Effect of Hydrological Flow Pattern on Groundwater Arsenic Concentration in Bangladesh

by

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Abstract

Widespread arsenic contamination of groundwater has become a major concern in Bangladesh since the water supply, particularly in rural areas, is heavily dependent on groundwater. However, relative to the extent of research on biogeochemical processes of arsenic mobilization, very little work has been conducted to understand the complex transient dynamics of groundwater flow, and the transport of arsenic and other solutes that control its mobility in the area.

A detailed three-dimensional hydrological model of our study area in Munshiganj indicates that: (1) the shallow aquifer acts primarily as a conduit for flow from ponds and rice fields to irrigation wells and rivers; (2) most inflow to the aquifer occurs during the dry season, and monsoon contributes relatively little to the inflow since the aquifer storage is small; (3) since the increase in irrigation pumping and pond construction have changed the groundwater flow dynamics, arsenic concentrations are unlikely to be at steady-state. These observations are consistent with those from the lumped-parameter model.

Analysis of various fluxes from the three-dimensional groundwater model also reveals that ponds provide the largest source of recharge to the aquifer, and hence, is a potential source of dissolved arsenic to the subsurface. Accordingly, a “Pond Hypothesis” has been developed suggesting that arsenic mobilization in Bangladesh aquifer is deriving from reductive dissolution of various arsenic bearing oxides (the widely accepted mechanism for arsenic mobilization in Bangladesh) deposited at the pond bottoms. The process of reductive dissolution occurs in the presence of organic matter and under reducing environment, when residing microbes respire on oxygen from oxide-minerals (e.g. Fe and Mn oxides) to process the organic matter for growth, and subsequently causes release of arsenic associated with the oxide-minerals to the aqueous phase. Afterwards, at the end of flooding season, the dissolved arsenic along with mixture of various dissolved solutes from pond bottoms enters the aquifer and is driven towards the well screen both vertically due to overlying recharge and horizontally due to increased pumping.

Extensive small-scale pump tests and one large-scale extended pumping experiment carried out at our study area in Munshiganj indicates that the aquifer is anisotropic in nature creating flow convergence at the depth of irrigation well screen. Results from a three-dimensional hydrological model suggests that groundwater irrigation has changed the flow dynamics in the area – not only by reducing the residence and travel times, but also carrying solutes to particular depth from different sources and locations.

Model simulations carried out for three different scenarios – ‘Current Stage’ (if the current flow condition continues), ‘Ancient Stage’ (before the advent of habitation and irrigation practices), and ‘Inception Stage’ (the beginning of irrigation and creation of ponds) – indicates that in general, the rice field water dominates at the shallowest depth while pond water dominates at the depth of irrigation well, and the contribution from river water increases with depth. Analysis of the average groundwater age distribution indicates that younger age dominates at shallower depths. More importantly, the age values at the monitoring locations can be explained by the relative contribution of recharge water from different sources. Furthermore, modeling results indicate that the groundwater age at 30m depth in Bejgoan Field Site is about 24-60 years old, which is consistent with the tritium age measurement at the same depth.

The stable water isotope values in our study area shows a similar profile to the dissolved arsenic concentration, and their peak concentrations coincidence with the depth of irrigation well. Furthermore, comparison of calculated and measured isotopic values at the Bejgoan Field Site indicates that the calculated values are within the range of measured values, and thereby, confers that the observed isotopic profile results from the mixing of water from various recharge sources. More importantly, the lighter water at the depth of peak arsenic concentration can only be derived from lighter pond water recharge in November, whereas recharge from river and rainfall mainly occurs after March when those waters are actually heavier.

Finally, observation of two distinct peaks in the dissolved arsenic concentration profile from a recently installed cluster beside a highly recharging pond provides a direct evidence supporting the "Pond Hypothesis". While the peak concentration at 30-40m depth corresponds to the characteristic regional hump observed in our study area, the second peak at a shallower depth (20m) has been explained as the local arsenic plume originating from the nearby pond bottom.

Thesis Supervisor: Charles Harvey
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Dedicated

To

My Family

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Abbreviations

BWDB	Bangladesh Water Development Board
DR	Drinking Well
ET	Evapotranspiration
ET_0	Reference Evapotranspiration
GMWL	Global Meteoric Water Line
HB	Highway Bridge
IR	Irrigation Well
LB	Local Bridge
LMWL	Local Meteoric Water Line
MSL	Mean Sea Level
PWB	Power and Water Board
RF	Rainfall
SB	Steel Bridge
SMOW	Standard Mean Ocean Water
WL	Water Level

Chapter 1
Introduction

1.1. Background

Bangladesh is a tropical country with a total surface area of about 144,000 km^2 and an estimated population of 129 million as of July 2000. Of the surface area available, about 70% is arable and about 10-15% comprises of forests and woodlands. Estimation by World Bank shows that the contribution of the agricultural sector to national GDP is about 25%, while majority (about 75%) of the population lives in rural areas. Unfortunately, this huge rural population is the mostly affected by arsenic contamination in drinking water.

Awareness about the presence of arsenic has been growing since late 1993 when arsenic was first tested and detected in groundwater samples from the district of Chapai Nawabgonj bordering the West-Bengal district of India. Since then, high levels of arsenic have been detected in 270 out of 465 upazilas in Bangladesh (Saha 2006). Arsenic contamination has primarily affected the shallow aquifers, which are widely used for both domestic water supply and irrigation purposes. An estimated 10 to 12 million domestic hand tubewells constitute the backbone of rural water supply of the country. Besides domestic use, groundwater is also widely used for irrigation during dry season, particularly for growing the dry-season paddy called *boro*, which requires about 1 m of irrigation. According to a recent BADC survey (BADC 2005), a total of 925,152 shallow tubewells and 24,718 deep tubewells were used for irrigation during the 2004 boro season. The contribution of groundwater to total irrigated area was over 75% in 2004, and shallow tubewells accounted for over 60% of irrigated area.

1.2. Motivation

Widespread arsenic contamination of groundwater has become a major concern in Bangladesh since the water supply, particularly in rural areas, is heavily dependent on groundwater. High levels of arsenic have been detected in 59 out of 64 administrative districts. In some areas, arsenic concentration is as high as 1.0 mg/L compared with the WHO standard of 0.01 mg/L and Bangladesh standard of 0.05 mg/L. According to a recent estimate, about 27% and 46% of shallow (<150 m deep) wells have arsenic concentration exceeding 0.05 mg/L and

0.01mg/L, respectively. In acute arsenic-problem areas, more than 90% of the shallow wells are contaminated with arsenic. Ali et al. (Ali, Badruzzaman et al. 2003) have estimated that about 46 metric tons of arsenic is extracted each year along with groundwater extracted from domestic wells.

According to BGS/DPHE (DPHE 2001), 35 million people of Bangladesh are exposed to an arsenic concentration in drinking water exceeding the national standard of 50 μg/L and 57 million people exposed to a concentration exceeding 10 μg/L, the standard of the World Health Organization (WHO). It has also been estimated that in Bangladesh, if consumption of contaminated water continues, the prevalence of arsenicosis will be approximately 2,000,000 cases and of skin cancer will be approximately 100,000, and the incidence of death from cancer induced by arsenic will be approximately 3000 per year (Yu, Harvey et al. 2003).

However, relative to the extent of research on biogeochemical processes of arsenic mobilization, very little work has been conducted to understand groundwater flow and the transport of arsenic and the solutes that control its mobility. Groundwater flow, either naturally driven or anthropogenic in type, controls the chemical input and output into the subsurface thereby affecting the complex set of biogeochemical reactions that mobilize or immobilize arsenic. Furthermore, groundwater flow patterns may create areas within the subsurface where water from different sources and of different chemical characteristics can mix, and thereby results in complex nature of biogeochemical characteristics.

1.3. Objective and Hypothesis

Dissolved arsenic concentrations as well as stable water isotope ratios have been found to vary greatly over distances of only 10's or 100's of meters, even though the sediment at these locations displays no obvious differences. Furthermore, vertical distribution of dissolved arsenic concentrations (and other related chemical constituents) exhibits a distinct pattern with the peak concentration at a particular depth. Thereby, the objective of the present study has been to investigate the reasons behind such depth profile as well as the patchiness in concentrations.

It is hypothesized that arsenic is mobilized at shallow depth (e.g. pond bottom), which is then transported by the groundwater flow, and the peak concentration ends up at a particular depth due to irrigation pumping causing flow convergence from different sources at that depth. According to this hypothesis, nearby sampling wells of significantly different arsenic concentration may be drawing water from different recharge stream-tubes with different arsenic concentrations, and thereby, creating the spatial patchiness in concentration.

Over the last four decades, Bangladesh has almost tripled its population, causing a variety of dramatic changes to the environment of the Ganges delta that are affecting subsurface biogeochemistry. The greatly increased population is introducing ever increasing loads of waste into the environment, and in rural areas most goes directly into small ponds. These ponds, many of which have been recently created, provide a new path for recharge to enter the subsurface. As a result of high organic input and direct pathways of recharge to the aquifer, the ponds are considered as the major contributor behind the subsurface dissolved arsenic concentration.

In rural Bangladesh, local features such as ponds, rivers, irrigation and drinking wells are spaced at 10's and 100's of meters. Due to the flat topography of Bangladesh, these features have significant impact on groundwater flow pattern (i.e. recharge/discharge), which in turn, causes the small scale spatial variability in arsenic concentrations as well as stable water isotopes. For example, at the end of the flooding season, the floodwater start to recedes and the river levels drop quicker than ground (and pond) water levels, resulting in groundwater discharge to rivers. This scenario is changed once the groundwater irrigation starts, resulting in recharge of groundwater from ponds, rivers, and surface clay layers. This temporal nature of groundwater flow pattern results in contributions and mixing of recharge waters from different sources such as surface water, groundwater, rainwater, percolation of irrigation water etc.

1.4. Organization of the Thesis

This thesis consists of six chapters. Apart from the current "Introduction" chapter, the remainder of the thesis has been divided into five chapters.

Chapter 2 ("Literature Review") provides an insight on the prevailing arsenic mobilization hypotheses, and their comparative merits and limitations. The chapter also further explains the proposed "Pond Hypothesis".

Chapter 3 ("Study Area Data Assimilation") gives an overview of our study area in Munshiganj. Data from various hydrological components have also been presented and analyzed to explain the hydrological flow regime within the study area. Furthermore, measurement and usage of stable water isotope as tool to identify various recharge sources have also been explained.

Chapter 4 ("Field Site Characterization") depicts step by step the characterization process of the Basailbhog Field Site for testing the "Pond Hypothesis". It also analyzes the results from numerous single well pump tests, and an innovative pumping experiment to identify the aquifer characteristics on a regional scale.

Chapter 5 ("Groundwater Models") describes the various modeling works starting from the zero-dimensional lumped parameter model to the highly representative three-dimensional seasonal model using FEFLOW. Using the complex three-dimensional model, some key issue has also been investigated, such as – 'How might spatial patterns of arsenic concentration relate to groundwater flow patterns?', 'Over what time-scales does groundwater flow introduce solute loads into aquifers or flush solute from aquifers?', 'How has groundwater pumping changed the flow system?' etc. Some of issues have been further analyzed in chapter 6.

Finally, Chapter 6 ("Analysis and Discussions") presents a recap of the "Pond Hypothesis" followed by detailed analysis of various model simulations aimed to identify recharge sources and contaminant mass transport. The chapter also draws strong connection between the calculated and observed stable water isotope values on the basis of relative recharge contributions from various sources. At the end, a direct field evidence of dissolved arsenic concentration profile is investigated that complements the modeling results and isotopic observations supporting the "Pond Hypothesis".

References:

Ali, M. A., A. B. M. Badruzzaman, et al. (2003). Fate of Arsenic extracted with groundwater. BUET-UNU Internatioanl Symposium: Fate of Arsenic in the Environment. Dhaka, Bangladesh.

BADC (2005). Survey Report on Irrigation Equipment and Irrigated Area in Boro 2004 Season, Bangladesh Agricultural Development Corporation.

DPHE, B. a. (2001). Arsenic contamination of groundater in Bangladesh. Technical Report WC/00/19 (V2). D. G. K. a. P. L. Smedley, British Geological Survey.

Saha, G. C. (2006). Accumulation of Arsenic in Agricultural Soil and Selected Crops. Department of Civil Enginering. Dhaka, Bangladesh, Bangladesh University of Engineering and Technology. **PhD**.

Yu, W. H., C. M. Harvey, et al. (2003). "Arsenic in groundwater in Bangladesh: A geostatistical and epidemiological framework for evaluating health effects and potential remedies." Water Resources Research **39**(6): 17.

Chapter 2

Literature Review

2.1. Background

Widespread arsenic contamination of groundwater has become a major concern in Bangladesh since the water supply, particularly in rural areas, is heavily dependent on groundwater. High levels of arsenic have been detected in 59 out of 64 administrative districts. According to a recent estimate, about 27% of shallow (<150 m deep) wells have arsenic concentration exceeding 0.05 mg/L. In acute arsenic-problem areas, more than 90% of the shallow wells are contaminated with arsenic. Ali et al. (Ali, Badruzzaman et al. 2003) have estimated that about 46 metric tons of arsenic is extracted each year along with groundwater extracted from domestic wells. It has also been estimated that in Bangladesh, if consumption of contaminated water continues, the prevalence of arsenicosis will be approximately 2,000,000 cases and of skin cancer will be approximately 100,000, and the incidence of death from cancer induced by arsenic will be approximately 3000 per year (Yu, Harvey et al. 2003).

2.2. Arsenic Mobilization Hypotheses

Concentrations of dissolved arsenic in the shallow Bangladesh aquifer are often as high as 1.0 mg/L compared to WHO guideline of 0.01 mg/L and Bangladesh standard of 0.05 mg/L. However, across the country (and the Bengal Basin as well), the vertical dissolved arsenic concentration profile shows a distinct pattern with the peak around a particular depth. In most part of Bangladesh, the maximum dissolved arsenic concentration is found around 20-40m depth (Karim 1997; DPHE 1999; McArthur, Ravenscroft et al. 2001; Harvey, Swartz et al. 2002), whereas, in some part of the country, the peak has been observed at a little shallower [e.g. at 15m depth in Araihazar (van Geen, Zheng et al. 2003)] or greater depths [e.g. 50-70m in Manikganj, Faridpur and Gopalganj (Nickson, McArthur et al. 2000), 60m in Sylhet (Ravenscroft 2001)]. There are a number of hypotheses by various researchers on the mechanism of arsenic mobilization in Bangladesh groundwater, and the possible pathways and sources of responsible chemical constituents. However, the hypotheses can be divided into three broad categories:

- Oxidative dissolution of arsenic bearing pyrite

- Competitive exchange of arsenic with other chemical constituents
- Reductive dissolution of various arsenic bearing oxides

2.2.1. Oxidation of arsenic bearing pyrite

According to this premature hypothesis, arsenic in the shallow aquifer has been mobilized by oxidative dissolution of arsenic-rich pyrite residing in aquifer sediments when atmospheric oxygen enters the aquifer due to lowering of the water level by abstraction (Das 1995; Saha 1995; Das 1996; Roy Chowdhury 1998; Chowdhury, Basu et al. 1999). Researchers of this proposed hypothesis argue that majority of their sampled wells from Bangladesh and West Bengal have very high concentration of arsenic in shallow, and therefore (according to them) oxic, wells. They report more than 50 ppb of arsenic at less than 30m depth and more than 1000 ppb of arsenic at 11-15.8m depth from their sampled wells in Bangladesh (Chowdhury, Basu et al. 1999). However, other researchers (Nickson, McArthur et al. 1998; Nickson, McArthur et al. 2000; McArthur, Ravenscroft et al. 2001; Harvey, Swartz et al. 2002; van Geen, Zheng et al. 2003; Horneman, Van Geen et al. 2004; Van Geen, Rose et al. 2004; Polizzotto, Harvey et al. 2005; Polizzotto, Harvey et al. 2006) have nullified this hypothesis on the basis of various evidences:

First, it is not unlikely for the sampled well locations of having a surface clay layer that will prohibit the direct intrusion of atmospheric oxygen around a depth of 15-30m. Moreover, the drop in water levels nearby irrigation wells during the dry season is about 3 to 4m (chapter 3 of this thesis). Furthermore, at the end of flooding and before the start of irrigation, the water table is at the ground surface across the flat topography of Bangladesh, and hence, it is highly unlikely that the water table will drop beyond 5-6m below ground surface, which will allow invasion of atmospheric oxygen to depth.

Secondly, the arsenic released from arsenic-rich pyrite through oxidation would have been absorbed to iron-oxyhydroxide (FeOOH), a product of the proposed oxidation process (Mok 1994; Thronton 1996), rather than be released to groundwater. Moreover, some researchers have also reported that the arsenic-rich pyrite are rare or even absent in the sediments of the Ganges delta (Acharyya, Chakraborty et al. 1999), while some have argued that pyrite is a sink rather than a source of arsenic in Bangladesh groundwater (McArthur, Ravenscroft et al. 2001).

Thirdly, there are reports of oxidized groundwater in the Dupi Tila aquifer of the Madhupur Tract (Plio-Pleistocene) containing little arsenic (Nickson, McArthur et al. 2000). Moreover, some researchers (McArthur, Ravenscroft et al. 2001) have even argued that according to the "oxidative dissolution of arsenic-rich pyrite" hypothesis, the shallow dug-wells, which rarely have arsenic pollution (DPHE 1999), would have been mostly contaminated with dissolved arsenic.

Finally, in anoxic groundwater of Bangladesh, dissolved arsenic and sulfate (an oxidative product of the proposed pyrite hypothesis) concentrations are mutually exclusive, and also acid volatile sulfide (AVS) is present in the sediments near the dissolved arsenic peak (Harvey, Swartz et al. 2002; Swartz, Blute et al. 2004), which indicate that the observed dissolved arsenic in Bangladesh shallow aquifer cannot be derived from oxidative dissolution of the in-situ arsenic-rich pyrite.

2.2.2. Competitive exchange of arsenic with other chemical constituents

Based on the presence of various chemical constituents and their competing properties with arsenic for the limited adsorption sites on the soil matrix, some researchers have hypothesized arsenic being displaced from the soil matrix by various competing species, such as pH, phosphate, bicarbonate etc, and ending up in dissolved phase.

2.2.2.1. Competitive exchange of arsenic with hydrogen

Based on some observations of high arsenic concentration associated with high pH, it has been suggested by several researchers (Welch, Lico et al. 1988; Robertson 1989; Welch, Westjohn et al. 2000; Smedley and Kinniburgh 2002) that arsenic might have been displaced from the sediment matrix by proton (H^+) ions. Robertson (1989) used the mechanism of pH-dependent desorption of arsenic in the alluvial basins of Arizona, USA, where he observed increasing arsenic concentration with increasing pH along the flowlines. However, his observations and the corresponding hypothesis have been revoked by McArthur et al (McArthur, Banerjee et al. 2004) with the reasoning of inconsistency in observations, weak correlation between pH and arsenic concentration, and possible influences of evaporo-concentration, mixing with deeper saline water or weathering.

Moreover, it has been shown that sorption of As(II) and As(V) on iron-oxides become less sensitive to pH as arsenic concentration as well as the ratio of dissolved arsenic and Fe-sediment decreases (Dixit and Hering 2003). The authors have also shown that sorption of arsenic on aquifer sediment is almost independent of pH over the typical pH range in the Bengal aquifer.

Finally, the hypothesis loses its merit for areas where high arsenic concentration is associated with low or circumneutral pH as observed in many aquifers, especially in the shallow aquifer of Bangladesh (Harvey, Swartz et al. 2002; Ayotte, Montgomery et al. 2003; Swartz, Blute et al. 2004).

2.2.2.2. Competitive exchange of arsenic with phosphate

Acharyya et al. (1999) hypothesize that arsenic anions adsorbed on aquifer matrix might have been displaced and mobilized into the dissolved phase through competitive exchange of phosphate anions. They suggest that arsenic is more likely to be associated with Fe(III) and Mn (IV) oxides in the aquifer sediment, and the increased phosphate anions derived from the excessive use of phosphate-fertilizer as well as from the decay of natural organic matter have displaced arsenic from the sediments. This hypothesis has further been evidenced by some observations (DPHE 2001) and supported by some other authors (Dixit and Hering 2003) as well.

However, this hypothesis loses its merit of being the foremost player of mobilizing arsenic in Bangladesh groundwater when there is a lack of distinct relationship between arsenic and phosphate concentrations – high arsenic concentration has been reported to be associated with high as well as low phosphorous concentrations (McArthur, Ravenscroft et al. 2001). Moreover, in our study area in Munshiganj, farmers use no or very little phosphate-fertilizer (e.g. Triple-Super-Phosphate, TSP) though the dissolved arsenic concentration is in the order of hundreds of ppb, which indicates that fertilizer phosphate is not the major contributor in arsenic mobilization.

2.2.2.3. Competitive exchange of arsenic with bicarbonate

Based on model calculations, Appelo et al (Appelo, Van der Weiden et al. 2002) suggest that carbonate concentration in groundwater (and soil) reduces the sorption capacity of arsenic on aquifer material, such as ferrihydrite. Anawar et al (Anawar, Akai et al. 2004) carried out six-day long incubation study to investigate arsenic leaching from sediment surface by bicarbonate ions, and reports that bicarbonate ions can extract arsenic from sediment samples in both oxic and anoxic conditions. Both group of authors hypothesize that sediments containing high amounts of sorbed arsenic are deposited in surface water with low carbonate (or bicarbonate) concentrations, followed by mobilization of arsenic from the sediment surface through displacement by carbonate (or bicarbonate) after the sediments become exposed to groundwater with high dissolved carbonate (or bicarbonate) content. They also claim that the high alkalinity acts as the major driving force for mobilizing arsenic in Bangladesh groundwater, and mobilization of arsenic via reductive dissolution of iron oxyhydroxides is not even necessary in this context.

McArthur et al (McArthur, Banerjee et al. 2004) argues against this hypothesis citing the examples of a variety of aquifers in the UK as well as in the Bengal Basin that contain very high bicarbonate concentration (in the order of hundreds of mg/L), but very low dissolved arsenic concentration (<10 ppb). Furthermore, they provide evidences from their study area where arsenic concentrations bear no relation to concentrations of bicarbonate.

Contrary to the claims by Appelo et al and Anawar et al, bicarbonate in groundwater is derived from the reaction of aquifer calcite with CO_2, which is a product of reductive dissolution of iron oxyhydroxide by microbial activity that mobilizes arsenic (McArthur 1999; Harvey, Swartz et al. 2002; Swartz, Blute et al. 2004). Although carbonate has the potential to mobilize arsenic from the soil matrix, it is therefore could be at most the secondary player (along with phosphate) in regard to the high concentration of arsenic in Bangladesh aquifer.

More interestingly, one group of authors invoking the bicarbonate theory to be major driving force behind arsenic mobilization in the Bengal delta, carried out some more incubation experiments (Akai, Izumi et al. 2004; Anawar, Akai et al. 2006) where they observed glucose addition increased arsenic mobilization from reduction of iron-oxyhydroxide under anoxic environment. Based on these experiments, they reports that iron and manganese oxides (or oxyhydroxides) are the most important source minerals for arsenic in the Bengal delta. They also hypothesize the major pathway of arsenic release being the microbial activity that mobilizes arsenic through reduction of iron-oxyhydroxide in the presence of young organic matter.

2.2.3. Reductive dissolution of various arsenic bearing oxides

The mechanism of reductive dissolution of various arsenic bearing oxides is so far the most plausible and widely accepted hypothesis for arsenic mobilization in Bangladesh groundwater. This hypothesis states that in the presence of organic matter and under reducing environment, microbes reduces the metals (e.g. Fe and Mn) from oxide-minerals (e.g. Fe and Mn oxides) to process the organic matter for growth, and subsequently causes release of arsenic associated with the oxide-minerals to the aqueous phase. Incubation studies carried out by various researchers on sediment samples collected from different parts of Bengal basin also confirms the stated mobilization process being the most significant contributor of dissolved arsenic (Akai, Izumi et al. 2004; Horneman, Van Geen et al. 2004; Islam, Gault et al. 2004; Van Geen, Rose et al. 2004; Gault, Islam et al. 2005; Anawar, Akai et al. 2006; Polizzotto, Harvey et al. 2006; Radloff, Cheng et al. 2007). However, there exist some debates among various researchers about the location of arsenic mobilization, and the possible pathways as well as sources of responsible chemical constituents.

2.2.3.1. Arsenic mobilization from co-deposited organic carbon

Based on the positive correlation between arsenic and organic carbon in their collected sediment cores, Meharg et al (Meharg, Scrimgeour et al. 2006) has hypothesized that arsenic was co-deposited with organic carbon along with Fe(III) oxides in vegetated zone of the deltaic environment. Upon burial of these sediments, degradation of the co-deposited organic carbon drives the release of arsenic into the porewater through reductive dissolution of the Fe(III) oxides. In their attempt to come up with a novel hypothesis, they have also discounted some of the competing hypothesis (McArthur, Banerjee et al. 2004; Van Geen, Rose et al. 2004) citing the rarity of organic carbon bearing peat lenses in the Bengal basin, as well as the absence of asymptotic decline in dissolved organic carbon with depth – both of which has been the major components of the competing hypotheses. They also criticizes the hypothesis initially put forward by Harvey et al (Harvey, Swartz et al. 2002) and later modified by Polizzotto et al (Polizzotto, Harvey et al. 2005) by referring to the peak of dissolved organic carbon (DOC) being at the same depth of the dissolved arsenic peak. However, they failed to realize that the observed DOC have been originated from old organic carbon, whereas the dissolved inorganic carbon, showing the similar depth-profile of arsenic concentration, have been derived from young organic carbon as indicated by the radiocarbon dating (Harvey, Swartz et al. 2002). In fact, the presence of DOC indicates that the old organic carbon, being recalcitrant, is not favorable for microbial oxidation (Meharg, Scrimgeour et al. 2006), and would have been consumed by microbes otherwise.

Another important but flawed component of the hypothesis by Meharg et al is it requires a very high and unrealistic sediment depositional rate for the As-OC co-deposited sediment to be at a depth of around 30m, but at the same time, criticizes the importance of irrigation pumping which has great impact on the hydrologic flow pattern, and thereby, on the dissolved arsenic as well as other chemical constituents (Harvey, Ashfaque et al. 2006). While irrigation pumping is not supplying the organic matter (as misinterpreted by Meharg et al), it is certainly transporting various dissolved chemicals from one location to another (Harvey, Swartz et al. 2002; Harvey, Ashfaque et al. 2006).

Finally, the hypothesis loses its merit when the authors have tried to explain the heterogeneity in dissolved arsenic concentration on small spatial scale by predicting that arsenic concentration will be low along river banks due to lower organic carbon input. On the contrary, the reality most of the high arsenic concentrations are observed along the river banks (DPHE 1999).

2.2.3.2. Arsenic mobilization from Mn-oxide

Smedley and Kinniburgh (Smedley and Kinniburgh 2002) suggests that in addition to Fe-oxide, reductive dissolution of arsenic-rich Mn-oxides can contribute to high dissolved arsenic concentration. While some researchers have observed high dissolved manganese concentration concomitant with high dissolved arsenic concentration in few areas (van Geen, Zheng et al. 2003), some other researchers (McArthur, Banerjee et al. 2004) have argued against this hypothesis stating that the reduction of Mn-oxides being thermodynamically more favorable than the reduction of Fe-oxides, the arsenic released from Mn-oxides would have resorbed to Fe-oxides, and thereby, will not have contributed to dissolved arsenic concentration. On the other hand, it is possible that all the sorption sites on Fe-oxides have already been occupied (either with arsenic or other species), in which case arsenic released from the reductive dissolution of Mn-oxides will contribute to dissolved arsenic concentration in groundwater. However, Mn-oxides are less abundant than the Fe-oxides, and hence, the contribution is of less importance.

2.2.3.3. Arsenic mobilization from FeOOH through microbial degradation of buried peat

According to the hypothesis, organic carbon in buried peat is the driver of microbial reduction of arsenic-rich iron-oxyhydroxide (FeOOH) in the aquifer sediments, and releases the sorbed arsenic to groundwater (Nickson, McArthur et al. 1998; Nickson, McArthur et al. 2000; McArthur, Ravenscroft et al. 2001; McArthur, Banerjee et al. 2004). The authors provide various evidences of buried peat deposit at their field sites, supporting their argument that the severity and distribution of arsenic in groundwater is controlled more by the presence of buried peat deposit since organic matter is needed to drive the microbial reduction of FeOOH that contains arsenic (McArthur, Ravenscroft et al. 2001). However, contrary to their peat theory, high dissolved arsenic concentration has been reported in other areas of Bangladesh where no buried peat layer has been observed and surface sources of organic matter have been hypothesized to be the driver of microbial reduction process (Harvey, Swartz et al. 2002; Horneman, Van Geen et al. 2004; Swartz, Blute et al. 2004; Van Geen, Rose et al. 2004). Moreover, Harvey et al (Harvey, Swartz et al. 2002) reports presence of young dissolved inorganic carbon (DIC) and very old dissolved organic carbon (DOC) at depths of peak arsenic concentration as evident by the ^{14}C measurements. Groundwater dating by Dowling et al (Dowling, Poreda et al. 2002) also confirms that young water is found around 30m depth, where arsenic concentration peaks in most part of Bangladesh. In light of this evidence, Harvey et al (Harvey, Swartz et al. 2002) argue that young DIC being the resultant of young DOC, the organic matter responsible for microbial reduction of FeOOH must be young. On the other hand, the presence of very old DOC indicates that it has originated from resident sediment, and more importantly, is not viable for microbial reduction process.

2.2.3.4. *Arsenic mobilization from FeOOH in aquifer sediment*

Based on laboratory experiments, it has been hypothesized that arsenic is present in the aquifer material adsorbed on FeOOH surfaces in sufficient amount which releases into the dissolved phase due to reductive dissolution of FeOOH through microbial activity in the presence of surface drawn organic matter (van Geen, Zheng et al. 2003; Horneman, Van Geen et al. 2004; Van Geen, Rose et al. 2004; Zheng, Stute et al. 2004). The cohorts of this hypothesis have also attempted to draw a connection between the permeability of the surface soil and the dissolved arsenic concentration in groundwater by referring to their observations within their study area (van Geen, Aziz et al. 2006; van Geen, Zheng et al. 2006). They report that in the absence of surface clay layer, elevated surface recharge during wet season prevents arsenic accumulating in groundwater, whereas the dissolved arsenic concentration is high in areas where local recharge is restricted by surface clay layer.

The stated hypothesis has several limitations. First, Meharg et al (Meharg, Scrimgeour et al. 2006) have argued that if arsenic mobilization from aquifer sediment at depth have been driven by surface drawn organic matter, there would have been an asymptotic decline in DOC rather than the profile reported by Harvey et al (Harvey, Swartz et al. 2002).

Secondly, according to the stated hypothesis, one can expect that dissolved arsenic and Fe(II) would have strong correlation since arsenic is being derived from the dissolution of FeOOH. However, on the contrary, the authors have observed lack of correlation between the two dissolved species, and similar results have also been reported in other studies (DPHE 2001). They tried to explain the lack of Fe(II) in the dissolved phase through the notion of reprecipitation of Fe(II) with soil matrix, although they failed to identify the Fe(II) phase in the soil matrix (Horneman, Van Geen et al. 2004).

Finally, their observation of the connection between the surface soil permeability and dissolved arsenic concentration could be true though their rationale behind it is flawed. Most of the recharge in the Bangladesh shallow aquifer occurs during the dry season rather than in the wet season (Harvey, Ashfaque et al. 2006). Moreover, it is imperative that recharge from other sources, such as neighboring ponds and rivers, is an essential component of the hydrologic cycle, and therefore, needs to be considered while drawing such connections.

2.2.3.5. *Arsenic mobilization from oxides at near surface environment*

So far the most robust and plausible hypothesis for arsenic mobilization in Bangladesh groundwater has been suggested Harvey et al (Harvey, Swartz et al. 2002), which later has been modified by Polizzotto et al (Polizzotto, Harvey et al. 2005) and finally has been completed in this current thesis. The proposed hypothesis overcomes the limitations of aforementioned hypotheses and proves the theory with direct evidences and model simulations.

According to the suggested mechanism, the source of arsenic sorbed to oxide (e.g. FeOOH) surfaces lie upstream of Bangladesh. During the annual monsoon season, these sediments are carried to the Bengal basin by the rivers and subsequently get deposited. Moreover, the several meters high standing flood water, rich in organic matter from human and plant waste, creates anoxic condition near the surface that is favorable for reductive dissolution of arsenic-rich iron oxides through microbial activity. Once the flood water recedes and the dry season irrigation starts, the dissolved arsenic, along with the other by-products of the reductive dissolution process, are drawn in to the aquifer due to aquifer discharge into the river and the impact of irrigation pumping. Furthermore, the peak of dissolved arsenic as well as other related dissolved constituents (e.g. calcium, ammonium, DIC, DOC and methane) coincides with the depth of well-screen since pumping creates flow convergence at that depth.

The first component of the hypothesis is the source of dissolved arsenic in the aquifer: the authors argue that rather than the aquifer sediment, the source of arsenic lie upstream of Bangladesh, and in fact, originates in the Himalayas. Weathering of arsenic-rich minerals releases finely divided FeOOH which strongly sorbs co-weathered arsenic (Mok 1994; Thronton 1996). During the annual flooding event, these arsenic-rich FeOOH are transported to the Bengal basin as riverine sediment, and thus provide fresh source of arsenic every year once it gets deposited near the surface. Other researchers have also indicated that the sediments with high proportion of clay (such as the flood deposits and the surface clay) have much higher concentration of arsenic than in the sand (Acharyya, Chakraborty et al. 1999). Moreover, laboratory analysis (Harvey, Swartz et al. 2002; Swartz, Blute et al. 2004; Polizzotto, Harvey et al. 2005) suggest that there is not enough arsenic in the aquifer sediment that can explain such high dissolved arsenic concentration in the groundwater.

The second component of the hypothesis is the source of organic carbon and the location thereof for arsenic mobilization. Radiocarbon dating of organic and inorganic carbon (Harvey, Swartz et al. 2002) indicates that the DIC is much younger than the DOC at the depth of high dissolved arsenic. Since young DIC can only be derived from young DOC, the source must lie near the surface rather than in old buried peat deposit as suggested by some researchers (Nickson, McArthur et al. 2000; McArthur, Ravenscroft et al. 2001; McArthur, Banerjee et al. 2004). Furthermore, the reductive dissolution of FeOOH by microbial activity is suggested to be occurring near the surface where the favorable anoxic condition takes place during the flooding season and at the pond bottom. In the absence of atmospheric oxygen and under strong reducing condition (e.g. at pond bottoms which are approximately 10-12m below the flood water surface), arsenic bearing (iron and manganese) oxides are bound to get dissolved and release arsenic. While young DIC refers to the source of organic carbon driving the arsenic release to be young, the absence of asymptotically decline in young DOC profile from the surface indicates that young organic carbon is not being drawn in to the aquifer to drive the reductive dissolution process as claimed by some researchers (van Geen, Zheng et al. 2003; Horneman, Van Geen et al. 2004; Van Geen, Rose et al. 2004).

Finally, the concentration profile of dissolved arsenic, as well as other related by-products of the reductive dissolution process, shows a distinct pattern with depth with the peak concentration coinciding with the depth of well screens (Karim 1997; DPHE 1999; Nickson, McArthur et al. 2000; McArthur, Ravenscroft et al. 2001; Ravenscroft 2001; Harvey, Swartz et al. 2002; van Geen, Zheng et al. 2003). This phenomenon suggests that hydrologic flow pattern, specially the irrigation pumping, has significant impact on the observed bell-shaped vertical profiles of the concerned solutes. Once the flood water starts to recede at the end of flooding season, and also the reductive dissolution process liberating arsenic might have been completed by then, the mixture of various dissolved solutes from pond bottoms enters the aquifer and is driven towards the well screen both vertically due to overlying recharge and horizontally due to increased pumping.

In order to completely define the process of arsenic mobilization and transportation in the Bangladesh aquifer, it is necessary to understand the local hydrologic flow pattern. This thesis attempts to surmise and complement the theory of arsenic mobilization process through modeling efforts and direct observations as discussed in the following chapters.

References:

Acharyya, S. K., P. Chakraborty, et al. (1999). "Arsenic poisoning in the Ganges delta." Nature **401**(6753): 545-545.

Akai, J., K. Izumi, et al. (2004). "Mineralogical and geomicrobiological investigations on groundwater arsenic enrichment in Bangladesh." Applied Geochemistry **19**(2): 215-230.

Ali, M. A., A. B. M. Badruzzaman, et al. (2003). Fate of Arsenic extracted with groundwater. BUET-UNU Internatioanl Symposium: Fate of Arsenic in the Environment. Dhaka, Bangladesh.

Anawar, H. M., J. Akai, et al. (2004). "Mobilization of arsenic from subsurface sediments by effect of bicarbonate ions in groundwater." Chemosphere **54**(6): 753-762.

Anawar, H. M., J. Akai, et al. (2006). "Mobilization of arsenic in groundwater of Bangladesh: evidence from an incubation study." Environmental Geochemistry and Health **28**(6): 553-565.

Appelo, C. A. J., M. J. J. Van der Weiden, et al. (2002). "Surface complexation of ferrous iron and carbonate on ferrihydrite and the mobilization of arsenic." Environmental Science & Technology **36**(14): 3096-3103.

Ayotte, J. D., D. L. Montgomery, et al. (2003). "Arsenic in groundwater in eastern New England: Occurrence, controls, and human health implications." Environmental Science & Technology **37**(10): 2075-2083.

Chowdhury, T. R., G. K. Basu, et al. (1999). "Arsenic poisoning in the Ganges delta." Nature **401**(6753): 545-546.

Das, D., Basu, G., Chowdhury, T.R., Chakraborty, D. (1995). Bore-hole soil-sediment analysis of some As affected areas. Proceedings of the International Conference on Arsenic in Groundwater: cause, effect and remedy, Calcutta.

Das, D., Samanta, G., Mandal, B.K., Chowdhury, T.R., Chanda, C.R. Chowdhury, P.P., Basu, G.K., Chakraborty, D. (1996). Environmental Geochemical Health **18**: 5-15.

Dixit, S. and J. G. Hering (2003). "Comparison of arsenic(V) and arsenic(III) sorption onto iron oxide minerals: Implications for arsenic mobility." Environmental Science & Technology **37**(18): 4182-4189.

Dowling, C. B., R. J. Poreda, et al. (2002). "Geochemical study of arsenic release mechanisms in the Bengal Basin groundwater." Water Resources Research **38**(9): 18.

DPHE (1999). Main report and volumes S1-S5, report on Phase I. Groundwater studies for arsenic contamination in Bangladesh. Dhaka, Bangladesh, Department of Public Health Engineering, Government of Bangladesh.

DPHE, B. a. (2001). Arsenic contamination of groundater in Bangladesh. Technical Report WC/00/19 (V2). D. G. K. a. P. L. Smedley, British Geological Survey.

Gault, A. G., F. S. Islam, et al. (2005). "Microcosm depth profiles of arsenic release in a shallow aquifer, West Bengal." Mineralogical Magazine **69**(5): 855-863.

Harvey, C. F., K. N. Ashfaque, et al. (2006). "Groundwater dynamics and arsenic contamination in Bangladesh." Chemical Geology **228**(1-3): 112-136.

Harvey, C. F., C. H. Swartz, et al. (2002). "Arsenic mobility and groundwater extraction in Bangladesh." Science **298**(5598): 1602-1606.

Horneman, A., A. Van Geen, et al. (2004). "Decoupling of As and Fe release to Bangladesh groundwater under reducing conditions. Part 1: Evidence from sediment profiles." Geochimica Et Cosmochimica Acta **68**(17): 3459-3473.

Islam, F. S., A. G. Gault, et al. (2004). "Role of metal-reducing bacteria in arsenic release from Bengal delta sediments." Nature **430**(6995): 68-71.

Karim, M., Komori, Y., Alam, M. (1997). "Subsurface As occurrence and depth of contamination in Bangladesh." Journal of Environmental Chemistry(7): 783-792.

McArthur, J. M. (1999). "Arsenic poisoning in the Ganges delta - Reply." Nature **401**(6753): 546-547.

McArthur, J. M., D. M. Banerjee, et al. (2004). "Natural organic matter in sedimentary basins and its relation to arsenic in anoxic ground water: the example of West Bengal and its worldwide implications." Applied Geochemistry **19**(8): 1255-1293.

McArthur, J. M., P. Ravenscroft, et al. (2001). "Arsenic in groundwater: Testing pollution mechanisms for sedimentary aquifers in Bangladesh." Water Resources Research **37**(1): 109-117.

Meharg, A. A., C. Scrimgeour, et al. (2006). "Codeposition of organic carbon and arsenic in Bengal Delta aquifers." Environmental Science & Technology **40**(16): 4928-4935.

Mok, W. M., Wai, C.M. (1994). Mobilization of As in contaminated river waters. Arsenic in the Environment, Part 1, Cycling and Characterization. J. O. Nriagu. New York, John Wiley and Sons Limited: 99-117.

Nickson, R., J. McArthur, et al. (1998). "Arsenic poisoning of Bangladesh groundwater." Nature **395**(6700): 338-338.

Nickson, R. T., J. M. McArthur, et al. (2000). "Mechanism of arsenic release to groundwater, Bangladesh and West Bengal." Applied Geochemistry **15**(4): 403-413.

Polizzotto, M. L., C. F. Harvey, et al. (2006). "Solid-phases and desorption processes of arsenic within Bangladesh sediments." Chemical Geology **228**(1-3): 97-111.

Polizzotto, M. L., C. F. Harvey, et al. (2005). "Processes conducive to the release and transport of arsenic into aquifers of Bangladesh." Proceedings of the National Academy of Sciences of the United States of America **102**(52): 18819-18823.

Radloff, K. A., Z. Cheng, et al. (2007). Mobilization of Arsenic During One-Year Incubations of Grey Aquifer Sands from Araihazar, Bangladesh. **41:** 3639-3645.

Ravenscroft, P., McArthur, J.M., Hoque, B.A. (2001). Geochemical and palaeohydrological controls on pollution of groundwater by arsenic. Arsenic Exposure and Health Effects IV. W. R. Chappell, Abernathy, C.O., Calderon, R.L. Oxford, Elsevier: 53-77.

Robertson, F. N. (1989). "Arsenic in Groundwater under Oxidizing Conditions, South-West United-States." Environmental Geochemistry and Health **11**(3-4): 171-185.

Roy Chowdhury, T., Basu, G.K., Samanta, G., Chanda, C.R., Mandal, B.K., Dhar, R.K., Biswas, B.K., Lodh, D., Ray, S.L., Chakraborti, D. (1998). Proceedings of the Internation Conference on Arsenic in Groundwater in Bangladesh: Causes, Effects and Remedies, Dhaka, Bangladesh.

Saha, A. K., Chakrabarti, C. (1995). Proceedings of the International Conference on Arsenic in Groundwater, Calcutta.

Smedley, P. L. and D. G. Kinniburgh (2002). "A review of the source, behaviour and distribution of arsenic in natural waters." Applied Geochemistry **17**(5): 517-568.

Swartz, C. H., N. K. Blute, et al. (2004). "Mobility of arsenic in a Bangladesh aquifer: Inferences from geochemical profiles, leaching data, and mineralogical characterization." Geochimica Et Cosmochimica Acta **68**(22): 4539-4557.

Thronton, I. (1996). "Sources and pathways of As in the geochemical environment: health implications." Environmental Geochemistry and Health **113**: 153-161.

van Geen, A., Z. Aziz, et al. (2006). "Preliminary evidence of a link between surface soil properties and the arsenic content of shallow groundwater in Bangladesh." Journal of Geochemical Exploration **88**(1-3): 157-161.

Van Geen, A., J. Rose, et al. (2004). "Decoupling of As and Fe release to Bangladesh groundwater under reducing conditions. Part II: Evidence from sediment incubations." Geochimica Et Cosmochimica Acta **68**(17): 3475-3486.

van Geen, A., Y. Zheng, et al. (2006). "A transect of groundwater and sediment properties in Araihazar, Bangladesh: Further evidence of decoupling between As and Fe mobilization." Chemical Geology **228**(1-3): 85-96.

van Geen, A., Y. Zheng, et al. (2003). "Spatial variability of arsenic in 6000 tube wells in a 25 km(2) area of Bangladesh." Water Resources Research **39**(5): 16.

Welch, A. H., M. S. Lico, et al. (1988). "Arsenic in Ground-Water of the Western United-States." Ground Water **26**(3): 333-347.

Welch, A. H., D. B. Westjohn, et al. (2000). "Arsenic in ground water of the United States: Occurrence and geochemistry." Ground Water **38**(4): 589-604.

Yu, W. H., C. M. Harvey, et al. (2003). "Arsenic in groundwater in Bangladesh: A geostatistical and epidemiological framework for evaluating health effects and potential remedies." Water Resources Research **39**(6): 17.

Zheng, Y., M. Stute, et al. (2004). "Redox control of arsenic mobilization in Bangladesh groundwater." Applied Geochemistry **19**(2): 201-214.

Chapter 3

Study Area Data Assimilation

3.1. Study Area

Our study area is located at Sreenagar, in Munshiganj district of Bangladesh, about 30km south to Dhaka and 7km north to the Ganges (Fig.3.1). Sreenagar is the largest thana in Munshiganj occupying an area of 203 km^2, and a population of about 281,000 (BAMWSP 2005). In 1991, the population in Sreenagar was about 206,000 people, 94% of which use tubewells as a main source of potable drinking water.

Fig.3.2 shows an IKONOS satellite image of our 16km^2 study area in Sreenagar, Munshiganj highlighting various hydrologic features, such as: 51 irrigation wells (blue squares; generic ID is IR), 34 drinking wells (red circles; generic ID is DR), 12 ponds (green polygons; generic ID is P), 9 river locations (yellow rectangles; generic IDs are HB for highway bridges, SB for steel bridges, LB for local bridges), and 2 field sites (yellow triangles; Bejgoan and Basailbhog). At both of our field sites, we have installed clusters of peizometric wells – one cluster of 25 piezometers at Bejgoan field site, and eight clusters of total 61 piezometers at Basailbhog field site, screened at different depths, and are identified by the depth of the well screen in feet. Fig.3.3 shows snapshots of the two field sites, and Tables 3.1 and 3.2 illustrate the details of various piezometers at the two field sites:

Table 3.1: Piezometers at Bejgoan field site

Well ID	Screen Depth (m)	Well ID	Screen Depth (m)
2	0.6	125	38.1
6	1.8	150	45.7
9	2.7	200(1)	61.0
15	4.6	200(2)	61.0
30	9.1	200(3)	61.0
45	13.7	200(4)	61.0
60	18.3	200(5)	61.0
80(1)	24.4	200(6)	61.0
80(2)	24.4	250	68.6
100(1)	30.5	350	106.7
100(2)	30.5	540	164.6
100(3)	30.5		
100(4)	30.5		
100(5)	30.5		

Table 3.2: Piezometers at Basailbhog field site

Well ID	Screen Depth of piezometers in different clusters (m)							
	C0	C1	C2	C3	C4	C5	C6	S1
17	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
30	9.1	9.1	9.1	9.1			9.1	9.1
45	13.7	13.7	13.7	13.7				13.7
65	19.8	19.8	19.8	19.8	19.8	19.8		19.8
90	27.4	27.4	27.4	27.4	27.4	27.4	27.4	27.4
105					32.0	32.0		
120	36.6	36.6	36.6	36.6	36.6	36.6		36.6
155							47.2	
170	51.8	51.8	51.8	51.8			51.8	51.8
230	70.1	70.1	70.1	70.1				70.1

3.2. Surveyed Water Levels

In order to understand the local hydrology, we have been monitoring the surface and ground water levels within our study area over the last six years. As shown in Fig.3.2, surface water monitoring locations include 12 ponds and 9 river locations, whereas ground water monitoring locations include 51 irrigation wells, 34 drinking wells and 86 piezometers at the two field sites. We used hand-held global positioning system (GPS) units to record the location of each water level monitoring points, and carried out three extensive surveys for identifying the reference levels of the monitoring points with respect to the Mean Sea Level (MSL). Tables A.1-A.3 in Appendix A show the global coordinates and the reference levels of the surveyed monitoring points.

3.2.1. Bejgoan Field Site

The Bejgoan Field Site is located at the center of our study area, and just beside the Dhaka-Maowa highway. We installed a total of 25 piezometers at the Bejgoan field site, and we used down-hole pressure transducers data-loggers (In-Situ MiniTrolls) for monitoring the water levels of the piezometers from 2001 to 2005. Data was recorded every hour, and the pressure was converted into water levels with respect to the MSL. In addition, bi-weekly to monthly water levels were recorded manually using dippers. The recorded water level data is presented in Appendix B, and is shown in Fig.3.4. The seasonal data indicates that the water level start to rise in May at the beginning of monsoon, and declines in November once the flood recedes.

Peizometric data between December 2003 and June 2004 (Fig.3.5) shows that water level at the surface clay layer remains highest throughout the season indicating a downward vertical flow. However, an interesting point to note is that the rate of decline in water levels of the surface clay layer (~20 cm/month) is more due to evaporation (~15cm/month) than recharging the aquifer. On the other hand, the minimum water level at 30.5m indicates flow of water from above and below at that layer, incidentally where all the irrigation wells are screened.

Water levels recorded by the In-Situ probes provide an insight of the daily fluctuation in water levels over the entire season (Fig.3.6). The probe data confers that in general, the dry season extends from November to June, and the flooding occurs between July and October when the water levels go above the ground surface. During the dry season, the daily oscillations in water levels from December to April are due to irrigation pumping, whereas the rapid and large jumps in the water levels towards the end of irrigation season in May can be attributed to increased rainfall combined with lack of pumping. A zoom in view at the data during the beginning and end of irrigation (Fig. 3.7 and 3.8) provides a better understanding of the events. The figures also indicate that the beginning and conclusion of irrigation vary slightly from year to year.

3.2.2. Ponds within Study Area

Numerous ponds are visible within our study area, each being surrounded by villages. Information from local people suggests that most of these ponds have likely been excavated over the last 50 years as the population has greatly increased. The ponds are excavated to provide clay/silt material for construction of villages above the monsoon flood levels.

We adopted the water leveling technique to measure the pond water levels, and Fig. 3.9 depicts the process pictorially. At first, a clear flexible thin tube is filled up with water, and it is ensured that there is no air bubble inside. Then, one end of the tube is attached to a 5m-long survey scale, which is held vertically up just above the pond water level. The other end of the tube is held against a reference point, whose elevation has already been determined with respect to the Mean Sea Level (MSL) through the extensive surveys. Once the water level inside the tube is leveled with the reference point, the height of water level is read from the survey scale. Afterwards, the pond water level with respect to the MSL is calculated by subtracting the measured water level height from the elevation of the reference point [Data is tabulated in Appendix C].

Fig.3.10 shows the seasonal fluctuations in pond water levels in our study area. In general, the fluctuations follow the seasonal monsoon pattern. However, the water levels vary over a wide range due to the spatial separation and lack of connection among the ponds. All the ponds are surrounded by villages, and therefore, they not only differ in water levels, but also in fluctuation patterns. In addition, in cases of a few of the ponds, villagers sometimes manipulate them according to their needs, e.g. dry out the pond for fishing purpose, or cut the barrier at one corner for facilitating the escape of the flood water etc., which also contribute in the variations from pond to pond. Only considering the ponds free of any artificial manipulation, a comparison of the rate of pond water level decline and the evaporation rate (Fig. 3.11) shows that the ponds lose water at a rate faster than can be explained by evaporation, indicating loss to the aquifer. The average decline for the ponds over the period from January 15, 2004 to April 24, 2004 indicates that ponds contribute about 0.53 mm/day of water to the aquifer, which is about 42% of irrigation pumping [(Harvey, Ashfaque et al. 2006)]. From the rate of pond water level decline in Fig.3.11, it can also be concluded that Pond-5 and Pond-6 contribute the most water to the aquifer, whereas, Pond-4 contributes little or no water at all as it follows the rate of evaporation very closely.

3.2.3. River within Study Area

The Ichhamati River flows through the center of our study area. Water level of the Ichhamati River has been recorded at nine locations by means of measuring tape from bridges. Fig.3.12 shows the seasonal fluctuations in the river, which essentially follows the monsoon pattern [Data is tabulated in Appendix D]. Except for couple of locations on the side channels, the water levels follow each other very closely inferring their connectivity over spatial domain. Moreover, water level measurements show that the river flows both north to south and south to north depending on the time of the year. The Icchamati is connected to the Dhaleswari River to the north and to the Ganges River to the south. As can be seen from Fig.3.13, the Ichhamati water level follows the Ganges water level very closely all the time inferring that Ichhamati is hydraulically connected to the Ganges.

3.2.4. Groundwater Levels within Study Area

In addition to the peizometric water levels at the two field sites, groundwater levels have also been measured through 34 drinking wells (DR) and 51 irrigation wells (IR) over the entire study area [Water level data at monitoring drinking and irrigation wells are tabulated in Appendix E and F, respectively; depth of well screen and pumping rates of the irrigation wells are tabulated in Appendix G]. Fig.3.14 shows the seasonal fluctuations in groundwater level as measured from the drinking wells. The oscillations in the water levels correspond to the monsoon fluctuation, as well as the dry season irrigation. In general, water levels decline from December to March in response to increased pumping for irrigation. Water levels rise in April in response to pre-monsoon rainfall and rising river levels. This pattern is consistent with the probe and dipping data as recorded from the piezometers.

3.2.5. Comparison of Water Levels

Plotting the water levels as recorded from the various features reveals the seasonal groundwater flow pattern within the study area. Fig.3.15 shows the average seasonal water level fluctuations in groundwater, pond and river locations. The plot indicates that during the flooding season (June to October), all the water levels are clustered together inferring that there is no or very little gradient between the surface and ground water. However, throughout the dry season, the pond water levels are higher than the groundwater and river water levels, in general. During the early part of the dry season, the groundwater level is higher than the river water level suggesting that the aquifer acts as a conduit for flow from the pond to the river. But, at the later stage of the dry season, the groundwater level goes below the river water level due to intense groundwater pumping as well as rise in river level due to pre-monsoon rain, and therefore, groundwater gets recharged both from the ponds and the river. When the irrigation stops in May, the groundwater levels start to bounce back rapidly (due to lack of pumping and rise in river level) until they come together with the surface water levels, and stay there throughout the flooding season (June-October).

Furthermore, three sub-zones within the 16km^2 study area have been identified (Fig.3.2), where each sub-zone has different hydrologic features and plots of water levels of those features have been presented in Fig.3.16. In general, all the plots show a somewhat similar trend to that for the entire region. However, there are few differences: in zone-1 (panel A), pond-3 water level drops below the river and groundwater levels earlier (mid-June) as well as towards the end (September) of the flooding season. The reason for lower water level of pond-3 during early flood season is that it being surrounded by village homes, which are built above the flood levels and thus prevent floodwater from entering the pond. On the other hand, during the later stage of the flood, villagers make a small channel-cut at one corner of the pond and water is allowed to flow out of the pond resulting in rapid decrease in its water level. The data point of pond-2 water level in zone-2 (panel B) during mid-June may be a measurement error since there isn't any logical reason for a particular water level being more than a meter higher than all other water levels within the study area. In zone-3, pond-6 water level deviates from river and groundwater levels for most part of the flooding season (panel C). The pond is surrounded by road on one side and by villages on other sides. As a result, floodwater cannot intrude into the pond early in the season, and hence, the pond water level is lower than other water levels. However, once the flood water enters the pond, it cannot escape quickly with receding floodwater due to the surrounding boundaries, resulting in higher water level in the pond.

Fig.3.17 shows the temporal fluctuation of river and groundwater levels in a segment of zone-2. From 14-Dec-03 to 11-Mar-04, the groundwater levels are higher than the river water level, which infers groundwater discharge to the river during this time period. After that, river water level goes above the groundwater levels and recharges the groundwater. However, in general, the difference in fluctuation rates between river and groundwater infers that there is some kind of hydraulic barrier (e.g. low conductive river bed) between them. The error bars (of

20cm) associated with the groundwater levels account for the water level fluctuation due to irrigation pumping (the 20cm daily fluctuation has been observed from the probe data, Fig.3.7 and 3.8). As can be seen from Fig.3.17, the groundwater levels drop much faster after 29-Dec-03 due to irrigation. The groundwater levels keep dropping until 25-Mar-04 and afterwards it starts to rise due to surface water recharge and possibly some rainfall. On the other hand, the river water level changes somewhat differently. There is an increase in river water level initially, then the water level drops (but at a different rate from that of the groundwater) until 11-Mar-04. Afterwards, between 11-Mar-04 and 25-Mar-04, there is a big increase in river water level (unlike a drop in groundwater levels) since the villagers created a temporary barrier at the downstream of the river for excavation of river bed. After 25-Mar-04, both river and groundwater levels increase with time. Another interesting point to note is that all the groundwater levels (in different drinking wells) fluctuate in a similar manner and there is little or no hydraulic gradient among them.

Looking at the maximum and minimum water levels (Fig.3.18), it is evident that there is very little spread for the groundwater and river levels, in general, that infers very little horizontal hydraulic gradient within the study area. However, there is consistently a large spread for the pond levels, which is, in fact, due to the spatial separation and lack of connectivity of the ponds among themselves.

3.2.6. Basailbhog Field Site

The Basailbhog Field Site is located about 1km south-east of the Bejgoan Field Site, and it is a 500m X 500m area centered around the irrigation well, IR-8 (Fig.3.19). At this field site, we have installed four single piezometers screened at 30.5m depth, and eight clusters of piezometers, where each cluster again has 5 to 8 single piezometers screened at different depths (Table 3.2). Continuous water level measurements using data-loggers shows that the groundwater response is similar to the entire study area – flooding from June to October, and groundwater irrigation from December to April (Fig. 3.20 - 3.22; daily average water level data is tabulated in Appendix H). A closer look at the water level fluctuations during the 2006-2007 irrigation season (Fig.3.22) reveals that the aquifer head (at 36.6m depth) falls quickly at the onset of irrigation, whereas the steady decline in water level at the shallowest depth (5.2m) corresponds to the daily evaporation rate. The figure also depicts that the drawdowns in the aquifer heads are greater at wells located closer to irrigation wells, as expected.

Unlike the Bejgoan Field Site, the continuous peizometric water levels at the Basailbhog Field Site have been recorded using two kinds of data-loggers – one that records the water level with barometric pressure correction (from In-Situ Inc), while the other doesn't (from Solinst). This phenomenon is also evident from Fig.3.21 that shows the little humps in the water levels of C1-120, C2-120, C3-120 and S1-120 wells (recorded using Solinst probes) due to the barometric pressure effect, whereas the water levels of C0-120 and H2-100 wells (recorded using In-Situ probes) are free from any such effect. Comparing the data from the two kinds of probes, the barometric pressure effect has been removed from the affected wells following the process as describes in Fig.3.23. After removing the barometric pressure effect, the water levels have been re-plotted (Fig.3.24) for the post-irrigation period in 2006, and the plot reveals a regional horizontal hydraulic gradient from west to east at the field side during that time.

Plotting the seasonal dipping data of the peizometric water levels at cluster C0 (Fig.3.25) show that there is vertical flow converging at 20-40m depth from above and below during the irrigation season [plots of dipping data from other clusters at the Basailbhog Field Site have been presented in Appendix I]. Moreover, the vertical gradient is greater at the clusters closer to the irrigation wells due to the greater influence of pumping. After the irrigation season, the vertical gradient wipes off, and the water levels throughout the entire depth remain uniform. However, comparing the water levels between post and pre irrigation season (Fig.3.26) reveals that post-irrigation hydraulic heads are higher at shallower depths indicating downward flow, which might be attributed to higher rainfall and greater storage at the shallow depth. On the other hand, during the post-flood pre-irrigation period, the situation is reversed – there is vertically upward gradient due to lower head at shallower depth, which might be the effect of more evaporation than rainfall.

Water level data of the ponds at the Basailbhog Field Site (Fig.3.27) indicates that unlike other ponds in the area, pond P4 is not only spatially farthest from the rest (Fig.3.19), but also surrounded all around by village areas, and hence, behaves differently from the other ponds. The water level in P4 is consistently higher than that in P10 (and other ponds) until the rain event during late May'06, when the water levels in P10, P11 and P12 rise more rapidly due to added runoff from the neighboring rice field areas. However, during the flooding season, all pond water levels come together – a similar phenomenon we observed for the entire study area. Interestingly, in general, all the pond water levels seems to decline at a steady rate (except during rain events), and the rate is very close to the average daily evaporation rate, which infers that there is very little recharge from these ponds into the aquifer.

3.3. Meteorological Data

Bangladesh Water Development Board (BWDB) continuously records meteorological data at the Bhagakul Meteorological Station, about 4km south-west to our field sites in Munshiganj. We have collected various meteorological information such as daily rainfall, wind speed, maximum and minimum temperatures, maximum and minimum humidity, amount of water added or removed from the evaporation pan etc. from BWDB and sometimes directly from the Bhagakul Meteorological Station.

3.3.1. Rainfall

Fig.3.28 shows daily rainfall data for the period of June 2001 to May 2007 [data presented in Appendix J]. The plot also compares the monthly total rainfall between the stated time periods with that obtained from averaging 30-year rainfall data. The average yearly total rainfall is about 2000 mm, with less than 1mm of average rainfall in January to a maximum of 450mm average rainfall in June/July. As can be seen from the figure, the pattern of daily rainfall is consistent over the years, and also, the monthly average compares well with the 30-year average data. Also, the plot indicates that most of the rainfall occurs between April and October, while the months from November to March are mostly dry and thus, necessitates groundwater irrigation for dry season rice cultivation.

3.3.2. Evaporation

Based on the meteorological data as recorded at the Bhagakul Meteorological Station, the daily pan evaporation was calculated from the amount of water added or removed from the evaporation pan (dia 1.22m, height 0.46m; ET calculated from the pan data is presented in Appendix K). On the other hand, the daily reference ET has been calculated using the FAO Penman-Monteith equation (Allen, Pereira et al. 1998) as follows (data tabulated in Appendix L):

$$ET_0 = \frac{0.408\Delta(R_n - G) + \gamma \dfrac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \tag{3.1}$$

Where,

ET_o reference evapotranspiration [mm day^{-1}],

R_n net radiation at the crop surface [MJ m^{-2} day^{-1}],

G soil heat flux density [MJ m^{-2} day^{-1}],

T mean daily air temperature at 2 m height [°C],

u_2 wind speed at 2 m height [m s^{-1}],

e_s saturation vapour pressure [kPa],

e_a actual vapour pressure [kPa],

e_s - e_a saturation vapour pressure deficit [kPa],

Δ slope vapour pressure curve [kPa °C^{-1}],

γ psychrometric constant [kPa °C^{-1}].

The net radiation at the crop surface (R_n) has been calculated as:

$$R_n = R_{ns} - R_{nl} \tag{3.2}$$

$$R_{ns} = (1-\alpha)R_s \tag{3.3}$$

$$R_s = \left(a_s - b_s.\frac{n}{N}\right)R_a \tag{3.4}$$

$$R_{nl} = \sigma\left[\frac{T_{\max,K} + T_{\min,K}}{2}\right]\left(0.34 - 0.14\sqrt{e_a}\right)\left(1.35\frac{R_s}{R_{so}} - 0.35\right) \tag{3.5}$$

$$R_{so} = \left(0.75 + 2\times10^{-5}z\right)R_a \tag{3.6}$$

Where,

R_n net radiation at the crop surface [MJ m^{-2} day^{-1}],

R_{ns} net solar or shortwave radiation [MJ m^{-2} day^{-1}],

α albedo or canopy reflection coefficient, which is 0.23 for the hypothetical grass reference crop [dimensionless],

R_s incoming solar radiation [MJ m^{-2} day^{-1}],

a_s regression constant, expressing the fraction of extraterrestrial radiation reaching the earth on overcast days (n = 0),

a_s+b_s fraction of extraterrestrial radiation reaching the earth on clear days (n = N),
Due to the lack of actual solar radiation data and calibration for improved a_s and b_s parameters, the values of a_s = 0.25 and b_s = 0.50 have been used as recommended

n actual duration of sunshine [hour],

N maximum possible duration of sunshine or daylight hours [hour], values acquired from table 2.7 of FAO report (Allen, Pereira et al. 1998) for 23^{0}N latitude

n/N relative sunshine duration [-],

R_a extraterrestrial radiation [MJ m^{-2} day^{-1}], values acquired from table 2.6 of FAO report for 23^{0}N latitude

R_{nl} net outgoing longwave radiation [MJ m^{-2} day^{-1}],

σ Stefan-Boltzmann constant [4.903 10^{-9} MJ K^{-4} m^{-2} day^{-1}],

$T_{max, K}$ maximum absolute temperature during the 24-hour period [K = °C + 273.16],

$T_{min, K}$ minimum absolute temperature during the 24-hour period [K = °C + 273.16],

e_a actual vapour pressure [kPa],

R_{so} clear-sky solar radiation [MJ m^{-2} day^{-1}],

z station elevation above sea level [m], used 4m for our case

R_s/R_{so} relative shortwave radiation (limited to £ 1.0),

Due to the unavailability of actual daylight hour data (n), a range of relative sunshine duration (n/N) has been assumed based on rainfall data and the time of the year. At the higher end, n/N has been assigned 1 for no rainfall (RF) days, 0 for >50mm RF days (assuming RF intensity of 4mm/hr in Jun-Jul-Aug, 3mm/hr in Sep-Oct, 2mm/hr in Nov-Mar, 3mm/hr in Apr-May), and interpolated values for corresponding rainfall data. On the other hand, for assigning n/N values at the lower end of the range, it has been assumed that there are always some cloud covers but at various proportions depending on the time of year. Accordingly, n/N has been assigned 0 for all RF days (assuming there are cloud covers even if it doesn't rain much on a rainy day), and for no RF days the ratio has been 0.4 for Jun-Aug, 0.6 for Sep-Oct, 0.8 for Nov-Jan, and 0.6 for Feb-May.

The values of saturation vapor pressure (e_s in equation 3.1) and actual vapor pressure (e_a in equations 3.1 and 3.5) have been calculated as following (Allen, Pereira et al. 1998):

$$e_s = \frac{e^0(T_{max}) + e^0(T_{min})}{2} \tag{3.7}$$

$$e^0(T) = 0.6108e^{\left[\frac{17.27T}{T+237.3}\right]} \tag{3.8}$$

$$e_a = e^0(T_{wet}) - \gamma_{psy}(T_{dry} - T_{wet}) \tag{3.9}$$

$$\gamma_{psy} = a_{psy} \times P \tag{3.10}$$

Where,

e_s saturation vapour pressure [kPa],

$e°(T)$ saturation vapour pressure at the air temperature T [kPa],

T air temperature [°C],

e_a actual vapour pressure [kPa],

$e°(T_{wet})$ saturation vapour pressure at wet bulb temperature [kPa],

T_{dry}-T_{wet} wet bulb depression, with T_{dry} the dry bulb and T_{wet} the wet bulb temperature [°C].

γ_{psy} psychrometric constant of the instrument [kPa °C^{-1}],

a_{psy} coefficient depending on the type of ventilation of the wet bulb [°C^{-1}], assumed to be 0.00062 for ventilated psychrometers with an air movement of some 5m/s

P atmospheric pressure, 101.25 kPa from table 2.1 in FAO report for 4m elevation

However, the values of psychrometric constant (γ) and wind speed at 2 m height (u_2) in equation 3.1 have been taken as 0.067 kPa °C^{-1} (from table 2.2 in FAO report for 4m elevation) and 2-5 m/s (annual average in Bangladesh), respectively.

Finally, the soil heat flux density (G) and the slope vapour pressure curve (Δ) have been calculated as:

$$G = c_s \frac{T_i - T_{i-1}}{\delta t}.\delta z \tag{3.11}$$

$$\Delta = \frac{4098\left[0.6108\exp\left(\frac{17.27T}{T+237.3}\right)\right]}{(T+237.3)^2} \tag{3.12}$$

Where,

G soil heat flux [MJ m^{-2} day^{-1}],

c_s soil heat capacity [MJ m^{-3} °C^{-1}], 2.1 in our case

T_i air temperature at time i [°C],

T_{i-1} air temperature at time i-1 [°C],

δt length of time interval [day], 1 day in our case

δz effective soil depth [m], 0.15 assumed for δt of 1 day

Δ slope of saturation vapour pressure curve at air temperature T [kPa °C^{-1}],

T air temperature [°C], used mean value since Δ appears both in the numerator and denominator in equation 3.1

Since the actual duration of daily sunshine data has not been available, upper and lower limits of reference ET have been calculated using the FAO Penman-Monteith equation by varying the possible daylight hours depending on the rain events and the time of the year. Afterwards, the values have been compared with the calculated pan evaporation data as well as the reference ET data collected from BWDB (Fig.3.29). In general, the calculated pan evaporation data falls within the range of calculated high and low reference ET values. The BWDB reference ET, where it is usually calculated as 70% of the pan evaporation (Matin 2007), follows the lower bound of the calculated reference ET quite closely. However, most importantly, since most of the recharge and discharge occurs between November and April, the significance of ET is highest during that time, and the plot shows that the band of the various ET values is narrowest during that time which gives more confidence on using the calculated reference ET values.

Comparing the calculated daily reference ET (ET_0) data between 2003 and 2006 (Fig.3.30) shows that the values are consistent from year to year. Moreover, the plot also reveals that the calculated monthly average ET_0 values compare well with that of the literature values except for the months of June to September. This might be due to the reason that the actual daily sunshine data has not been available, and the plotted reference ET has been calculated for the higher values of n/N ratio.

3.4. Stable Water Isotope Data

Isotope methodology is an effective process for hydrogeological characterization. Different water pools (e.g. ocean water, river water, pond water, rainwater, standing water in the rice fields, groundwater from clay, shallow and deeper layers etc.) have different isotopic compositions, and thus isotopic analysis (e.g. stable water isotope) can provide an insight to the various recharge sources of groundwater. Agarwal et al (Aggarwal, Basu et al. 2000) carried out several different isotopic analysis of groundwater in the southwest part of Bangladesh. According to their report, the stable oxygen and hydrogen isotope ratios (e.g. $^{18}O/^{16}O$ and D/H) in Bangladesh groundwater vary from -2.4 to -7.1‰ and from -12 to -50‰, respectively. The large range of isotope values indicate groundwater recharge and mixing from different water sources, and again, each source is affected by different hydrological processes (Appendix M). Although Agarwal et al (Aggarwal, Basu et al. 2000) carried out stable water isotope analysis for Bangladesh, they did not analyze any local rain or surface water samples; rather they assumed some values based on the data from distant locations in India, Myanmar and Thailand. Also, they did not mathematically interpret or explain (by a model) the groundwater isotope data in terms of various recharge sources and proportional mixing. Furthermore, based on their stable water isotope data from 1979 and 1999, Agarwal et al (Aggarwal, Basu et al. 2000) and Basu et al (Basu, Jacobsen et al. 2002) invoked that irrigation pumping has not significantly impacted the groundwater flow regime in Bangladesh, and hence, there is no recharge from rivers or highly evaporative water bodies to the shallow aquifer. However, they did not mention if the same wells were analyzed in both 1979 and 1999, which is a serious flaw for their conclusion.

For our study area in Munshiganj, samples for stable water isotope analysis has been collected following the methodology described in Appendix N. Fig.3.31 and Fig.3.32 represent the deuterium and ^{18}O analysis of well waters within our study area. The $\delta^{18}O$ and δD values of groundwater vary from -6.3 to -0.6‰ and from -47.9 to -12.36‰, respectively, referring to a large variability in isotopic values. However, these values are well within the overall range of various end members' (e.g. river water, pond water, rainwater, and the standing water in rice fields) isotopic values: -7.99 (pond water) to 5.5‰ (rainwater) for $\delta^{18}O$ and -57.17 (pond water) to 24.37‰ (rainwater) for δD. The literature value of rainfall isotope data, obtained by interpolating measured data (Bowen 2007) within the vicinity of study area, compares well with the measured data of our collected rainwater samples. Moreover, the equation of the Local Meteoric Water Line (LMWL) for our study area is $\delta D = 6.5\delta^{18}O - 4.2$ (Fig.3.32), which is comparable with the Global Meteoric Water Line (GMWL) of $\delta D = 8.0\delta^{18}O + 10.0$. The observed variability in the groundwater isotopic values at our study area can easily be attributed to the contribution of different recharge sources over the study area. Different recharge pools of water (e.g. river water, pond water, rainwater, and the standing water in the rice fields) have different isotopic signatures, and thus, the groundwater, which is a mixture from different water pools, has somewhat different isotopic value based on the proportional contribution of various recharge sources. Fig.3.33 shows the temporal trend in isotopic values of surface waters, and the impact of surface evaporation that makes the water heavier with time by evaporating the lighter water. It should also be noted that lighter isotopic values of the surface water at the end of flood constitutes one end of the isotopic spectrum that contributes to the groundwater isotopic values.

In addition to the well and surface waters, isotopic measurements of peizometric water samples from our field site have also been carried out (Fig.3.34). The water becomes lighter with depth up to 24.4m, and then there is a large variability at 30.5m depth. Afterwards, the water becomes heavy again followed by a slightly increasing trend of water becoming lighter with depth. It can be attributed as due to the flow convergence around 30.5m depth, which might have mixed lighter water from above and heavier water from below 30.5m. According to this phenomenon, waters (with distinct isotopic values) at different depths above and below 30.5m are assumed to be transported through individual stream tubes, where each tube originates from different recharge pools. The heavier waters at 4.6m and 38.1m depths probably have originated from highly evaporative pond or rice field waters, whereas the lighter waters might have originated from river or rainwater and/or mixture of different waters. Moreover, the higher (heavier) isotopic values of April'02 samples reflect the much warmer temperature in April than in December. However, on the other hand, the stable isotopes seem to become lighter over the years, which might be due to more contribution from the river and/or from lighter isotopic rainfalls.

Reference:

Aggarwal, P. K., A. R. Basu, et al. (2000). Isotope Hydrology of Groundwater in Bangladesh: Implications for Characterization and Mitigation of Arsenic in Groundwater. Vienna, International Atomic Energy Agency.

Allen, R. G., L. S. Pereira, et al. (1998). Crop evapotranspiration - Guidelines for computing crop water requirements. FAO Irrigation and Drainage paper 56. Rome, FAO - Food and Agriculatural Organization of the United Nations.

BAMWSP (2005). Bangladesh Arsenic Mitigation and Water Supply Project.

Basu, A. R., S. B. Jacobsen, et al. (2002). "Groundwater flow in the Ganges delta - Response." Science **296**(5573): 2.

Bowen, G. (2007). "OIPC: The Online Isotopes in Precipitation Calculator." from http://wateriso.eas.purdue.edu/waterisotopes/pages/data_access/oipc.html.

Harvey, C. F., K. N. Ashfaque, et al. (2006). "Groundwater dynamics and arsenic contamination in Bangladesh." Chemical Geology **228**(1-3): 112-136.

Matin, M. A. (2007). Calculating Reference ET from Pan data. Dhaka, Bangladesh, Bangladesh Water Development Board (BWDB).

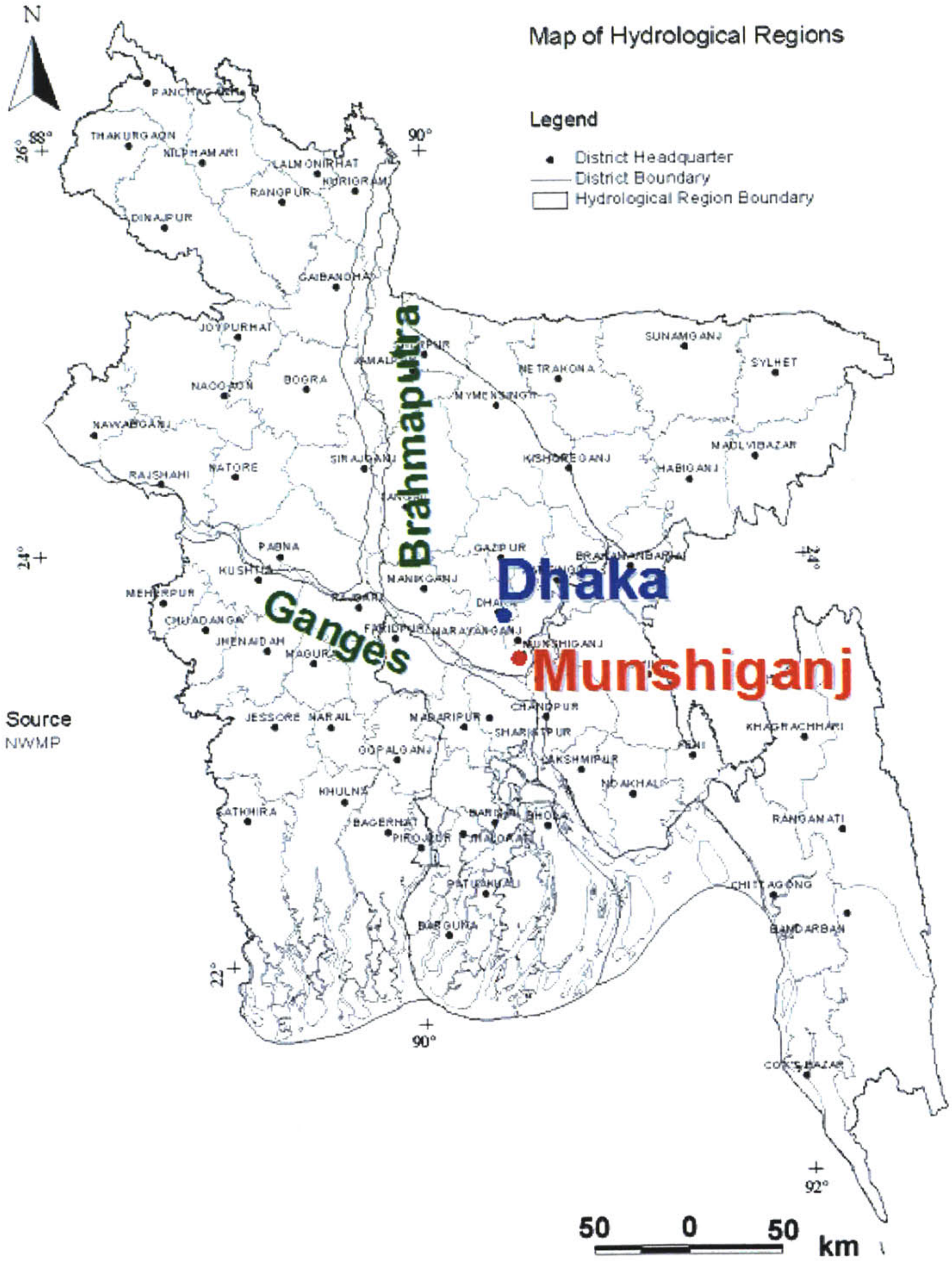


Fig.3.1 **Map of Bangladesh:** showing the location of Munshiganj which is about 30 km south to Dhaka and 7km north to the Ganges.

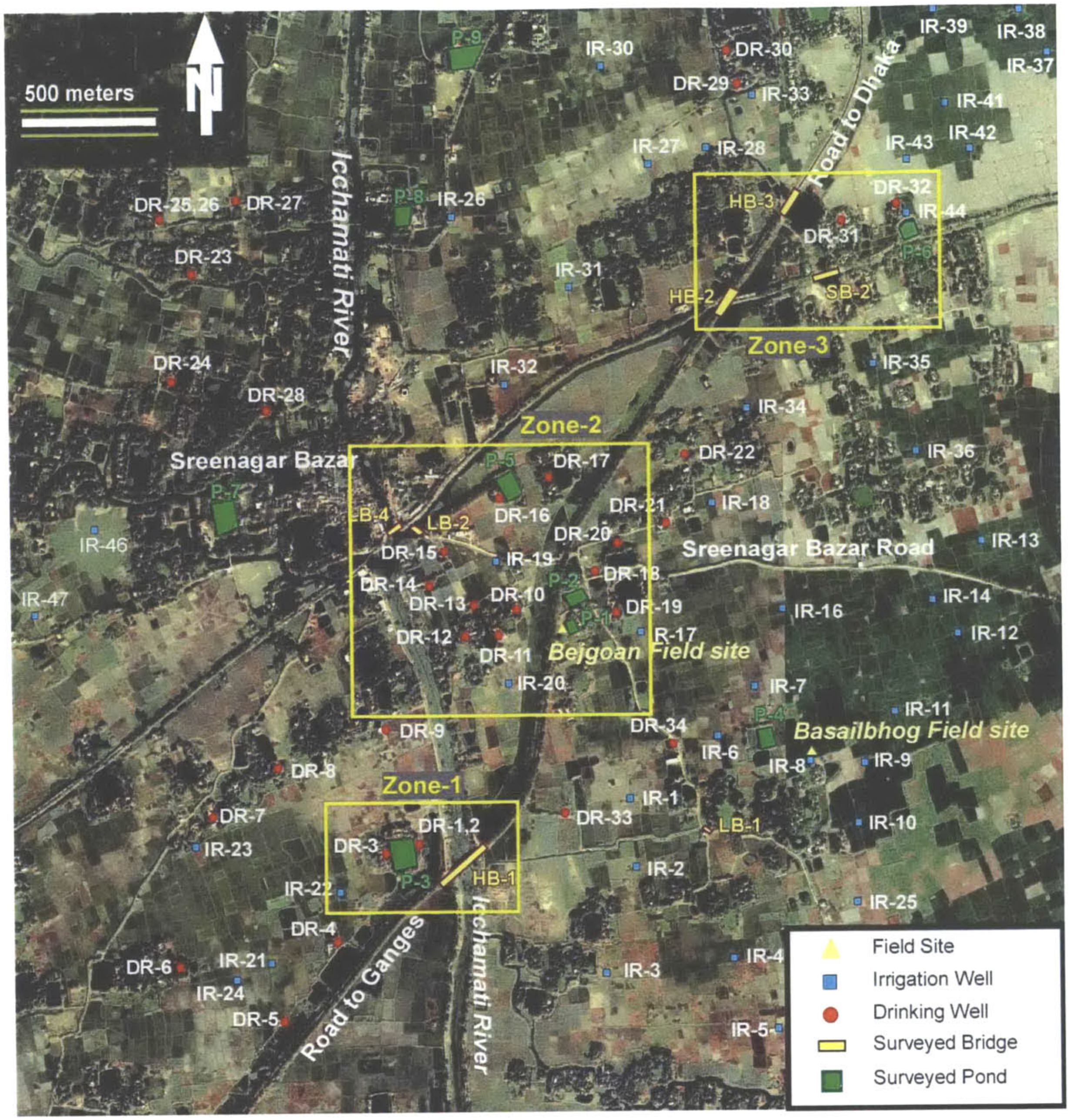


Fig.3.2 **Study Area:** IKONOS satellite image of our 16km^2 study area highlighting various hydrologic features, such as: 51 irrigation wells (blue squares; generic ID is IR), 34 drinking wells (red circles; generic ID is DR), 12 ponds (green polygons; generic ID is P), 9 river locations (yellow rectangles; generic IDs are HB for highway bridges, SB for steel bridges, LB for local bridges), and 2 field sites (yellow triangles; Bejgoan and Basailbhog). There are also three sub-zones, where the groundwater flow patterns have been analyzed and compared with that for the entire region.

Fig.3.3 Snap-shots of Two Field Sites – Bejgoan Field Site (top picture) and Basailbhog Field Site (bottom picture)

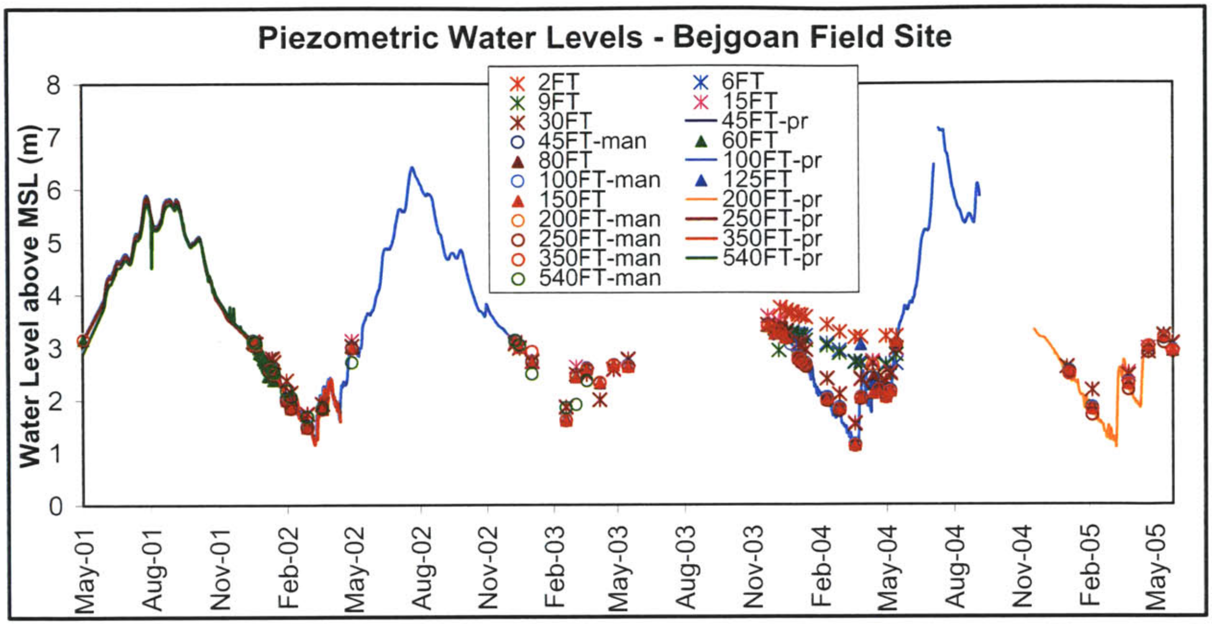


Fig.3.4 Piezometric Water Levels – Bejgoan Field Site: water levels at the 25 piezometers at Bejgoan field site for four years between June 2001 and June 2005. The 2ft (0.6m), 6ft (1.8m), and 9ft (2.7m) piezometers are screened at the surface clay, the 540ft (164.6m) well is screened at the deep aquifer, and the rest are at the shallow aquifer. Water levels were recorded both by manually on a bi-monthly basis (sparse points) and by down-hole In-Situ pressure transducers on an hourly basis (solid lines).

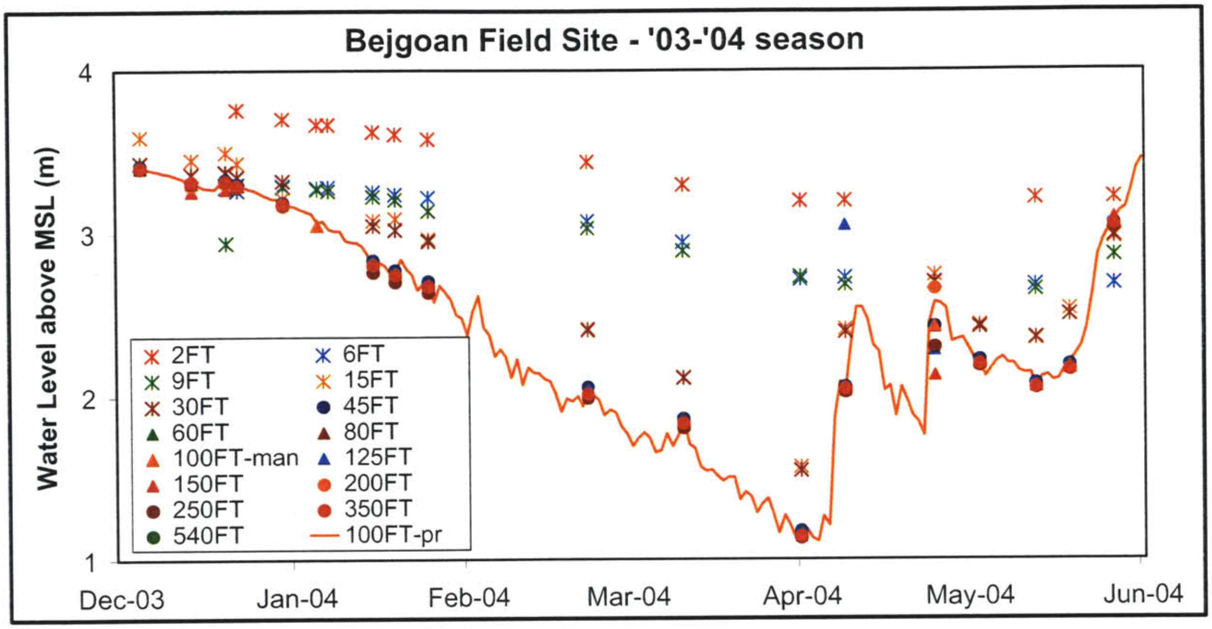


Fig.3.5 Bejgoan Field Site – '03-'04 season: zooming into the 2003-2004 irrigation season, the piezometric water level measurements at the Bejgoan field site indicates that the hydraulic heads at the surface clay are highest throughout the season, and therefore, infers a downward vertical hydraulic gradient. Moreover, the data indicates that during the dry season, there is flow convergence around 30.5m (100ft) depth from above and below.

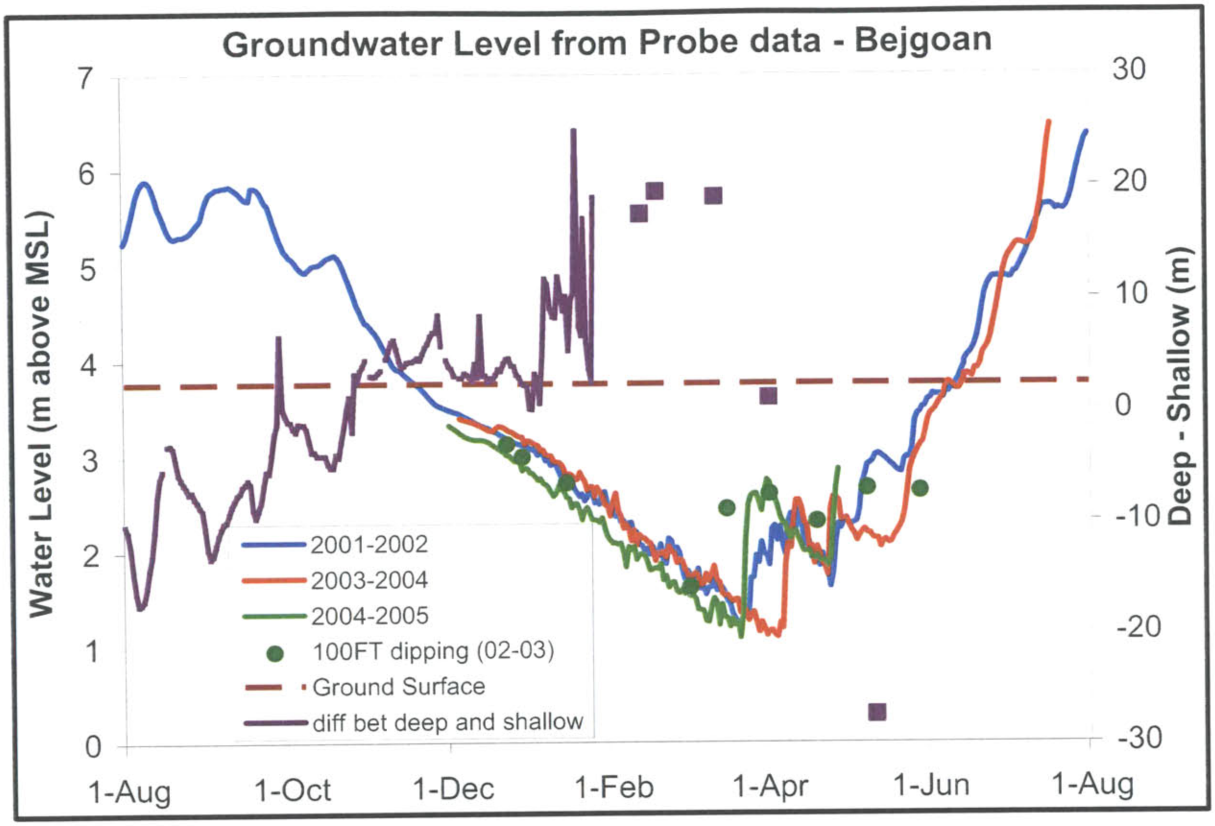


Fig.3.6 Groundwater Level from Probe data – Bejgoan Field Site: Daily fluctuations in ground water level (GWL) as observed in 100ft piezometer using In-Situ probe and manual dipping between 2001 and 2005. The small oscillations in the water levels from December to April are due to irrigation pumping. Towards the end of irrigation season, the rapid and large jumps in the water levels can be attributed to increased rainfall combined with lack of pumping since the farmers do not run their pumps during large rain events. The plot of water level difference between the shallow and deep aquifer shows that there is a vertically upward gradient from the deep to the shallow aquifer from November (end of flood) to May (end of irrigation), and the direction reverses during other time of the year.

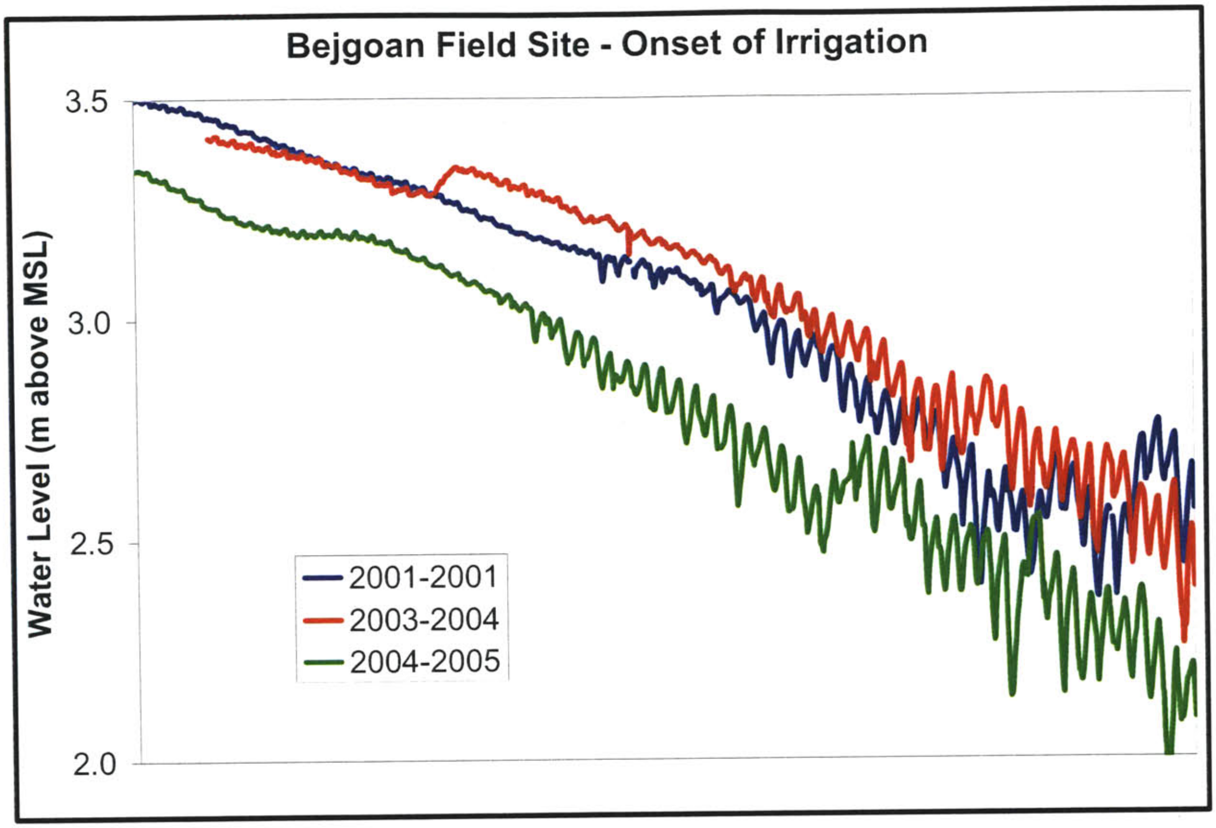


Fig.3.7 Bejgoan Field Site – Onset of Irrigation: zooming into the probe data during the onset of irrigation season for three different years, a change in slope and oscillations indicate the start of irrigation pumping. As the irrigation season progresses, the oscillations in the water levels increases with increased pumping.

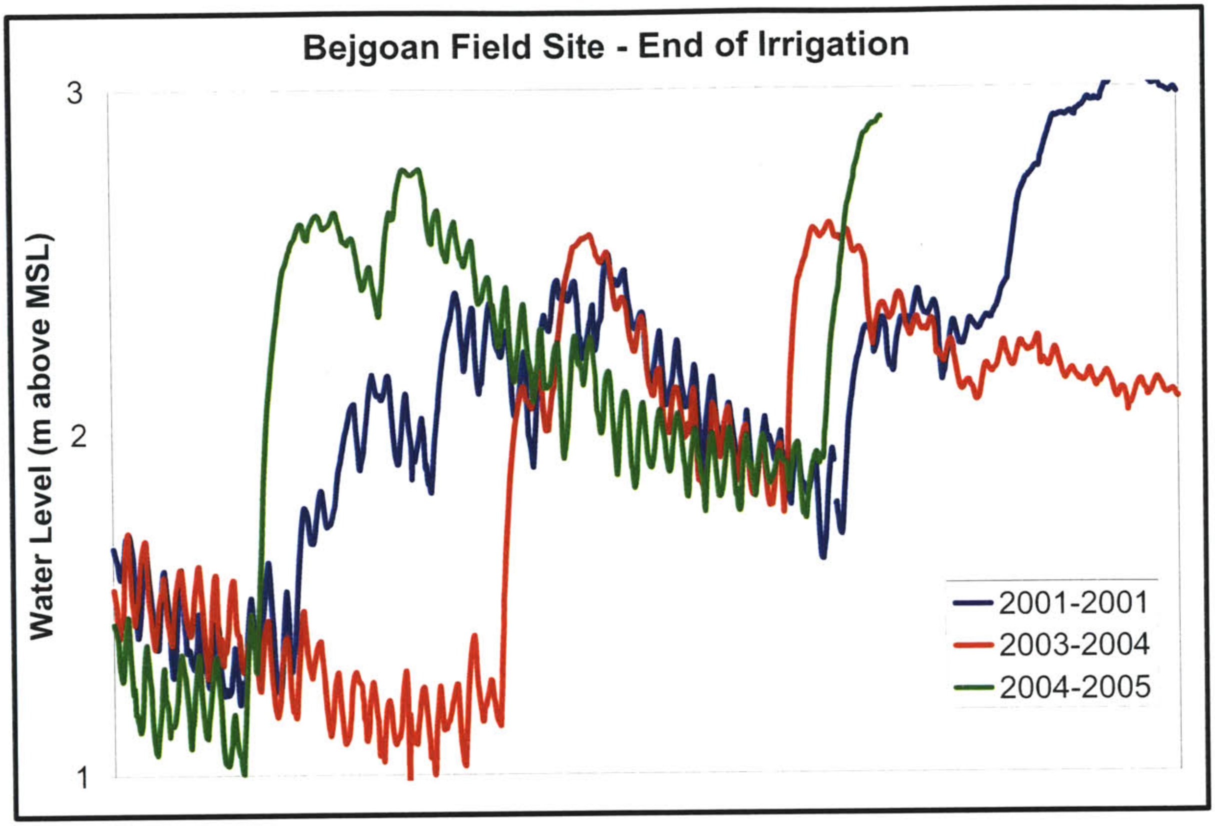


Fig.3.8 Bejgoan Site – End of Irrigation: zooming into the probe data during the end of irrigation season for three different years, the rapid and large jumps in the water levels can be attributed to increased rainfall combined with lack of pumping since the farmers do not run their pumps during large rain events. The diminishing nature in the oscillation in water levels towards end of May infers fewer pumps in operation at lower rate as the rice growing season comes to an end.

First Person Second Person Third Person

Fig.3.9 Measuring Pond Water Levels: Water leveling technique was adopted in measuring the pond water levels within our study area. In this process, a clear flexible thin tube is filled up with water, and it is ensured that there is no air bubble inside. Then, the "First person" attaches one end of the tube to a 5m-long survey scale, and holds the scale vertically up just above the pond water level. Afterwards, the "Second Person" holds the other end of the tube against a reference point with known elevation with respect to the Mean Sea Level (MSL). Once he levels the water level inside the tube with the reference point, the "Third Person" reads the height of water level from the survey scale. Afterwards, the pond water level with respect to the MSL is calculated by subtracting the measured water level height from the elevation of the reference point.

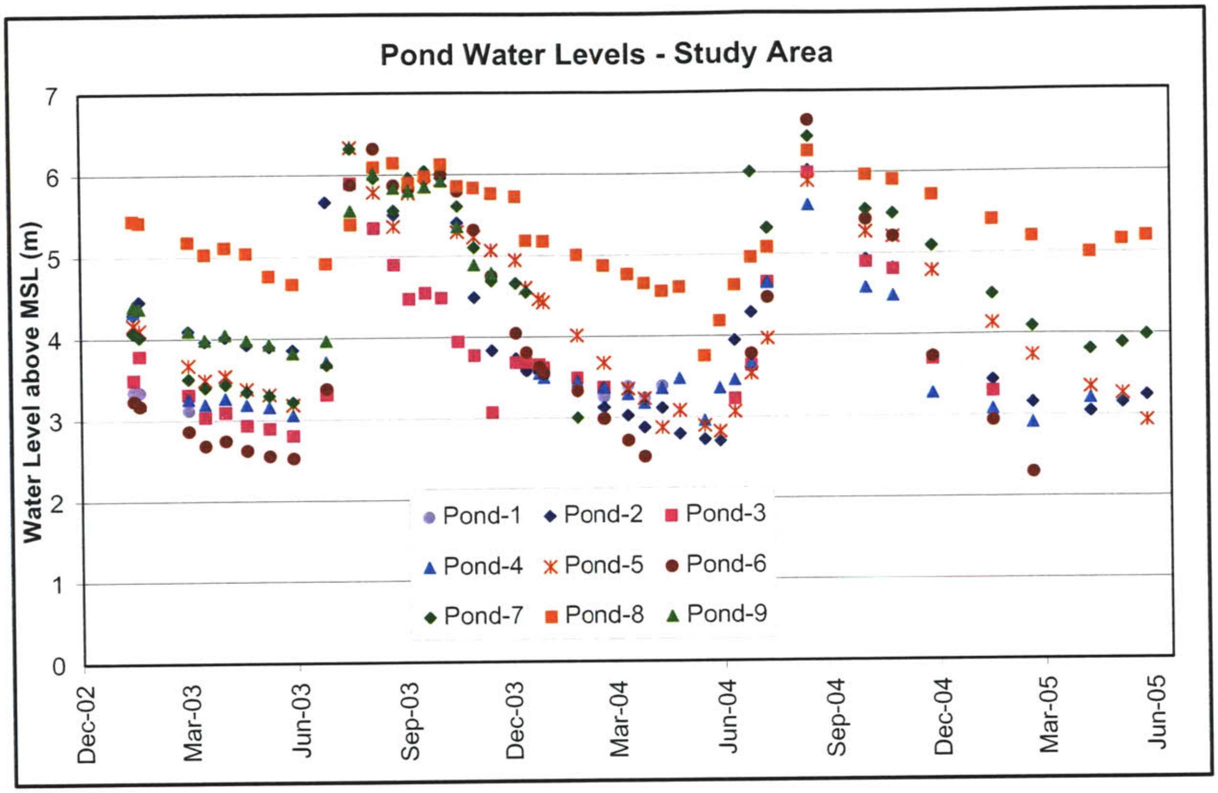


Fig.3.10 Pond Water Levels – Study Area: water level fluctuations at the 9 (nine) monitoring ponds within our 16km^2 study area as recorded from December 2002 to June 2005. All the ponds are surrounded by villages, and therefore, they not only differ in water levels but also in fluctuation patterns. In addition, in cases of a few of the ponds, villagers sometimes manipulate them according to their needs, e.g. dry out the pond for fishing purpose, or cut the barrier at one corner for facilitating the escape of the flood water etc., which also contribute in the variations from pond to pond.

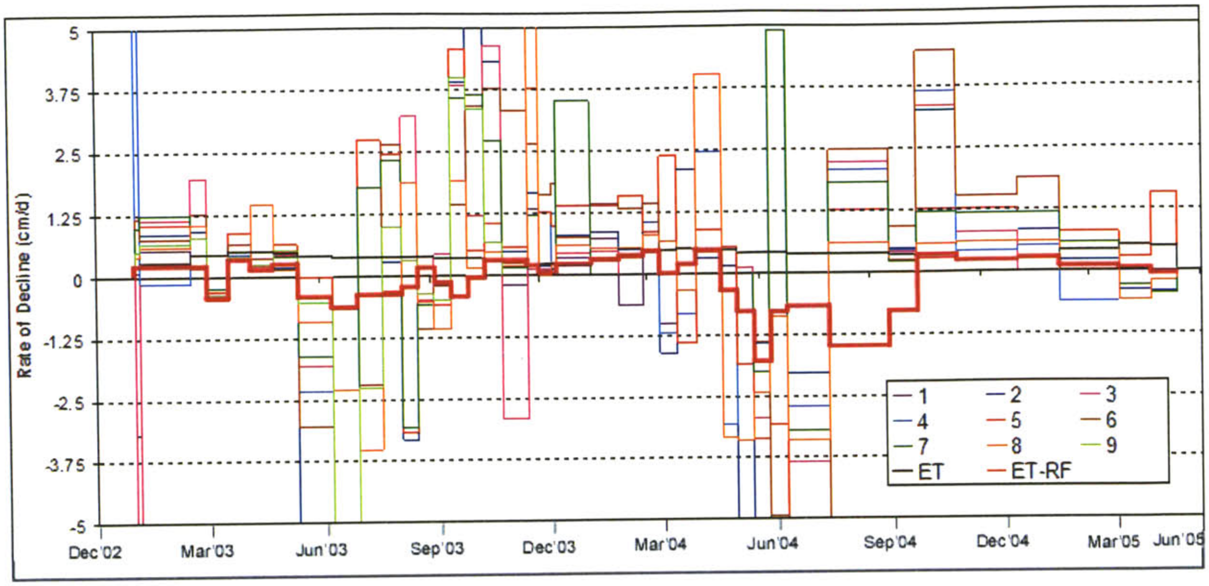


Fig.3.11 Rate of Pond Water Level Decline: The rate of pond water level (PWL) decline for 7 ponds (mapped in Fig.3.2), and the rate of pan evaporation (ET) and rainfall (RF) for the period of December 2002 to June 2005. Rates of PWL decline were calculated by dividing the difference in pond water levels by the duration between the two measurements. Positive differences indicate a decline.

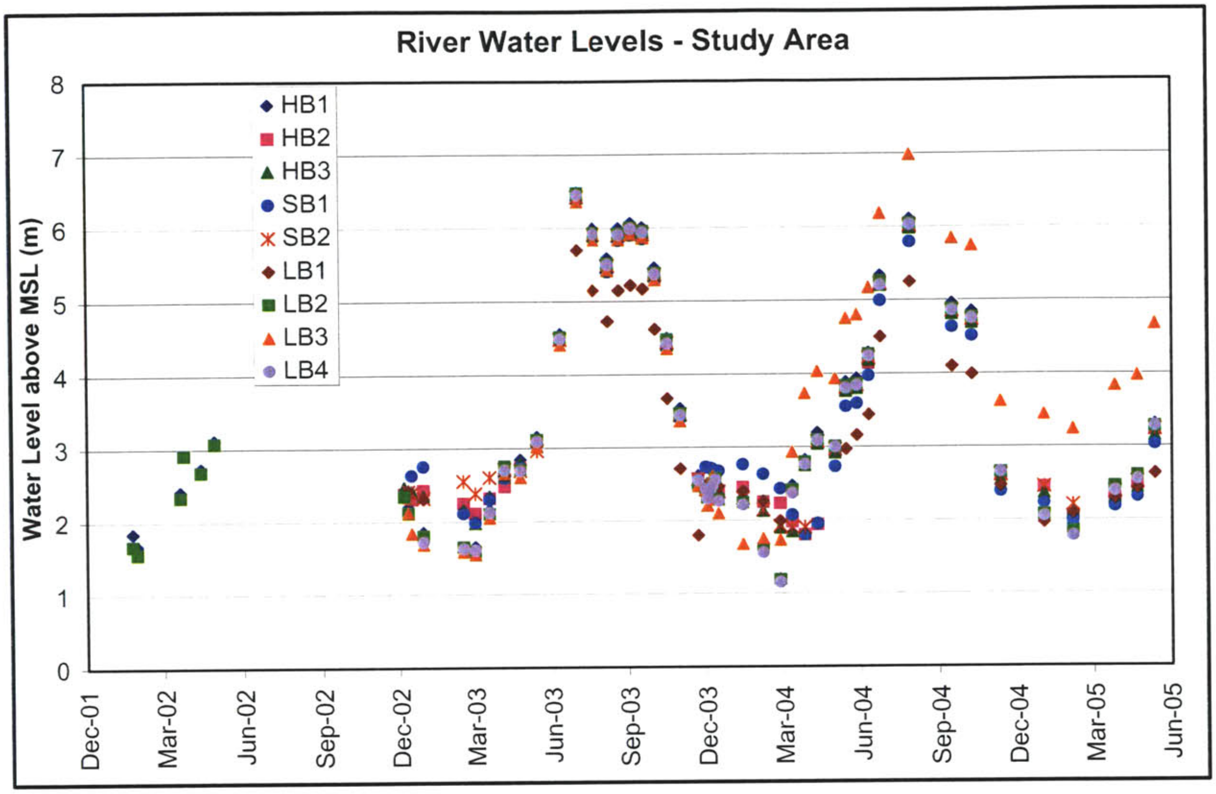


Fig.3.12 River Water Levels – Study Area: water level fluctuations in the Ichhamati river as recorded at 9 (nine) monitoring locations within our 16km^2 study area from December 2001 to June 2005. The monitoring points of HB1, LB2 and LB4 are located on bridges over the main channel, whereas the rest are located over the side channels. However, as a result of various natural and artificial reasons (e.g. some part dry out during the dry season due to lack of flow, or villagers create barriers for fishing purposes, etc), some end-part of the side channels sometimes behave like a pond as can be observed from the data of LB1 and LB3 monitoring locations.

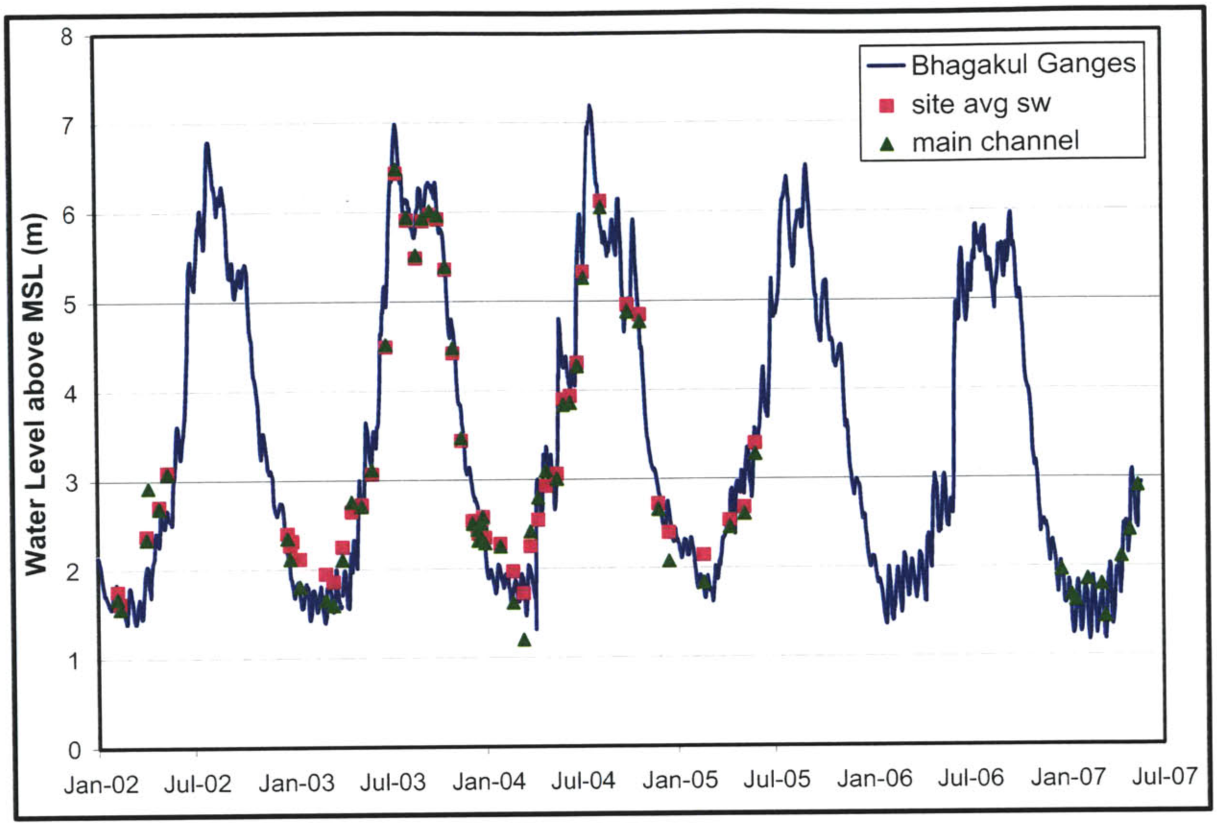


Fig.3.13 Comparison of Ganges and Ichhamati Water Levels: Comparison between seasonal fluctuations of Ganges water level (as recorded in Bhagakul Meteorological Station) and Ichhamati water level (within the study area) since January 2002. The water levels follow each other closely. The pink squares represent the average of both the main and side channels of the Ichhamati river (Fig.2), whereas the green triangles represent the water levels in the main channel only. Measurements for the Ganges are taken twice every day at the same time, so tidal oscillations in the Ganges appear as cycles with 14 day frequencies.

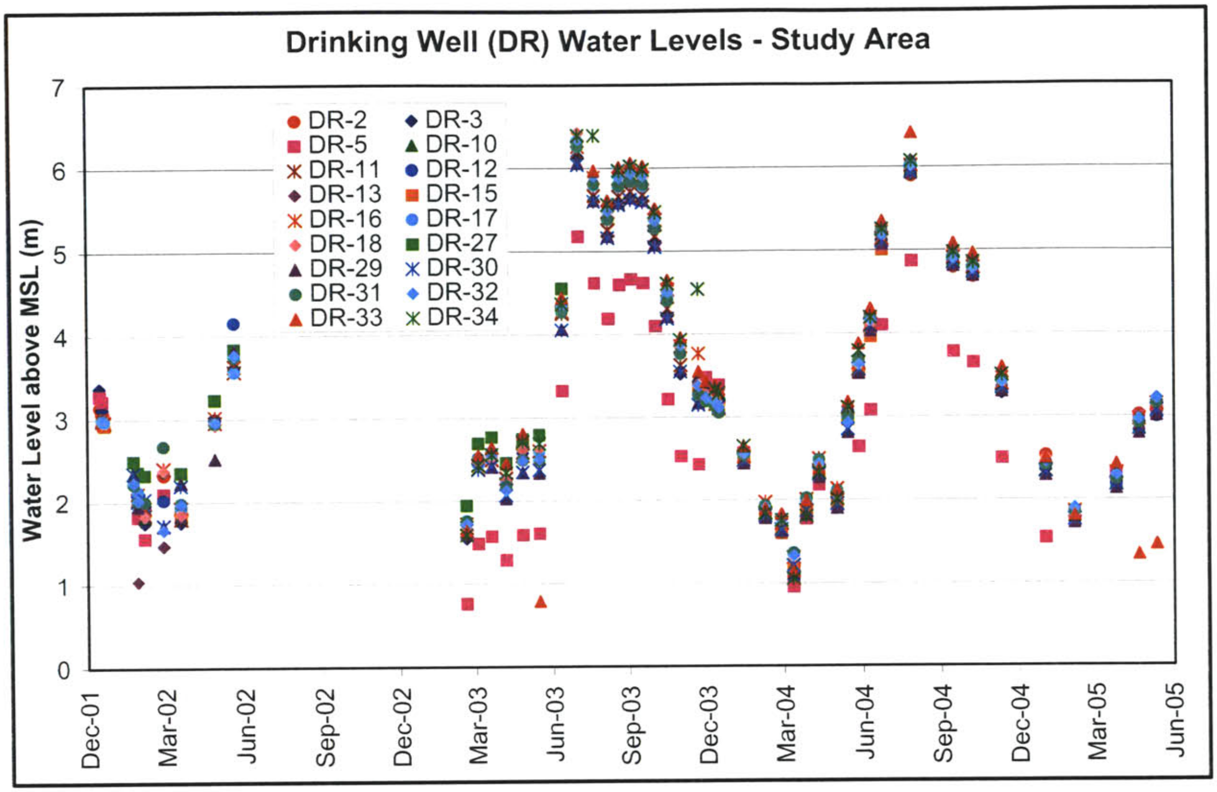


Fig.3.14 Drinking Well Water Levels – Study Area: water level fluctuations at 18 monitoring drinking wells (DR) within our 16km^2 study area from December 2001 to June 2005. The water levels are mostly clustered together inferring that there is very little horizontal gradient within the study area. At the location of DR5, the well appeared to be raised from its original position by about a meter, which explains the consistently lower water levels at DR5 during some part of monitoring period.

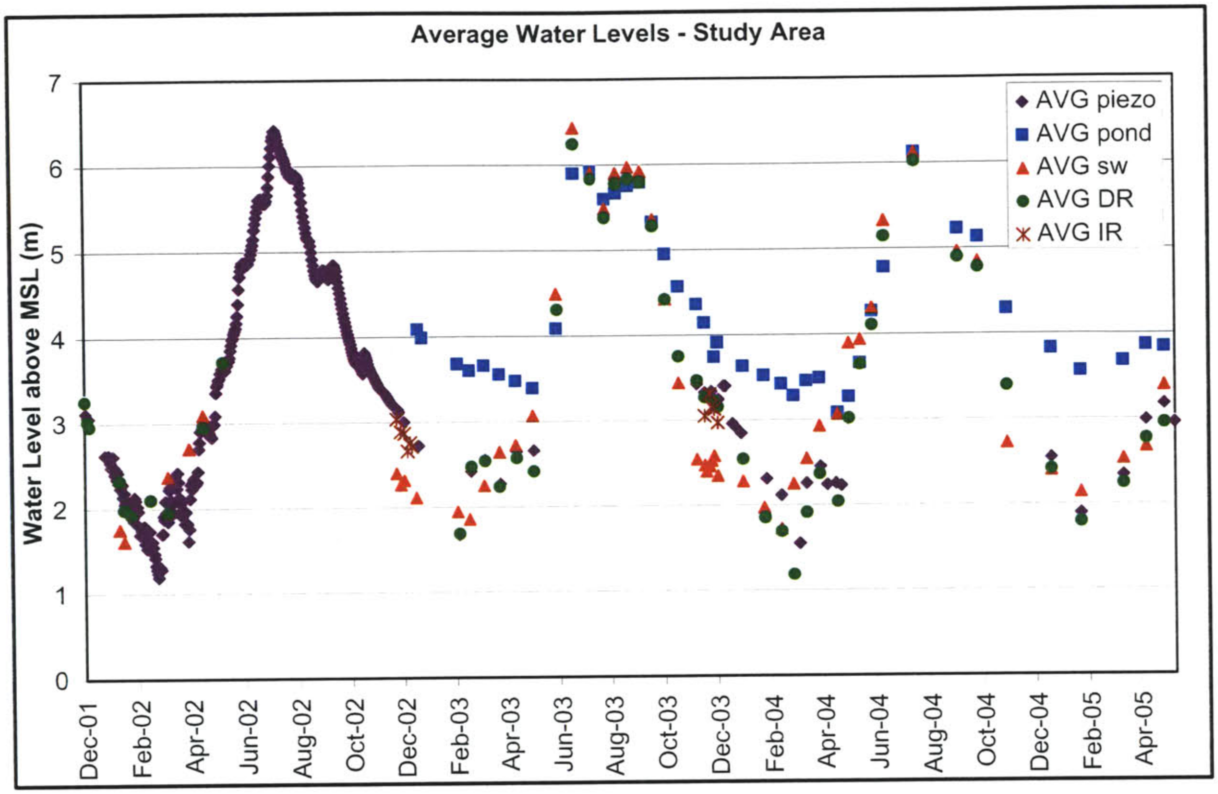
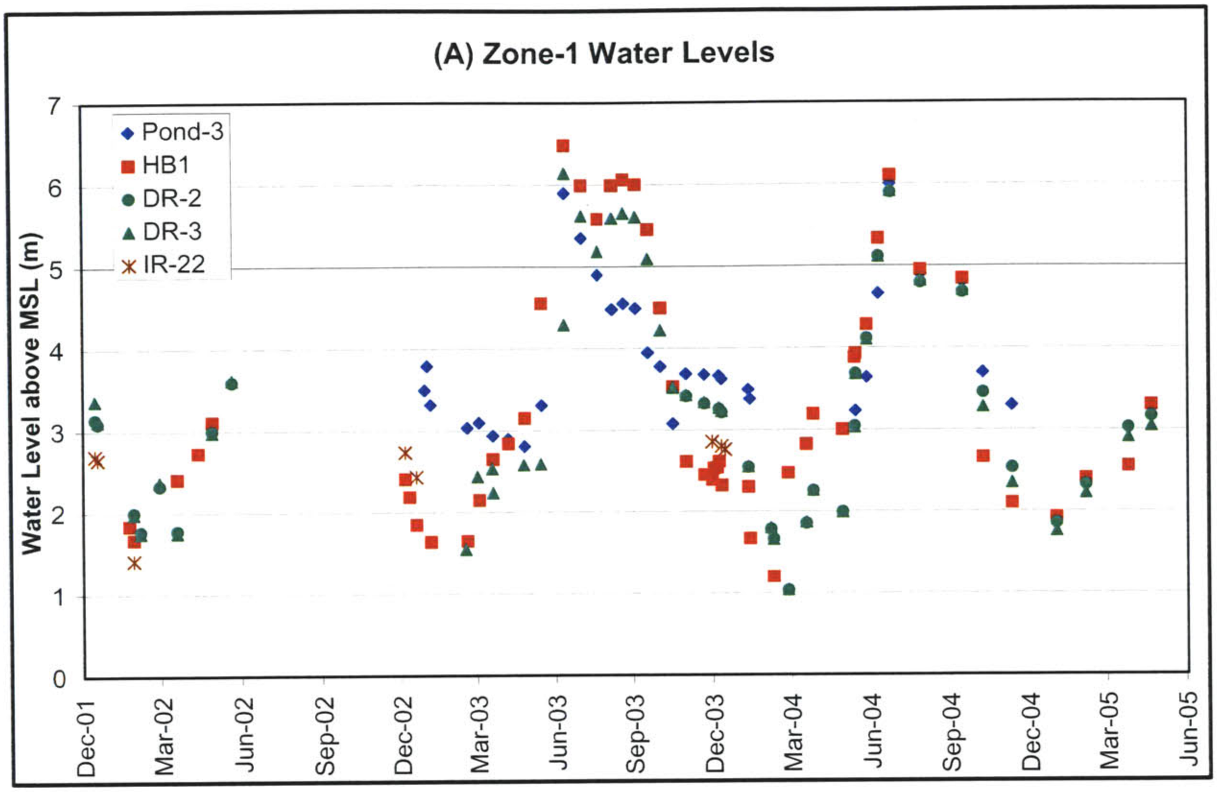
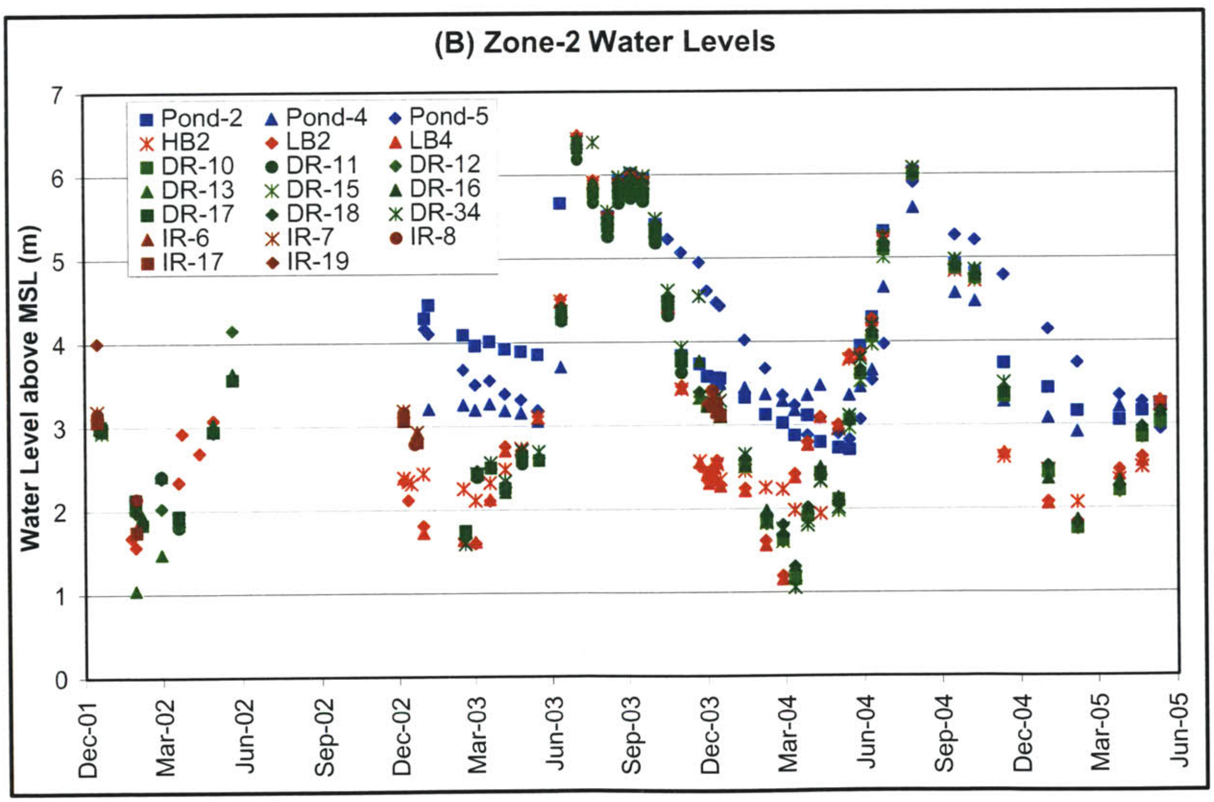


Fig.3.15 Average Water Levels – Study Area: temporal variation in various water levels from December 2001 to June 2005 as observed in different features and averaged over 25 piezometers (peizo), 9 ponds, 8 river locations (sw), 17 drinking wells (DR) and 34 irrigation wells (IR) throughout the study area. The plot indicates that during the flooding season (June to October), all the water levels are clustered together inferring that there is no or very little gradient between the surface and ground water. During the dry season, the pond water levels are higher than the groundwater (i.e. peizo, DR, IR) and river (sw) water levels, in general. During the early part of the dry season, the groundwater level is higher than the river water level suggesting that the aquifer acts as a conduit for flow from the pond to the river. However, at the later stage of the dry season, the groundwater level goes below the river water level due to intense groundwater pumping, and so, groundwater gets recharged both from the pond and the river.


(A) Zone-1 Water Levels
Pond-3
HB1
DR-2
DR-3
IR-22
Water Level above MSL (m)
0
1
2
3
4
5
6
7
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05


(B) Zone-2 Water Levels
Pond-2
Pond-4
Pond-5
HB2
LB2
LB4
DR-10
DR-11
DR-12
DR-13
DR-15
DR-16
DR-17
DR-18
DR-34
IR-6
IR-7
IR-8
IR-17
IR-19
Water Level above MSL (m)
0
1
2
3
4
5
6
7
Dec-01
Mar-02
Jun-02
Sep-02
Dec-02
Mar-03
Jun-03
Sep-03
Dec-03
Mar-04
Jun-04
Sep-04
Dec-04
Mar-05
Jun-05

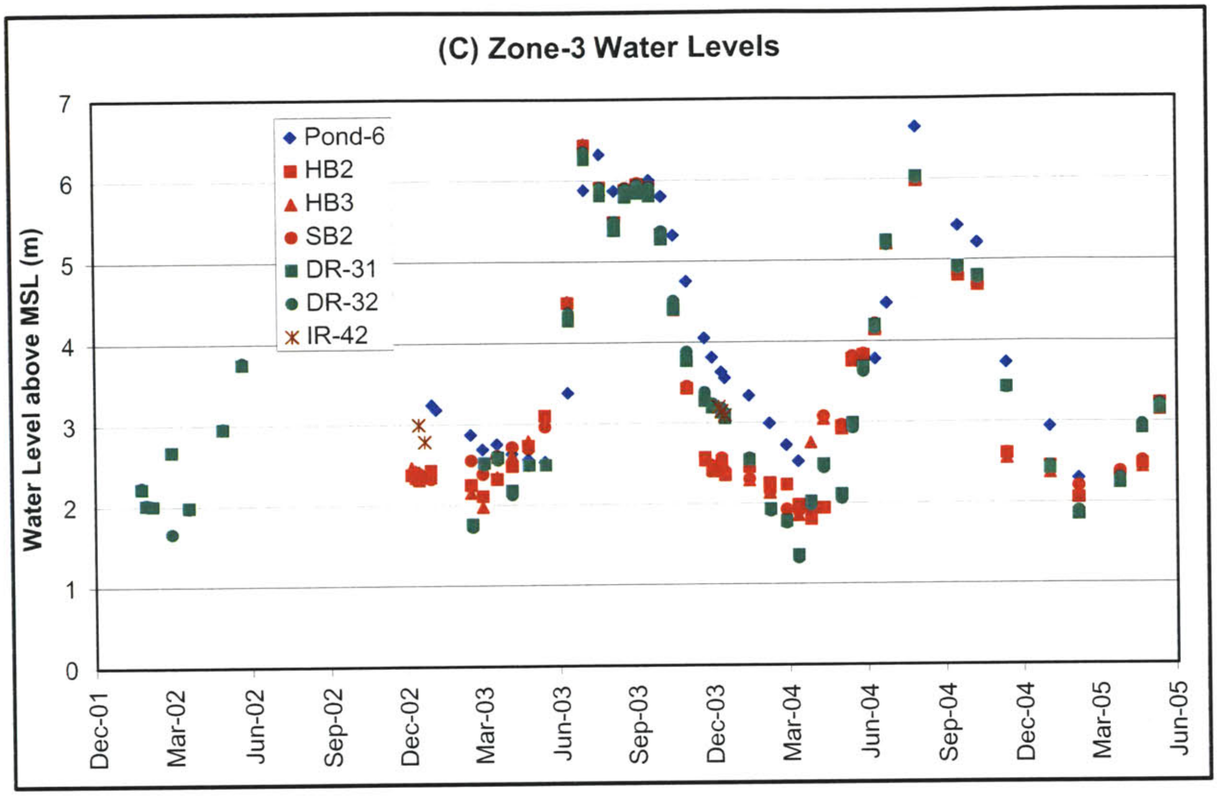


Fig.3.16 Zonal Water Levels: Panels (A), (B) and (C) show the water level fluctuations from December 2001 to June 2005 at the monitoring ponds (points in blue), river locations (points in red), drinking wells (points in green) and irrigation wells (points in brown) within zone-1, 2 and 3 as outlined in Fig.3.2. The observed data at the various features indicate that during the flooding season, all water levels are together indicating there is no flow among the various features. During the dry season, the pond water levels are usually higher than the others (except during the 2003 season at zone-1 when the villagers dry out the pond-3 to some extent for fishing purposes) inferring recharge from the pond to the groundwater. However, the river water levels goes below and above the groundwater levels during the early and later part of the dry season, respectively. It indicates groundwater discharge to the river when river water declines rapidly just after the flooding season, and groundwater recharge from the river on the onset of irrigation.

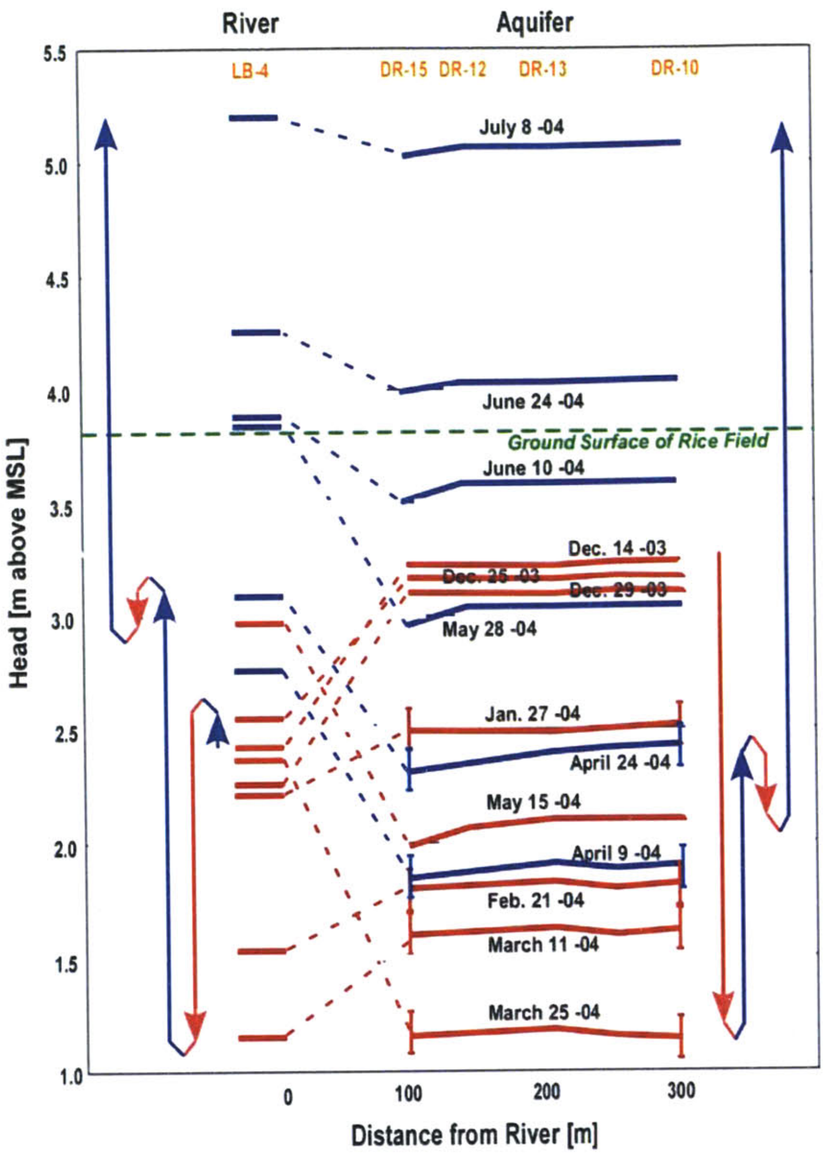


Fig.3.17 Comparison between River and Groundwater Levels: River stage of the Ichhamati River and hydraulic head measured in nearby wells during December 2003 to July 2004. The error bars (of 20 cm) associated with the groundwater levels (from January to April) account for the water level fluctuation due to irrigation pumping (Fig.3.6). The groundwater heads are located along a transect roughly perpendicular to the river, but show no appreciable hydraulic gradient even though the river head differs from the aquifer head by more than a meter.

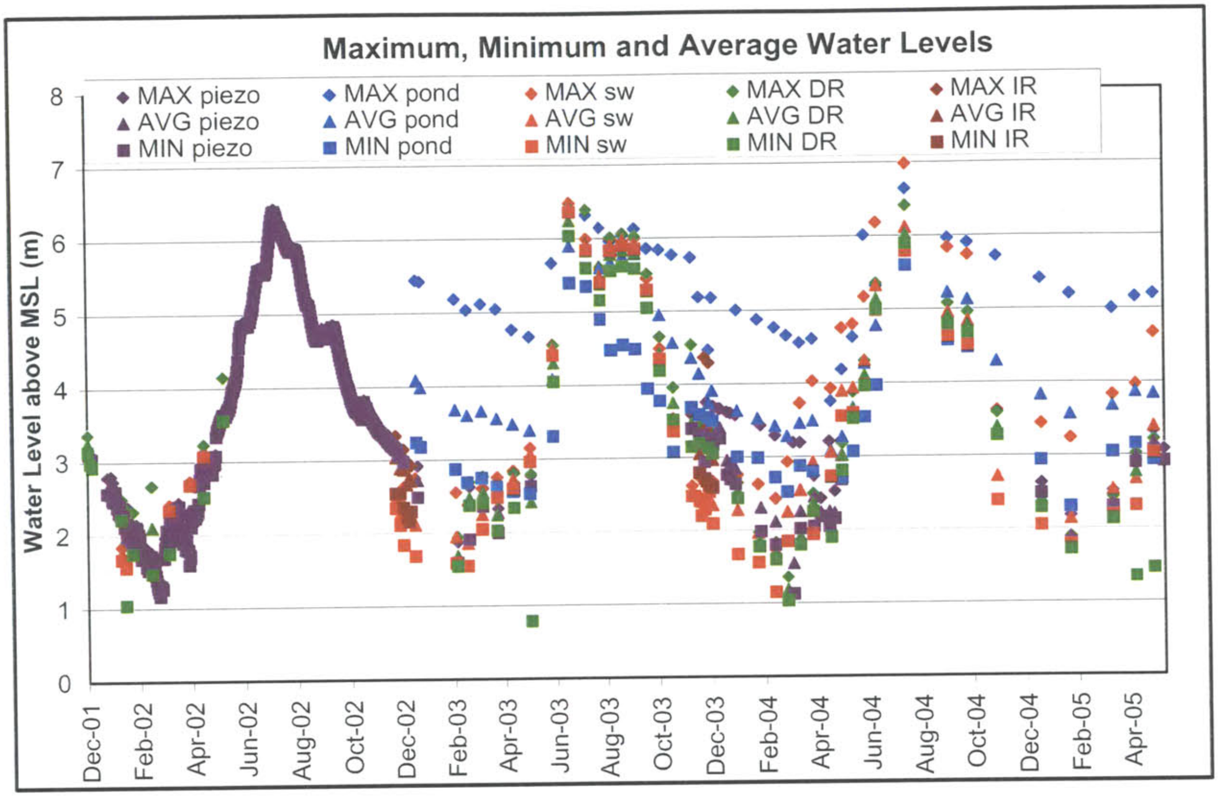


Fig.3.18 Maximum, Minimum and Average Water Levels – Study Area: maximum, minimum and average of observed water levels in ponds, rivers (sw), piezometers (peizo), drinking (DR) and irrigation (IR) wells from December 2001 to June 2005 within our 16km^2 study area. In general, the ground water levels (as observed from the peisometric, drinking and irrigation wells) show very little spread between the maximum and minimum values inferring that there is no or very little horizontal and vertical gradient. The only time we observe some significant spread between the maximum and minimum values of peizometric wells (December 2003 to May 2004) is due to the fact that the data also includes peizometric water levels from the surface clay layer, which shows higher heads in the clay than the underlying aquifer and hence, a downward vertical gradient. On the other end of the spectrum, there is consistently a large spread between the maximum and minimum values of pond water levels, which indicates that the ponds are separated both spatially and vertically. Moreover, the temporal variation within the spread implies that each pond behaves differently over time due to natural and human interventions. In addition, the pond water levels are generally higher than that of groundwater level since the ponds are sitting in the surface clay, and thereby, are separated from the aquifer. For the river water levels, there is no or very little difference between the maximum and minimum values during the flooding season; however, there is some difference during the dry season since the water level in some part of the side channels become very low to dry, and thereby, somewhat disconnected from the main channel.

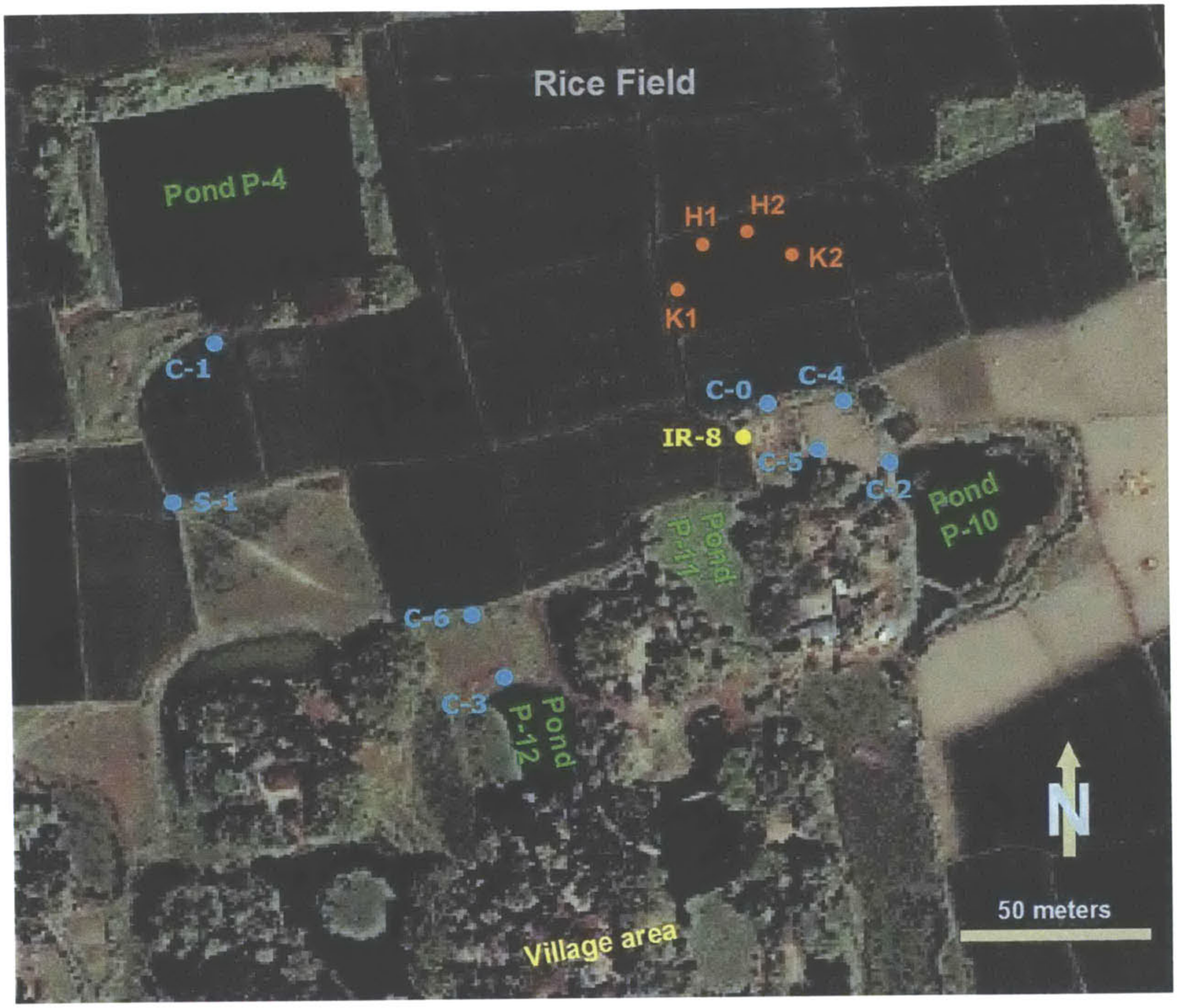


Fig.3.19 **Basailbhog Field Site:** IKONOS satellite image of 500m X 500m area at the Basailbhog field site highlighting the irrigation well (IR-8), eight well clusters (C-0, C-1, C-2, C-3, C-4, C-5, C-6, S-1), four single wells (K1, K2, H1, H2), and four monitoring ponds (P-4, P-10, P-11, P-12). Moreover, each of the eight well clusters has 5 to 8 single wells screened at different depths.

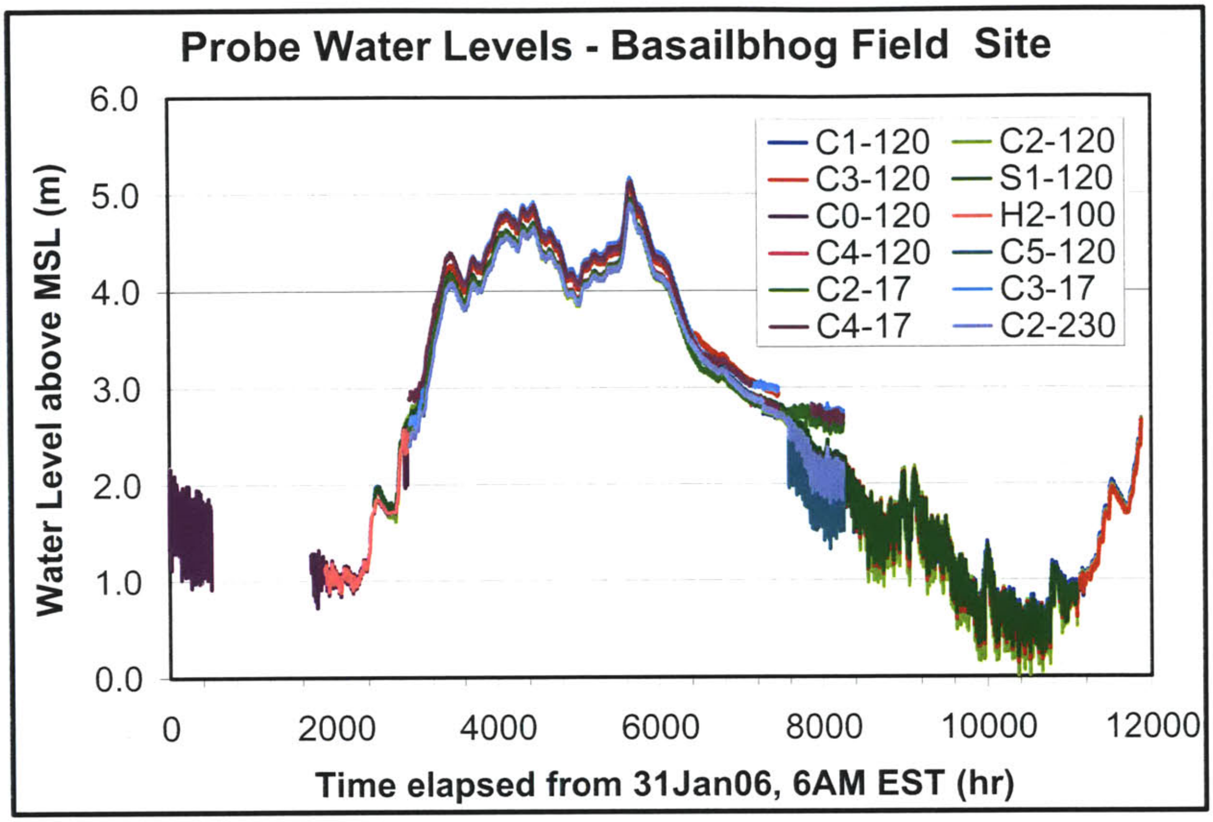


Fig.3.20 Probe Water Levels – Basailbhog Field Site: hourly water level fluctuations around 5.2m (17ft) and 30.5-36.6m (100-120ft) depth within an area of 0.25km^2 Basailbhog Field Site. The rice field surface is at 3.16m above the MSL; therefore, the field site is flooded from Jun'06 to Oct'06. Similar to the entire study area, there is very little horizontal hydraulic gradient during the flooding season. The large oscillations between 0 and ~2000 hours (Jan'06 to late Apr'06) and between ~7500 to ~11000 hours (mid Dec'06 to early May'07) indicate the dry season irrigation pumping.

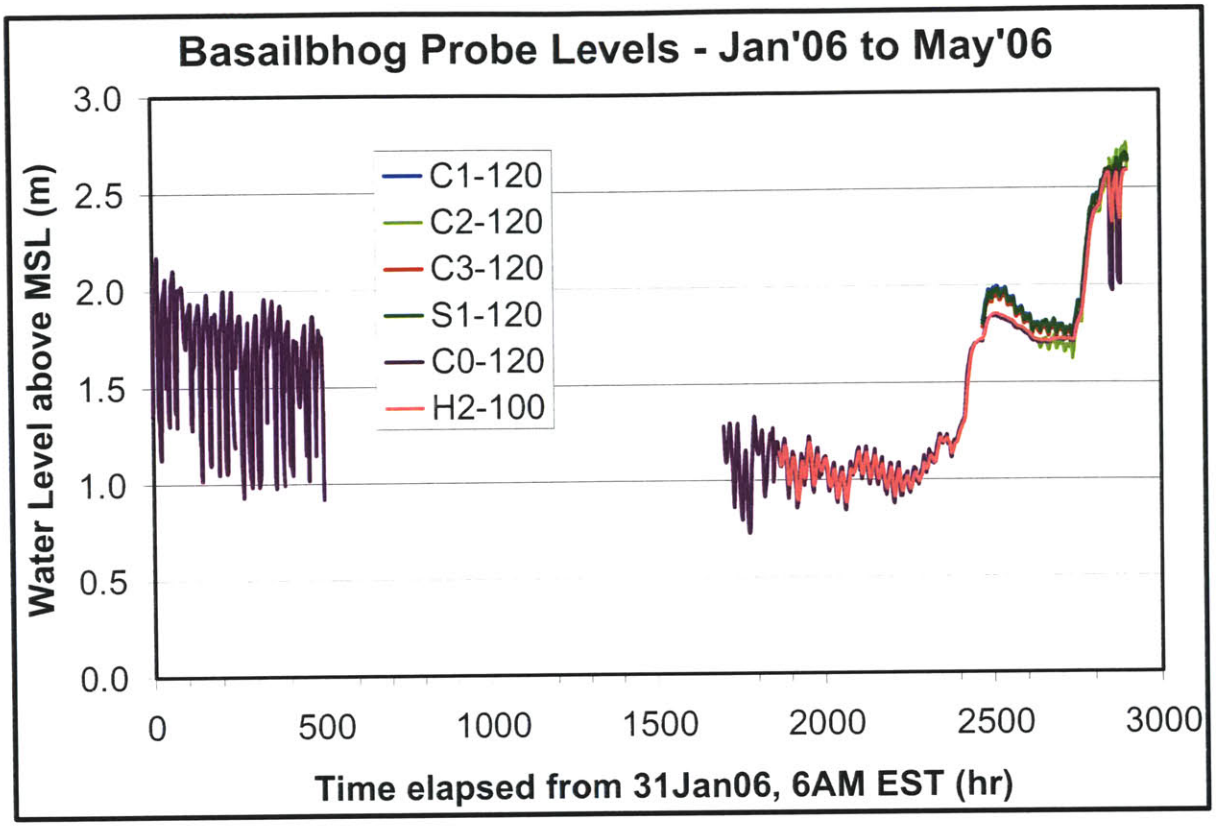


Fig.3.21 Basailbhog Probe Levels – Jan'06 to May'06: hourly water level fluctuations during the 2006 pre-flood period. The water levels in C0-120 and H2-100 wells have been recorded using In-Situ probes (that removes barometric pressure effect), and the water levels in C1-120, C2-120, C3-120 and S1-120 wells have been recorded using Solinst probes (that doesn't remove barometric pressure effect). The large oscillations in the C0-120 well upto ~500 hours are due to the impact of multiple neighboring irrigation wells with longer pumping duration, whereas the diminishing oscillations in the C0-120 and H2-100 wells between 1700-2300 hours reflect the end of irrigation season with a few irrigation wells pumping for shorter duration. Therefore, from the figure, it can be inferred that irrigation pumping stopped during the first week of May at the current field site. On the other hand, the oscillations in water levels of the remaining wells (i.e. C1-120, C2-120, C3-120 and S1-120) can be attributed as the effect of diurnal barometric pressure change. The two big jumps in the probe water levels (around 2500 and 2700 hours) can be explained by the two rain-storms occurred during May 11-13 and May 27-31. And finally, the two large drops in the water levels towards the end (around 2900 hours) are due to the 2-day pumping experiment (Chapter 4), which has been carried out on May 31 – June 1, 2006.

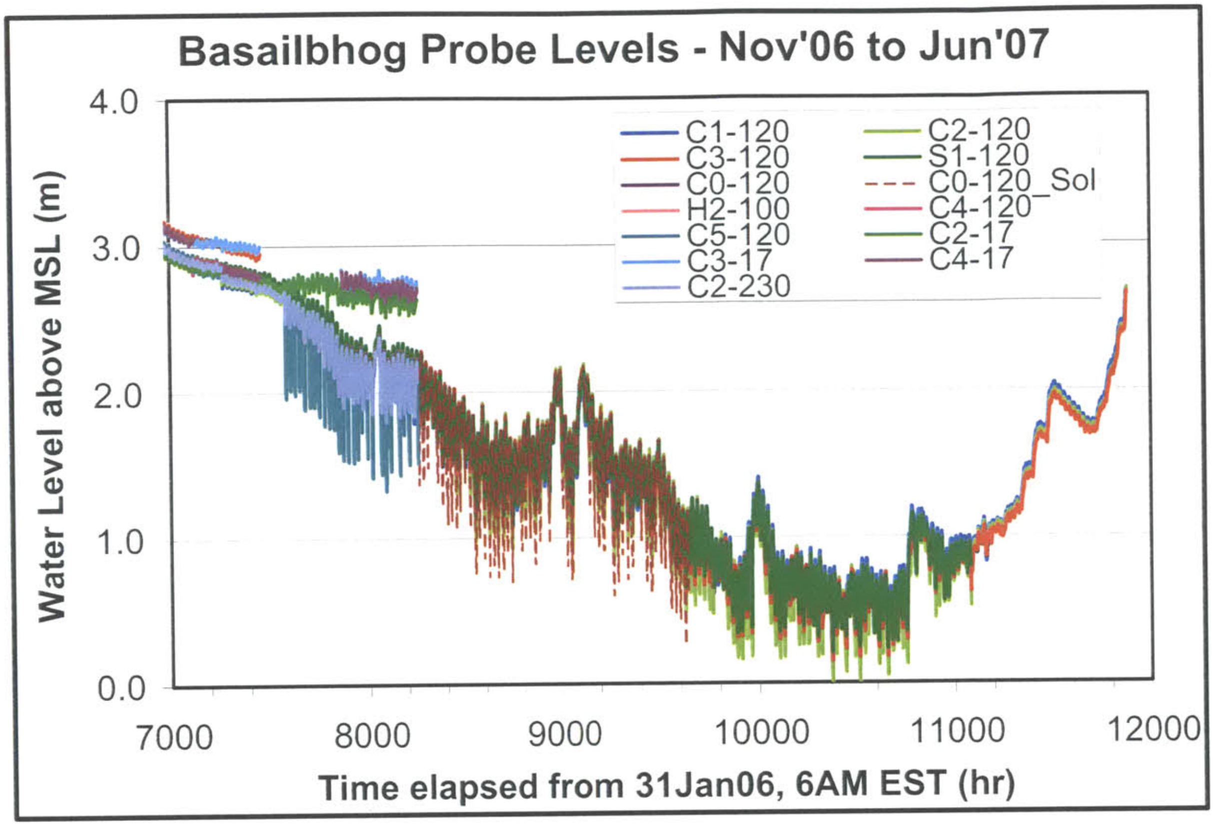


Fig.3.22 Basailbhog Probe Levels – Nov'06 to Jun'07: hourly water level fluctuations during the post-flood irrigation period in 2007. All the water levels have been recorded using the Solinst probes; therefore, the small oscillations in the water levels are the effect of barometric pressure. On the other hand, the large oscillations in the 33.6m wells around mid-December of 2006 indicate the start of irrigation season, and the wells in close proximity of the irrigation well, IR-8 experiences the greater drawdowns. However, irrigation pumping has very little effect on the shallow wells around 5.2m depth, and the rate of decline in water levels in those wells follows the daily evaporation rate very closely.

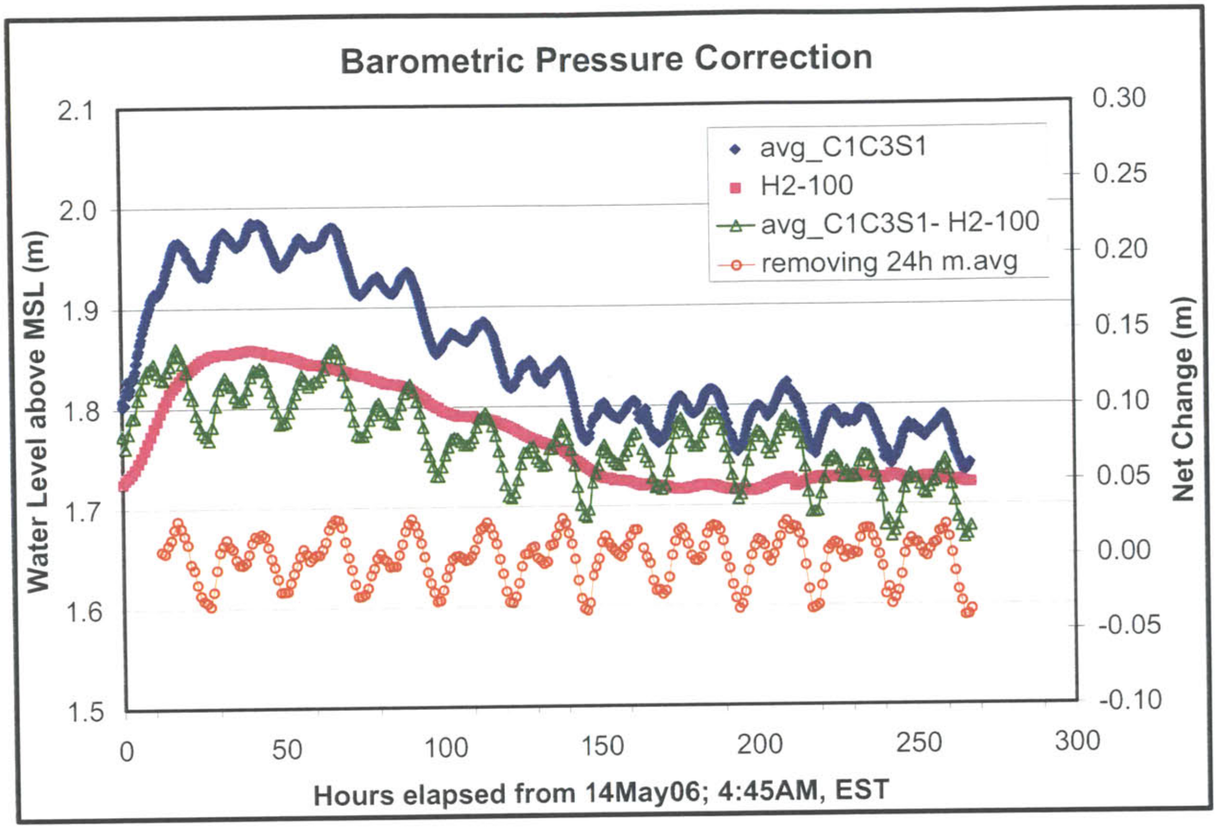


Fig.3.23 Barometric Pressure Correction: the plot shows the process of barometric pressure correction for the water levels recorded by the Solinst probes. At first, the average water levels (blue dots) have been calculated for the C1-120, C3-120 and S1-120 wells since there are very little difference among them. Afterwards, the average value has been subtracted from the H2-100 water levels (pink dots), which has been measured using In-Situ probes, and thereby, is already corrected for barometric pressure. The difference resulted in the oscillation due to the barometric pressure only (green dots and line). In order to remove the seasonality from the oscillation, a 24hr-moving average has been subtracted, which has produced the pure barometric oscillation (red dots and line).

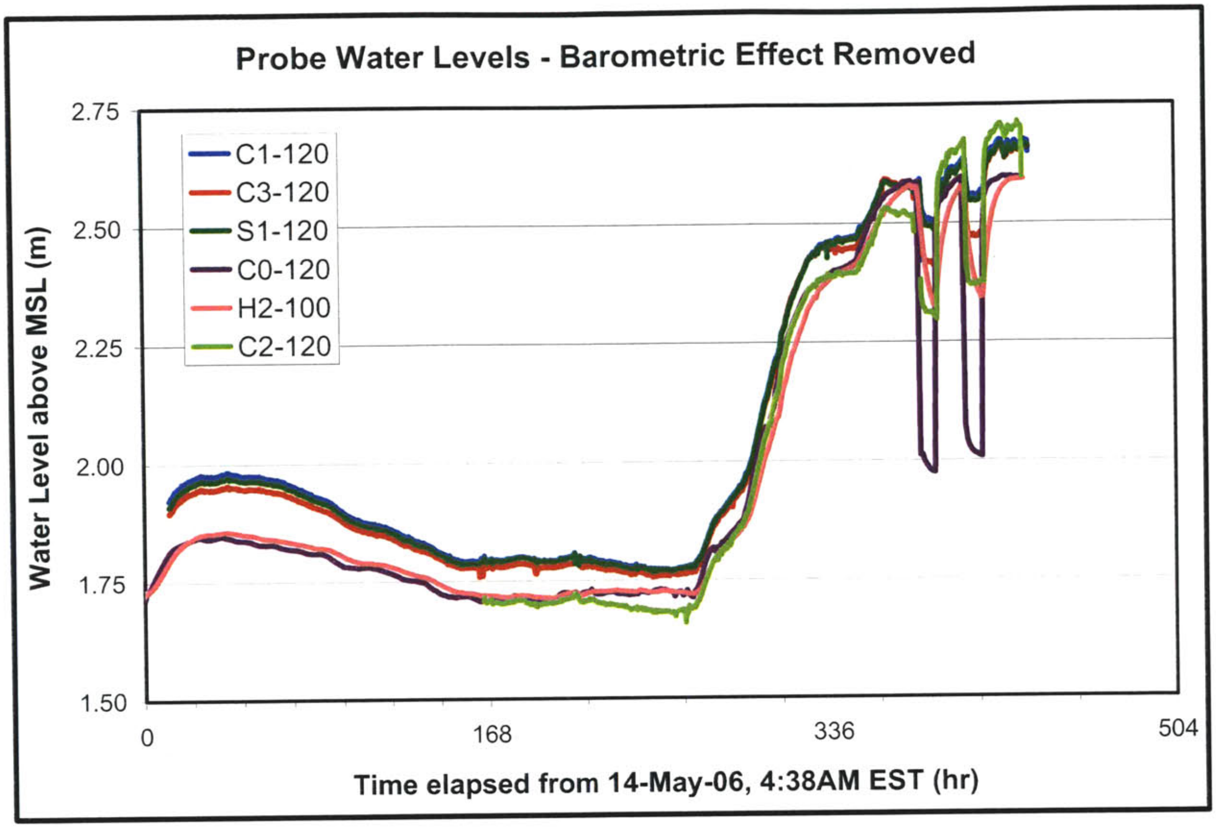
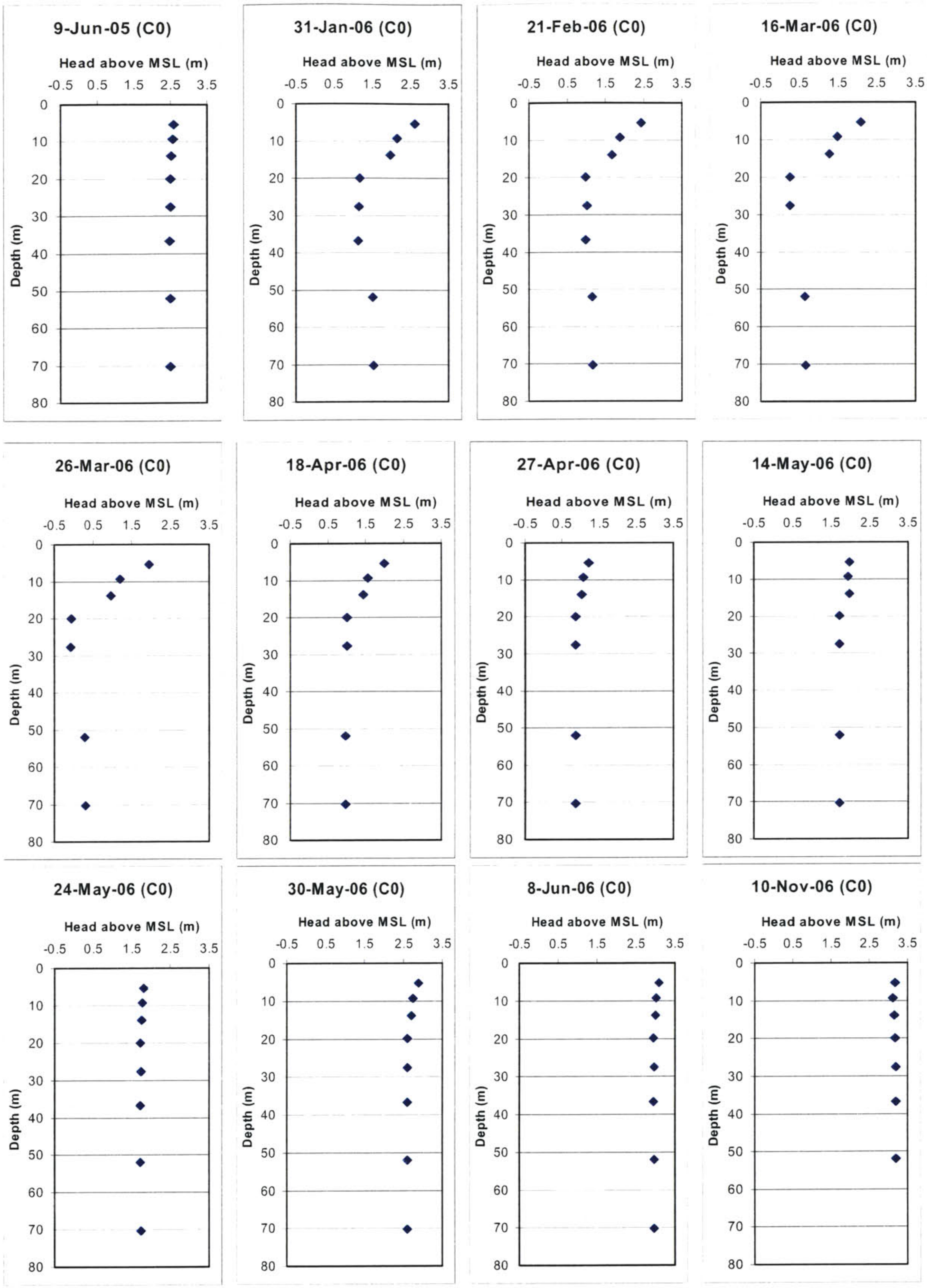


Fig.3.24 Probe Water Levels – Barometric Effect Removed: a zoom-in plot of hourly variations in water levels during the 2006 pre-flood period as recorded in the C1-120, C2-120, C3-120 and S1-120 wells using Solinst probes (after removing the barometric effect), and in the C0-120 and H2-100 wells using In-Situ probes. In addition to the large jump and drops in the water levels (as already explained in Fig.3.21), the plot indicates that the water levels in clusters C1, S1, and C3 are higher than those in C0 and H2, which in turns, are higher than that in C2. This means that at the end of the irrigation season, there is a regional horizontal gradient from west to east at the field site.


9-Jun-05 (C0)
31-Jan-06 (C0)
21-Feb-06 (C0)
16-Mar-06 (C0)
26-Mar-06 (C0)
18-Apr-06 (C0)
27-Apr-06 (C0)
14-May-06 (C0)
24-May-06 (C0)
30-May-06 (C0)
8-Jun-06 (C0)
10-Nov-06 (C0)
Head above MSL (m)
-0.5 0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

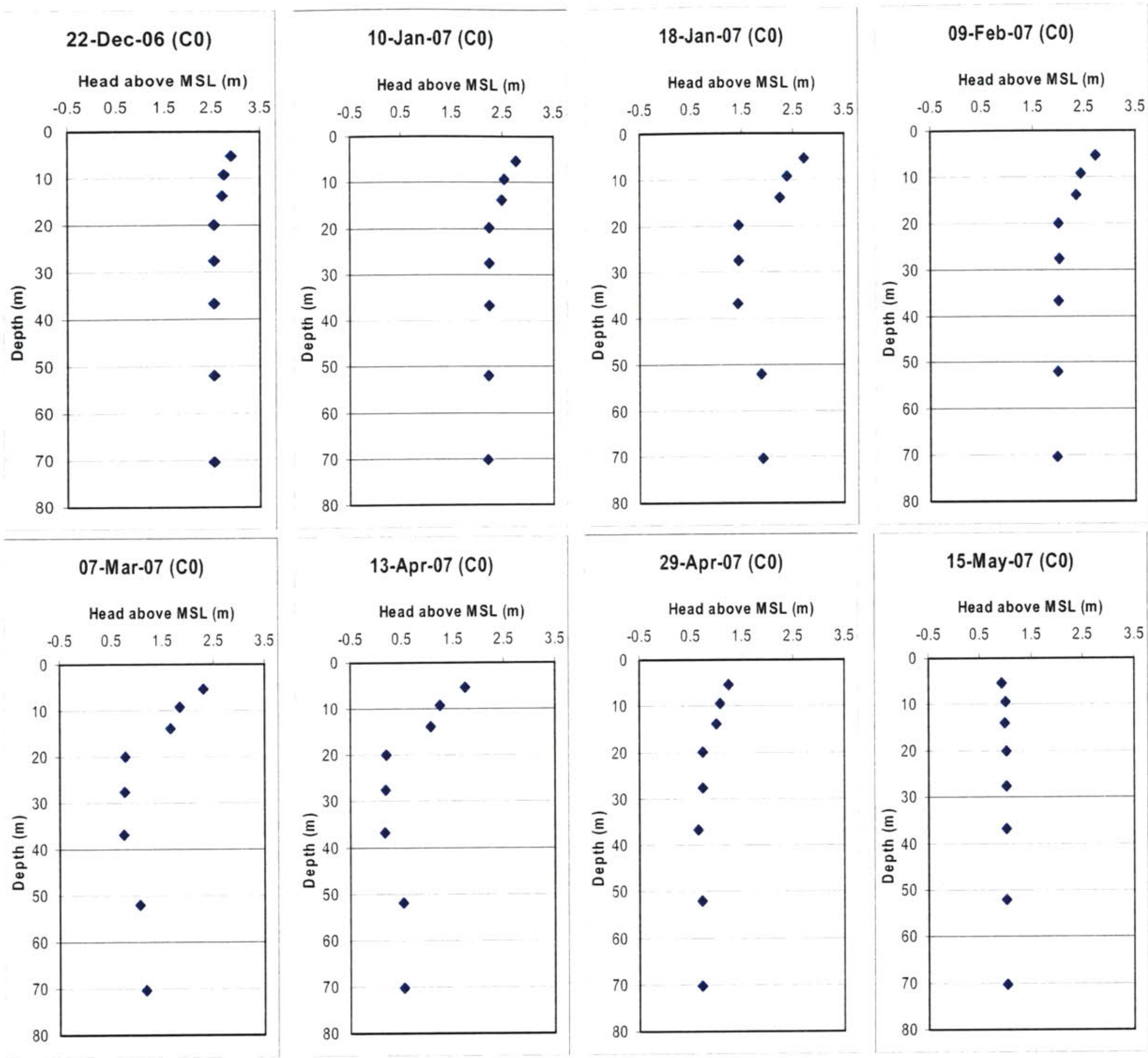


Fig.3.25 Time-series Head Fluctuation at Clusters: the above plots show the change in heads in the well clusters with time at the Basailbhog field site. Head plots for cluster C0 show that during the irrigation period (January to April) head is minimum around 20-40m depth creating high vertical gradient and flow from above and below at that depth. The large head difference (~2m) is due to the fact that cluster C0 is situated just beside the irrigation well, IR-8, and the irrigation well is screened around 30-40m depth. At the end of the irrigation season, the head difference decreases by an order of magnitude, and the slightly higher head at the shallow depth (also observed in other clusters) might be the effect of higher storage of the surface clay. Similar trend is observed at other clusters as well (Appendix I), though the magnitude of the vertical head differences during the irrigation season vary depending on the proximity of the cluster to irrigation well.

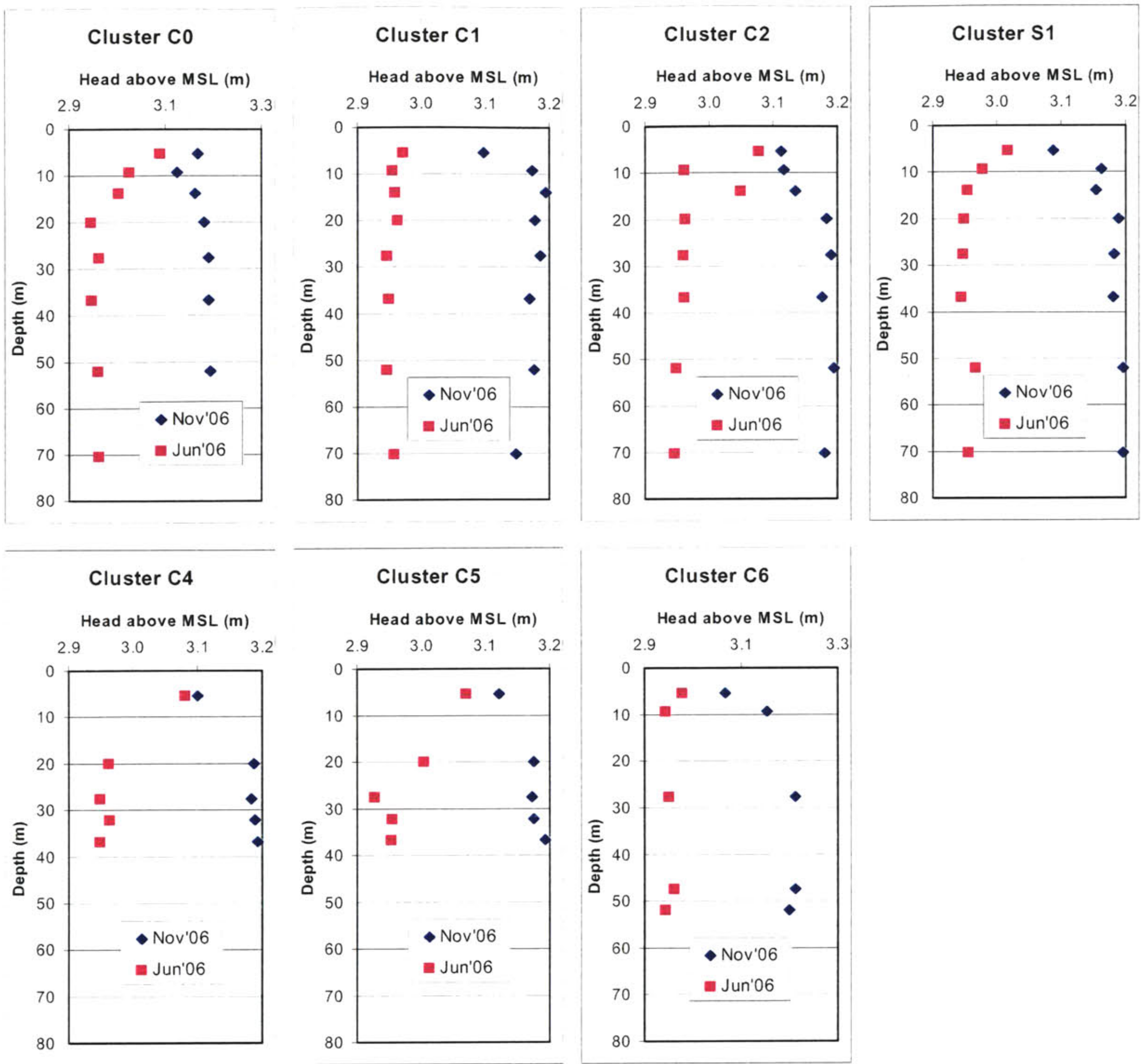


Fig.3.26 Seasonal Head Differentiation at Clusters: comparing the heads at the clusters between the end of irrigation season (June) and end of flooding season (November), a distinct difference in the vertical gradient is observed. At the end of irrigation season (June), hydraulic heads are higher at shallower depths indicating downward flow, which might be attributed to higher rainfall and greater storage at the shallow Depth. On the other hand, at the end of flooding season (and also before the irrigation season), the situation is reversed – there is vertically upward gradient due to lower head at shallower depth, which might be the effect of more evaporation than rainfall.

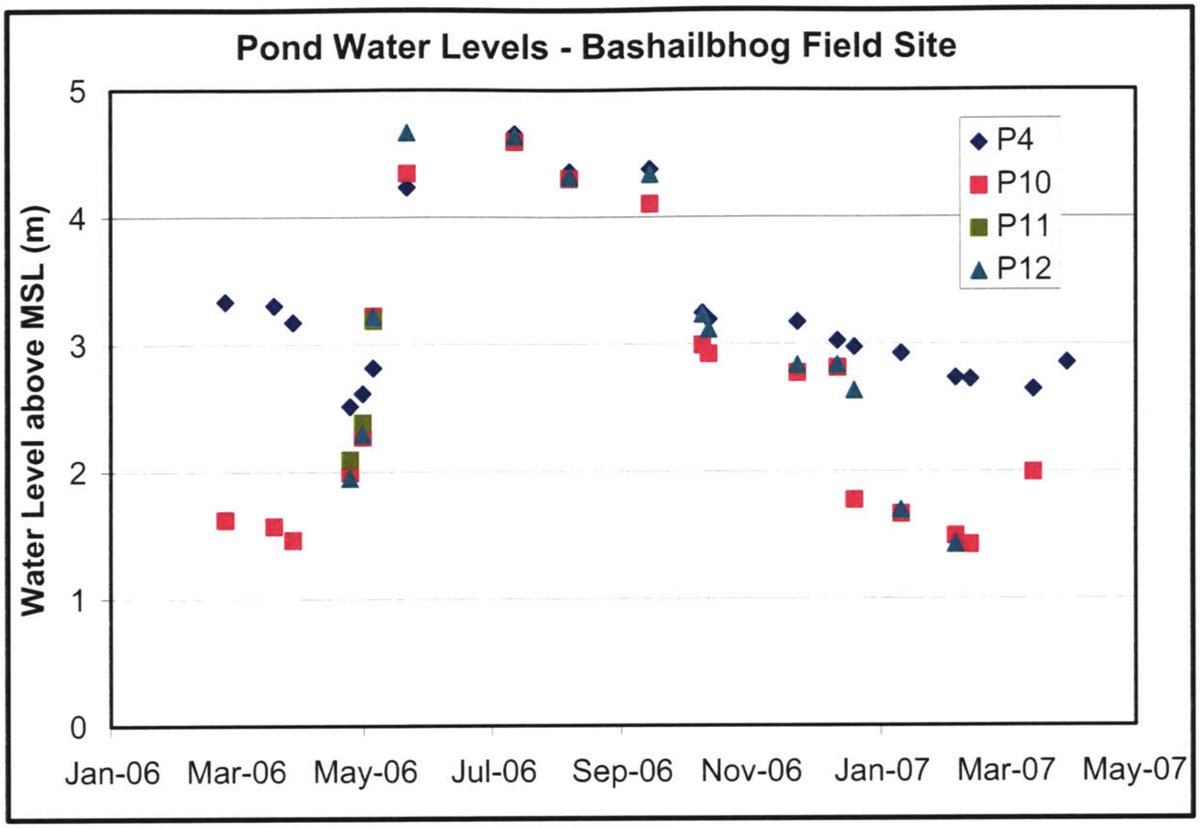


Fig.3.27 Pond Water Levels – Basailbhog Field Site: temporal change in water levels of the four ponds at the Basailbhog Field Site (Fig.3.19). Data indicates the fact that unlike other ponds in the area, pond P4 is not only spatially farthest from the rest, but also surrounded all around by village areas, and hence, behaves differently from the other ponds. The water level in P4 is consistently higher than that in P10 (and other ponds) until the rain event during May 27-31, 2006, when the water levels in P10, P11 and P12 rise more rapidly due to added runoff from the neighboring rice field areas. However, during the flooding season, all pond water levels come together – a similar phenomenon we have observed for the entire study area. Interestingly, in general, all the pond water levels seems to decline at a steady rate (except during rain events), and the rate is very close to the average daily evaporation rate, which infers that there is very little recharge from these ponds into the aquifer.

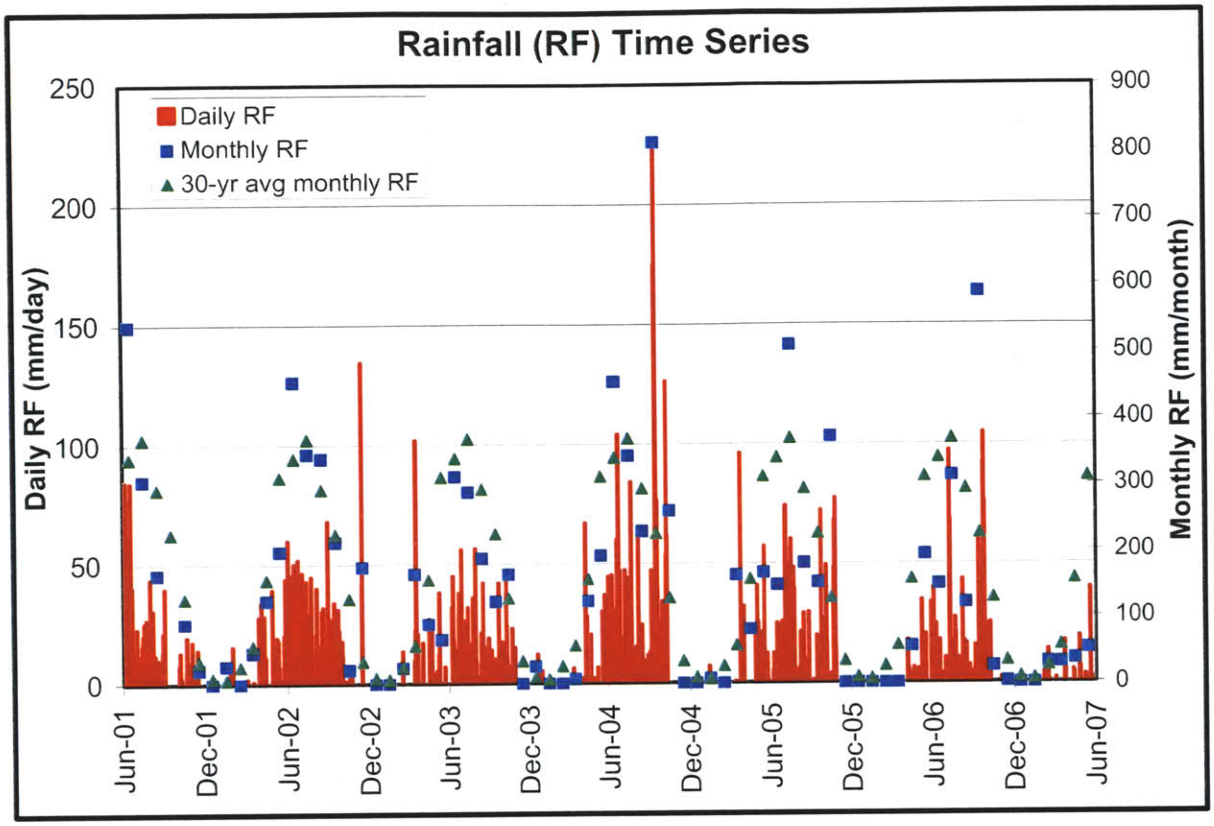


Fig.3.28 Rainfall (RF) Time Series: daily rainfall data (as recorded at Bhagakul meteorological station) from June 2001 to May 2007. The plot also compares the monthly total rainfall between the stated time periods with that obtained from averaging 30-year rainfall data. The pattern of daily rainfall is consistent over the years, and also, the monthly average compares well with the 30-year average data. As can be been from the plot, most of the rainfall occurs between April to October, while the months from November to March are mostly dry (and thus, necessitates groundwater irrigation for dry season rice cultivation).

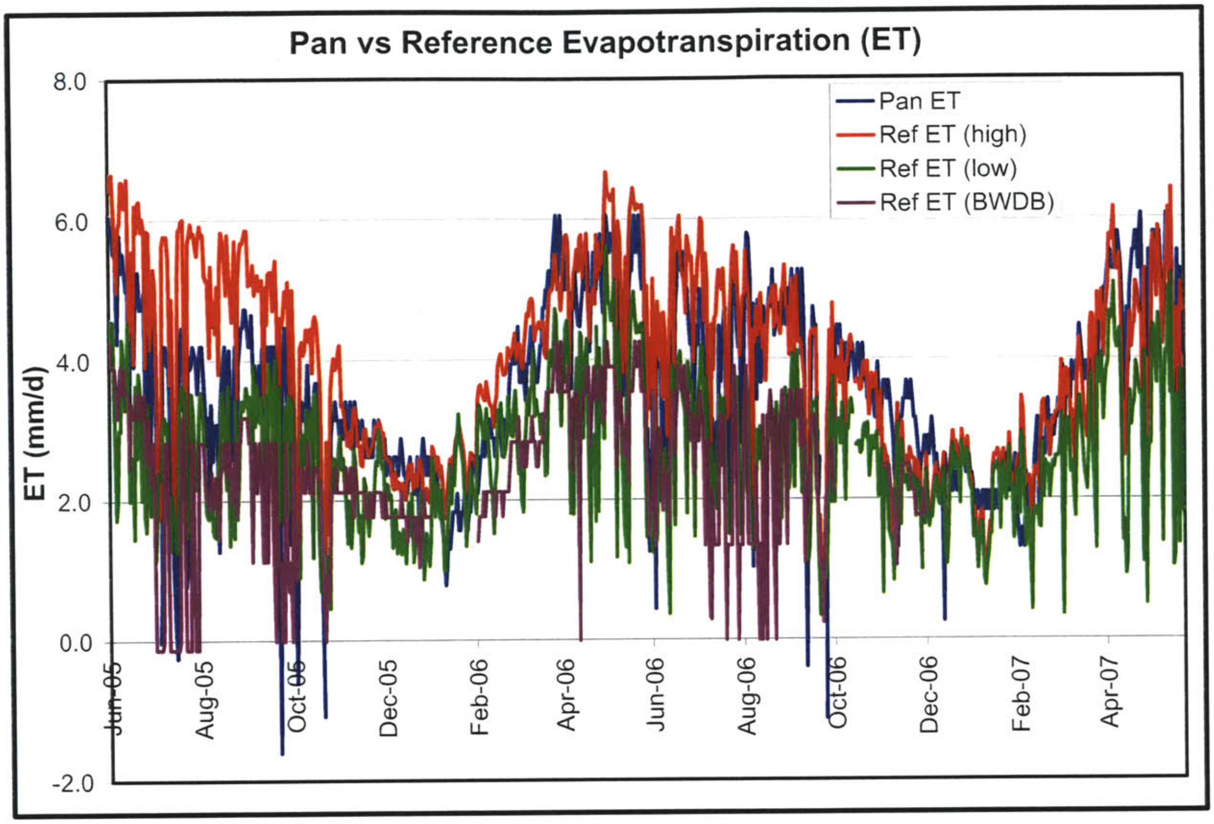


Fig.3.29 Pan vs Reference Evapotranspiration (ET): comparison of daily pan and reference evapotranspiration, ET_0 from June 2005 to May 2007. The daily Pan ET (solid blue line) has been calculated using the evaporation-pan data as collected from the Bhagakul Meteorological Station. The daily ref. ET values have been calculated using the Penmann-Monteith equation (FAO report), and the meteorological data obtained from Bhagakul Meteorological Station. In the absence of actual daylight hours data, the high and low ref. ET values have been calculated by varying the possible daylight hours depending on the rain events and the time of the year (Appendix L). In addition, ref. ET data has also been collected from the Bangladesh Water Development Board (BWDB), where it is calculated as 70% of the Pan ET, in general, and it follows the lower bound of the calculated ref. ET quite closely. However, most importantly, since most of the recharge and discharge occurs between November and April, the significance of ET is highest during that time, and the plot shows that the band of the various ET values is tightest during that time.

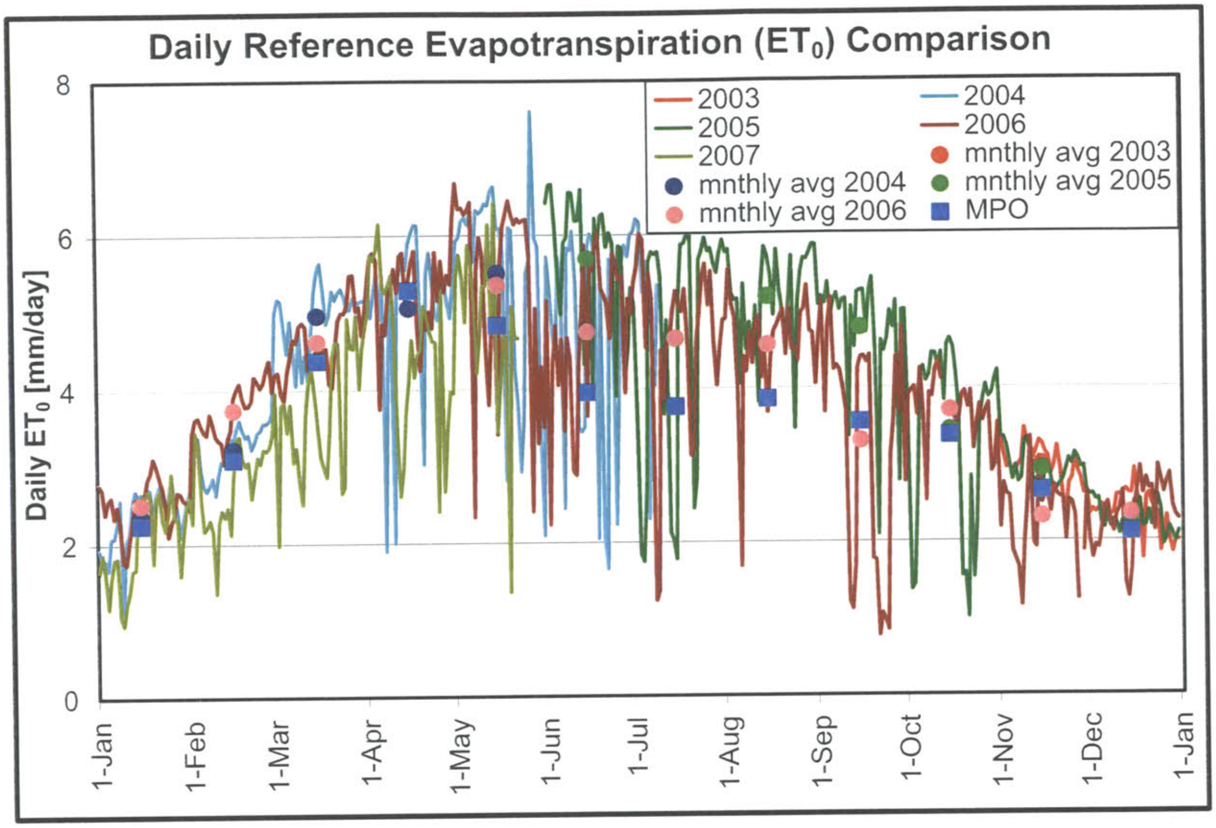


Fig.3.30 Daily Reference Evapotraspiration (ET_0) Comparison: comparison of daily reference evapotranspiration, ET_0, between 2003 and 2007. The plot also compares monthly average ET_0 values with that obtained from the literature for Munshiganj. The daily ET_0 values have been calculated using the Penmann-Monteith equation (FAO report), and the meteorological data obtained from Bhagakul Meteorological Station. The daily ET_0 values are consistent from year to year, and the monthly averages also compare well with that of the literature value. However, the calculated monthly average ET_0 values are a bit higher than the literature values for the months of June to September. This might be due to the reason that daily sunshine hours have been assumed to be proportional with the rainfall since actual data has not been available, which resulted in higher approximation of the ET values.

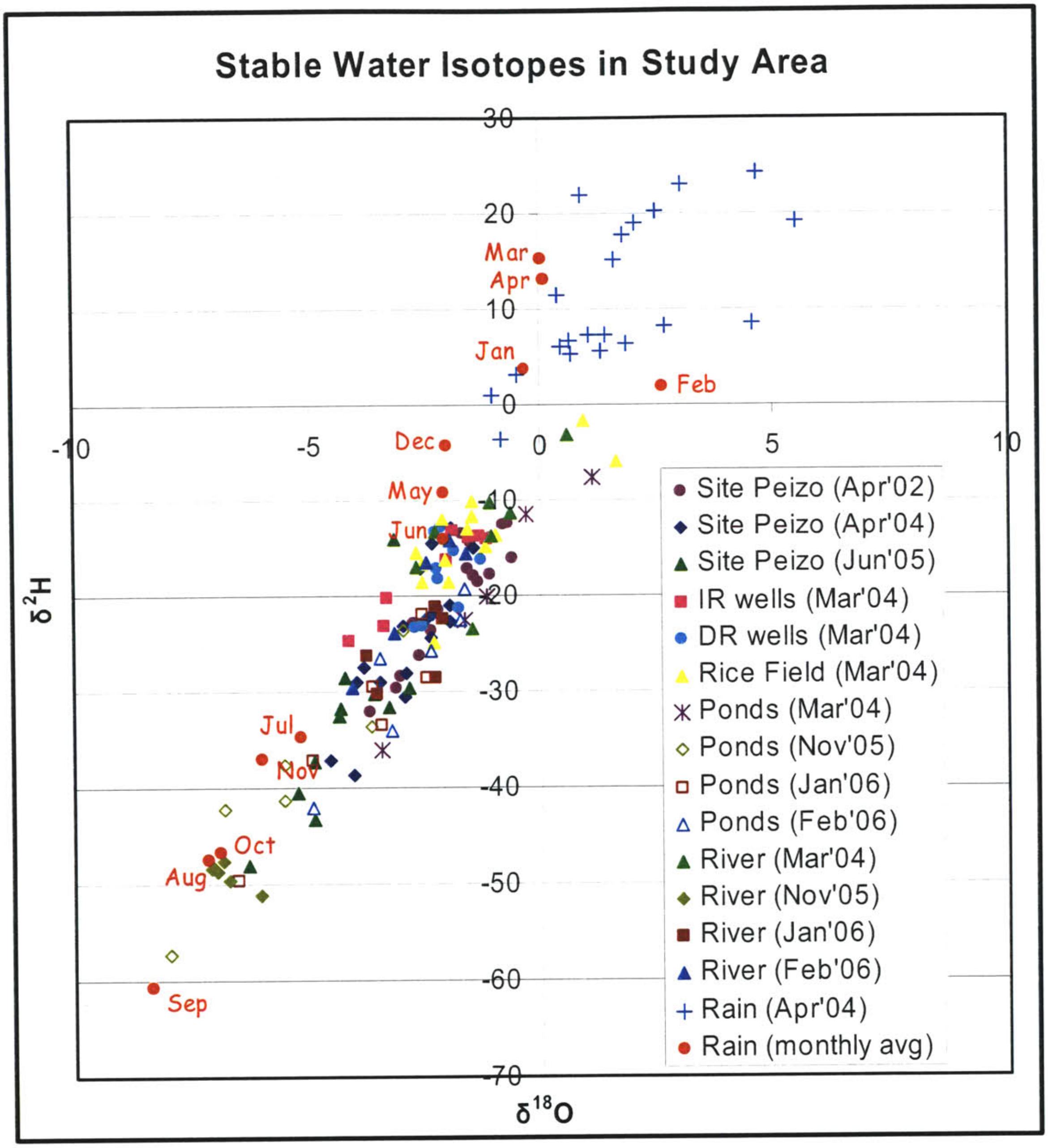


Fig.3.31 Stable Water Isotopes in Study Area: Stable water isotopic composition within our study area shows a wide variability with isotopic values ranging from -7.99 (pond water) to 5.5‰ (rainwater) for $\delta^{18}O$, and -57.17 (pond water) to 24.37‰ (rainwater) for δD. However, the $\delta^{18}O$ and δD values of groundwater vary from -6.3 to -0.6‰ and from -47.9 to -12.36‰, respectively, which are well within the overall range inferring groundwater as a mixture of water from different pools or end members (e.g. pond, river, rainfall, and the rice-field water). The plot also shows that the literature isotopic value of rainfall compares well with that of the measured values at our study area.

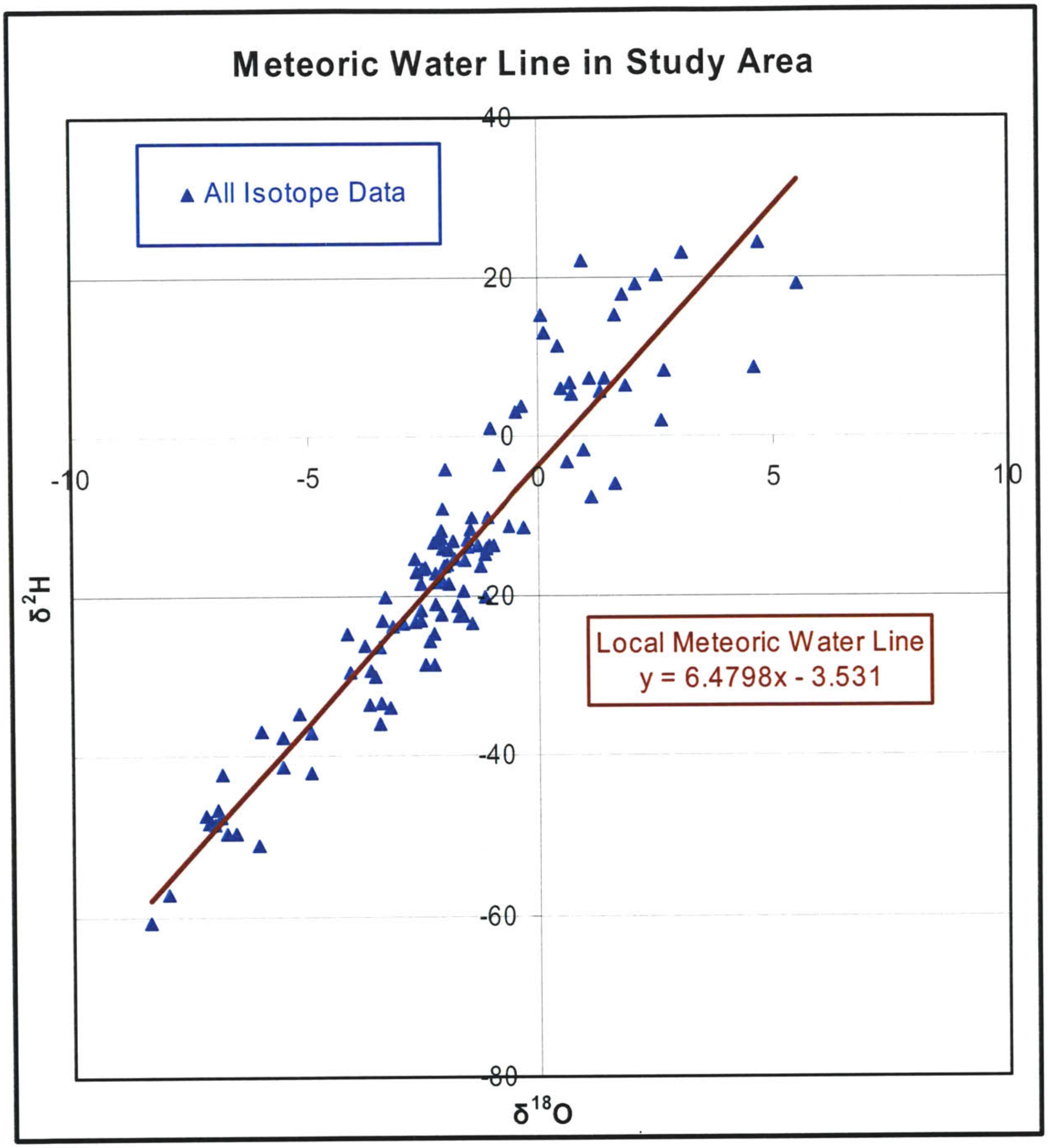


Fig.3.32 Meteoric Water Line in Study Area: Plot of Local Meteoric Water Line (LMWL) considering all the isotopic data from various sources (e.g. pond, river, rainfall, rice-filed and groundwater) within our study area. The equation of LMWL compares well with that of Global Meteoric Water Line (GMWL) of Standard Mean Ocean Water (SMOW): $\delta D = 8.0\delta^{18}O + 10.0$; the LMWL is almost parallel to the GMWL with some variation in the intersection. In general, the stable water composition within our study area tends to be bit heavier as compared to the SMOW.

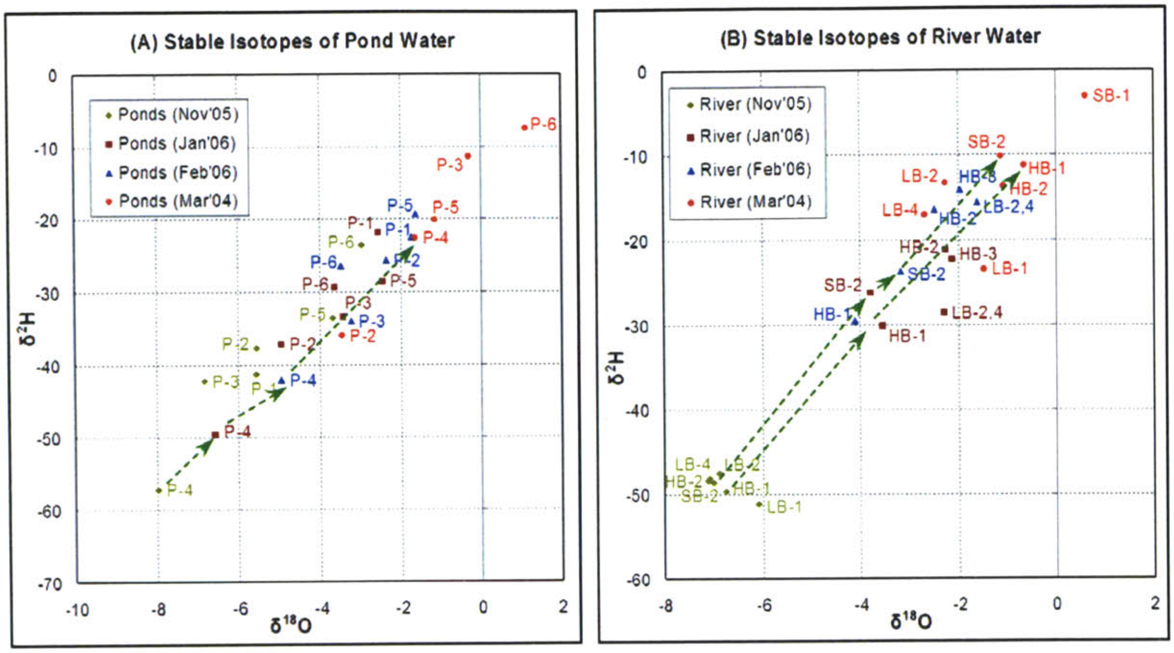


Fig.3.33 Temporal nature of Stable Water Isotopes in Surface Waters: Temporal trend of stable isotopes for (A) pond and (B) river waters. Data indicate that the surface water is lightest just after the monsoon season in November, and it becomes heavier with time throughout the dry season due to the impact of surface evaporation. It should also be noted that the isotopic values of the surface water at the end of flood provides one end of the isotopic spectrum that contributes to the groundwater isotope values.

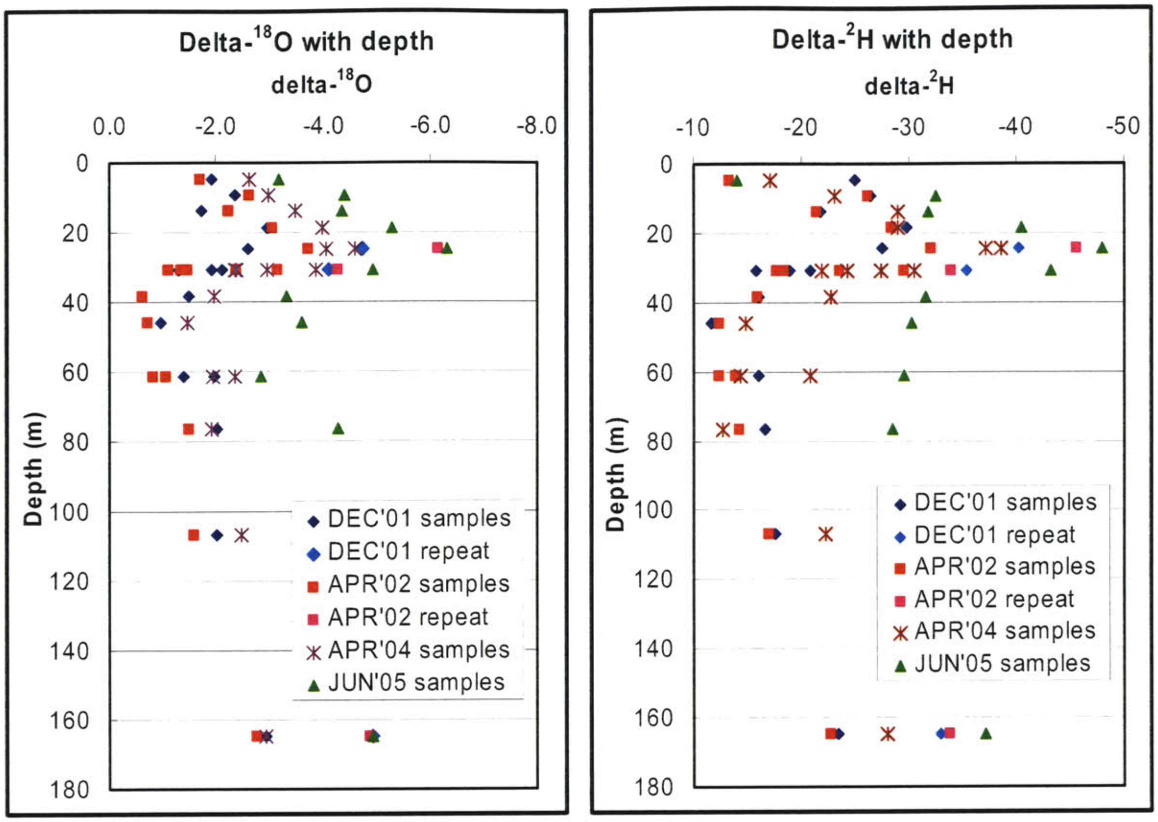


Fig.3.34 Vertical Profile of Stable Water Isotopes at Bejgoan Field Site: depth profile of stable water isotopes at our Bejgoan Field Site between Dec'01 and Jun'05. As can be seen from the plot, water becomes lighter with depth up to 24.4m, and then there is a large variability at 30.5m depth. Afterwards, the water becomes heavy again followed by an increasing trend of lighter water with depth. The trend can be attributed to the flow convergence around 30.5m depth, which might have mixed lighter water from above and heavier water from below. The plot also indicates that the stable isotopes have become lighter over the years, which might be due to more contribution from the river and/or from lighter isotopic rainfalls.

Chapter 4

Field Site Characterization

4.1. Basailbhog Field Site

At our Bejgoan Field Site, we observe a distinct pattern of dissolved arsenic concentration profile with the peak around at 30-40m depth (Fig.4.1). In order to investigate if the depth profile is similar at other neighboring areas, we have installed a cluster (C0, Fig.3.19) of eight wells screened at various depths (Table 3.2) at the Basailbhog Field Site, which is located about 1km south-east of the Bejgoan Field Site, and is a 500m X 500m area centered around the irrigation well, IR-8 (Fig.3.19). Interestingly, the arsenic concentration profile (Fig.4.2) has come out to be very similar as we have observed at the Bejgoan Field Site with the peak concentration around 30m depth.

4.2. Pond Hypothesis

It is assumed that there is an influx of fresh sediments containing naturally occurring solid-phase arsenic (mostly adsorbed on iron-oxide surfaces) every year during the flooding season by the Ganges and Brahmaputra rivers from the Himalayas. The sediments eventually get deposited on the Bengal delta, and under anaerobic conditions at the pond bottoms, arsenic gets released into the dissolved phase through microbial activity. Afterwards, it can be hypothesized that the plume of high dissolved arsenic is brought to the depth around 20-40m by irrigation induced groundwater flow (Fig.4.3). Accordingly, a cluster of eight wells, with each well screened at different depths, can be conceptualized nearby a pond where the shallow wells of such a cluster taps into the high arsenic plume, and the deeper wells (20-70m) have low arsenic concentrations. In order to test the hypothesis, four new clusters of wells have been installed – three beside ponds, and one away from the pond in the middle of the rice-field (Fig.4.4). According to the hypothesis, the arsenic concentration is assumed to be higher at shallow depths at the clusters C-1, C-2, and C-3, whereas the arsenic profile at cluster S-1 is thought to be somewhat similar to that of cluster C-0. However, the arsenic concentration profiles at all the new clusters have been found to be very similar to that of C-0 (Fig.4.5). Interestingly though, the peak at cluster C-2 is observed at around 27m (similar to at C-0), whereas the peaks at other clusters are at around 37m. For further investigating the nature and consistency of the arsenic profile, three more clusters (C-4, C-5 and C-6) have been installed at intermediate locations (Fig.3.19), and measurement of dissolved arsenic concentration at those tertiary clusters show similar profile as in other clusters (Fig.4.6), with the peak concentration around at 27m at clusters C-4 and C-5 (similar to the neighboring C-0 and C-2 clusters), whereas the peak concentration is at around 37m at C-6 (similar to the neighboring clusters C-1, C-3 and S-1). The occurrence of arsenic peak at two distinct depths over the field area indicates that the high arsenic concentration resides between the depths of 27.4-36.6m. Furthermore, the consistency of the arsenic concentration profile over the entire area and the lack of recharge from the neighboring ponds into the aquifer at the Basailbhog Field Site (Fig.3.11) infer that the primary hypothesis of the arsenic plume being directly transported from the pond bottom to the depth of the irrigation wells needs to be modified.

4.3. Field Site Characterization

Prior to modify the primary pond hypothesis, it is necessary to characterize the field site to better understand the aquifer properties and local hydrology. For that purpose, single well pump tests have been carried out at all the 60 piezometers of the eight clusters. Moreover, a unique and innovative large scale multi observation well pumping experiment has been carried out to delineate the aquifer characteristics on a regional scale.

4.3.1. Single Well Pump Tests

Single-well pump tests have been carried out in all of the 60 wells at the well clusters using a Grundfos submersible pump with pumping rate ranging between 0.2-0.6 L/s. The panels (A) to (H) of Fig.4.7 show the drawdown at the wells of various well clusters with time. As the plots show, asymptotic drawdown is reached within a minute at most of the wells indicating quicker response from the aquifer storage. Also, the drawdowns at shallower wells are greater compared to those at deeper wells, which indicates increase in hydraulic conductivity with depth. Panels (A) to (H) of Fig.4.8 depict the 'inverse of asymptotic drawdown' (IAD) and the 'time to reach 90% of the asymptotic drawdown' for the wells at various well clusters. The inverse plot of asymptotic drawdown provides an idea about the horizontal conductivity surrounding the well-screen surroundings, whereas the time required to reach the asymptote relates to the storage property as well. Summarizing the data in panels (I) and (J) reveals that there isn't much difference among the inverse drawdown values throughout the depth, which infers that the transmissivity is fairly constant. On the other hand, the time required to reach 90% asymptotic drawdown in larger above 40m depth indicating that storage coefficient is higher above 40m compared to that below 40m. However, the single well pump tests do not provide any information about the vertical hydraulic conductivities at various depths.

4.3.2. Large Scale Pumping Experiment

In order to estimate the hydraulic properties of the aquifer for the entire area, a unique and innovative large scale multi observation wells pumping experiment has been designed and executed. This 2-day experiment has been carried out after the irrigation season and prior to monsoon flooding. During the experiment, the irrigation well, IR-8 (Fig.3.19) is pumped at its usual flow of 15 L/s for two consecutive days following a farmer's schedule – the pump is started early in the morning and is stopped at the end of the day. In-Situ and Solinst data-loggers have been housed at the well clusters to record the response in groundwater level to the pumping experiment. Fig.4.9 shows the fluctuation in water levels in the well clusters in response to the large-scale multi observation well pumping experiment. As expected, the drawdowns are the largest at the wells closest to the pumping well, and it decreases for the wells further away from the pumping well. Interestingly, "Noordbergum effect" is observed at the shallowest well (5.2m depth), where the well is screened just below the surface clay. According to the Noordbergum effect phenomenon, the water level at the well drops for a brief period of time when pumping starts, and rises for a short period of time when pumping stops. Such phenomenon is observed when the observation and pumping wells are separated by an aquitard and/or the vertical hydraulic conductivity of the successive layers is significantly different. As a result, mechanical propagation is faster than the hydraulic propagation resulting in such effect. However, this mechanical effect is usually ignored in groundwater modeling.

Plotting the drawdowns at various wells with time normalized by the square of distance from the pumping well for the 2-day pumping experiment (Fig.4.10), the drawdown lines are found to be parallel to each other indicating that the transmissivity is same throughout the aquifer. Also, the stepping pattern in the drawdowns of 36.5 wells as well as the decreasing trend in drawdown with distance from the pumping well indicates that there is leakance from above and below on the drawdown cones. Moreover, the two groups of drawdown lines correspond to the drawdowns at the wells screened at 36.5m and at other depths. Interestingly, a plot of the drawdowns (to the scale) at the respective wells (Fig.4.11) produces elliptical contours for the farthest wells, which indicates that the aquifer is anisotropic in nature. As we move towards the pumping well (IR-8), the drawdowns get greater and the contours loose the elliptical shape. Taking the ratio of the long and short axis of the ellipse provides some idea about the degree of anisotropy in the aquifer – a ratio of about 5 at our present case infers that the aquifer anisotropy (ratio of horizontal and vertical hydraulic conductivities) is around 25.

4.3.3. Modeling Anisotropic Aquifer

In order to evaluate the anisotropic nature of the aquifer, a 3D model has been developed for the study area using FEFLOW for the 2-day pumping experiment (Fig.4.12). Using the model, we have estimated 6 parameters (Fig.4.13): the hydraulic conductivity of field, single horizontal conductivity for the entire aquifer since we have previously observed from the single well pump tests and the large scale pumping experiment that the conductivity or the transmissivity of the aquifer is same throughout the entire depth. Also, the single well pump tests indicate that the specific storage is different above and below 15m – so, we have estimated it for two aquifer segments – 4-15m and 15-120m depths. However, the pump tests do not provide the vertical conductivities; so, we have estimated that for the two aquifer segments. Interestingly, the ratio of the estimated horizontal and vertical conductivities for the depth 15-120m has been found to be about 25, as anticipated from the drawdown contours (Fig.4.6). In general, the model outputs show good agreement with the observed data at various wells indicating a satisfactory calibration of the model (Fig.4.14) over the spatial extent. For further investigating the aquifer anisotropy, the model has been halved horizontally at the center, and the head contours are observed with time at the vertical cross-section (Fig.4.15). Not surprisingly, the head contours during the pumping period take the shape of ellipse inferring the anisotropic nature of the aquifer.

4.3.4. Modified Pond Hypothesis

Based on the obtained aquifer characteristics from the single well pump tests as well as the large scale pumping experiment, the initial pond hypothesis has been modified to reflect the possible groundwater flow paths under anisotropic scenario. As depicted in Fig.4.16, the groundwater flow paths converges directly towards the pumping depth for an isotropic scenario, whereas, under the anisotropic scenario, groundwater tends to move vertically down at first before flowing horizontally towards the pumping well. Accordingly, modifying the initial pond hypothesis under the observed anisotropic aquifer scenario, it can be thus conceptualized that the movement of the high arsenic plume is mostly vertical at the beginning followed by more horizontally converging flow around the depth of the pumping well screen. However, based on the evidence of lack of recharge from the pond bottoms into the aquifer at the Basailbhog Field Site (Fig.3.11), the in-situ peak in dissolved arsenic concentration can be hypothesized as regional contributions from other recharging ponds within the vicinity of the area.

More reasoning in support of this modified hypothesis have been provided in the following chapters.

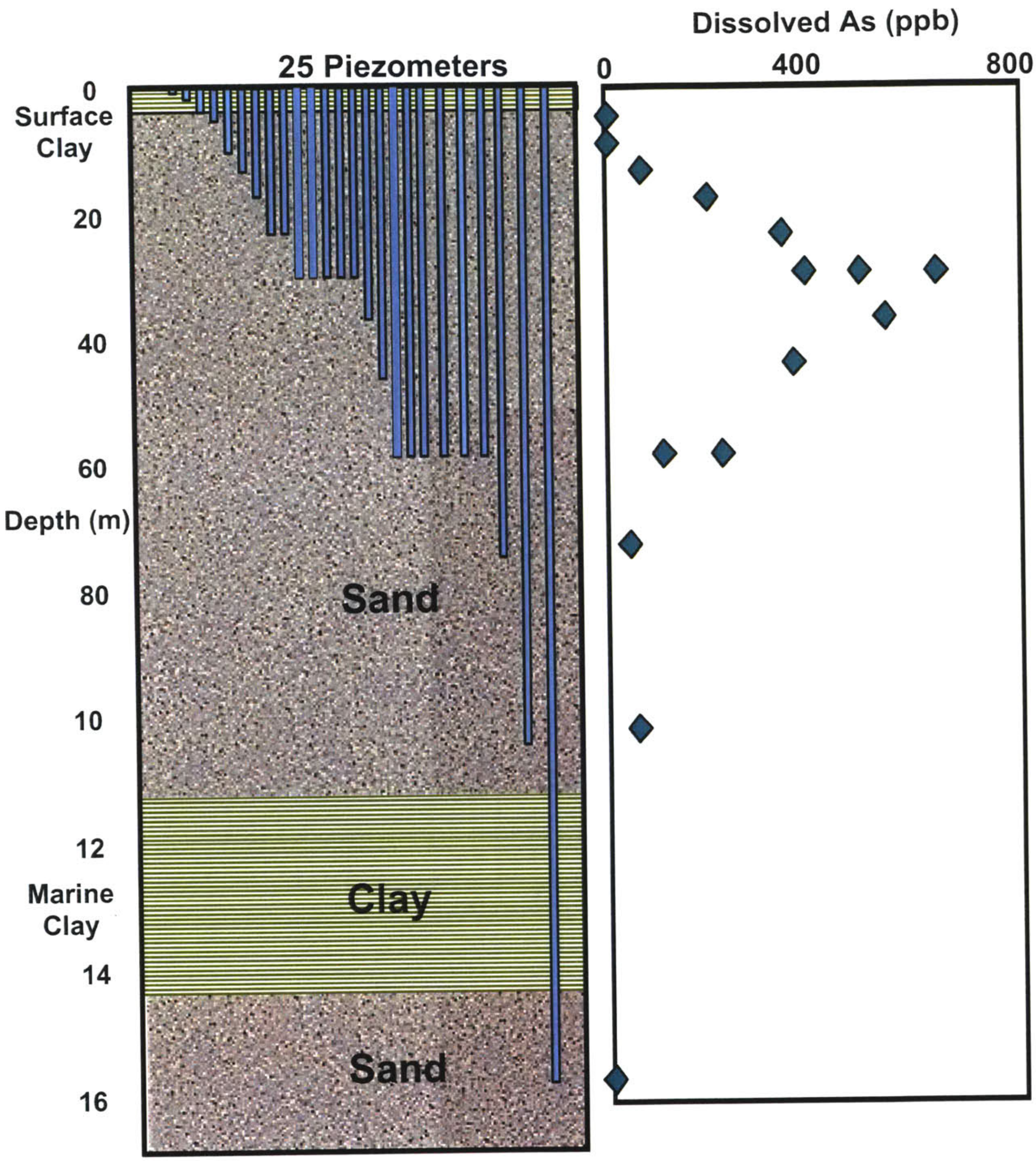


Fig.4.1 Dissolved Arsenic Concentration Profile: Dissolved arsenic concentration profile as observed at the peizometric depths in the Bejgoan Field Site. The dissolve arsenic concentration increases with depth and peaks around 30-40m depth, and decreases afterwards at greater depths.

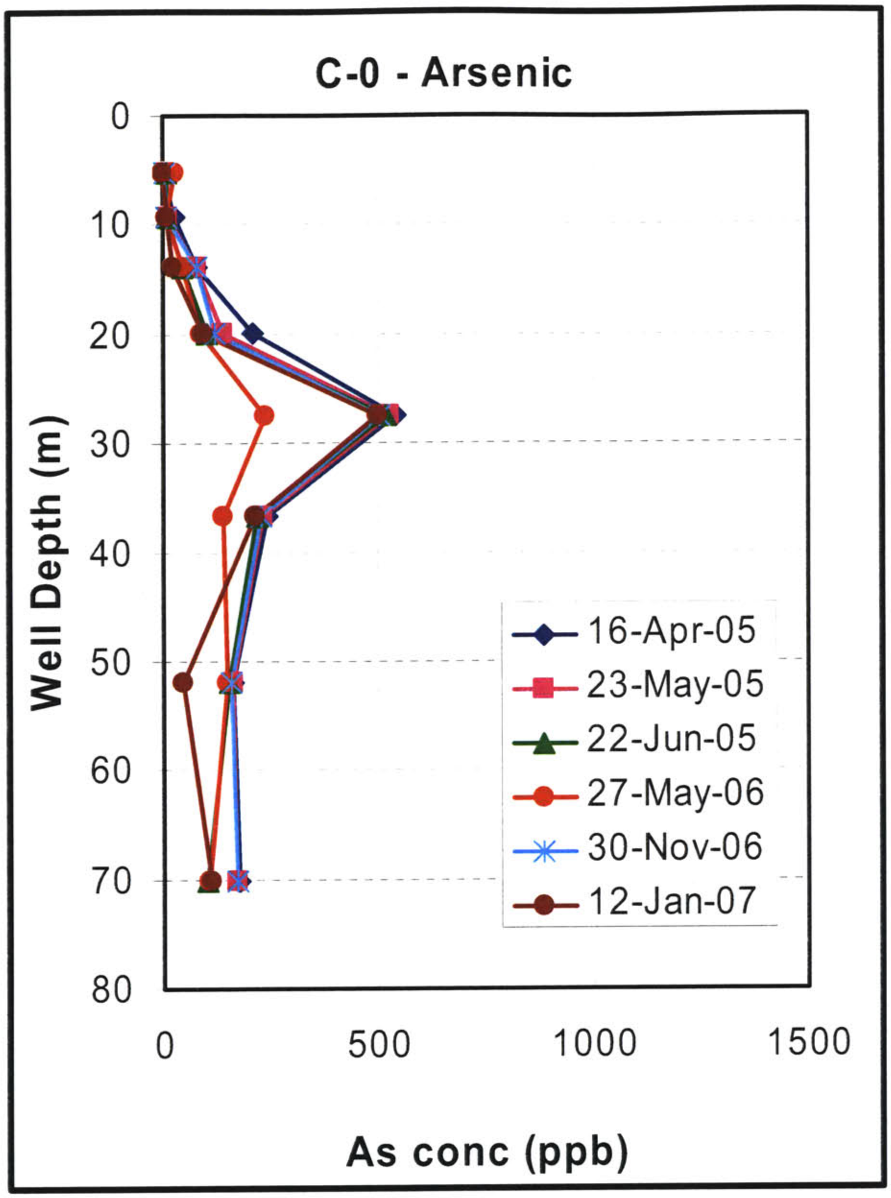


Fig.4.2 **Arsenic Profile at Primary Cluster, C0**: Dissolved arsenic concentration profile at cluster C-0 at the Basailbhog Field Site. The profile is very similar to the one we observed at the Bejgoan Field Site (Fig.4.1) though the two sites are about 1km apart. The arsenic concentration at C-0 peaks around 30m depth.

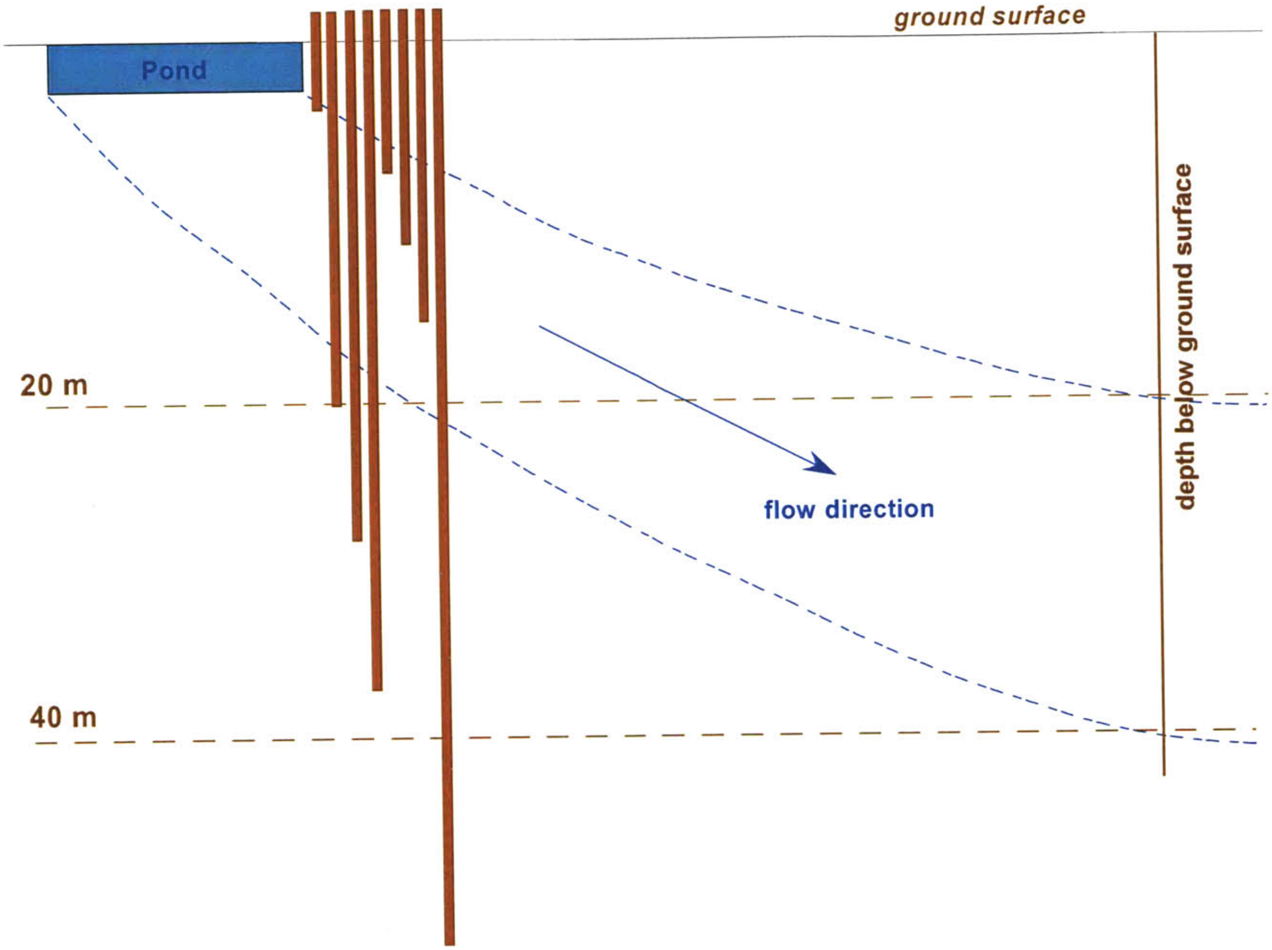


Fig.4.3 Hypothesized Scenario: It is hypothesized that arsenic is getting mobilized at the bottom of the pond and the plume of high dissolved arsenic is brought to the depth around 20-40m by irrigation induced groundwater flow. Accordingly, a cluster of eight wells, with each well screened at different depths, can be conceptualized nearby ponds where the shallow wells of such a cluster taps into the high arsenic plume, and the deeper wells (20-70m) have low arsenic concentrations.

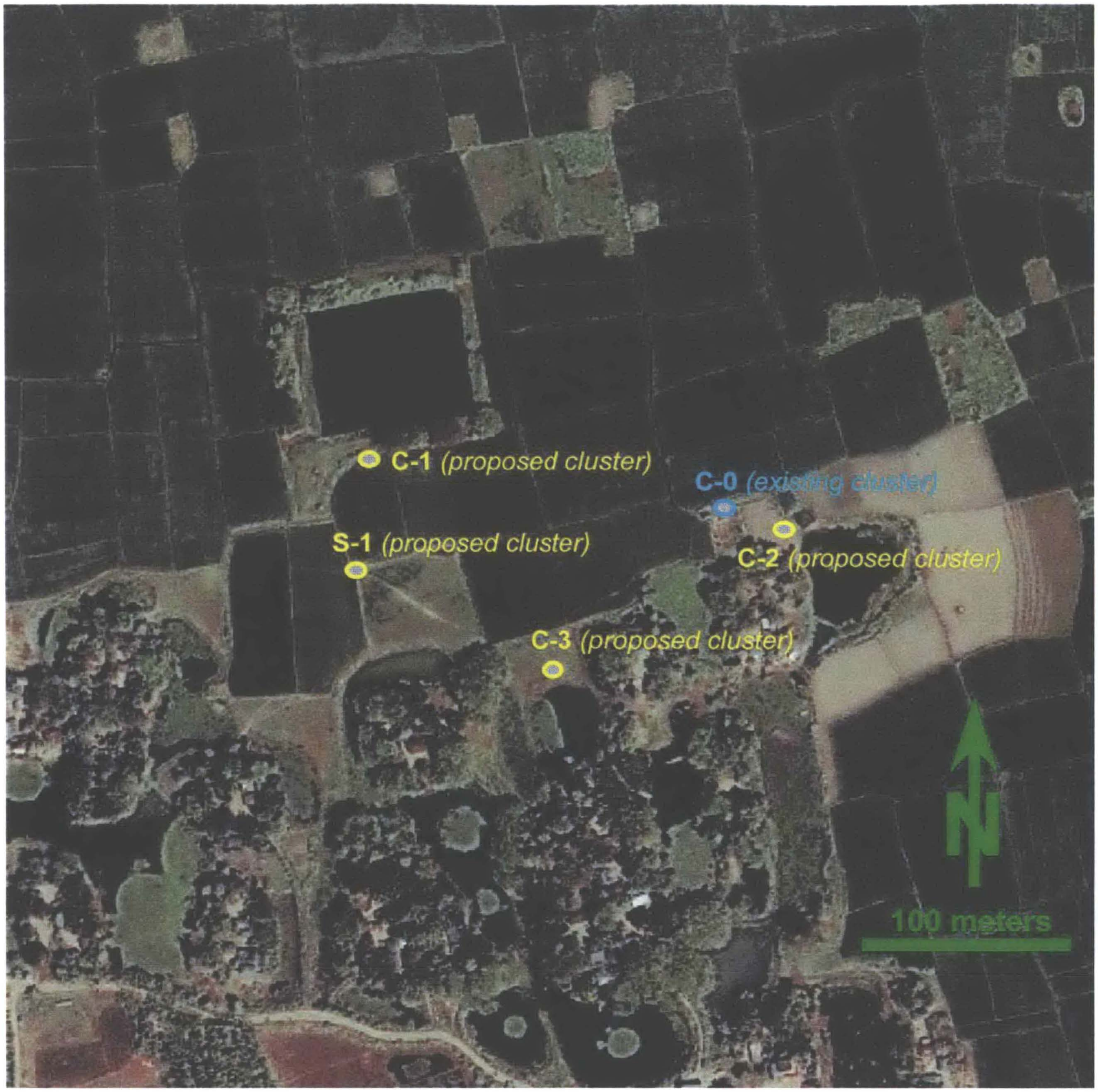


Fig.4.4 Secondary Well Clusters (C1, C2, C3 and S1): Based on the pond hypothesis, four new clusters of wells have been installed – three beside ponds, and away from the pond in the middle of the rice-field. According to the hypothesis (Fig.4.3), the arsenic concentration is assumed to be higher at shallow depths at the clusters C-1, C-2, and C-3, whereas the arsenic profile at cluster S-1 is thought to be somewhat similar to that of cluster C-0.

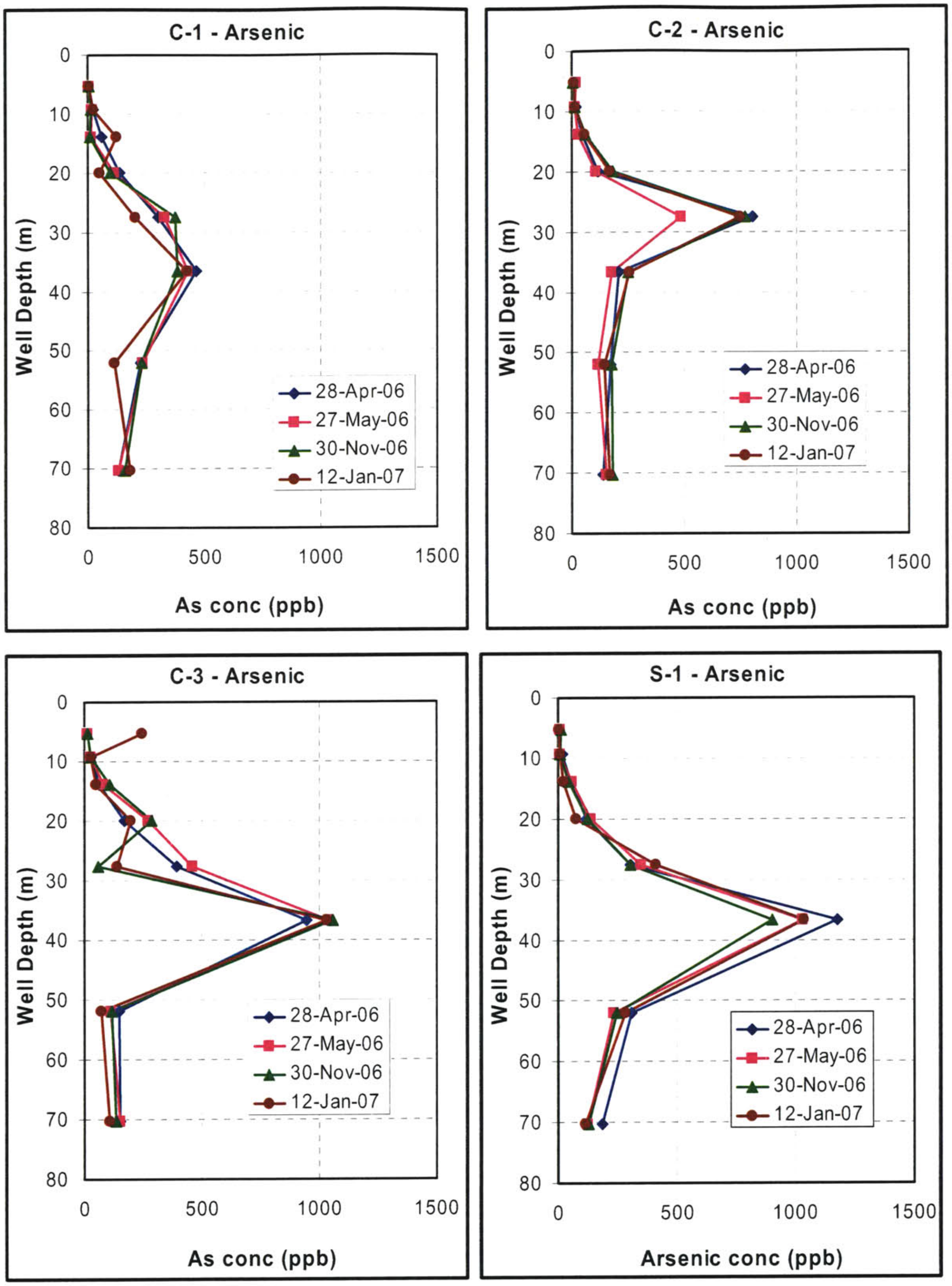


Fig.4.5 Arsenic Profiles at Secondary Clusters: Contrary to the expected profiles in accordance to the pond hypothesis, the arsenic concentration profiles at all the new clusters have been found to be very similar to that of C-0. However, the peak at cluster C-2 is observed at around 27m (similar to at C-0), whereas, the peaks at other clusters are at around 37m.

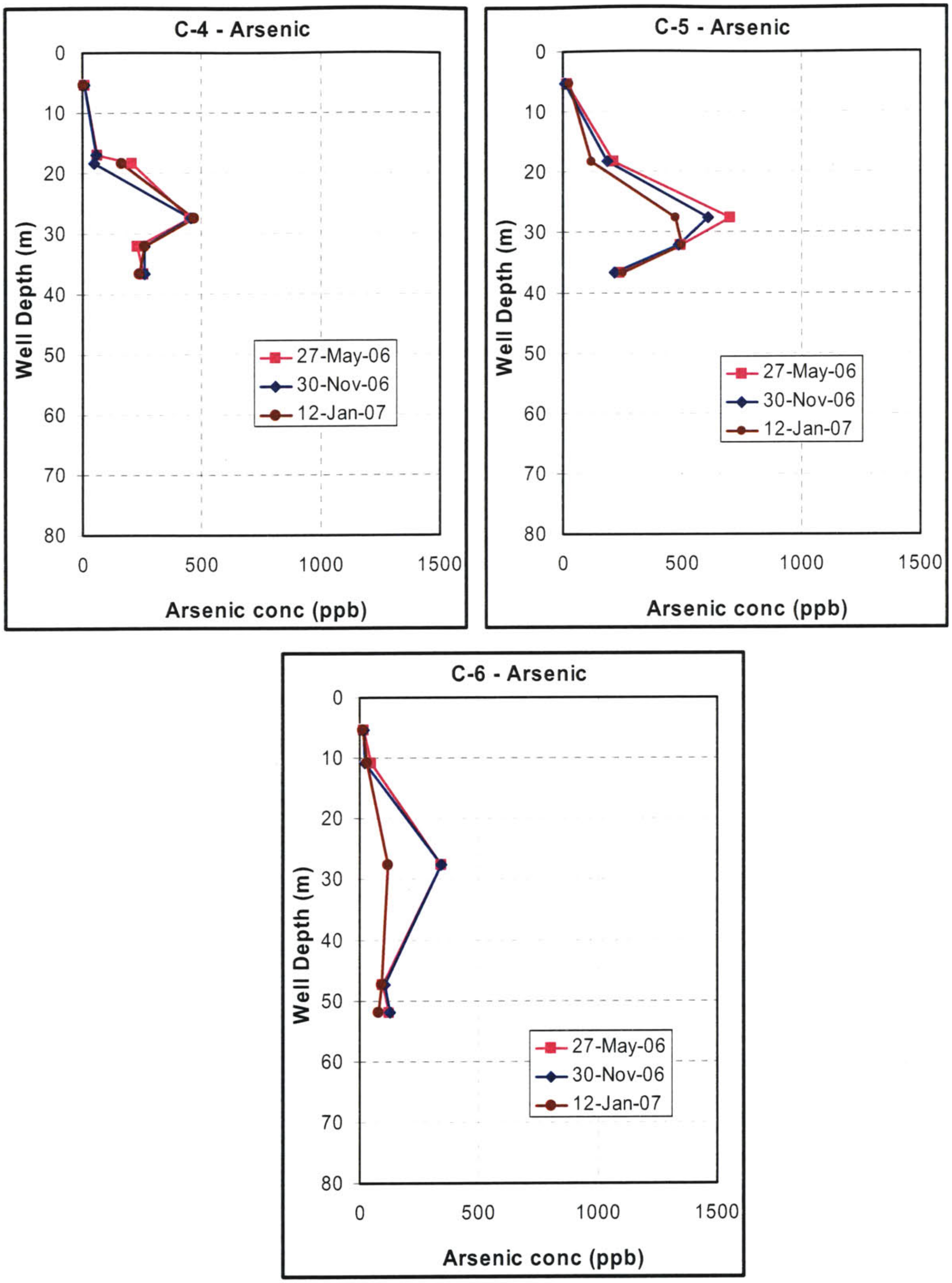
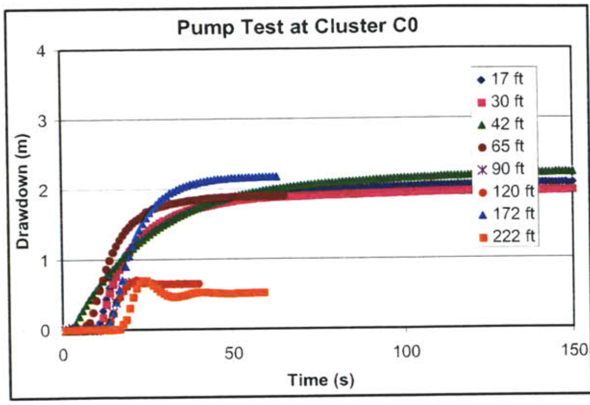
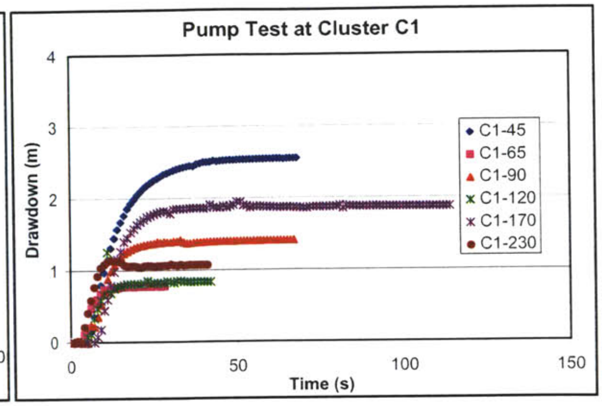


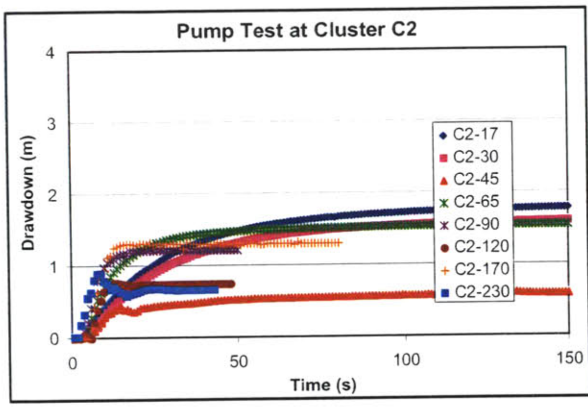
Fig.4.6 **Arsenic Profiles at Tertiary Clusters:** Dissolved arsenic concentration profiles at clusters C-4, C-5 and C-6 show similar pattern as in other clusters, with the peak concentration around 27m at clusters C-4 and C-5 (similar to the neighboring C-0 and C-2 clusters), whereas the peak concentration is at around 37m at cluster C-6 (similar to the neighboring clusters C-1, C-3 and S-1).



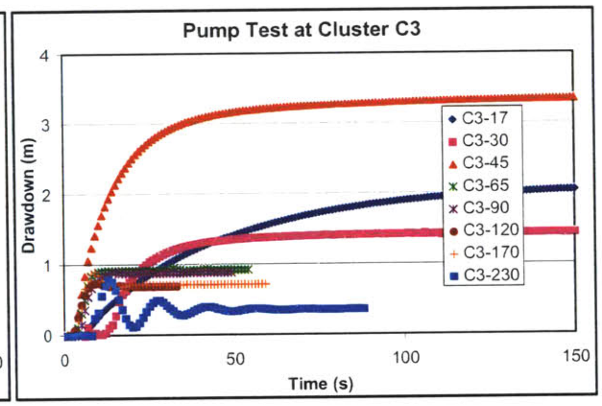
(A) Drawdown at Cluster C0



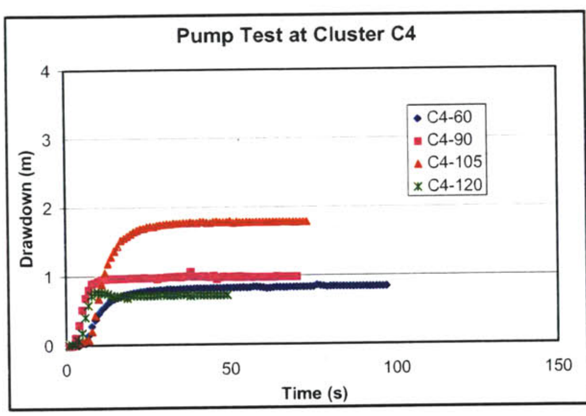
(B) Drawdown at Cluster C1



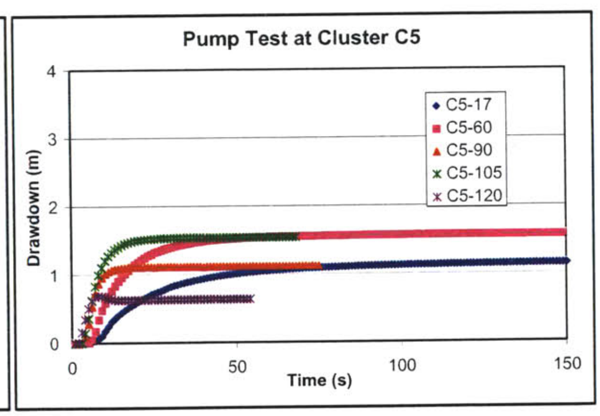
(C) Drawdown at Cluster C2



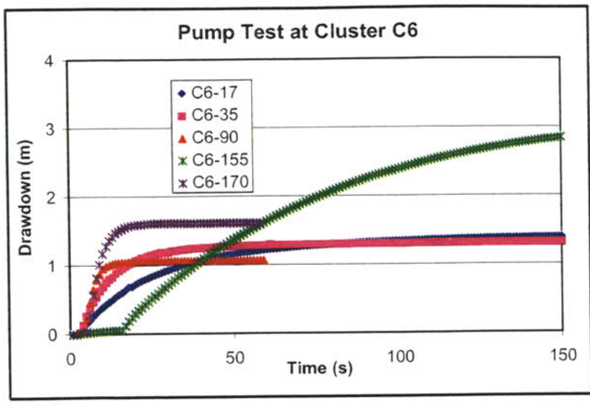
(D) Drawdown at Cluster C3

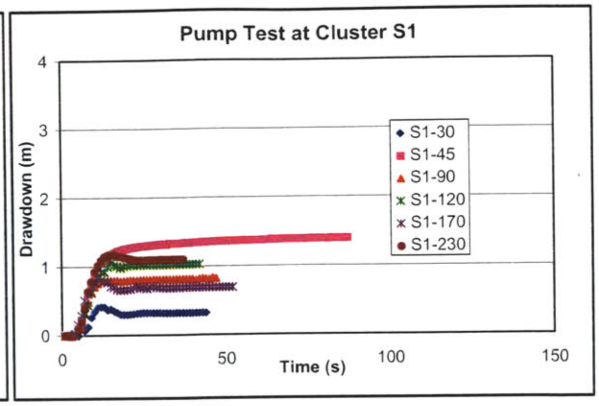


(E) Drawdown at Cluster C4



(F) Drawdown at Cluster C5

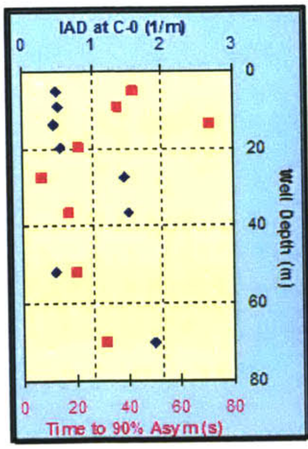




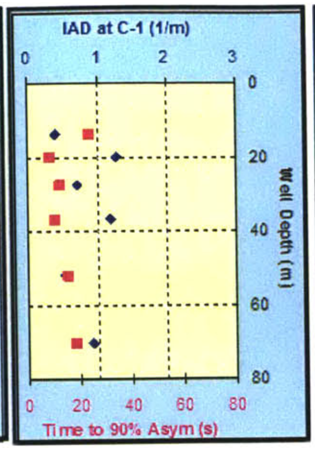
(G) Drawdown at Cluster C6

(H) Drawdown at Cluster S1

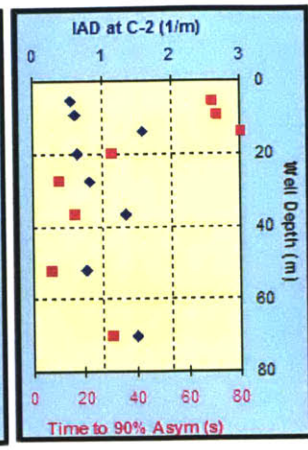
Fig.4.7 Single-well Pump-tests: Single-well pump tests have been carried out in all of the 60 wells at the well clusters using a Grundfos submersible pump with pumping rate ranging between 0.2-0.6 L/s. The panels (A) to (H) show the drawdown at the wells of various well clusters with time. As the plots show, asymptotic drawdown is reached within a minute at most of the wells. Also, the drawdowns at shallower wells are greater compared to those at deeper wells, which indicates increase in hydraulic conductivity with depth.



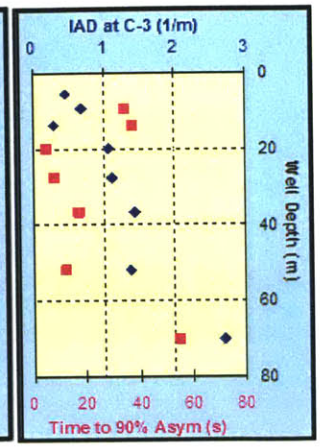
(A) Cluster C0



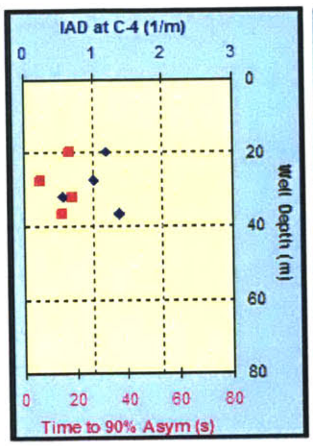
(B) Cluster C1



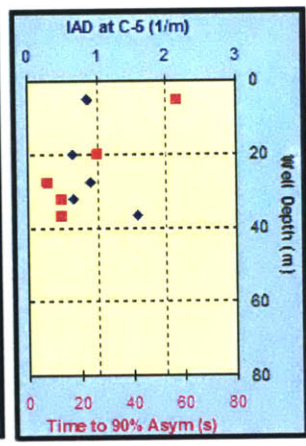
(C) Cluster C2



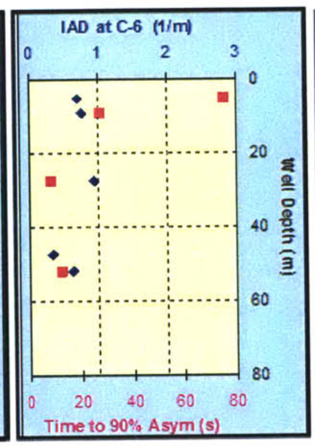
(D) Cluster C3



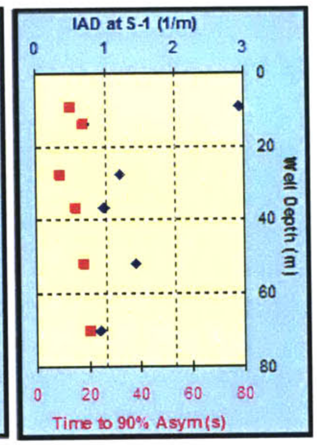
(E) Cluster C4



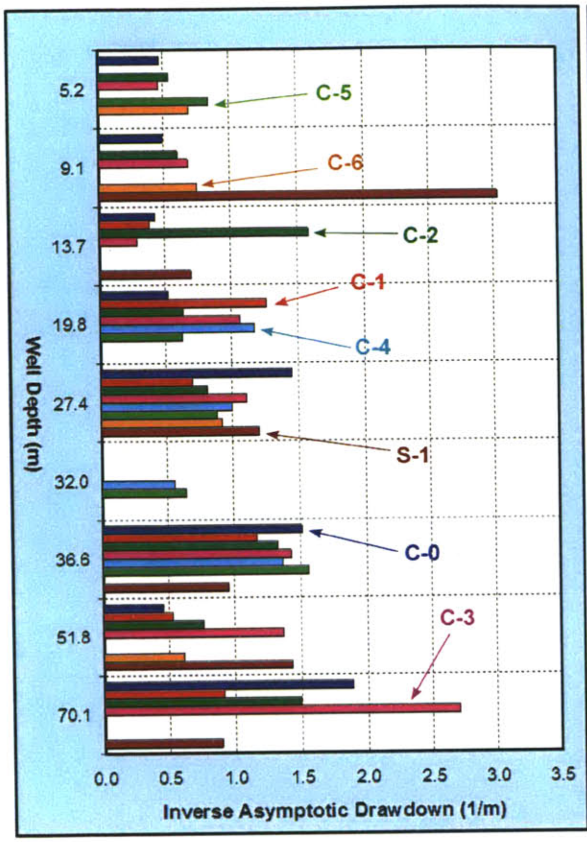
(F) Cluster C5



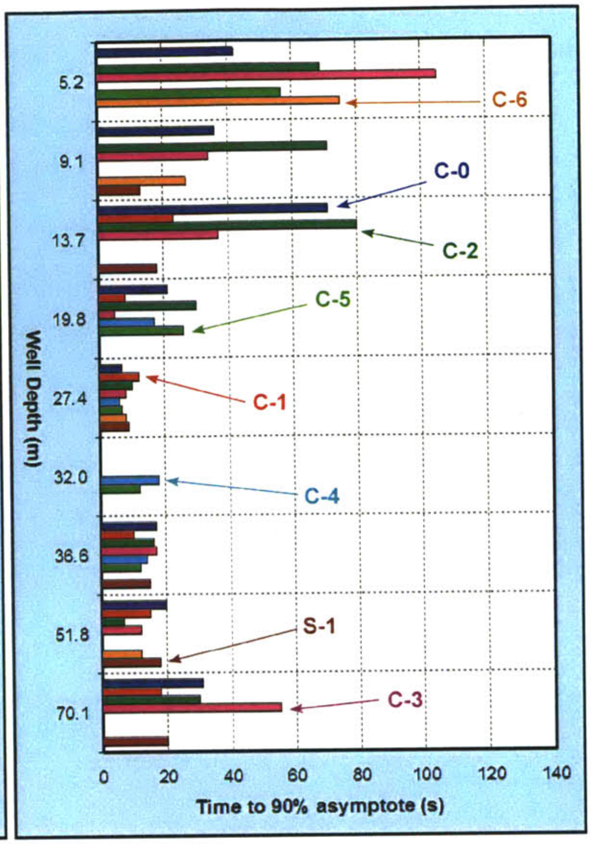
(G) Cluster C6



(H) Cluster S1



(I) Inverse Asymptotic Drawdown



(J) Time to 90% Asymptote

Fig.4.8 Asymptotic Drawdown and Time: Panels (A) to (H) show inverse of asymptotic drawdown (IAD) and time to reach 90% of the asymptotic drawdown for the wells at various well clusters. The inverse plot of asymptotic drawdown provides an idea about the horizontal conductivity surrounding the well-screen, whereas the time required to reach the asymptote relates to the storage property as well. Summarizing the data in panels (I) and (J) reveals that there isn't much difference among the inverse drawdown values throughout the depth, which infers that the transmissivity is fairly constant. However, the time required to reach 90% asymptotic drawdown in larger above 40m depth indicating that storage coefficient is higher above 40m compared to that below 40m.

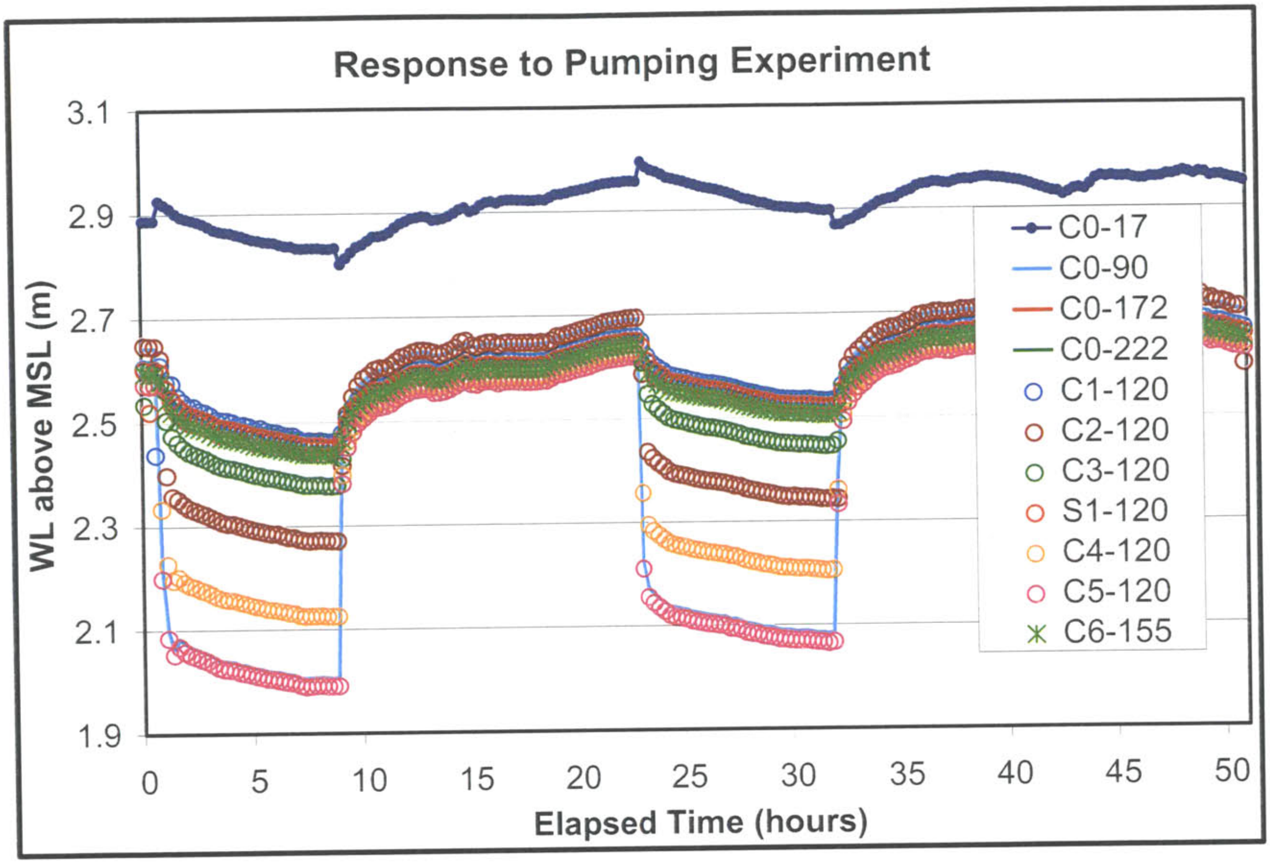
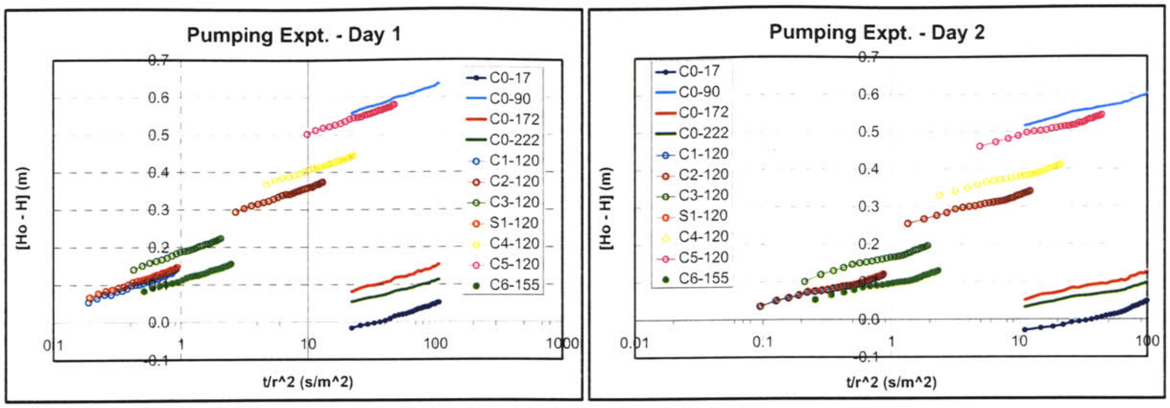


Fig.4.9 Response to Pumping Experiment: fluctuation in water levels in response to the large-scale multi observation well pumping experiment, where the irrigation well, IR-8 is pumped at 15 L/s for two days according to a farmer's schedule, and the change in water levels are observed at various well clusters using Solinst and In-situ probes. As expected, the drawdowns are the largest at the wells closest to the pumping well, and it decreases for the wells further away from the pumping well. Interestingly, "Noordbergum effect" is observed at the shallowest well (5.2m depth), where the well is screened just below the surface clay. The water level at the well drops for a brief period of time when pumping starts, and rises for a short period of time when pumping stops. Such phenomenon is observed when the observation and pumping wells are separated by an aquitard and/or the vertical hydraulic conductivity of the successive layers is significantly different. As a result, mechanical propagation is faster than the hydraulic propagation resulting in such effect.



(A) Pumping Experiment – Day 1 (B) Pumping Experiment – Day 2

Fig.4.10 Day-1 and Day-2 Drawdowns: Panels (A) and (B) shows the drawdowns at various wells with time normalized by the square of distance from the pumping well during the 2-day pumping experiment. The parallel nature of the drawdown lines indicate that the transmissivity in same throughout the aquifer. The two groups of lines refer to the drawdowns at the wells screened at 36.5m and at other depths. The stepping pattern in drawdowns of 36.5 wells and the decreasing trend in drawdown with distance from the pumping well indicates that there is leakance from above and below on the drawdown cones.

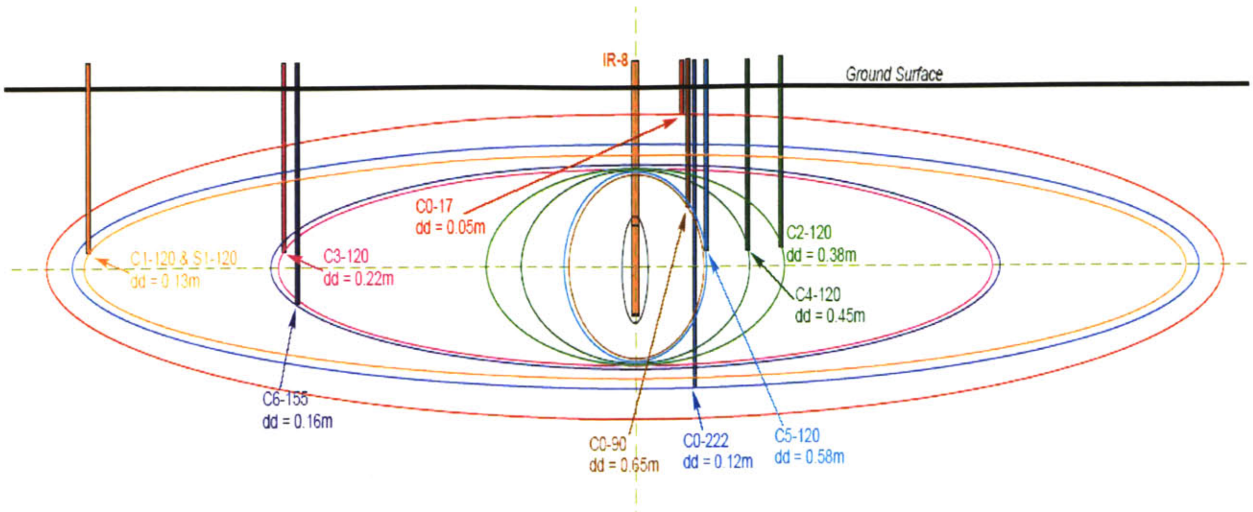


Fig.4.11 Anisotropic Aquifer: Plotting (to scale) the drawdowns at the respective wells produce elliptical contours for the farthest wells, which infers the anisotropic nature of the aquifer. As we move towards the pumping well (IR-8), the drawdowns get greater and the contours loose the elliptical shape. The greatest drawdown is observed at the nearest well of C0-90 to the pumping well, whereas, the smallest drawdown is observed at the farthest wells of C1-120 and S-120 (after C0-17, which is just below the surface clay). Taking the ratio of the long and short axis of the ellipse provides some idea about the degree of anisotropy in the aquifer – a ratio of about 5 in the present case infers that the aquifer anisotropy (ratio of horizontal and vertical hydraulic conductivities) is around 25.

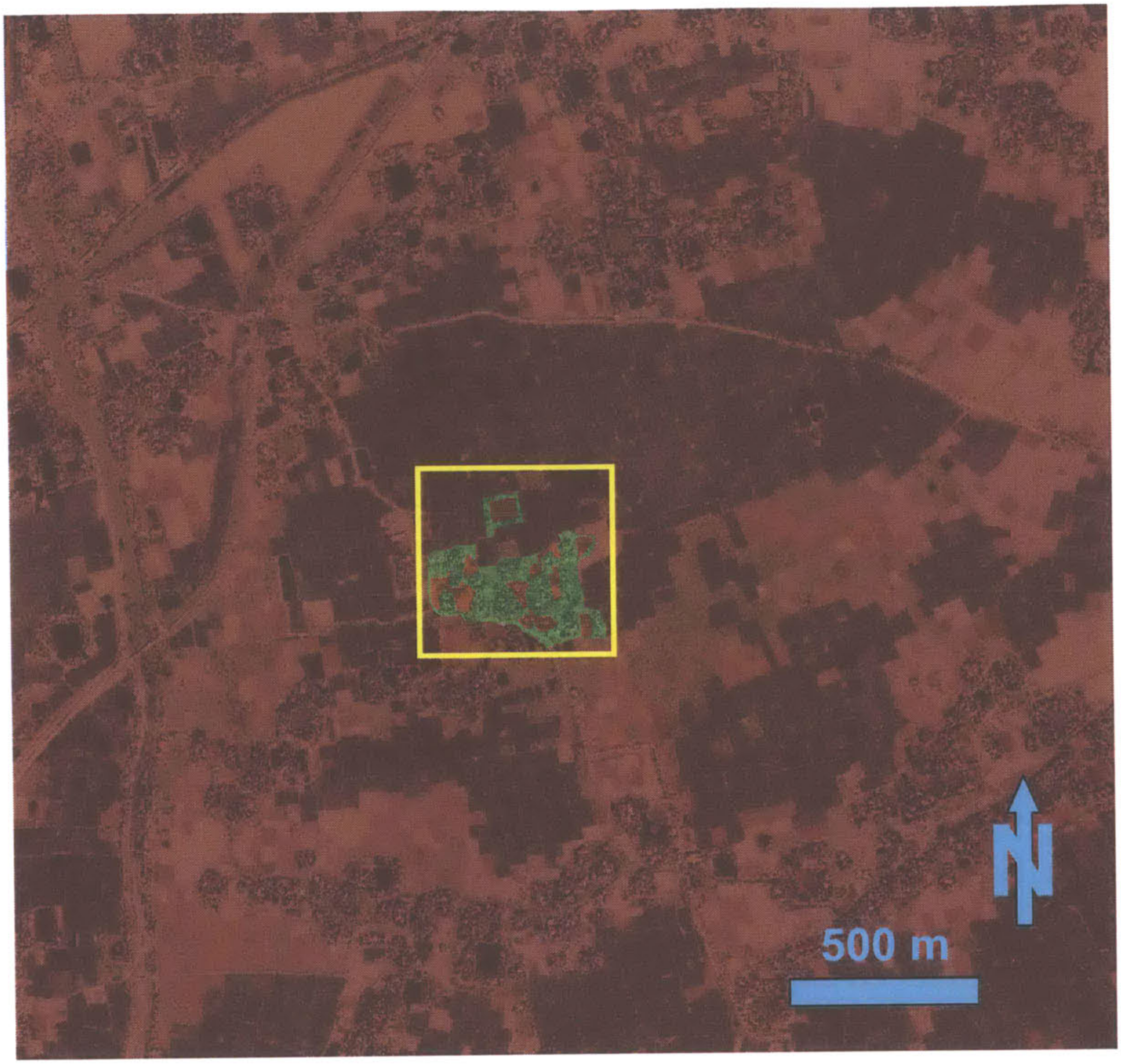


Fig.4.12 Modeling Pumping Experiment: 3km X 3km map view of our study area as modeled using FEFLOW for the 2-day pumping experiment. The model height is 120m in the vertical direction, and the assigned stratigraphy is consistent with the observed data from the sediment samples. The yellow square at the center indicates the 500m X 500m area where the monitoring well clusters and the pumping well are situated. Within the yellow square, the village, field and pond areas have been identified, whereas the area outside the yellow square have been modeled as field areas.

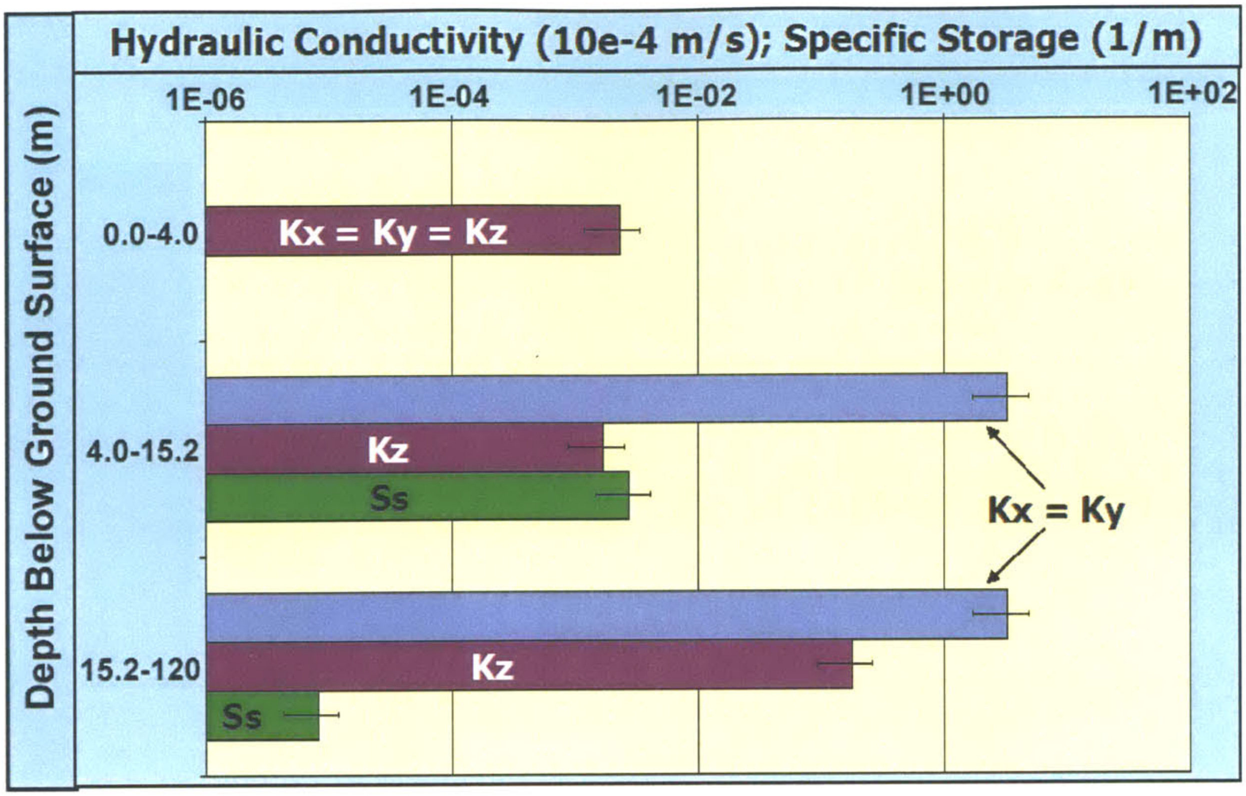
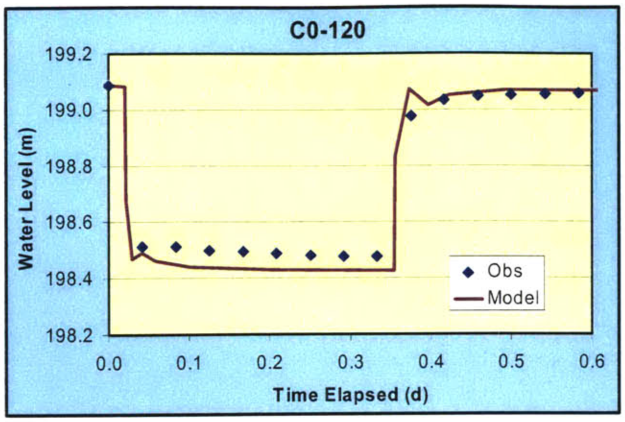
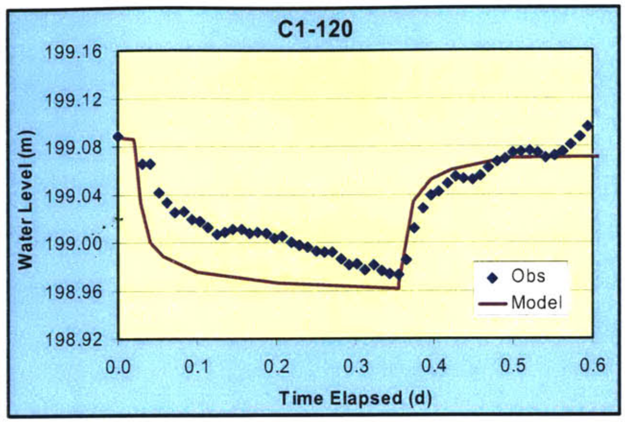


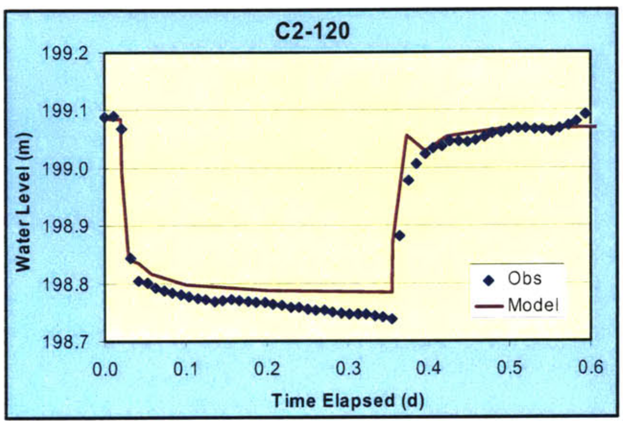
Fig.4.13 Estimated Parameters from Pumping Experiment: For the 500m x 500m study area, we have estimated 6 parameters: the hydraulic conductivity of field, single horizontal conductivity for the entire aquifer since we have observed from the single well pump tests and the large scale pumping experiment that the conductivity or the transmissivity of the aquifer is same throughout the entire depth. Also, the single well pump tests indicate that specific storage is different above and below 15m – so, we have estimated it for two aquifer segments – 4-15m and 15-120m depths. However, the pump tests do not give the vertical conductivities, so, we have estimated that for the two aquifer segments. Interestingly, the ratio of the estimated horizontal and vertical conductivities for the depth 15-120m has been found to be about 25, as anticipated from the drawdown contours (Fig.4.6)



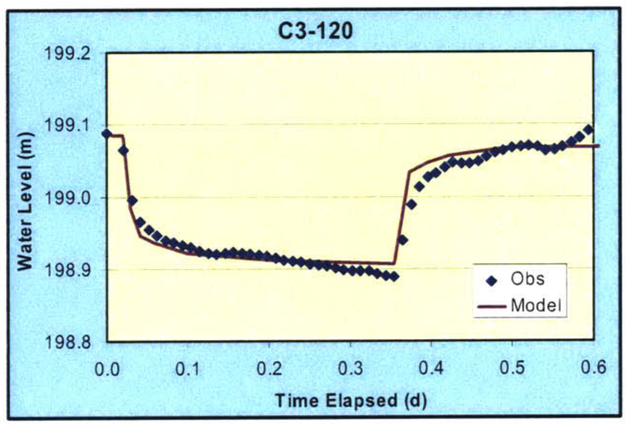
(A) Heads at Cluster C0



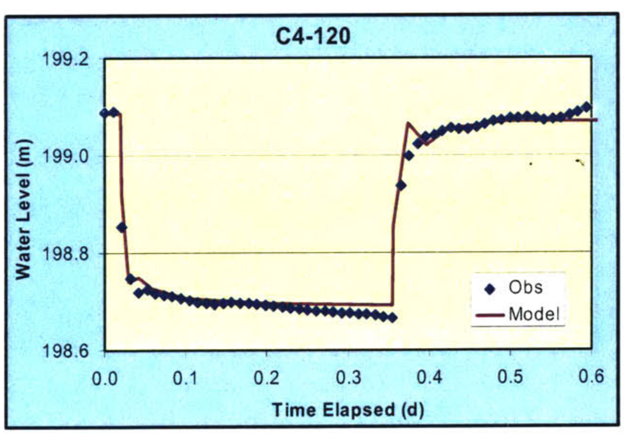
(B) Heads at Cluster C1



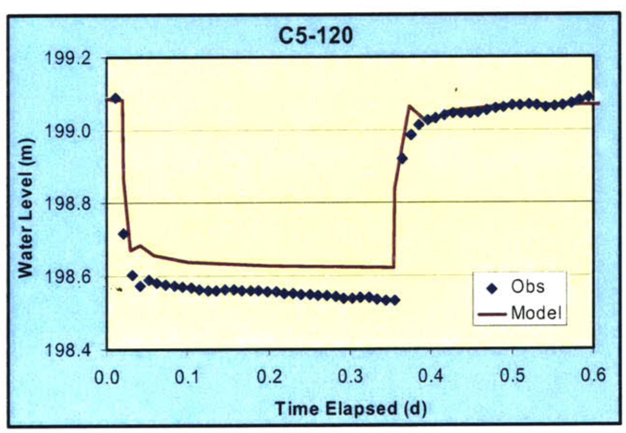
(C) Heads at Cluster C2



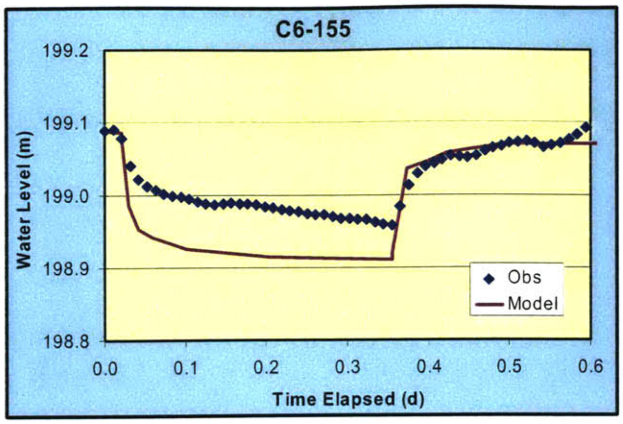
(D) Heads at Cluster C3



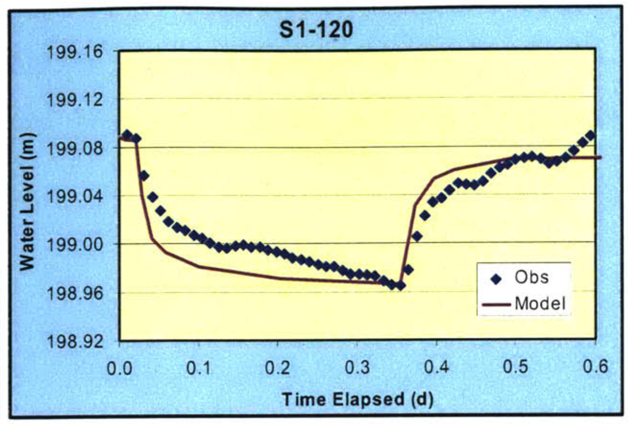
(E) Heads at Cluster C2



(F) Heads at Cluster C3

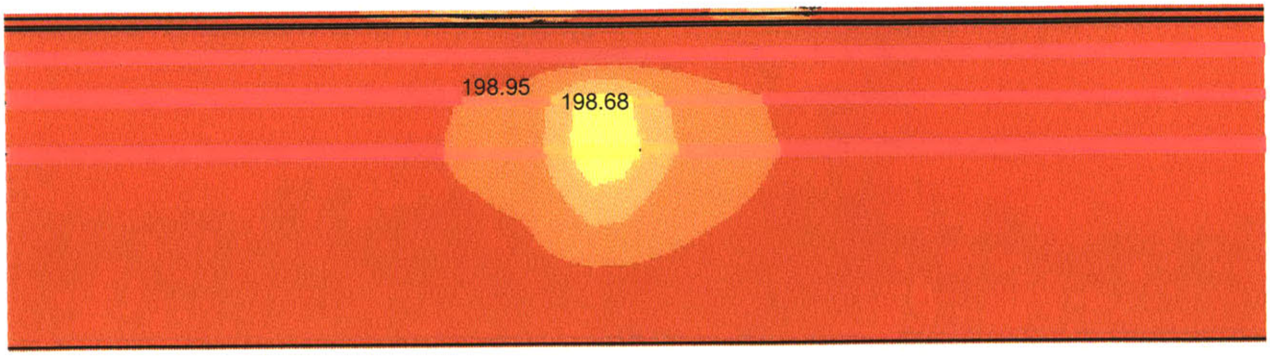


(E) Heads at Cluster C2

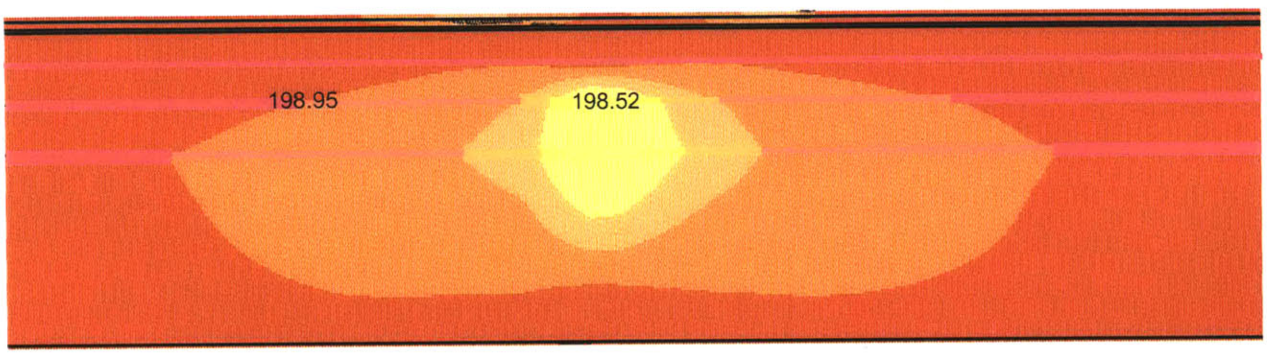


(F) Heads at Cluster C3

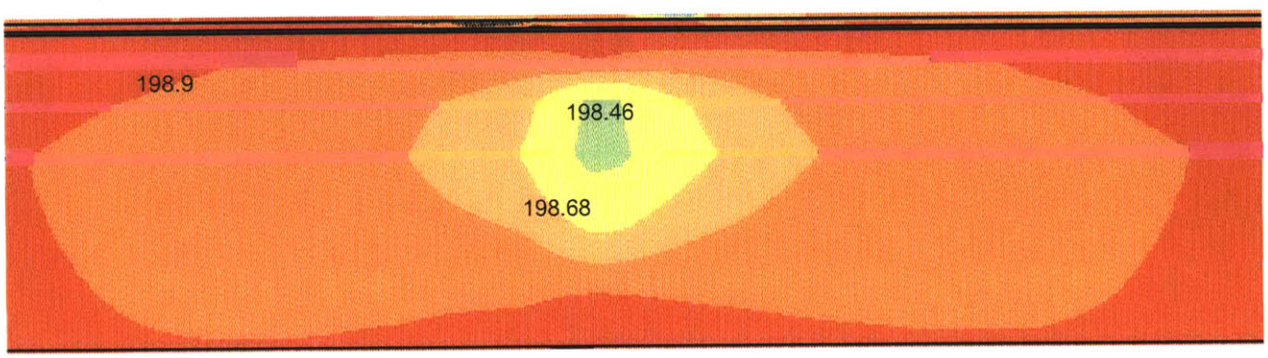
Fig.4.14 Comparison of Observed and Modeled Heads: Day-1 pumping data has been used to calibrate the FEFLOW 3D model. Comparison of the observed and model heads at all the clusters show good agreement inferring a good calibration of the model with respect to the pumping experiment data.



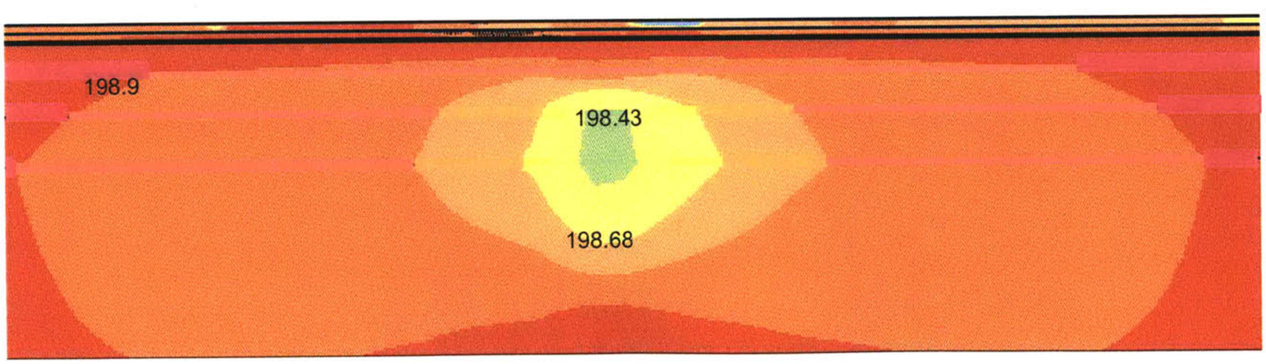
(A) Head contours at 0.021 day



(B) Head contours at 0.040 day

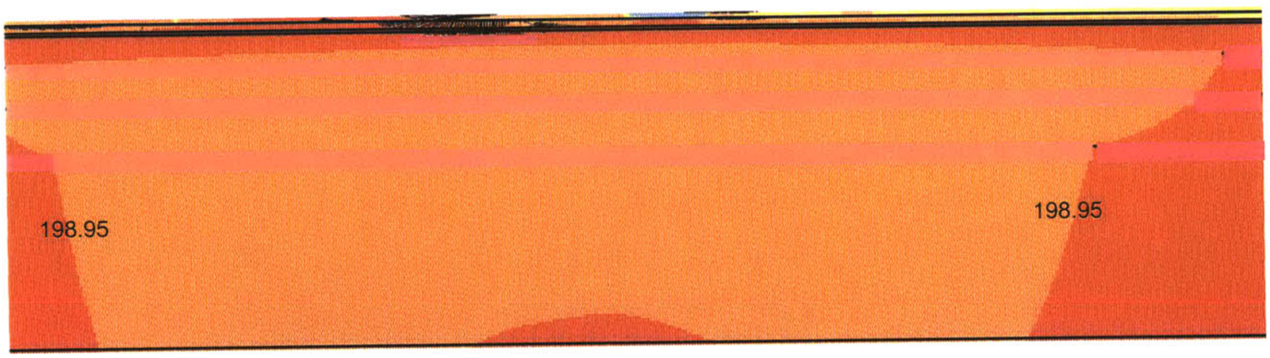


(C) Head contours at 0.124 day

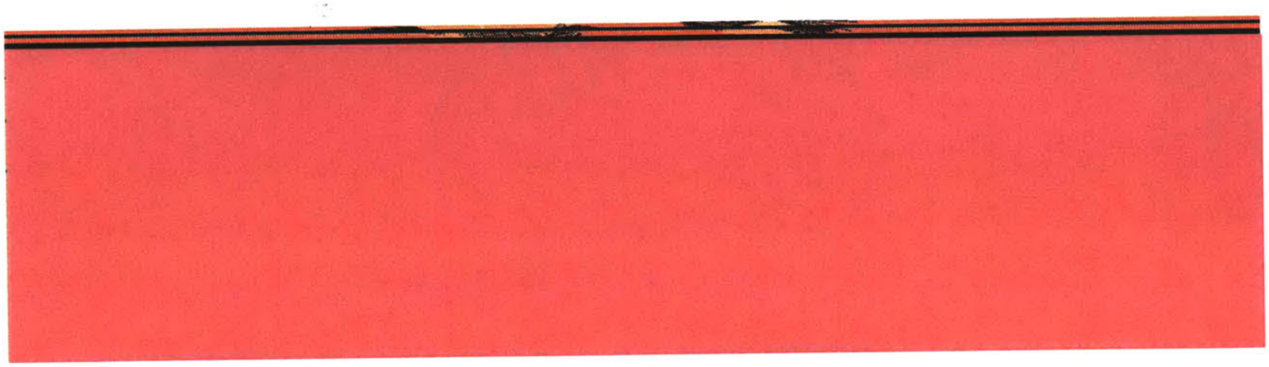


(D) Head contours at 0.198 day

(E) Head contours at 0.355 day



(F) Head contours at 0.367 day



(G) Head contours at 0.570 day

Fig.4.15 Head Contours: Panels (A) to (G) show the head contours at a vertical cross-section through the middle of the modeled area. At the beginning of pumping at 0.021 day, the head contours show up around the pumping well. As the pumping progresses, the head contours develop an elliptical shape, similar to Fig.4.5, indicating the anisotropic nature of the aquifer. The head contours revert back when pumping is stopped at 0.355 days, and goes back to its original stage after 0.57 days.

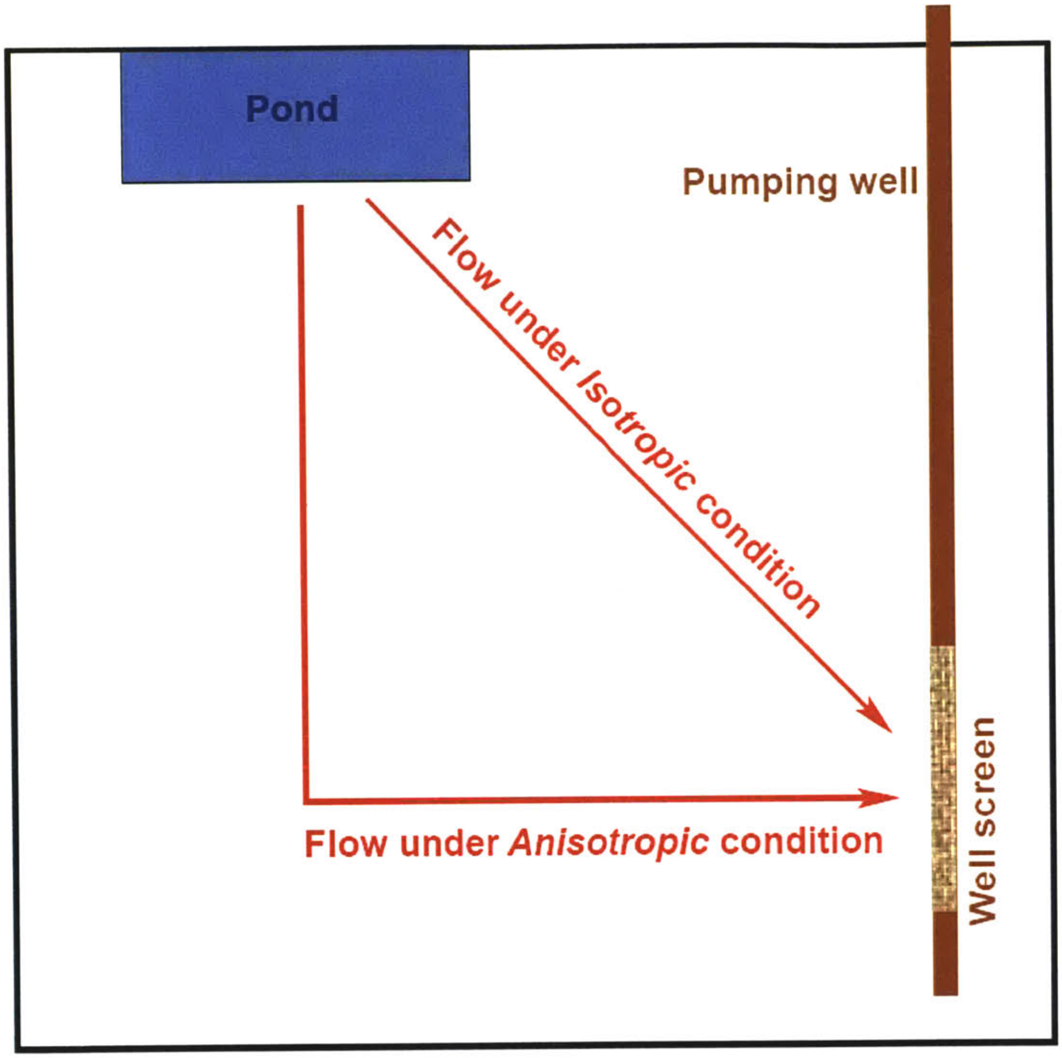


Fig.4.16 Modified Hypothesis: The cartoon depicts groundwater flow-paths for two extreme cases: completely isotropic and completely anisotropic cases. For the isotropic case, the flow paths converges directly towards the pumping depth, whereas, under the anisotropic scenario, groundwater tends to move vertically down at first before flowing horizontally towards the pumping well. According to the modified hypothesis under the anisotropic aquifer scenario, it can be thus hypothesized that the movement of the high arsenic plume is mostly vertical at the beginning followed by more horizontally converging flow around the depth of the pumping well screen.

Chapter 5

Groundwater Flow Models

5.1. Lumped Parameter Model

5.1.1. Model Background and Setup

In order to estimate the fluxes between the aquifer and the river, ponds, rice fields and villages, a dynamic zero-dimensional lumped parameter (or boxed) model has been developed for our study area in Munshiganj (Fig.5.1). Since the temporal gradients in hydraulic heads are much larger than the spatial gradients within the aquifer in our study area (Fig.3.4), the governing equations in the lumped parameter model are only time-dependant:

Aquifer:

$$S\frac{dh_a}{dt} = (h_f - h_a)k_f f_f + (h_p - h_a)k_p f_p + (h_r - h_a)k_r f_r + (h_v - h_a)k_v f_v - q_I - f_{av}\alpha_v ET_0 \quad (5.1)$$

Village:

$$S_y\frac{dh_v}{dt} - (h_a - h_v)k_v - (1 - f_{av})\alpha_v ET_0 + R \quad (5.2)$$

Field:

$$S_y\frac{dh_f}{dt} = (h_a - h_f)k_f - \alpha_f ET_0 + R + \frac{q_I}{f_f} \quad (5.3)$$

Pond:

$$\frac{dh_p}{dt} = (h_a - h_p)k_p - \alpha_p ET_0 + R \quad (5.4)$$

where,

h_a head in the aquifer $[L]$

h_f head (water level) in the rice fields $[L]$

h_p head (water level) in the ponds $[L]$

h_v head in the non-irrigated areas (e.g. villages) $[L]$

h_r the river stage, a function of time $[L]$

q_l the pumping rate $\left[\frac{L}{T}\right]$

ET_0 the reference crop evapotranspiration $\left[\frac{L}{T}\right]$

R the rainfall rate $\left[\frac{L}{T}\right]$

k_r hydraulic conductance between the river and the aquifer $\left[\frac{1}{T}\right]$

k_f hydraulic conductance between the rice fields and the aquifer $\left[\frac{1}{T}\right]$

k_p hydraulic conductance between the ponds and the aquifer $\left[\frac{1}{T}\right]$

k_v hydraulic conductance between the non-irrigated areas and the aquifer $\left[\frac{1}{T}\right]$

α_v the scaling factor for non-irrigated area transpiration (i.e. trees; 0.95)

α_f the scaling factor for rice field evapotranspiration (0.90)

α_p the scaling factor for pond evaporation (i.e. pan evaporation; 1.40)

S storativity of the aquifer (set as 0.01 assuming a specific storage of 0.0001 1/m for a 100m thick aquifer)

S_y specific yield of near-surface clay (0.2; this value is set to 1 when the head is above the land surface indicating standing water in the rice fields)

f_f fraction of area covered by fields (65%)

f_p fraction of area covered by ponds (10%)

f_v fraction of area covered by nonirrigated areas (e.g. villages; 23%)

f_r fraction of areas covered by rivers (2%)

f_{av} aquifer-clay partition coefficient (fraction of ET_{tree} coming out of aquifer)

In the model, the hydraulic head values of the aquifer, ponds, villages, and field areas are set as observed data (i.e. to which the model has been calibrated). The specific yield of the clay, storativity of the aquifer, river stages, pumping rate, rainfall and evapotranspiration (30-year average) data are specified (i.e. as model inputs). The model period is from 7-Nov'03 to 18-Jul'04 (i.e. 255 days).

At first, the model has been used to estimate the unknown hydrologic parameter (e.g. the hydraulic conductance between the aquifer and the river, pond, field and village; Table 5.1), and then the calibrated model has been used to estimate the various fluxes in and out of the aquifer for two different scenarios (Fig.5.2 and 5.3) (Harvey, Ashfaque et al. 2006).

Table 5.1: The estimated conductance parameter values when the storage coefficients are fixed, the respective objective functions (sum of square errors), and modeled residence times for the aquifer:

		Village ET from	
		Clay (Case A)	Aquifer (Case B)
k_f (1/d) [conductance for field]		$8.9X10^{-4}$	$8.9X10^{-4}$
k_v (1/d) [conductance for village]		$6.3X10^{-6}$	$9.1X10^{-4}$
k_p (1/d) [conductance for pond]		$9.3X10^{-3}$	$8.3X10^{-3}$
k_r (1/d) [conductance for river]		$7.7X10^{-2}$	$8.7X10^{-2}$
Objective Function	***w/ pumping***	0.59	0.57
Residence Time (yrs)	***w/ pumping***	19	13
	w/o pumping	42	22

[adapted from (Harvey, Ashfaque et al. 2006)]

Fig.5.2 shows the comparisons of modeled heads with those with the measured heads for the two cases – transpiration through village trees are extracted from the village clay and the aquifer, respectively. In general, the modeled heads compare well with the measured heads indicating a good estimation of the model parameters. Fluxes for the two cases mainly differ due to the source of transpiration through the trees. However, the fluxes for the "with pumping" and "without pumping" scenarios are significantly different in both cases. Fig.5.3 also supports the fact that the sources of inflow for the "with pumping" scenario are different from that of "without pumping". The plot shows that for the "with pumping" scenario, the major discharge is due to pumping, whereas the rice field and pond areas are the major contributors to the aquifer recharge. Results also indicate that the residence time is halved in the "with pumping" scenario (Table 5.1). Moreover, in the past, there were fewer ponds, and therefore, residence time would have been much longer in the "without pumping" scenario.

5.1.2. Model Limitations and Improvements

As can be seen from the figure (Fig.5.4), the model output lags in two areas: (1) the predicted heads (specially that for the field) differ more from the observed heads when the rainfall and ET values are changed from a 30-year average to actual data for the modeling period; and, (2) the model cannot produce the two humps in the rising aquifer head. The rainfall database and the inferred pumping duration (Fig.5.5) indicate that farmers stop their irrigation pumps on the days when it rains adequately. Accordingly, the pumping in the model has been stopped for specific days, and that have resulted the model to produce the humps which coincide nicely with those in the observed aquifer head (Fig.5.6). In addition, a slight reduction in the hydraulic conductance of the field area has improved the model prediction of the field head.

5.1.3. Changing Model Time-scale – from daily to hourly

After the modifications in the model setup and parameter value, the lumped-parameter model has been used to predict the hourly aquifer heads. For this purpose, the model has been zoomed into the peak pumping period – from April 1 to April 12 of 2004. In order to simulate the hourly aquifer head, the pumping module of the model is changed from a diurnal function to an hourly step-function: 12 hours of pumping at 24 L/s from 6AM-6PM and 12 hours of rest period from 6PM-6AM. The time dimension of other inputs and parameters is changed to hour to be consistent with the unit. Fig.5.7 shows that the predicted aquifer head matches well with that of the observed head, and thereby, demonstrates the applicability of the model at different time scales.

Assuming the hydraulic heads in the ponds, villages and fields are at steady-state between the period of April 1 and April 12, 2004, the analytical equation of aquifer head (eq. 5.1) for the hourly-scale model can be written as:

$$\frac{dh_a}{dt} = A + B.h_a + C.g(t) \tag{5.5}$$

where,

h_a	head in the aquifer (m)
A	a constant of value 0.455 m/d (or 0.019 m/hr)
B	a constant of value -0.322 m/d (or -0.013 m/hr)
C	a constant of value -4000

g(t) a step function for pumping – pumping occurs from 6AM-6PM and stops from 6PM-6AM

The values of the coefficients A and B have been calculated from the aquifer, pond, field, village and river head values for the 457th day (April 1 – beginning of the hourly model) of the diurnal model. The slope of the theoretical curve increases with the increase in the magnitude of coefficient A or decrease in the magnitude of coefficient B, which indicates increased amount of flow from the pond, field, village and river areas into the aquifer resulting in increasing aquifer head. The coefficient C is the inverse of storativity (0.01) times the number of pumps. With the increase in the number of pumps or decrease in the storativity value, the amplitude of the theoretical curve increases indicating greater response in the aquifer head. As can be seen from Fig.5.8, the theoretical aquifer head matches well with that of the observed data.

Furthermore, solving the analytical equation for the aquifer head, the solution becomes:

$$h_a = -\left(\frac{A}{B}\right) + C_0.e^{Bt} + C.e^{Bt}\int e^{-Bt}.g(t).dt \tag{5.6}$$

where,

C_0 a constant evaluated at time zero

After plotting the analytical solution (Fig.5.9) it becomes evident that similar to the theoretical equation, the solved aquifer head values also match very well with the observed aquifer head data.

5.1.4. Limitation of the Lumped Model

As can be seen from the Fig.5.7, the model simulations cannot replicate the hourly probe data well enough after about 130 hours. This might be due to the fact that the actual pumping schedule, rate and duration after the rain event are probably different from those in the model. Farmers might have started pumping quite later following the rain event, as well as used a lower pumping rate and/or shorter duration resulting in a greater jump in the aquifer head. However, since the actual pumping data is not available for that particular period of time, no further modification has been carried out.

Furthermore, and more importantly, the lumped model only provides information on fluxes from various generic sources (e.g. ponds and rice fields). But since it is a zero dimensional model, it does not provide any information about the groundwater flow paths, which is important to understand the characteristic arsenic profile in our study area.

5.2. MODFLOW Model:

5.2.1. Model Background and Setup

In order to understand the groundwater flow dynamics that may be influencing the mobilization of arsenic and to investigate the impacts of irrigated agriculture on the natural groundwater flow patterns, a transient three-dimensional groundwater model has been developed (Yu 2003) for the 4km X 4km study area in Sreenagar, Munshiganj (Fig.3.2) using the Finite Difference model, MODFLOW.

At first, the $16km^2$ study area has been discretized into 6400 square elements with grid-size of 50m X 50m. Afterwards, the various hydrologic features have been mapped out in the grided model with the appropriate area coverage: pond (~10%), river (~2%), village (~23%), rice field (~25%) irrigated by 46 irrigation wells, and other field (~40%). Fig.5.10 shows the grided study area in MODLFOW where the yellow, brown, green, sky-blue, dark-blue and gray squares represents the pond, river, village, rice field, irrigation well and other field areas, respectively. The pink squares denote the no-flow boundary outside the model where the model cells have been set as "inactive".

In the vertical direction, the model height of 201m (with the datum set at zero) has been divided into 19 hydrogeologic layers of non-uniform thickness to represent the observed stratigraphy (Fig.5.11). Based on the literature values and the extensive pump tests carried out at the well-cluster in the old field-site, the conductivity (anisotropy of 1 is assumed) and storage parameters for the different layers have been found as:

Table 5.2 Numerical Groundwater Model Layers in MODFLOW Model

Model Layer	Layer Type	Layer Top (m)	Layer Bottom (m)	Layer thickness (m)	Hydraulic Conductivity (m/s)	Specific Storage (1/m)	Specific Yield
1	Air	201.0	200.0	1.0	1.0	1.0	1.0
2	Surface Clay	200.0	199.0	1.0	1.0E-07	1.0E-02	0.03
3	Surface Clay	199.0	198.0	1.0	1.0E-07	1.0E-02	0.03
4	Surface Clay	198.0	197.0	1.0	1.0E-07	1.0E-02	0.03
5	Surface Clay	197.0	196.0	1.0	1.0E-07	1.0E-02	0.03
6	Sand	196.0	193.1	2.9	4.0E-05	1.0E-02	0.0
7	Sand	193.1	190.1	3.0	8.2E-05	1.0E-02	0.0
8	Sand	190.1	188.6	1.5	8.2E-05	1.0E-02	0.0
9	Sand	188.6	184.0	4.6	2.5E-04	1.0E-04	0.0
10	Sand	184.0	175.6	8.4	3.6E-04	1.0E-04	0.0
11	Sand	175.6	165.7	9.9	1.2E-04	1.0E-04	0.0
12	Sand	165.7	158.1	7.6	1.8E-04	1.0E-04	0.0
13	Sand	158.1	146.7	11.4	2.2E-04	1.0E-04	0.0
14	Sand	146.7	131.4	15.3	3.9E-04	1.0E-04	0.0
15	Sand	131.4	108.6	22.8	2.4E-04	1.0E-04	0.0
16	Sand	108.6	81.1	27.5	7.2E-05	1.0E-04	0.0
17	Marine Clay	81.1	65.9	15.2	1.0E-09	1.0E-03	0.0
18	Marine Clay	65.9	50.6	15.3	1.0E-09	1.0E-03	0.0
19	Sand	50.6	0.0	50.6	3.9E-05	1.0E-04	0.0

(Yu 2003)

It should be noted that layer-1 represents a 1m of air above ground surface to simulate the application and ponding of irrigation waters for rice production. Horizontal and vertical conductivities are assigned an artificially large value of 1 m/s for these cells.

Other model attributes include:

MODFLOW Packages: Recharge, Evapotranspiration, General Head Boundary, Wells, and Wetting Capability

Initial condition: End of flood (starting head 200m – assuming hydraulic heads are uniform throughout the model domain and equivalent to the surface elevation of 200 m)

Boundary condition: No flow boundary on the sides

Simulation time: 12-Nov'03 to 22-Jun'04 (total 224 days) i.e., for the dry season period. Observation of water-levels of different hydrologic features (Fig.3.15) infers that there is very little hydraulic gradient during the flooding period (mid-June to early November) and therefore, groundwater flow ceases during that time.

Simulation steps: 32 weekly Stress Periods, each consists of one weekly Time Step

Specified data: River heads, rainfall, area-specific evapotranspiration, pumping rate

Observation data: Hydraulic heads of the aquifer, pond and rice field areas

Parameters: Hydraulic conductivity, specific storage and specific yield of field, village, pond bottom, river border & bottom, and aquifer

5.2.2. Model Limitations and Improvements

Modeled results show (Yu 2003) that the simulated head differs quite significantly from the observed aquifer head, and hence, needs improvement to be representative of the study area. Furthermore, there have been some inconsistencies in the previous model that are fixed in the improved model as follows:

- In Sreenagar, the villages are about at a 3m higher elevation than that of the other areas. However, in the previous model, village areas have been assigned the same elevation as other areas. In the improved model, the thickness of the air layer has been increased to 3m, and the elevation of the village areas have been changed to 203m (Fig.5.12)

- The previous model has some ambiguous irrigation wells and rice field areas that has been corrected after several extensive field trips in the study area.

- The database for the model has also been improved by replacing the average rainfall, ET and water-level data with actual rainfall, ET and bi-weekly measured water-level data for the modeling period.

- Previously, the pond and river cells have been assigned specific storage of 1 in the model, which means that the particular cells have a very large storage of water. Therefore, any decline in the water level will be covered by water supply from the storage. In the improved model, the specific storage for the pond and river cells has been assigned as zero since there is no storage of water.

- However, the most important and significant change in the model has been the simulation of actual pumping scenario during rain events. When it rains, there is no need to irrigate the rice field, and so, farmers do not operate their irrigation wells during rain events. However, in the previous model, pumping has been carried out continuously throughout the irrigation period, even during the rain events. In the improved model, pumping is stopped based on rainfall records and pumping database. For this purpose, a number of weekly stress periods have been replaced by daily stress periods during the rain events. In addition, several weekly stress periods have been divided into daily time steps [Table 5.3]:

Table 5.3: Simulation Steps in the Improved MODFLOW Model

Stress Period	Model Date (1st day)	Model Date (last day)	Days Interval	Time Steps
1	11/12/2003	11/18/2003	7	1
2	11/19/2003	11/25/2003	7	1
3	11/26/2003	12/2/2003	7	1
4	12/3/2003	12/9/2003	7	1
5	12/10/2003	12/16/2003	7	1
6	12/17/2003	12/23/2003	7	1
7	12/24/2003	12/30/2003	7	1
8	12/31/2003	1/6/2004	7	1
9	1/7/2004	1/13/2004	7	1
10	1/14/2004	1/20/2004	7	1
11	1/21/2004	1/27/2004	7	1
12	1/28/2004	2/3/2004	7	1
13	2/4/2004	2/10/2004	7	1
14	2/11/2004	2/17/2004	7	1

15	2/18/2004	2/24/2004	7	1
16	2/25/2004	3/2/2004	7	1
17	3/3/2004	3/9/2004	7	1
18	3/10/2004	3/16/2004	7	1
19	3/17/2004	3/23/2004	7	1
20	3/24/2004	3/30/2004	7	1
21	3/31/2004	4/6/2004	7	7
22	4/7/2004	4/7/2004	1	1
23	4/8/2004	4/8/2004	1	1
24	4/9/2004	4/9/2004	1	1
25	4/10/2004	4/10/2004	1	1
26	4/11/2004	4/11/2004	1	1
27	4/12/2004	4/12/2004	1	1
28	4/13/2004	4/13/2004	1	1
29	4/14/2004	4/20/2004	7	7
30	4/21/2004	4/21/2004	1	1
31	4/22/2004	4/22/2004	1	1
32	4/23/2004	4/23/2004	1	1
33	4/24/2004	4/24/2004	1	1
34	4/25/2004	4/25/2004	1	1
35	4/26/2004	4/26/2004	1	1
36	4/27/2004	4/27/2004	1	1
37	4/28/2004	5/4/2004	7	7
38	5/5/2004	5/5/2004	1	1
39	5/6/2004	5/6/2004	1	1
40	5/7/2004	5/7/2004	1	1
41	5/8/2004	5/8/2004	1	1
42	5/9/2004	5/9/2004	1	1
43	5/10/2004	5/10/2004	1	1
44	5/11/2004	5/11/2004	1	1
45	5/12/2004	5/18/2004	7	7
46	5/19/2004	5/25/2004	7	1
47	5/26/2004	6/1/2004	7	1
48	6/2/2004	6/8/2004	7	1
49	6/9/2004	6/15/2004	7	1
50	6/16/2004	6/22/2004	7	1

The green color in the first column indicates the daily stress periods, and the blue colored dates indicate the days of rain event when the pumping is stopped.

It should be noted that with the change in the numbers of stress period and time steps, other packages such as recharge, general head boundary and evapotranspiration have also been modified accordingly.

5.2.3. Modeling Results from the Improved MODFLOW Model

Inverse modeling was carried out using PEST to estimate the hydraulic conductivities, specific storage and specific yield of field, village, pond bottom, river border & bottom, and aquifer areas. Assuming that the errors associated with the pond and field water level measurements are 5 and 10 times higher than that for the aquifer water levels recorded using probes, weighting factor of 10, 2 and 1 were assigned for the probe, pond and field measurements, respectively. After numerous optimization efforts using PEST, the final output of the improved model (Fig.5.13) appears to simulate the observed aquifer, pond and expected field head data reasonably well. Table 5.4 shows reasonable modeled values of various hydraulic properties, and Table 5.5 shows good agreement of the hydraulic properties between the modified lumped and improved MODFLOW models:

Table 5.4: Modeled Hydraulic Properties

	Estimated	Uncertainties	Best Fits
Field Conductivity (m/s)	1.65E-8	1.57E-9	1.49E-7
Village Conductivity (m/s)	2.00E-7	-	2.00E-7
Pond bottom Conductivity (m/s)	1.56E-7	4.22E-7	1.56E-7
River bottom + border Conductivity (m/s)	1.18E-4	2.46E-5	1.18E-4
Specific Yield, Sy	0.04	2.13E-3	0.2
Specific Storage (1/m)	0.0001	2.45E-5	0.0005

Table 5.5: Comparison of Hydraulic Properties

	Modified Lumped	Improved MODFLOW
Field Conductance (1/s)	7.95E-9	1.49E-7
Village Conductance (1/s)	1.05E-8	6.67E-7
Pond bottom Conductance (1/s)	9.59E-8	1.56E-7
River bottom Conductance (1/s)	1.01E-6	3.93E-4
Specific Yield, Sy	0.2	0.2
Storativity	0.01	0.05

5.2.4. Limitation of the MODFLOW Model

Although Fig.5.13 and Tables 5.4-5.5 indicate that the MODFLOW model is reproducing the observed heads fairly well with reasonable hydraulic properties, there are two major deficiencies in the model: (1) each irrigation well in the model has been represented with a block size of 50m X 50m which is far from the reality, and (2) the model calibration has been carried out using the aquifer data from a single point, and thus does not provide any information on the anisotropy of the hydraulic parameters.

5.3. Generic 3D Model

Results from the pumping experiment and the subsequent modeling (chapter 4) indicate that the aquifer in our study area is anisotropic. However, to understand the impact of anisotropy on the groundwater flow paths, a generic 3D model has been developed – first by a finite element model, FEFLOW, and then by a finite difference model, Visual MODFLOW.

5.3.1. Model Setup using FEFLOW

The IKONOS image (Fig.3.2) and numerous field visits have revealed that within the setting of 1km X 1km area surrounding Basailbhog Field Site, about 71% of the area is covered by rice fields, 15% by villages, 9% by other fields and 5% by ponds. Since there are ten (10) irrigation wells that supplies water to the rice field areas within the stated setting, it can be assumed that one irrigation well can cover about 0.07km^2 irrigated areas. Accordingly, the extent of the generic model has been chosen such that a single irrigation well can cover the modeled irrigated rice field area. Therefore, similar to our Basailbhog Field Site, a generic 300m X 300m model area has been designed with similar coverage of various features – about 7.1% pond area, 21.3% village area and 71.6% of irrigated rice field area (Fig.5.14). The model is 122m thick in the vertical direction with similar geological stratigraphy as observed in our study area upto the Marine Clay (Fig.5.11), and the vertical stratification of various layers is similar to the MODFLOW model (Fig.5.12, and Table 5.6). The irrigation well is situated in the middle of the irrigated area, and is screened between 150-170m elevation.

Other model attributes include:

Model type: Steady-State 3D Finite Element model

Model dimension: 300m X 300m; 122m in height (6 layers, Table 5.6)

Element: 23,000 triangular elements

Boundary condition: No-flow boundaries on the sides

Head condition: Constant head in the pond area

Hydraulic properties: Obtained from Pumping Experiment Model (Table 5.7)

Specified data: Fluxes from Lumped Parameter Model (Fig.5.14B)

Table 5.6 Numerical Groundwater Model Layers in FEFLOW Model

Model Layer	Layer Type	Layer Top (m)	Layer Bottom (m)	Layer thickness (m)
1	Air	203.0	200.0	3.0
2	Surface Clay	200.0	197.0	3.0
3	Surface Clay	197.0	196.0	1.0
4	Sand	196.0	169.5	26.5
5	Sand	169.5	151.2	18.3
6	Sand	151.2	81.1	70.1

Table 5.7 Hydraulic Properties at Various Areas in FEFLOW Model

Hydraulic Property	Layer 1		Layer 2			Layer 3		Layer 4-6
	Village	Other	Village	Field	Pond	Field	Other	All
Kx = Ky (m/s)	1.5E-7	1	1.5E-7	2.3E-7	1	2.3E-7	1.5E-7	3.29E-4
Kz (m/s)	1.5E-7	1	1.5E-7	2.3E-7	1	2.3E-7	1.5E-7	1.77E-5
Ss (1/m)	5.3E-6	0	5.3E-6	5.3E-6	0	5.3E-6	5.3E-6	8.2E-6
Sy	0.25	1	0.25	0.25	1	0.25	0.25	0

5.3.2. FEFLOW Modeling Results

The generic 3D FEFLOW model has been executed under two different scenarios – isotropic and anisotropic. In the later case, the aquifer has an anisotropy of about 20 as obtained from the pumping experiment. Particles tracking for the isotropic and anisotropic scenarios indicates that the flow-paths, originating from the pond bottom, are different in the two cases (Fig.5.15, Panels A and B). Stream-tube analysis reveals that the path-lines converts directly towards the pumping well in isotropic aquifer system, whereas, they take an elliptical shape in accordance to aquifer anisotropy in an anisotropic system. The elliptical pattern of the flow-paths for the anisotropic case also indicate that it probably takes longer time for a particle to move vertically down, but once the particle is at the depth of the well screen, it travels rapidly towards the pumping well. However, the plots don't provide any conclusive evidence of the velocity vectors, and hence, the generic 3D model setup has been replicated in Visual MODFLOW.

5.3.3. Model Setup using Visual MODFLOW

The generic 3D model setup in the Visual MODLFOW platform is similar to that in the FEFLOW platform except that the generic model in Visual MODFLOW has been discretized into more layers for finer resolution of velocity vectors (Table 5.8).

Table 5.8 Numerical Groundwater Model Layers in Visual MODFLOW Model

Model Layer	Layer Type	Layer Top (m)	Layer Bottom (m)	Layer thickness (m)
1	Air	203.0	200.0	3.0
2	Surface Clay	200.0	197.0	3.0
3	Surface Clay	197.0	196.0	1.0
4	Sand	196.0	190.0	6.0
5	Sand	190.0	185.0	5.0
6	Sand	185.0	180.0	5.0
7	Sand	180.0	175.0	5.0
8	Sand	175.0	170.0	5.0
9	Sand	170.0	165.0	5.0
10	Sand	165.0	160.0	5.0
11	Sand	160.0	155.0	5.0
12	Sand	155.0	150.0	5.0
13	Sand	150.0	145.0	5.0
14	Sand	145.0	140.0	5.0
15	Sand	140.0	135.0	5.0
16	Sand	135.0	130.0	5.0
17	Sand	130.0	125.0	5.0
18	Sand	125.0	120.0	5.0
19	Sand	120.0	115.0	5.0
20	Sand	115.0	110.0	5.0
21	Sand	110.0	105.0	5.0
22	Sand	105.0	100.0	5.0
23	Sand	100.0	95.0	5.0
24	Sand	95.0	90.0	5.0
25	Sand	90.0	85.0	5.0
26	Sand	85.0	80.0	5.0

5.3.4. Visual MODFLOW Modeling Results

Similar to the FEFLOW model, the generic 3D model has been executed under isotropic and anisotropic aquifer system to analyze the impact of aquifer anisotropy on groundwater flow-paths and velocity vectors. Modeling results indicate that the path-lines are different for the two cases: in isotropic system, the path-lines extends throughout the entire aquifer depth before converging towards the pumping well, whereas in anisotropic system, the path-lines are more condensed around the depth of pumping well screen (Fig.5.15, panels C and D). Plots of velocity vectors (Fig.5.15, panels E and F) outside 50m radius from the pumping well (since the velocity vectors near pumping regions are much greater and so overshadow the vectors at other areas) show that in the anisotropic scenario, the horizontal component of the velocity vectors are much greater than the vertical component – specially closer to the pumping well – indicating that it takes particle longer time to move vertically downward from the pond bottom, but once the particles are at the depth of the well screen (i.e. at 150-170m elevation in the model) they travels rapidly towards the pumping well.

Further analysis of the velocity vectors have been carried out to investigate the influence of anisotropy on the different components of the velocity vector. For this purpose, the horizontal and vertical components of the velocity vectors have been obtained from the generic 3D Visual MODFLOW model (Fig.5.15, panels C-F). Afterwards, the vertically downward velocities (denoted by –ve values) have been separated from the vertically upward velocities (denoted by +ve values). Then, the average vertical velocity at each layer [Vz(-) and Vz(+) as plotted in Fig.5.16] has been calculated by multiplying the individual vertical velocity component with the corresponding horizontal cross-sectional area of the cell, followed by summing up the products, and finally averaging over the entire model area (equation 5.7).

$$Vz_i = \frac{\sum_{j=1}^{n}\left(Vz_j \times A_j\right)}{A} \qquad (5.7)$$

Where,

Vz_i average vertical velocity at layer i

Vz_j vertical velocity at cell j

A_j horizontal cross-sectional area of cell j

A total area of the model extent (i.e. 90000 m^2)

However, the average horizontal velocity (Vh as plotted in Fig.5.16) for each layer has been found by first calculating the absolute horizontal velocity from Vx and Vy at each cell, followed by summing up the values from all the cells within the layer, and finally averaging over the entire model area (equation 5.8).

$$Vh_i = \frac{\sum_{j=1}^{n} \sqrt{(Vx_j)^2 + (Vy_j)^2}}{N} \tag{5.8}$$

Where,

Vh_i average horizontal velocity at layer i

Vx_j horizontal velocity component in x-direction at cell j

Vy_j horizontal velocity component in y-direction at cell j

N total number of cells in each layer

Plot of the average velocity vectors for the entire region (Fig.5.16, panel A) shows that the downward vertical velocity is fairly constant up to the well screen, whereas the upward vertical velocity dominates below the well screen indicating flow convergence towards the well screen from above and below. For investigating the horizontal component of the velocity vectors, an area of 50m radius around the pumping well has been excluded since the velocity vectors near pumping regions are much greater and thus overshadow the vectors at other areas. Analysis of the data (Fig.5.16, panel B) indicates that the horizontal component of the velocity vectors is much larger than the vertical component. Moreover, the values are largest at the layers of pond bottom and well screen indicating the influence of well pumping. The plots of the velocity vector components supports the notion that in an anisotropic aquifer system, it takes longer time for particles to move vertically downward from the pond bottom, but once the particles are at the depth of the well screen (i.e. at 150-170m elevation in the model), they travels very rapidly towards the pumping well.

5.4. FEFLOW Large Scale Seasonal Model

To investigate the actual groundwater flow dynamics on seasonal scale, and to examine our pond hypothesis of contributing source to the high arsenic concentration at the depth of irrigation wells, the Basailbhog Field Site has been numerically modeled using the finite difference model, FEFLOW.

5.4.1. Model Setup

At first, an area of 3km X 3km surrounding the Basailbhog field site has been selected for the modeling purpose (Fig.5.17). The extent of the model area has been selected to include the Ichhamati River on the west side and the side-channels on the north and south sides of the model, whereas the boundary on the east side has been far enough to reduce the boundary effect on the heads within the Basailbhog field site. Since the flow to and from river is symmetrical on both sides of the channel, the model area covers half of the channel width referring that the obtained flow patterns will be symmetrical on the other side of the channels. The various hydrologic features, such as ponds and villages (~33%), river (~2%), rice field (~38%) irrigated by 35 irrigation wells, and other field (~27%) have been mapped out in the model, and the entire model area has been discretized with triangular elements (Fig.5.18). However, the number of total elements in the model has been constrained by several factors:

- Adequate resolution to the mosaic of various areas
- Finer resolution around the irrigation wells for investigating the large head gradients
- Number of layers in the vertical direction of the model
- Optimized execution of the model (the model run slows down significantly for higher number of elements)

As a result, the pond and village areas have been considered as a single entity called 'pseudo pond', where the ponds cover about one-third of the area and the villages cover the rest two-third of the area (Fig.5.18). The settings and rationale of the pseudo-pond area has been discussed further later in the chapter.

Information on location and pumping rates of the irrigation wells within the model area has been obtained from the field visits. However, for a few rice field areas (as evident from the IKONOS image) some 'make-up wells' have been assigned where no information on irrigation well is available. These 'make-up wells' pump at an average rate of 24L/s (Harvey, Ashfaque et al. 2006), and the number of such 'make-up wells' have been identified based on the average area coverage by each irrigation well within our study area (one irrigation well covers about 0.07km^2 irrigated area).

The model is 122m thick in the vertical direction with similar geological stratigraphy as observed in our study area upto the Marine Clay (Fig.5.11). The model elevation ranges from 81.1m to 203m (with the datum set at zero), and has been divided into 20 hydrogeologic layers of non-uniform thickness to represent the observed stratigraphy and to accommodate the well-screens at various depths (Table 5.9). As depicted in Fig.5.19, the model has a 3m layer of air above the ground surface to simulate the application and ponding of irrigation waters for rice production. The 4m thick surface clay layer has been divided into four layers of 1m each, and the 3m-deep ponds (as observed from the field visits) are sitting on the surface clay with a 1m thick impermeable layer at their bottom. The Ichhamati River and its side channels are about 6m deep (as observed during the field visits), and the bottom of the river is fairly impermeable compared to the surrounding aquifer. As obtained from the pumping experiment, the aquifer is segmented into two layers with different vertical conductivities and storage coefficients, whereas the horizontal conductivity is fairly constant throughout the depth. The irrigation wells are screened between 150m and 170m elevation as observed within our study area. However, the monitoring piezometers have a screen length of 1.5m, and are screened at elevations of 194.0-196.0m (17ft wells), 172.6-174.1m (90ft wells), 165.0-166.5m (120ft wells), 155.8-157.3m (155ft wells), 148.2-149.7m (172ft wells) and 133.0-134.5m as shown in Table 5.9:

Table 5.9 Layers in the Large Scale Seasonal Model

Model Layer	Layer Type	Layer Top (m)	Layer Bottom (m)	Layer thickness (m)
1	Air	203.0	200.0	3.0
2	Surface Clay	200.0	199.0	1.0
3	Surface Clay	199.0	198.0	1.0
4	Surface Clay	198.0	197.0	1.0
5	Surface Clay	197.0	196.0	1.0
6	Sand	196.0	194.0	2.0
7	Sand	194.0	184.8	9.2
8	Sand	184.8	174.1	10.7
9	Sand	174.1	172.6	1.5
10	Sand	172.6	169.5	3.1
11	Sand	169.5	166.5	3.0
12	Sand	166.5	165.0	1.5
13	Sand	165.0	157.3	7.7
14	Sand	157.3	155.8	1.5
15	Sand	155.8	151.2	4.6
16	Sand	151.2	149.7	1.5
17	Sand	149.7	148.2	1.5
18	Sand	148.2	134.5	13.7
19	Sand	134.5	133.0	1.5
20	Sand	133.0	81.1	51.9

The hydraulic properties of the model at various sections and layers have been assigned according to the data obtained from the pumping experiment (Table 5.10):

Table 5.10 Hydraulic Properties at Various Areas in Large Scale FEFLOW Model

Layers	Segments	Hydraulic Properties			
		Kx = Ky (m/s)	Kz (m/s)	Ss (1/m)	Sy
1	Pseudo-pond	1.0E-10	1.0	0	0.5
	Other	1.0E-10	1.0	0	1
2-4	Field	2.3E-7	2.3E-7	5.3E-6	0.25
	Pseudo-pond	1.0E-10	1.0	0	0.5
	River	1.0E-10	1.0	0	1
5	Field	2.3E-7	2.3E-7	5.3E-6	0.25
	Pseudo-pond	1.5E-7	1.5E-7	5.3E-6	0.25
	River	1.0E-10	1.0	0	1
6	River	1.0E-10	1.0	0	1
	Other	3.3E-4	1.7E-7	2.8E-3	0
7	River	2.0E-6	2.0E-6	5.3E-6	0.25
	Other	3.3E-4	1.7E-7	2.8E-3	0
8-20	Aquifer	3.3E-4	1.8E-5	8.2E-6	0

Since layer-1 in the model represents a 3m of air above ground surface (Table 5.9) to simulate the application and ponding of irrigation water for rice production, the horizontal and vertical conductivities have been assigned artificially small and large values respectively to ensure free vertical movement of the water body. Moreover, there is no water-storage soil-matrix in a free water body, and therefore, the specific storage (Ss) and Specific Yield (Sy) for the field area in the air layer have been assigned values of 0 and 1, respectively. The same principles have been followed while assigning the hydraulic properties for river areas (layer 1-6). However, for the pseudo-pond area (layer 1-4), specific yield of 0.5 has been assigned as calculated from the weighted average of the contributing segments (i.e. pond and village):

[(Sy of pond area) x (pond area contribution)] + [(Sy of village area) x (village area contribution)]

Under the stated model setting, fluxes coming out of the pseudo-pond into the aquifer can be calculated as:

$$Q_{pv} = Q_p + Q_v \tag{5.9}$$

$$Q_p = A_p K_{pv} \frac{dh_p}{dl} = \frac{1}{3} A K_{pv} \frac{dh_p}{dl} \tag{5.10}$$

$$Q_v = A_v K_{pv} \frac{dh_v}{dl} = \frac{2}{3} A K_{pv} \frac{dh_v}{dl} \tag{5.11}$$

Where,

Q_{pv} Flux from pseudo-pond area $\left[\frac{L^3}{T}\right]$

Q_p Flux from pseudo-pond area $\left[\frac{L^3}{T}\right]$

Q_v Flux from pseudo-pond area $\left[\frac{L^3}{T}\right]$

A Total area of the pseudo-pond $\left[L^2\right]$

A_p Area coverage by ponds within the pseudo-pond area $\left[L^2\right]$

A_v Area coverage by villages within the pseudo-pond area $\left[L^2\right]$

K_{pv} Hydraulic Conductivity of the pseudo-pond bottom $\left[\frac{L}{T}\right]$

$\left[\frac{dh_p}{dl}\right]$ Hydraulic Gradient in the pond segment

$\left[\frac{dh_v}{dl}\right]$ Hydraulic Gradient in the village segment

For a specific amount of flux, assuming the head gradient in the pseudo-pond area is dh/dl, the head gradients for the pond and village segments can be written as:

$dh = dh_p$ and, $dh = \frac{dh_v}{\theta}$ where, θ is the porosity in the village area

Therefore, equations 5.9 and 5.11 can be re-written as:

$$Q_p = \frac{1}{3} A K_{pv} \frac{dh}{dl} \tag{5.12}$$

$$Q_v = \frac{2}{3} A K_{pv} \theta \frac{dh}{dl} \qquad (5.13)$$

Assuming a porosity of 0.4 for the village area, the ratio of the two fluxes becomes:

$$\frac{Q_p}{Q_v} = \frac{1}{2\theta} \qquad \text{or,} \qquad Q_p = 1.25 Q_v$$

However, if we assume that the flux from village areas is very negligible compared to the pond areas (e.g. Lumped Parameter model, Fig.5.3), then the K_{pv} value has to be multiplied by three to obtain the equivalent flux from the one-third pond segment within the pseudo-pond area.

Other model attributes include:

Model type:	Transient 3D Finite Element model
Model dimension:	3km X 3km; 122m in height (20 layers, Table 5.9)
Element:	250,000 triangular elements
Boundary condition:	Time-varying river head on north, west and south sides, no flow boundary on the east side
Initial condition:	End of flood. Starting head 200m – assuming hydraulic heads are uniform throughout the model domain and equivalent to the surface elevation of 200 m. However, for the river and pseudo-pond areas, the initial heads have been assigned as 199.69m and 201.45m, respectively, as obtained from field measurements.
Simulation time:	10-Nov'06 to 15-Jun'07 (total 217 days) i.e., for the dry season period. Observation of water-levels of different hydrologic features (Fig.3.15) infers that there is very little hydraulic gradient during the flooding period (mid-June to early November) and therefore, groundwater flow ceases during that time.
Time steps:	Initial time step of 0.001d; time steps during simulation period ranged from 0.001d to 1d

Specified data:	River heads – Ganges data from BWDB (since Ichhamati follows Ganges very closely; (Harvey, Ashfaque et al. 2006)) Rainfall – as recorded at Bhagakul Meteorological station Evapotranspiration – calculated from meteorological data, assigned as area-specific (e.g water bodies, trees, rice field) Pumping rate – well-specific rates as measured during field visits. Aquifer data indicates that pumping starts on 13-Dec-06 (33rd day), and stops on 04-Mar-07 with temporarily hiatus during rain events on 7-9 Feb'07, 14-15 Feb'07, 22-24 Mar'07 and 25-27 Apr'07 (89-91, 94-95, 132-134, and 166-168th days). It is also inferred from the aquifer data and the field visits that at any given time, about 40% of the irrigation wells are in operation from 13-Dec-06 to 9-Jan-07, and about 80% of the wells are in operation beyond that time
Observation data:	Hydraulic heads of the aquifer (measured using data-loggers as well as manually), pond (average of all ponds) and rice field areas (measured using data-loggers). All data points have been given equal weight.
Parameters:	Hydraulic conductivity of field, pseudo-pond bottom, and river bottom; Specific Storage, Horizontal and Vertical hydraulic conductivities of two aquifer segments

5.4.2. Seasonal Modeling Efforts

Inverse modeling has been carried out using PEST to estimate the hydraulic conductivities, and specific storage of field, pseudo pond bottom, river bottom, and aquifer areas. The initial parametric values for the estimation processes have been adopted from the pumping experiment results. In order to reduce the computational efforts, the number of estimated parameters has been kept to minimum and the model has been initially run for half of the season. Moreover, the sensitivity of the model parameters has been examined without considering the side-channels. Upon achieving reasonable values of the estimated parameters for the half of the season, the estimation process has been extended to the entire season. Following sections describe the various modeling efforts and the sensitivity analysis of the seasonal model.

5.4.2.1. Pumping Experiment 201

Since the pumping experiment has been carried out just for two days (compared to the entire season), the hydraulic conductivities at the pond and river bottoms couldn't be estimated using the data as the responses from these features are quite negligible within such short duration. Moreover, incidentally the neighboring ponds at the pumping experiment site contributes little or no recharge into the aquifer, and thereby, do not represent a generic recharging pond within the study area. Therefore, as a first step, the conductivities of the pseudo-pond and river bottom, along with the vertical conductivity of the field area, have been estimated keeping the aquifer properties constant as obtained from the pumping experiment results.

However, the estimated parametric values have come out to be several orders of magnitude greater than the expected values (Table 5.11):

Table 5.11: Estimated Parametric Values from Pumping Experiment 201

Hydraulic Properties	P-expt 201	P-expt. FEFLOW	Modified Lumped	Improved MODFLOW
Field Conductance (1/s)	7.3E-7	5.8E-8	8.0E-9	1.5E-7
Village Conductance (1/s)	1.4E-6		1.1E-8	6.7E-7
Pond bottom Conductance (1/s)			9.6E-8	1.6E-7
River bottom Conductance (1/s)	1.2E-3		1.0E-6	3.9E-4

The very high conductivity values of the pseudo-pond and river bottoms indicate that the estimated aquifer conductivities from the pumping experiment might be a bit lower for the regional scale for discharging water from the pseudo-pond and the river.

5.4.2.2. Pumping Experiment 301

On the basis of the observations from the previous estimation, the horizontal conductivities of the two aquifer segments have been included in the estimation process in addition to the conductivities of the field, pseudo-pond and the river bottom (Table 5.12).

Table 5.12: Estimated Parametric Values from Pumping Experiment 301

Hydraulic Properties	P-expt 301	P-expt. FEFLOW	Modified Lumped	Improved MODFLOW
Field Conductance (1/s)	7.4E-8	5.8E-8	8.0E-9	1.5E-7
Village Conductance (1/s)	7.3E-8		1.1E-8	6.7E-7

Pond bottom Conductance (1/s)			9.6E-8	1.6E-7
River bottom Conductance (1/s)	4.3E-5		1.0E-6	3.9E-4
Aquifer (up) Horz. Conductivity (m/s)	2.4E-2	3.3E-4		
Aquifer (up) Horz. Conductivity (m/s)	9.3E-1	3.3E-4		

As can be seen from Table 5.12, the current inverse estimation gives reasonable values for the field, pseudo-pond and river bottom conductivities. However, the horizontal conductivities of the two aquifer segments are unrealistically high indicating that the other parameters (e.g. vertical conductivities and storage) of the aquifer need to be included in the estimation process.

5.4.2.3. Pumping Experiment 401

After numerous optimization efforts using PEST, the final output of the half-season model (Fig.5.20) appears to simulate the observed aquifer, pseudo-pond and expected field head data reasonably well. Table 5.13 shows reasonable modeled values of various hydraulic properties, and Table 5.14 shows good agreement of the hydraulic properties with the modified lumped, improved MODFLOW and FEFLOW pumping experiment models:

Table 5.13: Hydraulic Properties in FEFLOW Half-Seasonal Model

Hydraulic Properties	Estimated	Lower Bound	Upper Bound
Field Conductivity (m/s)	3.6E-7	2.6E-7	5.0E-7
Pseudo-Pond bottom Conductivity (m/s)	9.5E-8	7.7E-8	1.2E-7
River bottom Conductivity (m/s)	4.8E-5	3.8E-5	6.2E-5
Aquifer Horizontal Conductivity (m/s)	1.1E-3	9.8E-4	1.3E-3
Aquifer Vertical Conductivity (m/s) [4-15m depth]	1.5E-6	1.3E-6	1.7E-6
Aquifer Vertical Conductivity (m/s) [15-120m depth]	5.6E-5	3.9E-5	8.3E-5
Specific Storage (1/m) [4-15m depth]	2.6E-3	1.7E-3	3.9E-3
Specific Storage (1/m) [15-120m depth]	1.3E-5	3.8E-6	4.6E-5

Table 5.14: Comparison of Hydraulic Properties from Various Models

Hydraulic Properties	P-expt. 401	P-expt. FEFLOW	Modified Lumped	Improved MODFLOW
Field Conductance (1/s)	8.9E-8	5.8E-8	8.0E-9	1.5E-7

Village Conductance (1/s)	9.5E-8		1.1E-8	6.7E-7
Pond bottom Conductance (1/s)			9.6E-8	1.6E-7
River bottom Conductance (1/s)	4.3E-6		1.0E-6	3.9E-4
Aquifer Horz. Conductivity (m/s)	1.1E-3	3.3E-4		
Aquifer Vert. Conductivity (m/s) [4-15m]	1.5E-6	1.7E-7		
Aquifer Vert. Conductivity (m/s) [15-120m]	5.6E-5	1.8E-5		
Storativity, [4-15m depth]	0.029	0.031	0.01	0.05
Storativity, [15-120m depth]	1.3E-3	8.5E-4		

5.4.2.4. Sensitivity Analysis of the Side Channels

The Ichhamati River is much wider as well as deeper than the side channels on the north and south ends, and therefore, plays a significant role in the groundwater flow dynamics within the area. However, to investigate the importance of the side channels, the model domain has been modified by replacing the northern and southern river boundaries with no flow boundaries. Estimation of hydraulic properties under the stated model set-up indicates that the aquifer parametric values are one to two orders of magnitude greater than usual values (Table 5.15). Moreover, the river bottom conductivity has also increased. Increase in estimated values of the aquifer and river bottom indicates that in the absence of the side-channels, all the water needs to be discharged to the Ichhamati River, and hence, indicates the importance of the side-channels.

Table 5.15: Comparison of Hydraulic Properties

Hydraulic Properties	Seasonal FEFLOW w/o side channels	Seasonal FEFLOW with side channels	P-expt. FEFLOW
Field Conductivity (m/s)	2.4E-7	3.6E-7	2.3E-7
Pseudo-Pond bottom Conductivity (m/s)	9.5E-8	9.5E-8	
River bottom Conductivity (m/s)	1.8E-4	4.8E-5	
Aquifer Horz. Conductivity (m/s)	4.5E-3	1.1E-3	3.3E-4
Aquifer Vert. Conductivity (m/s) [4-15m]	1.6E-6	1.5E-6	1.7E-7
Aquifer Vert. Conductivity (m/s) [15-120m]	2.0E-3	5.6E-5	1.8E-5
Storativity, [4-15m depth]	1.2E-2	2.6E-3	2.8E-3
Storativity, [15-120m depth]	4.0E-5	1.3E-5	8.2E-6

5.4.2.5. Full-Season Modeling

After achieving reasonable values of the estimated parameters for the half of the season (when the groundwater level is dropping due to irrigation pumping), and understanding the significance of the side channels, the parametric values have been re-estimated using the data from the entire dry season (when the groundwater level comes back to its post-flood level). Fig.5.21 shows good agreement of the modeled heads with the observed heads, while Table 5.16 compares the parametric values between the half-season and full-season estimations:

Table 5.16: Comparison of Hydraulic Properties between Half and Full season Models

Hydraulic Properties	Full-Season FEFLOW	Half-Season FEFLOW (P-expt. 401)
Field Conductivity (m/s)	7.2E-7	3.6E-7
Pseudo-Pond bottom Conductivity (m/s)	3.5E-8	9.5E-8
River bottom Conductivity (m/s)	1.4E-5	4.8E-5
Aquifer Horz. Conductivity (m/s)	4.3E-3	1.1E-3
Aquifer Vert. Conductivity (m/s) [4-15m]	2.9E-7	1.5E-6
Aquifer Vert. Conductivity (m/s) [15-120m]	2.5E-5	5.6E-5
Storativity, [4-15m depth]	1.2E-2	2.6E-3
Storativity, [15-120m depth]	1.6E-4	1.3E-5

Moreover, the tighter bounds of the estimated parameters (Table 5.17) indicate reasonable modeled values of various hydraulic properties for the full-season model:

Table 5.17: Hydraulic Properties in FEFLOW Full-Seasonal Model

Hydraulic Properties	Estimated	Lower Bound	Upper Bound
Field Conductivity, K_f (m/s)	7.2E-7	5.5E-7	9.6E-7
Pseudo-Pond bottom Conductivity, K_p (m/s)	3.5E-8	2.1E-8	5.8E-8
River bottom Conductivity, K_r (m/s)	1.4E-5	8.8E-6	2.3E-5
Aquifer Horizontal Conductivity, K_h (m/s)	4.3E-3	3.4E-3	5.6E-3
Aquifer Vertical Conductivity, K_v^U (m/s) [4-15m depth]	2.9E-7	1.2E-7	7.5E-7
Aquifer Vertical Conductivity, K_v^L (m/s) [15-120m depth]	2.5E-5	9.8E-6	6.6E-5
Specific Storage, S_s^U (1/m) [4-15m depth]	1.2E-2	2.2E-3	6.0E-2
Specific Storage, S_s^L (1/m) [15-120m depth]	1.6E-4	1.3E-4	1.9E-4

In order to understand the groundwater flow dynamics and the connectivity among various parameters, the correlation coefficient values among the parameters have also been examined (Table 5.18):

Table 5.18: Correlation Coefficient among Hydraulic Parameters

	K_f	K_p	K_h	K_r	K_v^U	K_v^L	S_s^U	S_s^L
K_f	1							
K_p	0.525	1						
K_h	-0.378	-0.280	1					
K_r	-0.149	0.065	0.627	1				
K_v^U	0.107	0.045	-0.877	-0.586	1			
K_v^L	-0.009	-0.036	0.171	-0.028	-0.231	1		
S_s^U	-0.133	0.127	0.086	0.594	0.133	-0.153	1	
S_s^L	-0.098	-0.114	0.689	0.380	-0.821	-0.084	-0.426	1

Analysis of the correlation coefficient values shows that the vertical conductivity of the upper aquifer has strong negative correlations with the aquifer horizontal conductivity and the river bottom conductivity, which indicates preferential flow direction in a highly anisotropic environment. On the other hand, the strong positive correlation between the aquifer horizontal conductivity and the river bottom conductivity implies that being the only discharge location, the river bottom conductivity has to increase with the increase in flow through the aquifer. Furthermore, the high positive correlation of the upper aquifer storage with the river bottom conductivity suggests that they affect the modeled heads in the same way – a decrease in aquifer head can be offset either by increasing the storage or the river bottom conductivity, and vice versa.

Fig.5.22 shows the average annual fluxes as obtained from the FEFLOW full-seasonal model. The plot indicates that pumping is the major sink for the aquifer, whereas most of the recharge is coming from pond and rice field areas. Furthermore, since the pond area covers only 11% of the area (one third of 33% pseudo-pond area) compared to the 38% coverage by rice field area, the incoming flux into the aquifer from the ponds are about an order of magnitude more than that from the rice field areas. These results are consistent with the fluxes obtained from the Lumped model. Using the values of annual fluxes, the average residence time for the FEFLOW full-seasonal model can be calculated as 33 years, which also compares well to the 38 years residence time from the Lumped model under similar conditions.

Reference:

Harvey, C. F., K. N. Ashfaque, et al. (2006). "Groundwater dynamics and arsenic contamination in Bangladesh." Chemical Geology **228**(1-3): 112-136.

Yu, W. (2003). Socio-Hydrologic approaches for managing groundwater contamination problems: strategies for the arsenic problem in Bangladesh. Division of Engineering and Applied Sciences. Cambridge, MA, USA, Harvard University. **PhD**.

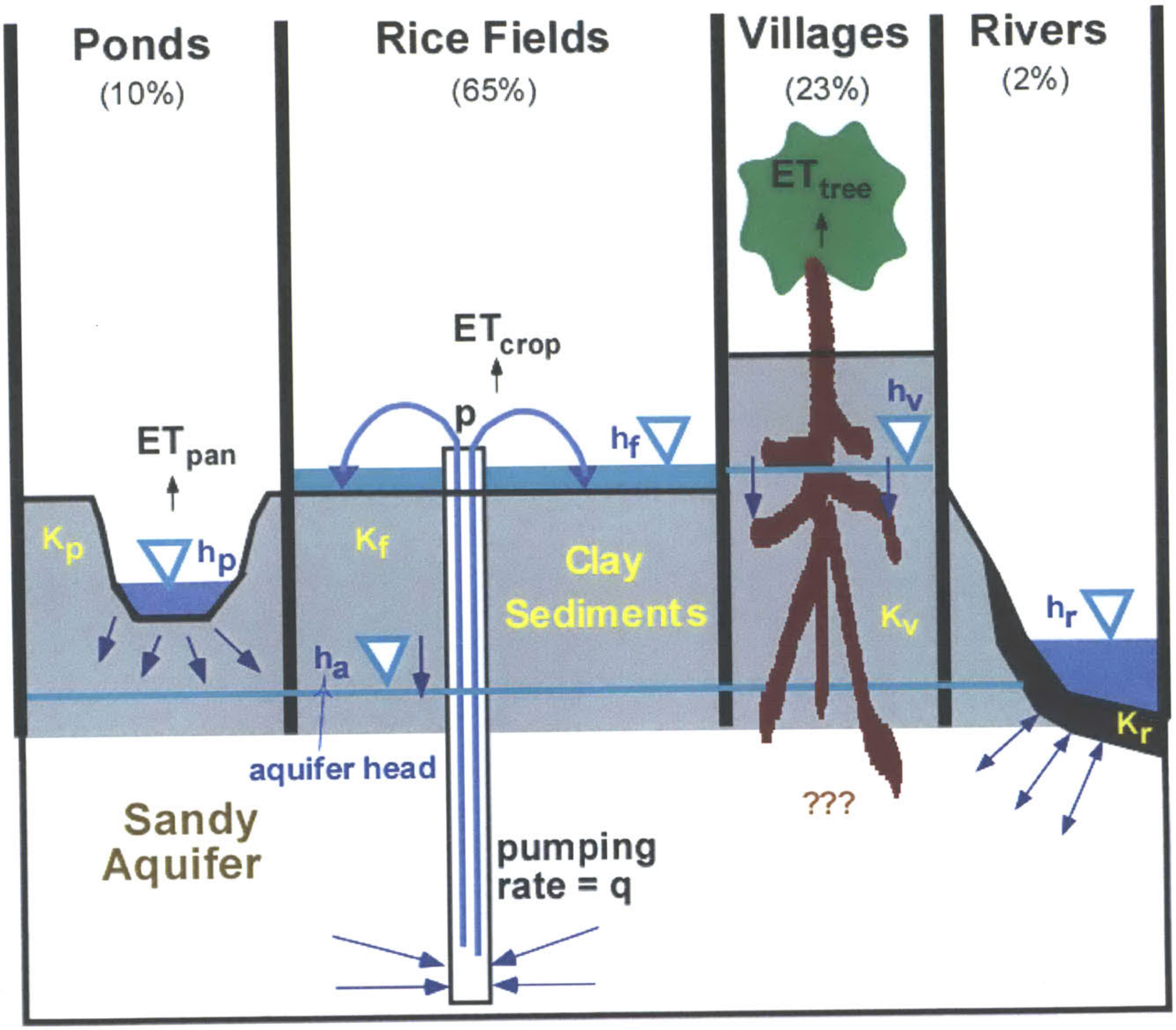


Fig.5.1 Lumped Parameter Model Cartoon: Model cartoon showing the setting of different areas and their connectivity with the aquifer. The percentage of different areas, such as the ponds, rice fields, villages and rivers have been assigned similar to that is observed in our study area. Moreover, the village heads are about 3m higher than the field clay water levels since the villages are about 3m above the rice field surfaces.

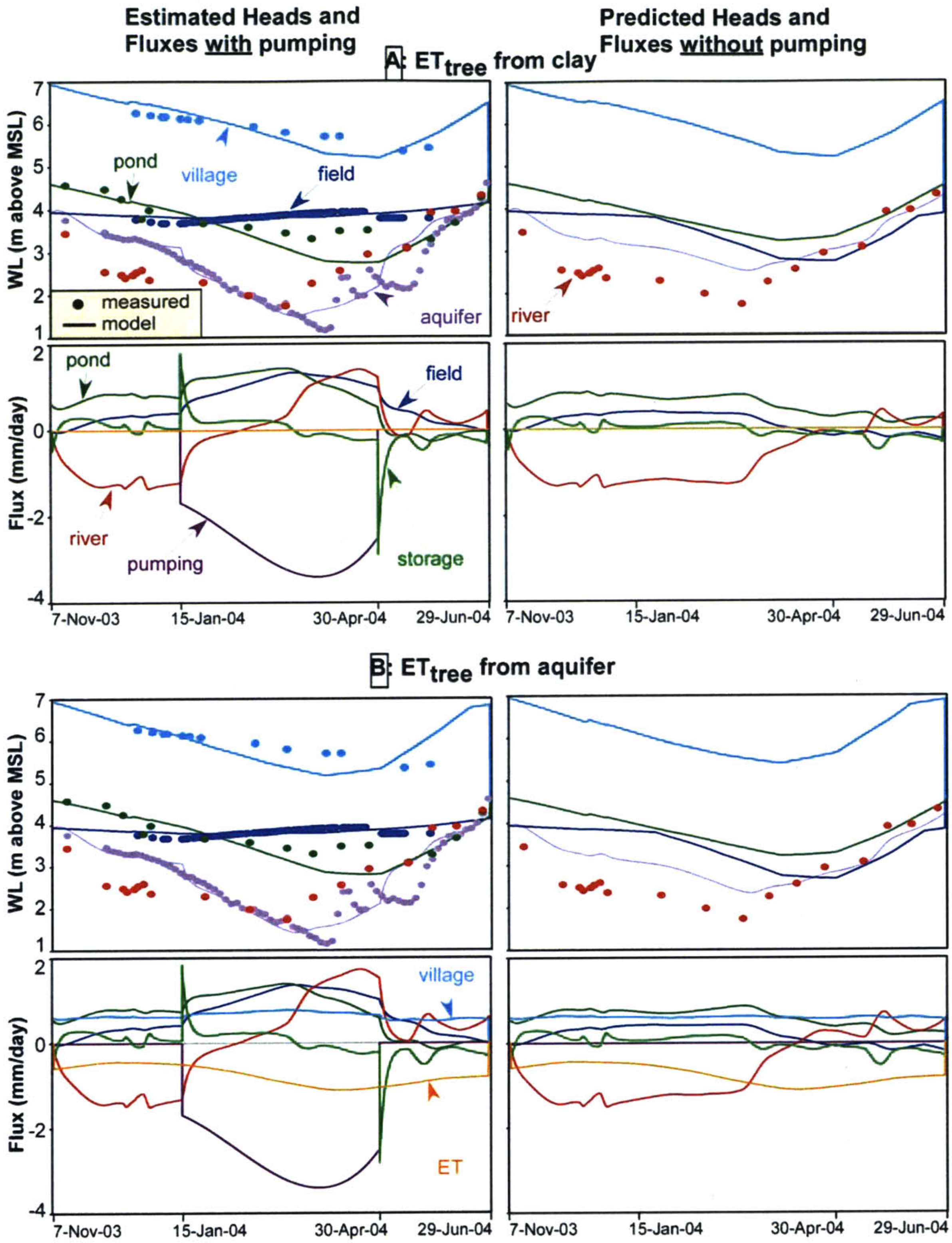


Fig.5.2 Lumped Parameter Model Fits: (A) Model fits and predictions for the case where transpiration from the villages (trees) is extracted from the village clay. The first pane (upper left) shows

the best model fit to the data, with the corresponding model fluxes in and out of the aquifer system plotted below. The pumping flux is prescribed. The upper right panel shows the predicted heads in the absence of pumping and irrigation, with the corresponding fluxes plotted below. (B) The same set of plots as in (A), except here the transpiration of the villages is modeled as coming from the aquifer (i.e. tree roots are all modeled as extending through the village clay). The model results differ because they now show significant ET from the aquifer and a roughly corresponding increase in recharge to the aquifer from the village clay (ref. Chemical Geology)

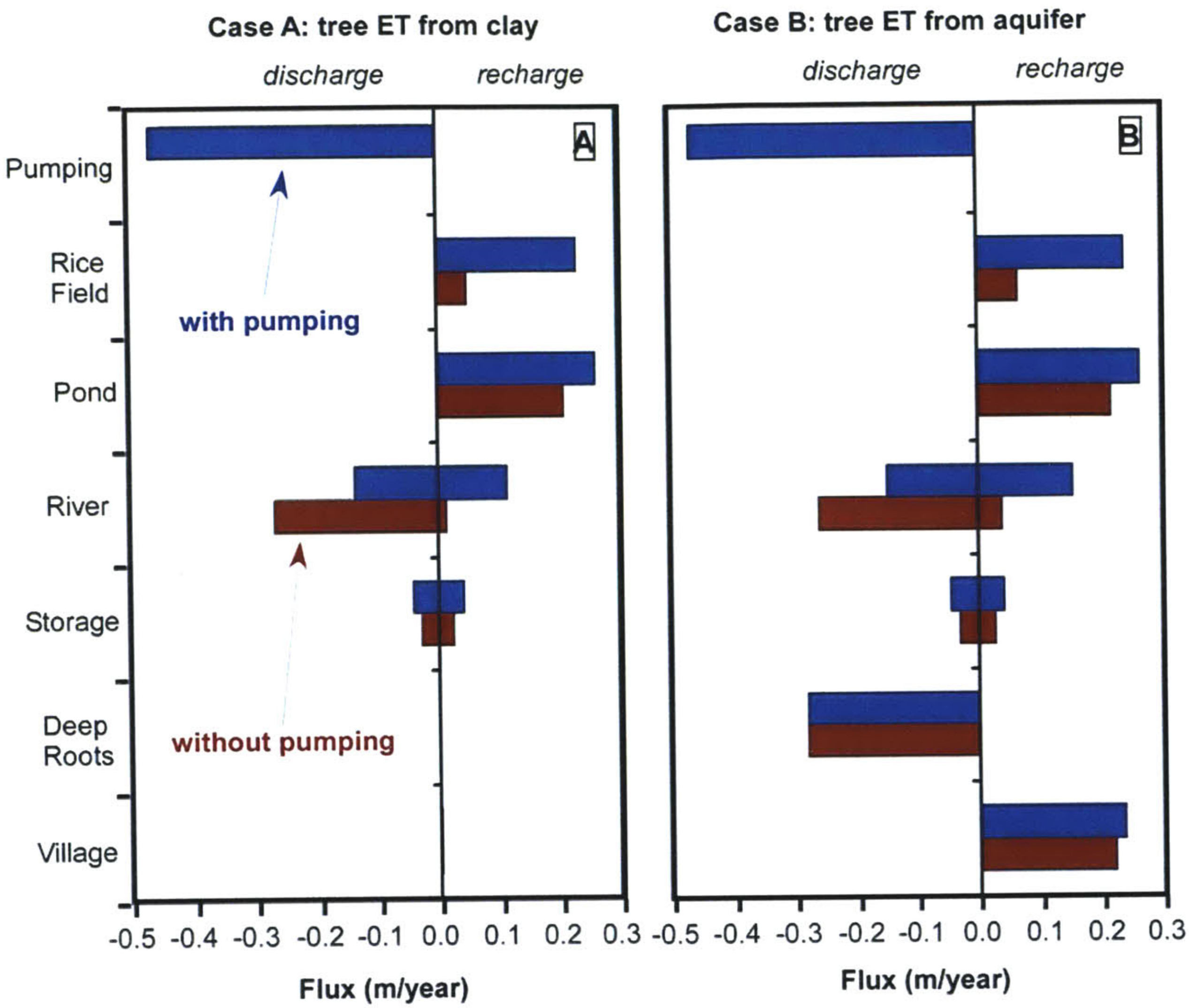


Fig.5.3 **Lumped Parameter Model Fluxes**: The estimated (with pumping) and predicted (without pumping) average annual water fluxes into and out of the aquifer, for the cases where transpiration from the village trees is extracted from the clay (A) and from the underlying aquifer (B). These yearly fluxes are calculated by integrating the instantaneous fluxes shown in Fig.5.2 over time (ref. Chemical Geology).

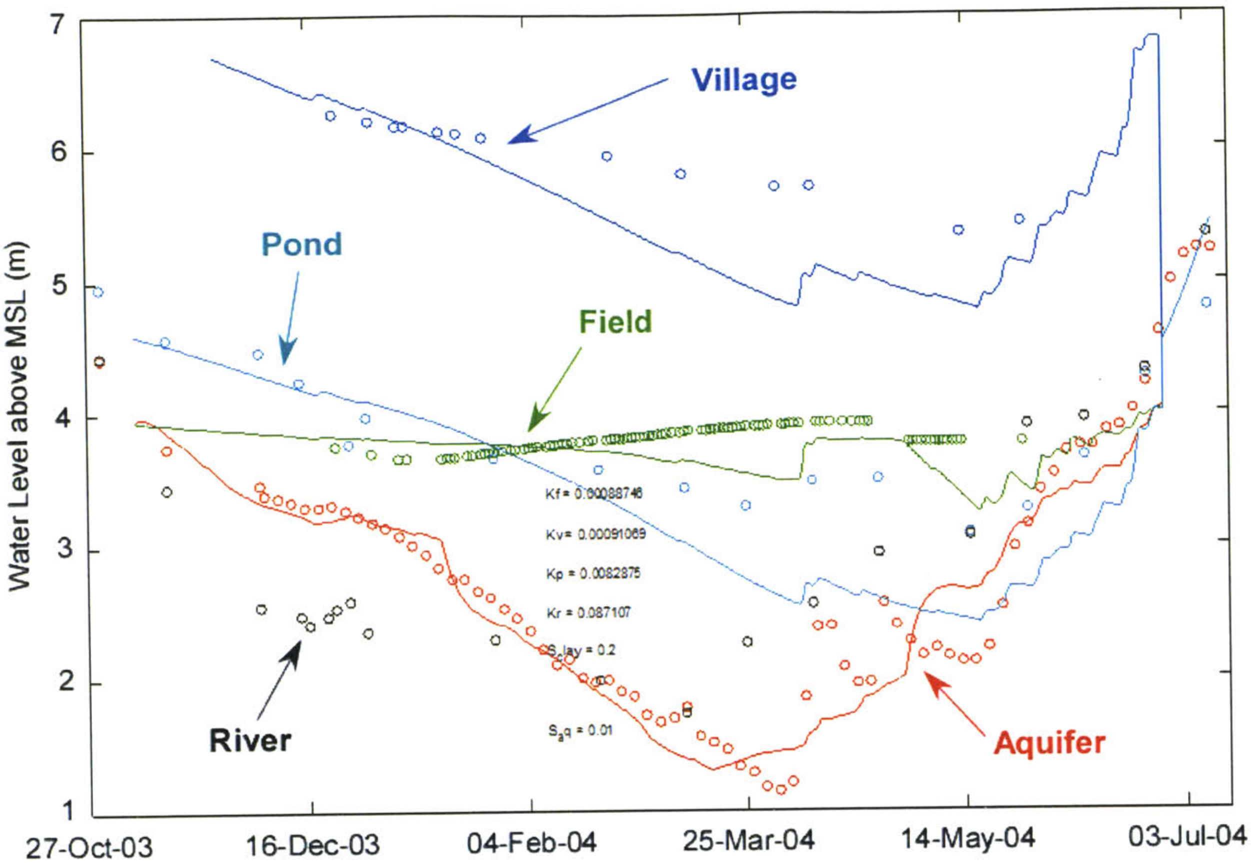


Fig.5.4 Modeled and Observed Heads Comparison: Comparison of modeled head (solid lines) with measured data (hollow circles) in the lumped parameter model shows that the model fails to replicate the two humps in aquifer heads during water level rising. Also, the modeled heads for the field shows a bad fit while using the actual rainfall and evaporation data.

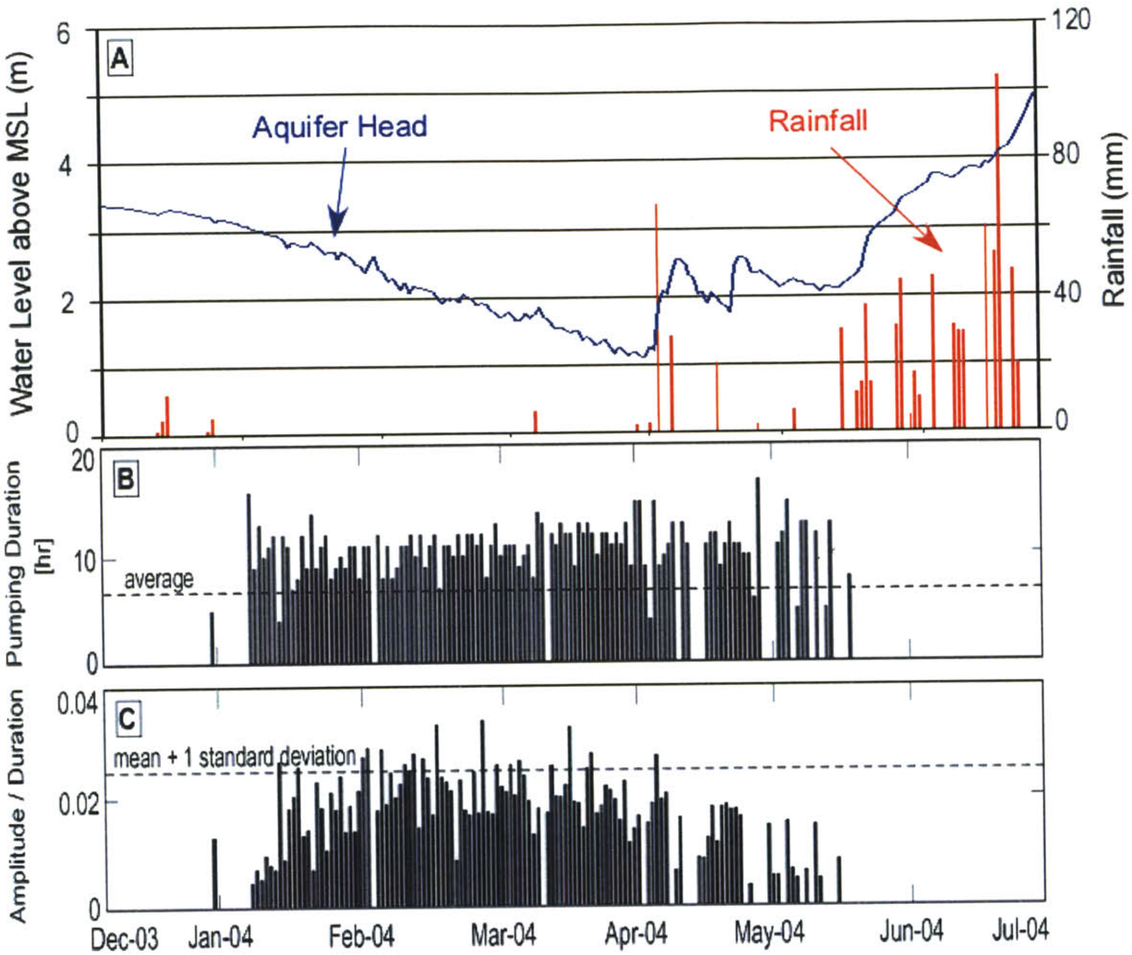


Fig.5.5 Rainfall and Pumping Schedule: (A) Daily rainfall and aquifer data for a 30-m well at the Bejgoan field site for the period of December 2003 to July 2004. (B) Calculated pumping duration for the 2003–2004 irrigation season. (C) Rate of daily aquifer drawdown, calculated by dividing the amplitude of head oscillations by the pumping duration for each day. Data is used to scale the number of wells pumping on each day

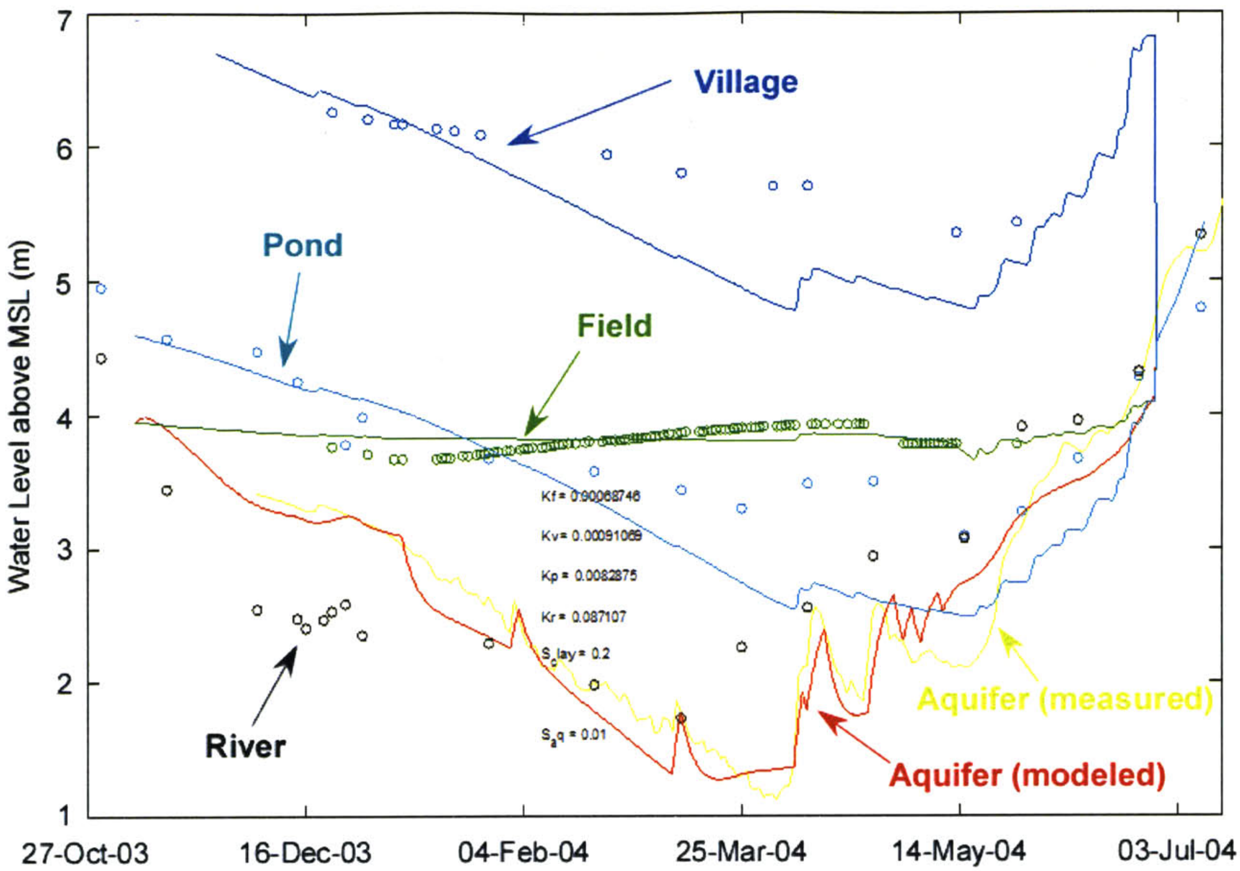


Fig.5.6 Modified Lumped Model Heads: Comparison of modeled head (solid lines) with measured data (hollow circles) after modifying the field conductivity and the pumping schedule for rainfall events. The plot shows good agreement between the modeled and measured heads of the aquifer and the field.

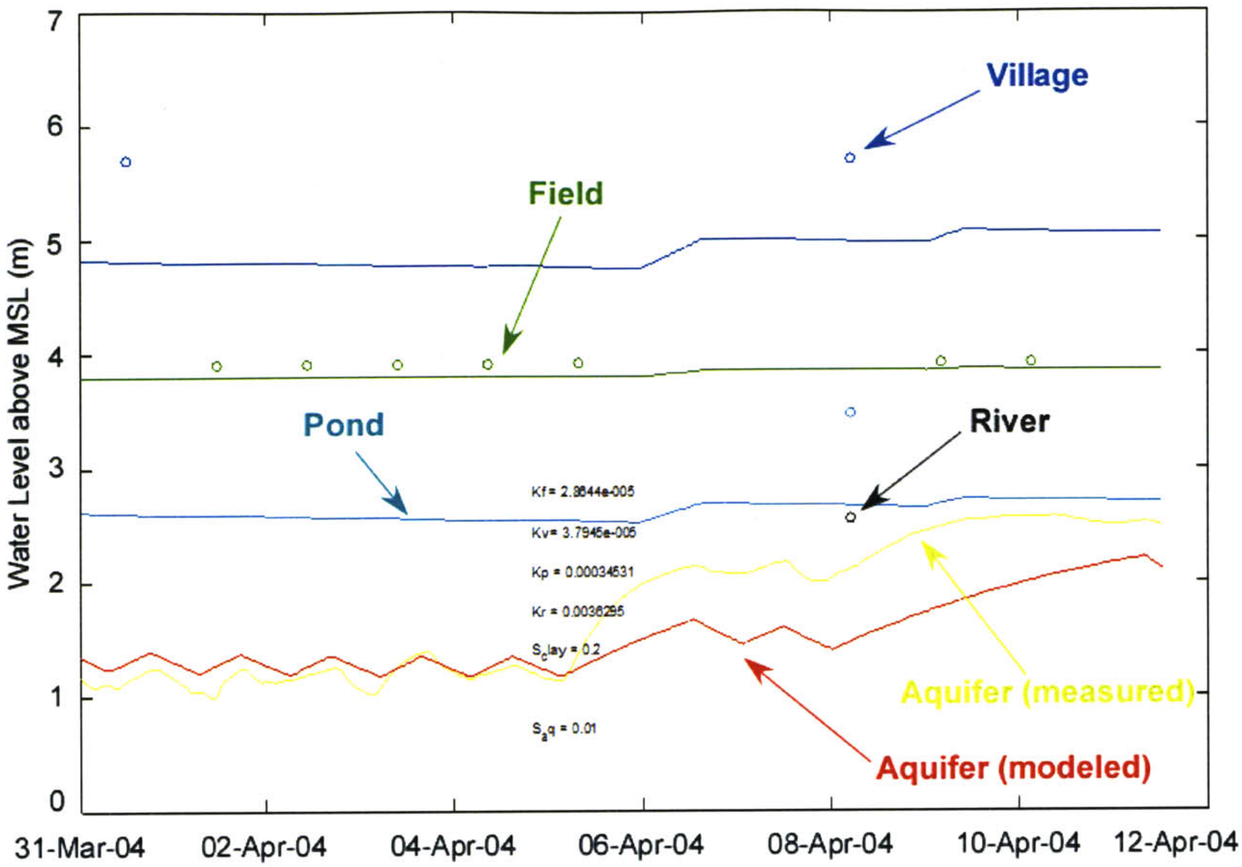


Fig.5.7 Hourly Lumped Parameter Model: Comparison of hourly modeled and measured heads from April 1 to 12, 2004. In the present case, the pumping module of the model is changed from a diurnal function to an hourly step-function: 12 hours of pumping at 24 L/s from 6AM-6PM and 12 hours of rest period from 6PM-6AM. The time dimension of other inputs and parameters is changed to hour to be consistent with the unit.

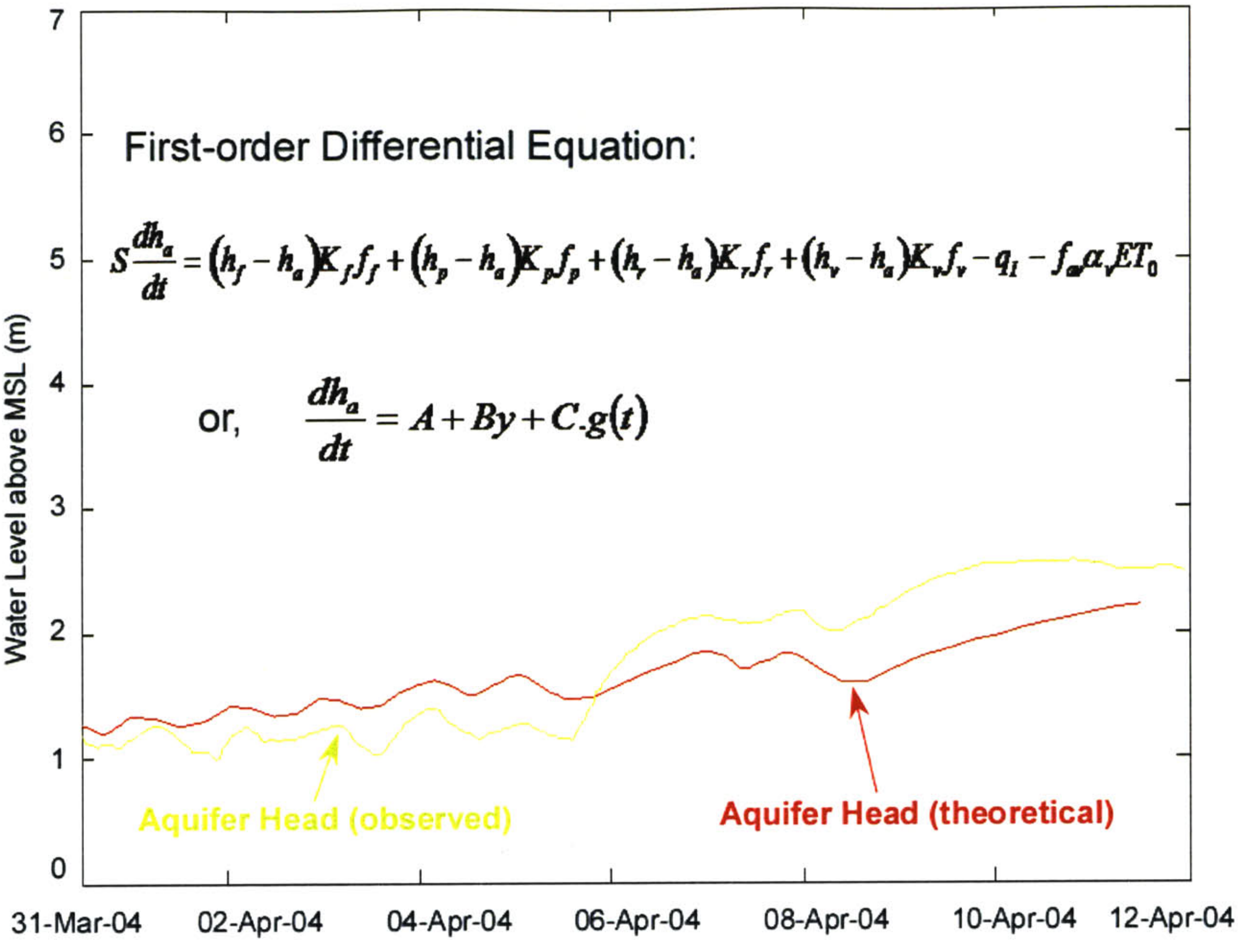


Fig.5.8 Theoretical vs. Observed Aquifer Heads: Comparison of the theoretical and observed aquifer heads from April 1 to 12, 2004. The aquifer head can be represented as a first order differential equation of dy/dt = A + By + C.g(t); where, y is the aquifer head, and g(t) is a step function for pumping. A (0.455 m/d = 0.019 m/hr), B (-0.322 m/d = -0.013 m/hr), C (-100*40) are coefficients calculated from the modeled aquifer (ha of 1.35m), field (hf of 3.8m), pond (hp of 2.62m), village (hv of 4.83m), and database river (hr of 2.56m) head values for the 457th day (April 1, 2004) from the diurnal model. The 457th day has been considered as the beginning of the hourly model. C is the inverse of storativity (which is 0.01 from the diurnal model) times the number of pumps (which is 40). No pumping on Apr 7th and Apr 10-12 (pumping stopped according to the rainfall information).

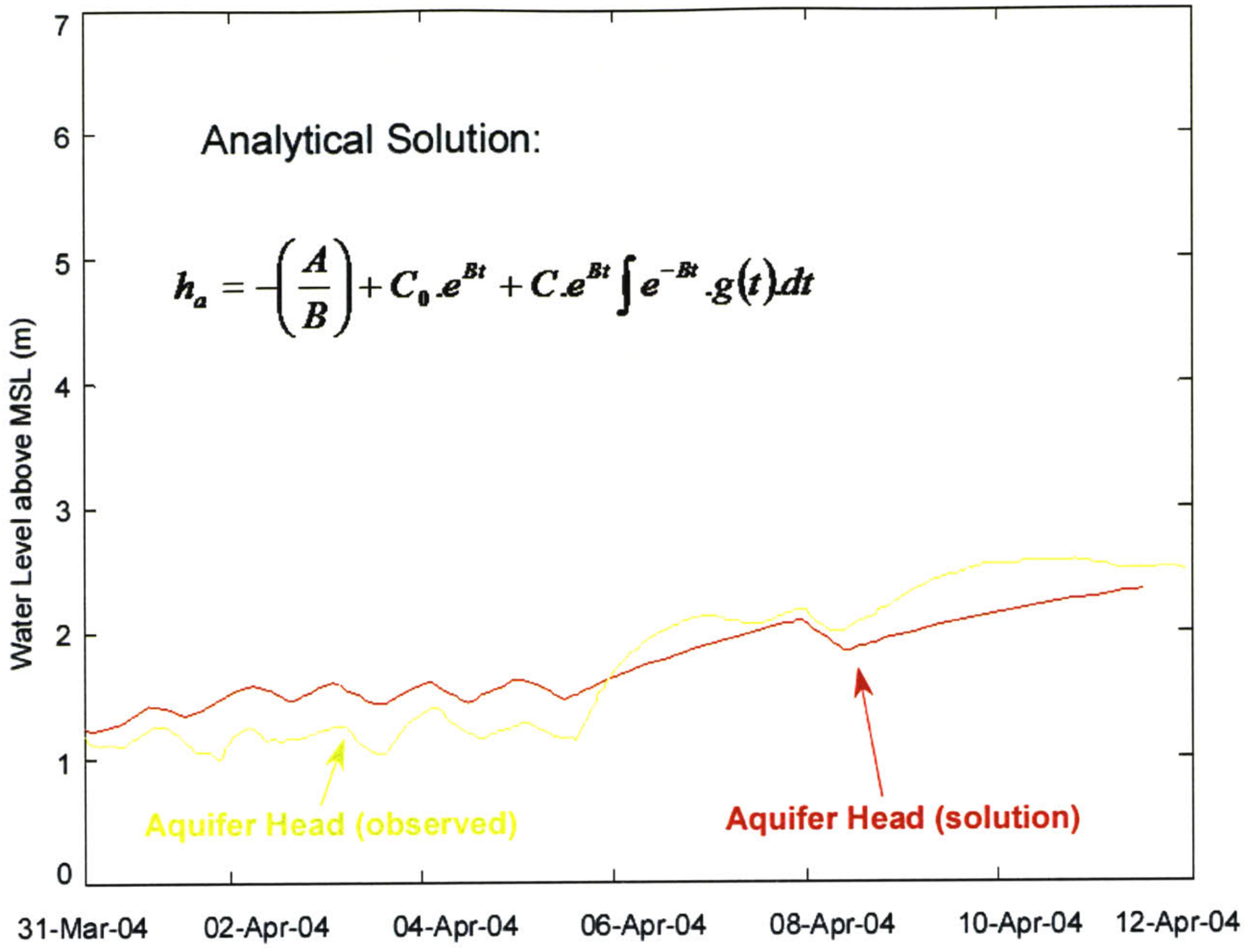


Fig.5.9 Observed vs. Solved Aquifer Heads: Comparison of the observed and solved aquifer heads from April 1 to 12, 2004. The solution to the first order differential equation of the aquifer head can be written as: y = -(A/B) + co*exp(Bt) + C*exp(Bt)*integral[exp(-Bt)*g(t)*dt; where, y is the aquifer head, and g(t) is the step function for pumping. co is the constant evaluated at time zero (i.e. at the 1st hour of 457th day). A (0.455 m/d = 0.019 m/hr), B (-0.322 m/d = -0.013 m/hr), C (-100*40) are coefficients calculated from the modeled aquifer (ha of 1.35m), field (hf of 3.8m), pond (hp of 2.62m), village (hv of 4.83m), and database river (hr of 2.56m) head values for the 457th day (April 1, 2004) from the diurnal model. The 457th day has been considered as the beginning of the hourly model. C is the inverse of storativity (which is 0.01 from the diurnal model) times the number of pumps (which is 40). No pumping on Apr 7th and Apr 10-12 (pumping stopped according to the rainfall information).

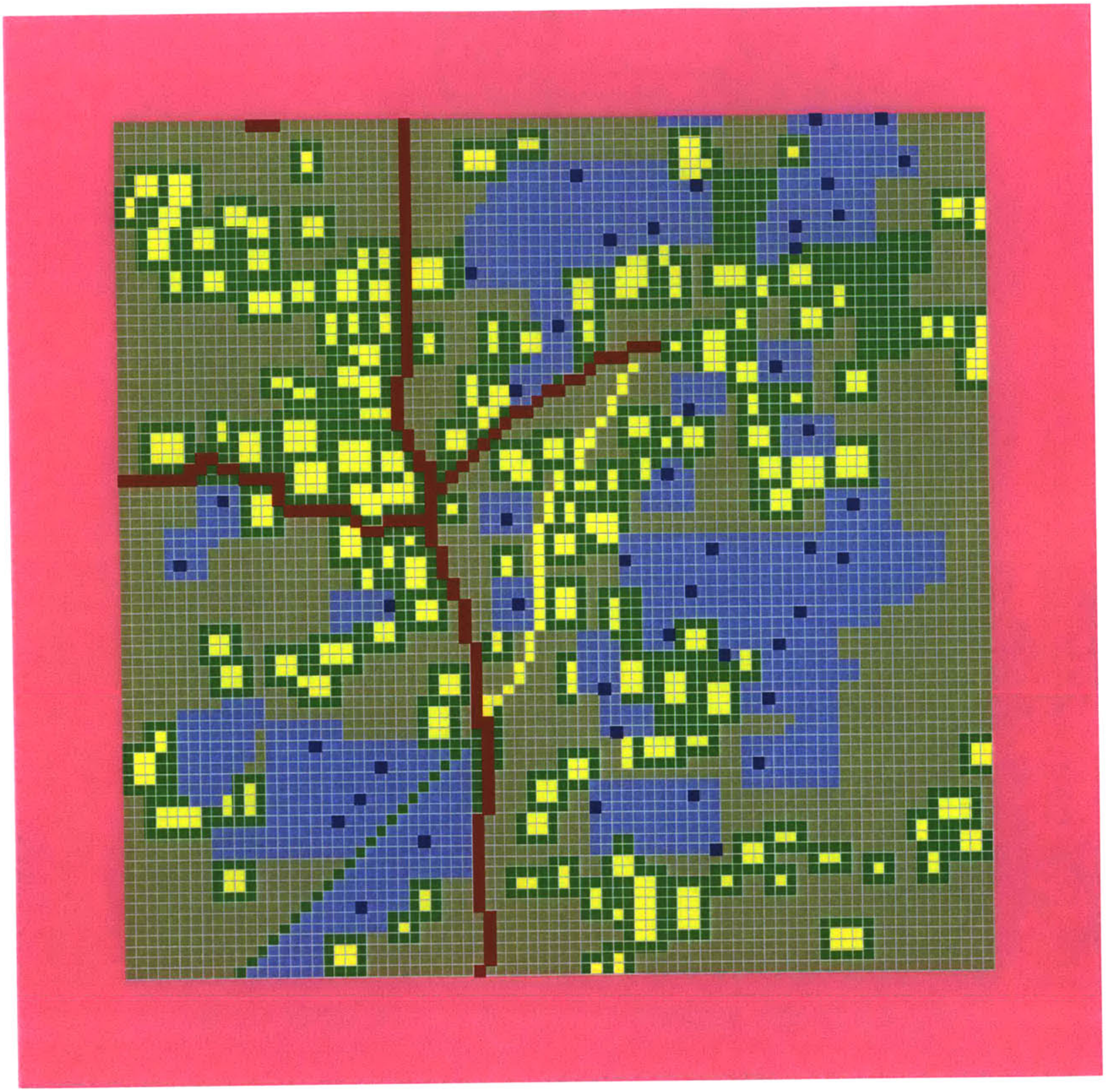


Fig.5.10 Finite Difference Model using MODFLOW: Discretization of the 4km X 4km study area (Fig.3.2) for the Finite Difference model using MODFLOW. Each grid size is 50m X 50m. The various hydrologic features have been mapped out in the grided model with the appropriate area coverage – the yellow, brown, green, sky-blue, dark-blue and gray squares represents the pond, river, village, rice field, irrigation well and other field areas, respectively. The pink squares denote the no-flow boundary outside the model where the model cells have been set as "inactive".

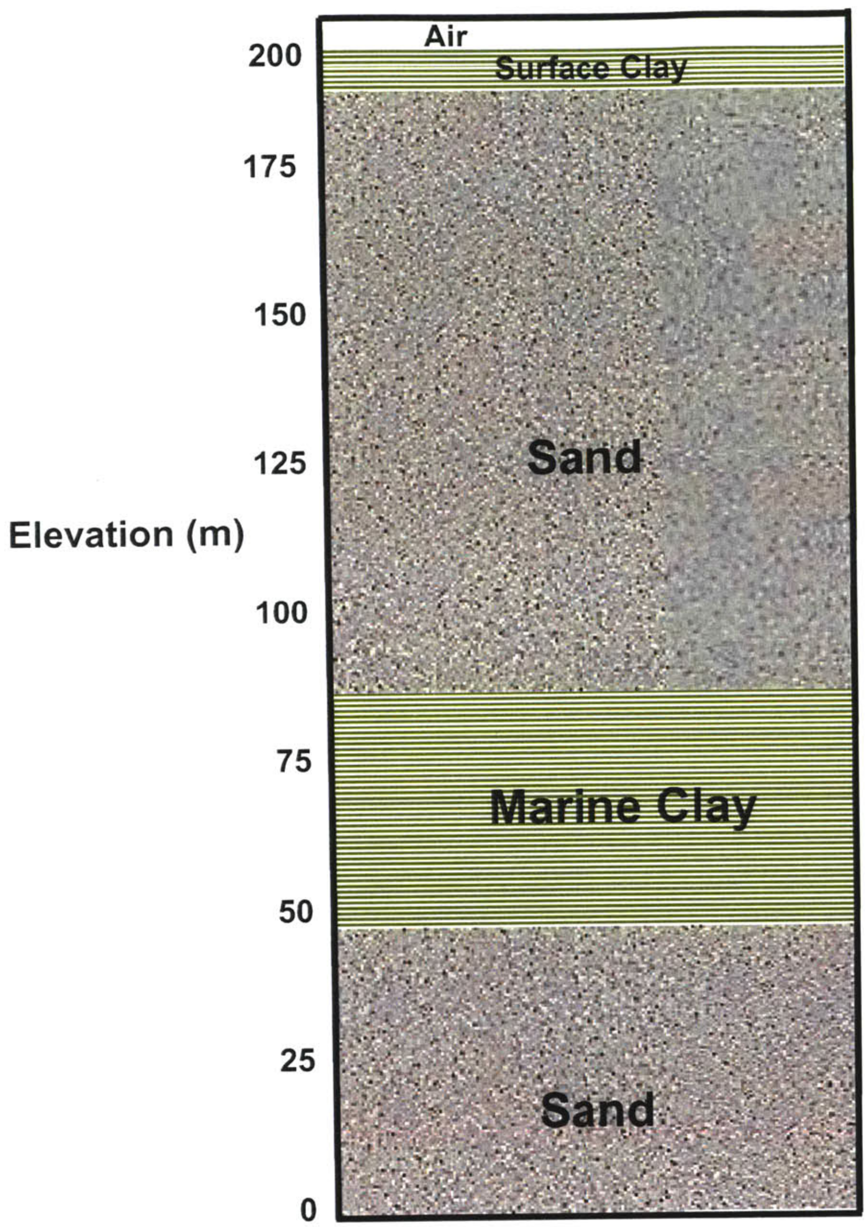


Fig.5.11 Observed Vertical Stratigraphy: Information on vertical stratigraphy of our study area has been obtained from the continuous core samples as collected through split tube sampler by the Bangladesh Water Development Board. In general, the stratigraphy contains of 3-4m of surface clay overlain by ~100m of Pleistocene aquifer. A ~50m thick Marine Clay separates the Pleistocene aquifer from the Holocene aquifer underneath, and this impermeable clay layer exists throughout the entire study area.

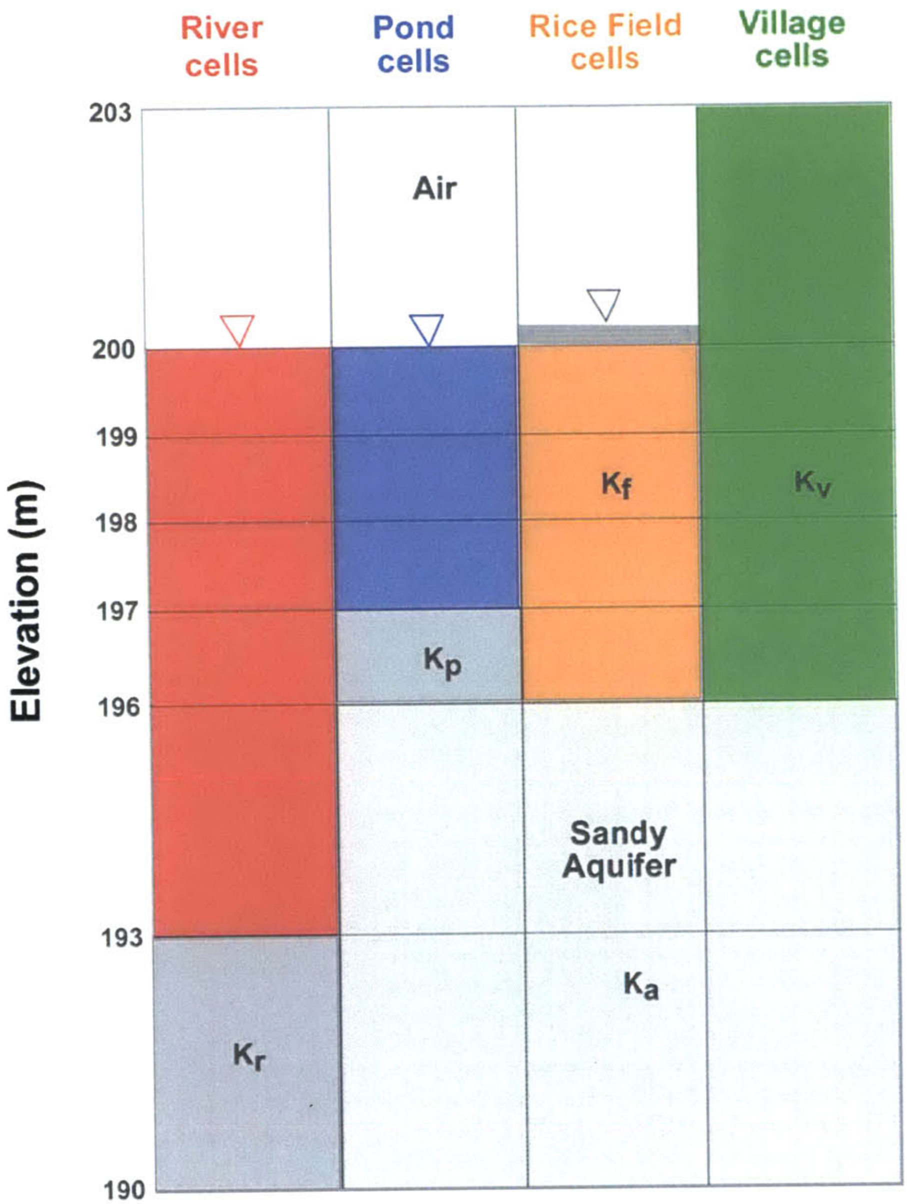


Fig.5.12 Modeled Vertical Stratigraphy in MODFLOW: In accordance with the observed stratigraphy, the vertical dimension of the model has been discretized into a number of layers to incorporate the various characteristics of the hydrologic system. In the model, a 3m layer of air above the ground surface has been introduced to simulate the application and ponding of irrigation waters for rice production, as well as to incorporate the village areas which are about 3m above the ground surface. The 4m thick surface clay layer has been into four layers of 1m each, and the 3m-deep ponds (as observed from the field visits) are sitting on the surface clay with a 1m thick impermeable layer at their bottom. The Ichhamati River is about 7m deep (as observed during the field visits) and the bottom of the river is fairly impermeable compared to the surrounding aquifer. The rest of the layers are based on the information from pump tests.

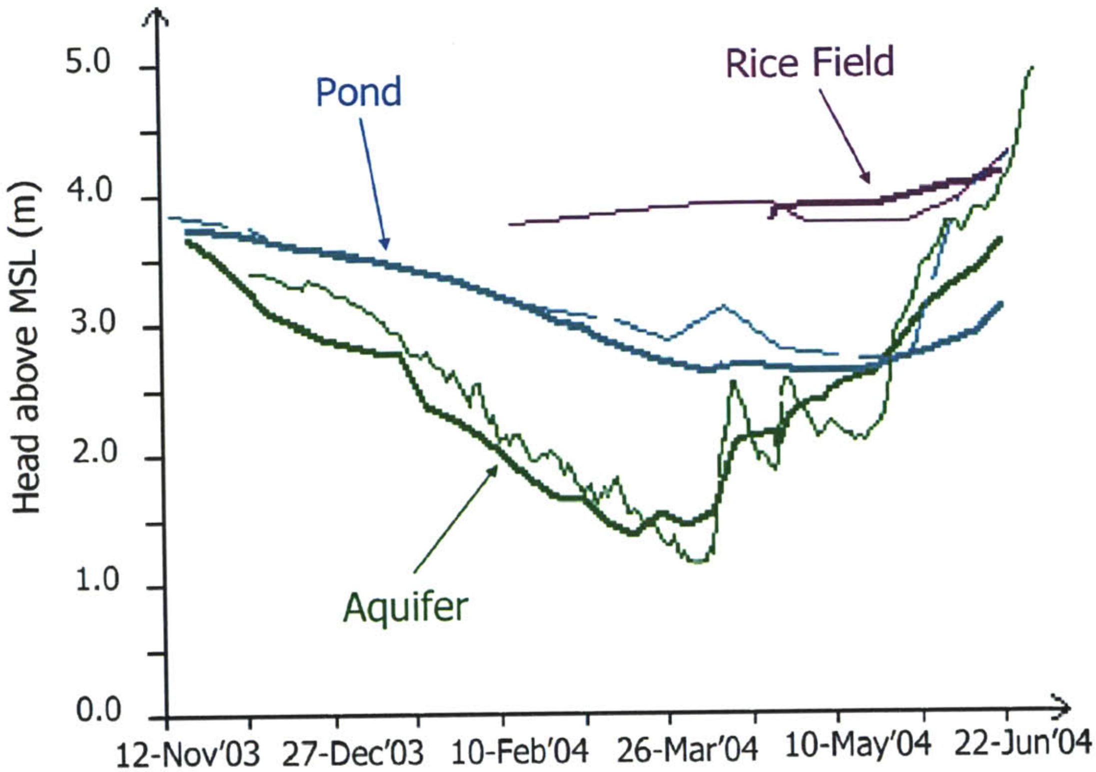


Fig.5.13 MODFLOW Heads Comparison: Comparison of observed heads (thin lines) with the modeled heads (thick lines) from November 2003 to June 2004 as obtained from the 3D Finite Difference MODLFOW model of the study area. The plot shows that the modeled heads, especially that of the aquifer, agrees well with the observed data inferring a good calibration of the model.

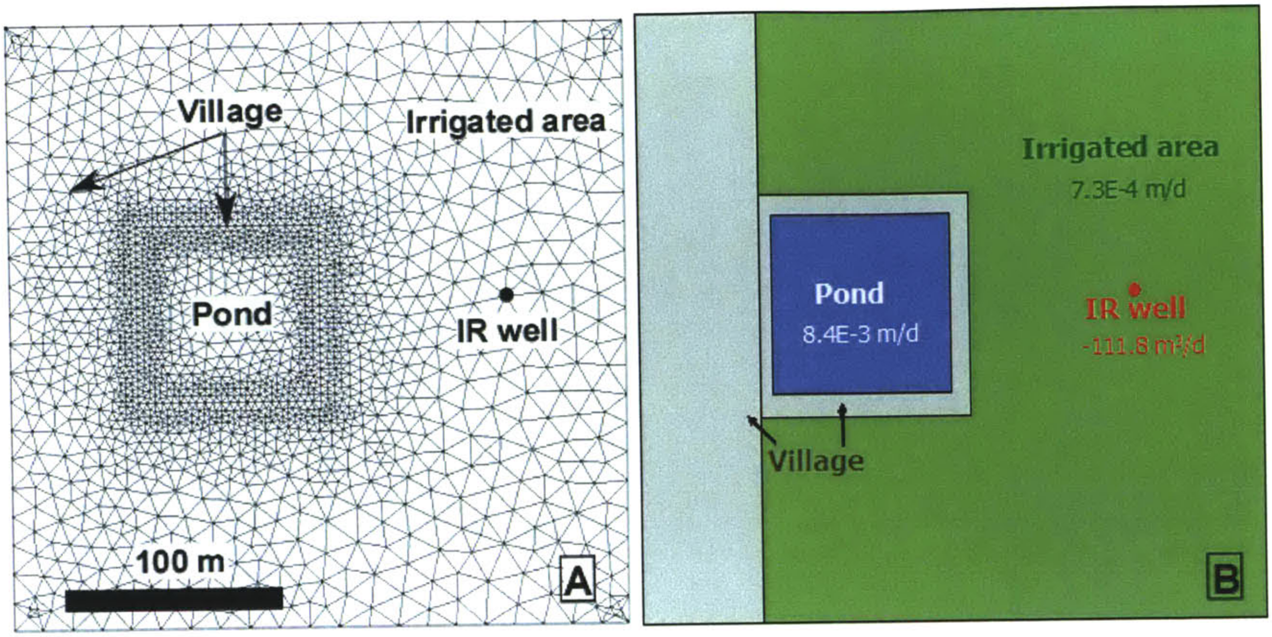


Fig.5.14 Generic 3D model: Panel (A) shows the map of a generic 300m X 300m model area. The model is 122m thick in the vertical direction with similar geological stratigraphy as observed in our study area upto the Marine Clay (Fig.5.11). The triangles denote the element distribution as used in the FEFLOW model. The square area in the middle represents a pond surrounded by villages. Panel (B) shows the distribution and coverage of various features within the generic model area – about 7.1% pond area, 21.3% village area and 71.6% of irrigated rice field area. The percentage coverage of these features are comparable with that is observed within our study area. The irrigation well, situated in the middle of the irrigated area, is screened between 150-170m elevation. The assigned fluxes to different features are obtained from the Lumped Parameter Model.

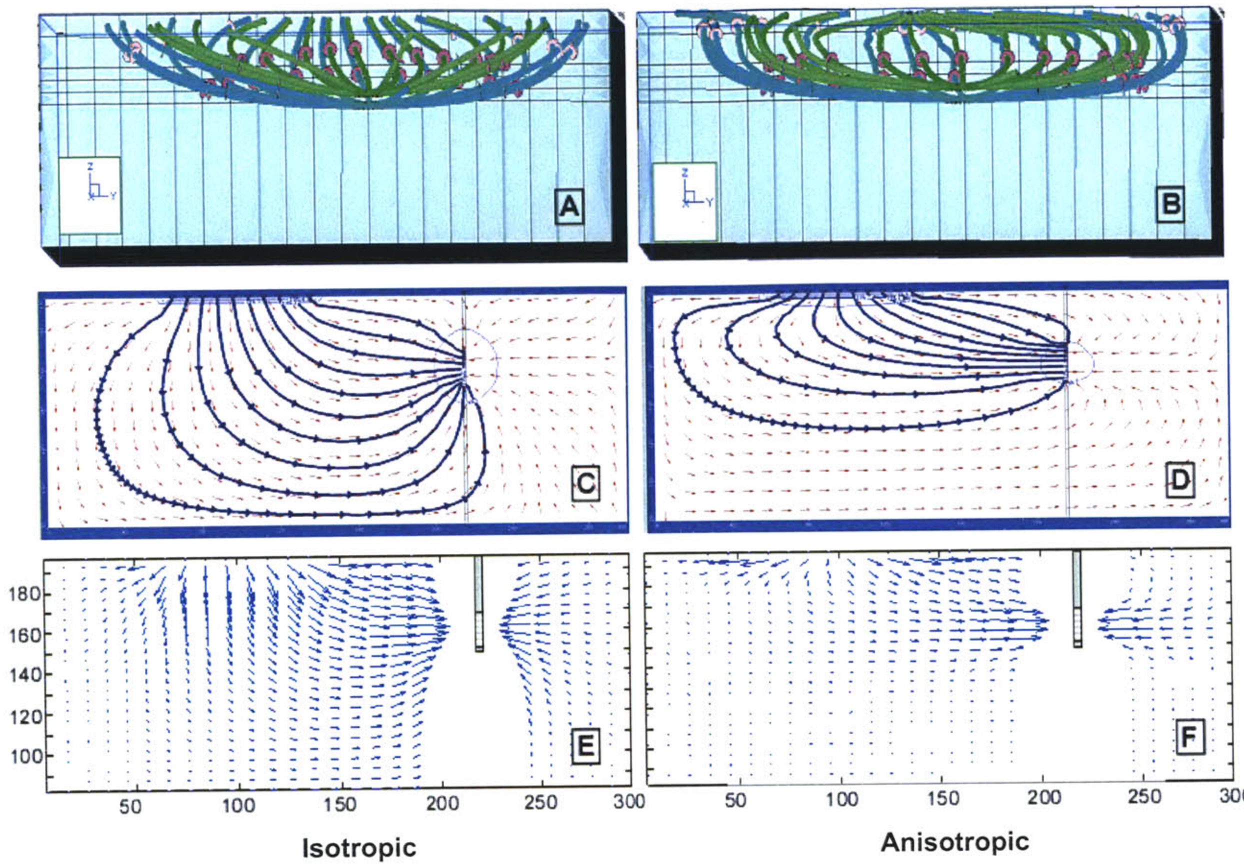
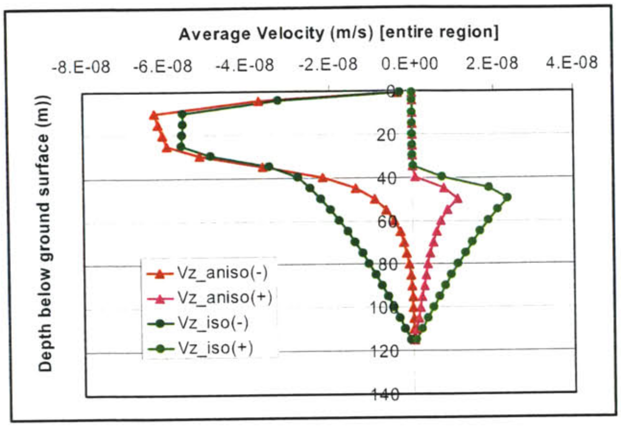
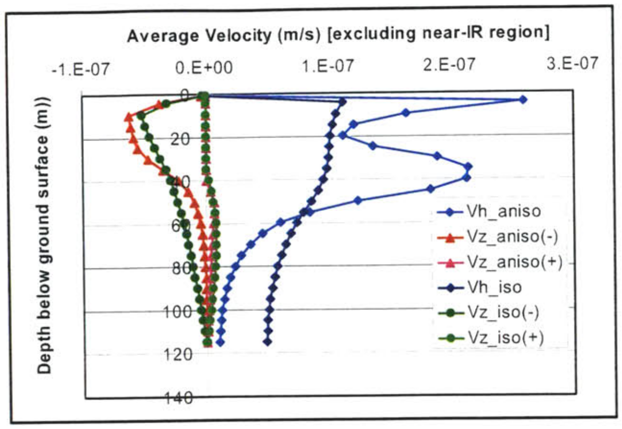


Fig.5.15 Flow-paths and Velocity Vectors: Panels (A) to (H) show the comparison of groundwater flow paths and velocity vectors for Isotropic (left panels) and Anisotropic (right panels) cases in the generic 3D model setup (Fig.5.14). The plots investigate the flow-paths that originate from the pond bottom. Stream-tube analysis in the FEFLOW model (panels A and B) reveals that the stream-tubes converts directly towards the pumping well in isotropic aquifer system, whereas, they take an elliptical shape in accordance to aquifer anisotropy in an anisotropic system. The path-lines modeled using Visual MODLFOW (panels C and D) also indicates that the path-lines are different for the two cases: in isotropic system, the path-lines extends throughout the entire aquifer depth before converging towards the pumping well, whereas in anisotropic system, the path-lines are more condensed around the depth of pumping well screen. Panels (E) and (F) show the velocity vectors for the two cases outside 50m radius from the pumping well (since the velocity vectors at the near pumping regions are much greater and so overshadow the vectors at other areas). The plots indicate that in the anisotropic scenario, the horizontal component of the velocity vectors are much greater than the vertical component specially closer to the pumping well indicating that it takes particle longer time to move vertically downward from the pond bottom, but once the particles are at the depth of the well screen (i.e. at 150-170m elevation in the model) they travels rapidly towards the pumping well.



(A) Entire region



(B) Excluding near pumping region

Fig.5.16 Average Velocities: Plots of velocity vector components for the two scenarios (isotropic and anisotropic as mentioned in Fig.5.15), where all the vectors have been considered (panel A) and only the vectors outside the 50m from the pumping well have been considered (panel B). The horizontal and vertical components of the velocity vectors have been obtained from the generic 3D Visual MODFLOW model (Fig.5.15, panels C-F). At first, the vertically downward velocities (denoted by –ve values) have been separated from the vertically upward velocities (denoted by +ve values). Afterwards, the average vertical velocity at each layer [Vz(-) and Vz(+) as plotted in Fig.5.16] has been calculated by multiplying the individual vertical velocity component with the corresponding horizontal cross-sectional area of the cell, followed by summing up the products, and finally averaging over the entire model area. However, the average horizontal velocity (Vh as plotted in Fig.5.16) for each layer has been found by first calculating the absolute horizontal velocity from Vx and Vy at each cell, followed by summing up the values from all the cells within the layer, and finally averaging over the entire model area. Panel (A) shows that the downward vertical velocity is fairly constant up to the well screen, whereas the upward vertical velocity dominates below the well screen indicating flow convergence towards the well screen from above and below. Panel (B) shows that the horizontal component of the velocity vectors is much larger than the vertical component. Moreover, the values are largest at the layers of pond bottom and well screen indicating the influence of well pumping.

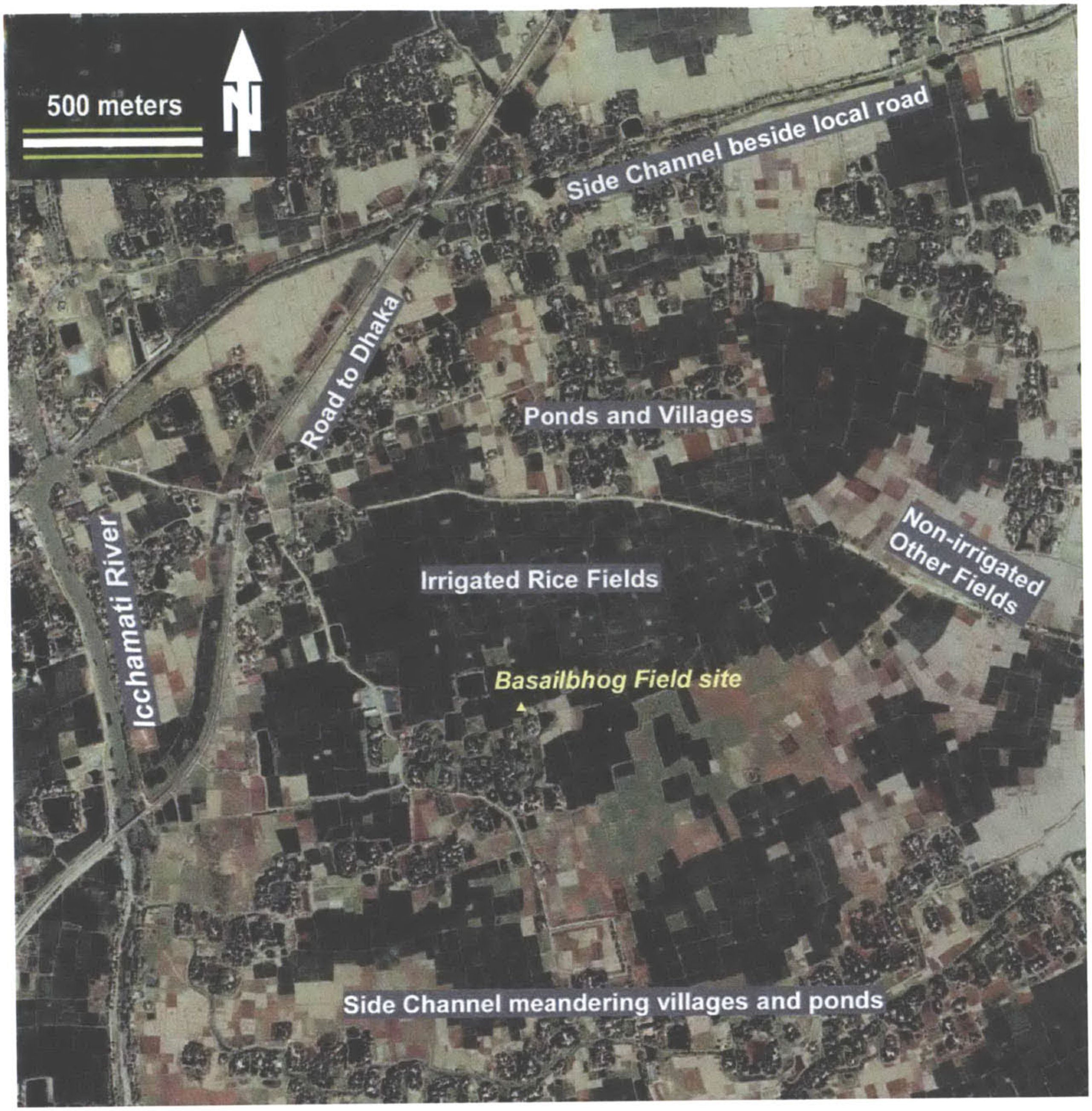


Fig.5.17 Seasonal Model Area: IKONOS image of 3km X 3km area as selected for the seasonal model using FEFLOW. The model area is bounded by the Ichhamati River on the west side and the side-channels on the north and south sides, whereas the model boundary on the east side has been far enough to reduce the boundary effect on the heads within the Basailbhog Field Site. Within the model area, various features, such as river, ponds and villages, irrigated rice field and other field cover 2%, 33%, 38% and 27%, respectively. Moreover, there are about 35 irrigation wells that supply groundwater to the irrigated areas for rice cultivation.

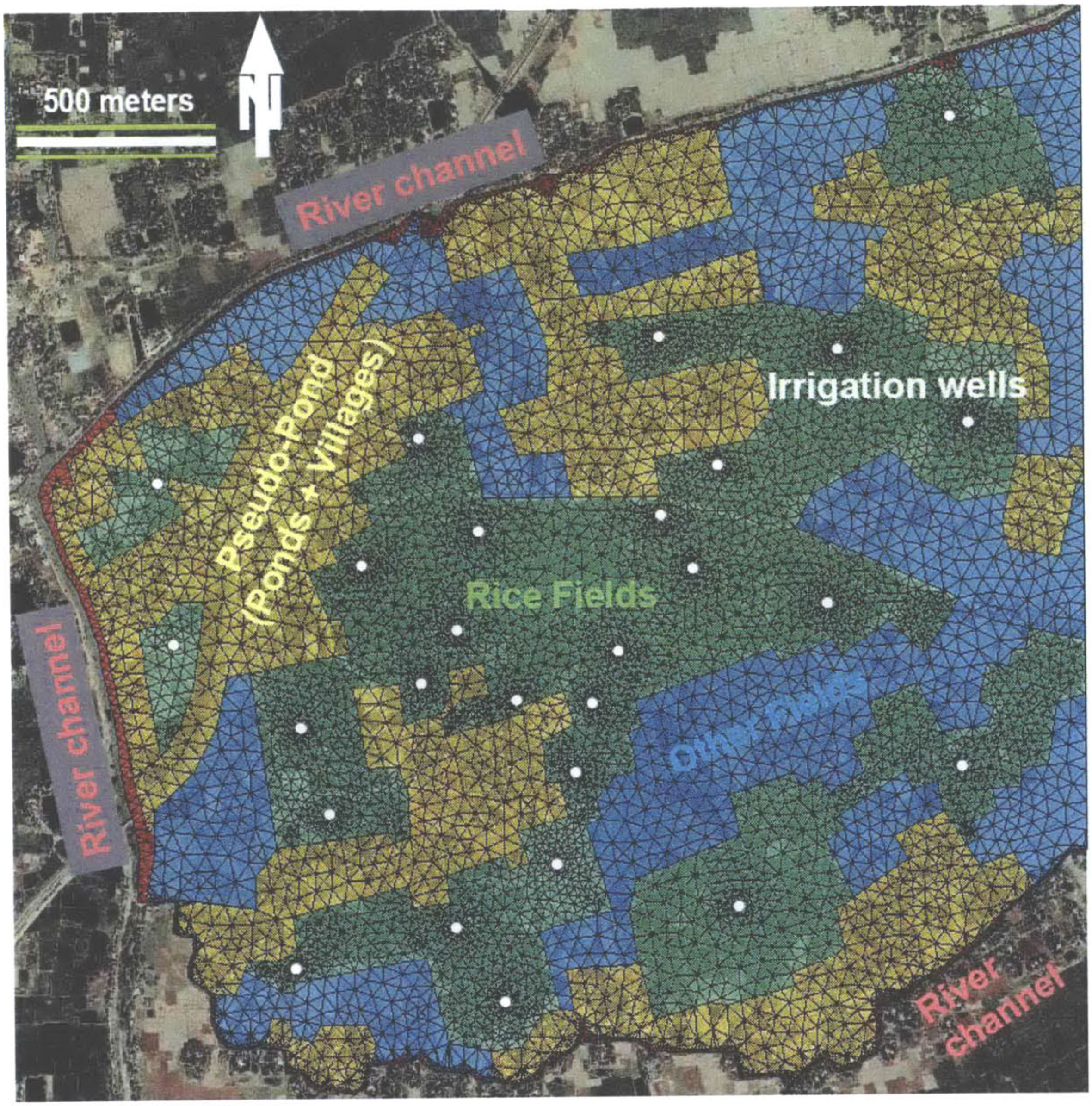


Fig.5.18 FEFLOW mapped area: Modeled area in FEFLOW of the 3km X 3km area surrounding the Basailbhog Field Site (Fig.5.17). The model area is bounded by the Ichhamati River and its side channels on the west, north and south ends, whereas the east end is a no-flow boundary. The various hydrologic features have been mapped out in the grided model with the appropriate area coverage – the red, yellow, green, and blue areas represent the river, pseudo-pond (ponds and villages), rice field, other field areas, respectively. The while circles represent irrigation wells placed at nodal points. The triangles represent discretized elements in FEFLOW with finer resolution around the irrigation wells.

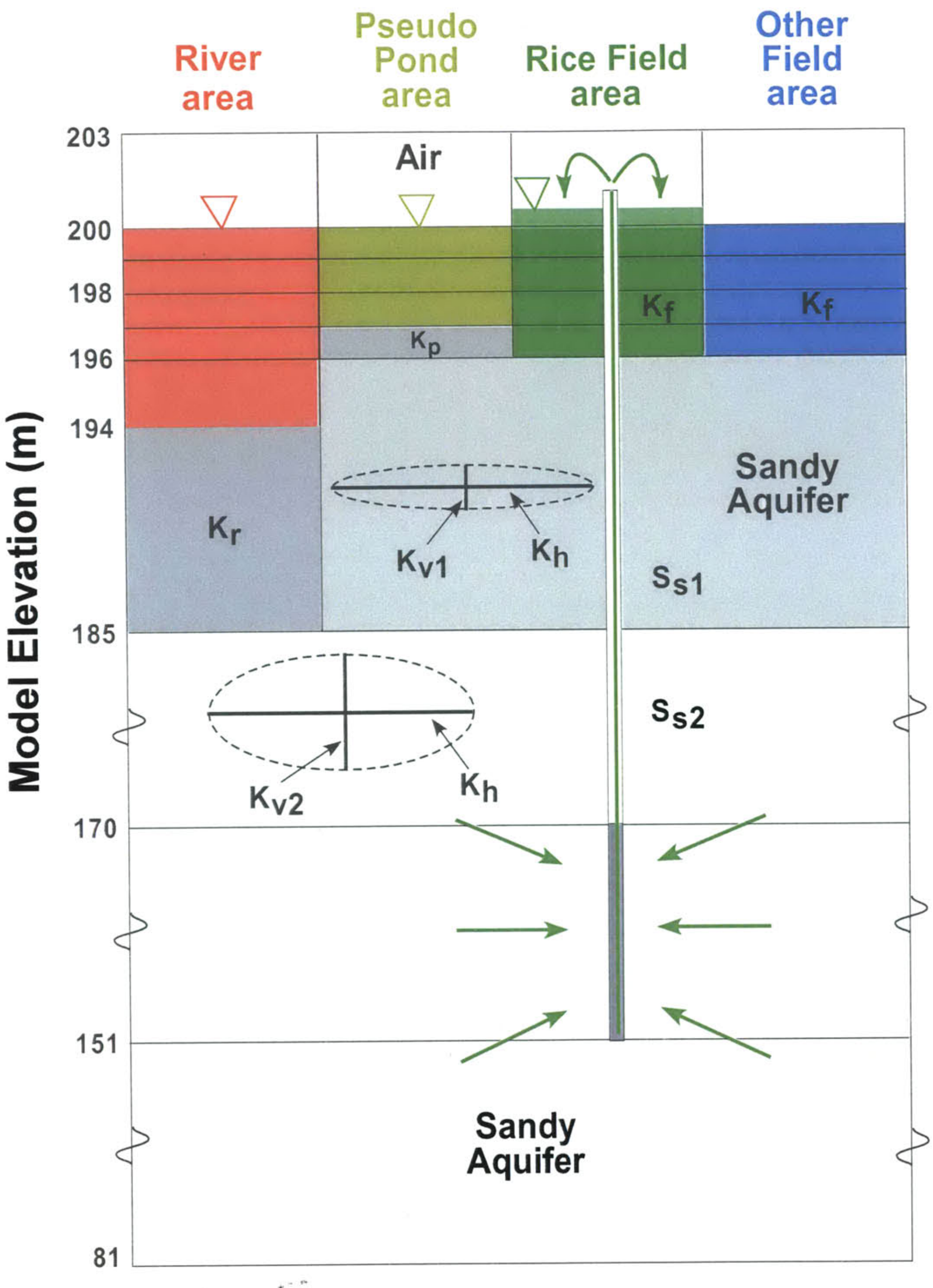


Fig.5.19 Modeled Vertical Stratigraphy in FEFLOW: In accordance with the observed stratigraphy, the vertical dimension of the model has been discretized into a number of layers to incorporate the various characteristics of the hydrologic system. In the model, a 3m layer of air above the ground surface has been introduced to simulate the application and ponding of irrigation waters for rice production. The 4m thick surface clay layer has been divided into four layers of 1m each, and the 3m-deep ponds (as observed from the field visits) are sitting on the surface clay with a 1m thick impermeable layer at their

bottom. The Ichhamati River and its side channels are about 6m deep (as observed during the field visits), and the bottom of the river is fairly impermeable compared to the surrounding aquifer. As obtained from the pumping experiment, the aquifer is segmented into two layers with different vertical conductivities and storage coefficients, whereas the horizontal conductivity is fairly constant throughout the depth. The irrigation wells are screened between 151m and 170m elevation based on the information collected from local farmers.

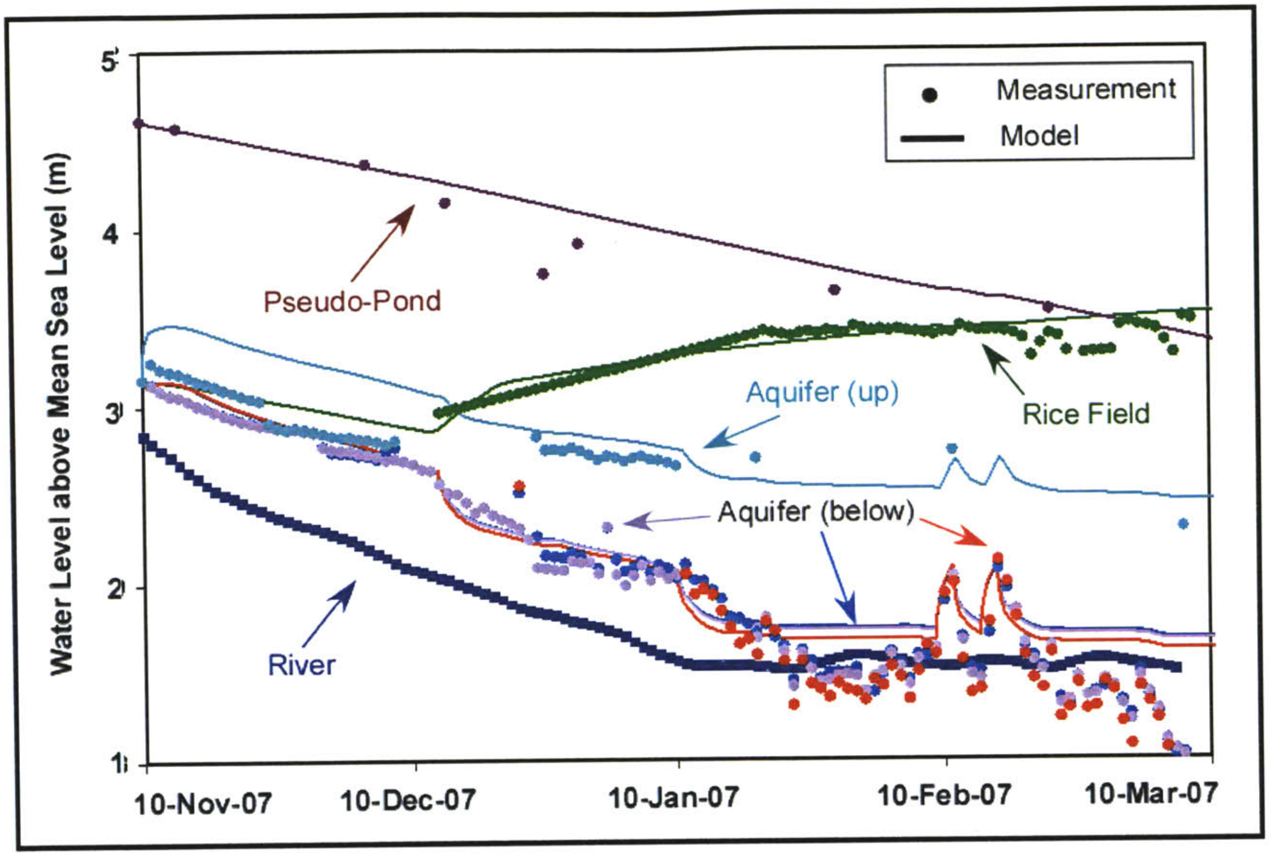


Fig.5.20 FEFLOW Heads Comparison – Half-season: Comparison of observed heads (dots) with the modeled heads (solid lines) from 10-Nov06 to 16-Mar-07 as obtained from the 3D Finite Element FELFOW model for the area as outlines in Fig.5.18. The plot shows that all the modeled heads agree well with the observed data inferring a good calibration of the model.

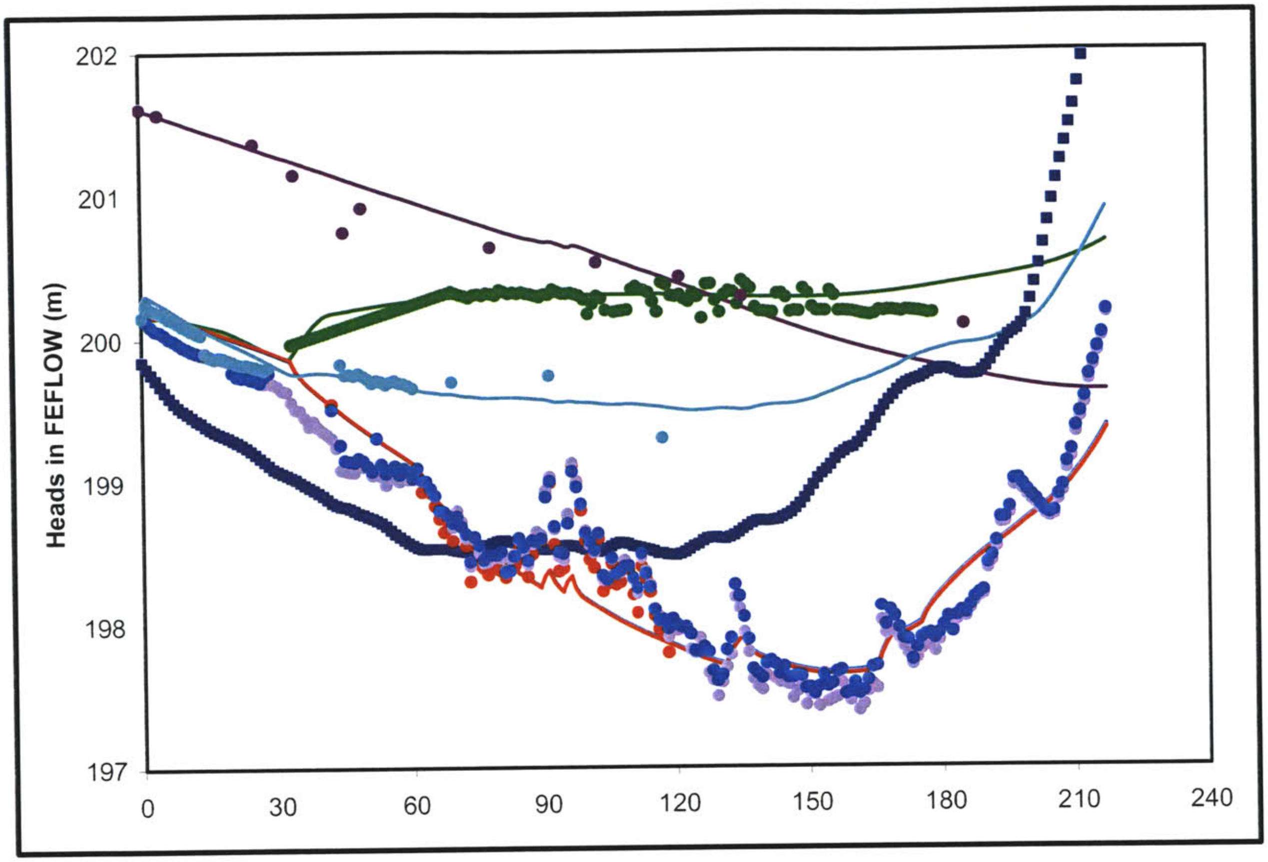


Fig.5.21 FEFLOW Heads Comparison – Full-season: Comparison of observed heads (dots) with the modeled heads (solid lines) from 10-Nov06 to 15-Jun-07 as obtained from the 3D Finite Element FELFOW full-season model for the area as outlines in Fig.5.18. The plot shows that all the modeled heads agree well with the observed data inferring a good calibration of the model. Interestingly, the head in the upper aquifer segment is always higher than the river water level, and thus discharging water into the river. On the other hand, the river head goes down (at the early part of the dry season) and above (towards the later part of the dry season) the lower aquifer head, and thereby, acts as a sink and source of groundwater.

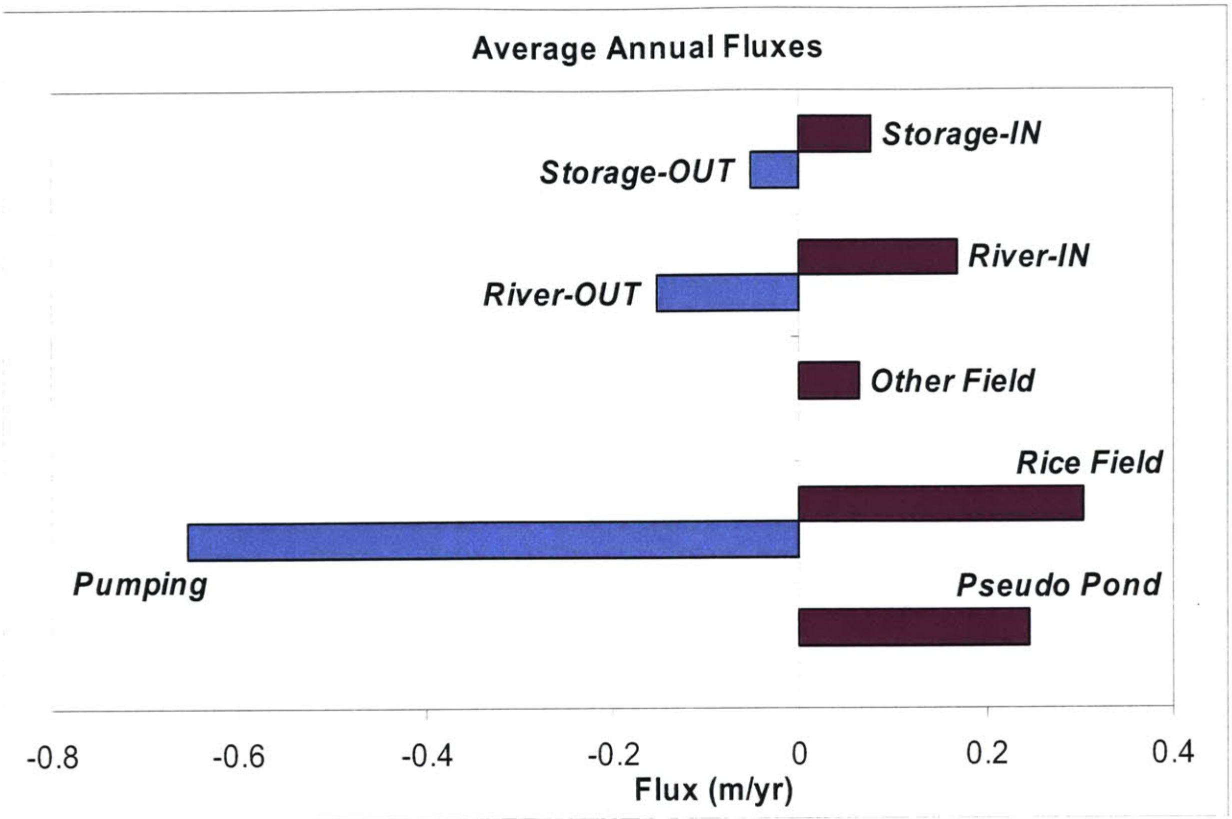


Fig.5.22 FEFLOW Model Fluxes: Estimated average annual water fluxes into and out of the aquifer for the FEFLOW seasonal model. These yearly fluxes have been calculated by integrating the fluxes at various time steps of the model simulation. The major flux out of the aquifer is due to pumping, whereas the Pseudo-Pond and Rice Fields accounts for most of the incoming fluxes. These flux values are comparable with those obtained from the Lumped Model.

Chapter 6

Analysis and Discussions

6.1. Arsenic Mobilization – Revisiting "Pond Hypothesis"

6.1.1. The Concept

The "Pond Hypothesis" suggests that arsenic mobilization in Bangladesh aquifer is deriving from reductive dissolution of various arsenic bearing oxides deposited at the pond bottoms. The process of reductive dissolution occurs in the presence of organic matter and under reducing environment, when residing microbes respire on oxygen from oxide-minerals (e.g. Fe and Mn oxides) to process the organic matter for growth, and subsequently causes release of arsenic associated with the oxide-minerals to the aqueous phase (chapter 2).

Fig.6.1 depicts the process of arsenic mobilization from pond-bottom, and subsequent entrance in to the aquifer along with groundwater flow due to irrigation pumping. According to the suggested mechanism of "Pond Hypothesis", the source of arsenic sorbed to oxide (e.g. FeOOH) surfaces lie upstream of Bangladesh, and in fact, originates in the Himalayas. Weathering of arsenic-rich minerals releases finely divided FeOOH which strongly sorbs co-weathered arsenic. During the annual monsoon season, these sediments are carried to the Bengal basin by the rivers and subsequently get deposited. The several meters high standing flood water, rich in organic matter from human and plant waste, creates anoxic condition at the pond-bottom (about 10-12m below the flood water surface) that is favorable for reductive dissolution of arsenic-rich iron oxides through microbial activity. Once the flood water recedes (the reductive dissolution process liberating arsenic might have been completed by then as well) and the dry season irrigation starts, the dissolved arsenic, along with the other by-products of the reductive dissolution process, are drawn in to the aquifer due to aquifer discharge into the river and the impact of irrigation pumping. Furthermore, the peak of dissolved arsenic as well as other related dissolved constituents (e.g. calcium, ammonium, DIC, DOC and methane) coincides with the depth of well-screen since pumping creates flow convergence at that depth. This phenomenon suggests that hydrologic flow pattern, specially the irrigation pumping, has significant impact on the observed bell-shaped vertical profiles of the concerned solutes.

6.1.2. Field Observations

Throughout our 4km x 4km study area in Munshiganj, we have observed a distinct pattern of dissolved arsenic concentration profile with the peak concentration being around 30m depth below ground surface (chapter 3). Incidentally, but not surprisingly, all the irrigation wells within our study area are screened around that depth. Analysis of numerous single well pump tests and the unique pumping experiment reveals that the aquifer is anisotropic (chapter 4), and hence, impacts the groundwater flow paths as well as the concentration profile of dissolved arsenic (chapter 5). It can be thus conceptualized that the movement of the high arsenic plume from the pond bottom is mostly vertical at the beginning followed by more horizontally converging flow around the depth of the pumping well screen.

In order to understand the groundwater flow dynamics that influences the mobilization of arsenic, and to examine the "Pond Hypothesis" of contributing source to the high arsenic concentration at the depth of irrigation wells, the study area has been numerically modeled using the finite difference model, FEFLOW (chapter 5).

6.2. Numerical Modeling Results and Analysis

Modeling results from a transient three-dimensional groundwater model shows that the stream-tube path-lines from different recharge sources (e.g. pond, rice field, river etc) converge at the depth of irrigation pumping (Fig.6.2). However, the wiggling nature of the stream-tubes indicates that the flow paths are very complex in nature, and there is considerable mixing of water from different sources that needs to be analyzed in a more systematic way. Moreover, transport of solutes to depth and the groundwater age distribution at various locations are also required to understand the movement of arsenic plume with time. For that purpose, model simulations have been carried out for three different scenarios:

- Current stage – if the current flow condition continues
- Ancient stage – before the advent of habitation and irrigation practices
- Inception stage – the beginning of irrigation and creation of ponds

6.2.1. Current Stage

The purpose of this simulation is to investigate the fate of the contaminant plume if the present flow system continues without any change. In order to simulate the condition, at first, the flow module of the seasonal model has been converted to steady-state. The observed average annual fluxes from the seasonal model (Fig.5.22) have been applied in the irrigation wells, pseudo-pond, rice field and other field areas, while the river area has been assigned a constant head of 199.037m as obtained by averaging the river water levels over the dry-season modeling period (i.e. 10-Nov-06 to 15-Jun-07). Flux analysis from the steady-state flow-only model (Fig.6.3) shows that the observed fluxes are comparable with those from the transient seasonal model, and hence, confers the applicability of the steady-state model for simulating long-term impacts with minimum computational effort. Interestingly, the steady-state head data and contour (Fig.6.4) reveal that head in the upper aquifer is greater than the average river water level, which, in turn, is greater than the lower aquifer head. This phenomenon indicates that the river is gaining water from the upper aquifer, but discharging water in to the lower aquifer. This observation is consistent with the transient model (Fig.5.21) though not obvious immediately. Based on the observed fact, it can be expected that contribution from river water will increase with depth of the aquifer.

For investigating the percent contribution of recharge from different sources at various locations within the aquifer, a steady-state transport part has been added to the steady-state flow model, and a constant input of mass has been applied separately in river, pseudo-pond, rice field and other field areas. Analysis of the mass concentration results for the entire modeled area from the simulations (Fig.6.5) reveals that rice field water dominates at the shallowest depth while pond water dominates at the depth of irrigation well, and the contribution from river water increases with depth. However, it should be noted that the number of nodes in the river areas are much greater than those in other areas, and therefore, the plot is skewed towards the river contribution by some factor.

The recharge contribution from different sources has also been analyzed at various monitoring well locations that are presented in Table 6.1. The results indicate that most of the recharge at 30m (depth of peak arsenic concentration as well as that of irrigation well screens) is coming from the pond that bolsters the “Pond Hypothesis” by supporting the notion of arsenic plume originating from pond bottom.

Table 6.1: Percent Contribution from Various Recharge Sources – Current Stage

Monitoring Locations	Depth below Ground (m)	Percent Contribution			
		Pond	Rice Field	Other Field	River
C0-17	5.2	87.7	12.3	0.0	0.0
C0-90	27.4	51.6	47.0	1.4	1.0
C0-120	36.6	58.1	29.9	9.7	6.7
C1-120	36.6	56.1	38.3	4.9	4.3
C2-120	36.6	66.6	23.0	9.8	5.0
C3-120	36.6	70.0	23.7	5.4	4.8
S1-120	36.6	66.4	27.4	5.6	4.8
C0-170	51.8	45.8	18.1	18.9	21.4
C0-230	70.1	26.4	19.0	19.0	39.4

In order to assess how long it takes for a plume to travel to depths, the steady-state transport part of the model has been modified by applying a zero mass flux at the top and a mass source of 1 $gm/m^3.d$ within the aquifer. As the water travels through the aquifer, it gains mass and thereby, its age is proportional to its final concentration. Fig.6.6 shows snap-shots of groundwater age distribution and Table 6.2 provides the range of age at selected depths:

Table 6.2: Groundwater Age at Various Depths – Current Stage

Depth below Ground (m)	Age (years)
6.0m	0 – 10
27.4	0 – 400
36.6	10 – 2500
51.8	400 – 7500
70.1	2500 – 15000

The plot of groundwater age contours (Fig.6.6) depicts a scenario if only the modern day water invades the aquifer under the current groundwater flow system. The patchiness in the contours and the wide range of ages at various depths indicate mixing of flow from different sources with different fluxes.

6.2.2. Ancient Stage

In contrast to the current situation, the ancient stage refers to the pre-habitation pre-irrigation condition. It is assumed that during that time, the Ichhamati River was flowing similar to present day while only tree-coverings existed in rest of the areas in the absence of specific pond and field areas. Therefore, for simulating the ancient scenario, all the pond and village areas have been converted into field areas, and the appropriate ET for tree has been applied in those areas. For the river section, ET for a surface water body has been applied. Moreover, the Ichhamati River has been assigned water levels from a typical year (2000-2001 in this case), while 30-year average rainfall and ET values (WARPO 2000) have been applied in the tree-covered areas.

Modeling results show that (Fig.6.7) unlike the 'Current Stage', the aquifer head drops only about a meter due to lack of pumping. Also the upper aquifer level drops more than the lower aquifer due to increased evaporation near the surface. More interestingly, in contrast to the 'Current Stage' model, the heads at various depths within the aquifer get separated from each other very early in the season because there are no irrigation wells in the 'Ancient Stage' model that can connect the aquifer segments even when there is no pumping.

During the early part of the dry season, ground water discharges into the river, whereas later in the season, the situation is reversed. However, during the modeling period, the river gets more recharge from the aquifer than discharge to the aquifer, which is also confirmed by the obtained fluxes (Fig.6.8). Further analysis of the fluxes indicate that the tree-covered field areas are loosing water due to net evaporation (evaporation subtracted from the rainfall), which is typical in an average year. In summary, the flux values from the 'Ancient Stage' model imply that the Ichhamati River is the only source of recharge to the aquifer, and hence, all the resident water in the aquifer is river water.

6.2.3. Inception Stage

This model investigates the temporal characteristics of contaminant plume at the advent of human habitation and groundwater irrigation at our study area in Munshiganj. While the 'Ancient Stage' and 'Current Stage' models provide the two extreme scenarios of groundwater flow dynamics and corresponding mass transport consequences, the 'Inception Stage' model presents the actual situation of transitioning from the ancient stage to the current stage.

Information obtained from the local people suggests that human habitation at our study area began about 50 years ago when people migrating from other areas started to build their houses on high lands made by the excavated soil which resulted in pond areas. At the early stage, the main professions of the people in the area had been fishing and boating. They eventually started dry season rice cultivation using groundwater about 30 years ago.

Though the creation of ponds and dry season irrigation – the two major components affecting the groundwater flow and contaminant transport in the modern day – was incepted at different times, the simplifying assumption in the current model has been that both events started about 40 years ago. Furthermore, it is also assumed that the number of modern day ponds and irrigation wells have been constant over the last forty years. The latter assumption supports the notion of using the 'Current Stage' steady-state fluxes for the flow part (Fig.6.3), and thus minimizes the computational efforts. However, the transport part of the model is transient to mimic the actual contaminant movement pathways since the inception of pond and irrigation practices.

Fig.6.9 shows the average recharge contribution from different sources throughout various depths. The recharge from the river sections has been separated into parts – pre (old) and post (new) inception periods (i.e. before and after 40 years). Analysis of the results for the entire modeled area from the simulations indicates similar outcome as the 'Current Stage' – the rice field water dominates at the shallowest depth while pond water dominates at the depth of irrigation well, and the contribution from river water (including both the old and new river waters) increases with depth. The plot also reveals that recharge from the newer sources (i.e. pond, field and post-inception river) penetrates up to about 50m in the past 40 years.

However, it should be noted that the number of nodes in the river areas are much greater than those in other areas, and therefore, the plot (Fig.6.9) is skewed towards the river contribution by some factor. Therefore, the recharge contribution from different newer sources (i.e. pond, rice field, other field, and post-inception river) has also been analyzed at various monitoring well locations (Fig.6.10), which also enables to examine the transience nature of the post-inception contributions. The results indicate that the recharge contributions at shallow depth (5.2m) are constant with time, and the ponds contribute the bulk of the recharge. At a depth of 30m (depth of peak arsenic concentration as well as that of irrigation well screens), most of the recharge is coming from the pond followed by the rice field. Interestingly, the temporal trend of the recharge tends towards asymptotic values indicating that the recharge contributions at that depth are reaching steady-state, and the values are comparable with those obtained from the 'Current Stage' model (Table.6.1). On the contrary, the recharge values at other depths (i.e. 36.6m and 70.1m in Fig.6.10) are increasing with time (within the modeled 40 years) referring that the contributions haven't reached steady-state. However, at all the monitoring locations, pond water contributes the most (excluding the resident old river water) followed by the rice field water.

For simulating the groundwater age distribution, a zero mass flux has been applied at the top model cells, and a mass source of 1 gm/m^3.d has been assigned throughout the aquifer. However, the initial age distribution of the resident water (derived from the pre-inception river) has been adopted from the sediment age rather than from the results of 'Ancient Stage' model since those values indicates groundwater age older than the sediment at depths. Since the sediment at 120m is about 10,000 years old, the resident water cannot be older than that. Accordingly, the initial age distribution of the resident water has been kept proportional to the sediment age at various depths.

Analysis of the average groundwater age distribution at selected depths indicates that younger age dominates at shallower depths. Moreover, the age values at the monitoring locations can be explained by the relative contribution of recharge water from different sources. For example, at 36.6m depth, pond and rice field water (which are very young) contributes about 70% of the recharge (Fig.6.10), whereas the rest 30% is the resident old river water. Considering the sediment age is 10,000 years at 120m and varies proportionally with depth, the age of resident water can be assumed to be about 3000 years old. Since 30% of the recharge is resident water (age 3000 years) and 70% is new water (age 40 years), the average age of water at the monitoring location can be calculated as ~900 years, which is consistent with the modeled age (400 to 1000 years). Similarly, the ages at 27.4m and 51.8m monitoring locations can be calculated as ~167 years and ~3000 years, respectively, which are again comparable with the modeled results. Furthermore, modeling results indicate that the groundwater age at 30m depth in Bejgoan Field Site is about 24-60 years old, which is consistent with the tritium age measurement at the same depth.

6.3. Comparison with Stable Water Isotope

As depicted in Fig.3.31, there is a large variability in the isotopic values from various sources, such as river water, pond water, rainwater, and the standing water in the rice fields within our study area. These different pools of water have different isotopic signatures, and thus, the groundwater, which is a mixture of different water pools, has somewhat different isotopic value based on the proportional contribution of various recharge sources. This is also evident from the fact that the groundwater isotope values are clustered in the middle of the meteoric water line, where the two ends of the line are bounded by the lighter isotopic values of the surface water (e.g. pond and river) at the end of flood and the heavier isotopic values of the rain and rice field water towards the end of dry season (Fig.3.31).

Analysis of the stable water isotope values with depth at our Bejgoan Field Site (Fig.3.34) reveals an interesting profile – the water becomes lighter with depth up to 24.4m, followed by a large variability at 30.5m depth, and afterwards, the water becomes heavy again followed by a slightly increasing trend of water becoming lighter with depth. Similar trend in stable water isotope profile has also been observed at the Basailbhog Field Site (Fig.6.12). Interestingly, the distinct hump in isotopic values around the depth of 20-40m is consistent with the observed peak dissolved arsenic concentration around the same depth within the study area (Fig.4.1, 4.2, 4.5, 4.6). However, the similarity of the profiles and their coincidence with the depth of irrigation well is not surprising – rather it bolsters the importance of groundwater flow dynamics induced by the irrigation pumping, and consequently the contribution of water from various sources, especially from the pond bottom to that very depth.

Fig.6.13 shows the relative contribution of recharge from various sources at the Bejgoan Field Site. Interestingly, the recharge profile from the pond follows the exact pattern of dissolved arsenic concentration as well as other related chemical constituents. This observation again signifies the importance of pond water contribution at the depth of arsenic peak. As can be seen from the figure, pond contributes about 40-50% of the total recharge followed by 40% contribution from rice field water at 20-30m depth. Seasonal hydrological flow pattern in our study area (Fig.5.21) indicates that pond water recharges the aquifer throughout the dry season, whereas recharges from the rice field occur after irrigation starts in January and recharge from the river occurs at the later part of the dry season in March. Seasonal rainfall database (Fig.3.28) shows very little or no rainfall at the early part of the dry season (December to February) followed by increasing amount of rainfall from March. This fact implies that rainfall recharge, mainly through the non-rice field areas, occurs concurrently with recharges from rice field and river areas.

Using the percent recharge contribution from various sources (Fig.6.13) coupled with the corresponding stable water isotope values (Fig.3.31), the isotopic profile at the Bejgoan Field Site has been calculated and then compared with the observed values (Fig.6.14). Based on the seasonal hydrological flow pattern and temporal recharge characteristics, isotope values for pond areas have been estimated as the average of the seasonal values (Fig.3.33A), whereas those for the river and rice field areas have been obtained from the later part of the dry season (Fig.3.31 and 3.33B). Comparison of the calculated and measured isotopic values in Fig.6.14 indicates that the calculated values are within the range of measured values, and thereby, confers that the observed isotopic profile results from the mixing of water from various recharge sources. The heavier waters at 4.6m and 38.1m depths are originating from highly evaporative rice field waters, whereas the lighter waters are mainly being derived from river and pond waters. Furthermore, the observed wide variability of isotopic values at 30.5m depth (Fig.6.14) can be attributed to the flow convergence around 30.5m depth (Fig.5.15) which results in mixing of lighter and heavier water mainly from the pond areas throughout the season (Fig.3.33A).

6.4. Direct Evidence in Support of "Pond Hypothesis"

In addition to the numerical analysis of groundwater flow dynamics, contaminant transport and isotopic comparison, so far the most direct evidence supporting the "Pond Hypothesis" has been observed from the dissolved arsenic concentration profile at a cluster beside a highly recharging pond (Fig.6.15).

As indicated in Fig.3.11, Pond-5 is one of the highly recharging monitoring ponds within our study area. Therefore, a cluster of peizometers (cluster, C-7) has been recently installed beside Pond-5 to tap in to the arsenic plume and verify the 'Pond Hypothesis'. Interestingly, the dissolved arsenic concentration profile (Fig.6.15) shows two distinct peaks – one at a depth of 30-40m and the other at 20m. While the peak concentration at 30-40m depth refers to the characteristic regional hump observed in our study area, the second peak at a shallower depth can be rationalized as the local arsenic plume originating from the bottom of Pond-5. Similar observations from two different sampling campaign confirms that the twin peaks are not a measurement error. The location of the second peak at the shallow depth, as well as the observed dissolved arsenic concentration can be explained through simple calculations: Pond-5 water level drops ~2.5m (after correcting for ET) during a season (Fig.3.10). Thus, for an effective aquifer porosity of ~15-20%, the plume from pond bottom travels to ~15m vertically downward during the dry season. Since the pond-bottom is about 5m below the ground surface, the plume from the pond bottom actually ends up at ~20m depth – the very depth where the shallow peak of dissolved arsenic concentration has been observed from the samples collected in May (i.e. towards the end of the dry season). At the same time, the level of measured dissolved arsenic concentration (400 ppb or 400 μg/L) can easily be explained by dissolution of arsenic at a rate of ~20μg/L (Horneman, Van Geen et al. 2004; Polizzotto, Harvey et al. 2006) from 1-2cm thick clay-sediment deposit [average sedimentation rate in a highly depositional environment is ~1-2 cm/yr (Polizzotto, Harvey et al. 2005)] with a porosity of 40%.

6.5. Conclusions

At our study area in Munshiganj, a wide variety of data supports the notion that the pattern of groundwater arsenic concentrations is related to the pattern of groundwater flow. Since the mineral composition of aquifer material is homogeneous, the large differences in groundwater arsenic concentration over small spatial distances are related to the groundwater flow path.

Results from the Lumped Parameter Model indicate that groundwater irrigation has greatly changed the groundwater flow dynamics in our study area. The hydrologic data from our site coupled with the modeling results suggest that vigorous groundwater flow is not only flushing the aquifer over time-scales of decades, but also rapidly transporting solute loads into the aquifer with recharge water from rice fields, ponds and rivers. Further analysis of the various fluxes reveals that ponds provide the largest source of recharge to the aquifer, and hence, is a potential source of dissolved arsenic to the subsurface.

In addition to the spatial patchiness, dissolved arsenic concentration in Bangladesh groundwater also exhibits a distinct profile with a peak concentration around 20-40m depth. Coherence to the modeling results and field observations, a theory called "Pond Hypothesis" has been proposed to explain the distinct profile as well as the spatial patchiness of dissolved arsenic concentration. The "Pond Hypothesis" suggests that arsenic mobilization in Bangladesh aquifer is deriving from reductive dissolution of various arsenic bearing oxides (the widely accepted mechanism for arsenic mobilization in Bangladesh) deposited at the pond bottoms. The process of reductive dissolution occurs in the presence of organic matter and under reducing environment, when residing microbes respire on oxygen from oxide-minerals (e.g. Fe and Mn oxides) to process the organic matter for growth, and subsequently causes release of arsenic associated with the oxide-minerals to the aqueous phase. Subsequently, at the end of flooding season, the dissolved arsenic along with mixture of various dissolved solutes from pond bottoms enters the aquifer and is driven towards the well screen both vertically due to overlying recharge and horizontally due to increased pumping.

Small and large scale pump tests indicate that the aquifer in our study area is anisotropic that creates flow convergence at the depth of irrigation well screen. Results from a three-dimensional transient model also reveal the aquifer anisotropy and its importance on the groundwater flow dynamics. In addition, the three-dimensional model indicates that the groundwater flow paths are extremely complex in nature, receiving recharge from different sources (e.g. ponds, rivers, rice fields) with varied proportions.

In order to investigate the recharge contributions at various locations, and subsequent movement of contaminant plume with time, model simulations have been carried out for three different scenarios – 'Current Stage' (if the current flow condition continues), 'Ancient Stage' (before the advent of habitation and irrigation practices), and 'Inception Stage' (the beginning of irrigation and creation of ponds). Analysis of the modeling results indicates that in general, the rice field water dominates at the shallowest depth while pond water dominates at the depth of irrigation well, and the contribution from river water (including both the old and new river waters) increases with depth.

Analysis of the average groundwater age distribution at selected depths indicates that younger age dominates at shallower depths. Moreover, it has been shown that the age values at the monitoring locations can be explained by the relative contribution of recharge water from different sources. Furthermore, modeling results indicate that the groundwater age at 30m depth in Bejgoan Field Site is about 24-60 years old, which is consistent with the tritium age measurement at the same depth.

Isotope methodology is an effective process for hydrologically characterizing the sources of recharge and hence, the other dissolved constituents transported along the flow. Interestingly, the stable water isotope values in our study area shows a similar profile to the dissolved arsenic concentration. The similarity of their profiles and the coincidence of their peak concentrations with the depth of irrigation well signify the importance of irrigation induced groundwater flow, and consequently, the contribution of water from various sources, especially that from the pond bottom to the very depth. Furthermore, comparison of calculated and measured isotopic values at the Bejgoan Field Site indicates that the calculated values are within the range of measured values, and thereby, confers that the observed isotopic profile results from the mixing of water from various recharge sources. More importantly, the lighter water at the depth of peak arsenic concentration can only be derived from lighter pond water recharge in November since only the pond water contributes recharge to the aquifer throughout the season, whereas the lighter river and rainfall water from September-November do not contribute to the groundwater recharge. These results, in turn, exemplifies that indeed pond water is the major contributor of recharge at 20-30m depth, and the major player behind the very high dissolved arsenic concentration at that depth.

Finally, a direct evidence supporting the "Pond Hypothesis" has been observed from the dissolved arsenic concentration profile at a recently installed cluster beside a highly recharging pond. The two distinct peaks in the dissolved arsenic concentration profile have been attributed and explained by a characteristic regional peak at 30-40m depth and a local peak at 20m originating from the nearby pond bottom.

In summary, the observed direct evidence, coupled with the numerous modeling results and isotopic characterization, strongly supports the "Pond Hypothesis" for explaining the distinct profile as well as the patchiness of dissolved arsenic concentration. However, it is recommended that a further analysis of dissolved arsenic concentration at the latest well cluster be carried at the very beginning of the dry season. An observation of high concentration of dissolved arsenic at the shallowest depth will then prove the "Pond Hypothesis" beyond any doubts.

Reference:

Horneman, A., A. Van Geen, et al. (2004). "Decoupling of As and Fe release to Bangladesh groundwater under reducing conditions. Part 1: Evidence from sediment profiles." Geochimica Et Cosmochimica Acta **68**(17): 3459-3473.

Polizzotto, M. L., C. F. Harvey, et al. (2006). "Solid-phases and desorption processes of arsenic within Bangladesh sediments." Chemical Geology **228**(1-3): 97-111.

Polizzotto, M. L., C. F. Harvey, et al. (2005). "Processes conducive to the release and transport of arsenic into aquifers of Bangladesh." Proceedings of the National Academy of Sciences of the United States of America **102**(52): 18819-18823.

WARPO (2000). National Water Management Plan, Volumes 1-11, Ministry of Water Resources, People's Repblic of Bangladesh.

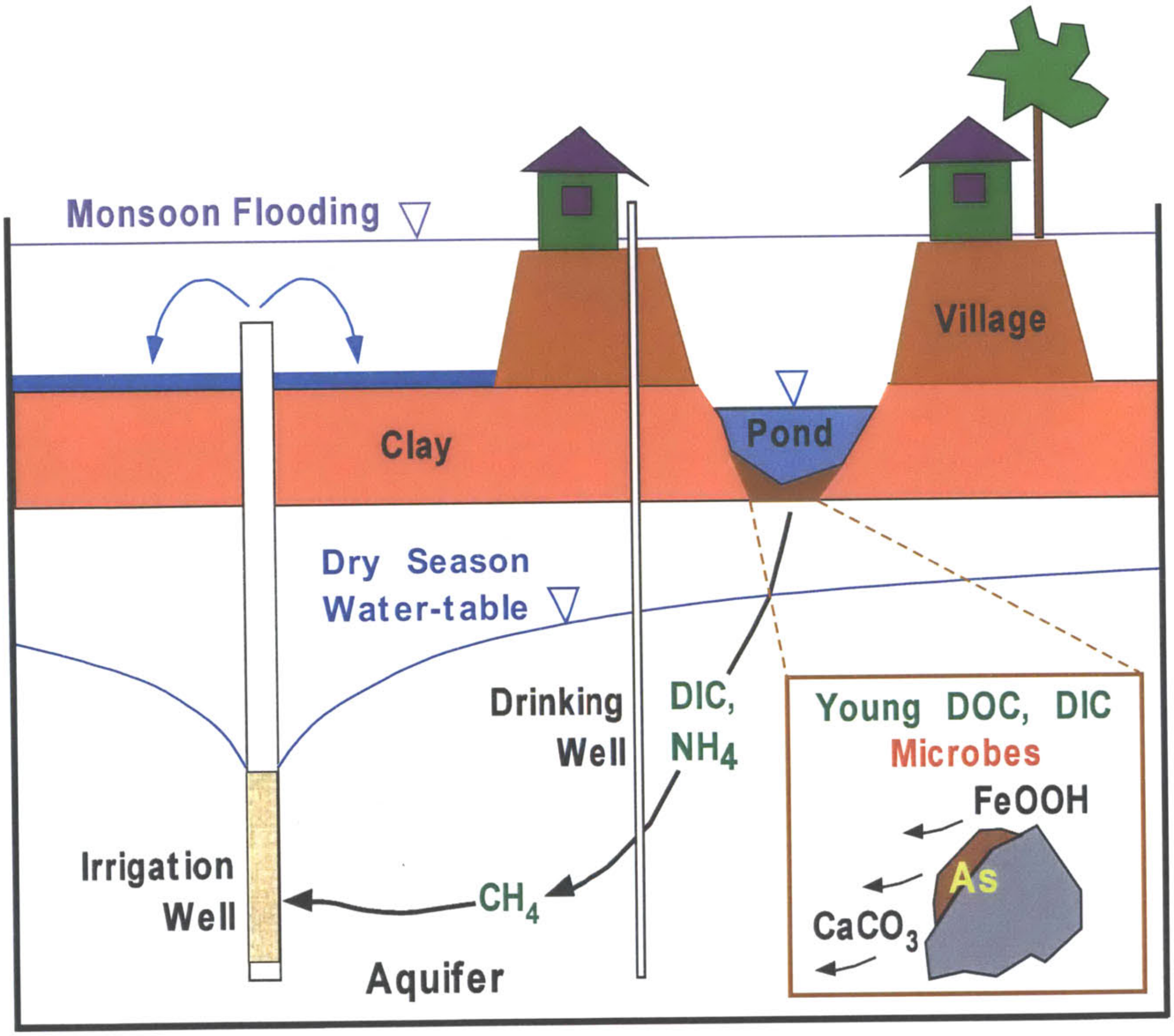


Fig.6.1 Schematic of Pond Hypothesis: Cartoon depicting the process of arsenic mobilization from pond-bottom, and subsequent entrance in to the aquifer along with groundwater flow due to irrigation pumping. During the annual monsoon season, the several meters high standing flood water, rich in organic matter from human and plant waste, creates anoxic condition at the pond-bottom (about 10-12m below the flood water surface) that is favorable for reductive dissolution of arsenic-rich iron oxides (e.g. FeOOH) through microbial activity. Once the flood water recedes and the dry season irrigation starts, the dissolved arsenic, along with the other by-products of the reductive dissolution process (e.g. calcium, ammonium, DIC, DOC and methane) coincides with the depth of well-screen since pumping creates flow convergence at that depth.

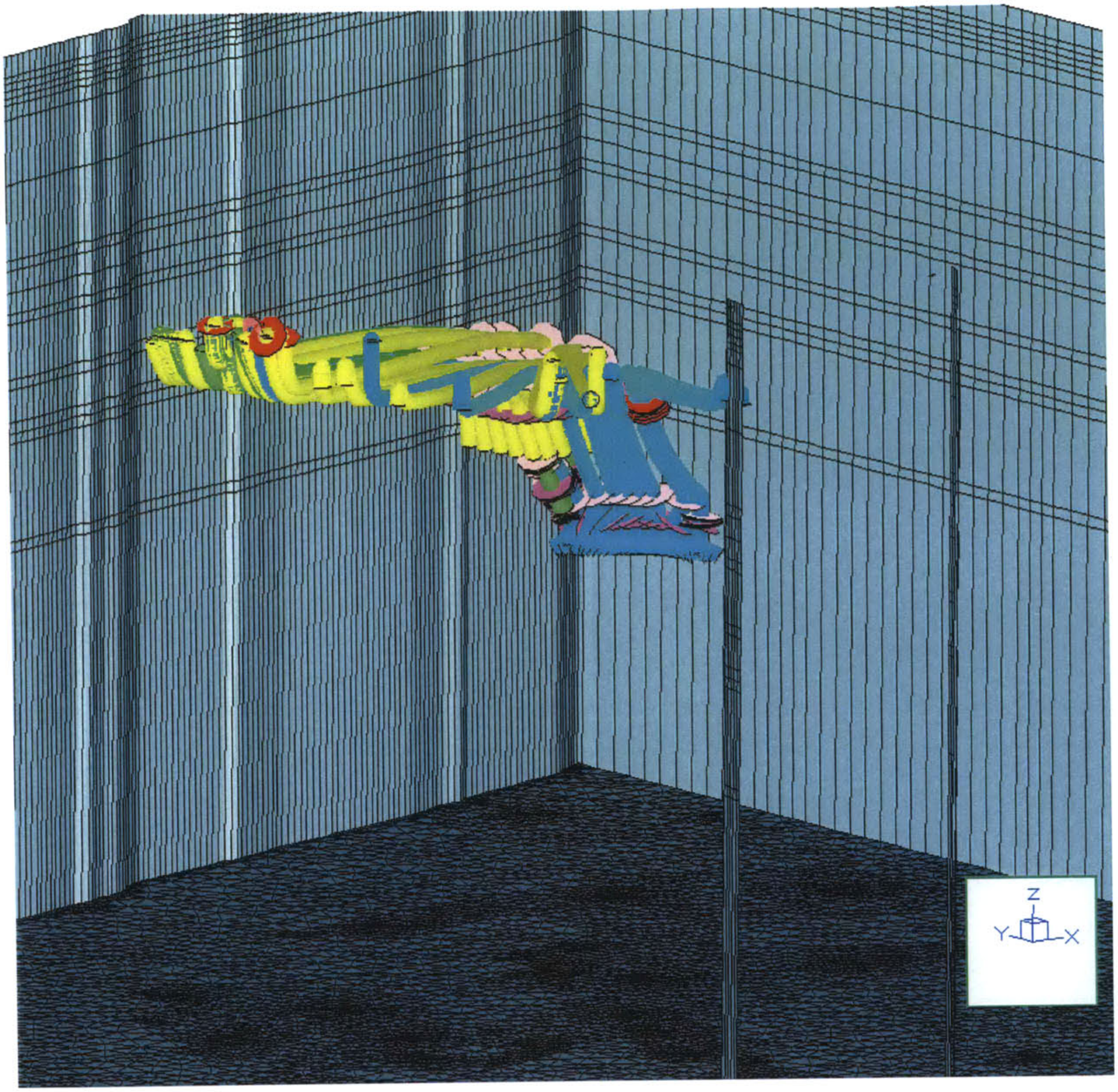


Fig.6.2 **Groundwater Flow Paths**: Modeling results from a transient three-dimensional groundwater model showing the complex nature of the stream-tube path-lines from different recharge sources (e.g. pond, rice field, river etc). The path-lines are converging at the depth of irrigation pumping. However, the wiggling nature of the stream-tubes makes it difficult to analyze the fluxes from various sources.

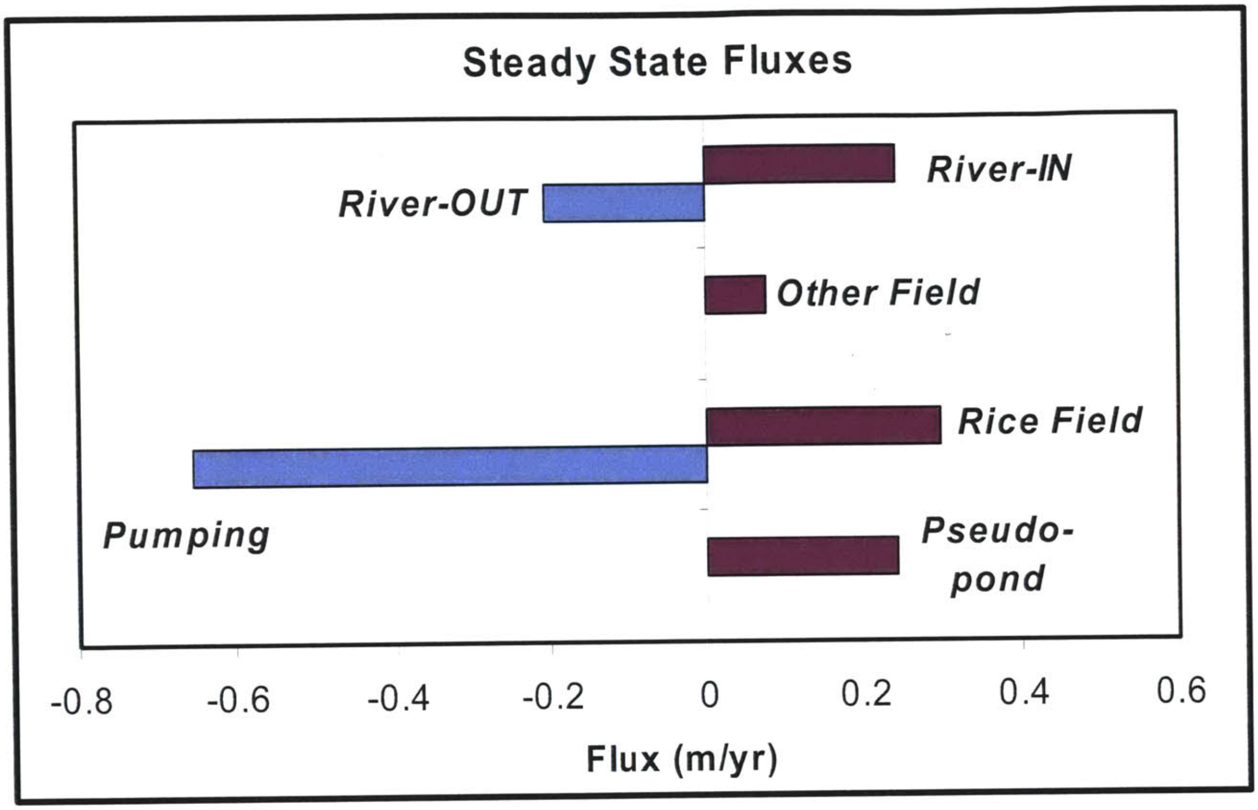
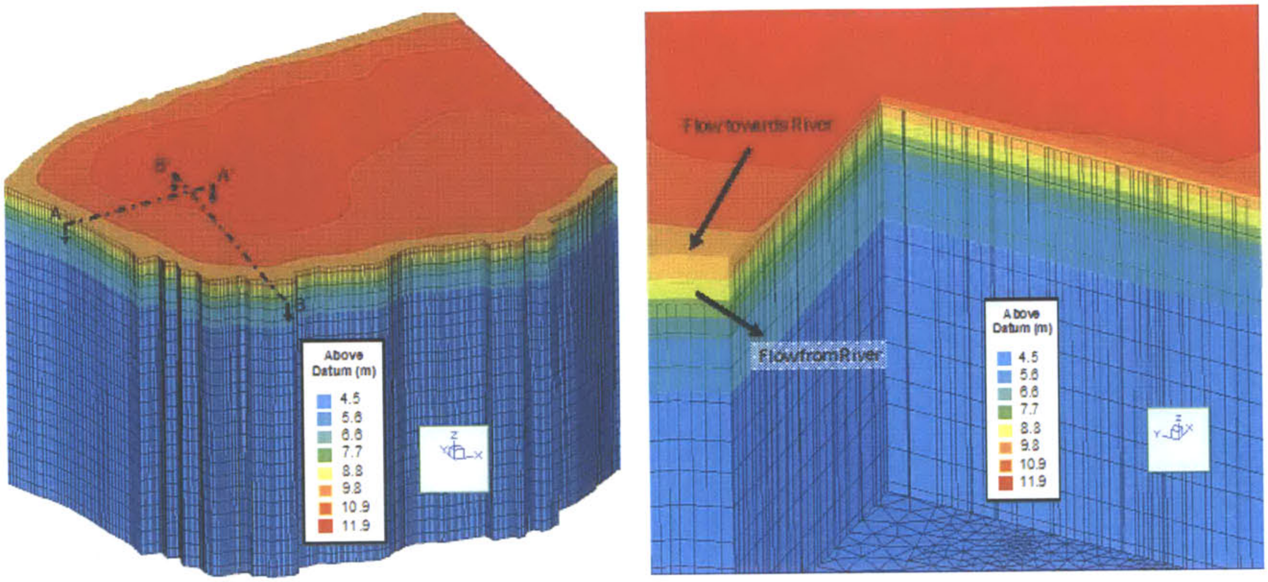


Fig.6.3 Steady-State Fluxes: Flux analysis from the steady-state flow-only model for the 'Current Stage" shows that the observed fluxes are comparable with those from the transient seasonal model (Fig.5.22), and hence, confers the applicability of the steady-state model for simulating long-term impacts with minimum computational effort.



(A) Isometric view of Head Contours

(B) Cross-sectional view from the left

Fig.6.4 Steady-State Head Contour: (A) Head contours of steady-state flow-only model for the 'Current Stage'. (B) A zoom-in view of the cut section reveals that the head in the upper aquifer is greater than the average river water level, which, in turn, is greater than the lower aquifer head. This phenomenon indicates that the river is gaining water from the upper aquifer, but discharging water in to the lower aquifer.

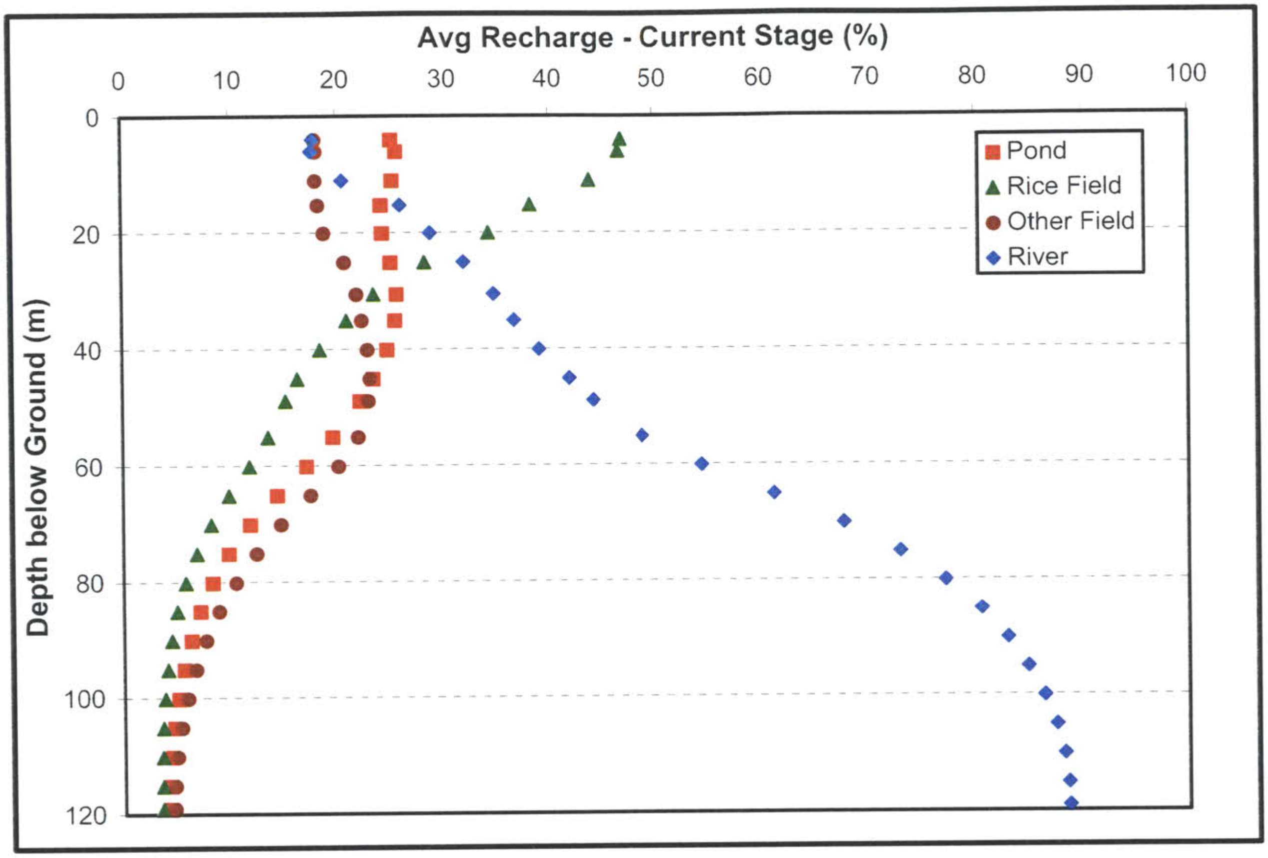
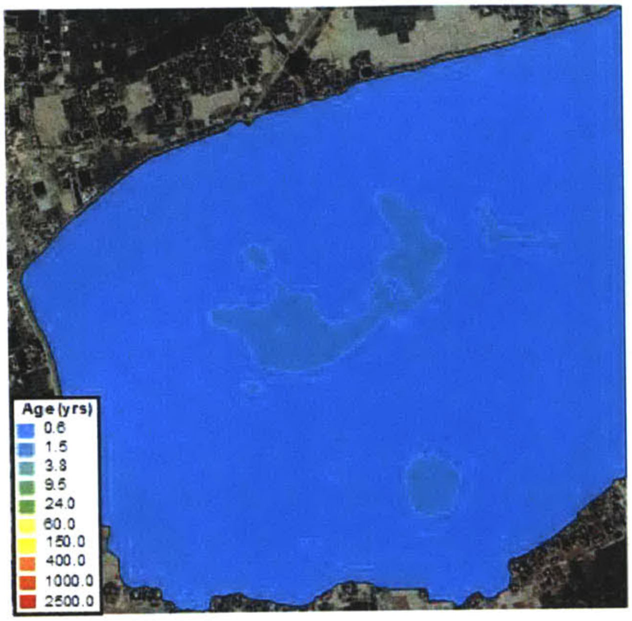
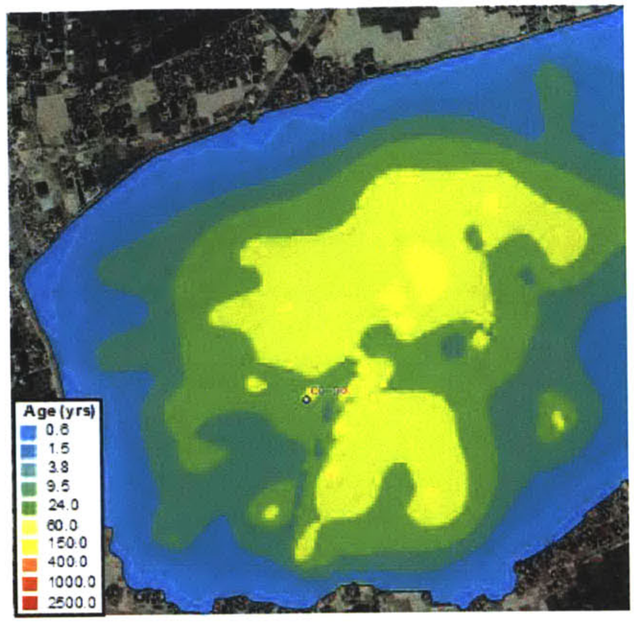


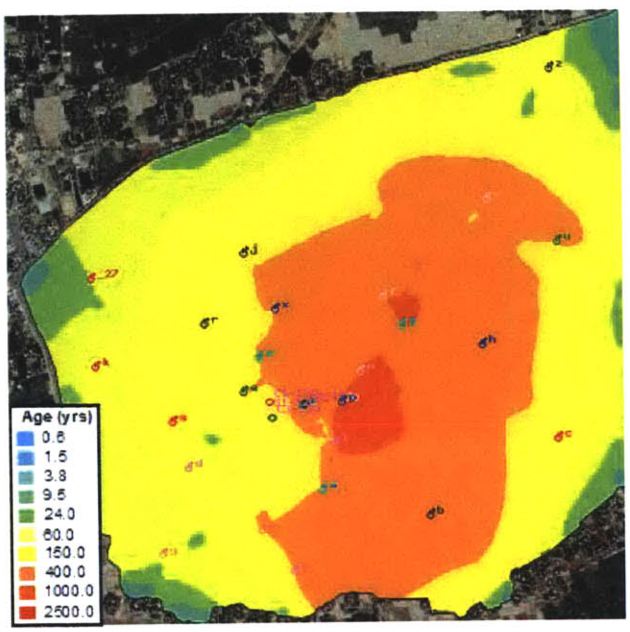
Fig.6.5 **Average Recharge – 'Current Stage' Model:** Plot of the recharge contribution profile from various sources (e.g. pond, rice field, other field and river) averaged over the entire modeled area for the 'Current Stage' model. The plot reveals that rice field water dominates at the shallowest depth while pond water dominates at the depth of irrigation well, and the contribution from river water increases with depth. However, it should be noted that the number of nodes in the river areas are much greater than those in other areas, and therefore, the plot is skewed towards the river contribution by some factor



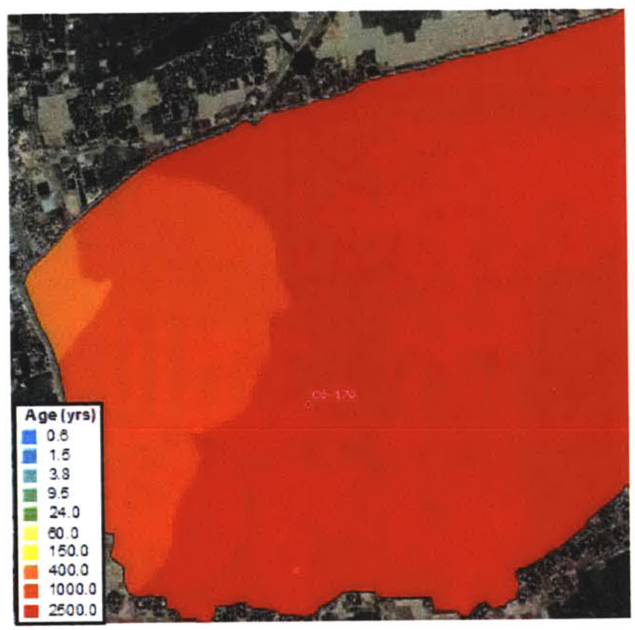
(A) 6m below ground surface



(B) 27.4m below ground surface



(C) 36.6m below ground surface



(D) 51.8m below ground surface

Fig.6.6 Age Distribution – 'Current Stage' Model: The plot of groundwater age contours at various depths depicting a scenario if only the modern day water invades the aquifer under the current groundwater flow system. The patchiness in the contours and the wide range of ages at various depths indicate mixing of flow from different sources with variable fluxes.

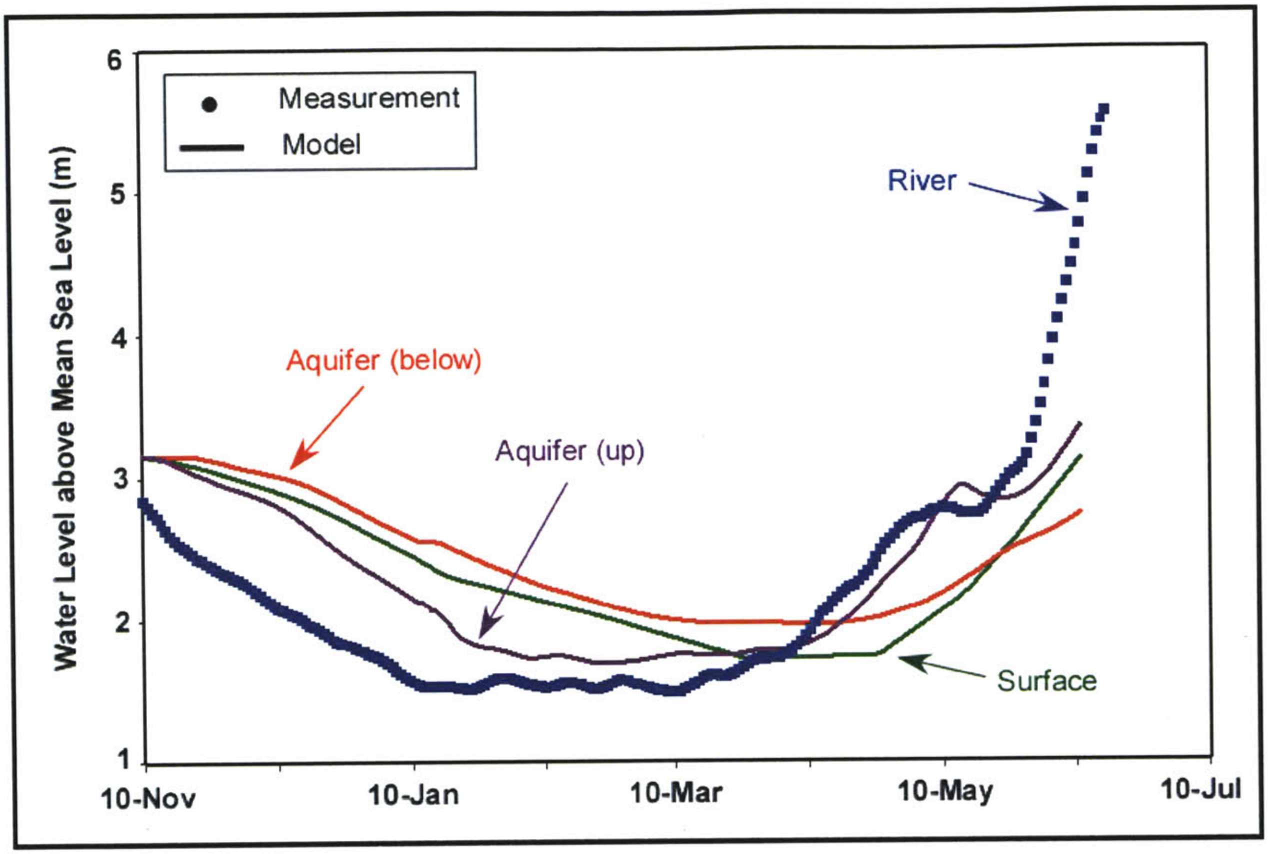


Fig.6.7 Ancient Model Heads: Average river head and modeled heads from the 'Ancient Stage' model. Unlike the 'Current Stage' model (Fig.5.21), the aquifer head drops only about a meter due to lack of pumping. Also the upper aquifer level drops more than the lower aquifer due to increased evaporation near the surface. More interestingly, in contrast to the 'Current Stage' model, the heads at various depths within the aquifer get separated from each other very early in the season because there are no irrigation well cells in the 'Ancient Stage' model that can connect the aquifer segments even when there is no pumping. During the early part of the dry season, ground water discharges into the river, whereas later in the season, the situation is reversed.

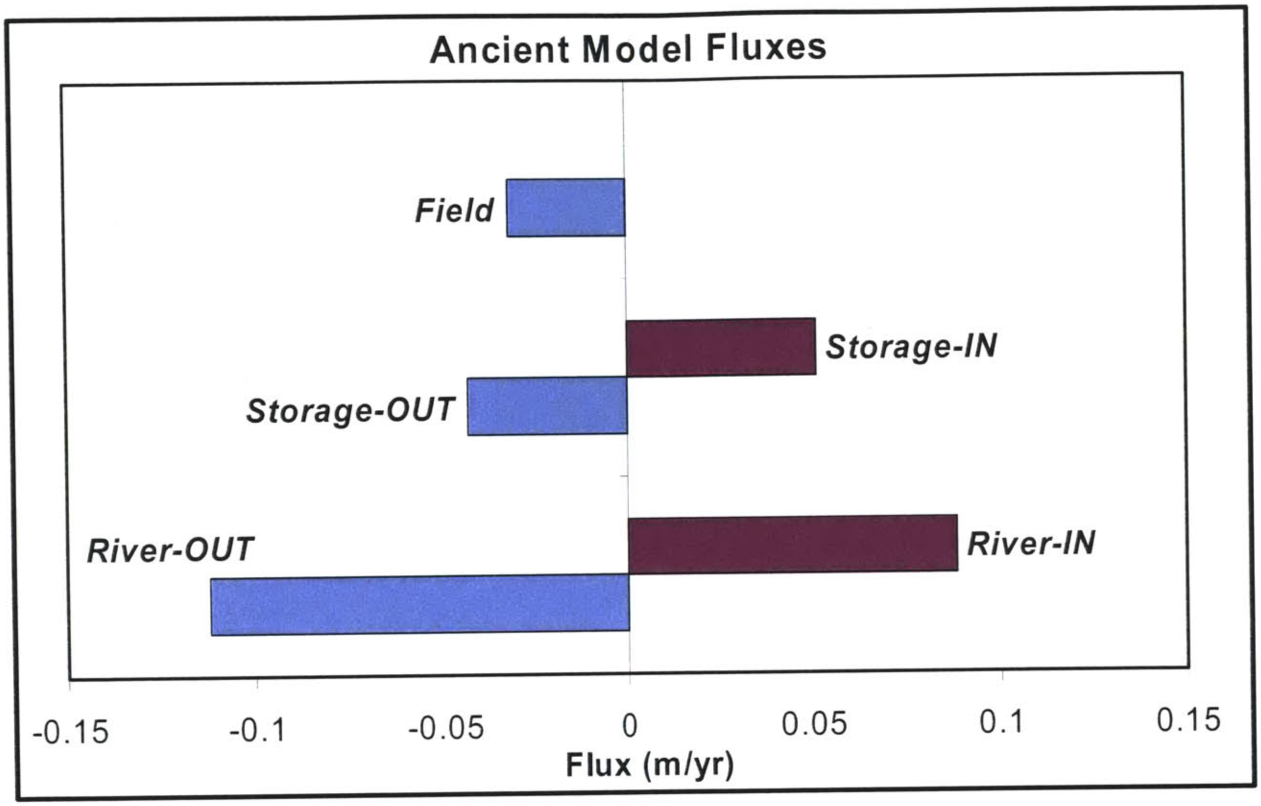


Fig.6.8 **Ancient Model Fluxes:** As indicated by the modeled heads (Fig.6.7), the river gets more recharge from the aquifer than discharge to the aquifer. This fact is also confirmed by the obtained fluxes. Further analysis of the fluxes indicate that the tree-covered field areas are loosing water due to net evaporation (evaporation subtracted from the rainfall), which is typical in an average year. In summary, the flux values from the 'Ancient Stage' model imply that the Ichhamati River is the only source of recharge to the aquifer, and hence, all the resident water in the aquifer is river water.

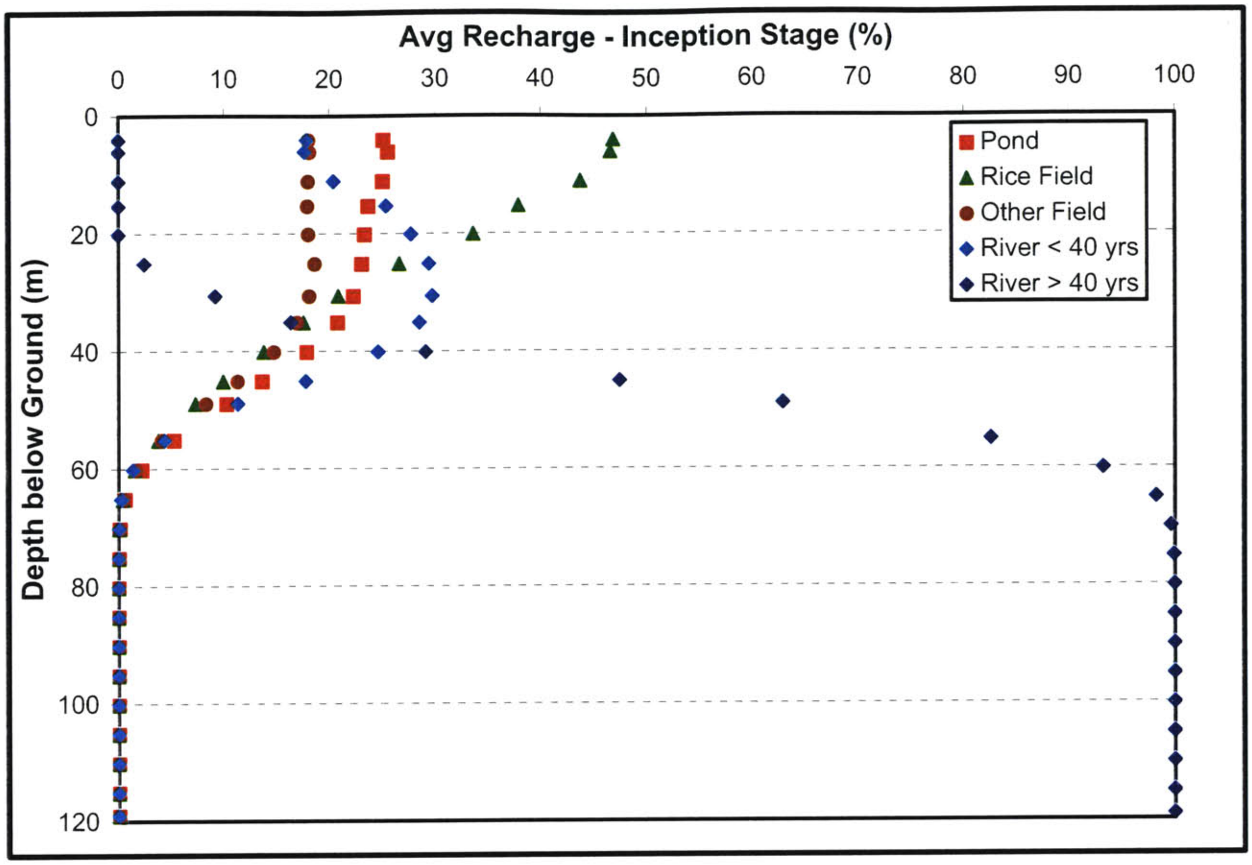
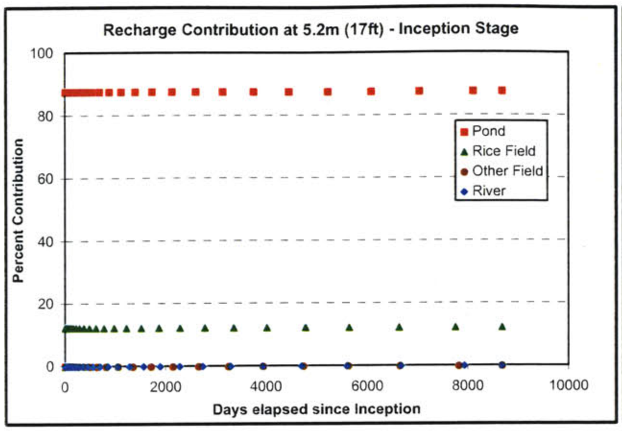
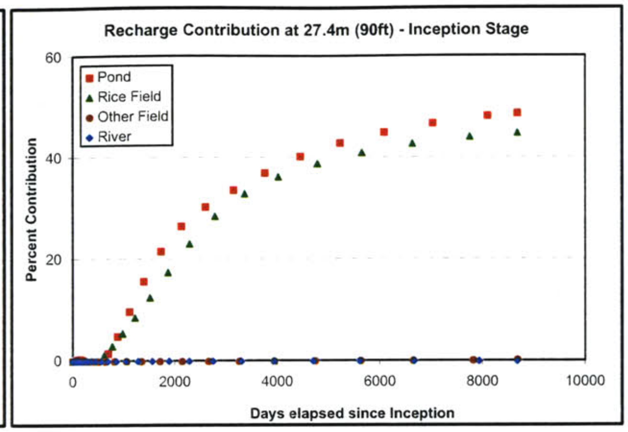


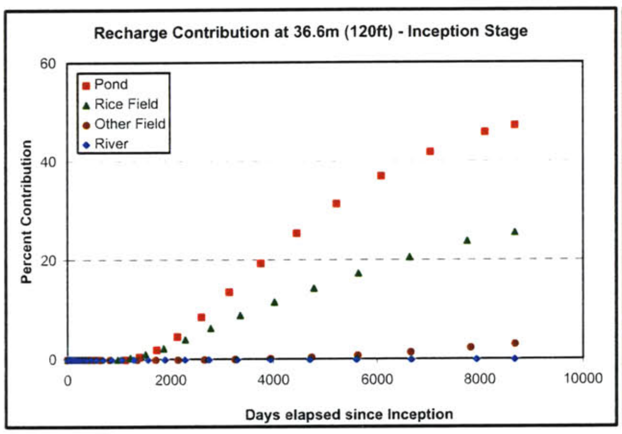
Fig.6.9 Average recharge – 'Inception Stage' Model: Plot of the recharge contribution profile from various sources (e.g. pond, rice field, other field and river) averaged over the entire modeled area for the 'Inception Stage' model. The recharge from the river sections has been separated into parts – pre (old) and post (new) inception periods (i.e. before and after 40 years). Analysis of the results indicates similar outcome as the 'Current Stage' – the rice field water dominates at the shallowest depth while pond water dominates at the depth of irrigation well, and the contribution from river water (including both the old and new river waters) increases with depth. The plot also reveals that recharge from the newer sources (i.e. pond, field and post-inception river) penetrates up to about 50m in the past 40 years.



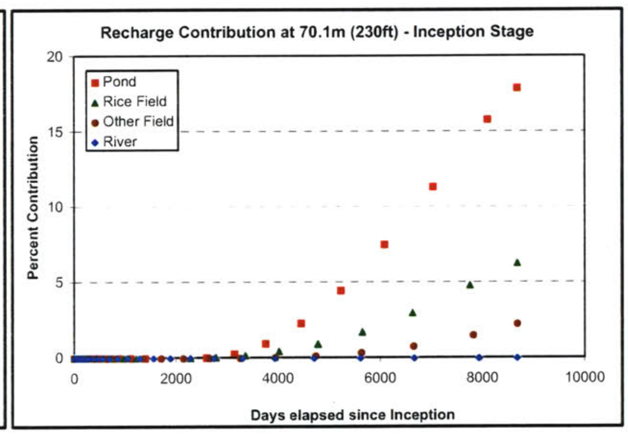
(A) Percent Recharge at 5.2m



(B) Percent Recharge at 27.4m

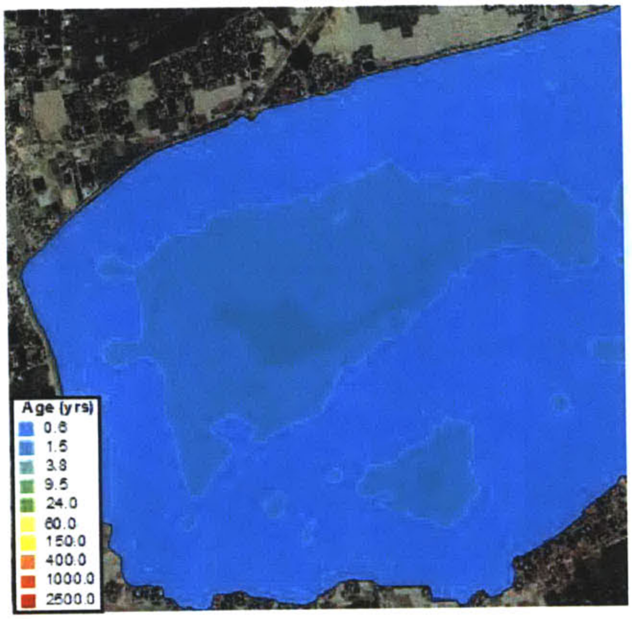


(C) Percent Recharge at 36.6m

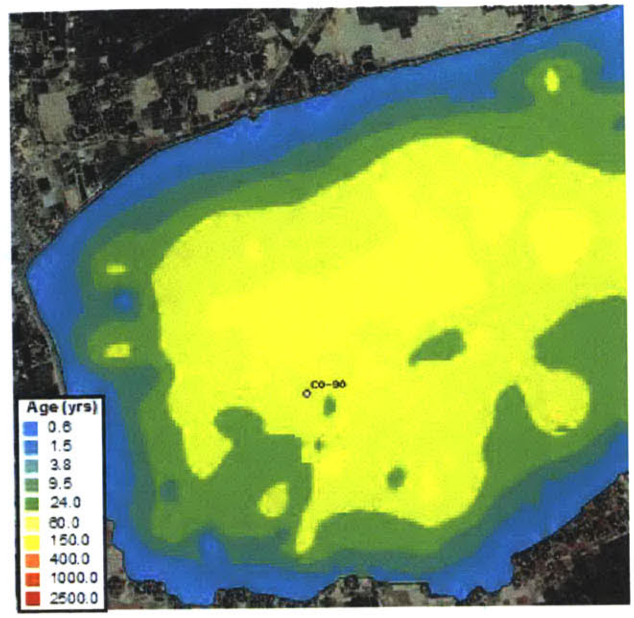


(D) Percent Recharge at 70.1m

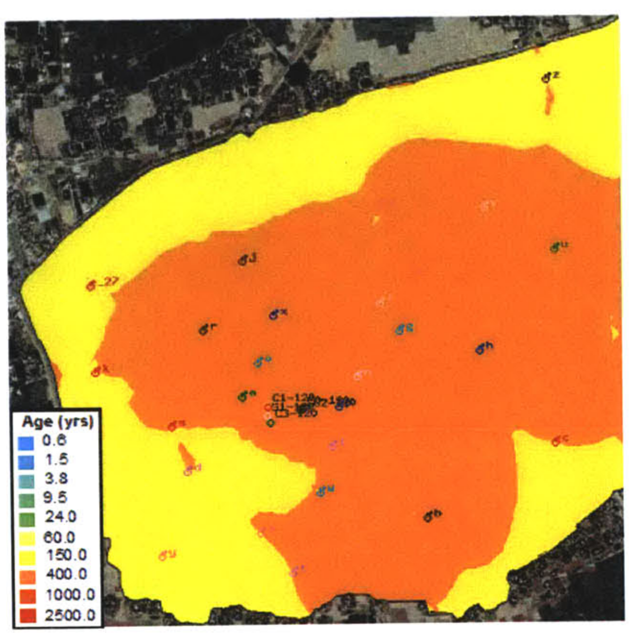
Fig.6.10 Percent Recharge Contribution: Recharge contribution from different newer sources (i.e. pond, rice field, other field, and post-inception river) analyzed at various monitoring well locations. The results indicate that the recharge contributions at shallow depth (5.2m) are constant with time, and the ponds contribute the bulk of the recharge. At a depth of 30m (depth of peak arsenic concentration as well as that of irrigation well screens), most of the recharge is coming from the pond followed by the rice field. Interestingly, the temporal trend of the recharge tends towards asymptotic values indicating that the recharge contributions at that depth are reaching steady-state, and the values are comparable with those obtained from the 'Current Stage' model (Table.6.1). On the contrary, the recharge values at other depths (i.e. 36.6m and 70.1m) are increasing with time (within the modeled 40 years) referring that the contributions haven't reached steady-state. However, at all the monitoring locations, pond water contributes the most (excluding the resident old river water) followed by the rice field water.



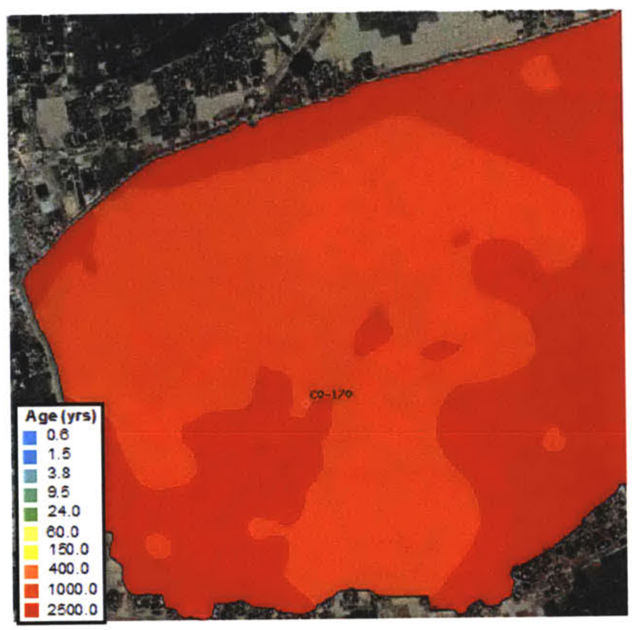
(A) 6m below ground surface



(B) 27.4m below ground surface



(C) 36.6m below ground surface



(D) 51.8m below ground surface

Fig.6.11 Age Distribution – 'Inception Stage' Model: Average groundwater age distribution at selected depths. The plots indicate that younger age dominates at shallower depths. Moreover, the age values at the monitoring locations can be explained by the relative contribution of recharge water from different sources. The average age of water at 27.4m, 36.6m and 51.8m can be calculated as ~167 years, ~900 years and ~3000 years, respectively, which are consistent with the modeled ages.

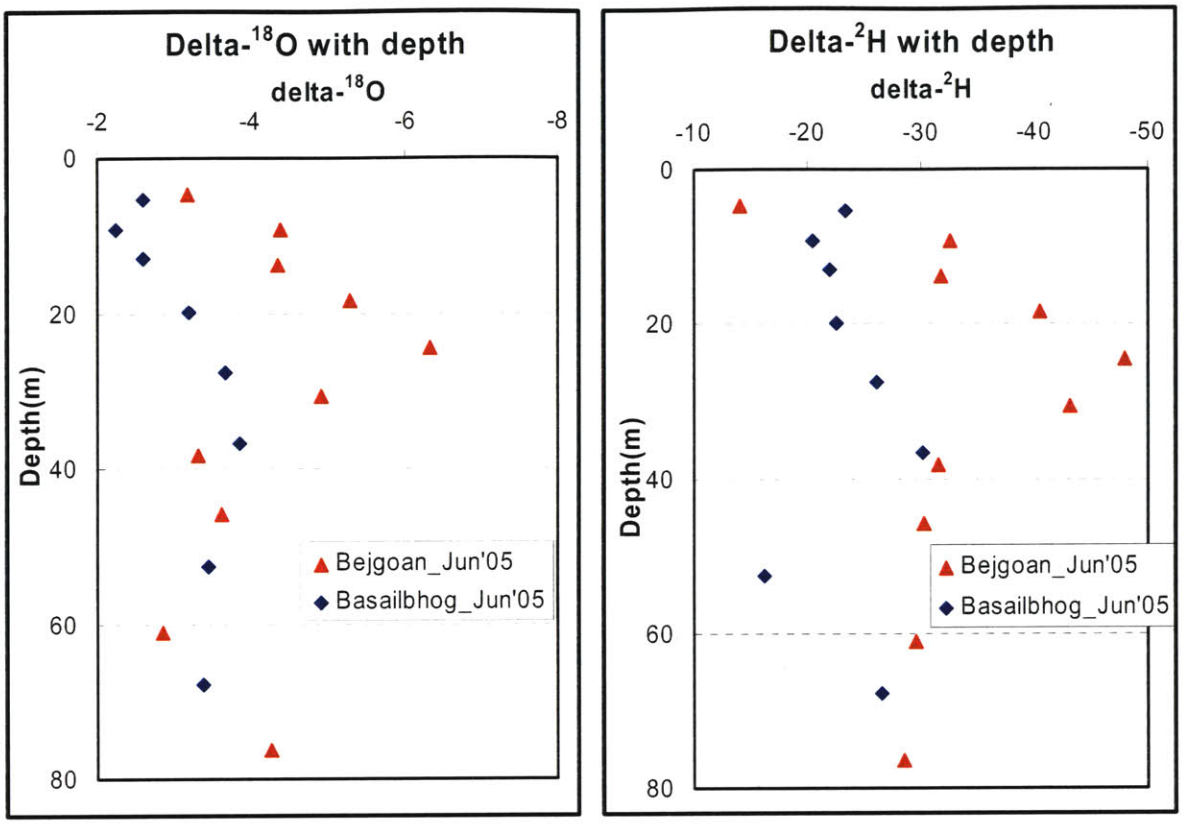


Fig.6.12 Stable Water Isotope Profiles at the two Field Sites: Comparison of the stable water isotope profiles at Bejgoan and Basailbhog Field Sites. The plot reveals an interesting profile – the water becomes lighter with depth up to 24.4m, followed by a large variability at 30.5m depth, and afterwards, the water becomes heavy again followed by a slightly increasing trend of water becoming lighter with depth.

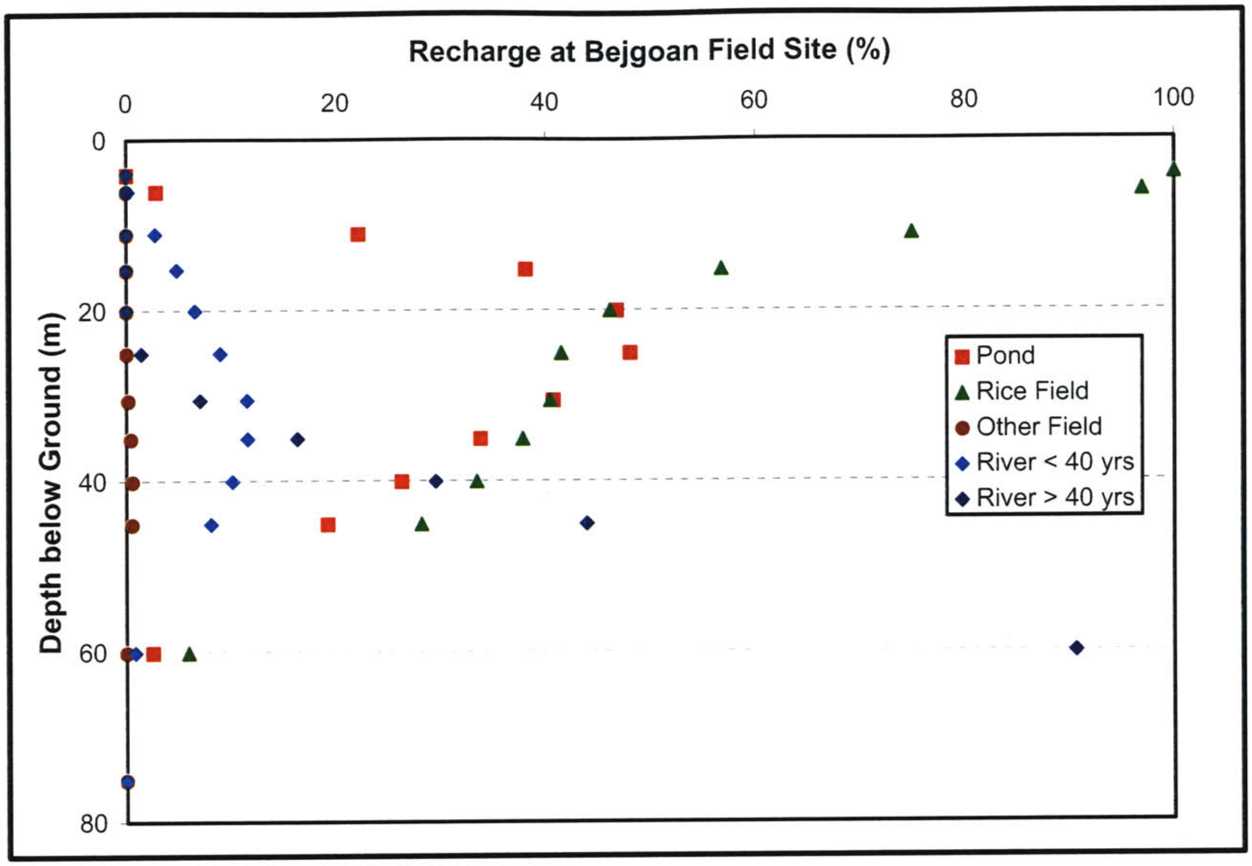


Fig.6.13 Recharge Contribution at Bejgoan Field Site: Relative contribution of recharge from various sources at the Bejgoan Field Site. Interestingly, the recharge profile from the pond follows the exact pattern of dissolved arsenic concentration as well as other related chemical constituents. The figure also shows that pond contributes about 40-50% of the total recharge followed by 40% contribution from rice field water at 20-30m depth.

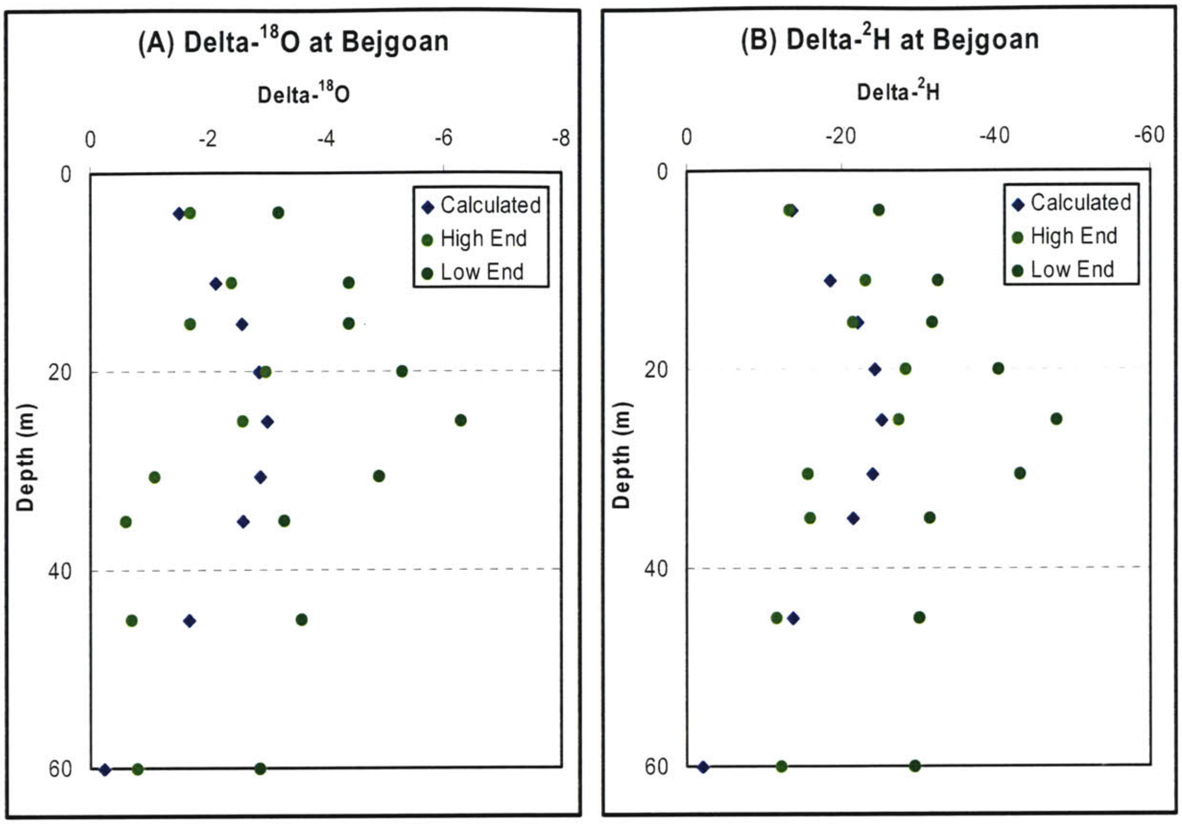


Fig.6.14 Comparison of Calculated and Measured Isotopic Values: Comparison of calculated and measured stable water isotope values at Bejgoan Field Site. The plot indicates that the calculated values are within the range of measured values, and thereby, confers that the observed isotopic profile results from the mixing of water from various recharge sources. The heavier waters at 4.6m and 38.1m depths are originating from highly evaporative rice field waters, whereas the lighter waters are mainly being derived from river and pond waters.

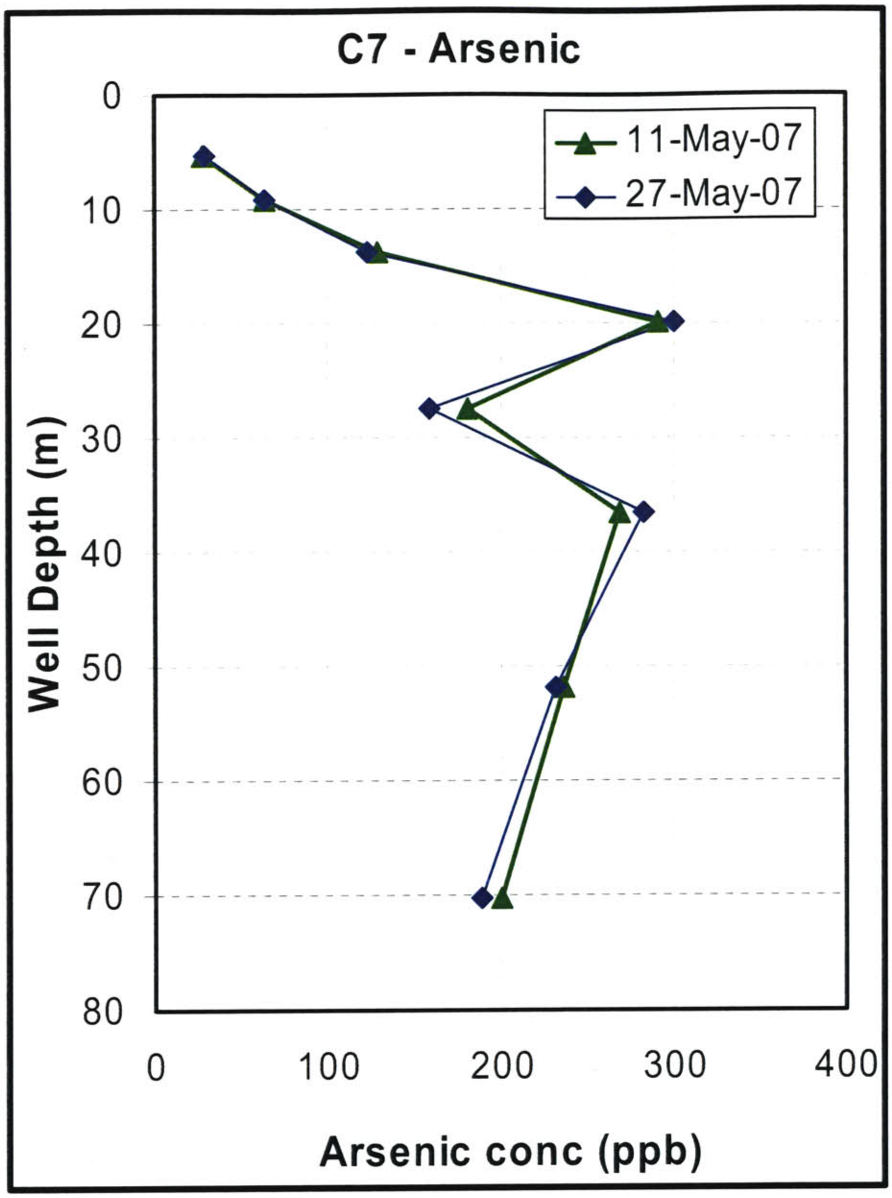


Fig.6.15 Arsenic Concentration Profile at Cluster, C-7: Dissolved arsenic concentration profile at a cluster beside a highly recharging pond (Pond-5). Interestingly, the profile shows two distinct peaks – one at a depth of 30-40m and the other at 20m. While the peak concentration at 30-40m depth refers to the characteristic regional hump observed in our study area, the second peak at a shallower depth can be rationalized as the local arsenic plume originating from the bottom of Pond-5.

Appendix A

Survey Data

Table A.1: Survey Data by BUET

Location: Srinagar, Munshiganj *May-03*

SL No.	Description	ID	Arbitrary Coordinates		GPS Coordinates		Elevation (Arbitrary)	Elevation (MSL)	Remarks
			Easting	Northing	Easting	Northing			
1	DR	2	9419.7270	9253.8050			19.5610	7.9950	
2	DR	3	9353.5810	9184.4550	17.1320	31.6390	19.3963	7.8303	
3	DR	5	8971.8410	8725.0400	16.9530	31.3680	19.0750	7.5090	
4	DR	7	8813.9350	9368.8930			19.5040	7.9380	
5	DR	8	9033.2060	9491.6100			19.8260	8.2600	
6	DR	10	9842.4560	9894.3880			19.3080	7.7420	
7	DR	11	9769.4450	9832.9590	17.3500	32.0300	19.8200	8.2540	
8	DR	12	9676.9210	9851.7490			19.1260	7.5600	
9	DR	13	9697.9720	9919.2910			18.4190	6.8530	
10	DR	14	9566.0820	10000.2830			18.6060	7.0400	
11	DR	15	9624.5180	10090.5280			19.0990	7.5330	
12	DR	15	9976.1850	9833.9270			15.7680	4.2020	PIEZOMETER
13	DR	16	9806.1450	10252.0990	17.3270	32.2450	20.0900	8.5240	
14	DR	17	9978.1550	10300.4560	17.4410	32.2840	19.1480	7.5820	
15	DR	18	10048.0910	9976.7250	17.4930	32.1140	19.0970	7.5310	
16	DR	19	10131.2550	9853.1950			18.8850	7.3190	
17	DR	20	10185.6450	10071.4900			19.2680	7.7020	
18	DR	21	10341.4190	10096.8880			19.3190	7.7530	
19	DR	22	10413.1450	10310.6740			18.3990	6.8330	
20	DR	26	8865.8700	11214.7680			19.4450	7.8790	
21	DR	27	9107.7010	11259.9330			19.3340	7.7680	
22	DR	28	9121.5130	10591.9460			19.4460	7.8800	
23	DR	29	10723.0880	11427.2370	17.7800	32.9100	19.3240	7.7580	
24	DR	30	10706.2380	11532.7560	17.7700	32.9900	19.2790	7.7130	
25	DR	30	9975.2470	9831.6230			15.7690	4.2030	PIEZOMETER
26	DR	31	10962.6780	10974.1340	17.9590	32.7110	19.9200	8.3540	
27	DR	32	11162.8430	10995.4930	18.0700	32.7360	20.0410	8.4750	
28	DR	45	9976.1550	9833.1250			15.7520	4.1860	
29	DR	60	9977.6910	9832.9500			15.8090	4.2430	
30	DR	80	9974.5060	9833.9300			15.7980	4.2320	
31	DR	125	9975.9120	9832.0250			15.6790	4.1130	
32	DR	150	9975.2640	9834.4780			15.7800	4.2140	
33	DR	250	9974.6360	9836.0030			15.7520	4.1860	
34	DR	350	9977.6920	9840.2060			15.8350	4.2690	
35	DR	540	9970.9000	9822.8790			15.6100	4.0440	
36	DR	100(1)	9975.2230	9833.1880			15.8000	4.2340	
37	DR	100(2)	9974.4560	9832.4690			15.8270	4.2610	
38	DR	100(3)	9980.0720	9832.3710			15.7130	4.1470	
39	DR	100(4)	9979.5864	9830.4784			15.7860	4.2200	
40	DR	100(5)	9977.5890	9826.2420			15.9220	4.3560	
41	DR	200(1)	9973.1430	9834.8780			15.7330	4.1670	
42	DR	200(2)	9972.9110	9833.6450			15.4870	3.9210	
43	IR	1	10119.9830	9276.1630	17.5850	31.7410	16.0600	4.4940	
44	IR	2	10129.4330	9073.9830	17.6020	31.6340	15.6580	4.0920	
45	IR	3	9980.4720	8754.0180	17.5400	31.4530	16.3160	4.7500	
46	IR	4	10403.6600	8756.8650	17.7820	31.4800	15.8810	4.3150	
47	IR	5	10510.3760	8534.9390	17.8630	31.3680	15.8740	4.3080	
48	IR	6	10431.4340	9433.9890	17.7490	31.8490	15.5860	4.0200	
49	IR	7	10522.8200	9633.3480	17.8040	31.9530	15.8880	4.3220	
50	IR	8	10694.3900	9340.5170	17.9120	31.8150	16.0130	4.4470	
51	IR	9	10805.3860	9140.3240	18.0220	31.8110	15.6200	4.0540	
52	IR	10	10883.2560	9334.4560	17.9890	31.7140	15.8340	4.2680	
53	IR	11	10975.5600	9468.0650	18.0670	31.9000	15.6020	4.0360	
54	IR	12	11157.0080	9450.5570	18.1820	32.0320	15.4400	3.8740	
55	IR	13	11098.5190	9758.9460			15.8160	4.2500	
56	IR	16	10675.4270	9835.9600	17.8700	32.0630	15.7370	4.1710	
57	IR	17	10216.3270	9789.2210	17.5980	32.0210	15.6750	4.1090	
58	IR	18	10502.5290	10110.5840	17.7370	32.2400	15.5950	4.0290	
59	IR	19	9791.1170	10065.2830	17.3390	32.1450	16.8680	5.3020	
60	IR	20	9804.0690	9667.2610	17.3700	31.9330	15.7440	4.1780	
61	IR	21	8837.1070	8874.7270	16.9280	31.4690	16.3240	4.7580	
62	IR	22	9182.4050	9102.9990	17.0510	31.5910	15.6450	4.0790	
63	IR	23	8749.7340	9280.7190	16.7800	31.6580	16.2840	4.7180	
64	IR	24	8952.2440	8909.7180	16.8630	31.4430	15.6900	4.1240	

	A	B	C	D	E	F	G	H	I	J
1	**Table A.2: Survey Data by Survey of Bangladesh**									
2	Location: Srinagar, Munshiganj									*Jun-03*
3										
4	**SL No.**	**Description**	**ID**	**Arbitrary Coordinates**		**GPS Coordinates**		**Elevation (Arbitrary)**	**Elevation (MSL)**	**Remarks**
5				**Easting**	**Northing**	**Easting**	**Northing**			
6	1	DR	3	9353.5980	9184.3557	17.1320	31.6390	19.3963	7.8303	Old
7	2	DR	5	8972.0676	8724.4876	16.9530	31.3680	19.0770	7.5110	Old
8	3	DR	11	9769.2172	9833.5223	17.3500	32.0300	19.4080	7.8420	Old
9	4	DR	16	9805.8196	10252.0408	17.3270	32.2450	19.4080	7.8420	Old
10	5	DR	17	9977.7551	10300.4972	17.4410	32.2840	19.1500	7.5840	Old
11	6	DR	18	10047.9326	9976.9870	17.4930	32.1140	19.1000	7.5340	Old
12	7	DR	29	10722.9149	11427.5585	17.7800	32.9100	19.3272	7.7612	Old
13	8	DR	30	10706.0889	11532.7840	17.7700	32.9900	19.2750	7.7090	Old
14	9	DR	31	10962.3496	10974.4021	17.9590	32.7110	19.4080	7.8420	Old
15	10	DR	32	11162.5601	10995.6886	18.0700	32.7360	19.4080	7.8420	Old
16	11	DR	33	9920.5123	9255.8697	17.4690	31.7190	18.3285	6.7625	New
17	12	DR	34	10280.3457	9448.1337	17.6730	31.8450	19.4080	7.8420	New
18	13	IR	1	10120.0567	9276.2563	17.5850	31.7410	16.0640	4.4980	Well Top
19	14	IR	2	10129.4473	9074.1518	17.6020	31.6340	15.6600	4.0940	Well Top
20	15	IR	4	10403.7154	8757.1563	17.7820	31.4800	15.9920	4.4260	Well Top
21	16	IR	18	10415.4161	10050.4770	17.7370	32.2400	15.5970	4.0310	Well Top
22	17	IR	19	9790.8615	10065.4929	17.3390	32.1450	16.3280	4.7620	Well Top
23	18	IR	20	9803.8275	9667.6044	17.3700	31.9330	15.7412	4.1752	Well Top
24	19	IR	21	8952.2966	8909.3477	16.9280	31.4690	16.3280	4.7620	TW bass
25	20	IR	25	10793.1826	8889.5345	18.0020	31.5790	16.1550	4.5890	Well Top
26	21	IR	26	9779.1712	11124.9327	17.2510	32.7130	16.3280	4.7620	TW bass
27	22	IR	27	10573.2314	11370.8946	17.6070	32.8040	16.3280	4.7620	bend Top
28	23	IR	28	10400.3917	11218.0812	17.7160	32.8330	16.3280	4.7620	TW bass
29	24	IR	30	10207.3887	11533.4333	17.5140	32.9530	16.1542	4.5882	Well Top
30	25	IR	31	10120.6908	10875.2373	17.4670	32.6010	16.8844	5.3184	bend Top
31	26	IR	33	10760.9764	11399.6984	17.8000	32.9280	16.3280	4.7620	TW bass
32	27	IR	35	11133.9339	10259.9822	18.0230	32.4720	16.1763	4.6103	Well Top
33	28	IR	36	10764.5833	10383.2159	18.1030	32.3350	16.3280	4.7620	TW bass
34	29	IR	37	11682.6258	11406.3081	18.3430	32.9890	16.3280	4.7620	TW bass
35	30	IR	39	11345.0019	11589.1940	18.1310	33.0650	17.0000	5.4340	TW bass
36	31	IR	42	11401.4471	11151.8653	18.1980	32.8340	16.3280	4.7620	Well Top
37	32	IR	45	10877.6701	11743.8839	17.8490	33.1180	16.3280	4.7620	Well Top
38	33	IR	46	8565.3221	10290.4807	16.6030	32.1860	16.3140	4.7480	Well Top
39	34	IR	47	8347.4199	10054.5035	16.4920	32.0420	16.3280	4.7620	Well Top
40	35	IR	48	7988.2102	10071.8942	16.2820	32.0310	16.2912	4.7252	Well Top
41	36	IR	49	8057.7866	9846.3821	16.3140	31.9140	16.5051	4.9391	Well Top
42	37	PEIZOMETER	15	9974.8906	9831.8399			15.7770	4.2110	Top Of Pipe
43	38	PEIZOMETER	30	9974.1005	9832.6898			15.8276	4.2616	Top Of Pipe
44	39	PEIZOMETER	45	9972.7385	9835.1303			15.7358	4.1698	Top Of Pipe
45	40	PEIZOMETER	60	9974.2598	9836.1926			15.7580	4.1920	Top Of Pipe
46	41	PEIZOMETER	80	9972.5071	9833.8702			15.4863	3.9203	Top Of Pipe
47	42	PEIZOMETER	101	9974.8784	9834.7037			15.7914	4.2254	Top Of Pipe
48	43	PEIZOMETER	102	9975.5859	9832.2671			15.6847	4.1187	Top Of Pipe
49	44	PEIZOMETER	103	9974.8446	9833.4283			15.8111	4.2451	Top Of Pipe
50	45	PEIZOMETER	104	9977.4576	9840.3752			15.8349	4.2689	Top Of Pipe
51	46	PEIZOMETER	105	9977.2267	9826.4597			15.9215	4.3555	Top Of Pipe
52	47	PEIZOMETER	125	9977.3425	9833.1415			15.8150	4.2490	Top Of Pipe
53	48	PEIZOMETER	150	9974.1721	9834.0945			15.7992	4.2332	Top Of Pipe
54	49	PEIZOMETER	201	9984.9657	9833.7021			15.6583	4.0923	Top Of Pipe
55	50	PEIZOMETER	202	9979.7003	9832.5766			15.7186	4.1526	Top Of Pipe
56	51	PEIZOMETER	203	9980.0048	9841.9206			15.8141	4.2481	Top Of Pipe
57	52	PEIZOMETER	204	9975.8061	9834.1184			15.7733	4.2073	Top Of Pipe
58	53	PEIZOMETER	205	9975.7633	9833.3435			15.7560	4.1900	Top Of Pipe
59	54	PEIZOMETER	206	9974.7246	9823.8005			15.8568	4.2908	Top Of Pipe
60	55	PEIZOMETER	250	9978.4828	9837.1028			15.7919	4.2259	Top Of Pipe
61	56	PEIZOMETER	350	9983.9109	9824.5663			15.8350	4.2690	Top Of Pipe
62	57	PEIZOMETER	540	9970.5201	9823.1090			15.6092	4.0432	Top Of Pipe
63	58	POND	1	10025.2838	9882.3243			19.1309	7.5649	Tin Shed Plinth Level
64	59	POND	2	10025.2838	9882.3243			19.1309	7.5649	Tin Shed Plinth Level
65	60	POND	3	9415.8932	9254.1529			19.5340	7.9680	Marked On The Tree

	A	B	C	D	E	F	G	H	I	J
66	61	POND	4	10513.4605	9448.5306			19.2332	7.6672	Marked On The Tree
67	62	POND	5	9830.0210	10272.9066			19.9630	8.3970	Marked On The Stair's 1st Step
68	63	POND	6	11146.9547	10932.0989			18.6060	7.0400	Marked On The Tree
69	64	POND	7	8994.0042	10327.5786			19.6850	8.1190	Marked On The Stair's 1st Step
70	65	POND	8	9591.9188	11143.4770			19.8424	8.2764	Marked On The Stair's 1st Step
71	66	POND	9	9812.1950	11579.5911			18.6926	7.1266	Marked On The Tree
72	67	BRIDGE (HB-1	1	9578.1043	9145.6209	17.2760	31.6330	24.3316	12.7656	Top Of Bridge (New)
73	68	BRIDGE (HB-2	2	10573.0053	10739.1898	17.7400	32.5610	21.6597	10.0937	Top Of Bridge (New)
74	69	BRIDGE (HB-3	3	10835.5854	11052.5986	17.8650	32.7390	22.7271	11.1611	Top Of Bridge (New)
75	70	BRIDGE (HB-4	4	10885.1110	11118.5645			20.8350	9.2690	Center Of Bridge (New)
76	71	BRIDGE (SB-1	5	10910.8801	10819.3560	18.5740	32.8120	21.3436	9.7776	Top Of Bridge (New)
77	72	BRIDGE (SB-2	6	12032.0337	11035.2418	17.9390	32.6280	21.3096	9.7436	Top Of Bridge (New)
78	73	BRIDGE (LB-1	7	10351.8831	9168.9050	17.7270	31.6960	19.2190	7.6530	Top Of Bridge (Old)
79	74	BRIDGE (LB-2	8	9539.4994	10184.3884	17.1850	32.1940	21.0335	9.4675	Top Of Bridge (Old)
80	75	BRIDGE (LB-3	9	10289.2601	12011.6622	17.4870	33.2250	20.8704	9.3044	Top Of Bridge (Old)
81	76	BRIDGE (LB-4	10	9472.0167	10182.4439	17.1340	32.1830	22.2816	10.7156	Top Of Bridge (New)
82										

	A	B	C	D	E
1	**Table A.3: Survey Data by BUET**				
2	**All The wells in Basailbhog Field Site (May 2006)**				
3	**Easting**	**Northing**	**Elevation (MSL)**	**Code**	**Remark**
4	224221.541	2604789.008	6.181	TREE	P-10
5	224207.101	2604821.117	4.317	C-4	60'
6	224206.569	2604821.808	4.361	C-4	17'
7	224206.155	2604822.200	4.369	C-4	55'
8	224205.602	2604822.771	4.344	C-4	90'
9	224205.099	2604823.119	4.319	C-4	105'
10	224204.707	2604823.579	4.353	C-4	120'
11					
12	224218.798	2604805.867	3.732	C-2	17'
13	224218.599	2604806.687	3.930	C-2	90'
14	224218.544	2604807.236	3.921	C-2	120'
15	224218.386	2604807.696	3.929	C-2	170'
16	224218.302	2604808.375	3.901	C-2	30'
17	224218.261	2604808.764	3.905	C-2	45'
18	224218.080	2604809.333	3.953	C-2	65'
19	224217.878	2604809.691	4.131	C-2	230'
20	224222.838	2604810.723	3.361	P-10	17'
21					
22	224196.873	2604805.174	4.351	C-5	17'
23	224196.779	2604805.658	4.525	C-5	60'
24	224196.588	2604806.081	4.503	C-5	90'
25	224196.437	2604806.551	4.475	C-5	105'
26	224196.234	2604807.107	4.503	C-5	120'
27					
28	224187.721	2604822.139	4.169	C-0	17'
29	224188.755	2604822.645	4.225	C-0	30'
30	224189.437	2604823.050	4.143	C-0	42'
31	224189.121	2604823.920	4.081	C-0	65'
32	224188.185	2604823.586	4.182	C-0	90'
33	224187.255	2604823.236	4.112	C-0	120'
34	224186.765	2604822.386	4.320	C-0	172'
35	224185.541	2604821.096	4.282	C-0	222'
36	224190.217	2604777.185	6.843	TREE	P-11
37					
38	224145.945	2604860.636	3.863	K-1	100'
39	224163.454	2604871.574	3.739	K-2	100'
40	224149.963	2604865.867	3.879	H-1	100'
41	224157.976	2604870.670	3.814	H-2	100'
42	224167.812	2604859.735	3.679	TC-1	
43	224168.108	2604859.350	3.524	TC-A	23a
44	224168.227	2604859.637	3.534	TC-B	23b
45	224170.142	2604855.826	4.001	WB	17'
46	224168.552	2604855.265	3.459	PVC	Paddy Land
47	224168.689	2604854.899	3.441	PVC	Paddy Land
48	224168.883	2604854.526	3.440	PVC	Paddy Land
49	224222.209	2604809.806		PVC	Pond-10
50	224222.385	2604810.082		PVC	Pond-10

	A	B	C	D	E
51	224222.551	2604810.410		PVC	Pond-10
52	224171.290	2604851.743	3.705	TB-1	
53	224171.003	2604852.043	3.558	TB-A	23a
54	224171.322	2604851.989	3.547	TB-B	23b
55	224174.589	2604844.618	3.668	TA-1	
56	224174.712	2604844.771	3.509	TA-A	23a
57	224175.071	2604844.925	3.522	TA-B	23b
58	224172.038	2604843.488	3.846	WA	17'
59	224170.524	2604842.785	3.548	GI	Paddy Land
60	224170.338	2604842.683	3.545	GI	Paddy Land
61	224169.931	2604842.551	3.563	GI	Paddy Land
62	224154.759	2604837.735		Tower	
63					
64	224174.470	2604811.753	**4.447**	TW	Deep Tube Well Base
65					
66	224107.473	2604744.641	3.618	C-6	17'
67	224106.979	2604744.511	3.673	C-6	35'
68	224106.583	2604744.363	3.662	C-6	90'
69	224105.947	2604744.055	3.667	C-6	155'
70	224105.304	2604743.732	3.639	C-6	170'
71	224114.754	2604725.824	3.563	C-3	17'
72	224115.204	2604726.101	3.469	C-3	90'
73	224115.785	2604726.318	3.437	C-3	120'
74	224116.271	2604726.589	3.457	C-3	170'
75	224116.701	2604726.773	3.453	C-3	30'
76	224116.921	2604726.899	3.449	C-3	45'
77	224117.149	2604727.068	3.455	C-3	65'
78	224117.495	2604727.387	3.431	C-3	230'
79	224120.315	2604723.367	2.859	C-3	P-12
80	224146.580	2604745.913	6.641	TREE	P-12
81					
82	224017.286	2604766.986	3.677	S-1	17'
83	224017.478	2604766.559	3.832	S-1	90'
84	224017.749	2604766.046	3.850	S-1	120'
85	224018.124	2604765.582	3.846	S-1	170'
86	224018.420	2604765.120	3.843	S-1	30'
87	224018.677	2604764.727	3.844	S-1	45'
88	224018.942	2604764.344	3.839	S-1	65'
89	224019.223	2604764.036	3.856	S-1	230'
90	224007.666	2604803.586	3.947	C-1	17'
91	224007.997	2604804.073	3.936	C-1	90'
92	224008.384	2604804.470	3.974	C-1	120'
93	224008.523	2604804.768	3.976	C-1	170'
94	224008.834	2604805.201	3.964	C-1	30'
95	224009.146	2604805.570	3.974	C-1	45'
96	224009.357	2604805.843	3.938	C-1	65'
97	224009.708	2604806.183	3.898	C-1	230'
98	223971.789	2604868.928	7.281	TREE	P-4

Appendix B

Piezometric Water Levels at Bejgoan Field Site

Peizometric Water Levels at Bejgoan Field Site

Row	Bangladesh Date	2 ft WL (m)	6 ft WL (m)	9 ft WL (m)	15 ft WL (m)	30 ft WL (m)	45 ft WL (m)	60 ft WL (m)	100(1) ft WL (m)	100(2) ft WL (m)	100(3) ft WL (m)	100(4) ft WL (m)	100(5) ft WL (m)	200 (1) ft WL (m)	200 (2) ft WL (m)	250 ft WL (m)	350 ft WL (m)	540 ft WL (m)
7	5/15/2001						3.172	3.166								3.168	3.167	2.921
8	6/11/2001						3.892			3.893						3.859		3.724
9	6/12/2001						3.913			3.913						3.880		3.763
10	6/13/2001						3.953			3.953						3.920		3.806
11	6/14/2001						4.079			4.068						4.043		3.919
12	6/15/2001						4.195			4.190						4.159		4.006
13	6/16/2001						4.259			4.260						4.225		4.071
14	6/17/2001						4.314			4.314						4.280		4.128
15	6/18/2001						4.352			4.354						4.319		4.163
16	6/19/2001						4.358			4.359						4.323		4.181
17	6/20/2001						4.387			4.390						4.352		4.216
18	6/21/2001						4.375			4.380						4.340		4.218
19	6/22/2001						4.372			4.376						4.338		4.218
20	6/23/2001						4.387			4.392						4.353		4.244
21	6/24/2001						4.422			4.424						4.387		4.278
22	6/25/2001						4.461			4.465						4.428		4.313
23	6/26/2001						4.494			4.498						4.458		4.347
24	6/27/2001						4.543			4.536						4.508		4.396
25	6/28/2001						4.582			4.586						4.547		4.401
26	6/29/2001						4.615			4.609						4.581		4.470
27	6/30/2001						4.659			4.661						4.623		4.509
28	7/1/2001						4.672			4.673						4.638		4.517
29	7/2/2001						4.663			4.665						4.627		4.523
30	7/3/2001						4.657			4.660						4.622		4.527
31	7/4/2001						4.651			4.653						4.615		4.531
32	7/5/2001						4.663			4.665						4.628		4.545
33	7/6/2001						4.677			4.680						4.641		4.562
34	7/7/2001						4.702			4.702						4.667		4.584
35	7/8/2001						4.734			4.733						4.698		4.611
36	7/9/2001						4.759			4.759						4.723		4.633
37	7/10/2001						4.783			4.782						4.746		4.655
38	7/11/2001						4.794			4.796						4.760		4.671
39	7/12/2001						4.791			4.790						4.756		4.671
40	7/13/2001						4.786			4.789						4.753		4.674
41	7/14/2001						4.766			4.771						4.732		4.661
42	7/15/2001						4.735			4.738						4.700		4.639
43	7/16/2001						4.706			4.708						4.672		4.619
44	7/17/2001						4.687			4.688						4.654		4.600
45	7/18/2001						4.679			4.678						4.646		4.596
46	7/19/2001						4.703			4.693						4.669		4.617
47	7/20/2001						4.772			4.763						4.739		4.667
48	7/21/2001						4.855			4.848						4.820		4.739
49	7/22/2001						4.933			4.927						4.897		4.804
50	7/23/2001						5.015			5.012						4.980		4.875
51	7/24/2001						5.096			5.090						5.060		4.949
52	7/25/2001						5.152			5.150						5.117		5.003
53	7/26/2001						5.179			5.181						5.144		5.035
54	7/27/2001						5.177			5.179						5.141		5.047

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
55	7/28/2001						5.177			5.178						5.143		5.054
56	7/29/2001						5.166			5.167						5.132		5.053
57	7/30/2001						5.204			5.197						5.170		5.086
58	7/31/2001						5.206			5.208						5.171		5.094
59	8/1/2001						5.252			5.249						5.218		5.134
60	8/2/2001						5.311			5.304						5.275		5.187
61	8/3/2001						5.412			5.405						5.375		5.274
62	8/4/2001						5.517			5.509						5.481		5.357
63	8/5/2001						5.645			5.635						5.605		5.466
64	8/6/2001						5.750			5.743						5.712		5.561
65	8/7/2001						5.831			5.826						5.792		5.642
66	8/8/2001						5.873			5.872						5.835		5.688
67	8/9/2001						5.899			5.900						5.862		5.727
68	8/10/2001						5.892			5.897						5.856		5.733
69	8/11/2001						5.861			5.867						5.826		5.716
70	8/12/2001						5.797			5.805						5.764		5.677
71	8/13/2001						5.709			5.720						5.675		5.615
72	8/14/2001						5.616			5.620						5.584		5.540
73	8/15/2001						5.549			5.554						5.517		5.480
74	8/16/2001						5.479			5.484						5.448		4.521
75	8/17/2001						5.407			5.411						5.376		5.360
76	8/18/2001						5.349			5.349						5.318		5.302
77	8/19/2001						5.310			5.310						5.279		5.261
78	8/20/2001						5.299			5.297						5.268		5.239
79	8/21/2001						5.311			5.308						5.280		5.239
80	8/22/2001						5.318			5.318						5.286		5.240
81	8/23/2001						5.317			5.318						5.286		5.235
82	8/24/2001						5.328			5.325						5.296		5.244
83	8/25/2001						5.341			5.340						5.309		5.252
84	8/26/2001						5.360			5.359						5.327		5.272
85	8/27/2001						5.396			5.392						5.365		5.305
86	8/28/2001						5.429			5.426						5.398		5.334
87	8/29/2001						5.460			5.460						5.427		5.360
88	8/30/2001						5.503			5.497						5.471		5.398
89	8/31/2001						5.606			5.603						5.574		5.487
90	9/1/2001						5.693			5.687						5.660		5.554
91	9/2/2001						5.752			5.749						5.719		5.606
92	9/3/2001						5.781			5.780						5.748		5.637
93	9/4/2001						5.792			5.794						5.761		5.659
94	9/5/2001						5.816			5.816						5.786		5.692
95	9/6/2001						5.817			5.818						5.785		5.698
96	9/7/2001						5.825			5.826						5.793		5.710
97	9/8/2001						5.827			5.827						5.796		5.713
98	9/9/2001						5.831			5.836						5.802		5.725
99	9/10/2001						5.833			5.839						5.804		5.735
100	9/11/2001						5.810			5.816						5.781		5.716
101	9/12/2001						5.794			5.798						5.765		5.704
102	9/13/2001						5.771			5.776						5.743		5.685
103	9/14/2001						5.740			5.748						5.713		5.659
104	9/15/2001						5.717			5.718						5.688		5.637
105	9/16/2001						5.691			5.694						5.664		5.616
106	9/17/2001						5.694			5.694						5.667		5.615
107	9/18/2001						5.828			5.824						5.799		5.725
108	9/19/2001						5.826			5.824						5.798		5.717

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
109	9/20/2001						5.809			5.811						5.782		5.707
110	9/21/2001						5.771			5.780						5.745		5.679
111	9/22/2001						5.722			5.730						5.697		5.641
112	9/23/2001						5.657			5.668						5.632		5.590
113	9/24/2001						5.637			5.643						5.612		5.569
114	9/25/2001						5.549			5.560						5.526		5.498
115	9/26/2001						5.457			5.466						5.434		5.424
116	9/27/2001						5.377			5.388						5.355		5.354
117	9/28/2001						5.311			5.301						5.289		5.367
118	9/29/2001						5.223			5.234						5.202		5.214
119	9/30/2001						5.168			5.161						5.147		5.153
120	10/1/2001						5.131			5.132						5.109		5.110
121	10/2/2001						5.095			5.097						5.072		5.072
122	10/3/2001						5.074			5.078						5.052		5.047
123	10/4/2001						5.042			5.045						5.020		5.011
124	10/5/2001						4.999			5.005						4.978		4.975
125	10/6/2001						4.967			4.973						4.945		4.944
126	10/7/2001						4.948			4.950						4.926		4.923
127	10/8/2001						4.941			4.943						4.920		4.913
128	10/9/2001						4.971			4.970						4.950		4.933
129	10/10/2001						4.999			4.997						4.976		4.949
130	10/11/2001						5.014			5.014						4.991		4.963
131	10/12/2001						5.017			5.017						4.995		4.964
132	10/13/2001						5.024			5.023						5.002		4.972
133	10/14/2001						5.043			5.042						5.020		4.991
134	10/15/2001						5.070			5.068						5.047		5.018
135	10/16/2001						5.092			5.090						5.069		5.032
136	10/17/2001						5.100			5.101						5.080		5.038
137	10/18/2001						5.115			5.114						5.094		5.053
138	10/19/2001						5.117			5.121						5.095		5.066
139	10/20/2001						5.090			5.095						5.069		5.037
140	10/21/2001						5.041			5.048						5.020		5.001
141	10/22/2001						4.976			4.984						4.956		4.951
142	10/23/2001						4.905			4.909						4.884		4.892
143	10/24/2001						4.829			4.836						4.810		4.830
144	10/25/2001						4.750			4.758						4.732		4.721
145	10/26/2001						4.666			4.675						4.651		4.690
146	10/27/2001						4.590			4.598						4.573		4.605
147	10/28/2001						4.530			4.536						4.515		4.556
148	10/29/2001						4.466			4.474						4.451		4.496
149	10/30/2001						4.411			4.416						4.396		4.447
150	10/31/2001						4.395			4.398						4.378		4.270
151	11/1/2001						4.364			4.369						4.349		4.388
152	11/2/2001						4.330			4.335						4.315		4.351
153	11/3/2001						4.295			4.301						4.281		4.318
154	11/4/2001						4.251			4.259						4.238		4.278
155	11/5/2001						4.200			4.208						4.188		4.230
156	11/6/2001						4.150			4.155						4.138		4.061
157	11/7/2001						4.099			4.107						4.088		4.139
158	11/8/2001						4.048			4.053						4.037		4.094
159	11/9/2001						3.994			3.997						3.983		4.047
160	11/10/2001						3.946			3.951						3.936		4.003
161	11/11/2001						3.925			3.930						3.915		3.973
162	11/12/2001						3.918			3.921						3.908		3.956

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
163	11/13/2001						3.898			3.900						3.888		3.930
164	11/14/2001						3.872			3.875						3.863		3.907
165	11/15/2001						3.846			3.849						3.837		3.883
166	11/16/2001						3.823			3.826						3.815		3.860
167	11/17/2001						3.803			3.804						3.793		3.840
168	11/18/2001						3.779			3.783						3.771		3.818
169	11/19/2001						3.757			3.762						3.749		3.798
170	11/20/2001						3.732			3.736						3.725		3.772
171	11/21/2001						3.701			3.707						3.694		3.748
172	11/22/2001						3.673			3.680						3.666		3.724
173	11/23/2001						3.640			3.647						3.635		3.697
174	11/24/2001						3.607			3.616						3.604		3.670
175	11/25/2001						3.581			3.587						3.576		3.648
176	11/26/2001						3.557			3.561						3.552		3.623
177	11/27/2001						3.543			3.544						3.538		3.625
178	11/28/2001						3.533			3.534						3.528		3.587
179	11/29/2001						3.519			3.520						3.513		3.783
180	11/30/2001						3.506			3.509						3.502		3.548
181	12/1/2001						3.496			3.499						3.491		3.532
182	12/2/2001						3.485			3.489						3.479		3.519
183	12/3/2001						3.475			3.478						3.470		3.504
184	12/4/2001						3.466			3.472						3.460		3.759
185	12/5/2001						3.452			3.458						3.446		3.478
186	12/6/2001						3.437			3.444						3.430		3.463
187	12/7/2001						3.421			3.430						3.414		3.451
188	12/8/2001						3.411			3.418						3.404		3.439
189	12/9/2001						3.395			3.402						3.388		3.423
190	12/10/2001						3.383			3.387						3.374		3.407
191	12/11/2001						3.367			3.372						3.360		3.406
192	12/12/2001						3.352			3.355						3.344		3.380
193	12/13/2001						3.336			3.339						3.329		3.420
194	12/14/2001						3.324			3.331						3.316		3.354
195	12/15/2001						3.316			3.319						3.307		3.343
196	12/16/2001						3.308			3.311						3.299		3.329
197	12/17/2001						3.292			3.294						3.283		3.316
198	12/18/2001						3.279			3.284						3.266		3.304
199	12/19/2001						3.261			3.269						3.250		3.290
200	12/20/2001						3.244			3.251						3.234		3.276
201	12/21/2001						3.229			3.235						3.215		3.259
202	12/22/2001						3.213			3.219						3.202		3.250
203	12/23/2001						3.195			3.199						3.184		3.237
204	12/24/2001						3.184			3.188						3.172		3.226
205	12/25/2001						3.175			3.177						3.163		3.211
206	12/26/2001						3.162			3.162						3.151		3.196
207	12/27/2001						3.151			3.151						3.140		3.180
208	12/28/2001						3.141			3.140						3.128		3.166
209	12/29/2001						3.134			3.133						3.123		3.155
210	12/30/2001				3.139	3.130	3.127	3.116	3.138	3.129				3.130	3.119	3.101	3.124	3.149
211	12/31/2001									3.118						3.093		3.142
212	1/1/2002				3.104	3.100	3.082	3.081	3.078	3.089	3.093			3.070	3.069	3.103	3.069	3.124
213	1/2/2002									3.096						3.089		3.110
214	1/3/2002				3.089	3.090	3.067	3.066	3.068	3.069	3.078			3.060	3.059	3.045	3.054	3.100
215	1/4/2002									3.027						3.030		3.079
216	1/5/2002									3.056						3.043		3.070

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
217	1/6/2002									3.037						2.982		3.056
218	1/7/2002									2.971						2.894		3.039
219	1/8/2002									2.979						2.880		3.020
220	1/9/2002									2.922						2.885		2.999
221	1/10/2002									2.945						2.870		2.982
222	1/11/2002									2.928						2.847		2.960
223	1/12/2002									2.859						2.787		2.932
224	1/13/2002									2.801						2.765		2.894
225	1/14/2002									2.815						2.747		2.867
226	1/15/2002									2.778						2.703		2.838
227	1/16/2002									2.786						2.727		2.812
228	1/17/2002									2.749						2.652		2.787
229	1/18/2002									2.675						2.611		2.749
230	1/19/2002									2.632						2.424		2.724
231	1/20/2002									2.593						2.566		2.676
232	1/21/2002				2.804	2.795	2.607	2.601	2.608	2.620	2.613			2.590	2.584	2.562	2.589	2.659
233	1/22/2002									2.545						2.427		2.633
234	1/23/2002									2.579						2.533		2.621
235	1/24/2002									2.663						2.557		2.619
236	1/25/2002				2.819	2.810	2.622	2.616	2.623	2.639	2.633			2.590	2.584	2.545	2.584	2.603
237	1/26/2002									2.522						2.351		2.585
238	1/27/2002				2.749	2.740	2.542	2.541	2.543		2.553	2.511	2.500	2.510	2.514	2.512	2.499	2.523
239	1/28/2002								2.508		2.517	2.477	2.478				2.462	
240	1/29/2002								2.630		2.639	2.599	2.612				2.572	
241	1/30/2002								2.640		2.649	2.608	2.612				2.586	
242	1/31/2002								2.516		2.525	2.485	2.475				2.456	
243	2/1/2002								2.426		2.435	2.397	2.399				2.367	
244	2/2/2002								2.479		2.488	2.448	2.471				2.439	
245	2/3/2002								2.382		2.392	2.349	2.322				2.317	
246	2/4/2002								2.450		2.459	2.420	2.408				2.402	
247	2/5/2002								2.325		2.332	2.294	2.304				2.278	
248	2/6/2002								2.340		2.350	2.311	2.298				2.289	
249	2/7/2002								2.268		2.277	2.238	2.231				2.217	
250	2/8/2002								2.311		2.320	2.281	2.284				2.263	
251	2/9/2002								2.318		2.326	2.289	2.276				2.270	
252	2/10/2002								2.169		2.178	2.139	2.129				2.114	
253	2/11/2002								2.216		2.225	2.186	2.176				2.168	
254	2/12/2002								2.083		2.094	2.056	2.054				2.036	
255	2/13/2002				2.394	2.390	2.042	2.036	2.076		2.085	2.048	2.051	2.000	2.004	2.012	2.113	2.193
256	2/14/2002								2.025		2.033	1.998	1.988				2.033	
257	2/15/2002								2.045		2.053	2.016	2.044				1.972	
258	2/16/2002								1.980		1.987	1.952	1.944				1.987	
259	2/17/2002								2.067		2.075	2.038	2.023				1.932	
260	2/18/2002								1.992		2.001	1.964	1.969				2.017	
261	2/19/2002				2.169	2.160	1.892	1.886	1.967		1.976	1.940	1.955	1.855	1.849	1.862	1.946	2.068
262	2/20/2002								2.088		2.098	2.061	2.076				1.923	
263	2/21/2002								1.927		1.936	1.899	1.882				2.048	
264	2/22/2002								1.880		1.890	1.852	1.861				1.869	
265	2/23/2002								2.148		2.158	2.121	2.159				1.833	
266	2/24/2002								2.121		2.132	2.095	2.097				2.120	
267	2/25/2002								1.982		1.992	1.955	1.931				2.081	
268	2/26/2002								2.052		2.063	2.025	2.025				1.938	
269	2/27/2002								1.997		2.006	1.971	1.974				2.012	
270	2/28/2002								1.823		1.831	1.795	1.784				1.955	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
271	3/1/2002								1.719		1.728	1.692	1.694				1.767	
272	3/2/2002								1.808		1.816	1.779	1.785				1.675	
273	3/3/2002								1.770		1.781	1.742	1.741				1.757	
274	3/4/2002								1.726		1.736	1.700	1.707				1.716	
275	3/5/2002								1.756		1.762	1.723	1.747				1.680	
276	3/6/2002								1.829		1.840	1.801	1.774				1.715	
277	3/7/2002								1.620		1.630	1.593	1.583				1.787	
278	3/8/2002								1.632		1.641	1.604	1.580				1.579	
279	3/9/2002								1.560		1.570	1.530	1.527				1.586	
280	3/10/2002								1.631		1.641	1.603	1.599				1.508	
281	3/11/2002								1.635		1.644	1.606	1.611				1.579	
282	3/12/2002								1.761		1.772	1.733	1.740				1.587	
283	3/13/2002				1.769	1.750	1.517	1.506	1.599		1.611	1.573	1.569	1.490	1.489	1.497	1.677	1.693
284	3/14/2002								1.637		1.647	1.606	1.622				1.572	
285	3/15/2002								1.635		1.645	1.604	1.615				1.598	
286	3/16/2002								1.584		1.594	1.553	1.536				1.598	
287	3/17/2002								1.501		1.510	1.469	1.468				1.526	
288	3/18/2002								1.461		1.471	1.429	1.396				1.454	
289	3/19/2002								1.360		1.367	1.329	1.354				1.421	
290	3/20/2002								1.311		1.322	1.279	1.296				1.316	
291	3/21/2002								1.264		1.273	1.233	1.240				1.263	
292	3/22/2002								1.209		1.218	1.177	1.211				1.215	
293	3/23/2002								1.345		1.355	1.313	1.333				1.167	
294	3/24/2002								1.344		1.355	1.312	1.299				1.300	
295	3/25/2002								1.306		1.316	1.273	1.314				1.297	
296	3/26/2002								1.733		1.744	1.698	1.700				1.271	
297	3/27/2002								1.734		1.744	1.700	1.716				1.693	
298	3/28/2002								1.968		1.979	1.932	1.831				1.696	
299	3/29/2002								1.894		1.905	1.859	1.899				1.937	
300	3/30/2002								2.110		2.122	2.076	2.102				1.867	
301	3/31/2002								1.985		1.996	1.949	1.950				2.081	
302	4/1/2002								1.975		1.987	1.942	1.949				1.950	
303	4/2/2002				1.949	1.940	1.862	1.856	1.866		1.878	1.833	1.842	1.845	1.839	1.847	1.903	1.863
304	4/3/2002								2.244		2.258	2.210	2.247				1.836	
305	4/4/2002								2.281		2.293	2.246	2.254				2.215	
306	4/5/2002								2.126		2.139	2.092	2.106				2.236	
307	4/6/2002								2.271		2.284	2.237	2.248				2.081	
308	4/7/2002								2.087		2.100	2.055	2.056				2.225	
309	4/8/2002								1.980		1.990	1.944	1.956				2.061	
310	4/9/2002								2.314		2.327	2.279	2.301				1.933	
311	4/10/2002								2.407		2.419	2.371	2.401				2.271	
312	4/11/2002								2.277		2.291	2.243	2.236				2.379	
313	4/12/2002								2.256		2.270	2.221	2.267				2.251	
314	4/13/2002								2.441		2.454	2.405	2.438				2.218	
315	4/14/2002								2.340		2.352	2.304	2.320				2.417	
316	4/15/2002								2.158		2.170	2.121	2.144				2.308	
317	4/16/2002								2.079		2.093	2.040	2.088				2.117	
318	4/17/2002								2.112		2.126	2.076	2.093				2.041	
319	4/18/2002								1.942		1.955	1.906	1.908				2.083	
320	4/19/2002								2.015		2.029	1.978	2.003				1.906	
321	4/20/2002								1.964		1.978	1.928	1.946				1.988	
322	4/21/2002								1.856		1.867	1.819	1.824				1.936	
323	4/22/2002								1.987		1.999	1.949	1.972				1.811	
324	4/23/2002								1.872		1.884	1.832	1.805				1.961	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
325	4/24/2002								1.846		1.855	1.807	1.833				1.826	
326	4/25/2002								1.642		1.656	1.606	1.625				1.815	
327	4/26/2002								1.787		1.808	1.800	1.711				1.609	
328	4/27/2002								2.123		2.133	2.123	2.141					
329	4/28/2002								2.298		2.303	2.293	2.294					
330	4/29/2002								2.255		2.257	2.249	2.223					
331	4/30/2002								2.327		2.335	2.323	2.324					
332	5/1/2002								2.367		2.371	2.362	2.353					
333	5/2/2002								2.303		2.298	2.289	2.244					
334	5/3/2002								2.299		2.302	2.291	2.285					
335	5/4/2002								2.315		2.320	2.310	2.307					
336	5/5/2002								2.329		2.335	2.324	2.332					
337	5/6/2002								2.442		2.452	2.440	2.469					
338	5/7/2002								2.722		2.731	2.720	2.687					
339	5/8/2002								2.804		2.813	2.786	2.772					
340	5/9/2002								2.918		2.925	2.914	2.920					
341	5/10/2002								2.933		2.941	2.927	2.887					
342	5/11/2002								2.961		2.971	2.959	2.926					
343	5/12/2002				3.139	3.045	3.017	3.021	3.018		3.028	3.016	3.020	3.005	3.014	3.007	3.009	2.728
344	5/13/2002								3.035		3.047	3.040	3.037					
345	5/14/2002								3.022		3.034	3.030	3.024					
346	5/15/2002								2.997		3.006	3.002	3.003					
347	5/16/2002								2.979		2.989	2.985	2.984					
348	5/17/2002								2.950		2.962	2.956	2.955					
349	5/18/2002								2.926		2.936	2.933	2.929					
350	5/19/2002								2.900		2.910	2.906	2.905					
351	5/20/2002								2.871		2.881	2.879	2.875					
352	5/21/2002								2.849		2.859	2.856	2.855					
353	5/22/2002								2.843		2.852	2.849	2.848					
354	5/23/2002								2.974		2.985	2.985	2.987					
355	5/24/2002								3.004		3.014	3.011	3.011					
356	5/25/2002								2.996		3.007	3.004	3.004					
357	5/26/2002								3.089		3.102	3.100	3.115					
358	5/27/2002								3.377		3.390	3.366	3.351					
359	5/28/2002								3.451		3.464	3.460	3.426					
360	5/29/2002								3.473		3.486	3.483	3.456					
361	5/30/2002								3.524		3.536	3.532	3.491					
362	5/31/2002								3.530		3.541	3.539	3.536					
363	6/1/2002								3.602		3.615	3.616	3.567					
364	6/2/2002								3.613		3.626	3.608	3.582					
365	6/3/2002								3.662		3.675	3.645	3.621					
366	6/4/2002								3.651		3.665	3.660	3.659					
367	6/5/2002								3.652		3.684	3.654	3.645					
368	6/6/2002								3.653		3.666	3.635	3.660					
369	6/7/2002								3.623		3.637	3.635	3.632					
370	6/8/2002								3.683		3.699	3.666	3.693					
371	6/9/2002								3.681		3.695	3.692	3.692					
372	6/10/2002								3.726		3.738	3.736	3.735					
373	6/11/2002								3.722		3.766	3.735	3.740					
374	6/12/2002								3.786		3.803	3.769	3.764					
375	6/13/2002								3.829		3.883	3.855	3.888					
376	6/14/2002								3.904		3.950	3.918	3.946					
377	6/15/2002								3.964		4.012	3.982	4.008					
378	6/16/2002								4.005		4.022	3.991	4.018					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
379	6/17/2002								4.051		4.069	4.038	4.066					
380	6/18/2002								4.084		4.102	4.071	4.098					
381	6/19/2002								4.118		4.136	4.105	4.132					
382	6/20/2002								4.175		4.194	4.165	4.193					
383	6/21/2002								4.262		4.279	4.248	4.279					
384	6/22/2002								4.403		4.416	4.383	4.424					
385	6/23/2002								4.578		4.591	4.559	4.592					
386	6/24/2002								4.724		4.737	4.706	4.736					
387	6/25/2002								4.798		4.809	4.779	4.803					
388	6/26/2002								4.847		4.860	4.829	4.854					
389	6/27/2002								4.880		4.894	4.862	4.887					
390	6/28/2002								4.878		4.889	4.858	4.881					
391	6/29/2002								4.887		4.898	4.866	4.891					
392	6/30/2002								4.867		4.879	4.848	4.878					
393	7/1/2002								4.881		4.893	4.862	4.884					
394	7/2/2002								4.885		4.898	4.866	4.890					
395	7/3/2002								4.869		4.881	4.850	4.875					
396	7/4/2002								4.874		4.887	4.855	4.885					
397	7/5/2002								4.930		4.943	4.911	4.935					
398	7/6/2002								4.935		4.948	4.914	4.940					
399	7/7/2002								4.988		5.001	4.970	4.997					
400	7/8/2002								5.042		5.054	5.023	5.048					
401	7/9/2002								5.093		5.111	5.074	5.101					
402	7/10/2002								5.159		5.176	5.140	5.165					
403	7/11/2002								5.270		5.281	5.249	5.277					
404	7/12/2002								5.342		5.355	5.324	5.349					
405	7/13/2002								5.412		5.424	5.394	5.419					
406	7/14/2002								5.484		5.497	5.464	5.487					
407	7/15/2002								5.549		5.563	5.531	5.557					
408	7/16/2002								5.622		5.635	5.603	5.627					
409	7/17/2002								5.625		5.639	5.606	5.632					
410	7/18/2002								5.630		5.643	5.610	5.635					
411	7/19/2002								5.630		5.643	5.614	5.638					
412	7/20/2002								5.611		5.624	5.591	5.617					
413	7/21/2002								5.577		5.591	5.558	5.586					
414	7/22/2002								5.594		5.607	5.569	5.601					
415	7/23/2002								5.582		5.596	5.555	5.587					
416	7/24/2002								5.579		5.593	5.560	5.586					
417	7/25/2002								5.609		5.622	5.591	5.617					
418	7/26/2002								5.672		5.684	5.654	5.680					
419	7/27/2002								5.768		5.783	5.751	5.779					
420	7/28/2002								5.891		5.909	5.872	5.905					
421	7/29/2002								6.018		6.032	5.999	6.029					
422	7/30/2002								6.126		6.140	6.107	6.136					
423	7/31/2002								6.224		6.238	6.206	6.235					
424	8/1/2002								6.314		6.328	6.295	6.321					
425	8/2/2002								6.361		6.374	6.342	6.368					
426	8/3/2002								6.414		6.431	6.398	6.439					
427	8/4/2002								6.428		6.442	6.409	6.434					
428	8/5/2002								6.397		6.412	6.381	6.404					
429	8/6/2002								6.364		6.377	6.345	6.370					
430	8/7/2002								6.320		6.333	6.302	6.327					
431	8/8/2002								6.275		6.287	6.254	6.279					
432	8/9/2002								6.229		6.241	6.211	6.236					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
433	8/10/2002								6.215		6.230	6.200	6.222					
434	8/11/2002								6.194		6.213	6.182	6.212					
435	8/12/2002								6.164		6.176	6.145	6.169					
436	8/13/2002								6.126		6.138	6.106	6.128					
437	8/14/2002								6.103		6.115	6.084	6.106					
438	8/15/2002								6.081		6.092	6.062	6.084					
439	8/16/2002								6.046		6.057	6.026	6.050					
440	8/17/2002								6.002		6.014	5.984	6.007					
441	8/18/2002								5.968		5.979	5.951	5.974					
442	8/19/2002								5.935		5.946	5.916	5.939					
443	8/20/2002								5.927		5.938	5.909	5.934					
444	8/21/2002								5.894		5.905	5.875	5.898					
445	8/22/2002								5.882		5.894	5.864	5.890					
446	8/23/2002								5.879		5.892	5.863	5.889					
447	8/24/2002								5.907		5.921	5.890	5.915					
448	8/25/2002								5.922		5.935	5.906	5.930					
449	8/26/2002								5.913		5.924	5.895	5.918					
450	8/27/2002								5.898		5.910	5.881	5.904					
451	8/28/2002								5.905		5.917	5.888	5.910					
452	8/29/2002								5.887		5.899	5.868	5.892					
453	8/30/2002								5.858		5.871	5.850	5.865					
454	8/31/2002								5.822		5.833	5.806	5.828					
455	9/1/2002								5.761		5.772	5.743	5.764					
456	9/2/2002								5.679		5.699	5.663	5.684					
457	9/3/2002								5.595		5.606	5.576	5.601					
458	9/4/2002								5.505		5.516	5.489	5.510					
459	9/5/2002								5.429		5.440	5.412	5.434					
460	9/6/2002								5.362		5.373	5.346	5.369					
461	9/7/2002								5.297		5.308	5.281	5.302					
462	9/8/2002								5.235		5.246	5.219	5.239					
463	9/9/2002								5.183		5.192	5.166	5.188					
464	9/10/2002								5.156		5.164	5.140	5.160					
465	9/11/2002								5.152		5.162	5.138	5.159					
466	9/12/2002								5.139		5.149	5.123	5.144					
467	9/13/2002								5.086		5.091	5.069	5.089					
468	9/14/2002								5.007		5.018	4.994	5.013					
469	9/15/2002								4.926		4.935	4.912	4.930					
470	9/16/2002								4.860		4.867	4.841	4.861					
471	9/17/2002								4.801		4.807	4.775	4.801					
472	9/18/2002								4.743		4.752	4.726	4.748					
473	9/19/2002								4.703		4.713	4.687	4.710					
474	9/20/2002								4.683		4.691	4.665	4.687					
475	9/21/2002								4.669		4.678	4.652	4.676					
476	9/22/2002								4.673		4.684	4.658	4.679					
477	9/23/2002								4.694		4.704	4.678	4.700					
478	9/24/2002								4.727		4.736	4.709	4.734					
479	9/25/2002								4.765		4.775	4.747	4.772					
480	9/26/2002								4.790		4.799	4.772	4.796					
481	9/27/2002								4.793		4.803	4.779	4.818					
482	9/28/2002								4.796		4.804	4.778	4.800					
483	9/29/2002								4.793		4.802	4.776	4.797					
484	9/30/2002								4.762		4.772	4.747	4.767					
485	10/1/2002								4.729		4.738	4.711	4.733					
486	10/2/2002								4.705		4.713	4.687	4.712					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
487	10/3/2002								4.692		4.701	4.675	4.698					
488	10/4/2002								4.692		4.701	4.677	4.700					
489	10/5/2002								4.708		4.718	4.692	4.716					
490	10/6/2002								4.744		4.755	4.727	4.751					
491	10/7/2002								4.784		4.797	4.771	4.796					
492	10/8/2002								4.830		4.840	4.814	4.837					
493	10/9/2002								4.854		4.864	4.838	4.862					
494	10/10/2002								4.852		4.859	4.834	4.854					
495	10/11/2002								4.822		4.831	4.807	4.826					
496	10/12/2002								4.786		4.795	4.772	4.789					
497	10/13/2002								4.724		4.735	4.707	4.725					
498	10/14/2002								4.655		4.665	4.640	4.661					
499	10/15/2002								4.590		4.600	4.575	4.592					
500	10/16/2002								4.529		4.538	4.514	4.532					
501	10/17/2002								4.466		4.477	4.452	4.469					
502	10/18/2002								4.406		4.415	4.390	4.407					
503	10/19/2002								4.352		4.362	4.336	4.353					
504	10/20/2002								4.293		4.302	4.278	4.294					
505	10/21/2002								4.238		4.246	4.222	4.240					
506	10/22/2002								4.188		4.201	4.174	4.190					
507	10/23/2002								4.140		4.150	4.123	4.140					
508	10/24/2002								4.091		4.103	4.077	4.094					
509	10/25/2002								4.046		4.061	4.032	4.048					
510	10/26/2002								4.008		4.021	3.994	4.010					
511	10/27/2002								3.966		3.982	3.957	3.974					
512	10/28/2002								3.930		3.943	3.916	3.931					
513	10/29/2002								3.881		3.894	3.868	3.884					
514	10/30/2002								3.838		3.851	3.826	3.842					
515	10/31/2002								3.800		3.812	3.788	3.804					
516	11/1/2002								3.762		3.774	3.749	3.767					
517	11/2/2002								3.731		3.744	3.721	3.737					
518	11/3/2002								3.708		3.721	3.696	3.714					
519	11/4/2002								3.696		3.708	3.683	3.700					
520	11/5/2002								3.689		3.700	3.675	3.691					
521	11/6/2002								3.683		3.694	3.669	3.687					
522	11/7/2002								3.673		3.685	3.660	3.677					
523	11/8/2002								3.659		3.671	3.646	3.662					
524	11/9/2002								3.640		3.651	3.626	3.642					
525	11/10/2002								3.613		3.630	3.601	3.617					
526	11/11/2002								3.582		3.597	3.572	3.587					
527	11/12/2002								3.618		3.632	3.605	3.632					
528	11/13/2002								3.826		3.836	3.815	3.831					
529	11/14/2002								3.817		3.829	3.753	3.817					
530	11/15/2002								3.779		3.790	3.733	3.779					
531	11/16/2002								3.738		3.750	3.726	3.739					
532	11/17/2002								3.698		3.709	3.687	3.699					
533	11/18/2002								3.665		3.677	3.655	3.667					
534	11/19/2002								3.637		3.649	3.626	3.639					
535	11/20/2002								3.613		3.625	3.602	3.615					
536	11/21/2002								3.596		3.608	3.580	3.596					
537	11/22/2002								3.577		3.589	3.567	3.578					
538	11/23/2002								3.557		3.570	3.547	3.557					
539	11/24/2002								3.538		3.549	3.527	3.538					
540	11/25/2002								3.517		3.530	3.507	3.518					

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
541	11/26/2002								3.492		3.505	3.488	3.497					
542	11/27/2002								3.477		3.490	3.467	3.478					
543	11/28/2002								3.459		3.472	3.450	3.461					
544	11/29/2002								3.435		3.447	3.424	3.437					
545	11/30/2002								3.418		3.431	3.409	3.421					
546	12/1/2002								3.404		3.417	3.395	3.408					
547	12/2/2002								3.394		3.406	3.385	3.398					
548	12/3/2002								3.387		3.400	3.378	3.389					
549	12/4/2002								3.375		3.389	3.367	3.378					
550	12/5/2002								3.368		3.381	3.359	3.370					
551	12/6/2002								3.356		3.370	3.348	3.358					
552	12/7/2002								3.347		3.360	3.338	3.347					
553	12/8/2002								3.330		3.346	3.322	3.331					
554	12/9/2002								3.313		3.326	3.304	3.316					
555	12/10/2002								3.296		3.311	3.286	3.298					
556	12/11/2002								3.278		3.293	3.269	3.279					
557	12/12/2002								3.260		3.274	3.264	3.262					
558	12/13/2002								3.248		3.261	3.245	3.248					
559	12/14/2002								3.232		3.246	3.230	3.236					
560	12/15/2002								3.217		3.232	3.210	3.219					
561	12/16/2002								3.209		3.222	3.207	3.212					
562	12/17/2002								3.203		3.215	3.197	3.205					
563	12/18/2002								3.192		3.211	3.187	3.195					
564	12/19/2002								3.177		3.192	3.175	3.181					
565	12/20/2002								3.174		3.184	3.161	3.172					
566	12/21/2002								3.160		3.172	3.168	3.160					
567	12/22/2002								3.150		3.163	3.165	3.152					
568	12/23/2002				3.114	3.075	3.142	3.141	3.138		3.153	3.146	3.140	3.135	3.134	3.132	3.129	3.133
569	12/29/2002				3.009	2.990	3.022	3.016	3.018		3.028	3.016	3.015	3.010	3.009	3.017	3.009	3.048
570	1/15/2003				2.754	2.735	2.742	2.741	2.743		2.753	2.736	2.735	2.720	2.729	2.732	2.929	2.503
571	3/3/2003				1.889	1.870	1.642	1.646	1.648		1.653	1.646	1.645	1.620	1.609	1.622	1.619	1.863
572	3/17/2003				2.639	2.500	2.462	2.456	2.458		2.473	2.456	2.455	2.450	2.449	2.452	2.449	1.923
573	4/2/2003				2.489	2.495	2.612	2.606	2.618		2.623	2.616	2.585	2.580	2.584	2.582	2.599	2.373
574	4/20/2003				2.019	2.010	2.332	2.336	2.338		2.343	2.336	2.335	2.340	2.339	2.342	2.339	
575	5/9/2003				2.579	2.600	2.672	2.676	2.678		2.688	2.676	2.675	2.670	2.664	2.672	2.669	
576	5/29/2003				2.769	2.790	2.662	2.656	2.648		2.653	2.656	2.655	2.640	2.639	2.642	2.639	
577	12/5/2003				3.599	3.440	3.422	3.406	3.418		3.433	3.426	3.425	3.410	3.409	3.412	3.409	
578	12/14/2003				3.459	3.370	3.322	3.321	3.323		3.338	3.331	3.325	3.315	3.314	3.317	3.324	
579	12/20/2003		3.290	2.949	3.504	3.385	3.337	3.336	3.338		3.348	3.341	3.340	3.325	3.324	3.327	3.324	
580	12/22/2003	3.765	3.270	3.309	3.439	3.355	3.312	3.311	3.313		3.323	3.316	3.315	3.295	3.299	3.297	3.299	
581	12/30/2003	3.710	3.300	3.294	3.224	3.330	3.197	3.206	3.198		3.213	3.201	3.200	3.185	3.184	3.187	3.189	
582	1/5/2004	3.675	3.285	3.279														
583	1/7/2004	3.675	3.290	3.269														
584	1/15/2004	3.630	3.260	3.234	3.089	3.055	2.842	2.841	2.843		2.853	2.846	2.835	2.815	2.819	2.772	2.814	
585	1/19/2004	3.615	3.245	3.214	3.099	3.030	2.782	2.781	2.783		2.788	2.786	2.780	2.750	2.749	2.712	2.754	
586	1/25/2004	3.585	3.225	3.144	2.974	2.960	2.712	2.706	2.708		2.723	2.716	2.705	2.680	2.684	2.647	2.679	
587	2/23/2004	3.445	3.080	3.039	2.424	2.415	2.062	2.056	2.058		2.063	2.061	2.055	2.015	2.019	1.997	2.019	
588	3/11/2004	3.305	2.950	2.899	2.124	2.120	1.867	1.861	1.863		1.878	1.861	1.870	1.830	1.824	1.812	1.839	
589	4/1/2004	3.205	2.720	2.739	1.574	1.550	1.177	1.176	1.178		1.183	1.176	1.175	1.145	1.144	1.137	1.144	
590	4/9/2004	3.205	2.730	2.689	2.419	2.400	2.062	2.061	2.068		2.073	2.071	2.060	2.045	2.044	2.032	2.049	
591	4/25/2004				2.749	2.705	2.432	2.431	2.433		2.443	2.431	2.060	2.665	2.464	2.307		
592	5/3/2004				2.444	2.430	2.227	2.221	2.223		2.233	2.221	2.220	2.200	2.199	2.192	2.199	
593	5/13/2004	3.220	2.685	2.659	2.359	2.365	2.082	2.076	2.083		2.088	2.076	2.080	2.060	2.059	2.057	2.059	
594	5/19/2004				2.539	2.505	2.197	2.196	2.193		2.198	2.186	2.195	2.170	2.174	2.167	2.169	

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
595	5/27/2004	3.225	2.695	2.869	2.979	2.990	3.062	3.056	3.068		3.073	3.066	3.075	3.050	3.054	3.047	3.054	
596	1/15/2005				2.639	2.630	2.552	2.546	2.558		2.563	2.556	2.555	2.530	2.529	2.532	2.499	
597	2/18/2005				2.189	2.190	1.862	1.866	1.868		1.873	1.866	1.865	1.830	1.829	1.832	1.829	
598	4/8/2005				2.529	2.480	2.322	2.326	2.338		2.343	2.336	2.335	2.310	2.309	2.312	2.309	
599	5/5/2005				2.989	2.910	3.022	3.016	3.028		3.033	3.026	3.025	3.020	3.019	2.912	3.019	
600	5/26/2005				3.239	3.230	3.202	3.196	3.173		3.133	3.076	3.345	3.190	3.199	3.092	3.194	
601	6/7/2005				3.069	3.090	2.947	2.946	2.958		2.963	2.946	2.955	2.935	2.939	2.932	2.929	

Appendix C

Pond Water Levels in the Study Area

Pond Water Levels in the Study Area

	Bangladesh Date	Pond-1 WL (m)	Pond-2 WL (m)	Pond-3 WL (m)	Pond-4 WL (m)	Pond-5 WL (m)	Pond-6 WL (m)	Pond-7 WL (m)	Pond-8 WL (m)	Pond-9 WL (m)	Pond-10 WL (m)	Pond-11 WL (m)	Pond-12 WL (m)
7	1/14/2003	3.359	4.305	3.508	4.341	4.177	3.250	4.079	5.456	4.407			
8	1/19/2003	3.354	4.465	3.803	3.217	4.117	3.190	4.029	5.436	4.382			
9	3/1/2003	3.129	4.105	3.328	3.267	3.687	2.880	3.519	5.196	4.107			
10	3/15/2003		3.975	3.048	3.207	3.507	2.700	3.409	5.046	3.997			
11	4/1/2003		4.025	3.108	3.277	3.557	2.760	3.449	5.126	4.057			
12	4/19/2003		3.935	2.948	3.197	3.397	2.640	3.359	5.056	3.987			
13	5/8/2003		3.905	2.908	3.167	3.327	2.570	3.309	4.776	3.937			
14	5/28/2003		3.865	2.818	3.067	3.197	2.540	3.229	4.676	3.827			
15	6/25/2003		5.675	3.318	3.717		3.390	3.679	4.926	3.977			
16	7/16/2003			5.908		6.347	5.890	6.329	5.406	5.567			
17	8/5/2003			5.358		5.797	6.330	5.969	6.106	6.017			
18	8/22/2003		5.515	4.908		5.377	5.880	5.569	6.156	5.847			
19	9/4/2003		5.945	4.488		5.787	5.830	5.969	5.911	5.807			
20	9/18/2003		6.025	4.558		5.867	5.980	6.049	5.986	5.857			
21	10/2/2003		5.965	4.498		5.947	6.010	6.119	6.136	5.927			
22	10/16/2003		5.415	3.958		5.307	5.810	5.619	5.866	5.367			
23	10/30/2003		4.495	3.788		5.237	5.330	5.109	5.846	4.897			
24	11/14/2003		3.845	3.088		5.077	4.760	4.699	5.776	4.797			
25	12/5/2003	3.719	3.745	3.698		4.957	4.060	4.669	5.736				
26	12/14/2003	3.599	3.595	3.688		4.617	3.820	4.559	5.196				
27	12/25/2003	3.589	3.575	3.673	3.557	4.477	3.640						
28	12/29/2003	3.549	3.570	3.633	3.507	4.437	3.565		5.186				
29	1/27/2004	3.449	3.340	3.503	3.457	4.027	3.345	3.014	5.016				
30	2/20/2004	3.269	3.135	3.388	3.377	3.687	3.000		4.886				
31	3/11/2004	3.394	3.035		3.297	3.367	2.730		4.776				
32	3/25/2004	3.249	2.885		3.187	3.247	2.530		4.666				
33	4/9/2004	3.399	3.125		3.367	2.887			4.566				
34	4/24/2004		2.805		3.487	3.097			4.616				
35	5/15/2004		2.735		2.967	2.907			3.766				
36	5/28/2004		2.715		3.367	2.837			4.196				
37	6/10/2004		3.955	3.238	3.467	3.077			4.636				
38	6/24/2004		4.295	3.648	3.667	3.547	3.790	6.019	4.976				
39	7/8/2004		5.325	4.668	4.657	3.977	4.480	5.329	5.096				
40	8/12/2004		6.035	6.008	5.607	5.907	6.650	6.449	6.276				
41	9/30/2004		4.935	4.908	4.587	5.277	5.430	5.549	5.976				
42	10/23/2004		4.825	4.818	4.487	5.217	5.220	5.499	5.916				
43	11/25/2004		3.745	3.708	3.287	4.797	3.740	5.099	5.726				
44	1/15/2005		3.445	3.308	3.087	4.147	2.950	4.499	5.416				

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
45	2/18/2005		3.165		2.917	3.747	2.310	4.099	5.206						
46	4/8/2005		3.055		3.217	3.357		3.819	5.006						
47	5/5/2005		3.165			3.277		3.899	5.166						
48	5/26/2005		3.255			2.947		3.999	5.206						
49	3/26/2006				3.341						1.631				
50	4/18/2006				3.311						1.581				
51	4/27/2006				3.181						1.471				
52	5/24/2006				2.521						2.001	2.103	1.956		
53	5/30/2006				2.621						2.281	2.393	2.301		
54	6/4/2006				2.821						3.231	3.193	3.221		
55	6/20/2006				4.241						4.351		4.671		
56	8/10/2006				4.661						4.601		4.641		
57	9/5/2006				4.361						4.311		4.321		
58	10/13/2006				4.381						4.111		4.341		
59	11/7/2006				3.251						3.001		3.241		
60	11/10/2006				3.201						2.931		3.121		
61	12/22/2006				3.181						2.781		2.841		
62	1/10/2007				3.031						2.821		2.841		
63	1/18/2007				2.981						1.781		2.641		
64	2/9/2007				2.931						1.671		1.701		
65	3/7/2007				2.741						1.501		1.431		
66	3/14/2007				2.731						1.431				
67	4/13/2007				2.651						2.001				
68	4/29/2007				2.861										

Appendix D

River Water Levels in the Study Area

River Water Levels in the Study Area

Bangladesh Date	HB1 WL (m)	HB2 WL (m)	HB3 WL (m)	SB1 WL (m)	SB2 WL (m)	LB1 WL (m)	LB2 WL (m)	LB3 WL (m)	LB4 WL (m)
2/6/2002	1.856						1.688		
2/11/2002	1.686						1.578		
4/2/2002	2.426						2.353		
4/26/2002	2.746						2.698		
5/12/2002	3.126						3.088		
12/20/2002	2.426	2.394	2.481				2.358		
12/25/2002	2.206	2.354	2.441		2.428	2.433	2.128	2.134	
12/29/2002		2.324	2.426	2.644	2.408			1.854	
1/12/2003	1.866	2.444	2.361	2.764	2.338	2.323	1.818	1.704	1.736
3/1/2003	1.656	2.264	2.166	2.124	2.568		1.668	1.604	1.646
3/15/2003	1.666	2.124	1.991	1.994	2.398		1.608	1.564	1.626
4/1/2003	2.166	2.334	2.361	2.314	2.618		2.118	2.064	2.136
4/19/2003	2.666	2.494	2.621	2.604	2.728		2.768	2.664	2.716
5/8/2003	2.856	2.744	2.801	2.754	2.708		2.718	2.614	2.706
5/28/2003	3.166	3.114	3.041	3.074	2.978		3.128	3.034	3.106
6/25/2003	4.566	4.504	4.521	4.474	4.498		4.528	4.424	4.506
7/16/2003	6.496	6.444	6.461	6.384	6.438	5.713	6.488	6.374	6.466
8/5/2003	6.006	5.924	5.901	5.864	5.928	5.163	5.948	5.854	5.936
8/22/2003	5.596	5.494	5.481	5.414	5.498	4.743	5.528	5.434	5.516
9/4/2003	6.006	5.894	5.911	5.844	5.918	5.163	5.938	5.854	5.926
9/18/2003	6.076	5.964	5.971	5.914	5.978	5.233	6.018	5.924	6.006
10/2/2003	6.016	5.914	5.921	5.864	5.928	5.183	5.968	5.874	5.956
10/16/2003	5.466	5.344	5.351	5.314	5.378	4.633	5.398	5.304	5.386
10/30/2003	4.506	4.424	4.411	4.384	4.448	3.683	4.488	4.364	4.436
11/14/2003	3.546	3.444	3.441	3.404	3.468	2.723	3.478	3.374	3.456
12/5/2003	2.626	2.584	2.551	2.514	2.578	1.813	2.518	2.484	2.566
12/14/2003	2.466	2.424	2.491	2.744	2.438		2.448	2.424	2.446
12/16/2003	2.406	2.414	2.441	2.734	2.428		2.328	2.214	2.316
12/20/2003	2.546	2.434	2.471	2.724	2.483		2.368	2.304	2.446
12/22/2003	2.556	2.424	2.481	2.714	2.483		2.518	2.619	2.496
12/25/2003	2.626	2.544	2.561	2.694	2.578		2.588		2.571
12/29/2003	2.336	2.364	2.401	2.689	2.408	2.473	2.298	2.109	2.281

	A	B	C	D	E	F	G	H	I	J
39	1/27/2004	2.316	2.464	2.301	2.774	2.318	2.413	2.258	1.689	2.226
40	2/20/2004	1.686	2.264	2.141	2.644	2.158	2.273	1.628	1.764	1.576
41	3/11/2004	1.216	2.244	1.911	2.444	1.938	2.003	1.208	1.744	1.166
42	3/25/2004	2.486	1.994	1.861	2.084	1.918		2.428	2.944	2.386
43	4/9/2004	2.836	1.814	2.761	1.814	1.918		2.808	3.744	2.776
44	4/24/2004	3.206	1.954	3.051	1.964	3.088		3.108	4.044	3.106
45	5/15/2004	3.016	2.964	2.931	2.744	2.978		3.018	3.944	3.016
46	5/28/2004	3.896	3.794	3.771	3.564	3.828	2.983	3.848	4.764	3.816
47	6/10/2004	3.946	3.844	3.811	3.604	3.858	3.173	3.868	4.814	3.856
48	6/24/2004	4.296	4.154	4.191	3.984	4.228	3.453	4.278	5.184	4.256
49	7/8/2004	5.346	5.234	5.211	5.004	5.238	4.513	5.268	6.194	5.216
50	8/12/2004	6.116	6.004	5.991	5.804	6.028	5.263	6.058	6.994	6.046
51	9/30/2004	4.966	4.854	4.821	4.644	4.868	4.113	4.888	5.854	4.876
52	10/23/2004	4.856	4.734	4.701	4.524	4.748	4.003	4.778	5.754	4.766
53	11/25/2004	2.676	2.624	2.561	2.404	2.628	2.483	2.668	3.634	2.676
54	1/15/2005	2.116	2.464	2.381	2.244	2.468	1.983	2.088	3.454	2.066
55	2/18/2005	1.936	2.074	2.111	2.004	2.218	2.103	1.848	3.254	1.796
56	4/8/2005	2.416	2.344	2.311	2.194	2.398	2.303	2.468	3.844	2.406
57	5/5/2005	2.566	2.494	2.451	2.324	2.528	2.443	2.618	3.984	2.566
58	5/26/2005	3.316	3.244	3.161	3.044	3.248	2.643	3.288	4.684	3.296
59	12/22/2006	2.055						1.976		1.968
60	1/10/2007	1.757						1.696		1.679
61	1/18/2007	1.702						1.635		1.602
62	2/9/2007	1.912						1.869		1.816
63	3/7/2007	1.891						1.811		1.786
64	3/14/2007	1.391						1.452		1.499
65	4/13/2007	2.189						2.122		2.090
66	4/29/2007	2.516						2.418		2.416
67	5/15/2007		1.794			2.828		2.918		2.866

Appendix E

Water Levels at Drinking Wells in the Study Area

Water Levels at Drinking Wells in the Study Area

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1																			
2																			
3																			
4																			
5	**Bangladesh**	**DR-2**	**DR-3**	**DR-5**	**DR-10**	**DR-11**	**DR-12**	**DR-13**	**DR-15**	**DR-16**	**DR-17**	**DR-18**	**DR-27**	**DR-29**	**DR-30**	**DR-31**	**DR-32**	**DR-33**	**DR-34**
6	**Date**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**
7	12/29/2001	3.155	3.380	3.291															
8	1/1/2002	3.105	3.130	3.231	3.022	2.999	3.020	2.993	3.013	3.019	3.004								
9	1/3/2002				2.997	2.969	2.980	2.963	2.943	2.984	2.984								
10	2/6/2002												2.508	2.351	2.359	2.232	2.248		
11	2/11/2002	2.010	1.995	1.836	2.032	2.054	2.070	1.053	2.083	2.119	2.139	1.989	2.378	1.961	2.024	2.027	2.038		
12	2/19/2002	1.780	1.760	1.576	1.842	1.859	1.885			1.944		1.844	2.338	2.021	2.049	2.017			
13	3/13/2002	2.340	2.385	2.111		2.419	2.035	1.483		2.424		2.394		1.717	1.729	2.685	1.673		
14	4/2/2002	1.790	1.765			1.809	1.860	1.843	1.903	1.944	1.944	1.869	2.368	2.241	2.209	1.997	1.988		
15	5/12/2002	3.010	2.990			2.969	3.000	2.968		3.034	2.954	2.939	3.243	2.531		2.962	2.973		
16	6/4/2002	3.605	3.630			3.579	4.161	3.593		3.644	3.574		3.848	3.831		3.757	3.778		
17	3/3/2003		1.560	0.771		1.694				1.739	1.754	1.684	1.958	1.611	1.659	1.772	1.738	1.653	1.602
18	3/17/2003		2.450	1.501		2.399				2.449	2.444	2.474	2.708		2.389	2.532	2.508	2.563	2.442
19	4/2/2003		2.545	1.586		2.509				2.514	2.514	2.534	2.783	2.421	2.429	2.602	2.568	2.658	2.572
20	4/19/2003		2.250	1.301		2.289				2.219	2.264	2.264	2.473	2.041	2.079	2.192	2.138	2.463	2.352
21	5/9/2003		2.590	1.601		2.559				2.599	2.649	2.624	2.758	2.351	2.359	2.502	2.498	2.823	2.722
22	5/29/2003		2.600	1.616		2.614				2.619	2.599	2.639	2.808	2.346	2.384	2.502	2.518	0.798	2.702
23	6/26/2003		4.300	3.336		4.264				4.289	4.349	4.419	4.563	4.076	4.064	4.282	4.368	4.453	4.382
24	7/16/2003		6.150	5.191		6.199				6.269	6.334	6.434		6.071	6.049	6.272	6.358		6.402
25	8/5/2003		5.630	4.631		5.679				5.899	5.804	5.904		5.621	5.609	5.822	5.918	5.983	6.402
26	8/22/2003		5.195	4.201		5.269				5.489	5.394	5.484		5.191	5.169	5.392	5.498	5.623	5.572
27	9/4/2003		5.600	4.611		5.669				5.889	5.789	5.894		5.591	5.569	5.802	5.898	6.023	5.982
28	9/18/2003		5.660	4.676		5.729				5.939	5.844	5.944		5.651	5.629	5.852	5.948	6.073	6.032
29	10/2/2003		5.615	4.631		5.689				5.889	5.794	5.904		5.621	5.599	5.817	5.918	6.033	5.992
30	10/16/2003		5.100	4.111		5.189				5.389	5.294	5.394		5.086	5.059	5.282	5.378	5.523	5.482
31	10/30/2003		4.230	3.231		4.319				4.549	4.454	4.534		4.221	4.199	4.412	4.518	4.663	4.622
32	11/14/2003		3.530	2.541		3.639				3.869	3.774	3.844		3.581	3.559	3.777	3.888	3.973	3.942
33	12/5/2003	3.425	3.440	2.441			3.350	3.333	3.343	3.779		3.404		3.181	3.159	3.282	3.388	3.563	4.552
34	12/14/2003	3.335	3.350	3.491	3.252		3.250	3.233	3.243	3.239		3.284				3.202	3.248	3.443	
35	12/25/2003	3.270	3.280		3.192		3.195	3.178	3.188	3.169		3.224				3.137	3.193	3.398	3.352
36	12/29/2003	3.225	3.240	3.401	3.132		3.125	3.108	3.113	3.114		3.174		3.111	3.134	3.067	3.133	3.348	3.302
37	1/27/2004	2.555	2.560	2.581	2.542		2.525	2.513	2.513	2.534		2.614		2.451	2.489	2.552	2.573	2.663	2.662
38	2/21/2004	1.795	1.810	1.821	1.842		1.820	1.853	1.833	1.989		1.944		1.791	1.819	1.942	1.918	1.903	1.852
39	3/11/2004	1.675	1.670	1.611	1.642		1.610	1.643	1.613	1.729		1.814		1.631	1.654	1.792	1.768	1.843	1.767
40	3/25/2004	1.045	1.050	0.961	1.162		1.170	1.213	1.173	1.319		1.314		1.181	1.219	1.372	1.338	1.153	1.062
41	4/9/2004	1.865	1.880	1.781	1.922		1.900	1.933	1.863	2.019		2.024		1.831	1.879	2.032	1.988	2.003	1.812
42	4/24/2004	2.265	2.270	2.191	2.442		2.430	2.413	2.333	2.509		2.394		2.281	2.319	2.492	2.448	2.383	2.342

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
43	5/15/2004	2.005	2.000	1.941	2.122		2.090	2.103	1.983	2.149		2.064		1.911	1.959	2.122	2.068	2.133	2.022
44	5/28/2004	3.055	3.040	3.001	3.072		3.070	3.083	2.973	3.119		3.054		2.821	2.859	3.002	2.938	3.193	3.122
45	6/10/2004	3.695	3.690	2.651	3.622		3.620	3.623	3.533	3.659		3.674		3.531	3.579	3.692	3.638	3.893	3.802
46	6/24/2004	4.125	4.110	3.091	4.062		4.050	4.073	3.973	4.119		4.114		4.041	4.099	4.212	4.168	4.313	4.202
47	7/8/2004	5.125	5.120	4.111	5.112		5.090	5.103	5.013	5.149		5.174		5.081	5.119	5.252	5.198	5.363	5.262
48	8/12/2004	5.905	5.920	4.881	6.002		5.980	6.083		6.029		6.014		5.931	5.949	6.042	6.028	6.423	6.082
49	9/30/2004	4.805	4.830	3.791	4.882		4.870	4.983		4.919		4.924		4.821	4.859	4.932	4.908	5.093	4.982
50	10/23/2004	4.690	4.710	3.661	4.762		4.740	4.873		4.799		4.804		4.701	4.744	4.812	4.788	4.973	4.862
51	11/25/2004	3.465	3.290	2.511	3.342		3.330	3.373		3.399		3.414		3.311	3.359	3.442	3.428	3.603	3.512
52	1/15/2005	2.545	2.360	1.551	2.432		2.410	2.433		2.359		2.514		2.301	2.349	2.432	2.468	2.513	
53	2/18/2005	1.865	1.770	1.851	1.762		1.750	1.773		1.869		1.814		1.731	1.769	1.862	1.908	1.813	
54	4/8/2005	2.335	2.230	2.311	2.212		2.190	2.213		2.329		2.264		2.141	2.189	2.252	2.308	2.443	
55	5/5/2005	3.035	2.920	3.001	2.872		2.840	2.853		2.979		2.974		2.811	2.859	2.932	2.978	1.353	
56	5/26/2005	3.175	3.055	3.131	3.052		3.005	3.033		3.159		3.154		3.021	3.079	3.172	3.228	1.473	
57	12/22/2006	2.712	2.801																
58	1/10/2007	2.426	2.432																
59	1/18/2007	2.118	2.130																
60	2/9/2007	1.929	1.935																
61	3/7/2007	1.012	1.006																
62	4/13/2007	0.850	0.847																
63	4/29/2007	0.995	1.050																

Appendix F

Water Levels at Irrigation Wells in the Study Area

Water Levels at Irrigation Wells in the Study Area

Bangladesh	IR-1	IR-2	IR-3	IR-4	IR-6	IR-7	IR-8	IR-11	IR-12	IR-14	IR-16	IR-17	IR-18	IR-19	IR-20	IR-22	IR-23
Date	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)	WL (m)
12/20/2002	3.233	3.219	3.25	3.346	3.185	3.197	3.177	2.621	3.139	2.558	2.556	3.079	3.156	3.119	3.145	2.749	3.318
12/25/2002																	
12/29/2002																2.449	3.058
1/2/2003	2.998	2.954	2.86	2.966			2.797	2.226	2.804	2.228	2.251						
1/5/2003					2.94	2.942						2.819	2.881	2.854	2.88		
1/7/2003																	
12/14/2003														3.269	3.305	2.869	
12/20/2003	3.378	4.379	3.415	3.511	3.37	3.362	3.422	2.816	3.314	2.723	2.726	3.239					
12/22/2003																	
12/25/2003	3.298	4.304	2.905	2.891	3.29	3.272	3.282	2.711	3.209	2.628	2.636	3.164		3.209	3.25	2.814	
12/29/2003					3.245							3.119		3.144	3.185	2.774	

Water Levels at Irrigation Wells in the Study Area

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
41																		
42																		
43	Water Levels at Irrigation Wells in the Study Area																	
44																		
45	**Bangladesh**	**IR-24**	**IR-25**	**IR-26**	**IR-27**	**IR-28**	**IR-30**	**IR-31**	**IR-33**	**IR-36**	**IR-37**	**IR-39**	**IR-42**	**IR-45**	**IR-46**	**IR-47**	**IR-48**	**IR-49**
46	**Date**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**
47	12/20/2002	2.674	3.249															
48	12/25/2002			2.906	3.153	2.718	3.008	3.053	2.56									
49	12/29/2002	2.364	2.859							2.4	3.011	2.984	3.01	2.973	3.018	3.159	3.085	3.084
50	1/2/2003																	
51	1/5/2003									2.17	2.696	2.744	2.8					
52	1/7/2003			2.651	2.893	2.463	2.768	2.778	2.31					2.753	2.838	2.939	2.855	2.764
53	12/14/2003	2.804																
54	12/20/2003		3.469															
55	12/22/2003			3.096		2.873	3.148	3.173	2.685	3.21	3.201		3.21		3.248	3.404	3.345	3.374
56	12/25/2003		3.359										3.155					
57	12/29/2003	2.714		2.986		2.778	3.0632	3.083	2.6				3.105					

Appendix G

Flow Rates of Irrigation Wells

Flow Rates of Irrigation Wells (L/s)

IRs	Time required to fill up 100L bucket (sec)				Average (sec)	Flow Rate (L/s)	Date Measured
IR 1	4.53	5.03	4.56	4.72	4.710	21.23	28-Jan-04
IR 3	3.8	3.98	3.49		3.757	26.62	20-Feb-04
IR 4	3.78	3.62	3.92		3.773	26.50	20-Feb-04
IR 5	3.5	3.37	3.09		3.320	30.12	20-Feb-04
IR 6	6.88	6.74	6.88		6.833	14.63	28-Jan-04
IR 6	3.08	3.21	3.27		3.187	31.38	20-Feb-04
IR 7	3.9	3.81	4		3.903	25.62	20-Feb-04
IR 8	8.81	8.43	8.48		8.573	11.66	20-Feb-04
IR 9	6.75	6.38	6.75	6.74	6.655	15.03	28-Jan-04
IR 10	4.47	4.72	4.41	4.29	4.473	22.36	28-Jan-04
IR 11	4.2	4.45	4.3		4.317	23.17	20-Feb-04
IR 12	4	4.25	4.18		4.143	24.14	20-Feb-04
IR 13	4.34	4.35	4.75		4.480	22.32	20-Feb-04
IR 14							
IR 15	3.9	3.81	3.65		3.787	26.41	20-Feb-04
IR 16	4.12	4.25	4.42		4.263	23.46	20-Feb-04
IR 17	3.88	3.65	3.52		3.683	27.15	20-Feb-04
IR 18							
IR 19	3.9	3.81	3.72		3.810	26.25	20-Feb-04
IR 20							
IR 21	4.57	4.48	4.45		4.500	22.22	20-Feb-04
IR 22	4.06	4.15	4.21		4.140	24.15	20-Feb-04
IR 23	3.78	3.9	3.68		3.787	26.41	20-Feb-04
IR 24	3.8	3.9	3.71		3.803	26.29	20-Feb-04
IR 25							
IR 26	3.7	3.62	3.51		3.610	27.70	20-Feb-04
IR 27							
IR 28	3.42	3.38	3.27		3.357	29.79	20-Feb-04
IR 29	3.01	3.19	2.9		3.033	32.97	20-Feb-04
IR 30							
IR 31	3.79	3.59	3.72		3.700	27.03	20-Feb-04
IR 32	4.82	4.63	4.48		4.643	21.54	20-Feb-04
IR 33							
IR 34							
IR 35	3.19	3	2.97		3.053	32.75	20-Feb-04
IR 36	4.72	4.56	4.62		4.633	21.58	20-Feb-04
IR 37	3.56	3.8	3.61		3.657	27.35	20-Feb-04
IR 38	4.79	4.57	4.35		4.570	21.88	20-Feb-04
IR 39	4.85	4.66	4.82		4.777	20.94	20-Feb-04
IR 40							
IR 41	4.59	4.59	4.5		4.560	21.93	20-Feb-04
IR 42	7.22	7.37	7.9		7.497	13.34	20-Feb-04
IR 43							
IR 44	12.19	11.9	12		12.030	8.31	20-Feb-04
IR 45							
IR 46	4.22	4.31	4.11		4.213	23.73	20-Feb-04
IR 47							
IR 48							
IR 49	3.98	3.81	3.77		3.853	25.95	20-Feb-04
IR 50	3.06	3	2.88		2.980	33.56	20-Feb-04
IR 51	3.42	3.37	3.22		3.337	29.97	20-Feb-04
					average flow rate	24.14	

Appendix H

Daily Average Water Levels from Probes at Basailbhog Field Site

Daily Average Water Levels from Probes at Basailbhog Field Site

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1														
2														
3														
4	**USA (EST)**	**C2-17**	**C3-17**	**C4-17**	**H1-100**	**H2-100**	**C0-120**	**C1-120**	**C2-120**	**C3-120**	**C4-120**	**C5-120**	**S1-120**	**C2-230**
5	**Date**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**	**WL (m)**
6	1/31/2006						1.919							
7	2/1/2006						1.685							
8	2/2/2006						1.843							
9	2/3/2006						1.823							
10	2/4/2006						1.797							
11	2/5/2006						1.752							
12	2/6/2006						1.663							
13	2/7/2006						1.678							
14	2/8/2006						1.731							
15	2/9/2006						1.605							
16	2/10/2006						1.655							
17	2/11/2006						1.434							
18	2/12/2006						1.487							
19	2/13/2006						1.528							
20	2/14/2006						1.801							
21	2/15/2006						1.650							
22	2/16/2006						1.504							
23	2/17/2006						1.489							
24	2/18/2006						1.566							
25	2/19/2006						1.638							
26	2/20/2006						1.648							
27	4/12/2006						1.199							
28	4/13/2006						1.108							
29	4/14/2006						0.978							
30	4/15/2006						1.014							
31	4/16/2006						1.189							
32	4/17/2006						1.091							
33	4/18/2006						1.161							
34	4/19/2006					1.149	1.127							
35	4/20/2006					1.073	1.052							
36	4/21/2006					1.045	1.003							
37	4/22/2006					1.048	1.117							
38	4/23/2006					1.107	1.040							
39	4/24/2006					1.070	1.079							
40	4/25/2006					1.049	1.008							
41	4/26/2006					0.987	0.973							

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
42	4/27/2006					0.985	0.985							
43	4/28/2006					1.048	1.097							
44	4/29/2006					1.097	1.087							
45	4/30/2006					1.069	1.066							
46	5/1/2006					1.073	1.033							
47	5/2/2006					1.000	1.010							
48	5/3/2006					0.990	0.993							
49	5/4/2006					0.974	0.989							
50	5/5/2006					0.977	1.013							
51	5/6/2006					1.015	1.051							
52	5/7/2006					1.080	1.107							
53	5/8/2006					1.107	1.174							
54	5/9/2006					1.217	1.207							
55	5/10/2006					1.193	1.181							
56	5/11/2006					1.207	1.289							
57	5/12/2006					1.343	1.593							
58	5/13/2006					1.677	1.710							
59	5/14/2006					1.725	1.778							
60	5/15/2006					1.836	1.845							
61	5/16/2006					1.857	1.834							
62	5/17/2006					1.838	1.814							
63	5/18/2006					1.815	1.783							
64	5/19/2006					1.788	1.757							
65	5/20/2006					1.754	1.721							
66	5/21/2006					1.721	1.715							
67	5/22/2006					1.719	1.718							
68	5/23/2006					1.720	1.725							
69	5/24/2006					1.729	1.726							
70	5/25/2006					1.725	1.766							
71	5/26/2006					1.821	1.948							
72	5/27/2006					2.074	2.293							
73	5/28/2006					2.370	2.423							
74	5/29/2006					2.474	2.542							
75	5/30/2006					2.492	2.332							
76	5/31/2006					2.433	2.442							
77	11/11/2006	3.081	3.246	3.259				3.139	3.136	3.299	3.154	3.163	3.159	3.139
78	11/12/2006	3.047	3.211	3.222				3.103	3.101	3.264	3.119	3.128	3.123	3.104
79	11/13/2006	3.025	3.188	3.208				3.075	3.074	3.236	3.092	3.101	3.095	3.076
80	11/14/2006	3.021	3.186	3.197				3.066	3.065	3.228	3.083	3.092	3.086	3.068
81	11/15/2006	3.004	3.170	3.177				3.045	3.045	3.207	3.062	3.072	3.065	3.047
82	11/16/2006	2.981	3.150	3.155				3.018	3.018	3.181	3.036	3.045	3.039	3.021

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
83	11/17/2006	2.969	3.141	3.144				3.004	3.003	3.166	3.021	3.031	3.025	3.006
84	11/18/2006	2.949	3.118	3.126				2.985	2.983	3.146	3.001	3.010	3.005	2.985
85	11/19/2006	2.926	3.096	3.104				2.963	2.960	3.124	2.978	2.988	2.983	2.963
86	11/20/2006	2.911	3.083	3.089				2.948	2.945	3.109	2.963	2.973	2.969	2.948
87	11/21/2006	2.893	3.066	3.070				2.932	2.928	3.093	2.946	2.956	2.953	2.931
88	11/22/2006	2.879	3.054	3.056				2.921	2.915	3.081	2.934	2.943	2.941	2.918
89	11/23/2006	2.867	3.043	3.043				2.911	2.904	3.070	2.923	2.931	2.931	2.907
90	11/24/2006	2.864	3.040	2.915				2.906	2.899	3.065	2.916	2.852	2.926	2.901
91	11/25/2006	2.853	3.032	2.891				2.894	2.887	3.053	2.906	2.842	2.914	2.890
92	11/26/2006	2.843	3.026	2.878				2.881	2.874	3.041	2.894	2.829	2.902	2.877
93	11/27/2006	2.852	3.041	2.884				2.885	2.878	3.045	2.898	2.833	2.906	2.881
94	11/28/2006	2.845	3.039	2.875				2.878	2.871	3.038	2.890	2.826	2.899	2.874
95	11/29/2006	2.839	3.038	2.868				2.868	2.861	3.029	2.880	2.816	2.889	2.864
96	11/30/2006	2.824	3.031	2.856				2.783	2.779	3.014	2.865	2.800	2.882	2.799
97	12/1/2006	2.811	3.016	2.841				2.751	2.766	2.996	2.848	2.783	2.866	2.783
98	12/2/2006	2.804	3.010	2.833				2.744	2.758	2.989	2.841	2.776	2.859	2.775
99	12/3/2006	2.805	3.015	2.834				2.744	2.756	2.988	2.839	2.774	2.857	2.773
100	12/4/2006	2.795	3.006	2.824				2.731	2.743	2.975	2.826	2.761	2.844	2.760
101	12/5/2006	2.789	3.003	2.819				2.725	2.737	2.969	2.819	2.755	2.839	2.754
102	12/6/2006	2.778	2.994	2.808				2.709	2.724	2.956	2.806	2.742	2.826	2.741
103	12/7/2006	2.764	2.981	2.793				2.753	2.704	2.937	2.786	2.722	2.807	2.720
104	12/8/2006	2.769	3.004	2.814				2.776	2.709	2.957	2.809	2.727	2.812	2.726
105	12/9/2006	2.762							2.698			2.716	2.799	2.714
106	12/10/2006	2.748							2.681			2.699	2.782	2.698
107	12/11/2006	2.723							2.652			2.670	2.753	2.669
108	12/12/2006	2.719							2.643			2.661	2.744	2.660
109	12/13/2006	2.747							2.570			2.552	2.712	2.626
110	12/14/2006	2.742							2.518			2.496	2.666	2.578
111	12/15/2006	2.755							2.511			2.489	2.654	2.573
112	12/16/2006	2.765							2.462			2.432	2.618	2.533
113	12/17/2006	2.734							2.403			2.375	2.562	2.474
114	12/18/2006	2.754							2.436			2.413	2.576	2.496
115	12/19/2006	2.755							2.391			2.370	2.556	2.458
116	12/20/2006	2.769							2.365			2.338	2.526	2.437
117	12/21/2006	2.755							2.344			2.358	2.485	2.372
118	12/22/2006	2.750							2.316			2.264	2.464	2.365
119	12/23/2006	2.730							2.252			2.224	2.387	2.263
120	12/24/2006	2.685	2.842	2.833				2.270	2.093	2.198	1.921	2.029	2.283	2.154
121	12/25/2006	2.659	2.755	2.758				2.162	2.088	2.147	2.088	2.064	2.236	2.102
122	12/26/2006	2.658	2.745	2.760				2.155	2.081	2.142	2.075	2.043	2.231	2.108
123	12/27/2006	2.651	2.744	2.753				2.148	2.078	2.133	2.076	2.050	2.221	2.093

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
124	12/28/2006	2.672	2.772	2.769				2.176	2.128	2.170	2.130	2.111	2.251	2.132
125	12/29/2006	2.661	2.766	2.750				2.159	2.119	2.149	2.127	2.116	2.229	2.104
126	12/30/2006	2.649	2.752	2.730				2.122	2.122	2.130	2.125	2.109	2.197	2.114
127	12/31/2006	2.621	2.734	2.701				2.085	2.057	2.080	2.055	2.031	2.156	2.066
128	1/1/2007	2.673	2.791	2.720				2.316	2.321	2.332	2.324	2.316	2.394	2.305
129	1/2/2007	2.629	2.746	2.711				2.135	2.049	2.109	2.040	1.997	2.206	2.097
130	1/3/2007	2.615	2.717	2.691				2.070	1.990	2.064	1.968	1.911	2.151	2.058
131	1/4/2007	2.621	2.712	2.708				2.091	2.044	2.086	2.043	2.020	2.167	2.056
132	1/5/2007	2.641	2.727	2.718				2.122	2.102	2.121	2.104	2.087	2.195	2.100
133	1/6/2007	2.618	2.720	2.701				2.061	2.015	2.066	2.002	1.957	2.144	2.066
134	1/7/2007	2.617	2.734	2.695				2.104	2.062	2.096	2.065	2.048	2.176	2.059
135	1/8/2007	2.604	2.726	2.681				2.085	2.027	2.056	2.019	1.983	2.157	2.060
136	1/9/2007	2.590	2.705	2.663				2.030	2.048	2.044	2.054	2.045	2.114	2.031
137	1/10/2007				2.676		2.053	2.106		2.104			2.108	
138	1/11/2007				2.664		1.941	2.019		2.037			2.033	
139	1/12/2007				2.657		1.969	2.013		2.023			2.020	
140	1/13/2007				2.645		1.935	1.962		1.966			1.961	
141	1/14/2007				2.639		1.843	1.912		1.929			1.924	
142	1/15/2007				2.621		1.753	1.806		1.836			1.824	
143	1/16/2007				2.620		1.657	1.798		1.807			1.812	
144	1/17/2007				2.622		1.686	1.769		1.784			1.781	
145	1/18/2007				2.603		1.595	1.720	1.690	1.731			1.735	
146	1/19/2007				2.584		1.780	1.765	1.805	1.812			1.790	
147	1/20/2007				2.575		1.728	1.694	1.729	1.731			1.714	
148	1/21/2007				2.571		1.558	1.643	1.615	1.654			1.658	
149	1/22/2007				2.575		1.311	1.449	1.418	1.479			1.477	
150	1/23/2007				2.571		1.560	1.621	1.602	1.630			1.635	
151	1/24/2007				2.548		1.432	1.561	1.514	1.566			1.577	
152	1/25/2007				2.529		1.402	1.459	1.441	1.477			1.476	
153	1/26/2007				2.523		1.358	1.493	1.449	1.500			1.511	
154	1/27/2007				2.524		1.433	1.494	1.473	1.500			1.507	
155	1/28/2007				2.512		1.398	1.492	1.482	1.515			1.513	
156	1/29/2007				2.497		1.384	1.518	1.473	1.520			1.530	
157	1/30/2007				2.489		1.339	1.372	1.388	1.410			1.397	
158	1/31/2007				2.479		1.455	1.382	1.472	1.462			1.418	
159	2/1/2007				2.481		1.420	1.484	1.499	1.518			1.508	
160	2/2/2007				2.479		1.528	1.611	1.598	1.618			1.623	
161	2/3/2007				2.450		1.469	1.548	1.524	1.560			1.568	
162	2/4/2007				2.410		1.343	1.453	1.426	1.460			1.470	
163	2/5/2007				2.414		1.501	1.593	1.570	1.588			1.599	
164	2/6/2007				2.418		1.646	1.586	1.654	1.630			1.606	

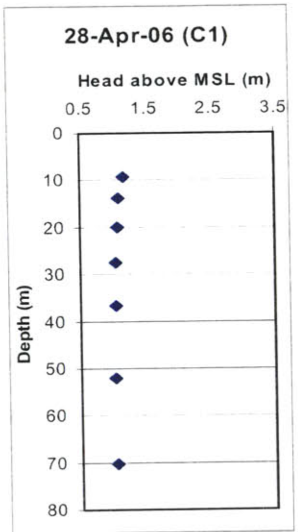
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
165	2/7/2007				2.423		1.598	1.607	1.631	1.629			1.621	
166	2/8/2007				2.440		1.938	1.897	1.944	1.920			1.909	
167	2/9/2007				2.436		2.000	2.008	2.038	2.019			2.016	
168	2/10/2007				2.415		1.567	1.691	1.674	1.712			1.713	
169	2/11/2007				2.400		1.380	1.514	1.481	1.525			1.534	
170	2/12/2007				2.378		1.401	1.503	1.458	1.501			1.513	
171	2/13/2007				2.370		1.774	1.713	1.779	1.751			1.729	
172	2/14/2007				2.365		2.124	2.075	2.134	2.100			2.086	
173	2/15/2007				2.372		2.001	1.966	2.009	1.990			1.980	
174	2/16/2007				2.361		1.806	1.846	1.849	1.854			1.856	
175	2/17/2007				2.369		1.591	1.642	1.661	1.662			1.657	
176	2/18/2007				2.366		1.460	1.583	1.561	1.592			1.600	
177	2/19/2007				2.355		1.404	1.524	1.508	1.538			1.543	
178	2/20/2007				2.343		1.607	1.642	1.642	1.650			1.653	
179	2/21/2007				2.320		1.239	1.347	1.315	1.350			1.359	
180	2/22/2007				2.290		1.291	1.318	1.336	1.348			1.337	
181	2/23/2007				2.284		1.432	1.468	1.464	1.466			1.474	
182	2/24/2007				2.272		1.285	1.358	1.358	1.382			1.379	
183	2/25/2007				2.260		1.302	1.381	1.368	1.388			1.392	
184	2/26/2007				2.259		1.437	1.408	1.452	1.440			1.426	
185	2/27/2007				2.263		1.393	1.412	1.416	1.423			1.423	
186	2/28/2007				2.242		1.215	1.330	1.312	1.338			1.344	
187	3/1/2007				2.232		1.084	1.259	1.222	1.263			1.274	
188	3/2/2007				2.233		1.412	1.500	1.469	1.488			1.505	
189	3/3/2007				2.237		1.326	1.359	1.377	1.373			1.370	
190	3/4/2007				2.222		1.233	1.264	1.280	1.268			1.269	
191	3/5/2007				2.207		1.065	1.106	1.114	1.130			1.121	
192	3/6/2007				2.177		0.968	1.028	1.055	1.054			1.045	
193	3/7/2007				2.151		0.936	1.033	1.022	1.023			1.041	
194	3/8/2007				2.152		0.805	0.971	0.915	0.944			0.978	
195	3/9/2007							1.039	0.974	1.025			1.059	
196	3/10/2007							0.997	0.959	0.995			1.016	
197	3/11/2007							0.981	0.970	0.991			1.004	
198	3/12/2007							0.982	0.974	0.993			1.006	
199	3/13/2007							0.933	0.826	0.902			0.950	
200	3/14/2007							0.816	0.802	0.831			0.839	
201	3/15/2007							0.810	0.904	0.855			0.861	
202	3/16/2007							0.841	0.837	0.836			0.810	
203	3/17/2007							0.807	0.662	0.743			0.779	
204	3/18/2007							0.677	0.609	0.657			0.652	
205	3/19/2007							0.605	0.497	0.560			0.561	

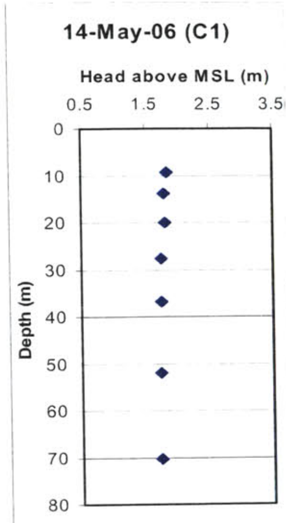
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
206	3/20/2007							0.645	0.596	0.641			0.623	
207	3/21/2007							0.820	0.701	0.759			0.784	
208	3/22/2007							0.904	0.790	0.857			0.874	
209	3/23/2007							1.279	1.193	1.221			1.241	
210	3/24/2007							1.198	1.113	1.142			1.163	
211	3/25/2007							1.051	0.945	0.980			1.010	
212	3/26/2007							0.895	0.805	0.836			0.858	
213	3/27/2007							0.688	0.620	0.664			0.667	
214	3/28/2007							0.656	0.566	0.622			0.633	
215	3/29/2007							0.627	0.543	0.592			0.600	
216	3/30/2007							0.727	0.642	0.686			0.699	
217	3/31/2007							0.746	0.747	0.747			0.726	
218	4/1/2007							0.721	0.619	0.670			0.689	
219	4/2/2007							0.653	0.595	0.634			0.631	
220	4/3/2007							0.703	0.595	0.649			0.673	
221	4/4/2007							0.626	0.580	0.588			0.595	
222	4/5/2007							0.627	0.483	0.555			0.593	
223	4/6/2007							0.643	0.531	0.570			0.601	
224	4/7/2007							0.637	0.601	0.598			0.603	
225	4/8/2007							0.552	0.434	0.480			0.512	
226	4/9/2007							0.556	0.513	0.536			0.538	
227	4/10/2007							0.517	0.505	0.500			0.494	
228	4/11/2007							0.563	0.424	0.488			0.523	
229	4/12/2007							0.642	0.653	0.647			0.629	
230	4/13/2007							0.565	0.456	0.525			0.538	
231	4/14/2007							0.584	0.474	0.531			0.547	
232	4/15/2007							0.666	0.489	0.561			0.617	
233	4/16/2007							0.678	0.589	0.614			0.632	
234	4/17/2007							0.512	0.520	0.515			0.491	
235	4/18/2007							0.525	0.465	0.499			0.501	
236	4/19/2007							0.590	0.541	0.581			0.573	
237	4/20/2007							0.514	0.397	0.455			0.477	
238	4/21/2007							0.536	0.440	0.476			0.494	
239	4/22/2007							0.608	0.531	0.559			0.571	
240	4/23/2007							0.698	0.576	0.632			0.662	
241	4/24/2007							0.708	0.549	0.637			0.674	
242	4/25/2007							1.124	1.023	1.057			1.084	
243	4/26/2007							0.994	0.932	0.952			0.959	
244	4/27/2007							1.099	1.042	1.065			1.071	
245	4/28/2007							1.051	0.941	0.992			1.017	
246	4/29/2007							0.970	0.897	0.922			0.931	

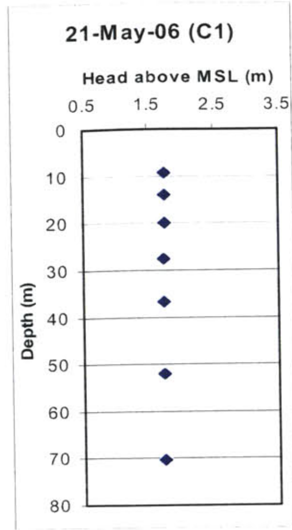
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
247	4/30/2007							0.897	0.840	0.870			0.870	
248	5/1/2007							0.888	0.790	0.832			0.850	
249	5/2/2007							0.749	0.717	0.730			0.724	
250	5/3/2007							0.834	0.763	0.789			0.799	
251	5/4/2007							0.903	0.825	0.846			0.862	
252	5/5/2007							0.922	0.850	0.873			0.885	
253	5/6/2007							0.933	0.874	0.883			0.897	
254	5/7/2007							0.899	0.806	0.835			0.865	
255	5/8/2007							0.935	0.885	0.870				
256	5/9/2007							0.988	0.977	0.967				
257	5/10/2007							1.049	1.015	1.005				
258	5/11/2007							0.942	0.965	0.947				
259	5/12/2007							1.056	1.027	1.013				
260	5/13/2007							1.092	1.068	1.050				
261	5/14/2007							1.071	1.050	1.027				
262	5/15/2007							1.130	1.103	1.087				
263	5/16/2007							1.184	1.158	1.135				
264	5/17/2007							1.213	1.190	1.165				
265	5/18/2007							1.233	1.209	1.183				
266	5/19/2007							1.425	1.389	1.365				
267	5/20/2007							1.475	1.437	1.411				
268	5/21/2007							1.577	1.536	1.516				
269	5/22/2007							1.743	1.705	1.677				
270	5/23/2007							1.743	1.709	1.677				
271	5/24/2007							1.814	1.774	1.751				
272	5/25/2007							2.008	1.966	1.940				
273	5/26/2007							2.014	1.974	1.945				
274	5/27/2007							1.974	1.937	1.908				
275	5/28/2007							1.933	1.897	1.869				
276	5/29/2007							1.897	1.866	1.836				
277	5/30/2007							1.866	1.838	1.807				
278	5/31/2007							1.823	1.797	1.767				
279	6/1/2007							1.787	1.763	1.732				
280	6/2/2007							1.770	1.746	1.716				
281	6/3/2007							1.786	1.760	1.732				
282	6/4/2007							1.899	1.865	1.842				
283	6/5/2007							1.966	1.925	1.905				
284	6/6/2007							2.129	2.085	2.068				
285	6/7/2007							2.215	2.165	2.148				
286	6/8/2007							2.379	2.338	2.323				
287	6/9/2007							2.480	2.443	2.427				

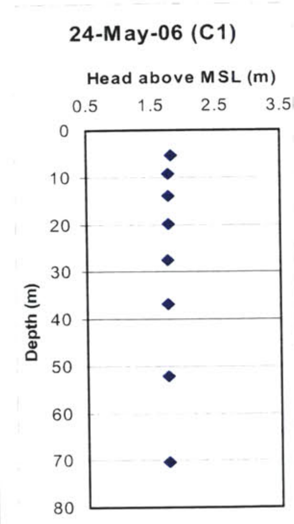
Appendix I

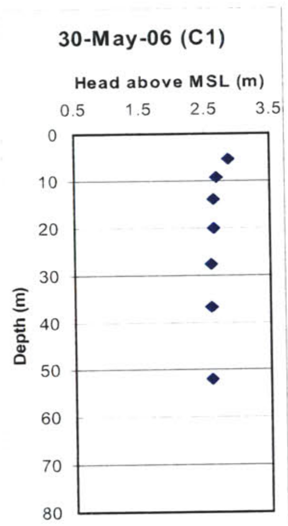
Piezometric Dipping Data at Basailbhog Field Site

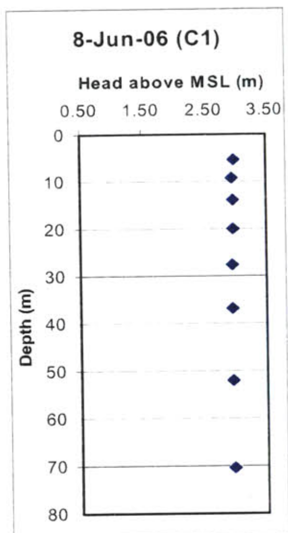

28-Apr-06 (C1)
Head above MSL (m)
Depth (m)

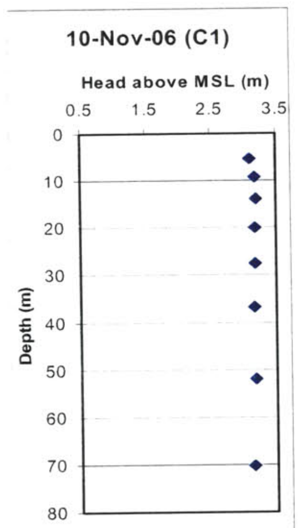

14-May-06 (C1)
Head above MSL (m)
Depth (m)

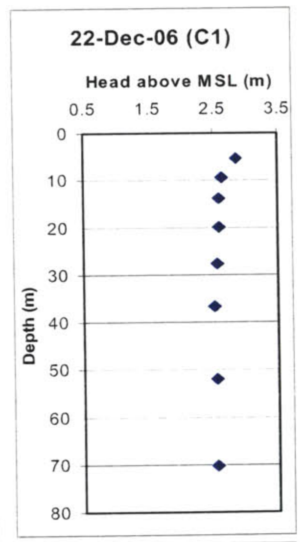

21-May-06 (C1)
Head above MSL (m)
Depth (m)

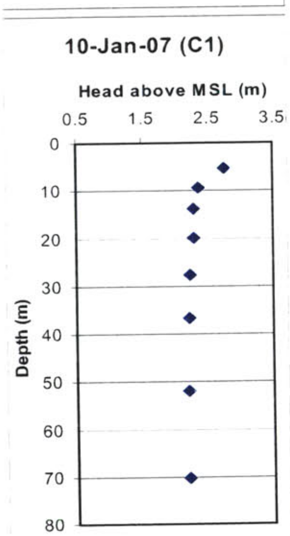

24-May-06 (C1)
Head above MSL (m)
Depth (m)

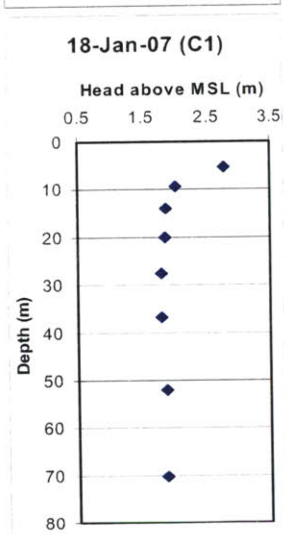

30-May-06 (C1)
Head above MSL (m)
Depth (m)

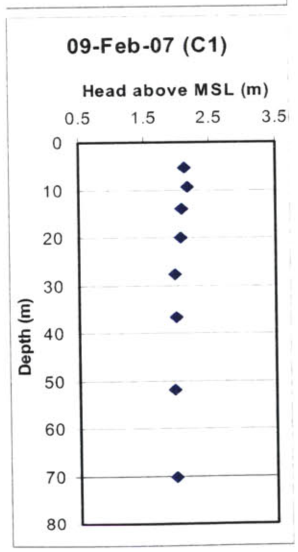

8-Jun-06 (C1)
Head above MSL (m)
Depth (m)

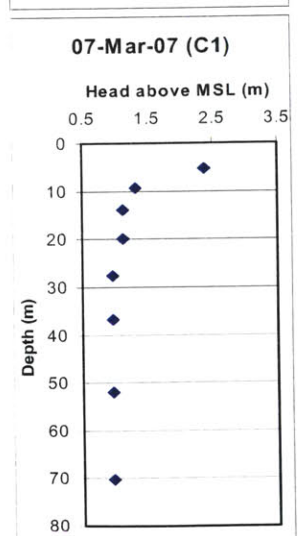

10-Nov-06 (C1)
Head above MSL (m)
Depth (m)

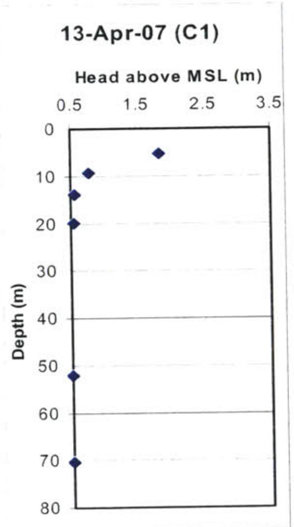

22-Dec-06 (C1)
Head above MSL (m)
Depth (m)

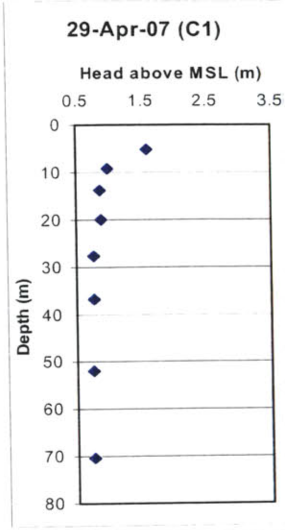

10-Jan-07 (C1)
Head above MSL (m)
Depth (m)

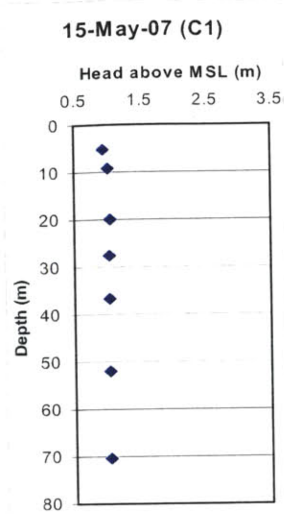

18-Jan-07 (C1)
Head above MSL (m)
Depth (m)

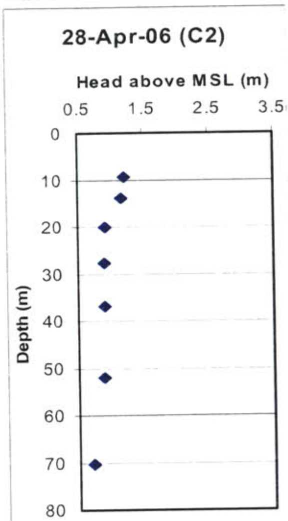

09-Feb-07 (C1)
Head above MSL (m)
Depth (m)

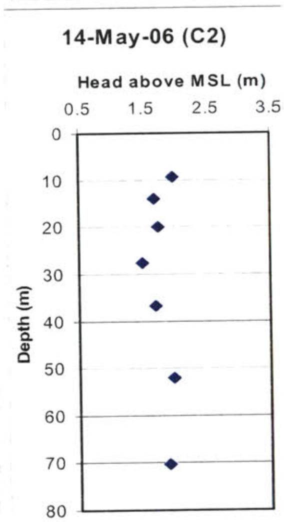

07-Mar-07 (C1)
Head above MSL (m)
Depth (m)

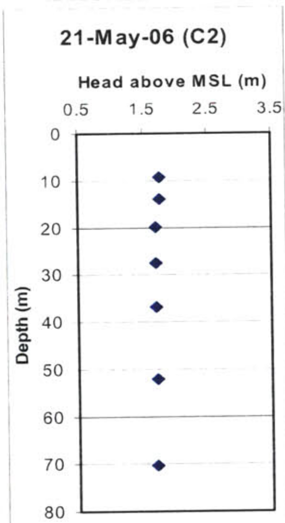

13-Apr-07 (C1)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

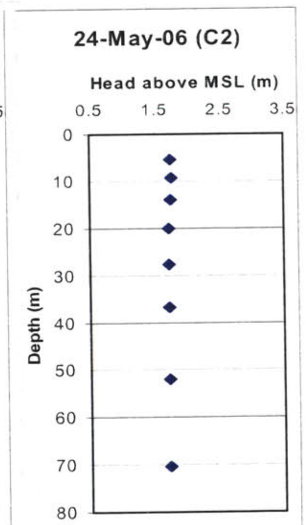

29-Apr-07 (C1)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

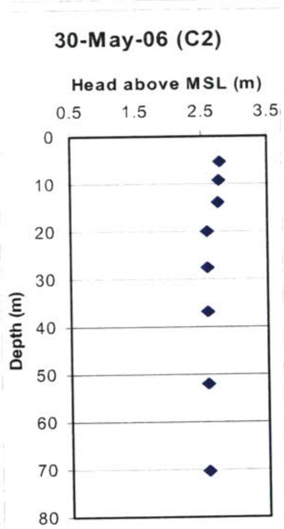

15-May-07 (C1)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

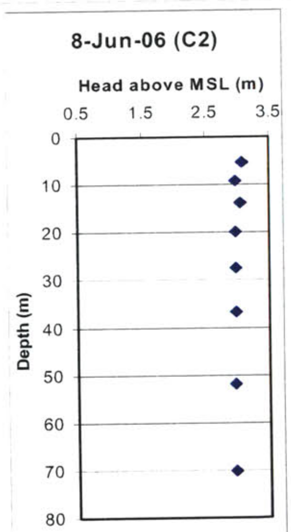

28-Apr-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

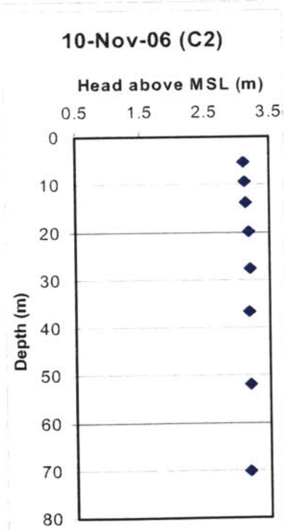

14-May-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

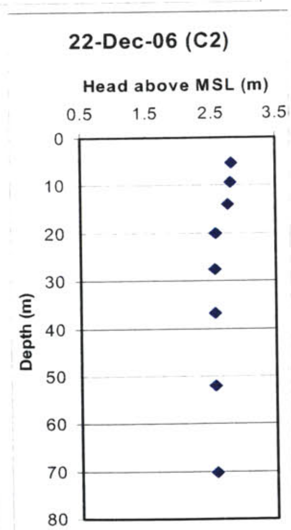

21-May-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

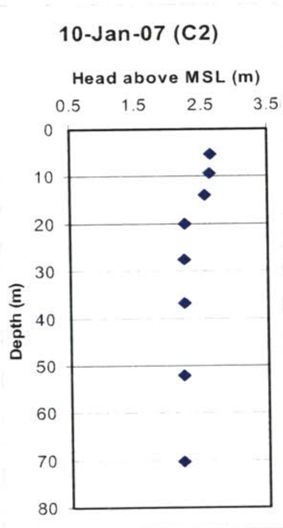

24-May-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

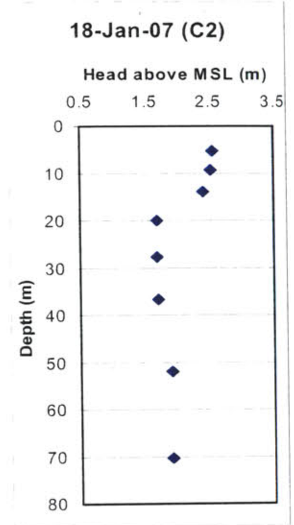

30-May-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

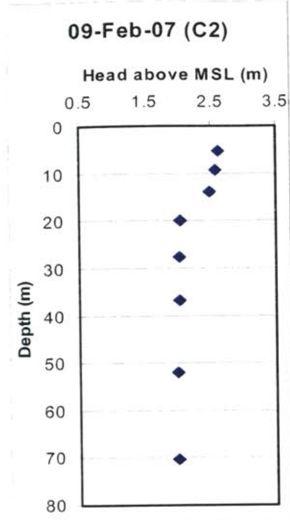

8-Jun-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

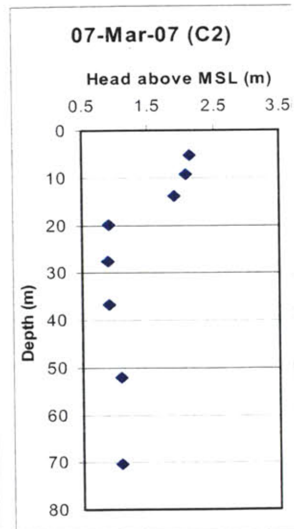

10-Nov-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

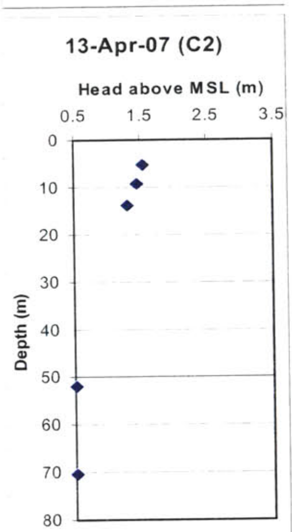

22-Dec-06 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

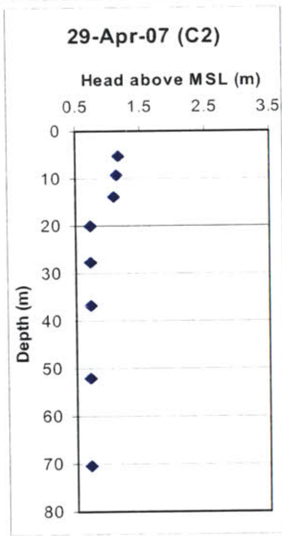

10-Jan-07 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

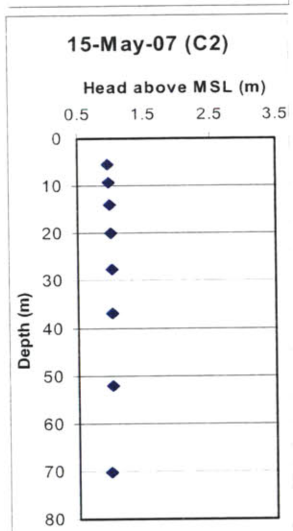

18-Jan-07 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80

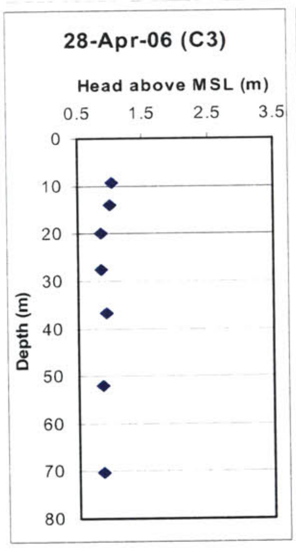

09-Feb-07 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


07-Mar-07 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


13-Apr-07 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


29-Apr-07 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


15-May-07 (C2)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


28-Apr-06 (C3)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
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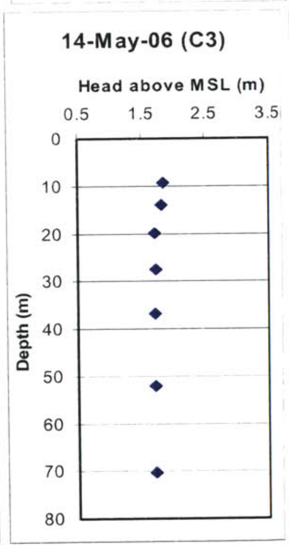
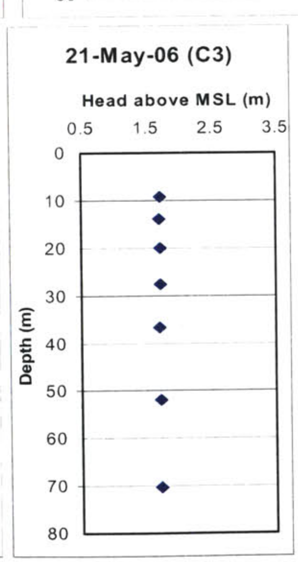
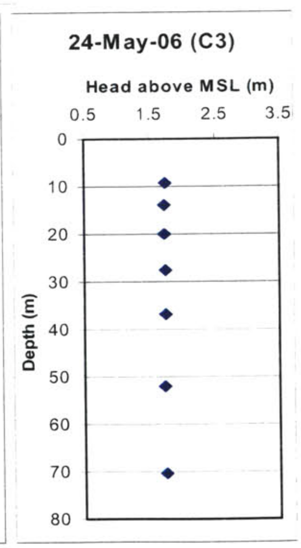
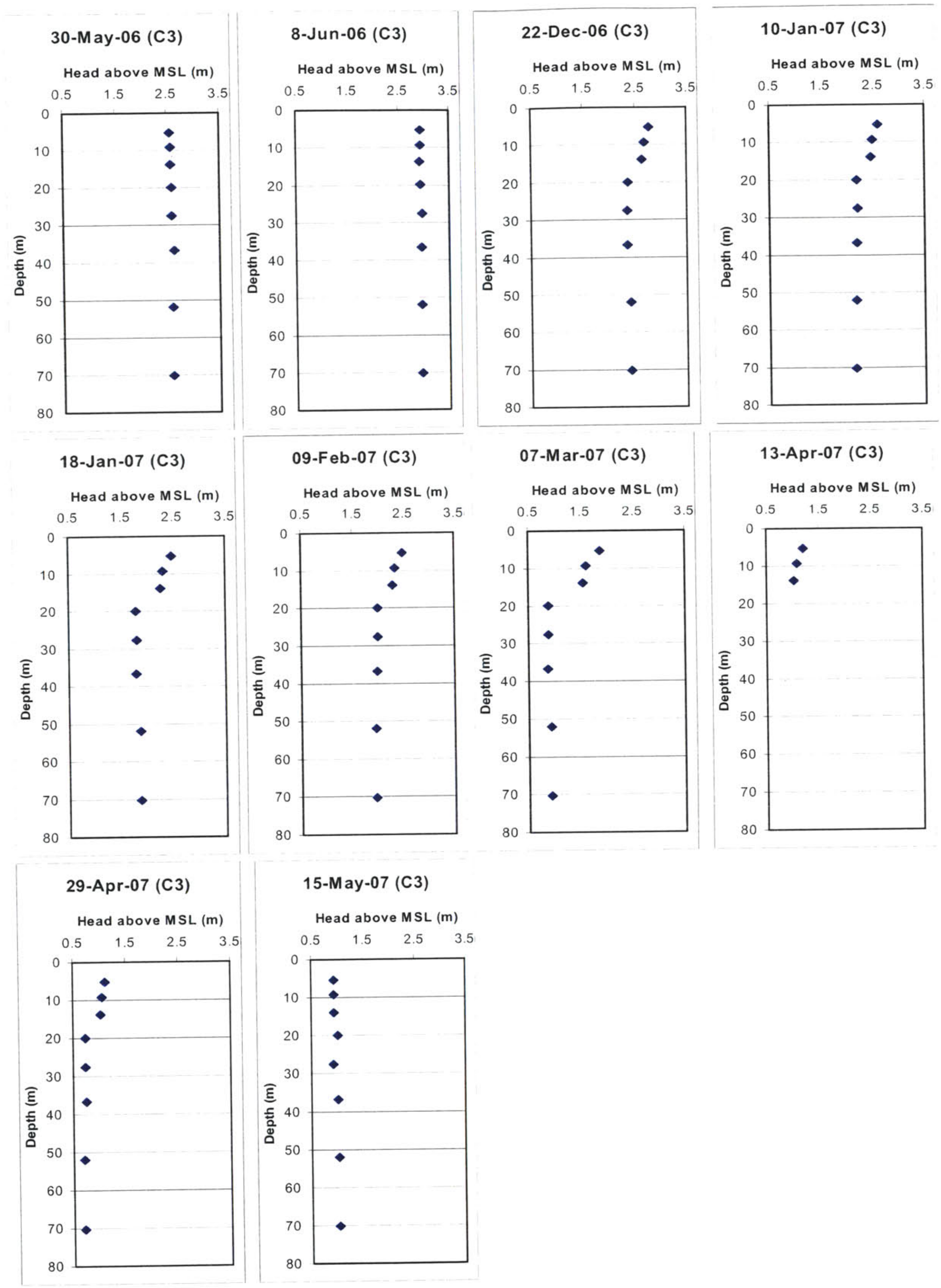
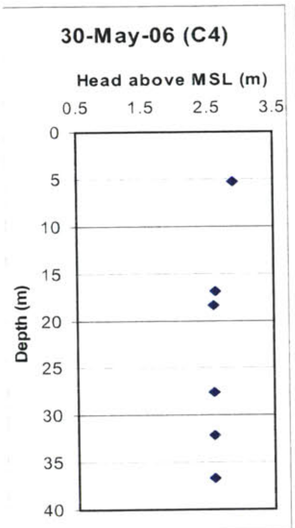

14-May-06 (C3)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


21-May-06 (C3)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


24-May-06 (C3)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


30-May-06 (C3)
8-Jun-06 (C3)
22-Dec-06 (C3)
10-Jan-07 (C3)
18-Jan-07 (C3)
09-Feb-07 (C3)
07-Mar-07 (C3)
13-Apr-07 (C3)
29-Apr-07 (C3)
15-May-07 (C3)
Head above MSL (m)
0.5
1.5
2.5
3.5
Depth (m)
0
10
20
30
40
50
60
70
80


30-May-06 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
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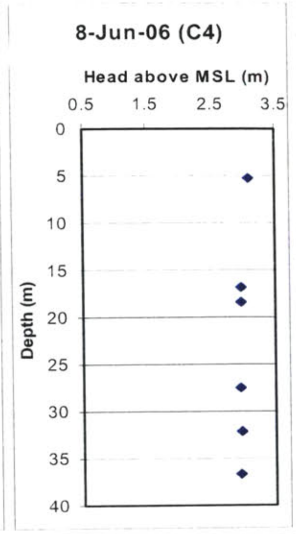
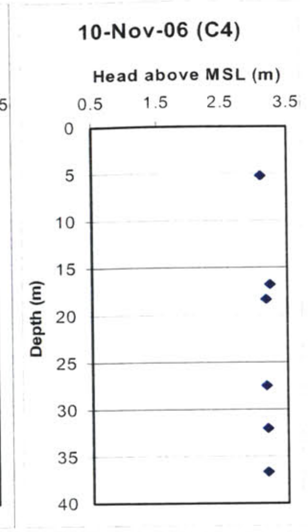
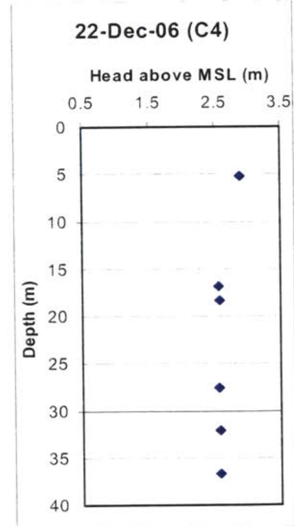
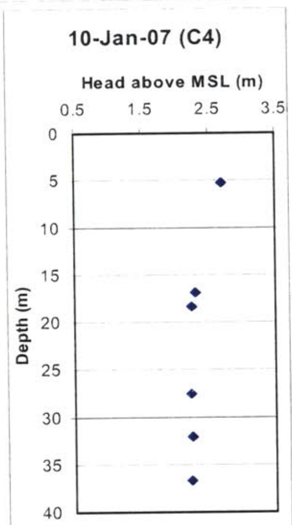
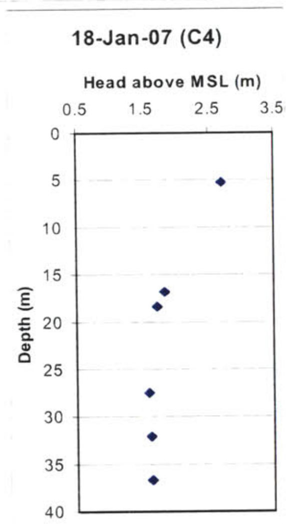
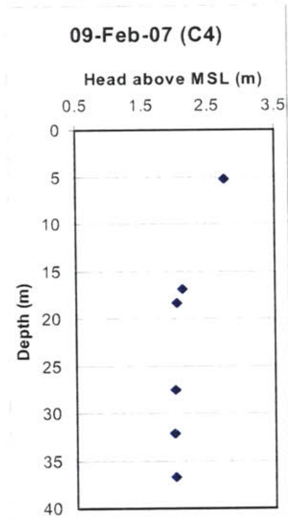
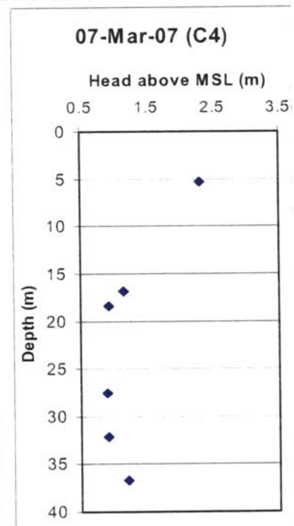
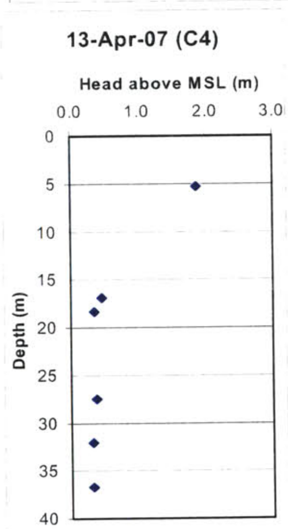
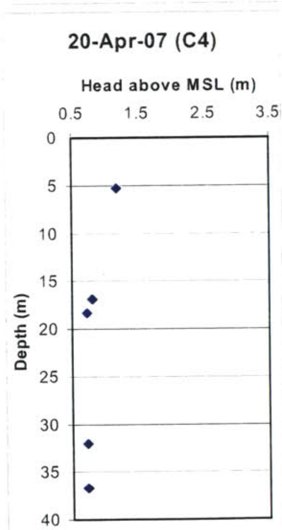
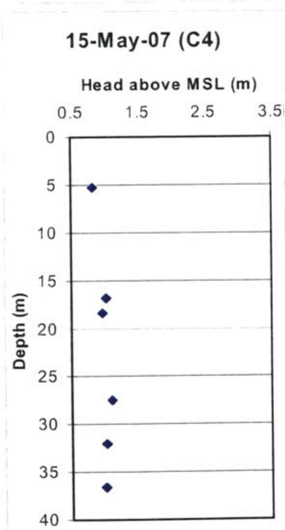
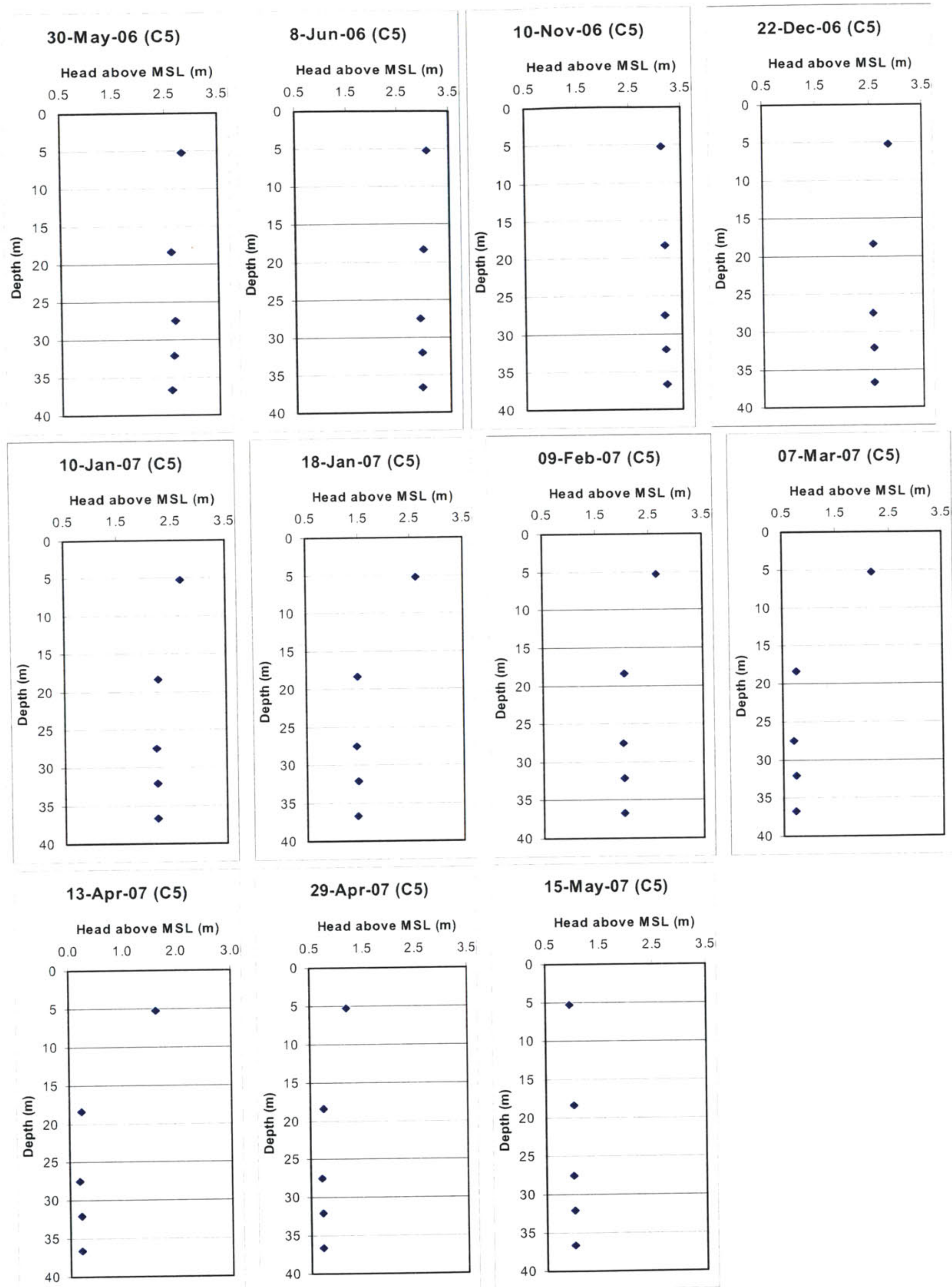
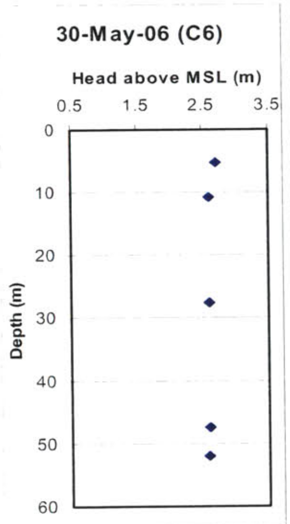
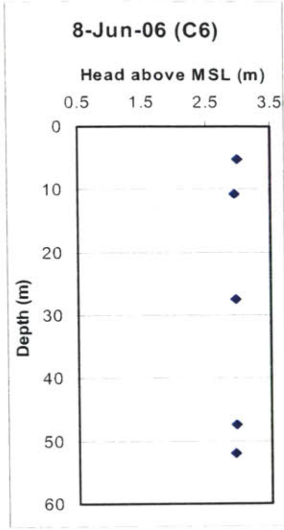
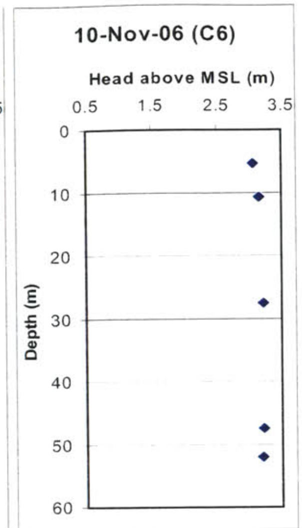
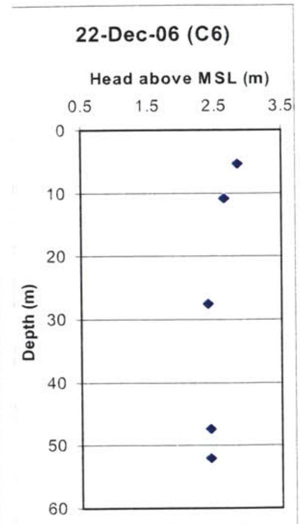

8-Jun-06 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

10-Nov-06 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

22-Dec-06 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

10-Jan-07 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

18-Jan-07 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

09-Feb-07 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

07-Mar-07 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

13-Apr-07 (C4)
Head above MSL (m)
0.0 1.0 2.0 3.0
Depth (m)
0 5 10 15 20 25 30 35 40

20-Apr-07 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

15-May-07 (C4)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 5 10 15 20 25 30 35 40

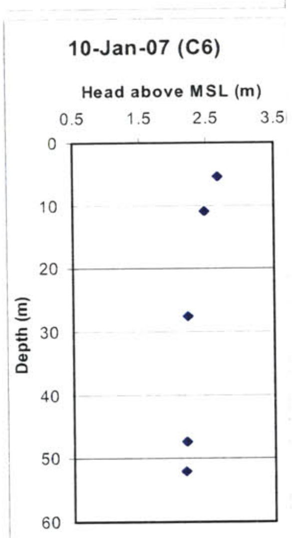

30-May-06 (C5)
8-Jun-06 (C5)
10-Nov-06 (C5)
22-Dec-06 (C5)
10-Jan-07 (C5)
18-Jan-07 (C5)
09-Feb-07 (C5)
07-Mar-07 (C5)
13-Apr-07 (C5)
29-Apr-07 (C5)
15-May-07 (C5)
Head above MSL (m)
Depth (m)
0.5
1.5
2.5
3.5
0.0
1.0
2.0
3.0
0
5
10
15
20
25
30
35
40

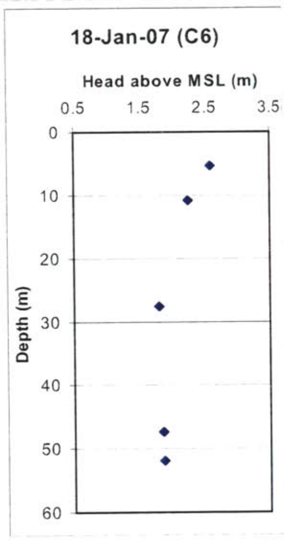

30-May-06 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60

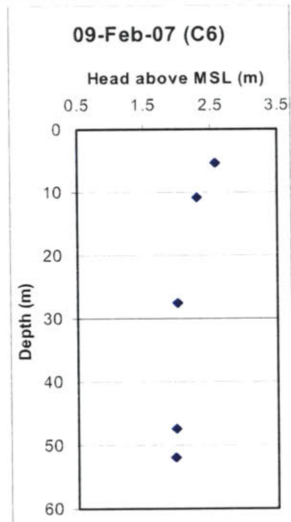

8-Jun-06 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60

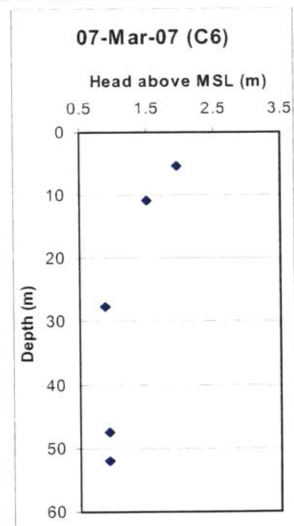

10-Nov-06 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60

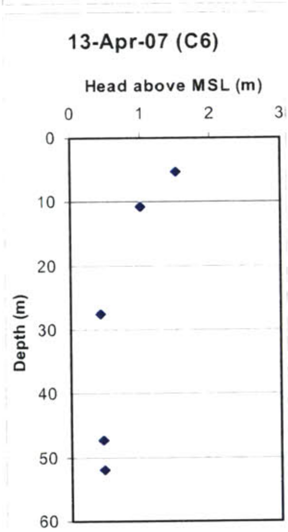

22-Dec-06 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60

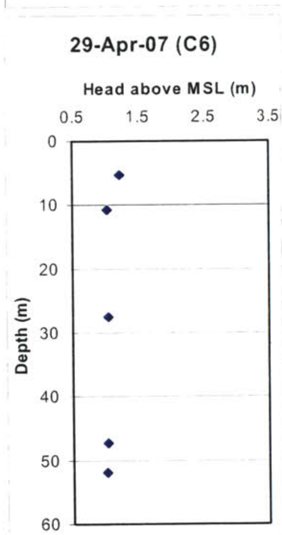

10-Jan-07 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60

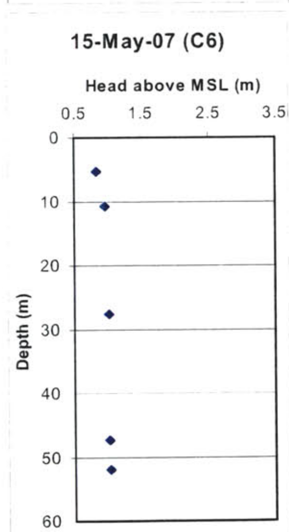

18-Jan-07 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60

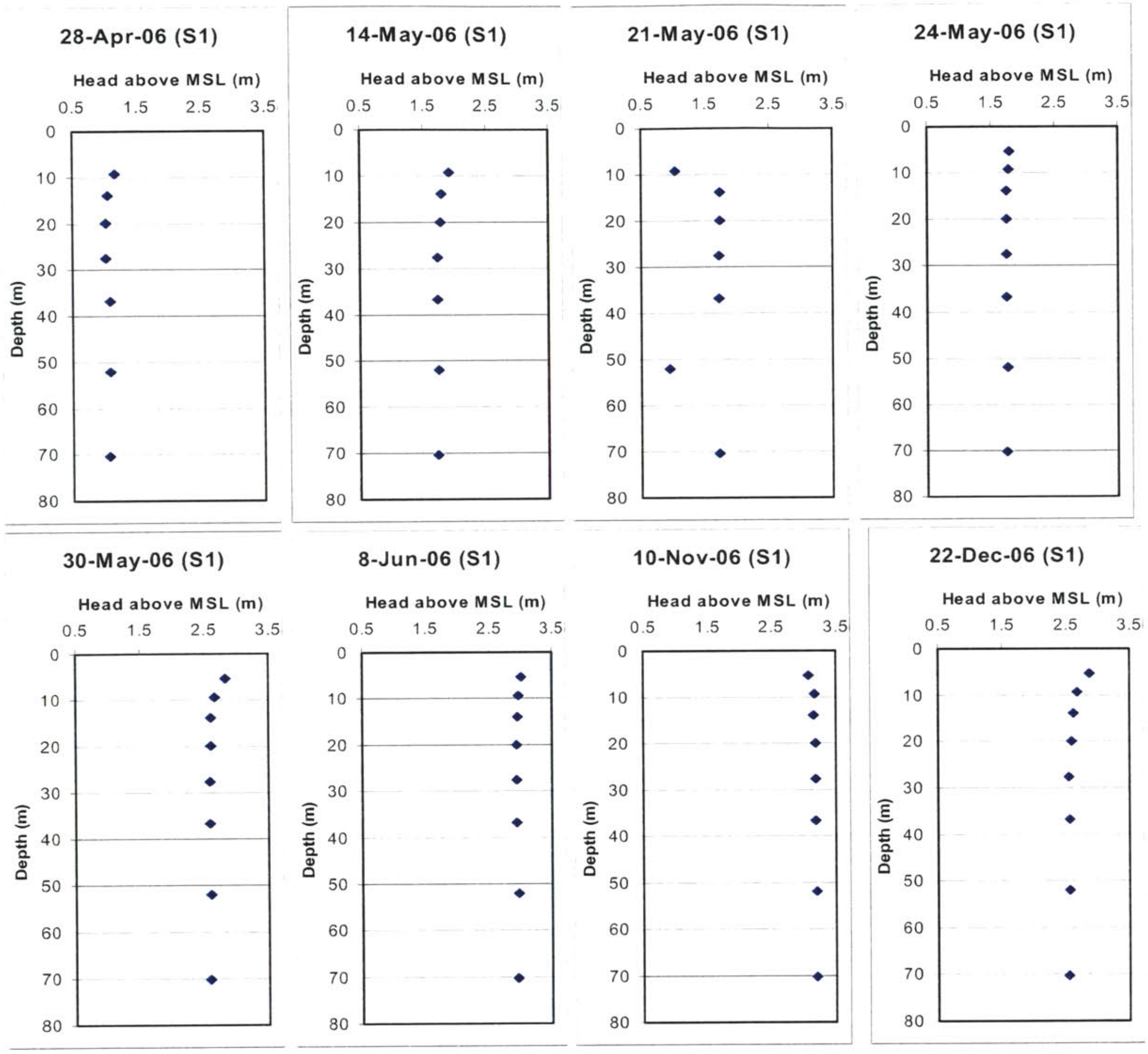

09-Feb-07 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60

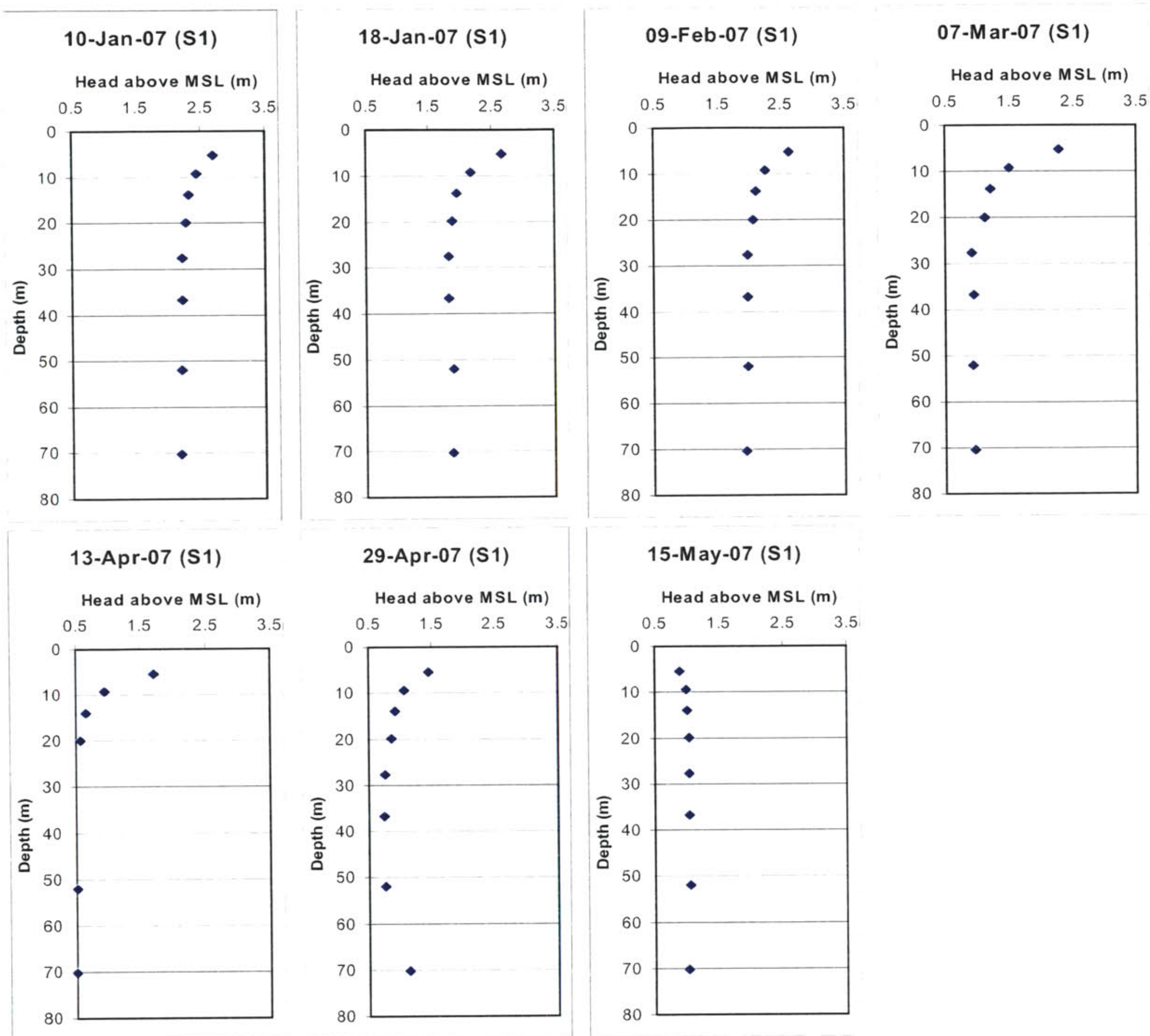

07-Mar-07 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60


13-Apr-07 (C6)
Head above MSL (m)
0 1 2 3
Depth (m)
0 10 20 30 40 50 60


29-Apr-07 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60


15-May-07 (C6)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60


28-Apr-06 (S1)
14-May-06 (S1)
21-May-06 (S1)
24-May-06 (S1)
30-May-06 (S1)
8-Jun-06 (S1)
10-Nov-06 (S1)
22-Dec-06 (S1)
Head above MSL (m)
0.5 1.5 2.5 3.5
Depth (m)
0 10 20 30 40 50 60 70 80


10-Jan-07 (S1)
18-Jan-07 (S1)
09-Feb-07 (S1)
07-Mar-07 (S1)
13-Apr-07 (S1)
29-Apr-07 (S1)
15-May-07 (S1)
Head above MSL (m)
Depth (m)
0.5 1.5 2.5 3.5
0 10 20 30 40 50 60 70 80

Appendix J

Rainfall Data

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Day**	**Jun. 2001**	**Jul. 2001**	**Aug. 2001**	**Sep. 2001**	**Oct. 2001**	**Nov. 2001**	**Dec. 2001**	**Jan. 2002**	**Feb. 2002**	**Mar. 2002**	**Apr. 2002**	**May. 2002**
2	**1**	6.5		12.4								3.0	
3	**2**	4.7				7.7							
4	**3**		8.0			8.5					2.4	34.5	
5	**4**	18.4				13.6						2.0	15.7
6	**5**	12.5		31.4		4.0							12.5
7	**6**	85.0				1.7						1.7	
8	**7**	77.6				2.5							19.7
9	**8**	32.7					2.4						4.2
10	**9**			12.5								29.0	
11	**10**		12.4										18.4
12	**11**		7.3				4.5						2.5
13	**12**		16.2				14.7					11.4	7.7
14	**13**		18.5				0.5						
15	**14**	62.5	20.7										
16	**15**	16.0		10.7									2.0
17	**16**	13.4	26.0	1.4							1.5		
18	**17**	84.7	13.0										
19	**18**	28.0				6.0							
20	**19**	10.8	5.5			20.0							
21	**20**	41.0	21.3	9.7									
22	**21**	7.5	27.5	7.5									
23	**22**		13.5										
24	**23**		20.0						4.0				20.7
25	**24**		8.5						6.0				2.0
26	**25**		17.0	4.0									19.5
27	**26**		2.0	13.5									44.4
28	**27**	14.4	3.5	21.7								40.0	7.6
29	**28**		5.7			9.5					28.5		
30	**29**		5.5						16.0				23.5
31	**30**	23.5	44.3						2.0		9.7	5.0	
32	**31**		10.4	40.5		18.0					5.4		
33													
34	**Total (mm)**	**539.2**	**306.8**	**165.3**	**0.0**	**91.5**	**22.1**	**0.0**	**28.0**	**0.0**	**47.5**	**126.6**	**200.4**
35	**Avg (mm)**	**18.0**	**9.9**	**5.3**	**0.0**	**3.0**	**0.7**	**0.0**	**0.9**	**0.0**	**1.5**	**4.2**	**6.5**
36													

	A	B	C	D	E	F	G	H	I	J	K	L	M
37	**Day**	**Jun. 2002**	**Jul. 2002**	**Aug. 2002**	**Sep. 2002**	**Oct. 2002**	**Nov. 2002**	**Dec. 2002**	**Jan. 2003**	**Feb. 2003**	**Mar. 2003**	**Apr. 2003**	**May. 2003**
38	**1**	60.5	20.5	15.0								17.5	1.5
39	**2**		47.0	21.3									
40	**3**	40.4	29.5	40.7	27.5	1.7							5.7
41	**4**		41.5	16.5									
42	**5**	46.0	28.0										
43	**6**		3.0	4.5	10.3								
44	**7**												12.5
45	**8**	30.4	11.3										
46	**9**	3.0											38.7
47	**10**	37.5		16.4	15.2	1.5							1.4
48	**11**	2.5	43.4	15.7	34.5								
49	**12**	5.0	2.5	5.4	9.7		42.0						
50	**13**	45.0		2.5			135.0			10.5	10.5		
51	**14**	50.7	30.0	5.5		1.5				14.0			
52	**15**	10.0		31.0		4.5					23.0	27.5	
53	**16**		13.4	16.3	10.5								
54	**17**		12.0		1.5						102.5		
55	**18**			32.5							1.7		
56	**19**			1.7		4.7							
57	**20**			15.5	31.7	8.0					21.3	12.7	
58	**21**		14.7									26.0	7.5
59	**22**	12.5	45.3	2.0	22.7								
60	**23**	52.4	5.4	2.0	2.0							2.5	
61	**24**	1.7		3.5	1.0								
62	**25**			3.0	5.5								
63	**26**	4.5		1.0	7.0								
64	**27**	12.0			5.5								
65	**28**	6.0		68.7	18.2								
66	**29**	26.2		15.0	12.0								
67	**30**	9.5		0.7								4.5	
68	**31**			4.2							7.4		
69													
70	**Total (mm)**	**455.8**	**347.5**	**340.6**	**214.8**	**21.9**	**177.0**	**0.0**	**0.0**	**24.5**	**166.4**	**90.7**	**67.3**
71	**Avg (mm)**	**15.2**	**11.2**	**11.0**	**7.2**	**0.7**	**5.9**	**0.0**	**0.0**	**0.9**	**5.4**	**3.0**	**2.2**
72													

	A	B	C	D	E	F	G	H	I	J	K	L	M
73	**Day**	**Jun. 2003**	**Jul. 2003**	**Aug. 2003**	**Sep. 2003**	**Oct. 2003**	**Nov. 2003**	**Dec. 2003**	**Jan. 2004**	**Feb. 2004**	**Mar. 2004**	**Apr. 2004**	**May. 2004**
74	**1**		17.1	3.7	5.7								
75	**2**			1.5								2.5	
76	**3**		1.5		1.0	14.5							
77	**4**		12.7		14.5								
78	**5**											3.0	
79	**6**	32.5			3.5								
80	**7**		5.7		4.0	10.7						67.5	7.0
81	**8**	45.5	27.0		3.7	47.5					0.5		
82	**9**		4.5	2.4	2.5	25.0							
83	**10**	18.0				11.5					6.7	28.7	
84	**11**	2.5		9.0									
85	**12**		32.4	21.5	1.0								
86	**13**		8.7	8.0	10.7								
87	**14**		10.4	3.0									
88	**15**		17.0	1.5	0.5								
89	**16**	14.5		42.7	5.0								
90	**17**	5.2		15.4				1.7					
91	**18**		2.0			7.7		5.0					30.6
92	**19**							12.5					
93	**20**			5.7								20.7	
94	**21**	29.7	4.5		42.5								12.0
95	**22**	38.5		15.7	1.0	23.5							14.5
96	**23**	20.0		7.0									37.4
97	**24**		36.5	12.5									15.0
98	**25**	29.0	17.4										
99	**26**	1.5											
100	**27**	3.0	4.0		3.0	9.7							
101	**28**	56.7	9.5	3.5		15.5		1.7					
102	**29**	10.5	12.4	19.4	8.5			5.6				2.5	
103	**30**	6.0	57.0	7.0	17.7								31.5
104	**31**		9.5	10.4									45.0
105													
106	**Total (mm)**	**313.1**	**289.8**	**189.9**	**124.8**	**165.6**	**0.0**	**26.5**	**0.0**	**0.0**	**7.2**	**124.9**	**193.0**
107	**Avg (mm)**	**10.4**	**9.3**	**6.1**	**4.2**	**5.3**	**0.0**	**0.9**	**0.0**	**0.0**	**0.2**	**4.2**	**6.2**
108													

	A	B	C	D	E	F	G	H	I	J	K	L	M
109	**Day**	**Jun. 2004**	**Jul. 2004**	**Aug. 2004**	**Sep. 2004**	**Oct. 2004**	**Nov. 2004**	**Dec. 2004**	**Jan. 2005**	**Feb. 2005**	**Mar. 2005**	**Apr. 2005**	**May. 2005**
110	**1**												9.5
111	**2**	5.0											26.0
112	**3**	17.5			47.5								
113	**4**	10.7	9.5	7.4	6.7								7.5
114	**5**			65.7		17.4							6.0
115	**6**		47.7	25.0	6.0	54.0							5.5
116	**7**	45.5	20.0	5.5		126.7							
117	**8**		19.4			62.4							
118	**9**			18.7									
119	**10**			7.5									21.4
120	**11**	0.5			20.7								
121	**12**	31.5			46.4				7.4				
122	**13**	29.7	44.5	25.0	175.5						0.9		
123	**14**	29.4		10.4	227.0								
124	**15**		2.4	3.5	54.7								
125	**16**		4.7		77.0								57.5
126	**17**		17.6		40.6								10.0
127	**18**		12.5										5.7
128	**19**	60.5	32.0	7.5	12.7						0.7		
129	**20**		84.5										
130	**21**	52.7	14.0	9.7									
131	**22**	104.5		4.0									12.7
132	**23**				26.6						14.0		3.5
133	**24**		2.0	8.7	17.5						96.4		2.0
134	**25**	47.5	7.0								19.0		
135	**26**	20.0		12.0								19.5	
136	**27**											21.4	
137	**28**		10.5	5.7	34.7								
138	**29**												
139	**30**		15.4		20.5							41.0	
140	**31**			13.5							32.5		
141													
142	**Total (mm)**	**455.0**	**343.7**	**229.8**	**814.1**	**260.5**	**0.0**	**0.0**	**7.4**	**0.0**	**163.5**	**81.9**	**167.3**
143	**Avg (mm)**	**15.2**	**11.1**	**7.4**	**27.1**	**8.4**	**0.0**	**0.0**	**0.2**	**0.0**	**5.3**	**2.7**	**5.4**
144													

	A	B	C	D	E	F	G	H	I	J	K	L	M
145	**Day**	**Jun. 2005**	**Jul. 2005**	**Aug. 2005**	**Sep. 2005**	**Oct. 2005**	**Nov. 2005**	**Dec. 2005**	**Jan. 2006**	**Feb. 2006**	**Mar. 2006**	**Apr. 2006**	**May. 2006**
146	**1**		1.0			9							
147	**2**		25.7	3		49.5							
148	**3**		74.4	6.5	1.5	35.0							
149	**4**		48.5	4.4		17.0							
150	**5**	5.5	45.2	4.0								18	
151	**6**	12.7		21.5								6.5	
152	**7**			5.5								5.5	35
153	**8**			13.4									
154	**9**			6									
155	**10**		2.5	12.5	0.5								
156	**11**		25.7	6.8	20							4.5	15.5
157	**12**		12	29.5									18
158	**13**		50.4	7.5	7.5	4							4
159	**14**	25.4	57.2										
160	**15**	13.5	60.4										20.5
161	**16**		4										
162	**17**	24.5		10	4.5	0.5							
163	**18**					1.5							
164	**19**			1		35						6.5	
165	**20**			8.4	6	48.5							
166	**21**		48.5	10	72.5	68.5							
167	**22**	4.5	40	1.5	4.5	11.0							
168	**23**		2.5		5.5	77.5		0.5				5	
169	**24**	0.5	1	30.0		15.0							
170	**25**	26.0										3.5	
171	**26**				2.5								
172	**27**	0.5	2										34
173	**28**	21.0	3		27.5								7.5
174	**29**	14.5	5.4									6	25
175	**30**												13.5
176	**31**												21.5
177													
178	**Total (mm)**	**148.6**	**509.4**	**181.5**	**152.5**	**372.0**	**0.0**	**0.5**	**0.0**	**0.0**	**0.0**	**55.5**	**194.5**
179	**Avg (mm)**	**5.0**	**16.4**	**5.9**	**5.1**	**12.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**1.9**	**6.3**
180													

	A	B	C	D	E	F	G	H	I	J	K	L	M
181	**Day**	**Jun. 2006**	**Jul. 2006**	**Aug. 2006**	**Sep. 2006**	**Oct. 2006**	**Nov. 2006**	**Dec. 2006**	**Jan. 2007**	**Feb. 2007**	**Mar. 2007**	**Apr. 2007**	**May. 2007**
182	**1**	0.00	0.00	0.00			2.40						
183	**2**	40.00	0.00	0.00							1		
184	**3**	2.50	0.00	0.00	15.70						2		
185	**4**	0.00	0.00	1.50									
186	**5**	15.50	8.50	2.50						4.5			
187	**6**	0.00	0.00	43.50									
188	**7**	25.00	0.00	4.00		25.50							
189	**8**	5.50	97.50	6.50	7.5					4			3.5
190	**9**	0.00	69.00	0.00						6.7			
191	**10**	16.50	0.00	17.50									
192	**11**	12.50	18.00	0.00	60							5.5	
193	**12**	0.00	15.50	10.00	47.4								
194	**13**	0.00	6.00	0.00	30.5							4.5	
195	**14**	0.00	12.00	0.00	4					14		0.5	
196	**15**	18.00	0.00	16.50						1.5			2.5
197	**16**	0.00	0.00	0.00									1.5
198	**17**	0.00	0.00	0.00						1			
199	**18**	0.00	0.00	0.00									
200	**19**	0.00	0.00	0.00	30.5								40
201	**20**	0.00	27.50	0.00	15								
202	**21**	0.00	21.50	7.50	57.4								2.5
203	**22**	0.00	7.50	0.00	92.5						2.5		2.5
204	**23**	4.00	3.00	0.00	105						17.5		
205	**24**	0.00	0.00	4.00	76.4						8		
206	**25**	0.00	0.00	3.50	10.5							19.5	
207	**26**	0.00	0.00	0.00									
208	**27**	0.00	0.00	0.00								6.5	
209	**28**	10.50	10.50	0.00	12								
210	**29**	0.00	4.50	0.00									
211	**30**	0.00	6.50	5.00	25								
212	**31**		6.00										
213													
214	**Total (mm)**	**150.0**	**313.5**	**122.0**	**589.4**	**25.5**	**2.4**	**0.0**	**0.0**	**31.7**	**31.0**	**36.5**	**52.5**
215	**Avg (mm)**	**5.0**	**10.1**	**3.9**	**19.6**	**0.8**	**0.1**	**0.0**	**0.0**	**1.1**	**1.0**	**1.2**	**1.7**

Appendix K

ET Calculated from Pan Data

	A	B	C	D	E	F	G	H	I	J	K
1											
2											
3					**ET Calculated from Pan Data**						
4											
5	**Bangladesh**		**water added**			**water removed**			**Pan ET**	**PanET*0.7**	**ET0-BWDB**
6	**Date**	**RF (mm)**	**cups**	**vol (mm^3)**	**height (mm)**	**cups**	**vol (mm^3)**	**height (mm)**	**(mm/d)**	**(mm/d)**	**(mm/d)**
7	6/1/2005		11.5	7079970	6.1		0	0.0	6.1	4.25	4.27
8	6/2/2005		11	6772145	5.8		0	0.0	5.8	4.06	3.91
9	6/3/2005		11	6772145	5.8		0	0.0	5.8	4.06	3.91
10	6/4/2005		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
11	6/5/2005	5.5		0	0.0		0	0.0	5.5	3.85	3.54
12	6/6/2005	12.7		0	0.0	16	9850393	8.4	4.3	2.98	3.20
13	6/7/2005		10	6156496	5.3		0	0.0	5.3	3.69	3.56
14	6/8/2005		11	6772145	5.8		0	0.0	5.8	4.06	3.91
15	6/9/2005		10	6156496	5.3		0	0.0	5.3	3.69	3.56
16	6/10/2005		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
17	6/11/2005		10	6156496	5.3		0	0.0	5.3	3.69	3.56
18	6/12/2005		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
19	6/13/2005		10	6156496	5.3		0	0.0	5.3	3.69	3.56
20	6/14/2005	25.4		0	0.0	42.5	26165107	22.4	3.0	2.09	2.49
21	6/15/2005	13.5		0	0.0	16.5	10158218	8.7	4.8	3.36	3.40
22	6/16/2005		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
23	6/17/2005	24.5		0	0.0	39	24010334	20.6	3.9	2.75	3.28
24	6/18/2005		9	5540846	4.7		0	0.0	4.7	3.32	3.20
25	6/19/2005		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
26	6/20/2005		10	6156496	5.3		0	0.0	5.3	3.69	3.56
27	6/21/2005		9	5540846	4.7		0	0.0	4.7	3.32	3.20
28	6/22/2005	4.5	0.5	307825	0.3		0	0.0	4.8	3.33	3.51
29	6/23/2005		9	5540846	4.7		0	0.0	4.7	3.32	3.20
30	6/24/2005	0.5	8.5	5233021	4.5		0	0.0	5.0	3.49	3.54
31	6/25/2005	26.0		0	0.0	44	27088582	23.2	2.8	1.96	2.55
32	6/26/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
33	6/27/2005	0.5	8	4925197	4.2		0	0.0	4.7	3.30	3.19
34	6/28/2005	21.0		0	0.0	34.5	21239911	18.2	2.8	1.96	2.25
35	6/29/2005	14.5		0	0.0	21	12928641	11.1	3.4	2.40	2.68
36	6/30/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
37	7/1/2005	1.0	7	4309547	3.7		0	0.0	4.7	3.28	-0.12
38	7/2/2005	25.7		0	0.0	43.5	26780757	22.9	2.8	1.93	-0.12
39	7/3/2005	74.4		0	0.0	145.5	89577015	76.7	-2.3	-1.63	-0.12
40	7/4/2005	48.5		0	0.0	92	56639762	48.5	0.0	-0.01	-0.12
41	7/5/2005	45.2		0	0.0	84.5	52022390	44.6	0.6	0.45	-0.12
42	7/6/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	0.00
43	7/7/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
44	7/8/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84

	A	B	C	D	E	F	G	H	I	J	K
45	7/9/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
46	7/10/2005	2.5	3	1846949	1.6		0	0.0	4.1	2.86	-0.12
47	7/11/2005	25.7		0	0.0	43	26472932	22.7	3.0	2.12	-0.12
48	7/12/2005	12		0	0.0	18.5	11389517	9.8	2.2	1.57	-0.12
49	7/13/2005	50.4		0	0.0	93.5	57563236	49.3	1.1	0.77	-0.12
50	7/14/2005	57.2		0	0.0	108	66490155	57.0	0.2	0.17	-0.12
51	7/15/2005	60.4		0	0.0	115	70799703	60.6	-0.2	-0.17	-0.12
52	7/16/2005	4		0	0.0	1	615650	0.5	3.5	2.43	-0.12
53	7/17/2005		7	4309547	3.7		0	0.0	3.7	2.58	0.00
54	7/18/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
55	7/19/2005		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
56	7/20/2005		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
57	7/21/2005	48.5		0	0.0	90.5	55716288	47.7	0.8	0.54	-0.12
58	7/22/2005	40		0	0.0	74	45558069	39.0	1.0	0.68	-0.12
59	7/23/2005	2.5	3	1846949	1.6		0	0.0	4.1	2.86	-0.12
60	7/24/2005	1	5.5	3386073	2.9		0	0.0	3.9	2.73	-0.12
61	7/25/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
62	7/26/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
63	7/27/2005	2	4	2462598	2.1		0	0.0	4.1	2.88	-0.12
64	7/28/2005	3	2	1231299	1.1		0	0.0	4.1	2.84	-0.12
65	7/29/2005	5.4		0	0.0	3.5	2154774	1.8	3.6	2.49	-0.12
66	7/30/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
67	7/31/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
68	8/1/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
69	8/2/2005	3	1.5	923474	0.8		0	0.0	3.8	2.65	2.81
70	8/3/2005	6.5		0	0.0	6	3693898	3.2	3.3	2.34	2.42
71	8/4/2005	4.4		0	0.0	3	1846949	1.6	2.8	1.97	2.01
72	8/5/2005	4		0	0.0	1.5	923474	0.8	3.2	2.25	2.09
73	8/6/2005	21.5		0	0.0	37	22779035	19.5	2.0	1.39	1.89
74	8/7/2005	5.5		0	0.0	4	2462598	2.1	3.4	2.37	2.43
75	8/8/2005	13.4		0	0.0	20.5	12620817	10.8	2.6	1.81	1.91
76	8/9/2005	6		0	0.0	5.5	3386073	2.9	3.1	2.17	2.07
77	8/10/2005	12.5		0	0.0	18	11081693	9.5	3.0	2.11	2.35
78	8/11/2005	6.8		0	0.0	7	4309547	3.7	3.1	2.18	2.27
79	8/12/2005	29.5		0	0.0	53.5	32937253	28.2	1.3	0.90	1.45
80	8/13/2005	7.5		0	0.0	8	4925197	4.2	3.3	2.30	2.41
81	8/14/2005		7	4309547	3.7		0	0.0	3.7	2.58	2.49
82	8/15/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
83	8/16/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
84	8/17/2005	10		0	0.0	13	8003445	6.9	3.1	2.20	2.38
85	8/18/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
86	8/19/2005	1	6	3693898	3.2		0	0.0	4.2	2.91	2.83
87	8/20/2005	8.4		0	0.0	11	6772145	5.8	2.6	1.82	1.97
88	8/21/2005	10		0	0.0	13.5	8311269	7.1	2.9	2.02	2.02

	A	B	C	D	E	F	G	H	I	J	K
89	8/22/2005	1.5	4	2462598	2.1		0	0.0	3.6	2.53	2.47
90	8/23/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
91	8/24/2005	30		0	0.0	53.5	32937253	28.2	1.8	1.25	1.80
92	8/25/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
93	8/26/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
94	8/27/2005		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
95	8/28/2005		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
96	8/29/2005		9	5540846	4.7		0	0.0	4.7	3.32	3.20
97	8/30/2005		9	5540846	4.7		0	0.0	4.7	3.32	3.20
98	8/31/2005		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
99	9/1/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
100	9/2/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
101	9/3/2005	1.5	6	3693898	3.2		0	0.0	4.7	3.26	1.14
102	9/4/2005		7	4309547	3.7		0	0.0	3.7	2.58	2.49
103	9/5/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
104	9/6/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
105	9/7/2005		7	4309547	3.7		0	0.0	3.7	2.58	2.49
106	9/8/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
107	9/9/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
108	9/10/2005	0.5	7	4309547	3.7		0	0.0	4.2	2.93	1.14
109	9/11/2005	20		0	0.0	34.5	21239911	18.2	1.8	1.26	1.14
110	9/12/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
111	9/13/2005	7.5		0	0.0	7.5	4617372	4.0	3.5	2.48	1.14
112	9/14/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
113	9/15/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
114	9/16/2005		8	4925197	4.2		0	0.0	4.2	2.95	2.84
115	9/17/2005	4.5		0	0.0	1.5	923474	0.8	3.7	2.60	1.14
116	9/18/2005		8	4925197	4.2		0	0.0	4.2	2.95	0.00
117	9/19/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
118	9/20/2005	6		0	0.0	4	2462598	2.1	3.9	2.72	1.14
119	9/21/2005	72.5		0	0.0	140.5	86498767	74.1	-1.6	-1.11	1.14
120	9/22/2005	4.5		0	0.0	3	1846949	1.6	2.9	2.04	0.00
121	9/23/2005	5.5		0	0.0	4	2462598	2.1	3.4	2.37	1.14
122	9/24/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	0.00
123	9/25/2005		8.5	5233021	4.5		0	0.0	4.5	3.14	2.84
124	9/26/2005	2.5	2	1231299	1.1		0	0.0	3.6	2.49	1.14
125	9/27/2005		6	3693898	3.2		0	0.0	3.2	2.21	0.71
126	9/28/2005	27.5		0	0.0	49.5	30474655	26.1	1.4	0.98	1.14
127	9/29/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	0.00
128	9/30/2005		7	4309547	3.7		0	0.0	3.7	2.58	2.84
129	10/1/2005	9		0	0.0	14	8619094	7.4	1.6	1.13	1.32
130	10/2/2005	49.5		0	0.0	95	58486711	50.1	-0.6	-0.42	0.87
131	10/3/2005	35.0		0	0.0	64.5	39709398	34.0	1.0	0.69	1.39
132	10/4/2005	17.0		0	0.0	29	17853838	15.3	1.7	1.19	1.59

	A	B	C	D	E	F	G	H	I	J	K
133	10/5/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
134	10/6/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
135	10/7/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
136	10/8/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
137	10/9/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
138	10/10/2005		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
139	10/11/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
140	10/12/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
141	10/13/2005	4		0	0.0	1.5	923474	0.8	3.2	2.25	2.09
142	10/14/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
143	10/15/2005		7	4309547	3.7		0	0.0	3.7	2.58	2.49
144	10/16/2005		7	4309547	3.7		0	0.0	3.7	2.58	2.49
145	10/17/2005	0.5	6	3693898	3.2		0	0.0	3.7	2.56	2.31
146	10/18/2005	1.5	3.5	2154774	1.8		0	0.0	3.3	2.34	2.31
147	10/19/2005	35		0	0.0	64.5	39709398	34.0	1.0	0.69	1.39
148	10/20/2005	48.5		0	0.0	94	57871061	49.6	-1.1	-0.75	0.52
149	10/21/2005	68.5		0	0.0	135	83112694	71.2	-2.7	-1.88	0.00
150	10/22/2005	11.0		0	0.0	18.5	11389517	9.8	1.2	0.87	0.94
151	10/23/2005	77.5		0	0.0	151	92963088	79.6	-2.1	-1.49	0.55
152	10/24/2005	15.0		0	0.0	27	16622539	14.2	0.8	0.53	0.90
153	10/25/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
154	10/26/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
155	10/27/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
156	10/28/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
157	10/29/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
158	10/30/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
159	10/31/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
160	11/1/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
161	11/2/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
162	11/3/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
163	11/4/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
164	11/5/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
165	11/6/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
166	11/7/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
167	11/8/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
168	11/9/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
169	11/10/2005		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
170	11/11/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
171	11/12/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
172	11/13/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
173	11/14/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
174	11/15/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
175	11/16/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
176	11/17/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78

	A	B	C	D	E	F	G	H	I	J	K
177	11/18/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
178	11/19/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
179	11/20/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
180	11/21/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
181	11/22/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
182	11/23/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
183	11/24/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
184	11/25/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
185	11/26/2005		6	3693898	3.2		0	0.0	3.2	2.21	2.13
186	11/27/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
187	11/28/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
188	11/29/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
189	11/30/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
190	12/1/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
191	12/2/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
192	12/3/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
193	12/4/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
194	12/5/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
195	12/6/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
196	12/7/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
197	12/8/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
198	12/9/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
199	12/10/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
200	12/11/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
201	12/12/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
202	12/13/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
203	12/14/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
204	12/15/2005		4	2462598	2.1		0	0.0	2.1	1.48	1.42
205	12/16/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
206	12/17/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
207	12/18/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
208	12/19/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
209	12/20/2005		4	2462598	2.1		0	0.0	2.1	1.48	1.42
210	12/21/2005		4	2462598	2.1		0	0.0	2.1	1.48	1.42
211	12/22/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
212	12/23/2005	0.5	2	1231299	1.1		0	0.0	1.6	1.09	1.06
213	12/24/2005		4	2462598	2.1		0	0.0	2.1	1.48	1.42
214	12/25/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
215	12/26/2005		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
216	12/27/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
217	12/28/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
218	12/29/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78
219	12/30/2005		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
220	12/31/2005		5	3078248	2.6		0	0.0	2.6	1.85	1.78

	A	B	C	D	E	F	G	H	I	J	K
221	1/1/2006		5	3078248	2.6		0	0.0	2.6	1.85	
222	1/2/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
223	1/3/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
224	1/4/2006		5	3078248	2.6		0	0.0	2.6	1.85	
225	1/5/2006		4	2462598	2.1		0	0.0	2.1	1.48	
226	1/6/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
227	1/7/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
228	1/8/2006		3	1846949	1.6		0	0.0	1.6	1.11	
229	1/9/2006		2.5	1539124	1.3		0	0.0	1.3	0.92	
230	1/10/2006		1.5	923474	0.8		0	0.0	0.8	0.55	
231	1/11/2006		2	1231299	1.1		0	0.0	1.1	0.74	
232	1/12/2006		3	1846949	1.6		0	0.0	1.6	1.11	
233	1/13/2006		2.5	1539124	1.3		0	0.0	1.3	0.92	
234	1/14/2006		3	1846949	1.6		0	0.0	1.6	1.11	
235	1/15/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
236	1/16/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
237	1/17/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
238	1/18/2006		4	2462598	2.1		0	0.0	2.1	1.48	
239	1/19/2006		3	1846949	1.6		0	0.0	1.6	1.11	
240	1/20/2006		3	1846949	1.6		0	0.0	1.6	1.11	
241	1/21/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
242	1/22/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
243	1/23/2006		4	2462598	2.1		0	0.0	2.1	1.48	
244	1/24/2006		4	2462598	2.1		0	0.0	2.1	1.48	
245	1/25/2006		3	1846949	1.6		0	0.0	1.6	1.11	
246	1/26/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
247	1/27/2006		3.5	2154774	1.8		0	0.0	1.8	1.29	
248	1/28/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
249	1/29/2006		5	3078248	2.6		0	0.0	2.6	1.85	
250	1/30/2006		5	3078248	2.6		0	0.0	2.6	1.85	
251	1/31/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
252	2/1/2006		4	2462598	2.1		0	0.0	2.1	1.48	1.42
253	2/2/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
254	2/3/2006		5	3078248	2.6		0	0.0	2.6	1.85	1.78
255	2/4/2006		5	3078248	2.6		0	0.0	2.6	1.85	1.78
256	2/5/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
257	2/6/2006		5	3078248	2.6		0	0.0	2.6	1.85	1.78
258	2/7/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
259	2/8/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
260	2/9/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
261	2/10/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
262	2/11/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
263	2/12/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
264	2/13/2006		5	3078248	2.6		0	0.0	2.6	1.85	1.78

	A	B	C	D	E	F	G	H	I	J	K
265	2/14/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
266	2/15/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
267	2/16/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
268	2/17/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
269	2/18/2006		5	3078248	2.6		0	0.0	2.6	1.85	1.78
270	2/19/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
271	2/20/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
272	2/21/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.13
273	2/22/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
274	2/23/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
275	2/24/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
276	2/25/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
277	2/26/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
278	2/27/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
279	2/28/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
280	3/1/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
281	3/2/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
282	3/3/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
283	3/4/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
284	3/5/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
285	3/6/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
286	3/7/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
287	3/8/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
288	3/9/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
289	3/10/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
290	3/11/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
291	3/12/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
292	3/13/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
293	3/14/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
294	3/15/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
295	3/16/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
296	3/17/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
297	3/18/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
298	3/19/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
299	3/20/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
300	3/21/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
301	3/22/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
302	3/23/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
303	3/24/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
304	3/25/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
305	3/26/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
306	3/27/2006		11.5	7079970	6.1		0	0.0	6.1	4.25	4.27
307	3/28/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
308	3/29/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91

	A	B	C	D	E	F	G	H	I	J	K
309	3/30/2006		11.5	7079970	6.1		0	0.0	6.1	4.25	4.27
310	3/31/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
311	4/1/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
312	4/2/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
313	4/3/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
314	4/4/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
315	4/5/2006	18	0	0	0.0	26.5	16314714	14.0	4.0	2.82	3.00
316	4/6/2006	6.5	0	0	0.0	5.5	3386073	2.9	3.6	2.52	2.42
317	4/7/2006	5.5	0	0	0.0	1	615650	0.5	5.0	3.48	3.44
318	4/8/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
319	4/9/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
320	4/10/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.44
321	4/11/2006	4.5	0	0	0.0		0	0.0	4.5	3.15	0.00
322	4/12/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
323	4/13/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
324	4/14/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
325	4/15/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
326	4/16/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
327	4/17/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
328	4/18/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
329	4/19/2006	6.5	0	0	0.0	4.5	2770423	2.4	4.1	2.89	2.77
330	4/20/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
331	4/21/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
332	4/22/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
333	4/23/2006	5	0	0	0.0		0	0.0	5.0	3.50	3.44
334	4/24/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
335	4/25/2006	3.5	3.5	2154774	1.8		0	0.0	5.3	3.74	3.44
336	4/26/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
337	4/27/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
338	4/28/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
339	4/29/2006	6	0	0	0.0	2.5	1539124	1.3	4.7	3.28	3.13
340	4/30/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
341	5/1/2006		11.5	7079970	6.1		0	0.0	6.1	4.25	4.27
342	5/2/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
343	5/3/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
344	5/4/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
345	5/5/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
346	5/6/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
347	5/7/2006	35	0	0	0.0	61.5	37862450	32.4	2.6	1.80	2.45
348	5/8/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
349	5/9/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
350	5/10/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
351	5/11/2006	15.5	0	0	0.0	22	13544291	11.6	3.9	2.73	3.03
352	5/12/2006	18	0	0	0.0	27.5	16930364	14.5	3.5	2.45	2.64

	A	B	C	D	E	F	G	H	I	J	K
353	5/13/2006	4	0	0	0.0		0	0.0	4.0	2.80	2.80
354	5/14/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
355	5/15/2006	20.5	0	0	0.0	34	20932086	17.9	2.6	1.80	2.26
356	5/16/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
357	5/17/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
358	5/18/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
359	5/19/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
360	5/20/2006		11.5	7079970	6.1		0	0.0	6.1	4.25	4.27
361	5/21/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
362	5/22/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
363	5/23/2006		11.5	7079970	6.1		0	0.0	6.1	4.25	4.27
364	5/24/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
365	5/25/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
366	5/26/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
367	5/27/2006	34	0	0	0.0	59	36323326	31.1	2.9	2.02	2.82
368	5/28/2006	7.5	0	0	0.0	8.5	5233021	4.5	3.0	2.11	2.05
369	5/29/2006	25	0	0	0.0	45	27704231	23.7	1.3	0.89	1.50
370	5/30/2006	13.5	0	0	0.0	20.5	12620817	10.8	2.7	1.88	1.98
371	5/31/2006	21.5	0	0	0.0	37	22779035	19.5	2.0	1.39	1.89
372	6/1/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
373	6/2/2006	40	0	0	0.0	75	46173719	39.6	0.4	0.31	1.33
374	6/3/2006	2.5	3	1846949	1.6		0	0.0	4.1	2.86	2.82
375	6/4/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
376	6/5/2006	15.5	0	0	0.0	22	13544291	11.6	3.9	2.73	3.03
377	6/6/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
378	6/7/2006	25	0	0	0.0	43.5	26780757	22.9	2.1	1.44	1.85
379	6/8/2006	5.5	0	0	0.0	4	2462598	2.1	3.4	2.37	2.43
380	6/9/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
381	6/10/2006	16.5	0	0	0.0	26	16006889	13.7	2.8	1.95	2.30
382	6/11/2006	12.5	0	0	0.0	19.5	12005167	10.3	2.2	1.55	1.64
383	6/12/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
384	6/13/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
385	6/14/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
386	6/15/2006	18	0	0	0.0	27.5	16930364	14.5	3.5	2.45	2.64
387	6/16/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
388	6/17/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
389	6/18/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
390	6/19/2006		11	6772145	5.8		0	0.0	5.8	4.06	3.91
391	6/20/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
392	6/21/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
393	6/22/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.91
394	6/23/2006	4	2	1231299	1.1		0	0.0	5.1	3.54	3.25
395	6/24/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
396	6/25/2006		8.6	5294586	4.5		0	0.0	4.5	3.17	3.20

	A	B	C	D	E	F	G	H	I	J	K
397	6/26/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
398	6/27/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
399	6/28/2006	10.5	0	0	0.0	13.5	8311269	7.1	3.4	2.37	2.37
400	6/29/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
401	6/30/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
402	7/1/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
403	7/2/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
404	7/3/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
405	7/4/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
406	7/5/2006	8.5	0	0	0.0	9	5540846	4.7	3.8	2.63	1.36
407	7/6/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	2.84
408	7/7/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
409	7/8/2006	97.5	0	0	0.0	190.5	117281246	100.5	-3.0	-2.07	0.33
410	7/9/2006	69	0	0	0.0	135	83112694	71.2	-2.2	-1.53	0.29
411	7/10/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
412	7/11/2006	18	0	0	0.0	29	17853838	15.3	2.7	1.89	1.36
413	7/12/2006	15.5	0	0	0.0	25	15391240	13.2	2.3	1.62	1.36
414	7/13/2006	6	0	0	0.0	5.5	3386073	2.9	3.1	2.17	1.36
415	7/14/2006	12	0	0	0.0	18	11081693	9.5	2.5	1.76	1.36
416	7/15/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
417	7/16/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
418	7/17/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.84
419	7/18/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
420	7/19/2006		9	5540846	4.7		0	0.0	4.7	3.32	0.00
421	7/20/2006	27.5	0	0	0.0	48	29551180	25.3	2.2	1.53	1.36
422	7/21/2006	21.5	0	0	0.0	37.5	23086860	19.8	1.7	1.21	1.36
423	7/22/2006	7.5	0	0	0.0	8	4925197	4.2	3.3	2.30	1.36
424	7/23/2006	3	1.5	923474	0.8		0	0.0	3.8	2.65	1.36
425	7/24/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.56
426	7/25/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.91
427	7/26/2006		10.5	6464321	5.5		0	0.0	5.5	3.88	3.20
428	7/27/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	0.00
429	7/28/2006	10.5	0	0	0.0	12	7387795	6.3	4.2	2.92	1.36
430	7/29/2006	4.5	0	0	0.0		0	0.0	4.5	3.15	1.36
431	7/30/2006	6.5	0	0	0.0	7	4309547	3.7	2.8	1.97	1.36
432	7/31/2006	6	0	0	0.0	4.5	2770423	2.4	3.6	2.54	3.20
433	8/1/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.56
434	8/2/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.91
435	8/3/2006		11	6772145	5.8		0	0.0	5.8	4.06	1.37
436	8/4/2006	1.5	8	4925197	4.2		0	0.0	5.7	4.00	1.37
437	8/5/2006	2.5	5	3078248	2.6		0	0.0	5.1	3.60	1.37
438	8/6/2006	43.5	0	0	0.0	80.5	49559792	42.5	1.0	0.73	1.37
439	8/7/2006	4	1.5	923474	0.8		0	0.0	4.8	3.35	1.37
440	8/8/2006	6.5	0	0	0.0	4.5	2770423	2.4	4.1	2.89	2.49

	A	B	C	D	E	F	G	H	I	J	K
441	8/9/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	1.37
442	8/10/2006	17.5	0	0	0.0	24	14775590	12.7	4.8	3.39	0.00
443	8/11/2006		7	4309547	3.7		0	0.0	3.7	2.58	1.37
444	8/12/2006	10	0	0	0.0	12	7387795	6.3	3.7	2.57	0.00
445	8/13/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
446	8/14/2006		9	5540846	4.7		0	0.0	4.7	3.32	1.37
447	8/15/2006	16.5	0	0	0.0	23	14159941	12.1	4.4	3.06	0.00
448	8/16/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
449	8/17/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
450	8/18/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
451	8/19/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
452	8/20/2006		10	6156496	5.3		0	0.0	5.3	3.69	1.37
453	8/21/2006	7.5	0	0	0.0	6	3693898	3.2	4.3	3.04	0.00
454	8/22/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
455	8/23/2006		9	5540846	4.7		0	0.0	4.7	3.32	1.37
456	8/24/2006	4	1.5	923474	0.8		0	0.0	4.8	3.35	1.37
457	8/25/2006	3.5	2	1231299	1.1		0	0.0	4.6	3.19	3.20
458	8/26/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.56
459	8/27/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.20
460	8/28/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
461	8/29/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	1.37
462	8/30/2006	5	0	0	0.0		0	0.0	5.0	3.50	3.20
463	8/31/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.56
464	9/1/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	3.56
465	9/2/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.15
466	9/3/2006	15.7	0	0	0.0	22	13544291	11.6	4.1	2.87	3.20
467	9/4/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
468	9/5/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.56
469	9/6/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.56
470	9/7/2006		9.5	5848671	5.0		0	0.0	5.0	3.51	2.76
471	9/8/2006	7.5	0	0	0.0	6.5	4001722	3.4	4.1	2.85	3.56
472	9/9/2006		10	6156496	5.3		0	0.0	5.3	3.69	3.20
473	9/10/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	1.11
474	9/11/2006	60	0	0	0.0	114.5	70491878	60.4	-0.4	-0.27	2.24
475	9/12/2006	47.4	0	0	0.0	87	53561514	45.9	1.5	1.06	1.79
476	9/13/2006	30.5	0	0	0.0	55	33860727	29.0	1.5	1.05	2.09
477	9/14/2006	4	0	0	0.0	1.5	923474	0.8	3.2	2.25	2.84
478	9/15/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	3.20
479	9/16/2006		9	5540846	4.7		0	0.0	4.7	3.32	3.20
480	9/17/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	3.20
481	9/18/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	2.15
482	9/19/2006	30.5	0	0	0.0	54	33245078	28.5	2.0	1.42	1.97
483	9/20/2006	15	0	0	0.0	23.5	14467765	12.4	2.6	1.83	1.06
484	9/21/2006	57.4	0	0	0.0	119	73262301	62.8	-5.4	-3.75	1.10

	A	B	C	D	E	F	G	H	I	J	K
485	9/22/2006	92.5	0	0	0.0	178.5	109893451	94.1	-1.6	-1.14	0.25
486	9/23/2006	105	0	0	0.0	206	126823815	108.6	-3.6	-2.54	1.21
487	9/24/2006	76.4	0	0	0.0	147	90500489	77.5	-1.1	-0.78	2.02
488	9/25/2006	10.5	0	0	0.0	14.5	8926919	7.6	2.9	2.00	2.13
489	9/26/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	2.49
490	9/27/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.71
491	9/28/2006	12	0	0	0.0	16	9850393	8.4	3.6	2.49	2.84
492	9/29/2006		8	4925197	4.2		0	0.0	4.2	2.95	2.20
493	9/30/2006	25	0	0	0.0	43.5	26780757	22.9	2.1	1.44	2.11
494	10/1/2006		8	4925197	4.2		0	0.0	4.2	2.95	
495	10/2/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	
496	10/3/2006		8	4925197	4.2		0	0.0	4.2	2.95	
497	10/4/2006		8.5	5233021	4.5		0	0.0	4.5	3.14	
498	10/5/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	
499	10/6/2006		8	4925197	4.2		0	0.0	4.2	2.95	
500	10/7/2006	25.5	0	0	0.0	44	27088582	23.2	2.3	1.61	
501	10/8/2006		8	4925197	4.2		0	0.0	4.2	2.95	
502	10/9/2006		7	4309547	3.7		0	0.0	3.7	2.58	
503	10/10/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	
504	10/11/2006		8	4925197	4.2		0	0.0	4.2	2.95	
505	10/12/2006		8	4925197	4.2		0	0.0	4.2	2.95	
506	10/13/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	
507	10/14/2006		7	4309547	3.7		0	0.0	3.7	2.58	
508	10/15/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	
509	10/16/2006		8	4925197	4.2		0	0.0	4.2	2.95	
510	10/17/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	
511	10/18/2006		7	4309547	3.7		0	0.0	3.7	2.58	
512	10/19/2006		8	4925197	4.2		0	0.0	4.2	2.95	
513	10/20/2006		7	4309547	3.7		0	0.0	3.7	2.58	
514	10/21/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	
515	10/22/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	
516	10/23/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	
517	10/24/2006		7	4309547	3.7		0	0.0	3.7	2.58	
518	10/25/2006		7	4309547	3.7		0	0.0	3.7	2.58	
519	10/26/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	
520	10/27/2006		6	3693898	3.2		0	0.0	3.2	2.21	
521	10/28/2006		7	4309547	3.7		0	0.0	3.7	2.58	
522	10/29/2006		7.5	4617372	4.0		0	0.0	4.0	2.77	
523	10/30/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	
524	10/31/2006		6	3693898	3.2		0	0.0	3.2	2.21	
525	11/1/2006	2.4	2	1231299	1.1		0	0.0	3.5	2.42	2.49
526	11/2/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
527	11/3/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
528	11/4/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49

	A	B	C	D	E	F	G	H	I	J	K
529	11/5/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
530	11/6/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.13
531	11/7/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
532	11/8/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	1.78
533	11/9/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	1.42
534	11/10/2006		4	2462598	2.1		0	0.0	2.1	1.48	1.07
535	11/11/2006		2.5	1539124	1.3		0	0.0	1.3	0.92	1.78
536	11/12/2006		5	3078248	2.6		0	0.0	2.6	1.85	2.13
537	11/13/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
538	11/14/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.49
539	11/15/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
540	11/16/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
541	11/17/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.49
542	11/18/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
543	11/19/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.49
544	11/20/2006		7	4309547	3.7		0	0.0	3.7	2.58	2.13
545	11/21/2006		6.5	4001722	3.4		0	0.0	3.4	2.40	2.13
546	11/22/2006		6	3693898	3.2		0	0.0	3.2	2.21	2.13
547	11/23/2006		6	3693898	3.2		0	0.0	3.2	2.21	1.78
548	11/24/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	1.78
549	11/25/2006		5	3078248	2.6		0	0.0	2.6	1.85	1.78
550	11/26/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	1.78
551	11/27/2006		5	3078248	2.6		0	0.0	2.6	1.85	1.78
552	11/28/2006		5	3078248	2.6		0	0.0	2.6	1.85	2.13
553	11/29/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	1.78
554	11/30/2006		5	3078248	2.6		0	0.0	2.6	1.85	
555	12/1/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	
556	12/2/2006		5	3078248	2.6		0	0.0	2.6	1.85	
557	12/3/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	
558	12/4/2006		6	3693898	3.2		0	0.0	3.2	2.21	
559	12/5/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	
560	12/6/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
561	12/7/2006		5	3078248	2.6		0	0.0	2.6	1.85	
562	12/8/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
563	12/9/2006		4	2462598	2.1		0	0.0	2.1	1.48	
564	12/10/2006		4	2462598	2.1		0	0.0	2.1	1.48	
565	12/11/2006		4	2462598	2.1		0	0.0	2.1	1.48	
566	12/12/2006		0.5	307825	0.3		0	0.0	0.3	0.18	
567	12/13/2006		5	3078248	2.6		0	0.0	2.6	1.85	
568	12/14/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
569	12/15/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
570	12/16/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
571	12/17/2006		5	3078248	2.6		0	0.0	2.6	1.85	
572	12/18/2006		4	2462598	2.1		0	0.0	2.1	1.48	

	A	B	C	D	E	F	G	H	I	J	K
573	12/19/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
574	12/20/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
575	12/21/2006		4	2462598	2.1		0	0.0	2.1	1.48	
576	12/22/2006		5	3078248	2.6		0	0.0	2.6	1.85	
577	12/23/2006		5	3078248	2.6		0	0.0	2.6	1.85	
578	12/24/2006		5.5	3386073	2.9		0	0.0	2.9	2.03	
579	12/25/2006		5	3078248	2.6		0	0.0	2.6	1.85	
580	12/26/2006		5	3078248	2.6		0	0.0	2.6	1.85	
581	12/27/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
582	12/28/2006		5	3078248	2.6		0	0.0	2.6	1.85	
583	12/29/2006		5	3078248	2.6		0	0.0	2.6	1.85	
584	12/30/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
585	12/31/2006		4.5	2770423	2.4		0	0.0	2.4	1.66	
586	1/1/2007		4	2462598	2.1		0	0.0	2.1	1.48	
587	1/2/2007		4	2462598	2.1		0	0.0	2.1	1.48	
588	1/3/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
589	1/4/2007		4	2462598	2.1		0	0.0	2.1	1.48	
590	1/5/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
591	1/6/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
592	1/7/2007		4	2462598	2.1		0	0.0	2.1	1.48	
593	1/8/2007		4	2462598	2.1		0	0.0	2.1	1.48	
594	1/9/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
595	1/10/2007		4	2462598	2.1		0	0.0	2.1	1.48	
596	1/11/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
597	1/12/2007		4	2462598	2.1		0	0.0	2.1	1.48	
598	1/13/2007		4	2462598	2.1		0	0.0	2.1	1.48	
599	1/14/2007		4	2462598	2.1		0	0.0	2.1	1.48	
600	1/15/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
601	1/16/2007		4	2462598	2.1		0	0.0	2.1	1.48	
602	1/17/2007		4	2462598	2.1		0	0.0	2.1	1.48	
603	1/18/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
604	1/19/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
605	1/20/2007		4	2462598	2.1		0	0.0	2.1	1.48	
606	1/21/2007		4.5	2770423	2.4		0	0.0	2.4	1.66	
607	1/22/2007		4.5	2770423	2.4		0	0.0	2.4	1.66	
608	1/23/2007		5	3078248	2.6		0	0.0	2.6	1.85	
609	1/24/2007		4.5	2770423	2.4		0	0.0	2.4	1.66	
610	1/25/2007		4	2462598	2.1		0	0.0	2.1	1.48	
611	1/26/2007		4.5	2770423	2.4		0	0.0	2.4	1.66	
612	1/27/2007		4.5	2770423	2.4		0	0.0	2.4	1.66	
613	1/28/2007		4.5	2770423	2.4		0	0.0	2.4	1.66	
614	1/29/2007		5	3078248	2.6		0	0.0	2.6	1.85	
615	1/30/2007		3.5	2154774	1.8		0	0.0	1.8	1.29	
616	1/31/2007		3	1846949	1.6		0	0.0	1.6	1.11	

	A	B	C	D	E	F	G	H	I	J	K
617	2/1/2007		2.5	1539124	1.3		0	0.0	1.3	0.92	
618	2/2/2007		3	1846949	1.6		0	0.0	1.6	1.11	
619	2/3/2007		3	1846949	1.6		0	0.0	1.6	1.11	
620	2/4/2007		2.5	1539124	1.3		0	0.0	1.3	0.92	
621	2/5/2007	4.5		0	0.0	4	2462598	2.1	2.4	1.67	
622	2/6/2007		4	2462598	2.1		0	0.0	2.1	1.48	
623	2/7/2007		3	1846949	1.6		0	0.0	1.6	1.11	
624	2/8/2007	4		0	0.0	4.5	2770423	2.4	1.6	1.14	
625	2/9/2007	6.7		0	0.0	10	6156496	5.3	1.4	1.00	
626	2/10/2007		4	2462598	2.1		0	0.0	2.1	1.48	
627	2/11/2007		5	3078248	2.6		0	0.0	2.6	1.85	
628	2/12/2007		5.5	3386073	2.9		0	0.0	2.9	2.03	
629	2/13/2007		6	3693898	3.2		0	0.0	3.2	2.21	
630	2/14/2007	14		0	0.0	23.5	14467765	12.4	1.6	1.13	
631	2/15/2007	1.5	2	1231299	1.1		0	0.0	2.6	1.79	
632	2/16/2007		4.5	2770423	2.4		0	0.0	2.4	1.66	
633	2/17/2007	1	3.5	2154774	1.8		0	0.0	2.8	1.99	
634	2/18/2007		5	3078248	2.6		0	0.0	2.6	1.85	
635	2/19/2007		6	3693898	3.2		0	0.0	3.2	2.21	
636	2/20/2007		6.5	4001722	3.4		0	0.0	3.4	2.40	
637	2/21/2007		5.5	3386073	2.9		0	0.0	2.9	2.03	
638	2/22/2007		6	3693898	3.2		0	0.0	3.2	2.21	
639	2/23/2007		6	3693898	3.2		0	0.0	3.2	2.21	
640	2/24/2007		5.5	3386073	2.9		0	0.0	2.9	2.03	
641	2/25/2007		6	3693898	3.2		0	0.0	3.2	2.21	
642	2/26/2007		6	3693898	3.2		0	0.0	3.2	2.21	
643	2/27/2007		6.5	4001722	3.4		0	0.0	3.4	2.40	
644	2/28/2007		6.5	4001722	3.4		0	0.0	3.4	2.40	
645	3/1/2007		6.5	4001722	3.4		0	0.0	3.4	2.40	
646	3/2/2007	1	5.5	3386073	2.9		0	0.0	3.9	2.73	
647	3/3/2007	2	2	1231299	1.1		0	0.0	3.1	2.14	
648	3/4/2007		7	4309547	3.7		0	0.0	3.7	2.58	
649	3/5/2007		7	4309547	3.7		0	0.0	3.7	2.58	
650	3/6/2007		6.5	4001722	3.4		0	0.0	3.4	2.40	
651	3/7/2007		6.5	4001722	3.4		0	0.0	3.4	2.40	
652	3/8/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
653	3/9/2007		7	4309547	3.7		0	0.0	3.7	2.58	
654	3/10/2007		7	4309547	3.7		0	0.0	3.7	2.58	
655	3/11/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
656	3/12/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
657	3/13/2007		8.5	5233021	4.5		0	0.0	4.5	3.14	
658	3/14/2007		8	4925197	4.2		0	0.0	4.2	2.95	
659	3/15/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
660	3/16/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	

	A	B	C	D	E	F	G	H	I	J	K
661	3/17/2007		7	4309547	3.7		0	0.0	3.7	2.58	
662	3/18/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
663	3/19/2007		7	4309547	3.7		0	0.0	3.7	2.58	
664	3/20/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
665	3/21/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
666	3/22/2007	2.5	2.5	1539124	1.3		0	0.0	3.8	2.67	
667	3/23/2007	17.5		0	0.0	28.5	17546013	15.0	2.5	1.73	
668	3/24/2007	8		0	0.0	10	6156496	5.3	2.7	1.91	
669	3/25/2007		7	4309547	3.7		0	0.0	3.7	2.58	
670	3/26/2007		8	4925197	4.2		0	0.0	4.2	2.95	
671	3/27/2007		8.5	5233021	4.5		0	0.0	4.5	3.14	
672	3/28/2007		9	5540846	4.7		0	0.0	4.7	3.32	
673	3/29/2007		8.5	5233021	4.5		0	0.0	4.5	3.14	
674	3/30/2007		9.5	5848671	5.0		0	0.0	5.0	3.51	
675	3/31/2007		9.5	5848671	5.0		0	0.0	5.0	3.51	
676	4/1/2007		10	6156496	5.3		0	0.0	5.3	3.69	
677	4/2/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
678	4/3/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
679	4/4/2007		10	6156496	5.3		0	0.0	5.3	3.69	
680	4/5/2007		10	6156496	5.3		0	0.0	5.3	3.69	
681	4/6/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
682	4/7/2007		10	6156496	5.3		0	0.0	5.3	3.69	
683	4/8/2007		11	6772145	5.8		0	0.0	5.8	4.06	
684	4/9/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
685	4/10/2007		10	6156496	5.3		0	0.0	5.3	3.69	
686	4/11/2007	5.5		0	0.0	1.5	923474	0.8	4.7	3.30	
687	4/12/2007		6.5	4001722	3.4		0	0.0	3.4	2.40	
688	4/13/2007	4.5		0	0.0	2	1231299	1.1	3.4	2.41	
689	4/14/2007	0.5	8	4925197	4.2		0	0.0	4.7	3.30	
690	4/15/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
691	4/16/2007		9.5	5848671	5.0		0	0.0	5.0	3.51	
692	4/17/2007		10	6156496	5.3		0	0.0	5.3	3.69	
693	4/18/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
694	4/19/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
695	4/20/2007		11	6772145	5.8		0	0.0	5.8	4.06	
696	4/21/2007		11	6772145	5.8		0	0.0	5.8	4.06	
697	4/22/2007		10	6156496	5.3		0	0.0	5.3	3.69	
698	4/23/2007		11	6772145	5.8		0	0.0	5.8	4.06	
699	4/24/2007		11.5	7079970	6.1		0	0.0	6.1	4.25	
700	4/25/2007	19.5		0	0.0	29	17853838	15.3	4.2	2.94	
701	4/26/2007		10	6156496	5.3		0	0.0	5.3	3.69	
702	4/27/2007	6.5		0	0.0	2.5	1539124	1.3	5.2	3.63	
703	4/28/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
704	4/29/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	

	A	B	C	D	E	F	G	H	I	J	K
705	4/30/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
706	5/1/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
707	5/2/2007		11	6772145	5.8		0	0.0	5.8	4.06	
708	5/3/2007		11	6772145	5.8		0	0.0	5.8	4.06	
709	5/4/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
710	5/5/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
711	5/6/2007		11	6772145	5.8		0	0.0	5.8	4.06	
712	5/7/2007		10	6156496	5.3		0	0.0	5.3	3.69	
713	5/8/2007	3.5	3	1846949	1.6		0	0.0	5.1	3.56	
714	5/9/2007		9.5	5848671	5.0		0	0.0	5.0	3.51	
715	5/10/2007		10	6156496	5.3		0	0.0	5.3	3.69	
716	5/11/2007		11.5	7079970	6.1		0	0.0	6.1	4.25	
717	5/12/2007		11.5	7079970	6.1		0	0.0	6.1	4.25	
718	5/13/2007		10	6156496	5.3		0	0.0	5.3	3.69	
719	5/14/2007		9	5540846	4.7		0	0.0	4.7	3.32	
720	5/15/2007	2.5	0.5	307825	0.3		0	0.0	2.8	1.93	
721	5/16/2007	1.5	2	1231299	1.1		0	0.0	2.6	1.79	
722	5/17/2007		7.5	4617372	4.0		0	0.0	4.0	2.77	
723	5/18/2007		10.5	6464321	5.5		0	0.0	5.5	3.88	
724	5/19/2007	40		0	0.0	72.5	44634595	38.2	1.8	1.24	
725	5/20/2007		10	6156496	5.3		0	0.0	5.3	3.69	
726	5/21/2007	2.5	3.5	2154774	1.8		0	0.0	4.3	3.04	
727	5/22/2007	2.5	3	1846949	1.6		0	0.0	4.1	2.86	
728											
729											

Appendix L

Calculated Reference ET from Meteorological Data

Table L1: Calculated Reference ET (ET_0) from Meteorological Data between June 2005 and May 2006

Row	A: Date	B: Tmax_C	C: Tmin_C	D: Tmean_C	E: Twet_C	F: Tdry_C	G: slope (delta)	H: e(Tmax)	I: e(Tmin)	J: e(s)	K: e(Twet)	L: e(a)	M: Ra (for 23N)	N: N (for 23N)	O: n/N (high)	P: n/N (low)	Q: Rs	R: Rso	S: Rns	T: Rnl	U: Rn	V: G	W: ET0_low (mm/d)	X: ET0_high (mm/d)
8	6/1/2005	35	27.5	31.25	30.6	33.2	0.259	5.623	3.671	4.647	4.391	4.218	40.15	13.4	1	0.4	18.07	30.12	13.91	1.02	12.90	9.84	1.70	6.42
9	6/2/2005	35.5	28	31.75	30.4	34	0.265	5.780	3.780	4.780	4.341	4.101	40.15	13.4	1	0.4	18.07	30.12	13.91	1.10	12.81	0.16	4.58	6.65
10	6/3/2005	35.2	28	31.6	30.2	33.4	0.263	5.685	3.780	4.733	4.292	4.078	40.15	13.4	1	0.4	18.07	30.12	13.91	1.11	12.80	-0.05	4.56	6.67
11	6/4/2005	33.5	25.2	29.35	30	32.6	0.236	5.173	3.206	4.189	4.243	4.069	40.15	13.4	1	0.4	18.07	30.12	13.91	1.09	12.82	-0.71	3.41	6.11
12	6/5/2005	34.3	23.5	28.9	30.4	33.2	0.230	5.409	2.896	4.152	4.341	4.154	40.15	13.4	0.9	0	10.04	30.12	7.73	0.22	7.51	-0.14	1.74	5.44
13	6/6/2005	33.4	24.5	28.95	29.8	32.8	0.231	5.144	3.075	4.109	4.195	3.994	40.15	13.4	0.76	0	10.04	30.12	7.73	0.25	7.48	0.02	1.99	4.98
14	6/7/2005	34.7	26.2	30.45	31.4	33.7	0.249	5.530	3.401	4.466	4.596	4.442	40.15	13.4	1	0.4	18.07	30.12	13.91	0.86	13.05	0.47	3.03	5.90
15	6/8/2005	34.8	25.6	30.2	31.5	34	0.246	5.561	3.283	4.422	4.622	4.455	40.15	13.4	1	0.4	18.07	30.12	13.91	0.85	13.06	-0.08	3.01	5.98
16	6/9/2005	36.4	28.5	32.45	31.4	34.6	0.275	6.073	3.891	4.982	4.596	4.382	40.15	13.4	1	0.4	18.07	30.12	13.91	0.92	12.99	0.71	4.32	6.56
17	6/10/2005	35.7	27.3	31.5	31.2	34	0.262	5.844	3.629	4.736	4.544	4.357	40.15	13.4	1	0.4	18.07	30.12	13.91	0.93	12.98	-0.30	4.05	6.55
18	6/11/2005	34.2	27.8	31	31.5	33.5	0.256	5.379	3.736	4.557	4.622	4.488	40.15	13.4	1	0.4	18.07	30.12	13.91	0.84	13.07	-0.16	3.32	6.19
19	6/12/2005	34	26.8	30.4	30.6	33.2	0.248	5.319	3.524	4.421	4.391	4.218	40.15	13.4	1	0.4	18.07	30.12	13.91	1.01	12.91	-0.19	3.56	6.20
20	6/13/2005	35.4	28.4	31.9	30.4	34	0.267	5.748	3.869	4.809	4.341	4.101	40.15	13.4	1	0.4	18.07	30.12	13.91	1.10	12.81	0.47	4.56	6.60
21	6/14/2005	33.5	25.3	29.4	30.2	32.2	0.236	5.173	3.225	4.199	4.292	4.158	40.15	13.4	0.53	0	10.04	30.12	7.73	0.22	7.50	-0.79	2.01	4.33
22	6/15/2005	32.5	25	28.75	29.2	31.4	0.229	4.891	3.168	4.029	4.052	3.905	40.15	13.4	0.75	0	10.04	30.12	7.73	0.26	7.47	-0.20	2.05	4.96
23	6/16/2005	31.5	25.6	28.55	29.7	31.2	0.226	4.622	3.283	3.952	4.171	4.070	40.15	13.4	1	0.4	18.07	30.12	13.91	1.08	12.84	-0.06	2.64	5.58
24	6/17/2005	34.2	25	29.6	31	33	0.239	5.379	3.168	4.273	4.493	4.359	40.15	13.4	0.54	0	10.04	30.12	7.73	0.20	7.53	0.33	1.47	3.97
25	6/18/2005	34.6	28.5	31.55	31.2	33.4	0.263	5.500	3.891	4.695	4.544	4.397	40.15	13.4	1	0.4	18.07	30.12	13.91	0.90	13.01	0.61	3.66	6.22
26	6/19/2005	33	26.2	29.6	31.2	32.7	0.239	5.030	3.401	4.216	4.544	4.444	40.15	13.4	1	0.4	18.07	30.12	13.91	0.85	13.06	-0.61	2.63	5.84
27	6/20/2005	34.6	27.5	31.05	30.6	33.4	0.256	5.500	3.671	4.585	4.391	4.204	40.15	13.4	1	0.4	18.07	30.12	13.91	1.02	12.89	0.46	3.84	6.25
28	6/21/2005	35	27.6	31.3	31.5	34	0.260	5.623	3.693	4.658	4.622	4.455	40.15	13.4	1	0.4	18.07	30.12	13.91	0.86	13.05	0.08	3.57	6.28
29	6/22/2005	34	27.5	30.75	31.2	33.2	0.253	5.319	3.671	4.495	4.544	4.410	40.15	13.4	0.92	0	10.04	30.12	7.73	0.19	7.54	-0.17	2.03	5.85
30	6/23/2005	32.8	27.4	30.1	30.6	32.8	0.245	4.974	3.650	4.312	4.391	4.244	40.15	13.4	1	0.4	18.07	30.12	13.91	0.98	12.93	-0.20	3.24	6.04
31	6/24/2005	33	27	30	30.7	32.7	0.243	5.030	3.565	4.298	4.416	4.283	40.15	13.4	0.99	0	10.04	30.12	7.73	0.21	7.52	-0.03	1.80	5.90
32	6/25/2005	31	25.7	28.35	29.4	31	0.224	4.493	3.302	3.897	4.099	3.992	40.15	13.4	0.51	0	10.04	30.12	7.73	0.24	7.48	-0.52	1.57	3.92
33	6/26/2005	32.2	25.8	29	29	31.5	0.231	4.809	3.322	4.065	4.006	3.839	40.15	13.4	1	0.4	18.07	30.12	13.91	1.24	12.68	0.20	3.41	5.86
34	6/27/2005	31	26	28.5	28.4	31	0.226	4.493	3.361	3.927	3.869	3.695	40.15	13.4	0.99	0	10.04	30.12	7.73	0.29	7.44	-0.16	2.29	5.84
35	6/28/2005	27	25.5	26.25	26.4	27.2	0.201	3.565	3.263	3.414	3.442	3.388	40.15	13.4	0.61	0	10.04	30.12	7.73	0.32	7.40	-0.71	1.81	4.17
36	6/29/2005	28.4	25.4	26.9	26.7	28	0.208	3.869	3.244	3.556	3.503	3.416	40.15	13.4	0.73	0	10.04	30.12	7.73	0.32	7.41	0.20	1.93	4.53
37	6/30/2005	28	26	27	27.5	28.4	0.209	3.780	3.361	3.571	3.671	3.611	40.15	13.4	1	0.4	18.07	30.12	13.91	1.35	12.56	0.03	2.64	5.32
38	7/1/2005	29.2	25.5	27.35	28.5	29.4	0.213	4.052	3.263	3.658	3.891	3.831	39.75	13.25	0.98	0	9.94	29.82	7.65	0.26	7.39	0.11	1.16	5.12
39	7/2/2005	28	25	26.5	26.8	27.6	0.204	3.780	3.168	3.474	3.524	3.470	39.75	13.25	0.52	0	9.94	29.82	7.65	0.31	7.34	-0.27	1.65	3.72
40	7/3/2005	26.4	24.4	25.4	26	26.3	0.193	3.442	3.056	3.249	3.361	3.341	39.75	13.25	0	0.4	17.89	29.82	13.77	1.51	12.27	-0.35	2.40	1.86
41	7/4/2005	26.5	24.5	25.5	26.2	26.7	0.194	3.462	3.075	3.268	3.401	3.368	39.75	13.25	0	0.4	17.89	29.82	13.77	1.49	12.28	0.03	2.32	1.76
42	7/5/2005	31.4	24.6	28	26.8	27.4	0.220	4.596	3.093	3.844	3.524	3.484	39.75	13.25	0.15	0	9.94	29.82	7.65	0.32	7.33	0.79	2.37	2.72
43	7/6/2005	32.2	25.2	28.7	29	30.6	0.228	4.809	3.206	4.007	4.006	3.899	39.75	13.25	1	0.4	17.89	29.82	13.77	1.19	12.58	0.22	3.08	5.65
44	7/7/2005	32.5	26.2	29.35	29.6	31.7	0.236	4.891	3.401	4.146	4.147	4.006	39.75	13.25	1	0.4	17.89	29.82	13.77	1.13	12.64	0.20	3.21	5.79
45	7/8/2005	32.2	26.5	29.35	30	32	0.236	4.809	3.462	4.135	4.243	4.109	39.75	13.25	1	0.4	17.89	29.82	13.77	1.06	12.71	0.00	3.00	5.75
46	7/9/2005	31.7	26.8	29.25	29.5	31.2	0.234	4.675	3.524	4.099	4.123	4.009	39.75	13.25	1	0.4	17.89	29.82	13.77	1.13	12.65	-0.03	3.14	5.78
47	7/10/2005	30.5	26.4	28.45	29	30.7	0.225	4.366	3.442	3.904	4.006	3.892	39.75	13.25	0.95	0	9.94	29.82	7.65	0.26	7.39	-0.25	1.76	5.47
48	7/11/2005	29.2	25.4	27.3	28.4	29.4	0.212	4.052	3.244	3.648	3.869	3.802	39.75	13.25	0.52	0	9.94	29.82	7.65	0.27	7.38	-0.36	1.31	3.68
49	7/12/2005	32	26.8	29.4	29.2	31.2	0.236	4.755	3.524	4.139	4.052	3.919	39.75	13.25	0.77	0	9.94	29.82	7.65	0.26	7.39	0.66	2.08	4.90

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
50	7/13/2005	27	26.2	26.6	26.8	27	0.205	3.565	3.401	3.483	3.524	3.510	39.75	13.25	0	0	9.94	29.82	7.65	0.31	7.34	-0.88	1.71	2.14
51	7/14/2005	28	24.6	26.3	26.2	26.7	0.202	3.780	3.093	3.437	3.401	3.368	39.75	13.25	0	0	9.94	29.82	7.65	0.33	7.32	-0.09	1.78	2.04
52	7/15/2005	26.5	24.5	25.5	26	25.6	0.194	3.462	3.075	3.268	3.361	3.388	39.75	13.25	0	0	9.94	29.82	7.65	0.32	7.33	-0.25	1.28	1.79
53	7/16/2005	31.5	25.5	28.5	28.6	30.7	0.226	4.622	3.263	3.943	3.914	3.774	39.75	13.25	0.92	0	9.94	29.82	7.65	0.28	7.38	0.95	1.87	5.18
54	7/17/2005	33.2	26.2	29.7	29.7	32.2	0.240	5.087	3.401	4.244	4.171	4.004	39.75	13.25	1	0.4	17.89	29.82	13.77	1.14	12.64	0.38	3.42	5.88
55	7/18/2005	32	26.8	29.4	29.5	31.7	0.236	4.755	3.524	4.139	4.123	3.976	39.75	13.25	1	0.4	17.89	29.82	13.77	1.15	12.62	-0.09	3.33	5.89
56	7/19/2005	32	27.4	29.7	29.2	31.8	0.240	4.755	3.650	4.202	4.052	3.878	39.75	13.25	1	0.4	17.89	29.82	13.77	1.22	12.55	0.09	3.66	6.00
57	7/20/2005	32.6	27.5	30.05	29.7	32	0.244	4.918	3.671	4.295	4.171	4.017	39.75	13.25	1	0.4	17.89	29.82	13.77	1.13	12.64	0.11	3.59	6.02
58	7/21/2005	31.4	26.4	28.9	28.6	30.8	0.230	4.596	3.442	4.019	3.914	3.767	39.75	13.25	0	0.4	17.89	29.82	13.77	1.28	12.49	-0.36	3.55	2.45
59	7/22/2005	30	25.5	27.75	28.5	29.2	0.217	4.243	3.263	3.753	3.891	3.845	39.75	13.25	0.25	0	9.94	29.82	7.65	0.26	7.39	-0.36	1.50	2.85
60	7/23/2005	32	27	29.5	29	31.7	0.237	4.755	3.565	4.160	4.006	3.825	39.75	13.25	0.95	0	9.94	29.82	7.65	0.27	7.38	0.55	2.38	5.68
61	7/24/2005	32.2	26.8	29.5	29.7	32	0.237	4.809	3.524	4.166	4.171	4.017	39.75	13.25	0.98	0	9.94	29.82	7.65	0.24	7.41	0.00	2.07	5.80
62	7/25/2005	32.4	26.5	29.45	29.4	32.4	0.237	4.863	3.462	4.163	4.099	3.899	39.75	13.25	1	0.4	17.89	29.82	13.77	1.20	12.57	-0.02	3.54	5.96
63	7/26/2005	30.4	27.2	28.8	28.8	30.7	0.229	4.341	3.607	3.974	3.960	3.833	39.75	13.25	1	0.4	17.89	29.82	13.77	1.24	12.54	-0.20	3.25	5.79
64	7/27/2005	31.8	26.8	29.3	28.5	31	0.235	4.701	3.524	4.113	3.891	3.724	39.75	13.25	0.96	0	9.94	29.82	7.65	0.29	7.37	0.16	2.59	5.83
65	7/28/2005	31.6	26.5	29.05	29	31.2	0.232	4.648	3.462	4.055	4.006	3.859	39.75	13.25	0.94	0	9.94	29.82	7.65	0.27	7.39	-0.08	2.19	5.64
66	7/29/2005	31.7	26.7	29.2	28.8	31	0.234	4.675	3.503	4.089	3.960	3.813	39.75	13.25	0.89	0	9.94	29.82	7.65	0.27	7.38	0.05	2.35	5.51
67	7/30/2005	31	27.3	29.15	29.2	30.8	0.233	4.493	3.629	4.061	4.052	3.945	39.75	13.25	1	0.4	17.89	29.82	13.77	1.17	12.61	-0.02	3.18	5.77
68	7/31/2005	31.8	27	29.4	29	31.4	0.236	4.701	3.565	4.133	4.006	3.845	39.75	13.25	1	0.4	17.89	29.82	13.77	1.24	12.54	0.08	3.57	5.93
69	8/1/2005	32.8	27.5	30.15	29.8	32	0.245	4.974	3.671	4.323	4.195	4.048	38.35	12.8	1	0.4	17.26	28.77	13.29	1.11	12.18	0.24	3.44	5.78
70	8/2/2005	32.5	26.4	29.45	28.2	31.4	0.237	4.891	3.442	4.166	3.824	3.610	38.35	12.8	0.94	0	9.59	28.77	7.38	0.30	7.08	-0.22	3.01	5.81
71	8/3/2005	31.4	26.4	28.9	28.6	30.8	0.230	4.596	3.442	4.019	3.914	3.767	38.35	12.8	0.87	0	9.59	28.77	7.38	0.28	7.10	-0.17	2.27	5.24
72	8/4/2005	31	26.2	28.6	29	31	0.227	4.493	3.401	3.947	4.006	3.872	38.35	12.8	0.91	0	9.59	28.77	7.38	0.26	7.12	-0.09	1.82	5.16
73	8/5/2005	31.2	26.6	28.9	29.2	30.7	0.230	4.544	3.483	4.013	4.052	3.952	38.35	12.8	0.92	0	9.59	28.77	7.38	0.25	7.13	0.09	1.76	5.17
74	8/6/2005	31.4	27.2	29.3	29.5	31.2	0.235	4.596	3.607	4.102	4.123	4.009	38.35	12.8	0.58	0	9.59	28.77	7.38	0.24	7.14	0.13	1.84	4.07
75	8/7/2005	32.2	27	29.6	29.2	31.5	0.239	4.809	3.565	4.187	4.052	3.899	38.35	12.8	0.89	0	9.59	28.77	7.38	0.26	7.12	0.09	2.32	5.36
76	8/8/2005	30	26.8	28.4	29	30.2	0.225	4.243	3.524	3.883	4.006	3.925	38.35	12.8	0.74	0	9.59	28.77	7.38	0.25	7.13	-0.38	1.59	4.52
77	8/9/2005	30.5	25.4	27.95	28.7	30	0.220	4.366	3.244	3.805	3.937	3.850	38.35	12.8	0.88	0	9.59	28.77	7.38	0.26	7.12	-0.14	1.51	4.86
78	8/10/2005	30	25.7	27.85	28.4	29.2	0.218	4.243	3.302	3.773	3.869	3.815	38.35	12.8	0.76	0	9.59	28.77	7.38	0.27	7.11	-0.03	1.49	4.41
79	8/11/2005	31.5	25.6	28.55	28.2	30	0.226	4.622	3.283	3.952	3.824	3.704	38.35	12.8	0.87	0	9.59	28.77	7.38	0.29	7.10	0.22	2.17	5.08
80	8/12/2005	31.5	26	28.75	27.8	30.4	0.229	4.622	3.361	3.992	3.736	3.562	38.35	12.8	0.42	0	9.59	28.77	7.38	0.31	7.07	0.06	2.64	3.83
81	8/13/2005	32	27.4	29.7	28.6	31.7	0.240	4.755	3.650	4.202	3.914	3.707	38.35	12.8	0.85	0	9.59	28.77	7.38	0.29	7.09	0.30	2.75	5.35
82	8/14/2005	33.5	26.6	30.05	29.8	32.5	0.244	5.173	3.483	4.328	4.195	4.014	38.35	12.8	1	0.4	17.26	28.77	13.29	1.13	12.15	0.11	3.56	5.84
83	8/15/2005	32.8	25.3	29.05	29.4	32.4	0.232	4.974	3.225	4.099	4.099	3.899	38.35	12.8	1	0.4	17.26	28.77	13.29	1.20	12.09	-0.32	3.33	5.72
84	8/16/2005	32.7	25	28.85	29.7	31.7	0.230	4.946	3.168	4.057	4.171	4.037	38.35	12.8	1	0.4	17.26	28.77	13.29	1.10	12.19	-0.06	2.84	5.47
85	8/17/2005	31.4	27.3	29.35	29	31	0.236	4.596	3.629	4.112	4.006	3.872	38.35	12.8	0.8	0	9.59	28.77	7.38	0.26	7.12	0.16	2.18	4.95
86	8/18/2005	31.5	28	29.75	28.8	30.8	0.240	4.622	3.780	4.201	3.960	3.826	38.35	12.8	1	0.4	17.26	28.77	13.29	1.26	12.03	0.13	3.66	5.80
87	8/19/2005	30.5	26.5	28.5	29.5	30.6	0.226	4.366	3.462	3.914	4.123	4.049	38.35	12.8	0.98	0	9.59	28.77	7.38	0.24	7.15	-0.39	1.38	5.28
88	8/20/2005	30	25.6	27.8	27.2	28.5	0.218	4.243	3.283	3.763	3.607	3.521	38.35	12.8	0.84	0	9.59	28.77	7.38	0.31	7.07	-0.22	2.23	4.98
89	8/21/2005	29.8	25	27.4	28	29.7	0.213	4.195	3.168	3.681	3.780	3.666	38.35	12.8	0.8	0	9.59	28.77	7.38	0.29	7.09	-0.13	1.63	4.57
90	8/22/2005	30.9	26.5	28.7	29.2	30.2	0.228	4.467	3.462	3.965	4.052	3.985	38.35	12.8	0.97	0	9.59	28.77	7.38	0.25	7.14	0.41	1.48	5.15
91	8/23/2005	32.5	27.4	29.95	29.4	31.4	0.243	4.891	3.650	4.270	4.099	3.966	38.35	12.8	1	0.4	17.26	28.77	13.29	1.16	12.12	0.39	3.46	5.72
92	8/24/2005	30	26.6	28.3	28.7	30	0.223	4.243	3.483	3.863	3.937	3.850	38.35	12.8	0.41	0	9.59	28.77	7.38	0.26	7.12	-0.52	1.75	3.48
93	8/25/2005	30.5	25	27.75	29.2	30.6	0.217	4.366	3.168	3.767	4.052	3.959	38.35	12.8	1	0.4	17.26	28.77	13.29	1.14	12.15	-0.17	2.26	5.12
94	8/26/2005	32.1	26.7	29.4	29.4	31.6	0.236	4.782	3.503	4.142	4.099	3.952	38.35	12.8	1	0.4	17.26	28.77	13.29	1.17	12.12	0.52	3.14	5.52
95	8/27/2005	31.5	26.5	29	28.7	31.2	0.231	4.622	3.462	4.042	3.937	3.770	38.35	12.8	1	0.4	17.26	28.77	13.29	1.28	12.01	-0.13	3.44	5.69
96	8/28/2005	32.4	27.3	29.85	29.6	31.5	0.242	4.863	3.629	4.246	4.147	4.020	38.35	12.8	1	0.4	17.26	28.77	13.29	1.13	12.16	0.27	3.31	5.68
97	8/29/2005	32.2	27.4	29.8	29.7	32.4	0.241	4.809	3.650	4.229	4.171	3.990	38.35	12.8	1	0.4	17.26	28.77	13.29	1.15	12.14	-0.02	3.40	5.77
98	8/30/2005	32.5	28	30.25	29.6	32	0.246	4.891	3.780	4.335	4.147	3.986	38.35	12.8	1	0.4	17.26	28.77	13.29	1.16	12.13	0.14	3.63	5.87

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
99	8/31/2005	33.6	27	30.3	30.2	32.7	0.247	5.202	3.565	4.384	4.292	4.125	38.35	12.8	1	0.4	17.26	28.77	13.29	1.06	12.22	0.02	3.48	5.87
100	9/1/2005	32	27.5	29.75	30.4	32	0.240	4.755	3.671	4.213	4.341	4.234	35.15	12.1	1	0.6	19.33	26.37	14.89	1.37	13.52	-0.17	3.14	5.09
101	9/2/2005	32.6	27	29.8	30	32.5	0.241	4.918	3.565	4.242	4.243	4.076	35.15	12.1	1	0.6	19.33	26.37	14.89	1.52	13.37	0.02	3.50	5.19
102	9/3/2005	32	27.4	29.7	29.4	31.4	0.240	4.755	3.650	4.202	4.099	3.966	35.15	12.1	0.96	0	8.79	26.37	6.77	0.25	6.51	-0.03	2.08	5.11
103	9/4/2005	33.2	27.5	30.35	29.7	32.2	0.248	5.087	3.671	4.379	4.171	4.004	35.15	12.1	1	0.6	19.33	26.37	14.89	1.59	13.29	0.20	3.96	5.38
104	9/5/2005	29.5	26.5	28	28.5	29.8	0.220	4.123	3.462	3.792	3.891	3.805	35.15	12.1	1	0.6	19.33	26.37	14.89	1.73	13.16	-0.74	3.08	4.95
105	9/6/2005	32.8	27.4	30.1	29.6	31.6	0.245	4.974	3.650	4.312	4.147	4.013	35.15	12.1	1	0.6	19.33	26.37	14.89	1.58	13.31	0.66	3.66	5.15
106	9/7/2005	33	26.7	29.85	30	32.2	0.242	5.030	3.503	4.267	4.243	4.096	35.15	12.1	1	0.6	19.33	26.37	14.89	1.50	13.39	-0.08	3.54	5.23
107	9/8/2005	32.2	25.4	28.8	29.7	32	0.229	4.809	3.244	4.026	4.171	4.017	35.15	12.1	1	0.6	19.33	26.37	14.89	1.55	13.34	-0.33	3.14	5.02
108	9/9/2005	34	25.4	29.7	30.2	33.2	0.240	5.319	3.244	4.282	4.292	4.092	35.15	12.1	1	0.6	19.33	26.37	14.89	1.50	13.39	0.28	3.50	5.15
109	9/10/2005	32.5	26.4	29.45	29.4	32	0.237	4.891	3.442	4.166	4.099	3.925	35.15	12.1	0.98	0	8.79	26.37	6.77	0.26	6.51	-0.08	2.10	5.16
110	9/11/2005	31.8	24.5	28.15	28.6	30.7	0.222	4.701	3.075	3.888	3.914	3.774	35.15	12.1	0.45	0	8.79	26.37	6.77	0.27	6.49	-0.41	1.83	3.38
111	9/12/2005	31.6	27	29.3	29	31	0.235	4.648	3.565	4.107	4.006	3.872	35.15	12.1	1	0.6	19.33	26.37	14.89	1.69	13.19	0.36	3.52	5.06
112	9/13/2005	31.5	25.2	28.35	28.3	31.4	0.224	4.622	3.206	3.914	3.846	3.639	35.15	12.1	0.79	0	8.79	26.37	6.77	0.30	6.47	-0.30	2.21	4.54
113	9/14/2005	32.4	26.2	29.3	28.6	31.8	0.235	4.863	3.401	4.132	3.914	3.700	35.15	12.1	1	0.6	19.33	26.37	14.89	1.86	13.03	0.30	3.97	5.25
114	9/15/2005	33.8	26	29.9	30	33.2	0.242	5.260	3.361	4.311	4.243	4.029	35.15	12.1	1	0.6	19.33	26.37	14.89	1.56	13.32	0.19	3.73	5.27
115	9/16/2005	34.5	26	30.25	30.7	33.4	0.246	5.469	3.361	4.415	4.416	4.236	35.15	12.1	1	0.6	19.33	26.37	14.89	1.38	13.51	0.11	3.57	5.28
116	9/17/2005	32	25.2	28.6	29.2	31.5	0.227	4.755	3.206	3.980	4.052	3.899	35.15	12.1	0.88	0	8.79	26.37	6.77	0.26	6.51	-0.52	1.80	4.73
117	9/18/2005	33	27.4	30.2	29.6	32.2	0.246	5.030	3.650	4.340	4.147	3.973	35.15	12.1	1	0.6	19.33	26.37	14.89	1.62	13.27	0.50	3.86	5.26
118	9/19/2005	33.5	27	30.25	29.7	32.6	0.246	5.173	3.565	4.369	4.171	3.977	35.15	12.1	1	0.6	19.33	26.37	14.89	1.62	13.27	0.02	4.03	5.44
119	9/20/2005	30.5	26	28.25	28.6	29.8	0.223	4.366	3.361	3.864	3.914	3.834	35.15	12.1	0.83	0	8.79	26.37	6.77	0.27	6.50	-0.63	1.68	4.49
120	9/21/2005	32.4	25.2	28.8	28.7	31.5	0.229	4.863	3.206	4.035	3.937	3.750	35.15	12.1	0	0.6	19.33	26.37	14.89	1.80	13.09	0.17	3.64	2.10
121	9/22/2005	31.8	26.4	29.1	29	29.6	0.233	4.701	3.442	4.072	4.006	3.966	35.15	12.1	0.88	0	8.79	26.37	6.77	0.25	6.52	0.09	1.73	4.62
122	9/23/2005	30.5	25.4	27.95	28.4	30.5	0.220	4.366	3.244	3.805	3.869	3.729	35.15	12.1	0.85	0	8.79	26.37	6.77	0.28	6.49	-0.36	1.72	4.49
123	9/24/2005	30.6	26.7	28.65	29.7	30.2	0.227	4.391	3.503	3.947	4.171	4.137	35.15	12.1	1	0.6	19.33	26.37	14.89	1.44	13.45	0.22	2.54	4.65
124	9/25/2005	32.2	25.5	28.85	28.6	29	0.230	4.809	3.263	4.036	3.914	3.887	35.15	12.1	1	0.6	19.33	26.37	14.89	1.67	13.22	0.06	3.36	5.00
125	9/26/2005	32.6	25.2	28.9	29	29.8	0.230	4.918	3.206	4.062	4.006	3.952	35.15	12.1	0.93	0	8.79	26.37	6.77	0.25	6.51	0.02	1.75	4.79
126	9/27/2005	32.5	27	29.75	29.6	31.4	0.240	4.891	3.565	4.228	4.147	4.026	35.15	12.1	1	0.6	19.33	26.37	14.89	1.56	13.33	0.27	3.52	5.13
127	9/28/2005	33.5	24.5	29	29.7	32.5	0.231	5.173	3.075	4.124	4.171	3.983	35.15	12.1	0.24	0	8.79	26.37	6.77	0.25	6.52	-0.24	1.89	2.80
128	9/29/2005	30	26.4	28.2	27.7	28.7	0.222	4.243	3.442	3.842	3.714	3.648	35.15	12.1	1	0.6	19.33	26.37	14.89	1.88	13.01	-0.25	3.47	5.02
129	9/30/2005	31.5	26.8	29.15	29	30.8	0.233	4.622	3.524	4.073	4.006	3.885	35.15	12.1	1	0.6	19.33	26.37	14.89	1.68	13.21	0.30	3.42	5.02
130	10/1/2005	27.6	25.3	26.45	26.7	27.4	0.203	3.693	3.225	3.459	3.503	3.456	30.6	11.45	0.74	0	7.65	22.95	5.89	0.31	5.58	-0.85	1.39	3.44
131	10/2/2005	28	25	26.5	27.2	28	0.204	3.780	3.168	3.474	3.607	3.554	30.6	11.45	0	0	7.65	22.95	5.89	0.30	5.59	0.02	1.00	1.38
132	10/3/2005	29.2	25.2	27.2	27.6	28.6	0.211	4.052	3.206	3.629	3.693	3.626	30.6	11.45	0	0	7.65	22.95	5.89	0.29	5.60	0.22	1.19	1.45
133	10/4/2005	29.5	25	27.25	28.2	29	0.212	4.123	3.168	3.645	3.824	3.771	30.6	11.45	0.51	0	7.65	22.95	5.89	0.27	5.62	0.02	0.91	2.62
134	10/5/2005	31.4	26	28.7	28.8	31.2	0.228	4.596	3.361	3.979	3.960	3.799	30.6	11.45	1	0.6	16.83	22.95	12.96	1.75	11.21	0.46	2.89	4.19
135	10/6/2005	31.4	24.2	27.8	28.2	31	0.218	4.596	3.020	3.808	3.824	3.637	30.6	11.45	1	0.6	16.83	22.95	12.96	1.88	11.08	-0.28	2.96	4.28
136	10/7/2005	32.2	24.4	28.3	29.3	31.5	0.223	4.809	3.056	3.933	4.076	3.929	30.6	11.45	1	0.6	16.83	22.95	12.96	1.62	11.34	0.16	2.53	4.09
137	10/8/2005	31.5	25	28.25	29	31.6	0.223	4.622	3.168	3.895	4.006	3.832	30.6	11.45	1	0.6	16.83	22.95	12.96	1.71	11.25	-0.02	2.69	4.18
138	10/9/2005	33	25.8	29.4	29.2	32.4	0.236	5.030	3.322	4.176	4.052	3.838	30.6	11.45	1	0.6	16.83	22.95	12.96	1.73	11.23	0.36	3.32	4.46
139	########	33	25.8	29.4	29.7	32.6	0.236	5.030	3.322	4.176	4.171	3.977	30.6	11.45	1	0.6	16.83	22.95	12.96	1.60	11.36	0.00	3.10	4.45
140	########	31.5	26.5	29	29.6	31.8	0.231	4.622	3.462	4.042	4.147	4.000	30.6	11.45	1	0.6	16.83	22.95	12.96	1.57	11.39	-0.13	2.74	4.29
141	########	32.8	25	28.9	28.7	31.2	0.230	4.974	3.168	4.071	3.937	3.770	30.6	11.45	1	0.6	16.83	22.95	12.96	1.78	11.18	-0.03	3.29	4.47
142	########	32	24.8	28.4	29.6	32	0.225	4.755	3.130	3.943	4.147	3.986	30.6	11.45	0.88	0	7.65	22.95	5.89	0.25	5.65	-0.16	1.20	3.84
143	########	34	25.7	29.85	29.5	33	0.242	5.319	3.302	4.311	4.123	3.889	30.6	11.45	1	0.6	16.83	22.95	12.96	1.69	11.27	0.46	3.52	4.56
144	########	33.6	25.2	29.4	29.2	32.7	0.236	5.202	3.206	4.204	4.052	3.818	30.6	11.45	1	0.6	16.83	22.95	12.96	1.75	11.21	-0.14	3.54	4.64
145	########	33.2	26	29.6	29.4	32.2	0.239	5.087	3.361	4.224	4.099	3.912	30.6	11.45	1	0.6	16.83	22.95	12.96	1.66	11.30	0.06	3.35	4.54
146	########	30.5	25.8	28.15	28.6	30.4	0.222	4.366	3.322	3.844	3.914	3.794	30.6	11.45	0.98	0	7.65	22.95	5.89	0.27	5.62	-0.46	1.49	4.20
147	########	29.5	25	27.25	28.7	29.6	0.212	4.123	3.168	3.645	3.937	3.877	30.6	11.45	0.95	0	7.65	22.95	5.89	0.26	5.63	-0.28	0.71	3.70

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
148	########	29	23.4	26.2	26.8	28	0.201	4.006	2.878	3.442	3.524	3.444	30.6	11.45	0	0	7.65	22.95	5.89	0.32	5.57	-0.33	1.26	1.56
149	########	24.2	21.6	22.9	23.2	23.8	0.169	3.020	2.580	2.800	2.844	2.804	30.6	11.45	0	0	7.65	22.95	5.89	0.40	5.49	-1.04	1.28	1.61
150	########	25.4	22.6	24	25.4	26	0.179	3.244	2.742	2.993	3.244	3.204	30.6	11.45	0	0	7.65	22.95	5.89	0.34	5.55	0.35	0.46	1.02
151	########	27	23.5	25.25	25.6	26.4	0.191	3.565	2.896	3.230	3.283	3.229	30.6	11.45	0.68	0	7.65	22.95	5.89	0.34	5.55	0.39	1.08	2.85
152	########	24	21	22.5	22.7	23	0.165	2.984	2.487	2.735	2.759	2.739	30.6	11.45	0	0	7.65	22.95	5.89	0.41	5.49	-0.87	1.23	1.54
153	########	27.5	21.5	24.5	26	26.7	0.184	3.671	2.564	3.118	3.361	3.315	30.6	11.45	0.56	0	7.65	22.95	5.89	0.33	5.56	0.63	0.47	2.24
154	########	30.2	22.8	26.5	27.8	29	0.204	4.292	2.776	3.534	3.736	3.656	30.6	11.45	1	0.6	16.83	22.95	12.96	1.83	11.13	0.63	1.95	3.59
155	########	30.5	23.5	27	28	29.6	0.209	4.366	2.896	3.631	3.780	3.673	30.6	11.45	1	0.6	16.83	22.95	12.96	1.83	11.13	0.16	2.29	3.86
156	########	31	24.5	27.75	28.4	30.8	0.217	4.493	3.075	3.784	3.869	3.708	30.6	11.45	1	0.6	16.83	22.95	12.96	1.81	11.15	0.24	2.62	4.04
157	########	29.8	25	27.4	28.6	30	0.213	4.195	3.168	3.681	3.914	3.820	30.6	11.45	1	0.6	16.83	22.95	12.96	1.70	11.26	-0.11	2.16	3.89
158	########	30.9	23.8	27.35	28.5	30.2	0.213	4.467	2.948	3.708	3.891	3.778	30.6	11.45	1	0.6	16.83	22.95	12.96	1.74	11.22	-0.02	2.30	3.93
159	########	31	24.5	27.75	28.2	30.5	0.217	4.493	3.075	3.784	3.824	3.670	30.6	11.45	1	0.6	16.83	22.95	12.96	1.85	11.11	0.13	2.73	4.10
160	########	31.2	26	28.6	28.4	30	0.227	4.544	3.361	3.953	3.869	3.762	30.6	11.45	1	0.6	16.83	22.95	12.96	1.78	11.18	0.27	2.94	4.23
161	11/1/2005	29.5	24.5	27	27.6	29.2	0.209	4.123	3.075	3.599	3.693	3.586	26.05	10.85	1	0.8	16.93	19.54	13.04	2.44	10.59	-0.50	2.46	3.37
162	11/2/2005	30	25.3	27.65	27.8	29.7	0.216	4.243	3.225	3.734	3.736	3.609	26.05	10.85	1	0.8	16.93	19.54	13.04	2.44	10.60	0.20	2.62	3.36
163	11/3/2005	30.4	21.5	25.95	27.2	29.2	0.198	4.341	2.564	3.453	3.607	3.474	26.05	10.85	1	0.8	16.93	19.54	13.04	2.55	10.49	-0.54	2.30	3.24
164	11/4/2005	29.6	23	26.3	27.5	28.8	0.202	4.147	2.809	3.478	3.671	3.584	26.05	10.85	1	0.8	16.93	19.54	13.04	2.42	10.62	0.11	1.98	3.02
165	11/5/2005	30.5	19.6	25.05	28	29.8	0.189	4.366	2.281	3.324	3.780	3.660	26.05	10.85	1	0.8	16.93	19.54	13.04	2.30	10.74	-0.39	1.40	2.81
166	11/6/2005	30	22.5	26.25	27.6	29.7	0.201	4.243	2.726	3.484	3.693	3.552	26.05	10.85	1	0.8	16.93	19.54	13.04	2.46	10.58	0.38	2.01	2.99
167	11/7/2005	30	20	25	28	30	0.189	4.243	2.338	3.291	3.780	3.646	26.05	10.85	1	0.8	16.93	19.54	13.04	2.31	10.73	-0.39	1.34	2.77
168	11/8/2005	28.2	21.5	24.85	26.6	28.4	0.187	3.824	2.564	3.194	3.483	3.362	26.05	10.85	1	0.8	16.93	19.54	13.04	2.64	10.40	-0.05	1.71	2.82
169	11/9/2005	31.2	23	27.1	27.4	30.7	0.210	4.544	2.809	3.677	3.650	3.429	26.05	10.85	1	0.8	16.93	19.54	13.04	2.64	10.40	0.71	2.76	3.30
170	########	30.7	23.4	27.05	27.5	29.4	0.210	4.416	2.878	3.647	3.671	3.544	26.05	10.85	1	0.8	16.93	19.54	13.04	2.50	10.54	-0.02	2.58	3.34
171	########	30	21.5	25.75	27.2	29.7	0.196	4.243	2.564	3.404	3.607	3.440	26.05	10.85	1	0.8	16.93	19.54	13.04	2.58	10.46	-0.41	2.21	3.18
172	########	28.5	19.5	24	26.4	28.4	0.179	3.891	2.267	3.079	3.442	3.308	26.05	10.85	1	0.8	16.93	19.54	13.04	2.68	10.36	-0.55	1.57	2.80
173	########	28	21.6	24.8	26.2	28	0.187	3.780	2.580	3.180	3.401	3.281	26.05	10.85	1	0.8	16.93	19.54	13.04	2.74	10.30	0.25	1.80	2.80
174	########	27.5	18.5	23	26	27.6	0.170	3.671	2.130	2.901	3.361	3.255	26.05	10.85	1	0.8	16.93	19.54	13.04	2.71	10.33	-0.57	1.13	2.53
175	########	28.5	19	23.75	26.5	28.4	0.177	3.891	2.197	3.044	3.462	3.335	26.05	10.85	1	0.8	16.93	19.54	13.04	2.64	10.40	0.24	1.22	2.51
176	########	29.4	20.4	24.9	25.8	28.6	0.188	4.099	2.397	3.248	3.322	3.135	26.05	10.85	1	0.8	16.93	19.54	13.04	2.93	10.11	0.36	2.34	3.02
177	########	29.5	19.5	24.5	26	29	0.184	4.123	2.267	3.195	3.361	3.161	26.05	10.85	1	0.8	16.93	19.54	13.04	2.88	10.16	-0.13	2.21	3.04
178	########	28.4	18.6	23.5	25.6	28.2	0.174	3.869	2.143	3.006	3.283	3.109	26.05	10.85	1	0.8	16.93	19.54	13.04	2.90	10.13	-0.32	1.80	2.82
179	########	28.2	16.4	22.3	25.2	28	0.164	3.824	1.865	2.845	3.206	3.019	26.05	10.85	1	0.8	16.93	19.54	13.04	2.97	10.07	-0.38	1.51	2.64
180	########	27.8	17.8	22.8	24.7	27.4	0.168	3.736	2.038	2.887	3.112	2.931	26.05	10.85	1	0.8	16.93	19.54	13.04	3.10	9.94	0.16	1.79	2.69
181	########	27	19.5	23.25	24.6	27	0.172	3.565	2.267	2.916	3.093	2.933	26.05	10.85	1	0.8	16.93	19.54	13.04	3.11	9.93	0.14	1.90	2.75
182	########	27.5	18.5	23	24.4	26.7	0.170	3.671	2.130	2.901	3.056	2.903	26.05	10.85	1	0.8	16.93	19.54	13.04	3.14	9.90	-0.08	1.97	2.80
183	########	28.6	18.3	23.45	24.6	27.6	0.174	3.914	2.103	3.009	3.093	2.893	26.05	10.85	1	0.8	16.93	19.54	13.04	3.17	9.86	0.14	2.28	2.94
184	########	27.8	18.5	23.15	23.8	27.4	0.171	3.736	2.130	2.933	2.948	2.708	26.05	10.85	1	0.8	16.93	19.54	13.04	3.40	9.64	-0.09	2.58	3.08
185	########	26	18.2	22.1	22.5	25.7	0.162	3.361	2.090	2.726	2.726	2.512	26.05	10.85	1	0.8	16.93	19.54	13.04	3.61	9.43	-0.33	2.52	3.01
186	########	24.5	18.4	21.45	20.6	24.4	0.156	3.075	2.116	2.596	2.427	2.173	26.05	10.85	1	0.8	16.93	19.54	13.04	4.05	8.99	-0.20	3.02	3.15
187	########	27	17.7	22.35	22.4	26.7	0.164	3.565	2.025	2.795	2.709	2.422	26.05	10.85	1	0.8	16.93	19.54	13.04	3.75	9.29	0.28	2.85	3.08
188	########	27.2	17.2	22.2	23	26.5	0.163	3.607	1.962	2.785	2.809	2.576	26.05	10.85	1	0.8	16.93	19.54	13.04	3.53	9.51	-0.05	2.47	2.97
189	########	27.5	17.4	22.45	23	26.2	0.165	3.671	1.987	2.829	2.809	2.596	26.05	10.85	1	0.8	16.93	19.54	13.04	3.52	9.52	0.08	2.53	2.98
190	########	26.7	15.5	21.1	23.4	26.4	0.154	3.503	1.761	2.632	2.878	2.678	26.05	10.85	1	0.8	16.93	19.54	13.04	3.35	9.69	-0.43	1.76	2.66
191	12/1/2005	27.4	15.8	21.6	22.5	26	0.158	3.650	1.795	2.723	2.726	2.492	23.9	10.6	1	0.8	15.54	17.93	11.96	3.62	8.34	0.16	2.25	2.60
192	12/2/2005	27.2	16.5	21.85	22.8	26.5	0.160	3.607	1.877	2.742	2.776	2.528	23.9	10.6	1	0.8	15.54	17.93	11.96	3.58	8.38	0.08	2.23	2.62
193	12/3/2005	27	17	22	23.2	26.6	0.161	3.565	1.938	2.752	2.844	2.616	23.9	10.6	1	0.8	15.54	17.93	11.96	3.47	8.49	0.05	2.03	2.54
194	12/4/2005	26.5	17.2	21.85	22.6	25.4	0.160	3.462	1.962	2.712	2.742	2.555	23.9	10.6	1	0.8	15.54	17.93	11.96	3.54	8.42	-0.05	2.09	2.56
195	12/5/2005	25.7	13.5	19.6	22.4	25.2	0.142	3.302	1.547	2.425	2.709	2.522	23.9	10.6	1	0.8	15.54	17.93	11.96	3.48	8.48	-0.71	1.34	2.23
196	12/6/2005	26.5	15	20.75	23	26	0.151	3.462	1.705	2.584	2.809	2.609	23.9	10.6	1	0.8	15.54	17.93	11.96	3.42	8.54	0.36	1.44	2.18

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
197	12/7/2005	26.8	16.2	21.5	22.8	25.8	0.157	3.524	1.842	2.683	2.776	2.575	23.9	10.6	1	0.8	15.54	17.93	11.96	3.50	8.46	0.24	1.88	2.42
198	12/8/2005	26.7	14.5	20.6	23.4	26	0.150	3.503	1.651	2.577	2.878	2.704	23.9	10.6	1	0.8	15.54	17.93	11.96	3.29	8.67	-0.28	1.26	2.19
199	12/9/2005	26.5	14.5	20.5	22.7	25.7	0.149	3.462	1.651	2.557	2.759	2.558	23.9	10.6	1	0.8	15.54	17.93	11.96	3.48	8.49	-0.03	1.56	2.28
200	########	26	14.4	20.2	22.5	25.6	0.146	3.361	1.641	2.501	2.726	2.518	23.9	10.6	1	0.8	15.54	17.93	11.96	3.51	8.45	-0.09	1.50	2.24
201	########	24.7	15	19.85	22.2	24.8	0.144	3.112	1.705	2.408	2.676	2.503	23.9	10.6	1	0.8	15.54	17.93	11.96	3.52	8.45	-0.11	1.25	2.10
202	########	26.4	14.4	20.4	22.5	25.7	0.148	3.442	1.641	2.541	2.726	2.512	23.9	10.6	1	0.8	15.54	17.93	11.96	3.53	8.43	0.17	1.61	2.26
203	########	25.8	14.2	20	22.3	25	0.145	3.322	1.619	2.471	2.693	2.512	23.9	10.6	1	0.8	15.54	17.93	11.96	3.51	8.45	-0.13	1.42	2.19
204	########	25.6	15.7	20.65	23	25	0.150	3.283	1.784	2.533	2.809	2.676	23.9	10.6	1	0.8	15.54	17.93	11.96	3.33	8.63	0.20	1.12	2.03
205	########	27.2	15.5	21.35	23.2	25.6	0.156	3.607	1.761	2.684	2.844	2.683	23.9	10.6	1	0.8	15.54	17.93	11.96	3.35	8.61	0.22	1.59	2.29
206	########	28.5	15	21.75	23.5	26.8	0.159	3.891	1.705	2.798	2.896	2.675	23.9	10.6	1	0.8	15.54	17.93	11.96	3.38	8.58	0.13	1.98	2.52
207	########	27	15.7	21.35	23.6	26.5	0.156	3.565	1.784	2.675	2.913	2.719	23.9	10.6	1	0.8	15.54	17.93	11.96	3.31	8.66	-0.13	1.52	2.32
208	########	26.4	18.3	22.35	22.8	25.6	0.164	3.442	2.103	2.772	2.776	2.589	23.9	10.6	1	0.8	15.54	17.93	11.96	3.52	8.44	0.32	2.12	2.54
209	########	26.8	15.3	21.05	24	26.4	0.153	3.524	1.739	2.631	2.984	2.824	23.9	10.6	1	0.8	15.54	17.93	11.96	3.16	8.80	-0.41	1.13	2.18
210	########	27.2	14.4	20.8	23.6	26.5	0.151	3.607	1.641	2.624	2.913	2.719	23.9	10.6	1	0.8	15.54	17.93	11.96	3.28	8.68	-0.08	1.33	2.21
211	########	27.8	15	21.4	23.4	26.7	0.156	3.736	1.705	2.721	2.878	2.658	23.9	10.6	1	0.8	15.54	17.93	11.96	3.39	8.57	0.19	1.78	2.40
212	########	21.5	18.6	20.05	20.5	21	0.145	2.564	2.143	2.354	2.412	2.378	23.9	10.6	1	0.8	15.54	17.93	11.96	3.69	8.28	-0.43	1.50	2.21
213	########	25.8	18.7	22.25	21.6	24.7	0.163	3.322	2.157	2.739	2.580	2.373	23.9	10.6	0.98	0	5.98	17.93	4.60	0.46	4.14	0.69	1.75	2.61
214	########	26	15.8	20.9	22	25.4	0.152	3.361	1.795	2.578	2.644	2.417	23.9	10.6	1	0.8	15.54	17.93	11.96	3.68	8.28	-0.43	2.12	2.59
215	########	26.5	15.2	20.85	22.4	25.6	0.152	3.462	1.727	2.595	2.709	2.495	23.9	10.6	1	0.8	15.54	17.93	11.96	3.58	8.39	-0.02	1.87	2.42
216	########	25	14.4	19.7	22.6	24.2	0.142	3.168	1.641	2.404	2.742	2.635	23.9	10.6	1	0.8	15.54	17.93	11.96	3.34	8.62	-0.36	0.88	1.95
217	########	24.7	13.7	19.2	21.7	24	0.139	3.112	1.568	2.340	2.596	2.442	23.9	10.6	1	0.8	15.54	17.93	11.96	3.57	8.40	-0.16	1.18	2.04
218	########	25.4	13.5	19.45	21.5	24.4	0.140	3.244	1.547	2.396	2.564	2.371	23.9	10.6	1	0.8	15.54	17.93	11.96	3.67	8.29	0.08	1.54	2.19
219	########	25.6	13	19.3	22	24.8	0.139	3.283	1.498	2.390	2.644	2.457	23.9	10.6	1	0.8	15.54	17.93	11.96	3.55	8.41	-0.05	1.29	2.09
220	########	25.5	12.5	19	22.2	25	0.137	3.263	1.449	2.356	2.676	2.489	23.9	10.6	1	0.8	15.54	17.93	11.96	3.50	8.46	-0.09	1.07	1.99
221	########	25.8	13	19.4	21.8	24.6	0.140	3.322	1.498	2.410	2.612	2.425	23.9	10.6	1	0.8	15.54	17.93	11.96	3.60	8.36	0.13	1.42	2.13
222	1/1/2006	26	13.6	19.8	20.4	24.6	0.143	3.361	1.558	2.460	2.397	2.116	25.15	10.75	1	0.8	16.35	18.86	12.59	4.05	8.54	0.13	2.61	2.79
223	1/2/2006	25.6	13.2	19.4	20.6	25	0.140	3.283	1.517	2.400	2.427	2.133	25.15	10.75	1	0.8	16.35	18.86	12.59	4.00	8.59	-0.13	2.41	2.72
224	1/3/2006	25.2	12.7	18.95	21	24.2	0.137	3.206	1.469	2.337	2.487	2.273	25.15	10.75	1	0.8	16.35	18.86	12.59	3.78	8.81	-0.14	1.78	2.41
225	1/4/2006	25.2	14	19.6	20.7	24.5	0.142	3.206	1.599	2.402	2.442	2.188	25.15	10.75	1	0.8	16.35	18.86	12.59	3.93	8.66	0.20	2.20	2.58
226	1/5/2006	24.8	13.4	19.1	20.2	24	0.138	3.130	1.537	2.334	2.367	2.113	25.15	10.75	1	0.8	16.35	18.86	12.59	4.01	8.58	-0.16	2.25	2.63
227	1/6/2006	23.2	13	18.1	19.5	22	0.130	2.844	1.498	2.171	2.267	2.100	25.15	10.75	1	0.8	16.35	18.86	12.59	3.97	8.62	-0.32	1.76	2.36
228	1/7/2006	23.5	11.4	17.45	18.7	22.4	0.126	2.896	1.348	2.122	2.157	1.909	25.15	10.75	1	0.8	16.35	18.86	12.59	4.21	8.38	-0.20	2.16	2.51
229	1/8/2006	19.6	12	15.8	16.4	18.5	0.115	2.281	1.403	1.842	1.865	1.725	25.15	10.75	1	0.8	16.35	18.86	12.59	4.38	8.21	-0.52	1.80	2.26
230	1/9/2006	18.2	11.8	15	16.5	17.2	0.110	2.090	1.384	1.737	1.877	1.830	25.15	10.75	1	0.8	16.35	18.86	12.59	4.17	8.41	-0.25	1.00	1.79
231	1/10/2006	18	12.5	15.25	16.7	17.6	0.111	2.064	1.449	1.757	1.901	1.841	25.15	10.75	1	0.8	16.35	18.86	12.59	4.17	8.41	0.08	0.99	1.76
232	1/11/2006	22.2	10	16.1	18	20.5	0.117	2.676	1.228	1.952	2.064	1.897	25.15	10.75	1	0.8	16.35	18.86	12.59	4.15	8.44	0.27	1.50	2.06
233	1/12/2006	23.2	9.5	16.35	18.4	22.3	0.118	2.844	1.187	2.016	2.116	1.856	25.15	10.75	1	0.8	16.35	18.86	12.59	4.23	8.36	0.08	1.89	2.31
234	1/13/2006	24.5	10.2	17.35	18.2	22.4	0.125	3.075	1.245	2.160	2.090	1.809	25.15	10.75	1	0.8	16.35	18.86	12.59	4.36	8.23	0.32	2.51	2.60
235	1/14/2006	24.8	12	18.4	20	23.5	0.133	3.130	1.403	2.266	2.338	2.104	25.15	10.75	1	0.8	16.35	18.86	12.59	3.99	8.60	0.33	1.96	2.40
236	1/15/2006	25.5	13.4	19.45	20.2	24	0.140	3.263	1.537	2.400	2.367	2.113	25.15	10.75	1	0.8	16.35	18.86	12.59	4.03	8.56	0.33	2.39	2.64
237	1/16/2006	25.5	12.6	19.05	20.5	24.4	0.137	3.263	1.459	2.361	2.412	2.151	25.15	10.75	1	0.8	16.35	18.86	12.59	3.96	8.63	-0.13	2.22	2.62
238	1/17/2006	27.4	12.8	20.1	21	25.8	0.146	3.650	1.478	2.564	2.487	2.166	25.15	10.75	1	0.8	16.35	18.86	12.59	3.99	8.59	0.33	2.76	2.86
239	1/18/2006	27	14.5	20.75	20.8	25	0.151	3.565	1.651	2.608	2.457	2.176	25.15	10.75	1	0.8	16.35	18.86	12.59	4.01	8.58	0.20	2.89	2.94
240	1/19/2006	28	16.2	22.1	21.5	26.2	0.162	3.780	1.842	2.811	2.564	2.250	25.15	10.75	1	0.8	16.35	18.86	12.59	3.98	8.61	0.43	3.25	3.13
241	1/20/2006	26.7	14	20.35	20.7	24.7	0.148	3.503	1.599	2.551	2.442	2.174	25.15	10.75	1	0.8	16.35	18.86	12.59	3.99	8.59	-0.55	2.85	3.02
242	1/21/2006	26.6	12.8	19.7	20.4	24.5	0.142	3.483	1.478	2.480	2.397	2.123	25.15	10.75	1	0.8	16.35	18.86	12.59	4.03	8.55	-0.20	2.71	2.88
243	1/22/2006	25.5	13	19.25	20	23.8	0.139	3.263	1.498	2.381	2.338	2.084	25.15	10.75	1	0.8	16.35	18.86	12.59	4.06	8.53	-0.14	2.49	2.74
244	1/23/2006	25	11.4	18.2	20	23.6	0.131	3.168	1.348	2.258	2.338	2.098	25.15	10.75	1	0.8	16.35	18.86	12.59	3.99	8.60	-0.33	2.06	2.53
245	1/24/2006	22.5	12.6	17.55	19.4	21.2	0.127	2.726	1.459	2.092	2.253	2.133	25.15	10.75	1	0.8	16.35	18.86	12.59	3.90	8.69	-0.20	1.36	2.12

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
246	1/25/2006	24.5	12	18.25	19.8	22.2	0.132	3.075	1.403	2.239	2.309	2.149	25.15	10.75	1	0.8	16.35	18.86	12.59	3.91	8.67	0.22	1.75	2.29
247	1/26/2006	25.5	12	18.75	20.2	22.4	0.135	3.263	1.403	2.333	2.367	2.220	25.15	10.75	1	0.8	16.35	18.86	12.59	3.84	8.74	0.16	1.87	2.38
248	1/27/2006	26.5	12.7	19.6	20.6	24.5	0.142	3.462	1.469	2.465	2.427	2.166	25.15	10.75	1	0.8	16.35	18.86	12.59	3.97	8.62	0.27	2.45	2.69
249	1/28/2006	27.2	12.7	19.95	21.4	25	0.144	3.607	1.469	2.538	2.549	2.308	25.15	10.75	1	0.8	16.35	18.86	12.59	3.79	8.80	0.11	2.30	2.67
250	1/29/2006	26.5	13.5	20	21.5	24.7	0.145	3.462	1.547	2.505	2.564	2.351	25.15	10.75	1	0.8	16.35	18.86	12.59	3.73	8.86	0.02	2.09	2.59
251	1/30/2006	26.5	13	19.75	21.4	24.5	0.143	3.462	1.498	2.480	2.549	2.342	25.15	10.75	1	0.8	16.35	18.86	12.59	3.73	8.86	-0.08	2.05	2.57
252	1/31/2006	27	14.5	20.75	22.5	25.2	0.151	3.565	1.651	2.608	2.726	2.545	25.15	10.75	1	0.8	16.35	18.86	12.59	3.51	9.08	0.32	1.82	2.46
253	2/1/2006	28	14.5	21.25	22	26	0.155	3.780	1.651	2.716	2.644	2.377	29.25	11.25	1	0.8	19.01	21.94	14.64	3.76	10.88	0.16	3.05	3.45
254	2/2/2006	29	15.4	22.2	22.6	27.2	0.163	4.006	1.750	2.878	2.742	2.435	29.25	11.25	1	0.8	19.01	21.94	14.64	3.73	10.91	0.30	3.37	3.63
255	2/3/2006	29.2	15.2	22.2	23	27.7	0.163	4.052	1.727	2.890	2.809	2.495	29.25	11.25	1	0.8	19.01	21.94	14.64	3.65	10.99	0.00	3.30	3.66
256	2/4/2006	28.5	17	22.75	23.2	27	0.168	3.891	1.938	2.915	2.844	2.590	29.25	11.25	1	0.8	19.01	21.94	14.64	3.54	11.10	0.17	3.09	3.56
257	2/5/2006	27.8	15	21.4	22.4	25.8	0.156	3.736	1.705	2.721	2.709	2.482	29.25	11.25	1	0.8	19.01	21.94	14.64	3.62	11.02	-0.43	2.89	3.48
258	2/6/2006	29.5	16	22.75	23.7	27	0.168	4.123	1.818	2.971	2.931	2.710	29.25	11.25	1	0.8	19.01	21.94	14.64	3.38	11.26	0.43	2.89	3.44
259	2/7/2006	30	15.4	22.7	23.5	27.8	0.167	4.243	1.750	2.996	2.896	2.608	29.25	11.25	1	0.8	19.01	21.94	14.64	3.52	11.12	-0.02	3.32	3.71
260	2/8/2006	30.2	15.4	22.8	24.2	28.2	0.168	4.292	1.750	3.021	3.020	2.753	29.25	11.25	1	0.8	19.01	21.94	14.64	3.33	11.31	0.03	3.00	3.58
261	2/9/2006	29.5	15.5	22.5	24.5	28.4	0.165	4.123	1.761	2.942	3.075	2.814	29.25	11.25	1	0.8	19.01	21.94	14.64	3.24	11.40	-0.09	2.62	3.41
262	2/10/2006	29.3	16.2	22.75	24.7	28.6	0.168	4.076	1.842	2.959	3.112	2.851	29.25	11.25	1	0.6	16.09	21.94	12.39	2.50	9.89	0.08	2.24	3.37
263	2/11/2006	29.4	16	22.7	25	29	0.167	4.099	1.818	2.959	3.168	2.900	29.25	11.25	1	0.6	16.09	21.94	12.39	2.45	9.94	-0.02	2.12	3.34
264	2/12/2006	26.5	19.2	22.85	25.4	29.2	0.169	3.462	2.225	2.844	3.244	2.990	29.25	11.25	1	0.6	16.09	21.94	12.39	2.36	10.03	0.05	1.54	3.06
265	2/13/2006	29.4	17	23.2	25	28.7	0.172	4.099	1.938	3.018	3.168	2.921	29.25	11.25	1	0.6	16.09	21.94	12.39	2.44	9.94	0.11	2.24	3.39
266	2/14/2006	29	18.6	23.8	24.8	28.2	0.177	4.006	2.143	3.074	3.130	2.903	29.25	11.25	1	0.6	16.09	21.94	12.39	2.48	9.91	0.19	2.45	3.49
267	2/15/2006	31	20.2	25.6	25.4	30	0.195	4.493	2.367	3.430	3.244	2.937	29.25	11.25	1	0.6	16.09	21.94	12.39	2.51	9.88	0.57	3.30	3.91
268	2/16/2006	31.2	21.5	26.35	26.2	30.6	0.202	4.544	2.564	3.554	3.401	3.107	29.25	11.25	1	0.6	16.09	21.94	12.39	2.36	10.03	0.24	3.28	4.03
269	2/17/2006	30.7	21	25.85	25.7	30.5	0.197	4.416	2.487	3.452	3.302	2.982	29.25	11.25	1	0.6	16.09	21.94	12.39	2.47	9.92	-0.16	3.40	4.10
270	2/18/2006	30.5	22.2	26.35	26.4	30	0.202	4.366	2.676	3.521	3.442	3.201	29.25	11.25	1	0.6	16.09	21.94	12.39	2.26	10.13	0.16	2.99	3.91
271	2/19/2006	30.2	22.5	26.35	27	30.2	0.202	4.292	2.726	3.509	3.565	3.352	29.25	11.25	1	0.6	16.09	21.94	12.39	2.11	10.27	0.00	2.63	3.80
272	2/20/2006	29.3	22.3	25.8	26.2	29.4	0.197	4.076	2.693	3.384	3.401	3.188	29.25	11.25	1	0.6	16.09	21.94	12.39	2.26	10.13	-0.17	2.72	3.81
273	2/21/2006	30.5	22.4	26.45	26.5	29.7	0.203	4.366	2.709	3.538	3.462	3.248	29.25	11.25	1	0.6	16.09	21.94	12.39	2.22	10.17	0.20	2.91	3.88
274	2/22/2006	32.5	22.4	27.45	27	31.2	0.214	4.891	2.709	3.800	3.565	3.285	29.25	11.25	1	0.6	16.09	21.94	12.39	2.21	10.17	0.32	3.49	4.19
275	2/23/2006	32.4	21.5	26.95	27.4	31.6	0.209	4.863	2.564	3.714	3.650	3.369	29.25	11.25	1	0.6	16.09	21.94	12.39	2.12	10.27	-0.16	3.17	4.12
276	2/24/2006	33.5	22.3	27.9	28.6	32.2	0.219	5.173	2.693	3.933	3.914	3.673	29.25	11.25	1	0.6	16.09	21.94	12.39	1.85	10.54	0.30	2.94	4.05
277	2/25/2006	34	21.7	27.85	29	33	0.218	5.319	2.596	3.958	4.006	3.738	29.25	11.25	1	0.6	16.09	21.94	12.39	1.79	10.60	-0.02	2.92	4.11
278	2/26/2006	34.2	22.5	28.35	28.7	33.2	0.224	5.379	2.726	4.052	3.937	3.636	29.25	11.25	1	0.6	16.09	21.94	12.39	1.90	10.49	0.16	3.36	4.28
279	2/27/2006	34.5	21.8	28.15	28.4	33.2	0.222	5.469	2.612	4.041	3.869	3.548	29.25	11.25	1	0.6	16.09	21.94	12.39	1.98	10.41	-0.06	3.58	4.40
280	2/28/2006	31	21.7	26.35	27.2	31	0.202	4.493	2.596	3.544	3.607	3.353	29.25	11.25	1	0.6	16.09	21.94	12.39	2.11	10.27	-0.57	2.84	4.00
281	3/1/2006	30.5	21	25.75	27.6	30	0.196	4.366	2.487	3.427	3.693	3.532	33.8	11.85	1	0.6	18.59	25.35	14.31	1.93	12.39	-0.19	2.39	4.22
282	3/2/2006	31	20	25.5	27.5	30.7	0.194	4.493	2.338	3.415	3.671	3.457	33.8	11.85	1	0.6	18.59	25.35	14.31	1.99	12.32	-0.08	2.50	4.24
283	3/3/2006	29	20.2	24.6	27	29.5	0.185	4.006	2.367	3.187	3.565	3.398	33.8	11.85	1	0.6	18.59	25.35	14.31	2.02	12.29	-0.28	2.01	3.97
284	3/4/2006	30.6	18.5	24.55	27.6	30.2	0.184	4.391	2.130	3.261	3.693	3.519	33.8	11.85	1	0.6	18.59	25.35	14.31	1.91	12.40	-0.02	1.84	3.88
285	3/5/2006	29.5	20.8	25.15	26.3	29.6	0.190	4.123	2.457	3.290	3.422	3.201	33.8	11.85	1	0.6	18.59	25.35	14.31	2.23	12.09	0.19	2.73	4.23
286	3/6/2006	32.2	19.4	25.8	27.2	31	0.197	4.809	2.253	3.531	3.607	3.353	33.8	11.85	1	0.6	18.59	25.35	14.31	2.10	12.21	0.20	3.03	4.44
287	3/7/2006	32	21	26.5	27	31.4	0.204	4.755	2.487	3.621	3.565	3.271	33.8	11.85	1	0.6	18.59	25.35	14.31	2.20	12.12	0.22	3.49	4.67
288	3/8/2006	33	21	27	27.8	30.7	0.209	5.030	2.487	3.759	3.736	3.542	33.8	11.85	1	0.6	18.59	25.35	14.31	1.95	12.36	0.16	3.23	4.63
289	3/9/2006	33.8	21.7	27.75	28.2	32	0.217	5.260	2.596	3.928	3.824	3.570	33.8	11.85	1	0.6	18.59	25.35	14.31	1.94	12.37	0.24	3.60	4.84
290	3/10/2006	33.5	22.3	27.9	28.4	32.4	0.219	5.173	2.693	3.933	3.869	3.602	33.8	11.85	1	0.6	18.59	25.35	14.31	1.92	12.40	0.05	3.59	4.89
291	3/11/2006	24.6	21.4	23	21	24.5	0.170	3.093	2.549	2.821	2.487	2.253	33.8	11.85	1	0.6	18.59	25.35	14.31	3.13	11.18	-1.54	4.16	4.84
292	3/12/2006	29.6	17.6	23.6	24.2	28	0.175	4.147	2.013	3.080	3.020	2.766	33.8	11.85	1	0.6	18.59	25.35	14.31	2.61	11.70	0.19	3.21	4.29
293	3/13/2006	29.5	19.6	24.55	24.5	28.5	0.184	4.123	2.281	3.202	3.075	2.807	33.8	11.85	1	0.6	18.59	25.35	14.31	2.60	11.71	0.30	3.45	4.43
294	3/14/2006	31.4	19.5	25.45	26.4	30.8	0.193	4.596	2.267	3.431	3.442	3.148	33.8	11.85	1	0.6	18.59	25.35	14.31	2.29	12.02	0.28	3.24	4.47

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
295	3/15/2006	32	21	26.5	27.3	31.2	0.204	4.755	2.487	3.621	3.629	3.368	33.8	11.85	1	0.6	18.59	25.35	14.31	2.10	12.21	0.33	3.23	4.55
296	3/16/2006	31	20	25.5	27	31	0.194	4.493	2.338	3.415	3.565	3.298	33.8	11.85	1	0.6	18.59	25.35	14.31	2.14	12.17	-0.32	2.95	4.46
297	3/17/2006	31.2	21	26.1	26.8	30.8	0.200	4.544	2.487	3.516	3.524	3.256	33.8	11.85	1	0.6	18.59	25.35	14.31	2.20	12.11	0.19	3.24	4.53
298	3/18/2006	31.4	19.4	25.4	26.5	30.7	0.193	4.596	2.253	3.424	3.462	3.181	33.8	11.85	1	0.6	18.59	25.35	14.31	2.25	12.06	-0.22	3.24	4.55
299	3/19/2006	30.5	16	23.25	26.4	30.7	0.172	4.366	1.818	3.092	3.442	3.154	33.8	11.85	1	0.6	18.59	25.35	14.31	2.22	12.10	-0.68	2.36	4.10
300	3/20/2006	32	15.5	23.75	27	31.4	0.177	4.755	1.761	3.258	3.565	3.271	33.8	11.85	1	0.6	18.59	25.35	14.31	2.12	12.19	0.16	2.39	4.04
301	3/21/2006	33.8	17.4	25.6	27.2	32.5	0.195	5.260	1.987	3.624	3.607	3.253	33.8	11.85	1	0.6	18.59	25.35	14.31	2.20	12.12	0.58	3.44	4.56
302	3/22/2006	33.2	20.4	26.8	26.7	32.2	0.207	5.087	2.397	3.742	3.503	3.136	33.8	11.85	1	0.6	18.59	25.35	14.31	2.34	11.97	0.38	4.10	4.92
303	3/23/2006	32.5	23.2	27.85	27	31.6	0.218	4.891	2.844	3.867	3.565	3.258	33.8	11.85	1	0.6	18.59	25.35	14.31	2.25	12.06	0.33	4.15	5.01
304	3/24/2006	34	20	27	27.6	32.5	0.209	5.319	2.338	3.829	3.693	3.365	33.8	11.85	1	0.6	18.59	25.35	14.31	2.12	12.19	-0.27	3.92	5.01
305	3/25/2006	35.2	21.2	28.2	28.2	33.2	0.222	5.685	2.518	4.101	3.824	3.490	33.8	11.85	1	0.6	18.59	25.35	14.31	2.04	12.28	0.38	4.19	5.11
306	3/26/2006	37.8	23.5	30.65	30	35.4	0.251	6.553	2.896	4.724	4.243	3.882	33.8	11.85	1	0.6	18.59	25.35	14.31	1.72	12.59	0.77	4.74	5.50
307	3/27/2006	34.6	25	29.8	28.6	33	0.241	5.500	3.168	4.334	3.914	3.620	33.8	11.85	1	0.6	18.59	25.35	14.31	1.95	12.37	-0.27	4.63	5.50
308	3/28/2006	33	24.6	28.8	29	32.4	0.229	5.030	3.093	4.062	4.006	3.778	33.8	11.85	1	0.6	18.59	25.35	14.31	1.77	12.54	-0.32	3.62	5.04
309	3/29/2006	34	21.5	27.75	28.2	33.2	0.217	5.319	2.564	3.942	3.824	3.490	33.8	11.85	1	0.6	18.59	25.35	14.31	2.02	12.29	-0.33	3.95	5.09
310	3/30/2006	35	19.6	27.3	29.6	34	0.212	5.623	2.281	3.952	4.147	3.853	33.8	11.85	1	0.6	18.59	25.35	14.31	1.67	12.64	-0.14	3.07	4.72
311	3/31/2006	34.2	22.2	28.2	28.4	33.4	0.222	5.379	2.676	4.028	3.869	3.535	33.8	11.85	1	0.6	18.59	25.35	14.31	1.99	12.32	0.28	3.93	5.01
312	4/1/2006	33.5	23.7	28.6	29.3	32.6	0.227	5.173	2.931	4.052	4.076	3.855	37.7	12.55	1	0.6	20.74	28.28	15.97	1.70	14.27	0.13	3.69	5.45
313	4/2/2006	33.7	24	28.85	28.4	32.7	0.230	5.231	2.984	4.107	3.869	3.582	37.7	12.55	1	0.6	20.74	28.28	15.97	1.96	14.01	0.08	4.46	5.76
314	4/3/2006	32.5	25	28.75	27.8	32	0.229	4.891	3.168	4.029	3.736	3.455	37.7	12.55	1	0.6	20.74	28.28	15.97	2.08	13.89	-0.03	4.57	5.79
315	4/4/2006	32.5	24.5	28.5	28	31.9	0.226	4.891	3.075	3.983	3.780	3.519	37.7	12.55	1	0.6	20.74	28.28	15.97	2.01	13.96	-0.08	4.32	5.68
316	4/5/2006	33	20	26.5	28.5	32.6	0.204	5.030	2.338	3.684	3.891	3.617	37.7	12.55	0.52	0	9.43	28.28	7.26	0.29	6.97	-0.63	1.82	3.77
317	4/6/2006	33	21.5	27.25	27.8	32.4	0.212	5.030	2.564	3.797	3.736	3.429	37.7	12.55	0.83	0	9.43	28.28	7.26	0.32	6.93	0.24	2.42	4.87
318	4/7/2006	32.8	21.4	27.1	28.5	32	0.210	4.974	2.549	3.761	3.891	3.657	37.7	12.55	0.85	0	9.43	28.28	7.26	0.29	6.97	-0.05	1.81	4.73
319	4/8/2006	32.8	21.8	27.3	28.6	32.6	0.212	4.974	2.612	3.793	3.914	3.647	37.7	12.55	1	0.6	20.74	28.28	15.97	1.86	14.11	0.06	3.47	5.24
320	4/9/2006	32.5	24.5	28.5	29	32.2	0.226	4.891	3.075	3.983	4.006	3.792	37.7	12.55	1	0.6	20.74	28.28	15.97	1.75	14.21	0.38	3.60	5.34
321	4/10/2006	32.4	25.2	28.8	28.7	32.4	0.229	4.863	3.206	4.035	3.937	3.690	37.7	12.55	1	0.6	20.74	28.28	15.97	1.85	14.11	0.09	4.04	5.58
322	4/11/2006	32.5	25	28.75	28.2	31.5	0.229	4.891	3.168	4.029	3.824	3.604	37.7	12.55	0.88	0	9.43	28.28	7.26	0.30	6.95	-0.02	2.63	5.28
323	4/12/2006	33	25.6	29.3	28.5	32	0.235	5.030	3.283	4.156	3.891	3.657	37.7	12.55	1	0.6	20.74	28.28	15.97	1.90	14.07	0.17	4.40	5.75
324	4/13/2006	33.5	26	29.75	29.2	32.7	0.240	5.173	3.361	4.267	4.052	3.818	37.7	12.55	1	0.6	20.74	28.28	15.97	1.76	14.21	0.14	4.34	5.79
325	4/14/2006	32.6	22	27.3	29.5	32	0.212	4.918	2.644	3.781	4.123	3.956	37.7	12.55	1	0.6	20.74	28.28	15.97	1.58	14.39	-0.77	2.89	5.17
326	4/15/2006	32	25.4	28.7	28.6	31.8	0.228	4.755	3.244	3.999	3.914	3.700	37.7	12.55	1	0.6	20.74	28.28	15.97	1.84	14.12	0.44	3.84	5.43
327	4/16/2006	33.2	26	29.6	29.4	33	0.239	5.087	3.361	4.224	4.099	3.859	37.7	12.55	1	0.6	20.74	28.28	15.97	1.71	14.25	0.28	4.11	5.67
328	4/17/2006	33.4	26.5	29.95	29.5	33.2	0.243	5.144	3.462	4.303	4.123	3.876	37.7	12.55	1	0.6	20.74	28.28	15.97	1.71	14.26	0.11	4.31	5.81
329	4/18/2006	30.2	21.2	25.7	28.6	30.7	0.196	4.292	2.518	3.405	3.914	3.774	37.7	12.55	1	0.6	20.74	28.28	15.97	1.70	14.26	-1.34	2.32	4.84
330	4/19/2006	31.5	21.4	26.45	28.5	31.2	0.203	4.622	2.549	3.585	3.891	3.711	37.7	12.55	0.83	0	9.43	28.28	7.26	0.28	6.98	0.24	1.13	4.27
331	4/20/2006	32	21.6	26.8	28.7	31.6	0.207	4.755	2.580	3.667	3.937	3.743	37.7	12.55	1	0.6	20.74	28.28	15.97	1.76	14.21	0.11	2.87	4.94
332	4/21/2006	32.2	20.7	26.45	29.2	32	0.203	4.809	2.442	3.625	4.052	3.865	37.7	12.55	1	0.6	20.74	28.28	15.97	1.64	14.33	-0.11	2.49	4.80
333	4/22/2006	34	20.2	27.1	29.6	33.2	0.210	5.319	2.367	3.843	4.147	3.906	37.7	12.55	1	0.6	20.74	28.28	15.97	1.62	14.35	0.20	2.94	5.02
334	4/23/2006	33.5	22.4	27.95	29.5	33.4	0.220	5.173	2.709	3.941	4.123	3.862	37.7	12.55	0.87	0	9.43	28.28	7.26	0.26	7.00	0.27	1.70	4.81
335	4/24/2006	35	24.7	29.85	29.4	33.7	0.242	5.623	3.112	4.367	4.099	3.812	37.7	12.55	1	0.6	20.74	28.28	15.97	1.77	14.20	0.60	4.48	5.79
336	4/25/2006	34.5	21	27.75	29.7	33.4	0.217	5.469	2.487	3.978	4.171	3.923	37.7	12.55	0.91	0	9.43	28.28	7.26	0.25	7.00	-0.66	1.84	5.17
337	4/26/2006	35	25	30	30	34	0.243	5.623	3.168	4.395	4.243	3.976	37.7	12.55	1	0.6	20.74	28.28	15.97	1.61	14.35	0.71	4.18	5.68
338	4/27/2006	33.2	21.4	27.3	29.5	32.7	0.212	5.087	2.549	3.818	4.123	3.909	37.7	12.55	1	0.6	20.74	28.28	15.97	1.62	14.35	-0.85	3.12	5.28
339	4/28/2006	34	24.2	29.1	29.4	33	0.233	5.319	3.020	4.170	4.099	3.859	37.7	12.55	1	0.6	20.74	28.28	15.97	1.70	14.26	0.57	3.89	5.50
340	4/29/2006	35.6	24	29.8	29.7	34.6	0.241	5.812	2.984	4.398	4.171	3.843	37.7	12.55	0.84	0	9.43	28.28	7.26	0.27	6.99	0.22	2.89	5.38
341	4/30/2006	36.5	26.2	31.35	30.2	35	0.260	6.106	3.401	4.754	4.292	3.971	37.7	12.55	1	0.6	20.74	28.28	15.97	1.65	14.32	0.49	5.09	6.20
342	5/1/2006	35.7	26.2	30.95	29	33.2	0.255	5.844	3.401	4.623	4.006	3.725	39.6	13.15	1	0.6	21.78	29.70	16.77	1.87	14.90	-0.13	5.63	6.69
343	5/2/2006	34.4	27	30.7	29.7	32.6	0.252	5.439	3.565	4.502	4.171	3.977	39.6	13.15	1	0.6	21.78	29.70	16.77	1.63	15.14	-0.08	4.82	6.35

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
344	5/3/2006	35.4	26.4	30.9	30.2	33.5	0.254	5.748	3.442	4.595	4.292	4.071	39.6	13.15	1	0.6	21.78	29.70	16.77	1.54	15.23	0.06	4.81	6.37
345	5/4/2006	35.5	25.5	30.5	30.4	33.7	0.249	5.780	3.263	4.522	4.341	4.121	39.6	13.15	1	0.6	21.78	29.70	16.77	1.49	15.28	-0.13	4.57	6.28
346	5/5/2006	35.3	25.2	30.25	29.8	34	0.246	5.717	3.206	4.461	4.195	3.914	39.6	13.15	1	0.6	21.78	29.70	16.77	1.68	15.09	-0.08	4.84	6.34
347	5/6/2006	35.4	25.6	30.5	29.6	34.5	0.249	5.748	3.283	4.515	4.147	3.819	39.6	13.15	1	0.6	21.78	29.70	16.77	1.77	15.00	0.08	5.14	6.44
348	5/7/2006	33	21.5	27.25	30	32.8	0.212	5.030	2.564	3.797	4.243	4.056	39.6	13.15	0.11	0	9.90	29.70	7.62	0.23	7.39	-1.02	1.19	2.35
349	5/8/2006	33	23.4	28.2	29.4	33	0.222	5.030	2.878	3.954	4.099	3.859	39.6	13.15	1	0.6	21.78	29.70	16.77	1.68	15.09	0.30	3.56	5.56
350	5/9/2006	33.2	26.6	29.9	29.2	32.2	0.242	5.087	3.483	4.285	4.052	3.852	39.6	13.15	1	0.6	21.78	29.70	16.77	1.73	15.04	0.54	4.41	5.98
351	5/10/2006	34	21.8	27.9	29.6	33	0.219	5.319	2.612	3.966	4.147	3.919	39.6	13.15	1	0.6	21.78	29.70	16.77	1.62	15.15	-0.63	3.64	5.74
352	5/11/2006	34.4	25	29.7	29.4	32.8	0.240	5.439	3.168	4.303	4.099	3.872	39.6	13.15	0.61	0	9.90	29.70	7.62	0.27	7.36	0.57	2.60	4.59
353	5/12/2006	26.5	22.2	24.35	25	25.4	0.182	3.462	2.676	3.069	3.168	3.141	39.6	13.15	0.54	0	9.90	29.70	7.62	0.35	7.27	-1.69	1.63	3.81
354	5/13/2006	31.6	22.4	27	28.4	30.7	0.209	4.648	2.709	3.679	3.869	3.715	39.6	13.15	0.9	0	9.90	29.70	7.62	0.28	7.34	0.83	1.33	4.75
355	5/14/2006	31	24.4	27.7	28.5	31.8	0.217	4.493	3.056	3.774	3.891	3.671	39.6	13.15	1	0.6	21.78	29.70	16.77	1.85	14.93	0.22	3.53	5.47
356	5/15/2006	31.5	21.7	26.6	29	31.7	0.205	4.622	2.596	3.609	4.006	3.825	39.6	13.15	0.48	0	9.90	29.70	7.62	0.26	7.36	-0.35	1.11	3.43
357	5/16/2006	33.5	25	29.25	29.6	32.6	0.234	5.173	3.168	4.170	4.147	3.946	39.6	13.15	1	0.6	21.78	29.70	16.77	1.62	15.15	0.83	3.83	5.66
358	5/17/2006	34.5	25.5	30	29.6	33	0.243	5.469	3.263	4.366	4.147	3.919	39.6	13.15	1	0.6	21.78	29.70	16.77	1.67	15.10	0.24	4.53	6.12
359	5/18/2006	35	26.5	30.75	30.2	34.2	0.253	5.623	3.462	4.542	4.292	4.025	39.6	13.15	1	0.6	21.78	29.70	16.77	1.58	15.19	0.24	4.74	6.29
360	5/19/2006	36.2	26	31.1	30.5	34.7	0.257	6.007	3.361	4.684	4.366	4.086	39.6	13.15	1	0.6	21.78	29.70	16.77	1.53	15.24	0.11	4.98	6.46
361	5/20/2006	34.5	25.4	29.95	29.7	33.4	0.243	5.469	3.244	4.357	4.171	3.923	39.6	13.15	1	0.6	21.78	29.70	16.77	1.66	15.11	-0.36	4.63	6.27
362	5/21/2006	34.5	26.7	30.6	30.5	34	0.251	5.469	3.503	4.486	4.366	4.132	39.6	13.15	1	0.6	21.78	29.70	16.77	1.48	15.29	0.20	4.39	6.15
363	5/22/2006	35.2	25.2	30.2	30.4	34.5	0.246	5.685	3.206	4.445	4.341	4.067	39.6	13.15	1	0.6	21.78	29.70	16.77	1.53	15.24	-0.13	4.49	6.22
364	5/23/2006	34.8	26.5	30.65	30.6	34	0.251	5.561	3.462	4.511	4.391	4.164	39.6	13.15	1	0.6	21.78	29.70	16.77	1.45	15.32	0.14	4.40	6.18
365	5/24/2006	34	26	30	29.8	33.6	0.243	5.319	3.361	4.340	4.195	3.941	39.6	13.15	1	0.6	21.78	29.70	16.77	1.65	15.12	-0.20	4.52	6.20
366	5/25/2006	35	26.4	30.7	30.5	34.2	0.252	5.623	3.442	4.532	4.366	4.119	39.6	13.15	1	0.6	21.78	29.70	16.77	1.50	15.28	0.22	4.52	6.21
367	5/26/2006	30.4	25.2	27.8	28.4	30.4	0.218	4.341	3.206	3.774	3.869	3.735	39.6	13.15	1	0.6	21.78	29.70	16.77	1.79	14.98	-0.91	3.64	5.72
368	5/27/2006	29.6	24.4	27	28	29.6	0.209	4.147	3.056	3.601	3.780	3.673	39.6	13.15	0.14	0	9.90	29.70	7.62	0.29	7.34	-0.25	1.48	2.42
369	5/28/2006	30.4	27	28.7	27.8	29.8	0.228	4.341	3.565	3.953	3.736	3.602	39.6	13.15	0.81	0	9.90	29.70	7.62	0.30	7.32	0.54	2.40	5.06
370	5/29/2006	30	25.2	27.6	28.4	30	0.216	4.243	3.206	3.724	3.869	3.762	39.6	13.15	0.37	0	9.90	29.70	7.62	0.27	7.35	-0.35	1.61	3.31
371	5/30/2006	32.6	25	28.8	29.6	31.2	0.229	4.918	3.168	4.043	4.147	4.040	39.6	13.15	0.66	0	9.90	29.70	7.62	0.24	7.38	0.38	1.61	4.31
372	5/31/2006	33.2	23.2	28.2	30.2	32.4	0.222	5.087	2.844	3.965	4.292	4.145	39.6	13.15	0.46	0	9.90	29.70	7.62	0.22	7.40	-0.19	1.26	3.52
373																								
374																								
375																								
376	Note:	Tmax_C	max temp of the day (recorded mostly around 3PM) in celcius								for z=4m	P	101.25				a(s)	0.25				c(s)	2.1	
377		Tmin_C	min temp of the day (recorded mostly around 6AM) in celcius									γ	0.067				b(s)	0.5				del(z)	0.15	
378		Tmean_C	average of Tmax_C and Tmin_C									a(ψ)	0.00066	(say)			z	4	m			del(t)	1	
379		Twet_C	wet-bulb temp recorded around noon									γ(ψ)	0.066825				α	0.23				u	5	m/s
380		Tdry_C	dry-bulb temp recorded around noon														σ	4.9E-09						
381		Ra	from Table 2.6 of FAO report																					
382		N	from Table 2.7 of FAO report																					
383		n/N (high)	is 1 for no RF days, 0 for >50mm RF days (assumed RF intensity = 4mm/hr in Jun-Jul-Aug, 3mm/hr in Sep-Oct, 2mm/hr in Nov-Mar, 3mm/hr in Apr-May)																					
384		n/N (low)	for no RF days in Jun-Aug is 0.4, Sep-Oct is 0.6, Nov-Jan is 0.8, Feb-May is 0.6; 0 for RF days																					

Table L2: Calculated Reference ET (ET_0) from Meteorological Data between June 2006 and May 2007

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
5–6	Date	Tmax_C	Tmin_C	Tmean_C	Twet_C	Tdry_C	slope (delta)	e(Tmax)	e(Tmin)	e(s)	e(Twet)	e(a)	Ra (for 23N)	N (for 23N)	n/N (high)	n/N (low)	Rs	Rso	Rns	Rnl	Rn	G	ET0_low (mm/d)	ET0_high (mm/d)
8	6/1/2006	31.5	25	28.25	28.2	30.8	0.223	4.622	3.168	3.895	3.824	3.650	40.15	13.4	1	0.4	18.07	30.12	13.91	1.35	12.56	0.02	3.43	5.16
9	6/2/2006	28	25.7	26.85	27.4	28	0.208	3.780	3.302	3.541	3.650	3.610	40.15	13.4	0.254	0	10.04	30.12	7.73	0.29	7.44	-0.44	1.54	2.25
10	6/3/2006	32.5	24.8	28.65	29.6	30.7	0.227	4.891	3.130	4.011	4.147	4.073	40.15	13.4	0.953	0	10.04	30.12	7.73	0.23	7.50	0.57	1.42	4.31
11	6/4/2006	32.7	25.6	29.15	29.8	31.5	0.233	4.946	3.283	4.114	4.195	4.081	40.15	13.4	1	0.4	18.07	30.12	13.91	1.08	12.83	0.16	2.99	4.83
12	6/5/2006	31	25.5	28.25	28.6	30.6	0.223	4.493	3.263	3.878	3.914	3.780	40.15	13.4	0.711	0	10.04	30.12	7.73	0.27	7.45	-0.28	1.98	4.06
13	6/6/2006	30.7	25	27.85	28.5	30.4	0.218	4.416	3.168	3.792	3.891	3.764	40.15	13.4	1	0.4	18.07	30.12	13.91	1.27	12.65	-0.13	2.92	4.66
14	6/7/2006	29.8	26	27.9	28	29.7	0.219	4.195	3.361	3.778	3.780	3.666	40.15	13.4	0.534	0	10.04	30.12	7.73	0.29	7.44	0.02	1.94	3.47
15	6/8/2006	32	26.2	29.1	29.4	31.8	0.233	4.755	3.401	4.078	4.099	3.939	40.15	13.4	0.897	0	10.04	30.12	7.73	0.25	7.47	0.38	1.96	4.68
16	6/9/2006	28	26	27	27.4	27.6	0.209	3.780	3.361	3.571	3.650	3.637	40.15	13.4	1	0.4	18.07	30.12	13.91	1.34	12.58	-0.66	2.73	4.41
17	6/10/2006	25.8	25.4	25.6	26.5	26	0.195	3.322	3.244	3.283	3.462	3.495	40.15	13.4	0.692	0	10.04	30.12	7.73	0.31	7.42	-0.44	1.09	2.95
18	6/11/2006	33.6	25.8	29.7	32.2	33.5	0.240	5.202	3.322	4.262	4.809	4.722	40.15	13.4	0.767	0	10.04	30.12	7.73	0.15	7.58	1.29	0.37	2.89
19	6/12/2006	33.5	28	30.75	32.4	33.4	0.253	5.173	3.780	4.476	4.863	4.796	40.15	13.4	1	0.4	18.07	30.12	13.91	0.64	13.27	0.33	2.34	4.37
20	6/13/2006	33.2	28.5	30.85	31.7	33.7	0.254	5.087	3.891	4.489	4.675	4.541	40.15	13.4	1	0.4	18.07	30.12	13.91	0.80	13.11	0.03	3.00	4.98
21	6/14/2006	34.4	28.3	31.35	30.8	33.5	0.260	5.439	3.846	4.643	4.442	4.261	40.15	13.4	1	0.4	18.07	30.12	13.91	0.99	12.92	0.16	3.93	5.88
22	6/15/2006	33.5	23.4	28.45	30.2	32.6	0.225	5.173	2.878	4.026	4.292	4.132	40.15	13.4	0.664	0	10.04	30.12	7.73	0.23	7.50	-0.91	1.64	3.66
23	6/16/2006	34.2	27	30.6	30	33	0.251	5.379	3.565	4.472	4.243	4.043	40.15	13.4	1	0.4	18.07	30.12	13.91	1.12	12.79	0.68	3.86	5.74
24	6/17/2006	34	26.6	30.3	30.4	33.4	0.247	5.319	3.483	4.401	4.341	4.141	40.15	13.4	1	0.4	18.07	30.12	13.91	1.05	12.86	-0.09	3.65	5.55
25	6/18/2006	33.6	27.5	30.55	29.7	32.5	0.250	5.202	3.671	4.437	4.171	3.983	40.15	13.4	1	0.4	18.07	30.12	13.91	1.16	12.75	0.08	4.04	5.92
26	6/19/2006	35	27.7	31.35	30.5	33.2	0.260	5.623	3.714	4.669	4.366	4.186	40.15	13.4	1	0.4	18.07	30.12	13.91	1.04	12.87	0.25	4.12	6.06
27	6/20/2006	30	26.5	28.25	28	30.2	0.223	4.243	3.462	3.853	3.780	3.633	40.15	13.4	1	0.4	18.07	30.12	13.91	1.36	12.55	-0.98	3.59	5.32
28	6/21/2006	32.7	25.8	29.25	29.2	31.5	0.234	4.946	3.322	4.134	4.052	3.899	40.15	13.4	1	0.4	18.07	30.12	13.91	1.20	12.71	0.32	3.42	5.23
29	6/22/2006	32.6	26.4	29.5	29.6	31.2	0.237	4.918	3.442	4.180	4.147	4.040	40.15	13.4	1	0.4	18.07	30.12	13.91	1.11	12.80	0.08	3.28	5.13
30	6/23/2006	32	26.8	29.4	30	32	0.236	4.755	3.524	4.139	4.243	4.109	40.15	13.4	0.925	0	10.04	30.12	7.73	0.23	7.50	-0.03	1.81	4.67
31	6/24/2006	32.6	26.5	29.55	28.7	31.6	0.238	4.918	3.462	4.190	3.937	3.743	40.15	13.4	1	0.4	18.07	30.12	13.91	1.31	12.60	0.05	3.97	5.77
32	6/25/2006	33.3	27	30.15	29.6	32	0.245	5.115	3.565	4.340	4.147	3.986	40.15	13.4	1	0.4	18.07	30.12	13.91	1.15	12.76	0.19	3.78	5.64
33	6/26/2006	33.4	27	30.2	30.2	32.5	0.246	5.144	3.565	4.355	4.292	4.138	40.15	13.4	1	0.4	18.07	30.12	13.91	1.05	12.86	0.02	3.52	5.41
34	6/27/2006	32	26.5	29.25	29	31.8	0.234	4.755	3.462	4.108	4.006	3.819	40.15	13.4	1	0.4	18.07	30.12	13.91	1.25	12.66	-0.30	3.68	5.48
35	6/28/2006	32.2	25.8	29	30.2	32	0.231	4.809	3.322	4.065	4.292	4.172	40.15	13.4	0.804	0	10.04	30.12	7.73	0.22	7.51	-0.08	1.48	3.96
36	6/29/2006	31.8	26.6	29.2	29	30.6	0.234	4.701	3.483	4.092	4.006	3.899	40.15	13.4	1	0.4	18.07	30.12	13.91	1.20	12.71	0.06	3.37	5.18
37	6/30/2006	32	27	29.5	29.7	31	0.237	4.755	3.565	4.160	4.171	4.084	40.15	13.4	1	0.4	18.07	30.12	13.91	1.08	12.83	0.09	3.13	4.98
38	7/1/2006	33	26.6	29.8	29.7	32.6	0.241	5.030	3.483	4.256	4.171	3.977	39.75	13.25	1	0.4	17.89	29.82	13.77	1.16	12.62	0.09	3.58	5.40
39	7/2/2006	32.5	27.5	30	29.5	32.5	0.243	4.891	3.671	4.281	4.123	3.922	39.75	13.25	1	0.4	17.89	29.82	13.77	1.20	12.58	0.06	3.77	5.59
40	7/3/2006	33	27.6	30.3	29	32	0.247	5.030	3.693	4.361	4.006	3.805	39.75	13.25	1	0.4	17.89	29.82	13.77	1.28	12.49	0.09	4.21	6.02
41	7/4/2006	32.8	28	30.4	29.2	31.9	0.248	4.974	3.780	4.377	4.052	3.872	39.75	13.25	1	0.4	17.89	29.82	13.77	1.24	12.54	0.03	4.12	5.95
42	7/5/2006	31.7	27.2	29.45	29.6	31	0.237	4.675	3.607	4.141	4.147	4.053	39.75	13.25	0.84	0	9.94	29.82	7.65	0.24	7.41	-0.30	1.99	4.55
43	7/6/2006	31.2	27.6	29.4	28.5	30.5	0.236	4.544	3.693	4.118	3.891	3.758	39.75	13.25	1	0.4	17.89	29.82	13.77	1.30	12.48	-0.02	3.75	5.52
44	7/7/2006	31.4	28.2	29.8	29.7	31.7	0.241	4.596	3.824	4.210	4.171	4.037	39.75	13.25	1	0.4	17.89	29.82	13.77	1.12	12.66	0.13	3.33	5.16
45	7/8/2006	29	23.8	26.4	27.7	28	0.203	4.006	2.948	3.477	3.714	3.694	39.75	13.25	0	0	9.94	29.82	7.65	0.28	7.37	-1.07	1.25	1.25
46	7/9/2006	30.2	24.6	27.4	28.3	29.5	0.213	4.292	3.093	3.693	3.846	3.766	39.75	13.25	0	0	9.94	29.82	7.65	0.27	7.38	0.32	1.37	1.37
47	7/10/2006	30.5	25.6	28.05	28.6	30	0.221	4.366	3.283	3.825	3.914	3.820	39.75	13.25	1	0.4	17.89	29.82	13.77	1.23	12.54	0.20	2.78	4.51
48	7/11/2006	31	25.5	28.25	28.5	30.6	0.223	4.493	3.263	3.878	3.891	3.751	39.75	13.25	0.66	0	9.94	29.82	7.65	0.28	7.37	0.06	1.96	3.86
49	7/12/2006	31.5	26.7	29.1	28.4	31	0.233	4.622	3.503	4.063	3.869	3.695	39.75	13.25	0.708	0	9.94	29.82	7.65	0.29	7.36	0.27	2.52	4.58

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
50	7/13/2006	33	27.2	30.1	30.5	32.5	0.245	5.030	3.607	4.319	4.366	4.233	39.75	13.25	0.887	0	9.94	29.82	7.65	0.22	7.44	0.32	1.87	4.65
51	7/14/2006	33.2	27.2	30.2	29.6	32.6	0.246	5.087	3.607	4.347	4.147	3.946	39.75	13.25	0.774	0	9.94	29.82	7.65	0.26	7.39	0.03	2.66	5.03
52	7/15/2006	31.5	27	29.25	29	31	0.234	4.622	3.565	4.094	4.006	3.872	39.75	13.25	1	0.4	17.89	29.82	13.77	1.22	12.56	-0.30	3.49	5.28
53	7/16/2006	32	26.8	29.4	29.5	31.6	0.236	4.755	3.524	4.139	4.123	3.983	39.75	13.25	1	0.4	17.89	29.82	13.77	1.15	12.63	0.05	3.28	5.09
54	7/17/2006	32	26.7	29.35	29.7	32	0.236	4.755	3.503	4.129	4.171	4.017	39.75	13.25	1	0.4	17.89	29.82	13.77	1.12	12.65	-0.02	3.19	5.01
55	7/18/2006	32.7	27.5	30.1	30	32.4	0.245	4.946	3.671	4.309	4.243	4.083	39.75	13.25	1	0.4	17.89	29.82	13.77	1.09	12.68	0.24	3.45	5.30
56	7/19/2006	30.2	27.4	28.8	29.4	30.4	0.229	4.292	3.650	3.971	4.099	4.032	39.75	13.25	1	0.4	17.89	29.82	13.77	1.10	12.67	-0.41	2.83	4.63
57	7/20/2006	30	26.5	28.25	28.7	30.2	0.223	4.243	3.462	3.853	3.937	3.837	39.75	13.25	0.481	0	9.94	29.82	7.65	0.27	7.39	-0.17	1.74	3.14
58	7/21/2006	29.6	25.6	27.6	28.6	30.6	0.216	4.147	3.283	3.715	3.914	3.780	39.75	13.25	0.594	0	9.94	29.82	7.65	0.27	7.38	-0.20	1.52	3.21
59	7/22/2006	32	25.7	28.85	29	31.5	0.230	4.755	3.302	4.029	4.006	3.839	39.75	13.25	0.858	0	9.94	29.82	7.65	0.27	7.38	0.39	2.06	4.58
60	7/23/2006	32.5	26.2	29.35	29.5	32	0.236	4.891	3.401	4.146	4.123	3.956	39.75	13.25	0.943	0	9.94	29.82	7.65	0.25	7.40	0.16	2.13	4.96
61	7/24/2006	33.4	27	30.2	30	32.7	0.246	5.144	3.565	4.355	4.243	4.063	39.75	13.25	1	0.4	17.89	29.82	13.77	1.10	12.67	0.27	3.60	5.45
62	7/25/2006	34	27.4	30.7	30.4	33.2	0.252	5.319	3.650	4.485	4.341	4.154	39.75	13.25	1	0.4	17.89	29.82	13.77	1.05	12.72	0.16	3.74	5.63
63	7/26/2006	30.6	27.7	29.15	29.2	31	0.233	4.391	3.714	4.053	4.052	3.932	39.75	13.25	1	0.4	17.89	29.82	13.77	1.18	12.60	-0.49	3.30	5.09
64	7/27/2006	32.2	27	29.6	29	31.8	0.239	4.809	3.565	4.187	4.006	3.819	39.75	13.25	1	0.4	17.89	29.82	13.77	1.26	12.51	0.14	3.75	5.53
65	7/28/2006	31.4	25.5	28.45	28.4	31	0.225	4.596	3.263	3.930	3.869	3.695	39.75	13.25	0.802	0	9.94	29.82	7.65	0.29	7.36	-0.36	2.33	4.63
66	7/29/2006	28.5	25.6	27.05	27.7	28.4	0.210	3.891	3.283	3.587	3.714	3.668	39.75	13.25	0.915	0	9.94	29.82	7.65	0.29	7.37	-0.44	1.50	4.05
67	7/30/2006	31.2	25.8	28.5	28.4	30	0.226	4.544	3.322	3.933	3.869	3.762	39.75	13.25	0.877	0	9.94	29.82	7.65	0.28	7.37	0.46	1.99	4.53
68	7/31/2006	32.6	26.6	29.6	29.6	32.5	0.239	4.918	3.483	4.200	4.147	3.953	39.75	13.25	0.887	0	9.94	29.82	7.65	0.25	7.40	0.35	2.22	4.90
69	8/1/2006	31.6	27	29.3	29.4	31.6	0.235	4.648	3.565	4.107	4.099	3.952	38.35	12.8	1	0.4	17.26	28.77	13.29	1.16	12.12	-0.09	3.19	4.91
70	8/2/2006	32.5	27.2	29.85	29	32.2	0.242	4.891	3.607	4.249	4.006	3.792	38.35	12.8	1	0.4	17.26	28.77	13.29	1.28	12.01	0.17	3.84	5.55
71	8/3/2006	31	26.8	28.9	28.6	31	0.230	4.493	3.524	4.008	3.914	3.754	38.35	12.8	1	0.4	17.26	28.77	13.29	1.29	12.00	-0.30	3.43	5.11
72	8/4/2006	31.5	25.2	28.35	28.2	30.7	0.224	4.622	3.206	3.914	3.824	3.657	38.35	12.8	0.971	0	9.59	28.77	7.38	0.29	7.09	-0.17	2.27	4.93
73	8/5/2006	26.4	23.8	25.1	25.2	25.6	0.190	3.442	2.948	3.195	3.206	3.179	38.35	12.8	0.951	0	9.59	28.77	7.38	0.35	7.03	-1.02	1.73	4.03
74	8/6/2006	28.5	24.5	26.5	27	27.5	0.204	3.891	3.075	3.483	3.565	3.532	38.35	12.8	0.15	0	9.59	28.77	7.38	0.30	7.08	0.44	1.31	1.70
75	8/7/2006	32	26	29	29.5	32.6	0.231	4.755	3.361	4.058	4.123	3.916	38.35	12.8	0.922	0	9.59	28.77	7.38	0.26	7.13	0.79	1.80	4.42
76	8/8/2006	30.5	26.4	28.45	28.7	30	0.225	4.366	3.442	3.904	3.937	3.850	38.35	12.8	0.873	0	9.59	28.77	7.38	0.26	7.12	-0.17	1.78	4.23
77	8/9/2006	33	25.6	29.3	29.8	31.9	0.235	5.030	3.283	4.156	4.195	4.054	38.35	12.8	1	0.4	17.26	28.77	13.29	1.10	12.19	0.27	2.99	4.74
78	8/10/2006	31.2	25	28.1	27.6	30.6	0.221	4.544	3.168	3.856	3.693	3.492	38.35	12.8	0.658	0	9.59	28.77	7.38	0.32	7.07	-0.38	2.58	4.34
79	8/11/2006	33.6	26.4	30	30.4	32.7	0.243	5.202	3.442	4.322	4.341	4.188	38.35	12.8	1	0.4	17.26	28.77	13.29	1.02	12.27	0.60	3.05	4.84
80	8/12/2006	32	27	29.5	28.8	32	0.237	4.755	3.565	4.160	3.960	3.746	38.35	12.8	0.805	0	9.59	28.77	7.38	0.28	7.10	-0.16	2.67	4.94
81	8/13/2006	31.5	26.4	28.95	30.2	31.2	0.231	4.622	3.442	4.032	4.292	4.225	38.35	12.8	1	0.4	17.26	28.77	13.29	0.98	12.31	-0.17	2.39	4.15
82	8/14/2006	31.2	26.5	28.85	29.6	31.5	0.230	4.544	3.462	4.003	4.147	4.020	38.35	12.8	1	0.4	17.26	28.77	13.29	1.11	12.18	-0.03	2.75	4.47
83	8/15/2006	32.2	24.5	28.35	29.2	31.8	0.224	4.809	3.075	3.942	4.052	3.878	38.35	12.8	0.678	0	9.59	28.77	7.38	0.26	7.12	-0.16	1.80	3.70
84	8/16/2006	32	23.8	27.9	29	31.4	0.219	4.755	2.948	3.852	4.006	3.845	38.35	12.8	1	0.4	17.26	28.77	13.29	1.21	12.07	-0.14	2.74	4.41
85	8/17/2006	33.2	24.6	28.9	29.5	32	0.230	5.087	3.093	4.090	4.123	3.956	38.35	12.8	1	0.4	17.26	28.77	13.29	1.16	12.13	0.32	3.03	4.74
86	8/18/2006	32.7	25	28.85	29.4	32.2	0.230	4.946	3.168	4.057	4.099	3.912	38.35	12.8	1	0.4	17.26	28.77	13.29	1.18	12.10	-0.02	3.12	4.82
87	8/19/2006	33.6	24.7	29.15	29.7	32.6	0.233	5.202	3.112	4.157	4.171	3.977	38.35	12.8	1	0.4	17.26	28.77	13.29	1.15	12.14	0.09	3.20	4.93
88	8/20/2006	33.4	26	29.7	30	32.9	0.240	5.144	3.361	4.253	4.243	4.049	38.35	12.8	1	0.4	17.26	28.77	13.29	1.11	12.18	0.17	3.27	5.03
89	8/21/2006	32.7	25.6	29.15	29.6	32	0.233	4.946	3.283	4.114	4.147	3.986	38.35	12.8	0.854	0	9.59	28.77	7.38	0.25	7.13	-0.17	1.99	4.45
90	8/22/2006	32.6	24.6	28.6	28.6	31	0.227	4.918	3.093	4.006	3.914	3.754	38.35	12.8	1	0.4	17.26	28.77	13.29	1.29	12.00	-0.17	3.38	5.05
91	8/23/2006	32.5	24.7	28.6	29.7	32.5	0.227	4.891	3.112	4.001	4.171	3.983	38.35	12.8	1	0.4	17.26	28.77	13.29	1.13	12.15	0.00	2.80	4.51
92	8/24/2006	32.4	25.2	28.8	29.5	32.6	0.229	4.863	3.206	4.035	4.123	3.916	38.35	12.8	0.922	0	9.59	28.77	7.38	0.26	7.13	0.06	1.90	4.52
93	8/25/2006	31.7	25.4	28.55	29.2	31.2	0.226	4.675	3.244	3.959	4.052	3.919	38.35	12.8	0.932	0	9.59	28.77	7.38	0.26	7.13	-0.08	1.73	4.37
94	8/26/2006	32.5	24.6	28.55	28.7	31.5	0.226	4.891	3.093	3.992	3.937	3.750	38.35	12.8	1	0.4	17.26	28.77	13.29	1.29	12.00	0.00	3.32	4.98
95	8/27/2006	33.2	25.7	29.45	29.6	32.4	0.237	5.087	3.302	4.195	4.147	3.960	38.35	12.8	1	0.4	17.26	28.77	13.29	1.16	12.13	0.28	3.30	5.03
96	8/28/2006	33.5	26.4	29.95	29.7	32.7	0.243	5.173	3.442	4.307	4.171	3.970	38.35	12.8	1	0.4	17.26	28.77	13.29	1.16	12.13	0.16	3.59	5.34
97	8/29/2006	32.6	26	29.3	30	32.4	0.235	4.918	3.361	4.140	4.243	4.083	38.35	12.8	1	0.4	17.26	28.77	13.29	1.08	12.21	-0.20	3.00	4.75
98	8/30/2006	32.6	25.5	29.05	29.3	32.2	0.232	4.918	3.263	4.091	4.076	3.882	38.35	12.8	0.902	0	9.59	28.77	7.38	0.26	7.12	-0.08	2.16	4.72

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
99	8/31/2006	32	24.8	28.4	30	31.6	0.225	4.755	3.130	3.943	4.243	4.136	38.35	12.8	1	0.4	17.26	28.77	13.29	1.03	12.26	-0.20	2.34	4.07
100	9/1/2006	33.5	26.2	29.85	29.7	32.2	0.242	5.173	3.401	4.287	4.171	4.004	35.15	12.1	1	0.6	19.33	26.37	14.89	1.59	13.30	0.46	3.66	4.72
101	9/2/2006	34.2	26.5	30.35	29.8	32.7	0.248	5.379	3.462	4.420	4.195	4.001	35.15	12.1	1	0.6	19.33	26.37	14.89	1.60	13.29	0.16	4.07	5.13
102	9/3/2006	34.6	25.4	30	30.2	33	0.243	5.500	3.244	4.372	4.292	4.105	35.15	12.1	0.567	0	8.79	26.37	6.77	0.23	6.53	-0.11	2.18	3.70
103	9/4/2006	33.5	25.7	29.6	29.6	32.4	0.239	5.173	3.302	4.238	4.147	3.960	35.15	12.1	1	0.6	19.33	26.37	14.89	1.62	13.27	-0.13	3.77	4.81
104	9/5/2006	34.2	26.4	30.3	29.7	32.9	0.247	5.379	3.442	4.410	4.171	3.957	35.15	12.1	1	0.6	19.33	26.37	14.89	1.64	13.25	0.22	4.12	5.18
105	9/6/2006	32.7	26.2	29.45	30.2	32	0.237	4.946	3.401	4.174	4.292	4.172	35.15	12.1	1	0.6	19.33	26.37	14.89	1.42	13.46	-0.27	3.18	4.25
106	9/7/2006	32.5	25.6	29.05	29.8	32.5	0.232	4.891	3.283	4.087	4.195	4.014	35.15	12.1	1	0.6	19.33	26.37	14.89	1.56	13.33	-0.13	3.26	4.30
107	9/8/2006	34	26.5	30.25	30.2	32.9	0.246	5.319	3.462	4.391	4.292	4.112	35.15	12.1	0.793	0	8.79	26.37	6.77	0.23	6.53	0.38	2.10	4.23
108	9/9/2006	31.8	26.7	29.25	30.4	32.5	0.234	4.701	3.503	4.102	4.341	4.201	35.15	12.1	1	0.6	19.33	26.37	14.89	1.39	13.49	-0.32	2.94	4.01
109	9/10/2006	29.2	25.2	27.2	28.2	29.5	0.211	4.052	3.206	3.629	3.824	3.737	35.15	12.1	1	0.6	19.33	26.37	14.89	1.77	13.11	-0.65	2.75	3.72
110	9/11/2006	27.4	24	25.7	26.5	27.4	0.196	3.650	2.984	3.317	3.462	3.402	35.15	12.1	0	0	8.79	26.37	6.77	0.32	6.45	-0.47	1.24	1.24
111	9/12/2006	28.2	24.5	26.35	27	27.5	0.202	3.824	3.075	3.449	3.565	3.532	35.15	12.1	0	0	8.79	26.37	6.77	0.30	6.46	0.20	1.13	1.13
112	9/13/2006	30	25.6	27.8	28.2	29	0.218	4.243	3.283	3.763	3.824	3.771	35.15	12.1	0.16	0	8.79	26.37	6.77	0.27	6.49	0.46	1.33	1.72
113	9/14/2006	31.5	26	28.75	28.4	30.4	0.229	4.622	3.361	3.992	3.869	3.735	35.15	12.1	0.89	0	8.79	26.37	6.77	0.28	6.48	0.30	2.03	4.26
114	9/15/2006	32.2	26.2	29.2	29.2	30.6	0.234	4.809	3.401	4.105	4.052	3.959	35.15	12.1	1	0.6	19.33	26.37	14.89	1.61	13.27	0.14	3.37	4.41
115	9/16/2006	32.5	25.7	29.1	29.4	31.5	0.233	4.891	3.302	4.097	4.099	3.959	35.15	12.1	1	0.6	19.33	26.37	14.89	1.61	13.28	-0.03	3.39	4.42
116	9/17/2006	31.7	25.5	28.6	29	31.4	0.227	4.675	3.263	3.969	4.006	3.845	35.15	12.1	1	0.6	19.33	26.37	14.89	1.70	13.18	-0.16	3.33	4.34
117	9/18/2006	31.2	25.8	28.5	28.7	31.6	0.226	4.544	3.322	3.933	3.937	3.743	35.15	12.1	1	0.6	19.33	26.37	14.89	1.80	13.09	-0.03	3.44	4.44
118	9/19/2006	30	25.2	27.6	28.5	30.4	0.216	4.243	3.206	3.724	3.891	3.764	35.15	12.1	0.16	0	8.79	26.37	6.77	0.27	6.49	-0.28	1.40	1.79
119	9/20/2006	28.4	24.3	26.35	28.6	29	0.202	3.869	3.038	3.453	3.914	3.887	35.15	12.1	0.587	0	8.79	26.37	6.77	0.25	6.51	-0.39	0.35	1.77
120	9/21/2006	28.2	24	26.1	27.4	27.6	0.200	3.824	2.984	3.404	3.650	3.637	35.15	12.1	0	0	8.79	26.37	6.77	0.29	6.48	-0.08	0.79	0.79
121	9/22/2006	27.8	23.6	25.7	26.7	27.6	0.196	3.736	2.913	3.325	3.503	3.443	35.15	12.1	0	0	8.79	26.37	6.77	0.31	6.45	-0.13	1.08	1.08
122	9/23/2006	26.2	24	25.1	26	26.4	0.190	3.401	2.984	3.193	3.361	3.335	35.15	12.1	0	0	8.79	26.37	6.77	0.33	6.44	-0.19	1.00	1.00
123	9/24/2006	27.8	24.6	26.2	27.2	27.5	0.201	3.736	3.093	3.415	3.607	3.587	35.15	12.1	0	0	8.79	26.37	6.77	0.29	6.47	0.35	0.86	0.86
124	9/25/2006	29.5	25.2	27.35	27.7	29	0.213	4.123	3.206	3.664	3.714	3.628	35.15	12.1	0.711	0	8.79	26.37	6.77	0.29	6.47	0.36	1.44	3.15
125	9/26/2006	30.6	25.5	28.05	29	29.6	0.221	4.391	3.263	3.827	4.006	3.966	35.15	12.1	1	0.6	19.33	26.37	14.89	1.58	13.30	0.22	2.59	3.60
126	9/27/2006	31.5	26	28.75	28.7	30.7	0.229	4.622	3.361	3.992	3.937	3.803	35.15	12.1	1	0.6	19.33	26.37	14.89	1.75	13.14	0.22	3.40	4.41
127	9/28/2006	32.7	25.8	29.25	29.4	32	0.234	4.946	3.322	4.134	4.099	3.925	35.15	12.1	0.669	0	8.79	26.37	6.77	0.26	6.51	0.16	1.96	3.69
128	9/29/2006	33.2	26.2	29.7	29.6	32.6	0.240	5.087	3.401	4.244	4.147	3.946	35.15	12.1	1	0.6	19.33	26.37	14.89	1.63	13.25	0.14	3.75	4.80
129	9/30/2006	33.6	26	29.8	30.2	33.2	0.241	5.202	3.361	4.282	4.292	4.092	35.15	12.1	0.311	0	8.79	26.37	6.77	0.23	6.53	0.03	1.96	2.79
130	10/1/2006	32.7	26.2	29.45	29.8	32.4	0.237	4.946	3.401	4.174	4.195	4.021	30.6	11.45	1	0.6	16.83	22.95	12.96	1.56	11.40	-0.11	3.03	3.91
131	10/2/2006	33	26.5	29.75	30	32.7	0.240	5.030	3.462	4.246	4.243	4.063	30.6	11.45	1	0.6	16.83	22.95	12.96	1.53	11.43	0.09	3.07	3.97
132	10/3/2006	32.8	25.8	29.3	29.4	31.8	0.235	4.974	3.322	4.148	4.099	3.939	30.6	11.45	1	0.6	16.83	22.95	12.96	1.63	11.33	-0.14	3.15	4.02
133	10/4/2006	31.5	26	28.75	29.2	31.2	0.229	4.622	3.361	3.992	4.052	3.919	30.6	11.45	1	0.6	16.83	22.95	12.96	1.64	11.32	-0.17	2.80	3.66
134	10/5/2006	33.2	26.4	29.8	29.3	31.7	0.241	5.087	3.442	4.264	4.076	3.915	30.6	11.45	1	0.6	16.83	22.95	12.96	1.67	11.29	0.33	3.38	4.26
135	10/6/2006	32.6	25.5	29.05	29.6	31.2	0.232	4.918	3.263	4.091	4.147	4.040	30.6	11.45	1	0.6	16.83	22.95	12.96	1.54	11.42	-0.24	2.80	3.68
136	10/7/2006	32.8	25.4	29.1	28.7	30.5	0.233	4.974	3.244	4.109	3.937	3.816	30.6	11.45	0.258	0	7.65	22.95	5.89	0.27	5.62	0.02	1.99	2.54
137	10/8/2006	33	26	29.5	29.8	32.6	0.237	5.030	3.361	4.196	4.195	4.008	30.6	11.45	1	0.6	16.83	22.95	12.96	1.57	11.39	0.13	3.06	3.94
138	10/9/2006	33.2	26	29.6	30	32.5	0.239	5.087	3.361	4.224	4.243	4.076	30.6	11.45	1	0.6	16.83	22.95	12.96	1.51	11.45	0.03	3.00	3.90
139	########	33.5	25.5	29.5	29.2	31.4	0.237	5.173	3.263	4.218	4.052	3.905	30.6	11.45	1	0.6	16.83	22.95	12.96	1.67	11.29	-0.03	3.37	4.24
140	########	34	26.5	30.25	30	33	0.246	5.319	3.462	4.391	4.243	4.043	30.6	11.45	1	0.6	16.83	22.95	12.96	1.56	11.40	0.24	3.44	4.34
141	########	33.2	26.2	29.7	29.8	32.5	0.240	5.087	3.401	4.244	4.195	4.014	30.6	11.45	1	0.6	16.83	22.95	12.96	1.57	11.39	-0.17	3.23	4.12
142	########	34.2	26	30.1	39.9	32.6	0.245	5.379	3.361	4.370	7.336	7.824	30.6	11.45	1	0.6	16.83	22.95	12.96	-1.37	14.33	0.13		
143	########	32.8	25.7	29.25	30	32	0.234	4.974	3.302	4.138	4.243	4.109	30.6	11.45	1	0.6	16.83	22.95	12.96	1.48	11.48	-0.27	2.78	3.67
144	########	33.4	26.2	29.8	30.4	32.4	0.241	5.144	3.401	4.273	4.341	4.208	30.6	11.45	1	0.6	16.83	22.95	12.96	1.40	11.56	0.17	2.81	3.72
145	########	32.7	25.6	29.15	29.7	31.5	0.233	4.946	3.283	4.114	4.171	4.050	30.6	11.45	1	0.6	16.83	22.95	12.96	1.53	11.43	-0.20	2.83	3.71
146	########	33.2	25.5	29.35	30.2	32	0.236	5.087	3.263	4.175	4.292	4.172	30.6	11.45	1	0.6	16.83	22.95	12.96	1.42	11.54	0.06	2.66	3.56
147	########	32.6	25.4	29	29.7	31.4	0.231	4.918	3.244	4.081	4.171	4.057	30.6	11.45	1	0.6	16.83	22.95	12.96	1.52	11.44	-0.11	2.70	3.59

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
148	########	33.7	26	29.85	30.2	32.6	0.242	5.231	3.361	4.296	4.292	4.132	30.6	11.45	1	0.6	16.83	22.95	12.96	1.47	11.49	0.27	3.01	3.91
149	########	32.8	26.2	29.5	29.8	32.5	0.237	4.974	3.401	4.188	4.195	4.014	30.6	11.45	1	0.6	16.83	22.95	12.96	1.57	11.39	-0.11	3.08	3.96
150	########	32.6	25.4	29	29.5	31.6	0.231	4.918	3.244	4.081	4.123	3.983	30.6	11.45	1	0.6	16.83	22.95	12.96	1.59	11.37	-0.16	2.88	3.75
151	########	33	25.4	29.2	29.4	32	0.234	5.030	3.244	4.137	4.099	3.925	30.6	11.45	1	0.6	16.83	22.95	12.96	1.64	11.32	0.06	3.10	3.97
152	########	32.8	24.2	28.5	30	31.7	0.226	4.974	3.020	3.997	4.243	4.129	30.6	11.45	1	0.6	16.83	22.95	12.96	1.44	11.52	-0.22	2.33	3.22
153	########	32.8	24.5	28.65	29.7	32.4	0.227	4.974	3.075	4.024	4.171	3.990	30.6	11.45	1	0.6	16.83	22.95	12.96	1.57	11.39	0.05	2.66	3.53
154	########	33.6	25.4	29.5	30	32.2	0.237	5.202	3.244	4.223	4.243	4.096	30.6	11.45	1	0.6	16.83	22.95	12.96	1.49	11.47	0.27	2.90	3.79
155	########	32.4	24.7	28.55	29.4	31.5	0.226	4.863	3.112	3.987	4.099	3.959	30.6	11.45	1	0.6	16.83	22.95	12.96	1.60	11.36	-0.30	2.71	3.58
156	########	32.8	24.4	28.6	29.2	31.5	0.227	4.974	3.056	4.015	4.052	3.899	30.6	11.45	1	0.6	16.83	22.95	12.96	1.66	11.30	0.02	2.85	3.71
157	########	33	23.8	28.4	29	31.7	0.225	5.030	2.948	3.989	4.006	3.825	30.6	11.45	1	0.6	16.83	22.95	12.96	1.72	11.24	-0.06	2.96	3.80
158	########	31.8	24.2	28	29.6	30.6	0.220	4.701	3.020	3.861	4.147	4.080	30.6	11.45	1	0.6	16.83	22.95	12.96	1.48	11.48	-0.13	2.05	2.92
159	########	32	23.7	27.85	29.5	31.2	0.218	4.755	2.931	3.843	4.123	4.009	30.6	11.45	1	0.6	16.83	22.95	12.96	1.54	11.42	-0.05	2.14	3.00
160	########	32.6	23.4	28	28.9	31.4	0.220	4.918	2.878	3.898	3.983	3.816	30.6	11.45	1	0.6	16.83	22.95	12.96	1.72	11.24	0.05	2.71	3.55
161	11/1/2006	31.4	23.7	27.55	29.2	31	0.215	4.596	2.931	3.763	4.052	3.932	26.05	10.85	0.889	0	6.51	19.54	5.01	0.25	4.76	-0.14	0.66	2.19
162	11/2/2006	31.7	24.2	27.95	29	31.5	0.220	4.675	3.020	3.847	4.006	3.839	26.05	10.85	1	0.8	16.93	19.54	13.04	2.17	10.86	0.13	2.42	2.77
163	11/3/2006	31.8	22.4	27.1	28.7	31.4	0.210	4.701	2.709	3.705	3.937	3.756	26.05	10.85	1	0.8	16.93	19.54	13.04	2.25	10.79	-0.27	2.29	2.63
164	11/4/2006	32	21.4	26.7	28.5	31.6	0.206	4.755	2.549	3.652	3.891	3.684	26.05	10.85	1	0.8	16.93	19.54	13.04	2.32	10.72	-0.13	2.27	2.60
165	11/5/2006	29.6	22	25.8	28	29.4	0.197	4.147	2.644	3.395	3.780	3.686	26.05	10.85	1	0.8	16.93	19.54	13.04	2.29	10.75	-0.28	1.57	1.89
166	11/6/2006	30.2	22.5	26.35	28.7	30.2	0.202	4.292	2.726	3.509	3.937	3.837	26.05	10.85	1	0.8	16.93	19.54	13.04	2.13	10.91	0.17	1.45	1.78
167	11/7/2006	29.5	22.2	25.85	28.2	29	0.197	4.123	2.676	3.400	3.824	3.771	26.05	10.85	1	0.8	16.93	19.54	13.04	2.19	10.85	-0.16	1.35	1.68
168	11/8/2006	30	21	25.5	29	30.2	0.194	4.243	2.487	3.365	4.006	3.925	26.05	10.85	1	0.8	16.93	19.54	13.04	2.01	11.03	-0.11	0.84	1.17
169	11/9/2006	26.4	22.5	24.45	25.7	26.5	0.183	3.442	2.726	3.084	3.302	3.249	26.05	10.85	1	0.8	16.93	19.54	13.04	2.77	10.27	-0.33	1.72	2.01
170	########	27	22.5	24.75	25	26.4	0.186	3.565	2.726	3.145	3.168	3.074	26.05	10.85	1	0.8	16.93	19.54	13.04	2.99	10.04	0.09	2.26	2.53
171	########	28.6	23	25.8	25.2	28.8	0.197	3.914	2.809	3.362	3.206	2.965	26.05	10.85	1	0.8	16.93	19.54	13.04	3.18	9.86	0.33	3.08	3.36
172	########	27.4	20.2	23.8	25.6	27.2	0.177	3.650	2.367	3.009	3.283	3.176	26.05	10.85	1	0.8	16.93	19.54	13.04	2.83	10.21	-0.63	1.71	1.99
173	########	28.5	19.8	24.15	26	27.6	0.181	3.891	2.309	3.100	3.361	3.255	26.05	10.85	1	0.8	16.93	19.54	13.04	2.75	10.29	0.11	1.64	1.93
174	########	30	20.5	25.25	25.5	29	0.191	4.243	2.412	3.327	3.263	3.029	26.05	10.85	1	0.8	16.93	19.54	13.04	3.08	9.96	0.35	2.83	3.10
175	########	29.7	19.5	24.6	26	28.6	0.185	4.171	2.267	3.219	3.361	3.188	26.05	10.85	1	0.8	16.93	19.54	13.04	2.85	10.19	-0.20	2.23	2.51
176	########	30	18.6	24.3	25.7	28.7	0.182	4.243	2.143	3.193	3.302	3.102	26.05	10.85	1	0.8	16.93	19.54	13.04	2.95	10.09	-0.09	2.34	2.62
177	########	29.8	18.2	24	25.5	28.6	0.179	4.195	2.090	3.142	3.263	3.056	26.05	10.85	1	0.8	16.93	19.54	13.04	2.99	10.05	-0.09	2.30	2.57
178	########	29.5	18	23.75	25.7	29.2	0.177	4.123	2.064	3.093	3.302	3.068	26.05	10.85	1	0.8	16.93	19.54	13.04	2.97	10.07	-0.08	2.12	2.39
179	########	29	18	23.5	24.8	28.8	0.174	4.006	2.064	3.035	3.130	2.863	26.05	10.85	1	0.8	16.93	19.54	13.04	3.22	9.82	-0.08	2.47	2.74
180	########	29.5	17.8	23.65	25.2	29	0.176	4.123	2.038	3.081	3.206	2.952	26.05	10.85	1	0.8	16.93	19.54	13.04	3.11	9.93	0.05	2.35	2.62
181	########	30	17.6	23.8	25.6	29.5	0.177	4.243	2.013	3.128	3.283	3.022	26.05	10.85	1	0.8	16.93	19.54	13.04	3.03	10.01	0.05	2.31	2.58
182	########	29.6	17.8	23.7	25.4	29.2	0.176	4.147	2.038	3.092	3.244	2.990	26.05	10.85	1	0.8	16.93	19.54	13.04	3.06	9.97	-0.03	2.31	2.57
183	########	29	17.5	23.25	25.7	28.7	0.172	4.006	2.000	3.003	3.302	3.102	26.05	10.85	1	0.8	16.93	19.54	13.04	2.91	10.13	-0.14	1.76	2.03
184	########	30.5	18	24.25	26	29.6	0.181	4.366	2.064	3.215	3.361	3.121	26.05	10.85	1	0.8	16.93	19.54	13.04	2.92	10.12	0.32	2.27	2.54
185	########	29.7	20	24.85	26.2	29.2	0.187	4.171	2.338	3.254	3.401	3.201	26.05	10.85	1	0.8	16.93	19.54	13.04	2.84	10.20	0.19	2.22	2.51
186	########	28.5	18.8	23.65	25.4	28.5	0.176	3.891	2.170	3.031	3.244	3.037	26.05	10.85	1	0.8	16.93	19.54	13.04	3.00	10.04	-0.38	2.08	2.35
187	########	26	14.5	20.25	24	26.4	0.147	3.361	1.651	2.506	2.984	2.824	26.05	10.85	1	0.8	16.93	19.54	13.04	3.13	9.91	-1.07	1.01	1.25
188	########	26	14.5	20.25	26.4	26	0.147	3.361	1.651	2.506	3.442	3.468	26.05	10.85	1	0.8	16.93	19.54	13.04	2.37	10.67	0.00		
189	########	26.6	15	20.8	23.2	26.4	0.151	3.483	1.705	2.594	2.844	2.630	26.05	10.85	1	0.8	16.93	19.54	13.04	3.40	9.64	0.17	1.65	1.88
190	########	28	14.6	21.3	23	27.6	0.155	3.780	1.662	2.721	2.809	2.502	26.05	10.85	1	0.8	16.93	19.54	13.04	3.59	9.44	0.16	2.42	2.65
191	12/1/2006	24.8	14.2	19.5	21	24	0.141	3.130	1.619	2.375	2.487	2.287	23.9	10.6	1	0.8	15.54	17.93	11.96	3.79	8.17	-0.57	1.84	2.02
192	12/2/2006	24.5	13.4	18.95	20.7	23.4	0.137	3.075	1.537	2.306	2.442	2.261	23.9	10.6	1	0.8	15.54	17.93	11.96	3.80	8.16	-0.17	1.61	1.79
193	12/3/2006	25	12.3	18.65	20.4	23.5	0.134	3.168	1.431	2.299	2.397	2.190	23.9	10.6	1	0.8	15.54	17.93	11.96	3.88	8.08	-0.09	1.78	1.95
194	12/4/2006	24.8	13.6	19.2	21	24.7	0.139	3.130	1.558	2.344	2.487	2.240	23.9	10.6	1	0.8	15.54	17.93	11.96	3.84	8.12	0.17	1.74	1.92
195	12/5/2006	25.5	14.5	20	21.5	25.8	0.145	3.263	1.651	2.457	2.564	2.277	23.9	10.6	1	0.8	15.54	17.93	11.96	3.83	8.13	0.25	2.00	2.18
196	12/6/2006	26.7	15	20.85	22	26.4	0.152	3.503	1.705	2.604	2.644	2.350	23.9	10.6	1	0.8	15.54	17.93	11.96	3.78	8.19	0.27	2.26	2.45

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
197	12/7/2006	27	15.2	21.1	22.2	26.5	0.154	3.565	1.727	2.646	2.676	2.389	23.9	10.6	1	0.8	15.54	17.93	11.96	3.73	8.23	0.08	2.32	2.51
198	12/8/2006	26.6	15.2	20.9	22.5	26.6	0.152	3.483	1.727	2.605	2.726	2.452	23.9	10.6	1	0.8	15.54	17.93	11.96	3.64	8.32	-0.06	2.03	2.23
199	12/9/2006	27.2	16	21.6	23	26.2	0.158	3.607	1.818	2.713	2.809	2.596	23.9	10.6	1	0.8	15.54	17.93	11.96	3.48	8.48	0.22	1.92	2.13
200	########	27.2	16	21.6	22.8	26.5	0.158	3.607	1.818	2.713	2.776	2.528	23.9	10.6	1	0.8	15.54	17.93	11.96	3.57	8.39	0.00	2.15	2.35
201	########	27	16.2	21.6	22.6	26.4	0.158	3.565	1.842	2.703	2.742	2.488	23.9	10.6	1	0.8	15.54	17.93	11.96	3.62	8.34	0.00	2.24	2.43
202	########	28	18.5	23.25	23.4	26.7	0.172	3.780	2.130	2.955	2.878	2.658	23.9	10.6	1	0.8	15.54	17.93	11.96	3.47	8.49	0.52	2.44	2.66
203	########	25.4	15	20.2	22.8	25	0.146	3.244	1.705	2.475	2.776	2.629	23.9	10.6	1	0.8	15.54	17.93	11.96	3.37	8.59	-0.96	1.26	1.46
204	########	24.5	13.2	18.85	21.5	23.4	0.136	3.075	1.517	2.296	2.564	2.437	23.9	10.6	1	0.8	15.54	17.93	11.96	3.56	8.40	-0.43	1.08	1.27
205	########	24	12	18	20.2	23	0.130	2.984	1.403	2.193	2.367	2.180	23.9	10.6	1	0.8	15.54	17.93	11.96	3.86	8.10	-0.27	1.47	1.64
206	########	25.5	14.5	20	20.6	24.6	0.145	3.263	1.651	2.457	2.427	2.159	23.9	10.6	1	0.8	15.54	17.93	11.96	4.00	7.97	0.63	2.27	2.45
207	########	27	15.7	21.35	21.8	26	0.156	3.565	1.784	2.675	2.612	2.331	23.9	10.6	1	0.8	15.54	17.93	11.96	3.83	8.14	0.43	2.50	2.69
208	########	26.4	16.5	21.45	21.2	25.4	0.156	3.442	1.877	2.659	2.518	2.237	23.9	10.6	1	0.8	15.54	17.93	11.96	3.96	8.00	0.03	2.79	2.97
209	########	27.2	17	22.1	22.6	26.5	0.162	3.607	1.938	2.773	2.742	2.482	23.9	10.6	1	0.8	15.54	17.93	11.96	3.66	8.31	0.20	2.43	2.63
210	########	28	16.2	22.1	22.5	26.4	0.162	3.780	1.842	2.811	2.726	2.465	23.9	10.6	1	0.8	15.54	17.93	11.96	3.68	8.28	0.00	2.63	2.83
211	########	28.5	16.7	22.6	23.2	26.8	0.166	3.891	1.901	2.896	2.844	2.603	23.9	10.6	1	0.8	15.54	17.93	11.96	3.52	8.44	0.16	2.48	2.69
212	########	27.1	16.5	21.8	22.4	26.5	0.159	3.586	1.877	2.732	2.709	2.435	23.9	10.6	1	0.8	15.54	17.93	11.96	3.71	8.26	-0.25	2.52	2.71
213	########	26.8	15.6	21.2	22.6	25.6	0.154	3.524	1.772	2.648	2.742	2.542	23.9	10.6	1	0.8	15.54	17.93	11.96	3.53	8.43	-0.19	1.94	2.14
214	########	25.8	15	20.4	20.2	24.4	0.148	3.322	1.705	2.514	2.367	2.087	23.9	10.6	1	0.8	15.54	17.93	11.96	4.12	7.84	-0.25	2.82	2.99
215	########	25.2	13	19.1	19.7	24.5	0.138	3.206	1.498	2.352	2.295	1.974	23.9	10.6	1	0.8	15.54	17.93	11.96	4.21	7.75	-0.41	2.66	2.82
216	########	25	13	19	19.7	24.2	0.137	3.168	1.498	2.333	2.295	1.994	23.9	10.6	1	0.8	15.54	17.93	11.96	4.18	7.78	-0.03	2.47	2.64
217	########	25.4	14.2	19.8	20	24.5	0.143	3.244	1.619	2.432	2.338	2.038	23.9	10.6	1	0.8	15.54	17.93	11.96	4.16	7.80	0.25	2.61	2.78
218	########	26	14	20	20.2	24.7	0.145	3.361	1.599	2.480	2.367	2.067	23.9	10.6	1	0.8	15.54	17.93	11.96	4.13	7.83	0.06	2.72	2.88
219	########	25.3	13.5	19.4	20.4	24.5	0.140	3.225	1.547	2.386	2.397	2.123	23.9	10.6	1	0.8	15.54	17.93	11.96	4.02	7.95	-0.19	2.29	2.47
220	########	24.6	14	19.3	20	23.4	0.139	3.093	1.599	2.346	2.338	2.111	23.9	10.6	1	0.8	15.54	17.93	11.96	4.02	7.94	-0.03	2.17	2.34
221	########	24	13.4	18.7	19.6	23.2	0.135	2.984	1.537	2.261	2.281	2.040	23.9	10.6	1	0.8	15.54	17.93	11.96	4.09	7.87	-0.19	2.13	2.29
222	1/1/2007	25.2	12.4	18.8	21.6	25	0.136	3.206	1.440	2.323	2.580	2.353	25.15	10.75	1	0.8	16.35	18.86	12.59	3.67	8.92	0.03	1.46	1.65
223	1/2/2007	24	12	18	20.2	23.6	0.130	2.984	1.403	2.193	2.367	2.140	25.15	10.75	1	0.8	16.35	18.86	12.59	3.92	8.67	-0.25	1.70	1.88
224	1/3/2007	23.2	11.5	17.35	19.6	22.2	0.125	2.844	1.357	2.100	2.281	2.107	25.15	10.75	1	0.8	16.35	18.86	12.59	3.93	8.66	-0.20	1.46	1.64
225	1/4/2007	19.4	10.7	15.05	17.2	18.4	0.110	2.253	1.287	1.770	1.962	1.882	25.15	10.75	1	0.8	16.35	18.86	12.59	4.11	8.48	-0.72	1.02	1.18
226	1/5/2007	21.6	10	15.8	17.5	19.5	0.115	2.580	1.228	1.904	2.000	1.866	25.15	10.75	1	0.8	16.35	18.86	12.59	4.18	8.41	0.24	1.43	1.59
227	1/6/2007	22.2	10.5	16.35	18	20.8	0.118	2.676	1.270	1.973	2.064	1.877	25.15	10.75	1	0.8	16.35	18.86	12.59	4.20	8.39	0.17	1.66	1.83
228	1/7/2007	22.7	11.2	16.95	18.4	20.8	0.122	2.759	1.330	2.045	2.116	1.956	25.15	10.75	1	0.8	16.35	18.86	12.59	4.12	8.47	0.19	1.67	1.84
229	1/8/2007	22	12.4	17.2	19.7	21	0.124	2.644	1.440	2.042	2.295	2.208	25.15	10.75	1	0.8	16.35	18.86	12.59	3.78	8.81	0.08	0.88	1.07
230	1/9/2007	21.8	12.2	17	19.5	20.2	0.123	2.612	1.421	2.017	2.267	2.220	25.15	10.75	1	0.8	16.35	18.86	12.59	3.75	8.84	-0.06	0.77	0.95
231	1/10/2007	23.6	11.6	17.6	20.2	21.8	0.127	2.913	1.366	2.140	2.367	2.260	25.15	10.75	1	0.8	16.35	18.86	12.59	3.73	8.86	0.19	1.05	1.24
232	1/11/2007	24.5	10.5	17.5	20.4	22.5	0.126	3.075	1.270	2.172	2.397	2.256	25.15	10.75	1	0.8	16.35	18.86	12.59	3.73	8.85	-0.03	1.21	1.39
233	1/12/2007	24.4	10.4	17.4	19.8	22.2	0.126	3.056	1.261	2.159	2.309	2.149	25.15	10.75	1	0.8	16.35	18.86	12.59	3.87	8.71	-0.03	1.49	1.68
234	1/13/2007	24	11.7	17.85	19.8	22	0.129	2.984	1.375	2.179	2.309	2.162	25.15	10.75	1	0.8	16.35	18.86	12.59	3.88	8.71	0.14	1.51	1.69
235	1/14/2007	24.5	13.2	18.85	19.2	22.3	0.136	3.075	1.517	2.296	2.225	2.018	25.15	10.75	1	0.8	16.35	18.86	12.59	4.13	8.45	0.32	2.33	2.51
236	1/15/2007	24.4	13.5	18.95	19	22	0.137	3.056	1.547	2.302	2.197	1.997	25.15	10.75	1	0.8	16.35	18.86	12.59	4.17	8.42	0.03	2.46	2.64
237	1/16/2007	23.6	15.4	19.5	19.4	22.7	0.141	2.913	1.750	2.331	2.253	2.032	25.15	10.75	1	0.8	16.35	18.86	12.59	4.15	8.44	0.17	2.44	2.62
238	1/17/2007	25.2	14.5	19.85	20	23.4	0.144	3.206	1.651	2.428	2.338	2.111	25.15	10.75	1	0.8	16.35	18.86	12.59	4.06	8.53	0.11	2.53	2.72
239	1/18/2007	25.5	13.5	19.5	20.2	23.7	0.141	3.263	1.547	2.405	2.367	2.134	25.15	10.75	1	0.8	16.35	18.86	12.59	4.01	8.58	-0.11	2.42	2.61
240	1/19/2007	24	14.4	19.2	20.7	22.6	0.139	2.984	1.641	2.312	2.442	2.315	25.15	10.75	1	0.8	16.35	18.86	12.59	3.74	8.85	-0.09	1.58	1.77
241	1/20/2007	24.8	16.4	20.6	20	22	0.150	3.130	1.865	2.498	2.338	2.205	25.15	10.75	1	0.8	16.35	18.86	12.59	3.96	8.63	0.44	2.42	2.62
242	1/21/2007	25	14.6	19.8	19.6	22	0.143	3.168	1.662	2.415	2.281	2.121	25.15	10.75	1	0.8	16.35	18.86	12.59	4.04	8.55	-0.25	2.52	2.71
243	1/22/2007	25.2	14.7	19.95	20.7	23.4	0.144	3.206	1.673	2.439	2.442	2.261	25.15	10.75	1	0.8	16.35	18.86	12.59	3.85	8.74	0.05	2.14	2.33
244	1/23/2007	25.4	15	20.2	21.2	23.7	0.146	3.244	1.705	2.475	2.518	2.351	25.15	10.75	1	0.8	16.35	18.86	12.59	3.74	8.85	0.08	1.99	2.19
245	1/24/2007	24.5	17.4	20.95	20.7	22.4	0.152	3.075	1.987	2.531	2.442	2.328	25.15	10.75	1	0.8	16.35	18.86	12.59	3.80	8.78	0.24	2.22	2.42

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
246	1/25/2007	24.5	15.6	20.05	19.6	23	0.145	3.075	1.772	2.423	2.281	2.054	25.15	10.75	1	0.8	16.35	18.86	12.59	4.15	8.44	-0.28	2.75	2.94
247	1/26/2007	22.7	13.6	18.15	18.4	20.7	0.131	2.759	1.558	2.158	2.116	1.963	25.15	10.75	1	0.8	16.35	18.86	12.59	4.17	8.42	-0.60	2.19	2.37
248	1/27/2007	22.6	11.7	17.15	17.6	20.2	0.124	2.742	1.375	2.059	2.013	1.839	25.15	10.75	1	0.8	16.35	18.86	12.59	4.30	8.29	-0.32	2.18	2.34
249	1/28/2007	22	10.4	16.2	18	19.8	0.117	2.644	1.261	1.953	2.064	1.944	25.15	10.75	1	0.8	16.35	18.86	12.59	4.09	8.50	-0.30	1.44	1.61
250	1/29/2007	23.6	11.5	17.55	18.3	20.5	0.127	2.913	1.357	2.135	2.103	1.956	25.15	10.75	1	0.8	16.35	18.86	12.59	4.15	8.44	0.43	1.95	2.12
251	1/30/2007	25	13.4	19.2	19.4	22	0.139	3.168	1.537	2.353	2.253	2.079	25.15	10.75	1	0.8	16.35	18.86	12.59	4.07	8.52	0.52	2.30	2.48
252	1/31/2007	26.3	12.6	19.45	20	22.7	0.140	3.422	1.459	2.440	2.338	2.158	25.15	10.75	1	0.8	16.35	18.86	12.59	3.97	8.62	0.08	2.43	2.62
253	2/1/2007	21.5	16.7	19.1	19.7	21.2	0.138	2.564	1.901	2.233	2.295	2.195	29.25	11.25	1	0.6	16.09	21.94	12.39	3.04	9.35	-0.11	1.79	2.29
254	2/2/2007	25.3	17	21.15	20	23	0.154	3.225	1.938	2.581	2.338	2.138	29.25	11.25	1	0.6	16.09	21.94	12.39	3.19	9.20	0.65	2.96	3.47
255	2/3/2007	22.5	15.5	19	18.2	21.2	0.137	2.726	1.761	2.243	2.090	1.890	29.25	11.25	1	0.6	16.09	21.94	12.39	3.38	9.01	-0.68	2.85	3.31
256	2/4/2007	21.8	10.5	16.15	17.4	20.6	0.117	2.612	1.270	1.941	1.987	1.774	29.25	11.25	1	0.6	16.09	21.94	12.39	3.38	9.00	-0.90	2.17	2.59
257	2/5/2007	22.5	10.6	16.55	17.7	20.3	0.120	2.726	1.278	2.002	2.025	1.852	29.25	11.25	0.8	0	7.31	21.94	5.63	0.52	5.11	0.13	1.33	2.19
258	2/6/2007	22.3	11.5	16.9	18.2	20.5	0.122	2.693	1.357	2.025	2.090	1.936	29.25	11.25	1	0.6	16.09	21.94	12.39	3.23	9.16	0.11	1.79	2.23
259	2/7/2007	24	12.7	18.35	19.6	21.9	0.132	2.984	1.469	2.226	2.281	2.127	29.25	11.25	1	0.6	16.09	21.94	12.39	3.08	9.30	0.46	1.85	2.33
260	2/8/2007	24.4	13.6	19	20.2	22.4	0.137	3.056	1.558	2.307	2.367	2.220	29.25	11.25	0.822	0	7.31	21.94	5.63	0.47	5.16	0.20	1.15	2.17
261	2/9/2007	26	13.2	19.6	22.4	24.2	0.142	3.361	1.517	2.439	2.709	2.589	29.25	11.25	0.702	0	7.31	21.94	5.63	0.41	5.22	0.19	0.42	1.37
262	2/10/2007	27.2	14.6	20.9	22.7	24.5	0.152	3.607	1.662	2.635	2.759	2.639	29.25	11.25	1	0.6	16.09	21.94	12.39	2.65	9.74	0.41	1.73	2.29
263	2/11/2007	28.4	13.8	21.1	23.4	26	0.154	3.869	1.578	2.723	2.878	2.704	29.25	11.25	1	0.6	16.09	21.94	12.39	2.59	9.80	0.06	1.88	2.45
264	2/12/2007	28.5	15	21.75	24	26.4	0.159	3.891	1.705	2.798	2.984	2.824	29.25	11.25	1	0.6	16.09	21.94	12.39	2.49	9.89	0.20	1.77	2.37
265	2/13/2007	29.2	14.6	21.9	24.3	27	0.160	4.052	1.662	2.857	3.038	2.858	29.25	11.25	1	0.6	16.09	21.94	12.39	2.47	9.92	0.05	1.89	2.49
266	2/14/2007	28.5	14	21.25	22.8	26.2	0.155	3.891	1.599	2.745	2.776	2.548	29.25	11.25	0.378	0	7.31	21.94	5.63	0.43	5.20	-0.20	1.62	2.14
267	2/15/2007	28.8	13.7	21.25	23	26.7	0.155	3.960	1.568	2.764	2.809	2.562	29.25	11.25	0.933	0	7.31	21.94	5.63	0.43	5.20	0.00	1.59	2.89
268	2/16/2007	28.4	16.5	22.45	22.8	26.5	0.165	3.869	1.877	2.873	2.776	2.528	29.25	11.25	1	0.6	16.09	21.94	12.39	2.82	9.57	0.38	2.81	3.37
269	2/17/2007	29	16.5	22.75	23.2	27	0.168	4.006	1.877	2.941	2.844	2.590	29.25	11.25	0.956	0	7.31	21.94	5.63	0.43	5.20	0.09	2.03	3.41
270	2/18/2007	29.2	14.4	21.8	23.5	27.4	0.159	4.052	1.641	2.846	2.896	2.635	29.25	11.25	1	0.6	16.09	21.94	12.39	2.69	9.70	-0.30	2.55	3.12
271	2/19/2007	28.8	15.5	22.15	23.6	27.4	0.162	3.960	1.761	2.860	2.913	2.659	29.25	11.25	1	0.6	16.09	21.94	12.39	2.67	9.71	0.11	2.45	3.03
272	2/20/2007	27.7	18.7	23.2	24	27.9	0.172	3.714	2.157	2.936	2.984	2.723	29.25	11.25	1	0.6	16.09	21.94	12.39	2.64	9.75	0.33	2.48	3.08
273	2/21/2007	27.2	16.6	21.9	23.2	25	0.160	3.607	1.889	2.748	2.844	2.723	29.25	11.25	1	0.6	16.09	21.94	12.39	2.60	9.79	-0.41	2.03	2.61
274	2/22/2007	28.2	15.8	22	23.5	27	0.161	3.824	1.795	2.810	2.896	2.662	29.25	11.25	1	0.6	16.09	21.94	12.39	2.66	9.72	0.03	2.31	2.88
275	2/23/2007	29	17.2	23.1	24.2	28.2	0.171	4.006	1.962	2.984	3.020	2.753	29.25	11.25	1	0.6	16.09	21.94	12.39	2.61	9.78	0.35	2.54	3.14
276	2/24/2007	29.4	16.5	22.95	24.4	28	0.169	4.099	1.877	2.988	3.056	2.816	29.25	11.25	1	0.6	16.09	21.94	12.39	2.54	9.85	-0.05	2.45	3.06
277	2/25/2007	30.7	16.5	23.6	25	28.8	0.175	4.416	1.877	3.147	3.168	2.914	29.25	11.25	1	0.6	16.09	21.94	12.39	2.47	9.92	0.20	2.62	3.24
278	2/26/2007	29.4	17.8	23.6	24.4	27.5	0.175	4.099	2.038	3.069	3.056	2.849	29.25	11.25	1	0.6	16.09	21.94	12.39	2.53	9.86	0.00	2.61	3.23
279	2/27/2007	30	18	24	25	28.7	0.179	4.243	2.064	3.154	3.168	2.921	29.25	11.25	1	0.6	16.09	21.94	12.39	2.47	9.92	0.13	2.64	3.28
280	2/28/2007	30.5	19.8	25.15	25.6	28.9	0.190	4.366	2.309	3.338	3.283	3.062	29.25	11.25	1	0.6	16.09	21.94	12.39	2.37	10.02	0.36	2.77	3.43
281	3/1/2007	28.2	19	23.6	23.5	25.9	0.175	3.824	2.197	3.011	2.896	2.735	33.8	11.85	1	0.6	18.59	25.35	14.31	2.64	11.67	-0.49	3.23	3.98
282	3/2/2007	22	18.2	20.1	22	21.6	0.146	2.644	2.090	2.367	2.644	2.671	33.8	11.85	0.958	0	8.45	25.35	6.51	0.40	6.10	-1.10	0.35	1.99
283	3/3/2007	29	17	23	23.2	27.2	0.170	4.006	1.938	2.972	2.844	2.576	33.8	11.85	0.916	0	8.45	25.35	6.51	0.44	6.07	0.91	2.17	3.81
284	3/4/2007	27.5	17.5	22.5	22.7	26	0.165	3.671	2.000	2.836	2.759	2.538	33.8	11.85	1	0.6	18.59	25.35	14.31	2.81	11.51	-0.16	3.15	3.86
285	3/5/2007	28.2	15	21.6	23	26.2	0.158	3.824	1.705	2.765	2.809	2.596	33.8	11.85	1	0.6	18.59	25.35	14.31	2.72	11.60	-0.28	2.77	3.47
286	3/6/2007	28.9	14.4	21.65	22.8	27	0.158	3.983	1.641	2.812	2.776	2.495	33.8	11.85	1	0.6	18.59	25.35	14.31	2.83	11.49	0.02	3.14	3.83
287	3/7/2007	27.8	14	20.9	23.2	26.7	0.152	3.736	1.599	2.667	2.844	2.610	33.8	11.85	1	0.6	18.59	25.35	14.31	2.68	11.63	-0.24	2.39	3.08
288	3/8/2007	29	15.2	22.1	24	27.5	0.162	4.006	1.727	2.867	2.984	2.750	33.8	11.85	1	0.6	18.59	25.35	14.31	2.58	11.73	0.38	2.54	3.26
289	3/9/2007	28.5	15	21.75	24.2	26.5	0.159	3.891	1.705	2.798	3.020	2.866	33.8	11.85	1	0.6	18.59	25.35	14.31	2.45	11.86	-0.11	2.08	2.81
290	3/10/2007	29.5	15.4	22.45	25.4	27.2	0.165	4.123	1.750	2.936	3.244	3.124	33.8	11.85	1	0.6	18.59	25.35	14.31	2.23	12.09	0.22	1.76	2.53
291	3/11/2007	31	17	24	25.7	30	0.179	4.493	1.938	3.215	3.302	3.015	33.8	11.85	1	0.6	18.59	25.35	14.31	2.38	11.94	0.49	2.89	3.67
292	3/12/2007	33	19.2	26.1	27.2	31.2	0.200	5.030	2.225	3.628	3.607	3.340	33.8	11.85	1	0.6	18.59	25.35	14.31	2.12	12.19	0.66	3.23	4.09
293	3/13/2007	31.5	20.4	25.95	26.5	30.8	0.198	4.622	2.397	3.509	3.462	3.175	33.8	11.85	1	0.6	18.59	25.35	14.31	2.28	12.04	-0.05	3.47	4.30
294	3/14/2007	28	20.5	24.25	24.6	28.2	0.181	3.780	2.412	3.096	3.093	2.853	33.8	11.85	1	0.6	18.59	25.35	14.31	2.54	11.77	-0.54	3.20	3.97

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
295	3/15/2007	29.5	17.5	23.5	25	28.5	0.174	4.123	2.000	3.061	3.168	2.934	33.8	11.85	1	0.6	18.59	25.35	14.31	2.44	11.87	-0.24	2.79	3.56
296	3/16/2007	27.5	17.3	22.4	24.2	27.4	0.165	3.671	1.975	2.823	3.020	2.806	33.8	11.85	1	0.6	18.59	25.35	14.31	2.53	11.78	-0.35	2.41	3.14
297	3/17/2007	29	14.8	21.9	24.6	28.2	0.160	4.006	1.684	2.845	3.093	2.853	33.8	11.85	1	0.6	18.59	25.35	14.31	2.47	11.84	-0.16	2.28	3.01
298	3/18/2007	29.2	15	22.1	25	28.6	0.162	4.052	1.705	2.879	3.168	2.927	33.8	11.85	1	0.6	18.59	25.35	14.31	2.40	11.91	0.06	2.14	2.88
299	3/19/2007	31	15.4	23.2	25.6	30.2	0.172	4.493	1.750	3.121	3.283	2.975	33.8	11.85	1	0.6	18.59	25.35	14.31	2.39	11.92	0.35	2.72	3.49
300	3/20/2007	32.7	18.5	25.6	26.2	31.2	0.195	4.946	2.130	3.538	3.401	3.067	33.8	11.85	1	0.6	18.59	25.35	14.31	2.38	11.94	0.76	3.63	4.45
301	3/21/2007	31.5	22	26.75	26.5	31.2	0.207	4.622	2.644	3.633	3.462	3.148	33.8	11.85	1	0.6	18.59	25.35	14.31	2.33	11.99	0.36	3.79	4.63
302	3/22/2007	32	23.2	27.6	27	31.5	0.216	4.755	2.844	3.799	3.565	3.265	33.8	11.85	0.895	0	8.45	25.35	6.51	0.35	6.16	0.27	2.66	4.62
303	3/23/2007	32	21	26.5	27.4	31.8	0.204	4.755	2.487	3.621	3.650	3.356	33.8	11.85	0.262	0	8.45	25.35	6.51	0.33	6.18	-0.35	2.10	2.67
304	3/24/2007	32.2	19.6	25.9	28.2	32	0.198	4.809	2.281	3.545	3.824	3.570	33.8	11.85	0.662	0	8.45	25.35	6.51	0.30	6.21	-0.19	1.30	2.76
305	3/25/2007	33.2	24.4	28.8	28	32.4	0.229	5.087	3.056	4.072	3.780	3.486	33.8	11.85	1	0.6	18.59	25.35	14.31	2.05	12.26	0.91	4.01	4.94
306	3/26/2007	34.4	20.5	27.45	28.5	32.8	0.214	5.439	2.412	3.925	3.891	3.604	33.8	11.85	1	0.6	18.59	25.35	14.31	1.91	12.41	-0.43	3.65	4.57
307	3/27/2007	34	19	26.5	27.8	33	0.204	5.319	2.197	3.758	3.736	3.389	33.8	11.85	1	0.6	18.59	25.35	14.31	2.09	12.22	-0.30	3.67	4.55
308	3/28/2007	33.6	22.2	27.9	27.6	32.7	0.219	5.202	2.676	3.939	3.693	3.352	33.8	11.85	1	0.6	18.59	25.35	14.31	2.16	12.15	0.44	4.09	4.98
309	3/29/2007	33.8	19.4	26.6	28.7	33.4	0.205	5.260	2.253	3.757	3.937	3.623	33.8	11.85	1	0.6	18.59	25.35	14.31	1.87	12.45	-0.41	3.13	4.03
310	3/30/2007	35.5	20.5	28	29.2	34	0.220	5.780	2.412	4.096	4.052	3.731	33.8	11.85	1	0.6	18.59	25.35	14.31	1.80	12.51	0.44	3.61	4.55
311	3/31/2007	35.2	21.8	28.5	29.2	34.2	0.226	5.685	2.612	4.149	4.052	3.718	33.8	11.85	1	0.6	18.59	25.35	14.31	1.83	12.49	0.16	3.85	4.80
312	4/1/2007	34.2	22	28.1	29	33.4	0.221	5.379	2.644	4.011	4.006	3.712	37.7	12.55	1	0.6	20.74	28.28	15.97	1.82	14.15	-0.13	3.95	5.02
313	4/2/2007	34.5	24.5	29.5	28.8	33.7	0.237	5.469	3.075	4.272	3.960	3.632	37.7	12.55	1	0.6	20.74	28.28	15.97	1.93	14.04	0.44	4.67	5.77
314	4/3/2007	34.8	24.7	29.75	29.4	34	0.240	5.561	3.112	4.336	4.099	3.792	37.7	12.55	1	0.6	20.74	28.28	15.97	1.78	14.18	0.08	4.57	5.69
315	4/4/2007	34	26	30	29.2	34	0.243	5.319	3.361	4.340	4.052	3.731	37.7	12.55	1	0.6	20.74	28.28	15.97	1.85	14.12	0.08	4.71	5.83
316	4/5/2007	34	25.2	29.6	28.3	33.6	0.239	5.319	3.206	4.262	3.846	3.492	37.7	12.55	1	0.6	20.74	28.28	15.97	2.07	13.90	-0.13	5.08	6.16
317	4/6/2007	33.4	25	29.2	29	32.8	0.234	5.144	3.168	4.156	4.006	3.752	37.7	12.55	1	0.6	20.74	28.28	15.97	1.81	14.16	-0.13	4.26	5.36
318	4/7/2007	33.5	25	29.25	29.2	33	0.234	5.173	3.168	4.170	4.052	3.798	37.7	12.55	1	0.6	20.74	28.28	15.97	1.76	14.20	0.02	4.16	5.27
319	4/8/2007	33.6	23.4	28.5	28.6	33.2	0.226	5.202	2.878	4.040	3.914	3.607	37.7	12.55	1	0.6	20.74	28.28	15.97	1.93	14.04	-0.24	4.30	5.37
320	4/9/2007	33	24.6	28.8	28.2	32.4	0.229	5.030	3.093	4.062	3.824	3.544	37.7	12.55	1	0.6	20.74	28.28	15.97	2.00	13.97	0.09	4.43	5.49
321	4/10/2007	33.2	23	28.1	29	32	0.221	5.087	2.809	3.948	4.006	3.805	37.7	12.55	1	0.6	20.74	28.28	15.97	1.73	14.23	-0.22	3.60	4.68
322	4/11/2007	26.2	23	24.6	25.4	26.2	0.185	3.401	2.809	3.105	3.244	3.191	37.7	12.55	0.854	0	9.43	28.28	7.26	0.35	6.91	-1.10	1.42	3.42
323	4/12/2007	27	19.5	23.25	26	26.7	0.172	3.565	2.267	2.916	3.361	3.315	37.7	12.55	1	0.6	20.74	28.28	15.97	2.06	13.90	-0.43	1.70	2.63
324	4/13/2007	30.2	17.2	23.7	26.4	28.8	0.176	4.292	1.962	3.127	3.442	3.281	37.7	12.55	0.88	0	9.43	28.28	7.26	0.33	6.93	0.14	0.93	2.97
325	4/14/2007	31	22.5	26.75	28	29.7	0.207	4.493	2.726	3.609	3.780	3.666	37.7	12.55	0.987	0	9.43	28.28	7.26	0.29	6.97	0.96	1.16	3.72
326	4/15/2007	33.2	23	28.1	29.7	32.2	0.221	5.087	2.809	3.948	4.171	4.004	37.7	12.55	1	0.6	20.74	28.28	15.97	1.55	14.42	0.43	3.00	4.11
327	4/16/2007	33.5	24	28.75	29.6	32.6	0.229	5.173	2.984	4.078	4.147	3.946	37.7	12.55	1	0.6	20.74	28.28	15.97	1.62	14.35	0.20	3.54	4.66
328	4/17/2007	32.4	24.2	28.3	29.8	32.2	0.223	4.863	3.020	3.942	4.195	4.034	37.7	12.55	1	0.6	20.74	28.28	15.97	1.53	14.44	-0.14	3.06	4.17
329	4/18/2007	33.5	24.7	29.1	30.2	32.7	0.233	5.173	3.112	4.142	4.292	4.125	37.7	12.55	1	0.6	20.74	28.28	15.97	1.46	14.51	0.25	3.31	4.46
330	4/19/2007	33.8	23.5	28.65	30	33	0.227	5.260	2.896	4.078	4.243	4.043	37.7	12.55	1	0.6	20.74	28.28	15.97	1.53	14.44	-0.14	3.40	4.52
331	4/20/2007	34	25.2	29.6	29.8	33.2	0.239	5.319	3.206	4.262	4.195	3.967	37.7	12.55	1	0.6	20.74	28.28	15.97	1.61	14.35	0.30	3.96	5.10
332	4/21/2007	33.5	25.6	29.55	29.8	32.4	0.238	5.173	3.283	4.228	4.195	4.021	37.7	12.55	1	0.6	20.74	28.28	15.97	1.56	14.40	-0.02	3.83	4.98
333	4/22/2007	34.2	25	29.6	30.4	33	0.239	5.379	3.168	4.273	4.341	4.168	37.7	12.55	1	0.6	20.74	28.28	15.97	1.43	14.54	0.02	3.62	4.78
334	4/23/2007	35.6	22.4	29	30.7	33.7	0.231	5.812	2.709	4.260	4.416	4.216	37.7	12.55	1	0.6	20.74	28.28	15.97	1.38	14.59	-0.19	3.49	4.64
335	4/24/2007	34.5	21.8	28.15	29.6	32.6	0.222	5.469	2.612	4.041	4.147	3.946	37.7	12.55	1	0.6	20.74	28.28	15.97	1.60	14.36	-0.27	3.52	4.62
336	4/25/2007	33.5	21.4	27.45	30	32.8	0.214	5.173	2.549	3.861	4.243	4.056	37.7	12.55	0.482	0	9.43	28.28	7.26	0.23	7.02	-0.22	1.11	2.43
337	4/26/2007	35.4	25.7	30.55	30.5	34	0.250	5.748	3.302	4.525	4.366	4.132	37.7	12.55	1	0.6	20.74	28.28	15.97	1.48	14.48	0.98	4.10	5.28
338	4/27/2007	30.2	22	26.1	29	29.7	0.200	4.292	2.644	3.468	4.006	3.959	37.7	12.55	0.827	0	9.43	28.28	7.26	0.24	7.02	-1.40	0.50	2.69
339	4/28/2007	33	22.3	27.65	30.2	32.2	0.216	5.030	2.693	3.861	4.292	4.158	37.7	12.55	1	0.6	20.74	28.28	15.97	1.40	14.56	0.49	2.38	3.49
340	4/29/2007	33.5	23.4	28.45	30.4	32.8	0.225	5.173	2.878	4.026	4.341	4.181	37.7	12.55	1	0.6	20.74	28.28	15.97	1.40	14.57	0.25	2.86	3.99
341	4/30/2007	34.5	23.5	29	31.2	33.2	0.231	5.469	2.896	4.182	4.544	4.410	37.7	12.55	1	0.6	20.74	28.28	15.97	1.21	14.76	0.17	2.79	3.96
342	5/1/2007	36	24.5	30.25	31	35.2	0.246	5.941	3.075	4.508	4.493	4.212	39.6	13.15	1	0.6	21.78	29.70	16.77	1.40	15.37	0.39	4.21	5.46
343	5/2/2007	36.6	25.4	31	31.5	36	0.256	6.139	3.244	4.692	4.622	4.321	39.6	13.15	1	0.6	21.78	29.70	16.77	1.32	15.45	0.24	4.48	5.76

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
344	5/3/2007	35	24.5	29.75	30.6	35	0.240	5.623	3.075	4.349	4.391	4.097	39.6	13.15	1	0.6	21.78	29.70	16.77	1.50	15.27	-0.39	4.24	5.46
345	5/4/2007	35	23.6	29.3	31	34.8	0.235	5.623	2.913	4.268	4.493	4.239	39.6	13.15	1	0.6	21.78	29.70	16.77	1.36	15.41	-0.14	3.65	4.88
346	5/5/2007	35.6	26	30.8	30.6	35	0.253	5.812	3.361	4.587	4.391	4.097	39.6	13.15	1	0.6	21.78	29.70	16.77	1.52	15.25	0.47	4.64	5.88
347	5/6/2007	34.6	25.5	30.05	30.2	34.3	0.244	5.500	3.263	4.381	4.292	4.018	39.6	13.15	1	0.6	21.78	29.70	16.77	1.58	15.19	-0.24	4.47	5.69
348	5/7/2007	33.8	25.7	29.75	30.4	33.4	0.240	5.260	3.302	4.281	4.341	4.141	39.6	13.15	1	0.6	21.78	29.70	16.77	1.46	15.31	-0.09	3.92	5.15
349	5/8/2007	34	24.5	29.25	31	33.2	0.234	5.319	3.075	4.197	4.493	4.346	39.6	13.15	0.911	0	9.90	29.70	7.62	0.20	7.43	-0.16	1.39	4.22
350	5/9/2007	32.8	24.6	28.7	30	33.2	0.228	4.974	3.093	4.034	4.243	4.029	39.6	13.15	1	0.6	21.78	29.70	16.77	1.54	15.23	-0.17	3.52	4.71
351	5/10/2007	34.8	25.2	30	30.4	33.8	0.243	5.561	3.206	4.383	4.341	4.114	39.6	13.15	1	0.6	21.78	29.70	16.77	1.49	15.28	0.41	4.11	5.34
352	5/11/2007	35	26.5	30.75	31.2	34.2	0.253	5.623	3.462	4.542	4.544	4.344	39.6	13.15	1	0.6	21.78	29.70	16.77	1.29	15.48	0.24	4.08	5.36
353	5/12/2007	34.2	23.4	28.8	27.5	30	0.229	5.379	2.878	4.128	3.671	3.504	39.6	13.15	1	0.6	21.78	29.70	16.77	2.04	14.73	-0.61	5.02	6.15
354	5/13/2007	35.4	23.6	29.5	31.2	34.2	0.237	5.748	2.913	4.331	4.544	4.344	39.6	13.15	1	0.6	21.78	29.70	16.77	1.27	15.50	0.22	3.51	4.75
355	5/14/2007	28.2	34	31.1	28.3	29	0.257	3.824	5.319	4.572	3.846	3.800	39.6	13.15	1	0.6	21.78	29.70	16.77	1.81	14.97	0.50	5.21	6.43
356	5/15/2007	26.7	22.4	24.55	26.4	26.7	0.184	3.503	2.709	3.106	3.442	3.422	39.6	13.15	0.937	0	9.90	29.70	7.62	0.31	7.31	-2.06	1.05	3.45
357	5/16/2007	34	22.5	28.25	30	32.2	0.223	5.319	2.726	4.022	4.243	4.096	39.6	13.15	0.962	0	9.90	29.70	7.62	0.23	7.39	1.17	1.22	4.08
358	5/17/2007	34.2	24.3	29.25	30.6	33.4	0.234	5.379	3.038	4.208	4.391	4.204	39.6	13.15	1	0.6	21.78	29.70	16.77	1.39	15.38	0.32	3.48	4.70
359	5/18/2007	33.6	26.2	29.9	31	33	0.242	5.202	3.401	4.302	4.493	4.359	39.6	13.15	1	0.6	21.78	29.70	16.77	1.26	15.51	0.20	3.44	4.70
360	5/19/2007	34	25.5	29.75	31.2	32.6	0.240	5.319	3.263	4.291	4.544	4.450	39.6	13.15	0	0	9.90	29.70	7.62	0.18	7.44	-0.05	1.37	1.37
361	5/20/2007	34.5	25.4	29.95	30.7	33.2	0.243	5.469	3.244	4.357	4.416	4.249	39.6	13.15	1	0.6	21.78	29.70	16.77	1.36	15.41	0.06	3.84	5.09
362	5/21/2007	33	25.5	29.25	30.2	33	0.234	5.030	3.263	4.147	4.292	4.105	39.6	13.15	0.937	0	9.90	29.70	7.62	0.23	7.39	-0.22	1.85	4.69
363	5/22/2007	33.4	25.4	29.4	30.5	33.8	0.236	5.144	3.244	4.194	4.366	4.146	39.6	13.15	0.937	0	9.90	29.70	7.62	0.23	7.40	0.05	1.81	4.67
364																								
365																								
366																								
367	Note:	Tmax_C	max temp of the day (recorded mostly around 3PM) in celcius								for z=4m	P	101.25				a(s)	0.25				c(s)	2.1	
368		Tmin_C	min temp of the day (recorded mostly around 6AM) in celcius									γ	0.067				b(s)	0.5				del(z)	0.15	
369		Tmean_C	average of Tmax_C and Tmin_C									a(ψ)	0.00066	(say)			z	4	m			del(t)	1	
370		Twet_C	wet-bulb temp recorded around noon									γ(ψ)	0.066825				α	0.23				u	5	m/s
371		Tdry_C	dry-bulb temp recorded around noon														σ	4.9E-09						
372		Ra	from Table 2.6 of FAO report																					
373		N	from Table 2.7 of FAO report																					
374		n/N (high)	is 1 for no RF days, 0 for >50mm RF days (assumed RF intensity = 4mm/hr in Jun-Jul-Aug, 3mm/hr in Sep-Oct, 2mm/hr in Nov-Mar, 3mm/hr in Apr-May)																					
375		n/N (low)	for no RF days in Jun-Aug is 0.4, Sep-Oct is 0.6, Nov-Jan is 0.8, Feb-May is 0.6; 0 for RF days																					

Appendix M

Hydrologic Processes on Stable Water Isotope

Effects of Hydrologic Processes on Stable Water Isotope

In general, evaporation tends to enrich surface water in ^{18}O and D (deuterium) since the lighter isotopes vaporize more easily. As a result, the $\delta^{18}O$ and δD [δ indicates deviations from the "Standard Mean Ocean Water" (SMOW) standard; $\delta = \{(R_{sample}/R_{std}) - 1\} \times 1000$, where R = $^{18}O/^{16}O$ or D/H] values of precipitation are lower (more negative) than their surface water source. On the other hand, raining out makes precipitation progressively depleted in ^{18}O and D since the heavy isotopes fall down with earlier rain. Also, the $\delta^{18}O$ and δD values of the precipitation becomes more negative towards inland (away from the source), during winter season and higher altitude (i.e. lower temperature). On a global scale, the linear relationship between $\delta^{18}O$ and δD of meteoric waters is known as "Global Meteoric Water Line" (GMWL), which is represented by the equation of $\delta D = 8\delta^{18}O + 10$. The slope value of 8 results from equilibrium process (between liquid and vapor phases) that fractionate hydrogen isotope eight times more than that of oxygen. The intercept of the GMWL equation implies that the line does not pass through the seawater composition ($\delta^{18}O = \delta D = 0$). The intercept, also known as "deuterium excess" (d), is the effect of kinetic process that fractionate oxygen isotope twice than that of hydrogen. The intercept value depends on humidity sensitively, and thereby, can be different for Local Meteoric Water Lines (LMWL). Analysis of stable water isotopes of different water pools can provide insights to the possible groundwater recharge sources, as well as to their proportional mixing through the following principle:

$\sum_{i=1}^{m} x_i \delta_i = \delta_{system}$, where m is the number of recharge sources for the groundwater system

Appendix N

Sampling for Stable Water Isotope

Sampling Protocol for Stable Water Isotope Analysis

Sources of groundwater recharge can be identified by comparing their isotopic signatures with that of rainwater, surface water and other evaporative water bodies. Therefore, a sampling campaign has been undertaken to collect temporal water samples from different pools of water in the Munshigonj study area.

A. Sampling sources:

Sample type	Location ID	Sample frequency
Pond water	P-1, P-2, P-3, P-4, P-5, P-6	1) During irrigation (March/April) 2) Beginning of flood (May/June) 3) After flood (October/November) 4) Before irrigation (January)
Surface water	HB1, HB2, SB1, SB2, LB2 / LB4	
Irrigation water	IR-6, IR-8, IR-17, IR-19, IR-20, IR-22, IR-24, IR-31, IR-32, IR-34, IR-35, IR-42, IR-44, IR-50	
Drinking water	DR-2, DR-3, DR-10, DR-12, DR-13, DR-15, DR-16, DR-18, DR-19, DR-33, DR-34	
Monitoring wells	Peizometric wells from the field site	
Rice-field water	Standing water from the rice fields which are fed by IR-8, IR-17, IR-19, IR-22, IR-42	At least twice during the irrigation season
Rain water	BUET + Bhagakul Meteorological Station	Every major rain event between October and beginning of flood

B. Sampling Protocol:

- Samples have been collected in 15ml centrifuge tubes
- Tubes have been filled completely with no head space (to prevent evaporation)
- No acid or filtration during sampling
- Immediately after collection, samples have been put in a cooler (filled with ice) to prevent any evaporation (only 5% evaporation can change the isotopic value quite significantly)
- Upon returning to BUET, the tube caps have been sealed with parafilm, and have been stored in a refrigerator (not freezing to avoid displacement of caps)

C. Collecting Rainwater:

Isotopic values may change from one rainstorm to another. In addition to temporal sampling, rain waters have also been collected at two different locations (BUET and Bhagakul Meteorological Station) to see if there is any spatial variation.