CONSERVATION OF DEEPORBEEL WETLAND IN ASSAM

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

of

MASTER OF TECHNOLOGY

in

CONSERVATION OF RIVERS AND LAKES

By

BHASKAR JYOTI DAS

ALTERNATE HYDRO ENERGY CENTRE
INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
ROORKEE - 247 667 (INDIA)

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CANDIDATE'S DECLARATION

I hereby declare that the work which is being presented in this dissertation entitled **"CONSERVATION OF DEEPORBEEL WETLAND IN ASSAM"** in partial fulfillment of the requirement for the award of the degree of **Master of Technology in Conservation of Rivers and Lakes**, submitted in Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee, is an authentic record of my own work carried out during the period from July 2005 to June 2006 under the supervision and guidance of Shri Sunil Kumar Singal, Senior Scientific Officer, Alternate Hydro Energy Centre, Indian Institute of Technology, Roorkee and Dr. Ranvir Singh, Professor, Department of Hydrology, Indian Institute of Technology, Roorkee.

The matter embodied in this dissertation has not been submitted by me for award of any other degree or diploma.

Date: 29th June, 2006
Place: Roorkee

Bhaskar Jyoti Das
(BHASKAR JYOTI DAS)
Candidate's Signature

CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge and belief.

(S.K. SINGAL)
Senior Scientific Officer,
Alternate Hydro Energy Centre,
Indian Institute of Technology,
Roorkee.

(Dr. RANVIR SINGH)
Professor,
Department of Hydrology,
Indian Institute of Technology,
Roorkee.

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Bhaskar Jyoti Das

(BHASKAR JYOTI DAS)

ABSTRACT

Deeporbeel Wetland is a permanent, freshwater lake, in a former channel of the Brahmaputra River, to the South of the main river south-west of Guwahati city. It is a large natural wetland having great biological and environmental importance besides being the only major storm water storage basin for the Guwahati city. The wetland is endowed with rich floral and faunal diversity. In addition to huge congregation of residential water birds, the Deeporbeel ecosystem harbours large number of migratory waterfowl each year. The wetland has been designated as a Ramsar Site in November 2002.

During the last few years the wetland area has undergone rapid changes in respect of industrialization, agricultural activities, forest cover, human settlement and water spread in its fringe zone resulting in an imbalance in the wetland eco-system. Moreover, inflow of wastewater from Guwahati city to this wetland is degrading its water quality making it hazardous for the aquatic flora and fauna. The major threats faced by the wetland are deterioration of water quality, gully erosion in the catchment and silt deposition in the wetland, mining / quarry operation in the catchment area, encroachment (conversion of wetland area for agriculture, industry and human settlement), decrease in biological diversity, growth of obnoxious aquatic weeds, etc.

In this study three aspects were taken into consideration with regard to the conservation of Deeporbeel Wetland. These aspects are

- Surface Water Quality of the wetland.
- Erosion in the Wetland Catchment and subsequent silt deposition in the wetland.
- Hydrological study.

The water quality was monitored for Post-monsoon season of 2005 and Pre-monsoon season of 2006. The experimentally obtained data was compared with that of the Base Year (1989). NSFWQI was computed and compared with the Base Year Index Value and statistical analysis using F test of the equality of two variances was done for nine parameters. The gross soil loss from the wetland catchment was computed for the

year 1996 and 2005 and these were compared with that of the Base Year (1972). The silt load coming into and moving out of the wetland was determined for monsoon and post-monsoon seasons of the year 2005 and for pre-monsoon season of the year 2006. A monthly water balance for the year 2005 was also prepared.

The study indicates that there has been deterioration in the water quality parameters since the Base Year (1989). The NSFWQI indicates that the water quality has shifted from "Good Category" to "Medium Category" during the last 16 years. From the Statistical Analysis using F test it is seen that when compared with the Base Year, the difference among the means with respect to time was found to be significant for the parameters BOD, DO, COD, Conductivity, Turbidity, NO_3 and PO_4, which indicates that these parameters have undergone significant changes.

The average annual estimated soil loss during the base year was 26.63 t / (ha-year). During the year 1996 it was 24.83 t / (ha-year) and during 2005 it was 24.73 t / (ha-year). The change in the soil loss rate can be attributed mainly to the change in Land Use and variation in average annual rainfall, thus variation in the value of Rainfall Erosivity Index (R). The net sediment load deposited into the wetland during the year 2005 was found to be 209,471 t, which is only about 39 % of the gross soil loss from the catchment for the year 2005. The sediment delivery ratio was calculated to be 57.30 %.

During the year 2005 the minimum water volume in the wetland was found to be 7,477,700 m^3 during the month of December and the maximum water volume to be 64,593,982 m^3 in the month of August. Correspondingly the minimum monthly average water spread area was during December (1080.09 ha) and maximum water spread area was during August (2225.52 ha).

Thirteen gullies have been identified in the wetland catchment. Out of these, only three gullies are found to be active. Accordingly, gully control measures have been suggested.

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ABBREVIATIONS / NOTATIONS

ABBREVIATIONS/ NOTATIONS	DESCRIPTIONS
AGNPS Model	Agricultural Non-point Source Pollution Model
AM	Ante Meridiem
ANSWERS Model	Aerial Non-point Sources Watershed Environment Response Model
APHA	American Public Health Association
ARSAC	Assam Remote Sensing Application Centre
ASCE	American Society of Civil Engineering
ASTEC	Assam Science Technology and Environment Council
AWWA	American Water Works Association
BIS	Bureau of Indian Standards
CEQ	Council of Environmental Quality
CPCB	Central Pollution Control Board
DBU	Designated Best Use
DL	Danger Level
DR	Delivery Ratio
E	East
FAO	Food and Agricultural Organization
Govt.	Government
GPS	Global Positioning System
HFL	Highest Flood Level
ICAR	Indian Council of Agricultural Research
ICPMS	Inductively Coupled Mass Spectrometer
IIC	Institute Instrumentation Centre
IUCN	International Union for the Conservation of Nature
LU	Land Use

MMC	Million Meter Cube
MPN	Most Probable Number
MUSLE	Modified Universal Soil Loss Model
N	North
NC	North Cachar
NESAC	North East Space Application Centre
NFL	Normal Flood Level
NH	National Highway
NRS	National Remote Sensing Agency
NSFQWI	National Sanitation Foundation Water Quality Index
NTU	Nephelometric Turbidity Unit
PCBA	Pollution Control Board, Assam
RETCEN	Regional Environmental Testing Centre
RH	Relative Humidity
RL	Reduced Level
RMC	Regional Meteorological Centre
RUSLE	Revised Universal Soil Loss Model
SAR	Sodium Absorption Ratio
SHESED Model	System Hydrologique European Sediment Model
USLE	Universal Soil Loss Model
USPH Standards	United States Public Health Standards
WL	Water Level
WEF	Water Environment Federation
WHO	World Health Organization
WR Deptt.	Water Resources Department
NH	National Highway
WWF	World Wildlife Fund
A_{ET}	Actual evapo-transpiration
P_{ET}	Potential evapo-transpiration
E_t	Daily potential evapo-transpiration
E_T	Monthly potential evapo-transpiration

T_{Et}	Monthly total actual evapo-transpiration
D1	Sampling location at main inlet channel (Basistha-Morabharalu)
D2	Sampling location at residential area (Ullubari)
D3	Sampling location at industrial area (Dharapur)
D4	Sampling location at outlet channel (Khanajan)
D5	Sampling location at middle of the wetland
D6	Sampling location near hilly catchment at the Southern fringes
ha	Hectare
t	Metric tonne
T_a	Mean air temperature in ^oK
mm	Millimeter
cm	Centimeter
dm	Decimeter
m	Meter
m^2	Meter square
m^3	Meter cube
km	Kilometer
km^2	Kilometer square
km^3	Kilometer cube
ml	Milliliter
l	Liter
mg	Milligram
gm	Gram
Mg	Mega gram
^oC	Degree centigrade
^oK	Degree Kelvin
^{o}	Degree
’	Minute
”	Second
%	Percentage
µ	Micro

in	Inch
υ_1	Degree of freedom for numerator
υ_2	Degree of freedom for denominator
σ	Stefan-Bolzman Constant
No.	Number
BDO	Bio-chemical Oxygen Demand
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen
pH	Negative Log Hydrogen Ion Concentration
Temp.	Temperature
TS	Total Solids
TDS	Total Dissolved Solids
TSS	Total Suspended Solids
PO_4	Phosphate
SO_4	Sulphate
NO_3	Nitrate
Cl	Chloride
TKN	Total Kjeldahl Nitrogen
Pb	Lead
As	Arsenic
Hg	Mercury
Zn	Zinc
Mn	Manganese
Ca	Calcium
Mg	Magnesium
Na	Sodium
K	Potassium
F	Fluoride
B	Boron
N	Nitrogen
T	Total

NPK	Sodium Phosphorous Potassium
NH_3	Ammonia
H_e	Effective dam height
V_s	Volume of sediment deposition
L_{HE}	Average length of dam
L_B	Bottom width of gully
L_U	Bank width of gully
D	Depth of gully
L	Effective length of weir
Q	Discharge
L_{AS}	Effective length of spillway
H_{SV}	Spillway depth
L_{BSV}	Bottom length of spillway
V_{SDF}	Volume of spillway
V_{DF}	Quantity of rocks required
H_D	Dam height
M_{LD}	Length of weir mesh
N_{DF}	Number of fence posts

CHAPTER 1

INTRODUCTION

1.1 GENERAL

Wetland has been regarded as one of the most productive ecosystem in the world by international agencies like International Union for the Conservation of Nature (IUCN), World Wildlife Fund (WWF), Wetland International, etc. The value of the world's wetlands is increasingly receiving due attention as wetlands contribute to a healthy environment in many ways. Wetlands retain water during dry periods, thus keeping the water table high and relatively stable. During periods of floods, wetlands mitigate floods and trap suspended solids and attached nutrients. Therefore, wetlands perform numerous valuable functions such as recycling nutrients, purify water, attenuate floods, maintain stream flow, recharge groundwater, and also serve to provide drinking water, fish, fodder, fuel, control rate of runoff in urban areas, buffer shore lines against erosion and offer recreation to the society. In addition, wetlands are important feeding and breeding ground for wildlife, habitat for innumerable aquatic flora and fauna and provide a stopping place and refuge for waterfowls.

However, the interaction of man with wetlands during the last few decades has been of concern largely due to the rapid population growth accompanied by intensified industrial, commercial and residential development that leads to pollution of wetlands by domestic and industrial waste and agricultural runoff such as chemical fertilizers, insecticides, pesticides etc.

Deeporbeel wetland is a permanent, fresh water lake, in a former channel of the Brahmaputra River, to its south. It is a large natural wetland having great biological and environmental importance, besides being the only major storm water storage basin for the Guwahati city. The wetland is endowed with rich floral and faunal diversity. In addition to huge congregation of residential water birds, the wetland ecosystem harbours a large number of migratory water fowl each year. The wetland also interacts with the wild life of the adjacent Rani-Garbhanga Reserve forest. 414 ha of the wetland was declared as a Bird Sanctuary by the Govt. in the year 1991. In 1994-95 it was declared as a National

Wetland. In the year 2002, it was accorded as a wetland of International Importance and was designated as a Ramsar Site and was added to that list as number 1207 (The only one in the state of Assam).

Several educational institutions, including the Gauhati University, the Assam Engineering College, the Assam Forest School, the Assam Ayurvedic College, the Government Sanskrit College etc are situated almost along the northern perimeter of the wetland. In the Eastern catchment of the wetland, different types of industries and business establishments have rapidly sprung up on both sides of the NH-37.

1.2 DESCRIPTION OF THE AREA UNDER STUDY

1.2.1 Location

Deeporbeel Wetland is located between 91°36' 39" E and 91 °41' 25"E longitude and 26°05'26"N and 26°09'26"N latitude, to the South of Brahmaputra River in Kamrup District, 18 km South West of Guwahati city, Assam. It lies at an altitude of about 50 meter above MSL and covers an area of about 4,000 ha. Fig. 1.1 shows the location of Deeporbeel wetland.

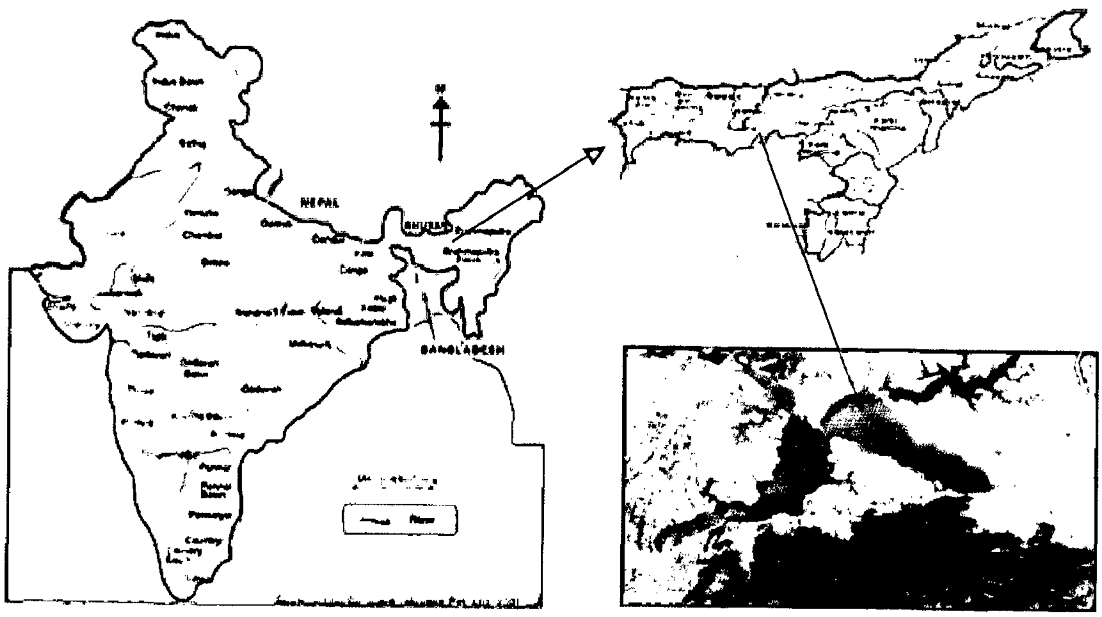


Fig. 1.1:- Location of Deeporbeel Wetland

The wetland is surrounded by the Bharalu River basin on the East, Basistha basin in the South East, Kalmoni River on the West, Jalukbari Wetland on the North and Rani and Garbhanga Reserve forests on the South. The National Highway (NH-37) passes a little distance away from the Eastern boundary of the wetland.

1.2.2 Climate

Deeporbeel has a mesothermal climate characterized by high humidity and moderate temperature. The minimum and maximum temperatures range between 7° to 26°C in January and 23° to 37°C in July/August respectively. The average annual rainfall in the area is 1733 mm and about 90% of the rain occurs between April and September, the maximum rainy months being July and August. Relative humidity varies between 50% to 90%.

1.2.3 Geology and Hydrology

Deeporbeel region basically forms part of the Shillong plateau. It is the Northerly extension of Shillong plateau of precambrian age. It was subjected to manifold tectonic activity which ultimately resulted in the present geological setup.

During December to April the water level in the wetland sinks down to 90 to 100 cm in the middle and 20 to 30 cm along the banks of the wetland, while in rainy season starting from May to August the water level rises to 3.0 to 4.5 m in the middle and 1.0 to 2.0 m near the banks.

1.2.4 Land Use in the Catchment

Major part of the catchment area of the wetland is the reserve forest of Rani Garbhanga forest and the run off water from the area flows into the wetland mainly through Basistha and Kalmoni rivers. Human activity exists on the Eastern and Northern parts of the wetland. Sewage from the Eastern part of Guwahati city flows into the wetland without treatment through Basistha River. According to the master plan of Guwahati city the land use pattern in the wetland catchment can be classified as follows:

- Agricultural
- Industrial and Commercial
- Public and semipublic
- Residential
- Transport & Communication.

1.2.5 Inflow and Outflow of Water

The wetland receives surface runoff from the adjacent hills and also from the Guwahati city situated in the East. The main inlets of the wetland are the Mora-Bharalu River and the Basistha-Bahini River which carry sewage as well as storm water from Guwahati city. The only outlet of the wetland is Khanajan River located towards the North West.

1.2.6 Flora and Fauna

Deeporbeel has a unique floral and faunal diversity. A large variety of common species of flora and fauna have been found in the basin area of the wetland. Tropical evergreen and semi-evergreen forests, herbs, bushes, grasses, reeds, etc. are common vegetation. There are a large number of valuable trees such as Sal, Teak, etc., in the adjoining Rani and Garbhanga Reserve Forests. During summer, large parts of the wetland are covered by aquatic vegetation like water hyacinth, aquatic grasses, water lilies and other submerged, emergent and floating vegetation. The high land areas, which remain completely dry during winter, also get covered by aquatic and semi-aquatic vegetation during the rainy season. Though the aquatic plants are generally termed as Aquatic Weeds and regarded as a 'menace', yet these are now considered as a source of multipurpose raw materials. As a matter of fact, these plants have been proved to be good source of fodder for herbivores, human food (water chestnuts), fish feed, organic or biofertilizer, fibre, medicine etc. Furthermore, aquatic plants have the capacity to purify polluted water through the uptake of dissolved nitrogen, phosphorus and undesirable excessive minerals including heavy metals. During the winter season, a variety of habitats such as deep open water areas (hydro phase), marshy lands, mud flat, emergent vegetation, water hyacinth patches, wet grass land patches, paddy field area, dry grassland areas and scattered forest areas, etc., support manifold habitats for migratory waterfowl, residential waterfowl and terrestrial avifauna.

Deeporbeel is a permanent deep and shallow water wetland; hence the natural breeding of some of diverse habitat types takes place within the wetland itself. As reported by ASTEC [3] the wetland supports 50 different fish species under 19 families. A survey also revealed the presence at least 20 amphibians, 12 lizards, 18 snakes and 6 turtle and tortoise species in Deeporbeel. But the most important feature of the wetland is its large avifaunal population. The wetland supports both migratory and residential species. A total of 62 species of birds belonging to 13 families have been identified in the wetland area [6].

1.2.7 Human Population

A number of settlements have come up over the years in the fringe areas of the wetland. These are Khanamukh on the Northern fringe, Tetelia and Gorchuk on the Eastern fringe, Matiapara and settlements of Chakardeo revenue villages such as Mikirpara, Nepalipara and Kalitapara, Deochutal, Maghupara, Pamohi and Mainakhurung, parts of Azara revenue villages such as Hirapara, Nowapara, Natunbasti, Kewatpara and Borbori on the Western fringe of the wetland. Formerly most of the areas where the present settlements are situated were covered with thick grasses, bushes and trees of various types. These were cleared by the people who first came and settled down in this area. With the increase of population, people started to fill up parts of the wetland areas for construction of houses. The basic information of the villages in the fringe areas of Deeporbeel is given in Table 1.1.

Table 1.1:- Basic information of the Villages in the fringe areas of Deeporbeel [3]

Name of Village	Major Caste/Tribe	Approximate No. of Households	Approximate Population	Main Occupation
Matiapara	Keot	300	1400	Wage labour
Chakardeo	Karbi / Kalita	84	500	Cultivation
Deochutal	Karbi / Nepali	65	325	Cultivation
Maghupara	Karbi	35	200	Cultivation
Pamohi	Karbi / Bodo	120	750	Cultivation
Mainakhurung	Karbi	25	120	Cultivation
Tetelia	Kaibarta	45	275	Fishing / Small business
Kewatpara	Keot	113	800	Fishing
Natunbasti	Hira	35	250	Fishing
Hirapara	Hira	45	320	Pottery making
Nowapara	Keot	35	250	Fishing
Borbori	Keot	150	1000	Wage labour / Fishing
Khanamukh	Kalita	35	200	Agriculture
TOTAL		1087	6390	

(Source: ASTEC)

1.2.8 Industries

Though there is no major industry, there are a few minor industries, mainly brick fields in and around Deeporbeel. All these units are situated mainly on the Northern and Western fringes by the side of National Highway 37. Apart from these brick fields, the industries situated on the Northern fringe of the wetland are Seotea Rolling Mill and Goenka Woolen Mill. The industries situated on the Eastern fringe along NH-37 are Purbanchal Rolling Mill, Saynjee Ispat Pvt. Ltd. (2 units), Brahmaputra Iron and Steel Ltd. (2 units), Bhagwati Rolling Mill Pvt. Ltd. (2 units), Mahavir Coke and Guwahati Carbon.

1.3 EXISTING CONSERVATION MEASURES TAKEN

Deeporbeel Wetland is under the control of three State Govt. Departments namely:

- Forest Department as Bird Sanctuary
- Fisheries Department as a Registered Fishery
- Revenue Department in the fringe areas (outside the shoreline of the wetland)

Moreover, there is a Deeporbeel Management Committee (with officials and experts from various departments/organisations) to look after the developments and execution of conservation measures under different government sponsored schemes.

There is no habitat protection in Deeporbeel area. Though shooting and bird-trapping are prohibited by law, there is no enforcement to prevent these activities. Scot, in the year 1989, supported this fact by reporting that Deeporbeel Wetland is "heavily hunted and fished both day and night" [17].

Based on the recommendations of the Deeporbeel Management Committee, the Assam Science Technology & Environment Council (ASTEC) has already taken the following steps in regard to conservation of Deeporbeel with financial assistance from the Ministry of Environment & Forests, Govt. of India:

- Tree plantation around Deeporbeel through Assam State Zoo in the years 2000 and 2002.
- A socio-economic survey in the areas around Deeporbeel was carried out in the year 2000.
- Documentation of weeds and plants in the year 2000.

- Weed control measures were taken up through Assam State Zoo in the year 2000 and Assam Fisheries Development Corporation in the year 2002.
- Education and awareness programmes through Regional Centre for Environmental Education & Training in the year 2000, Guwahati Regional Centre of WWF (India) in 2001 and Aranyak Nature Club in 2002.
- Preparation of a map of Deeporbeel with the help of National Remote Sensing Agency (NRSA) data by Assam Remote Sensing Application Centre (ARSAC).
- Production of a video film on Deeporbeel focusing the rich biodiversity, importance of storm water reservoir, potentiality as a tourist spot and highlighting the present problems regarding conservation of the wetland.
- Establishment of a Wetland Interpretation Centre in the southern side of Deeporbeel is in process.
- De-weeding and de-siltation which has been started from the eastern side of the wetland.

1.4 PROBLEMS FACED BY THE WETLAND

The major threats faced by the wetland are listed below:

- Deterioration of water quality.
- Gully erosion in the catchment and silt deposition in the wetland.
- Mining / Quarry operation in the catchment area.
- Encroachment - Conversion of wetland area for agriculture, industry and human settlement.
- Decrease in biological diversity.
- Growth of obnoxious aquatic weeds, etc.

The pictorial views of these problems have been shown in Fig. 1.2 to 1.10.

1.5 OBJECTIVES OF THE STUDY

As a part of conservation of Deeporbeel Wetland three aspects are studied. These aspects are:

- Surface Water Quality of the wetland.
- Erosion in the Wetland Catchment and subsequent silt deposition in the wetland.

- Hydrological study.

And accordingly the following objectives have been identified for the study:

- Assessment of water quality of the inlet and outlet and wetland water, determination of Water Quality Index of the wetland water and suggesting appropriate measures to maintain water quality of the wetland.
- Estimation of soil loss from the wetland catchment.
- Estimation of silt carried in and out by the incoming and outgoing channels and silt deposition in the wetland.
- Collection and analysis of hydrological data of inlets and outlets of the wetland and prepare the water balance of the wetland.
- To suggest conservation measures with emphasis on control of Gully erosion in the catchment area so as to minimize silt deposition in the wetland

1.6 PROBLEMS FACED AT A GLANCE

Fig. 1.2:- Deterioration of Water Quality

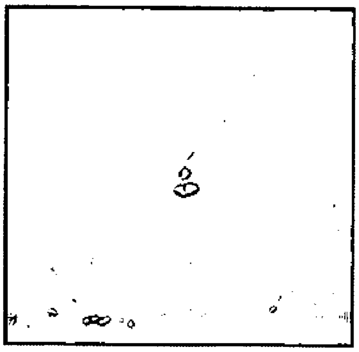


Fig. 1.3:- Gully erosion in the catchment

Fig. 1.4:-Quarry operation in the catchment

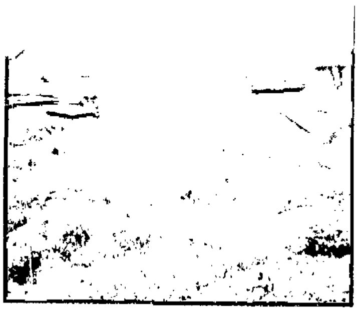


Fig. 1.5:-Encroachment for human settlement

Fig. 1.6:-Encroachment for industry

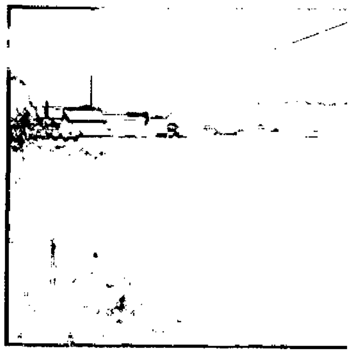


Fig. 1.7:-Encroachment for industry

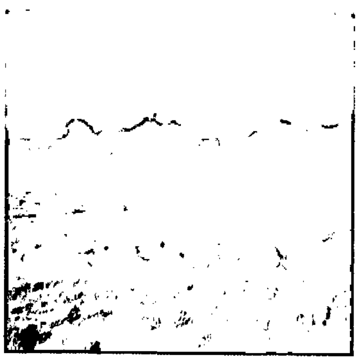


Fig. 1.8:-Fertilizers /Pesticides from agriculture

Fig. 1.9:- Growth of obnoxious aquatic weeds

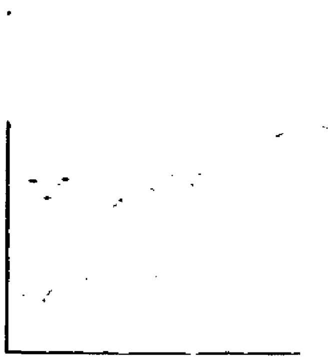


Fig. 1.10:- Growth of obnoxious aquatic weeds

CHAPTER 2

REVIEW OF LITERATURE

2.1 GENERAL

Wetlands are transitional zones between land and water, a collective term for marshes, swamps, bogs and similar areas. These have been described as the "kidneys" of the landscape as they filter sediments and nutrients from surface water. Wetlands are often referred to as "biological supermarkets" because they support all life forms through extensive food webs and biodiversity. They help regulate water levels within watersheds, improve water quality, reduce flood and storm damages, provide habitat for important fish and wildlife, support hunting, fishing, other recreational activities and perform some useful functions in the maintenance of ecological balance [24].

Wetlands are estimated to occupy 8.6 million km^2 (6.4 %) of the earth's surface with about 4.8 million km^2 in the tropics and sub-tropics. The major proportion is made up of bogs (30%), fens (26%), swamps (20%) and floodplains (15%). This estimation was compared with the area that existed in the 19th century and it was found that around 50% of the world's wetlands have disappeared during the last century [39, 46].

Wetlands are under increasing stress due to urbanization, technology development, economic growth and various other anthropogenic activities, which have accounted for their over exploitation and degradation. Major threats faced by wetlands are hunting and associated disturbances; encroachment; human settlements; reclamation for urban and industrial development; pollution from industries, domestic and agricultural areas; fishing and associated disturbances; commercial logging; removal of vegetative layer in the catchment and consequent soil erosion; weed infestation; conversion to aquaculture ponds; diversion of water for farming; water supply; hydroelectricity generation, etc. It has been estimated that nearly 1 hectare of the world's wetland area is getting degraded every minute [41].

The quality and quantity declinations, have contributed to loss of the biological diversity of flora and fauna, migratory birds and also the productivity of the system. Simultaneously several thousand species have now become extinct and many other sustainable species, products like fish, timber, medicinal plants, water transport and water supply are over exploited [41].

Now, there is increasing concern to conserve and restore perishing wetlands and endangered habitats to achieve ecological sustainability [46].

In this dissertation work, the literature has been reviewed under three headings, namely (i) Surface Water Quality, (ii) Soil Erosion and (iii) Water Balance.

2.2 SURFACE WATER QUALITY

Water, the most vital resource for all kinds of life on this planet is also the resource, adversely affected both qualitatively and quantitatively by all kinds of human activities on land, in air or in water. The increasing industrialization, urbanization and developmental activities and the consequent pollution of water has brought a veritable water crisis. Today, most of the water bodies of the world receive millions of liters of sewage, domestic waste, industrial and agricultural effluents containing substances varying in characteristics from simple nutrients to highly toxic substances [48].

2.2.1 Water Quality Requirements and Standards

Water may be used for various purposes. Water Quality Requirements vary according to the proposed use of water. Set by the potential user, Water Quality Requirements represent a known or assumed need and are based on the prior experience of the water user. Water Quality Standards are set by a governmental agency and represent a statutory requirement [36].

The acceptable level of pollution of water depends upon its use. For different uses, different water quality parameters and standards are prescribed by Central Pollution Control Board (CPCB), United Sates Public Health (USPH Standards), Bureau of Indian Standards (BIS), World health Organization (WHO) etc.

2.2.1.1 *Designated Best Use*

Water is utilized for different uses as per needs of the users. Among various uses, the use which demand highest water quality possessed by the water body is known as Designated Best Use (DBU) of that water body. Therefore, a natural water body is designated by its DBU. Water pollution control programmes are designed, planned to maintain the water quality such that its DBU is maintained [10].

Classification of natural water bodies based on Designated Best Use (DBU) is given in Table 2.1.

Table 2.1:- Classification of Natural Water Bodies Based on DBU

Designated Best Use (DBU)	Quality Class	Primary Quality Criteria							
		pH	DO (mg/l)	BOD (mg/l)	Total Coliform (MPN/ 100ml)	Free NH_3 (mg/l)	Elect. Cond. (μmho/cm)	SAR	Boron (mg/l)
Drinking water source without conventional treatment but with disinfection	A	6.5 to 8.5	6 or more	2 or less	< 50	Nil	-	Nil	-
Organized outdoor bathing	B	6.5 to 8.5	5 or more	3 or less	<500	Nil	-	Nil	-
Drinking water source with conventional treatment followed by disinfection	C	6.5 to 8.5	4 or more	3 or less	<5000	Nil	-	Nil	-
Propagation of wildlife and fisheries	D	6.5 to 8.5	4 or more	-	-	1.2	-	Nil	-
Irrigation, industrial cooling and controlled waste disposal	E	6 to 8.5	-	-	-	-	2250	26	2

(Reproduced from CPCB Website)

2.2.1.2 *Recreational Water*

Water may be utilized for recreational purposes like swimming, fishing, etc. For swimming most important water quality parameter is coliform density. The allowable limit in USA varies from 50 No. / 100ml in Tennessee Valley to 2,400 No. /100ml in

New York State. However, CPCB allows 500 MPN/ 100ml for Class B water (outdoor bathing) [26].

2.2.2 Physico-chemical Study on Deeporbeel Wetland

A few of the related studies are listed below:

- Baruah and Bordoloi (1990) made an investigation to ascertain the pollution status of the Deeporbeel Wetland water. The physico-chemical characteristics of the water body as well as biotic factors were taken into consideration for the study. This study revealed that the pollution level of the wetland water was low [4].
- Gohain (1991) studied eighteen physico-chemical parameters of the wetland water from the year 1990 to 1991. These parameters were BOD, DO, COD, pH, Conductivity, Turbidity, Alkalinity, Suspended Solids, Total Dissolved Solids, Total Solids, Hardness as $CaCO_3$, Hardness as $MgCO_3$, Total Hardness, Chlorides, Sulphates, Ammoniacal Nitrogen, Temperature and Colour. The study revealed that the wetland water was slightly alkaline in nature with low values of Chlorides, Sulphates, BOD and COD [16].
- Kakoti (1991) studied three chemical parameters of the wetland water. These parameters were DO, BOD and COD. The study was undertaken for pre-monsoon, monsoon, post-monsoon and winter season in only one sampling point at the Gorchuk Area (Eastern Fringe) .The DO level was found to be low [22].
- Baruah (1995) studied the water quality of the wetland. He analyzed the physico-chemical parameters such as Temperature, Turbidity, pH, Conductivity, DO, BOD, COD, Total Alkalinity, Ammoniacal Nitrogen, Nitrate Nitrogen, Phosphate, Sulphate and Chloride. These parameters were monitored for pre-monsoon, monsoon and post-monsoon seasons of the years 1989 to 1991, at four sampling points. The study revealed that the pollution level of the wetland water was low [4].
- The State Pollution Control Board has been monitoring twenty three physico-chemical parameters and two bacteriological parameters of the wetland water on quarterly basis at only one sampling point, since the year 2002. The parameters

taken into consideration are pH, Temperature, Turbidity, Conductivity, DO, COD, BOD, TKN, Ca, Mg, Cl, SO_4, PO_4, Na, K, F, B, T.Alkalinity, T. Hardness, Nitrate-N, Ammoniacal-N, TDS, TSS, T. Coliform and F.Coliform. [Water Quality Report of PCBA].

- Dutta et al. (2005) studied the heavy metal accumulation in polluted water bodies and subsequent bioaccumulation in Water Hyacinth (Eichhonia Crassipes) grown in polluted water bodies of greater Guwahati. Out of the six sampling stations considered in the study, two sampling stations were located at the Deeporbeel Wetland, one at the inlet and other at the outlet. In the study it was found that the absorption of heavy metal by water hyacinth was higher at this wetland than that of another water body which does not receive any domestic sewage and industrial effluent [13].

2.2.3 Water Quality Index

A Water Quality Index can be defined as a scheme that transforms the (weighted) values of individual water pollution related parameters into a single number. Ideally, an Index can be described as a means, devised to reduce large quantity of data down to its simple form so that it is easier to work with and also easy to understand.

Thus, the index is basically a mathematical means of calculating a single value from multiple test results. The index result represents the level of water quality in a given water basin, such as a lake, river, or stream [51].

The calculation of the Index value involves two basic steps.

(i) Step – I: Calculation of sub-indices of pollutant variables used in the Index.

(ii) Step –II: Once the sub-indices are calculated, these are aggregated together to get the Index value [33].

2.2.3.1 *History of Development*

It is reported that attempts were made in Germany as early as 1848 to relate the level of water pollution to the occurrence of certain biological organisms. Since then, various European countries have developed and applied different systems to classify the quality of surface waters. Indices that use a numerical scale to represent the gradation in water quality levels were first introduced by Horton in 1965 [26].

2.2.3.2 *Classification of Water Quality Indices*

There are two types of Water Quality Index forms:

(i) Increasing Scale form – those in which the index numbers increase with increasing pollution level.

(ii) Decreasing Scale form – those in which the index numbers decrease with increasing pollution level.

Some specialists refer to the former as "Water Pollution Indices" and later as "Water Quality Indices". In increasing scale form, an index of zero indicates no pollution, while, in decreasing scale form, an index of zero indicates maximum pollution or 100% polluted water. Both the terms are inter-related and, therefore, in practice both type of indices are called "Water Quality Indices".

Some of the water quality Indices which are generally used are:

- Horton's Quality Index
- National Sanitation Foundation Water Quality Index
- Prati's Implicit Index of Pollution
- Dinius Social Accounting System
- McDuffie's River Pollution Index, etc.

Water Quality Indices show considerable variation in-terms of number of variables, scales, ranges and aggregation method. Table 2.2 shows the various Water Quality Indices at glance [26].

The Council of Environmental Quality (CEQ) had proposed following five criteria for Water Quality Index formulation.

(a) It should facilitate communication of environmental quality information to the public.

(b) It should be readily derived from available monitoring data.

(c) It should strike a balance between over simplification and complex technical conceptualization.

(d) It should impart an understanding of significance of data represented.

(e) It should be objectively designed but amenable to comparison with expert judgment so that their validity can be assessed.

NSFWQI meets all the five of above mentioned criteria. Out of the many General Water Quality Indices developed so far, the NSFWQI is the most widely accepted Water Quality Index. It has got the effectiveness and flexibility, while it is simple to formulate [26].

Table 2.2:- Various Water Quality Indices at a Glance

Index Name	No. of Variables	Type of Scale	Range of Index Value
General Water Quality Indices			
Horton's Quality Index (HQI)	10	Decreasing	0 to 100
National Sanitation Foundation Water Quality Index (NSFWQI)	9	Decreasing	0 to 100
Prati's Implicit Index of Pollution (PIIP)	13	Increasing	0 to 15
Dinius Social Accounting System (SAS)	11	Decreasing	0 to 100
McDuffie's River Pollution Index (RPI)	8	Increasing	0 to 1,000
Specific-Use Water Quality Indices			
O'Conner Fish and Wildlife (FAWL) Index	9	Decreasing	0 to 100
O'Conner Public Water Supply (PWS) Index	13	Decreasing	0 to 100
Deininger's Index for Public Water Supply	13	Decreasing	0 to 100
Walski and Parker's Index for Recreation	12	Decreasing	0 to 1
Stoner's Index for Dual Water Uses	31	Decreasing	-100 to 100
Nemero's Index for Three Water Uses	14	Increasing	0 tol
Statistical Approaches			
Composite Pollution Index (CPI)	18	Increasing	-2 to 2
Index for Partial Nutrient	5	Decreasing	0 to 100
Index for Total Nutrient	5	Decreasing	0 to 100
Harkin's Index (Kendall Ranking)	Any number	Increasing	0 to 1,000
Beta Function Index	Any number	Increasing	0 to 1
Planning Indices			
Prevalence Duration Intensity (PDI)Index	Any number	Increasing	0 to 1
National Planning Priorities Index (NPPI)	Any number	Increasing	0 to 1
Priority Action Index (PAI)	Any number	Increasing	0 to 1
Environmental Evaluation System (EES)	78	Decreasing	0 to 1,000
Canadian National Index	Any number	Increasing	0 to 1
Potential Pollution Index (PPI)	3	Increasing	0 to 1,000
Johanson's Pollution Index (PI)	Any number	Increasing	0 to 100

2.2.3.3 *National Sanitation Foundation Water Quality Index (NSFWQI)*

This Index was developed by Brown, Mc Clelland, Deininger and Tozer using a formal procedure based on Rand Corporation's Delphi Technique to combine the opinion of a selected large panel of water quality experts. Total numbers of 142 experts were selected, of which 101 were Regulatory Officials, 5 were Managers of Public Utility Services, 6 were Consulting Engineers, 26 were Academicians and 4 were from Professional Organizations.

Initially 35 water quality parameters were considered in the questionnaire prepared on a rating scale of 5 (1 to 5). Based on the opinion of the panel of experts, finally 9 parameters were selected as the sub-indices and accordingly weights were assigned to these 9 parameters and average graphs (0-100 ordinate) were prepared for each sub-index based on Delphi technique [33].

These 9 parameters and the assigned weights are shown in the Table 2.3 [33].

Table 2.3:- Significance Ratings and Weights of NSFWQI

Parameter	Arithmetic mean of all significance ratings	Temporary weights	Final weights
D.O.	1.4	1.0	0.17
Faecal Coliform	1.5	0.93	0.15
pH	2.1	0.66	0.11
BOD	2.3	0.61	0.11
NO_3	2.4	0.58	0.10
PO_4	2.4	0.58	0.10
Temperature	2.4	0.58	0.10
Turbidity	2.9	0.48	0.08
Total Solids	3.2	0.44	0.07
		Total	1.00

$$\text{Temporary Weights} = \frac{\text{Heighest Significance Rating}}{\text{Individual Rating}}$$

$$\text{Final Weights} = \frac{\text{Temporary Weights}}{\text{Sum of Temporary Weights}}$$

2.3 SOIL EROSION

Soil erosion by water is the detachment and transport of soil from the land by water, including runoff from melted snow and ice. Types of water erosion include interrill (raindrop and sheet), rill, gully and stream channel erosion. Water erosion is accelerated by farming, forestry and construction activities. Since the early 1770's, greater emphasis has been given to erosion as a contributor to nonpoint pollution. Nonpoint refers to erosion from land surface rather than from channels and gullies. Eroded sediment can carry nutrients, particularly, phosphates, to waterways, and contribute to eutrophication of lakes and streams. Adsorbed pesticides are also carried with eroded sediments, adversely affecting surface water quality [42].

About 150 million ha land is subjected to soil erosion in India. The total loss of surface soil is estimated to be about 6000 million tonnes with loss of major plant nutrients (NPK) varying from 5.37 million tonnes to 8.4 million tonnes. Of 164 million ha cultivable land, 104.6 million ha is reported to be affected by soil erosion [14].

The current rate of soil loss from agricultural lands in India is 20 to 30 t / (ha-year), though maximum erosion of 100 t / (ha-year) has been reported to occur at some places [11].

In the United States, estimates of annual soil erosion in the 1970s were as high as 4 billion Mg. This amount represents about 30 percent increase over that estimated in the 1930s [42].

2.3.1 Development of Soil Loss Estimation Models [11, 18]

- The scientific investigation of erosion of soil particles began in the year 1877. Wollny (1895), a German Scientist, carried out an extensive study on small plots of land to determine quantity of soil erosion. He studied wide range of effects such as vegetation and surface mulches on the interceptions of rainfall, deterioration of soil structures and also effects of soil type as well as slope on runoff and erosion, during the period 1877 to 1895.
- Cook (1936) had established a mathematical relationship describing effects of various factors of soil erosion, such as soil erodibility, soil erosivity of rainfall

and degree of protection afforded by vegetal cover on process of land deterioration.

- Zing (1940) published the result of his comprehensive study on the effect of degree of slope (S in percentage), slope length (L in feet) and recommended the following relationship,

  $A = CS^{1.4}L^{0.6}$

  where A = average annual soil loss in t per acre.

  C = constant of variation.

- Smith (1941) added crop factor (C) and supporting practice factor (P), to the equation formulated by Zing.

  $A = CS^{7/5}L^{3/5}P$

- Ellison (1945) formulated the following equation for sheet erosion,

  $E = KV^{4.33}d^{1.07}I^{0.65}$

  where, E = Soil intercepted in splash samplers during 30 minutes period in gm.

  V = velocity of drop in m/s.

  d = diameter of drop in mm.

  I = intensity of rainfall in cm/hour.

  K = constant.

- The National Committee of USA (1946) added the rainfall factor in the land slope practice method and suggested the following equation which is known as Musgrave equation.

  $$A = F.C.\left(\frac{S^{1.35}}{10}.\frac{L^{0.35}}{72.6}.\frac{P_{30}^{\ 1.75}}{1.375}\right)$$

  where A = sheet erosion in tonnes per acre.

  F = soil factor basic erosion rate in tonnes/ acre/year.

  C = cover factor.

  S = degree of slope in percent.

  L = length of slope in feet.

  P_{30} = maximum 30 minutes duration 2 years frequency rainfall in inches.

- The above equation was further modified by Musgrave (1947) for estimating average soil losses from large, heterogeneous watershed as

  $$A = K.C.R.\left(\frac{S^{1.35}}{10}.\frac{L^{0.35}}{76.6}\right)$$

  where A = soil loss in tonnes per acre.

  R = rainfall factor (rainfall erosion index).

  K = soil factor in tonnes/ acre/year/unit-rainfall index.

- Smith (1949) presented the following erosion estimating equation

  A = C.L. S. K. P

  where A = soil loss in tonnes per acre.

  C = annual average soil loss from a 3 percent slope, 90 feet long plot, farmed up and down slope.

  The other factors for slope (S), length (L), soil group (K) and conservation practice (P) are dimensionless multiplies to adjust the value of C to other conditions.

- The joint conferences of personnel from SCS, the Soil and Water Conservation Research Branch of the Agricultural Research Service and Co-operating State Agencies of USA were held at Purdue University in February and July, 1955. They concentrated on the need of reconciling differences among existing soil loss equation and extended this technique to regions where no measurements of erosion by rain storm has been made. At this workshop they proposed the following equation,

  A = C.M.S.L.P.K.E

  where, A = estimated soil loss in tonnes per acre.

  C = crop rotation factor (C = 100 for continuous corn).

  M = management factor (values from 0.5 to 0.8 for different residues and method of tillage).

  S = degree or percent of slope factor.

  L = the length of slope factor.

  P = conservation practice factor (specific values for slope groups from 1.1 to 24%).

K = soil erodobility factor (0.75, 1.0, 1.25, 1.5 or 1.75).

E = previous erosion factor.

- Wischmeier and Smith (1965) have developed the Universal Soil Loss Equation (USLE) by combining the crop rotation and management factors to the rainfall factor.

  A = RKLSCP

  where, A = average annual soil loss, t/ (ha-year).

  R = rainfall erosivity index.

  K = soil erodibility factor.

  L = slope length factor.

  S = slope steepness factor.

  C = crop management factor.

  P = conservation practice factor.

- Williams (1975) modified the USLE by replacing its rainfall energy factor with the runoff factor, and called the model as Modified Universal Soil Loss Equation (MUSLE). The MUSLE estimates sediment yield on a per storm basis, instead of average soil erosion per year as done by the USLE. The MUSLE is stated as

  $Y = 11.8\ (Qq_p)^{0.56}\ K\ L\ S\ C\ P$

  where, Y = sediment yield from an individual storm in t.

  Q = storm runoff volume in m^3.

  q_p = peak runoff rate m3/sec.

  K L S C P are the factors of the USLE

A revised version of the USLE, Revised Universal Soil Loss Equation (RUSLE) was developed for computer applications, allowing more detailed consideration of farming practices and topography for erosion prediction by Renard et al. (1991). Since the mid-1960s, scientists have been developing process-based erosion computer programmes that estimate soil loss by considering the processes of infiltration, runoff, detachment, transport and deposition of sediment. Numerous research programmes have been developed, and the programmes are being improved for field use. Some of these process-based models are the Aerial Non-point Sources Watershed Environment

Response (ANSWERS) model, Agricultural Non-point Source (AGNPS) Pollution model, Water Erosion Prediction Project (WEPP) model and System Hydrologique European Sediment (SHESED) model [30].

2.3.2 Application of USLE to Indian Conditions [47]

A few of the studies related to application of USLE to Indian condition is discussed below:

- Applicability of USLE to Indian Conditions was conducted at Soil Conservation Research Demonstration and Training Centre (ICAR) by Nema et al. (1974) to determine some parameters of the USLE from runoff plot study.
- Narain et al. (1980) determined the value of the parameters of USLE for the watershed of Kota, Rajasthan.
- Singh et al. (1981) evaluated the USLE parameters for different regions of the country and presented a report on soil prediction research in India. It shows the applicability of this equation for different land use pattern, soil condition, rainfall condition, erosion control practices and topographic condition.
- Rao (1981) evaluated the crop management factor of USLE under natural rainfall condition of Kharagpur, India.
- Pathak (1991) evaluated the R (rainfall erosivity factor) and K (soil erodibility factor) of USLE in the hill areas of N.C. Hills in Assam.
- Sidhwal et al. (1994) evaluated the ULSE parameters for the Doon Valley.
- Suresh (1998) worked on USLE and evaluated the optimal land use planning model of watershed in the Kumaon Hills.
- Suresh et al. (2002) presented the soil loss trend corresponding to various land use activities at Ramganga Catchment.
- Talukdar et al. (2005) had evaluated the conservation practice factor P for Baltijan Watershed, Puthimari River Basin in Assam.

2.3.3 Gully Erosion

Soil erosion, if left unchecked, leads to the formation of gullies and ravines, depletion of soil fertility resulting in conversion of vast tract of lands into waste lands [45].

Gully erosion produces channels larger than rills. These channels carry water during and immediately after rains. The amount of sediment from gully erosion is usually less than from upland areas, but the nuisance from having fields divided by large gullies has been the greater problem. In tropical areas, gully growth following deforestation and cultivation has led to severe problems of soil loss, and damage to buildings, roads and airports [42].

The rate of gully erosion depends primarily on the runoff-producing characteristics of the watershed; the drainage area; soil characteristics; the alignment, size and shape of the gully; and the slope in the channel. Evaluation and prediction of gully development are difficult because the factors are not well defined and field records of gullying are inadequate. From aerial photographs and field topographic surveys, Beer and Johnson in the year 1963 developed a prediction equation for the deep loess region in western Lowa (USA) based on the watershed runoff characteristics and soil properties. Gully formation was found to depend on soil shear, infiltration and depth of water table by Bradford in the year 1973 [42].

In India, it is estimated that about 23 lakh ha of land has been severely affected by gully erosion [11].

2.4 WATER BALANCE

The basic components of the hydrologic cycle include precipitation, evaporation, evapotranspiration, infiltration, overland flow, streamflow and ground water flow. The movement of water through various phases of the hydrologic cycle varies greatly in time and space, giving rise to extremes of flood or droughts. The magnitude and the frequency of occurrence of these extremes are of great interest to the engineering hydrologist from design and operation standpoint. It is possible to perform a water budget calculation in order to predict changes in storage to be expected based on inputs and outputs from the system [5].

For, any hydrologic system, a water budget can be developed to account for various flow pathways and storage components. The hydrologic continuity equation for any system is

$$I - Q = \frac{dS}{dt},$$

where, I = inflow in volume per unit time

Q = outflow in volume per unit time

$\frac{dS}{dt}$ = change in storage per unit time

Based on the equation, for a given time period, a conceptual mathematical model of the overall water budget would become, in units of depth (in. or cm) over the basin,

$$P - R - G - E - T = \Delta S,$$

where, P = precipitation,

R = surface runoff,

G = ground water flow,

E = evaporation,

T = transpiration,

ΔS = change in storage in a specified time period.

Infiltration I is a loss from the surface system and a gain to ground water, and thus cancels out of the overall water budget. The unit of inches (or cm) represents a volume of water when multiplied by the surface areas of the watershed [5].

2.4.1 Definition of Water Balance

- C. Warren Thornthwaite has defined the term 'Water Balance' as "the balance between the income of water from precipitation and snowmelt and the outflow of water by evapotranspiration, groundwater recharge, and streamflow" [12].
- According to Mutreja, "Water Balance is nothing but the 'book-keeping' of water of a basin or region in relation to the components of the entire hydrologic cycle or part thereof, carried over a specified period of time" [32].

- ASCE defines the term 'Water Balance' as "an accounting of the inflow (recharge), outflow (from discharge), and storage in a hydrologic unit such as a drainage basin or aquifer" [12].

2.4.2 Need for Water Balance Study

- To evaluate the net available water resources, both on the surface and subsurface.
- To assess the existing water utilization patterns and practices. This information will help in planning the optimal and sufficient management of water resources [32].

2.4.3 Wetland/Lake Water Balance Studies

A few of wetland/lake water balance studies are discussed below:

- Harbeck et al. (1954) used the water balance equation to measure the evaporation from reservoirs such as Lake Hefner in Oklahoma and Elephant Butte in New Mexico [43].
- Nobilis et al. (1991) used the water balance equation in analyzing the volume variation of Lake Neusiedl in Hungary. The daily variation of the water level was found to be in the range of cm and the monthly variation within the range of dm [34].
- Kotwicki et al. (1991) calculated the water balance of Lake Eyre, Lake Coongie and Lake Alexandrina in Australia. The methods used in calculation of the water balance include streamflow measurement, estimates of spatial and temporal evaporation, rainfall-runoff modelling, and comparative studies investigating the existence of large-scale climatic forcing. In the study it was observed that evaporation was the major factor in the outgoing water balance [22].
- Vali-Khodjeini (1991) calculated the water balance of Caspian Sea. According to the study the annual water deficit due to reduced inflow from rivers into the Caspian Sea could rise to as much as 60 km^3 by the end of the 20^{th} century [50].
- Kadukin et al. (1991) calculated the water balance of the Aral Sea and the Caspian Sea. The study showed that the increase in the volume of Caspian Sea for

the last 10 years (450 km^3) equals to the decrease in volume of the Aral Sea for the last 25 years [21].

- Kebede et al. (2006) studied the water balance of Lake Tana in Ethiopia and its sensitivity to rainfall variations. The study showed a drastic (40% to 45%) and sustained (7 to 8 yrs.) rainfall reduction is required to change the lake from out flowing to terminal (cessation of flow) [23].

CHAPTER 3

METHODOLOGY

3.1 GENERAL

In this study, three aspects of the Deeporbeel Wetland are taken into consideration. These aspects are:

- Surface Water Quality of the wetland.
- Erosion in the Wetland Catchment and subsequent silt deposition in the wetland.
- Hydrological study.

The methodologies adopted for these three aspects are described separately.

3.2 SURFACE WATER QUALITY

Monitoring of water quality through physical senses, general appearance, taste and odour, is a very old practice. Modern monitoring techniques can be classified as conventional, automatic recording and remote sensing techniques. In the present study the surface water quality of the wetland was monitored conventionally (i.e. samples were collected manually) for post-monsoon season (October-November, 2005) and for pre-monsoon season (April, 2006). After conducting reconnaissance survey, six representative sampling locations were chosen. From these sampling locations, samples were collected and transported to the Regional Environmental Testing Center (RETCEN) at the Assam Engineering College to carry out analysis for the various water quality parameters. The primary data obtained by analyses of the water quality parameters are compared with that of the Base Year (1989) data.

3.2.1 Sampling Locations

Before deciding on the sampling locations a reconnaissance survey was conducted. Based on the reconnaissance survey six sampling points were selected for the study. The details of these sampling locations are given in Table 3.1.

Table 3.1: - Details of Sampling Locations

Sampling Station	Sampling Station Code	Latitude	Longitude	Description of Station
1	D1	26°6'32.96"	91°40'46.18"	Main Inlet Channel
2	D2	26°8'07.11"	91°40'04.92"	Residential Area
3	D3	26°8'10.25"	91°38'00.57"	Industrial Area
4	D4	26°8'13.86"	91°38'29.10"	Outlet Channel
5	D5	26°7'16.89"	91°39'04.13"	Middle of Wetland
6	D6	26°6'40.57"	91°38'09.55"	Near Hilly Catchment at Southern the Fringe

The above sampling locations satisfy the following site selection criteria.

- The sampling site should be accessible in all seasons of the year.
- At the sampling site, there should be proper mixing of pollutants and thus represent the water quality of the water body at that particular location.
- Facilities to take water samples should be available.

The locations (Latitude and Longitude) of these six sampling points were recorded in a GPS and shown in Fig. 4.1 using Arc View 8.2 software.

3.2.2 Sample Collection

There are generally three types of samples:

- Grab Sampling
- Integrated Sampling
- Integrated Sampling

In this study, grab samples were collected from the six sampling locations. The water samples were collected at about 25 cm depth from the water surface. The sample collection was done during the morning hours between 8 A.M. to 9:50 A.M. in pre-cleaned, dried polythene containers (two liter capacity) and labeled appropriately for identification. Water samples for determination of DO were collected separately in 300 ml capacity BOD bottles which were pre-sterilized at 103°C for 24 hours. The bottles were closed with the lids under water so that no air bubbles can enter into the BOD bottles. During the period of sample collection, the weather was sunny.

After collection of the samples, these were taken to the Regional Environmental Testing Centre at the Assam Engineering College, which is located on the Northern bank of the Deeporbeel Wetland.

3.2.3 Period of Sampling

Samples were collected during Pre-monsoon and Post-monsoon season. For the Post-monsoon season, samples were collected from 19/10/2005 to 5/11/2005 and for the Pre-monsoon season, it was done from 6/04/2006 to 20/04/2006. Due to the limitation of time and available resources, samples were collected for three days for each of the six locations during both Pre-monsoon and Post-monsoon seasons. The sampling schedule for both the seasons is shown in Table 3.2.

Table 3.2:- Sampling Schedule

Post-monsoon Season (2005)			Pre-monsoon Season (2006)		
Sampling Station	**Date of Sampling**	**Time of Sampling**	**Sampling Station**	**Date of Sampling**	**Time of Sampling**
D1	19/10/2005 25/10/2005 31/10/2005	8:30 AM 8:00 AM 8:30 AM	D1	06/04/2006 10/04/2006 17/10/2006	8:15 AM 8:15 AM 8:20 AM
D2	19/10/2005 25/10/2005 31/10/2005	8:45 AM 8:15 AM 8:45 AM	D2	06/04/2006 10/04/2006 17/10/2006	8:30AM 8:30 AM 8:45 AM
D3	21/10/2005 27/10/2005 3/11/2005	8:00 AM 8:30 AM 8:15 AM	D3	07/04/2006 12/04/2006 18/10/2006	8:30 AM 8:30 AM 8:30 AM
D4	21/10/2005 27/10/2005 3/11/2005	8:20 AM 8:45 AM 8:30 AM	D4	07/04/2006 12/04/2006 18/10/2006	8:45 AM 8:45 AM 8:45AM
D5	24/10/2005 29/10/2005 05/11/2005	9:10 AM 9:15AM 9:30 AM	D5	08/04/2006 14/04/2006 20/10/2006	8:00AM 8:40 AM 8:00 AM
D6	24/10/2005 29/10/2005 05/11/2005	9:30 AM 9:30AM 9:50 AM	D6	08/04/2006 14/04/2006 20/10/2006	8:20 AM 9:00 AM 8:20 AM

3.2.4 Experimental Study

The quality of water for a given use depends on the following

- Parameters which significantly affect the utility for the use,
- Individual values of each significant parameter.

In the present study, the focus of interest is primarily on water quality for drinking purpose, contact sports such as swimming and bathing and on propagation of wildlife and fishery. Considering the above points and based on the limitation of time and resource, thirteen physico-chemical parameters were analyzed. These parameters are Temperature, pH, Conductivity, DO, BOD, COD, Total Solids, Total Dissolved Solids, Total Suspended Solids, Turbidity, Nitrates, Phosphates and Chlorides.

In addition to these physico-chemical parameters, analyses were done for five heavy metals viz. Lead, Arsenic, Mercury, Zinc and Manganese. For the analyses of heavy metals, the water samples were preserved in nitric media at a pH of less than 2. These preserved samples were brought and analyzed at the Institute Instrumentation Centre (IIC), IIT Roorkee.

The physico-chemical parameters were evaluated according to the methods specified in the "Standard Methods for the Examination of Water and Wastewater" (APHA-AWWA-WPCF 1998) [1]. The techniques, instruments and principles involved in arriving at the different water quality parameters are tabulated in Table 3.3.

Table 3.3:- Summary of Analytical Methods

Sl. No.	Parameters	Principle	Instrument/Technique Used
1	Temperature	Electrometric method	Digital Thermometer
2	pH	Electrometric method	Digital pH Meter
3	Conductivity	Electrometric method	Digital Conductivity Meter
4	DO	Volumetric	Modified Winkler Method Titrant : 0.025 N Sodium thiosulphate Indicator : Starch
5	BOD	Volumetric	Winkler Method (Three days incubation at 27°C) Titrant : 0.025 N Sodium thiosulphate Indicator : Starch
6	COD	Volumetric	Reflux Method Titrant : 0.01 N Ferrous ammonium sulphate Indicator : Ferroin
7	Total Solids	Gravimetric	Evaporation of unfiltered sample in an evaporating dish at about 98°C. Residue heated between 103 – 105°C in oven for 1 hour
8	Total Dissolved Solids	Gravimetric	Evaporation of filtered sample in an evaporating dish at about 98°C. Residue heated between 103 – 105°C in oven for 1 hour
9	Total Suspended Solids	Gravimetric	Difference in weight between Total Solids and Total Dissolved Solids
10	Turbidity	Photometric	Nephelometer (Turbidimeter)
11	Nitrates	Colorimetric	U.V. Spectrometer, Phenol disulphonic acid method.
12	Phosphate	Colorimetric	U.V. Spectrometer, Stannous chloride method.
13	Chloride	Volumetric	Titrant : 0.025 N Sodium thiosulphate Indicator : Starch
14	Heavy Metals (Pb, As, Hg, Zn and Mn)	Computerized Flame Photometer	Inductively Coupled Mass Spectrometer (ICPMS)

3.2.5 National Sanitation Foundation Water Quality Index (NSFWQI)

The NSFWQI has been calculated for the Post-monsoon (2005) and for Pre-monsoon (2006) seasons based on primary data. These values were compared with that of the Base Year (1989). In calculating the Sub-index and Index values the calculating software developed by Wilkes University has been used [33]. Using this software the NSFWQI value for parameters less than nine can also be determined. While calculating Index value for Post-monsoon (2005) and Pre-monsoon (2006) seasons, eight parameters were considered. In case of Pre-monsoon (1989) and Post-monsoon (1989) season, only six parameters were considered. In calculating the Yearly Average Index Value for Sampling location D3, six parameters were taken into consideration for the years 1989 and 1990 and for the years 2002, 2003, 2004 and 2005, eight parameters were considered.

The Index calculation is based on Eq. 3.1. The rating scale for the NSFWQI is shown in Table 3.4.

$$NSFWQI = \sum_{i=1}^{n} Wi \;\; fi \qquad \text{.................... (3.1)}$$

where, n = no. of parameters

Wi = final weight of the i^{th} parameter

fi = sub-index value of the i^{th} parameter

Table 3.4:- Rating Scale for the NSFWQI [33]

Index value	Rating	Indicating Colour
0 and <=25	Very bad	Red
>25 and <=50	Bad	Orange
>50 and <=70	Medium	Yellow
>70 and <=90	Good	Green
>90 and <=100	Excellent	Blue

3.2.6 Statistical Analysis (F Test)

Time variance of water quality parameters of raw water samples was studied statistically using a one-sided F test of the equality of two variances. The calculated value of F (as obtained from Eq. 3.2) has been compared with the table value of F for the given degree of freedom at a critical level. In the study 5 % level of significance has been taken into consideration.

$$F = \frac{S_1^2}{S_2^2} \qquad \text{.................. (3.2)}$$

where, S_1 and S_2 are the variances of independent random samples of size n_1 and n_2 respectively.

If the calculated value of F is greater than the table value, the null hypothesis is rejected. On the other hand, if the calculated value of F is less than the table value, the null hypothesis is accepted [29].

3.3 EROSION AND SILT DEPOSITION

Soil erosion is the result of soil exposure to erosive energy of rainfall and flowing water. To estimate the gross soil loss from the wetland catchment the Universal Soil Loss Equation has been used. The catchment area has been delineated based on 1972 Toposheet. The Total catchment area has been sub-divided into three catchments, viz. catchment area for the main inlet channel (Basistha and Morabharalu River), catchment area for the second inlet channel (Kalmoni River) and catchment area which contributes to direct run-off. Using Planimeter the catchment areas and land use area of each catchment has been calculated.

For the year 1996 and 2005, the land use statistics of the wetland catchtment have been obtained from Assam Remote Sensing Application Centre (ARSAC), which are based on LISS-II and LISS-III satellite images respectively.

3.3.1 Estimation of Gross Annual Soil Loss

The Universal Soil Loss Equation (USLE) continues to be widely accepted method of estimating sediment loss despite its simplification of the many variables involved. It is useful for determining the adequacy of conservation measures in farm planning and for predicting non-point sediment losses in pollution control programs. The average annual soil loss, as determined by Wischmeier and Smith (1965), can be estimated from the Eq. 3.3 [2, 11, and 52].

$$A = RKLSCP \qquad \text{.................. (3.3)}$$

where, A = average annual soil loss, t/ (ha-year)

R = rainfall erosivity index

K = soil erodibility factor

L = slope length factor

S = slope steepness factor

C = crop management factor

P = conservation practice factor

The magnitude of soil erosion depends on two forces – the detachment of soil particles by the impact of rainfall energy, called the erosivity of rain, and the ability of the soil to resist the detachment of its particles by this force, called the erodibility of soil. This relationship is expressed as shown in Eq. 3.4.

$$\text{Soil erosion} = f\,[(\text{erosivity of rain}) \times (\text{erodibility of soil}) \qquad \text{......... (3.4)}$$

The USLE is also based on similar principles. The erosivity of rain is represented by the factor R and the erodibility of soil surface system by the multiples of the factors KLSCP. In systems terminology, considering the watershed as a system represented by the multiples of factors KLSCP, the input force is represented by the rainfall erosivity factor R and the output (the response to the input), which is the gross soil erosion, is represented by the letter A. The system model of USLE is shown in Fig. 3.1.

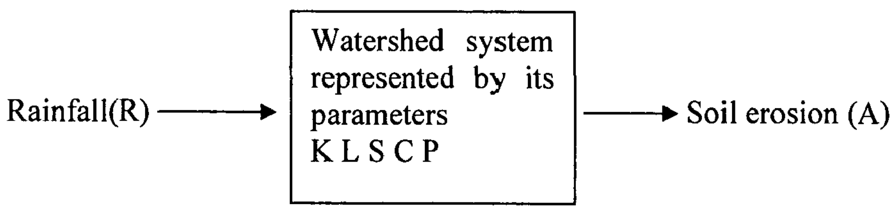


Fig. 3.1: - System Model of the Universal Soil Loss Equation (USLE)

3.3.1.1 ***Evaluation of USLE Factors***

The gross annual soil loss is obtained by the multiplication of the six factors depicted in the Eq. 3.3.

(i) Rainfall Erosivity Factor (R)

The erosivity factor of rainfall (R) is a function of the falling raindrops and the rainfall intensity. Wischmeier and Smith had found that the product of kinetic energy of the raindrop and the maximum intensity of rainfall over duration of 30 minutes, in a storm, is the best estimator of soil loss. This product is known as the *EI* value.

However, in the absence of rainfall intensity data, the R-factor can be approximated using monthly mean and annual precipitation data. Renard and Freimund [27, 40] had developed R-factor equation based on monthly precipitation value. For Indian conditions, as reported by Choudhury [9], Singh et al. (1981), derived a simple relationship between R-factor and the total annual rainfall. This relationship was developed after analyzing the data collected from 45 stations distributed in different rainfall zones throughout India. The relationship can be expressed by the following equation

$$R = 79 + 0.363 \times X_a \qquad \text{..................(3.5)}$$

where, R = annual rainfall erosivity factor

X_a = average annual rainfall in mm.

The coefficient of correlation for the above equation was found to be 0.83.

In the present study, the above equation (Eq. 3.5) has been used to find the value of R-factor. For the year 1972, the average annual rainfall of 30 years i.e. from 1951 to 1980 has been taken into consideration. For the year 1996, the average annual rainfall of 45 years i.e. from 1951 to 1996 (except for the year 1989) and for the year 2005, the average annual rainfall of 54 years i.e. from 1951 to 2005 (except for the year 1989) has been taken into consideration. Rainfall data for the whole year of 1989 was not available and as such it was not considered while calculating the average rainfall.

(ii) Soil Erodibility Factor (K)

The soil erodibility factor (K) is the susceptibility of the soil particles to erosion per unit of rainfall erosivity factor. In the study The 'K' value has been estimated from the following the Table 3.5.

Table 3.5:- Magnitude of Soil Erodibility Factor (K) [9, 35]

Textural Class	**Organic Matter Content (%)**		
	< 0.5	**2.0**	**4.0**
Sand	0.05	0.03	0.02
Fine Sand	0.16	0.14	0.10
Very Fine Sand	0.42	0.36	0.28
Loamy Sand	0.12	0.10	0.08
Loamy Fine Sand	0.24	0.20	0.16
Loamy Very Fine Sand	0.44	0.38	0.30
Sandy Loam	0.27	0.24	0.19
Fine Sandy Loam	0.35	0.30	0.24
Very Fine Sandy Loam	0.47	0.41	0.33
Loam	0.38	0.34	0.25
Silt Loam	0.48	0.42	0.29
Silt	0.60	0.52	0.42
Sandy Clay Loam	0.27	0.25	0.21
Clay Loam	0.28	0.25	0.21
Silty Clay Loam	0.37	0.32	0.26
Sandy Clay	0.14	0.13	0.12
Silty Clay	0.25	0.23	0.19
Clay	0.13 – 0.2		

For obtaining the Textural Classification, two soil sample, one each from hilly catchment and from plain area have been collected, brought and analyzed at the Geo-tech Laboratory of the Department of Civil Engineering, IIT Roorkee. The Specific Gravity of the soil samples were determined by Pycnometer Method. Then, Hydrometer Analysis of the soil samples was done to determine the percentage of Sand, Clay and Silt content [31]. Details of the experimental data are shown in Appendix V and Appendix VI. Based on the percentage of Sand, Clay and Silt content, the Textural Class of the soil has been determined from the Textural Classification Chart (U.S. Public Roads Administration) [38].

To determine the percentage of Organic Matter present in the soil, the Modified Walky and Black Method has been used [48]. This is a volumetric method based on the following equation

$$\% \text{ Carbon (C)} = \frac{3.951}{g} \times \left(1 - \frac{T}{S}\right) \qquad \text{.................... (3.6)}$$

$$\% \text{ Organic Matter} = \% \text{ C} \times 1.724 \qquad \text{.................... (3.7)}$$

where, g = weight of soil sample in gm

S = ml ferrous solution with blank titration

T = ml ferrous solution with sample titration

Therefore, based on the Textural Classification and % Organic Matter content, the 'K' values of the soil samples were determined (Appendix IV).

(iii) Topographic Factor (LS Factor)

The larger the slope length, there is higher concentration of overland flow, and also a higher velocity of flow which triggers a higher rate of soil erosion. On steep slopes the flow velocity is high, which causes scouring and cutting of soil.

In the study, for the year 1972, the average Slope Length (L_p) and the average Percentage Slope (s) for each of the three sub-catchments were calculated from the 1972 Toposheet. The 'L' value and 'S' value have been individually calculated using the following equations

$$L = \left(\frac{L_p}{22.13}\right)^{0.5} \qquad \text{.................... (3.8)}$$

$$S = \frac{0.43 + 0.30s + 0.043s^2}{6.613} \qquad \text{.................... (3.9)}$$

Then the product of L and S was calculated.

Again, combined LS value was determined from the following equation

$$LS = \frac{L_p^{0.5}\left(1.36 + 0.97s + 0.1385s^2\right)}{100} \qquad \text{.................... (3.10)}$$

The higher LS value has been taken into consideration.

For the year 1996 and 2005, the weighted average LS value was taken into consideration for the total catchment area, as data for only the total catchment was available.

(iv) Land Cover and Management Practices Factor (CP Factor)

Vegetative cover dissipates the impact force of raindrops on the soil surface, and protects the soil from splash erosion by modifying the volume, drop size, coefficient of distribution, impact velocity and kinetic energy of rainfall. The conservation practice factor (P) is the ratio of soil loss from a plot with a specific conservation practice to the corresponding soil loss from a plot with up and down cultivation under identical conditions.

In the study, the Land Cover (C) factor has been taken into consideration based on the results of the field experiments conducted by Gurmel Singh et al., as reported by Choudhury [9], for open forest, agricultural land, barren/grazing land and settlement for Indian conditions. The values found by Gurmel Singh et al. are shown in Table 3.6.

Table 3.6:- Values of C Factor for Various Land Use [9]

Land Use	C Factor
Open Forest	0.02
Agricultural Land	0.27
Barren Land / Grazing Land	0.21
Settlement	0.15

The Management Practice (P) factor is applied only in the agricultural land. The value of 'P' factor varies from 0.5 to 0.9 based on the slope steepness of the land surface [9]. According to G. Das [11], for up and down cultivation, the value of 'P' is considered as 1 and for contour farming its value is considered as 0.80 for slope less than 1 %. In the present study, the value of 'P' factor has been taken as 1 for agricultural land and also for non-agricultural land.

3.3.2 Gully Erosion

A reconnaissance survey was done in the catchment area which contributes to the direct run-off and thirteen gullies were identified. The locations (Latitude and Longitude) of the gullies were determined by a GPS and are shown in Fig. 5.1 using Arc View 8.2 software.

Physical measurement of the gullies was taken and the cross-sections at every 25 m interval along the length were measured to find the average cross-sectional area. Information regarding the initiation of the gullies is not available. According to the information collected from the local people the gullies have started forming since the early part of 1980s.

Based on the field measurements, the total soil loss was calculated and the potential soil loss was estimated as per the Guidelines for Watershed Management, FAO of the United Nations, 1986. As a part of conservation measures, check bunds are designed, the design of which is based on the FAO Guidelines [19].

3.3.3 Calculation of Suspended Load and Bed Load

For calculating the sediment load into the wetland, suspended sediment concentration were measured for monsoon and post-monsoon seasons of the year 2005 and pre-monsoon season of the year 2006. As pre-monsoon suspended sediment data of 2005 was not available, it is assumed to be equivalent to the pre-monsoon data of 2006. Suspended sediment loads were computed by combining the water discharge (as obtained from the calculated Water Balance) and suspended sediment concentration for the respective seasons. The Bed load has been estimated based on the empirical relationship between Suspended Load and Bed Load, which is shown in Table 3.7.

Table 3.7:- Relationship between Bed load and Suspended load [11]

Concentration of Suspended load (mg/l)	**Stream Channel Material**	**Suspended Material Texture**	**% Bed load in Terms of Suspended**
< 1000	Sand	Similar to bed material	15 to 25
< 1000	Gravel, rock or Consolidated clay	Small amount of sand	5 to 12
1000 - 7500	Sand	Similar to bed material	10 to 35
1000 - 7500	Gravel, rock or Consolidated clay	25 % sand or less	5 to 12
>7500	Sand	Similar to bed material	5 to 15
>7500	Gravel, rock or Consolidated clay	25 % sand or less	2 to 8

(Source: G. Das, 2002)

3.3.4 Sediment Delivery Ratio

The long term average annual sediment yield can be predicted by applying a delivery ratio to the estimated gross soil erosion. Eq. 3.11 was used for determining the delivery ratio (DR)

$$DR = \frac{Measured\ Se\dim ent\ Yield\ at\ the\ Watershed\ Outlet}{Estimated\ Gross\ Soil\ Erosion\ (A)} \quad \text{........ (3.11)}$$

where, A = soil erosion estimated by using USLE

3.4 HYDROLOGICAL STUDY

As a part of the hydrological study, the Water Balance for the wetland was prepared. The Water Balance has been calculated for a period of 12 months i.e. from January/05 to December/05. In the calculation, ground water inflow was assumed to balance the ground water infiltration.

The basic Water Balance Equation is:

$$S_t = S_{t-1} + \Sigma\ \text{Inflows} - \Sigma\ \text{Outflows} \quad \text{................. (3.12)}$$

where, S_t = storage at the end of time t

S_{t-1}= storage at the beginning of time t

3.4.1 Bathymetric Survey

A Bathymetric Survey was conducted from 9th January/2006 to 15th January/2006 to ascertain the average depth of the wetland. The survey was carried out using a boat with the help of a GPS, an Echo Sounding Meter and a marked Bamboo Pole. The depth of water at sixty six points was recorded. The location (Latitude and Longitude) of these sixty six were recorded in a GPS for plotting the same in satellite imagery. Arc View 8.2 software was used for this purpose. The depth was measured with an Echo Sounding Meter (in the case where the depth is more than 2 m) and a marked Bamboo Pole. Based on the depth at these sixty six points the average depth has been calculated. This average depth has been assumed to be that for December/2005. The total water spread area of the wetland varies from 1048 (during lean flow period) ha to 2225 ha (during monsoon) and as such the wet-contours of the wetland could not be prepared, due to limitation of time and resource.

3.4.2 Calculation of Average Monthly Water Spread Area

For a span of 20 years, only 8 water spread statistics of the wetland are available. These data are based on satellite images from the year 1985 to 2004, the details of which are shown in Table 3.8.

Table 3.8:- Water Spread Area

Month/Year	Rainfall (mm)/Month	Water-spread Area (ha)	Data Source
November, 1985	13.54	1549.96	MSS Image
March, 1986	69.64	1918.43	MSS Image
February, 1991	7.90	1334.04	LISS-2 Image
May, 1994	170.90	1588.85	LISS-2 Image
January, 2000	4.60	1316.35	LISS-3 Image
November, 2001	1.70	1116.28	PAN Image
May, 2004	126.00	1885.87	LISS-3 Image
October, 2004	354.40	2114.33	PAN Image

(Source: P.Phukan for NESAC)

Based on these 8 water spread statistics and corresponding monthly precipitation, a mathematical model (Eq. 3.13) has been developed using MS Office Excel (2003), which is shown in Fig.3.2. The co-efficient of co-relation for the relationship was found to be 0.85. Based on this relationship, the water spread area from December/2004 to December/2005 has been calculated.

$$y = 1105.60 \times X^{0.1046} \qquad \text{................ (3.13)}$$

where, y = water spread area in ha.

X = rainfall in mm.

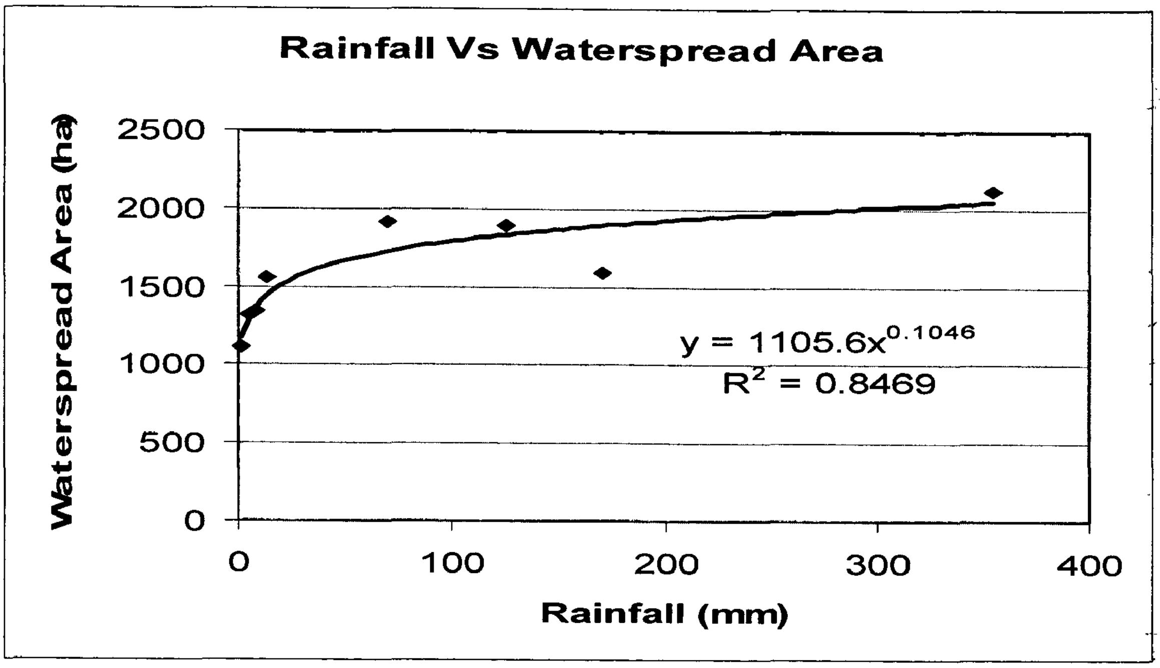


Fig. 3.2:- Relationship between Rainfall and Water Spread Area

3.4.3 Calculation of Initial Storage Volume

It has been assumed that the average water depth during December/2004 to be same as that during December/2005. Based on this average water depth and the calculated water spread area for December/2004, the storage volume for the month of December/2004 has been calculated.

The storage volume for the excavated portion of the wetland on the eastern side has been calculated separately. These together represent the Initial Storage for the monthly water balance prepared for the year 2005.

3.4.4 Components of the Water Balance

The inflows considered in the study are:

- Inflow from Main Inlet Channel (Combined flow of Basistha and Mora-Bharalu River)
- Inflow from Second Inlet Channel (Kalmoni River)
- Direct Runoff
- Direct Precipitation

The outflows and losses considered are:

- Outflow from the Outlet Channel (Khanajan River)
- Domestic water demand
- Evapo-transpiration

Water for agricultural use has not been considered as agriculture is done only during the monsoon in the fringe areas of the wetland.

Monthly discharge data of the Basistha and Mora-Bharalu combined; Kalmoni and Khanajan Rivers have been obtained from the Site Engineer, W.R.Department. The inflow from direct runoff has been computed using Khosla's Equation (Eq. 3.14).

$$Q_m = P_m - l_m \qquad \text{................ (3.14)}$$

where, Q_m = monthly runoff (cm)

P_m = monthly rainfall (cm)

l_m = monthly runoff loss (cm)

If t_m = monthly temperature of the catchment (°C), then

for $t_m > 4.5\,^0C$, $l_m = 0.48\, t_m$

and $t_m \leq 4.5\,^0C$, $l_m = 2.17$ at $4.5\,^0C$

= 1.78 at $-1\,^0C$

= 1.52 at $-6.5\,^0C$

Direct precipitation data has been obtained from the Regional Meteorological Centre (RMC), Guwahati.

Domestic water demand has been calculated by taking the per capita water requirement as 135 lpcd [20].

Evapotranspiration has been estimated from climatological data using Penman's equation [15]. Penman's equation is given as:

$$E_t = \frac{A \times H_n + E_a \gamma}{A + \gamma} \qquad \text{.................. (3.15)}$$

where, E_t = daily potential evapo-transpiration

E_T = monthly potential evapo-transpiration

A = slope of the saturation vapour pressure Vs temperature curve at the mean air temperature and its values are given in Table VIII.1 (Appendix VIII).

H_n = net incoming solar radiation or energy, expressed in mm of evaporable water per day (Eq. 3.16).

E_a = a parameter including wind velocity and saturation deficit, as given by Eq. 3.17, in mm/day.

γ = psychrometic constant
= 0.49 mm of Hg/^{0}C.

The net radiation (H_n) in the above equation (Eq. 3.15) is given by

$$H_n = H_c(1-r)\left(a + b.\frac{n}{N}\right) - \sigma.T_a^{\,4}(0.56 - 0.092\sqrt{e_a}) \times \left(0.10 + 0.90\frac{n}{N}\right) \quad \ldots\ldots (3.16)$$

where, H_c = mean incident solar radiation at the top of the atmosphere on a horizontal surface, expressed in mm of evaporable water per day. This value is a function of latitude (Φ) of the place and the period of the year, as per the mean monthly values given in Table VIII.2 (Appendix VIII).

r = reflection coefficient (albedo) of the given area. Usual values of this coefficient for different types of areas are given in Table VIII .3 (Appendix VIII).

a = a constant depending upon the latitude (Φ)
= 0.29 cos Φ.

b = a constant having an average value
= 0.52.

n = actual duration of bright sunshine in hours.

N = maximum possible hours of bright sunshine (mean value). This is a function of latitude (Φ), and its values are given in Table VIII.4 (Appendix VIII), for each month of the year.

σ = Stefan-Bolzman constant
= 2.01×10^{-9} mm/day.

T_a = mean air temperature in ^{0}K
= 273 + °C.

e_a = actual mean vapour pressure in the air in mm of Hg.

The parameter E_a is estimated as:

$$E_a = 0.35\left(1+\frac{V_2}{160}\right) \times (e_s - e_a) \text{ mm/day} \quad \ldots\ldots\ldots\ldots\ldots (3.17)$$

where, V_2 = mean wind speed at 2 m above the ground in km/day.

e_s = saturation vapour pressure at mean air temperature in mm of Hg (Table VIII .1) (Appendix VIII).

e_a = actual mean vapor pressure of air in mm of Hg.

Actual Evapo-transpiration (A_{ET}) = K ×Potential Evapo-transpiration (P_{ET})
For Lake Evapo-transpiration, the value of K = 0.7.

All Meteorological data such as Rainfall, Air Temperature, RH, Mean Wind Speed, Actual Mean Vapour Pressure and Actual Duration of Bright Sunshine Hours used in the study has been obtained from the Regional Meteorological Centre (RMC), Guwahati, which is shown in Table. VIII .7 of Appendix VIII . In calculating the storage capacity, the RL of the HFL of the Railway Department has been considered.

CHAPTER 4

ANALYSIS AND DISCUSSION OF RESULTS

4.1 GENERAL

The water quality of the Deeporbeel wetland has been monitored for certain physico-chemical parameters viz. Temperature, pH, Specific Conductance, DO, BOD, COD, TS, TDS, TSS, Turbidity, Nitrates, Phosphates and Chlorides for the post-monsoon (2005) and pre-monsoon (2006) seasons. Analyses for heavy metals viz. Pb, As, Hg, Ni, Zn and Mn were also done. The experimental results of these water quality parameters were compared with the Base Year (1989) data. NSFWQI has been computed and compared with the Base Year Index Value. Statistical analysis using F test of the equality of two variances is done for nine parameters viz. BOD, DO, COD, pH, Specific Conductivity, Turbidity, Cl, NO_3 and PO_4. Gross soil erosion in the catchment area of the wetland has been estimated using USLE. The silt load coming into and moving out of the wetland has also been calculated for the pre-monsoon, monsoon and post-monsoon seasons of 2005. A monthly water balance for the year 2005 has been prepared.

In this chapter, the three aspects considered in the study are discussed separately.

4.2 SURFACE WATER QUALITY

The six sampling locations considered in this study are shown in Fig. 4.1.

Fig. 4.1:-Sampling Locations

4.2.1 Data Analysis

The values of various water quality parameters as analyzed for post-monsoon (2005) and pre-monsoon (2006) are tabulated in Table 4.1, 4.2, 4.3, and 4.4. The Base Year (1989) water quality parameter data are tabulated in Table 4.5.

Table 4.1:- Water Quality Analysis Report (Post-monsoon, 2005)

Sampling Station	Date of Sample Collection	Time of Collection	Temp. (^0C)	Temp. Variation (^0C)	pH	Conductivity µ mho/cm	DO mg/l	BOD mg/l	COD mg/l	TS mg/l	TDS mg/l	TSS mg/l	Turbidity NTU	NO_3 mg/l	PO_4 mg/l	Cl mg/l
D1	19/10/05	8:30 am	24.7	0.5	7.1	143	5.3	8	22	260	80	180	22	1.6	2.2	12.4
D2	19/10/05	8:45 am	25.5	0.6	7.2	159	3.2	12	28	140	90	50	6	2.6	3.6	14.6
D3	21/10/05	8:00 am	26.5	0.3	7.7	120	3	16	34	160	70	110	12	2.1	3.8	16.5
D4	21/10/05	8:20 am	25.9	0.6	7.5	107	5.1	10	36	120	80	50	8	1.8	4.2	15.6
D5	24/10/05	9:10 am	27.8	0.3	7.5	100	6.8	6	12	100	60	40	6	0.18	1.8	12.8
D6	24/10/05	9:30 am	28.1	0.2	7.1	210	5.4	16	20	220	90	130	16	2.8	4.8	17.0
D1	25/10/05	8:00 am	25.1	0.4	7.5	110	5.1	6	18	210	60	150	18	1.8	2	10.8
D2	25/10/05	8:15 am	26.1	0.4	7.8	170	4	10	22	180	100	80	8	2.2	3.8	15.2
D3	27/10/05	8:30 am	27.2	0.2	7.6	136	3.8	18	38	180	80	100	16	2.4	2.8	14.8
D4	27/10/05	8:45 am	24.8	0.5	7.9	110	5.2	8	32	140	80	60	12	1.1	3.8	16.3
D5	29/10/05	9:15 am	28.2	0.2	7.6	129	6.2	8	10	120	70	50	8	0.16	2.2	13.5
D6	29/10/05	9:30 am	28.6	0.1	7.8	190	5.2	12	22	200	80	120	12	2	3.8	16.8
D1	31/10/05	8:30 am	25.9	0.4	7.4	123	5.2	10	16	230	70	160	18	2	2.6	13.6
D2	31/10/05	8:45 am	25.2	0.5	7.5	145	4.2	16	18	160	80	80	8	2.8	2.8	15.2
D3	3/11/05	8:15 am	26.9	0.4	7.8	210	3.2	14	36	120	60	60	8	1.2	2.2	16.2
D4	3/11/05	8:30 am	25.2	0.7	8	90	5.2	10	30	130	70	60	14	1.2	3.8	15.2
D5	5/11/05	9:30 am	27.6	0.4	7.4	140	6.4	8	8	120	80	80	6	0.16	1.6	13.6
D6	5/11/05	9:50 am	28.4	0.3	7.2	155	5	12	12	210	70	70	16	2	3.2	16.2

(Source: Primary Data as analyzed at RETCEN)

Table 4.2:- Water Quality Analysis Report (Pre-monsoon, 2006)

Sampling Station	Date of Sample Collection	Time of Collection	Temp. (^0C)	Temp. Variation (^0C)	pH	Conductivity µ ho/cm	DO mg/l	BOD mg/l	COD mg/l	TS mg/l	TDS mg/l	TSS mg/l	Turbidity NTU	NO_3 mg/l	PO_4 mg/l	Cl mg/l
D1	06/04/06	8:15 am	24.5	0.5	6.8	120	4.3	10	14	170	120	50	12	0.8	1.2	12.8
D2	06/04/06	8:30 am	26.0	0.6	7.5	110	3.4	14	30	120	80	40	6	1.4	2.2	15.6
D3	07/4/06	8:30 am	25.5	0.3	7.6	130	3.2	12	32	180	90	90	10	1.9	2.6	18.2
D4	07/4/06	8:45 am	26.2	0.6	6.9	116	4.8	8	38	130	80	50	10	1.7	3.4	14.8
D5	08/04/06	8:00 am	25.2	0.3	7.3	90	4.8	8	14	80	40	40	8	0.12	0.90	13.2
D6	08/04/06	8:20 am	25.5	0.2	6.9	190	5.7	14	22	180	90	90	12	1.4	3.6	16.8
D1	10/04/06	8:15 am	26.8	0.4	7.2	106	4.4	8	16	160	90	70	14	1.2	1.4	12.6
D2	10/04/06	8:30 am	27.5	0.4	7.6	110	3.6	12	28	140	80	60	6	1.6	2.8	14.8
D3	12/04/06	8:30 am	27.2	0.2	7.4	126	3.4	14	40	180	100	80	12	1.8	2.2	15.4
D4	12/04/06	8:45 am	27.5	0.5	7.8	122	4.6	10	34	120	80	60	8	0.8	2.8	16.8
D5	14/04/06	8:40 am	28.0	0.2	7.2	110	4.9	10	14	110	60	50	6	0.18	1.2	13.2
D6	14/04/06	9:00 am	28.5	0.1	7.5	180	5.6	14	18	160	90	70	8	1.8	3.2	16.2
D1	17/04/06	8:20 am	27.2	0.4	7.5	110	5.4	12	18	130	60	70	14	0.9	1.2	13.2
D2	17/04/06	8:45 am	28.0	0.5	7.2	120	3.8	14	22	130	80	50	8	1.8	2.0	15.8
D3	18/04/06	8:30am	27.5	0.4	7.6	118	3.0	16	38	130	60	70	6	1.4	1.8	17.5
D4	18/04/06	8:45 am	28.0	0.7	7.8	105	5.4	12	26	110	70	60	10	0.9	2.9	15.4
D5	20/04/06	8:00 am	25.2	0.4	7.0	130	4.7	10	16	120	90	30	6	0.14	1.8	14.2
D6	20/04/06	8:20 am	25.9	0.3	7.4	140	5.3	12	18	160	70	90	10	1.6	2.9	16.4

(Source: Primary Data as analyzed at RETCEN)

Table 4.3:- Average Values (Post-monsoon, 2005)

Sampling Station	Temp. (^0C)	Temp. Variation (^0C)	pH	Conductivity µ mho/cm	DO mg/l	BOD mg/l	COD mg/l	TS mg/l	TDS mg/l	TSS mg/l	Turbidity NTU	NO_3 mg/l	PO_4 mg/l	Cl mg/l
D1	25.2	0.5	7.3	125	5.2	8	18.6	233	70	163	19	1.8	2.3	12.2
D2	25.6	0.5	7.5	158	3.8	12.6	22.6	160	90	70	7	2.5	3.4	15.0
D3	26.8	0.3	7.7	155	3.3	16	36	153	70	90	12	1.9	2.9	15.8
D4	25.3	0.6	7.8	102	5.1	9.3	32.6	130	74	56	11	1.4	3.9	15.7
D5	27.8	0.3	7.5	123	6.5	7.3	11.5	113	70	43	7	0.17	1.9	13.3
D6	28.3	0.2	7.4	185	5.2	13.3	20	210	80	130	15	2.3	3.9	16.6

(Source: Primary Data as analyzed at RETCEN)

Table 4.4:- Average Values (Pre-monsoon, 2006)

Sampling Station	Temp. (^0C)	Temp. Variation (^0C)	pH	Conductivity µ mho/cm	DO mg/l	BOD mg/l	COD mg/l	TS mg/l	TDS mg/l	TSS mg/l	Turbidity NTU	NO_3 mg/l	PO_4 mg/l	Cl mg
D1	26.2	0.5	7.2	112	4.7	10	16	153	90	63	13	0.9	1.3	12.9
D2	27.1	0.5	7.4	113	3.6	13	26	130	80	50	6	1.6	2.3	15.4
D3	26.7	0.3	7.5	124	3.2	14	36	163	83	80	9	1.7	2.7	17.0
D4	27.2	0.6	7.5	114	4.9	10	32	120	77	43	9	1.1	3.0	15.6
D5	26.1	0.3	7.2	110	4.8	9	15	103	63	40	7	0.15	1.3	13.5
D6	26.6	0.2	7.3	170	5.5	13	19	166	83	83	10	1.6	2.9	16.5

(Source: Primary Data as analyzed at RETCEN)

Table 4.5:- Base Year Water Quality Data (1989, Seasonal Mean)

Season	Sampling Station	Temp. (°C)	pH	Conductivity µ ho/cm	DO mg/l	BOD mg/l	COD mg/l	Turbidity NTU	NO_3 mg/l	PO_4 mg/l	Cl mg/l	SO_4 mg/l	Total Alkalinity as $CaCo_3$ mg/l	NH_3 mg/l
Post-Monsoon	D1	21.7	6.8	103	5.9	4	14	10	0.2	0.65	13.4	8.1	44.9	1.05
	D2	22.5	6.6	110	6.1	2	13	10	0.3	0.60	10.1	8.0	40.0	0.70
	D3	23.2	6.8	103	5.7	3	18	11	0.41	0.82	14.0	17.1	53.8	1.00
	D6	21.5	6.9	109	6.0	2	12	12	0.2	0.70	8.0	8.1	40.0	0.80
Pre-Monsoon	D1	20.5	6.3	103	6.2	3	11	9	0.25	0.65	14.0	8.2	44.3	1.10
	D2	23.0	6.6	103	5.9	2	12	9	0.30	0.65	10.0	7.2	38.7	0.85
	D3	21.8	6.8	110	6.1	3	18	8	0.40	0.80	13.7	16.1	52.1	0.95
	D6	20.0	6.9	103	6.6	2	13	9	0.20	0.65	8.1	7.1	40.2	0.83

(Source: PhD Thesis of D.K.Baruah)

These parameters are discussed below:

4.2.1.1 *Temperature*

Temperature is a critical water quality and environmental parameter because it governs the kinds and types of aquatic life, regulates the maximum dissolved oxygen concentration of the water, and influences the rate of chemical and biological reactions. The higher the water temperature, the higher is the rate of chemical and metabolic reactions. Seasonal variations in stream temperature may be caused by changing air temperature, solar angle, meteorological events, and a number of physical aspects related to the stream and watershed such as stream origin, velocity, vegetation types and coverage, stream configuration and land-use.

The temperature values were recorded at site at the time of sampling. The variation in temperature recorded at the various sampling location is mainly due to the variation of time of collection. Fig. 4.2 shows the temporal and spatial variation of Temperature.

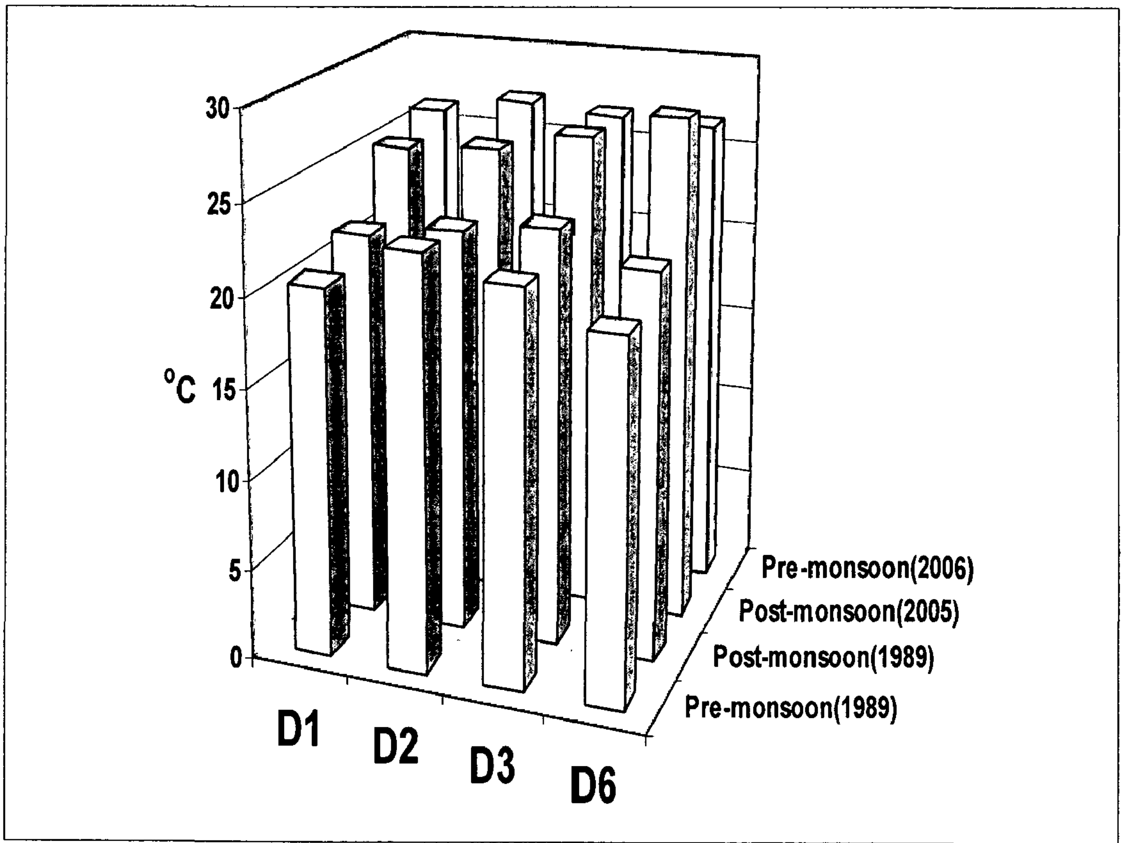


Fig. 4.2:- Temporal and Spatial Variation of Temperature

4.2.1.2 *Negative Log Hydrogen Ion Concentration (pH)*

The pH measured for the year 2005-06 was observed to vary from 7.2 to 7.8. IS 2296-1963 and USPH standards have specified pH value between 6.0 to 9.0 and 6.0 to 8.5 respectively for domestic water supply. Thus, the wetland water is safe for domestic water supply including drinking, swimming, outdoor bathing, etc. with regards to pH. As per CPCB, for Class 'D' water body i.e. for DBU 'Propagation of Wildlife and Fisheries', the pH value ranges from 6.5 to 8.5. Thus, the wetland water is suitable for fishery also, from the view point of pH.

From secondary data, it was observed that in the base year (1989), the pH value varied from 6.3 to 6.9. Thus, within a course of 16 years the water quality of the wetland has changed from slightly acidic to slightly alkaline. Fig. 4.3 shows the temporal and spatial variation of pH.

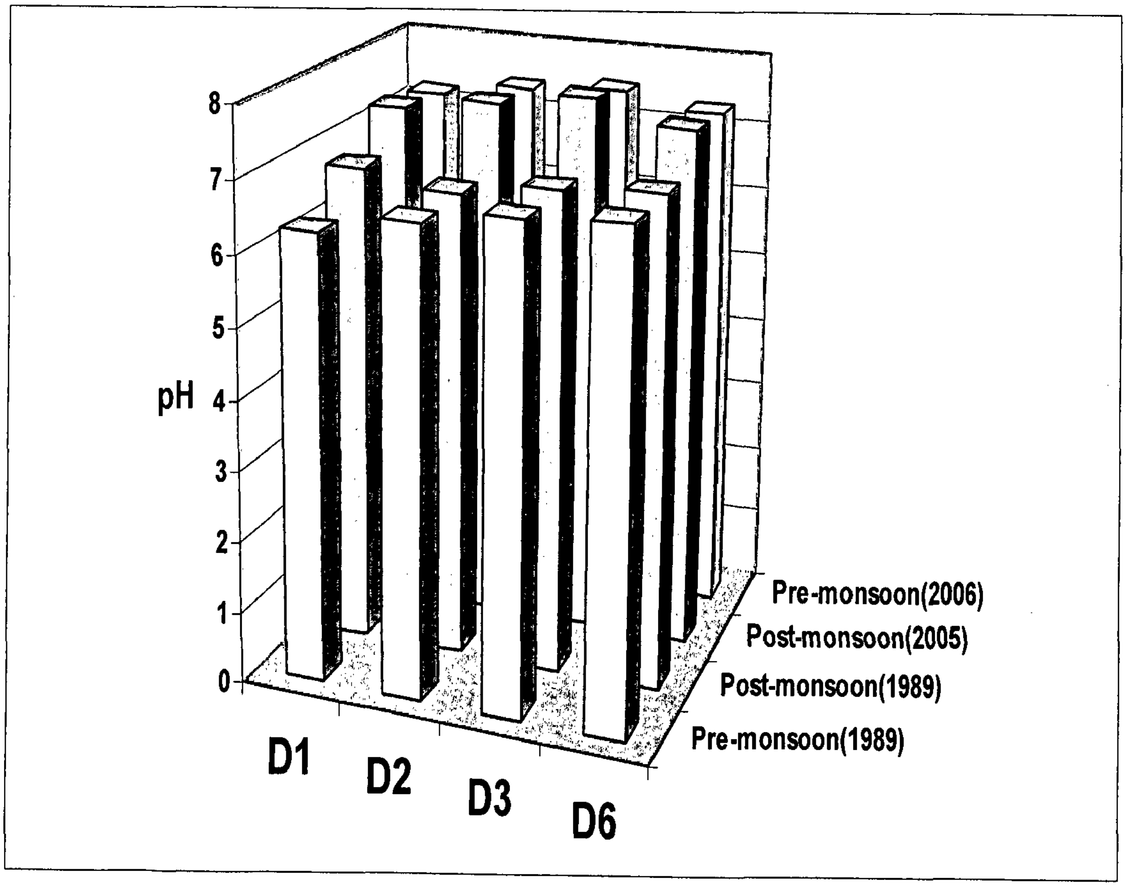


Fig. 4.3:- Temporal and Spatial Variation of pH Value

4.2.1.3 *Dissolved Oxygen (DO)*

DO is an essential requirement for aquatic life. It indicates the overall health of the water body. The solubility of atmospheric oxygen in fresh water ranges from 14.6 mg/l at 0°C to about 7 mg/l at 35°C under 1 atmospheric pressure. Generally in water bodies having DO less than 4 mg/l fish do not survive. If DO is nil, anaerobic condition prevail and anaerobic bacteria predominate and start oxidizing organic matter evolving H_2S and CO_2, which give rise to foul smell.

For the year 2005-06, the DO value was observed to vary from 3.24 mg/l to 6.54 mg/l at the various sampling locations. The DO value at sampling locations D1 (inlet channel) and D5 (middle of the wetland) was much higher than at D2 (residential area) and D3 (industrial area). DO at D1 and D5 was higher because of better mixing and less pollution load respectively.

In the base year the DO value was much higher, varying from 5.74 mg/l to 6.64 mg/l. Thus, due to the inflow of pollution load (domestic sewage, industrial wastes, human activities in the agricultural fields and other debris and solid waste washed down by rains) the DO value has come down substantially particularly at sampling locations D2 and D3. As per CPCB, the DO for Class C and Class D water body should be at least 4.0 mg/l. As per USPH standards the DO for domestic water supplies should be at least 4.6 mg/l and as per IS: 2296, 1963, it should be at least 3.0 mg/l.

Fig. 4.4 to 4.13 shows the temporal and spatial variation of DO.

4.2.1.4 *Biochemical Oxygen Demand (BOD)*

BOD is defined as the amount of oxygen required by micro-organisms in stabilizing the biologically degradable organic matter present in water under aerobic conditions. The BOD value for the wetland water was found to fluctuate from 8 mg/l to 16 mg/l during post-monsoon (2005) and from 9 mg/l to 14 mg/l during pre-monsoon (2006) at the various sampling locations. It was observed that the BOD value was higher at sampling locations D2, D3 and D6. This was because D2 is located at residential area, D3 in between two industries and D6 is located near the agricultural fields in the southern banks of the wetland.

In the base year the BOD value was much lower, varying from 2 mg/l to 4 mg/l. Thus in a time span of 16 years, the BOD value has increased significantly due to the inflow of pollution load resulting from the change in land use of the catchment. As per CPCB, the BOD for Class C water body should be 3.0 mg/l or less.

Fig. 4.4 to 4.13 shows the temporal and spatial variation of BOD.

4.2.1.5 ***Chemical Oxygen Demand (COD)***

COD is the measure of oxygen consumed during oxidation of oxidizable organic matter by strong oxidizing agent. The COD value for the wetland water was found to fluctuate from 12 mg/l to 36 mg/l during post-monsoon (2005) and from 15 mg/l to 36 mg/l during pre-monsoon (2006) at the various sampling locations. It was observed that the COD value was higher at sampling locations D2, D3 and D4. This was because D2 is located at residential area, D3 at industrial area and D4 at the outlet channel (Khanajan River) which passes through residential area.

The base year COD value varied from 11 mg/l to 18 mg/l, which is much lower than the present values. Fig. 4.4 to 4.13 shows the temporal and spatial variation of COD.

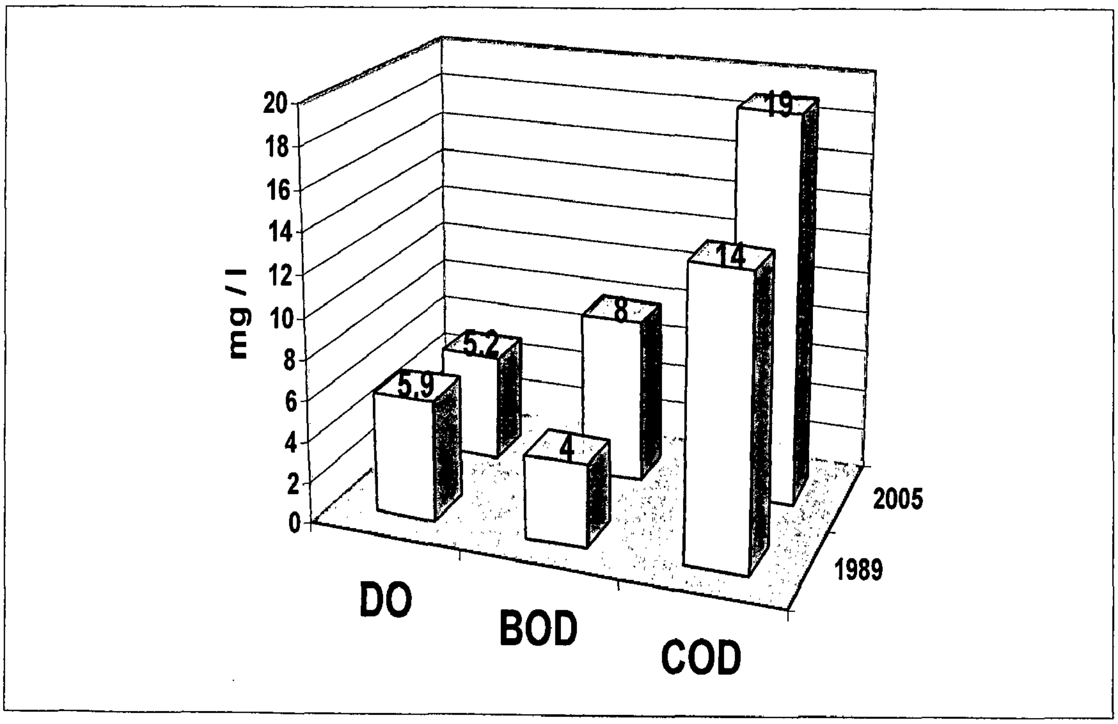


Fig. 4.4:- Temporal Variation of DO, BOD and COD at Sampling Location D1 for Post-monsoon Season

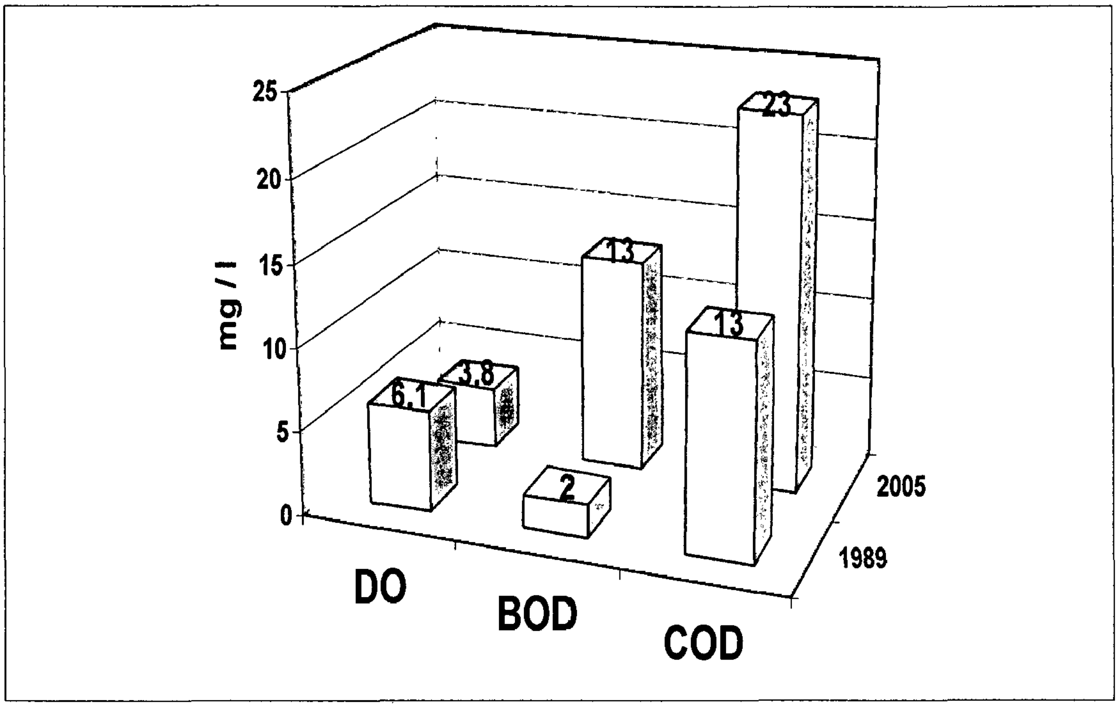


Fig. 4.5:- Temporal Variation of DO, BOD and COD at Sampling Location D2 for Post-monsoon Season

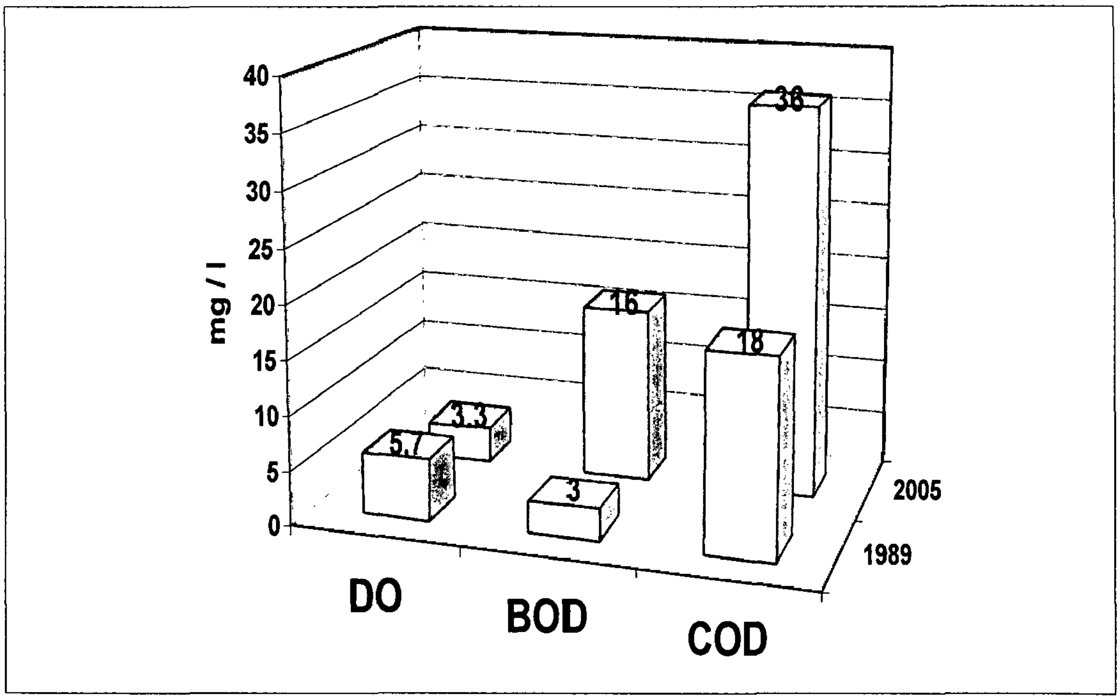


Fig. 4.6:- Temporal Variation of DO, BOD and COD at Sampling Location D3 for Post-monsoon Season

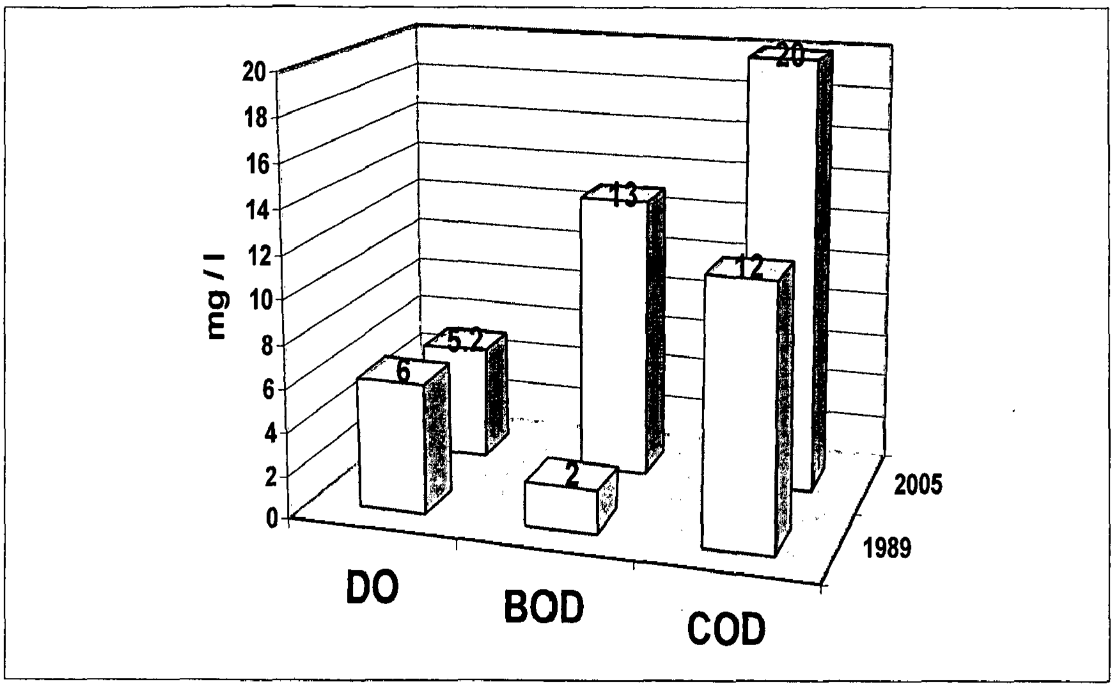


Fig. 4.7:- Temporal Variation of DO, BOD and COD at Sampling Location D6 for Post-monsoon Season

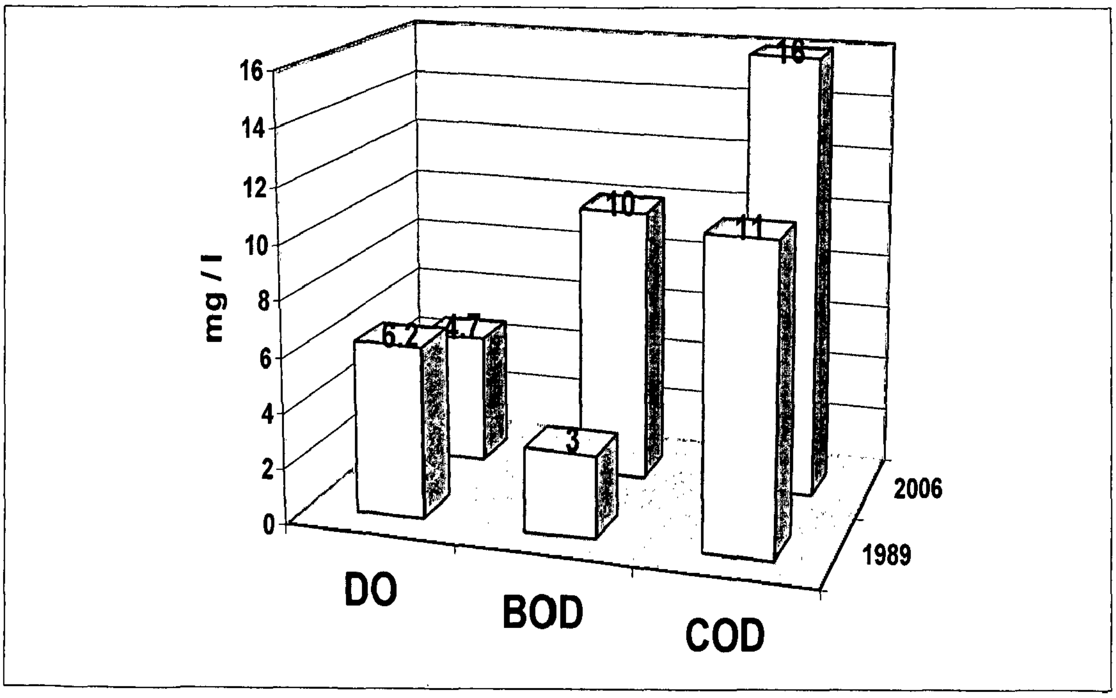


Fig. 4.8:- Temporal Variation of DO, BOD and COD at Sampling Location D1 for Pre-monsoon Season

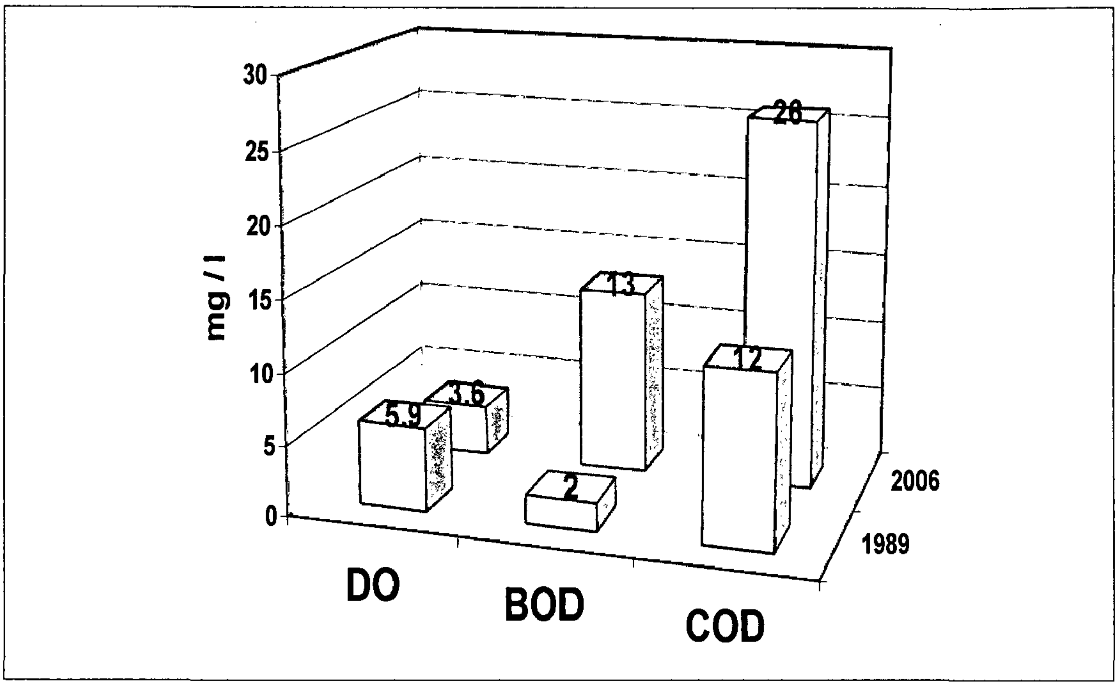


Fig. 4.9:- Temporal Variation of DO, BOD and COD at Sampling Location D2 for Pre-monsoon Season

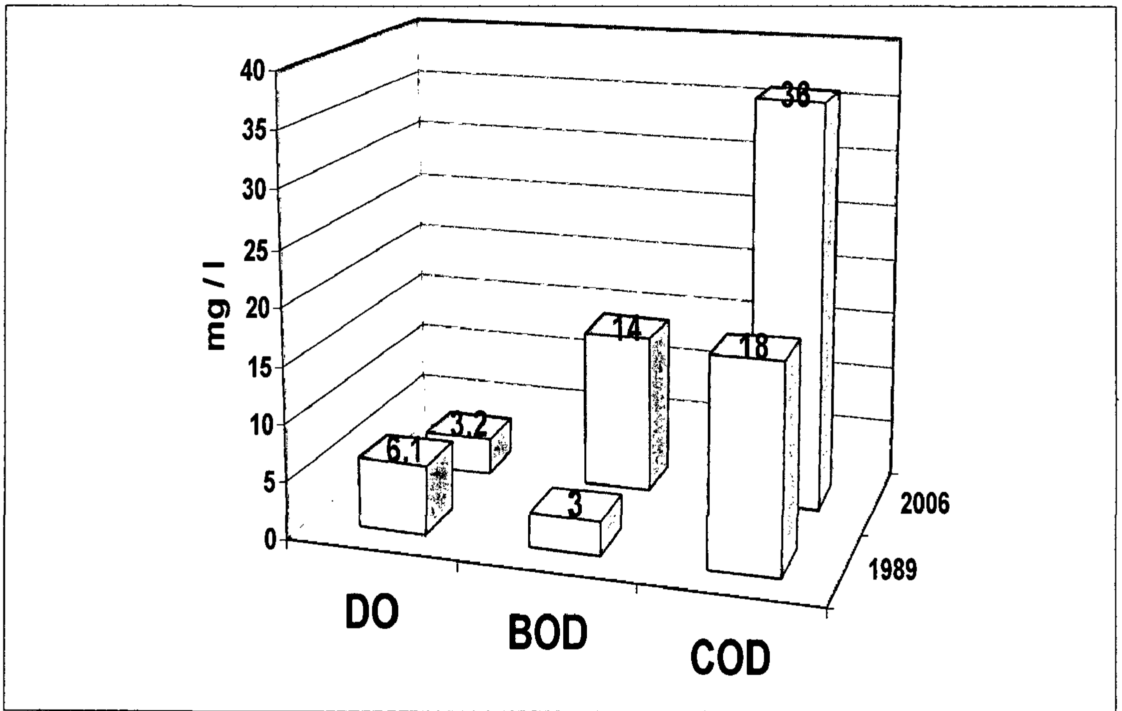


Fig. 4.10:- Temporal Variation of DO, BOD and COD at Sampling Location D3 for Pre-monsoon Season

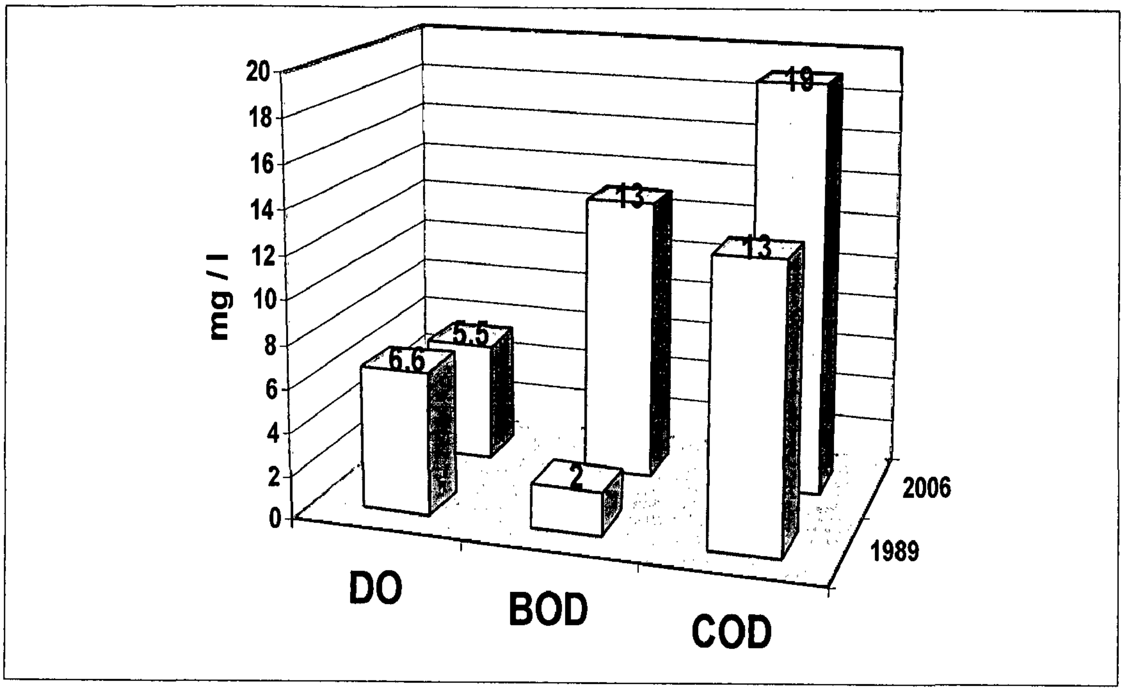


Fig. 4.11:- Temporal Variation of DO, BOD and COD at Sampling Location D6 for Pre-monsoon Season

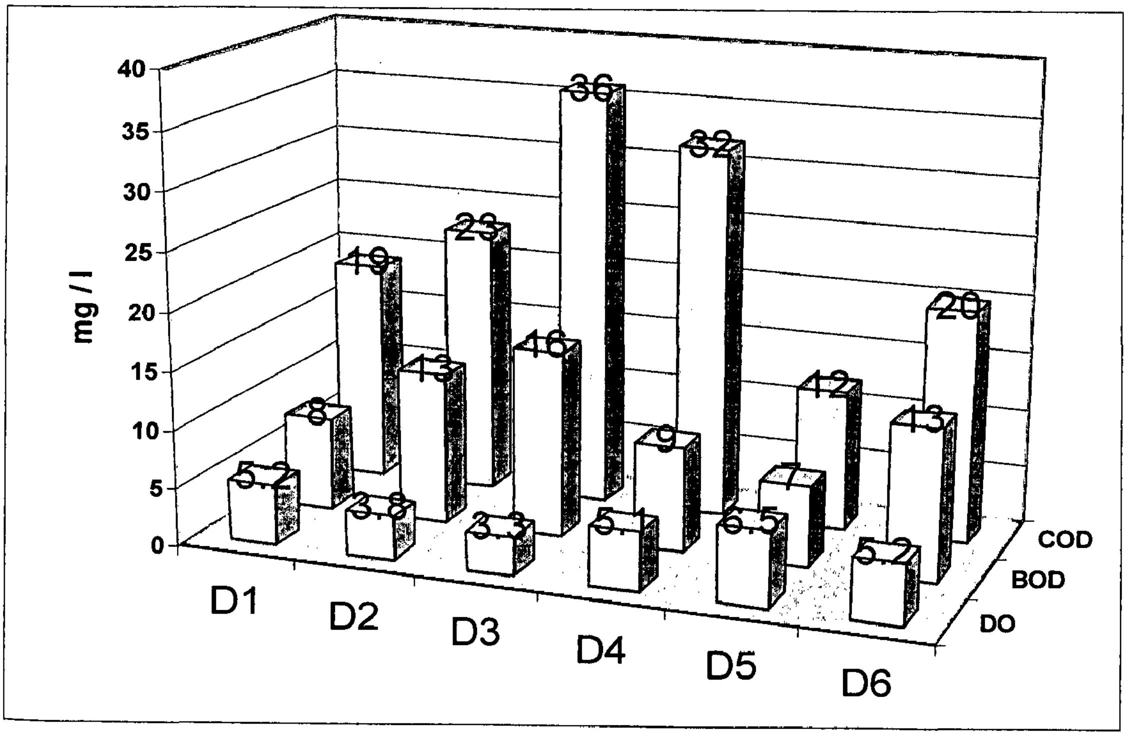


Fig. 4.12:- Spatial Variation of DO, BOD and COD for Post-monsoon Season (2005)

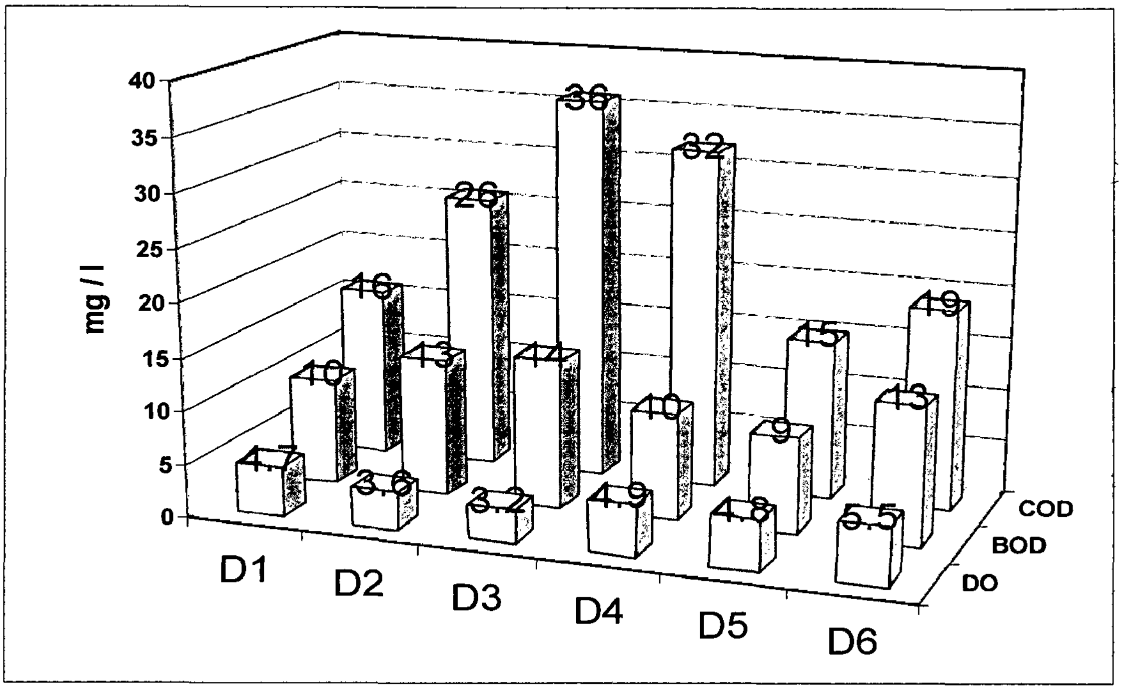


Fig. 4.13:- Spatial Variation of DO, BOD and COD for Pre-monsoon Season (2006)

4. 2.1.6 *Conductivity*

Conductivity is an indirect measure of total dissolved salts in water. The more the total dissolved salts in water, the more will be the value of conductivity. The temporal and spatial variation of conductivity is shown in Fig. 4.14.

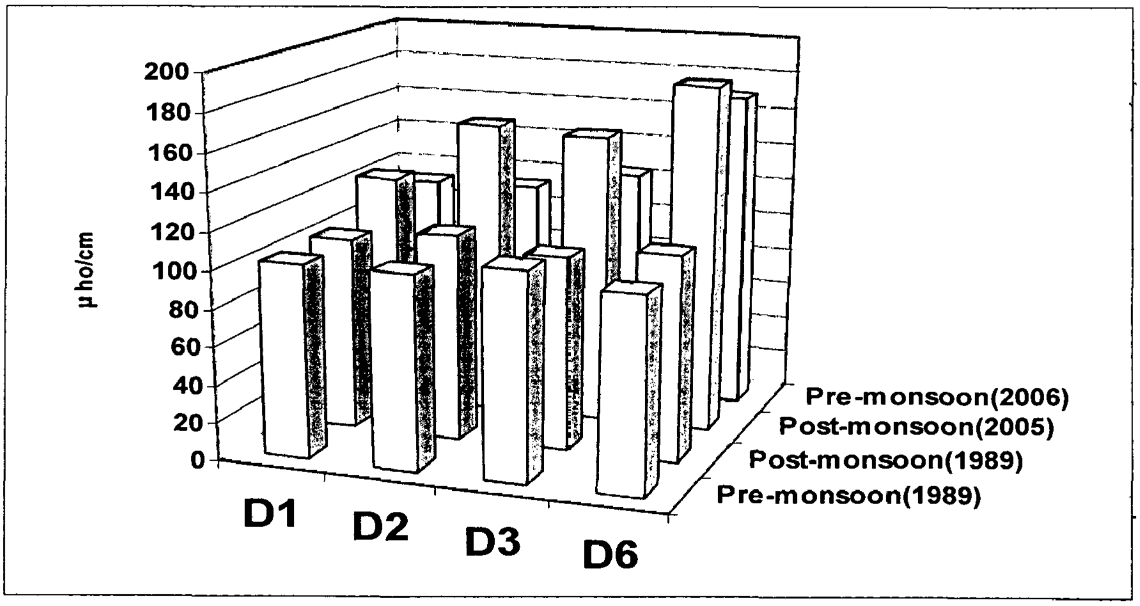


Fig. 4.14:- Temporal and spatial variation of Conductivity

During 2005-06 the conductivity at sampling location D6 was observed to be higher than that of the other sampling locations. This was due to the agricultural runoff from the southern fringe area. But, it is much lower than the USPH limit for domestic water supplies, which is 300 μmho/cm.

4.2.1.7 *Solids*

During the year 2005-06, the value of Total Solids (TS) was observed to vary from 103 mg/l to 233 mg/l, Total Dissolved Solids (TDS) from 63 mg/l to 90 mg/l and Total Suspended Solids (TSS) from 40 mg/l to 163 mg/l at the various sampling locations. This shows that there is a wide variation of Solids in all the sampling locations. The temporal and spatial variation of TDS and TSS is shown in Fig. 4.15 and 4.16.

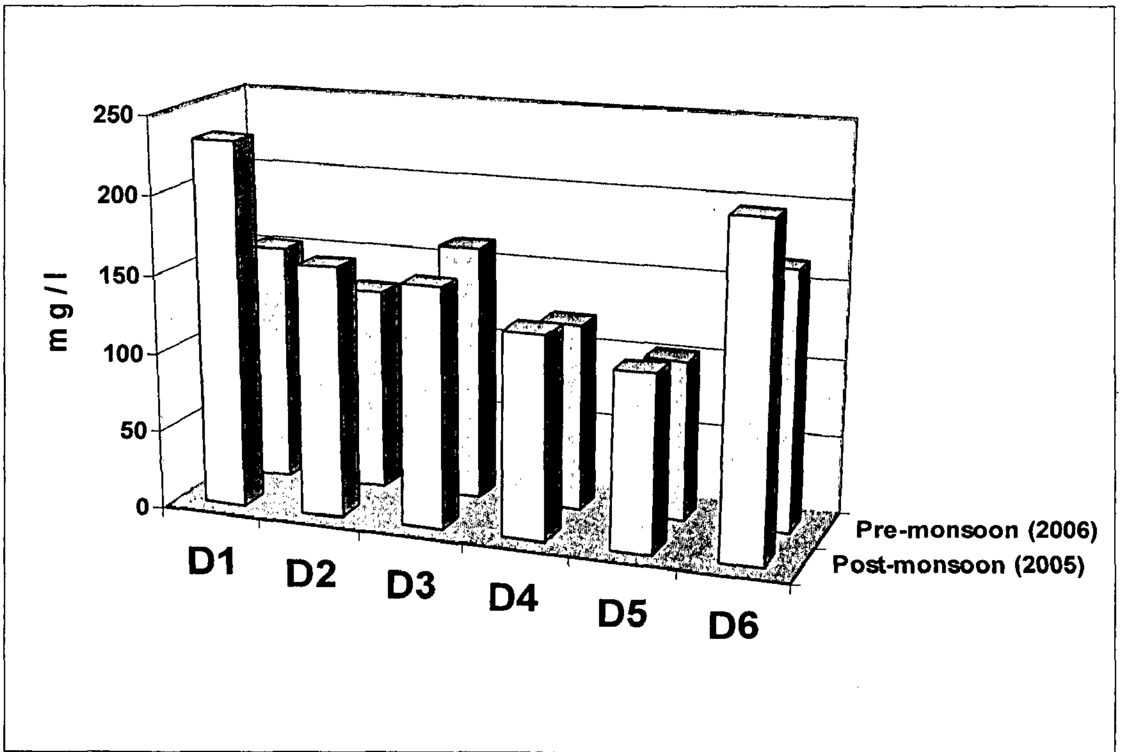


Fig. 4.15:- Temporal and spatial variation of Total Solids

The high value of TS and TSS at D1 and D6 during post-monsoon was due to the silt carried by runoff during the monsoon to the inlet, and from the agricultural fields (situated at the southern fringe area of the wetland) into the wetland respectively.

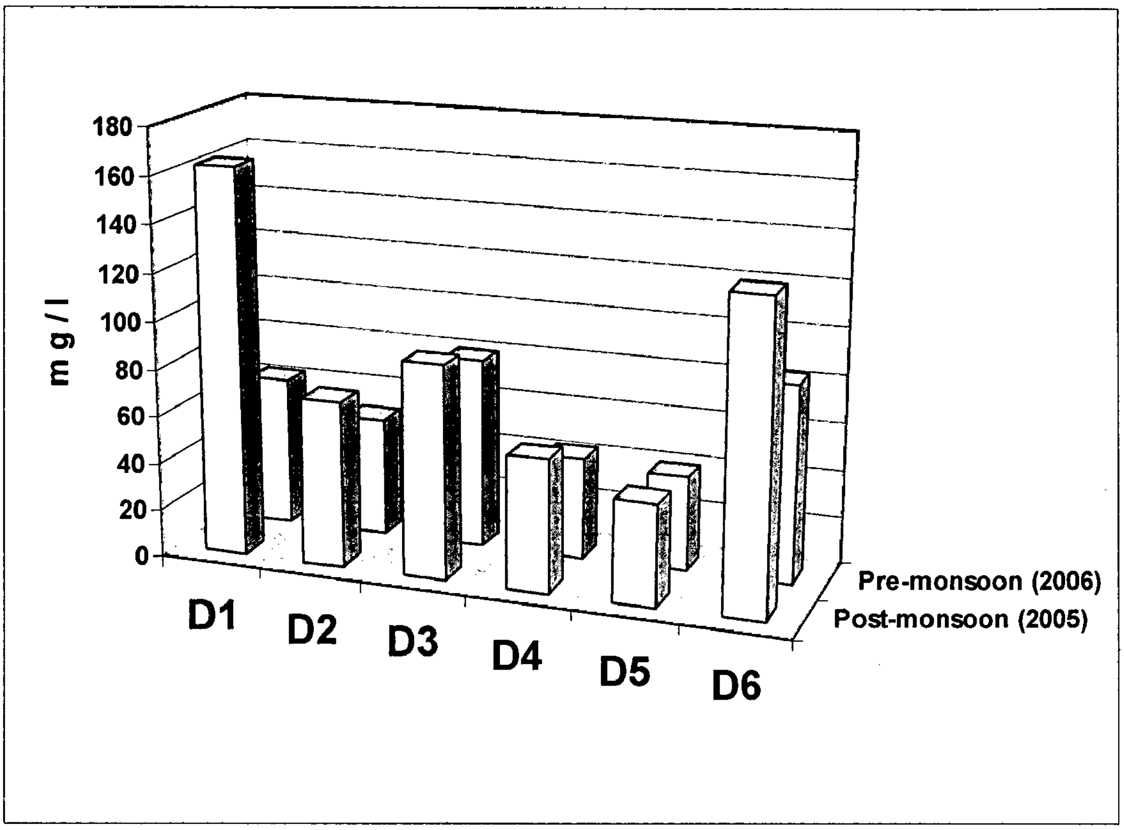


Fig. 4.16:- Temporal and spatial variation of Total Suspended Solids

4.2.1.8 ***Turbidity***

Turbidity depends on the fineness of the particles and on the scattering power of the particles. During post-monsoon (2005), the turbidity value varied from 7 NTU to 19 NTU and during pre-monsoon (2006), it varied from 6 NTU to 13 NTU at the various sampling locations. As in the case of TS and TSS, the turbidity value was also observed to be high at D1 and D6 during post-monsoon.

As per BIS: 10500, 1991, the maximum turbidity limit for drinking water is 10 NTU. It was observed that during post-monsoon (2005) the turbidity value was less than 10 NTU only at sampling locations D2 and D5 and during pre-monsoon (2006) the value was less than 10 NTU at D2, D3, D4 and at D5. Hence, with respect to turbidity the wetland water is not fit for drinking at all the locations. But with conventional treatment this value can be brought down within the prescribed limit. Low turbidity not only improves the aesthetics of the water body, but also leads to greater penetration of light resulting in better photosynthesis which ultimately improves the water quality. Fig. 4.17 shows the temporal and spatial variation of turbidity.

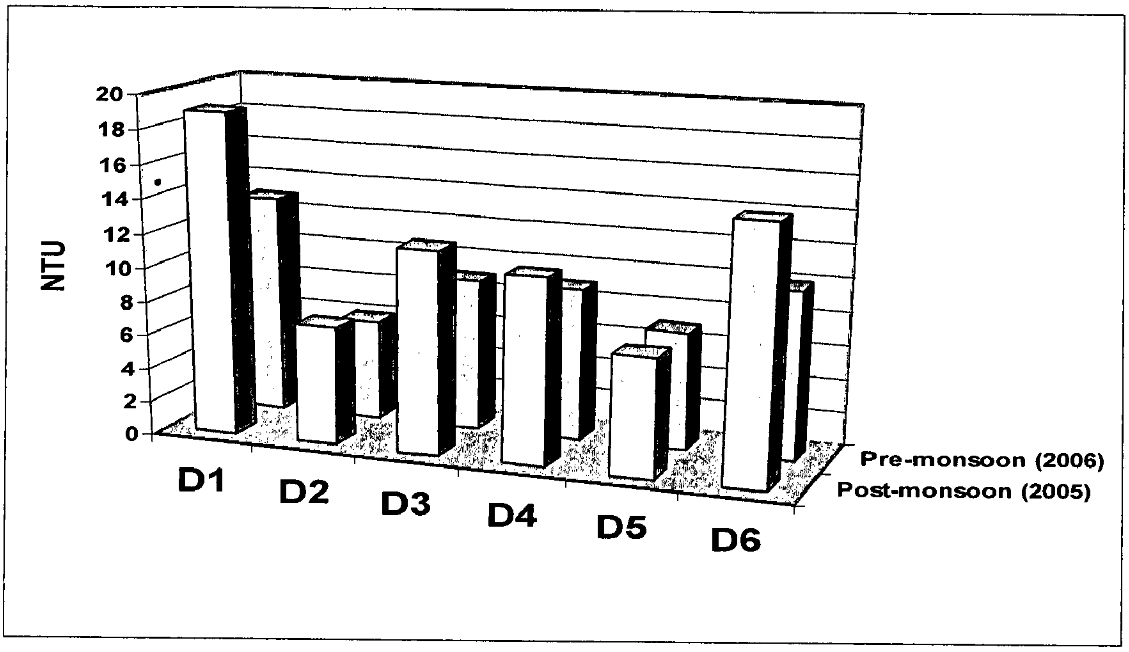


Fig. 4.17:- Temporal and spatial variation of Turbidity

4.2.1.9 ***Nitrates (NO_3)***

Nitrates are formed by the aerobic oxidation of NH_4-N and other nitrogenous organic compounds. Water that contain mostly organic and ammonia nitrogen are considered to have been recently polluted. On the other hand, water in which most of the nitrogen is in the form of nitrate are considered to have been polluted a long time previously.

During post-monsoon (2005), the nitrate value varied from 0.17 mg/l to 2.5 mg/l and during pre-monsoon (2006), it varied from 0.15 mg/l to 1.7 mg/l at the various sampling locations. There has been a substantial increase in nitrate since the base year. This was due to increase in the inflow of pollution load (domestic sewage, human and animal activities in the agricultural fields and other debris and solid waste washed down by rains). However, this increased value is well within the BIS prescribed limit for drinking water. According to BIS: 10500, 1991, the maximum concentration limit for nitrate is 100 mg/l. Fig. 4.18 shows the temporal and spatial variation of Nitrates.

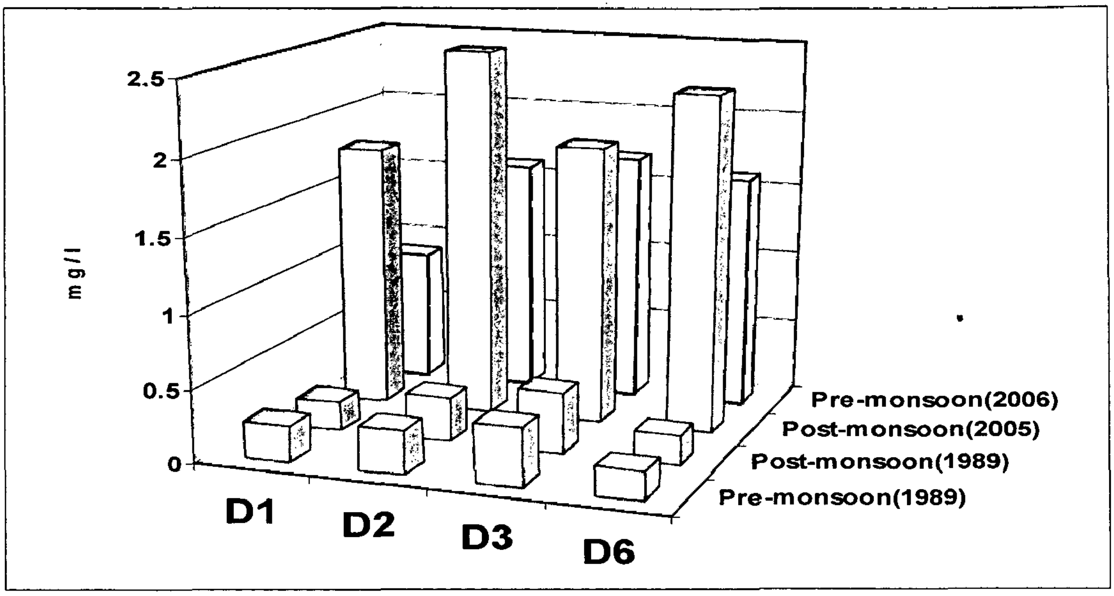


Fig. 4.18:- Temporal and spatial variation of Nitrate

4.2.1.10 *Phosphate (PO_4)*

In lakes and wetlands, phosphate is typically the limiting nutrient for algal bloom, although the presence of nitrate is also important. Fig. 4.19 shows the temporal and spatial variation of Phosphate. There has been a substantial increase in phosphate since the base year. During post-monsoon (2005), the phosphate value varied from 1.9 mg/l to 3.9 mg/l and during pre-monsoon (2006), it varied from 1.3 mg/l to 3.0mg/l at the various sampling locations.

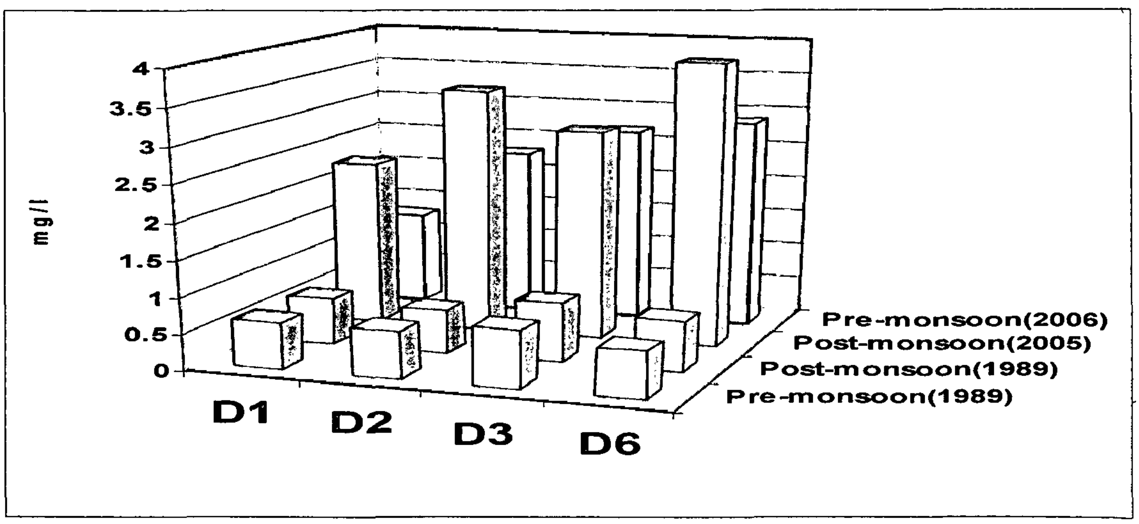


Fig. 4.19:- Temporal and spatial variation of Phosphate

According to Metcalf and Eddy [28], algal blooms will tend to occur if the concentration of inorganic nitrogen and phosphorous exceed respective values of 0.3 mg/l and 0.01 mg/ l. Thus, the high value of nitrate and phosphate is responsible for eutrophication in the wetland.

4.2.1.11 *Chloride*

Chlorides impart a particular taste to water rendering it unacceptable for the purpose of drinking. The Chloride concentration in the wetland water was found to be very low. During post-monsoon (2005), the Chloride value varied from 12.2 mg/l to 16.6 mg/l and during pre-monsoon (2006), it varied from 12.9 mg/l to 17.0 mg/l at the various sampling locations. The value for domestic water supply, according to BIS, USPH standards is 250 mg/l and according to WHO Guidelines it is 200 mg/l. Fig. 4.20 shows the temporal and spatial variation of Chlorides.

The maximum concentration of Chloride in the wetland water was found to be 17 mg/l. This value is very low in comparison with the standard value of 250 mg/l. As such, the wetland water has no adverse effect when used for agriculture and other purposes.

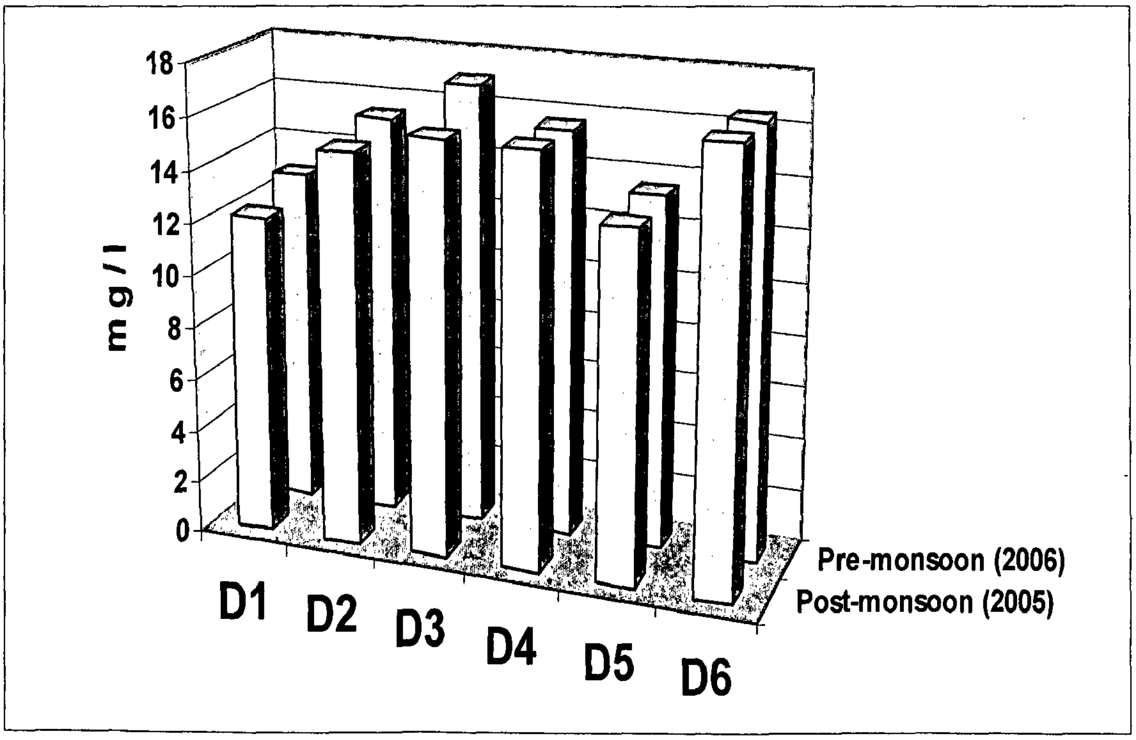


Fig. 4.20:- Temporal and spatial variation of Chlorides

4.2.2 Heavy Metal Pollution

Though there is no metal based cottage industry in the catchment area of Deeporbeel wetland, analysis for heavy metal was carried because a study conducted by Sharma et al. [13], inferred that there was accumulation of heavy metal in the aquatic plants (water hyacinth) in two locations of the wetland. In the study it was found that the absorption of heavy metal by water hyacinth in the Deeporbeel Wetland was higher than that of another water body which does not receive any domestic sewage and industrial effluent.

Accordingly, water samples preserved in nitric medium were brought and test for Pb, As, Hg, Zn and Mn at IIC, IIT Roorkee. The test results are shown in Table 4.6.

Table 4.6:- Analysis Results for Heavy Metal Concentration (2005 - 2006)

Heavy Metal	Station D1	Station D2	Station D3	Station D4	Station D5	Station D6	BIS Limit(ppm)
Pb (ppb)	6.839	2.889	2.877	3.418	6.973	13.979	0.05
As (ppb)	0.074	0.022	0.017	0.013	0.114	0.011	0.05
Hg (ppb)	0.210	0.343	0.266	0.260	0.221	0.017	0.001
Zn (ppb)	0.083	0.053	0.051	0.037	0.053	0.025	5.00
Mn (ppb)	0.001	0.034	0.032	0.136	0.090	0.072	0.10

(Source: Analysis carried out at the IIC, IIT Roorkee)

The above result shows that the heavy metal concentration in wetland water is much below the CPCB limit. The water hyacinth in the wetland acts as a water purifier by absorbing the heavy metals present thus lowers its concentration in water.

4.2.3 National Sanitation Foundation Water Quality Index (NSFWQI)

NSFWQI is calculated for pre-monsoon (1989), post-monsoon (1989), post-monsoon (2005) and pre-monsoon (2006). The sub-index values are shown in Table 4.7, 4.8, 4.9 and 4.10.

Table 4.7:- Sub-Index Value (Base Year, 1989, Pre-monsoon)

Parameter	Station D1		Station D2		Station D3		Station D6	
	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value
D.O.(mg/l)	6.2	73	5.9	72	6.1	74	6.6	77
pH	6.3	64	6.6	75	6.8	83	6.9	86
BOD (mg/l)	3	67	2	80	3	67	2	80
NO_3 (mg/l)	0.25	97	0.30	97	0.40	97	0.20	97
PO_4 (mg/l)	0.65	53	0.65	53	0.80	47	0.65	53
Temp. ^{0}C	20.5	-	23.0	-	21.8	-	20.0	-
Turbidity NTU	9	78	9	78	8	80	9	78

(Source: PhD Thesis of D.K.Baruah)

Table 4.8:- Sub-Index Value (Base Year, 1989, Post-monsoon)

Parameter	Station D1		Station D2		Station D3		Station D6	
	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value
D.O.(mg/l)	5.9	70	6.1	74	5.7	68	6.0	72
pH	6.8	83	6.6	75	6.8	83	6.9	86
BOD (mg/l)	4	61	2	80	3	67	2	80
NO_3 (mg/l)	0.2	97	0.30	97	0.41	97	0.2	97
PO_4 (mg/l)	0.65	53	0.60	55	0.82	46	0.70	50
Temp. ^{0}C	21.7	-	22.5	-	23.2	-	21.5	-
Turbidity NTU	10	76	10	76	11	74	12	72

(Source: PhD Thesis of D.K.Baruah)

Table 4.9:- Sub-Index Value (Post-monsoon, 2005)

Parameter	Station D1		Station D2		Station D3		Station D4		Station D5		Station D6	
	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value
D.O.(mg/l)	5.2	62	3.8	39	3.3	31	5.1	58	6.5	89	5.2	69
pH	7.3	93	7.5	93	7.7	91	7.8	90	7.5	93	7.4	93
BOD (mg/l)	8	42	12.6	26	16	18	9.3	37	7.3	45	13.3	24
NO_3 (mg/l)	1.8	95	2.5	93	1.9	95	1.4	96	0.17	97	2.3	94
PO_4 (mg/l)	2.3	25	3.4	19	2.9	22	3.9	17	1.9	28	3.9	17
Temp. ^{0}C	25.2		25.6		26.8		25.3		28.9		29.4	
Temp. Variation ^{0}C	0.5	91	0.5	91	0.3	92	0.6	91	0.3	92	0.2	92
Turbidity NTU	19	62	7	82	12	72	11	74	7	82	15	67
Total solids (mg/l)	233	68	160	78	153	79	130	81	113	82	210	71

Table 4.10:- Sub-Index Value (Pre-monsoon, 2006)

Parameter	Station D1		Station D2		Station D3		Station D4		Station D5		Station D6	
	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value
D.O.(mg/l)	4.7	54	3.6	36	3.2	29	4.9	58	4.8	55	5.5	72
pH	7.2	92	7.4	93	7.5	93	7.5	93	7.2	92	7.3	93
BOD (mg/l)	10	34	13	25	14	23	10	34	9	38	13	25
NO_3 (mg/l)	0.9	96	1.6	95	1.7	95	1.1	96	0.15	97	1.6	95
PO_4 (mg/l)	1.3	34	2.3	23	2.7	23	3.0	21	1.3	34	2.9	22
Temp. ^{0}C	26.2		27.1		26.7		27.2		26.1		26.6	
Temp. Variation ^{0}C	0.5	91	0.5	91	0.3	92	0.6	91	0.3	92	0.2	92
Turbidity NTU	13	70	6	84	9	78	9	78	7	82	10	76
Total solids (mg/l)	153	79	130	81	163	77	120	82	103	83	166	77

The summary of the Index Value for the base year and for 2005-06 is shown in Table 4.11 to 4.14.

Table 4.11:- Summary of Index Value (Base Year, 1989, Pre-monsoon)

Station No.	Calculated NSFWQI	Rating	Remarks
D1	72	Good	At the four sampling locations for Pre-monsoon season of the Base Year (1989) quality of the wetland water falls in the "Good Category".
D2	75	Good	
D3	74	Good	
D6	78	Good	

Table 4.12:- Summary of Index Value (Base Year, 1989, Post-monsoon)

Station No.	Calculated NSFWQI	Rating	Remarks
D1	73	Good	At the four sampling locations for Post-monsoon season of the Base Year (1989) quality of the wetland water falls in the "Good Category".
D2	76	Good	
D3	72	Good	
D6	76	Good	

Table 4.13:- Summary of Index Value (Post-monsoon, 2005)

Station No.	Calculated NSFWQI	Rating	Remarks
D1	67	Medium	At all the six sampling locations the quality of the wetland water falls in the "Medium Category". Thus, there has been deterioration in the water quality since the base year (1989).
D2	62	Medium	
D3	62	Medium	
D4	66	Medium	
D5	66	Medium	
D6	66	Medium	

Table 4.14:- Summary of Index Value (Pre-monsoon, 2006)

Station No.	Calculated NSFWQI	Rating	Remarks
D1	67	Medium	At all the six sampling locations the quality of the wetland water falls in the "Medium Category". Thus, there has been deterioration in the water quality since the base year (1989).
D2	63	Medium	
D3	60	Medium	
D4	67	Medium	
D5	69	Medium	
D6	69	Medium	

Fig. 4.21 and 4.22 shows the temporal and spatial variation of NSFWQI

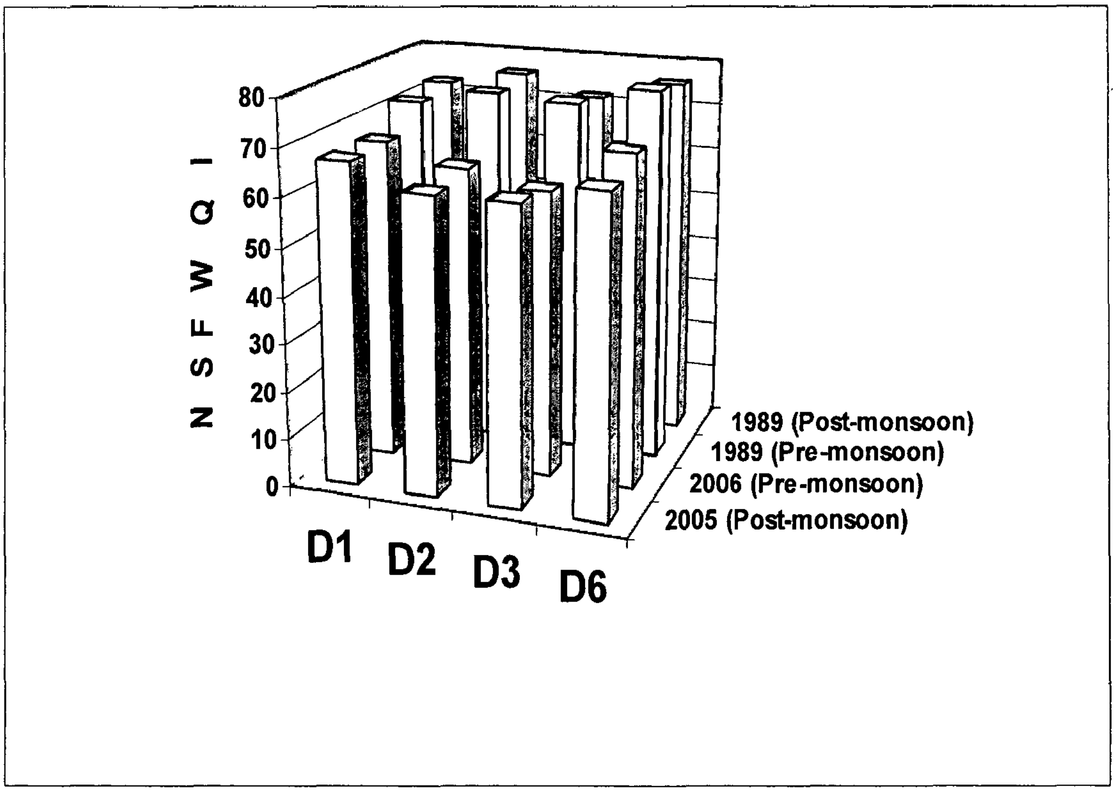


Fig. 4.21:- Temporal and Spatial Variation of NSFWQI

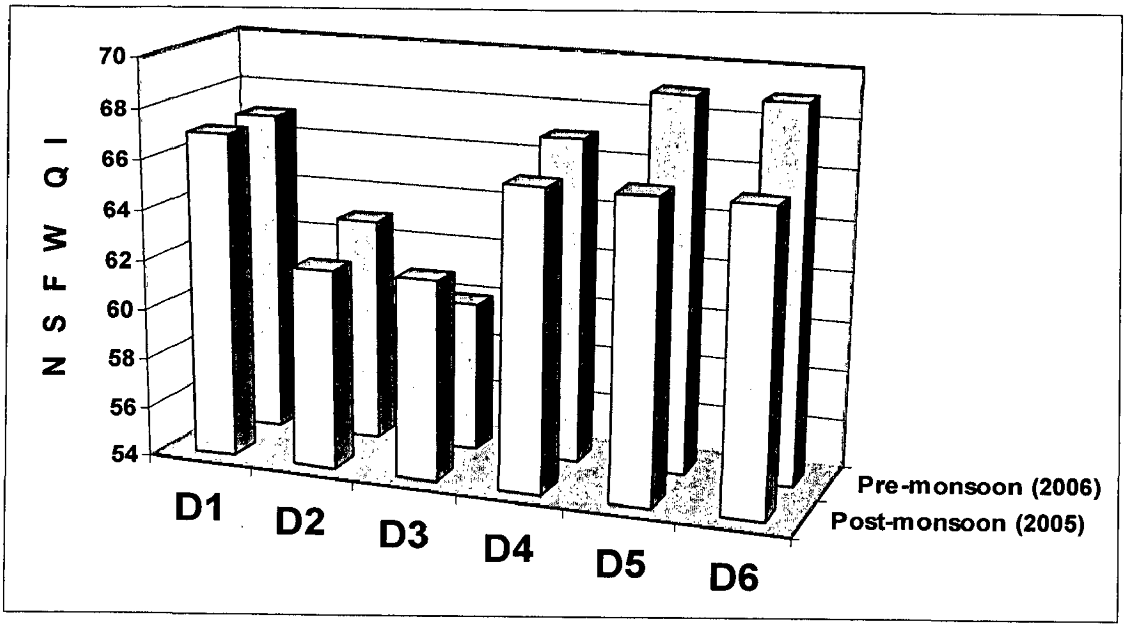


Fig. 4.22:- Temporal and Spatial Variation of NSFWQI

For sampling station D3, secondary data is available since 2002, apart from the base year data. Accordingly, the yearly average NSFWQI is calculated since 2002 and compared with the base year value. For the year 2005, the mean value is attained based on both primary and secondary data. The yearly mean water quality data of sampling location D3 is shown in Table 4.15 and the sub-index value in Table 4.16. The summary of the Index Value is shown in Table 4.17.

Table 4.15:-Yearly Mean Water Quality Data of Sampling Station D3

Year	Temp (^{0}C)	pH	DO mg/l	BOD mg/l	Turbidity NTU	NO_3 mg/l	PO_4 mg/l	Total Solids mg/l	Faecal Coliform MPN/ 100ml
1989	23.1	6.9	5.9	3	10	0.30	0.80	-	-
1990	23.7	7.1	6.0	3	12	0.25	0.81	-	-
2002	26.3	7.5	2.3	4	20	0.7	3.51	131	3×10^3
2003	28.0	7.5	5.8	3	12	1.0	3.2	115	18×10^3
2004	24.7	7.3	5.8	5	20	1.9	2.23	153	700
2005	26.8	7.1	7.5	4	18	1.4	3.9	161	6×10^3

(Source: PhD Thesis of D.K.Baruah, Water Quality Report of PCBA and Analysis carried at RETCEN)

Table 4.16:- Average Sub-Index Value for Sampling Location D3

Parameter	1989		1990		2002		2003		2004		2005	
	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value	Value	Sub-index value
D.O.(mg/l)	5.9	72	6.0	76	5.8	76	5.8	73	6.5	84	6.2	82
Faecal Coliform MPN/100ml	-	-	-	-	3×10^3	16	18×10^3	8	700	25	6×10^3	13
pH	6.9	86	7.1	90	7.5	93	7.5	93	7.3	93	7.1	90
BOD (mg/l)	3	67	3	67	4	61	3	67	5	56	4	61
NO_3 (mg/l)	0.30	97	0.25	97	0.70	96	1.0	96	1.9	95	1.4	96
PO_4 (mg/l)	0.80	47	0.81	46	3.51	19	3.2	20	2.23	26	3.9	17
Temp. ^{0}C	23.1	-	23.7	-	26.3	-	28.0	-	24.7	-	26.8	-
Turbidity NTU	10	76	12	72	20	61	12	72	20	61	18	63
Total solids (mg/l)	-	-	-	-	131	81	115	82	153	79	161	78

Table 4.17:- Summary of Index Value for Sampling Location D3

Year	Calculated NSFWQI	Rating	Remarks
1989	74	Good	At sampling location D3, the base year water quality of the wetland falls in the "Good Category". However, since the year 2002 to 2005 the quality of the wetland water falls in the "Medium Category".
1990	75	Good	
2002	61	Medium	
2003	60	Medium	
2004	64	Medium	
2005	60	Medium	

Fig. 4.23 shows the temporal variation of NSFWQI for sampling location D3.

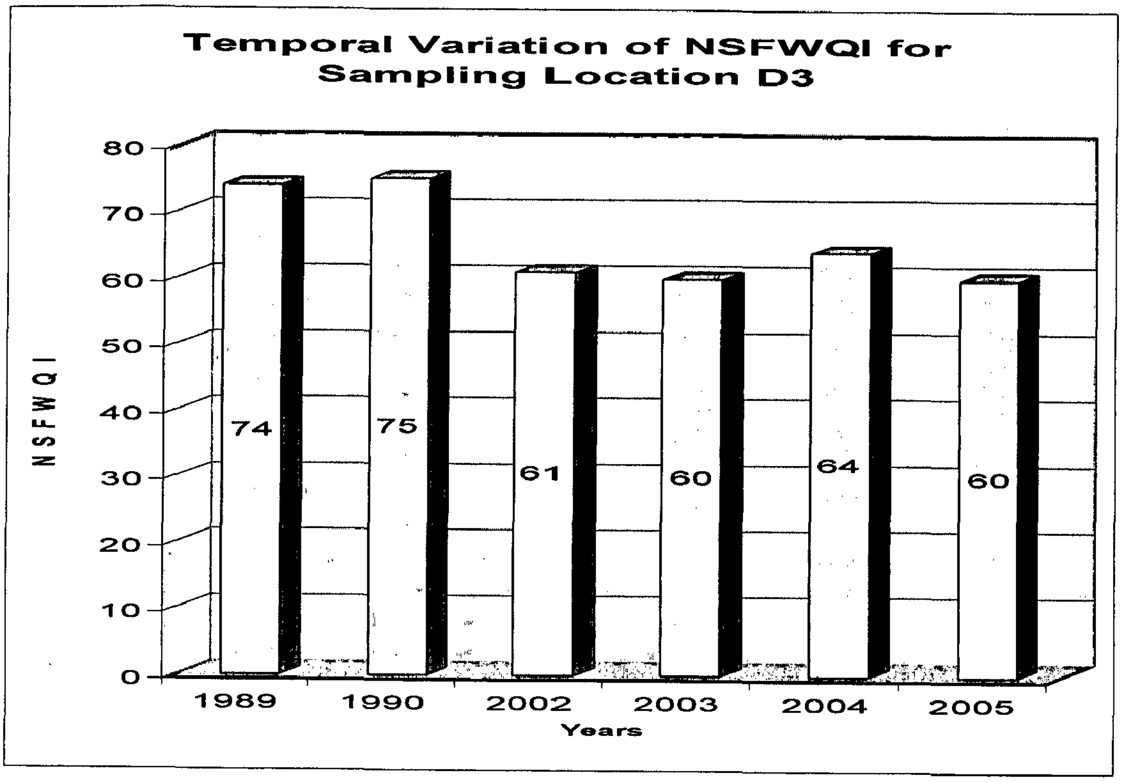


Fig. 4.23:- Temporal Variation of NSFWQI for Sampling Location D3

4.2.4 Statistical Analysis (F Test)

Statistical Analysis using F test of the equality of two variances was done for nine parameters viz. BOD, DO, COD, pH, Conductivity, Turbidity, Cl, NO_3 and PO_4. The difference in means for the parameters was studied for three time periods, viz.

- Between Pre-monsoon (1989) and Pre-monsoon (2006)
- Between Post-monsoon (1989) and Post-monsoon (2005)
- Between Post-monsoon (2005) and Pre-monsoon (2006)

The difference in means between Pre-monsoon (1989) and Pre-monsoon (2006) for BOD is shown as sample calculation.

Table 4.18:- Variation of BOD means between Pre-monsoon (1989) and Pre-monsoon (2006)

Sampling Station Code	Pre-monsoon (1989)	Pre-monsoon (2006)
D1	3	10
D2	2	13
D3	3	14
D4	-	10
D5	-	9
D6	2	13
Average, $\bar{x}=$	2.5	11.5
$\sum(x_i - \bar{x})^2 =$	1	21.5
Variance, $\frac{\sum(x_i - \bar{x})^2}{(n-1)} =$	0.33	4.3

Null Hypothesis: There is no significant difference between means with respect to time.

Alternative Hypothesis: There is significant difference between means with respect to time.

$$F = \frac{S_2^2}{S_1^2}$$

$$= \frac{4.3}{0.33}$$

$= 13.03 > 9.01$, the value of $F_{0.05}$ for $\upsilon_1 = 5$ and $\upsilon_2 = 3$

υ_1 = degree of freedom for numerator

$= n_1 - 1$

υ_2 = degree of freedom for denominator

$= n_2 - 1$

Hence, the Null Hypothesis is rejected i.e. it can be concluded that the difference between the means with respect to time is significant.

The difference in means for all the nine parameters for the three time periods is tabulated in Table 4.19 to Table 4.21.

Table 4.19:- Difference in means between Pre-monsoon (1989) and Pre-monsoon (2006)

Parameter	S_1^2	S_2^2	Calculated F Ratio	$F_{0.05}$	Remarks
BOD	4.3	0.33	13.03	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
DO	0.76	0.03	25.33	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
COD	76	10	7.6	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
pH	0.07	0.02	3.5	5.41, for $\upsilon_1=3$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
Conductivity	535	12.3	43	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
Turbidity	6	0.25	24	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
Cl	8.3	2.7	3.07	5.41, for $\upsilon_1=3$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
NO_3	0.35	0.007	5	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is not significant
PO_4	0.60	0.006	100	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant

Table 4.20:- Difference in means between Post-monsoon (1989) and Post-monsoon (2005)

Parameter	S_1^2	S_2^2	Calculated F Ratio	$F_{0.05}$	Remarks
BOD	9.73	0.92	10.57	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
DO	1.31	0.01	131	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
COD	84	7	12.4	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
pH	0.04	0.02	2	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is not significant
Conductivity	904	14.3	63.2	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
Turbidity	22	0.92	23.9	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
Cl	8	2.8	2.9	5.41, for $\upsilon_1=3$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
NO_3	0.69	0.01	69	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant
PO_4	0.50	0.009	55.6	9.01, for $\upsilon_1=5$ & $\upsilon_2=3$	Difference among the means w. r. t. time is significant

Table 4.21:- Difference in means between Post-monsoon (2005) and Pre-monsoon (2006)

Parameter	S_1^2	S_2^2	Calculated F Ratio	$F_{0.05}$	Remarks
BOD	9.73	4.3	2.26	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
DO	1.31	0.76	1.72	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
COD	84	76	1.10	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
pH	0.04	0.02	2	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
Conductivity	904	535	1.69	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
Turbidity	22	6	3.7	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means with respect to time is not significant
Cl	2.8	2.7	1.04	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
NO_3	0.69	0.35	1.97	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant
PO_4	0.60	0.50	1.2	5.05, for $\upsilon_1=5$ & $\upsilon_2=5$	Difference among the means w. r. t. time is not significant

4.3 EROSION AND SILT DEPOSITION

The gross soil loss from the wetland catchment was estimated using USLE for the year 1996 and 2005 and compared with that of base year (1972).The sediment inflow was measured and the Delivery Ratio calculated.

4.3.1 Catchment Area Delineation

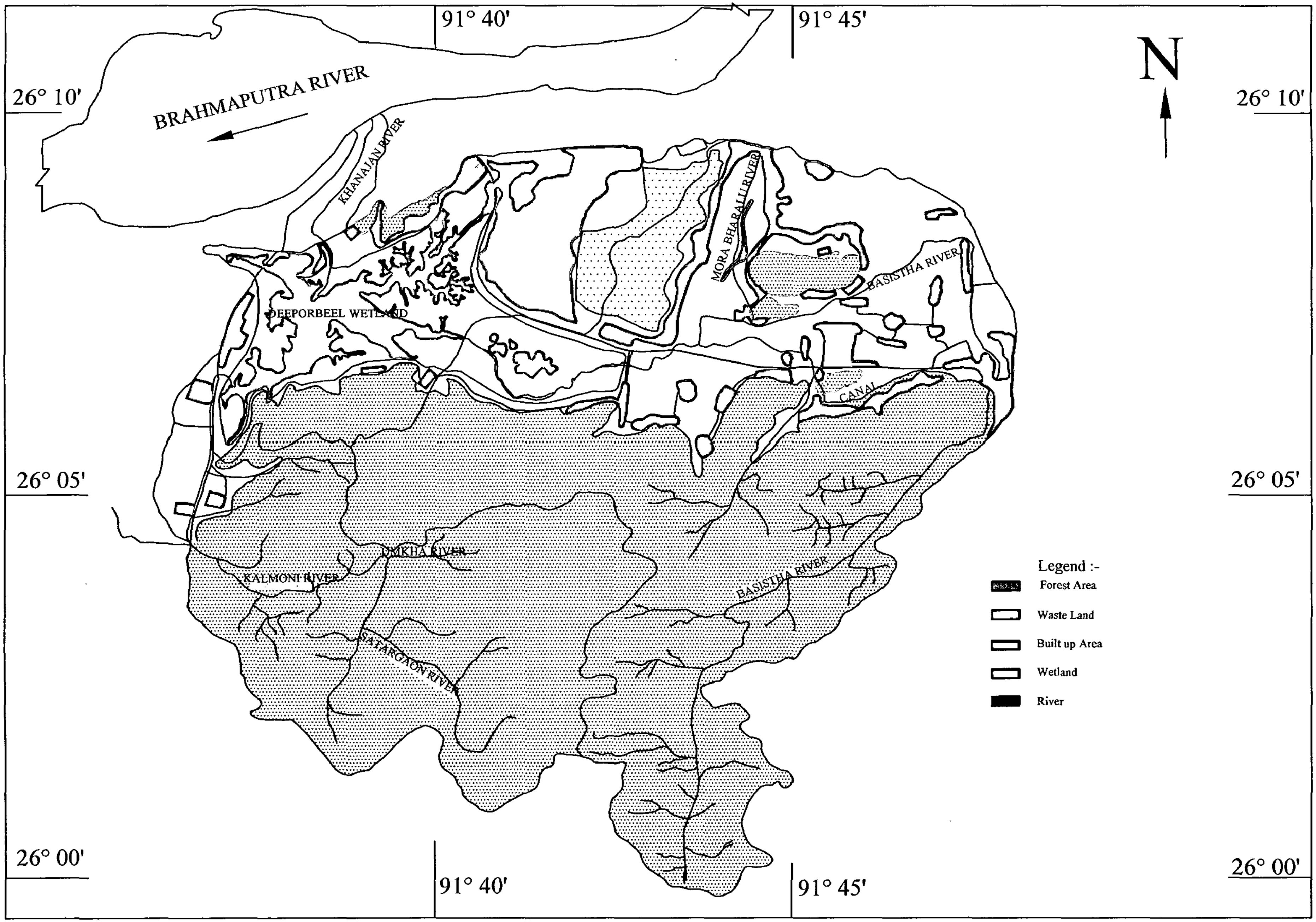
The catchment area has been delineated based on 1972 Toposheet. The Total catchment area has been sub-divided into three catchments, viz. catchment area for the main inlet channel (Basistha and Morabharalu River), catchment area for the second inlet channel (Kalmoni River) and catchment area contributing to direct run-off. Using Planimeter the catchment areas and land use area of each catchment have been calculated. The total area was found to be 220.20 km^2. The land use details of the catchment and the corresponding areas are shown in Table 4.22.

Table No 4.22:- Land Use Details of Catchment Area (As per 1972 Toposheet)

Sl. No.	Details	LU of Catchment of Basistha and Morabharalu River (km^2) (Catchment – I)	LU of Catchment of Kalmoni River (km^2) (Catchment – II)	LU of Catchment Contributing to Direct Run-Off (km^2) (Catchment– III)	Total (km^2)
1	Forest	79.10	42.20	13.40	134.70
2	Barren Land	1.40	-	4.70	6.10
3	Settlement Area	9.95	0.65	4.40	15.00
4	Grazing Land	7.90	1.00	4.00	12.90
5	Crop Land	31.60	3.90	16.00	51.50
	Total	129.95	47.75	42.50	220.20

Catchment Area of Wetland = 220.20 km^2
Extra Catchment Area for outlet (Khana River) = 3.10 km^2
Total Catchment Area = 223.30 km^2

The catchment area of the Deeporbeel Wetland (Based on 1972 Toposheet) is shown in Fig No. 4.24.


91° 40'
91° 45'
N
26° 10'
26° 10'
BRAHMAPUTRA RIVER
KHANAJAN RIVER
MORA BHARALU RIVER
BASISTHA RIVER
DEEPORBEEL WETLAND
CANAL
26° 05'
26° 05'
OMKHA RIVER
KALMONI RIVER
BASISTHA RIVER
SATARGAON RIVER
Legend :-
Forest Area
Waste Land
Built up Area
Wetland
River
26° 00'
26° 00'
91° 40'
91° 45'

4.3.2 Estimation of Gross Soil Loss

The gross soil loss from the wetland catchment has been estimated using USLE. The calculation for Catchment – I, i.e. catchment for the Basistha and Mora-bharalu River for the year 1972 is illustrated as an example.

4.3.2.1 *Estimation of Gross Soil Loss for the year 1972*

Catchment I:-

1. **Forest**

   Area = 7910 ha

   R = 702.53

   K = 0.12

   LS = 15.95

   C = 0.02

   P = 1

   Therefore, $A = R \times K \times LS \times C \times P$ t / (ha-year)

   = 26.89 t / (ha-year)

2. **Barren land**

   Area = 140 ha

   R = 702.53

   K = 0.22

   LS = 0.80

   C = 0.21

   P = 1

   Therefore, $A = R \times K \times LS \times C \times P$ t / (ha-year)

   = 25.97 t / (ha-year)

3. **Settlement Area**

   Area = 995 ha

   R = 702.53

   K = 0.22

   LS = 0.80

   C = 0.15

$P = 1$

Therefore, $A = R \times K \times LS \times C \times P$ t / (ha-year)

$= 18.55$ t / (ha-year)

4. **Grazing land**

Area = 790 ha

$R = 702.53$

$K = 0.22$

$LS = 0.80$

$C = 0.21$

$P = 1$

Therefore, $A = R \times K \times LS \times C \times P$ t / (ha-year)

$= 25.97$ t / (ha-year)

5. **Cropland**

Area = 3160 ha

$R = 702.53$

$K = 0.22$

$LS = 0.80$

$C = 0.27$

$P = 1$

Therefore, $A = R \times K \times LS \times C \times P$ t / (ha-year)

$= 33.38$ t / (ha-year)

Summary of Gross Annual Soil Loss for Catchment I

Forest = 26.89 × 7910 = 212,699 t /year

Barren land = 25.97 × 140 = 3,636 t /year

Settlement Area = 18.55 × 995 = 18,457 t /year

Grazing land = 25.97 ×790 = 20,516 t /year

Cropland = 33.38 × 3169 = 105,781 t /year

Total = 361,089 t /year

Therefore, rate of erosion per hectare per year = 361,089 / 12995

= 27.78 t / (ha-year)

The abstract of gross soil loss during the year 1972 is shown in Table 4.23.

Table 4.23: - Abstract of Gross Soil Loss during the year 1972

Sl. No	Details	Catchment of Basistha and Morabharalu River (Catchment – I)		Catchment of Kalmoni River (Catchment – II)		Catchment Contributing to Direct Run-off (Catchment–III)		Total	
		Area (km^2)	Soil Loss (t/year)	Area (km^2)	Soil Loss (t/yar)	Area (km^2)	Soil Loss (t/year)	Area (km^2)	Soil Loss (t/year)
1	Forest	79.10	212,699	42.20	97,187	13.4	27,135	134.7	337,021
2	Barren Land	1.40	3,636	-	-	4.7	12,206	6.1	15,842
3	Settlement Area	9.95	18,457	0.65	1,206	4.4	8,162	15.0	27,825
4	Grazing Land	7.90	20,516	1.00	2,597	4.0	10,388	12.9	33,501
5	Crop Land	31.60	105,781	3.90	13,018	16.0	53,408	51.5	172,207
	TOTAL	129.95	361,089	47.75	114,008	42.5	111,299	220.2	586,396

Therefore, the average annual rate of erosion per hectare = 26.63 t / (ha-year)

4.3.2.2 *Estimation of Gross Soil Loss for the year 1996 and 2005*

For the years 1996 and 2005, the land use statistics of the wetland catctment have been obtained from Assam Remote Sensing Application Centre (ARSAC), which are based on LISS-II and LISS-III satellite images respectively. The details are shown in Table 4.24.

Table 4.24: - Land Use Details of Catchment Area (As Per LISS-II Image, 1996 and LISS-III Image, 2005)

Sl. No.	DETAILS	LU OF CATCHMENT (As per LISS-II Image, 1996)	LU OF CATCHMENT (As per LISS-III Image, 2005)
1	Forest	127.33 (km^2)	116.89 (km^2)
2	Barren Land	10.98 (km^2)	18.36 (km^2)
3	Settlement Areas	51.22 (km^2)	54.72 (km^2)
4	Grazing Land	-	0.21 (km^2)
5	Crop Land	27.93 (km^2)	27.60 (km^2)
	TOTAL	217.46 (km^2)	217.78 (km^2)

For the years 1996and 2005, the total catchment is not divided into three sub-catchments as data for the total catchment only is available. The abstract of estimated gross soil loss for the base year (1972) and that for the year 1996 and 2005 are shown in Table 4.25.

Table 4.25:- Abstract of Gross Soil Loss during the year 1972 (Base Year), 1996 and 2005

Sl. No.	Details	Year					
		1972		1996		2005	
		Area (km^2)	Soil Loss (t/year)	Area (km^2)	Soil Loss (t/year)	Area (km^2)	Soil Loss (t/year)
1	Forest	134.70	337,021	127.33	321,381	116.89	294,796
2	Barren Land	6.10	15,842	10.98	28,756	18.36	48,048
3	Settlement Area	15.00	27,825	51.22	95,833	54.72	102,272
4	Grazing Land	12.90	33,501	-	-	0.21	550
5	Crop Land	51.50	172,207	27.93	94,068	27.60	92,874
	Total	220.20	586,396	217.46	540,038	217.78	538,540

The average annual soil loss during the base year has been estimated to be 26.63 t / (ha-year). During the year 1996 it was estimated to be 24.83 t / (ha-year) and during 2005 it was 24.73 t / (ha-year). This soil loss rate is within the current rate of soil loss from agricultural land in India i.e. 20 to 30 t / (ha-year), as reported by Das, 2002. The change in the soil loss rate is mainly due to the change in Land Use and variation in average annual rainfall, thus due to variation in the value of Rainfall Erosivity Index (R). The other factors viz. Soil Erodibility Factor (K), Slope Length Factor (L), Slope Steepness Factor (S), Crop Management Factor (C) and Conservation Practice Factor (P) are considered as same for the Base Year and for the year 2005.

From Toposheet and satellite image data, the change in land use since 1972 has been computed. It is found that the forest area in the wetland catchment has decreased by 13.22 %, barren land has increased by 33.22 %, settlement areas have increased by 27.41 %, grazing land has almost ceased to exist (98.37 % reduction) and agricultural land has decreased by 46.41 %. The value of R-factor for 1972 was 702.53 and for 2005 it was 708.06, the respective average annual rainfall being 1717.7 mm and 1732.94 mm. Although the R-factor value for 2005 was more than that of the base year, there has been a decrease in the soil erosion rate, which can be attributed to the change in land use particularly conversion of agricultural and grazing land into settlement areas. The decrease in forested area and increase in barren land has increased the soil erosion, but the rapid increase in the settlement area has decreased the overall soil erosion rate during the year 2005. Fig. 4.25, 4.26, 4.27 and 4.28 shows the percentage of the land use pattern in the wetland catchment and the percentage of the gross soil loss for the years 1972 and 2005.

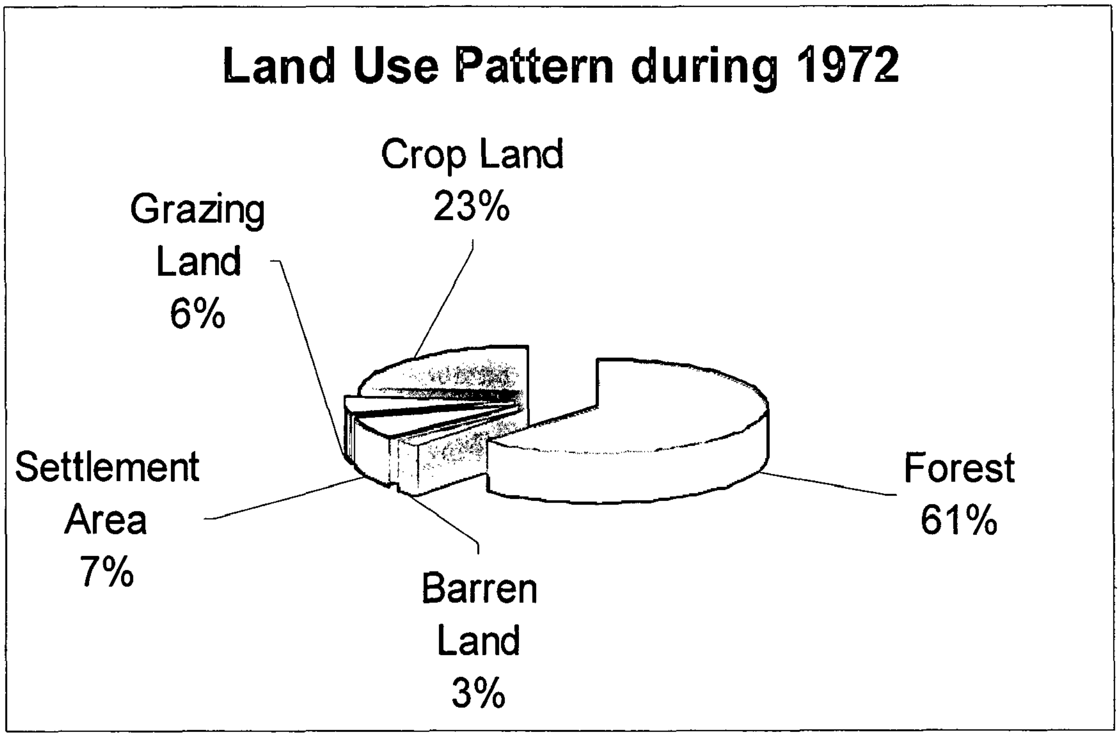


Fig. 4.25:- Land Use Pattern during 1972

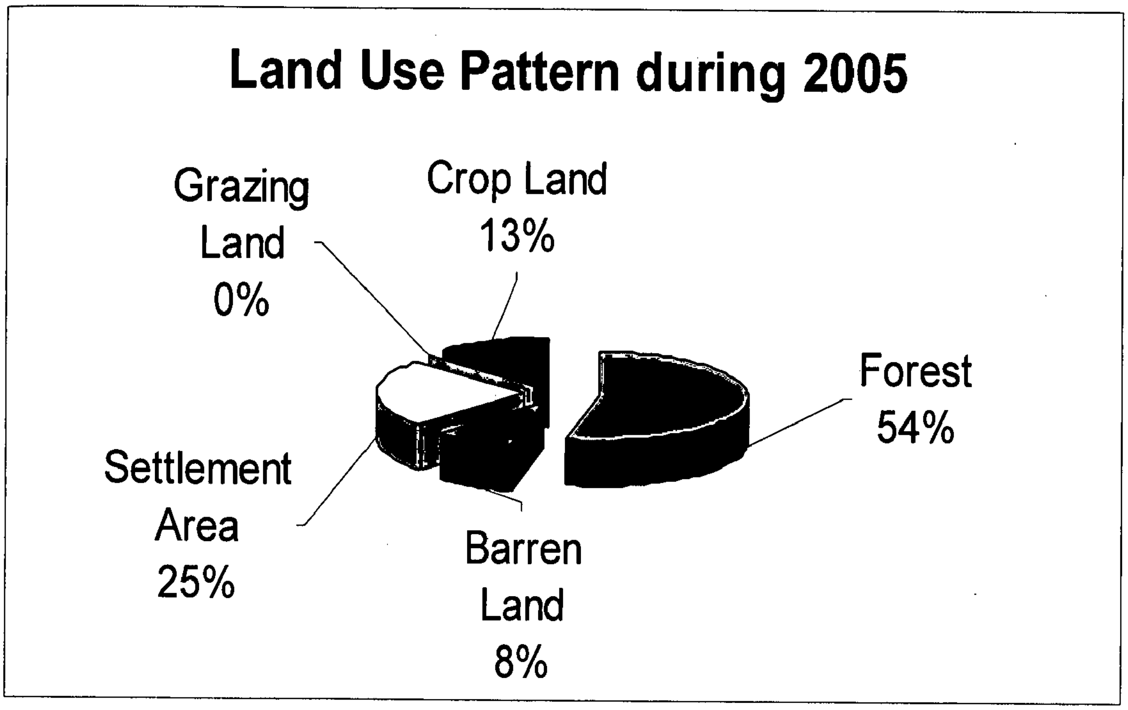


Fig. 4.26:- Land Use Pattern during 2005

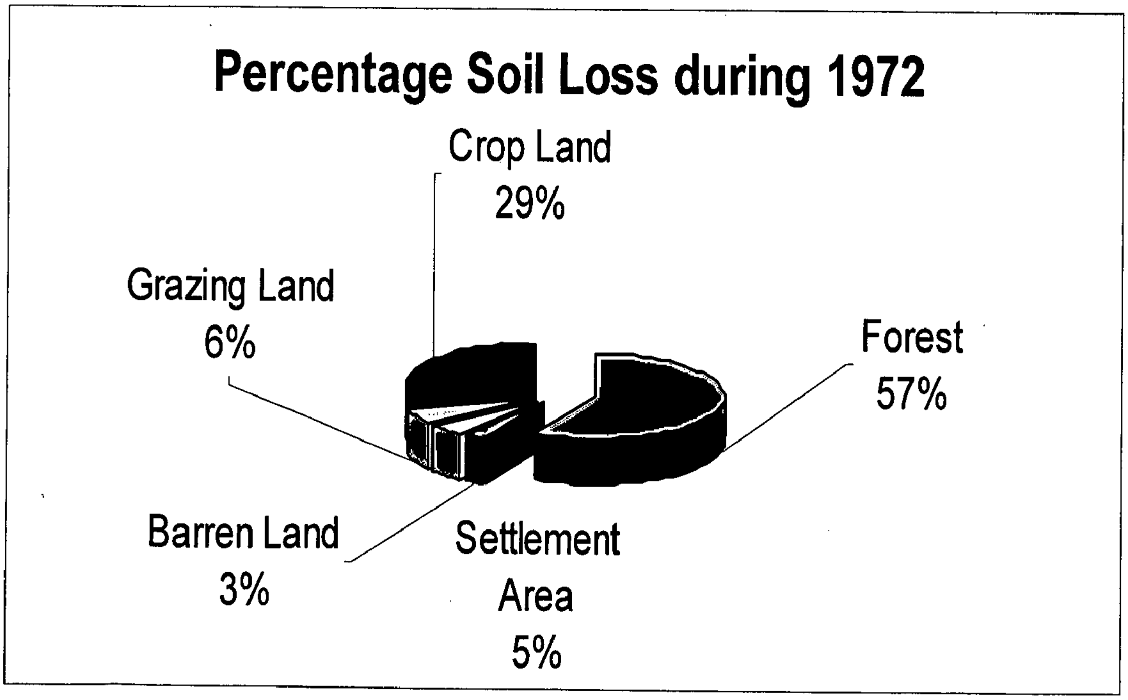


Fig. 4.27:- Percentage Soil Loss during 1972

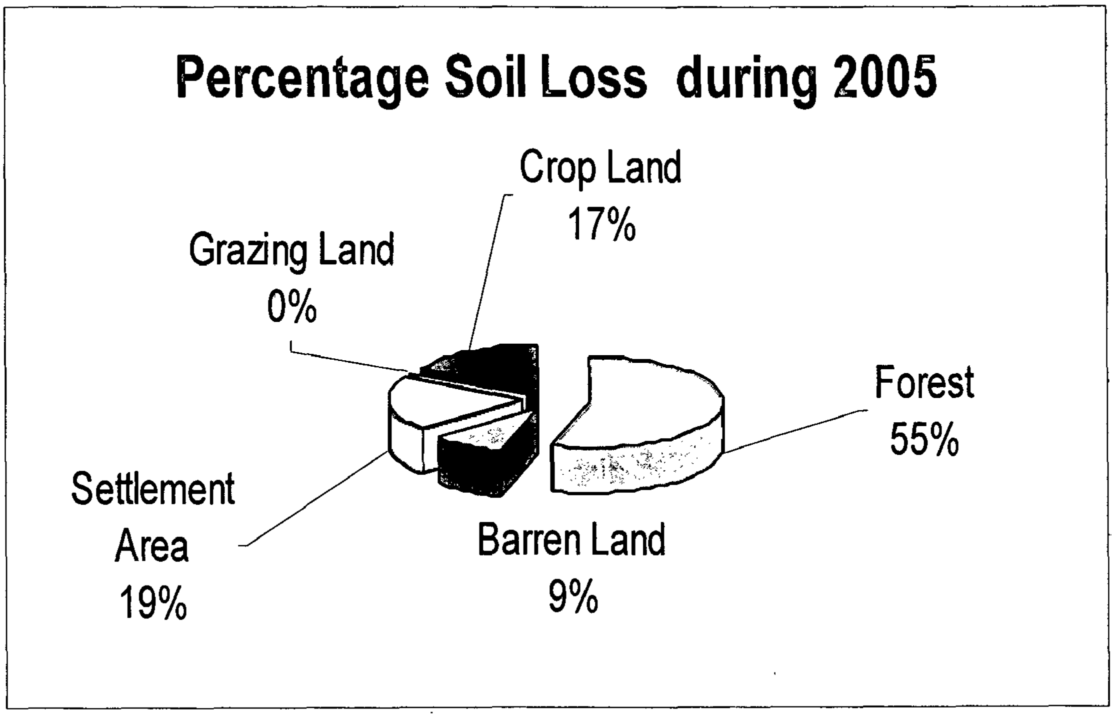


Fig. 4.28:- Percentage Soil Loss during 2005

4.3.3 Suspended and Bed Load Deposition

The sediment load into the wetland has been estimated for the year 2005. Inflow of sediment during monsoon (May to August) was very high, particularly through the main inlet channel (combined flow of Basistha and Mora-bharalu Rivers). The total sediment load entering into wetland during the year has been estimated to be 308,685 t and that flowing out of the wetland to be 99,214 t. Thus, the net sediment load deposited during the year 2005 was 209,471 t, which is only about 39 % of the estimated gross soil loss from the catchment for the year 2005. Table 4.26 shows the calculation of Suspended and Bed Load deposited into the wetland during 2005.

Therefore, volume of silt deposited into the wetland during the year 2005 is :

$$\text{Volume} = \frac{Mass}{Density}$$

$$= \frac{209{,}471}{1.60}$$

$$= 130{,}919 \text{ m}^3$$

If the total silt load carried in is assumed to be uniformly distributed over the wetland, the annual rate of silt deposition for the year 2005 (considering the average water spread area of the wetland as 1834.02 ha, as calculated from values in Table 4.28) will be as below.

$$\text{Annual silt deposition rate} = \frac{130{,}919}{18{,}340{,}200} \text{ m / year}$$

$$= 7.10 \text{ mm / year}$$

Table 4.26:- Calculation of Suspended and Bed Load Deposition during the year 2005

Season	Inflows															Outlet					Net Sediment Deposition		
	Main Inlet					Second Inlet					Direct Runoff												
	SS (mg/l)	Q (m^3)	SL (t)	BL (t)	TL (t)	SS (mg/l)	Q (m^3)	SL (t)	BL (t)	TL (t)	SS (mg/l)	Q (m^3)	SL (t)	BL (t)	TL (t)	SS (mg/l)	Q (m^3)	SL (t)	BL (t)	TL (t)	SL (t)	BL (t)	TL (t)
Pre-Monsoon (Jan – April)	63	51,187,212	3,225	645	3,870	61	4,143,420	252	51	303	40	2,203,030	22	5	27	43	22,282,223	958	192	1,150	2,541	509	3,050
Monsoon (May – Aug)	960	209,325,814	200,953	40,191	241,144	770	30,515,374	23,496	4,699	28,195	620	36,282,760	22,495	4,499	26,994	280	272,155,068	76,203	15,241	91,444	170,741	34,148	204,889
Post-monsoon (Sept – Dec)	163	39,954,203	6,513	1,303	7,816	122	2,296,669	280	56	336	0	0	0	0	0	56	98,523,995	5,517	1,103	6,620	1,276	256	1,532
																				Total	174,558	34,913	209,471

4.3.4 Sediment Delivery Ratio

Based on the estimated soil erosion (A) calculated using USLE and the measured sediment deposition into the wetland, the delivery ratio has been calculated for the year 2005.

$$DR = \frac{308,685}{538,540} \times 100\ \%$$

$$= 57.30\ \%$$

4.4 HYDROLOGICAL STUDY

Based on the Bathymetric Survey, the average depth of the wetland was calculated by measuring the depth at sixty six locations. These locations (Latitude and Longitude) were recorded in a GPS and are shown in Fig. 4.29.

The measured depth at these sixty six points are shown in Table 4.27 and the depth profile is shown in Fig. 4.30.

The monthly water spread area has been calculated based on a mathematical model developed using MS Office Excel (2003), from the available eight numbers of water spread statistics obtained from satellite image.

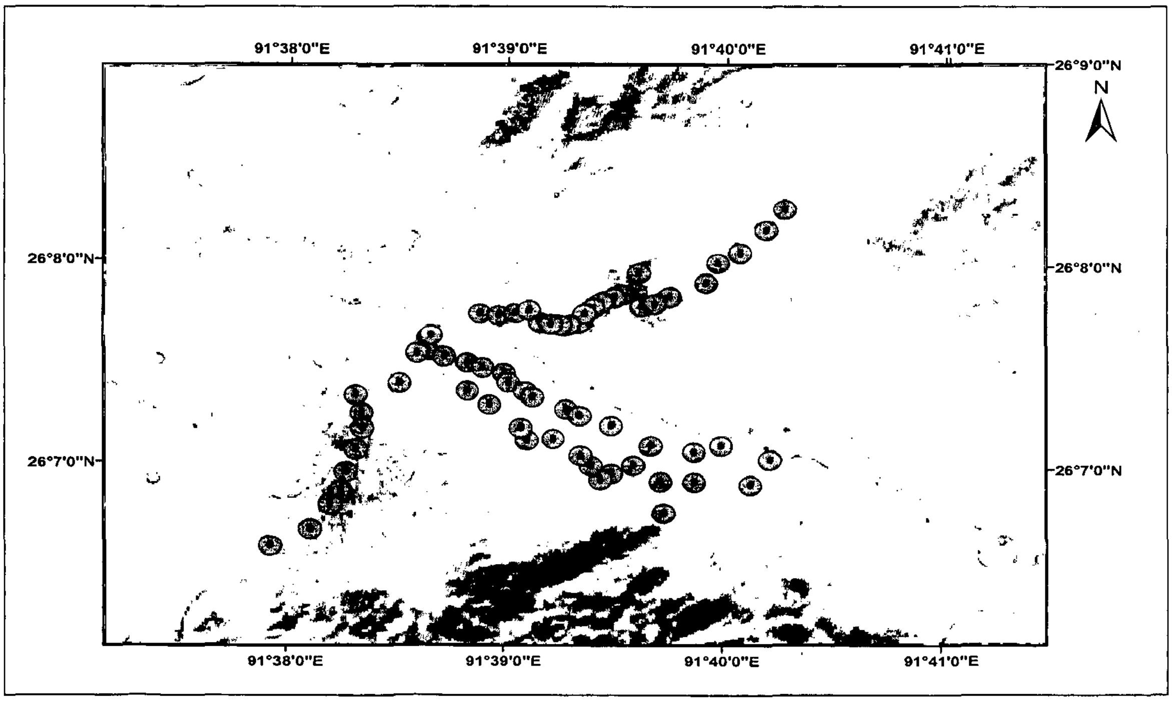


Fig. 4.29:- Location of Depth Measurement Points

Based on the measured average water depth and the calculated water spread area the storage volume for December/2004 was calculated. This is taken as the initial storage for the monthly water balance prepared for the year 2005. The water balance is shown in Table 4.29.

Table 4.27:- Measured Depth at the Specified Locations

Sl. No.	Latitude	Longitude	Easting(m)	Northing(m)	Depth(m)
1	26° 8' 12.52"	91° 39' 56.41"	366629.277	2891288.66	0.15
2	26° 8' 6.22"	91° 39' 51.37"	366487.277	2891096.66	0.45
3	26° 8' 3.55"	91° 39' 48.06"	366394.277	2891015.66	0.65
4	26° 7' 57.14"	91° 39' 44.53"	366294.277	2890819.66	0.70
5	26° 7' 53.26"	91° 39' 39.60"	366156.277	2890700.66	0.75
6	26° 7' 51.31"	91° 39' 35.21"	366033.277	2890642.66	0.85
7	26° 7' 50.59"	91° 39' 31.32"	365925.277	2890621.66	0.85
8	26° 7' 49.58"	91° 39' 29.48"	365874.277	2890590.66	0.80
9	26° 7' 48.25"	91° 39' 25.99"	365776.277	2890550.66	0.85
10	26° 7' 46.63"	91° 39' 23.69"	365712.277	2890501.66	0.60
11	26° 7' 24.49"	91° 39' 21.10"	365633.277	2889821.66	0.65
12	26° 7' 41.05"	91° 39' 21.96"	365662.277	2890330.66	0.60
13	26° 7' 40.83"	91° 39' 21.38"	365647.277	2890446.66	0.55
14	26° 7' 49.91"	91° 39' 22.00"	365666.277	2890602.66	0.70
15	26° 7' 51.49"	91° 39' 20.66"	365630.277	2890651.66	0.65
16	26° 7' 52.03"	91° 39' 22.36"	365677.277	2890668.66	0.70
17	26° 7' 51.60"	91° 39' 26.96"	365805.277	2890653.66	0.55
18	26° 7' 53.33"	91° 39' 36.11"	366059.277	2890704.66	0.50
19	26° 8' 00.24"	91° 39' 42.01"	366225.277	2890923.66	0.80
20	26° 7' 37.63"	91° 38' 38.36"	364450.277	2890237.66	0.45
21	26° 7' 33.85"	91° 38' 38.08"	364441.277	2890121.66	0.50
22	26° 7' 31.98"	91° 38' 42.72"	364569.277	2890062.66	0.80
23	26° 7' 30.11"	91° 38' 49.16"	364748.277	2890003.66	1.15
24	26° 7' 28.76"	91° 38' 53.45"	364866.277	2889957.66	1.20
25	26° 7' 27.19"	91° 38' 59.46"	365033.277	2889910.66	0.35
26	26° 7' 24.46"	91° 39' 00.54"	365062.277	2889825.66	0.80
27	26° 7' 21.90"	91° 39' 05.22"	365191.277	2889745.66	0.80
28	26° 7' 20.10"	91° 39' 07.16"	365245.277	2889689.66	0.85
29	26° 7' 16.68"	91° 39' 16.63"	365506.277	2889582.66	0.80
30	26° 7' 17.40"	91° 39' 20.95"	365627.277	2889602.66	0.35
31	26° 7' 14.74"	91° 39' 20.30"	365608.277	2889521.66	0.70
32	26° 7' 11.96"	91° 39' 28.84"	365844.277	2889433.66	0.70
33	26° 7' 05.92"	91° 39' 43.85"	366259.277	2889243.66	0.50
34	26° 7' 04.22"	91° 39' 51.70"	366476.277	2889188.66	0.40
35	26° 7' 06.20"	91° 39' 59.11"	366683.277	2889247.66	0.15
36	26° 7' 02.10"	91° 40' 12.54"	367055.277	2889117.66	0.15
37	26° 7' 03.54"	91° 39' 45.54"	366305.277	2889169.66	0.35
38	26° 7' 00.30"	91° 39' 41.44"	366190.277	2889070.66	0.35
39	26° 6' 54.04"	91° 39' 29.95"	365869.277	2888881.66	0.75
40	26° 6' 51.55"	91° 39' 23.83"	365698.277	2888806.66	0.85
41	26° 6' 49.64"	91° 39' 20.92"	365617.277	2888748.66	0.30

Contd…

42	26° 6' 53.71"	91° 39' 18.40"	365548.277	2888874.66	0.90
43	26° 6' 56.77"	91° 39' 15.52"	365469.277	2888969.66	1.25
44	26° 7' 01.59"	91° 39' 07.92"	365260.277	2889120.66	0.85
45	26° 7' 01.12"	91° 39' 00.61"	365057.277	2889108.66	0.30
46	26° 7' 04.76"	91° 38' 48.48"	365009.277	2889220.66	1.00
47	26° 7' 11.56"	91° 38' 50.24"	364772.277	2889432.66	1.35
48	26° 7' 15.60"	91° 38' 44.20"	364605.277	2889558.66	1.20
49	26° 7' 21.29"	91° 38' 04.27"	363498.277	2889744.66	0.50
50	26° 7' 16.21"	91° 38' 14.60"	363783.277	2889585.66	0.55
51	26° 7' 09.05"	91° 38' 12.41"	363720.277	2889365.66	0.65
52	26° 7' 05.99"	91° 38' 10.82"	363675.277	2889272.66	0.60
53	26° 6' 44.93"	91° 39' 00.61"	365051.277	2888609.66	0.20
54	26° 7' 19.34"	91° 37' 57.40"	363306.277	2889686.66	0.15
55	26° 7' 18.55"	91° 37' 59.66"	363369.277	2889661.66	0.50
56	26° 7' 20.35"	91° 38' 16.08"	363826.277	2889712.66	0.25
57	26° 7' 20.56"	91° 38' 18.45"	363892.277	2889718.66	0.75
58	26° 7' 24.02"	91° 38' 30.41"	364225.277	2889821.66	0.65
59	26° 7' 32.99"	91° 38' 35.16"	364360.277	2890095.66	0.65
60	26° 7' 38.28"	91° 38' 39.05"	364469.277	2890257.66	0.35
61	26° 7' 44.76"	91° 38' 52.73"	364851.277	2890452.66	0.60
62	26° 7' 44.22"	91° 38' 57.84"	364993.277	2890434.66	0.55
63	26° 7' 44.90"	91° 39' 02.38"	365120.277	2890454.66	0.55
64	26° 7' 45.88"	91° 39' 06.12"	365224.277	2890483.66	0.60
65	26° 7' 49.01"	91° 39' 11.92"	365386.277	2890578.66	0.65
66	26° 7' 50.16"	91° 39' 11.99"	365388.277	2890613.66	0.75
				Avg. Depth	0.64

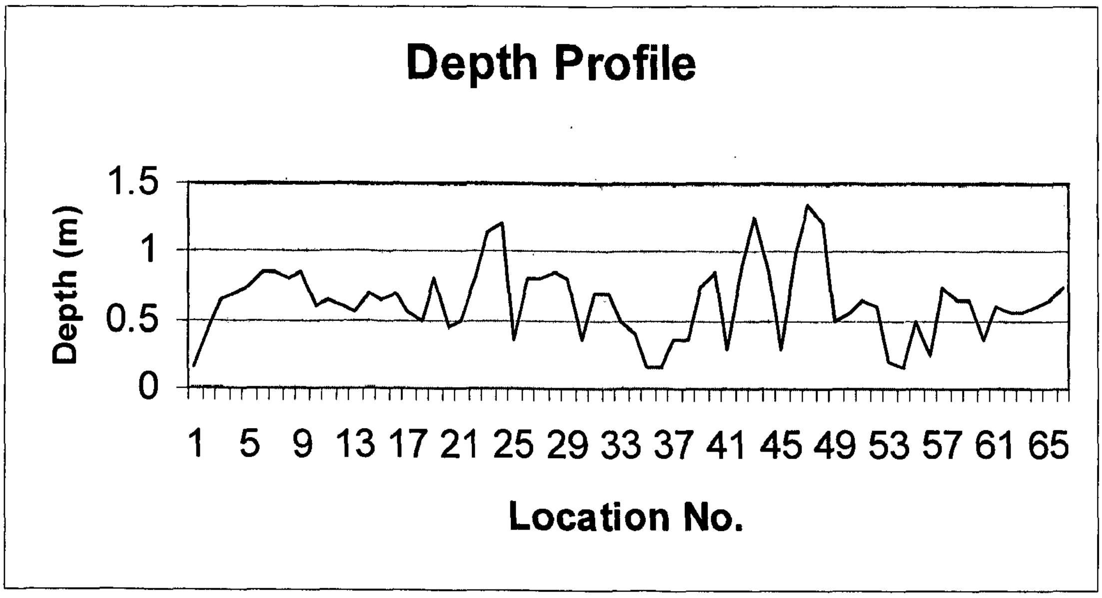


Fig. 4.30:- Depth Profile

4.4.1 Calculation of Water Spread Area

Based on the available 8 numbers of water spread statistics and corresponding monthly precipitation, a mathematical model was developed using MS Excel, which is shown in Fig.4.31.

This relationship was used to calculate the water spread area from December/2004 to December/2005, which is shown in Table 4.28.

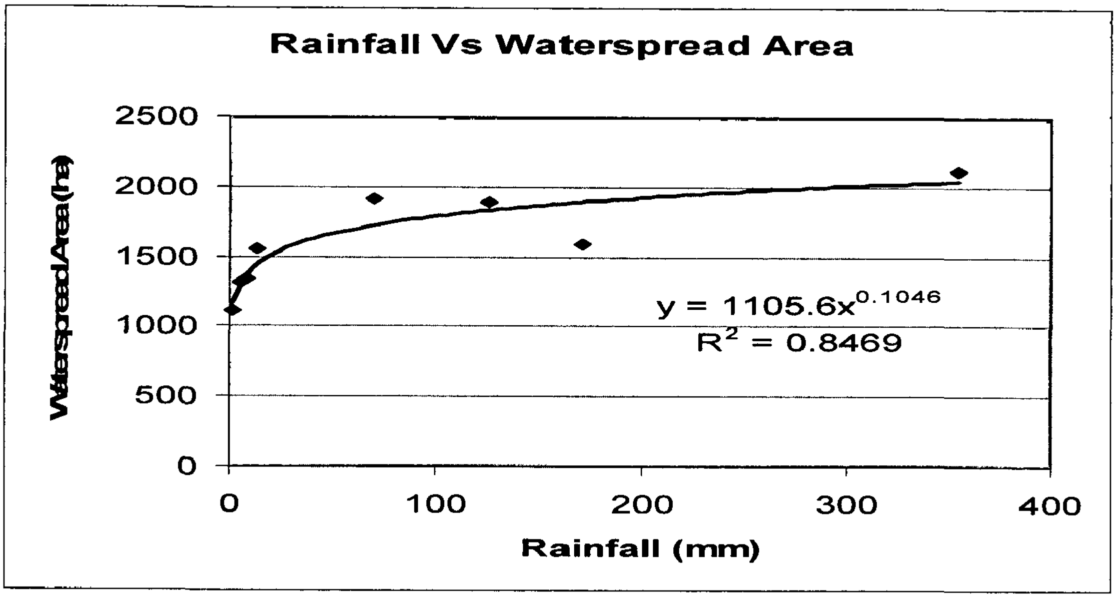


Fig. 4.31:- Relationship between Rainfall and Water Spread Area

Table 4.28:- Monthly Average Water Spread Area

Month	Rainfall (mm)	Waterspread Area (ha)
4-Dec	0.6	1048.075698
5-Jan	16.6	1483.273836
5-Feb	3.9	1274.745208
5-Mar	150.7	1868.222836
5-Apr	134.8	1846.560719
5-May	284.5	1996.618246
5-Jun	104.6	1798.212632
5-Jul	174.5	1897.098288
5-Aug	803	2225.518845
5-Sep	82.1	1753.227703
5-Oct	117.2	1819.733785
5-Nov	1.4	1145.204439
5-Dec	0.8	1080.093227

4.4.2 Model Validation

The water spread area obtained from the mathematical model is compared with the available actual data for the month of November 2005. As per LISS-III Image dated 22nd Nov. 2005, the water spread area was 1128 ha. The computed water spread area is 1145 ha. There is a difference of only 1.5 %; hence the accuracy of the computed mathematical model is 98.5%.

4.4.3 Calculation of Average Storage Capacity

Average Water Spread Area during December/04

$$A_1 = 1048.08 \text{ ha}$$
$$= 10.48 \text{ km}^2$$
$$= 10.48 \times 10^6 \text{ m}^2$$

Average Depth of the Wetland during December/04 = 0.64 m

Average Water Volume during December/04

$$V_1 = (10.48 \times 10^6 - 100 \times 800) \times 0.64 + (100 \times 800) \times 3.15$$
$$= (10.40 \times 10^6 \times 0.64) + (80{,}000 \times 3.15)$$
$$= 6{,}908{,}000 \text{ m}^3$$
$$= 6.91 \text{ MMC}$$

Average Water Spread Area during August/05

$$A_2 = 2225.52 \text{ ha}$$
$$= 22.25 \text{ km}^2$$
$$= 22.25 \times 10^6 \text{ m}^2$$

Average Water Volume during August/05

$$V_2 = V_1 + \{(A_1 + A_2)/2\} \times 3.4$$
$$= 6.908{,}000 + \{(10.48 + 22.25)/2\} \times 10^6 \times 3.4$$
$$= 62{,}566{,}000 \text{ m}^3$$
$$= 62.57 \text{ MMC}$$

Water Spread Area during HFL (48.58m)

$$A3 = 24.70 \text{ km}^2$$

Water Volume during HFL (48.58m)

$$V_{max} = V_2 + \{(A_2 + A_3)/2\} \times 0.75$$
$$= 62{,}566{,}000 + \{(22.26 + 24.70)/2\} \times 10^6 \times 0.75$$
$$= 80{,}176{,}000 \text{ m}^3$$
$$= 80.18 \text{ MMC}$$

Table 4.29:- Water Balance for the year 2005

Period	Initial Storage (m^3)	Inflows (m^3)					Outflows and Losses (m^3)				Final Storage (M^3)
		Main Inlet Channel	Second Inlet Channel	Direct Run-off	Direct Precipitation	Total Inflow	Outlet Channel	Domestic Water Demand	Evapo-transpiration	Total Outflow	
	(S_{t-1})	(Ic_1)	(Ic_2)	(I_d)	(P)	(I)	(O_c)	(O_d)	(T_{Et})	(O)	(S_t)
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(3)+(4)+(5)+(6)	(8)	(9)	(10)	(11)=(8)+(9)+(10)	(12)
Jan/05	**6,908,000**	5,117,342	462,198	0	240,932	5,820,472	3,117,176	26,742	682,306	3,826,224	8,902,248
Feb/05	8,902,248	3,153,345	307,269	0	58,656	3,519,270	2,657,309	24,154	850,079	3,531,542	8,889,976
Mar/05	8,889,976	22,543,637	1,769,673	1,631,150	2,597,013	28,541,473	4,571,346	26,742	1,700,083	6,298,171	31,133,278
Apr/05	31,133,278	20,372,888	1,604,280	571,880	2,579,937	25,128,985	11,936,392	25,879	2,049,682	14,011,953	42,250,310
May/05	42,250,310	39,930,947	3,074,223	6,738,290	5,623,996	55,367,456	40,986,323	26,742	2,216,246	43,229,311	54,388,455
Jun/05	54,388,455	16,448,398	1,309,830	0	2,105,598	19,863,826	32,651,538	25,879	2,067,944	34,745,361	39,506,920
Jul/05	39,506,920	45,636,447	12,001,723	1,414,570	3,524,726	62,577,466	46,524,332	26,742	2,143,721	48,694,795	53,389,591
Aug/05	53,389,591	107,310,022	14,129,598	28,129,900	16,102,559	165,672,079	151,992,875	26,742	2,448,071	154,467,688	64,593,982
Sep/05	64,593,982	13,524,523	1,090,455	0	1,555,959	16,170,937	41,184,310	25,879	1,840,889	43,051,078	37,713,841
Oct/05	37,713,841	18,190,312	434,048	0	2,161,754	20,786,114	27,455,174	26,742	1,546,774	29,028,690	29,471,265
Nov/05	29,471,265	4,629,446	423,068	0	198,184	5,250,698	17,617,519	25,879	767,287	18,410,685	16,311,278
Dec/05	16,311,278	3,609,922	349,098	0	62,784	4,021,804	12,266,992	26,742	561,648	12,855,382	**7,477,700**
Σ		300,467,229	36,955,463	38,485,790	36,812,098	**412,720,580**	**392,961,286**	**314,864**	**18,874,730**	412,150,880	

Water Balance Equation:

$S_t = S_{t-1} + \Sigma I - O_c - O_d - T_{Et}$

$= 6{,}908{,}000\ m^3 + 412{,}720{,}580\ m^3 - 392{,}961{,}286\ m^3 - 314{,}864\ m^3 - 18{,}874{,}730\ m^3$

$= 7{,}477{,}700\ m^3$, hence balanced.

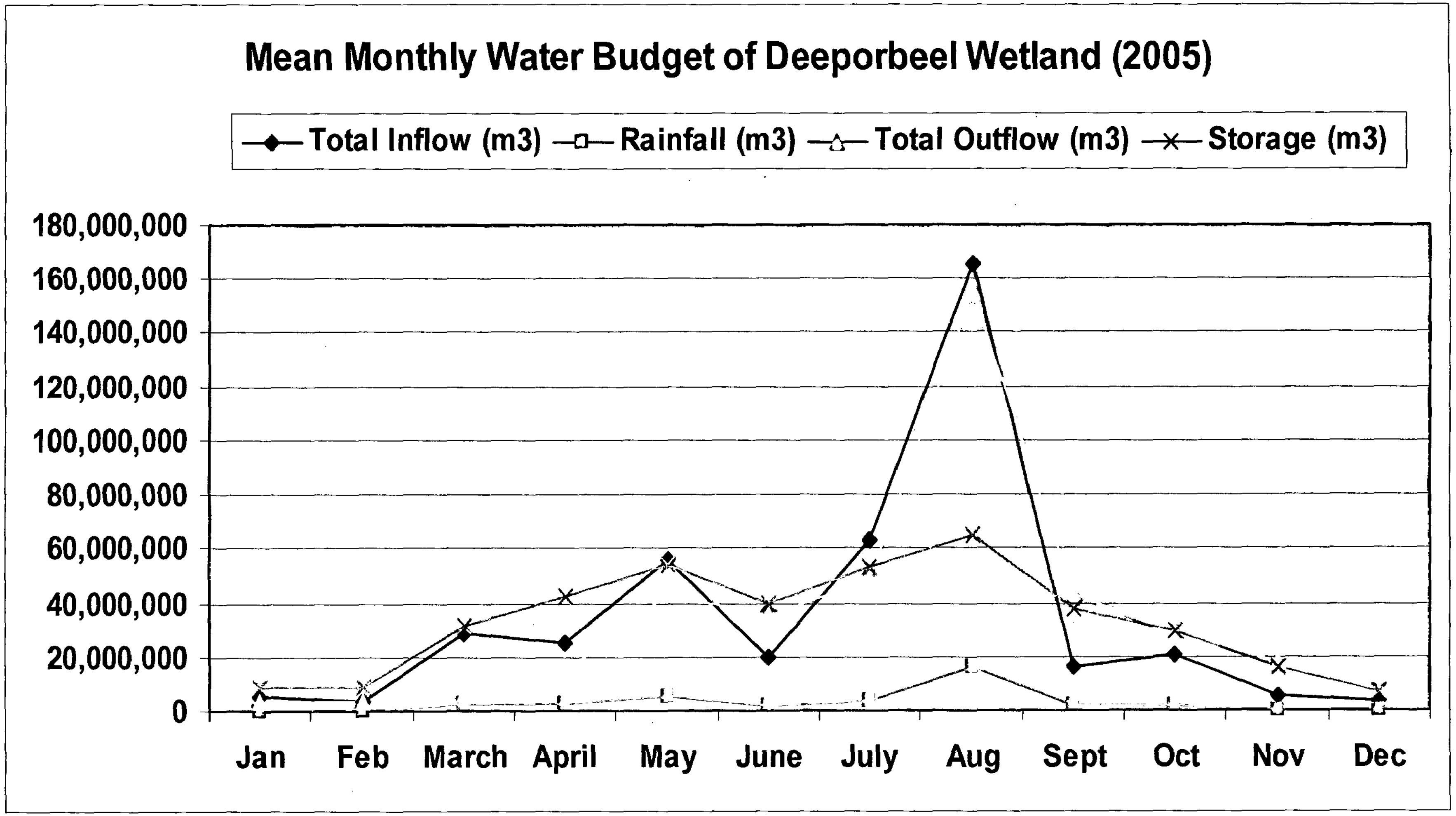


Fig. 4.32:- Mean Monthly Water Budget of Deeporbeel Wetland for the year 2005

4.4.2 Model Validation

The water spread area obtained from the mathematical model is compared with the available actual data for the month of November 2005. As per LISS-III Image dated 22^{nd} Nov. 2005, the water spread area was 1128 ha. The computed water spread area is 1145 ha. There is a difference of only 1.5 %; hence the accuracy of the computed mathematical model is 98.5%.

4.4.3 Calculation of Average Storage Capacity

Average Water Spread Area during December/04

$$A_1 = 1048.08 \text{ ha}$$
$$= 10.48 \text{ km}^2$$
$$= 10.48 \times 10^6 \text{m}^2$$

Average Depth of the Wetland during December/04 = 0.64 m

Average Water Volume during December/04

$$V_1 = (10.48 \times 10^6 - 100 \times 800) \times 0.64 + (100 \times 800) \times 3.15$$
$$= (10.40 \times 10^6 \times 0.64) + (80{,}000 \times 3.15)$$
$$= 6{,}908{,}000 \text{ m}^3$$
$$= 6.91 \text{ MMC}$$

Average Water Spread Area during August/05

$$A_2 = 2225.52 \text{ ha}$$
$$= 22.25 \text{ km}^2$$
$$= 22.25 \times 10^6 \text{m}^2$$

Average Water Volume during August/05

$$V_2 = V_1 + \{(A_1 + A_2)/2\} \times 3.4$$
$$= 6.908{,}000 + \{(10.48 + 22.25)/2\} \times 10^6 \times 3.4$$
$$= 62{,}566{,}000 \text{ m}^3$$
$$= 62.57 \text{ MMC}$$

Water Spread Area during HFL (48.58m)

$$A3 = 24.70 \text{ km}^2$$

Water Volume during HFL (48.58m)

$$V_{max} = V_2 + \{(A_2 + A_3)/2\} \times 0.75$$
$$= 62{,}566{,}000 + \{(22.26 + 24.70)/2\} \times 10^6 \times 0.75$$
$$= 80{,}176{,}000 \text{ m}^3$$
$$= 80.18 \text{ MMC}$$

Additional Storage Capacity during Lean Flow Period

$= V_{max} - V_1$
$= (80,176,000 - 6,908,000)\ m^3$
$= 73,268,000\ m^3$
$= 73.27$ MMC

Additional Storage Capacity during Monsoon

$= V_{max} - V_2$
$= (80,176,000 - 62,566,000)\ m^3$
$= 17,610.000\ m^3$
$= 17.61$ MMC

[Note:
DL = 48.73 m
HFL = 48.58 m
NFL = 47.83 m
WL (December/04) = 44.43 m]

4.4.4 Calculation of Monthly Water Balance

The monthly water balance for the year 2005 is shown in Table 4.29. The calculation for Direct Run-off, Domestic Water Demand and Evapo-transpiration are shown in Appendix VII and Appendix VIII.

Thus, in the year 2005 the minimum water volume in the wetland was during the month of December and the maximum water volume was during the month of August. The minimum and maximum water volumes are 7,477,700 m^3 and 64,593,982 m^3 respectively. Correspondingly the minimum monthly average water spread area was during December (1080.09 ha) and maximum water spread area is during August (2225.52 ha). Fig. 4.32 shows the mean monthly water budget of Deeporbeel wetland for the year 2005. Fig. 4.33 shows the monthly water volume Vs monthly average water depth curve and Fig. 4.34 shows the monthly rainfall and monthly water volume curve. The capacity to store additional water by the wetland during monsoon is found to be 17.61 MMC and that during lean flow period is 73.27 MMC.

Table 4.29:- Water Balance for the year 2005

Period	Initial Storage (m^3) (S_{t-1})	Inflows (m^3) Main Inlet Channel (Ic_1)	Second Inlet Channel (Ic_2)	Direct Run-off (I_d)	Direct Precipitation (P)	Total Inflow (I)	Outflows and Losses (m^3) Outlet Channel (O_c)	Domestic Water Demand (O_d)	Evapo-transpiration (T_{Et})	Total Outflow (O)	Final Storage (M^3) (S_t)
(1)	(2)	(3)	(4)	(5)	(6)	(7)=(3)+(4)+(5)+(6)	(8)	(9)	(10)	(11)=(8)+(9)+(10)	(12)
Jan/05	**6,908,000**	5,117,342	462,198	0	240,932	5,820,472	3,117,176	26,742	682,306	3,826,224	8,902,248
Feb/05	8,902,248	3,153,345	307,269	0	58,656	3,519,270	2,657,309	24,154	850,079	3,531,542	8,889,976
Mar/05	8,889,976	22,543,637	1,769,673	1,631,150	2,597,013	28,541,473	4,571,346	26,742	1,700,083	6,298,171	31,133,278
Apr/05	31,133,278	20,372,888	1,604,280	571,880	2,579,937	25,128,985	11,936,392	25,879	2,049,682	14,011,953	42,250,310
May/05	42,250,310	39,930,947	3,074,223	6,738,290	5,623,996	55,367,456	40,986,323	26,742	2,216,246	43,229,311	54,388,455
Jun/05	54,388,455	16,448,398	1,309,830	0	2,105,598	19,863,826	32,651,538	25,879	2,067,944	34,745,361	39,506,920
Jul/05	39,506,920	45,636,447	12,001,723	1,414,570	3,524,726	62,577,466	46,524,332	26,742	2,143,721	48,694,795	53,389,591
Aug/05	53,389,591	107,310,022	14,129,598	28,129,900	16,102,559	165,672,079	151,992,875	26,742	2,448,071	154,467,688	64,593,982
Sep/05	64,593,982	13,524,523	1,090,455	0	1,555,959	16,170,937	41,184,310	25,879	1,840,889	43,051,078	37,713,841
Oct/05	37,713,841	18,190,312	434,048	0	2,161,754	20,786,114	27,455,174	26,742	1,546,774	29,028,690	29,471,265
Nov/05	29,471,265	4,629,446	423,068	0	198,184	5,250,698	17,617,519	25,879	767,287	18,410,685	16,311,278
Dec/05	16,311,278	3,609,922	349,098	0	62,784	4,021,804	12,266,992	26,742	561,648	12,855,382	**7,477,700**
Σ		300,467,229	36,955,463	38,485,790	36,812,098	**412,720,580**	**392,961,286**	**314,864**	**18,874,730**	412,150,880	

Water Balance Equation:

$S_t = S_{t-1} + \Sigma I - O_c - O_d - T_{Et}$

$= 6,908,000\ m^3 + 412,720,580\ m^3 - 392,961,286\ m^3 - 314,864\ m^3 - 18,874,730\ m^3$

$= 7,477,700\ m^3$, hence balanced.

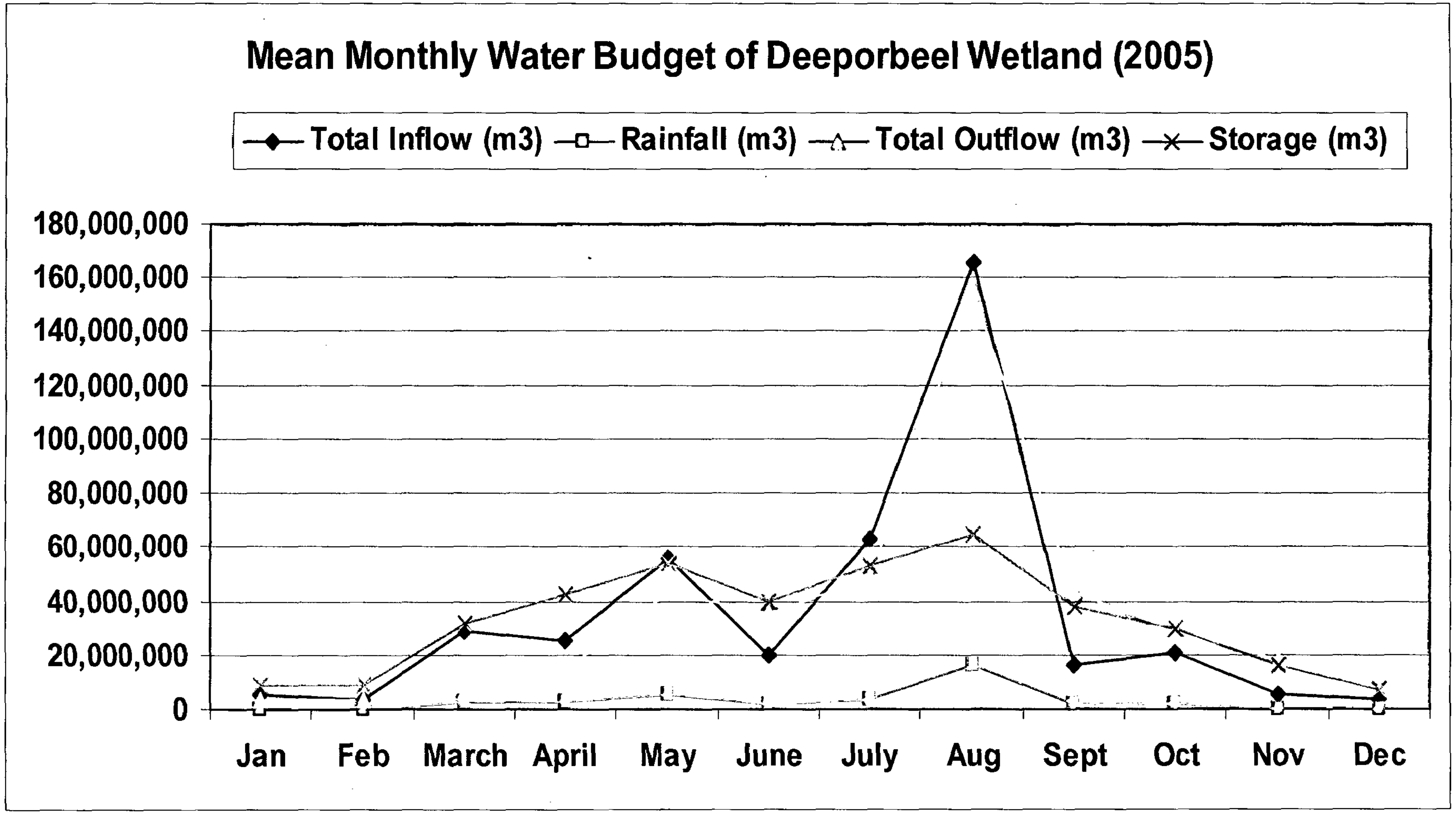


Fig. 4.32:- Mean Monthly Water Budget of Deeporbeel Wetland for the year 2005

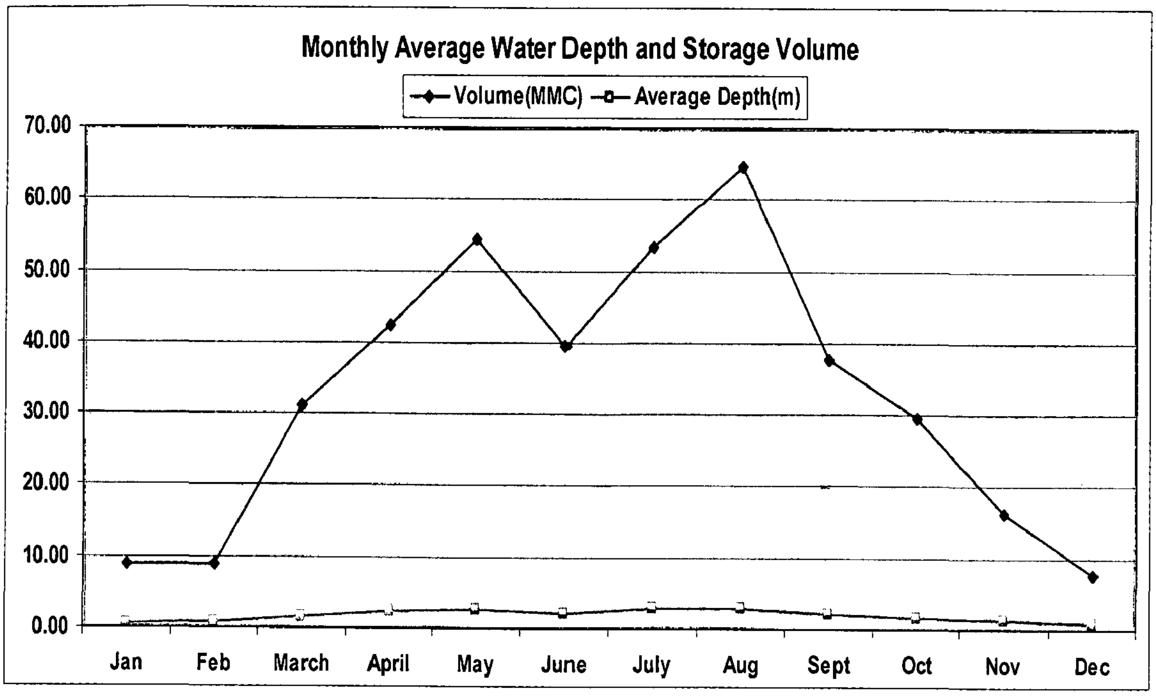


Fig. 4.33:- Monthly Average Water Depth and Storage Volume for the year 2005

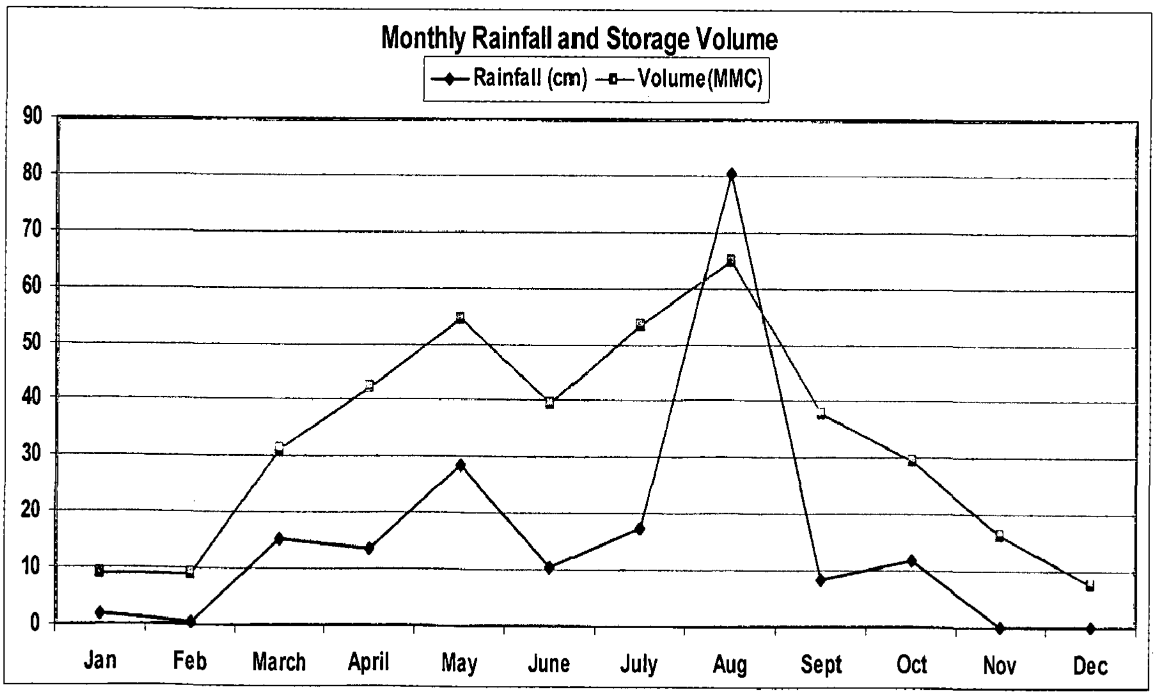


Fig. 4.34:- Monthly Rainfall and Storage Volume for the year 2005

CHAPTER 5

GULLY EROSION

5.1 GENERAL

Gullies are highly eroded natural drainage channels. When rills get larger in size and shape due to prolonged occurrence of flow through them and cannot be removed by tillage operations, gullies are said to occur. Large gullies and their networks are called 'Ravines'.

It is a highly visible form of soil erosion that affects soil productivity, restricts land use and can threaten roads, fences, buildings, etc. Gullies are relatively steep-sided watercourses which experience ephemeral flows during monsoon. Soil eroded from the gullied area can cause siltation of lakes, wetlands, road culverts, dams, reservoirs, etc. Suspended sediments, which may have attached nutrients and pesticides, can adversely affect water quality. These fines, colloidal clay particles remain in suspension and may clog groundwater aquifers, pollute water course and affect aquatic life [8].

5.2 FACTORS AFFECTING GULLY EROSION

The factors affecting gully erosion can be categorized into two groups, man-made factors, and physical factors [37, 42].

5.2.1 Man-made Factors

5.2.1.1 *Improper Land use*

In developing countries, rapidly-increasing populations usually migrate upland to occupy forests or rangeland. Most migrants cut trees, burn litter and grasses, and cultivate hillsides without using conservation measures. After a few years, the productivity of the soil is lost because of sheet, rill and gully erosion, and the land is abandoned. This kind of cultivation, (shifting cultivation) is repeated by farmers on other hillsides until the land loses its productivity there as well. Thus, the whole of an area may be completely destroyed by gullying as the gully heads advance to the upper ends of the watershed.

5.2.1.2 *Forest and Grass Fire*

Many forest fires are caused by the uncontrolled burning used in shifting cultivation. These fires can easily spread into the forest and destroy the undergrowth and litter. Grass fires are usually ignited by farmers near the end of the dry season in order to obtain young shoots for their livestock or new land for cultivation. On slopes, the soil that is exposed after forest and grass fires is usually gullied during the first rainy season.

5.2.1.3 *Overgrazing*

Overgrazing removes too much of the soil's protective vegetal cover and trampling compacts the soil; thus the infiltration capacity of the land is reduced. The increased run-off, caused by the insufficient water holding capacity of the soil, produces new gullies or enlarges old ones.

5.2.1.4 *Mining*

Underground (block cave) mining is another factor that can cause gullying. Initially, cracks in the ground and soil creep (a kind of gravity erosion) are observed in the mining areas. Then, during rainy seasons, gullies are formed. Gullying in open-pit mining areas is also a big problem in many countries.

5.2.1.5 *Road Construction*

If road cuts and fill slopes are not revegetated during or immediately following road construction, gullies may form on both sides of the road. Inadequate drainage systems for roads (small number of culverts, insufficient capacity of road ditches, etc.) are a major cause of gullying.

5.2.1.6 *Livestock and Vehicle Trails*

Gullies are also formed on livestock and vehicle trails that run along hillsides. This is because the traffic on them compacts the soil and reduces the water holding capacity.

5.2.1.7 *Destructive Logging*

In forest regions, logging with tractors down slopes can lead to gully erosion, because the run-off becomes concentrated along the skid trails.

5.2.2 Physical Factors

Gullies are formed by increased surface run-off which acts as a cutting agent. The main physical factors effecting the rate and amount of surface run-off are precipitation, topography, soil properties and vegetative cover.

5.2.2.1 *Precipitation*

(a) *Monthly Distribution of Rainfall*

The monthly distribution of rainfall is more significant than total annual rainfall because of its effects on the growth of vegetation, as well as the fact that it gives some indications about rainfall intensity. In humid regions with uniform distribution of rainfall, surface erosion, including gully formation, may not be a serious problem because vegetation grows throughout the year. However, in areas that do not have uniform rainfall, the vegetation (especially grass) dries up during the prolonged dry season (3 to 5 months or more). If the land is not properly used, or if forest or grass fires occur during the dry period, it cannot sufficiently hold rainwater and so the increased surface run-off in the rainy season produces large scale landslides and gullies.

(b) *Rainfall Intensity and Runoff*

If the amount of rainfall is more than the water holding capacity of the soil, there will be an increase in surface run-off, followed by surface erosion and gullying. In some tropical and subtropical countries, after the soil is completely saturated, almost all of the rainfall turns into run-off during the wettest months, which include the monsoon season, tropical cyclones and especially typhoons. It rains intensively for two or three days without stopping during each typhoon period and the increased run-off causes landslides, huge gullies and devastating floods.

(c) *Rapid Snowmelts*

Rapid snowmelts turn into high run-off. This increased surface run-off acts as a cutting agent and produces gullies. Like prolonged rains of moderate intensity and short intensive rain storms, rapid snowmelts cause destructive floods.

5.2.2.2 *Topography*

The size and shape of a drainage area, as well as the length and gradient of its slopes have an effect on the run-off rate and amount of surface water.

5.2.2.3 *Soil Properties*

Physical properties of soil affect the infiltration capacity and the extent to which particles can be detached and transported. Soil detachability increases as the size of the soil particle or aggregate increase and soil transportability increases with the decrease in the particle or aggregate size. Clay particles are more difficult to detach than sand, but clay is more easily transported. The properties that influence erosion include soil structure, texture, organic matter, water content, clay mineralogy and density or compactness as well as chemical and biological characteristics of the soil.

5.2.2.4 *Vegetative Cover*

The role of vegetative cover is to intercept rainfall, to keep the soil covered with litter, to maintain soil structure and pore space, and to create openings and cavities by root penetration. This is best achieved by an undisturbed multistory forest cover. Under special conditions, however, a well-protected, dense grass cover may also provide the necessary protection. In general, it is management and protection rather than the type of the vegetative cover which determines its effectiveness in gully control. Any vegetation which is well-adapted to local conditions and which shows vigorous growth may be used.

The formation of gullies in the study area can be attributed primarily to man-made factors. During the early part of 1980s, small channels were made along the hill slopes by clearing jungles for the purpose of sliding timber down hill. In due course of time these small channels progressed into gullies due to action of runoff water.

5.3 LOCATION OF GULLIES

Based on a reconnaissance survey, 13 gullies were identified in the catchment area which contributes to direct runoff. The locations (Latitude and Longitude) of these gullies were recorded in a GPS and are shown in Fig. 5.1. Physical measurement at every 25 m interval along the length of each gully was taken to find the average cross-sectional area.

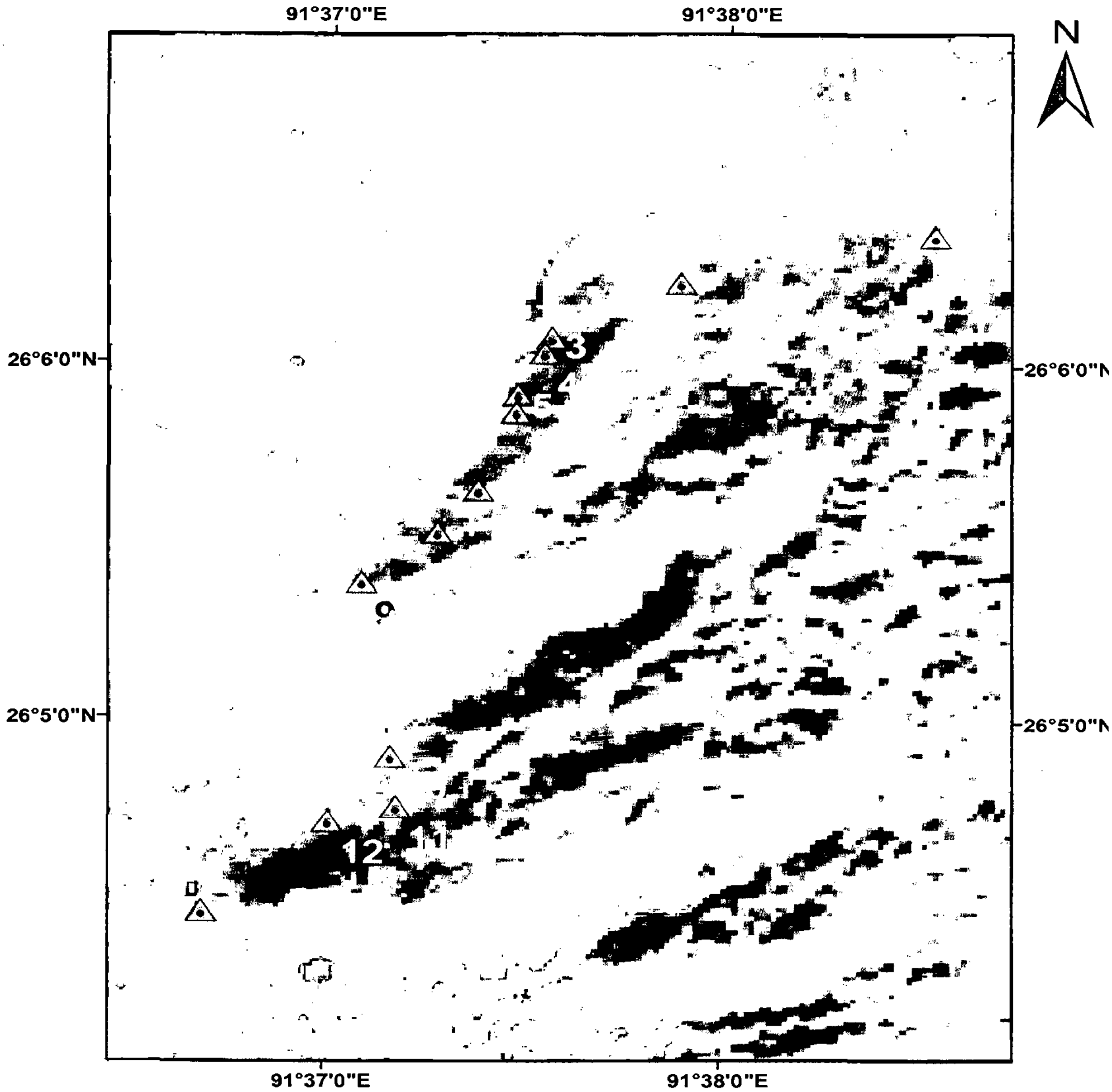


Fig. No. 5.1:- Locations of Gullies

Information regarding the initiation of the gullies is not available. According to the information collected from the local people the gullies have started to form since the early part of 1980s. The total soil losses i.e. silt deposition into the wetland during these 25 years due to gully erosion is shown in Table 5.1.

Table 5.1:- Calculation of Soil Loss from Gully Erosion

Sl./ G.No.	Latitude	Longitude	Dimensions of Gullies				Volume of Soil Loss (m^3)	Location
			Length L(m)	Avg. Top Width W (m)	Avg. Depth D (m)	Avg. X-Sec. Area (m^2)		
1	26° 6' 22.12"	91° 38' 37.03"	31.52	1.10	1.25	0.69	21.67	At Matiapara
2	26° 6' 13.84"	91° 37' 52.71"	29.10	0.52	0.60	0.16	4.54	At Matiapara
3	26° 6' 04.31"	91° 37' 32.73"	102.40	1.56	0.95	0.74	75.88	2 Adjacent at Matiapara
4	26° 6' 01.84"	91° 37' 32.17"	105.20	1.12	0.92	0.52	54.20	
5	26° 5' 54.76"	91° 37' 28.16"	92.20	1.65	0.62	0.51	47.16	2 Adjacent at Matiapara
6	26° 5' 51.49"	91° 37' 27.65"	95.60	1.83	0.42	0.38	36.74	
7	26° 5' 38.50"	91° 37' 22.31"	72.20	1.25	0.61	0.38	27.53	At Matiapara
8	26° 5' 31.58"	91° 37' 16.15"	103.50	2.24	1.62	1.81	187.79	At Matiapara
9	26° 5' 23.02"	91° 37' 04.74"	118.20	2.52	1.20	1.51	178.72	At Matiapara
10	26° 4' 54.01"	91° 37' 09.57"	115.20	0.74	0.42	0.16	17.90	3 Adjacent at Sajjanpara
11	26° 4' 45.39"	91° 37' 10.45"	116.60	0.93	0.52	0.24	28.19	
12	26° 4' 43.18"	91° 37' 00.14"	116.80	0.75	0.45	0.17	19.71	
13	26° 4' 27.50"	91° 36' 41.22"	122.50	2.42	1.16	1.40	171.94	At Sajjanpara
					Total		871.97	

Therefore, Volume of Soil Loss = 871.97 m^3

Density = 1.65 t / m^3

Mass of Soil Loss = Volume × Density

= 871.97 × 1.56

= 1,360.27 t

Thus, the total soil loss from gully erosion is only about 0.3 % of the gross soil loss from sheet erosion from the wetland catchment during the year 2005.

5.4 GULLY CLASSIFICATION

Based on the gully shape, the gullies in the study area can be classified as 'V-shaped gullies'. V-shaped gullies are very commonly seen in hilly areas with steep slope, where the area contributing the runoff is comparatively less. Thus, the flow passing through these channels is low, but the velocity is very high due to steep slope. These gullies develop where the subsoil has more resistance against erosion than topsoil. This is the most common type of gully form. Fig. 5.2 shows the picture of a V-shaped gully.

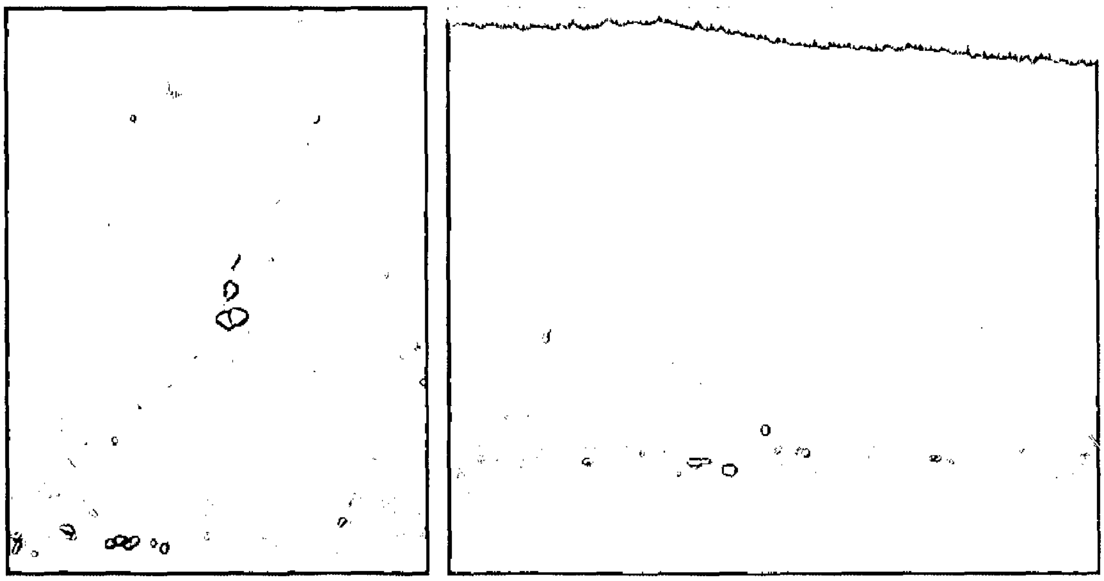


Fig. 5.2:- V-shaped Gully (Stage II and Stage III)

Based on gully size, all the thirteen gullies can be classified as 'Very Small Gully' as the width and depth are within the specification for this class i.e. width < 18.0 m and depth ≤ 3.0 m.

Based on the nature of flow, the gullies listed at Sl. 8, 9 and 13 of Table 5.1 can be classified as 'Active' and the other gullies as 'Inactive'. Active gullies are those, which have flow in them leading to soil erosion. Inactive gullies are those where further erosion of soil has ceased to occur and their stabilization has commenced.

5.5 STAGES OF GULLY FORMATION

In the course of its formation and development, a gully passes through the following four stages:

Stage I : It is the beginning of the formation stage of rills and subsequently that of the gullies.

Stage II: It is the development stage of gullies. The gully head starts moving upstream, beginning from the outlet, where a waterfall is created. The waterfall causes undercutting by the flowing water, leading to caving in of the soil mass. During this stage the soil erosion is very heavy, leading to deeper cuts into the subsoil and washing out of sandy layers below the subsoil.

Stage III: During this stage, the vegetation starts growing and the gully starts establishing itself. It is also called the healing stage of gullies.

Stage IV: During this stage, the gully starts establishing itself by forming a stable channel gradient and stable side slopes. The side slopes get established with the growth of vegetation over its sides. The various stages of gully formation are shown in Fig. 5.3.

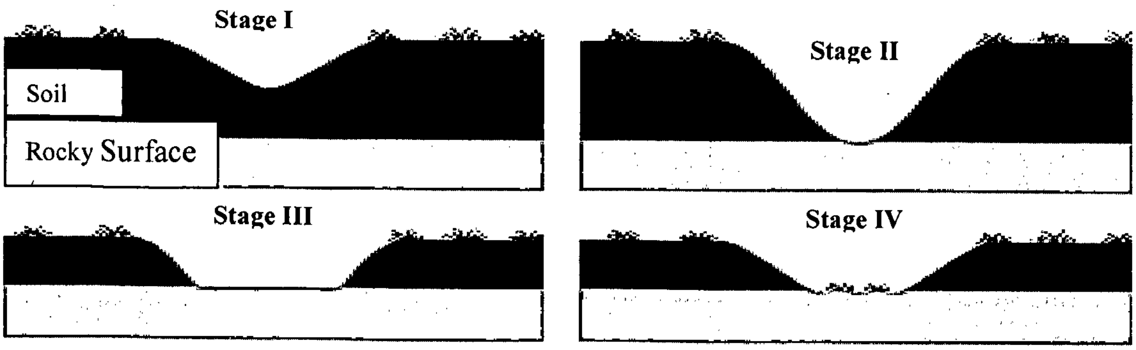


Fig. 5.3:- Stages of Gully Formation

The gullies listed at Sl. 8, 9 and 13 of Table 5.1 are at Stage II of development, where soil erosion is seen to be active. The other gullies are at Stage III, where vegetation has started to grow.

The mechanics of gully erosion can be reduced to two main processes: down cutting and head cutting. Down cutting of gully bottom leads to gully deepening and widening. Head cutting extends the channel into ungullied headwater areas and increase the stream net and its density by developing tributaries. The gullies under study are subjected to the down cutting process.

5.6 ESTIMATION OF GULLY EROSION

Apart from the gullies listed at Sl. 8, 9 and 13 of Table 5.1, the other gullies have reached their Stage III of formation and vegetation has started growing. So, these gullies are not likely to widen much. However Gully No.8, 9 and 13 are in the Stage II of formation and are subjected to soil erosion and are likely to widen further.

The widening of these gullies is estimated as per the Guidelines for Watershed Management, FAO of the United Nations, 1986 [49]. The Guidelines states that:

- On the average, where the gully advances through cohesive materials, the gully width is about three times the depth.
- In non-cohesive materials the gully width is about 1.75 the depth.

Based on the analysis of soil samples, it was found that the soil in the gully affected area consisted of 54.11% sand and as such it is considered to be non-cohesive soil. The soil profile at a nearby stone quarry shows that rocky surface lies at a depth of 2.25 m from the soil surface. So, assuming the maximum potential gully depth to be 2.25 m, the maximum potential gully width of Gully No. 8, 9 and 13 will be 3.94 m. The potential soil erosion for these three gullies is estimated, which is shown in Table 5.2.

Table 5.2:- Estimation of Potential Soil Loss from Gully Erosion

Gully No.	Length (m)	Present Avg. X-sectional Area (m^2)	Projected Avg. X-sectional Area (m^2)	Present Volume of Soil Loss	Projected Volume of Gully (m^3)	Projected Soil Loss (m^3)
8	103.50	1.81	4.43	187.79	458.51	270.72
9	118.20	1.51	4.43	178.72	523.63	344.91
13	122.50	1.40	4.43	171.94	542.68	370.74
					Total	986.37

Thus, when the gully bed reaches the underlying rocky surface, there will be a soil loss of 986.37 m^3. If the gullying process is not checked the soil loss will be more than the total soil loss occurred till date from the thirteen gullies. This eroded soil will ultimately be carried by surface runoff into the wetland, thus adding to the siltation problem.

5.7 GULLY CONTROL MEASURES

Gullies are one of the most destructive forms of soil erosion on a landscape. Gullies spread fast and destroy large tracts of land, and eventually engulf the entire land mass of the area. Thus, the spread of gullies need to be checked and brought under control at the early stage of their growth. However, when the gullies are already formed, prevention and control measures can then only check their further growth.

Gully control measures can be broadly classified as (a) Permanent and (b) Temporary. Permanent structures are installed when erosion and consequent enlargement of large gullies into ravines needs to be checked. Permanent structures are very expensive and are recommended only when the benefits obtained justify the high cost of construction.

As per the conditions of the study area temporary measures will be best suitable for restricting the developmental process of Gully No. 8, 9 and 13. Vegetative measures coupled with engineering structures are advisable. Low height, dense cover, dense and deep rooted vegetation adds stability to soil surface and is suitable for gully control. On the other hand, long flexible plants such as certain tall grasses; lie down on the gully bottom under the impact of flow. These provide a smooth interface between the flow and the original bed and increase the flow velocities. The increased velocity endangers meandering gully banks in spite of bottom protection and widens the gully. However, growing conditions may not permit the direct establishment of vegetation due to climatic or site restriction or due to severity of gully erosion. Hence, engineering measures is required along with vegetative measures. The most commonly applied engineering measures for the down cutting of the gully bed is the provision of small check dam, placed in series in V-shaped gullies. The sides of the V-shaped gullies should be protected from erosion by planting vegetations, such as grasses, vines, etc. Vegetations with strong root system, such as Kudzu (Pueraria lobata), which has a low demand for soil moisture, soil fertility and are locally available is recommended to be planted on the sides of Gully No. 8, 9 and 13.

Some of the most effective and inexpensive check dams are

- Loose Rock Check Dam
- Wire-bound Loose Rock Check Dam
- Single Fence Check Dam
- Double Fence Check Dam
- Gabion Check Dam

As the slope steepness is high, it is suggested to construct Double Fence Check Dams in series along the V-shaped gullies. The design of Double Fence Check Dam based on the FAO Guidelines for Watershed Management, 1986 [19], is shown below.

5.7.1 Design of Double Fence Check Dam

The design details of check dam for Gully No. 8 are shown as sample calculation. Design details of check dam for Gully No. 9 and 13 are shown in Appendix IX and X.

5.7.1.1 *Rock Gradation*

The affective rock gradation for rock dam of height between 1 to 2 m is as stated below.

Rock Size Class	Percentage
10 – 14 mm	25
15 – 19 mm	20
20 – 30 mm	25
31 – 45 mm	30

5.7.1.2 *Effective Height of Check Dam*

As the average depth of the gully is 1.62 m, the height of the check dam is taken as 1.5 m. Assuming spillway depth as 0.15m, the effective height of the dam

$H_E = (1.5 - 0.15)$ m = 1.35 m.

5.7.1.3 *Spacing of Check Dam*

The spacing between the check dams is calculated using the formula developed by Heede and Mufich, which is as shown below

$$S = \frac{H_E}{K.G.\cos a} \qquad \text{..................... (5.1)}$$

where, S = spacing of dam

H_E = effective dam height

a = angle corresponding to the gully gradient

G = gully gradient as a ratio = tan a

K = constant

= 0.3 for $G \leq 0.20$ .... (5.2)

= 0.5 for $G > 0.20$ .... (5.3)

From Eq. 5.1, $S = \frac{1.35}{(0.5 \times 0.3 \times \cos 16.7^{o})}$, $a = 16.7^{o}$

$= 9.40$ m

Therefore, No. of gullies required $= \frac{Length}{Spacing} + 1$

$= \frac{103.5}{9.4} + 1$

= 12 Nos.

5.7.1.4 *Keys*

Keying a check dam into the side slopes and bottom of the gully greatly enhances the stability of the structure. The objective of extending the key into the gully side slopes is to prevent destructive flows of water around the dam and scouring of the banks.

Under normal gully conditions i.e. where cracks and fissures in the bank wall have not developed, the following dimensions of Keys are considered.

Width = 0.60 m

Depth = 0.60 m

5.7.1.5 *Volume of Sediment Deposits*

The volume of sediment deposition in the check dam is calculated using the formula developed Heede and Mufich.

$V_S = 0.5\ H_E\ S \cos a\ L_{HE}$ .... (5.4)

where, V_S = sediment volume

H_E = effective dam height

S = spacing of dam

a = angle corresponding to the gully gradient

L_{HE} = average length of dam

Again, $L_{HE} = L_B + \frac{L_U - L_B}{2D} H_E$ .... (5.5)

where, L_B = bottom width of gully

L_U = bank width of gully

D = depth of gully

H_E = effective dam height

Substituting the value of S in Eq. 5.4

$V_S = \frac{H_E^{\ 2}}{2KG} L_{HE}$ .... (5.6)

where, K = a constant (As per Eq. 5.2 and 5.3)

Eq. 5.6 indicates that the sediment deposits increase as the square of the effective dam height.

Therefore, $L_{HE} = 0.10 + \frac{2.24 - 0.10}{2 \times 1.62} \times 1.35$

$= 0.99$ m

Therefore, $V_S = \frac{1.35^2}{2 \times 0.5 \times 0.3} \times 0.99$

$= 6.01\ m^3$

5.7.1.6 *Design of Spillway*

Since spillways of rock check dams can be considered as broad-crested weirs, the discharge formula for broad-crested weir is applicable

$Q = CLH^{3/2}$ .... (5.7)

where, Q = discharge in m^3/sec

C = coefficient of the weir

$= 1.65$

L = effective length of the weir in m

H = head of flow above the weir crest in m

The effective length of spillway,

$$L_{AS} = \frac{L_U}{D}\ H_E - f \qquad \text{..................... (5.8)}$$

where, $f = 0.60$ (for $D > 1.5$m)

$$\text{Therefore, } L_{AS} = \frac{2.24}{1.62} \times 1.35 - 0.60$$

$$= 1.27 \text{ m}$$

Assuming value of H to be same as the spillway depth

$$Q = 1.65 \times 1.27 \times 0.15^{3/2}$$

$$= 0.12 \text{ m}^3\text{/sec}$$

$$\text{The spillway depth, } H_{SV} = \left(\frac{Q}{C\,L_{AS}}\right)^{2/3} \qquad \text{..................... (5.9)}$$

$$= \left(\frac{0.12}{1.65 \times 1.27}\right)^{2/3}$$

$= 0.15$ m, which is same as the assumed value

For spillways having side slope of 1:1, the bottom length of the spillway,

$$L_{BSV} = L_{AS} - H_{SV} \qquad \text{..................... (5.10)}$$

$$= 1.27 - 0.15$$

$$= 1.12 \text{ m}$$

5.7.1.7 Design of Apron

Aprons must be provided on the gully bottom below the check dam to prevent undercutting from down stream, and subsequent failure of the structure. The length of the apron is taken as 1.5 times the height of the structure in channels where the gradient does not exceed 15 %. Where the channel gradient exceeds 15 %, the apron length is taken as 1.75 times of the height of the structure.

As the gradient of Gully No. 8 is 30 %, the apron length is taken as 1.75 times of the structure height.

Therefore, Apron length L = 1.75 × 1.5 = 2.60 m

Thickness of apron't' is taken as 0.30 m.

At the downstream end of the apron, a loose rock sill of 0.15 m height should be provided. This end sill creates a pool in which the water will cushion the impact of the waterfall. Fig. 5.4 shows the cross-section of a Double Fence Check Dam.

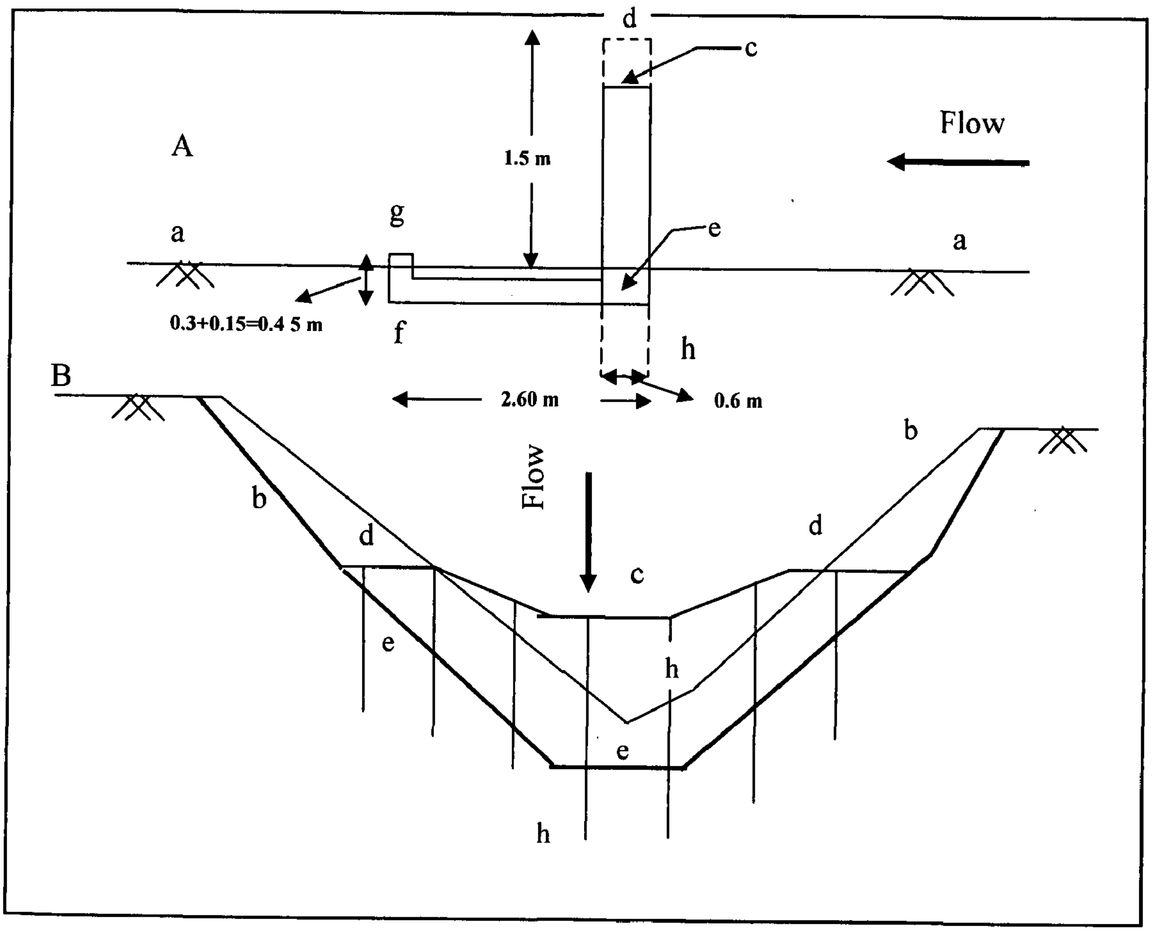


Fig. 5.4:- Cross-section of a Double Fence Check Dam

Note: A – Section of dam parallel to the centerline of the gully.
B – Section of dam at the cross section of the gully
a – original gully bottom
b – original gully cross section
c – spillway
d – crest of free board
e – excavation for key
f – excavation for apron
g – end sill
h - steel fence post

5.7.2 Estimation of Quantities

The main materials required for the construction of a Double Fence Check Dam are

- Rock
- Wire Mesh
- Iron Fence Post

The quantity of materials required for Gully No. 8 is estimated below and shown as sample calculation. Estimation of quantities for Gully No. 9 and 13 are shown in Appendix IX and X. The estimation has been done based on the FAO Guidelines, 1986 [19].

5.7.2.1 *Quantity of Rock*

Distance between two parallel fences = 0.60 m

Therefore, width of the Check Dam = 0.60 m

Quantity of rocks required for check dam, $V_{DF} = 0.60\ H_D\ L_{HE} - V_{SDF}$ .... (5.11)

where, H_D = dam height

$= 1.5$ m

L_{HE} = average length of the dam

$= 0.99$ m

V_{SDF} = volume of spillway

$V_{SDF} = H_{SV} \times L_{AS} \times 0.6$ .... (5.12)

where, H_{SV} = spillway depth

$= 0.15$ m

L_{AS} = effective length of the spillway

$= 1.27$ m

0.6 represents the standard breadth of the dam in meters.

Now, $V_{SDF} = 0.15 \times 1.27 \times 0.6$

$= 0.11\ m^3$

And $V_{DF} = 0.60 \times 1.5 \times 0.99 - 0.11$

$= 0.78\ m^3$

$\approx 0.80\ m^3$

Quantity of rocks required for apron = $2.6 \times 0.3 \times 3.78$

$= 2.95\ m^3$

Quantity of rocks required for sill = $0.10 \times 0.15 \times 3.78$

$= 0.06\ m^3$

Quantity of rocks required for Keys = $0.6 \times 0.6 \times 3.78$

$= 1.36$

No. of check dams required for Gully No. 8 = 12

Therefore, total quantity of rocks required in the 12 Nos. of check dams

$= 12 \times (0.8 + 2.95 + 0.06 + 1.36)$

$= 62.04\ m^3$

5.7.2.2 *Quantity of Wire Mesh*

Length of wire mesh, $M_{LD} = 2 \times L_B + \frac{L_U - L_B}{D} \times 2 \times H_D$ .... (5.13)

where, L_B = bottom width of gully

L_U = bank width of gully

D = depth of gully

H_D = dam height

$$M_{LD} = 2 \times 0.1 + \frac{2.24 - 0.1}{1.62} \times 2 \times 1.5$$

$= 4.2$ M

Width of wire mesh = dam height

$= 1.5$ m

Therefore, wire mesh required in one dam = $4.2 \times 1.5 \times 2$ (in two rows)

$= 12.60\ m^2$

5.7.2.3 *Quantity of Iron Fence Post*

No. of fence post required, $N_{DF} = \frac{L_B}{0.6} + \frac{L_U - L_B}{0.6D} \times H_D + 2$ .... (5.14)

where, 0.6 is a constant representing post spacing

$$= \frac{0.1}{0.6} + \frac{2.24 - 0.1}{0.6 \times 1.62} \times 1.5 + 2$$

$= 5.5$

≈ 6

Considering half of the post up to dam height and the bottom half up to the rocky surface, which is at a distance of about 2.25 m from the soil surface, the total length of post required in one dam $= 6 \times (1.5 + 0.63)$

$= 12.78$ m

5.7.3 Cost Estimate

The cost estimate for check dams at Gully No. 8 is shown as sample calculation. Estimate for Gully No. 9 and 13 are shown in Appendix IX and X.

Item No.	Item in short		Amount
1	Loose rock of size 10 cm to 45 cm.....		Rs.40,326.00
	Qnty. 62.04 m^3 @ Rs.650.00 / m^3		
	(Local Market Rate)		
2	High strength corrosion resistant wire meshes.....		Rs.9,761.00
	Qnty. (12.60×12) m^2 @ Rs.64.56 / m^2		
	(Local Market Rate)		
3	Iron fence post of 25mm dia.......		Rs.35,573.00
	Qnty. (12.78×12) m @ Rs. 245.00/ m		
	(Local Market Rate)		
		Total	Rs.85,660.00
	Labour Cost @ 40% of material cost		Rs.34,264.00
		Total	Rs.119,924.00
	Contingencies and Miscellaneous......5 %		Rs.5,996.00
		Grand Total	Rs.1,25,920.00
		Say	Rs.1,26,000.00

(Rupees one lakh twenty six thousand) only.

CHAPTER 6

SUMMARY AND CONCLUSIONS

6.1 SUMMARY

Three aspects were studied with regard to the conservation of Deeporbeel Wetland. These aspects are

- Surface Water Quality of the wetland.
- Erosion in the Wetland Catchment and subsequent silt deposition in the wetland.
- Hydrological study.

The water quality was monitored for Post-monsoon season of the year 2005 and Pre-monsoon season of the year 2006. The experimentally obtained data were compared with that of the Base Year (1989). NSFWQI was computed and compared with the Base Year Index Value and statistical analysis using F test of the equality of two variances was done for nine water quality parameters.

The gross soil loss from the wetland catchment was estimated for the year 1996 and 2005 and these were compared with that of the Base Year (1972). The silt load coming into and moving out of the wetland was determined for the monsoon and post-monsoon seasons of the year 2005 and the pre-monsoon season of the year 2006. A monthly water balance for the year 2005 was also prepared. Thirteen gullies were identified in the catchment area and accordingly control measures are suggested.

6.2 CONCLUSIONS

The conclusions derived from this study are as follows:

1. The pH values at the various sampling locations of the wetland have changed from slightly acidic to slightly alkaline since the base year (1989), but are within the prescribed limits for domestic water supply as per IS 2296-1963 and USPH standards.
2. The DO value has come down substantially (particularly at sampling locations D2 and D3) due to the inflow of pollution load (domestic sewage, industrial wastes, human activities in the agricultural fields and other debris and solid waste washed down by surface runoff).

3. The BOD value has increased significantly due to the inflow of pollution load resulting from the change in land use of the catchment in a time span of 16 years.

4. The COD value was found to be higher at those sampling locations which were in residential area or industrial area, due to the inflow of pollution load.

5. The conductivity at sampling location D6 was observed to be higher due to the agricultural runoff from the southern fringe area.

6. There is a wide variation of solid concentration at the various sampling locations, with very high concentration at D1 and D6 during post-monsoon season.

7. From the view point of turbidity the wetland water is not fit for drinking at all the sampling locations.

8. The high value of nitrate and phosphate is responsible for eutrophication in the wetland.

9. The maximum concentration of Chloride found in the wetland water was very low, and is well within the BIS limit for drinking water.

10. The heavy metal concentration in the wetland water was much below the BIS limit for drinking water. The water hyacinth in the wetland acts as a water purifier by absorbing the heavy metals present, thus, lowers its concentration in water.

11. From the NSFWQI it can be concluded that the quality of the wetland water has shifted from the "Good Category" to the "Medium Category" since the Base Year.

12. From the F test it can be concluded that the difference among the means with respect to time is significant for the parameters BOD, DO, COD, Conductivity, Turbidity, NO_3 and PO_4, which indicates that these parameters have undergone significant changes.

13. Although the R-factor value was more than that of the base year, there has been a decrease in the soil erosion rate, which can be attributed to the change in land use particularly conversion of agricultural and grazing land into settlement areas.

14. The total sediment load entering into wetland during the year is only about 39 % of the gross soil loss from the catchment.

15. The minimum monthly water volume in the wetland was found to be 7,477,700 m^3 during the month of December and the maximum to be 64,593,982 m^3 during the month of August.

16. If the gullying process in the three active gullies is not checked, the potential soil loss will be more than the total soil loss that has occurred from the thirteen gullies. This eroded soil will ultimately be carried by surface runoff into the wetland, thus adding to the siltation problem.

17. To check the gullying process, total 57 Nos. of check dams will be required involving an estimated cost of Rs.5, 41,000.00.

In order to improve the water quality of the wetland and to minimize the siltation problem, the following measures are suggested.

- Use of chemical fertilizers, pesticides etc. in agriculture in the fringe and catchment areas of the wetland should be completely stopped.
- Inflow of untreated domestic sewage, industrial effluents and solid waste discharged from municipal areas should be stopped from flowing into the wetland.
- It is necessary to remove the obnoxious aquatic weeds from the wetland on a regular basis. This will reduce the organic bottom deposits and provide a better environment for fish and other aquatic life and improve the wetland aesthetic.
- Siltation of the wetland bottom is becoming a serious problem leading to the degeneration of the wetland. The sediment should be trapped in the catchment areas through afforestation and by constructing check dams parallel to the shoreline. This will help in accumulation of silt in the littoral zones. Hill cutting and quarry operation in the wetland catchment should be stopped immediately.
- In addition, contour cultivation should be practiced instead of the currently followed up and down cultivation in the wetland catchment.
- To check further gullying process, vegetations with strong root system, such as Kudzu (Pueraria lobata), which has a low demand for soil moisture, soil fertility and are locally available is recommended to be planted on the sides of gullies along with the construction of check dams at the required interval.
- Wetland boundary should be clearly demarcated to prevent further encroachment. This work should be started from the northern and eastern parts of the wetland,

where the encroachment problem is more severe. Indiscriminate construction of engineering structures across wetland for different purposes should be stopped.

- The wetland can be developed into recreational and tourist spot. This will not only help in revenue generation, but also help in employment of the local unemployed youth.
- All conservation measures without the awareness and participation of the public may become futile eventually. Therefore, the public should be made aware of the importance of the wetland so that they also contribute to the conservation of the wetland. The role of the NGOs and other voluntary agencies is very important in generating public awareness and in initiating programmes for conservation of the wetlands.

6.3 FURTHER SCOPE

- More frequent sampling (fortnightly) can be done at all the six sampling locations to get a more precise picture of the wetland water quality and of the sediment flow.
- Plot study in the wetland catchment can be carried out to experimentally determine the values of K, L, S, C and P factors of the USLE.
- A wet contour of the wetland may be prepared to get a more accurate value of the storage volume.
- Field measurement of Evapo-transpiration can be carried out.
- To know the actual rate of silt deposition at various location of the wetland, nuclear analysis of soil samples, such as Lead dating or Cesium dating can be carried out.

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APPENDIX I

PARAMETERS FOR WATER QUALITY CHARACTERIZATION AND STANDARDS (DOMESTIC WATER SUPLLIES)

Parameters	USPH Standards	ISI Standards (IS:2296-1963)
Colour, Odour, Taste	Colourless, Odourless, Tasteless	-
pH	6.0 – 8.5	6.0 - 9.0
Specific Conductance	300 μ mho/cm	-
D.O	4.6 – 6.0 mg/l	3.0 mg/l
TDS	500 mg/l	-
SS	5.0 mg/l	-
Chloride	250 mg/l	600 mg/l
Sulphate	250 mg/l	1000 mg/l
COD	4.0 mg/l	-
Lead	0.05 mg/l	0.1 mg/l
Iron (filterable)	0.03 mg/l	-
Ammonia	0.5 mg/l	-
Phosphate	0.1 mg/l	-
Calcium	100 mg/l	-
Magnesium	30 mg/l	-
Cadmium	0.01 mg/l	-
Arsenic	0.05 mg/l	0.2 mg/l
Mercury	0.001 mg/l	-

DRINKING WATER STANDARDS OF THE WORLD HEALTH ORGANIZATION (WHO)

Parameters	Permissible Limit	Excessive Limit
Total Solids	500 mg/l	1500 mg/l
Colour	5 Hazen Units	50Hazen Units
Turbidity	5 JTU	25 JTU
Calcium	75 mg/l	200 mg/l
Magnesium	50 mg/l	150 mg/l
Sulphate	200 mg/l	400 mg/l
pH	7.0 – 8.5	6.5 – 9.2
Iron	0.3 mg/l	1.0 mg/l
Chloride	200 mg/l	600 mg/l
Lead	-	0.1 mg/l
Arsenic	-	0.2 mg/l
Zinc	5.0 mg/l	15.0 mg/l
Nickel	0.02	

INDIAN STANDARD DRINKING WATER SPECIFICATION

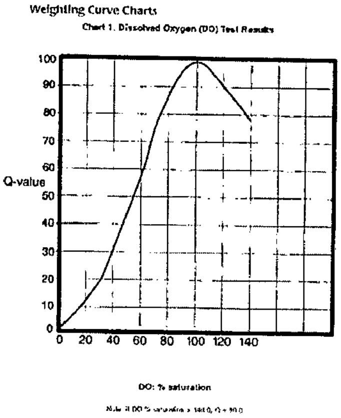
(BIS-10500-1991)

Parameters	Desirable Limit	Permissible Limit in the absence of Alternate Source
Colour	5 Hazen Units	25 Hazen Units
Odour	Unobjectionable	Unobjectionable
Taste	Abreeable	Abreeable
pH	6.5 – 8.5	No Relaxation
Turbidity	5 NTU	10 NTU
Total Hardness (as $CaCo_3$)	300 mg/l	600 mg/l
Iron	0.3 mg/l	1.0 mg/l
Chlorides	250 mg/l	1000 mg/l
TDS	500 mg/l	2000 mg/l
Calcium	75 mg/l	200 mg/l
Copper	0.05 mg/l	1.5 v
Manganese	0.10 mg/l	0.3 mg/l
Sulphate	200 mg/l	400 mg/l
Nitrate	45 mg/l	100 mg/l
Mercury	0.001 mg/l	No Relaxation
Cadmium	0.01 mg/l	No Relaxation
Selenium	0.01 mg/l	No Relaxation
Arsenic	0.05 mg/l	No Relaxation
Lead	0.05 mg/l	No Relaxation
Zinc	5 mg/l	15 mg/l
Pesticides	Absent	0.001 mg/l
Boron	1.0 mg/l	5.0 mg/l

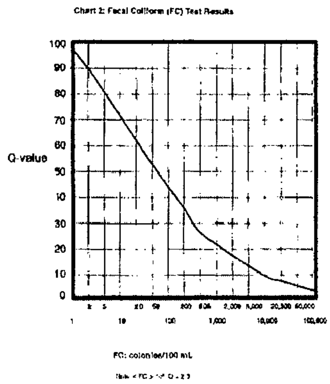
APPENDIX II

SUB-INDEX FUNCTION GRAPHS FOR NSFWQI

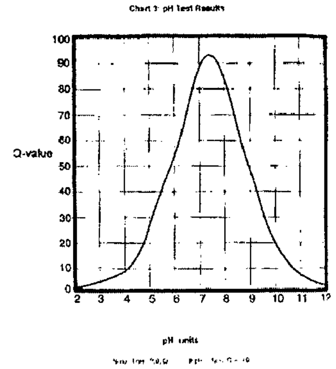
WQI: DO sat (%)



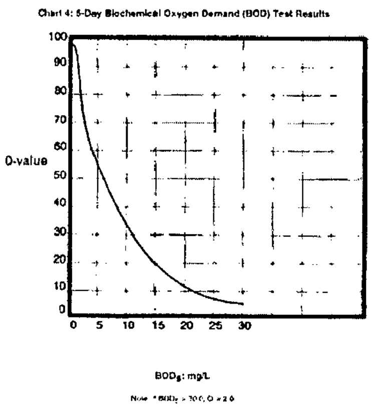
WQI: Faecal Coliform



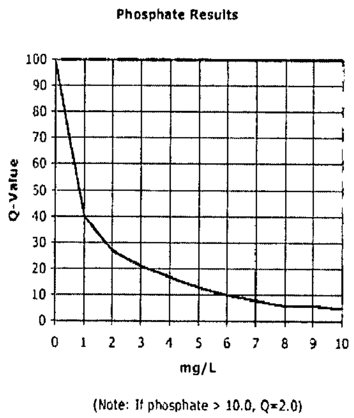
WQI: pH



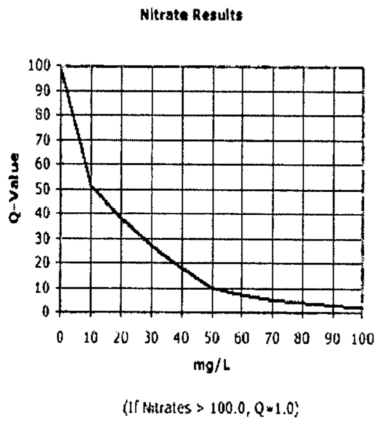
WQI: BOD



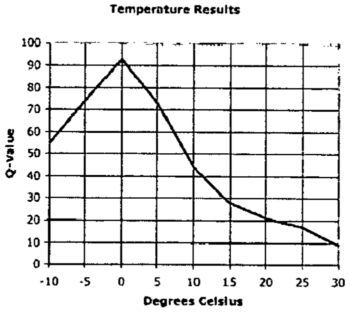
WQI: Nitrate



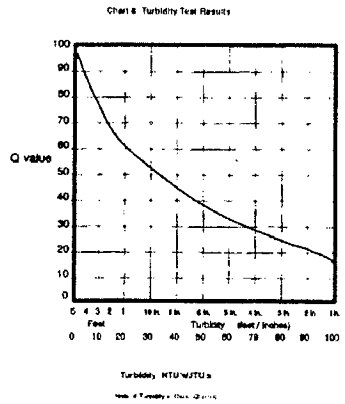
WQI: Phosphate



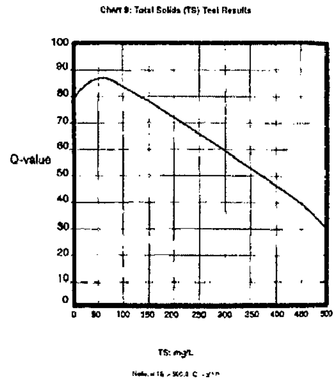
WQI:Temperature Variation



WQI: Turbidity



WQI: Total Solids



APPENDIX III

CALCULATION OF LS FACTOR

Hilly Catchment:

Catchment I

Average Slop Length, L_p = 275m

Average Percentage Slope, s = 22.90%

$$L = \left(\frac{L_p}{22.13}\right)^{0.5}$$

$$= 3.53$$

$$S = \frac{0.43 + 0.30s + 0.043s^2}{6.613}$$

$$= 4.51$$

$$LS = 3.53 \times 4.51$$

$$= 15.92$$

$$LS = \frac{L_p^{\;0.5}\left(1.36 + 0.97s + 0.1385s^2\right)}{100}$$

$$= 15.95$$

Let us consider LS as 15.95

Catchment II

Average Slop Length, L_p = 306m

Average Percentage Slope, s = 20.30%

$$L = \left(\frac{L_p}{22.13}\right)^{0.5}$$

$$= 3.7$$

$$S = \frac{0.43 + 0.30s + 0.043s^2}{6.613}$$

$$= 3.66$$

$$LS = 3.7 \times 3.66$$

$$= 13.54$$

$$LS = \frac{L_p^{0.5}\left(1.36 + 0.97s + 0.1385s^2\right)}{100}$$

$= 13.66$

Let us consider LS as 13.66

Catchment III

Average Slop Length, L_p = 185m

Average Percentage Slope, s = 21.80%

$$L = \left(\frac{L_p}{22.13}\right)^{0.5}$$

$= 2.89$

$$S = \frac{0.43 + 0.30s + 0.043s^2}{6.613}$$

$= 4.14$

$LS = 2.89 \times 4.14$

$= 11.96$

$$LS = \frac{L_p^{0.5}\left(1.36 + 0.97s + 0.1385s^2\right)}{100}$$

$= 12.01$

Let us consider LS as 12.01

Agricultural Fields/Plains:

Average Slop Length, L_p = 1460m

Average Percentage Slope, s = 0.71%

$$L = \left(\frac{L_p}{22.13}\right)^{0.5}$$

$= 8$

$$S = \frac{0.43 + 0.30s + 0.043s^2}{6.613}$$

$= 0.10$

$LS = 8 \times 0.10$

$= 0.8$

$$LS = \frac{L_p^{0.5}\left(1.36 + 0.97s + 0.1385s^2\right)}{100}$$

$= 0.80$

Let us consider LS as 0.8

APPENDIX IV

ORGANIC MATTER PRESENT IN SOIL

Method: Modified Walkey and Black Method [48]

The organic matter present in the soil is digested with excess of potassium dichromate and sulphuric acid, and the residual unutilized dichromate is then titrated with ferrous ammonium sulphate.

$$\% \text{ Carbon (C)} = 3.951/g \times \left(1 - \frac{T}{S}\right)$$

% Organic Matter = % C × 1.724

where, g = weight of soil sample in gm

S = ml ferrous solution with blank titration

T = ml ferrous solution with sample titration

Sample 1 (Soil Sample from Hilly Catchment)

g = 1gm

S = 39.00 ml

T = 20.00 ml

% C = 3.951/1 × (1 – 20.00/39.00)

= 1.92

% Organic Matter = 1.92 × 1.724

= 3.3 %

Sample 2 (Soil Sample Agricultural Fields / Plains)

g = 1gm

S = 39.00 ml

T = 18.00 ml

% C = 3.951/1 × (1 – 18.00/39.00) = 2.13

% Organic Matter = 2.13 × 1.724 = 3.7 %

Therefore, from Table 3.5 the value of Soil Erodibility Factor (K) is as follows

K for soil sample 1 (Sandy Clay, Organic Matter = 3.3%) = 0.12

K for soil sample 2 (Clay Loam, Organic Matter = 3.7%) = 0.22

APPENDIX V

DETERMINATION OF SPECIFIC GRAVITY OF SOIL BY PYCNOMETER METHOD

Specific gravity of soil is the ratio of the weight of a given volume of soil particles in air to the weight of an equal volume of distilled water at a temperature of 4^0C. The specific gravity of a soil is often used in relating a weight of soil to its volume. It is an important factor required for computing the most of the soil properties *e.g.* void ratio of soil, unit weight, particle size determination by hydrometer method, degree of saturation of a soil, etc [31].

Mathematically, it is expressed as

$$Gs = (W_2\text{-}W_1) / \{(W_2\text{-}W_1)\text{-}(W_3\text{-}W_4)\}$$

Where, W_1 = Weight of Pycnometer (gm)

W_2 = Weight of Pycnometer + Soil (gm)

W_3 = Weight of Pycnometer + Soil + Water (gm)

W_4 = Weight of Pycnometer full of Water (gm)

Determination of Specific Gravity of Soil from Hilly Catchment (Soil Sample 1)

Here, W_1 = 684.80 gm

W_2 = 710.10 gm

W_3 = 1579.60 gm

W_4 = 1563.70 gm

Therefore, Gs = (710.10 – 684.80) / {(710.10 – 684.80) – (1579.60 – 1563.70)}

= 2.69

Determination of Specific Gravity of Soil from Agricultural Fields / Plains (Soil Sample 2)

Here, W_1 = 684.80 gm

W_2 = 712.40 gm

W_3 = 1580.80 gm

W_4 = 1563.70 gm

Therefore, $G_s = (712.40 - 684.80) / \{(712.40 - 684.80) - (1580.80 - 1563.70)\}$

$= 27.60 / (27.60 - 17.10)$

$= 2.63$

NB: - The bulk density of soil sample 1 and 2 was determined by Core-Cutter Method [31]. For soil sample 1, the bulk density was found to be 1.56 and for soil sample 2 it was found to be 1.65. The average bulk density of sediment is considered as 1.60 (i.e. the average value for soil sample 1 and 2).

APPENDIX VI

HYDROMETER ANALYSIS

This method is used for the grain size analysis of the soil passing through 75 micron I.S. sieve to determine the percentage of various sized (silt and clay) particles and to plot the grain size distribution curve. This method is not applicable if less than 10 percent of the materials passes 75 micron I.S. sieve [31].

Hydrometer Analysis for Soil from Hilly Catchment

Soil Sample No. 1 (Soil from Hilly Catchment)

Date of Experiment: - 20.02.06 (9:30 AM)

(a) Percentage of soil passing 75μ IS Sieve = 44%

(b) Mass of dry soil (passing 75μ IS Sieve), W_d = 123.5 gm.

(c) Meniscus correction (C_m) = 0.50 mm

(d) Dispersion correction (C_d) = 2 mm

(e) C_t = temperature correction

(f) Effective Depth, $H_e = H + \frac{1}{2}\left[h - \frac{V_h}{A}\right]$

where, H = length from the neck of the bulb to the graduation mark R_h (cm)

h = twice the distance from the neck of hydrometer bulb to the centre of volume (cm)

V_h = volume of bulb (ml)

A = cross-sectional area of sedimentation jar (cm^2)

(g) Specific gravity G_s of soil (passing 75μ IS Sieve) = 2.69 (from Pycnometer Analysis)

$M_1 = \sqrt{[30\eta/980(Gs-1)]}$

$= 0.013$

$M_2 = G_s \times 100 / W_d\,(Gs-1)$

$= 1.29$

Table No. VI.1:- HYDROMETER ANALYSIS FOR SOIL FROM HILLY CATCHMENT

Observation and Calculation

Sl. No.	Time (As In Watch) Hrs.	Time Elapsed (Min.) t	Hydrometer Reading (R_h)	Corrected Hydrometer Reading ($R_1 = R_h - C_m$)	Effective Depth (H_e)	Temp. (^0C)	C_d	$\sqrt{\frac{H_e}{t}}$	η (Poise)	Factor M_1	Particle Size D (mm)	C_t	$R_1 - C_d \pm C_t$	% finer than w.r.to mass W_d	% finer than w.r.to total mass
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)=(9)×(11)	(13)	(14)=(5)-(8)±(13)	(15)= $M_{2\times(14)}$	(16)=(a)×(15)
1	9:30AM & 30 sec.	0.5	36.5	37.0	9.65	23	2	4.30	9.38× 10^-3	0.013	0.05	0.58	35.58	45.89	20.20
2	9:31AM	1.00	35.5	36.0	9.75	23	2	3.12	9.38× 10^-3	0.013	0.04	0.58	34.58	44.60	19.63
3	9:32AM	2.00	34.5	35.0	9.85	23	2	2.22	9.38× 10^-3	0.013	0.03	0.58	33.58	43.32	19.06
4	9:34AM	4.00	33.0	33.5	10.00	23	2	1.58	9.38× 10^-3	0.013	0.02	0.58	32.08	41.38	18.20
5	9:38AM	8.00	31.0	31.5	10.20	23	2	1.12	9.38× 10^-3	0.013	0.01	0.58	30.08	38. 80	17.07
6	9:45AM	15.00	29.0	29.5	10.41	23	2	0.83	9.38× 10^-3	0.013	0.01	0.58	28.08	36.22	15.94
7	10:00AM	30.00	27.0	27.5	10.61	23	2	0.59	9.38× 10^-3	0.013	0.007	0.58	26.08	33.64	14.80
8	10:30AM	60.00	25.0	25.5	10.80	23.5	2	0.39	9.27× 10^-3	0.013	0.005	0.68	24.18	31.19	13.72
9	11:30AM	120.00	6.0	6.5	12.71	24	2	0.32	9.16× 10^-3	0.013	0.004	0.82	5.32	6.86	3.12
10	9:30AM (Next Day)	1440.00	-35.4	-34.9	16.80	23.5	2	0.11	9.27× 10^-3	0.013	0.001	0.68	-36.22	-	-

Hydrometer Analysis For Soil From Agricultural Fields / Plains

Soil Sample No. 2 (Soil from Agricultural Fields / Plains)

Date of Experiment: - 20.02.06 (10:50 AM)

(a) Percentage of soil passing 75μ IS Sieve = 50%

(b) Mass of dry soil (passing 75μ IS Sieve), W_d = 113 gm.

(c) Meniscus correction (C_m) = 0.50

(d) Dispersion correction (C_d) = 2 mm

(e) C_t = temperature correction

(f) Effective Depth, $H_e = H + \frac{1}{2}\left[h - \frac{V_h}{A}\right]$

where, H = length from the neck of the bulb to the graduation mark R_h (cm)

h = twice the distance from the neck of hydrometer bulb to the centre of volume (cm)

V_h = volume of bulb (ml)

A = cross-sectional area of sedimentation jar (cm^2)

(g) Specific gravity Gs of soil (passing 75μ IS Sieve) = 2.63 (from Pycnometer Analysis)

$M_1 = \sqrt{[30\eta/980(Gs-1)]}$

$= 0.013$

$M_2 = Gs \times 100 / W_d\ (Gs-1)$

$= 1.43$

Table No. VI.2 :- HYDRO METER ANALYSIS FOR SOIL FROM AGRICULTURAL FIELDS / PLAINS

Observation and Calculation

Sl. No.	Time (As In Watch) Hrs.	Time Elapsed (Min.) t	Hydrometer Reading (R_h)	Corrected Hydrometer Reading ($R_1 = R_h - C_m$)	Effective Depth (H_e)	Temp. (^0C)	C_d	$\sqrt{\frac{H_e}{t}}$	η (Poise)	Factor M_1	Particle Size D (mm)	C_t	$R_1 - C_d \pm C_t$	% finer than w.r.to mass W_d	% finer than w.r.to total mass
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)=(9)×(11)	(13)	(14)=(5)-(8)±(13)	(15)= $M_{2\times(14)}$	(16)=(a)×(15)
1	10:50AM & 30 sec.	0.5	40.0	40.5	9.34	23	2	4.30	9.38× 10^-3	0.013	0.05	0.58	39.08	55.88	27.94
2	10:51AM	1.00	39.0	39.5	9.44	23	2	3.07	9.38× 10^-3	0.013	0.04	0.58	38.08	54.45	23.96
3	10:52AM	2.00	37.5	38.0	9.59	23	2	2.19	9.38× 10^-3	0.013	0.03	0.58	36.58	52.31	23.02
4	10:54AM	4.00	35.0	35.5	9.84	23	2	1.56	9.38× 10^-3	0.013	0.02	0.58	34.08	48.73	21.44
5	10:58AM	8.00	33.0	33.5	10.04	23.5	2	1.12	9.27× 10^-3	0.013	0.015	0.68	32.18	46.02	20.25
6	11:05AM	15.00	29	29.5	10.44	23.5	2	0.83	9.27× 10^-3	0.013	0.011	0.68	28.18	40.29	17.73
7	11:20AM	30.00	25	25.5	10.84	24.5	2	0.60	9.06× 10^-3	0.013	0.008	0.92	24.42	34.92	15.37
8	11:50AM	60.00	20	20.5	11.34	24.5	2	0.43	9.06× 10^-3	0.013	0.005	0.92	19.42	27.77	12.22
9	12:50AM	120.00	2.5	3	13.09	25	2	0.33	8.95× 10^-3	0.013	0.004	1.03	2.03	2.90	1.28
10	10:50AM (Next Day)	1440.00	-64.2	-63.7	19.76	23.5	2	0.12	9.27× 10^-3	0.013	0.002	0.68	-65.12	-	-

Therefore, as per the Textural Classification Chart (Fig. No. VIII.1) , soil sample No.1 i.e. soil sample from the hilly catchment falls in the class of 'Sandy Clay' and soil sample No.2 i.e. soil sample from the agricultural fields/ plains falls in the class of 'Clay Loam'.

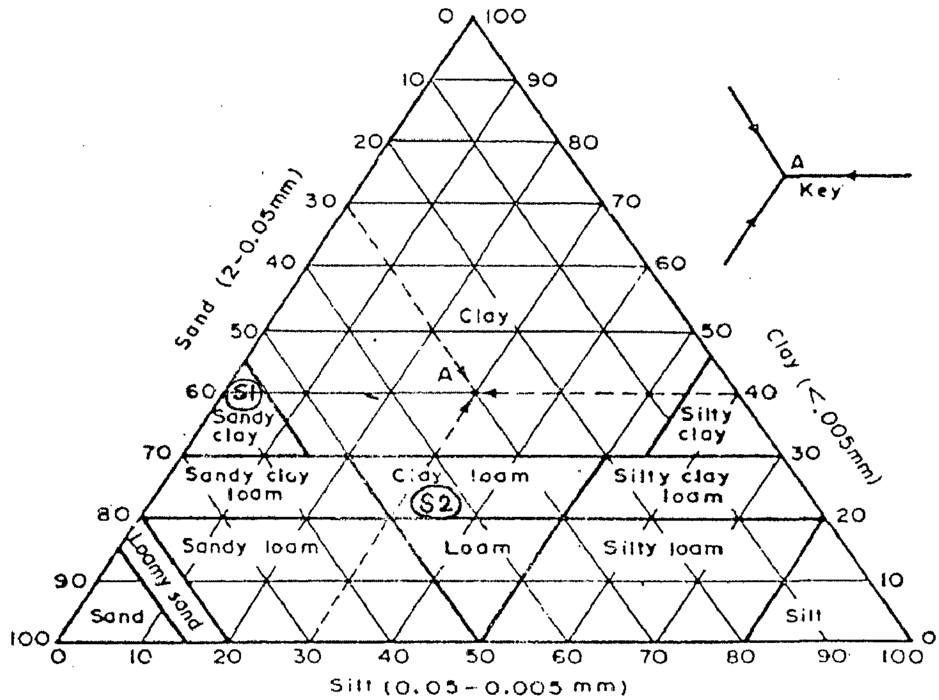


Fig. No. VIII.1 :- Textural Classification Chart (U.S. Public Road Administration) [38]

APPENDIX VII

CALCULATION OF DIRECT RUN-OFF AND DOMESTIC WATER DEMAND

The inflow from direct run-off has been computed using Khosla's Equation, which is shown below

$Q_m = P_m - l_m$

where, Q_m = monthly run-off (cm)

P_m = monthly rainfall (cm)

l_m = monthly run-off loss (cm)

If t_m = monthly temperature of the catchment (°C), then

for $t_m > 4.5$ °C, $l_m = 0.48\ t_m$

and $t_m \leq 4.5$ °C, $l_m = 2.17$ at 4.5 °C

= 1.78 at -1 °C

= 1.52 at -6.5 °C

The calculation is shown in Table No. VII.1.

Table No. VII.1:- Monthly Inflow from Direct Run-off

Month	Monthly Rainfall (cm) P_m	Monthly Run-off Loss (cm) l_m	Monthly Run-off (cm) Q_m
Jan/05	16.60	7.96	0
Feb/05	3.90	10.01	0
March/05	150.70	11.23	1,631,150
April/05	134.80	12.13	571,880
May/05	284.50	12.60	6,738,290
June/05	104.60	14.15	0
July/05	174.50	14.12	1,414,570
Aug/05	803.00	14.11	28,129,900
Sept/05	82.10	14.21	0
Oct/05	117.20	12.53	0
Nov/05	1.40	10.99	0
Dec/05	0.80	9.22	0

Table No. VII.2:- Monthly Domestic Water Demand

Month	No. of Days	Per Capita Water Demand (lpcd)	Population (No.)	Total Monthly Domestic Water Demand (m^3)
Jan/05	31	135	6390	26,742
Feb/05	28	135	6390	24,154
March/05	31	135	6390	26,742
April/05	30	135	6390	25,879
May/05	31	135	6390	26,742
June/05	30	135	6390	25,879
July/05	31	135	6390	26,742
Aug./05	31	135	6390	26,742
Sept./05	30	135	6390	25,879
Oct./05	31	135	6390	26,742
Nov./05	30	135	6390	25,879
Dec./05	31	135	6390	26,742

APPENDIX VIII

CALCULATION OF EVAPO-TRANSPIRATION USING PENMAN'S EQUATION

Table No. VIII.1:-Saturation Vapour Pressure (e_s) and Slope of Saturation Vapour Pressure Vs Temperature Curve (A) [15]

Temperature (°C)	Saturation Vapour Pressure (e_s) in mm of Hg	Slope A in mm/°C
0	4.58	0.30
5.5	6.54	0.45
7.5	7.78	0.54
10.0	9.21	0.60
12.5	10.87	0.71
15.0	12.79	0.80
17.5	15.00	0.95
20.0	17.54	1.05
22.5	20.44	1.24
25.0	23.76	1.40
27.5	27.54	1.61
30.0	31.82	1.85
32.5	36.68	2.07
35.0	42.81	2.35
37.5	48.36	2.62
40.5	55.32	2.95
45.0	71.20	3.66

Table No. VIII.2:-Mean Monthly Solar Radiation at Top of Atmosphere H_c in mm of evaporable water/day [15]

North Lat.	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0°	14.5	15.0	15.2	14.7	13.9	13.4	13.5	14.2	14.9	15.0	14.6	14.3
10°	12.8	13.9	14.8	15.2	15.0	14.8	14.8	15.0	14.9	14.1	13.1	12.4
20°	10. 8	12.3	13.9	15.2	15.7	15.8	15.7	15.3	14.4	12.9	11.2	10.3
30°	8.5	10.5	12.7	14.8	16.0	16.5	16.2	15.3	13.5	11.3	9.1	7.9
40°	6.0	8.3	11.0	13.9	15.9	16.7	16.3	14.8	12.2	9.3	6.7	5.4
50°	3.6	5.9	9.1	12.7	15.4	16.7	16.1	13.9	10.5	7.1	4.3	3.0

Table No. VIII.3:-Values of Reflection Coefficient r (albedo) [15]

Surface	Range of r values
Close grained crops	0.15 – 0.25
Bare lands	0.05 – 0.45
Water surface	0.05
Snow	0.45 – 0.90

Table No. VIII.4:-Mean Monthly Values of Possible Sunshine Hours (N) [15]

North Lat.	Jan	Feb	March	April	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0°	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1	12.1
10°	11.6	11.8	12.1	12.4	12.6	12.7	12.6	12.4	12.9	11.9	11.7	11.5
20°	11.1	11.5	12.0	12.6	13.1	13.3	13.2	12.8	12.3	11.7	11.2	10.9
30°	10.4	11.1	12.0	12.9	13.7	14.1	13.9	13.2	12.4	11.5	10.6	10.2
40°	9.6	10.7	11.9	13.2	14.4	15.0	14.7	13.8	12.5	11.2	10.0	9.4
50°	8.6	10.1	11.8	13.8	15.4	16.4	16.0	14.5	12.7	10.8	9.1	8.1

Table No. VIII .5:-Calculation of Evapo-transpiration

Month	Mean Air Temp (°C)	e_s (mm of Hg)	A (mm/°C)	γ (mm of Hg/°C)	H_c(mm of eva. water/day)	r	a	b	n (hrs)	N (hrs)	σ (mm/day)	T_a (°K)	e_a (mm of Hg)	$\sqrt{e_a}$ (mm of Hg)	Vel. at 11m Height (km/day)	V_2 (km/day)	H_n(mm of eva. water/day)	E_a (mm/day)	E_t (mm/day)
5-Jan	16.6	14.16	0.89	0.49	9.4	0.05	0.26	0.5	5.22	10.7	2.01×10^-9	289.6	11.78	3.4	30.24	23.7	2.71	0.95	2.09
5-Feb	20.9	18.53	1.12	0.49	11.2	0.05	0.26	0.5	6.55	11.3	2.01×10^-9	293.9	12.15	3.5	46.32	36.3	3.75	2.72	3.44
5-Mar	23.4	21.56	1.29	0.49	13.2	0.05	0.26	0.5	5.41	12	2.01×10^-9	296.4	15.04	3.9	70.32	55.1	4.62	3.09	4.2
5-Apr	25.3	24.18	1.43	0.49	14.9	0.05	0.26	0.5	6.97	12.8	2.01×10^-9	298.3	17.89	4.2	86.16	67.5	6.06	3.13	5.31
5-May	26.2	25.51	1.5	0.49	15.9	0.05	0.26	0.5	5.43	13.5	2.01×10^-9	299.2	20.41	4.5	64.8	50.8	6	2.36	5.1
5-Jun	29.5	30.92	1.8	0.49	16.2	0.05	0.26	0.5	5.07	13.8	2.01×10^-9	302.5	24.31	4.9	51.84	40.6	6.15	2.91	5.46
5-Jul	29.4	30.74	1.79	0.49	16	0.05	0.26	0.5	4.57	13.6	2.01×10^-9	302.4	25.22	5	51.84	40.6	5.93	2.43	5.18
5-Aug	29.4	30.74	1.79	0.49	15.3	0.05	0.26	0.5	4.74	13	2.01×10^-9	302.4	25.44	5	49.44	38.8	5.82	2.28	5.06
5-Sep	29.6	31.31	1.81	0.49	13.9	0.05	0.26	0.5	5.57	12.4	2.01×10^-9	302.6	24.57	4.9	38.4	30.1	5.59	2.79	4.99
5-Oct	26.1	25.36	1.49	0.49	11.9	0.05	0.26	0.5	5.58	11.6	2.01×10^-9	299.1	21.04	4.6	36.48	28.6	4.59	1.79	3.89
5-Nov	22.9	20.94	1.27	0.49	9.9	0.05	0.26	0.5	7.31	10.9	2.01×10^-9	295.9	16.99	4.1	32.88	25.8	3.74	1.64	3.16
5-Dec	19.2	16.68	1.02	0.49	8.9	0.05	0.26	0.5	7.4	10.5	2.01×10^-9	292.2	13.02	3.6	30.24	23.7	2.84	1.48	2.4

Table No. VIII.6 :- Calculation of Actual Evapo-transpiration

Month	Et	No. of Days	E_T in mm	E_T in m	A_{ET} in m	Water Spread Area in sq. m	Total Evapotranspiratiom in cum. (T_{Et})
5-Jan	2.09	31	64.79	0.065	0.046	14832738	682,306
5-Feb	3.44	28	96.32	0.096	0.067	12747452	850,079
5-Mar	4.2	31	130.2	0.13	0.091	18682228	1,700,083
5-Apr	5.31	30	159.3	0.159	0.111	18465607	2,049,682
5-May	5.1	31	158.1	0.158	0.111	19966182	2,216,246
5-Jun	5.46	30	163.8	0.164	0.115	17982126	2,067,944
5-Jul	5.18	31	160.58	0.161	0.113	18970983	2,143,721
5-Aug	5.06	31	156.86	0.157	0.11	22255188	2,448,071
5-Sep	4.99	30	149.7	0.15	0.105	17532277	1,840,889
5-Oct	3.89	31	120.59	0.121	0.085	18197338	1,546,774
5-Nov	3.16	30	94.8	0.095	0.067	11452044	767,287
5-Dec	2.4	31	74.4	0.074	0.052	10800932	561,648

Table No. VIII.7 : - Meteorological Data

Year 2005										
Month	Total Rainfall (mm)	Mean Air Temp (^{o}C)	Mean Relative Humidity (%)			Mean Wind Speed (km/hr)	Actual Mean Vapour Pressure in Air (mm of Hg)			Actual Duration of Bright Sunshine (hr)
			8:30 am	5:30 am	Mean		8:30 am	5:30 am	Mean	
January	16.60	16.60	90	71	80.5	30.24	11.63	11.93	11.78	5.22
February	3.90	20.90	76	53	64.5	46.32	12.75	11.55	12.15	6.55
March	150.70	23.40	76	60	68	70.32	15.15	14.93	15.04	5.41
April	134.80	25.30	76	66	71	86.16	17.4	18.38	17.89	6.97
May	284.50	26.20	83	73	78	64.8	20.33	20.48	20.41	5.43
June	104.60	29.50	81	75	78	51.84	24.08	24.53	24.31	5.07
July	174.50	29.40	85	79	82	51.84	25.2	25.23	25.22	4.57
August	803.00	29.40	85	83	84	49.44	25.05	25.83	25.44	4.74
September	82.10	29.60	81	78	79.5	38.4	24.83	24.3	24.57	5.57
October	117.20	26.10	86	82	84	36.48	21.3	20.78	21.04	5.58
November	1.40	22.90	84	76	80	32.88	16.73	17.25	16.99	7.31
December	0.80	19.20	84	65	74.5	30.24	12.75	13.28	13.02	7.4

(Source: Regional Meteorological Centre, Guwahati)

APPENDIX IX

DESIGN OF CHECK DAM FOR GULLY NO. 9

IX.1 DESIGN OF DOUBLE FENCE CHECK DAM

IX.1.1 Rock Gradation

The affective rock gradation for rock dam of height between 1 to 2 m is as stated below.

Rock Size Class	Percentage
10 – 14 mm	25
15 – 19 mm	20
20 – 30 mm	25
31 – 45 mm	30

IX.1.2 Effective Height of Check Dam

As the average depth of the gully is 1.20 m, the height of the check dam is taken as 1.1 m. Assuming spillway depth as 0.15m, the effective height of the dam

$H_E = (1.1 - 0.15)$ m = 0.95 m.

IX.1.3 Spacing of Check Dam

The spacing between the check dams is calculated using the formula developed by Heede and Mufich, which is as shown below

$$S = \frac{H_E}{K.G.\cos a}$$

where, S = spacing of dam

H_E = effective dam height

a = angle corresponding to the gully gradient

G = gully gradient as a ratio = tan a

K = constant

= 0.3 for $G \leq 0.20$

= 0.5 for $G > 0.20$

Therefore, S =0.95/ (0.5 × 0.3 × cos 16.7^0), a = 16.7°

$= 6.60$ m

Therefore, No. of gullies required $= \frac{Length}{Spacing} + 1$

$$= \frac{118.2}{6.6} + 1$$

$= 18.9$ Nos.

$= 19$ Nos.

IX.1.4 Keys

Keying a check dam into the side slopes and bottom of the gully greatly enhances the stability of the structure. The objective of extending the key into the gully side slopes is to prevent destructive flows of water around the dam and scouring of the banks.

Under normal gully conditions i.e. where cracks and fissures in the bank wall have not developed, the following dimensions of Keys are considered.

Width = 0.60 m

Depth = 0.60 m

IX.1.5 Volume of Sediment Deposits

The volume of sediment deposition in the check dam is calculated using the formula developed Heede and Mufich.

$$V_S = 0.5\ H_E\ S \cos a\ L_{HE}$$

where, V_S = sediment volume

H_E = effective dam height

S = spacing of dam

a = angle corresponding to the gully gradient

L_{HE} = average length of dam

Again, $L_{HE} = L_B + \frac{L_U - L_B}{2D} H_E$

where, L_B = bottom width of gully

L_U = bank width of gully

D = depth of gully

H_E = effective dam height

Substituting the value of S, $V_S = \frac{H_E^2}{2KG} L_{HE}$

where, K = a constant

The above Equation indicates that the sediment deposits increase as the square of the effective dam height.

Therefore, $L_{HE} = 0.10 + \frac{2.52 - 0.1}{2 \times 1.20} \times 0.95$

$= 1.06$ m

Therefore, $V_S = \frac{0.95^2}{2 \times 0.5 \times 0.3} \times 1.06$

$= 3.20\ m^3$

IX.1.6 Design of Spillway

Since spillways of rock check dams can be considered as broad-crested weirs, the discharge formula for broad-crested weir is applicable

$Q = CLH^{3/2}$

where, Q = discharge in m^3/sec

C = coefficient of the weir

= 1.65

L = effective length of the weir in m

H = head of flow above the weir crest in m

The effective length of spillway, $L_{AS} = \frac{L_U}{D} H_E - f$

where, f = 0.30 (for D < 1.5m)

Therefore, $L_{AS} = \frac{2.52}{1.20} \times 0.95 - 0.30$

$= 1.69$ m

Assuming value of H to be same as the spillway depth

$Q = 1.65 \times 1.69 \times 0.15^{3/2}$

$= 0.16\ m^3$/sec

The spillway depth, $H_{SV} = \left(\dfrac{Q}{C\,L_{AS}}\right)^{2/3}$

$$= \left(\frac{0.16}{1.65 \times 1.69}\right)^{2.3}$$

= 0.15 m, which is same as the assumed value

For spillways having side slope of 1:1, the bottom length of the spillway,

$L_{BSV} = L_{AS} - H_{SV}$

$= 1.69 - 0.15$

$= 1.54$ m

IX.1.7 Design of Apron

Aprons must be provided on the gully bottom below the check dam to prevent undercutting from down stream, and subsequent failure of the structure. The length of the apron is taken as 1.5 times the height of the structure in channels where the gradient does not exceed 15 %. Where the channel gradient exceeds 15 %, the apron length is taken as 1.75 times of the height of the structure.

As the gradient of Gully No. 9 is 30 %, the apron length is taken as 1.75 times of the structure height.

Therefore, Apron length L = 1.75 × 1.1 = 1.90 m

Thickness of apron t is taken as 0.30 m.

At the downstream end of the apron, a loose rock sill of 0.15 m height should be provided. This end sill creates a pool in which the water will cushion the impact of the waterfall.

IX.2 ESTIMATION OF QUANTITIES

The main materials required for the construction of a Double Fence Check Dam are

- Rock
- Wire Mesh
- Iron Fence Post

The estimation has been done based on the FAO Guidelines, 1986 [19].

IX.2.1 Quantity of Rock

Distance between two parallel fences = 0.60 m

Therefore, width of the Check Dam = 0.60 m

Quantity of rocks required for check dam, $V_{DF} = 0.60\ H_D\ L_{HE} - V_{SDF}$

where, H_D = dam height

$= 1.1$ m

L_{HE} = average length of the dam

$= 1.06$ m

V_{SDF} = volume of spillway

$V_{SDF} = H_{SV} \times L_{AS} \times 0.6$

where, H_{SV} = spillway depth

$= 0.15$ m

L_{AS} = effective length of the spillway

$= 1.69$ m

0.6 represents the standard breadth of the dam in meters.

Now, $V_{SDF} = 0.15 \times 1.69 \times 0.6$

$= 0.15\ m^3$

And $V_{DF} = 0.60 \times 1.1 \times 1.06 - 0.15$

$= 0.55\ m^3$

$\approx 0.60\ m^3$

Quantity of rocks required for apron = $1.9 \times 0.3 \times 3.37 = 1.92\ m^3$

Quantity of rocks required for sill = $0.10 \times 0.15 \times 3.37 = 0.05\ m^3$

Quantity of rocks required for Keys = $0.6 \times 0.6 \times 3.37 = 1.21\ m^3$

No. of check dams required for Gully No. 9 = 19.

Therefore, total quantity of rocks required in the 19 Nos. of check dams

$= 19 \times (0.6 + 1.92 + 0.05 + 1.21) = 71.82\ m^3$

IX.2.2 Quantity of Wire Mesh

Length of wire mesh, $M_{LD} = 2 \times L_B + \frac{L_U - L_B}{D} \times 2 \times H_D$

where, L_B = bottom width of gully

L_U = bank width of gully

D = depth of gully

H_D = dam height

$$M_{LD} = 2 \times 0.1 + \frac{2.52 - 0.1}{1.20} \times 2 \times 1.1$$

$$= 4.6 \text{ M}$$

Width of wire mesh = dam height

= 1.1 m

Therefore, wire mesh required in one dam = 4.6 × 1.1 × 2 (in two rows)

= 10.12 m^2

IX.2.3 Quantity of Iron Fence Post

No. of fence post required, $N_{DF} = \frac{L_B}{0.6} + \frac{L_U - L_B}{0.6D} \times H_D + 2$

where, 0.6 is a constant representing post spacing

$$= \frac{0.1}{0.6} + \frac{2.52 - 0.1}{0.6 \times 1.2} \times 1.1 + 2$$

$$= 5.9$$

$$\approx 6$$

Considering half of the post up to dam height and the bottom half up to the rocky surface, which is at a distance of about 2.25 m from the soil surface, the total length of post required in one dam = 6× (1.1 + 1.05)

= 12.90 m

IX.3 COST ESTIMATE

Item No.	Item in short		Amount
1	Loose rock of size 10 cm to 45 cm.... Qnty. 71.82 m^3 @ Rs. 650.00/ m^3 (Local Market Rate)		Rs.46,683.00
2	High strength corrosion resistant wire meshes..... Qnty. (10.12 × 19) m^2 @ Rs.64.56 / m^2 (Local Market Rate)		Rs.12,414.00
3	Iron fence post of 25mm dia....... Qnty. (12.90 × 19) m @ Rs. 245.00/m (Local Market Rate)		Rs.60,050.00
		Total	Rs.1,19,147.00
	Labour Cost @ 40% of material cost		Rs.47,659.00
		Total	Rs.1,66,806.00
	Contingencies and Miscellaneous......5 %		Rs.8,340.00
		Grand Total	Rs.1,75,146.00
		Say	Rs.1,75,000.00

Rupees (one lakh seventy five thousand) only.

APPENDIX X

DESIGN OF CHECK DAM FOR GULLY NO. 13

X.1.DESIGN OF DOUBLE FENCE CHECK DAM

X.1.1 Rock Gradation

The affective rock gradation for rock dam of height between 1 to 2 m is as stated below.

Rock Size Class	Percentage
10 – 14 mm	25
15 – 19 mm	20
20 – 30 mm	25
31 – 45 mm	30

X.1.2 Effective Height of Check Dam

As the average depth of the gully is 1.16 m, the height of the check dam is taken as 1.1 m. Assuming spillway depth as 0.15m, the effective height of the dam

$H_E = (1.1 - 0.15)\ m = 0.95\ m.$

X.1.3 Spacing of Check Dam

The spacing between the check dams is calculated using the formula developed by Heede and Mufich, which is as shown below

$$S = \frac{H_E}{K.G.\cos a}$$

where, S = spacing of dam

H_E = effective dam height

a = angle corresponding to the gully gradient

G = gully gradient as a ratio = tan a

K = constant

= 0.3 for $G \leq 0.20$

= 0.5 for $G > 0.20$

Therefore, $S = \frac{0.95}{0.5 \times 0.41 \times \cos 22.2^0}$, $a = 22.2^0$

$= 5.0$ m

Therefore, No. of gullies required $= \frac{Length}{Spacing} + 1$

$= \frac{122.50}{5.0} + 1$

$= 26$ Nos.

X.1.4 Keys

Keying a check dam into the side slopes and bottom of the gully greatly enhances the stability of the structure. The objective of extending the key into the gully side slopes is to prevent destructive flows of water around the dam and scouring of the banks.

Under normal gully conditions i.e. where cracks and fissures in the bank wall have not developed, the following dimensions of Keys are considered.

Width = 0.60 m

Depth = 0.60 m

X.1.5 Volume of Sediment Deposits

The volume of sediment deposition in the check dam is calculated using the formula developed Heede and Mufich.

$V_S = 0.5\ H_E\ S \cos a\ L_{HE}$

where, V_S = sediment volume

H_E = effective dam height

S = spacing of dam

a = angle corresponding to the gully gradient

L_{HE} = average length of dam

Again, $L_{HE} = L_B + \frac{L_U - L_B}{2D} H_E$

where, L_B = bottom width of gully

L_U = bank width of gully

D = depth of gully

H_E = effective dam height

Substituting the value of S, $V_S = \frac{H_E^{\ 2}}{2KG} L_{HE}$

where, K = a constant

The above equation indicates that the sediment deposits increase as the square of the effective dam height.

Therefore, $L_{HE} = 0.10 + \frac{2.42 - 0.1}{2 \times 1.16} \times 0.95$

$= 1.05$ m

Therefore, $V_S = \frac{0.95^2}{2 \times 0.5 \times 0.41} \times 1.05$

$= 2.31$ m^3

X.1.6 Design of Spillway

Since spillways of rock check dams can be considered as broad-crested weirs, the discharge formula for broad-crested weir is applicable

$Q = CLH^{3/2}$

where, Q = discharge in m^3/sec

C = coefficient of the weir

= 1.65

L = effective length of the weir in m

H = head of flow above the weir crest in m

The effective length of spillway, $L_{AS} = \frac{L_U}{D} H_E - f$

where, f = 0.30 (for D < 1.5m)

Therefore, $L_{AS} = \frac{2.42}{1.16} \times 0.95 - 0.30$

$= 1.68$ m

Assuming value of H to be same as the spillway depth

$Q = 1.65 \times 1.68 \times 0.15^{3/2}$

$= 0.16$ m^3/sec

The spillway depth, $H_{SV} = \left(\frac{Q}{C\,L_{AS}}\right)^{2/3}$

$$= \left(\frac{0.16}{1.65 \times 1.68}\right)^{2/3}$$

= 0.15 m, which is same as the assumed value

For spillways having side slope of 1:1, the bottom length of the spillway,

$L_{BSV} = L_{AS} - H_{SV}$

$= 1.68 - 0.15$

$= 1.53$ m

X.1.7 Design of Apron

Aprons must be provided on the gully bottom below the check dam to prevent undercutting from down stream, and subsequent failure of the structure. The length of the apron is taken as 1.5 times the height of the structure in channels where the gradient does not exceed 15 %. Where the channel gradient exceeds 15 %, the apron length is taken as 1.75 times of the height of the structure.

As the gradient of Gully No. 13 is 41 %, the apron length is taken as 1.75 times of the structure height.

Therefore, Apron length L = 1.75 × 1.1 = 1.9 m

Thickness of apron t is taken as 0.30 m.

At the downstream end of the apron, a loose rock sill of 0.15 m height should be provided. This end sill creates a pool in which the water will cushion the impact of the waterfall.

X.2 ESTIMATION OF QUANTITIES

The main materials required for the construction of a Double Fence Check Dam are

- Rock
- Wire Mesh
- Iron Fence Post

The estimation has been done based on the FAO Guidelines, 1986 [19].

X.2.1 Quantity of Rock

Distance between two parallel fences = 0.60 m

Therefore, width of the Check Dam = 0.60 m

Quantity of rocks required for check dam, $V_{DF} = 0.60\ H_D\ L_{HE} - V_{SDF}$

where, H_D = dam height

$= 1.1$ m

L_{HE} = average length of the dam

$= 1.05$ m

V_{SDF} = volume of spillway

$V_{SDF} = H_{SV} \times L_{AS} \times 0.6$

where, H_{SV} = spillway depth

$= 0.15$ m

L_{AS} = effective length of the spillway

$= 1.68$ m

0.6 represents the standard breadth of the dam in meters.

Now, $V_{SDF} = 0.15 \times 1.68 \times 0.6$

$= 0.15\ m^3$

And $V_{DF} = 0.60 \times 1.1 \times 1.05 - 0.15$

$= 0.55\ m^3$

$\approx 0.60\ m^3$

Quantity of rocks required for apron = $1.9 \times 0.3 \times 3.29$

$= 1.88\ m^3$

Quantity of rocks required for sill = $0.10 \times 0.15 \times 3.29$

$= 0.05\ m^3$

Quantity of rocks required for Keys = $0.6 \times 0.6 \times 3.29$

$= 1.18$

No. of check dams required for Gully No. 13 = 26.

Therefore, total quantity of rocks required in the 26 Nos. of check dams

$= 26\times (0.6 + 1.88 + 0.05 + 1.18)$

$= 96.46\ m^3$

X.2.2 Quantity of Wire Mesh

Length of wire mesh, $M_{LD} = 2 \times L_B + \frac{L_U - L_B}{D} \times 2 \times H_D$

where, L_B = bottom width of gully

L_U = bank width of gully

D = depth of gully

H_D = dam height

$$M_{LD} = 2 \times 0.1 + \frac{2.42 - 0.1}{1.16} \times 2 \times 1.1$$

$$= 4.6\ M$$

Width of wire mesh = dam height

= 1.1 m

Therefore, wire mesh required in one dam = 4.6 × 1.1 × 2 (in two rows)

$= 10.12\ m^2$

X.2.3 Quantity of Iron Fence Post

No. of fence post required, $N_{DF} = \frac{L_B}{0.6} + \frac{L_U - L_B}{0.6D} \times H_D + 2$

where, 0.6 is a constant representing post spacing

$$= \frac{0.1}{0.6} + \frac{2.42 - 0.1}{0.1 \times 1.16} \times 1.1 + 2$$

$$= 5.8$$

$$\approx 6$$

Considering half of the post up to dam height and the bottom half up to the rocky surface, which is at a distance of about 2.25 m from the soil surface, the total length of post required in one dam = 6 × (1.1 + 1.09)

= 13.14 m

X.3 COST ESTIMATE

Item No.	Item in short		Amount
1	Loose rock of size 10 cm to 45 cm.... Qnty. 96.46 m^3 @ Rs. 650.00 / m^3 (Local Market Rate)		Rs.62,699.00
2	High strength corrosion resistant wire mesh..... Qnty. (10.12 × 26) m^2 @ Rs. 64.56 / m^2 (Local Market Rate)		Rs.16,987.00
3	Iron fence post of 25mm dia....... Qnty. (13.14 × 26) m @ Rs. 245.00/m (Local Market Rate)		Rs.83,702.00
		Total	Rs.1,63,388.00
	Labour Cost @ 40% of material cost		Rs.65,355.00
		Total	Rs.2,28,743.00
	Contingencies and Miscellaneous......5 %		Rs.11,437.00
		Grand Total	Rs.2,40,180.00
		Say	Rs.2,40,000.00

(Rupees two lakh forty thousand) only.