

**ASSESSMENT OF CROP DAMAGE
DUE TO FLOOD
USING GIS TECHNOLOGY**

Submitted by

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CERTIFICATE

This is to certify that this project work **Assessment of Crop Damage due to Flood using GIS Technology** has been done by me. Neither of this thesis nor any part thereof has been submitted elsewhere for the award of any degree or diploma.



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**"ASSESSMENT OF CROP DAMAGE DUE TO FLOOD USING GIS
TECHNOLOGY"** be accepted as fulfilling this part of the requirements for the degree of
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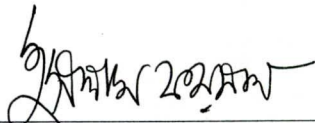
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ABSTRACT

Bangladesh has a reputation for being disaster-prone. Floods, cyclones, tornadoes and droughts strike with depressing regularity and intensity. None of these hazards are new, but in recent years, there have been some significant developments. On the one hand, the potential for loss of life, damage to property and agriculture is increasing as population pressure forces people to occupy more marginal and exposed land. On the other hand, sophisticated satellite communication systems, computer softwares now offer better warnings of impending climatic shocks and the country should generally be better prepared to cope with emergencies and to mitigate their impact.

This study is set to assess crop damage due to flood using the Geographic Information System (GIS) as a tool. A part of the Compartmentalization Pilot Project (CPP) under Flood Action Plan (FAP) in Tangail has been taken as the study area. One of the main objectives of this project is to boost crop production through water management by controlled flooding. Field survey was done to obtain the existing cropping pattern. Additional data such as land contour, crop damage functions were collected from the Bangladesh Water Development Board and CPP. Flood model results for water level series were collected from Surface Water Modelling Centre (SWMC). These information were used finally in the PC ARC/INFO GIS software to assess crop damage for different years.

Results obtained in the system were compared with the field situation, though a detail damage information covering a number of years on such a small area (403 hectares) as the study area, is not available. However, for the year 1995 the damage information was available. The system result for the year 1995 for with project situation shows good match with the field situation. In this year partial water management testing was performed in the study area. For other areas, both inside and outside the project area, where the flood water of 1995 flood got its way to damage crop fields, damage scenario can be compared with that of 1991. Because the years 1991 and 1995 experienced almost the same kind of flood having a return period of 5 years. The

system result for the year 1991 also shows 5 year return period damage to crops which indicates that the system that has been developed in the GIS may be considered reliable.

The study showed in case of the year 1995 that no damage to crops occurred during monsoon in the study area, which complied with the field situation. In this year when flood came, water levels in the crop fields were maintained according to the farmers necessity in 80% of cropping area. Analysis was done considering the target water levels which are designed to be maintained in the crop field according to the water management plan. The result showed good match with the field situation. In the study area in 1995 no damage to crops found during field survey. Analysis with the system developed in the GIS also assessed the same result. However, sometimes it is found that the system result is over estimated. This may have occurred due to lack of information about the plantation time in the actual field condition. If in a certain area the crop fields can be identified by proper monitoring activities when the monsoon comes, the system could have been applied more efficiently in assessing crop yield or crop damage. Another expected finding is that the cropping pattern in 1995 monsoon, which has been surveyed later on, is similar to the cropping pattern that has been obtained in the present study. Actual cropping pattern in the field in 1995 monsoon, which was found out in the survey, was expected as the farmers were trained to choose and plant crops according to CPP's water management target. However GIS can be used to find out suitable cropping pattern in project planning activities especially in water management projects. Finally recommendations are put forward to apply the GIS technique for assessing flood damage to other areas of the country.

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Abbreviations

AEZ	- Agro-Ecological Zone
AVHRR	- Advanced Very High Resolution Radiometer
BADC	- Bangladesh Agricultural Development Corporation
BBS	- Bangladesh Bureau of Statistics
BWDB	- Bangladesh Water Development Board
CPP	- Compartmentalization Pilot Project
DAE	- Department of Agricultural Extension
DEM	- Digital Elevation Model
DPHE	- Department of Public Health Engineering
DW Aman	- Deep Water Aman
ESRI	- Environmental System Research Institute
FAP	- Flood Action Plan
FMM	- Flood Management Model
GIS	- Geographical Information System
GoB	- Government of Bangladesh
ha	- Hectares
HYV	- High Yielding Variety
ISPAN	- Irrigation Support Project for Asia and the Near East
LGED	- Local Government Engineering Department
MPO	- Master Plan Organization
m.+PWD	- Meter above Public Works Datum (elevation)
NAS	- Need Assessment Survey
NCA	- Net Cultivable Area
NGO	- Non-Government Organization
NVI	- Normalized Vegetation Index
SC	- Sub-compartment
SCWMC	- Sub-compartment Water Management Committee
SPARRSO	- Space Research And Remote Sensing Organization
SWMC	- Surface Water Modeling Centre
TIGER	- Topographically Integrated Geographic Encoding and referencing
ToR	- Terms of Reference

UNDP - United Nations Development Program
WMO - World Meteorological Organization

Glossary

Aquaculture	- cultivation of aquatic products (mainly fish and shrimp)
Aman	- photoperiod-sensitive rice planted in July-August and harvested in November-December.
Aus	- photoperiod-insensitive rice varieties sown during March-April and harvested during June-August.
Beel	- small lake, low-lying depression, a permanent body of water in a floodplain or a body of water created by rains or floods.
Boro	- photoperiod-insensitive but fairly cold tolerant rice varieties transplanted in December-February and harvested in April-May.
Chawk	- a readily recognizable manageable field unit bounded by village roads and settlement areas. These are physical entities and are easily recognized by village people. Each chawk has water inlets or outlets through bridges, culverts, road breaches etc., and may have one or more regulating structures on these inlets and outlets.
Compartment	- a (semi) protected area or part thereof in which effective water management particularly through controlled flooding and controlled drainage, is made possible through physical and institutional arrangements. A compartment will be subdivided into sub-compartments and operational water management units.
Compartmentalization-	establishment of inter-linked compartments in the flood plains, with the objective to provide a more secure environment for agriculture, fisheries and integrated rural and urban development through water management (controlled flooding and drainage, flood control), while allowing seasonal beneficial flooding.
Controlled drainage	- control of the water flow out of a (sub)compartment according to the local or regional requirements.
Controlled flooding	- spreading of the monsoon flood over the land in a (semi)controlled way with the help of provisions incorporated in compartments, embankments, roads etc.
Flood Control	- protection against harmful flooding.
Khal	- natural channel.

- Pagar
 - small waterbody, generally excavated near a homestead, which is used for fish stocking as well as for household activities.
- Sub-compartment
 - sub-unit of a compartment, in which to a certain extent the water management can be controlled by a SCWMC representing the people living in the area. The sub-compartment is mostly separated from the adjoining ones by embankments or roads provided with (semi)controlled structures. Ideally it has an independent inlet and outlet. Sometimes there is no inlet and the sub-compartment is dependent on rainfall only. Sometimes the outlet drains into the sub-compartment downstream, not into the main drainage channel.
- System
 - sub-unit of a sub-compartment, a chain of one or more chawks, being a hydrological watershed and a (part of) a command area of a relatively important outlet structure. The smallest system is just one chawk, while sometimes a system comprises an entire sub-compartment.
- Water Management
 - the controlled quantitative and qualitative usage of water, including early, late and deep flooding, rainfall and groundwater for agriculture, fisheries, transport, sanitation, domestic and industrial purposes

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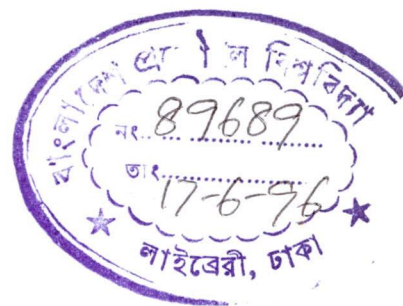
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1. INTRODUCTION



1.1 Introduction

Bangladesh is an agrobased country where more than 80% of the population is involved in agriculture. Agriculture here is the main economic activity. It should also be noted that Bangladesh is the country with a population within the first ten countries in the world with respect to population (BBS, 1994). It has a reputation for being disaster-prone. Almost every year it is visited by natural calamities, floods being the most common, which cause heavy losses to life and property. It is very often that it faces severe damage to crops mainly due to flood and drought.

The country, with its limited resources and millions to feed, can not afford to be exposed to the vagaries of nature without taking precautionary measures. In order to safeguard against the fury of nature and make the maximum use of the country's limited natural resources, it is essential that a proper management planning method be developed. However, this needs the creation of a sound database and regular surveying of renewable and non renewable resources and monitoring and forecasting of natural/manmade disasters. This requires a substantial amount of resource investment and consumes a lot time if only the conventional data and methods are applied. Here, however, Geographic Information System (GIS) has a big role to play.

Crop damage assessment here in Bangladesh is very important from a number of points of view. Bangladesh is a low lying area. Moreover major rivers originating from outside the country are falling into the Bay of Bengal through this country. They carry a huge amount of water and sediment from a catchment area of which more than 90% lie outside Bangladesh. Though there is no rainfall locally yet this country can face severe flood, when carrying capacity of these major rivers is exceeded by a heavy upstream flow from outside Bangladesh, which happens so often (Chowdhury 1989). These devastating floods cause heavy losses to life, industry, agriculture etc. As

cropping is our main economic activity and more than 80% of the population is being involved in agriculture, water management practices here mainly focus on agricultural production. Assessment of flood damage, specially crop damage is necessary for the post flood rehabilitation programs, for assessing the amount of grains to be imported when a huge scarcity of food is being expected after the flood. All the water management projects now in Bangladesh are being projected towards a sustainable development, where boosting up of crop production is the prima-facie objective. Damage calculations due to flood for with and without project situations for these water management projects are required both in planning and monitoring stages.

For the proposed study Compartmentalization Pilot Project (CPP) Tangail has been taken to be the study area. This is a water management project with a new concept namely compartmentalization in the water resources sector of Bangladesh. One of the main objectives of CPP is to facilitate agricultural production through effective water management. Crop damage assessment in this project is directly related to water management plan.

Immediately after the 1988 flood disaster, several studies were carried out by the international community to find out a lasting solution to the flood problem. In June 1989, the World Bank agreed with the government of Bangladesh to coordinate the various flood control and related initiatives, which was named as Flood Action Plan (FAP). The Compartmentalization Pilot Project, approved on September 28, 1989 is one of them and is under FAP 20. The project was formally commissioned on October 21, 1991 (CPP.a., 1995).

1.2 Application

Crop damage assessment is of utmost importance from water management planning point of view. This will help in mitigating flood damage and optimizing cropping pattern for higher yield which is very urgent now for a growing population. Also for flood monitoring activities it will help a lot. It will help to assess the economic benefit

of any flood control or water management project. It will also help in post flood rehabilitation program by assessing the amount of damage due to flood.

1.3 Objective of the study

- (a) Crop damage assessment for existing and projected cropping pattern in one part of Tangail CPP will be done by MIKE11-GIS modeling tool.
- (b) An attempt will be made to find out a suitable higher yielding cropping pattern by trial and error.

1.4 Literature Review

Geographic Information System and its application in assessing crop damage is a new idea in Bangladesh. After a wide range of review only very few literature were found relating to this new concept. Though in Bangladesh, the concept is new but this kind of application of GIS, especially in assessing flood damage, had been started about ten years back in other countries (SPARRSO 1989).

Before looking at different computer applications in assessing crop damage due to flood, a brief description of the conventional means of damage assessment due to flood in Bangladesh is given here. The study was done jointly by Bangladesh Agricultural Research Council and Bangladesh Agricultural Research Institute after the flood of 1987. First of all districtwise damage data for affected crop fields were collected from different sources such as- public media, agriculture officer, field survey etc. Districtwise ratio of Aus, Broad Casted Aman and Transplanted Aman was collected from 'Food Production Program' published by the Ministry of Agriculture. Districtwise ratio for the local and high yielding variety was also collected from the same source. Then the flood tolerance depths for different crops and weekly data of rainfall and water level for different rivers were collected. Damage assessment was done based on those data and statistics.

But with the development of different computer programs now-a-days, this kind of assessment work has become more efficient, less time consuming, accurate and flexible

to deal with. It is the remote sensing technology, which was applied first in flood assessment. Introduction of the GIS technology has enhanced and supplemented the remote sensing technology. However, GIS has been proved to be operational in flood assessment without taking any help from remote sensing. Before going through the GIS applications, some examples of remote sensing applications are given below.

The use of satellite data in flood assessment was instituted in the United States of America in early 1973 to study the flooding of the Mississippi River (United Nations 1985). It was found that the satellite data could be used very effectively to map the water-covered areas using the near infra-red bands from the Landsat MSS (Multi-Spectral Scanner). In Bangladesh, satellite imagery has revealed potential new areas for rice production in poorly mapped, flooded areas. Satellite imagery was also used as the major source of information for flood plain mapping in Myanmar (formerly Burma), under WMO/UNDP project BUR/84/008. In China, satellite remote sensing techniques were used to investigate flooded areas flood hazards in the San Jiang Plain in 1981 and in the He Fai area in 1984 (United Nations 1985). Data provided by Landsat and weather satellites, together with ground-truth input, were submitted to photoprocessing and digital processing methods in order to delineate the extent of flooding and flood hazards. In Malaysia, the application of remote sensing techniques to flood mapping is restricted to black-and-white aerial photographs taken from airplane (United Nations 1985). In Sri Lanka, aerial photographs and other remotely sensed data are stored at the Sri Lanka Centre for Remote Sensing (United Nations 1985). Although Landsat data are primarily used for general land-use mapping, the country has started using them to isolate flood-prone sites. A study on flood inundation in northeast Thailand demonstrated that a visual analysis of Landsat black-and-white imagery and colour composites provided good results for flood mapping (United Nations 1985). The area covered was the Mun Chi basin and the results of the study were a detailed inventory of flooded roads and villages that became inaccessible during floods. The Pakistan Space and Upper Atmosphere Research Commission remote sensing applications program on water resources and hydrology includes flood inundation studies, river course change mapping, estimation of the areal extent of snow cover etc. (United Nations 1985). In India remote sensing plays an important

role in studies and surveys in the Brahmaputra basin, where intensive flood control measures were planned (United Nations 1985).

In Bangladesh, however, this kind of practice is relatively new. Space Research and Remote Sensing Organization (SPARRSO) is the leader in Bangladesh in assessing crop conditions using computer technology with the additional input from satellites. In 1986 SPARRSO has conducted a study which includes a countrywide monitoring of crop conditions using Advanced Very High Resolution Radiometer (AVHRR) data from NOAA series of meteorological satellites. This monitoring program was carried out for the period from June to December, 1985. The vegetation conditions have been observed in the satellite data through calculation of Normalized Vegetation Index using the I²S vegetation index software developed by SPARRSO scientists and engineers using the widely used algorithm, $NVI = (Channel\ 2 - Channel\ 1) / (Channel\ 2 + Channel\ 1)$. The imagery which have been analyzed were not totally cloud free and this created problem for time sequential interpretation of the imagery over whole of Bangladesh. However, attempts were made to look at the cloud free areas. The vegetation intensity is directly proportional to the vegetation index values which limits from -1 to +1. The interpretation was done using the digital values of the NVI and the corresponding colour codes. This interpretation technique is based on the physical meaning of the vegetation index and has not been verified with the actual field data. The NVI imagery from June to December, 1985 shows the stages of summer crops and the spatial and temporal distribution of Aman harvesting process over the whole country. The interpretation of the imagery are based on the available crop calendar in Bangladesh. This study suggests to do the same exercise for a number of seasons in order to establish the degree of reliability of the Vegetation Index with crop yield (SPARRSO, 1986).

SPARRSO has carried out an estimation of the damage to Aman crop due to the 1987 and 1988 floods (Chowdhury 1989) using its satellites facilities. An analysis of a NOAA-10 image for 24 September 1988 showed that in heavily flooded areas like Dhaka, Faridpur, Brahmanbaria and Habiganj, damage to crops was very extensive.

Crop conditions were assessed by a vegetative index, showing the health of crops. However, crop conditions in north-western Bangladesh were very good.

In China, the remote sensing evaluation of flood damage started in early 1980s (Shupeng 1989). The first application was for compensation evaluation and emigration investigation for small reservoirs. Real time monitoring and transmission experiments for flood disasters have been carried out for the Liaohe, Yongding and yellow rivers and Dongting Lake since 1985. An experiment on the Jinjiang river was finished in 1989. All-weather aerial monitoring and multiple elements flood control database construction have also been realized. Digital terrain model, flood model, SPOT, TM and aerial images were used in those studies. Some other remote sensing and GIS pilot projects were carried out in China with co-operation and support from the Space International Development Association and the International Development and Research Centre, Canada.

Another paper (Wu and Shupeng 1989) describes briefly the nonstructural methods based on GIS and remote sensing that have been used in China. Over the course of several years, a middle Yangtze meander/Dongting Lake region geographic information system was created, using ARC/INFO GIS software on a VAX 11/785 and PC ARC/INFO GIS software on a compaq 386. The data which were included in this system were as follows.

- Regional hydrography
- Digital terrain model
- Background data for flood control
- Socio-economic data
- Remotely sensed data.

A probability model was used to perform flood risk analysis and a two-dimensional flood model was used to simulate flood inundation time, depth and duration. Based on the above data final analysis of damage was done using GIS.

The paper (Walker, Abrahamse, Bolton, Kahan, Riet, Kok, Braber, 1993) describes a four month study performed for the Dutch Minister of Transport, Public Works, and

Water Management that examined the consequences of alternative policies for providing flood protection to the non-tidal branches of the Rijn and Mass Rivers in The Netherlands. The paper focuses on estimating the flood damage that would occur under alternative dike improvement strategies, and estimating the damage that would be inflicted on the landscape, natural, and cultural values along the rivers under each of these strategies. The primary objective of the study was to identify policies that would provide a high level of safety, would not cost too much, and would preserve as much as possible of the existing landscape, natural, and cultural values along the rivers. Less than six months after the completion of the study, the Dutch Parliament approved a new river dike policy that was based on the study's results. For this study a one-dimensional hydraulic model was used to simulate the water levels and discharges in the rivers. A UNIX based GIS was used to represent the land surface and the inundation depths as a surface that is, actually flood maps and finally a spreadsheet model was used to calculate the flood damages for different options.

Another study was triggered in 1994 by the Dutch Government immediately after the 1993 flood of the river Mass, which caused a damage of about 160 million US Dollars (Kok, 1995). That study produced a number of combination of (institutional and technical) measures to reduce future flood damage. These combination of measures were produced by considering the following set of criteria :

protection

- reduction of Present Value of Flood Damage
- reduction of number of people evacuated

cost

- minimizing total cost
- maximizing total earnings gravel/sand
- minimizing financial risks

time of completion

- reduction of flood damage within 10 years

- minimizing completion time

ecology and landscape

- maximising potential for nature development
- minimising loss of current nature value
- maximising new nature area
- minimising length of embankments

A number of tools were used to assess the consequences of the strategies. These were models describing the physics of the river that is a one dimensional hydraulic model, GIS (UNIX) technology and spreadsheets.

Flood Modelling and Management unit of FAP or FAP25 carried out a study to assess crop damage using the model developed by them namely Flood Management Model (FMM) in 1994. The main study of FAP25 was to present a methodology aimed at generating flood depth and flood impact maps. They developed finally a modelling system for flood management (FMM), which integrates flood models and Geographic Information System (GIS). It's been a long practice in Bangladesh to use MIKE11 flood models in modelling floods which give flood levels along the rivers and over the flood plains, and more importantly, simulate the impacts of interventions on flood levels. GIS technology was used to perform multi-sectoral impact analysis and produce impact maps. FMM was applied and demonstrated at three levels : national, regional and compartment. On compartment level, a detailed FMM was developed for the Tangail Compartment of the Compartmentalization Pilot Project (FAP20). Using the compartment level FMM, crop damage assessment study was done. However, this was only a demonstration of FMM, not an assessment study and for this they have considered the whole compartment of CPP to be planted with HYV paddy. In this study a crop is defined as damaged if it is inundated for more than 3 consecutive days at a depth greater than its critical depth. The critical depth is defined for half-monthly periods based on the crop's growth rate and resistance to flooding.

Compartmentalization Pilot Project (CPP) Tangail (FAP-20) has done two exercises relating to flood damage. First one was carried out in 1992 and the other was done recently in December, 1995. The first study took the series of water level data from MIKE11 one dimensional hydraulic model and used the landuse type of 1964, which is the last one recorded by Bangladesh Water Development Board (BWDB). This study assessed only crop damage. The maximum three day mean water level per decade has been assessed for the station at Jugini, located at the river of Dhaleswari near the project area. It is shown in fig.3.1. The flooded area within the compartment has been related to the water level at Jugini. The whole compartment is subdivided into 16 subcompartments and an average land level had been assigned to each of them for calculating the flood water depth in the field. The rest of the calculation except the MIKE11 simulation, were carried out manually. For Boro, T.Aus, B.Aus, T.Aman HYV and T.Aman Local, the most critical stage of those crops were considered for damage calculations. This critical stage is a certain growing stage when the crop is to be most vulnerable to flood. But for Deep Water Aman all the growing stages were considered. This exercise lacks two things, one, the actual field water levels as the exercise considered only Jugini water level and the other, for low lying area crops specially for T.Aman Local, it didn't consider different growing stages. This exercise calculated the potential damage index for the years 1983 to 1991 (CPP 1992).

CPP's recent study (CPP 1995) comprises the development of a flood damage assessment model which is a complex interface of MIKE11, workstation based GIS, pc based GIS and a Window based database software. This study calculated damages to crops, houses, roads and fisheries in a certain portion of the CPP namely clusterIb for five historical years and this was done for with and without project situation. MIKE11 one dimensional hydraulic model supplied the water level series for the historical years those were considered in the damage study and this was done in the Surface Water Modelling Centre (SWMC) Dhaka. Digital Elevation Model (DEM) supplied the land elevation for the study area. A workstation GIS was used to convert the DEM from grid format to vector format or in the form of polygons and this was also done in the SWMC. The base landuse coverage was prepared in CPP Tangail using a pc based GIS. Extensive field survey was done to prepare the landuse

coverage. Then the damage calculations were done in a window based database software. For assessing crop damage a general crop damage function was used, which is actually a BWDB standard and the whole monsoon period was considered from July to October. For houses and roads only the peak water level of each historical year was considered and if a road or a house is inundated with that level, those were considered damaged. For houses the inundation depth was considered as a function of damage. For fisheries, inundation depth, area and duration were considered to assess the catch rates. This study is no doubt a unique one but is a complex process of interaction between different kinds computer softwares.

2. GEOGRAPHIC INFORMATION SYSTEM

2.1 *Introduction*

About 25 years ago, a number of geographers conceived a system for storing and organizing spatial information in a computer. In the past ten years, this growing technology has come to be known as Geographic Information System (GIS). A GIS is an information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well a set of operations for working with the data.

A GIS can, of course, be either manual (sometimes called analog) or automated (that is, based on a digital computer). Manual geographic information systems usually comprise several data elements including maps, sheets of transparent materials used as overlays, aerial and ground photographs, statistical reports and field survey reports. These sets of data are compiled and analyzed with such instruments as stereo viewers, transfer scopes of various kinds, and mechanical and electronic planimeters (Star and Estes, 1990).

From the manual approach, advances in computing, cartography, and photogrammetry laid the technological foundations for the automated geographic information systems that began to appear in 1960s. The conceptual framework within which early geographic information systems were implemented involved individuals in many disciplines. Researchers and resource managers in diverse areas realized that there was need for integrating data from a variety of sources, to manipulate the sets of data to analyze them, and then to be able to provide information for a resource planning and management decision process.

Three important factors helped lead to the creation of digital GIS in the 1960's :

- refinements in cartographic technique.
- rapid developments in digital computer systems, and
- the quantitative revolution in spatial analysis.

These developments were very important in that they helped to provide analytic tools as well as simulation to researchers and professionals in a variety of applications (Star and Estes, 1990).

The first system in the modern era to be generally acknowledged as a GIS was the Canadian Geographic Information System or CGIS (Star and Estes, 1990). Roger Tomlinson (1982), involved in the design and development of the system, states that CGIS was designed specially for the Agricultural Rehabilitation and Development Agency Program within the Canadian government. The CGIS was implemented in 1964 (Star and Estes, 1990). This was one year after the first conference on Urban Planning Information Systems and Programs, a conference which led to the establishment of the Urban and Regional Information Systems Association. The New York Landuse and Natural Resources Information System was implemented in 1967, and the Minnesota Land Management Information System in 1969 (Star and Estes, 1990).

Paralleling advancements in the technology, there have been a growth of applications. From high-quality cartography to land planning, natural resource management, environmental assessment and planning, tax mapping, ecological research, emergency vehicle dispatch, demographic research, and more, GIS promises to be one of the largest computer applications ever to emerge.

Because GIS provides a means of integrating information to understand and address some of the most pressing problems we face today - tropical deforestation, acid rain, rapid urbanization, overpopulation, hunger, and impacts from changes in our global climate to name but a few. GIS technology helps us organize data about these problems and to understand their spatial relationship. Such an understanding is the basis for more sensitive and intelligent decision making (ESRI 1994.a).

In summery, the development of geographic information systems, in terms of both the underlying concepts and the technology, has drawn on the talent and experience of many researchers and investigators. It has grown out concerns about state of the physical and cultural environment, and it has been advanced to solve relatively narrow, specific kinds of problems. The past twenty years have seen an explosion in the technological base for these systems, particularly in the areas of data processing and remote sensing systems. The 1980s have seen continued growth in GIS applications, significant system refinements, and a modest expansion of the commercial availability and applicability of GIS.

While many operational systems may be limited in terms of the geographic area, the number of data types, and the modelling and analytic capabilities they can provide, they can perform many operations that only 25 years ago were considered unfeasible.

2.2 Definition and Terminologies

GIS - An organized collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyze, and display all forms of geographically referenced information.

arc - string of x,y coordinates; a line feature

attributes - tabular data associated with geographic features

coverage - automated map layer

feature attribute table - data file storing descriptive map data

geographic features - the points, lines, and polygons that make up the map

item - one type of information about all entries in a data file

label point - x,y coordinate used to identify a polygon

node - x,y coordinate; the endpoint of an arc

point - x,y coordinate; a point feature

polygon - area defined by a closed strings of x,y coordinates

record - all information about one entry in a data file

relate - an operation connecting corresponding records of two tables

relational joint - an operation relating and merging two tables

spatial overlay - an operation merging the features of two coverage layers into a layer and relationally joining their feature attribute tables

tic - x,y coordinate used for registration

topology - a list of explicit relationships between geographic features (connectivity, contiguity, and definition of area)

vertex - x,y coordinate pair occurring along an arc between the nodes and helping to define the shape of the arc.

2.3 Description

2.3.1 Spatial Operations

Many widely used computer programs, such as spreadsheets (e.g., Lotus 1-2-3), statistics packages (e.g., SAS and Minitab), or drafting packages (e.g., AutoCAD) can handle simple geographic or spatial data. Why, then, are they not thought of as a GIS? The generally accepted answer is that a GIS permits spatial operations on data. As a simple example, consider the table below

TABLE 2.1 GIS POPULATION IN DIFFERENT CITIES (ESRI, 1994.A)

Name	Latitude	Longitude	GIS Population
London(England)	51N	0	80
Zurich(Switzerland)	47N	8E	25
Utrecht(Holland)	52N	5E	40
Santa Barbara	34N	119W	50
Orono(U.S.A)	45N	69W	30

This table shows the approximate number of people working with certain GIS application, in selected centers of activity, in 1989

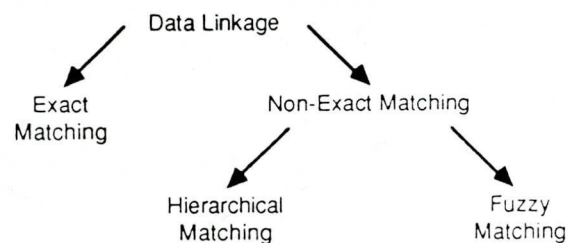
Aspatial queries Asking "What's the average number of people working with GIS in each location" is an aspatial query - the answer doesn't require the stored value of longitude and latitude; nor does it describe where the places are in relation to each other.

Spatial queries "How many people work in GIS in the major centres of Western Europe?" "Which centres lie within 1,000 miles of each other?" "What is the shortest

route passing through all of these centres?" These are spatial queries that can only be answered using latitude and longitude data and other information such as the radius of the earth. A GIS readily answer such questions.

Linkage A GIS typically links different data sets. Suppose we want to know the mortality rate due to cancer among children under 10 years of age in each country. If we have one file that contains the number of children in this age group, and another that contains the mortality rate, we first combine or link the two data files. Once done, we can divide one figure by the other to extract the desired answer.

If this seems trivial - and hardly needing a GIS - consider the different ways in which



data sets may need to be linked.

2.3.2 Matching

Exact matching occurs when we have information in one computer file about many geographic features (e.g., counties) and additional information in another file about the same set of features. The operation to bring them together is easy, achieved by using a key common to both files - in this case, the county name. Thus, the record in

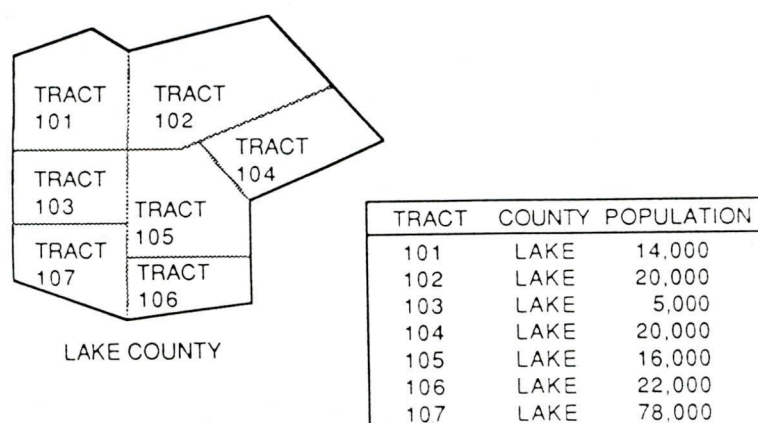
COUNTY	POPULATION	COUNTY	AVG HOUSING COST
LAKE	108,000	LAKE	89,000
LINCOLN	45,000	LINCOLN	77,000
MADISON	213,000	MADISON	104,000
ORANGE	1,145,000	ORANGE	167,000
PENN	22,000	PENN	75,000

COUNTY	POPULATION	AVG. HOUSING COST
LAKE	108,000	89,000
LINCOLN	45,000	77,000
MADISON	213,000	104,000
ORANGE	1,145,000	167,000
PENN	22,000	75,000

each file with the same county name is extracted and the two are joined and stored in another file.

2.3.3 Hierarchical Matching

Some types of information, however, are collected in more detail or less frequently than other types of information. For example, finance and unemployment data covering a large area is collected quite frequently. On the other hand, population data is collected by small areas, but at less frequent intervals. If the smaller areas nest (i.e., fit exactly within) the larger ones, then the solution for making the data match the

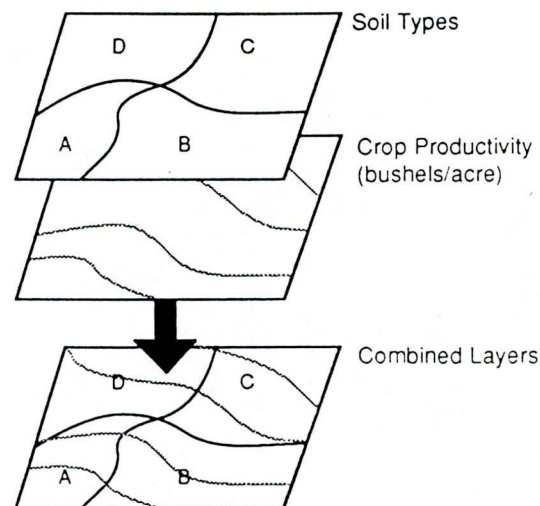


The hierarchical structure illustrated in this diagram shows that this county is composed of several tracts. To obtain meaningful values for the county, the tract values must be added together.

small area is to use hierarchical matching - add the data for the small areas together until the grouped areas match the bigger ones - and then do an exact match.

2.3.4 Fuzzy Matching

On many occasions, the boundaries of the smaller areas don't match those of the larger ones. This is especially true when dealing with environmental data. For example, crop boundaries usually defined by field edges, rarely match the boundary between types of soil. If we want to determine the most productive soil for a particular crop, we need to overlay the two sets of data and compute crop productivity.



When data boundaries between layers don't match, the layers can be joined creating a new layer containing the characteristics of both.

A GIS can do all of these operations because it uses geography, or space, as the common key between the data sets. Information is linked only if it relates to the same geographical area.

2.4 Question a GIS can Answer

So far GIS has been described in two ways 1) through formal definitions, and 2) through its ability to carry out spatial operations, linking data sets together using location as common key. We can also, however, distinguish a GIS by listing the types of questions it can (or should be able to) answer. If we stand back far enough from a particular application, we can see that there are five generic questions that a sophisticated GIS can answer.

location

The first of these questions seeks to find out what exists at a particular location. A location can be described in many ways using, for example, place name, post or zip code, or geographic references such as latitude and longitude.

condition

The second question is the converse of the first and requires spatial analysis to answer. Instead of identifying what exists at a given location, we want to find a location where certain conditions are satisfied (e.g., an nonflooded section of land at least 2,000 square meters in size, within 100 meters of a road, and with soils suitable for supporting building).

trends

The third question might involve both of the first two and seeks to find the difference within an area over time.

Patterns

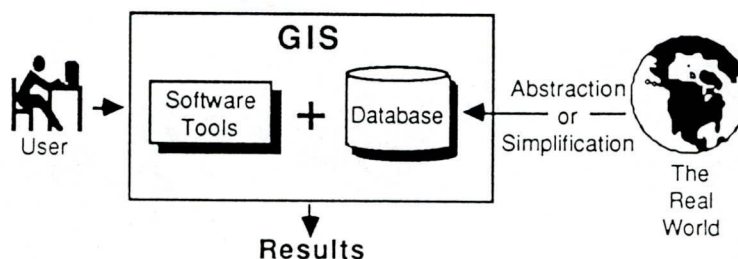
This question is more sophisticated. We might ask this question to determine whether an area is inundated by river water or rain water and which is causing the crop in that area to be damaged. Just as important, we might want to know which areas are being flooded only with rain water and where they are located.

modelling

“What if...” questions are posed to determine what happens, for example, if new areas are allowed to be flooding to a desirable level not causing any undesirable damage to crops in the adjacent areas. Answering this type of question requires both geographic and other information relating to crops and flooding.

2.5 Components of a GIS

Several components comprise a GIS :



The user also becomes part of the GIS whenever complicated analysis, such as spatial analysis and modeling, have to be carried out. These usually requires skills in selecting and using tools from the GIS toolbox and intimate knowledge of the data being used. At present and for years to come, off-the-shelf and general-purpose GIS will rely upon users to know what they are doing- pressing a button is not enough.

What a GIS is not A GIS is not simply a computer system for making maps, although it can create maps at different scales, in different projections and with different colours. A GIS is an analysis tool. The major advantage of a GIS is that it allows us to identify the spatial relationships between map features.

A GIS doesn't store a map in any conventional sense; nor does it store a particular image or view of a geographic area. Instead, it stores the data from which we can create the desired view, drawn to suit a particular purpose.

A GIS links spatial data with geographic information about a particular feature on a map. The information is stored as attributes or characteristics of the geographically represented feature. For example, a road network might be represented by road centerlines, in which case, the actual visual representation of the road wouldn't yield much information about it. To obtain information about the road, such as its width or type, we would query the database. Then we could create a display symbolizing the roads according to the type of information that needs to be shown.

A GIS can also use the stored attributes to compute new information about map features; for example, to calculate the length of a particular road or determine the total area of a particular soil type

Geographic database In short, a GIS does not hold maps or picture - it holds a database. The database concept is central to a GIS and is the main difference between a GIS and a simple drafting or computer mapping system which can only produce good graphic output. All contemporary GISs incorporate a database management system.

If we want to go beyond just making pictures, we need to know three pieces of information about every feature stored in the computer: what it is, where it is, and how it relates to other features (e.g., which roads link to form a network). Database systems provide the means of sorting a wide range of such information and updating it without the need to rewrite programs as new data is entered. In ARC/INFO, ARC handles where the feature are, while INFO handles the feature descriptions and how each feature is related to others.

Essentially, a GIS gives us the ability to associate information with a feature on a map and to create new relationships that can determine the suitability of various sites for development, evaluate environmental impacts, calculate harvest volumes, identify the best location for a new facility, and so on.

2.6 Some GIS Applications

The first applications of GIS varied between different parts of the world, depending on the local needs.

In mainland Europe, the major thrust went into building land registration systems and environmental databases. Britain's greatest GIS expenditure in the 1980s, however, was for systems for utility companies and for the creation of comprehensive topographic database for the whole country.

In Canada, an important forestry application planned the volume of timber to be cut, identified access paths to the timber, and then reported the results to the provincial governments.

In China and Japan, heavy emphasis has been placed on monitoring and modeling possible environmental changes.

In the U.S.A, all of these applications have been important. Another deserving special mention is the use of GIS technology in the TIGER (Topographically Integrated Geographic Encoding and Referencing) project, designed to facilitate taking and reporting the 1990 census, produced a computerized description of the U.S. transportation network at a cost of about \$170 million.(ESRI, 1994.a)

Use of GIS is a recent development in Bangladesh. Local Government Engineering Department (LGED), Surface Water Modelling Centre (SWMC), ISPAN (FAP-19), CPP (FAP-20), SPARRSO, FAP-10 these organizations are using GIS successfully in their respective fields.

SWMC has developed a Flood Management Model (FMM) in 1994, which is a MIKE11-GIS interface. MIKE11 one dimensional model is used to simulate the

discharges and water levels at various stations and GIS is using the results from the model to produce the flood maps.(FAP25, 1994)

The most important point to note is that all these applications have been carried out using similar software and techniques. Thus, a GIS is a general purpose tool.

2.7 Limitations

Being the most unique, general, efficient and widely used geographic analysis tool, a GIS also has got some disadvantages. Though useful and efficient, it is still in growing stage of development. As a result, it is still not very much user friendly and the user must be very much knowledgeable about the software especially about the modules and commands the software has. Moreover it needs skill hand when spatial analysis is done. On the whole, we can say that it is still a complicated software.

It has got another limitation in that a person or a little organization will have to think about price when they decide to use a GIS as it is a very costly item.

3. DESCRIPTION OF THE STUDY AREA

3.1 Introduction

Immediately after the 1988 flood disaster, several studies were carried out by the international community to find out a lasting solution to the flood problem of Bangladesh. In June 1989, the World Bank agreed with the government of Bangladesh to coordinate the various flood control and related initiatives named as Flood Action Plan (FAP). FAP comprises a phased program of flood control activities, supported by special studies, surveys and pilot projects. Priority was given in the Flood Action Plan to launch flood control activities on both sides of the Brahmaputra as it is the main source of severe flooding. The Compartmentalization Pilot Project (CPP) FAP 20 is a key component of this plan and has been conceived to test the concept of compartmentalization and to develop criteria and guidelines for planning and designing the first full scale projects on the right and left banks. It was approved on September 28, 1989. The project was formally commissioned on October 21, 1991 (CPP.a, 1995). The principle of compartmentalization was formulated early in 1989 when, having recognized that a pilot scheme would be necessary to resolve the various problems. Tangail was visited and considered to be a possible site by the Project Identification Mission. They undertook a reconnaissance of the Tangail area, established its boundaries and confirmed that it was reasonably representative of the main areas to be protected on the left bank of the Brahmaputra. The project area, lying between the Dhaleswari and the Pungli rivers in the vicinity of Tangail town, is well protected by a horse-shoe embankment to the north and by a village road to the south. The area already has some protection from the low embankment and some degree of controlled flooding from existing inlet sluices on the western part of the embankment. Drainage is uncontrolled and congested in some places. Irrigation from deep and shallow tubewells for boro rice has become widespread; however, cultivation of the transplanted aman crop is constrained by the lack of drainage and fear of floods. The problems to be examined are fairly typical of the greater part of the area to be protected on the Brahmaputra left bank.

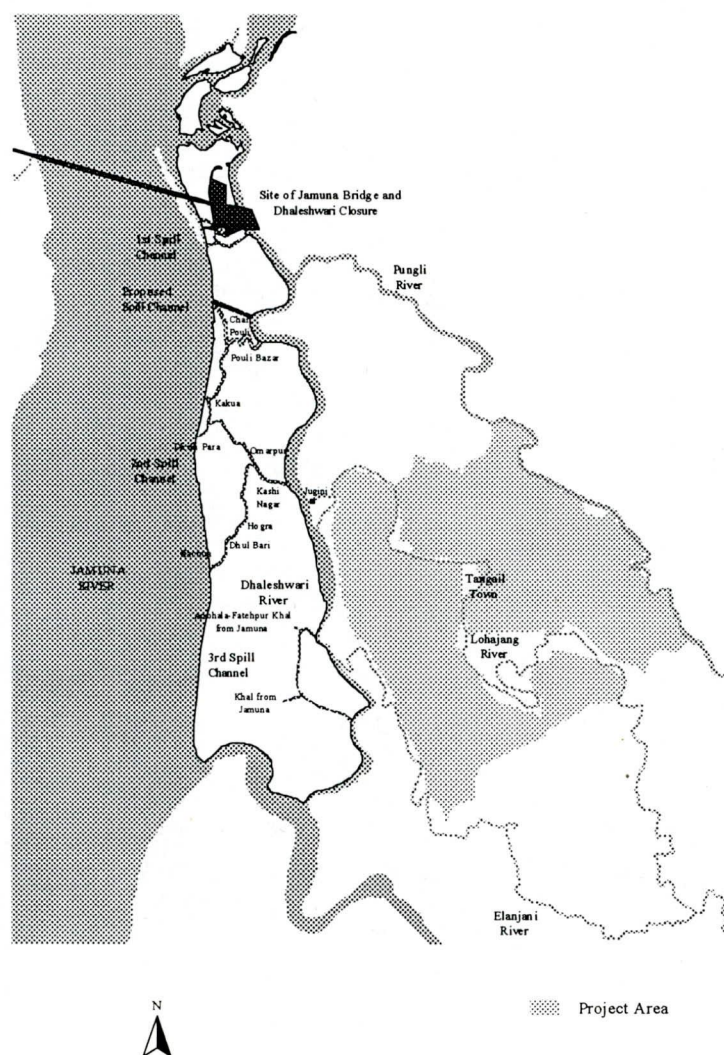


FIGURE 3.1 LOCATION OF CPP, TANGAIL.

For the proposed study CPP Tangail has been taken to be the study area. Location of CPP is shown in fig.3.1. This is a water management project with a new concept namely compartmentalization in the water resources sector of Bangladesh. One of the main objectives of CPP is to facilitate agricultural production through effective water management. Crop damage assessment in this project is directly related to water management plan. CPP has conducted studies on agricultural damage due to flood both by manual calculation of water depths in the fields and by field survey. Another study was done in Surface Water Modelling Center (SWMC) using the Flood

Management Model (FMM). This model was developed in SWMC at three levels : National, Regional and Compartmental. For the compartment level a detailed FMM for CPP Tangail was developed (FAP25, 1994). Crop damage maps due to flood were produced by this FMM. But this model considered the whole compartment (CPP) to be planted with HYV paddy instead of the actual cropping pattern.

The proposed damage assessment work would consider only a part of the whole compartment as shown in fig. 3.2. The Tangail compartment is divided into five clusters (Ib, II, III, IV, V) and construction of different interventions is almost completed for cluster Ib only. Construction of interventions in other clusters are in progress. These interventions are major regulator, minor regulator, gated culvert, culvert, bridge, embankment etc. These can be seen in fig.3.3. MIKE11 software at present is operating for cluster Ib. Damage assessment analysis will be done for system 1 of cluster Ib. System 1 has got an area of 405 hectares. System 1 is also the subcompartment 9. A system is a sub-unit of a subcompartment (or in case of one system, this system is equivalent with subcompartment), which acts as a catchment area controlled in many (but not all) cases by an independent inlet and outlet. A system may consists of one or more chawks. Chawk is the smallest hydrological or physiographic unit which are easily recognizable in the field because of its homogeneity. Most chawks have inlet(s) and outlet(s). The lowest level of hydrological uniformity are the chawks.



FIGURE 3.2 STUDY AREA

3.2 Description of the Project

3.2.1 Area and Geographical Location

The Tangail CPP area is located on the left bank of Brahmaputra, in the vicinity of Tangail town. The area is bounded by a horse-shoe embankment along the Dhaleswari

and Elanjani river in the west, the Lohajang and Gala khal in the north and the Pungli river in the east. The southern boundary is formed by an earthen road between Silimpur and Karatia as shown in fig. 3.3. CPP covers an area of 13,200 hectares and is located between latitude 24 degrees and 24.25 degrees north and between longitude 90 degrees and 90.25 degrees east.(FAP20, 1994)

3.2.2 Climate

The area within the project has got a fairly homogeneous climatic features. This climate is dominated by the monsoon. The northeast monsoon coming from the Siberian anticyclones, blows during the winter months, giving weather that is generally dry and cool. Typical temperatures range between 12⁰C to 28⁰C from December to February, rainfall in this period amounts to 4% of the annual and average wind speed is also at its lowest value (2 km/hr). The availability of soil moisture during this period falls short of crop requirements. Solar radiation is high during this dry season. During the following months, from March to June or pre-monsoon period, rainfall is 36% of the annual total. The average annual total rainfall is 2014 mm. The rainfall is measured at Atia station which is located at Tangail district town. Temperatures rise to a maximum of 34⁰C; humidity, which was minimum in February/March increases quickly; the weather is generally unstable, with a succession of sunny and rainy days and high average wind speeds (5 km/hr). Erratic distribution of rainfall during this period also causes soil-moisture deficits, but heavy thunder showers may sometimes damage the crops.

The south-west monsoon winds usually begin to blow in the month of June and last until October. During this season heavy rains fall over the region (60% of the annual total), relative humidity remains very high, between 80 to 90%, temperatures remain stable on average which is typically between 25⁰C and 31⁰C, solar radiation is low. This is the period when soil-moisture availability is in excess of crop requirements. The climatological parameters at Atia station is shown in table 3.1.

TABLE 3.1 CLIMATOLOGICAL PARAMETERS OF THE CPP AREA, TANGAIL

Month	Temperature (°C) Max. Min.	Rainfall * (mm)	Sunshine (hours/day)	Humidity (%) 9 a.m p.m.	6	Wind Speed (km/hr)
January	25 12	3	8.8	62	62	2.3
February	28 14	23	8.8	77	54	2.8
March	32 18	45	8.6	73	49	3.9
April	34 22	110	8.4	76	56	5.2
May	32 24	263	8.7	82	74	5.0
June	31 25	314	5.0	87	82	5.0
July	31 26	407	5.4	87	81	6.0
August	31 26	212	5.6	88	81	4.6
September	31 25	353	5.9	85	82	3.7
October	31 24	224	7.3	85	79	3.0
November	29 18	43	9.2	81	73	2.3
December	26 14	17	9.1	84	67	1.9

Source : Mymensingh Station, quoted from Manalo, E.M., Agro-climatic Survey of Bangladesh, BRRI/IRRI, 1976.

* Atia Station, Tangail, Average of seven years 1985-86 to 1991-92.

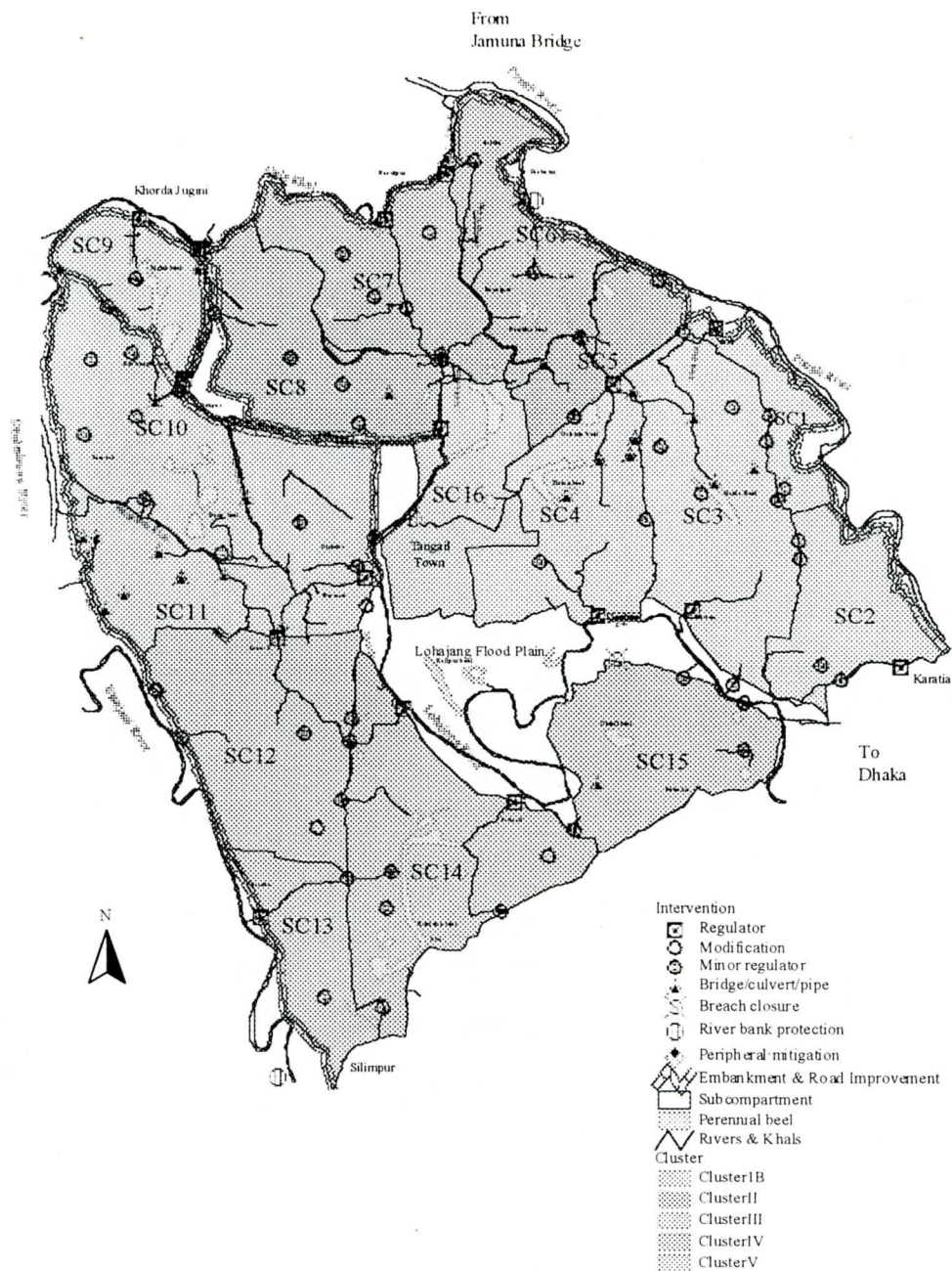


FIGURE 3.3 CPP AREA IN DETAIL (WITH PROPOSED INTERVENTIONS)

3.2.3 Agro-Ecological Zones (AEZ)

Bangladesh includes a wide range of environmental conditions. Environmental diversity occurs not only at national and regional levels, it occurs also at Thana and village levels. In fact, small scale complexity of soil and hydrological conditions is an important characteristic of Bangladesh's environment. Thirty agro-ecological regions and 88 sub-regions are known.(FAP20, 1994)

The Tangail pilot project area is situated in two sub-regions namely the High Jamuna Floodplain (AEZ 8c) and the Low Jamuna Floodplain (AEZ 8d) of young Brahmaputra and Jamuna Floodplain (AEZ 8). They have been differential mainly on the basis of relative age, nature of deposits and characteristics of relief within the area (CPP, 1992).

The High Jamuna Floodplain (AEZ 8c), located in the south-west part of the project, has mainly a smooth relief and is partly protected from river flooding by an embankment. It covers upto 54% of the CPP Tangail. The highest ridge soils lie above normal flood levels, but are submerged for a weeks in years with exceptionally high flood. The medium high land and medium low land are mainly subject to shallow flooding. The western part of the floodplain is generally higher than the eastern part, so drainage is away from the Jamuna and Dhaleswary rivers towards the south east. Ridge tops generally have permeable sandy loam or silt loam soils, downslope soils become progressively heavier and less permeable. These are silty clay loams and silty clays.

Much of the land is inundated in the monsoon season. Flooding is mainly by rain water, a combination of local run-off from ridges into depressions, river floods and the gradual raising of the ground table above the ground surface as a result of heavy monsoon rainfall. Overland drainage within the project area is impeded by the low overall gradient, the presence of crops on the land, raised boundaries around fields, inefficient drainage channels, road embankments with inadequate bridges/culverts, and sometimes by high water levels in the major rivers.

The Low Jamuna Floodplain area (AEZ8d), located in the north-eastern part of the project, covers 46% of the Tangail CPP area. The northern part is largely a medium highland, shallow flooded in the rainy season whereas in the eastern and southern parts mainly medium lowland. The latter parts are moderately deeply flooded in the monsoon season. Basin centers are subjected to early and rapid flooding by run-off from adjoining higher land when heavy pre-monsoon or early rain occurs locally or in

adjacent regions whose run-off drain into this region. At other times flood levels are controlled by levels in the Jamuna river. Flooding is almost entirely by rain water or the raised ground water table pounded on the land by high external flood levels.

Drainage is impeded by bunds on the fields on slowly permeable soils medium highland areas, road embankments with inadequate bridges/culverts. Ridge tops have silt loams and silty clay loam soils and heavy clays occur in the lower basins.

3.2.4 River Systems

Bangladesh is a land of rivers. This is very much true if we take a look at the river network around the CPP Tangail as shown in fig.3.1. The river Dhaleswari is flowing along the western boundary of the CPP. Dhaleswari has two offtakes from the Jamuna. One at the Eastern Jamuna Bridge Site and another about 20 km downstream of the first one. The first one is called the Old Dhaleswari and this one is the main source of river water for the CPP Tangail area. From the Old Dhaleswari, two other small rivers originate, one is the Lohajang and the other is the Elanjani. The Lohajang flows through the CPP area, which is being considered as the drainage channel for the CPP area. The Elanjani takes water from the Old Dhaleswari about 8 km down stream of the Lohajang intake and flows along the western boundary of the CPP area. The river Pungli, which originates also from the Old Dhaleswari but just after the intake point of the Old Dhaleswari from the Jamuna.

3.2.5 Agriculture

Agriculture in the Tangail CPP area is dominated by rice crops. Cropping intensity of the area is 203 with 26%, 38% and 34% of net cultivable area(NCA) is planted to single, double and triple crops respectively. Other crops apart from rice are jute, wheat, mustered, vegetables, sugarcane and pulses (CPP, 1992).

Rice is the most important crop and is grown throughout the year. It can be grown on all soil types prevalent in the project area. The traditional rice crops Aus, Aman and

Boro are grown in Kharif-I (end March to mid June), Kharif-II (mid June to end November) and rabi (November to March) seasons respectively.

Rice cropping may be single, double or even triple depending on land type, soils and irrigation availability. Double rice cropping in the project area is practised on high lands, medium highlands and irrigated medium low lands. In medium lowlands and in some lowlands mixed cropping of Aus and Broad Casted Aman (deep water aman) is common practice, followed by other crops. In deeply flooded lands single cropping of B. Aman in the Kharif season and Boro in the Rabi season is practised.

The non-rice crops are generally grown as a sequential with rice. Most of the non-rice crops are dry land crops, although some crops like jute (white type), millets (kaon) and sugarcane can tolerate some degree of submergence at later stages of growth. Jute is grown in the Kharif- I season, competing with Aus for land and is considered a substitute crop for Aus in cropping patterns. The Rabi season crops may be early, middle or late depending on land types, recession of floods and dates of harvest of preceding crops.

In rainfed, dryland areas, growing of tolerant, short duration crops has been an important feature. Although high crop yields have been difficult to obtain, traditional cropping patterns do exhibit a high degree of stability. Another feature is mixed cropping and inter cropping of annual crops. These practices provide farmers with opportunities of harvesting different crops from the same land, increasing total land productivity and maintaining and improving soil fertility through the use of legumes and jute. The most important dryland crops are Aus, Jute, Vegetables, Potatoes, Wheat, Mustard and Sugarcane. The cultivation of mustard has been increasing rapidly. The acreage of wheat has been receding because of the increase of Boro rice cultivation, while jute is decreasing due to low market prices.

3.3 Fisheries

A survey in the CPP area was carried out in the dry season of 1991 to gather information about the fisheries activities (FAP20, 1992). It was found that two kinds of fish species were there with respect to their reproductive behaviour.

River fish, such as the major carps (Katla, Rui, Mrigal), spawn upstream in the major rivers at the beginning of the monsoon. The eggs, fingerlings and some adults of these species flow with the water current into the Dhaleswari and Pungli river and finally enter the floodplain of the project area from the north side, through the Lohajang river and Sadullapur Khal at the end of June. The carps migrate passively back to the main rivers as soon as the water recedes from the floodplain.

Beel fish, such as snakeheads (Taki, Shol), catfish (Magur), climbing perch (Koi), gouramies (Khaisha), barb (Puti) etc. can survive the harsh environment condition of the floodplain during dry season. This group reproduces in the pre-monsoon as soon as water level in the beel rises. Later on they disperse all over the floodplain with the entrance of river flood water. With the receding water this group migrates back or gets trapped in the low lying beels and pagars.

The main fisheries activities in the project area can be divided into three classes.

Professional fishermen : There are approximately 1000 fishermen, mostly Hindus, within the project area. They catch fish throughout the year. During monsoon, they catch fish in the rivers, beels and pagars. They mainly use cast nets and seine nets combined with grill nets.

Part-time fishermen : These fishermen, who are mostly Muslim, have an alternative occupation, apart from fishing. They mainly use cast nets.

Occasional fishermen : In the majority of the households within the project area some form of fishing takes place for home consumption discretely during the year, with peaks during the monsoon. These kind of fishing can be carried out freely in the rivers and beels using scoop nets, baskets, traps, lift nets etc.

3.4 Concept of Compartmentalization

Water management within the concept of compartmentalization has been narrated as under in the "Bangladesh Flood Policy Study" (UNDP/GoB, May 1989):

The principle of controlled flooding is to allow natural flooding of floodplain lands to occur without causing damage to crops, fisheries, infrastructure and urban land. Within flood protection compartments, intake regulators and drainage sluices will be managed to control the timing, depth and duration of flooding on the land during the rainy season within the limits that ensure secure growing conditions for the major rice and other crops. The migration of fish to and from natural floodplain spawning and production areas must be allowed. To the extent possible in different agro-ecological regions, flooding will be managed to maximize opportunities for increased agricultural production through the use of high-yielding crop technologies.

Given a preamble as above, the concept of compartmentalization appears instrumental (can be confirmed after testing under real operation conditions) for the implementation of water management interventions. Respecting this, the following definition is used:

A compartment is an area in which effective water management, particularly through semi-controlled flooding and controlled drainage, is made possible through structural and institutional arrangements. Compartmentalization is linked to area development with sound water management as the main agent. A compartment is sub-divided into sub-compartments and operational management units (Clusters).

It is obvious that to make the participation of the beneficiaries in the project planning, design, construction, operation and maintenance successful, it will be necessary to sub-divide the compartment into smaller units. In a first stage the compartment has been sub-divided into 17 sub-compartments mainly based on physical parameters like road, infrastructures, land setting, hydrological criteria etc. and the location of the rivers and khals keeping an overview and strengthening of the peripheral geographic situation of the compartment as a protected area as shown in Fig. 3.2. Interventions have been developed, planned and designed accordingly involving the participation in the interest groups (beneficiaries and disadvantaged groups) in Needs Assessment Survey(NAS), consultation process meetings etc.

Now to realize the ultimate objective of the project for real water management in the field level entailing the lands to be cultivated under a secure agro-environment to be developed, micro-level plan development, design and implementation procedures have to be evolved involving the beneficiaries.

3.5 Objective of Compartmentalization

The overall objective is to ensure a protected agro-environment and thereby prevent damages to agricultural and fisheries resources, rural and urban infrastructures and enhance crop productions with minimum losses to fisheries through a systematic water management system in a protected agro-environment to be developed by structural and non-structural interventions.

This, to a farmer or a group of farmers in a chawk, means that he/they can have a secured agro-environment especially in respect of water control to save crops from damages (due to flood or drainage congestion) and to cultivate better yielding rice varieties in monsoon season, and also to diversify their winter cropping as early drainage would be possible in post monsoon. When CPP would be materialized the following benefits would be accrued.

- Due to systematic drainage network, early flood waters or drainage congestion will be removed in pre-monsoon to save matured Boro crops.
- Water level in the floodplain will be regulated through peripheral control and sub-compartmental regulatory systems in monsoon in such a way that better yielding rice varieties can be extended to the majority of lands instead of existing local low-yielding variety "chamara". This would also reduce the dependency on costly Boro rice cropping.
- In medium - low to lowlands transplanted deep water rice can be grown with security (from damage) in monsoon to be followed by Boro or other crops in Rabi and Kharif-I season increasing the cropping intensity.
- Due to early drainage provisions, more lands would be made available for diversified cropping in Rabi season.

To realize the above benefits, it is undeniable that a loss of floodplain area and fisheries will occur. Hence project strategy accommodates mitigation measures including some enhancement activities in fisheries. These are:

- * Designing of some control structures as fish friendly for easy passage of fish fries
- * Aquaculture extension program
- * Beel concept for beel dependent fish
- * Facilitating hatchling migration route.

3.6 Principles of Compartmentalization

Accepting integrated development as a basic principle for the planning, it is proposed to achieve this by sub-dividing the flood plain into a number of compartments.

The concept of compartmentalization is to spread water (originating from the river system or from local rainfall) over the protected area and/or reduce the risk of deep flooding and associated damages and secure environment for agriculture, fisheries and

integrated rural and urban development through water management as shown in Fig. 3.4.

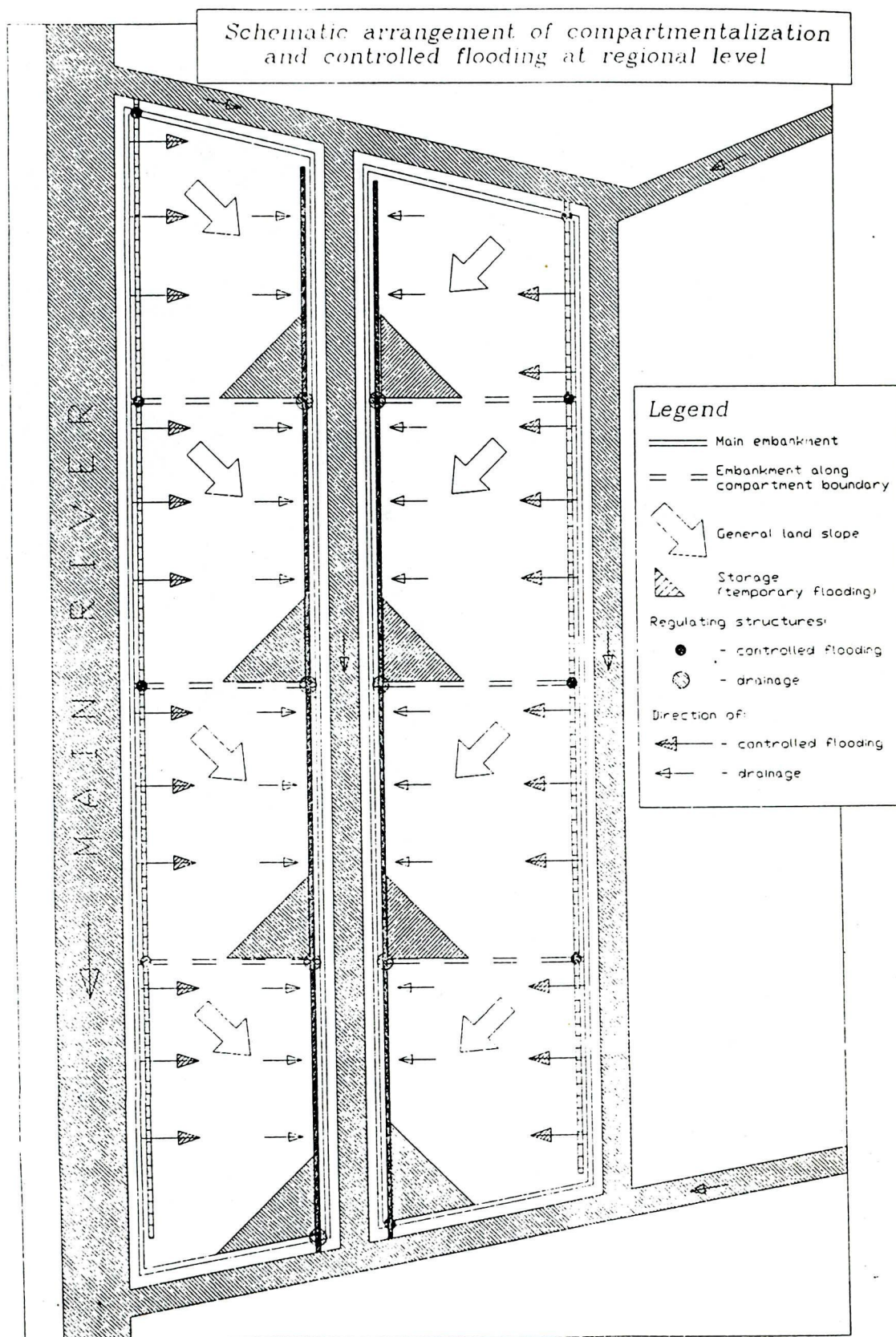
The concept of compartmentalization is based on a number of considerations as discussed below:

- i) While recognizing that benefits of compartmentalization in Bangladesh will have to accrue mainly from agriculture, the realization of these benefits will start earlier if the agricultural development is implemented in small sized and better manageable units.
- ii) By subdividing the protected area into individual compartments, the required area development works can be broken into manageable packages and the responsibilities for detailed planning, design, implementation, operation and maintenance can be decentralized, which should be organized in such a way that people's participation is ensured to a maximum extent.
- iii) Water management can also be delegated to the level of sub-compartments; this applies particularly to controlled flooding and drainage. Varying topographical and other conditions require operational responsibilities to be placed at an appropriately low level.

Compartmentalization has some additional important advantages:

- i) If the embankment along the main river falls at one point, the resulting inundation could be contained in one compartment only, without spreading to the entire embanked area.
- ii) Local rainfall in the protected area will accumulate in the lowest part, and inundation to some extent will follow. Without compartmentalization the water would accumulate in the downstream part of the protected area, possibly causing extensive deep flooding. Cross bunds, as part of the compartmentalization concept, can retain part of the flood water. The depth of inundation would be less and possibly not reach a harmful stage.

FIGURE 3.4 SCHEMATIZATION OF COMPARTMENTALIZATION



In the CPP, it is proposed to separate the area by means of secondary embankments, mainly using existing physical features, such as roads, flood protection embankment or other boundaries by which water inflow and outflow of the area will be controlled by hydraulic structures located on the compartment boundary. A compartment is also a unit in which effective water management particularly through controlled flooding and controlled drainage is made possible through structural and institutional measures and in close consultation with the local people.

On the general level, a series of compartments is complementary to the main river system. In that, they may buffer the excess water from the local rainfall and the river system on a temporary basis. In order to implement this function, provisions must be made to regulate the water movement between the main rivers and the compartments, where minor rivers may function as flooding or drainage channels for one or more compartments. On the compartment level, the purpose is related to the satisfaction of local objectives e.g., by controlled flooding and drainage or possibly water retention. During the life time of the compartment, the needs may change, requiring an adjustment to the system. Therefore, the design of the compartment's structural and non-structural components will allow flexible operation.

3.6.1 Controlled flooding and drainage

Embankments separate interior parts of the floodplain from the river regimes. The positive effect is that damaging floods are excluded from the rural areas and the urban centres. However, the disadvantage is that beneficial effects of annual floods are lost.

This disadvantage is mitigated by adopting the concept of controlled flooding. In essence, this implies that moderate floods within the compartment are allowed to spread over the land, but in a controlled way. Appropriate provisions have to be incorporated in the embankments. Their operation depends on the needs of agriculture, fisheries and inland navigation, taking into account direct rainfall in the area.

Sometimes, embankments may fail for a variety of reasons. This may cause a sudden inrush of water creating more serious conditions than the flooding which normally occurs gradually. The control provisions incorporated in the embankments, as described above, will be helpful in this event. By allowing water into the embanked area gradually, an unexpected inrush can be prevented or at least mitigated.

If controlled flooding is achieved by gated structures in the embankment, they should be "fish-friendly". In some cases it will be necessary to construct navigation passes as an integral part of the structure or to provide mooring facilities to mitigate the restricted navigation movement.

The provisions for controlled flooding incorporated in the embankments also serve to discharge excess water from the embanked areas; an efficient system of drainage channels is needed. In times of heavy rainfall and when outside river stages are high, inundation will be unavoidable in the embanked areas, but to a lesser extent than before. Low areas have to be designated as conservation areas, where some flooding is allowed to occur.

In conclusion, some areas will be protected against undue flooding by means of embankments. Facilities will be created to control the flow of water entering into or flowing out of the area in accordance with the requirements of local or regional water management policies.

3.6.2 Flood management

Flood protection should not only mean the provision of static structures; it should be viewed as a dynamic concept designed for economic and social growth. therefore, flood control projects will require a high degree of water control and management generally to give the beneficiaries a sense of confidence for sustained development.

Internal management will be mainly concerned with :

Keeping unwanted water out through maintenance of embankment;

Allowing water in through operation of inlet regulators and internal waterways for controlled flooding, replenishment of water resources, irrigation, fisheries, urban flushing, navigation etc. ;

Allowing excess water out through the internal drainage system and outlet regulators, to provide drainage control for agriculture, urban areas, etc.; and flood relief from local rainfall.

3.6.3 Water Management

Water management implies that direct rainfall, drainage, intake of water (controlled flooding) are all elements that have to be combined such that the requirements of agriculture, fisheries and other purposes are met in an optimum way.

To that end not only structures in the internal embankments are required depending on topography, soils, landuse, but also different water levels have to be maintained within each individual compartment. For those reasons it may have to be divided into sub-compartments, separated by low embankments and roads provided with regulating structure, culverts, bridges etc.

The principle of controlled flooding is to allow natural flooding of floodplain land without causing damage to crops, fisheries, infrastructure and urban land. Within flood protection compartments, intake regulators and drainage sluices will be managed to control the timing, depth and duration of flooding during the rainy season within limits that ensure growing conditions for the major rice and jute crops. The migration of fish to and from natural floodplain spawning and production areas must be allowed. Whenever possible in different agro-ecological regions, flooding will be managed to maximize opportunities for increased agricultural production through the use of high-yielding crop technologies.

Controlled flooding will be affected by opening and closing regulators and sluices in embankments at critical periods of agricultural and fisheries calendars. In many compartments, internal rivers and khals will need to be desilted to improve their capacity to drain excess rainwater during periods of heavy monsoon rainfall. This will

be done by the beneficiaries under operation and maintenance programme. Increased numbers and sizes of bridges and culverts may also be needed to facilitate rapid drainage.

In years when excessive monsoon rainfall over a compartment coincides with high river levels, it will not be possible to evacuate excess floodwater through embankment drainage sluices for a number of days or weeks. This may cause damage to crops by submergence. Consideration needs to be given to the feasibility of evacuating floodwater to neighbouring lower compartments or to provide pumping facilities for drainage in such circumstances. Requirements will vary among compartments because of differences in size, rainfall, topography, soils and associated cropping patterns, and in population and development infrastructure.

3.7 General compartmental and subcompartmental setting

For the planning of the water management, the input from the Needs Assessment Survey (NAS) has been most helpful. The majority of suggestions by the people has been taken into account in the planning. During the NAS needs of the people in several sectors were surveyed such as - agriculture, fisheries, women issues, non-farm activities, engineering and environment. NAS was done through consultation meeting with different groups of people within the project area.

The peripheral flood control system does provide increased security during high flood situations and permits a lowering of the water level in the sub-compartments closest to the main inlet by lowering the water level in the Lohajang river.

The aim of the interior water management system is that the water availability can be influenced (within certain limits) to match the water requirements more satisfactory. These requirements differ in time, area and per water users group.

The water availability differs through the season as well as from year to year. It will not be possible to maintain desirable water levels within the sub-compartment to its full

extent. However, the interior water management system should be such that it can cope with different situations and optimize water availability.

Some general principles which can be applied to support controlled flooding and drainage are:

- reduce the length of the channels within the compartment,
- control the flow at the outfall of the channels,
- improve the capacity of the channels,
- improve management capacity and consistency with regard to flood control and drainage.

The following definitions are being used in CPP :

1) **Compartment**: an area in which effective water management, particularly through controlled flooding and controlled drainage, is made possible through structural and institutional arrangements.

2) **Subcompartment**: a sub-unit of a compartment, in which to a certain extent, the water management can be controlled by the people living in the area represented by a subcompartmental water management committee (SCWMC). A subcompartment may consists of one or more systems.

3) **System**: a sub-unit of a subcompartment (or in case of one system, this system is equivalent with subcompartment), which acts as a catchment area controlled in many (but not all) cases by an independent inlet and outlet. A system may consists of one or more chawks. Systems are shown in fig.3.5.

4) **Chawk**: The smallest hydrological or physiographic unit which are easily recognizable in the field because of its homogeneity, as shown in fig.3.5. Most chawks have inlet(s) and outlet(s). The lowest level of hydrological uniformity are the chawks.

The "chawks" are readily recognizable as manageable field unit usually bordered by topographical features; generally located in between villages (settlements), roads, khals/rivers or embankments etc. These chawks are socially and agriculturally quite familiar to rural people in the project area. The chawks might have both high, medium and lowlands, and sometimes may contain a "beel" or khal; but since their border is formed by infrastructure (roads, villages, khals etc.), it would be possible to regulate water level to suit certain desirable and profitable crops in monsoon flood period and to retain or drain out water in pre and post monsoon.

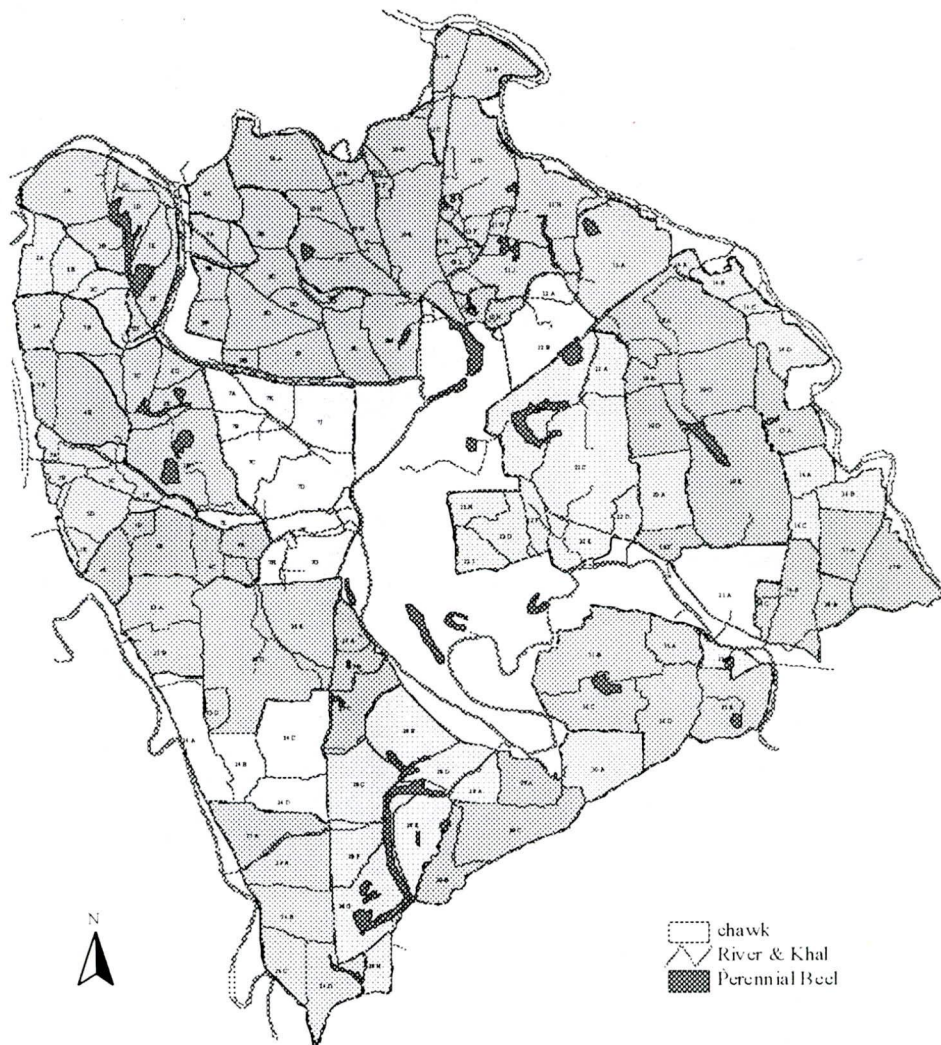


FIGURE 3.5 CHAWKS AND SYSTEMS

3.8 Adverse Effects

The concept of compartmentalization is a very new concept in Bangladesh and when this concept is being materialized through a pilot project namely Compartmentalization Pilot Project, it is very obvious and also it is anticipated that some adverse effects would come. Effects are anticipated and questions are being raised in various sectors of our environment mainly by some local NGOs and people living just outside the project area. The probable sectors those are thought to be affected are discussed below

- As the project area is bounded by a peripheral embankment with some inlet structures and one of the three rivers in and around the project area namely the Lohajang river is being controlled by a major regulator which is called Jugini Main Regulator, people living in the adjacent areas are thinking that they would be inundated when the flood would come by a depth of 5 to 6 feet of water than they would be under the without project situation. But the model studies that was developed in SWMC, showed that some 5.6 hectares of land will be inundated by a maximum of 40-50 cm of water than they will be under the without project situation. This effect will be gradually decreased in the adjacent areas and due to the closure of the main regulator a total of 220 hectares of the outside area will be affected which is only 2% of the benefited area. If we draw a back water effect curve, this phenomena could also be visualized. The affected area from model study can be seen in fig.3.6.

- People living both inside and outside of the project area are claiming that due to construction of some control structures, drainage congestion will occur in the upstream and downstream side of the structures. This may happen if proper maintenance work is not performed.

- It has been a common question that soil fertility would decrease as a consequence of Compartmentalization or controlled flooding. Flood is seen to be a curse in one way but other way it is known as the blessings to the farmers as it carries river-borne algae with it and enriches the land with it. It should be very much clear that CPP will not prevent the flood water from entering into project area. What it will do is for the

extreme flood events, it will allow a certain level of water to come in so that no

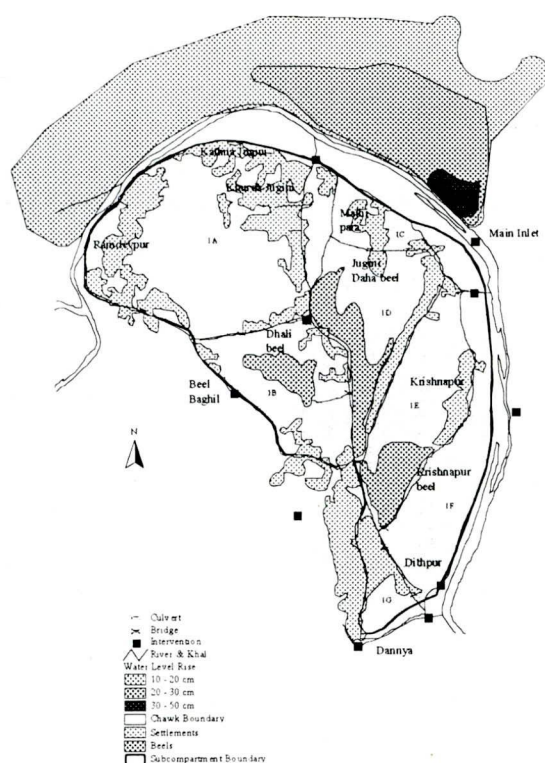


FIGURE 3.6 RISE OF WATER LEVELS DUE TO THE CLOSURE OF THE MAIN REGULATOR OF CPP

damage to the crops can occur. For normal flooding years no sluice of CPP will be operational and they will be kept open for the free passage of water. So in both cases controlled or non-controlled, flood water gets the opportunity to enrich the fields with river-borne algae.

- It is also thought that due to controlled flooding, there will be a significant reduction in recharging of ground water and as a result ground water tables will be gradually depleted. The environment section of CPP has been continuously collecting data on ground water availability from Bangladesh Agricultural Development Corporation (BADC), Department of Public Health Engineering (DPHE) etc. These organizations have some observation wells where they monitor ground water availability.

Observations are not showing any tendency in depletion of ground water tables but it will take some years to conclude about this tendency.

- The most affected sector due to compartmentalization is the fisheries especially the captured fisheries. Due to the structure operation during monsoon, which are located on the rivers and khals, the fish migration will be affected largely. It is the flood water which carries the eggs and fingerlings with it and then they grow in the low lying areas or beels. As the free passage of flood water is obstructed by the control structures, these hatchlings and fingerlings will also be obstructed on their way to the beels. Some of them may also suffer death when they will pass through the gates of the structures, where a high flow velocity prevails due to the head difference between the upstream and downstream side of the structures. A large scale aquaculture program has been launched to mitigate that effect and this program has been proved to be a successful measure within the project area.

It should be mentioned that testing of compartmentalization is yet to be performed effectively as the construction of different interventions are in progress and will take some more time to be finished. The anticipated adverse effects are also very much time dependent. So only future will be able to answer those questions when CPP will be operational fully with its compartmentalization water management concept.

4. Data collection And Methodology of Data Analysis

4.1 Data Collection

Monsoon cropping pattern (existing) in the study area was collected by field survey and then digitized in the computer. This digitized cropping pattern was then converted to a polygon coverage, which can be analyzed in the GIS. This cropping pattern is shown in fig.4.1.

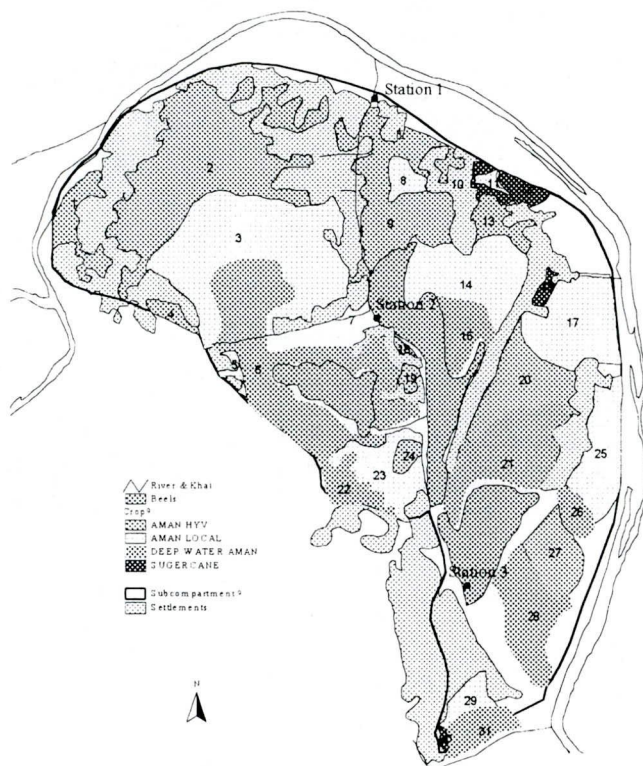


FIGURE 4.1 EXISTING CROPPING PATTERN OF THE STUDY AREA AND WATER LEVEL STATIONS.

For each type crop, there are different growing stages and for different growing stages for each crop, there are different crop tolerance depths. These crop tolerance depths were collected from Compartmentalization Pilot Project, Tangail. Such flood tolerance depths are shown in table 4.2.

For the present study, series water level data in the monsoon period was necessary. Two different flooding years were considered for the present damage assessment study. Water level data in the study area for those two years were collected from Surface Water Modelling Center (SWMC). Actually these series water level data are the simulation results i.e., output from MIKE11 river network model. A compartmental model was developed in SWMC for the CPP Tangail area.

Topographic data i.e., the land contours of the study area was also required for the present study. This has been collected from the FINNMAP map (photomap 1990) and they were put into the GIS database as land elevations. One of these can be seen in fig.4.2 and table 4.1.

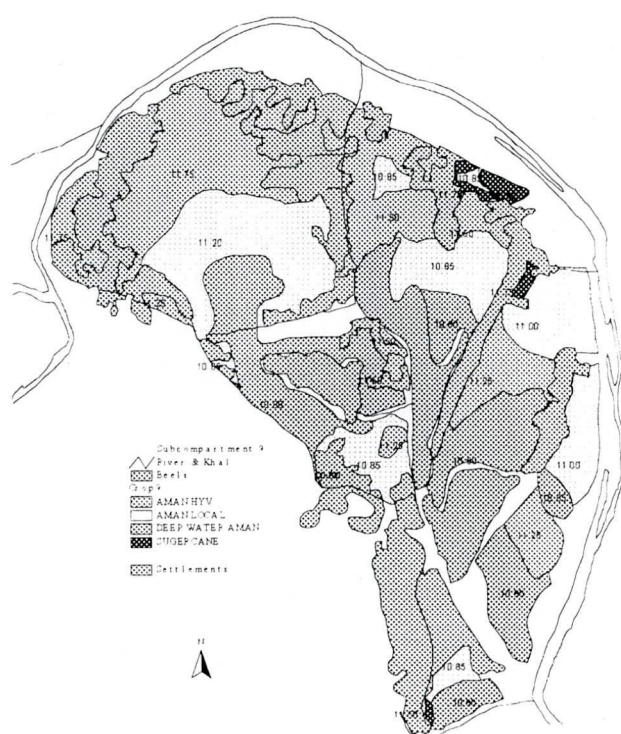


FIGURE 4.2 LAND ELEVATION OF DIFFERENT UNITS.

4.2 Data Processing for analysis

Data on series water level were obtained from MIKE11 model simulation. These database were then transferred into the GIS database. In the study area there are

three water level stations as shown in fig. 4.1. For each station, water level values are available on daily basis for the period from 1st of July to 28th October. Each station is representing a certain location and the water level for this station is representative for a certain extent of area.

Each plot with a certain crop like HYV Aman, Local Aman or Deep Water Aman etc. has been assumed as a damage unit. In the study area there are 31 such damage units with the existing cropping pattern as shown in fig. 4.1.

These damage units have got an average land elevation. Deducting these levels from the representative water level for the respective damage units, actual field water levels have been calculated. One such land elevation may be seen in fig. 4.2 and also in table 4.1.

4.3 Damage Criteria

For each crop there are two, three or four different growing stages. For these different growing stages, there are different flood tolerance depths. These are shown in table 4.2. There is also a damage function, which is dependent on the number of inundation days when the tolerance depth is being exceeded in a certain growing stage. These are shown in table 4.3. If for a certain type of crop within a certain growing stage, the actual flood depth, which is higher than the flood tolerance depth, continues to prevail for a number of consecutive days, there will be a reduction in crop yield according to the yield reduction function given in table 4.3. This yield reduction function is only for rice crop. Another function was considered when a suitable cropping pattern was found out. This is very important if we look at the actual field practice by the farmers. If the farmers can not plant HYV Aman or a Local Variety Aman within the month of July due to high water levels in the field, they have the choice to plant those up to the first week of September (Field survey data). Even some time, it may happen that the crops become damaged due to flood in the month of July. Farmers also have the option in such a situation to plant for the second time.

TABLE 4.1 DAMAGE UNIT DESCRIPTION

Unit Number	Crop Type	Area hectare	Land Elevation m.+PWD
1	HYV Aman	5	11.75
2	HYV Aman	36	11.75
3	Local Aman	32	11.20
4	HYV Aman	1	11.25
5	Local Aman	1	10.75
6	Deep Water Aman	30	10.70
8	Local Aman	2	10.75
9	HYV Aman	19	11.50
10	Local Aman	1	11.75
11	Sugarcane	1	11.75
12	Sugarcane	2	11.75
13	HYV Aman	3	11.50
14	Local Aman	15	10.75
15	Deep Water Aman	6	10.70
16	Sugarcane	1	11.75
17	Local Aman	13	11.00
18	HYV Aman	1	11.50
19	HYV Aman	1	11.50
20	HYV Aman	10	11.25
21	Deep Water Aman	14	10.50
22	Deep Water Aman	4	10.70
23	Local Aman	7	10.75
24	HYV Aman	1	11.25
25	Local Aman	9	11.00
26	Deep Water Aman	2	10.70
27	HYV Aman	7	11.25
28	Deep Water Aman	11	10.70
29	Local Aman	3	10.75
30	Sugarcane	1	11.50
31	Deep Water Aman	5	10.70

TABLE 4.2 FLOOD TOLERANCE DEPTHS (CM)

	July		August		September		October	
	1-15	16-31	1-15	16-31	1-15	16-30	1-15	16-31
HYV	15	15	15	15	15	30	30	50
Local Aman	15	15	15	15	30	30	50	70
Deep Water Aman	30	50	70	90	180	180	120	90
Sugar-cane	70	70	90	90	90	90	0	0

Source : BWDB, 1993.

TABLE 4.3 YIELD REDUCTION AS A FUNCTION OF GROWTH STAGE AND NUMBER OF DAYS EXCEEDING THE FLOOD TOLERANCE DEPTHS.

Days of Submergence	Yield reduction			
	1-2	3-4	5-7	7
20 days after transplanting	10%	20%	30%	50%
Young panicle formation	25%	45%	80%	90%
Meading stage	15%	25%	30%	70%
Heading stage	0%	15%	20%	20%

Source : BWDB, 1993.

4.4 Damage years considered for analysis

For damage calculation with the existing cropping pattern, the years 1991 and 1993 had been selected as MIKE11 model simulations (without project situation) were available only for these years. With respect to water levels at Jugini station the years 1991 and 1993 have return periods of 5 and 2 years respectively. A frequency analysis for this station is shown in table 4.5 and fig. 4.3. Jugini is the place which is very important for the water level conditions around Tangail compartment (CPP), as embankments around CPP and the major structures have been designed considering water levels at this station. Location of Jugini is shown in fig. 3.1. Results from Log-Normal Distribution is considered here. From fig. 4.4 it is found that Gumbel Distribution gives a higher value of return period. This can be found easily from table 4.4 where historical maximum water levels at Jugini are shown.

TABLE 4.4 MAXIMUM WATER LEVEL FOR THE STATION AT JUGINI AND SIRAJGANJ

Year	Water level (m + PWD)	
	Jugini	Seraganj
1967	12,74	13,64
1968	12,56	13,94
1969	12,13	13,82
1970	12,84	14,22
1971	-----	-----
1972	12,68	13,90
1973	12,72	14,22
1974	13,11	14,24
1975	12,15	13,60
1976	12,56	13,46
1977	12,69	13,90
1978	11,86	13,52
1979	12,46	13,67
1980	13,17	14,50
1981	12,58	13,87
1982	12,50	13,73
1983	12,64	14,19
1984	12,82	14,62
1985	12,63	14,14
1986	11,10	13,66
1987	12,90	14,57
1988	13,43	15,11
1989	12,58	13,65
1990	12,59	13,97
1991	12,95	14,37
1992	-----	13,25
1993	12,44	13,75
1994	10,85	-----
1995	12,98	-----

Table 4.5 FREQUENCY ANALYSIS FOR THE STATION AT JUGINI

Series code = JUGINI HA1 1 (1971, 1992 excluded)
 First year = 1968
 Last year = 1995 (minimum = 12.4 m: 1969, 1975, 1986, 1994 excluded)

Fitting the log-normal distribution function

Series code JUGINI HA1 1

Modified maximum likelihood method is used

Number of data = 22

Mean $\ln(x-x_0)$ = -.862

St. dev. $\ln(x-x_0)$ = .498

Location x_0 = 12.275

Nr./year	observation	obs.freq.	theor.freq.	p	return-per.	st.dev.xp	st.dev.p
21	12.440	.0313	.0296		1.03	.0340	.0279
9	12.460	.0759	.0487		1.05	.0324	.0356
2	12.500	.1205	.1031		1.11	.0321	.0514
2	12.560	.1652	.2149		1.27	.0356	.0732
7	12.560	.2098	.2149		1.27	.0356	.0732
18	12.580	.2545	.2568		1.35	.0371	.0788
11	12.580	.2991	.2568		1.35	.0371	.0788
19	12.590	.3438	.2781		1.39	.0380	.0812
15	12.630	.3884	.3637		1.57	.0414	.0879
13	12.670	.4330	.3848		1.63	.0423	.0889
4	12.670	.4777	.4665		1.87	.0460	.0907
8	12.690	.5223	.4860		1.95	.0470	.0906
5	12.720	.5670	.5418		2.18	.0500	.0896
1	12.740	.6116	.5756		2.36	.0522	.0883
14	12.820	.6563	.6956		3.28	.0625	.0806
3	12.840	.7009	.7204		3.58	.0656	.0784
16	12.900	.7455	.7842		4.63	.0760	.0715
20	12.950	.7902	.8267		5.77	.0863	.0657
22	12.990	.8348	.8481		6.58	.0931	.0623
6	13.110	.8795	.9143		11.67	.1284	.0493
10	13.170	.9241	.9341		15.18	.1476	.0424
17	13.430	.9788	.9782		45.98	.2481	.0224

Values for distinct return periods

Return per.	prob.(risk) p	value x	st. dev. x	95% confidence intervals	
				lower	upper
2	.50000	12.697	.042	12.613	12.802
5	.80000	12.917	.079	12.779	13.093
10	.90000	13.075	.118	12.874	13.343
25	.96000	13.256	.187	12.976	13.733
50	.98000	13.451	.257	13.041	14.079
100	.99000	13.622	.337	13.099	14.474
250	.99600	13.859	.461	13.170	15.079
500	.99800	14.043	.570	13.219	15.605
1000	.99900	14.245	.692	13.265	16.196
1250	.99920	14.311	.734	13.280	16.401
2500	.99960	14.521	.873	13.323	17.028
5000	.99980	14.741	1.027	13.365	17.853
10000	.99990	14.970	1.195	13.405	18.704

Fitting results of probability distribution function (without low waterlevels)

Water level (m+PWD)

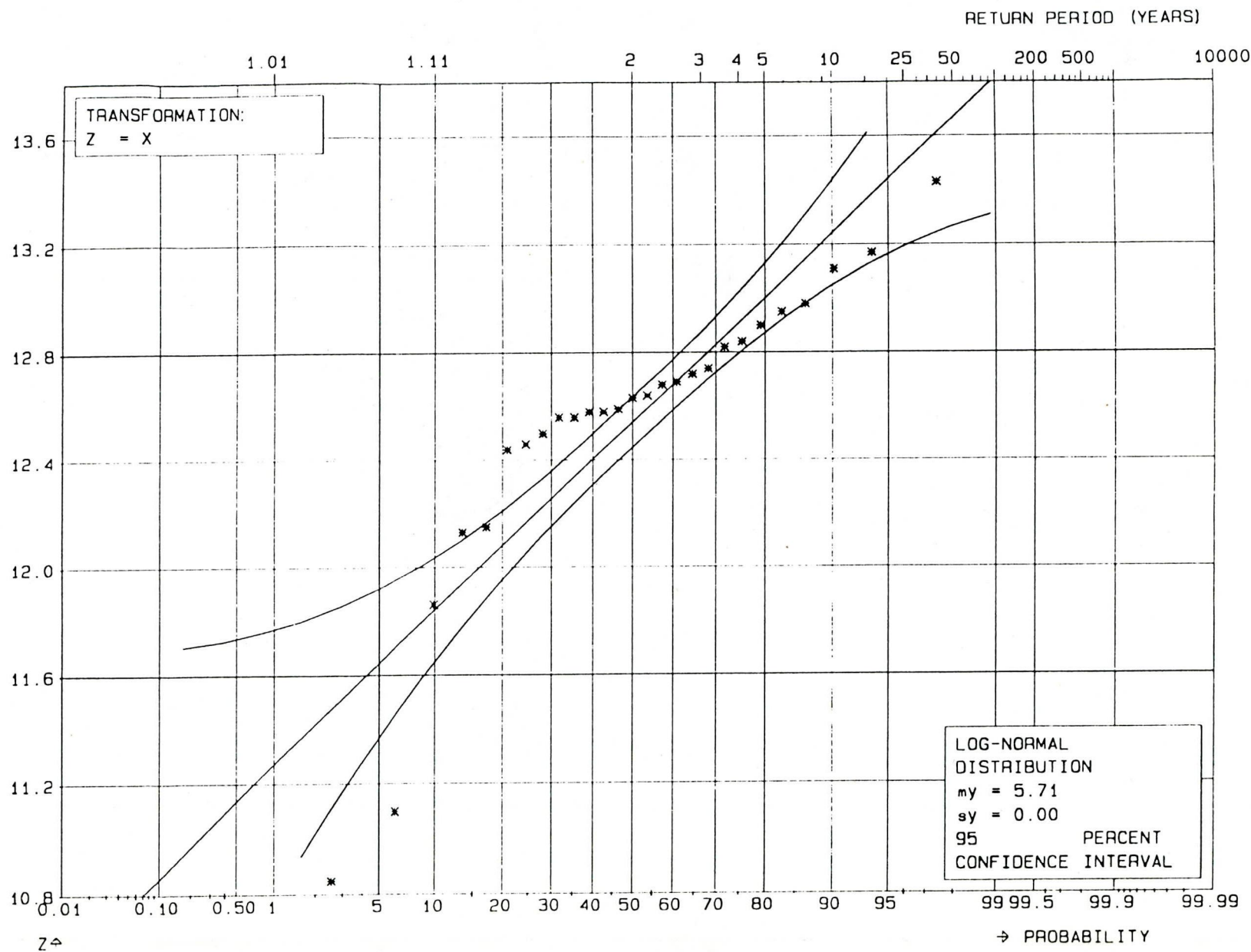


FIGURE 4.3 FREQUENCY ANALYSIS FOR THE STATION AT JUGINI (LOG-NORMAL DISTRIBUTION)

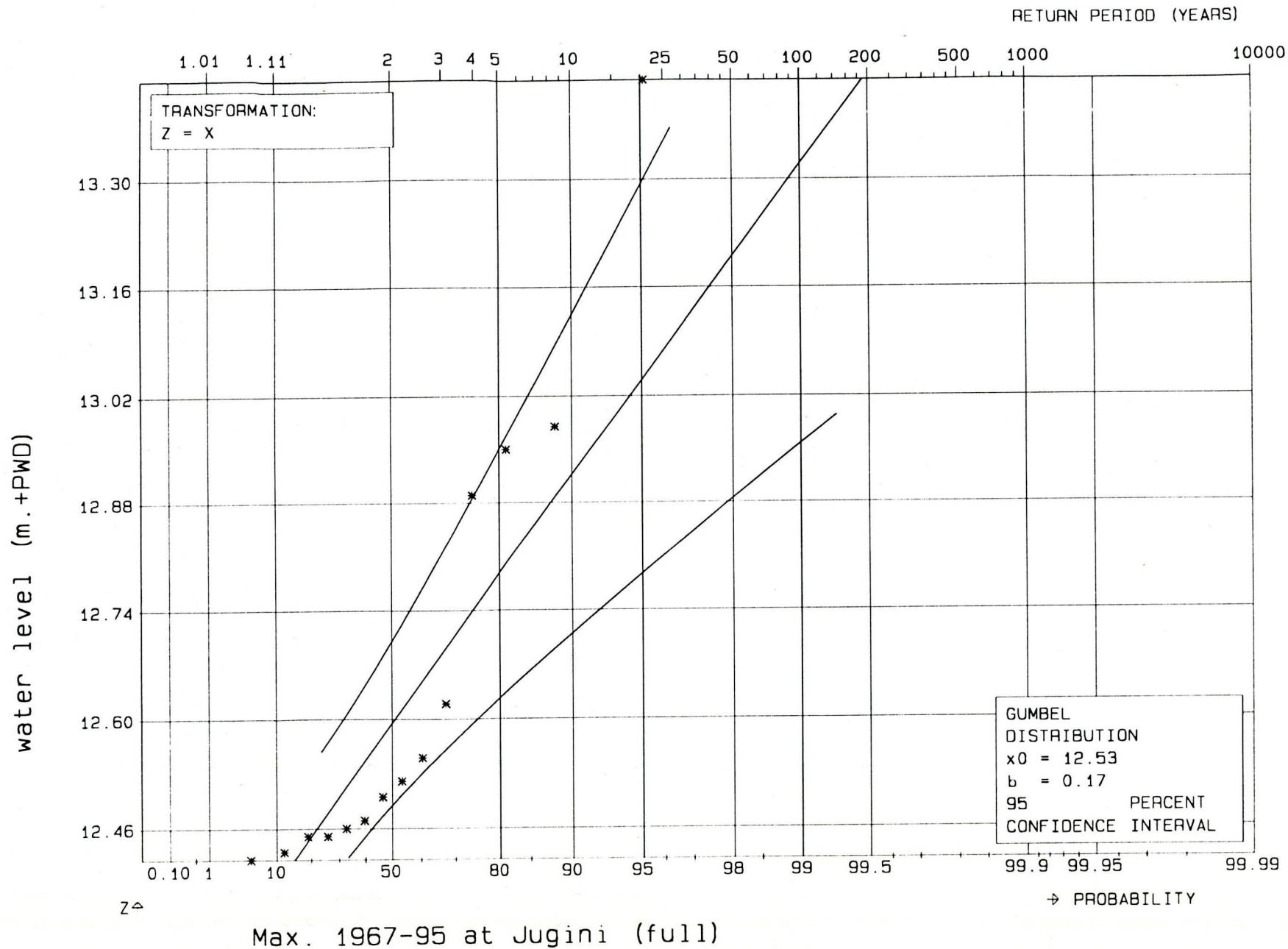


FIGURE 4.4 FREQUENCY ANALYSIS FOR THE STATION AT JUGINI (GUMBEL DISTRIBUTION)

4.5 Methodology followed during analysis

There are 31 damage units in the study area, each unit having a certain type of crop as shown in fig.4.1. Farmers usually follow the land contour to cultivate their land with a definite type of crop. On higher elevated lands (F_0) they usually plant HYV varieties. On moderately elevated lands (F_1) they go for local varieties of paddy and on lower elevated lands (F_2) they plant deep water Aman. The above land types defined on the basis of flood depth is shown in table 4.6.

TABLE 4.6: LAND TYPES DEFINED ON THE BASIS OF FLOOD DEPTH

<i>Land Type</i>	<i>Flood Depth</i>	<i>Flooding</i>	<i>Remarks</i>
F_0	0 - 30 cm	Intermittent	Land suited to HYV rice in wet season
F_1	30 - 90 cm	Seasonal	Land suited to Local Varieties of Aus and T. Aman in monsoon
F_2	90 - 180 cm	Seasonal	Land suited to B. Aman in wet season
F_3	> 180 cm	Seasonal	Land on which B. Aman can be grown in wet season
F_0	> 180 cm	Seasonal/ Perennial	not suited for crop cultivation

Source : MPO, 1990.

There are three water level stations within the study area. These are shown in fig.4.1. Water level of station 1 at Khorda Jugini is representative for the damage units of 1, 2, 3, 4, 5, 8, 9, 10, 11, 12, 13, 14, 16. Water level of station 2 at Krishnapur is representative for the damage units of 6, 15, 17, 18, 19, 20, 21, 22,

23, 24, 25, 26, 27. Water level of station 3 at Krishnapur is representative for the damage units of 28, 29, 30, 31.

The system which has been developed in the GIS for assessing crop damage due to flood considering the criteria mentioned in art 4.2, starts searching from damage unit 1 and stop after finishing with unit 31. For each damage unit, the system will search for each growing stage of the crop planted in that unit and find out if the flood tolerance depths in each growing stage is being exceeded. Not only that, it will also search for number of inundation days for damage to occur, partial or full, in a certain unit. As damage to crop is not only a function of the flood tolerance depth but also of the number of inundation days.

The Compartmentalization Pilot Project is planned to start operation from 15th of July to the end of October, if any flood occurs. That is why the analysis begins at 15th of July to assess the damage for with and without project situation.

4.6 Methodology followed in finding a suitable cropping pattern

As described earlier, the lowest hydrological unit in CPP is a chawk. The desired water level will be maintained chawk by chawk. So, for finding out a higher yield cropping pattern, these chawk water (target water level) levels have been used. Target water levels are those water levels, which will be maintained in the chawks by controlled flooding and which will permit the crops in the chawks to grow without any damage.

Fig. 4.5 shows chawks in Sub-compartment 9 (study area) and Appendix A shows the target water levels. In the first row of these tables, there are chawknames and in the first column there are dates, starting from 15th of July and up to 28th of October. From these chawk water levels, the water depths (desired or target) in the damage units were found out easily. These are shown in Appendix B.

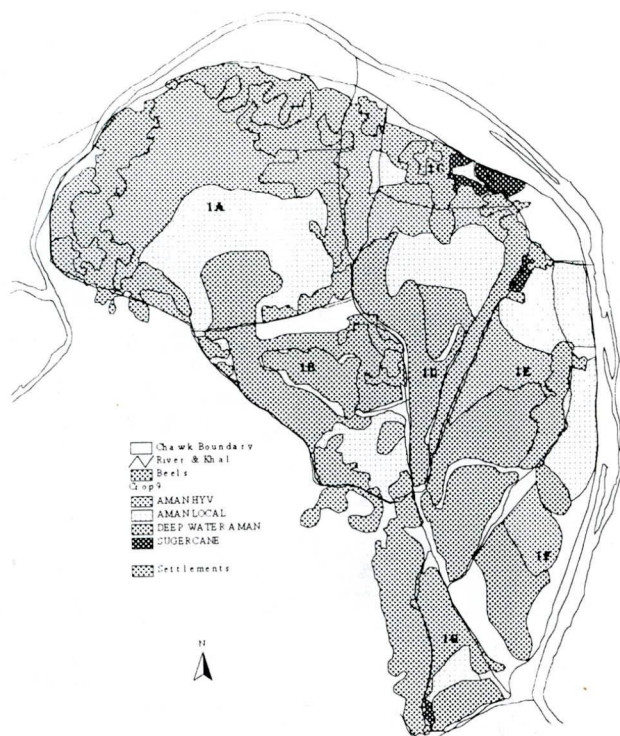


FIGURE 4.5 CHAWK BOUNDARIES IN THE STUDY AREA.

The next step is to go for the trial and error to find out a suitable cropping pattern. For example, in damage unit 3 existing crop is local variety Aman. It was checked whether a HYV could be planted there maintaining the desired water level by controlled flooding. Or instead of Deep Water Aman, local varieties could be introduced. In this way all the damage units were checked for HYV varieties. In this trial and error process the changeable parameter was only the crop type in a damage unit. The system takes the crop type and damage unit as the initial data and reads other data relating to that crop and damage unit such as flood tolerance depths, yield reduction functions, land elevation and water levels.

Land type or land classification suggested by MPO was considered during analysis. The objective of finding out a suitable cropping pattern that will yield optimum amount of production is set as the study area is a part of CPP, whose target is also to increase crop yield and moreover using GIS as tool to perform the job. Concept of CPP is to control flood to a desirable degree, so that F_1 lands

can be promoted to F_0 lands and F_2 lands can be promoted to F_1 lands. This concept was kept in mind during analysis.

5. Results and Discussion

A system has been developed in the GIS which can find out the damaged areas due to flood. The water level series during monsoon period are the input to the system. Maps are readily produced in the GIS which is another very important aspect of a GIS. Maps were produced in ArcView which is a supporting program of PC Arc/Info GIS, special for map preparation. This software takes coverages (files) from Arc/Info GIS and related tables in making maps.

5.1 Calibration of the system to simulate the damage

During analysis it was needed to calibrate the system to simulate the actual field situation. Field data were collected for 1993 and 1995. Only some rise in the topographic level (land level) was needed. After that the system was proved to be well functioning in assessing crop damage.

5.2 Damage in Year 1993

With respect to Jugini water level, the year 1993 has a return period of 2 years. Frequency analysis shown in table 4.5 and fig. 4.3. Appendix C shows the field water depths in different damage units under different water level station. In the first row of these tables, station name and unit numbers are mentioned and under each of them respective field water depths are written. These water depths are from 15th of July to 28th of October. The system analyzed these tables to find out the damaged units. Fig.5.1 shows the damaged units during 1993 and table 5.1 shows statistics. Out of 242 hectares of cropping area 98 hectares of land which is 40% of the cropping land suffered from damage to crops. Of the damaged crops 23.5% is HYV Aman, 82% is Local Aman and 14.5% is Deep Water Aman. No damage to sugarcane was found which was cultivated only in 2% of the cropping area.

TABLE 5.1 RESULTS OF THE ANALYSIS FOR 1993

Total crop area	=	242 ha.	Total damaged area	=	98 ha.
HYV Aman	=	84 ha.	HYV Aman	=	23 ha.
Local Aman	=	82 ha.	Local Aman	=	82 ha.
Deep Water Aman	=	71 ha.	Deep Water Aman	=	14 ha.
Sugarcane	=	5 ha.	No damage to sugarcane was found.		



FIGURE 5.1 DAMAGED UNITS IN 1993.

5.3 Damage in Year 1991

With respect to Jugini water level, the year 1991 has a return period of 5 years. Frequency analysis shown in table 4.5 and fig. 4.3. Appendix D show the field water depths in different damage units under different water level stations. In the first row of these tables, station name and unit numbers are mentioned and under each of them respective field water depths are written. These water depths are from 15th of July to 28th of October. The system analyzed these tables to find out the damaged units. Fig.5.2 shows the damaged units during 1991 and table 5.2 shows statistics. Out of 242 hectares of cropping area 237 hectares of land which is 97.5% of the cropping land suffered from damage to crops. Of the damaged crops 35.4% is HYV Aman, 34.6% is Local Aman and 30% is Deep Water Aman. No damage to sugarcane was found which was cultivated only in 2% of the cropping area.

TABLE 5.2 RESULTS OF THE ANALYSIS FOR 1991

Total crop area	=	242 ha.	Total damaged area	=	237 ha.
HYV Aman	=	84 ha.	HYV Aman	=	84 ha.
Local Aman	=	82 ha.	Local Aman	=	82 ha.
Deep Water Aman	=	71 ha.	Deep Water Aman	=	71 ha.
Sugarcane	=	5 ha.	No damage to sugarcane was found.		

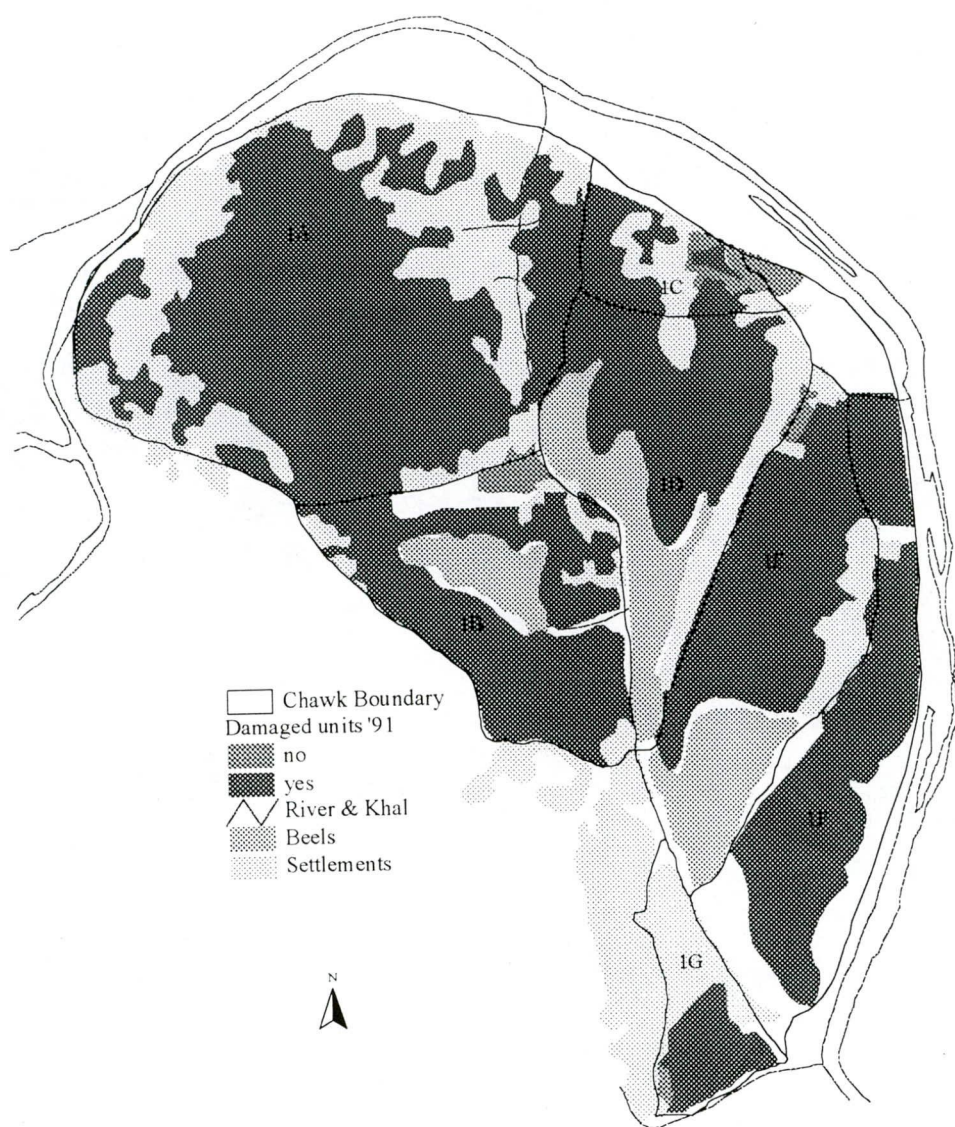


FIGURE 5.2 DAMAGED UNITS IN 1991.

5.4 With project situation

As mentioned earlier, in the with project situation, water levels in the field will be maintained chawkwise. These water levels in chawk have been named as target water levels.

Appendix B shows the water depths during monsoon in different units. In the first row of these tables, unit numbers are mentioned and in the columns under each unit, field water depths are written starting from 15th of July to 28th of October.

Analysis shows that no damage occurred in the study area with the target water levels (such as unit 8) maintained in the field. For existing cropping pattern in the study area 98 hectares of land out of 242 cropping land could be saved with the project in operation which is 40% of the cropping land. This should be noted that this scenario is for a flood of 2 years return period.

For existing cropping pattern in the study area 237 hectares of land out of 242 cropping land could be saved with the project in operation which is 97.5% of the cropping land and this scenario is for a flood of 1 in 5 years return period. This estimation is taken from the damage analysis of the year 1991, which is a year with a 1 in 5 year flood.

During the flood in 1995, which has got a return period of 5 years, water management was partially possible (80% of the study area) in the study area, i.e. the target water levels were maintained partially. An extensive field survey was done in the study area after the flood 1995. There was no sign of damage to crops found, which complies with the model result. It should be mentioned that some changes in the cropping pattern occurred this year. Those were mostly from deep water Aman to local Aman and from local Aman to HYV Aman. However, HYV's have lower tolerance depths than local varieties. So, if the new cropping pattern this year could survive 1995 flood (which has a return period of 5 years with respect to Jugini water level. Frequency.

analysis shown in table 4.5), the existing cropping pattern could also easily tolerate the flood of 1995.

5.5 Comparison of Results with Field Situations

No detail crop damage information is available for the study area. Results of the first study(1992) carried out by CPP in assessing flood damage show only average results for the whole compartment and that time no cropping pattern coverage was available for the project area.

The second study, which was carried out in December 1995 by developing a computer model is yet to be calibrated to simulate the field situation. However, damage data for 1995 flood is available, which is very helpful to compare the withproject situation and also to compare 1991 flood damage (without project situation) as this flood has got the same return period as 1995 flood has in terms of peak water level. This can be in tables 4.4, 4.5 and fig. 4.3. To compare the assessed system result of 1991 crop damage (without project situation) to the field situation, damage data from the field survey during 1995 flood in the adjacent area and in areas within the project boundary, where flood water couldn't be controlled, were used. Survey showed that more than 90% of these areas suffered from damage to crops.

During the flood in 1995 water management was partially possible in the study area, i.e. the target water levels were maintained partially. An extensive field survey was done in the study area after the flood 1995. There was no sign of damage to crops found, which complies with the study result for with project situation.

Field survey showed that the outside area and inside area of the project, where flood water couldn't be controlled, suffered more than 90% damage to crops. For 1991 the present study shows almost the same amount of damage to crops. As mentioned earlier, 1991 and 1995 floods have got the same return period in terms of peak water level.

5.6 Optimum Cropping Pattern for monsoon

As the study area is a part of the Compartmentalization Pilot Project area, project's objective was considered in finding out the optimum cropping pattern during monsoon. The cropping intensity in the project area is already very high (212%). But this area is very much flood prone and too much damage to crops happens so often.

The objective of CPP is to reduce this flood damage by controlled flooding and to increase crop yield by replacing Local varieties of paddy by Higher Yield Varieties, and Broad Casted Aman (Deep Water Aman) by Local Aman.

In GIS it was easy to see or check whether those kind of replacement in each unit is possible or not. Target water depths (desired levels with project) are shown in Appendix B, which were analyzed to find out a suitable higher yielding cropping pattern. Fig.5.3 shows the suitable cropping pattern. Here is a brief description of different units with the planned crop :

The lands which have an average elevation of 10.85 m.+PWD or greater than that in subcompartment 9, can be planted with higher yielding varieties crop. Previous practice was to plant local varieties on those lands. Land contour map as shown in fig.5.4 was followed during this analysis.

The lands, which have an average elevation of 10.70 m.+PWD in subcompartment 9, can not be planted fully with local varieties Aman as the target water depths do not permit in doing so. The average elevation of these lands is 10.70 m.+PWD. So fifty percent lands in this category have got an elevation higher than 10.70 m.+PWD. Following the land contours these lands were chosen to be planted with local varieties Aman.

Water management testing in the study area was partially possible in 1995 monsoon, which experienced a flood having a return period of 1 in 5 years. The study reveals that the cropping pattern in 1995 monsoon, which has been surveyed later on, is

similar to the cropping pattern that has been obtained in the present study. This can be seen in fig. 5.3.

The difference between the existing cropping pattern and the higher yielding cropping pattern is shown below,

TABLE 5.3 DIFFERENCE IN CROPPING AREA BETWEEN EXISTING PATTERN AND PLANNED HIGHER YIELDING PATTERN.

	Existing (hectares)	Planned (hectares)	Percentage of increase (+) or decrease (-)
Higher Yielding Variety	84	181	115% (+)
Local Variety	82	53	35% (-)
Deep Water Aman	71	14	80% (-)
Sugarcane	5	0	100% (-)
Total cropping area	242	248	2.5% (+)

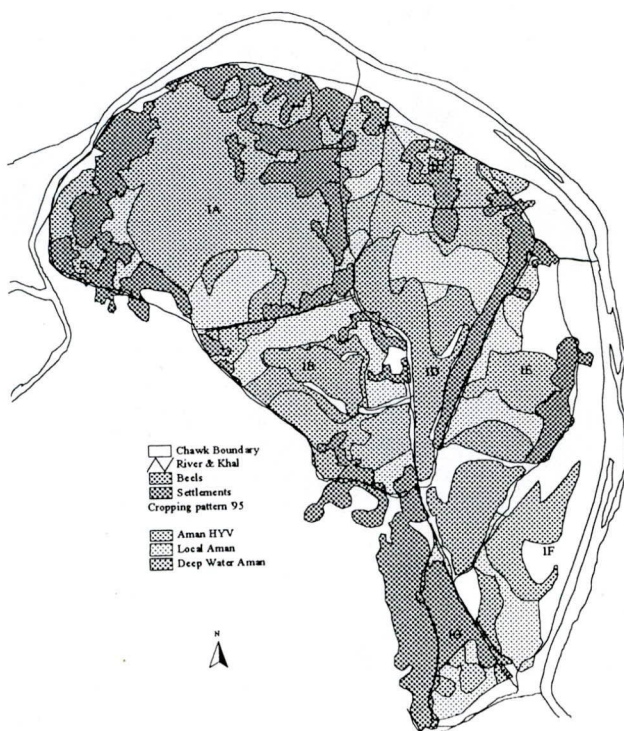
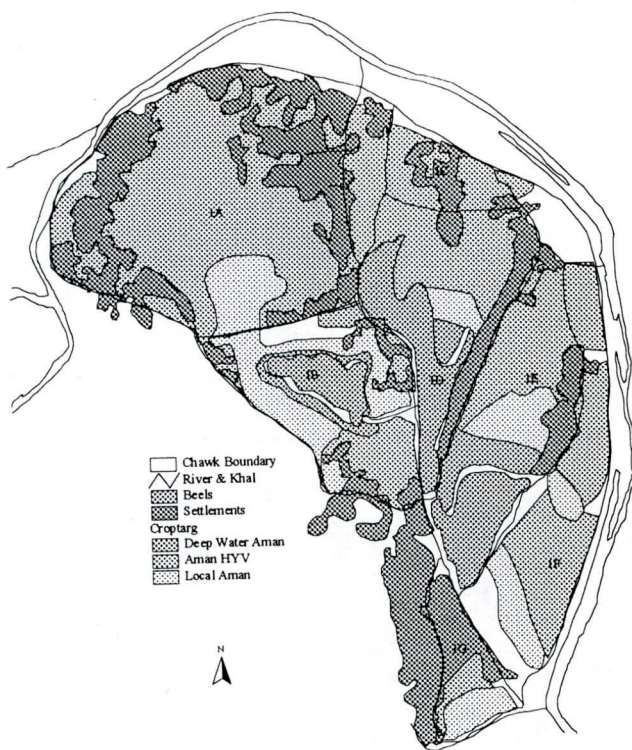


FIGURE 5.3 SUITABLE HIGHER YIELDING CROPPING PATTERN (TOP), MONSOON CROPPING PATTERN '95 (BOTTOM)

FIGURE 5.4 LAND CONTOUR MAP



SOURCE: FINNMAP MAP, 1990

6. Conclusion and Recommendation

6.1 Conclusion

Though crop damage is related to a number of governing factors, here in this study only inundation depth and duration were considered as functions of damage. Results obtained are to some extent representative of the field situation, however, as a new technology to apply in assessing crop damage, the Geographic Information System has got a high potential. It has got the capacity to deal with a large volume of spatial data, analyze them and to show the results of the analysis through maps, tables and graphs. The following conclusions may be drawn from the present study.

1. Damage results in the study area is quite good specially with respect to 1995 flood which gave the opportunity to check the system results both for with and without project situation. During the flood in 1995 water management was partially possible in the study area, i.e. the target water levels were maintained partially. Field survey showed that there was no damage to crops during the flood, which complies with the study result for with project situation.
2. Field survey showed that the adjacent area and inside area of the project, where flood water could not be controlled during 1995 flood, suffered from more than 90% damage to crops. For 1991 the present study shows almost the same amount of damage to crops. It assessed 97.5% of the crops damaged in 1991. As mentioned earlier, 1991 and 1995 floods have got the same return period in terms of peak water level.
3. Through field survey and the present study it was found that damage is not only dependent on inundation depth and duration but also on the plantation time, soil type etc. For the existing cropping pattern, it was considered that all kinds of monsoon crops were there in the field within the first or second week of July. Field survey shows that this kind of assumption is not true at all. It varies from field to field. If farmers predict a flood to come in July, they wait for sometime to plant in their fields. This is very important in crop damage assessment. If the crop fields within a certain

area as for example within the Compartmentalization Pilot Project. Tangail area can be monitored when monsoon comes, GIS can be uniquely applied to assess crop yield or crop damage. The deviations of the system result from the field situation which came during analysis is due to lack of information about plantation time in different damage units.

4. Another finding of the study is that the cropping pattern in 1995 monsoon, which has been surveyed later on, is similar to the cropping pattern that has been obtained in the present study. During the flood in 1995 water management was partially possible in the study area, i.e. the target water levels were maintained partially and it was expected that farmers would plant higher yielding varieties rice crops on lands where they used to plant local varieties rice crops. It was expected because the farmers were trained and inspired to plant HYV instead of local varieties maintaining desired water level in fields. Not only that, crop demonstration plots were also prepared and showed by CPP, which inspired and led the farmers to go for planting as it was obtained in this study. So, it is not very useful to find out a suitable cropping pattern for an existing project using GIS but for project planning activities it can do a lot.

However, this study opens up a field to use GIS as an analyzing tool which will lead to various other studies using GIS such as flood damage assessment, crop monitoring activities, flood monitoring activities, environment monitoring activities, evaluation of flood control and flood management projects etc.

6.2 Recommendation

It is well known that Bangladesh is a country of rivers and of natural calamities as well. It is predicted that in the coming century the frequency of these calamities would increase as an effect of deforestation and of the so called green house effect. We have to be prepared for that situation to reduce the hazards and damages before it comes. As non-structural measures latest computer technologies like GIS can serve a lot of purposes. This study was a little step towards that end. This kind of study can be

extended to produce effective systems to be applied in damage assessment due to the natural calamities we face so often.

A more in-depth study is recommended in assessing crop damage using GIS considering plantation time, soil type, depth and duration of inundation. An easier and more flexible method or system can be developed in GIS to deal with the complex process of crop growth and damage. As GIS is not very user friendly, by customizing it the system can be made more user friendly.

Finally this system can be extended to monitor and to assess crop yield on regional level.

REFERENCES

- Ahmad, A.A.Z.(1989) 'SPARRSO Activities' paper, Remote sensing for flood plain mapping and flood monitoring. ESCAP/UNDP AND SPARRSO.
- BWDB, (1993), 'Small Scale Water Control Structures' Manual for the Design Workshop sponsored by BWDB and CIDA, volume1.
- Chowdhury, A M.(1989) 'Flood Plain Mapping and Flood Monitoring Using SPARRSO Facilities' paper, Remote sensing for flood plain mapping and flood monitoring. ESCAP/UNDP AND SPARRSO.
- CPP, (1992), 'Interim Report' Annex2, Agriculture, Draft.
- CPP, (1995), 'Flood Damage Assessment Model' Technical Note.
- CPP, (1995.a), 'The Press Speaks' Report.
- ESRI, (1994.a), 'Understanding GIS' Redlands, USA.
- ESRI, (1994.b), 'Simple Macro Language for PC ARC/INFO' User's Guide, Redlands, USA.
- FAP, (1989), 'Compartmentalization Pilot Project' Report of the project identification mission.
- FAP20, (1992), 'Inception Report' Revised, Main Volume.
- FAP20, (1994), 'Water Management Subcompartment 9, 10, 11; Tangail Compartment' First Draft, Working Paper vol.1&2.

- FAP25, (1994), 'Flood Management Model' Draft Final Report-vol.1, Main Report.
- FAP25, (1992b), 'Flood Hydrology Study' Annex-1. June.
- Hossain, M. and Nishat, A. (1989) 'The Flood Policy of Bangladesh and its Relationship to Remote Sensing in Flood Plain Mapping And Flood Monitoring.' paper, Remote sensing for flood plain mapping and flood monitoring. ESCAP/UNDP AND SPARRSO.
- ILRI, (1982), 'Land Reclamation and Water Management' ILRI Publication 27, Wageningen.
- Kok, M. (1995), 'Flood damage assessment of the compartmentalization pilot project Tangail' 2nd concept.
- Kok, M. (1995), 'Decision Support for Assessing Flood Damage Reduction Strategies of Meuse river in the Netherlands' Delft Hydraulics Publication.
- Manalo, E.M. (1976), Agro-climatic Survey of Bangladesh, BRRI/IRRI.
- MPO, (1990), 'Agricultural Production Systems' Technical Report 14.
- Shupeng, C. (1989), 'Remote sensing for monitoring and evaluating flood damage' paper, Remote sensing for flood plain mapping and flood monitoring. ESCAP/UNDP AND SPARRSO.
- SPARRSO (1986), 'Country wide Monitoring of Crop Conditions using AVHRR Data from NOAA Series of Meteorological Satellites'.
- Star. J. and Estes. J. (1990), 'Geographic Information Systems - An Introduction' University of California,.

- BBS, (1994), Statistical Pocketbook Bangladesh, Statistics Division, Ministry of Planning.
- United Nations, (1985). Proceedings of the seminar on the Application of Remote Sensing Techniques to Flood Hazard Assessment and Flood Loss Prevention and Management, ST/ESCAP/323, United Nations.
- UNDP/GoB, (1989), 'Bangladesh Flood Policy Study'.
- Visser, H. and Rahman, M.O. (1993), 'Case study, compartmentalization pilot project, Tangail.' paper, Workshop, BUET-DUT Linkage Project.
- Walker, E. W.; Abrahamse, A.; Bolton, J.; Kahan, P. J.; van de Riet, O.; Kok, M.; den Braber, M.; (1994), 'A Policy Analysis of Dutch River Dike Improvements : Trading of Safety, Cost and Environmental Impacts' Operations Research, Vol 42, No. 5, Sept-Oct. 1994.
- Wu, B. and Shupeng, C. (1989) 'A flood disaster analysis system based on GIS and Remote sensing' paper, Remote sensing for flood plain mapping and flood monitoring. ESCAP/UNDP AND SPARRSO.

APPENDIX A TARGET WATER LEVELS (M.+PWD)IN DIFFERENT CHAWKS IN THE STUDY AREA

DATE	Chawk 1A	Chawk 1B	Chawk 1C	Chawk 1D	Chawk 1E	Chawk 1F	Chawk 1G
15-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
16-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
17-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
18-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
19-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
20-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
21-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
22-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
23-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
24-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
25-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
26-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
27-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
28-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
29-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
30-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
31-Jul	11.40	10.90	10.90	10.90	10.90	10.90	10.90
1-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
2-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
3-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
4-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
5-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
6-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
7-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
8-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
9-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
10-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
11-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
12-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
13-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
14-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
15-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
16-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
17-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
18-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
19-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
20-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
21-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
22-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
23-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
24-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
25-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
26-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
27-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
28-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
29-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
30-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90
31-Aug	11.40	10.90	10.90	10.90	10.90	10.90	10.90

DATE	Chawk 1A	Chawk 1B	Chawk 1C	Chawk 1D	Chawk 1E	Chawk 1F	Chawk 1G
22-Oct	11.75	11.20	11.20	11.20	11.20	11.20	11.20
23-Oct	11.75	11.20	11.20	11.20	11.20	11.20	11.20
24-Oct	11.75	11.20	11.20	11.20	11.20	11.20	11.20
25-Oct	11.75	11.20	11.20	11.20	11.20	11.20	11.20
26-Oct	11.75	11.20	11.20	11.20	11.20	11.20	11.20
27-Oct	11.75	11.20	11.20	11.20	11.20	11.20	11.20
28-Oct	11.75	11.20	11.20	11.20	11.20	11.20	11.20

APPENDIX B TARGET WATER DEPTHS (CM) IN DIFFERENT UNITS WITH PROJECT SITUATION

DATE	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
15-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
16-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
17-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
18-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
19-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
20-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
21-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
22-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
23-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
24-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
25-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
26-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
27-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
28-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
29-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
30-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
31-Jul	0	0	15	5	5	5	0	5	0	0	0	5	0
1-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
2-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
3-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
4-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
5-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
6-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
7-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
8-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
9-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
10-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
11-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
12-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
13-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
14-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
15-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
16-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
17-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
18-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
19-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
20-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
21-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
22-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
23-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
24-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
25-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
26-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
27-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
28-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
29-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
30-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
31-Aug	0	0	15	5	5	5	0	5	0	0	0	5	0
1-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
2-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
3-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
4-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
5-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
6-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0

DATE	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
7-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
8-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
9-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
10-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
11-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
12-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
13-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
14-Sep	0	0	15	5	5	5	0	5	0	0	0	5	0
15-Sep	0	0	30	20	5	5	0	5	0	0	0	5	0
16-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
17-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
18-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
19-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
20-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
21-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
22-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
23-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
24-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
25-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
26-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
27-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
28-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
29-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
30-Sep	0	0	30	20	15	15	0	15	0	0	0	15	0
1-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
2-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
3-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
4-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
5-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
6-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
7-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
8-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
9-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
10-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
11-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
12-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
13-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
14-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
15-Oct	0	0	30	20	15	15	0	15	0	0	0	15	0
16-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
17-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
18-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
19-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
20-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
21-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
22-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
23-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
24-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
25-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
26-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
27-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0
28-Oct	0	0	50	40	35	35	0	35	0	0	0	35	0

DATE	unit6	unit15	unit17	unit18	unit19	unit20	unit21	unit22	unit23	unit24	unit25	unit26	unit27
15-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
16-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
17-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
18-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
19-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
20-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
21-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0

DATE	unit6	unit15	unit17	unit18	unit19	unit20	unit21	unit22	unit23	unit24	unit25	unit26	unit27
22-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
23-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
24-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
25-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
26-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
27-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
28-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
29-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
30-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
31-Jul	20	20	0	0	0	0	40	20	5	0	0	20	0
1-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
2-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
3-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
4-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
5-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
6-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
7-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
8-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
9-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
10-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
11-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
12-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
13-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
14-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
15-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
16-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
17-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
18-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
19-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
20-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
21-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
22-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
23-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
24-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
25-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
26-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
27-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
28-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
29-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
30-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
31-Aug	20	20	0	0	0	0	40	20	5	0	0	20	0
1-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
2-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
3-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
4-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
5-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
6-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
7-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
8-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
9-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
10-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
11-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
12-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
13-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
14-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
15-Sep	20	20	0	0	0	0	40	20	5	0	0	20	0
16-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
17-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
18-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
19-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
20-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
21-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
22-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0

DATE	unit6	unit15	unit17	unit18	unit19	unit20	unit21	unit22	unit23	unit24	unit25	unit26	unit27
23-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
24-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
25-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
26-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
27-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
28-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
29-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
30-Sep	30	30	0	0	0	0	50	30	15	0	0	30	0
1-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
2-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
3-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
4-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
5-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
6-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
7-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
8-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
9-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
10-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
11-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
12-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
13-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
14-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
15-Oct	30	30	0	0	0	0	50	30	15	0	0	30	0
16-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
17-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
18-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
19-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
20-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
21-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
22-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
23-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
24-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
25-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
26-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
27-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
28-Oct	50	50	20	0	0	0	70	50	35	0	20	50	0
DATE	unit28	unit29	unit30	unit31									
15-Jul	20	5	0	20									
16-Jul	20	5	0	20									
17-Jul	20	5	0	20									
18-Jul	20	5	0	20									
19-Jul	20	5	0	20									
20-Jul	20	5	0	20									
21-Jul	20	5	0	20									
22-Jul	20	5	0	20									
23-Jul	20	5	0	20									
24-Jul	20	5	0	20									
25-Jul	20	5	0	20									
26-Jul	20	5	0	20									
27-Jul	20	5	0	20									
28-Jul	20	5	0	20									
29-Jul	20	5	0	20									
30-Jul	20	5	0	20									
31-Jul	20	5	0	20									
1-Aug	20	5	0	20									
2-Aug	20	5	0	20									
3-Aug	20	5	0	20									
4-Aug	20	5	0	20									
5-Aug	20	5	0	20									
6-Aug	20	5	0	20									
7-Aug	20	5	0	20									

DATE	unit28	unit29	unit30	unit31
8-Aug	20	5	0	20
9-Aug	20	5	0	20
10-Aug	20	5	0	20
11-Aug	20	5	0	20
12-Aug	20	5	0	20
13-Aug	20	5	0	20
14-Aug	20	5	0	20
15-Aug	20	5	0	20
16-Aug	20	5	0	20
17-Aug	20	5	0	20
18-Aug	20	5	0	20
19-Aug	20	5	0	20
20-Aug	20	5	0	20
21-Aug	20	5	0	20
22-Aug	20	5	0	20
23-Aug	20	5	0	20
24-Aug	20	5	0	20
25-Aug	20	5	0	20
26-Aug	20	5	0	20
27-Aug	20	5	0	20
28-Aug	20	5	0	20
29-Aug	20	5	0	20
30-Aug	20	5	0	20
31-Aug	20	5	0	20
1-Sep	20	5	0	20
2-Sep	20	5	0	20
3-Sep	20	5	0	20
4-Sep	20	5	0	20
5-Sep	20	5	0	20
6-Sep	20	5	0	20
7-Sep	20	5	0	20
8-Sep	20	5	0	20
9-Sep	20	5	0	20
10-Sep	20	5	0	20
11-Sep	20	5	0	20
12-Sep	20	5	0	20
13-Sep	20	5	0	20
14-Sep	20	5	0	20
15-Sep	20	5	0	20
16-Sep	30	15	0	30
17-Sep	30	15	0	30
18-Sep	30	15	0	30
19-Sep	30	15	0	30
20-Sep	30	15	0	30
21-Sep	30	15	0	30
22-Sep	30	15	0	30
23-Sep	30	15	0	30
24-Sep	30	15	0	30
25-Sep	30	15	0	30
26-Sep	30	15	0	30
27-Sep	30	15	0	30
28-Sep	30	15	0	30
29-Sep	30	15	0	30
30-Sep	30	15	0	30
1-Oct	30	15	0	30
2-Oct	30	15	0	30
3-Oct	30	15	0	30
4-Oct	30	15	0	30
5-Oct	30	15	0	30
6-Oct	30	15	0	30

DATE	unit28	unit29	unit30	unit31
7-Oct	30	15	0	30
8-Oct	30	15	0	30
9-Oct	30	15	0	30
10-Oct	30	15	0	30
11-Oct	30	15	0	30
12-Oct	30	15	0	30
13-Oct	30	15	0	30
14-Oct	30	15	0	30
15-Oct	30	15	0	30
16-Oct	50	35	0	50
17-Oct	50	35	0	50
18-Oct	50	35	0	50
19-Oct	50	35	0	50
20-Oct	50	35	0	50
21-Oct	50	35	0	50
22-Oct	50	35	0	50
23-Oct	50	35	0	50
24-Oct	50	35	0	50
25-Oct	50	35	0	50
26-Oct	50	35	0	50
27-Oct	50	35	0	50
28-Oct	50	35	0	50

APPENDIX C FIELD WATER DEPTHS(CM) IN DIFFERENT UNITS IN 1993

C 1 STATION I

DATE	Station 1 m.+PWD	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
2/7/93	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
3/7/93	10.58	0	0	0	0	0	0	0	0	0	0	0	0	0
4/7/93	10.69	0	0	0	0	0	0	0	0	0	0	0	0	0
5/7/93	10.79	0	0	0	0	0	0	0	0	0	0	0	0	0
6/7/93	10.92	0	0	0	0	7	7	0	7	0	0	0	7	0
7/7/93	11.12	0	0	0	0	26	26	0	26	0	0	0	26	0
8/7/93	11.27	0	0	1	0	41	41	0	41	0	0	0	41	0
9/7/93	11.42	0	0	16	7	57	57	0	57	0	0	0	57	0
10/7/93	11.50	0	0	25	15	65	65	0	65	0	0	0	65	0
11/7/93	11.55	0	0	30	20	70	70	5	70	0	0	5	70	0
12/7/93	11.43	0	0	17	8	58	58	0	58	0	0	0	58	0
13/7/93	11.19	0	0	0	0	33	33	0	33	0	0	0	33	0
14/7/93	10.97	0	0	0	0	12	12	0	12	0	0	0	12	0
15/7/93	10.79	0	0	0	0	0	0	0	0	0	0	0	0	0
16/7/93	10.69	0	0	0	0	0	0	0	0	0	0	0	0	0
17/7/93	10.61	0	0	0	0	0	0	0	0	0	0	0	0	0
18/7/93	10.55	0	0	0	0	0	0	0	0	0	0	0	0	0
19/7/93	10.50	0	0	0	0	0	0	0	0	0	0	0	0	0
20/7/93	10.52	0	0	0	0	0	0	0	0	0	0	0	0	0
21/7/93	10.90	0	0	0	0	5	5	0	5	0	0	0	5	0
22/7/93	11.33	0	0	8	0	48	48	0	48	0	0	0	48	0
23/7/93	11.62	0	0	36	26	76	76	11	76	0	0	11	76	0
24/7/93	11.70	0	0	44	34	84	84	19	84	0	0	19	84	0
25/7/93	11.64	0	0	39	29	79	79	14	79	0	0	14	79	0
26/7/93	11.55	0	0	30	20	70	70	5	70	0	0	5	70	0
27/7/93	11.46	0	0	21	11	61	61	0	61	0	0	0	61	0
28/7/93	11.34	0	0	8	0	49	49	0	49	0	0	0	49	0
29/7/93	11.20	0	0	0	0	34	34	0	34	0	0	0	34	0
30/7/93	11.05	0	0	0	0	20	20	0	20	0	0	0	20	0
31/7/93	10.92	0	0	0	0	7	7	0	7	0	0	0	7	0
1/8/93	10.89	0	0	0	0	4	4	0	4	0	0	0	4	0
2/8/93	10.93	0	0	0	0	8	8	0	8	0	0	0	8	0
3/8/93	10.95	0	0	0	0	9	9	0	9	0	0	0	9	0
4/8/93	10.92	0	0	0	0	7	7	0	7	0	0	0	7	0
5/8/93	10.90	0	0	0	0	5	5	0	5	0	0	0	5	0
6/8/93	10.94	0	0	0	0	8	8	0	8	0	0	0	8	0
7/8/93	11.03	0	0	0	0	17	17	0	17	0	0	0	17	0
8/8/93	11.14	0	0	0	0	29	29	0	29	0	0	0	29	0
9/8/93	11.27	0	0	1	0	41	41	0	41	0	0	0	41	0
10/8/93	11.35	0	0	9	0	50	50	0	50	0	0	0	50	0
11/8/93	11.43	0	0	17	8	58	58	0	58	0	0	0	58	0
12/8/93	11.48	0	0	23	13	63	63	0	63	0	0	0	63	0
13/8/93	11.53	0	0	27	17	67	67	2	67	0	0	2	67	0
14/8/93	11.58	0	0	33	23	73	73	8	73	0	0	8	73	0
15/8/93	11.61	0	0	35	25	75	75	10	75	0	0	10	75	0
16/8/93	11.65	0	0	40	30	80	80	15	80	0	0	15	80	0
17/8/93	11.67	0	0	41	32	82	82	16	82	0	0	16	82	0
18/8/93	11.65	0	0	40	30	80	80	15	80	0	0	15	80	0
19/8/93	11.62	0	0	36	26	76	76	11	76	0	0	11	76	0
20/8/93	11.57	0	0	32	22	72	72	7	72	0	0	7	72	0
21/8/93	11.54	0	0	28	18	68	68	3	68	0	0	3	68	0
22/8/93	11.53	0	0	27	17	67	67	2	67	0	0	2	67	0

DATE	Station 1 m.+PWD	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
23/8/93	11.50	0	0	25	15	65	65	0	65	0	0	0	65	0
24/8/93	11.52	0	0	26	16	67	67	1	67	0	0	1	67	0
25/8/93	11.51	0	0	25	16	66	66	0	66	0	0	0	66	0
26/8/93	11.53	0	0	27	17	67	67	2	67	0	0	2	67	0
27/8/93	11.56	0	0	31	21	71	71	6	71	0	0	6	71	0
28/8/93	11.59	0	0	33	24	74	74	8	74	0	0	8	74	0
29/8/93	11.62	0	0	36	26	76	76	11	76	0	0	11	76	0
30/8/93	11.66	0	0	41	31	81	81	16	81	0	0	16	81	0
31/8/93	11.70	0	0	44	34	84	84	19	84	0	0	19	84	0
1/9/93	11.76	0	0	50	41	91	91	25	91	0	0	25	91	0
2/9/93	11.84	8	8	58	49	99	99	33	99	8	8	33	99	8
3/9/93	11.87	11	11	61	51	101	101	36	101	11	11	36	101	11
4/9/93	11.84	8	8	58	49	99	99	33	99	8	8	33	99	8
5/9/93	11.76	0	0	50	41	91	91	25	91	0	0	25	91	0
6/9/93	11.66	0	0	41	31	81	81	16	81	0	0	16	81	0
7/9/93	11.58	0	0	33	23	73	73	8	73	0	0	8	73	0
8/9/93	11.50	0	0	25	15	65	65	0	65	0	0	0	65	0
9/9/93	11.43	0	0	17	8	58	58	0	58	0	0	0	58	0
10/9/93	11.33	0	0	8	0	48	48	0	48	0	0	0	48	0
11/9/93	11.21	0	0	0	0	36	36	0	36	0	0	0	36	0
12/9/93	11.08	0	0	0	0	23	23	0	23	0	0	0	23	0
13/9/93	10.99	0	0	0	0	14	14	0	14	0	0	0	14	0
14/9/93	10.94	0	0	0	0	8	8	0	8	0	0	0	8	0
15/9/93	10.94	0	0	0	0	8	8	0	8	0	0	0	8	0
16/9/93	10.94	0	0	0	0	8	8	0	8	0	0	0	8	0
17/9/93	10.94	0	0	0	0	8	8	0	8	0	0	0	8	0
18/9/93	10.89	0	0	0	0	4	4	0	4	0	0	0	4	0
19/9/93	10.83	0	0	0	0	0	0	0	0	0	0	0	0	0
20/9/93	10.78	0	0	0	0	0	0	0	0	0	0	0	0	0
21/9/93	10.75	0	0	0	0	0	0	0	0	0	0	0	0	0
22/9/93	10.73	0	0	0	0	0	0	0	0	0	0	0	0	0
23/9/93	10.74	0	0	0	0	0	0	0	0	0	0	0	0	0
24/9/93	10.75	0	0	0	0	0	0	0	0	0	0	0	0	0
25/9/93	10.75	0	0	0	0	0	0	0	0	0	0	0	0	0
26/9/93	10.76	0	0	0	0	0	0	0	0	0	0	0	0	0
27/9/93	10.76	0	0	0	0	0	0	0	0	0	0	0	0	0
28/9/93	10.78	0	0	0	0	0	0	0	0	0	0	0	0	0
29/9/93	10.79	0	0	0	0	0	0	0	0	0	0	0	0	0
30/9/93	10.83	0	0	0	0	0	0	0	0	0	0	0	0	0
1/10/93	10.81	0	0	0	0	0	0	0	0	0	0	0	0	0
2/10/93	10.80	0	0	0	0	0	0	0	0	0	0	0	0	0
3/10/93	10.82	0	0	0	0	0	0	0	0	0	0	0	0	0
4/10/93	10.90	0	0	0	0	5	5	0	5	0	0	0	5	0
5/10/93	10.97	0	0	0	0	12	12	0	12	0	0	0	12	0
6/10/93	10.95	0	0	0	0	9	9	0	9	0	0	0	9	0
7/10/93	10.87	0	0	0	0	1	1	0	1	0	0	0	1	0
8/10/93	10.77	0	0	0	0	0	0	0	0	0	0	0	0	0
9/10/93	10.70	0	0	0	0	0	0	0	0	0	0	0	0	0
10/10/93	10.65	0	0	0	0	0	0	0	0	0	0	0	0	0
11/10/93	10.57	0	0	0	0	0	0	0	0	0	0	0	0	0
12/10/93	10.46	0	0	0	0	0	0	0	0	0	0	0	0	0
13/10/93	10.36	0	0	0	0	0	0	0	0	0	0	0	0	0
14/10/93	10.28	0	0	0	0	0	0	0	0	0	0	0	0	0
15/10/93	10.20	0	0	0	0	0	0	0	0	0	0	0	0	0
16/10/93	10.12	0	0	0	0	0	0	0	0	0	0	0	0	0
17/10/93	10.06	0	0	0	0	0	0	0	0	0	0	0	0	0
18/10/93	10.00	0	0	0	0	0	0	0	0	0	0	0	0	0
19/10/93	9.91	0	0	0	0	0	0	0	0	0	0	0	0	0
20/10/93	9.84	0	0	0	0	0	0	0	0	0	0	0	0	0
21/10/93	9.79	0	0	0	0	0	0	0	0	0	0	0	0	0

DATE	Station 1 m. +PWD	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
22/10/93	9.73	0	0	0	0	0	0	0	0	0	0	0	0	0
23/10/93	9.64	0	0	0	0	0	0	0	0	0	0	0	0	0
24/10/93	9.51	0	0	0	0	0	0	0	0	0	0	0	0	0
25/10/93	9.31	0	0	0	0	0	0	0	0	0	0	0	0	0
26/10/93	9.47	0	0	0	0	0	0	0	0	0	0	0	0	0
27/10/93	9.22	0	0	0	0	0	0	0	0	0	0	0	0	0
28/10/93	9.13	0	0	0	0	0	0	0	0	0	0	0	0	0

C 2 STATION 2

DATE	station2 m.+PWD	unit6	unit15	unit17	unit18	unit19	unit20	unit21	unit22	unit23	unit24	unit25	unit26	unit27
2/7/93	10.39	0	0	0	0	0	0	0	0	0	0	0	0	0
3/7/93	10.41	0	0	0	0	0	0	0	0	0	0	0	0	0
4/7/93	10.41	0	0	0	0	0	0	0	0	0	0	0	0	0
5/7/93	10.40	0	0	0	0	0	0	0	0	0	0	0	0	0
6/7/93	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
7/7/93	10.55	0	0	0	0	0	0	5	0	0	0	0	0	0
8/7/93	10.68	0	0	0	0	0	0	18	0	0	0	0	0	0
9/7/93	10.82	12	12	0	0	0	0	32	12	0	0	0	12	0
10/7/93	10.96	26	26	0	0	0	0	46	26	11	0	0	26	0
11/7/93	11.07	37	37	7	0	0	0	57	37	22	0	7	37	0
12/7/93	11.10	40	40	10	0	0	0	60	40	25	0	10	40	0
13/7/93	11.05	35	35	5	0	0	0	55	35	20	0	5	35	0
14/7/93	10.97	27	27	0	0	0	0	47	27	12	0	0	27	0
15/7/93	10.88	18	18	0	0	0	0	38	18	3	0	0	18	0
16/7/93	10.80	10	10	0	0	0	0	30	10	0	0	0	10	0
17/7/93	10.72	2	2	0	0	0	0	22	2	0	0	0	2	0
18/7/93	10.64	0	0	0	0	0	0	14	0	0	0	0	0	0
19/7/93	10.57	0	0	0	0	0	0	7	0	0	0	0	0	0
20/7/93	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
21/7/93	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
22/7/93	10.66	0	0	0	0	0	0	16	0	0	0	0	0	0
23/7/93	10.88	18	18	0	0	0	0	38	18	3	0	0	18	0
24/7/93	11.14	44	44	14	0	0	0	64	44	29	0	14	44	0
25/7/93	11.27	57	57	27	0	0	2	77	57	42	2	27	57	2
26/7/93	11.24	54	54	24	0	0	0	74	54	39	0	24	54	0
27/7/93	11.20	50	50	20	0	0	0	70	50	35	0	20	50	0
28/7/93	11.14	44	44	14	0	0	0	64	44	29	0	14	44	0
29/7/93	11.08	38	38	8	0	0	0	58	38	23	0	8	38	0
30/7/93	11.01	31	31	1	0	0	0	51	31	16	0	1	31	0
31/7/93	10.94	24	24	0	0	0	0	44	24	9	0	0	24	0
1/8/93	10.86	16	16	0	0	0	0	36	16	1	0	0	16	0
2/8/93	10.81	11	11	0	0	0	0	31	11	0	0	0	11	0
3/8/93	10.78	8	8	0	0	0	0	28	8	0	0	0	8	0
4/8/93	10.75	5	5	0	0	0	0	25	5	0	0	0	5	0
5/8/93	10.74	4	4	0	0	0	0	24	4	0	0	0	4	0
6/8/93	10.72	2	2	0	0	0	0	22	2	0	0	0	2	0
7/8/93	10.71	1	1	0	0	0	0	21	1	0	0	0	1	0
8/8/93	10.75	5	5	0	0	0	0	25	5	0	0	0	5	0
9/8/93	10.82	12	12	0	0	0	0	32	12	0	0	0	12	0
10/8/93	10.91	21	21	0	0	0	0	41	21	6	0	0	21	0
11/8/93	10.99	29	29	0	0	0	0	49	29	14	0	0	29	0
12/8/93	11.06	36	36	6	0	0	0	56	36	21	0	6	36	0
13/8/93	11.12	42	42	12	0	0	0	62	42	27	0	12	42	0
14/8/93	11.17	47	47	17	0	0	0	67	47	32	0	17	47	0
15/8/93	11.21	51	51	21	0	0	0	71	51	36	0	21	51	0
16/8/93	11.25	55	55	25	0	0	0	75	55	40	0	25	55	0
17/8/93	11.29	59	59	29	0	0	4	79	59	44	4	29	59	4
18/8/93	11.30	60	60	30	0	0	5	80	60	45	5	30	60	5
19/8/93	11.29	59	59	29	0	0	4	79	59	44	4	29	59	4
20/8/93	11.27	57	57	27	0	0	2	77	57	42	2	27	57	2
21/8/93	11.24	54	54	24	0	0	0	74	54	39	0	24	54	0
22/8/93	11.22	52	52	22	0	0	0	72	52	37	0	22	52	0
23/8/93	11.22	52	52	22	0	0	0	72	52	37	0	22	52	0
24/8/93	11.24	54	54	24	0	0	0	74	54	39	0	24	54	0
25/8/93	11.25	55	55	25	0	0	0	75	55	40	0	25	55	0
26/8/93	11.22	52	52	22	0	0	0	72	52	37	0	22	52	0
27/8/93	11.24	54	54	24	0	0	0	74	54	39	0	24	54	0
28/8/93	11.26	56	56	26	0	0	1	76	56	41	1	26	56	1

DATE	station2 m.+PWD	unit6	unit15	unit17	unit18	unit19	unit20	unit21	unit22	unit23	unit24	unit25	unit26	unit27
29/8/93	11.28	58	58	28	0	0	3	78	58	43	3	28	58	3
30/8/93	11.31	61	61	31	0	0	6	81	61	46	6	31	61	6
31/8/93	11.34	64	64	34	0	0	9	84	64	49	9	34	64	9
1/9/93	11.38	68	68	38	0	0	13	88	68	53	13	38	68	13
2/9/93	11.46	76	76	46	0	0	21	96	76	61	21	46	76	21
3/9/93	11.57	87	87	57	0	0	32	107	87	72	32	57	87	32
4/9/93	11.60	90	90	60	0	0	35	110	90	75	35	60	90	35
5/9/93	11.53	83	83	53	0	0	28	103	83	68	28	53	83	28
6/9/93	11.47	77	77	47	0	0	22	97	77	62	22	47	77	22
7/9/93	11.39	69	69	39	0	0	14	89	69	54	14	39	69	14
8/9/93	11.32	62	62	32	0	0	7	82	62	47	7	32	62	7
9/9/93	11.25	55	55	25	0	0	0	75	55	40	0	25	55	0
10/9/93	11.19	49	49	19	0	0	0	69	49	34	0	19	49	0
11/9/93	11.12	42	42	12	0	0	0	62	42	27	0	12	42	0
12/9/93	11.04	34	34	4	0	0	0	54	34	19	0	4	34	0
13/9/93	10.97	27	27	0	0	0	0	47	27	12	0	0	27	0
14/9/93	10.91	21	21	0	0	0	0	41	21	6	0	0	21	0
15/9/93	10.85	15	15	0	0	0	0	35	15	0	0	0	15	0
16/9/93	10.80	10	10	0	0	0	0	30	10	0	0	0	10	0
17/9/93	10.75	5	5	0	0	0	0	25	5	0	0	0	5	0
18/9/93	10.72	2	2	0	0	0	0	22	2	0	0	0	2	0
19/9/93	10.68	0	0	0	0	0	0	18	0	0	0	0	0	0
20/9/93	10.64	0	0	0	0	0	0	14	0	0	0	0	0	0
21/9/93	10.60	0	0	0	0	0	0	10	0	0	0	0	0	0
22/9/93	10.56	0	0	0	0	0	0	6	0	0	0	0	0	0
23/9/93	10.53	0	0	0	0	0	0	3	0	0	0	0	0	0
24/9/93	10.51	0	0	0	0	0	0	1	0	0	0	0	0	0
25/9/93	10.50	0	0	0	0	0	0	0	0	0	0	0	0	0
26/9/93	10.49	0	0	0	0	0	0	0	0	0	0	0	0	0
27/9/93	10.48	0	0	0	0	0	0	0	0	0	0	0	0	0
28/9/93	10.48	0	0	0	0	0	0	0	0	0	0	0	0	0
29/9/93	10.50	0	0	0	0	0	0	0	0	0	0	0	0	0
30/9/93	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
1/10/93	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
2/10/93	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
3/10/93	10.51	0	0	0	0	0	0	1	0	0	0	0	0	0
4/10/93	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
5/10/93	10.57	0	0	0	0	0	0	7	0	0	0	0	0	0
6/10/93	10.60	0	0	0	0	0	0	10	0	0	0	0	0	0
7/10/93	10.59	0	0	0	0	0	0	9	0	0	0	0	0	0
8/10/93	10.56	0	0	0	0	0	0	6	0	0	0	0	0	0
9/10/93	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
10/10/93	10.48	0	0	0	0	0	0	0	0	0	0	0	0	0
11/10/93	10.44	0	0	0	0	0	0	0	0	0	0	0	0	0
12/10/93	10.40	0	0	0	0	0	0	0	0	0	0	0	0	0
13/10/93	10.37	0	0	0	0	0	0	0	0	0	0	0	0	0
14/10/93	10.38	0	0	0	0	0	0	0	0	0	0	0	0	0
15/10/93	10.39	0	0	0	0	0	0	0	0	0	0	0	0	0
16/10/93	10.40	0	0	0	0	0	0	0	0	0	0	0	0	0
17/10/93	10.42	0	0	0	0	0	0	0	0	0	0	0	0	0
18/10/93	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
19/10/93	10.44	0	0	0	0	0	0	0	0	0	0	0	0	0
20/10/93	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
21/10/93	10.42	0	0	0	0	0	0	0	0	0	0	0	0	0
22/10/93	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
23/10/93	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
24/10/93	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
25/10/93	10.42	0	0	0	0	0	0	0	0	0	0	0	0	0
26/10/93	10.42	0	0	0	0	0	0	0	0	0	0	0	0	0
27/10/93	10.41	0	0	0	0	0	0	0	0	0	0	0	0	0

C 3 STATION 3

DATE	sattion3 m.+PWD	unit28	unit29	unit30	unit31
2/7/93	10.26	0	0	0	0
3/7/93	10.24	0	0	0	0
4/7/93	10.28	0	0	0	0
5/7/93	10.35	0	0	0	0
6/7/93	10.45	0	0	0	0
7/7/93	10.61	0	0	0	0
8/7/93	10.74	4	0	0	4
9/7/93	10.88	18	3	0	18
10/7/93	11.00	30	15	0	30
11/7/93	11.09	39	24	0	39
12/7/93	11.09	39	24	0	39
13/7/93	11.00	30	15	0	30
14/7/93	10.89	19	4	0	19
15/7/93	10.77	7	0	0	7
16/7/93	10.64	0	0	0	0
17/7/93	10.50	0	0	0	0
18/7/93	10.37	0	0	0	0
19/7/93	10.31	0	0	0	0
20/7/93	10.29	0	0	0	0
21/7/93	10.46	0	0	0	0
22/7/93	10.72	2	0	0	2
23/7/93	11.00	30	15	0	30
24/7/93	11.23	53	38	0	53
25/7/93	11.27	57	42	0	57
26/7/93	11.23	53	38	0	53
27/7/93	11.18	48	33	0	48
28/7/93	11.11	41	26	0	41
29/7/93	11.03	33	18	0	33
30/7/93	10.94	24	9	0	24
31/7/93	10.84	14	0	0	14
1/8/93	10.75	5	0	0	5
2/8/93	10.70	0	0	0	0
3/8/93	10.69	0	0	0	0
4/8/93	10.68	0	0	0	0
5/8/93	10.65	0	0	0	0
6/8/93	10.64	0	0	0	0
7/8/93	10.69	0	0	0	0
8/8/93	10.75	5	0	0	5
9/8/93	10.84	14	0	0	14
10/8/93	10.93	23	8	0	23
11/8/93	11.01	31	16	0	31
12/8/93	11.07	37	22	0	37
13/8/93	11.12	42	27	0	42
14/8/93	11.17	47	32	0	47
15/8/93	11.22	52	37	0	52
16/8/93	11.25	55	40	0	55
17/8/93	11.29	59	44	0	59
18/8/93	11.30	60	45	0	60
19/8/93	11.29	59	44	0	59
20/8/93	11.26	56	41	0	56
21/8/93	11.24	54	39	0	54
22/8/93	11.22	52	37	0	52
23/8/93	11.21	51	36	0	51
24/8/93	11.23	53	38	0	53
25/8/93	11.23	53	38	0	53
26/8/93	11.22	52	37	0	52
27/8/93	11.24	54	39	0	54
28/8/93	11.26	56	41	0	56

DATE	sattion3 m.+PWD	unit28	unit29	unit30	unit31
29/8/93	11.28	58	43	0	58
30/8/93	11.31	61	46	0	61
31/8/93	11.35	65	50	0	65
1/9/93	11.39	69	54	0	69
2/9/93	11.47	77	62	0	77
3/9/93	11.56	86	71	0	86
4/9/93	11.58	88	73	0	88
5/9/93	11.52	82	67	0	82
6/9/93	11.44	74	59	0	74
7/9/93	11.36	66	51	0	66
8/9/93	11.29	59	44	0	59
9/9/93	11.22	52	37	0	52
10/9/93	11.15	45	30	0	45
11/9/93	11.07	37	22	0	37
12/9/93	10.98	28	13	0	28
13/9/93	10.90	20	5	0	20
14/9/93	10.82	12	0	0	12
15/9/93	10.76	6	0	0	6
16/9/93	10.72	2	0	0	2
17/9/93	10.69	0	0	0	0
18/9/93	10.65	0	0	0	0
19/9/93	10.60	0	0	0	0
20/9/93	10.55	0	0	0	0
21/9/93	10.49	0	0	0	0
22/9/93	10.46	0	0	0	0
23/9/93	10.44	0	0	0	0
24/9/93	10.43	0	0	0	0
25/9/93	10.43	0	0	0	0
26/9/93	10.43	0	0	0	0
27/9/93	10.42	0	0	0	0
28/9/93	10.43	0	0	0	0
29/9/93	10.44	0	0	0	0
30/9/93	10.47	0	0	0	0
1/10/93	10.47	0	0	0	0
2/10/93	10.46	0	0	0	0
3/10/93	10.46	0	0	0	0
4/10/93	10.51	0	0	0	0
5/10/93	10.57	0	0	0	0
6/10/93	10.59	0	0	0	0
7/10/93	10.55	0	0	0	0
8/10/93	10.47	0	0	0	0
9/10/93	10.40	0	0	0	0
10/10/93	10.35	0	0	0	0
11/10/93	10.29	0	0	0	0
12/10/93	10.23	0	0	0	0
13/10/93	10.21	0	0	0	0
14/10/93	10.24	0	0	0	0
15/10/93	10.26	0	0	0	0
16/10/93	10.28	0	0	0	0
17/10/93	10.29	0	0	0	0
18/10/93	10.30	0	0	0	0
19/10/93	10.31	0	0	0	0
20/10/93	10.30	0	0	0	0
21/10/93	10.30	0	0	0	0
22/10/93	10.30	0	0	0	0
23/10/93	10.31	0	0	0	0
24/10/93	10.30	0	0	0	0
25/10/93	10.30	0	0	0	0
26/10/93	10.30	0	0	0	0
27/10/93	10.29	0	0	0	0

APPENDIX D FIELD WATER DEPTHS(CM) IN DIFFERENT UNITS IN 1991

D 1 STATION 1

DATE	Station 1 m.+PWD	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
2/7/91	10.70	0	0	0	0	0	0	0	0	0	0	0	0	0
3/7/91	10.71	0	0	0	0	0	0	0	0	0	0	0	0	0
4/7/91	10.71	0	0	0	0	0	0	0	0	0	0	0	0	0
5/7/91	10.82	0	0	0	0	0	0	0	0	0	0	0	0	0
6/7/91	10.95	0	0	0	0	9	9	0	9	0	0	0	9	0
7/7/91	11.06	0	0	0	0	21	21	0	21	0	0	0	21	0
8/7/91	11.23	0	0	0	0	38	38	0	38	0	0	0	38	0
9/7/91	11.41	0	0	16	6	56	56	0	56	0	0	0	56	0
10/7/91	11.57	0	0	32	22	72	72	7	72	0	0	7	72	0
11/7/91	11.72	0	0	47	37	87	87	22	87	0	0	22	87	0
12/7/91	11.84	8	8	58	49	99	99	33	99	8	8	33	99	8
13/7/91	12.03	27	27	77	67	117	117	52	117	27	27	52	117	27
14/7/91	12.14	39	39	89	79	129	129	64	129	39	39	64	129	39
15/7/91	12.20	44	44	94	84	134	134	69	134	44	44	69	134	44
16/7/91	12.19	43	43	93	83	134	134	68	134	43	43	68	134	43
17/7/91	12.18	42	42	92	83	133	133	67	133	42	42	67	133	42
18/7/91	12.15	40	40	90	80	130	130	65	130	40	40	65	130	40
19/7/91	12.15	40	40	90	80	130	130	65	130	40	40	65	130	40
20/7/91	12.05	30	30	80	70	120	120	55	120	30	30	55	120	30
21/7/91	11.85	9	9	59	50	100	100	34	100	9	9	34	100	9
22/7/91	11.69	0	0	43	33	83	83	18	83	0	0	18	83	0
23/7/91	11.61	0	0	35	25	75	75	10	75	0	0	10	75	0
24/7/91	11.51	0	0	25	16	66	66	0	66	0	0	0	66	0
25/7/91	11.36	0	0	10	0	50	50	0	50	0	0	0	50	0
26/7/91	11.18	0	0	0	0	33	33	0	33	0	0	0	33	0
27/7/91	11.06	0	0	0	0	21	21	0	21	0	0	0	21	0
28/7/91	10.96	0	0	0	0	11	11	0	11	0	0	0	11	0
29/7/91	10.86	0	0	0	0	0	0	0	0	0	0	0	0	0
30/7/91	10.77	0	0	0	0	0	0	0	0	0	0	0	0	0
31/7/91	10.71	0	0	0	0	0	0	0	0	0	0	0	0	0
1/8/91	10.65	0	0	0	0	0	0	0	0	0	0	0	0	0
2/8/91	10.65	0	0	0	0	0	0	0	0	0	0	0	0	0
3/8/91	10.71	0	0	0	0	0	0	0	0	0	0	0	0	0
4/8/91	10.83	0	0	0	0	0	0	0	0	0	0	0	0	0
5/8/91	11.01	0	0	0	0	16	16	0	16	0	0	0	16	0
6/8/91	11.19	0	0	0	0	33	33	0	33	0	0	0	33	0
7/8/91	11.32	0	0	7	0	47	47	0	47	0	0	0	47	0
8/8/91	11.38	0	0	13	3	53	53	0	53	0	0	0	53	0
9/8/91	11.42	0	0	16	7	57	57	0	57	0	0	0	57	0
10/8/91	11.46	0	0	21	11	61	61	0	61	0	0	0	61	0
11/8/91	11.51	0	0	25	16	66	66	0	66	0	0	0	66	0
12/8/91	11.55	0	0	30	20	70	70	5	70	0	0	5	70	0
13/8/91	11.59	0	0	33	24	74	74	8	74	0	0	8	74	0
14/8/91	11.63	0	0	38	28	78	78	13	78	0	0	13	78	0
15/8/91	11.65	0	0	40	30	80	80	15	80	0	0	15	80	0
16/8/91	11.63	0	0	38	28	78	78	13	78	0	0	13	78	0
17/8/91	11.62	0	0	36	26	76	76	11	76	0	0	11	76	0
18/8/91	11.67	0	0	41	32	82	82	16	82	0	0	16	82	0
19/8/91	11.75	0	0	50	40	90	90	25	90	0	0	25	90	0
20/8/91	11.77	1	1	51	41	92	92	26	92	1	1	26	92	1
21/8/91	11.74	0	0	49	39	89	89	24	89	0	0	24	89	0
22/8/91	11.69	0	0	43	33	83	83	18	83	0	0	18	83	0
23/8/91	11.61	0	0	35	25	75	75	10	75	0	0	10	75	0
24/8/91	11.50	0	0	25	15	65	65	0	65	0	0	0	65	0
25/8/91	11.36	0	0	10	0	50	50	0	50	0	0	0	50	0

DATE	Station 1 m.+PWD	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
26/8/91	11.19	0	0	0	0	33	33	0	33	0	0	0	33	0
27/8/91	11.07	0	0	0	0	22	22	0	22	0	0	0	22	0
28/8/91	11.01	0	0	0	0	16	16	0	16	0	0	0	16	0
29/8/91	11.00	0	0	0	0	15	15	0	15	0	0	0	15	0
30/8/91	11.02	0	0	0	0	16	16	0	16	0	0	0	16	0
31/8/91	11.05	0	0	0	0	20	20	0	20	0	0	0	20	0
1/9/91	11.01	0	0	0	0	16	16	0	16	0	0	0	16	0
2/9/91	11.02	0	0	0	0	16	16	0	16	0	0	0	16	0
3/9/91	11.06	0	0	0	0	21	21	0	21	0	0	0	21	0
4/9/91	11.12	0	0	0	0	26	26	0	26	0	0	0	26	0
5/9/91	11.20	0	0	0	0	34	34	0	34	0	0	0	34	0
6/9/91	11.29	0	0	3	0	43	43	0	43	0	0	0	43	0
7/9/91	11.36	0	0	10	0	50	50	0	50	0	0	0	50	0
8/9/91	11.40	0	0	15	5	55	55	0	55	0	0	0	55	0
9/9/91	11.46	0	0	21	11	61	61	0	61	0	0	0	61	0
10/9/91	11.66	0	0	41	31	81	81	16	81	0	0	16	81	0
11/9/91	11.88	13	13	63	53	103	103	38	103	13	13	38	103	13
12/9/91	12.01	25	25	75	66	116	116	50	116	25	25	50	116	25
13/9/91	12.04	28	28	78	68	118	118	53	118	28	28	53	118	28
14/9/91	11.95	19	19	69	59	109	109	44	109	19	19	44	109	19
15/9/91	11.85	9	9	59	50	100	100	34	100	9	9	34	100	9
16/9/91	11.74	0	0	49	39	89	89	24	89	0	0	24	89	0
17/9/91	11.67	0	0	41	32	82	82	16	82	0	0	16	82	0
18/9/91	11.60	0	0	34	25	75	75	9	75	0	0	9	75	0
19/9/91	11.53	0	0	27	17	67	67	2	67	0	0	2	67	0
20/9/91	11.43	0	0	17	8	58	58	0	58	0	0	0	58	0
21/9/91	11.29	0	0	3	0	43	43	0	43	0	0	0	43	0
22/9/91	11.18	0	0	0	0	33	33	0	33	0	0	0	33	0
23/9/91	11.10	0	0	0	0	25	25	0	25	0	0	0	25	0
24/9/91	11.09	0	0	0	0	24	24	0	24	0	0	0	24	0
25/9/91	11.21	0	0	0	0	36	36	0	36	0	0	0	36	0
26/9/91	11.27	0	0	1	0	41	41	0	41	0	0	0	41	0
27/9/91	11.20	0	0	0	0	34	34	0	34	0	0	0	34	0
28/9/91	11.12	0	0	0	0	26	26	0	26	0	0	0	26	0
29/9/91	11.07	0	0	0	0	22	22	0	22	0	0	0	22	0
30/9/91	11.02	0	0	0	0	16	16	0	16	0	0	0	16	0
1/10/91	11.00	0	0	0	0	15	15	0	15	0	0	0	15	0
2/10/91	10.98	0	0	0	0	13	13	0	13	0	0	0	13	0
3/10/91	10.95	0	0	0	0	9	9	0	9	0	0	0	9	0
4/10/91	10.88	0	0	0	0	3	3	0	3	0	0	0	3	0
5/10/91	10.79	0	0	0	0	0	0	0	0	0	0	0	0	0
6/10/91	10.67	0	0	0	0	0	0	0	0	0	0	0	0	0
7/10/91	10.53	0	0	0	0	0	0	0	0	0	0	0	0	0
8/10/91	10.41	0	0	0	0	0	0	0	0	0	0	0	0	0
9/10/91	10.30	0	0	0	0	0	0	0	0	0	0	0	0	0
10/10/91	10.21	0	0	0	0	0	0	0	0	0	0	0	0	0
11/10/91	10.14	0	0	0	0	0	0	0	0	0	0	0	0	0
12/10/91	10.06	0	0	0	0	0	0	0	0	0	0	0	0	0
13/10/91	10.03	0	0	0	0	0	0	0	0	0	0	0	0	0
14/10/91	10.12	0	0	0	0	0	0	0	0	0	0	0	0	0
15/10/91	10.09	0	0	0	0	0	0	0	0	0	0	0	0	0
16/10/91	10.00	0	0	0	0	0	0	0	0	0	0	0	0	0
17/10/91	9.91	0	0	0	0	0	0	0	0	0	0	0	0	0
18/10/91	9.89	0	0	0	0	0	0	0	0	0	0	0	0	0
19/10/91	9.96	0	0	0	0	0	0	0	0	0	0	0	0	0
20/10/91	10.00	0	0	0	0	0	0	0	0	0	0	0	0	0
21/10/91	10.01	0	0	0	0	0	0	0	0	0	0	0	0	0
22/10/91	9.95	0	0	0	0	0	0	0	0	0	0	0	0	0
23/10/91	9.79	0	0	0	0	0	0	0	0	0	0	0	0	0
24/10/91	9.65	0	0	0	0	0	0	0	0	0	0	0	0	0

DATE	Station 1 m.+PWD	unit1	unit2	unit3	unit4	unit5	unit8	unit9	unit10	unit11	unit12	unit13	unit14	unit16
25/10/91	9.49	0	0	0	0	0	0	0	0	0	0	0	0	0
26/10/91	9.29	0	0	0	0	0	0	0	0	0	0	0	0	0
27/10/91	9.24	0	0	0	0	0	0	0	0	0	0	0	0	0
28/10/91	9.24	0	0	0	0	0	0	0	0	0	0	0	0	0

D 2 STATION 2

DATE	station2 m. +PW D	unit6	unit15	unit17	unit18	unit19	unit20	unit21	unit22	unit23	unit24	unit25	unit26	unit27
2/7/91	10.78	8	8	0	0	0	0	28	8	0	0	0	8	0
3/7/91	10.78	8	8	0	0	0	0	28	8	0	0	0	8	0
4/7/91	10.78	8	8	0	0	0	0	28	8	0	0	0	8	0
5/7/91	10.80	10	10	0	0	0	0	30	10	0	0	0	10	0
6/7/91	10.88	18	18	0	0	0	0	38	18	3	0	0	18	0
7/7/91	10.93	23	23	0	0	0	0	43	23	8	0	0	23	0
8/7/91	11.00	30	30	0	0	0	0	50	30	15	0	0	30	0
9/7/91	11.12	42	42	12	0	0	0	62	42	27	0	12	42	0
10/7/91	11.29	59	59	29	0	0	4	79	59	44	4	29	59	4
11/7/91	11.45	75	75	45	0	0	20	95	75	60	20	45	75	20
12/7/91	11.60	90	90	60	10	10	35	110	90	75	35	60	90	35
13/7/91	11.76	106	106	76	26	26	51	126	106	91	51	76	106	51
14/7/91	11.92	122	122	92	42	42	67	142	122	107	67	92	122	67
15/7/91	12.00	130	130	100	50	50	75	150	130	115	75	100	130	75
16/7/91	12.03	133	133	103	53	53	78	153	133	118	78	103	133	78
17/7/91	12.02	132	132	102	52	52	77	152	132	117	77	102	132	77
18/7/91	12.01	131	131	101	51	51	76	151	131	116	76	101	131	76
19/7/91	12.02	132	132	102	52	52	77	152	132	117	77	102	132	77
20/7/91	11.97	127	127	97	47	47	72	147	127	112	72	97	127	72
21/7/91	11.80	110	110	80	30	30	55	130	110	95	55	80	110	55
22/7/91	11.65	95	95	65	15	15	40	115	95	80	40	65	95	40
23/7/91	11.54	84	84	54	4	4	29	104	84	69	29	54	84	29
24/7/91	11.44	74	74	44	0	0	19	94	74	59	19	44	74	19
25/7/91	11.32	62	62	32	0	0	7	82	62	47	7	32	62	7
26/7/91	11.16	46	46	16	0	0	0	66	46	31	0	16	46	0
27/7/91	11.05	35	35	5	0	0	0	55	35	20	0	5	35	0
28/7/91	10.97	27	27	0	0	0	0	47	27	12	0	0	27	0
29/7/91	10.91	21	21	0	0	0	0	41	21	6	0	0	21	0
30/7/91	10.86	16	16	0	0	0	0	36	16	1	0	0	16	0
31/7/91	10.78	8	8	0	0	0	0	28	8	0	0	0	8	0
1/8/91	10.72	2	2	0	0	0	0	22	2	0	0	0	2	0
2/8/91	10.69	0	0	0	0	0	0	19	0	0	0	0	0	0
3/8/91	10.69	0	0	0	0	0	0	19	0	0	0	0	0	0
4/8/91	10.72	2	2	0	0	0	0	22	2	0	0	0	2	0
5/8/91	10.79	9	9	0	0	0	0	29	9	0	0	0	9	0
6/8/91	10.90	20	20	0	0	0	0	40	20	5	0	0	20	0
7/8/91	11.03	33	33	3	0	0	0	53	33	18	0	3	33	0
8/8/91	11.13	43	43	13	0	0	0	63	43	28	0	13	43	0
9/8/91	11.19	49	49	19	0	0	0	69	49	34	0	19	49	0
10/8/91	11.24	54	54	24	0	0	0	74	54	39	0	24	54	0
11/8/91	11.29	59	59	29	0	0	4	79	59	44	4	29	59	4
12/8/91	11.34	64	64	34	0	0	9	84	64	49	9	34	64	9
13/8/91	11.39	69	69	39	0	0	14	89	69	54	14	39	69	14
14/8/91	11.44	74	74	44	0	0	19	94	74	59	19	44	74	19
15/8/91	11.47	77	77	47	0	0	22	97	77	62	22	47	77	22
16/8/91	11.48	78	78	48	0	0	23	98	78	63	23	48	78	23
17/8/91	11.47	77	77	47	0	0	22	97	77	62	22	47	77	22
18/8/91	11.49	79	79	49	0	0	24	99	79	64	24	49	79	24
19/8/91	11.55	85	85	55	5	5	30	105	85	70	30	55	85	30
20/8/91	11.59	89	89	59	9	9	34	109	89	74	34	59	89	34
21/8/91	11.59	89	89	59	9	9	34	109	89	74	34	59	89	34
22/8/91	11.56	86	86	56	6	6	31	106	86	71	31	56	86	31
23/8/91	11.51	81	81	51	1	1	26	101	81	66	26	51	81	26
24/8/91	11.41	71	71	41	0	0	16	91	71	56	16	41	71	16
25/8/91	11.30	60	60	30	0	0	5	80	60	45	5	30	60	5
26/8/91	11.15	45	45	15	0	0	0	65	45	30	0	15	45	0
27/8/91	11.04	34	34	4	0	0	0	54	34	19	0	4	34	0
28/8/91	10.98	28	28	0	0	0	0	48	28	13	0	0	28	0
29/8/91	10.96	26	26	0	0	0	0	46	26	11	0	0	26	0
30/8/91	10.98	28	28	0	0	0	0	48	28	13	0	0	28	0
31/8/91	11.00	30	30	0	0	0	0	50	30	15	0	0	30	0
1/9/91	10.98	28	28	0	0	0	0	48	28	13	0	0	28	0
2/9/91	10.97	27	27	0	0	0	0	47	27	12	0	0	27	0
3/9/91	10.98	28	28	0	0	0	0	48	28	13	0	0	28	0

DATE	station2 m.+PW D	unit6	unit15	unit17	unit18	unit19	unit20	unit21	unit22	unit23	unit24	unit25	unit26	unit27
4/9/91	11.00	30	30	0	0	0	0	50	30	15	0	0	30	0
5/9/91	11.05	35	35	5	0	0	0	55	35	20	0	5	35	0
6/9/91	11.09	39	39	9	0	0	0	59	39	24	0	9	39	0
7/9/91	11.18	48	48	18	0	0	0	68	48	33	0	18	48	0
8/9/91	11.22	52	52	22	0	0	0	72	52	37	0	22	52	0
9/9/91	11.27	57	57	27	0	0	2	77	57	42	2	27	57	2
10/9/91	11.40	70	70	40	0	0	15	90	70	55	15	40	70	15
11/9/91	11.60	90	90	60	10	10	35	110	90	75	35	60	90	35
12/9/91	11.78	108	108	78	28	28	53	128	108	93	53	78	108	53
13/9/91	11.86	116	116	86	36	36	61	136	116	101	61	86	116	61
14/9/91	11.82	112	112	82	32	32	57	132	112	97	57	82	112	57
15/9/91	11.77	107	107	77	27	27	52	127	107	92	52	77	107	52
16/9/91	11.66	96	96	66	16	16	41	116	96	81	41	66	96	41
17/9/91	11.58	88	88	58	8	8	33	108	88	73	33	58	88	33
18/9/91	11.51	81	81	51	1	1	26	101	81	66	26	51	81	26
19/9/91	11.45	75	75	45	0	0	20	95	75	60	20	45	75	20
20/9/91	11.37	67	67	37	0	0	12	87	67	52	12	37	67	12
21/9/91	11.24	54	54	24	0	0	0	74	54	39	0	24	54	0
22/9/91	11.12	42	42	12	0	0	0	62	42	27	0	12	42	0
23/9/91	11.03	33	33	3	0	0	0	53	33	18	0	3	33	0
24/9/91	11.06	36	36	6	0	0	0	56	36	21	0	6	36	0
25/9/91	11.12	42	42	12	0	0	0	62	42	27	0	12	42	0
26/9/91	11.20	50	50	20	0	0	0	70	50	35	0	20	50	0
27/9/91	11.13	43	43	13	0	0	0	63	43	28	0	13	43	0
28/9/91	11.05	35	35	5	0	0	0	55	35	20	0	5	35	0
29/9/91	11.00	30	30	0	0	0	0	50	30	15	0	0	30	0
30/9/91	10.97	27	27	0	0	0	0	47	27	12	0	0	27	0
1/10/91	10.95	25	25	0	0	0	0	45	25	10	0	0	25	0
2/10/91	10.95	25	25	0	0	0	0	45	25	10	0	0	25	0
3/10/91	10.94	24	24	0	0	0	0	44	24	9	0	0	24	0
4/10/91	10.91	21	21	0	0	0	0	41	21	6	0	0	21	0
5/10/91	10.91	21	21	0	0	0	0	41	21	6	0	0	21	0
6/10/91	10.83	13	13	0	0	0	0	33	13	0	0	0	13	0
7/10/91	10.73	3	3	0	0	0	0	23	3	0	0	0	3	0
8/10/91	10.63	0	0	0	0	0	0	13	0	0	0	0	0	0
9/10/91	10.52	0	0	0	0	0	0	2	0	0	0	0	0	0
10/10/91	10.39	0	0	0	0	0	0	0	0	0	0	0	0	0
11/10/91	10.26	0	0	0	0	0	0	0	0	0	0	0	0	0
12/10/91	10.15	0	0	0	0	0	0	0	0	0	0	0	0	0
13/10/91	10.09	0	0	0	0	0	0	0	0	0	0	0	0	0
14/10/91	10.50	0	0	0	0	0	0	0	0	0	0	0	0	0
15/10/91	10.53	0	0	0	0	0	0	3	0	0	0	0	0	0
16/10/91	10.43	0	0	0	0	0	0	0	0	0	0	0	0	0
17/10/91	10.27	0	0	0	0	0	0	0	0	0	0	0	0	0
18/10/91	10.12	0	0	0	0	0	0	0	0	0	0	0	0	0
19/10/91	10.04	0	0	0	0	0	0	0	0	0	0	0	0	0
20/10/91	10.05	0	0	0	0	0	0	0	0	0	0	0	0	0
21/10/91	10.06	0	0	0	0	0	0	0	0	0	0	0	0	0
22/10/91	10.04	0	0	0	0	0	0	0	0	0	0	0	0	0
23/10/91	9.95	0	0	0	0	0	0	0	0	0	0	0	0	0
24/10/91	9.87	0	0	0	0	0	0	0	0	0	0	0	0	0
25/10/91	9.80	0	0	0	0	0	0	0	0	0	0	0	0	0
26/10/91	9.73	0	0	0	0	0	0	0	0	0	0	0	0	0
27/10/91	9.69	0	0	0	0	0	0	0	0	0	0	0	0	0
28/10/91	9.68	0	0	0	0	0	0	0	0	0	0	0	0	0

D 3 STATION 3

DATE	sattion3 m.+PWD	unit28	unit29	unit30	unit31
2/7/91	10.79	9	0	0	9
3/7/91	10.80	10	0	0	10
4/7/91	10.78	8	0	0	8
5/7/91	10.80	10	0	0	10
6/7/91	10.87	17	2	0	17
7/7/91	10.92	22	7	0	22
8/7/91	10.96	26	11	0	26
9/7/91	11.03	33	18	0	33
10/7/91	11.18	48	33	0	48
11/7/91	11.32	62	47	0	62
12/7/91	11.46	76	61	0	76
13/7/91	11.61	91	76	11	91
14/7/91	11.75	105	90	25	105
15/7/91	11.84	114	99	34	114
16/7/91	11.88	118	103	38	118
17/7/91	11.88	118	103	38	118
18/7/91	11.88	118	103	38	118
19/7/91	11.90	120	105	40	120
20/7/91	11.88	118	103	38	118
21/7/91	11.73	103	88	23	103
22/7/91	11.59	89	74	9	89
23/7/91	11.48	78	63	0	78
24/7/91	11.39	69	54	0	69
25/7/91	11.28	58	43	0	58
26/7/91	11.14	44	29	0	44
27/7/91	11.04	34	19	0	34
28/7/91	10.97	27	12	0	27
29/7/91	10.92	22	7	0	22
30/7/91	10.87	17	2	0	17
31/7/91	10.81	11	0	0	11
1/8/91	10.75	5	0	0	5
2/8/91	10.70	0	0	0	0
3/8/91	10.69	0	0	0	0
4/8/91	10.72	2	0	0	2
5/8/91	10.76	6	0	0	6
6/8/91	10.84	14	0	0	14
7/8/91	10.95	25	10	0	25
8/8/91	11.05	35	20	0	35
9/8/91	11.11	41	26	0	41
10/8/91	11.16	46	31	0	46
11/8/91	11.20	50	35	0	50
12/8/91	11.25	55	40	0	55
13/8/91	11.29	59	44	0	59
14/8/91	11.34	64	49	0	64
15/8/91	11.37	67	52	0	67
16/8/91	11.38	68	53	0	68
17/8/91	11.38	68	53	0	68
18/8/91	11.39	69	54	0	69
19/8/91	11.44	74	59	0	74
20/8/91	11.49	79	64	0	79
21/8/91	11.49	79	64	0	79
22/8/91	11.47	77	62	0	77
23/8/91	11.43	73	58	0	73
24/8/91	11.35	65	50	0	65

DATE	sation3 m.+PWD	unit28	unit29	unit30	unit31
25/8/91	11.25	55	40	0	55
26/8/91	11.13	43	28	0	43
27/8/91	11.02	32	17	0	32
28/8/91	10.97	27	12	0	27
29/8/91	10.95	25	10	0	25
30/8/91	10.97	27	12	0	27
31/8/91	10.99	29	14	0	29
1/9/91	10.97	27	12	0	27
2/9/91	10.96	26	11	0	26
3/9/91	10.97	27	12	0	27
4/9/91	10.98	28	13	0	28
5/9/91	11.01	31	16	0	31
6/9/91	11.03	33	18	0	33
7/9/91	11.11	41	26	0	41
8/9/91	11.16	46	31	0	46
9/9/91	11.20	50	35	0	50
10/9/91	11.30	60	45	0	60
11/9/91	11.47	77	62	0	77
12/9/91	11.64	94	79	14	94
13/9/91	11.71	101	86	21	101
14/9/91	11.70	100	85	20	100
15/9/91	11.67	97	82	17	97
16/9/91	11.58	88	73	8	88
17/9/91	11.51	81	66	1	81
18/9/91	11.44	74	59	0	74
19/9/91	11.38	68	53	0	68
20/9/91	11.32	62	47	0	62
21/9/91	11.21	51	36	0	51
22/9/91	11.10	40	25	0	40
23/9/91	11.01	31	16	0	31
24/9/91	11.05	35	20	0	35
25/9/91	11.08	38	23	0	38
26/9/91	11.16	46	31	0	46
27/9/91	11.11	41	26	0	41
28/9/91	11.03	33	18	0	33
29/9/91	10.98	28	13	0	28
30/9/91	10.96	26	11	0	26
1/10/91	10.95	25	10	0	25
2/10/91	10.94	24	9	0	24
3/10/91	10.94	24	9	0	24
4/10/91	10.91	21	6	0	21
5/10/91	10.94	24	9	0	24
6/10/91	10.88	18	3	0	18
7/10/91	10.80	10	0	0	10
8/10/91	10.70	0	0	0	0
9/10/91	10.59	0	0	0	0
10/10/91	10.44	0	0	0	0
11/10/91	10.29	0	0	0	0
12/10/91	10.18	0	0	0	0
13/10/91	10.11	0	0	0	0
14/10/91	10.60	0	0	0	0
15/10/91	10.66	0	0	0	0
16/10/91	10.56	0	0	0	0
17/10/91	10.36	0	0	0	0
18/10/91	10.18	0	0	0	0
19/10/91	10.07	0	0	0	0
20/10/91	10.07	0	0	0	0

DATE	sattion3 m.+PWD	unit28	unit29	unit30	unit31
21/10/91	10.07	0	0	0	0
22/10/91	10.06	0	0	0	0
23/10/91	9.99	0	0	0	0
24/10/91	9.92	0	0	0	0
25/10/91	9.88	0	0	0	0
26/10/91	9.85	0	0	0	0
27/10/91	9.83	0	0	0	0
28/10/91	9.83	0	0	0	0

APPENDIX E COMPARISON OF ACTUAL WATER DEPTH IN UNIT 8 IN 1993, CROP TOLERANCE DEPTHS AND TARGET WATER DEPTH

