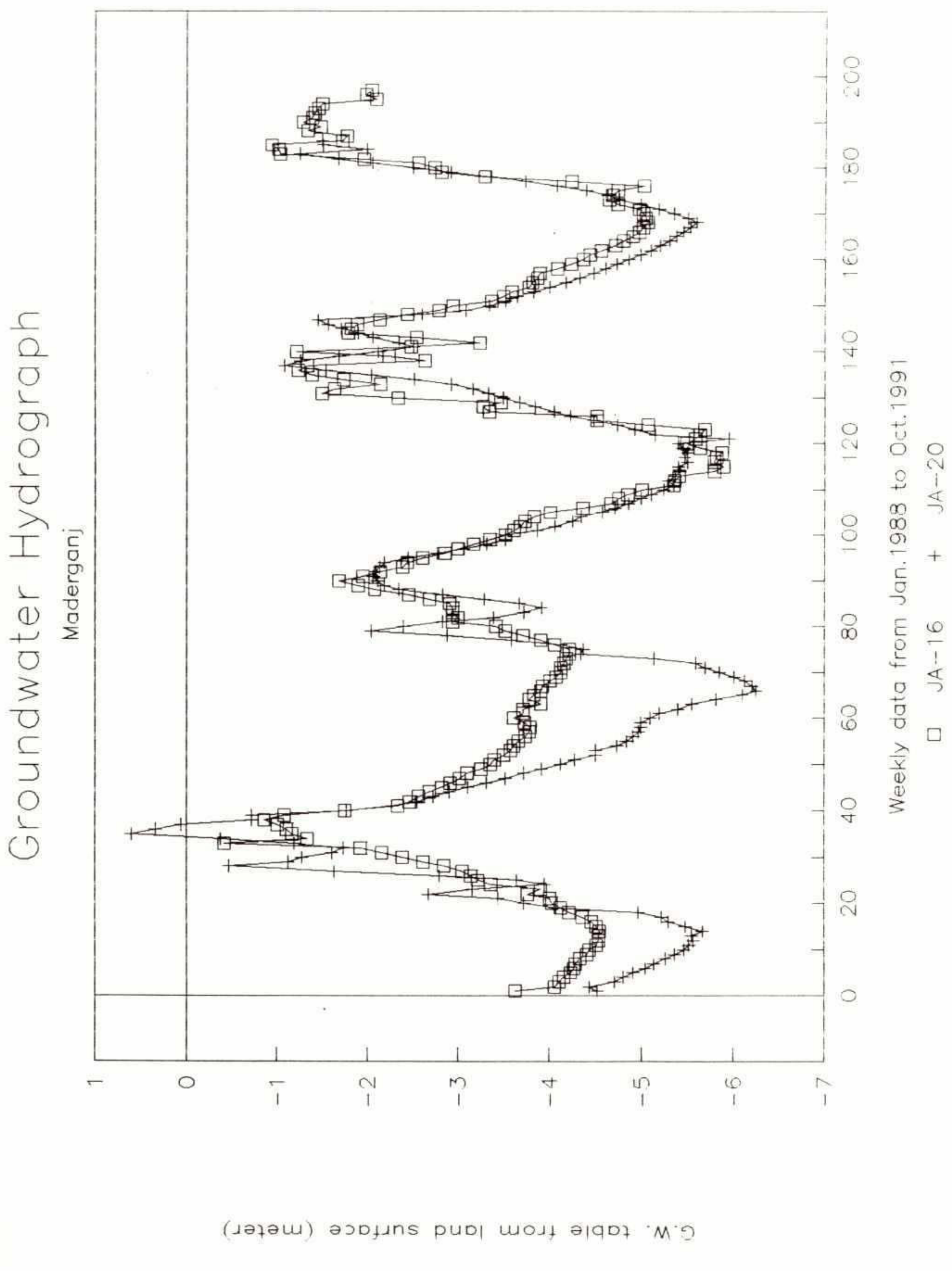
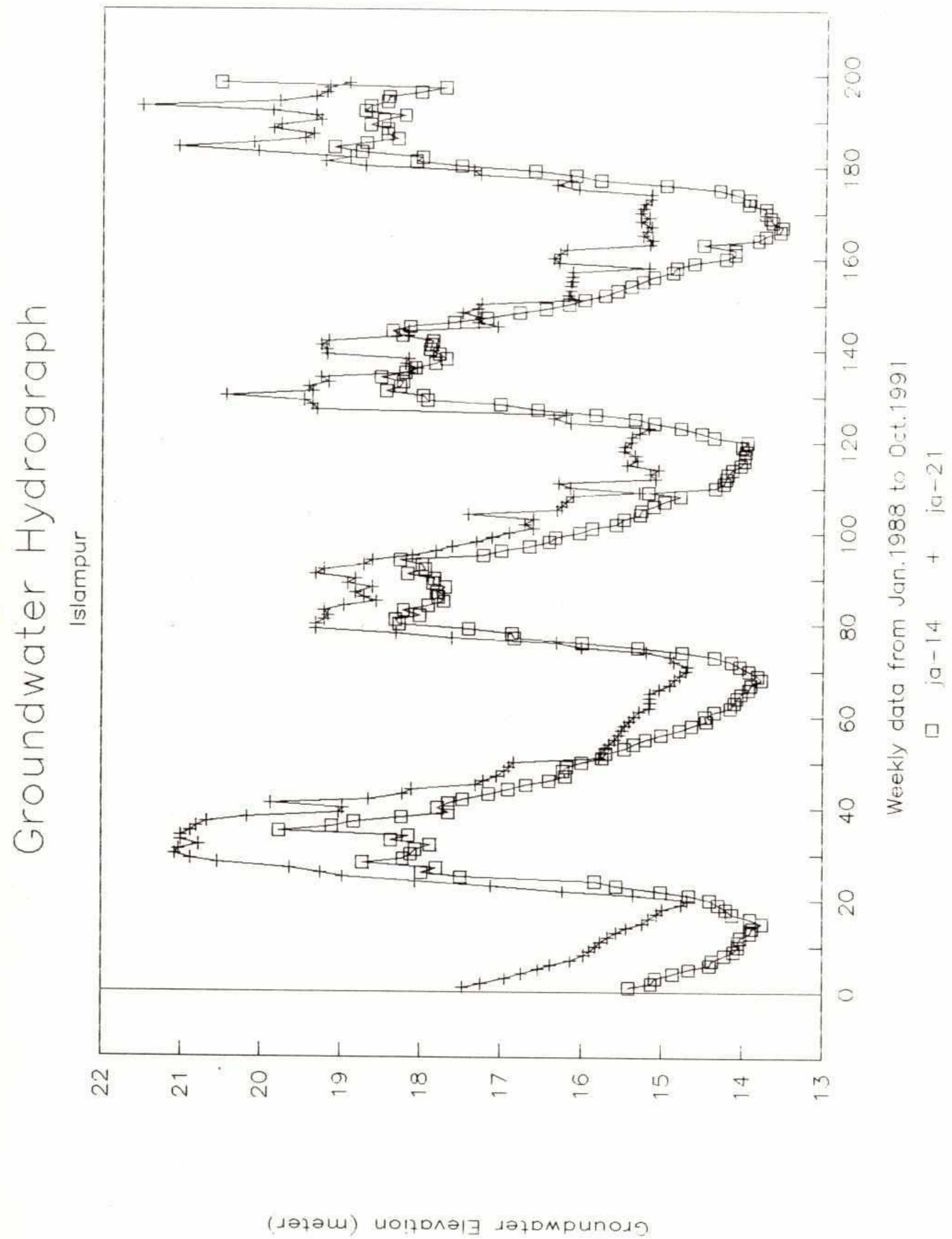
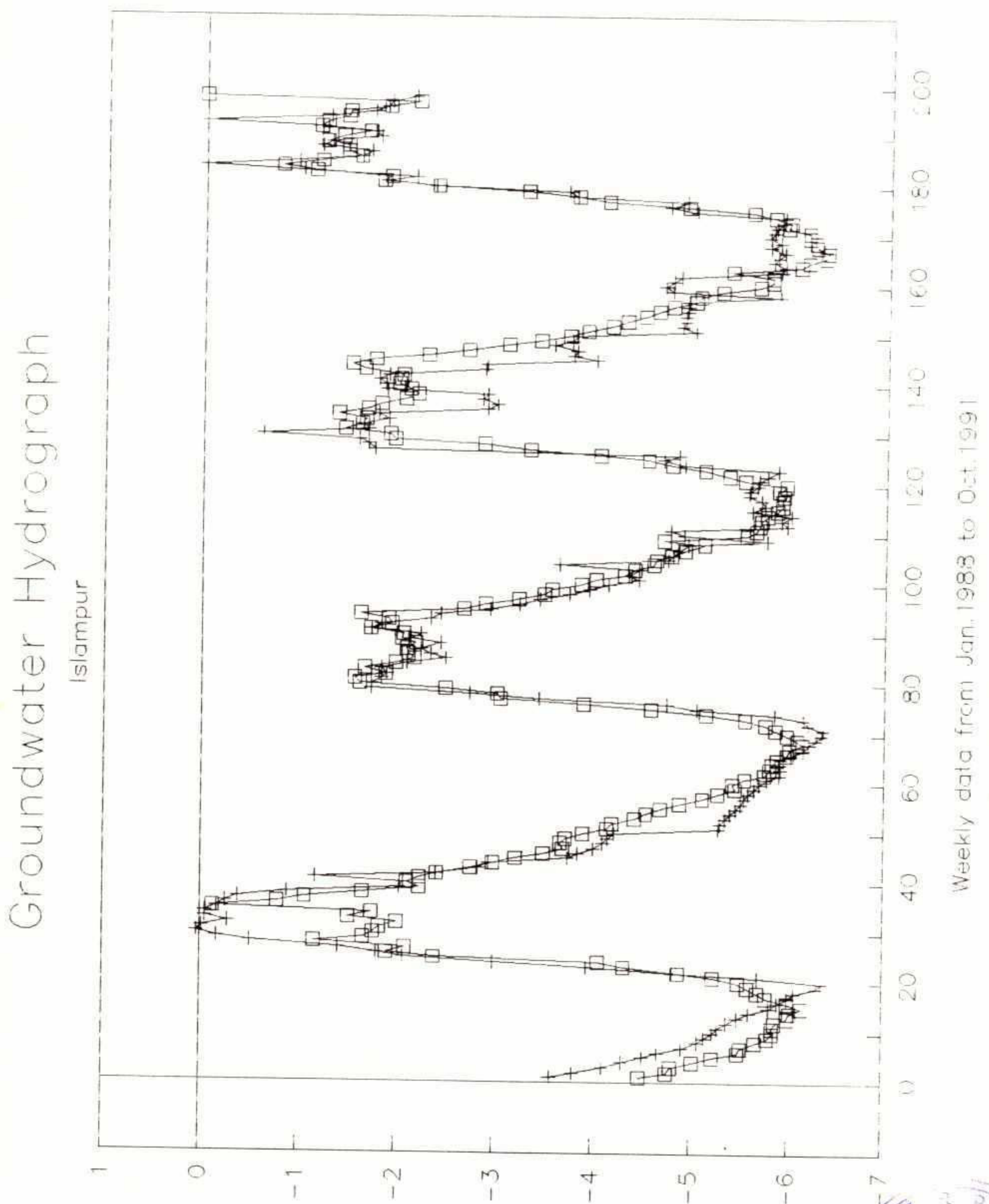

Groundwater Hydrograph
Maderganj
Weekly data from Jan.1988 to Oct.1991
□ JA-16 + JA-20
G.W. table from land surface (meter)
1
0
-1
-2
-3
-4
-5
-6
-7
0
20
40
60
80
100
120
140
160
180
200

FIGURE 1.2.3


Groundwater Hydrograph
Islampur
Weekly data from Jan.1988 to Oct.1991
□ ja-14 + ja-21
Groundwater Elevation (meter)
13 14 15 16 17 18 19 20 21 22
0 20 40 60 80 100 120 140 160 180 200


Groundwater Hydrograph
Islampur
Weekly data from Jan.1983 to Oct.1991
□ ja-14 + ja-21
G.W. table from land surface (meter)
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-1
-2
-3
-4
-5
-6
-7
0
20
40
60
80
100
120
140
160
180
200

FIGURE 1.2.5

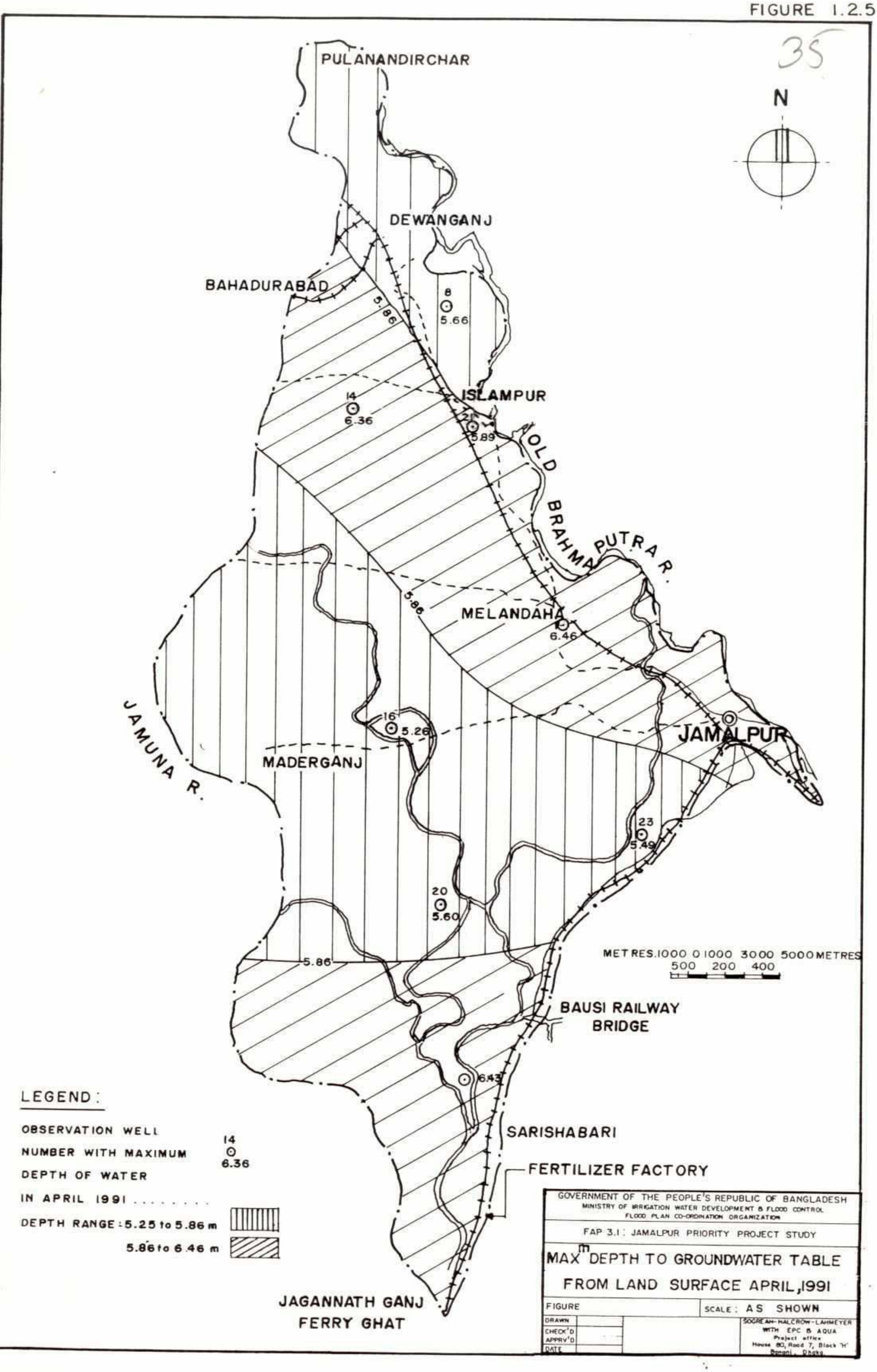
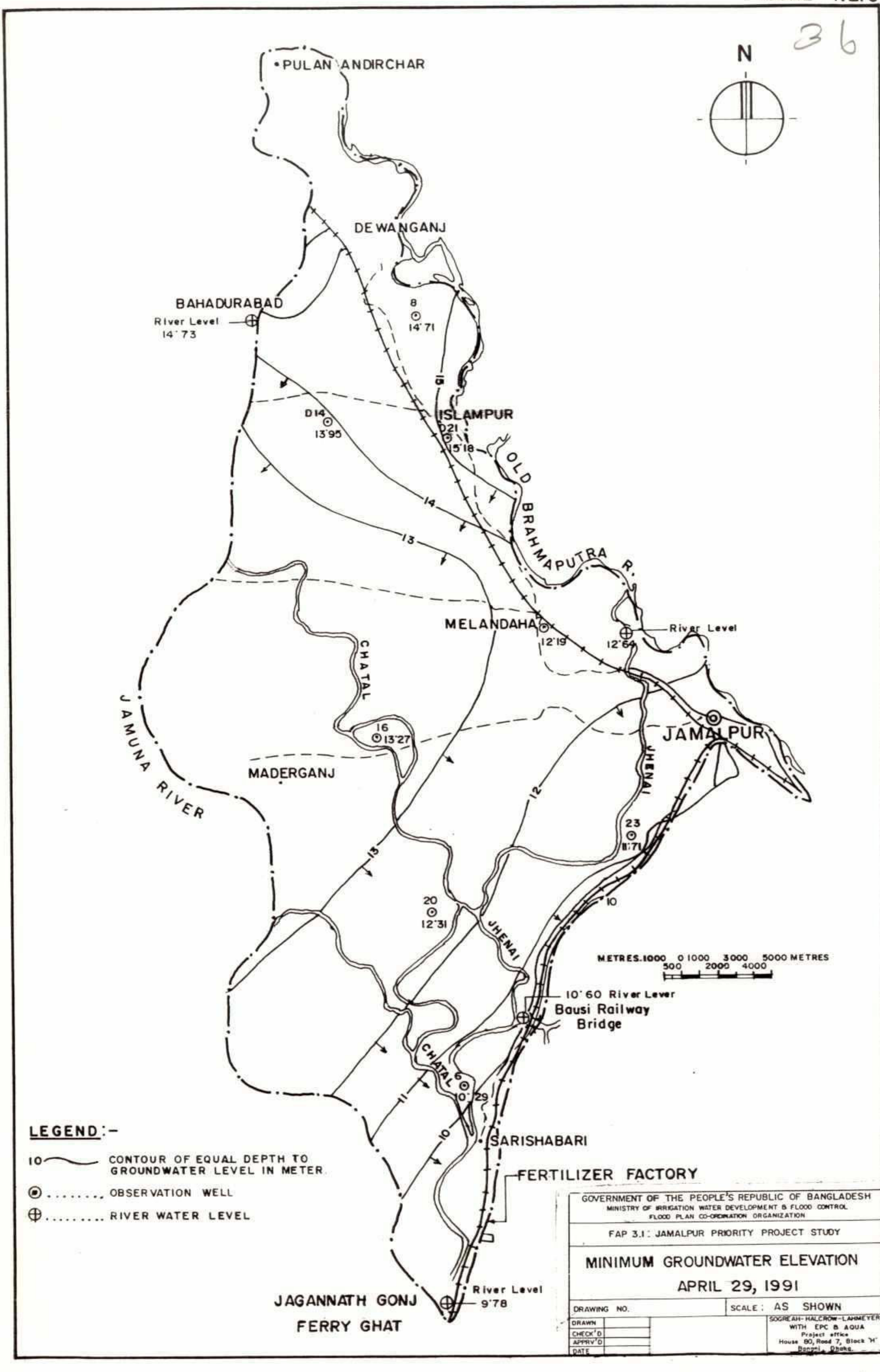

35
N
PULANANDIRCHAR
DEWANGANJ
BAHADURABAD
8
5.66
5.86
ISLAMPUR
14
6.36
21
5.89
OLD BRAHMA PUTRA R.
MELANDAHA
6.46
5.86
JAMUNA R.
16
5.26
MADERGANJ
JAMALPUR
23
5.49
20
5.60
5.86
METRES.1000 0 1000 3000 5000 METRES
500 200 400
BAUSI RAILWAY BRIDGE
6.43
SARISHABARI
FERTILIZER FACTORY
JAGANNATH GANJ FERRY GHAT
LEGEND:
OBSERVATION WELL NUMBER WITH MAXIMUM DEPTH OF WATER IN APRIL 1991 ....
14
6.36
DEPTH RANGE: 5.25 to 5.86 m
5.86 to 6.46 m
GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN CO-ORDINATION ORGANIZATION
FAP 3.1: JAMALPUR PRIORITY PROJECT STUDY
MAX^m DEPTH TO GROUNDWATER TABLE FROM LAND SURFACE APRIL, 1991
FIGURE
SCALE: AS SHOWN
DRAWN
CHECK'D
APPRV'D
DATE
SOGREAH-HALCROW-LAHMEYER WITH EPC & AQUA
Project office
House 80, Road 7, Block 'H'
Banani, Dhaka

FIGURE 1.2.6



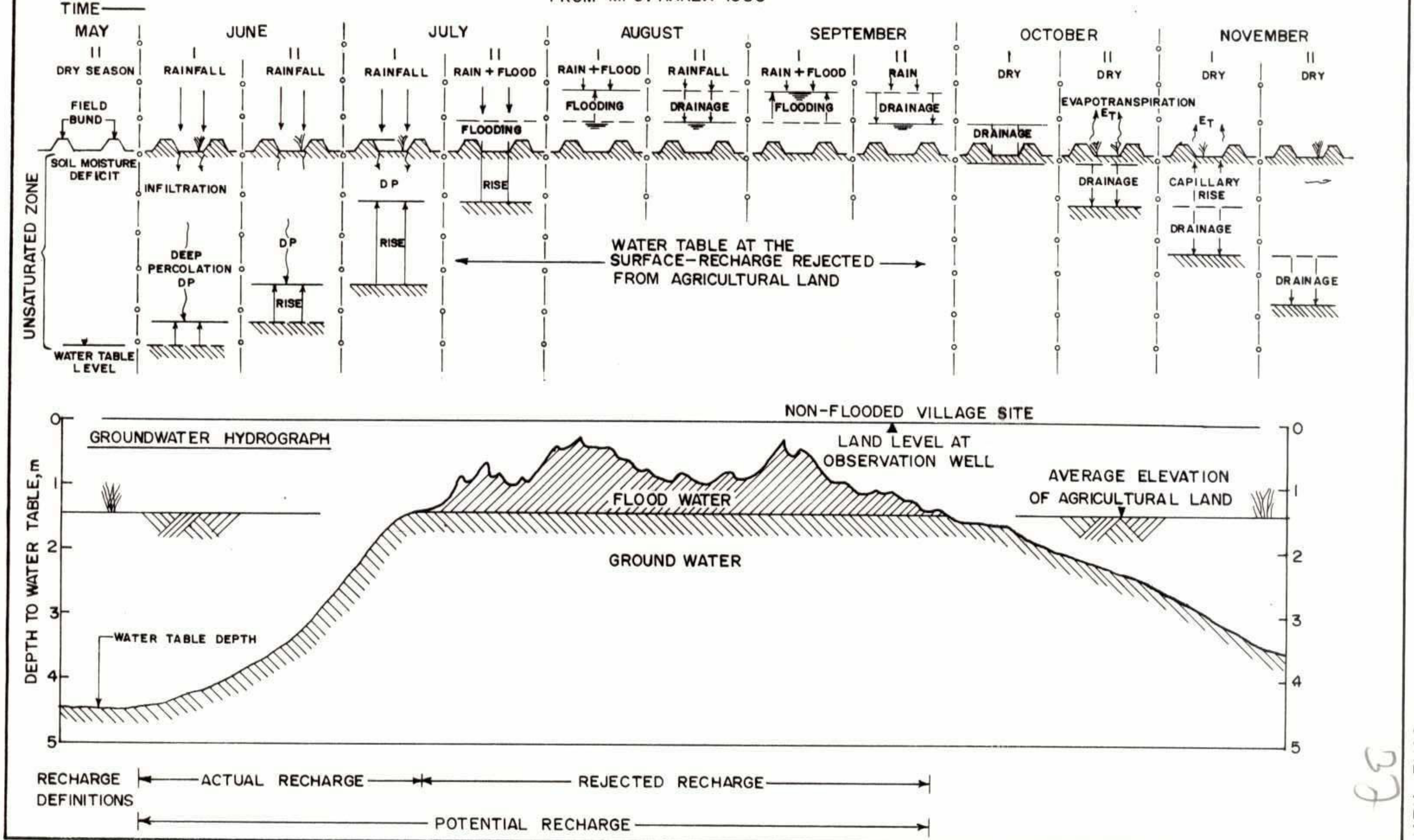
N
PULAN ANDIRCHAR
DEWANGANJ
BAHADURABAD
River Level 14'73
8
14'71
15
D14
13'95
ISLAMPUR
D21
15'18
OLD BRAHMAPUTRA R.
14
13
MELANDAHA
12'19
River Level
12'64
CHATAL
JAMUNA RIVER
16
13'27
MADERGANJ
JAMALPUR
JHENAI
12
23
11'71
13
10
20
12'31
JHENAI
METRES 1000 0 1000 3000 5000 METRES
500 2000 4000
10'60 River Lever
Bausi Railway Bridge
CHATAL
6
10'29
11
10
SARISHABARI
FERTILIZER FACTORY
JAGANNATH GONJ
FERRY GHAT
River Level
9'78
LEGEND:-
10 CONTOUR OF EQUAL DEPTH TO GROUNDWATER LEVEL IN METER
.... OBSERVATION WELL
.... RIVER WATER LEVEL
GOVERNMENT OF THE PEOPLE'S REPUBLIC OF BANGLADESH
MINISTRY OF IRRIGATION WATER DEVELOPMENT & FLOOD CONTROL
FLOOD PLAN CO-ORDINATION ORGANIZATION
FAP 3.1: JAMALPUR PRIORITY PROJECT STUDY
MINIMUM GROUNDWATER ELEVATION
APRIL 29, 1991
DRAWING NO.
SCALE: AS SHOWN
DRAWN
CHECK'D
APPRV'D
DATE
SOGREAH-HALCROW-LAHMEYER
WITH EPC & AQUA
Project office
House 80, Road 7, Block 'H'
Banani, Dhaka.

FIGURE 1.2.7

RECHARGE CONCEPTS

LAND, WATER AND GROUNDWATER ENVIRONMENT DURING THE MONSOON PERIOD

FROM MPO/HARZA 1986



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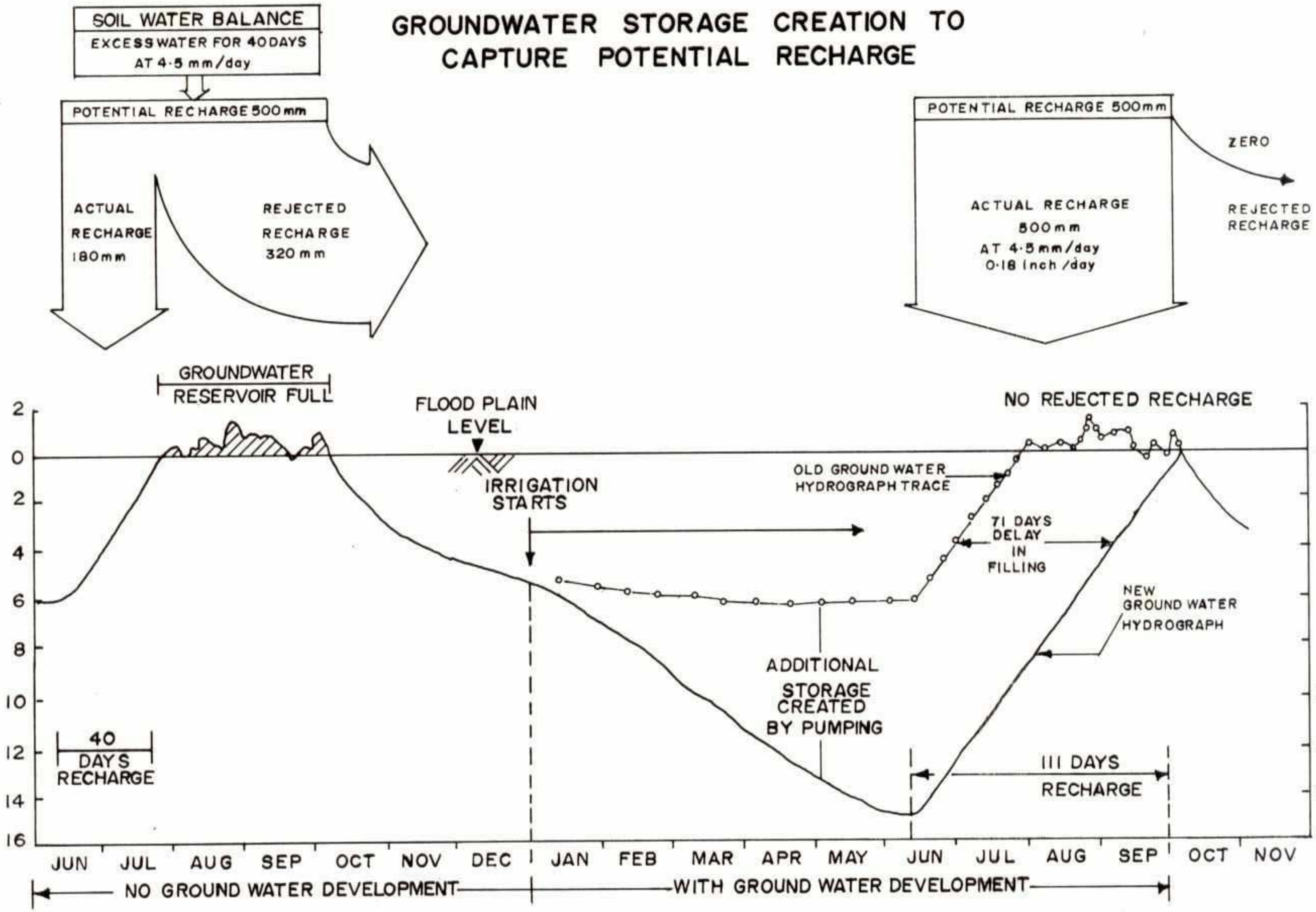
STORAGE MANIPULATION

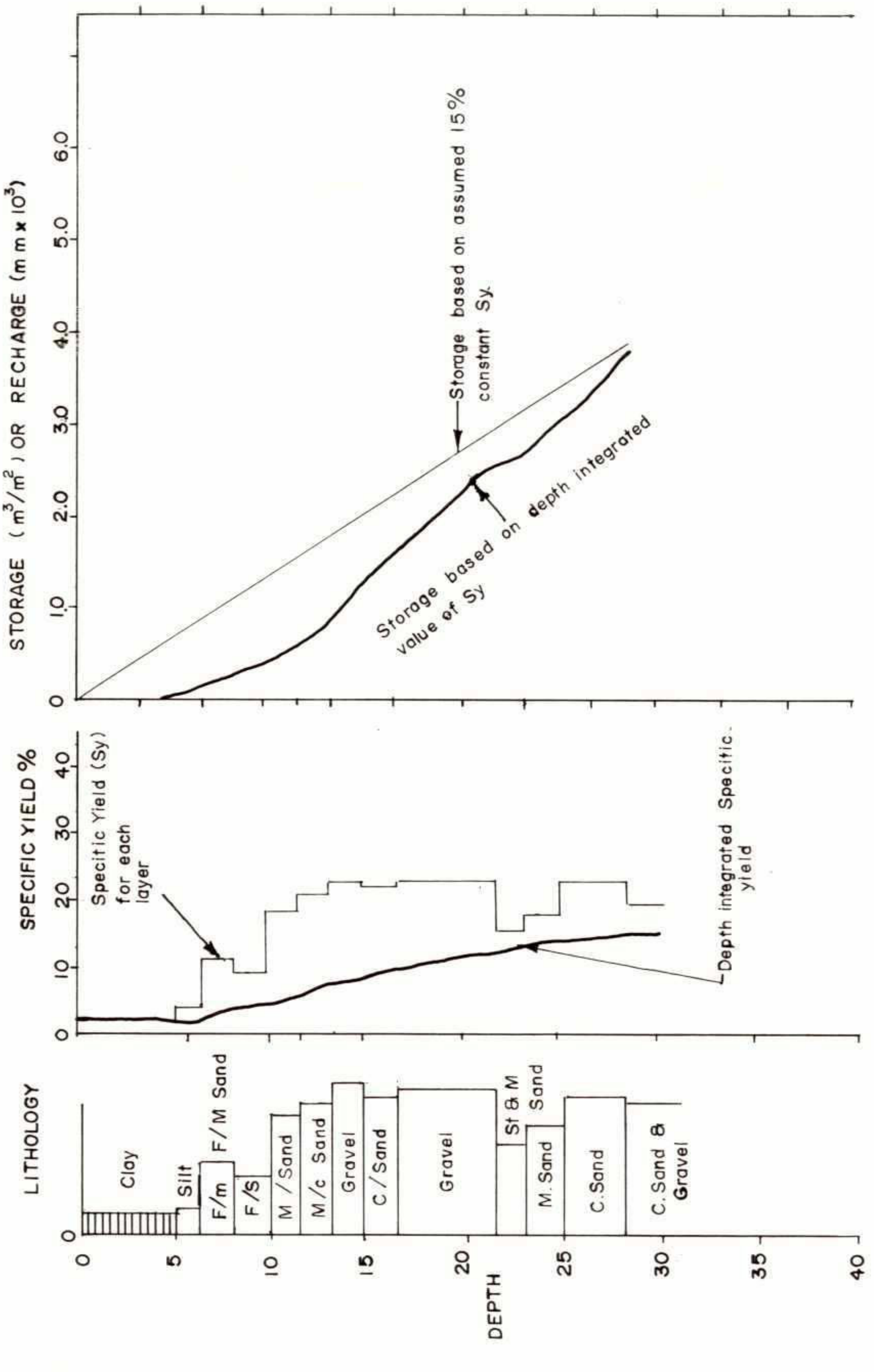
GROUNDWATER STORAGE CREATION TO CAPTURE POTENTIAL RECHARGE



SOURCE: MPO/ HARZA,1986

39

DEPTH-STORAGE RELATIONSHIP



SOURCE- MPO/HARZA, 1984