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EVALUATION OF WATER HARVESTING STRUCTURES IN THE KANDI BELT OF JAMMU REGION

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PREFACE

Kandi-belt is the steeply sloping submontane belt of the Himalayas fringing the Siwalik hills and extending discontinuously from Jammu and Kashmir to Assam. This belt flattens as one moves downstream in the south. Upper portion of the area consists of low hills covered by shrubs and forest while the lower terrain has cultivated lands. Major land and water management problems being faced in the region include excessive runoff, soil erosion, land degradation and erratic water distribution in space and time hampering agricultural production. Population in the entire belt suffers from water scarcity. Groundwater table is deep and streams carry huge debris material during monsoon. There are more than 350 ponds in the Kandi-belt which have played a crucial role in conserving water resources in the region. However, after the introduction of piped drinking water supply around 1960, most of the ponds are today in a state of disuse and utter neglect. A long-term solution to the water scarcity problem in the Kandi-belt lies in the rejuvenation of these village ponds. Any rejuvenation effort first requires the evaluation of the present status of the system.

With this need in view, an attempt has been made to evaluate the present status of ponds in terms of quantity and quality of the available resources. In this study, results of field investigations have been reported for 45 ponds in the Kandi-belt. In addition to the evaluation of ponds in terms of physical features, water quality parameters, soil properties, hydrological evaluation has been attempted and water balance analysis has been demonstrated for a large pond. In view of the lack of hydrological observations in the area, simple hydrological methods have been used to compute the unknown quantities. Two generalized computer programs have been developed for hydrological evaluation of a pond. Using the methodology presented in this study for a sample pond, hydrological analysis of any pond in the Kandi-belt can be carried out.

The present report has two important components. Field investigations and analysis has been carried out by Dr. Vivekanand Singh, Ex-Scientist "C", Mr. Rajan Vatsa, Sc. "B", Mr. Shabha Ram, PRA and Mr. Sanjay Mittal, SRA. The hydrological analysis and report writing has been carried out by Dr. M. K. Goel, Scientist "E1", Mr. Santosh S. Mali, Ex-Scientists "B", Mr. Shobha Ram, PRA and Mr. Naresh Kumar, PRA of the Western Himalayan Regional Centre, Jammu of the Institute.

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ABSTRACT

Kandi-belt is the steeply sloping submontane belt of the Himalayas fringing the Siwalik hills and extending discontinuously from Jammu and Kashmir to Assam. This dry-looking belt has undulating topography, steep and irregular slopes, erodible and low water retentive soils. Major land and water management problems being faced in the Kandi-belt include excessive runoff, soil erosion, land degradation and erratic water distribution in space and time hampering agricultural production. Population in the entire belt suffers from water scarcity. Groundwater table is deep and streams carry huge debris material during monsoon.

Ponds have played a crucial role in the Kandi-belt. Their water was utilized for domestic purposes and, to a limited extent, for irrigation purposes. These ponds also helped in improving the ground water regime in the region. Almost all villages in the Kandi-belt have one big pond to meet the domestic needs throughout the year. These big ponds were constructed with masonry work on three sides, the fourth side left open for the water to flow in. However, by the middle of the 20^{th} century, piped drinking water supply led to the neglect of these ponds most of which are today in a state of utter neglect. A long-term solution to the water scarcity problem in the Kandi-belt lies in the rejuvenation of these village ponds.

In this study, an attempt has been made to evaluate the present status of ponds in terms of quantity and quality of the available resources. Field investigations have been carried out for 45 ponds in the Kandi-belt. In addition to the evaluation of physical features, water quality parameters, and soil properties, hydrological evaluation has been attempted and water balance analysis has been demonstrated for a sample large pond. For the estimation of physical features, the shape, perimeter, area, depth, storage volume, age, utility, and annual status of the ponds (whether perennial or seasonal) have been determined for all the surveyed ponds. Various water quality parameters that have been evaluated from the samples of different ponds include: pH, electrical conductivity, alkalinity, calcium and magnesium hardness, chloride, sulphate, sodium, potassium, nitrate and total dissolved solids (TDS). The physical parameters such as temperature, pH and electrical conductivity were determined. In general, the water quality of the ponds was not found suitable for domestic purposes.

At the periphery of 37 ponds, soil samples were collected for textural analysis. Soil texture in 17 ponds was found to belong to sandy-loam type and in other 18 ponds, it was found to be silt-loam type. Further, infiltration tests were carried out in the bed of three ponds using double-ring infiltrometer. Infiltration capacities of the bed of the ponds were found to vary from 1.2 mm/hr in silt loam to 5.4 mm/hr in sandy loam type of soil.

For the hydrological evaluation, water balance studies have been carried out and demonstrated for a large pond so that different components of water balance (say inflow, evaporation losses, seepage

losses, outflow etc.) could be studied in detail. Because of the non-availability of any hydrological observations, inflow to a pond from its contributing catchment area was estimated by using the Soil Conservation Service (SCS) Curve Number method. A computer program was written to estimate the inflow to a pond using SCS method. Another computer program was written for the water balance computation of the pond at daily time step. The program reads daily rainfall, generated catchment flow, and evaporation depth and calculates the revised depth, area, storage, seepage and evaporation losses, and spill at daily time step.

Sohal pond was selected for water balance analysis. From the SCS analysis, the runoff coefficient for the catchment of Sohal pond was found to be 0.225. From the water balance analysis, it was observed that the pond remains perennial through out the year. Seepage loss is the major water loss factor for the pond. In the monsoon season, the spill from the pond is also appreciable. If the water of the pond is diverted for irrigation or other domestic use during such surplus periods, the storage of the pond can be optimally utilised. At present, the water of the pond is not used for any purpose. There is a strong need to conserve the quality and quantity of the water of Sohal pond which can benefit the society in the long run.

In this study, hydrological evaluation has been demonstrated for only one pond. However, generalized computer programs have been developed which can be used for the hydrological analysis of any other pond in the Kandi-belt. This study has the limitations of observation of hydrological data in the area. If only a simple staff gauge is installed in each pond and daily observations of pond water level are recorded, significant improvements in the analysis can be made and results can be verified. There is a strong need for the rejuvenation of ponds in the Kandi-belt for coping with the water scarcity problem. These ponds not only harness and preserve the surface water resources but also recharge the groundwater.

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CHAPTER - 1

INTRODUCTION

1.1 The Kandi-Belt

The submontane region of the Himalayas fringing the Siwalik hills is termed as Bhabhar zone or Kandi-belt. It is a steeply sloping belt of around 30 km width, extending discontinuously from Jammu and Kashmir to Assam. This belt flattens downstream merging with the Sirowal (Terai) region in the south. Towards the south and southeast of the Siwalik range, the soil material becomes finer grading from gravel and sand to silt and clay. This gradation of the material to fine sediment almost marks the southern limit of this tract. Hill torrents contain water only during freshets and run dry for most of the time. Vast stretch of boulders and dry streambeds present a very dry look to this tract. On account of its dry look, the track is locally known as the **Kandi-Belt**.

The upper portion of Kandi-belt consists of low hills covered by shrubs and forest, and the lower terrain has cultivated lands and gully beds. It has undulating topography, steep and irregular slopes, erodible and low water retentive soils and a terrain badly dissected by numerous gullies. Major land and water management problems being faced in the Kandi-belt include excessive runoff, soil erosion, land degradation and erratic water distribution in space and time, hampering agricultural production. Population in the entire belt suffers from water scarcity. Groundwater table is deep. Streams of the area carry huge amount of debris material during rainy season due to fragile geological conditions. The major causes of water shortage and soil erosion in the area are deforestation, denudation of slopes and rugged topography. Human activities such as cutting of trees and shrubs for domestic purposes and unmanaged agricultural practices have aggravated the denudation rate. Overgrazing of pastures and common grazing lands has made the whole landscape naked. Agriculture is uneconomic because of poor soils and low moisture content. In order to control the spread of the degraded lands in this area and to restore these for productive purposes, a comprehensive strategy for survey, monitoring and planning is required.

1.2 Ponds in Kandi-Belt

The semi-hilly Kandi-belt is generally devoid of any springs or *baolis*, which has made ponds an important source of water to meet the community needs in the region. Ponds are found more in the semi-hilly region whereas springs are found in the higher hills. Ponds have played a crucial role in the Kandi-belt and were the main source of drinking water till 1960s. Ponds have served not only small village communities but also the royalty and their army.

The ponds located in the Kandi-belt are primarily concentrated in the Jammu and Kathua districts. Udhampur district is predominantly hilly and has fewer ponds. There are three types of ponds in the Jammu region - *Chhappris*, *Big* ponds, and *Pucca* tanks. *Chhappris* are small shallow ponds with hardly any masonry work. They fill up in a single shower and serve the needs of cattle and grazers, and dry up during the summers. Almost all Kandi villages have one *Big* pond to meet the domestic needs throughout the year. These big ponds were constructed with masonry work on three sides, the fourth side left open for the water to flow in. The *Pucca* tanks have four-sided enclosures and are often found near temples, forts or highways. Almost all Kandi ponds had *Banyan* and *Peepal* trees on their banks. These trees provided shelter to travelers and animals, and also served as evaporation retardant. Figure – 1.1 shows a village pond in the Kandi-belt.

Fig. - 1.1: View of a village pond in the Kandi-belt

In the past, sites for construction of these ponds and tanks were selected very carefully. Unlike ponds in the plains, Kandi ponds were dug adjacent to a seasonal rivulet. During high floods, part of the river water was diverted into these ponds. These ponds were not used for irrigation purpose, crops being largely rainfed. An indigenous system of drip irrigation, however, existed in earlier days (Agrawal and Narain, 1997).

By the middle of the 20th century, piped drinking water supply led to the neglect of these ponds. Pressure on land and a decline in community institutions further speeded their decline. Most of the ponds in the Kandi-belt are today in a state of utter neglect and disuse. Village institutions, which organised annual desilting through voluntary labour and guarded the ponds against pollution, have since collapsed. In some cases, dirty water drains have been diverted into the ponds. High silt deposits have greatly reduced their storage capacity. With the advent of *pucca* houses, a rural women's need for pond silt to mudwash her house has lessened and, as a result, this need driven desilting of ponds is coming to an end. A long-term solution to solve the water scarcity problem in the Kandi-belt lies in the rejuvenation of these village ponds. This water could be utilized for domestic purposes and, to a limited extent, for irrigation purposes (e.g. in horticulture, agro-forestry etc.). These ponds could also help in improving the ground water regime in the region.

To provide comprehensive data for the local planners, a detailed inventory of ponds located in the Kandi-belt of Jammu region was prepared [Vijay Kumar et al. (2003)]. In that study, field survey was carried out and morphometric parameters (e.g., perimeter, water spread area) of selected ponds were determined. Storage volume and catchment area of the ponds were also evaluated using the field derived parameters and the SOI toposheets (Scale 1: 25,000), using a GIS package. The quality of water from thirty-two ponds was assessed to see the suitability of water mainly for domestic purposes.

1.3 Scope of the Present Study

For the preparation of any management plan for the restoration of ponds, evaluation of present status of ponds in terms of quantity and quality of the available resources is a prerequisite. This study is an extension of the previous study carried out by Vijay Kumar et al. (2003). In addition to the 56 ponds already surveyed in the previous study, field investigations have been carried out for further 45 ponds in the Kandi-belt. In addition to the evaluation of ponds in terms of physical features, water quality parameters, soil properties at the periphery and in the bed (of selected ponds) which has been reported in the previous study, hydrological evaluation of the ponds has also been carried out in the present study and demonstrated for a few larger ponds. For one year having rainfall closer to the annual average rainfall, daily inflow series for a large pond has been evaluated and water balance has been carried out.

A computer program has been developed to estimate the daily inflow to selected large ponds on the basis of daily rainfall series at a few select stations in the area. Using the long-term actual rainfall data, the corresponding inflow series can be worked out and used to plan the rejuvenation and management efforts for ponds in the area.

CHAPTER - 2

THE STUDY AREA

2.1 Kandi-belt in Jammu Region

The Kandi-belt is the foothill zone of the Siwalik of Jammu and Kashmir. This belt stretches between longitude 74^0 21′ to 75^0 45′ E and latitude 32^0 22′ to 32^0 55′ N, except in the western portion, where it lies between latitude 32^0 50'to 33^0 N. The Kandi-belt in the Jammu region lies between the River Ravi in the East and Munawar Tawi on the West within the Jammu and Kathua Districts (Figure – 2.1). The area is covered under the Survey of India toposheet nos. 43L/5, 9, 10, 11, 13, 14, 15 and 43P/2, 3, 6, 7, 11. The altitude of the area varies between 300 and 490 m above mean sea level. Transition zone of Kandi and Sirowal lies near Jammu-Pathankot National Highway, Ranbir canal and then along the Partap canal to the line of actual control on the Munawar Tawi.

Total area of the Kandi-belt in the Jammu region is estimated to be 811 km^2. The area is covered in two districts, namely Jammu and Kathua. The Kandi-belt is encompassed by only three out of the five tehsils of the Jammu district, and two out of the four tehsils of the Kathua district. The area of Kandi-belt falling within each of these tehsils is Jammu (189 Km^2), Akhnoor (147 Km^2) and Samba (163 Km^2) in the Jammu district, and Kathua (158 Km^2) and Hiranagar (155 Km^2) in the Kathua district. Jammu is the largest populated district in the State of Jammu & Kashmir, with fastest decadal variation in population over the last four decades. Kathua district is situated in the southeast of Jammu and Kashmir State and is surrounded on the north by Udhampur and Doda districts. The northern part of the Kathua district is situated in the foothills of the Himalayas. The southern part is alluvial plain. Ravi River flows in the east of the district.

2.1.1 Drainage

The surface of piedmont alluvial plain is dissected by numerous ephemeral streams originating from the Siwalik hills. A number of dry, wide and flat bouldery bottomed drainage lines, known as Khads, traverse the Kandi-belt and perennially drain the Sirowal belt downstream across the spring line. Lithology and structure of various geological units influence the drainage pattern in the area. The hills in the upper reaches display mostly the dendritic pattern with subtrellis to radial patterns at places. The drainage developed on the Lower Siwaliks is medium textured in contrast to fine texture developed on the Middle and Upper Siwaliks. Sharp and straight drainage lines indicate the influence of structural lineaments on the drainage pattern in the area.

2.1.2 Climate

The Kandi-belt experiences subtropical climate, where summers (April to June) are very hot and

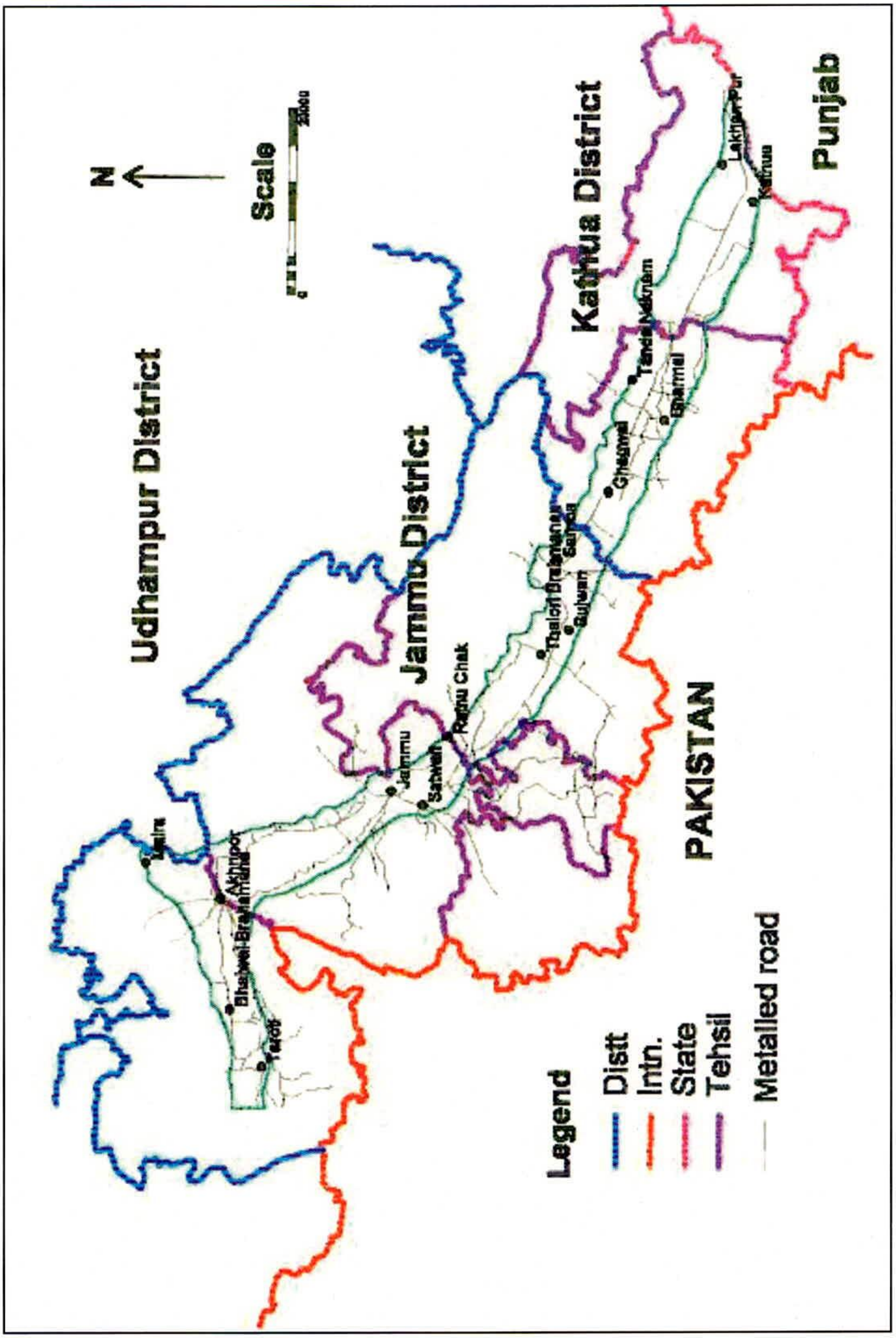


Fig. - 2.1 Base Map of Kandi-belt in Jammu Region winters (December to March) are cold and dry. June is the hottest month (Average temperature 39°C while highest temperature 46°C) and January is the coldest month (Average temperature 7°C while lowest temperature < 1°C). The winter season begins from December and ends up to March. The air generally remains dry except during the monsoon season, when the average relative humidity (RH) exceeds 70%. The summer months from April to June are the driest with average RH in the morning and evening is 40 to 48% and 23 to 32%, respectively. Evaporation in the area is generally high. Within a year, pan evaporation typically varies between less than 1 mm/day in January to about 9 mm/day in June.

The average annual rainfall in the region is about 1400 mm, of which about 74% is received during the monsoon period, i.e. from June to September (Goyal and Rai, 1999-2000). Winter rains are received during January to March due to western disturbances. Most of the rainwater goes as surface runoff due to flashy nature of the streams. A total of about 611 Mm^3 of rainwater is available in the Kandi area of which Jammu tehsil receives the highest rainwater at about 163 Mm^3, followed by Akhnoor (144 Mm^3), Samba (113 Mm^3), Hiranagar (97 Mm^3) and Kathua (94 Mm^3) (Goyal, 2002). The first showers of the southwest monsoon usually arrive in the first week of July.

2.1.3 Soils

Soil is a very important natural resource. The elements present in the soil depend to a large extent on climatic and geologic factors, and determine the type of crops that can be grown in a particular region. The importance of soil lies in its fertility, which varies from place to place. The Kandi-belt and its adjacent area have loose sandy loam type of soil comprising boulders and gravel with ferruginous clay matrix. Such type of soil is encountered in the Tehsils of Kathua, Hiranagar, Samba and Jammu. In Jammu plains, the soils are mostly alluvial in nature with medium fine and silt loamy texture. In the areas of Upland Dun and Siwalik hills, particularly, Udhampur, Ramnagar, Billawar and Basholi, the soils are of fine sandy loam to loam in texture. The water holding capacity of the soils is very low. Due to excessive permeability, losses of nutrients by leaching are high.

The Soil Survey Organisation of the Department of Agriculture of the Jammu & Kashmir state has identified eleven soil series of the entire Kandi-belt of Jammu region (Bhan et al., 1994). These are Jandial, Amb, Bansultan, Kotli, Aitham, Smailpur, Aitham Narka, Janakha Tara, Tara, Choha, and Punara. Bhan et al. (1994) reported that the soils in the Kandi-belt are, in general, of low fertility due to deficiency in nitrogen, phosphorous, potassium and organic matter. Locally, the soils of the Kandi-belt are named as (Bhan et al., 1994): *Gheo Mitti* (clay or silty clay loam in texture with presence of free $CaCO_3$ content in variable amount), *Phull Mitti* (loose in structure and sandy or loamy sand in texture), Mairall Stony and Sandy type (poor in fertility and occur in barani areas), *Gora* (lands which are manured constantly), *Parola* or *Golma* (greyish in colour, loam to clay loam), *Moongi* (brown or pink in colour with heavy texture and sometimes calcareous in nature) and *Bellas* (variable in texture). Gupta et al. (1990) and Sharma (1994a) have studied some typical soil profiles in the Jammu Siwaliks, of which the Kandi-belt is a part.

2.1.4 Hydrogeology

Typically the Kandi tract runs in the northeast-southwest direction up to Akhnoor, from where it takes a northwest-southeast turn. The tract is dissected intensely by streams and gullies of various dimensions. The topography of the area is typical to that of the piedmont/ alluvial deposits. The tract is widest in the proximity of the rivers such as Chenab, Tawi and Ravi. In the Kandi-belt, the general gradient is about 10 m per km (1:100) towards the south (CGWB, 1986). The area south and south-west of the Kandi-belt is gentler because boulders and pebbles almost disappear from the surface and their place is taken by the finer material. In this part of the area, groundwater occurs at shallow depth and it is more suitable for agriculture. The elevation in the area varies from 298 to 491 m above msl.

Based on the geology and aquifer characteristics, the piedmont deposits of older plains of Jammu are classified into the following hydro-geological sub-units:

1. Recent alluvium,
2. Kandi-belt, and
3. Sirowal belt

Lithologically, the Kandi are fan deposits comprising boulders, pebbles, and cobbles, mixed with clay. Kandi are fan deposits occurring immediately below the outer most Siwalik hills. This area is mainly made up of sub-recent to recent sediments deposited by streams originating from the hilly area. The sediments are poorly sorted and comprise boulders, cobbles, pebbles, gravels, sand, silt and clay. Topography is characterised by steep slopes. A continuous deposition of sediments has given rise to alluvial cones and fans. These fan deposits are highly porous and are capable of allowing *in-situ* percolation of large quantities of rain water/surface water, but are deprived of the water because of substantial runoff due to steep topographic gradient. Near the Siwalik range, sediments are coarse and range in size from boulder to pebble. Away from the hills, sediments are fine with varying percentage of silt and clay.

Because of sudden fall in topographic slope and emergence of spring line, all the dry streams of Kandi become flowing in Sirowal. A spring line, roughly following the topographic contours of 300 to 320 m above msl demarcates the Sirowal belt in the south from the Kandi-belt in the north. There is a general decrease in the particle size of sediments in the Sirowal belt as compared to Kandi-belt. Sirowal belt shows persistent clay beds occurring close to the ground surface, resulting in swampy or water logging conditions. At deeper depths, the strata consists of fine to coarse sands with occasional beds of gravels, pebbels, and intervening clayey to silty layers.

2.1.5 Surface Water Resources

Kandi-belt is dissected intensely by streams of various dimensions. A majority of these streams have their origin in the hills of Siwaliks. Chenab, Tawi, Basantar, Ujh and Ravi rivers perennially drain the area. Many other streams, e.g. Aik, Tarnah, Bein, Devak, are intermittent in the Kandi-belt but perennial in the Sirowals. All these streams are wide, bouldery, and flat bottomed. All the drainage east of Devak river are the tributaries of the Ravi river, while those on west join Tawi, which ultimately joins the Chenab river across the Indo-Pakistan international border. Chenab, and its two tributaries viz. Tawi and Munawar Tawi, drain the area in the western part. Devak, Basantar, Ujh and Ravi are the main rivers in the eastern part. All of these, except Devak, originate in the hilly tract on the north, and are perennial. The Chenab shows extreme variation of flow.

The Jammu region had a tradition of minor irrigation. *Kuhals* or *Kuhls* (diversion canals) constituted the ancient irrigation system in the region. The major source of irrigation in the State, however, continues to be canals. There are two major irrigation projects in existence in the Jammu province. These are Ranbir canal, the largest irrigation system in the province, and Ravi-Tawi Irrigation complex. The Ranbir canal, issuing from the Chenab at Akhnoor, irrigates the area between the Chenab and Tawi. There are numerous distributaries from this canal which feed the area. The old Pratap canal, which takes off from the Chenab south of Makhiawala, joins the Chenab at Nawanshahr after irrigating the tract south of Akhnoor-Chenab road. Ujh and Kashmir canals carry the water of the Ujh and Ravi Rivers for irrigation in Kathua district. Ravi-Tawi canal, the southern most canal system in the area runs between Tawi and Ravi rivers to irrigate land both in Jammu and Kathua districts (Table - 2.1). Apart from this, there are number of lift irrigation schemes operating in the Kandi-belt.

Ponds played a crucial role in the Kandi-belt and were the main source of drinking water till 1960s. The semi-hilly Kandi-belt is generally devoid of any springs or *baolis*, which made ponds an important source of water to meet the community needs in the region. Most ponds were so designed that a part of the runoff from adjoining rivulets could be tapped. This helped in reduction of runoff, erosion and downstream floods. Also, the ponds helped in improving the level of ground water in the surrounding area. These ponds were located in forts, near temples, and along highways. Over the years, the design of ponds, stone pitching of their berms, and the role of clay in checking heavy seepage in the highly porous Kandi-belt has got affected. By the middle of 20th century, piped drinking water supply led to the neglect of these ponds. Pressure on land and a decline in community institutions further speeded their decline. Sites for construction of these ponds and tanks were selected very carefully. Unlike ponds in the plains, Kandi ponds were dug adjacent to a seasonal rivulet. During high floods, part of the river water was diverted into these ponds. These ponds were not used for irrigation purposes, crops being largely rainfed. An indigenous system of drip irrigation, however, existed in earlier days (Agrawal and Narain, 1997).

Traditionally, these ponds use to have an elaborate community-based management system. Strict control was exercised for the economic use of water to ensure that it did not get polluted. Community leadership ensured a clean catchment for drinking water requirements. In many villages, there were separate ponds for humans and cattle, and guards were appointed and paid by the community to prevent animals from using the ponds meant for the humans. The construction and regular repairs of ponds were often done through voluntary labour.

2.1.6 *Groundwater Resources*

The primary source of groundwater in the Kandi area is rainfall. A part of the rainwater is lost in evapo-transpiration, part as run off and the remainder percolates down to reach the zone of saturation. Due to hot summers, evapo-transpiration losses are considerable in this area. The static water levels in Kandi are very deep. Few exploratory tubewells drilled in the Kandi-belt have indicated that potential aquifers capable of yielding water for irrigation occur at depths up to 300 m below ground level (CGWB, 1986).

The Kandi sediments being of boulder/gravel nature, rain water percolates down to great depth till it meets some obstruction (e.g. an impervious layer) and then starts rising occupying space in boulder/gravel. Nature of sediments in the Kandi-belt make the zone of saturation lie at great depth. Thus, Kandi-belt offers hydrogeologic setup characterized by deep water level, high permeability and high rainfall recharge. In Kandi area, groundwater occurs under water table conditions whereas in Sirowal belt it occurs under both water table and confined conditions.

Deep water table condition is one of the characteristic features of the Kandi-belt. Immediately south/southwest of the Siwalik hills, the static water table is very deep. Values of 100 to 120 m below ground level are not uncommon. Slightly away from the hills, depth to the static water table is 30 to 60 m below ground level, and further away it becomes shallow, in the general range of 8 to 30 m. Depth to static water level ranging from 45 to 84 m, 10 to 74 m and 0.5 to 5 m in the area immediately southwest of Siwalik hills, Kandi and Sirowal belts respectively, as observed by Pitale (1967).

Immediate south/southwest of the Siwalik hills, the hydraulic gradient is steep indicating a faster downward movement of groundwater. Dominant groundwater movement is from northeast to south in the tract between Chenab and Munawarwali Tawi. In general, the groundwater moves towards topographic depressions along *Khuds*, *choes* and river courses.

It has been established by CGWB that the entire Kandi area of Jammu region is falling in white category in respect of the level of development and utilization of the groundwater resource. Only about 1.25% of the total annual resource is being utilized for irrigation. Similarly, for domestic and industrial purposes, the utilization of ground water falls within the provision of 15% of the total available resource (CGWB, 1986).

Ground water has been an important source of water for domestic uses in Jammu and Kathua districts. It is generally believed that ground water resource in the J & K State is good for drinking purposes. Large population is still dependent upon the local unprotected sources, such as wells (dug and tube wells), hand pumps, springs, rivers, ponds and tanks etc. Due to increasing urbanisation and industrialisation, ground water is increasingly laced with pollutants from industries, municipal sewers and agricultural fields. The National Institute of Hydrology (Omkar et al., 1998-1999) has undertaken limited ground water quality monitoring and evaluation studies for drinking and irrigation purposes in parts of Jammu region (Table - 2.2). Higher concentrations of certain water quality parameters have been reported in Jammu and Kathua districts. Although there is nothing to panic, there is a need to be watchful on the quality of water available from both the ground water and surface water sources.

2.1.7 Agriculture

Agriculture is the main occupation of about 70% population in the Kandi-belt. In this region, *Rabi* crops are sown during October to November and harvested from April to mid May. Similarly, *Kharif* crops are sown during June to end of July, and harvesting takes place during September to October. Cultivation of *Zaid Kharif* and *Zaid Rabi* crops is done between regular *Kharif* and *Rabi* seasons, respectively.

The crops are dominated by millets like *Bajra* and *Jowar*, followed by Maize, Wheat and Barley. Lesser millets, such as *Kodra* and *Kangni* are also grown as mixed crops with maize and *bajra*. Rice is grown in some pockets of the region situated near *khads* by direct sowing. Pulses, like *Moth*, cowpea, *arhar* or pigeon pea, *rajmah*, peas, gram, *mash*, *moong*, lentil, and *kulth* are cultivated to some extent. Among the oilseeds, *til*, *raya*, *toria*, and groundnut are common. The productivity of various food crops in the region is much lower than the all India average, except in the case of Maize (Samra et al., 1999). The Kandi area is considered to be more suitable for growing of fruit plants.

2.1.8 Population and domestic demands

The total rural population in the Kandi-belt, residing in the five tehsils of Jammu and Kathua districts, is about 2.11 lakh. Estimated domestic water requirement for this population, based on the standard norms of per capita requirement of 100 litres per day (LPD), works out to be 21,151m^3/day. Tehsilwise distribution of this water demand is shown in Table 2.3.

The Jammu and Kathua districts have total livestock population of about 11 lakh and 10 lakh, respectively, against human population of 12 lakh and 5 lakh. Assuming a uniform population of livestock in the two districts, an estimate of the livestock population in the Kandi-belt under the identified tehsils can be found as the ratio of human population living in the Kandi-belt to the total population in the district. Accordingly, estimated livestock population in the Kandi-belt under the identified tehsils of the two districts is 1.28 lakh for Jammu and 1.38 lakh for Kathua. Computing on the basis of standard norms of 40 LPD per capita, the water requirement for the livestock works out to be 51.2 lakh LPD (5120m^3/day) for Jammu and 55.2 lakh LPD (5520m^3/day) for Kathua; and 10,640m^3/day for Kandi-belt.

2.2 Ponds in Kandi-Belt

Water scarcity is a characteristic feature of Kandi-belt of Jammu region, and therefore, ways and means to harvest and conserve the rainwater have been tried and developed since times immemorial.

The semi-hilly Kandi-belt is generally devoid of any springs or *baolis*, which has made ponds an important source of water to meet the community needs in the region. Construction of ponds has been a traditional way of harvesting and conserving this rainwater for all purposes. Several hundred small and big ponds exist in this area. But, most of the ponds in the Kandi-belt are today in a state of utter neglect and disuse. These ponds hold great potential for harvesting rainwater in this area. Ponds are found more in the semi-hilly region whereas springs are found in the higher hills. Ponds have played a crucial role in the Kandi-belt and were the main source of drinking water till 1960s. Ponds have served not only small village communities but also the royalty and their army.

The ponds located in the Kandi-belt are primarily concentrated in the Jammu and Kathua districts. Udhampur district is predominantly hilly and has fewer ponds. There are three types of ponds in the Jammu region - *Chhappris*, *Big* ponds, and *Pucca* tanks. *Chhappris* are small shallow ponds with hardly any masonry work. They fill up in a single shower and serve the needs of cattle and grazers, and dry up during the summers. Almost all Kandi villages have one *Big* pond to meet the domestic needs throughout the year. These big ponds were constructed with masonry work on three sides, the fourth side left open for the water to flow in. The *Pucca* tanks have four-sided enclosures and are often found near temples, forts or highways. Almost all Kandi ponds had *Banyan* and *Peepal* trees on their banks. These trees provided shelter, and also served as evaporation retardant (Figure – 2.2).

Fig. - 2.2: A village pond in the Kandi-belt

In the past, sites for construction of these ponds and tanks were selected very carefully. Unlike ponds in the plains, Kandi ponds were dug adjacent to a seasonal rivulet. During high floods, part of the river water was diverted into these ponds. These ponds were not used for irrigation purpose, crops being largely rainfed. An indigenous system of drip irrigation, however, existed in earlier days (Agrawal and Narain, 1997). Traditionally, these ponds used to have an elaborate community-based management system. Strict control was exercised for the economic use of water to ensure that it did not get polluted. Community leadership ensured a clean catchment for drinking water requirements. In many villages, there were separate ponds for humans and cattle, and guards were appointed and paid by the community to prevent animals from using the ponds meant for the humans. The construction and regular repairs of ponds were often done through voluntary labour.

By the middle of the 20^{th} century, piped drinking water supply led to the neglect of these ponds. Pressure on land and a decline in community institutions further speeded their decline. Most of the ponds in the Kandi-belt are today in a state of utter neglect and disuse (Figure – 2.3). Village institutions, which organised annual desilting through voluntary labour and guarded the ponds against pollution, have since collapsed. In some cases, dirty water drains have been diverted into the ponds. High silt deposits have greatly reduced their storage capacity. With the advent of *pucca* houses, a rural women's need for pond silt to mudwash her house has lessened and, as a result, this need driven desilting of ponds is coming to an end. A long-term solution to solve the water scarcity problem in the Kandi-belt lies in the rejuvenation of these village ponds. This water could be utilized for domestic purposes and, to a limited extent, for irrigation purposes (e.g. in horticulture, agro-forestry etc.). These ponds could also help in improving the ground water regime in the region.

Fig. - 2.3: Ponds being used for cattle in Kandi-belt

To provide comprehensive data for the local planners, a detailed inventory of ponds located in the Kandi-belt of Jammu region was prepared [Vijay Kumar et al. (2003)]. A total of 365 ponds have been delineated from the SOI toposheets (Scale 1:50,000). The toposheets used are 43L/13, 43L/14, 43P/2, 43P/3, 43P/6, 43P/7, 43P/11 and 43P/15. 249 ponds are located in the Kandi-belt falling in Jammu district and remaining 116 in Kathua district. The inventory includes location of the pond (i.e. name of the nearest village, geographical coordinates), perimeter, and surface area. The ponds were classified as perennial/seasonal as marked on the toposheets. The ponds are also classified as perennial or seasonal, as seen from the Survey of India toposheets and it is found that 165 ponds are perennial in nature. The total water spread area of all ponds in the Kandi-belt comes to 1.5 km^2. Sixteen ponds, with water spread area greater than 10,000 m^2, were mapped in the study area. Four ponds have a water-spread area of more than 20,000 m^2. Seventy one ponds have water spread area between 5,000 m^2 and 10,000 m^2. A list of ponds in different Tehsils of Jammu and Kathua districts is presented in Table - 2.4 to Table - 2.8.

CHAPTER - 3

EVALUATION OF PHYSICAL FEATURES

3.1 Selection of Ponds

In the previous study carried out for the mapping and inventory of village ponds in Kandi-belt [Vijay Kumar et al. (2003)], a total of 56 ponds were surveyed, their physical features were determined and the water quality parameters were estimated. In continuation of these efforts, 45 new ponds have been selected for the present study for evaluation. In addition to the physical features and water quality parameters, soil sample analysis has been carried out at the periphery/in the bed of the ponds and hydrological analysis has been carried out for a few large ponds. Ponds for the present study have been chosen so as to have a uniform representation in various Tehsils in the Jammu and Kathua districts within the Kandi-belt. Selection of ponds for survey and analysis in various Tehsils is presented below.

Tehsil	Ponds Surveyed Previously (Vijay Kumar et al., 2003)	Ponds Surveyed in Present Study
Akhnoor	0	15
Jammu	0	15
Samba	37	6
Hiranagar	13	6
Kathua	6	3

3.2 Field Survey

Forty five ponds were selected on the basis of their potential use, size, approachability, and to have uniform distribution within various tehsils in the Kandi-belt. Survey for these ponds was carried out in the pre-monsoon (May, 2005) and post-monsoon (October, 2005) months to measure their morphometric characteristics like perimeter, length, width, area, and depth of water and maximum depth (Table – 3.1). Samples were also taken from the water for quality assessment. In addition, soil samples were taken from the periphery/bed for particle size analysis. Infiltration tests were also carried out at 3 ponds. The observations of the field survey are presented in the tabular form.

3.2.1 Measurement of length/width and depth

Tightening a nylon rope between two ends of the pond and then measuring the length of corresponding rope gives the length/width of the pond (Figure – 3.1 & 3.2). Most of the ponds are of either oval (some are of round shape) or rectangular shapes. For oval and rectangular shape ponds, maximum length and maximum width were measured. To measure the depth of pond, the depth from outlet to the present water level (h_1 in sketch below) and the height of water level from the bottom of pond (h_2) were measured.

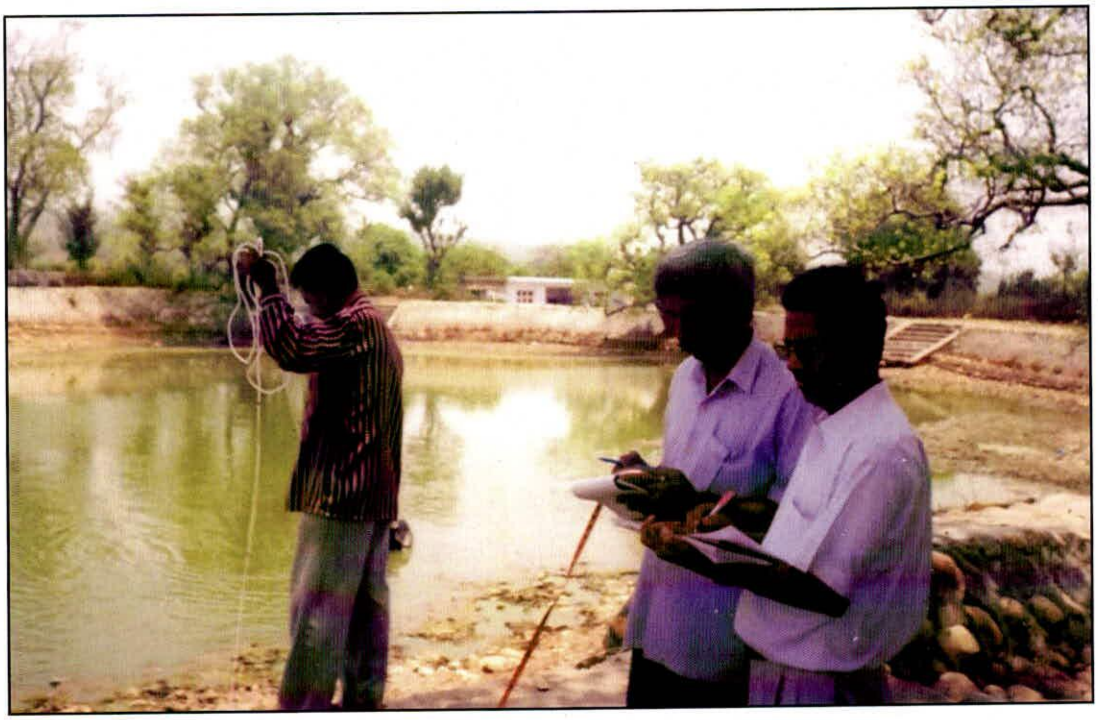
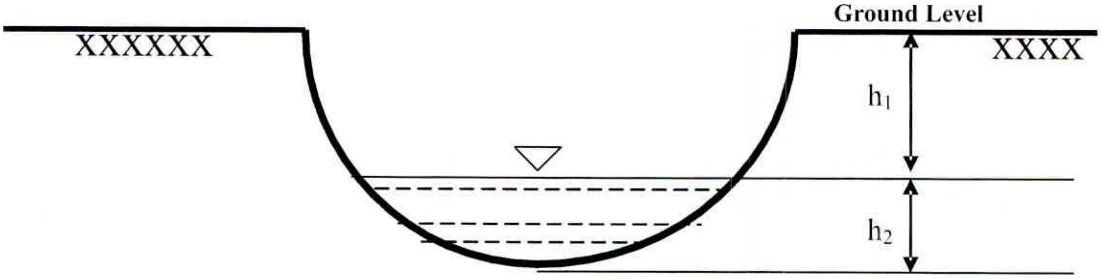


Fig. - 3.1: Physical measurements being taken in a pond in Kandi-belt

Fig. - 3.2: A view of physical measurements in a pond



Sketch of a Pond

3.1.2 Calculation of surface area, perimeter and storage volume

From the measured length/width and depth of a pond, its surface area, perimeter and storage volume were estimated using the following equations:-

Surface Area

Oval $$S = \frac{\pi}{4}(Length * Width) \quad ....(3.1)$$

Rectangular $$S = Length * Width \quad ....(3.2)$$

For any pond having irregular area, dimensions of the closest geometrical figures in different parts of the pond were measured and the summation of the area of all the individual areas was calculated to get the total area of the pond.

Perimeter

Oval $$P = \frac{\pi}{2}(Length + Width) \quad ....(3.3)$$

Rectangular $$P = 2(Length + Width) \quad ....(3.4)$$

For any pond having irregular shape, dimensions along the periphery were measured in different parts of the pond and then summed up to get the total perimeter of the pond.

Storage Volume

The storage volume has been calculated by considering all the ponds as segment of a sphere. If the segment of sphere has a radius 'r' and maximum depth 'h' then its volume is

$$V = \frac{\pi h}{6}(3r^2 - h^2) \quad ....(3.5)$$

Equivalent radius 'r' was calculated for all the ponds considering it as a circle having the same surface area as that of the pond.

In addition to the morphometric characteristics, miscellaneous other features, like the type of pond, its age, its present utilization, its status (perennial/seasonal) etc. were gathered from local enquiry. This information for various ponds is presented below in Table – 3.2.

3.3 Some Observations during Field Survey

Some important observations made during the field visit are as follows:

a) Excavation of the bed of ponds for the purpose of capacity increase has been done in some ponds which has adversely affected their capacity. This is because of the fact that mud/fine clay layer which works to reduce the infiltration from bed was removed by the action of dredging and thus the infiltration rates were increased.

b) Fisheries were observed in only one pond (pond no. 5). It may be highly beneficial for the inhabitants to have fisheries in these ponds as none of the ponds' water is used for drinking purpose.

c) There are lots of developmental activities such as road construction, water tank construction and urbanization in the vicinity of the pond which has adversely affected the inflow pattern to the ponds. Some such ponds are: Pond no. 2, 11, 12 and 23.

(d) A few ponds, particularly in Hiranager and Kathua, were found to be canal water fed. In these ponds, water level fluctuates according to the canal water supply.

CHAPTER - 4

EVALUATION OF WATER QUALITY FEATURES

4.1 Water Quality Observations

The main objective of the present study was to evaluate the present status of water harvesting structures in the Kandi-belt of Jammu region. To assess the quality of water of the ponds, various parameters were analyzed in the water quality laboratory at WHRC, Jammu and at the Headquarter at NIH, Roorkee. Some parameters, such as pH, EC, temperature etc. were measured in the field.

Initially, the purpose of these ponds was to store water for drinking purpose but, after the introduction of water supply system in various villages, the water requirements for drinking purpose from these ponds was reduced or completely vanished as observed during the field survey. However, the water of these ponds is still utilized for cattle drinking, bathing, washing clothes etc.

4.2 Sampling for Water Quality Evaluation

For evaluating the water quality of the ponds, surface water samples were collected from the 45 selected ponds. Sampling was carried out in the pre-monsoon period (June, 2005) and post-monsoon period (Oct., 2005). Clean plastic bottles fitted with caps were used for the purpose of collecting samples (Figure – 4.1). Some of the parameters like temperature, pH and electrical conductivity were measured

Fig. - 4.1: Samples being taken from the pond for water quality analysis in the field (Figure – 4.2) at the time of sample collection. For other parameters, samples were preserved by adding appropriate reagents.

Fig. - 4.2: In-situ measurements of few water quality parameters in the ponds

4.3 Various Water Quality Parameters

Various water quality parameters that were evaluated from the samples of different ponds included: pH, electrical conductivity, alkalinity, calcium and magnesium hardness, chloride, sulphate, sodium, potassium, calcium, magnesium, nitrate and total dissolved solids (TDS). Though dissolved oxygen is an important parameter for water quality evaluation and for analyzing the pollution status of water, it could not be determined in the present study due to some unavoidable logistic constraints.

Physico–chemical analysis of water samples was carried out following standard procedures of analysis. The physical parameters such as temperature, pH and electrical conductivity were determined in the field at the time of sample collection using portable kits available in the Water Quality Laboratory of WHRC, Jammu. Alkalinity, Chloride, total hardness and Calcium hardness were determined by the method of titration. Sodium, potassium, sulphate, and nitrate were determined by instruments such as flame photometer, spectrophotometer etc. The calcium (ca^{2+}) and magnesium (mg^{2+}) ions were determined by multiplying the calcium hardness with 0.401 & magnesium hardness with 0.243.

Summary of Analytical Methods and Equipment

Parameter	Analytical Method	Equipment used
(a) Physical Characteristics		
Temperature	---	Portable kit (thermometer)
pH	Electrometric	Portable kit (pHmeter)
Electrical Conductivity		Portable kit (EC meter)
(b) Major Cations		
Calcium	Titration	Volumetric Glassware
Magnesium	Titration	Volumetric Glassware
Sodium	Flame emission	Flame Photometer
Potassium	Flame emission	Flame Photometer
(c) Major Anions		
Carbonate	Titration	Volumetric Glassware
Bicarbonate	Titration	Volumetric Glassware
Sulphate	Turbidimetric	Turbiditimeter
Chloride	Titration	Volumetric glassware
(d) Others		
Nitrate	Colour development with absorption measurement	Spectrophotometer

On the domestic front, water is utilized for drinking, cooking, washing and bathing. For other purposes, water is used for cattle drinking, irrigation, navigation, and fisheries etc. The significance of these parameters with respect to different uses is described below:

a) pH

The pH value of water is very important indication of acidic and alkaline nature of water. It influences to a great extent the growth of both plant and soil micro-organisms since it affect the suitability of water for irrigation. The presence of considerable amount of $CaCo_3$ increases the pH value of water, making it alkaline.

b) *Electrical Conductivity (EC)*

The electrical conductivity is one of the useful parameters of water quality that indicates salinity hazards. In general, water with conductivity values below 250 micro mhos per cm can safely be used for irrigation except for salt sensitive crops that may be adversely affected by the use of irrigation water having conductivity values between 250 to 750 micro mhos per cm. However, if the EC of water is in the range of 750 to 2250 micro mhos per cm, then satisfactory crop growth can be obtained only under favourable drainage conditions and good management practices.

c) *Temperature*

The temperature of water is one of the most important characteristics which determines, to a considerable extent, the trends and tendencies of changes in its quality. It affects ion and phase equilibria and the rates of biochemical processes which accompany the changes of concentration and of content of organic and mineral substances. Numerous chemical reactions including catalytic and enzymatic ones depend considerably on changes in temperature. The concentration of carbonates, sulphides , or degree of alkalinity or electro- conductivity are also affected by temperature changes. In some cases, temperature is the direct index of the influence of man-made factors on the quality of water (thermal pollution).

d) *Alkalinity*

Alkalinity refers to the capability of water to neutralize acids. The most common cause of alkalinity in natural waters in the presence of carbonates, bicarbonates and hydroxides. Alkalinity values provide guidance in applying proper doses of chemicals in water and wastewater treatment processes. Natural waters may contain appreciable amounts of carbonates and hydroxide alkalinities, particularly surface waters blooming with algae.

e) *Chloride*

Chloride, in the form of chloride ion, is one of the major inorganic anions in water and waste water. Chlorides are present in all potable water supplies and in sewage, usually as a metallic salt. Chloride in excess of 250 mg/l give a salty taste when sodium is present in drinking water. High chloride concentrations in water do not have toxic effects on man, but it may be harmful to plant life. Maximum allowable limit of chloride of 250 mg/l in drinking water has been established for reasons of taste rather than safeguard against physical hazard.

f) *Total Hardness*

The total hardness, in current practice, is known as the characteristic of water which represents the total concentration of calcium and magnesium expressed as their calcium carbonate equivalent. Temporary hardness is caused by the presence of bicarbonates of calcium and magnesium. The permanent hardness of water is mostly due to sulphates.

When total hardness is greater than total alkalinity, the amount of hardness equivalent to alkalinity is called carbonate hardness and the excess amount is non-carbonate hardness.

g) Total dissolved solids

Solids refer to the matter suspended or dissolved in water. Solids may affect water quality adversely in a number of ways. Water with high dissolved solids generally are of inferior palatability. A limit of 500 mg/l of dissolved solids is desirable for drinking waters. High mineralized waters are also unsuitable for many industrial applications. Waters high in suspended solids may be aesthetically unsatisfactory for such purpose as bathing.

h) Sulphate

Sulphate occurs in natural waters in wide range of concentrations. Mine waters and industrial effluents frequently contain large amounts of sulphate from pyrite oxidation and the use of sulphuric acid. Its concentration above 250 mg/l in potable waters is objectionable. Sulphate causes scaling problem in industrial water supplies and problem of odour and corrosion in waste water treatment due to its reduction to hydrogen sulphide.

i) Fluoride

Fluoride occurs naturally in some ground waters and 1 mg/l level normally is maintained in public drinking water supplies for the prevention of dental carries. Excessive amount of fluoride causes fluorosis, although levels up to 8 mg/l have not been found to be physiologically harmful. Maintenance of an optimal fluoride concentration is essential in maintaining effectiveness and safety of fluoridation procedure.

j) Nitrate

In waters and waste waters, the forms of nitrogen of greatest interest are in order of decreasing oxidation state, nitrate, nitrite, ammonia, and organic nitrogen. All these forms of nitrogen are components of the nitrogen cycle. Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. Nitrate generally occurs in trace quantities in surface water but may attain high levels in groundwater. High levels of nitrate in water indicates biological wastes in the final stages of stabilization or runoff from heavily fertilized fields. The limit of 10 mg/l of nitrate as nitrogen has been established in public drinking water supplies since more nitrate concentration cause infant methemoglobinemia (blue babies).

k) Sodium

Sodium is present in nearly all natural waters. The levels may vary from less than 1 mg/l to more than 500 mg/l. Relatively high concentrations may be found in brines and hard water softened by sodium exchange process. Ratio of sodium to total cations is important in agriculture and human pathology. Soil permeability can be harmed by a high sodium ratio.

l) ***Potassium***

Potassium ranks seventh among the elements in order of abundance, yet its concentration in most drinking waters seldom reaches 20 mg/l. However, occasional brines contain more than 100 mg/l of potassium.

m) ***Calcium***

Calcium, the fifth most common element, is found in most natural waters in levels ranging from zero to several hundred milligrams per litter, depending on the source and treatment of water. Calcium contribute to the hardness properties of water and test result usually are reported as calcium hardness (mg/l- equivalent calcium carbonate).

n) ***Magnesium***

Magnesium ranks eighth among the demands in order of abundance and is a common constituent of natural water. It contributes to hardness properties of water and breaks down when heated forming scales in boilers. The levels of magnesium may very from zero to several hundreds milligram per litre. Concentrations greater than 125 mg/l can have a cathartic and diuretic effect.

o) ***Relative proportion of sodium to other cations (SAR)***

A high sodium concentration leads to development of an alkali soil. The sodium or alkali hazard in the use of a water irrigation is determined by the absolute and relative concentration of cations expressed as sodium adsorption ratio (SAR). If the proportion of sodium is high, the alkali hazard is high, and conversely, if calcium and magnesium predominate, the hazard is less. The irrigation water high in sodium and low in calcium, can destroy the soil structure. The SAR can be calculated by using the following equations

$$SAR = \frac{Na}{\sqrt{(Ca + Mg)/2}} \qquad ...(4.1)$$

4.4 Water quality evaluation for irrigation purposes

The quality of irrigation water depends primarily on its salt content. The usefulness of water for irrigation is mainly evaluated based on the following criteria:

a) ***Total concentration of soluble slots (TDS)***

The connects of irrigation water such as disjoins substances, as a general collective term, one called salts, they include relatively small but important amounts of dissolved solids. The salts present in water, besides affecting the growth of the plants, also affects of the soil structure, permeability and aeration , which indirectly affected the plant growth.

The classification of irrigation water based on the concentration of suitable salts is as follows:

Zone	TDS(mg/l)	EC(mg/cm)
1. Low salinity zone	<200	<250
2. Medium salinity zone	200-500	250-750
3. High salinity zone	500-1500	750-2250
4. Very high salinity zone	1500-3000	2250-5000

Calculation of SAR for a given water provides a useful information of sodium hazard for the irrigation waters:

SAR Values	Sodium hazard
2- 10	Little danger from sodium
7 - 18	Medium sodium hazard
18 - 26	High sodium hazard
>26	Very high sodium hazard

The values of various parameters for different ponds were obtained from the laboratory analysis of the water samples collected during field survey in the pre-monsoon (June 2005) and post-monsoon (October 2005). The values are presented in Table – 4.1 for the pre-monsoon survey and Table - 4.2 for the post-monsoon survey. In these tables, the unit of Electrical conductivity (EC) is in micro mhos/cm, and unit for other parameters (except SAR and pH) is in mg/l.

4.5 Summary of Water Quality Observations

The summary of water quality observations in terms of minimum, maximum, and average values of different parameters is presented in Table – 4.3.

In a number of ponds, water quality parameters were out of the permissible values. The parameters that exceeded the permissible range and the number of ponds in which the limits were exceeded are presented below.

Parameter	Permissible Range	Maximum Observed	Minimum Observed	Number ofponds exceeding permissible limit
EC (µmhos/cm)	250-750	1875	234	20
pH	6.5-8.5	11.02	6.88	27
TDS (mg/l)	200-500	5056	190	32
Alkalinity (mg/l)	200-600	351	3	0
F (mg/l)	1-1.5	1.35	0	0
NO3 (mg/l)	45-100	33	0.5	0
SAR	7-18	42.05	0.41	3

CHAPTER - 5

EVALUATION OF SOIL PROPERTIES

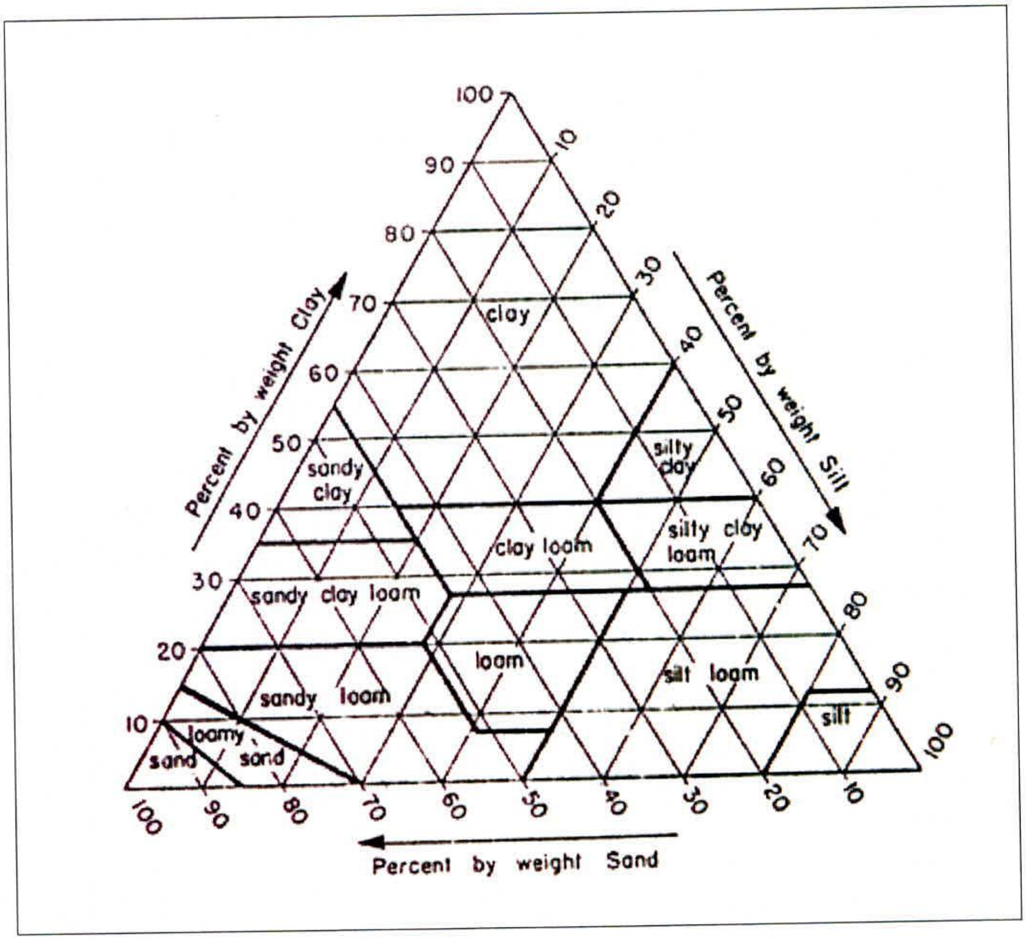
5.1 Soil Sampling & Grain-Size Analysis

The main objective of the present study was to evaluate the present status of water harvesting structures in the Kandi-belt. In addition to the evaluation of physical features and the water quality analysis, soil properties of the samples collected around the periphery of the ponds were evaluated. In three ponds, relatively dry bed conditions were found and infiltration tests were carried out in the bed of these ponds using double ring infiltrometer.

At the periphery of 37 ponds, soil samples (weighing around 0.5 to 1 kilogram) were collected and brought in the soil water laboratory for analysis. A part of these samples were then analyzed using the sieve shaker and the weight of soil retained on sieves of different sizes (4.25 mm, 2.00 mm, 1.18 mm, 600 micron, 425 micron, 250 micron, 212 micron, and 75 micron) was measured. Thereafter, percentage finer, for sieves of different sizes, was calculated and the percentage gravel, sand, silt, and clay was determined. Figure – 5.1 presents a photograph showing the sample collection near a pond for grain-size analysis. Using the texture triangle (shown in Figure – 5.2), the type of soil for each pond was determined. Table – 5.1 presents the percentage finer obtained for different sieve sizes and Table – 5.2 gives the estimated percentage gravel, sand, silt, and clay and the corresponding grading of soil type.

Fig. - 5.1: Collection of soil sample near a pond for textural analysis

The soil of size greater than 2.0 mm is classified as gravel, of size between 2.0 mm to 0.05 mm is classified as sand, of size between 0.05 mm to 200 micron is classified as silt, and of size below 200 micron is classified as clay. Based on the percentage finer for different sieve sizes, the percentage of gravel, sand, silt, and clay are found. The percentage of gravel, sand, silt, and clay for different soil samples is presented in Table 5.2. Using the percentage of sand, silt, and clay in a soil sample, the textural class of soil is determined from the tri-linear diagram (shown in Figure – 5.2). The textural class of each soil sample, so deducted, is also specified in Table – 5.2.



The grain-size analysis indicates that out of the 37 ponds analyzed, soil texture in 17 ponds belong to sandy-loam type while texture in 18 ponds belong to silt-loam type. These soil types have considerable seepage rates and are not conducive for retaining water for longer periods.

5.2 Infiltration Tests in Ponds

In the bed of three ponds, infiltration tests were carried out during the pre-monsoon observations

(May-June 2005). These ponds are: Tarore pond, Channi Himmat pond, and Pati pond in Nardani Bajwan village. Double-ring infiltrometer was used in this test. The double rings of the infiltrometer were dug in the pond bed and the water in the two reservoirs was filled to a specified height. Then, the scale readings were taken and the corresponding time was observed and the rate of fall was observed. The observations were continued till the constant rate of fall was obtained. The results of the infiltration tests for the three ponds are summarized below in tabular form:

Fig. - 5.2: A view of infiltration test being carried out in a pond

Infiltration tests carried out in three ponds indicate that infiltration capacities of the ponds bed varies from 1.2 mm/hr in silt loam type soil to 5.4 mm/hr in sandy loam type of soil. These rates are quite significant in view of the limited capacity and depth of ponds. There is a need to treat the beds of the ponds with suitable material, say Bentonite clay, to reduce the seepage losses and retain the water for longer duration.

CHAPTER - 6

HYDROLOGICAL EVALUATION OF PONDS

6.1 Strategy Adopted for Hydrological Evaluation

Ponds in the Kandi-belt have played a crucial role in harvesting the available water in the region and its use for different purposes. The ponds were the main source of drinking water till 1960s. Most of the ponds are artificial and their sites for construction were selected very carefully adjacent to a seasonal rivulet so that a part of the river water could be diverted to these ponds. However, after the introduction of piped drinking water supply and decline in community institutions, these ponds were largely neglected. Most of the ponds in the Kandi-belt are today in a state of utter neglect and disuse.

For hydrological evaluation, it is required to carry out the water balance studies for a pond so that different components of water balance (say inflow, evaporation losses, seepage losses, outflow etc.) can be studied in detail and then suitable measures can be taken to increase the water availability and its utilization and decrease the losses from the pond. No hydrological observations are recorded at any pond. Therefore, it was not possible to assess the inflow to the pond by direct measurements. Inflow to a pond from its contributing catchment area corresponding to any rainfall event was estimated by using the Soil Conservation Service (SCS) Curve Number method.

SCS method is an event-based method which requires the landuse, soil type, slope, and antecedent moisture conditions as the input and computes the curve number for each day corresponding to the specified conditions. The curve number is then used to find the rainfall excess which flows downstream towards the catchment outlet. In the present study, spatially distributed database has been developed at a grid size of 30 m. SCS method has been applied for each grid and for each day to find the runoff which has been accumulated at the catchment outlet. Infiltration capacities, as estimated from the infiltration tests were used to find the seepage losses. Evaporation losses were estimated by using the data of evaporimeter at one station in the Kandi-belt. Data files were prepared in GIS and a computer program was prepared to estimate the inflow to a pond. The generated GIS data files and the computer program can be used to find the inflow series for any pond and for any rainfall event. The water balance of the pond has been shown at daily time step for an average year of annual rainfall. For the sake of presentation, hydrological evaluation for one selected pond (having significant catchment area) is shown in this chapter. Various steps of the analysis are presented below.

6.2 Generation of GIS Database

For the spatially distributed hydrological analysis, most of the database was developed in GIS. ILWIS GIS system was used for the analysis. Various data layers that were required for the SCS based analysis included digital elevation model for the area, slope map, drainage map, catchment area map, land-use map, soil map, and the Thiessen polygon map. The database was generated at 30 m grid-size. The grid-size of 30 m was chosen because the land-use map was prepared from the Landsat TM data (data in free-domain downloaded from the internet) which has a resolution of 30 m. To have uniform grid-size, a common grid-size of 30 m was selected for all the data layers. Generation of various layers is described below.

6.2.1 Digital Elevation Model for Kandi-belt

Detailed Survey of India toposheets at the scale of 1:50,000 were not available for the whole Kandi region. Therefore, Shuttle Radar Topographic Mission (SRTM) elevation data at 90 m resolution were downloaded from the internet. Kandi-belt were covered in two grids. The two grids were geo-referenced and the boundary of the Kandi-belt was overlaid on the mosaic of the two digital elevation data grids. This is depicted in Figure – 6.1.

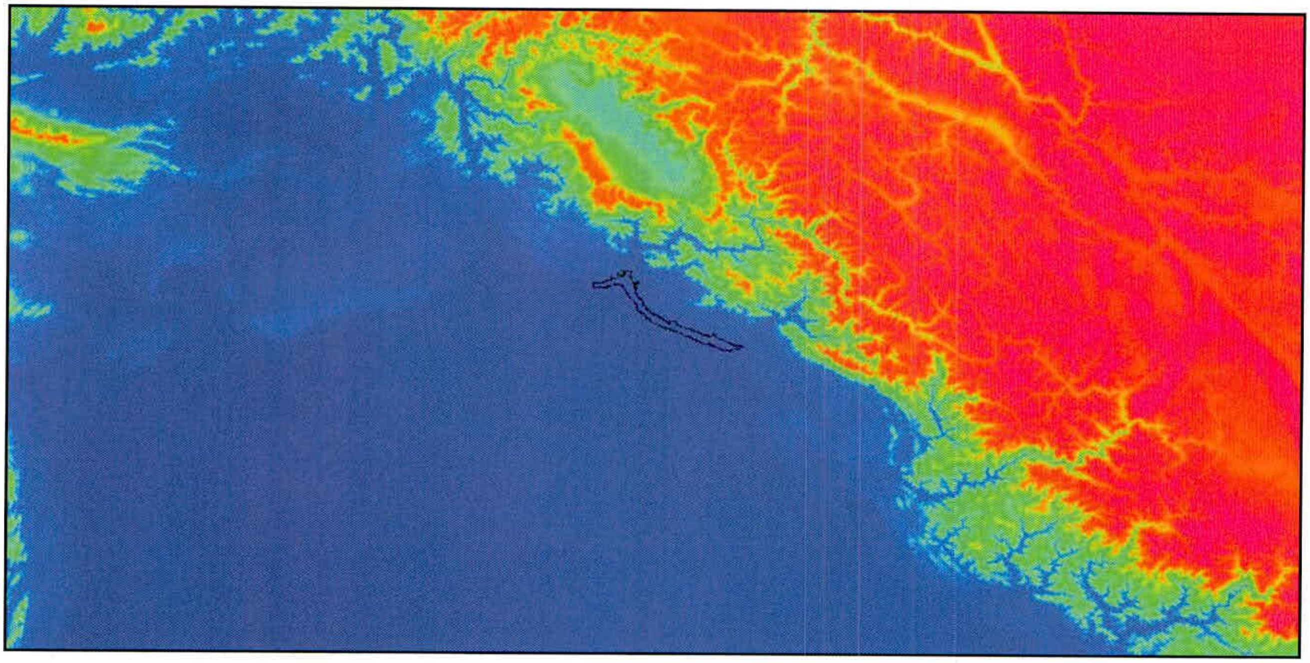


Fig. - 6.1: SRTM elevation data of western Himalayas and the location of Kandi-belt [Elevation values ranging from 84 m (blue) to 7403 m (red)]

SRTM data at 30 m resolution were not available for this area. So, the available data was resampled to 30 m resolution using GIS software. The digital elevation model for the Kandi area was separated from the larger map using various utilities of GIS (Map Calculation). The DEM for the Kandi-belt is depicted in Figure – 6.2. The elevation in Kandi-belt varies from 280 m to 543 m.

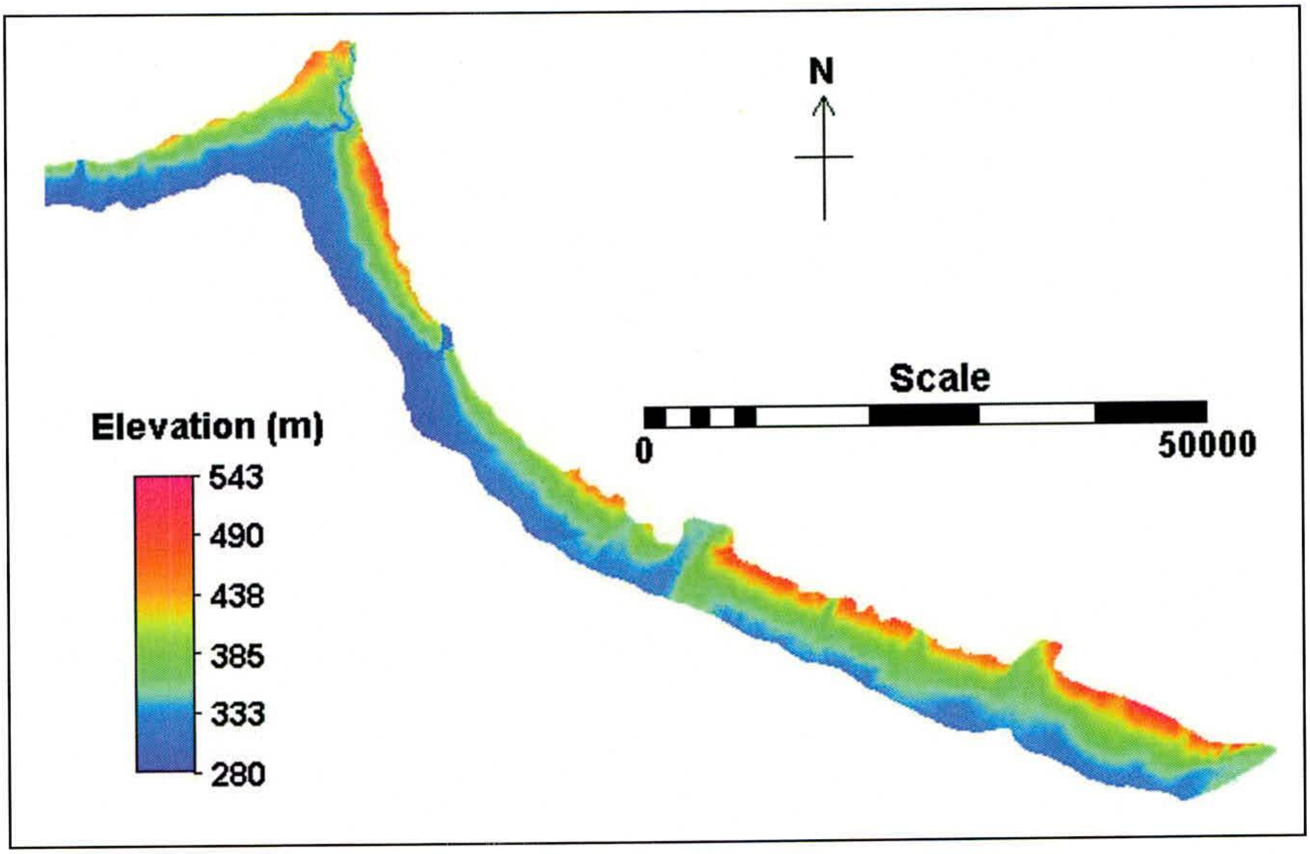


Fig. - 6.2: Digital Elevation Model of Kandi-belt as obtained from SRTM data

6.2.2 Slope map

Slope map is obtained from the digital elevation map by using GIS utilities. In the Kandi-belt, slope varies from 0.11 to 76.64 %. Figure - 6.3 shows the slope map of the area. In this figure, variation of slope is shown up to 8 % since major part of the Kandi-belt has slope up to 8 % only.

6.2.3 Catchment area map

This was an important major task in the analysis. For estimation of inflow, it was required to find out the contributing catchment area for a pond. In the absence of toposheets of the area, drainage could not be located. So, the elevation map was used to delineate the drainage channels in the Kandi-belt and based on the dense drainage network, the contributing catchment area for various ponds was determined. GIS system utilities were used for this rigorous analysis. Figure- 6.4 shows the drainage overlaid on the DEM for a part of the Kandi-belt while Figure – 6.5 shows some ponds overlaid on the drainage network. Figure – 6.6 & 6.7 shows the catchment areas demarcated for some ponds using GIS analysis.

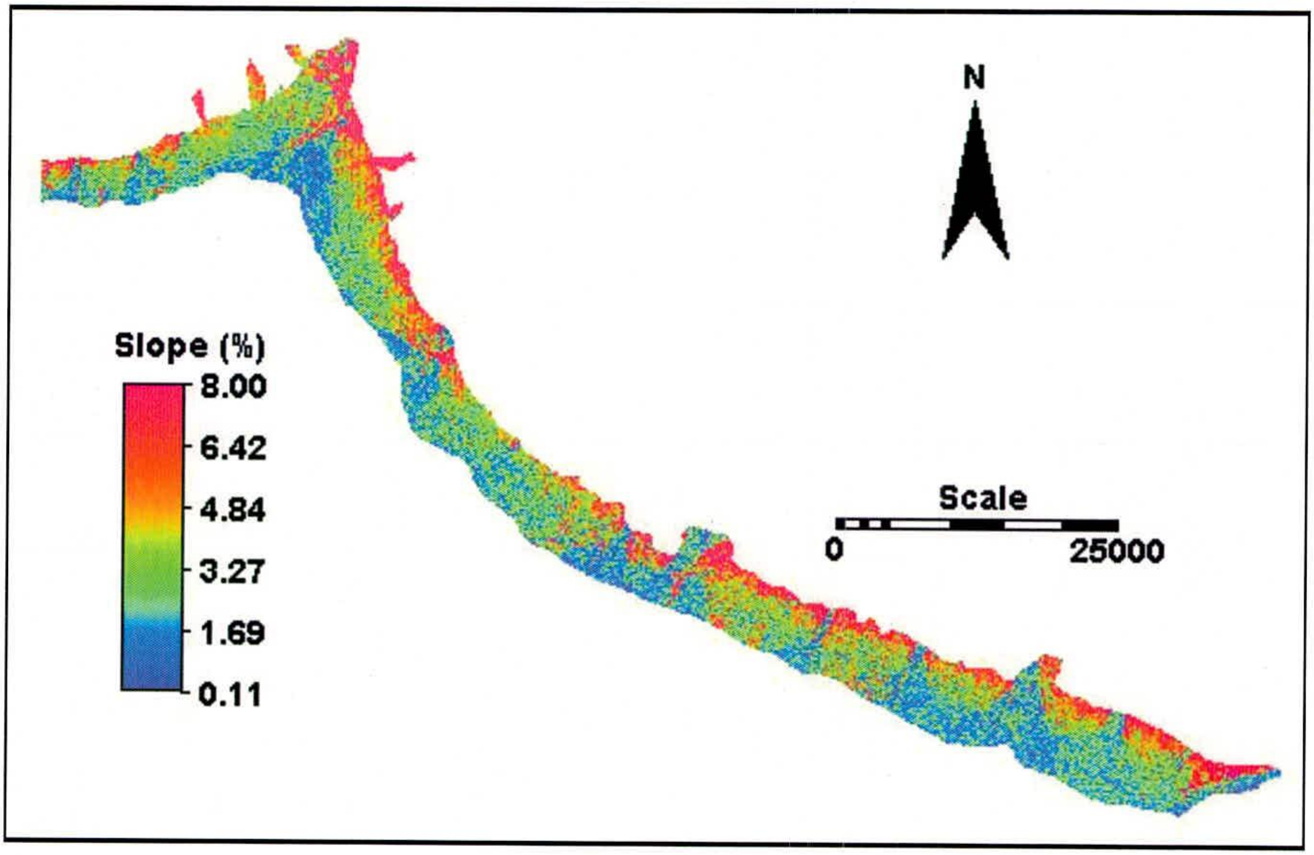


Fig. - 6.3: Slope map of Kandi-belt

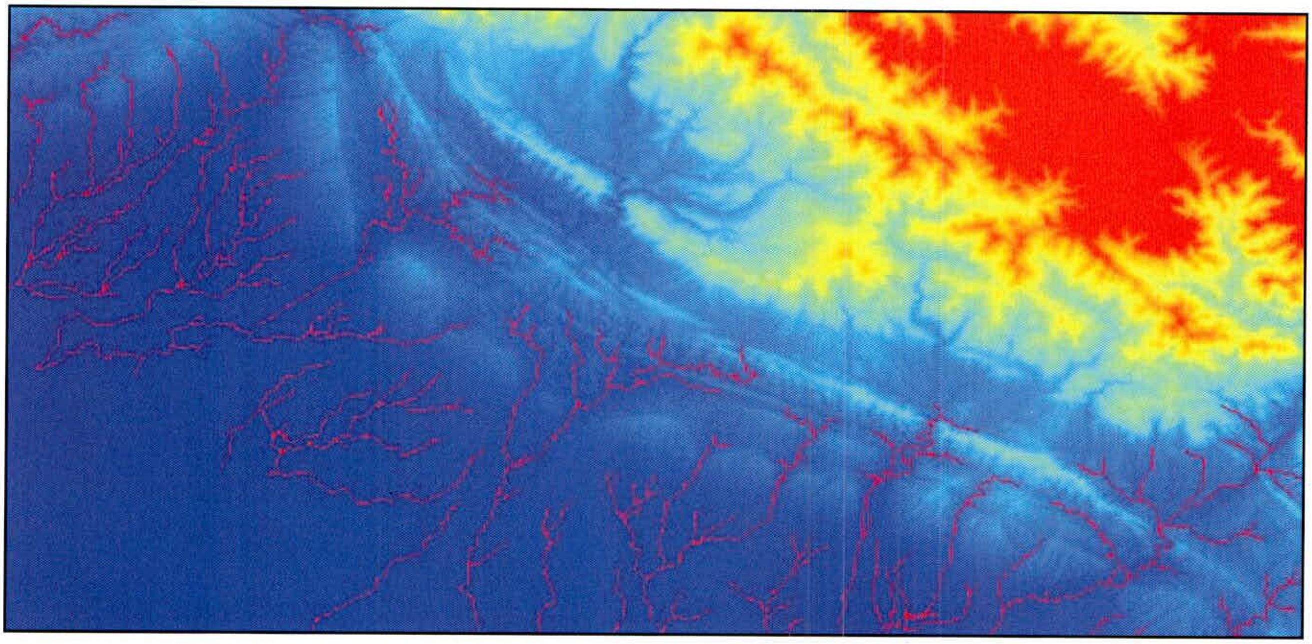


Fig. - 6.4: Drainage network derived from GIS analysis for a part of Kandi-belt

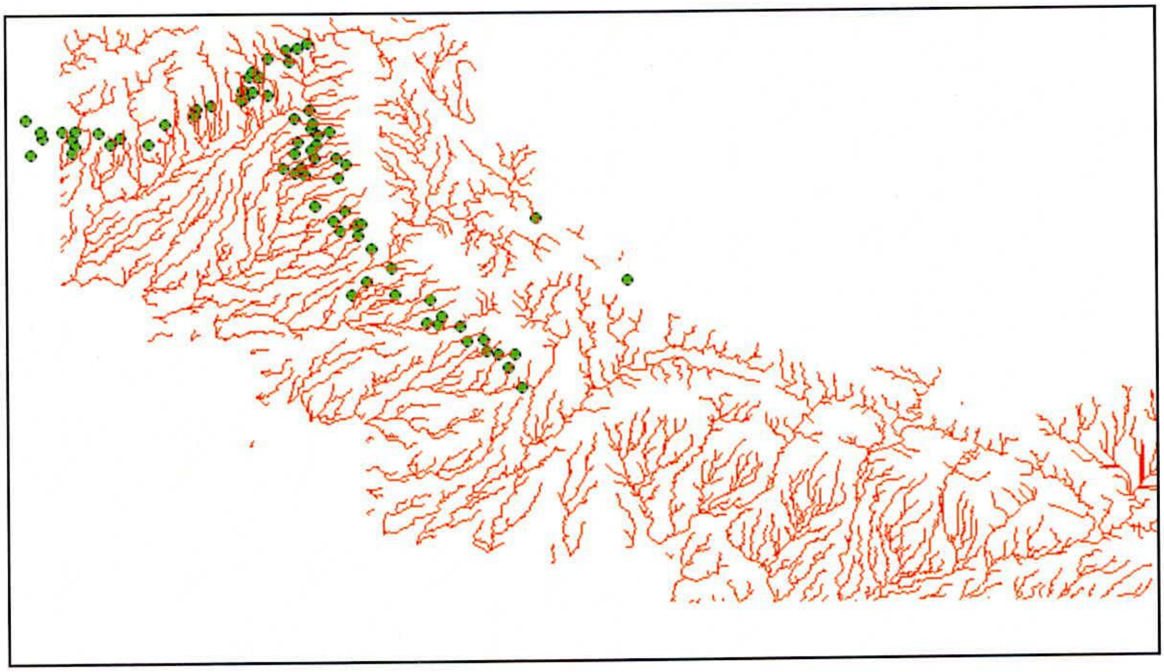


Fig. - 6.5: Some ponds located on the derived drainage network

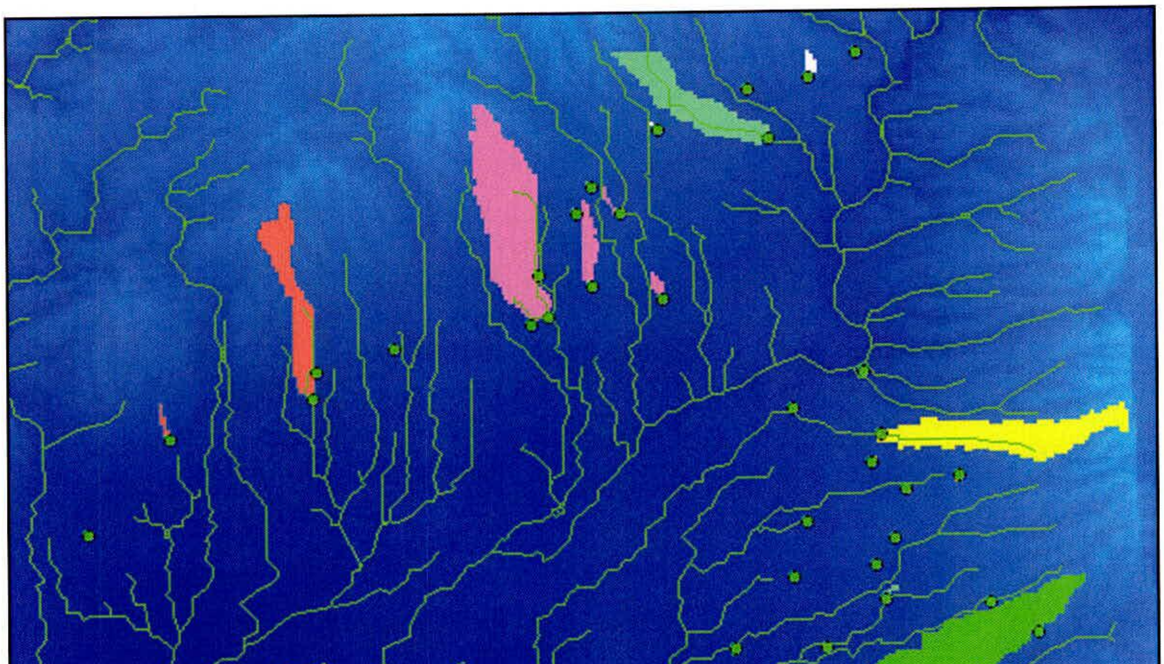


Fig. - 6.6: Catchment areas of a few ponds derived from GIS analysis

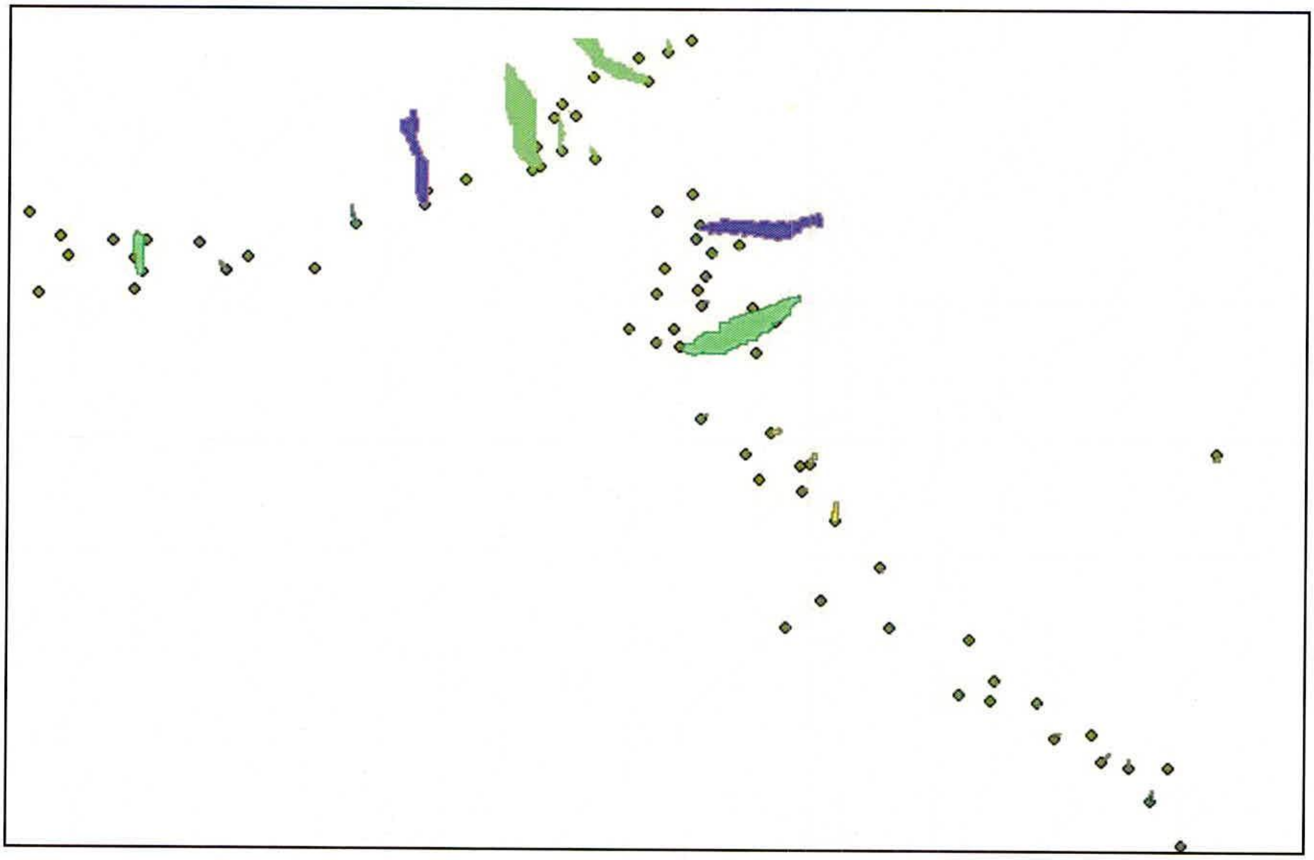


Fig.- 6.7: Catchment areas of some ponds in Kandi-belt derived from GIS

From this analysis, catchment area map is obtained in which catchment areas of different ponds are given different numeric identities. These catchment areas are then used to accumulate the excess rainfall at various grids which is obtained from the SCS method. For some of the ponds, catchment areas estimated by the GIS analysis are given in Table – 6.1.

6.2.4 Soil map

The soils of the Jammu Siwalik region range from alluvial soil with medium sand to fine loam in texture. The Kandi-belt and its adjacent area have loose sandy loam type of soil comprising boulders and gravel with ferruginous clay matrix. In Jammu plains, the soils are mostly alluvial in nature with medium fine and silt loamy texture. The water holding capacity of the soils is very low. Due to excessive permeability, losses of nutrients by leaching are high. The soil map of the area is obtained from Goyal and Rai (2000). The map is presented below.

6.2.5 Thiessen polygon map

There are four raingauge stations within the Kandi-belt: Akhoor, Jammu, Samba, and Kathua. To

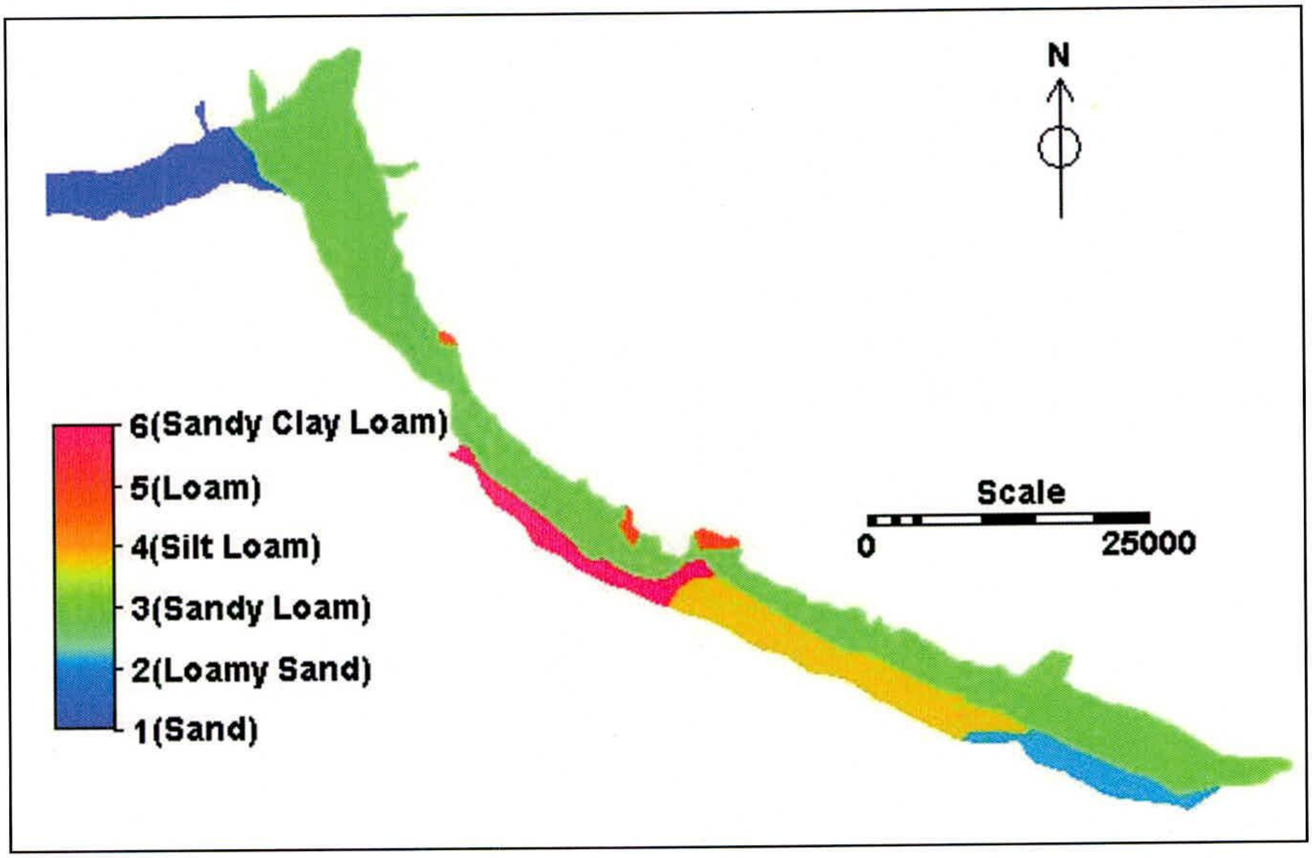


Fig. - 6.8: Soil map of the Kandi-belt (Goyal & Rai (2000)

take the variability of rainfall into account, thiessen polygon were drawn and the grid associated with any rainfall station was assigned the rainfall of the corresponding station. The Thiessen polygon map for Kandi-belt is presented in Figure – 6.9.

6.3 Remote Sensing Analysis for Land use Map

Application of SCS method requires determination of land use in the study area. For this study, land use at Level-I classification was determined by the remote sensing analysis. The data of Landsat TM with a spatial resolution of 30 m and available in public domain was downloaded from the internet (Global Land Cover Facility). The data were available for the years 1989 to 1992. Kandi-belt was covered in three images of the TM sensor. ERDAS IMAGINE image processing system was used for the analysis.

All the three images with three bands (Green, Red, and Near-InfraRed) were imported in the ERDAS and False Colour Composite was prepared for each image. All the images were geo-referenced with the specified latitude and longitude of four corner points. The geo-referenced images were then simultaneously opened and the common areas in different images were checked for accuracy using the

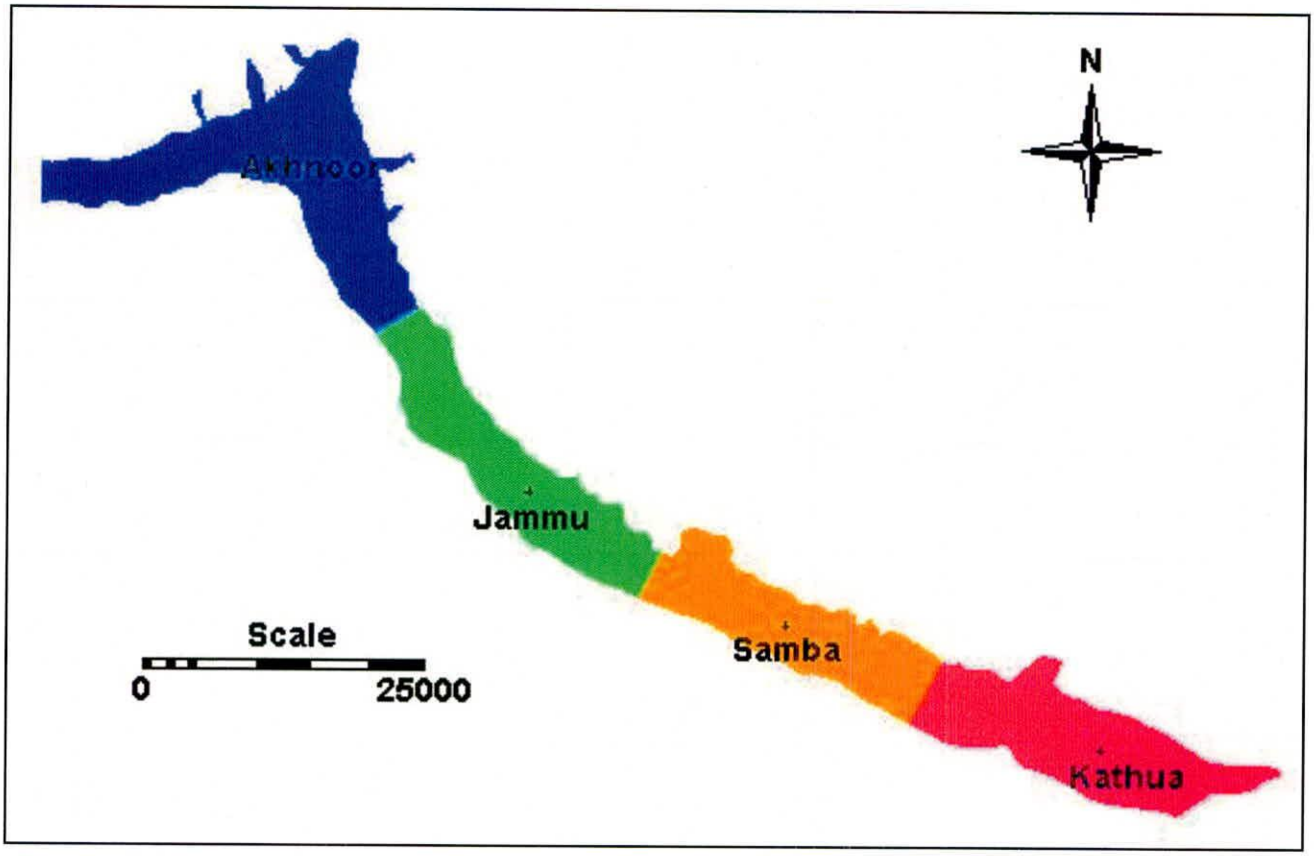


Fig. - 6.9: Thiessen polygon map for the Kandi-belt

SWIPE facility of ERDAS. Using one image as the master, the geo-reference of the other two images was fine-tuned so as to get accurate overlay of the three images. A mosaic of the three images was prepared which is presented in Figure – 6.10.

The boundary of the Kandi-belt was exported from ILWIS and imported in ERDAS for extracting the Kandi-belt area from the whole image. The layout of the Kandi-belt area on the remote sensing image is shown in Figure – 6.11.

Using the boundary of the Kandi-belt in the remote sensing image, the Kandi-belt area was separated from the whole image. Using the Unsupervised Classification procedure, the image of the Kandi-belt was classified in 10 different classes on the basis of reflectance characteristics of different land uses in different bands. These classes were the investigated for their signatures and the classes with closer signatures were merged so as to group the land use of Kandi-belt in five different categories: Forest, Plantation, Barren Land, Urban Land/Water Body, and Agriculture. The first level land use map for the Kandi-belt is presented in Figure – 6.12.

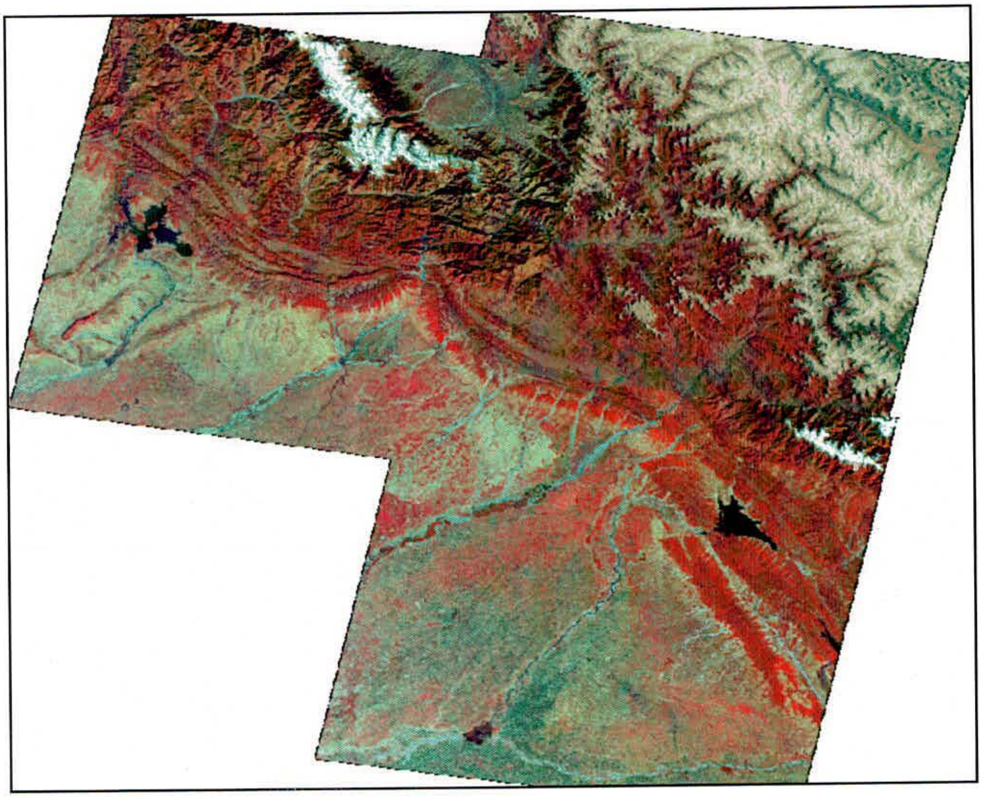


Fig. - 6.10: Mosaic of three Landsat TM images depicting Kandi-belt

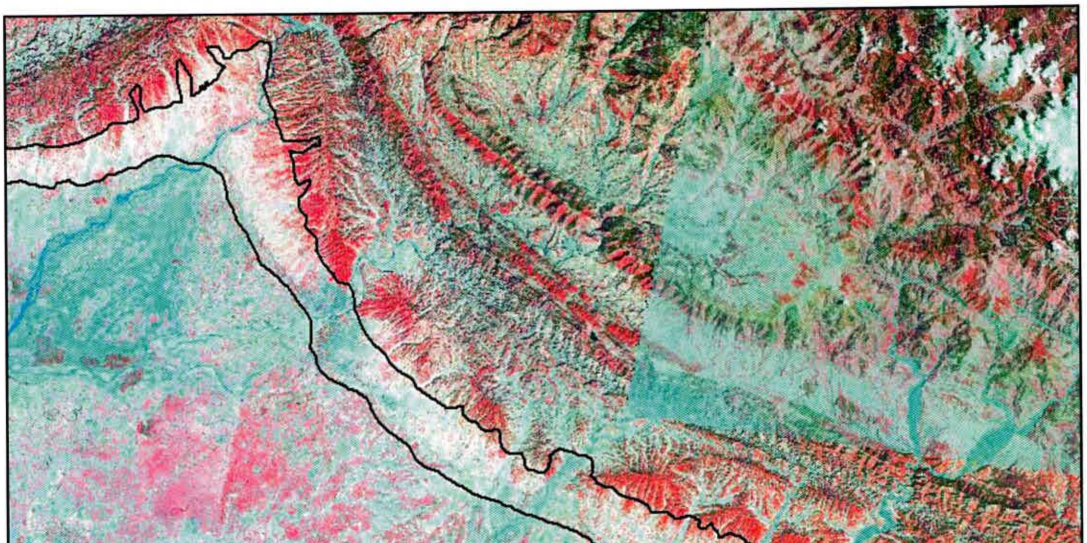


Fig. - 6.11: Kandi-belt coverage superimposed on remote sensing

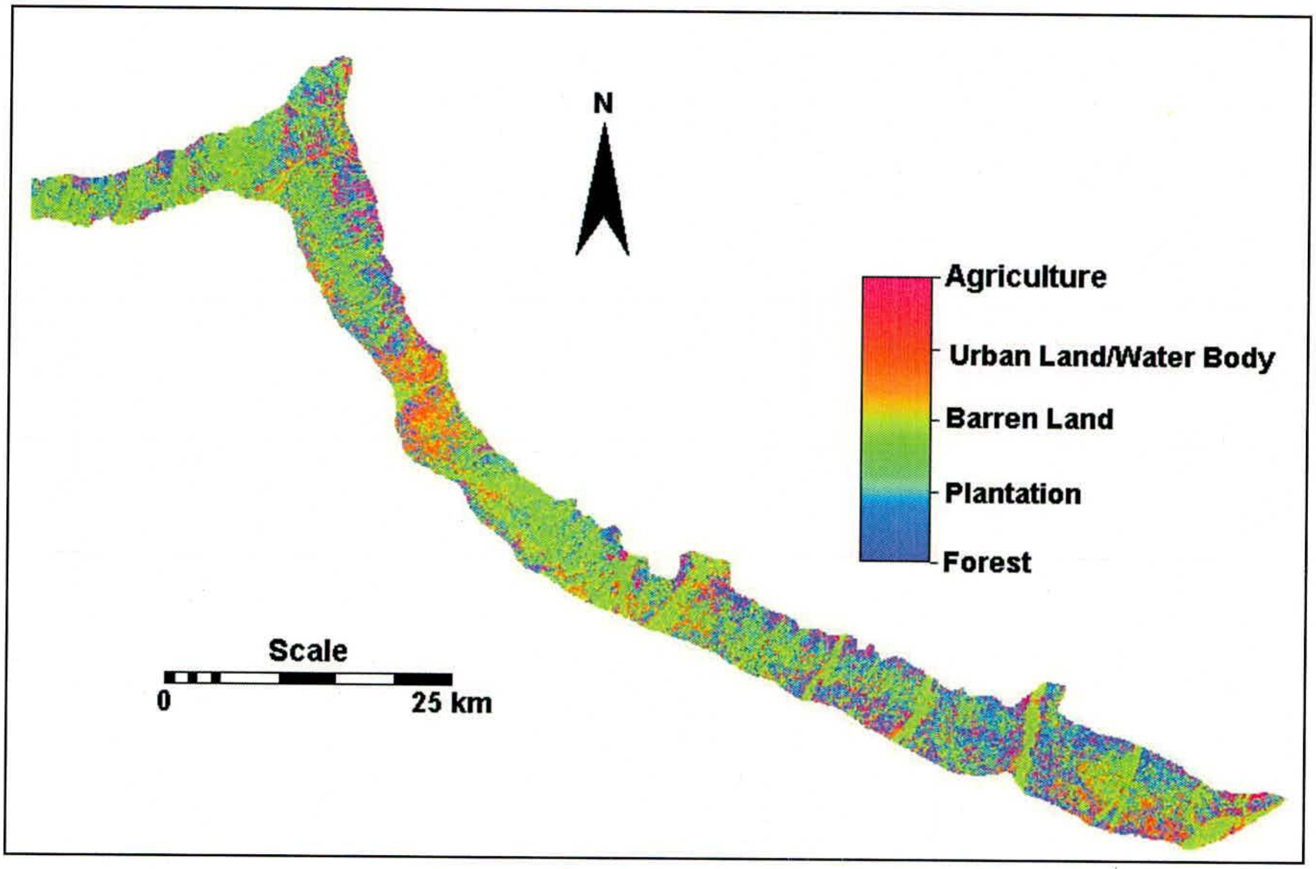


Fig. - 6.12: Land use map of the Kandi-belt

6.4 Application of the SCS Method

The USDA Soil Conservation Service (SCS) has developed a widely used curve number method for estimating runoff. The effects of land use, soil types, and antecedent moisture conditions are embodied in it. Recently, the method has been revised to include the effect of slope also. The procedure was empirically developed from the studies of small agricultural watersheds.

The procedure consists of selecting a storm and computing the direct runoff by the use of curves founded on field studies of the amount of measured runoff from numerous soil cover combinations. A runoff curve number, which is dependent on the type of cover and antecedent conditions, is extracted from the standard tables. According to the SCS method, the SCS runoff equation is

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S} \qquad ...(6.1)$$

where Q is the runoff depth, P is rainfall depth, S is maximum potential retention depth after runoff begins, and I_a is the initial abstraction which represents all losses before runoff begins. I_a includes water retained in surface depressions, water intercepted by vegetation, evaporation, and infiltration. I_a is highly variable but it has been approximated by the following empirical formula:

$$I_a = 0.2S \qquad ...(6.2)$$

By eliminating I_a as an independent parameter, the combination of S and P produces a unique runoff amount given by the following equation:

$$Q = \frac{(P - 0.2S)^2}{P + 0.8S} \qquad ...(6.3)$$

where the parameter S is related to the soil and cover conditions through the curve number CN. CN has a range of 30 to 100 and S is related to CN by:

$$S = \frac{1000}{CN} - 10 \qquad ...(6.4)$$

Eq. 6.4 calculates S in depth units. Major factors that determine CN are the hydrologic soil group, cover type and treatment, hydrologic condition, and the antecedent moisture condition. Based on the infiltration rate, all soils are classified into four hydrologic soil groups: A (High infiltration rate and low runoff potential with infiltration rate greater than 0.76 cm/h), B (moderate infiltration rate between 0.38 to 0.76 cm/h), C (slow infiltration rate between 0.13 to 0.38 cm/h), or D (very slow infiltration rate and high runoff potential with infiltration rate less than 0.13 cm/h). Treatment refers to the cover type modifier (such as contouring, terracing, crop rotation etc.) to describe the effect of cultivated agricultural land management on CN. Hydrologic condition indicates the effects of cover type and treatment (density of plants, residue cover etc.) on infiltration and runoff. A good hydrologic condition indicates that the soil has low runoff potential for the given soil group, cover type, and treatment. Antecedent moisture condition is an index of runoff potential for a storm event. For details on the SCS method, Maidment, D. R. (1992) can be referred.

In the present study, the SCS method has been used to compute the runoff to the ponds corresponding to a rainfall event. The stepwise procedure adopted in this study is described in the following:

a) The study area is divided into grids and for each grid, the land use, the soil type, the slope, the rainfall amount (based on the Thiessen polygon and the amount of daily rainfall at that station) are ascertained.

b) Based on the land use and the hydrological soil group, Curve Numbers are assigned to different grids for a day as specified in Table below.

Landuse	Hydrologic Soil Group			
	Group A	Group B	Group C	Group D
Forest	28	44	60	64
Plantation	45	58	69	73
Barren Land	70	80	85	88
Urban/Water	83	89	92	93
Agriculture	62	72	78	82

c) The curve number derived in step 'b' is then modified for slope. If the slope (SL) is in percentage, then the slope adjusted curve number CN_{sad} is calculated as per the following equation:

$$ICN = CN * e^{(0.00673*(100-CN))}$$

$$CN_{sad} = CN + (\frac{ICN - CN}{3}) * (1 - 2 * e^{(-13.86*SL)}) \qquad ...(6.5)$$

d) The slope adjusted curve number is then modified for the antecedent moisture conditions (AMC). To account for the AMC, the rainfall depth in the past five days is accumulated. If it lies in between 13 to 28 mm, then the curve number derived in step 'c' is not modified as it represents normal AMC. If rainfall is less than 13 mm, it is AMC1 condition and if it is more than 28 mm, then it is AMC3 condition. For these conditions, the revised curve number (RCN) is calculated as per the following equations:

For AMC1, $$RCN = \frac{CN_{sad} - (2000 - 20 * CN_{sad})}{(100 - CN_{sad} + e^{(2.533-0.0636*(100-CN_{sad}))})} \qquad ...(6.6)$$

For AMC3, $$RCN = CN_{sad} * e^{(0.00673*(100-CN_{sad}))} \qquad ...(6.7)$$

e) Knowing the revised curve number (RCN) after accounting for the slope and AMC, the surface retention 'S' is calculated as per Eq. 6.4.

f) Knowing 'S', the rainfall excess is calculated. If rainfall on a day is less than 0.3 * S, then rainfall excess is assumed to be zero. Otherwise, it is calculated by the formula:

$$Runoff = \frac{(Rain - 0.3 * S)^2}{Rain + 0.7 * S} \qquad ...(6.8)$$

g) After calculating the runoff for a day corresponding to some rainfall amount, the runoff generated at all the grids that supply water to a particular pond is accumulated to get the total daily inflow to the pond corresponding to the rainfall amount.

h) These steps are repeated for all the grids for a day and the runoff generated at each grid is calculated. Subsequently, the calculations proceed for the next day and the CN for each grid is computed again in the light of the revised AMC for finding the generated flow.

6.5 Water Balance for Sohal Pond

In the present study, SCS method has been used to estimate the daily inflow to the Sohal pnd in Akhnoor Tehsil, given the daily rainfall. This information can be used to carry out the water balance analysis for the pond. The major components of water balance in a pond are: inflow, rainfall, evaporation, seepage, consumptive water used for some purpose, outflow. In view of the non-availability of any measurement of flow in to a pond, the same is estimated from the SCS method. Rainfall amount observed at the nearest rain gauge station has been taken to fall over the surface area of the pond. Evaporation losses have been estimated from the average pan evaporation measurements that have been observed at Jammu. The results of infiltration tests carried out in the beds of various ponds have been utilized to estimate the seepage losses from the pond. Looking at the present usage of ponds, no consumptive use of water has been assumed from the ponds. From the long-term record of the rainfall, it is observed that the rainfall in the year 1970 was quite close to the normal rainfall in the area (1400 mm). Therefore, the water balance is carried out for the year 1970. The daily water balance for the pond is presented below.

Sohal pond has been selected for water balance analysis as this pond was visited and its physical features were measured during field investigations. Sohal pond is one among the 16 ponds in the Kandi-belt of Jammu region that has surface area more than 10000 sq. m. The shape of the pond is largely rectangular. Its pond index number in this study has been assigned as 27. Though its perimeter and surface area at maximum water depth (5.3 m) are 426.1 m and 10757.6 sq. m respectively, the perimeter and surface area as observed in the field at the water depth of 1.8 m were 380 m and 8961 sq. m. respectively. Assuming same slopes of the sides of the pond throughout its depth and linear variation of area with depth, the area of the pond at zero water depth (minimum area) comes out to be 8037 sq. m. The area at intermediate stages is computed by linear interpolation.

Around the periphery of the pond, the sol type is sandy loam (gravel – 3.44 %, sand – 52.61 %, silt – 41.57 %, and clay – 2.38 %). From selected infiltration tests carried out in the Kandi-belt, the infiltration rate in the sandy-loam soil has been observed to be 5.4 mm/hr. However, the duration for such tests is generally small in which water percolation through the entire geological strata up to the water table can not be ensured. Further, with the passage of time in perennial ponds, a layer of fine sediments get deposited on the bed which reduces the seepage rate through the pond bed. However, the movement of cattle in the pond bed (in case of shallow ponds) can disturb this layer. Because of these considerations, the seepage rate from the bed of Sohal pond has been taken to be 30 mm/day. Anyway, the water balance of the pond can be worked out assuming any value of the seepage rate.

Daily pan evaporation data has been observed at Western Himalayan Regional Centre, NIH, Jammu from 1992 to 1995 and the same has been used to find the average monthly evaporation depths in the region (presented in Table – 6.2). According to the Thiessen polygon map, the nearest rainfall station to the Sohal pond is at Akhnoor. Rainfall data of Akhnoor gauging site for the year 1970 (presented in Table – 6.3) has been used for the water balance computation of Sohal pond. Sohal pond is not used even for cattle purpose. Hence consumptive use has not been considered in the water balance. The runoff generated in the catchment of the Sohal pond, as estimated by SCS method is presented in Table – 6.5. The rainfall and generated runoff have also been plotted in Figure – 6.13. In the water balance, it is assumed that only a part of the catchment runoff (say, 80 %) is diverted to fill the pond and rest of the water (having higher sediment concentration) is let off in the main river.

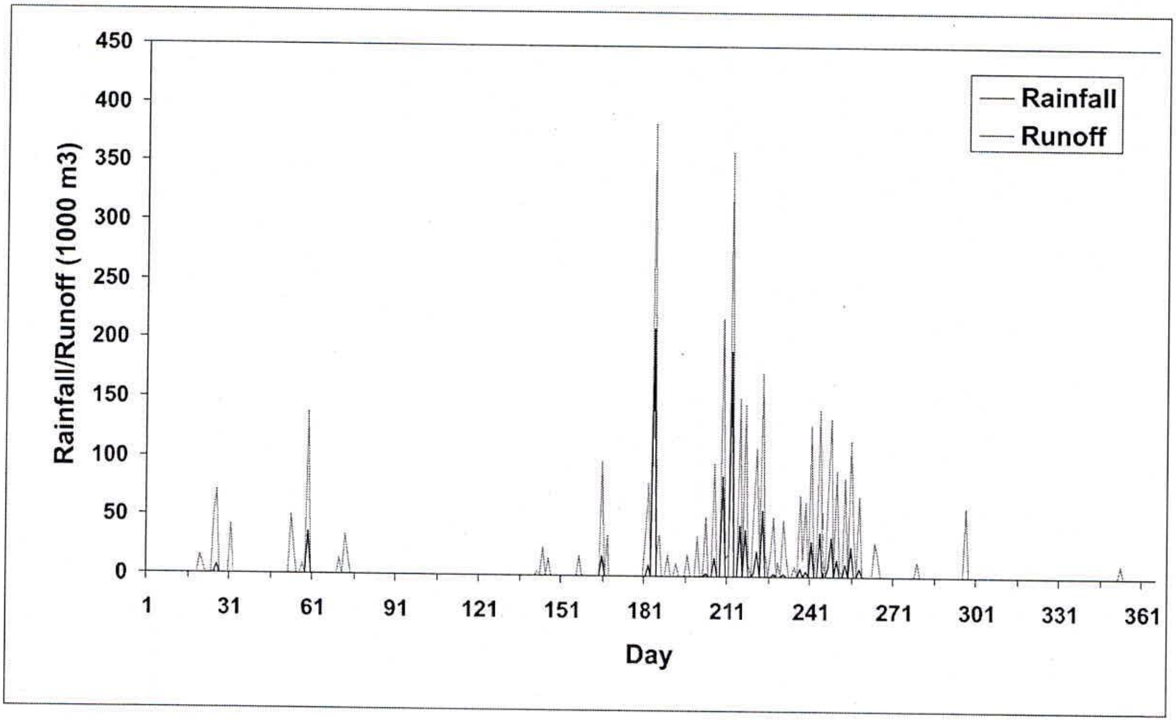


Fig. - 6.13: Rainfall and generated runoff in Sohal catchment for the year 1970

A computer program has been developed to carry out the water balance analysis for the pond. The program reads daily rainfall, generated catchment flow, and the evaporation depth and calculates the revised depth, area, and storage of the pond, seepage losses, evaporation losses, spill from the pond at daily time step. The program takes in to account the availability of water for various losses, variation of area with depth and the seepage loss from only the bed of the pond (excludes the sides which are artificially laid with bricks etc.). For finding the evaporation losses, the program calculates the revised areas iteratively. The program has been run for the Sohal pond with the rainfall data of the year 1970 and various components of water balance have been computed. The daily water balance of the Sohal pond is presented in Table – 6.5.

With the assumptions as stated above, the water balance analysis for the Sohal pond has been carried out. Initial water depth in the pond at the start of simulation (1st January) was obtained iteratively so as to have same water depth at the beginning and end of the year. Some of the observations on annual basis are presented in Table – 6.6.

From the SCS analysis, the runoff coefficient for the catchment of Sohal pond works out to be 0.225. From the water balance analysis, it is observed that the pond remains perennial through out the year with minimum water depth of 0.5 m. Seepage loss is the major water loss factor for the pond. With bed treatment with some suitable material, the seepage loss can be considerably reduced and water can be conserved for domestic use. Though bed seepage contributes to the recharging of the ground water aquifers, yet conservation of the pond water can be beneficially used for domestic purposes. In the monsoon season, the spill from the pond is also appreciable. If the water of the pond is diverted for irrigation or other domestic use during such surplus periods, the storage of the pond can be optimally utilised. At present, the water of the pond is not used for any purpose. There is a strong need to conserve the quality and quantity of the water of Sohal pond which can benefit the society in the long run.

CHAPTER – 7

PROBLEMS & RESTORATION REQUIREMENTS OF KANDI-BELT

7.1 Problems of Kandi-belt

The Kandi-belt in the western Himalayan region faces acute shortage of water for the entire year. During summer there is limited water availability while during monsoon, the quality of water (having high sediment concentration) is a matter of concern. The water related problems of the region need to be identified to evolve location specific package of solutions aimed at improving the productivity as well as the natural environment. A major problem in the Kandi-belt has been degradation of land due to adverse runoff characteristics of the streams in the region.

The region receives rainfall from the 3rd week of June to middle of September through the southwest monsoon. About 74% of the total rainfall is received in a short span of 4 months during the monsoon season. Winter rains are received during January to March due to western disturbances. Long rainless periods occur even during rainy season, causing water stress to crops. Most of the rainwater goes as surface runoff due to flashy nature of streams. A number of *Choes* (torrential streams) pass through the Kandi-belt, manifesting "too little or too high" syndrome, which is typical of the hilly areas, and are eroding the fertile soils of the area. Extinction of the age-old system of water harvesting through village ponds has resulted in the water scarcity during non-monsoon months. Though the area receives a fairly high average annual rainfall of more than 1200 mm, yet harvesting of this water is lacking, which is one of the root-causes for water crisis.

The combined effect of undulating topography, deforestation and torrential rains during monsoon season has severely denuded the once tropical deciduous forests to the present day degraded forests in the Kandi-belt. Majority of land is rainfed, risk prone and has low pay-off. Farmers do not pay adequate attention to land management and follow traditional farming practices which yield high runoff and soil loss. Because of undulating terrain, excessive runoff and high erodibility of soils, erosion is more prominent. Deposition of eroded material in the streambeds reduces the carrying capacity of the streams and causes floods in the down plains besides causing siltation of reservoirs.

A gradual decline in the forest area is the result of excessive harvesting of forests for fuel, fodder, timber and other products, and improper burning, lopping and cutting of trees. As a result, many important native plant species are facing acute problem of regeneration.

Water bearing aquifers in the region are deep and, therefore, ground water is inadequate and not economically feasible. Grain size of the aquifer material in the Kandi-belt is very coarse. The cost of drilling of wells is also high because of adverse hydro-geological conditions. Rapid urbanization has led the pollutants to enter the surface and ground water through sewage disposal, industrial wastes, fertilizers, insecticides and pesticides.

The semi-hilly Kandi-belt is generally devoid of any springs or *baolis*, which made the ponds an important source of water to meet the community needs in the region. By the middle of 20th century, piped drinking water supply led to the neglect of these ponds. Pressure on land and a decline in community institutions further speeded their decline. Most of the ponds in the Kandi-belt are today in a state of utter neglect and disuse. Village institutions, which organised annual desilting through voluntary labour and guarded the ponds against pollution, have since collapsed. In some cases, dirty water drains have been diverted into the ponds. High silt deposits have greatly reduced their storage capacity. With the advent of *pucca* houses, a rural women's need for pond silt to mudwash her house has decreased and, as a result, this need-driven desilting of ponds is coming to an end. Water inlet routes of several ponds have been encroached upon by influential persons, resulting into less runoff coming from the catchment area for storage. Although some efforts have been made to construct new ponds in the Kandi-belt for irrigation purposes, yet limited success was achieved because of ignorance of the importance of selection of suitable sites for this purpose. Water stored after good rainfall seeps out in just a few days (Agrawal and Narain, 1997).

In the Kandi-belt, long term hydrological data is presently available for only two major rivers, viz. Chenab and Tawi. No hydro-meteorological monitoring station is available in the catchment for monitoring rainfall, flow and sediment discharge of other important streams in the Kandi-belt, e.g. Devak, Basantar, Ujh, Tarnah etc.

7.2 Possible Solutions to the Hydrological Problems

Water demands in the Kandi-belt mainly comprise of domestic and irrigation requirements. The water availability problems in the area can be tackled by adopting two-tier approach - short-term and long-term. Under the former category, immediate solution of the domestic and, to a limited extent, irrigation water requirements can be handled by providing water from tube-wells, ponds, and small reservoirs created with the help of check-dams on seasonal streams and rivulets, wherever feasible. Solution under the later category would involve measures like watershed management, including set up of hydro-meteorological monitoring system in the region.

Two major physiographic sub-divisions of the Kandi-belt are - the Upper Kandi and Lower Kandi. There cannot be a general recommendation, which would suit the whole area of the region. In order to achieve sustainability of the efforts, it would be better to have a number of small schemes rather than one or two major schemes. Involvement of the local people and local institutions would assure the success of these schemes.

7.2.1 Short-term solutions

Ground water exploration in the Kandi-belt needs to be more systematised and efforts should be made to exploit deeper aquifers. Tapping of deep seated Siwalik aquifers in the Kandi region is suggested as a means of solving the water crisis in the region (CGWB, 1996). Special combination rig is required to drill in the bouldery formations successfully. Efforts are required to determine the aquifer parameters with the help of observation wells.

More than 350 ponds of various sizes, with a total surface area of approx. 1.7 sq. km, have been located in the Kandi-belt. Most ponds are so located and designed that a part of the runoff from adjoining rivulets could be trapped and diverted. Also, the ponds helped in improving the level of ground water in the surrounding areas. A long-term solution to solve the water scarcity problem in the Kandi-belt lies in the rejuvenation of these village ponds. Their water could be utilized for domestic purposes and, to a limited extent, for irrigation purposes (e.g. in horticulture, agro-forestry). These ponds would also help in improving the ground water regime in the region. A sound scheme for rejuvenation of the village ponds is required, which should use the traditional folk wisdom and the skills of the modern techniques, e.g. inputs from the hydrology, geology and geophysics, soil sciences, remote sensing and GIS. Specific objectives of the rejuvenation could be:

(1) Selection of suitable sites for location of new ponds,
(2) Improving inlets to the ponds, with augmentation of runoff from nearby areas,
(3) Necessary desilting of ponds,
(4) Deepening of ponds, if required, and improving the side walls/bunds,
(5) Lining of ponds with appropriate material to control seepage from the beds,
(6) Reduction of pond evaporation through appropriate measures (e.g. through plantation),
(7) Constructing separate sections for drinking water, bathing and washing, cattle needs,
(8) Networking of ponds, wherever feasible, for domestic and irrigation purposes
(9) Recharge of the ponds through dug wells near the stream beds, wherever feasible based on hydrogeology of the area. This is known as the Makowal model, which was successfully implemented in the Kandi areas of Punjab.

The cultivated areas, just below the foothills, have undulating topography, irregular slopes, and very small land holdings. Suitable engineering and agronomic measures are required for this area. A set of measures, including (i) terracing within field boundaries, (ii) land grading to bring down slope between 0.3 to 0.5%, (iii) field bunding, and (iv) outlet structur es for draining excess water from field to field, and from field to water ways and grassed water ways, has been found technically viable in the Kandi-belt of Punjab (Verma, 1992), and could well be attempted in Jammu and Kashmir.

There are numerous big gullies and ephemeral streams originating from low hills and flowing down into cultivated fields. Small earthen dams can be constructed at suitable locations near foothills to store considerable quantity of runoff water. These earthen dams can be constructed using clay (locally available) core wall and simple earthen spillway.

A network of canals is available in the Kandi-belt, drawing water from the rivers Chenab, Tawi, Ujh, Basantar, and Ravi. Water through these canals during lean demand months could be utilized, where ever feasible, to store in the village ponds, of course taking into consideration the topographic conditions. A considerable amount of runoff can be collected in tanks for supplemental irrigation to rainfed crops. Tanks in fields with loamy sand are preferred since runoff from these soils is low which can be easily managed in the field itself. Dug out tanks are most suitable for excess runoff storage in cultivated lands, provided heavy seepage is controlled through suitable methods.

Average annual rainfall in the Kandi-belt area is more than 1200 mm. Therefore, rainwater harvesting techniques can be adopted in the region for storing rooftop rainwater in underground tanks. Since groundwater exploitation in the area is difficult and expensive because of deeper groundwater table and hydrogeologic conditions and surface flows in the rivers is flashy and seasonal in nature and is coupled with large amount of sediment, all efforts need to be made for the conservation of every drop of water and the judicious and planned use of water resources.

7.2.2 Long-term solutions

Besides surface water storage, it is advisable to augment the ground water aquifers through recharge process. The ground water storage has advantage over surface water storage in that it reduces evaporation losses and helps natural filtration of water besides eliminating the need of large land areas needed in case of surface water reservoirs.

Natural seepage from ponds and reservoirs of the check-dams contribute to the ground water recharge. The type of ground water recharge system that can be developed at any specific site is controlled, to a large extent, by the geologic, hydrologic, and topographic conditions that exist at the site. Availability of water, either on a perennial or intermittent basis, is of prime concern in any recharge operation. The quality of recharge water should be considered to avoid contamination of the ground water.

Ephemeral, or flashy, streams in the Kandi-belt discharge into the plains and during times of severe floods cause great damage by spreading sand deposits on otherwise fertile lands. The ever-increasing demand of water, especially for irrigation purposes, can also be met by tapping ephemeral streams with small reservoirs, water harvesting tanks, diversion weirs, etc.

The forest resources of the Kandi-belt in Jammu region have been under mounting pressure owing to increasing human and livestock population. Excessive deforestation has resulted in the depletion, degradation and endangering natural regeneration of the forests which has become a cause of serious concern. The large-scale deforestation is causing significant changes to the high and low flow regimes of rivers and massive soil erosion. In order to achieve sustainable development of natural resources in the Kandi-belt, a watershed management approach is necessary to derive long-term benefits. The approach should include water conservation, land development, crop planning and management, and agro-forestry measures. The Kandi-belt can be divided into small watersheds having denuded hills in the upper part and undulating cultivated fields in the lower portion. It is necessary to develop this area on watershed basis and all engineering and non-engineering measures of rainwater management and soil conservation should be planned and implemented in the watersheds.

CHAPTER – 8

SUMMARY & CONCLUSIONS

The steeply sloping submontane belt of around 30 km width of the Himalayas fringing the Siwalik hills and extending discontinuously from Jammu and Kashmir to Assam is termed as Kandi-belt. This dry-looking belt flattens downstream in the south where the soil material becomes finer from gravel and sand to silt and clay. The upper portion of Kandi-belt consists of low hills covered by shrubs and forest, and the lower terrain has cultivated lands and gully beds. It has undulating topography, steep and irregular slopes, erodible and low water retentive soils. Major land and water management problems being faced in the Kandi-belt include excessive runoff, soil erosion, land degradation and erratic water distribution in space and time hampering agricultural production. Population in the entire belt suffers from water scarcity. Groundwater table is deep and streams carry huge debris material during monsoon.

The Kandi-belt is generally devoid of springs which has made ponds an important source of water to meet the community needs in the region. Ponds have played a crucial role in the Kandi-belt and were the main source of drinking water till 1960s. The ponds located in the Kandi-belt are primarily concentrated in the Jammu and Kathua districts. Udhampur district is predominantly hilly and has fewer ponds. Almost all Kandi villages have one big pond to meet the domestic needs throughout the year. These big ponds were constructed with masonry work on three sides, the fourth side left open for the water to flow in. By the middle of the 20^{th} century, piped drinking water supply led to the neglect of these ponds. Most of the ponds in the Kandi-belt are today in a state of utter neglect and disuse. A long-term solution to solve the water scarcity problem in the Kandi-belt lies in the rejuvenation of these village ponds. This water could be utilized for domestic purposes and, to a limited extent, for irrigation purposes (e.g. in horticulture, agro-forestry etc.). These ponds could also help in improving the ground water regime in the region.

In this study, an attempt has been made to evaluate the present status of ponds in terms of quantity and quality of the available resources. This study is an extension of the previous study carried out by Vijay Kumar et al. (2003). In addition to the 56 ponds already surveyed in the previous study, field investigations have been carried out for further 45 ponds in the Kandi-belt. In addition to the evaluation of ponds in terms of physical features, water quality parameters, soil properties, hydrological evaluation has been attempted and water balance analysis has been demonstrated for a large pond.

For the estimation of physical features, and evaluation of water quality parameters and soil characteristsics, field visits were carried out to 45 ponds in the pre-monsoon periods of the year 2005. As regards physical features, the shape, perimeter, area, depth, storage volume, age, utility, and annual status of the ponds (whether perennial or seasonal) were determined for all the ponds. Various water quality parameters that were evaluated from the samples of different ponds included: pH, electrical conductivity, alkalinity, calcium and magnesium hardness, chloride, sulphate, sodium, potassium, nitrate and total dissolved solids (TDS). The physical parameters such as temperature, pH and electrical conductivity were determined in the field at the time of sample collection using portable kits. Alkalinity, Chloride, total hardness and Calcium hardness were determined by the method of titration. Sodium, potassium, sulphate, and nitrate were determined by instruments such as flame photometer, spectrophotometer etc. The results of analysis have been presented in detail in the report. In general, the water quality of the ponds was not found suitable for domestic purposes. The electrical conductivity, pH, total dissolved solids, and sodium absorption ratio were found to exceed permissible limits in 20, 27, 32, and 3 ponds respectively.

At the periphery of 37 ponds, soil samples were collected for textural analysis. The percentage finer for sieves of different sizes were obtained. Using the tri-linear diagram, the type of soil for each pond was determined. Out of the 37 ponds analyzed, soil texture in 17 ponds was found to belong to sandy-loam type while soil textures in 18 ponds belong to silt-loam type. These soil types have considerable seepage rates and are not conducive for retaining water for longer periods. Further, infiltration tests were carried out in the bed of three ponds using double-ring infiltrometer. Infiltration capacities of the bed of the ponds were found to vary from 1.2 mm/hr in silt loam to 5.4 mm/hr in sandy loam type of soil.

For the hydrological evaluation, water balance studies have been carried out and demonstrated for a large pond so that different components of water balance (say inflow, evaporation losses, seepage losses, outflow etc.) could be studied in detail and suitable measures can be taken to increase the water availability and its utilization and decrease the losses from the pond. Because of the non-recording of hydrological observations at any pond, inflow to a pond from its contributing catchment area was estimated by using the Soil Conservation Service (SCS) Curve Number method. Remote sensing images were used to find the first-level landuse map. Based on the Shuttle Radar Topographic Mission digital elevation data, GIS analysis was carried out to find the flow pattern and demarcate the contributing catchment areas for some major ponds in the area. Data files were prepared in GIS and a computer program was written to estimate the inflow to a pond using SCS method. An average rainfall year (year having annual rainfall close to the long-term average) were selected (year 1970) and the water balance analysis was carried out for that year. Corresponding to the rainfall event in the catchment, inflow to the pond is estimated. Another computer program has been written for the water balance computation of the pond at daily time step. Major components of water balance are: inflow, rainfall over the pond, evaporation, seepage, consumptive water used for some purpose, and spill. Evaporation losses have been estimated from the average pan evaporation measurements in the region. Results of infiltration tests have been utilized to estimate the seepage losses. Present usage conditions have been used for estimating consumptive use. The program reads daily rainfall, generated catchment flow, and evaporation depth and calculates the revised depth, area, storage, seepage and evaporation losses, and spill at daily time step. The program takes in to account the availability of water for various losses, variation of area with depth and the seepage loss from only the bed of the pond (excludes the sides which are artificially laid with bricks etc.). For finding the evaporation losses, the program calculates the revised areas iteratively.

Sohal pond has been selected for water balance analysis as this pond was visited and its physical features were measured during field investigations. Sohal pond is one among the 16 ponds in the Kandi-belt of Jammu region that has surface area more than 10000 sq. m. Around the periphery of the pond, the soil type is sandy loam. Seepage rate from the bed of Sohal pond has been taken to be 30 mm/day. According to the Thiessen polygon map, the rainfall station nearest to the Sohal pond is at Akhnoor. Sohal pond is not used even for cattle purpose. Hence consumptive use has not been considered in the water balance. In the water balance, it is assumed that only a part of the catchment runoff (say, 80 %) is diverted to fill the pond and rest of the water (having higher sediment concentration) is let off in the main river. From the SCS analysis, the runoff coefficient for the catchment of Sohal pond works out to be 0.225. From the water balance analysis, it is observed that the pond remains perennial through out the year with minimum water depth of 0.5 m. Seepage loss is the major water loss factor for the pond. In the monsoon season, the spill from the pond is also appreciable. If the water of the pond is diverted for irrigation or other domestic use during such surplus periods, the storage of the pond can be optimally utilised. At present, the water of the pond is not used for any purpose. There is a strong need to conserve the quality and quantity of the water of Sohal pond which can benefit the society in the long run.

In the present report, hydrological evaluation has been demonstrated for only one pond. However, generalized computer programs have been developed which can be used for the hydrological analysis of any other pond in the Kandi-belt. One major limitation of the present study is the validation of the runoff computed by SCS method. This is due to lack of actual inflow observations at any pond in the area. If only a simple staff gauge is installed in a pond and daily observations of pond water level are recorded, significant improvements in the analysis can be made and the model parameters can be calibrated and results verified.

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Table 2.1 Irrigation Systems in Jammu & Kathua Districts

S No.	Name of Scheme	Year	Type of Scheme	Source of water	CCA (Ha)	Design Discharge (cusec)	Potential Created (Ha)
1	Ranbir Canal	1905	Gravity	Chenab	38,623	1000	67,814
2	Pratap Canal	1961-62	-do-	-do-	9,919	500	14,879
3	Parwai Canal	1974	do	do	2429	175	3,644
4.	Ranjan Canal	1994-95	Lift	-do-			3,036
5	Kathua Canal	1961 62	do	Ravi	11,741	400	17,611
6.	Ravi-Tawi Lift Canal	1978	Lift	Tawi	14,170	300	12,880
7	Ravi Canal Ph -I	1982-83	Gravity+Lift	Ravi + Ujh	32,185	250	12,000

Source: Prabhakara and Raina, 1997

Table 2.2 Chemical Characteristics of Ground Water in Jammu District

Parameters	Pre-monsoon (June 1998)	Post-monsoon (Feb 1999)
pH	8.16	7.8
EC (μ mhos/cm at 25^0C)	1374	1064
TDS (mg/l)	879	681
Alkalinity (mg/l)	329	315
Total Hardness as $CaCO_3$(mg/l)	270	327
Chloride (mg/l)	48	54
Sulphate (mg/l)	45	29
Phosphate (mg/l)	0.08	0.08
Nitrate (mg/l)	5	10
Calcium (mg/l)	71	85
Magnesium (mg/l)	23	28
Sodium (mg/l)	41	37
Potassium (mg/l)	19	27
Fluoride (mg/l)	-	0.45

Table - 2.3 Domestic Water Demand in Kandi-belt

Tehsil	Total Population	Population in Kandi-belt	Domestic Water Demand (m^3/day)
Jammu District			
Jammu	206916	64809*	6481
Akhnoor	140081	39125	3913
Samba	132237	38449	3845
Sub-Total (Jammu Dist.)	479234	142383	14239
Kathua District			
Kathua	85013	34215	3422
Hiranagar	109052	34900	3490
Sub-Total (Kathua Dist.)	194065	69115	6912
Total	673299	211498	21151

Table - 2.4 Details of Ponds in Kandi-belt in Akhnoor Tehsil (Distt. Jammu)

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
1	1	74.517	32.875	Potiyadi	Perennial	270.3	5136.9
2	2	74.515	32.859	Dhaleri	Perennial	252.3	4315.0
3	3	74.543	32.874	Kalith	Perennial	384.5	10452.7
4	4	74.552	32.846	Taroti	Perennial	493.6	14038.6
5	5	74.556	32.860	Rajwal	Perennial	271.5	4924.8
6	6	74.540	32.875	Kalith	Seasonal	240.8	3493.1
7	7	74.549	32.876	Kalith	Seasonal	174.2	1935.5
8	8	74.548	32.868	Dhangar	Seasonal	258.4	3632.3
9	9	74.569	32.857	Chak Bhagwana	Perennial	206.0	2817.0
10	10	74.600	32.861	Kansaliyan	Perennial	318.5	6462.5
11	11	74.582	32.877	Dhok Khalsa	Seasonal	184.6	1895.7
12	12	74.569	32.877	Phambrean Ki Dhok	Seasonal	231.7	2651.3
13	13	74.584	32.881	Dhok Khalsa	Seasonal	174.4	1968.6
14	14	74.579	32.882	Dhok Khalsa	Perennial	219.4	3241.2
15	15	74.615	32.874	Bhiri	Perennial	290.2	5302.6
16	16	74.631	32.865	Chak Najla	Perennial	319.8	5176.7
17	17	74.605	32.880	Bhiri	Seasonal	251.8	4175.8
18	18	74.613	32.882	Bhalwal Brahamana	Seasonal	232.6	3446.7
19	19	74.619	32.884	Bhalwal Brahamana	Seasonal	408.8	9650.7
20	20	74.608	32.892	Jad	Seasonal	266.9	4759.1
21	21	74.617	32.891	Jad	Seasonal	176.8	2074.6
22	22	74.631	32.898	Kangar	Perennial	219.9	3400.3
23	23	74.642	32.901	Gura	Perennial	399.7	10863.7
24	24	74.649	32.901	Gura	Seasonal	195.9	2313.3
25	25	74.645	32.890	Lehr	Seasonal	178.3	1962.0

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
26	26	74.650	32.892	Lehr	Seasonal	229.3	3327.4
27	27	74.654	32.893	Sohal	Perennial	426.1	10757.6
28	28	74.664	32.896	Dhok Khalsa	Perennial	218.1	3088.8
29	29	74.670	32.914	Badgal Kalan	Perennial	182.4	1855.9
30	30	74.681	32.911	Gopala	Seasonal	222.0	3194.8
31	31	74.705	32.910	Lehr	Seasonal	253.8	3884.2
32	32	74.714	32.902	Lehr	Seasonal	194.1	2631.4
33	33	74.705	32.902	Lehr	Seasonal	191.7	2425.9
34	34	74.713	32.889	Karangi	Seasonal	331.7	7549.6
35	35	74.734	32.898	Akhnur	Seasonal	183.8	2213.8
36	36	74.730	32.901	Ambi	Seasonal	228.9	3155.0
37	37	74.741	32.906	Uparla manda	Seasonal	273.4	4513.8
38	38	74.729	32.914	Bhandral Kalan	Seasonal	363.4	9259.7
39	39	74.720	32.919	Bharda Khurd	Seasonal	308.4	6058.2
40	40	74.728	32.929	Kothe	Seasonal	373.2	8457.6
41	41	74.772	32.928	Gura	Perennial	248.9	3990.2
42	42	74.763	32.930	Patiari	Perennial	224.2	3135.2
43	43	74.754	32.928	Patiari	Perennial	299.6	5740.1
44	44	74.754	32.936	Jakhari	Seasonal	238.7	3314.1
45	45	74.767	32.940	Talqual	Perennial	283.2	5130.3
46	46	74.770	32.948	Meshiani	Perennial	164.7	1551.0
47	47	74.763	32.954	Targah	Perennial	283.8	5706.9
48	48	74.753	32.961	Targah	Perennial	169.5	1869.2
49	49	74.758	32.966	Tacharwan	Perennial	176.9	1928.8
50	50	74.786	32.957	Pian	Perennial	257.5	3831.1
51	51	74.785	32.968	Rangani	Perennial	195.3	2432.6
52	52	74.780	32.970	Maira	Perennial	154.6	1484.7
53	53	74.783	32.974	Mandrean	Perennial	212.7	3068.9
54	54	74.772	32.969	Mundh	Perennial	275.0	5282.7
55	55	74.749	32.952	Sangani	Seasonal	244.2	3811.2
56	56	74.749	32.945	Janti	Seasonal	246.5	4036.6

Table - 2.5 Details of Ponds in Kandi-belt in Jammu Tehsil (Distt. Jammu)

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
1	57	74.742	32.856	Chhanni	Perennial	270.6	4281.9
2	58	74.733	32.867	Malpur	Perennial	359.1	7755.1
3	59	74.748	32.891	Gura Patan	Seasonal	230.0	3380.4
4	60	74.747	32.887	Gura Patan	Seasonal	256.3	4387.9
5	61	74.733	32.874	Malpur	Seasonal	207.3	2671.2
6	62	74.760	32.876	Sobka	Seasonal	206.0	2790.5
7	63	74.767	32.890	That Ranjan	Seasonal	177.9	2008.4
8	64	74.784	32.898	Garhi	Seasonal	243.3	3691.9
9	65	74.787	32.896	Gaur	Perennial	169.0	1471.5
10	66	74.794	32.894	Gaur	Perennial	172.5	1783.0

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
11	67	74.792	32.891	Jandial	Perennial	267.6	3221.3
12	68	74.786	32.877	Ghurota	Perennial	367.4	8172.6
13	69	74.792	32.878	Ghurota	Perennial	381.7	9180.1
14	70	74.776	32.877	Dharota	Perennial	191.8	2432.6
15	71	74.780	32.880	Ghurota	Perennial	232.0	3234.6
16	72	74.783	32.881	Ghurota	Perennial	160.9	1564.3
17	73	74.788	32.883	Ghurota	Perennial	238.5	3188.2
18	74	74.801	32.885	Ranjan	Perennial	193.8	2187.3
19	75	74.806	32.884	Ranjan	Perennial	225.1	3281.0
20	76	74.791	32.867	Amb	Seasonal	177.8	2154.2
21	77	74.799	32.867	Sajwal	Seasonal	305.1	5653.9
22	78	74.812	32.864	Chak Bawal	Seasonal	155.5	1491.4
23	79	74.800	32.862	Chak Bawal	Seasonal	264.8	4308.4
24	80	74.804	32.860	Chak Bawal	Seasonal	197.4	2598.3
25	81	74.795	32.857	Chak Budhe	Seasonal	310.0	6104.6
26	82	74.768	32.850	Marjali	Seasonal	374.3	8709.5
27	83	74.804	32.853	Balowan	Seasonal	233.6	2936.3
28	84	74.811	32.857	Balowan	Seasonal	241.7	3035.7
29	85	74.787	32.852	Chak Budhe	Perennial	202.3	2850.1
30	86	74.819	32.863	Seri Panditan	Perennial	230.3	2856.8
31	87	74.820	32.852	Balowan	Perennial	253.7	4281.9
32	88	74.772	32.840	Pathakhoh	Seasonal	262.9	4832.0
33	89	74.782	32.842	Masiti	Seasonal	335.5	7509.8
34	90	74.804	32.844	Barn	Seasonal	347.7	5773.2
35	91	74.809	32.850	Balowan	Seasonal	201.0	2518.7
36	92	74.815	32.849	Balowan	Seasonal	159.1	1471.5
37	93	74.817	32.843	Kurwanda	Seasonal	340.9	6157.6
38	94	74.814	32.842	Kurwanda	Perennial	311.5	6177.5
39	95	74.824	32.842	Bhulwal	Perennial	224.8	2962.8
40	96	74.796	32.838	Ratherwan	Seasonal	245.3	3923.9
41	97	74.790	32.837	Ratherwan	Seasonal	295.0	5965.4
42	98	74.805	32.837	Kurwanda	Seasonal	227.4	2783.9
43	99	74.775	32.832	Ratherwan	Seasonal	269.6	4540.4
44	100	74.767	32.825	Ghranghel	Perennial	274.8	4049.9
45	101	74.778	32.823	Asirkhan	Perennial	386.5	8185.9
46	102	74.809	32.829	Korwan	Perennial	397.9	10890.2
47	103	74.814	32.831	Korwan	Perennial	316.5	6117.9
48	104	74.825	32.835	Bhulwal	Perennial	414.5	10253.9
49	105	74.819	32.827	Kot	Seasonal	351.4	6794.0
50	106	74.811	32.823	Kalakam	Seasonal	343.5	7277.8
51	107	74.825	32.821	Bhulwal	Seasonal	239.0	3214.7
52	108	74.815	32.820	Kot	Perennial	255.7	3831.1
53	109	74.825	32.818	Bhulwal	Perennial	231.5	3506.3
54	110	74.821	32.816	Bhulwal	Perennial	258.4	4242.1
55	111	74.808	32.817	Kalakam	Perennial	334.8	8179.3
56	112	74.760	32.822	Gura Sango	Seasonal	220.7	3121.9
57	113	74.765	32.819	Gura Sango	Seasonal	212.7	2764.0
58	114	74.799	32.813	Tarhani Khad	Seasonal	324.8	7582.7
59	115	74.828	32.815	Bajuan	Perennial	296.0	5355.6

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
60	116	74.786	32.808	Porkhu	Seasonal	252.6	4202.3
61	117	74.793	32.805	Porkhu	Seasonal	312.0	6363.1
62	118	74.809	32.812	Tawa	Seasonal	304.1	6263.7
63	119	74.813	32.800	Malpur	Seasonal	279.4	5176.7
64	120	74.832	32.811	Raipur	Seasonal	304.8	4447.6
65	121	74.825	32.808	Raipur	Seasonal	312.4	4865.1
66	122	74.807	32.787	Toteali	Seasonal	281.0	5421.9
67	123	74.814	32.796	Toteali	Seasonal	287.3	5282.7
68	124	74.817	32.794	Toteali	Seasonal	238.6	3638.9
69	125	74.824	32.791	Thathar	Seasonal	356.8	6349.9
70	126	74.840	32.796	Keran	Seasonal	388.9	9876.1
71	127	74.843	32.790	Keran	Seasonal	239.5	3923.9
72	128	74.843	32.787	Keran	Seasonal	223.7	3241.2
73	129	74.838	32.784	Chanor	Seasonal	226.7	3334.0
74	130	74.815	32.783	Bantalab	Seasonal	226.1	2956.2
75	131	74.823	32.781	Bantalab	Seasonal	606.4	22662.0
76	132	74.783	32.773	Bantalab	Seasonal	267.4	5103.8
77	133	74.805	32.772	Barnal	Perennial	248.7	3877.5
78	134	74.815	32.779	Bantalab	Seasonal	246.6	4122.8
79	135	74.830	32.776	Bantalab	Seasonal	318.8	6250.4
80	136	74.829	32.772	Bantalab	Seasonal	237.6	3459.9
81	137	74.812	32.768	Barnal	Seasonal	269.6	4672.9
82	138	74.809	32.764	Barnal	Seasonal	224.1	2638.0
83	139	74.818	32.762	Muthi	Seasonal	255.0	4334.9
84	140	74.832	32.763	Palwarh	Seasonal	371.5	5189.9
85	141	74.838	32.763	Palwarh	Perennial	245.2	4248.7
86	142	74.843	32.765	Palwarh	Seasonal	235.5	3055.6
87	143	74.839	32.752	Janipur	Seasonal	313.8	5408.7
88	144	74.847	32.754	Janipur	Seasonal	181.3	1869.2
89	145	74.889	32.694	Chhanni Himmat	Perennial	260.9	3327.4
90	146	74.863	32.686	Digiana	Perennial	569.6	20786.2
91	147	74.881	32.684	Sangani	Perennial	150.2	1292.5
92	148	74.921	32.678	Delni	Perennial	211.8	2545.3
93	149	74.892	32.663	Kaluchak	Seasonal	216.1	2492.2
94	337	74.771	32.862	Dharmkhu	Perennial	358.2	8596.8
95	347	74.807	32.873	Satroma	Seasonal	315.1	6363.1
96	348	74.794	32.870	Gaink	Seasonal	266.5	4924.8
97	349	74.777	32.870	Dharota	Seasonal	220.7	3459.9
98	350	74.771	32.870	Dharota	Seasonal	261.0	4851.9
99	351	74.781	32.862	Amb	Seasonal	215.0	3108.7
100	352	74.786	32.863	Amb	Seasonal	286.6	5150.2

Table - 2.6 Details of Ponds in Kandi-belt in Samba Tehsil (Distt. Jammu)

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
1	150	74.926	32.660	Rajpur Kalaur	Perennial	150.3	1272.6
2	151	74.930	32.667	Ratnu chak	Perennial	252.5	3851.0
3	152	74.927	32.655	Rajpur Kalaur	Seasonal	225.9	2498.9
4	153	74.933	32.658	Rajpur Kalaur	Perennial	245.8	3347.3
5	154	74.939	32.657	Narwal	Seasonal	186.6	2147.6
6	155	74.940	32.639	Mihin Sarkar	Seasonal	169.3	1637.2
7	156	74.951	32.641	Mihin Sarkar	Seasonal	283.1	5150.2
8	157	74.953	32.642	Mihin Sarkar	Seasonal	152.6	1053.9
9	158	74.954	32.647	Dansal	Perennial	388.5	10313.6
10	159	74.946	32.646	Darni	Perennial	314.2	6336.6
11	160	74.953	32.640	Mihin Sarkar	Perennial	197.6	2604.9
12	161	74.904	32.638	Kalan	Perennial	280.6	5150.2
13	162	74.944	32.634	Barjani	Perennial	339.8	7476.7
14	163	74.962	32.630	Ismailpur	Perennial	454.7	14157.9
15	164	74.931	32.631	Kargal	Perennial	228.2	2969.5
16	165	74.923	32.625	Chhanni	Perennial	200.0	2147.6
17	166	74.980	32.632	Badhori	Perennial	290.4	4281.9
18	167	74.942	32.622	Mahin Charkan	Seasonal	228.2	3075.5
19	168	74.950	32.622	Mahin Charkan	Seasonal	163.1	1458.2
20	169	74.988	32.620	Pati	Perennial	264.4	3771.5
21	170	74.984	32.618	Pati	Perennial	244.4	4016.7
22	171	74.969	32.614	Pati	Perennial	301.9	6144.4
23	172	74.939	32.613	Mahin	Perennial	298.9	4851.9
24	173	75.000	32.619	Raya	Perennial	247.0	4056.5
25	174	74.998	32.616	Raya	Perennial	204.2	2439.2
26	175	75.002	32.614	Raya	Perennial	385.8	8616.7
27	176	75.012	32.616	Rajendra Pura	Perennial	230.3	3208.1
28	177	75.017	32.615	Rajendra Pura	Seasonal	225.4	2982.7
29	178	75.006	32.616	Raya	Seasonal	321.3	4600.0
30	179	74.989	32.614	Raya	Perennial	295.6	5852.7
31	180	75.011	32.611	Rajendra Pura	Seasonal	229.6	2863.4
32	181	75.017	32.612	Rajendra Pura	Seasonal	286.7	5110.4
33	182	74.951	32.610	Bhatli	Seasonal	238.0	3831.1
34	183	74.959	32.603	Taror	Seasonal	196.8	2266.9
35	184	74.967	32.605	Taror	Seasonal	242.6	3983.6
36	185	74.974	32.601	Ranjri	Seasonal	221.0	2644.7
37	186	74.983	32.606	Ranjri	Seasonal	166.7	1219.6
38	187	74.991	32.606	Ranjri	Seasonal	395.2	8868.6
39	188	74.997	32.595	Pekhri	Seasonal	479.6	11652.5
40	189	75.004	32.602	Pekhri	Seasonal	203.6	2445.8
41	190	75.003	32.595	Pekhri	Seasonal	174.8	1802.9
42	191	75.017	32.601	Sunghwal	Seasonal	272.9	4639.8
43	192	75.008	32.599	Sunghwal	Perennial	805.0	32697.1
44	193	75.022	32.606	Nathwal	Perennial	249.6	3221.3
45	194	75.038	32.609	Garh Mandi	Perennial	236.0	3340.6
46	195	75.001	32.587	Salmehri	Perennial	378.3	6760.8

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
47	196	75.024	32.577	Thalori Brahmanan	Perennial	310.8	6489.1
48	197	74.968	32.591	Jakh	Perennial	219.6	2624.8
49	198	75.029	32.594	Budhwal	Perennial	184.0	2028.2
50	199	75.032	32.596	Budhwal	Perennial	223.9	2903.2
51	200	75.033	32.600	Budhwal	Perennial	250.8	3208.1
52	201	75.046	32.589	Gura Salathia	Seasonal	224.3	3102.0
53	202	75.050	32.571	Bara	Perennial	197.8	2074.6
54	203	75.064	32.580	Dughor	Perennial	210.2	1749.9
55	204	75.070	32.584	Dughor	Perennial	368.0	7980.4
56	205	75.062	32.572	Bara	Perennial	212.8	3002.6
57	206	75.060	32.577	Bara	Seasonal	233.6	3214.7
58	207	75.029	32.567	Vijaypur	Seasonal	208.5	2465.7
59	208	75.023	32.568	Vijaypur	Seasonal	208.7	1942.1
60	209	75.012	32.567	Vijaypur	Seasonal	246.4	3327.4
61	210	75.062	32.571	Bara	Seasonal	179.9	1975.2
62	211	75.063	32.571	Bara	Seasonal	338.1	7589.3
63	212	75.053	32.550	Sujwan	Perennial	166.3	1617.3
64	213	75.055	32.552	Sujwan	Seasonal	198.4	1352.2
65	214	75.065	32.553	Supwal	Seasonal	246.7	3360.5
66	215	75.146	32.564	Garh Mandi	Perennial	159.2	1060.5
67	216	75.135	32.559	Sungali Mandi	Perennial	206.3	2611.5
68	217	75.131	32.558	Samba	Perennial	244.0	2691.1
69	218	75.145	32.579	Malah	Perennial	230.1	2797.1
70	219	75.130	32.574	Prel	Perennial	159.2	722.5
71	220	75.145	32.564	Garh Mandi	Seasonal	115.2	430.8
72	221	75.154	32.550	Deoni	Perennial	217.4	2465.7
73	222	75.157	32.545	Deoni	Perennial	381.5	8683.0
74	223	75.169	32.549	Deoni	Perennial	249.0	3977.0
75	224	75.126	32.559	Samba	Seasonal	238.6	3088.8
76	236	75.126	32.540	Karandal	Seasonal	249.4	2969.5
77	237	75.143	32.543	Katali	Perennial	182.4	1942.1
78	238	75.141	32.539	Katali	Perennial	271.3	4494.0
79	239	75.148	32.536	Katali	Perennial	336.6	6853.6
80	240	75.156	32.538	Deoni (south)	Perennial	278.8	4540.4
81	241	75.161	32.535	Parjani	Perennial	233.8	3155.0
82	242	75.154	32.527	Sargal	Perennial	202.0	2538.6
83	249	75.103	32.542	Mandhera	Seasonal	325.7	6383.0
84	250	75.105	32.544	Mandhera	Seasonal	198.9	2015.0
85	259	75.137	32.528	Karariyan	Perennial	217.0	2638.0
86	353	74.957	32.634	Gura	Seasonal	215.9	2684.4
87	354	74.966	32.635	Gura	Seasonal	192.4	2266.9
88	355	75.044	32.604	Gura Salathia	Perennial	205	2054.7
89	356	75.122	32.558	Samba	Seasonal	270.1	3521.2
90	357	75.137	32.555	Sungali Mandi	Perennial	143.2	1136.2
91	358	74.942	32.661	Narwal	Seasonal	186.3	2147.1
92	359	74.975	32.616	Patti	Seasonal	244.5	4016.3
93	360	74.993	32.618	Raya	Seasonal	181.3	1403.7

Table - 2.7 Details of Ponds in Kandi-belt in Hiranagar Tehsil (Distt. Kathua)

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
1	225	75.191	32.539	Baluni	Perennial	183.5	2028.2
2	226	75.185	32.529	Jatwal	Perennial	199.7	2359.7
3	227	75.191	32.529	Jatwal	Perennial	228.2	3029.1
4	228	75.191	32.534	Jatwal	Perennial	195.2	1670.3
5	229	75.202	32.527	Sungali	Perennial	251.6	3314.1
6	230	75.209	32.523	Nunath	Perennial	238.1	3022.5
7	231	75.209	32.531	Sungali	Perennial	187.4	2107.8
8	232	75.217	32.525	Nunath	Perennial	158.6	1391.9
9	233	75.214	32.518	Harsath	Perennial	191.5	1683.6
10	234	75.219	32.517	Mandi Pathwal	Perennial	251.2	3155.0
11	235	75.224	32.522	Mandi Pathwal	Perennial	260.8	4189.1
12	243	75.157	32.523	Sargal	Perennial	230.2	3519.6
13	244	75.170	32.517	Kant Chhan	Perennial	209.0	2856.8
14	245	75.178	32.526	Jatwal	Perennial	262.7	4242.1
15	246	75.212	32.510	Ghagwal	Perennial	339.9	6966.3
16	247	75.204	32.507	Jasath	Perennial	300.7	5468.3
17	248	75.217	32.501	Jasath	Perennial	230.8	3029.1
18	251	75.168	32.529	Jangi Chak	Seasonal	232.1	2465.7
19	252	75.186	32.523	Jatwal	Seasonal	220.4	2724.2
20	253	75.160	32.528	Jangi Chak	Perennial	172.7	1551.0
21	254	75.161	32.508	Naran	Perennial	290.3	5581.0
22	255	75.186	32.514	Chhan Malangar	Perennial	214.0	2969.5
23	256	75.205	32.500	Randwal	Perennial	195.1	1524.5
24	257	75.231	32.516	Rei	Perennial	164.9	1199.7
25	258	75.207	32.516	Badhal	Seasonal	132.2	788.8
26	260	75.260	32.505	Rasana	Perennial	221.2	2744.1
27	261	75.255	32.512	Phati Talab	Perennial	285.2	5143.5
28	262	75.280	32.504	Gadiyal	Perennial	209.6	2969.5
29	263	75.256	32.506	Patta	Perennial	162.4	1743.2
30	264	75.268	32.503	Gura Metyan	Perennial	190.1	2439.2
31	265	75.277	32.512	Satura	Perennial	201.7	2386.2
32	266	75.298	32.501	Mela Wadda	Perennial	217.0	2744.1
33	267	75.302	32.506	Mela Wadda	Perennial	209.8	2936.3
34	268	75.280	32.495	Gurha Mandiyan	Seasonal	361.7	7867.7
35	269	75.274	32.495	Gurha Mandiyan	Seasonal	181.0	1915.6
36	270	75.278	32.500	Gadiyal	Seasonal	189.1	1975.2
37	271	75.286	32.480	Gura Beldaran	Seasonal	239.7	3532.9
38	272	75.313	32.495	Salan	Seasonal	293.8	5189.9
39	273	75.312	32.494	Salan	Seasonal	176.7	1895.7
40	274	75.298	32.469	Pathwal	Seasonal	269.8	3095.4
41	275	75.260	32.490	Chhapar	Seasonal	274.4	4368.0
42	276	75.270	32.482	Parain	Perennial	237.9	3128.5
43	277	75.307	32.481	Chak Dayala	Perennial	443.7	12361.7
44	278	75.337	32.481	Datiyal	Perennial	212.6	2704.3
45	279	75.336	32.477	Paren	Perennial	193.4	2253.6
46	280	75.330	32.476	Paren	Perennial	239.9	3559.4

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
47	281	75.337	32.472	Chandwan	Perennial	206.0	1425.1
48	282	75.338	32.485	Balahar	Seasonal	222.3	2730.8
49	283	75.344	32.462	Kishanpur	Seasonal	241.7	3479.8
50	284	75.336	32.466	Kishanpur	Seasonal	238.0	3281.0
51	285	75.342	32.485	Balahar	Seasonal	194.6	1491.4
52	286	75.324	32.466	Chhardal	Seasonal	211.8	2498.9
53	287	75.359	32.473	Ban	Perennial	216.5	2777.2
54	288	75.365	32.457	Chhanarorian	Perennial	257.6	4036.6
55	289	75.363	32.450	Bhagwal	Perennial	567.9	20700.0
56	290	75.360	32.431	Bajari Chak	Seasonal	269.4	4646.4
57	291	75.359	32.479	Ban	Seasonal	199.8	2399.4
58	292	75.386	32.475	Amala	Seasonal	277.6	4951.3
59	293	75.381	32.469	Amala	Seasonal	196.9	2134.3
60	294	75.385	32.466	Girnari	Seasonal	272.1	4885.0
61	295	75.372	32.459	Chhanarorian	Seasonal	231.9	2770.6
62	296	75.391	32.464	Dhaloti	Seasonal	204.6	2578.4
63	297	75.393	32.465	Dhaloti	Seasonal	232.9	2823.6
64	298	75.376	32.476	Dhamyal	Seasonal	171.6	1683.6
65	299	75.366	32.474	Tandhiyari	Seasonal	194.9	2253.6
66	300	75.367	32.476	Tandhiyari	Seasonal	160.0	1140.1
67	301	75.367	32.473	Tandhiyari	Perennial	197.2	2412.7
68	302	75.376	32.472	Dhamyal	Seasonal	152.1	795.4
69	303	75.375	32.469	Dhamyal	Seasonal	196.7	2087.9
70	304	75.379	32.440	Hamirpur Muthi	Seasonal	186.7	1663.7
71	305	75.380	32.441	Hamirpur Muthi	Seasonal	292.7	4865.1
72	306	75.382	32.441	Hamirpur Muthi	Seasonal	215.2	2863.4
73	307	75.383	32.440	Hamirpur Muthi	Seasonal	181.6	2028.2
74	308	75.353	32.438	Balhan Paniyan	Seasonal	324.1	7238.0
75	309	75.319	32.449	Chhap ki Kalan	Seasonal	231.5	3075.5
76	361	75.352	32.452	Khilu Chak	Seasonal	180.2	3012.5
77	362	75.383	32.459	Girnari	Perennial	143.2	2136.2

Table - 2.8 Details of Ponds in Kandi-belt in Kathua Tehsil (Distt. Kathua)

S No.	Pond Index No.	Long. (°E)	Lat. (°N)	Site	Perennial/ Seasonal	Perimeter (m)	Surface Area (m^2)
1	310	75.392	32.455	Jasrota	Seasonal	204.5	1895.7
2	311	75.405	32.456	Jasrota	Seasonal	294.6	4122.8
3	312	75.405	32.454	Jasrota	Seasonal	214.9	2704.3
4	313	75.406	32.455	Jasrota	Seasonal	194.3	1988.5
5	314	75.407	32.456	Jasrota	Seasonal	194.3	2127.7
6	315	75.399	32.462	Jasrota	Seasonal	121.9	536.9
7	316	75.402	32.463	Jasrota	Seasonal	157.6	1332.3
8	317	75.450	32.477	Kalna	Seasonal	220.0	2876.7
9	318	75.443	32.470	Kalna	Seasonal	252.2	4248.7
10	319	75.443	32.464	Merath	Seasonal	242.2	3917.3
11	320	75.458	32.458	Merath	Seasonal	228.8	2412.7
12	321	75.445	32.460	Negreta	Perennial	204.3	2439.2
13	322	75.452	32.463	Merath	Perennial	254.5	3837.8
14	323	75.448	32.451	Budhi	Perennial	224.2	2624.8
15	324	75.452	32.485	Paniyar	Seasonal	201.3	2671.2
16	325	75.478	32.450	Barwal	Seasonal	216.1	2545.3
17	326	75.479	32.447	Barwal	Seasonal	228.7	3194.8
18	327	75.464	32.451	Budhi	Seasonal	209.6	2439.2
19	328	75.470	32.444	Jandor	Seasonal	249.2	3851.0
20	329	75.483	32.438	Otri	Seasonal	277.7	4692.8
21	330	75.485	32.434	Otri	Seasonal	187.5	2280.1
22	331	75.490	32.435	Otri	Seasonal	176.4	1232.9
23	332	75.492	32.440	Loget	Seasonal	238.4	3791.4
24	333	75.496	32.444	Loget	Seasonal	219.0	2942.9
25	334	75.474	32.431	Palli	Seasonal	339.7	5037.5
26	335	75.465	32.432	Palli	Seasonal	252.0	4083.0
27	336	75.462	32.406	Lachhimpur	Seasonal	240.7	3566.0
28	338	75.482	32.440	Otri	Perennial	222.1	2982.7
29	339	75.498	32.436	Sner Kotla	Perennial	213.0	2578.4
30	340	75.451	32.395	Muthi	Seasonal	230.4	2883.3
31	341	75.458	32.395	Muthi	Seasonal	224.1	2598.3
32	342	75.539	32.408	Drar	Perennial	517.0	15364.3
33	343	75.527	32.393	Sona Rupa Chak	Perennial	236.9	3294.2
34	344	75.545	32.427	Kanyari	Seasonal	488.8	15092.5
35	345	75.520	32.419	Parante	Perennial	345.0	7231.4
36	346	75.506	32.385	Manke Talab	Perennial	335.2	6164.3
37	363	75.457	32.436	Thanun	Seasonal	182.3	3521.2
38	364	75.464	32.437	Krakhar	Seasonal	130.8	2730.5
39	365	75.476	32.425	Bagiyal	Seasonal	210.6	2516.7

Table - 3.1 Morphometric Characteristics of Various Surveyed Ponds

. No.	Pond Name	Village	Tehsil	Shape	Perimeter (m)	Area (sq. m)	H1	H2
1	Badola Sangani	Badola Barui	Akhnoor	Rectangular	220	2904.00	4.0	0.6
2	Targah	Targah	Akhnoor	Rectangular	349	7612.36	2.2	1.2
3	Tacharwan	Tachrwan	Akhnoor	Oval	222	3902.09	2.0	0.5
4	Maira Mazoor	Maira Jajoor	Akhnoor	Oval	305	6941.97	4.5	1.8
5	Mandrian	Mandrian Maira	Akhnoor	Oval	232	4299.43	3.2	1.2
6	Uperla Manda	Uperla Manda	Akhnoor	Circular	162	2088.00	2.2	0.8
7	Sohal	Sohal	Akhnoor	Rectangular	380	8961.00	3.5	1.8
8	Badgal Kalan	Badgal Kalan	Akhnoor	Rect. + Trapezoidal	308	6041.00	8.1	0.4
9	Dhok Khalsa	Dhok Khalsa	Akhnoor	Circular	234.8	4387.00	5.5	1.4
10	Thindewala	Dhok Khalsa	Akhnoor	Circular	198.2	3126.00	3.3	0.7
11	Lehar	Lehar	Akhnoor	Trapezoidal	175	1912.00	2.2	0.4
12	Gurha	Gurha Jagir	Akhnoor	Hemi Circular	339	7008.00	3.6	1.4
13	Jadh	Jadh Sardar	Akhnoor	Trapezoidal	324	6798.00	3.1	0.7
14	Bhalwal	Bhalwal	Akhnoor	Circular	462.1	15543.70	3.1	1.4
15	Gopala	Gopala	Akhnoor	Rectangular	334	6930.00	4.5	1.1
16	Sagani	Janipur	Jammu	Rectangular	218	2914.00	0.9	1.2
17	Bantalab	Bantalab	Jammu	Circular	725	41817.67	3.6	1.8
18	Thathar	Thathar	Jammu	Circular	139	1541.96	8.1	0.3
19	Keran	Keran	Jammu	Circular	141	1591.07	7.7	1.3
20	Kalakam	Kalakam	Jammu	Circular	330	8666.00	5.9	0.9
21	Badani Pond	Kot	Jammu	Circular	300	7162.00	1.9	0.7
22	Rangani	Kot	Jammu	Rect. + Semi Circle	281.8	3255.00		
23	Pati	Nardani -Bajua	Jammu	Semi Circular	185	2036.00	2.7	0.4
24	Muthi	Muthi	Jammu	Circular	211	3543.00	1.3	1.2
25	Pargani	Chinoar	Jammu	Circular	153.7	1880.00	1.5	0.6
26	Karorwan	Bhalwal	Jammu	Circular + Triangle	313.3	7807.90	2.5	0.8
27	Manor	Bhalwal	Jammu	Circular	261	5421.00	2.9	0.7
28	Karwanda	Karwanda	Jammu	Oval	320	8058.00	3.4	1.4
29	Deeli	Deeli	Jammu	Trapezoidal	272	4554.00	2.4	1.8
30	Channi Himmat	Channi Himmat	Jammu	Trapezoidal			3.6	
31	Garh Mandi	Garh Mandi	Samba	Rect. + Trapezoidal	205	2540.00	8.9	0.3
32	Pushwali Mandi	Mandi Kheri	Samba	Semi Circular	195	2269.14	2.7	1.7
33	Parjani	Parjani	Samba	Circular	207	3410.00	2.7	0.7
34	Tarore	Tarore	Samba	Rectangular	368	7735.00	1.9	0.3
35	Nathwal	Nathwal	Samba	Circular +Triangular	229	2531.80	3.4	1.2
36	Kurpudi	Bhadwal	Samba	Oval	214	3426.00	3.5	1.8
37	Randwal	Randwal	Hiranagar	Semi Circle	161	1549.37	2.0	2.0
38	Harsath	Harsath	Hiranagar	Circular	270	5801.00	0.0	1.9
39	Nonath	Nonath	Hiranagar	Rect. + Trapezoidal	193.5	2391.00	6.8	0.7
40	Balloni	Balloni	Hiranagar	Oval	226	3758.86	8.1	1.7
41	Naran	Naran	Hiranagar	Semi Circle	177	1870.39	2.6	1.8
42	Chhan Rorian	Chhan Rorian	Hiranagar	Rect. + Semi Circle	386	10392.00	2.1	2.8
43	Barnala	Chadwal	Kathua-Hiranagar	Trapezoidal	321	6413.00	2.4	0.4

. No.	Pond Name	Village	Tehsil	Shape	Perimeter (m)	Area (sq. m)	H1	H2
44	Dhaloti	Dhaloti	Kathua-Hiranagar	Circular	171	2346.00	3.1	0.3
45	Hamirpur	Hamirpur	Kathua-Hiranagar	Rect. + Semi Circle	226	3506.00	1.3	1.4

Table - 3.2 Miscellaneous Features of Surveyed Ponds

No.	Pond Name	Village	Tehsil	Volume (cub. m)	Age of Pond	Type of Pond	Utility	Perennial/ Seasonal
1	Badola Sangani	Badola Barui	Akhnoor	871.09	100 yrs	Kachcha with stone pitching	For cattle	Seasonal
2	Targah	Targah	Akhnoor	4376.31	> 200 yrs	-do-	-do-	Perennial
3	Tacharwan	Tachrwan	Akhnoor	877.92	400-500	-do-	-do-	-do-
4	Maira Mazoor	Maira Jajoor	Akhnoor	6244.72	200-300	-do-	Cattle & domestic	-do-
5	Mandrian	Mandrian Maira	Akhnoor	2578.75	>300 yrs	-do-	Not even cattle	-do-
6	Uperla Manda	Uperla Manda	Akhnoor	834.93	500 yrs	-do-	-do-	Seasonal
7	Sohal	Sohal	Akhnoor	8061.85	200 yrs	-do-	-do-	Perennial
8	Badgal Kalan	Badgal Kalan	Akhnoor	1208.17	>200 yrs	-do-	-do-	Seasonal
9	Dhok Khalsa	Dhok Khalsa	Akhnoor	3069.46	> 500 yrs	-do-	-do-	Perennial
10	Thindewala	Dhok Khalsa	Akhnoor	1093.92	400 yrs	-do-	-do-	-do-
11	Lehar	Lehar	Akhnoor	334.58	400 yrs	-do-	Cattle & domestic	-do-
12	Gurha	Gurha Jagir	Akhnoor	4904.16	500 yrs	-do-	Cattle & domestic	-do-
13	Jadh	Jadh Sardar	Akhnoor	2209.21	200 yrs	-do-	Presently not used	-do-
14	Bhalwal	Bhalwal	Akhnoor	10490.71	400 yrs	-do-	Cattle & domestic	-do-
15	Gopala	Gopala	Akhnoor	3637.64	> 300 yrs	-do-	-do-	-do-
16	Sagani	Janipur	Jammu	1747.49	70-100	Kachcha	For cattle	-do-
17	Bantalab	Bantalab	Jammu	37632.85	>100 yrs	-do-	Cattle & domestic	-do-
18	Thathar	Thathar	Jammu	192.74	>200 yrs	Kachcha with stone pitching	For cattle	-do-
19	Keran	Keran	Jammu	993.40	>400 yrs	-do-	Cattle & domestic	-do-
20	Kalakam	Kalakam	Jammu	3899.32	400yrs	-do-	Cattle & domestic	-do-
21	Badani Pond	Kot	Jammu	2506.52	200 yrs	Kachcha	For cattle	-do-
22	Rangani	Kot	Jammu	0.00	>100 yrs	Kachcha with stone pitching	Cattle & domestic	-do-
23	Pati	Nardani-Bajua	Jammu	407.17	300 yrs	-do-	For cattle	-do-

No.	Pond Name	Village	Tehsil	Volume (cub. m)	Age of Pond	Type of Pond	Utility	Perennial/ Seasonal
24	Muthi	Muthi	Jammu	2124.89	150 yrs	-do-	-do-	-do-
25	Pargani	Chinoar	Jammu	563.89	100 yrs	-do-	-do-	-do-
26	Karorwan	Bhalwal	Jammu	3122.89	>500 yrs	-do-	Cattle & domestic	-do-
27	Manor	Bhalwal	Jammu	1897.17	>300 yrs	-do-	For cattle	-do-
28	Karwanda	Karwanda	Jammu	5639.16	>400 yrs	-do-	-do-	-do-
29	Deeli	Deeli	Jammu	4095.55	> 200 Yrs	Pakka except bed	-do-	-do-
30	Channi Himmat	Channi Himmat	Jammu	0.00	> 300 yrs	-do-	Presently not used	Dry for last 6 Yrs
31	Garh Mandi	Garh Mandi	Samba	380.99	200 yrs	Kachcha with stone pitching	For cattle	Seasonal
32	Pushwali Mandi	Mandi Kheri	Samba	1926.20	200 yrs	-do-	-do-	Perennial
33	Parjani	Parjani	Samba	1193.32	>100 yrs	-do-	-do-	-do-
34	Tarore	Tarore	Samba	1160.24	> 100 Yrs	Kachcha	-do-	Seasonal
35	Nathwal	Nathwal	Samba	1518.17	> 400 Yrs	Kachcha with stone pitching	Cattle & domestic	Perennial
36	Kurpudi	Bhadwal	Samba	3080.35	> 400 Yrs	-do-	Cattle & domestic	-do-
37	Randwal	Randwal	Hiranagar	1545.18	>200 yrs	-do-	For cattle	-do-
38	Harsath	Harsath	Hiranagar	5507.36	400 yrs	Kachcha	Cattle & domestic	-do-
39	Nonath	Nonath	Hiranagar	776.93	>200yrs	Kachcha with stone pitching	For cattle	Seasonal
40	Balloni	Balloni	Hiranagar	3192.46	500 yrs	-do-	Domestic except drinking	Perennial
41	Naran	Naran	Hiranagar	1680.30	250 yrs	Partly Kachcha partly cemented	-do-	Perennial
42	Chhan Rorian	Chhan Rorian	Hiranagar	14537.30	> 400 yrs	Kachcha	-do-	-do-
43	Barnala	Chadwal	Kathua-Hiranagar	1282.57	> 200 yrs	-do-	-do-	Seasonal
44	Dhaloti	Dhaloti	Kathua-Hiranagar	351.89	>500 Yrs	-do-	Cattle & domestic	Seasonal
45	Hamirpur	Hamirpur	Kathua-Hiranagar	2452.76	>300 yrs	-do-	For cattle	Perennial

Table - 4.1 Water quality parameters of different ponds (samples collected during pre-monsoon in June, 2005)

Pond Name	Village	Tehsil	Pond Index No.	Temp. (°C)	EC (µS/cm)	pH	TDS	Ca	Mg	SO_4	Chloride	Ca Hardness	Mg Hardness	Total Hardness	Na	K	F	Alkalinity	NO_3	SAR
Badola Sangani	Badola Barui	Akhnoor	-	33.3	969	7.90	998	17.6	3.9	28.0	50	44	16	60	16.7	74.8	0.0	121	19.00	11.79
Targah	Targah	Akhnoor	47	32.3	530	8.72	616	20.9	3.4	2.5	24	16	14	66	11.0	44.3	0.0	7	9.00	3.31
Tacharwan	Tachrwan	Akhnoor	49	36.4	825	8.53	5056	17.6	4.4	11.0	62	44	18	62	17.3	76.8	0.0	202	5.00	8.16
Maira Mazoor	Maira Jajoor	Akhnoor	52	35.2	900	8.73	630	17.6	8.3	1.5	26	44	34	78	14.8	25.1	1.4	5	3.45	6.75
Mandrian	Mandrian Maira	Akhnoor	53	35.0	947	8.57	810	16.0	1.9	8.5	20	40	8	48	3.1	38.4	0.0	210	1.05	1.22
Uperla Manda	Uperla Manda	Akhnoor	37	27.4	1630	7.24	2382	32.9	14.1	10.0	88	82	58	140	46.7	126.6	0.0	229	3.50	10.96
Sohal	Sohal	Akhnoor	27	29.9	462	7.85	230	13.6	2.4	0.5	24	34	10	44	7.0	36.0	1.1	268	4.15	3.24
Badgal Kalan	Badgal Kalan	Akhnoor	29	29.0	410	7.67	586	4.8	4.4	30.5	24	12	18	30	4.7	39.6	0.9	351	7.10	2.11
Dhok Khalsa	Dhok Khalsa	Akhnoor	13	33.5	999	8.70	606	24.9	1.0	2.0	70	62	4	66	28.0	92.0	0.0	124	16.50	8.38
Thindewah	Dhok Khalsa	Akhnoor	-	35.0	604	9.75	594	14.4	3.4	4.0	28	36	14	50	9.3	60.8	0.0	176	14.25	3.00
Lehar	Lehar	Akhnoor	31	34.3	512	6.88	860	23.3	3.4	1.5	18	58	14	72	1.6	48.9	0.8	124	7.70	0.45
Gurha	Gurha Jagir	Akhnoor	23	32.8	1044	7.17	620	20.0	6.3	2.0	60	50	26	76	40.1	125.0	0.0	281	4.60	11.59
Jadh	Jadh Sardar	Akhnoor	20	38.1	234	7.28	770	9.6	1.5	23.5	16	24	6	40	1.2	9.3	1.1	232	4.30	0.41
Bhalwal	Bhalwal	Akhnoor	19	35.6	363	7.49	240	5.6	3.9	1.0	52	14	16	30	2.9	32.8	0.0	25	3.20	1.78
Gopala	Gopala	Akhnoor	30	34.7	583	7.36	798	32.1	5.4	1.5	32	80	22	102	17.0	53.7	0.0	145	12.00	6.12
Janipur	Janipur	Jammu	147	42.8	1405	8.32	840	23.3	15.1	80.0	60	58	62	120	17.0	147.2	0.0	90	0.80	3.23
Bantalab	Bantalab	Jammu	131	33.7	724	7.82	630	22.5	3.4	4.0	58	56	14	70	29.2	15.1	0.0	3	4.95	10.06
Thathar	Thathar	Jammu	125	41.2	1875	10.80	1820	19.2	20.9	3.0	108	48	86	134	19.6	56.0	0.0	186	2.25	6.45
Keran	Keran	Jammu	128	37.9	272	9.89	492	10.4	1.5	1.0	28	26	6	32	2.8	12.8	0.0	6	2.50	1.74
Kalakam	Kalakam	Jammu	111	33.6	779	8.32	1206	27.3	7.1	10.5	32	68	29	97	27.0	31.2	0.0	116	3.70	6.03
Badani	Kot	Jammu	-	31.9	950	8.20	780	40.1	24.8	7.5	18	100	102	202	18.5	9.5	1.1	20	0.50	3.39
Rangani	Kot	Jammu	-	35.7	935	9.62	1064	20.0	7.8	28.0	44	50	32	82	42.1	36.8	1.3	60	9.10	12.69
Pati	Nardani-Bajua	Jammu	-	38.8	592	10.55	1396	31.3	2.4	7.5	42	78	10	88	6.0	18.6	0.0	94	2.75	1.87
Muthi	Muthi	Jammu	139	32.1	935	7.87	610	28.9	22.8	6.0	38	72	94	166	22.6	11.5	0.0	341	6.25	4.45
Pargani	Chinoar	Jammu	-	36.2	1390	7.70	1020	36.0	19.0	155.0	64	90	78	168	15.2	83.7	0.0	276	4.40	4.03
Karorwan	Bhalwal	Jammu	102	41.3	1531	11.02	1010	16.8	3.9	21.0	104	42	16	58	47.6	84.2	0.0	195	8.75	16.56
Manor	Bhalwal	Jammu	-	37.9	1749	8.99	2104	11.2	5.8	7.0	116	28	24	52	87.6	146.8	0.0	41	13.00	42.05
Karwanda	Karwanda	Jammu	94	36.5	1210	10.79	1040	10.4	2.9	1.0	54	26	12	38	70.7	41.7	1.2	26	12.00	27.91
Deeli	Deeli	Jammu	148	29.5	980	8.15	624	35.3	6.8	60.0	62	88	28	116	42.6	13.1	0.0	4	33.00	10.26
Channi Himmat	Channi Himmat	Jammu	145	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	-
Garh Mandi	Garh Mandi	Samba	215	37.7	276	9.84	430	16.0	1.9	24.5	16	40	8	48	3.6	10.3	0.0	29	8.70	1.80
Pushwali Mandi	Mandi Kheri	Samba	-	34.1	931	9.33	450	20.0	0.0	1.5	40	50	0	50	21.2	20.9	1.2	141	3.60	7.20

Pond Name	Village	Tehsil	Pond Index No.	Temp. (°C)	EC (µS/cm)	pH	TDS	Ca	Mg	SO_4	Chloride	Ca Hardness	Mg Hardness	Total Hardness	Na	K	F	Alkalinity	NO_3	SAR
Parjani	Parjani	Samba	241	35.5	567	9.42	588	4.8	1.0	3.0	44	12	4	16	6.2	41.1	0.0	276	10.00	3.86
Tarore	Tarore	Samba	184	27.9	602	7.55	1380	33.7	10.7	5.5	16	84	44	128	22.5	14.1	0.0	16	6.00	5.57
Nathwal	Nathwal	Samba	-	27.0	593	7.65	602	19.3	10.2	5.0	26	48	42	90	13.2	45.6	0.0	10	2.50	5.57
Kurpudi	Bhadwal	Samba	-	27.0	723	8.25	900	24.9	4.9	1.5	52	62	20	82	41.1	33.1	0.0	25	14.00	17.79
Randwal	Randwal	Hiranagar	256	33.2	325	8.40	360	26.5	4.4	6.5	28	66	18	84	4.5	3.4	0.0	3	1.90	1.11
Harsath	Harsath	Hiranagar	233	32.4	340	8.02	360	22.5	0.0	2.0	12	56	0	56	3.6	2.8	0.0	4	0.90	0.77
Nonath	Nonath	Hiranagar	230	34.9	373	9.10	580	6.4	1.0	20.0	26	16	4	20	6.1	30.9	0.0	207	8.50	1.44
Balloni	Balloni	Hiranagar	225	34.6	585	9.52	370	14.4	4.9	1.5	51	36	20	56	14.8	50.4	0.0	32	6.60	5.05
Naran	Naran	Hiranagar	254	34.6	457	8.65	240	27.3	0.5	3.0	44	68	2	70	11.6	5.6	1.3	5	2.75	3.01
Chhan Rorian	Chhan Rorian	Hiranagar	288	33.4	315	8.18	294	20.0	1.9	5.5	12	50	8	58	4.2	1.5	0.8	5	0.50	1.12
Barnala	Chadwal	Kathua-Hiranagar	-	31.7	294	7.23	190	22.5	2.9	6.0	8	56	12	68	3.9	1.5	1.2	10	0.70	1.07
Dhaloti	Dhaloti	Kathua-Hiranagar	297	36.9	1404	7.36	1190	62.6	19.9	315.0	26	156	82	238	7.8	64.3	0.0	127	3.50	1.69
Hamirpur	Hamirpur	Kathua-Hiranagar	-	35.5	310	7.95	456	18.4	3.4	1.0	18	46	14	60	4.6	3.4	1.3	6	1.55	1.76

Table - 4.2 Water quality parameters of different ponds (samples collected during post-monsoon in October, 2005)

Pond Name	Village	Tehsil	Pond Index No.	Temp. (°C)	EC (µS/cm)	pH	TDS	Ca	Mg	SO_4	Chloride	Ca Hardness	Mg Hardness	Total Hardness	Na	K	F	Alkalinity	NO_3	SAR
Badola Sangani	Badola Barui	Akhnoor	-	20.5	303	9.61	260	4.01	0.00	1.5	20	10	0	10	5.40	28.10	0.00	121	15.00	3.81
Targah	Targah	Akhnoor	47	21.2	320	9.10	40	21.65	0.49	1.5	4	54	2	56	4.50	23.00	0.18	7	4.95	1.35
Tacharwan	Tachrwan	Akhnoor	49	20.5	308	8.19	46	8.02	0.97	1.8	10	20	4	24	13.70	22.80	0.34	202	3.65	6.46
Maira Mazoor	Maira Jajoor	Akhnoor	52	22.4	351	8.84	46	9.62	0.00	1.5	16	24	0	24	8.30	24.70	0.50	5	4.15	3.78
Mandrian	Mandrian Maira	Akhnoor	53	22.3	366	8.80	20	12.83	0.00	1.5	10	32	0	32	2.20	34.40	0.89	210	4.00	0.87
Uperla Manda	Uperla Manda	Akhnoor	37	18.5	531	7.54	290	30.48	5.83	2.3	10	76	24	100	12.10	78.60	1.05	229	24.50	2.84
Sohal	Sohal	Akhnoor	27	22.2	343	9.45	32	8.82	0.49	1.5	8	22	2	24	4.30	30.80	0.10	268	5.50	1.99
Badgal Kalan	Badgal Kalan	Akhnoor	29	23.2	457	8.22	370	8.02	1.94	1.5	34	20	8	28	4.20	59.90	0.10	351	20.75	1.88
Dhok Khalsa	Dhok Khalsa	Akhnoor	13	24.9	670	9.54	320	20.85	1.46	2.0	24	52	6	58	4.80	84.70	0.62	124	16.50	1.44
Thindewala	Dhok Khalsa	Akhnoor	-	22.4	657	8.94	40	16.84	2.43	1.5	14	42	10	52	4.50	73.00	1.25	176	13.75	1.45
Lehar	Lehar	Akhnoor	31	26.1	330	10.07	950	17.64	7.78	3.5	32	44	32	76	7.30	205.5 0	0.69	124	18.50	2.05
Gurha	Gurha Jagir	Akhnoor	23	22.6	815	8.69	300	20.05	3.89	1.5	30	50	16	66	22.60	80.00	0.47	281	10.20	6.53
Jadh	Jadh Sardar	Akhnoor	20	25.6	386	8.91	90	16.04	1.46	1.5	8	40	6	46	2.10	7.10	0.00	232	1.25	0.71
Bhalwal	Bhalwal	Akhnoor	19	22.0	253	9.84	30	4.81	0.49	1.5	6	12	2	14	14.20	17.10	1.40	25	10.30	8.72
Gopala	Gopala	Akhnoor	30	22.9	473	8.14	20	14.44	0.97	1.8	20	36	4	40	8.40	45.30	0.33	145	6.80	3.03
Sagani	Janipur	Jammu	147	20.5	1201	8.02	610	40.90	14.58	60.0	12	102	60	162	15.70	125.5 0	0.00	90	18.50	2.98
Bantalab	Bantalab	Jammu	131	22.3	395	8.32	80	16.84	0.00	1.3	4	42	0	42	11.30	14.00	1.13	3	3.35	3.89
Thathar	Thathar	Jammu	125	22.3	497	8.45	160	16.04	2.43	1.5	4	40	10	50	2.90	50.30	0.00	186	16.00	0.95
Keran	Keran	Jammu	128	22.6	125	9.58	80	3.21	1.94	1.5	8	8	8	16	1.20	7.10	0.00	6	1.25	0.75
Kalakam	Kalakam	Jammu	111	24.2	741	8.61	250	35.29	4.86	2.0	14	88	20	108	7.90	42.90	0.00	116	22.00	1.76
Badani	Kot	Jammu	-	20.4	345	8.48	50	38.50	20.90	1.5	20	96	86	182	17.30	10.10	0.85	20	2.60	3.17
Rangani	Kot	Jammu	-	24.4	514	9.38	60	17.64	4.37	3.5	36	44	18	62	21.50	33.40	0.10	60	5.05	6.48
Pati	Nardani - Bajua	Jammu	-	28.8	291	9.53	18	20.05	0.49	1.5	28	50	2	52	2.30	14.80	0.84	94	3.65	0.72
Muthi	Muthi	Jammu	139	22.2	755	7.89	200	40.90	10.69	1.8	24	102	44	146	17.30	18.10	0.57	341	5.20	3.41
Pargani	Chinoar	Jammu	-	24.5	641	9.83	120	26.47	1.94	12.0	14	66	8	74	7.50	58.40	0.10	276	8.10	1.99
Karorwan	Bhalwal	Jammu	102	23.0	507	8.89	120	16.04	0.49	3.5	18	40	2	42	9.90	40.80	0.39	195	14.00	3.44
Manor	Bhalwal	Jammu	-	25.4	544	9.16	230	7.22	1.46	4.8	20	18	6	24	12.60	59.40	0.30	41	10.00	6.05
Karwanda	Karwanda	Jammu	94	22.7	586	8.96	60	12.83	0.00	1.5	36	32	0	32	27.60	23.60	0.41	26	7.90	10.90
Deeli	Deeli	Jammu	148	20.4	738	7.92	22	32.08	2.43	1.5	38	80	10	90	39.80	9.60	0.15	4	1.00	9.58
Channi Himmat	Channi Himmat	Jammu	145	29.5	146	8.93	78	0.00	0.00	3.3	8	20	0	20	0.00	0.00	0.00	0	0.00	-
Garh Mandi	Garh Mandi	Samba	215	25.2	497	8.92	70	8.02	0.00	1.5	20	42	2	44	1.00	5.60	0.10	29	2.45	0.50

Pond Name	Village	Tehsil	Pond Index No.	Temp. (°C)	EC (µS/cm)	pH	TDS	Ca	Mg	SO_4	Chloride	Ca Hardness	Mg Hardness	Total Hardness	Na	K	F	Alkalinity	NO_3	SAR
Pushwali Mandi	Mandi Kheri	Samba	-	27.2	318	10.53	62	16.84	0.49	2.3	12	8	8	16	16.90	21.10	0.10	141	3.60	5.74
Parjani	Parjani	Samba	241	28.0	644	9.38	140	3.21	1.94	22.0	36	68	22	90	1.90	27.50	0.50	276	11.30	1.18
Tarore	Tarore	Samba	184	17.5	428	8.50	140	27.27	5.35	1.8	10	28	0	28	25.90	36.30	0.39	16	23.00	6.41
Nathwal	Nathwal	Samba	-	20.7	243	9.20	10	11.23	0.00	1.5	18	6	34	40	8.20	32.60	0.88	10	4.80	3.46
Kurpudi	Bhadwal	Samba	-	26.1	402	8.91	40	2.41	8.26	5.8	8	82	0	82	2.90	50.30	0.00	25	16.00	1.26
Randwal	Randwal	Hiranagar	256	27.2	445	8.83	72	32.88	0.00	3.0	10	102	10	112	9.70	4.80	0.50	3	1.95	2.39
Harsath	Harsath	Hiranagar	233	28.0	243	10.15	38	40.90	2.43	2.0	8	90	0	90	8.50	9.40	0.24	4	2.60	1.83
Nonath	Nonath	Hiranagar	230	21.6	528	8.56	100	36.09	0.00	1.5	24	38	8	46	1.80	19.60	0.00	207	12.00	0.42
Balloni	Balloni	Hiranagar	225	25.6	467	8.46	62	15.24	1.94	5.0	8	74	0	74	11.00	43.40	0.23	32	9.10	3.75
Naran	Naran	Hiranagar	254	25.5	412	8.64	30	29.67	0.00	1.5	10	68	4	72	12.50	7.00	0.27	5	2.20	3.25
Chhan Rorian	Chhan Rorian	Hiranagar	288	22.0	355	9.02	24	27.27	0.97	1.3	14	66	8	74	8.40	5.90	0.00	5	1.65	2.24
Barnala	Chadwal	Kathua-Hiranagar	-	20.5	345	7.81	90	26.47	1.94	1.5	14	106	0	106	8.40	3.60	0.50	10	1.15	2.23
Dhaloti	Dhaloti	Kathua-Hiranagar	297	30.6	231	9.30	28	42.51	0.00	8.5	10	34	0	34	4.70	21.80	0.10	127	6.60	1.02
Hamirpur	Hamirpur	Kathua-Hiranagar	-	20.5	303	9.61	260	13.63	0.00	1.5	20	10	0	10	6.50	5.50	0.30	6	1.30	2.49

Table - 4.3 Summary of Water Quality Observations

Parameter	Pre-monsoon (June 2005)			Post-monsoon (October 2005)		
	Minimum	Maximum	Average	Minimum	Maximum	Average
Temp	27	42.8	34.27	17.5	30.6	23.55
EC	272	1875	782.6	125	1201	465.55
pH	7.17	11.02	8.5	7.54	10.53	8.92
TDS	190	5056	882.3	10	950	132.59
Calcium	4.8	40.1	21.43	2.41	42.51	19.81
Magnesium	0	24.8	6.35	0	20.29	2.68
Chloride	8	116	4060	4	38	16.64
Sulphate	0.5	315	20.93	1.25	60	4.35
Calcium Hardness	12	156	53.82	6	102	49.41
Magnesium Hardness	0	102	26.12	0	86	11.05
Total Hardness	16	202	79.8	10	182	60.27
Sodium	1.2	87.6	19	1.2	39.8	10.04
Potassium	1.5	147.2	43.67	3.6	205.5	36.76
Fluoride	0	1.35	0.33	0	1.4	0.38
Alkalinity	3	351	116.8	2	148	14.32
Nitrate	0.5	16.5	6.6	1	24.5	8.59
SAR	0.45	42.05	6.56	0.43	10.89	3.21

Table - 5.1 Grain-size analysis for ponds in various villages in Kandi-Belt

eve	Percentage finer from different sieve sizes for various villages							
ize	**Badola Sangani**	**Badola Lake**	**Tacharwan**	**Maira Mazoor**	**Mandrian**	**Bantalab**	**Thathar**	**Harshat**
75	100.00	97.20	98.00	93.56	73.15	100.00	86.45	95.94
	100.00	96.51	97.31	90.72	70.35	99.97	83.99	93.89
18	99.77	95.54	96.40	87.37	67.67	99.73	82.18	92.16
0	98.86	93.92	94.92	83.29	63.46	98.88	80.44	90.71
5	90.16	86.53	87.10	72.70	50.39	85.32	67.54	84.67
0	68.48	65.45	68.65	59.15	33.35	58.98	46.25	68.12
2	51.11	46.18	52.45	47.10	22.65	43.29	34.15	52.89
	1.77	1.55	2.86	1.69	1.44	1.84	1.56	2.51
	Nonath	**Garh Mandi**	**Mali**	**Kalakam**	**Badani**	**Rangani**	**Nardani**	**Muthi**
75	96.02	99.12	97.44	82.20	99.92	96.85	99.69	96.60
	94.49	98.96	95.67	79.24	98.74	94.29	99.24	95.40
18	92.96	98.53	93.54	77.83	97.73	92.21	98.51	93.47
0	90.31	97.75	91.14	76.53	95.97	89.57	96.57	91.33
5	74.60	92.51	79.78	66.22	82.66	74.57	73.95	85.71
0	47.73	74.64	60.64	46.48	59.01	53.41	45.68	72.42
2	31.17	57.59	45.77	32.48	44.23	40.45	32.09	58.82
	0.78	2.82	1.97	1.13	2.18	1.68	1.42	2.23
	Parjani	**Karorwan**	**Manor**	**Karwanda**	**Upparla Manda**	**Sohal**	**Badgal Kalan**	**Dhok Khalsa**
75	85.06	96.04	97.66	99.70	99.28	94.60	99.34	97.42
	81.03	93.66	95.73	99.19	98.28	93.24	98.90	95.60
18	77.62	89.95	93.02	98.33	97.66	92.05	98.38	93.83
0	74.24	85.63	90.09	96.71	96.68	90.81	97.38	91.55
5	63.76	65.79	73.83	81.79	91.57	83.32	90.92	81.75
0	48.14	40.84	49.52	54.18	76.00	61.43	66.94	56.60
2	36.61	28.04	36.35	35.80	59.23	43.02	45.43	37.25
	1.19	1.23	2.00	1.41	1.97	1.51	0.90	1.49
	Thindowala	**Lehar**	**Gura Jagir**	**Jadh**	**Bhalwal Brahamana**	**Barnala**	**Dhaloti**	**Hamirpur**
75	91.39	99.51	96.74	97.79	96.17	96.51	91.79	90.87
	89.95	98.44	95.52	97.43	95.72	95.66	87.23	90.25
18	88.13	97.50	94.19	96.88	95.35	94.35	82.81	89.48
0	86.19	96.05	91.88	96.00	94.77	92.57	79.20	87.40
5	78.20	83.05	62.92	87.91	90.12	77.74	67.97	76.10
0	60.44	54.91	29.67	61.41	71.75	51.65	47.70	56.33
2	44.25	36.97	0.92	40.34	53.54	35.66	32.24	40.57
	2.93	1.52	0.00	0.90	1.54	1.13	0.97	1.19

	Delni	Channi Himmat	Tarore	Nathwal	Bhadwal			
75	94.84	99.81	98.75	95.53	89.69			
	94.14	99.62	97.85	94.38	87.16			
18	93.72	99.18	97.45	93.33	84.60			
0	92.75	98.24	96.95	91.43	80.99			
5	85.15	90.39	91.18	77.23	61.93			
0	64.53	68.81	70.59	48.53	37.27			
2	47.31	49.13	50.51	29.83	23.75			

Table - 5.2 Result of Grain size analysis of Kandi-belt Study

S. No.	Name of Pond	% of Gravel	% of Sand	% of Silt	% of Clay	Textural Class
1.	Badola Sangani	0.0	49.86	45.48	4.66	Sandy Loam
2.	Badola Lake	0.9	30.65	61.49	6.96	Silt Loam
3	Tacharwan	0.78	33.24	60.96	5.02	Silt Loam
4.	Maira Mazoor	4.9	51.68	39.36	4.06	Sandy Loam
5.	Mandrian	5.87	21.27	64.42	8.44	Silt Loam
6.	Bantalab	0.01	39.47	54.50	6.02	Silt Loam
7.	Thathar	3.37	21.7	67.85	7.08	Silt Loam
8.	Harshat	1.09	26.02	67.04	5.85	Silt Loam
9.	Nonath	2.86	53.91	40.66	2.57	Sandy Loam
10.	Garh Mandi	0.17	29.93	64.20	5.70	Silt Loam
11.	Mali	0.98	29.19	64.43	5.40	Silt Loam
12.	Kalakam	7.27	33.83	54.26	4.64	Silt Loam
13.	Badani	0.31	27.68	65.95	6.06	Silt Loam
14.	Rangani	3.12	56.3	38.8	1.78	Sandy Loam
15.	Nardani	0.44	65.57	29.87	4.12	Sandy Loam
16.	Muthi	0.40	13.46	76.25	9.89	Silt Loam
17.	Parjani	10.58	49.12	36.80	3.50	Sandy Loam
18.	Karuruan	0.99	20.49	72.97	5.55	Silt Loam
19.	Manor	0.93	32.7	61.77	4.6	Silt Loam
20.	Karwanda	0.48	61.83	35.53	2.16	Sandy Loam
21.	Upparla Manda	0.76	46.75	48.73	3.76	Sandy Loam
22.	Sohal	3.44	52.61	41.57	2.38	Sandy Loam
23.	Badgal Kalan	0.77	72.52	25.00	1.71	Loamy Sand
24.	Dhok Khalsa	2.01	47.77	47.66	2.56	Sandy Loam
25.	Thindowala	3.58	34.04	57.48	4.90	Silt Loam
26.	Lehar	0.48	34.53	60.69	4.30	Silt Loam
27.	Gura Jagir	3.02	67.48	27.77	1.73	Sandy Loam
28.	Jadh	1.0	41.05	52.71	5.24	Silt Loam

29.	Bhalwal Brahamana	2.57	59.9	34.7	2.83	Sandy Loam
30.	Barnala	2.81	63.84	30.46	2.89	Sandy Loam
31.	Dhaloti	5.52	40.12	49.15	5.21	Silt Loam
32.	Hamirpur	4.93	47.03	44.15	3.89	Loam
33.	Delni	3.26	54.86	37.82	4.06	Sandy Loam
34.	Channi Himmat	0.18	51.38	44.84	3.60	Sandy Loam
35.	Tarore	0.75	37.53	57.12	4.6	Silt Loam
36.	Nathwal	4.25	73.3	20.97	1.48	Sandy Loam
37.	Bhadwal	9.07	66.77	22.82	1.34	Sandy Loam

Table - 5.3 Results of infiltration tests in three ponds in Kandi-belt

S. No.	Time	Change in time (min)	Scale reading (cm)	Change in head (cm)	Infiltration Capacity (cm/min)
			Tarore Pond		
1.	9.30	-	0.0	-	**0.02 cm/min**
2.	9.40	10	0.3	0.3	
3.	9.50	10	0.6	0.3	
4.	10.00	10	0.8	0.2	
5.	10.20	20	1.2	0.4	
6.	10.40	20	1.6	0.4	
7.	11.00	20	2.0	0.4	
			Channi Himmat Pond		
1.	2.10	10	0.0	0.0	**0.09 cm/min**
2.	2.20	10	1.3	1.3	
3.	2.30	10	2.1	0.8	
4.	2.40	10	3.2	1.1	
5.	2.50	10	4.2	1.0	
6.	3.00	10	5.1	0.9	
7.	3.10	10	6.0	0.9	
8.	3.20	10	6.9	0.9	
			Nardani Bajwan Pond		
1.	4.34	0.0	-	0.0	**0.08 cm/min**
2.	4.44	10	1.1	1.1	
3.	4.54	10	2.1	1.0	
4.	5.04	10	3.0	0.9	
5.	5.14	10	3.8	0.8	
6.	5.24	10	4.6	0.8	
7.	5.34	10	5.3	0.7	
8.	5.44	10	6.1	0.8	

Table - 6.1 Catchment areas of some selected ponds

Name of the Pond	Catchment area (sq. m)
Bhalwal Brahmana	109387
Sohal	2631263
Lehr	5753396
Bharda Khurd	533020
Ghurota	3965545
Asirkhan	6245758

Table - 6.2 Monthly evaporation depths at Jammu

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporation (mm)	0.9	1.3	2.5	3.4	5.9	7.5	5.0	3.7	2.9	2.3	1.4	0.7

Table - 6.3 Daily rainfall (mm) at Akhnoor in the year 1970

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.0	0.0	0.0	0.0	0.0	0.0	30.2	0.0	54.2	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	0.0	0.0	5.3	0.0	10.2	0.0	0.0	0.0
3	0.0	0.0	0.0	0.0	0.0	0.0	147.0	58.1	0.0	0.0	0.0	0.0
4	0.0	0.0	0.0	0.0	0.0	0.0	6.7	0.0	28.1	0.0	0.0	0.0
5	0.0	0.0	0.0	0.0	0.0	0.0	13.3	55.7	51.3	0.0	0.0	0.0
6	0.0	0.0	0.0	0.0	0.0	6.4	0.0	4.2	0.0	5.2	0.0	0.0
7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.7	0.0	0.0	0.0
8	0.0	0.0	0.0	0.0	0.0	0.0	6.7	21.7	2.3	0.0	0.0	0.0
9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	41.8	0.0	0.0	0.0	0.0
10	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	32.0	0.0	0.0	0.0
11	0.0	0.0	5.1	0.0	0.0	0.0	4.2	66.4	0.0	0.0	0.0	0.0
12	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	44.8	0.0	0.0	0.0
13	0.0	0.0	12.7	0.0	0.0	0.0	0.0	0.0	13.2	0.0	0.0	0.0
14	0.0	0.0	5.3	0.0	0.0	37.2	0.0	8.5	0.0	0.0	0.0	0.0
15	0.0	0.0	0.0	0.0	0.0	0.0	6.8	19.4	26.4	0.0	0.0	0.0
16	0.0	0.0	0.0	0.0	0.0	13.3	0.0	0.0	0.0	0.0	0.0	0.0
17	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.7	0.0	0.0	0.0	0.0
18	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0	0.0	0.0	13.1	18.6	0.0	0.0	0.0	4.3
20	6.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.0	0.0	0.0	0.0
21	3.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.2	0.0	0.0	0.0
22	0.0	19.1	0.0	0.0	1.5	0.0	19.2	0.0	6.8	0.0	0.0	0.0
23	0.0	9.2	0.0	0.0	0.0	0.0	0.0	3.2	0.0	0.0	0.0	0.0
24	0.0	0.0	0.0	0.0	9.2	0.0	0.0	0.0	0.0	22.4	0.0	0.0
25	19.2	0.0	0.0	0.0	0.0	0.0	37.0	26.7	0.0	0.0	0.0	0.0
26	27.1	3.2	0.0	0.0	5.3	0.0	0.0	5.6	0.0	0.0	0.0	0.0
27	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.4	0.0	0.0	0.0	0.0
28	0.0	52.7	0.0	0.0	0.0	0.0	83.7	0.0	0.0	0.0	0.0	0.0
29	0.0		0.0	0.0	0.0	0.0	6.0	49.0	0.0	0.0	0.0	0.0
30	0.0		0.0	0.0	0.0	13.1	7.3	0.0	0.0	0.0	0.0	0.0
31	16.3		0.0		0.0		137.8	10.5		0.0		0.0

Table - 6.4 Computed catchment runoff (m3) at Sohal pond in the year 1970

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0.00	0.00	0.00	0.00	0.00	0.00	9682.61	0.00	37650.82	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	2.44	0.00	219.71	0.00	0.00	0.00
3	0.00	0.00	0.00	0.00	0.00	0.00	210258.30	43273.66	0.00	0.00	0.00	0.00
4	0.00	0.00	0.00	0.00	0.00	0.00	32.49	0.00	7951.41	0.00	0.00	0.00
5	0.00	0.00	0.00	0.00	0.00	0.00	570.11	39787.58	33620.30	0.00	0.00	0.00
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
7	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13802.81	0.00	0.00	0.00
8	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3557.86	0.00	0.00	0.00	0.00
9	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21500.96	0.00	0.00	0.00	0.00
10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.44	11261.44	0.00	0.00	0.00
11	0.00	0.00	0.00	0.00	0.00	0.00	0.00	55917.77	0.00	0.00	0.00	0.00
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	85.92	25129.92	0.00	0.00	0.00
13	0.00	0.00	0.62	0.00	0.00	0.00	0.00	0.00	555.14	0.00	0.00	0.00
14	0.00	0.00	0.00	0.00	0.00	16356.79	0.00	111.95	0.00	0.00	0.00	0.00
15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2374.39	6645.97	0.00	0.00	0.00
16	0.00	0.00	0.00	0.00	0.00	570.11	0.00	0.00	0.00	0.00	0.00	0.00
17	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
19	0.00	0.00	0.00	0.00	0.00	0.00	2.47	2021.48	0.00	0.00	0.00	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35.80	0.00	0.00	0.00	0.00
21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
22	0.00	155.84	0.00	0.00	0.00	0.00	2283.16	0.00	0.00	0.00	0.00	0.00
23	0.00	152.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
24	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	321.74	0.00	0.00
25	160.12	0.00	0.00	0.00	0.00	0.00	16145.80	6869.79	0.00	0.00	0.00	0.00
26	7172.58	0.00	0.00	0.00	0.00	0.00	0.00	6.14	0.00	0.00	0.00	0.00
27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5232.18	0.00	0.00	0.00	0.00
28	0.00	35548.51	0.00	0.00	0.00	0.00	84715.57	0.00	0.00	0.00	0.00	0.00
29	0.00		0.00	0.00	0.00	0.00	13.49	30525.46	0.00	0.00	0.00	0.00
30	0.00		0.00	0.00	0.00	2.47	54.43	0.00	0.00	0.00	0.00	0.00
31	57.28		0.00		0.00		190688.70	242.42		0.00		0.00

Table - 6.5 Daily water balance computation for Sohal pond for the year 1970

Day	Initial			Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
	Depth (m)	Area (Sqm)	Storage (Cum)						
1	2.00	9063.6	17100.6	0.0	0.0	8.2	241.1	0.0	16851.4
2	1.97	9047.8	16851.4	0.0	0.0	8.1	241.1	0.0	16602.1
3	1.94	9031.9	16602.1	0.0	0.0	8.1	241.1	0.0	16352.9
4	1.91	9016.1	16352.9	0.0	0.0	8.1	241.1	0.0	16103.7
5	1.88	9000.2	16103.7	0.0	0.0	8.1	241.1	0.0	15854.5
6	1.85	8984.3	15854.5	0.0	0.0	8.1	241.1	0.0	15605.3
7	1.81	8968.5	15605.3	0.0	0.0	8.1	241.1	0.0	15356.1
8	1.78	8952.6	15356.1	0.0	0.0	8.1	241.1	0.0	15107.0
9	1.75	8936.7	15107.0	0.0	0.0	8.0	241.1	0.0	14857.8
10	1.72	8920.9	14857.8	0.0	0.0	8.0	241.1	0.0	14608.7
11	1.69	8905.0	14608.7	0.0	0.0	8.0	241.1	0.0	14359.6
12	1.66	8889.2	14359.6	0.0	0.0	8.0	241.1	0.0	14110.5
13	1.63	8873.3	14110.5	0.0	0.0	8.0	241.1	0.0	13861.4
14	1.60	8857.4	13861.4	0.0	0.0	8.0	241.1	0.0	13612.3
15	1.57	8841.6	13612.3	0.0	0.0	8.0	241.1	0.0	13363.2
16	1.54	8825.7	13363.2	0.0	0.0	7.9	241.1	0.0	13114.2
17	1.51	8809.9	13114.2	0.0	0.0	7.9	241.1	0.0	12865.2
18	1.47	8794.0	12865.2	0.0	0.0	7.9	241.1	0.0	12616.1
19	1.44	8778.1	12616.1	0.0	0.0	7.9	241.1	0.0	12367.1
20	1.41	8762.3	12367.1	64.5	0.0	7.9	241.1	0.0	12182.7
21	1.39	8749.5	12182.7	35.5	0.0	7.9	241.1	0.0	11969.2
22	1.36	8735.3	11969.2	0.0	0.0	7.9	241.1	0.0	11720.2
23	1.33	8719.5	11720.2	0.0	0.0	7.8	241.1	0.0	11471.3
24	1.30	8703.6	11471.3	0.0	0.0	7.8	241.1	0.0	11222.4
25	1.27	8687.7	11222.4	206.5	128.1	7.8	241.1	0.0	11308.1
26	1.27	8689.3	11308.1	291.5	5738.1	8.0	241.1	0.0	17088.6
27	1.91	9019.9	17088.6	0.0	0.0	8.1	241.1	0.0	16839.3
28	1.88	9004.1	16839.3	0.0	0.0	8.1	241.1	0.0	16590.1
29	1.85	8988.3	16590.1	0.0	0.0	8.1	241.1	0.0	16340.9
30	1.82	8972.4	16340.9	0.0	0.0	8.1	241.1	0.0	16091.8
31	1.79	8956.6	16091.8	175.3	45.8	8.1	241.1	0.0	16063.8
32	1.78	8951.7	16063.8	0.0	0.0	11.6	241.1	0.0	15811.0
33	1.75	8935.6	15811.0	0.0	0.0	11.6	241.1	0.0	15558.3
34	1.72	8919.5	15558.3	0.0	0.0	11.6	241.1	0.0	15305.6
35	1.69	8903.5	15305.6	0.0	0.0	11.6	241.1	0.0	15052.9
36	1.66	8887.4	15052.9	0.0	0.0	11.5	241.1	0.0	14800.3
37	1.63	8871.3	14800.3	0.0	0.0	11.5	241.1	0.0	14547.7
38	1.59	8855.3	14547.7	0.0	0.0	11.5	241.1	0.0	14295.0
39	1.56	8839.2	14295.0	0.0	0.0	11.5	241.1	0.0	14042.5
40	1.53	8823.1	14042.5	0.0	0.0	11.5	241.1	0.0	13789.9
41	1.50	8807.1	13789.9	0.0	0.0	11.4	241.1	0.0	13537.3
42	1.47	8791.0	13537.3	0.0	0.0	11.4	241.1	0.0	13284.8
43	1.44	8774.9	13284.8	0.0	0.0	11.4	241.1	0.0	13032.3
44	1.41	8758.9	13032.3	0.0	0.0	11.4	241.1	0.0	12779.8
45	1.37	8742.8	12779.8	0.0	0.0	11.4	241.1	0.0	12527.3
46	1.34	8726.7	12527.3	0.0	0.0	11.3	241.1	0.0	12274.9
47	1.31	8710.7	12274.9	0.0	0.0	11.3	241.1	0.0	12022.5

Day	Initial			Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
	Depth (m)	Area (Sqm)	Storage (Cum)						
48	1.28	8694.6	12022.5	0.0	0.0	11.3	241.1	0.0	11770.1
49	1.25	8678.5	11770.1	0.0	0.0	11.3	241.1	0.0	11517.7
50	1.22	8662.5	11517.7	0.0	0.0	11.3	241.1	0.0	11265.3
51	1.19	8646.4	11265.3	0.0	0.0	11.2	241.1	0.0	11013.0
52	1.16	8630.3	11013.0	0.0	0.0	11.2	241.1	0.0	10760.7
53	1.12	8614.3	10760.7	205.5	124.7	11.2	241.1	0.0	10838.5
54	1.13	8615.4	10838.5	99.0	122.3	11.2	241.1	0.0	10807.5
55	1.12	8611.4	10807.5	0.0	0.0	11.2	241.1	0.0	10555.2
56	1.09	8595.3	10555.2	0.0	0.0	11.2	241.1	0.0	10302.9
57	1.06	8579.3	10302.9	34.4	0.0	11.1	241.1	0.0	10085.1
58	1.03	8564.8	10085.1	0.0	0.0	11.1	241.1	0.0	9832.9
59	1.00	8548.8	9832.9	566.9	28438.8	12.1	241.1	0.0	38585.3
60	4.06	10123.3	38585.3	0.0	0.0	25.3	241.1	0.0	38318.9
61	4.03	10106.7	38318.9	0.0	0.0	25.2	241.1	0.0	38052.6
62	4.00	10090.0	38052.6	0.0	0.0	25.2	241.1	0.0	37786.3
63	3.97	10073.3	37786.3	0.0	0.0	25.2	241.1	0.0	37520.0
64	3.93	10056.7	37520.0	0.0	0.0	25.1	241.1	0.0	37253.8
65	3.90	10040.0	37253.8	0.0	0.0	25.1	241.1	0.0	36987.6
66	3.87	10023.3	36987.6	0.0	0.0	25.0	241.1	0.0	36721.4
67	3.84	10006.6	36721.4	0.0	0.0	25.0	241.1	0.0	36455.3
68	3.80	9989.9	36455.3	0.0	0.0	25.0	241.1	0.0	36189.2
69	3.77	9973.2	36189.2	0.0	0.0	24.9	241.1	0.0	35923.2
70	3.74	9956.6	35923.2	54.9	0.0	24.9	241.1	0.0	35712.1
71	3.71	9942.5	35712.1	0.0	0.0	24.8	241.1	0.0	35446.2
72	3.68	9925.8	35446.2	136.6	0.5	24.8	241.1	0.0	35317.4
73	3.66	9915.7	35317.4	57.0	0.0	24.8	241.1	0.0	35108.5
74	3.63	9901.7	35108.5	0.0	0.0	24.7	241.1	0.0	34842.6
75	3.60	9885.0	34842.6	0.0	0.0	24.7	241.1	0.0	34576.8
76	3.57	9868.4	34576.8	0.0	0.0	24.7	241.1	0.0	34311.1
77	3.54	9851.7	34311.1	0.0	0.0	24.6	241.1	0.0	34045.4
78	3.50	9835.0	34045.4	0.0	0.0	24.6	241.1	0.0	33779.7
79	3.47	9818.3	33779.7	0.0	0.0	24.5	241.1	0.0	33514.0
80	3.44	9801.6	33514.0	0.0	0.0	24.5	241.1	0.0	33248.4
81	3.41	9784.9	33248.4	0.0	0.0	24.4	241.1	0.0	32982.9
82	3.37	9768.3	32982.9	0.0	0.0	24.4	241.1	0.0	32717.4
83	3.34	9751.6	32717.4	0.0	0.0	24.4	241.1	0.0	32451.9
84	3.31	9734.9	32451.9	0.0	0.0	24.3	241.1	0.0	32186.5
85	3.28	9718.2	32186.5	0.0	0.0	24.3	241.1	0.0	31921.1
86	3.24	9701.5	31921.1	0.0	0.0	24.2	241.1	0.0	31655.8
87	3.21	9684.8	31655.8	0.0	0.0	24.2	241.1	0.0	31390.5
88	3.18	9668.2	31390.5	0.0	0.0	24.1	241.1	0.0	31125.2
89	3.15	9651.5	31125.2	0.0	0.0	24.1	241.1	0.0	30860.0
90	3.11	9634.8	30860.0	0.0	0.0	24.1	241.1	0.0	30594.8
91	3.08	9618.1	30594.8	0.0	0.0	32.7	241.1	0.0	30321.0
92	3.05	9601.0	30321.0	0.0	0.0	32.6	241.1	0.0	30047.3
93	3.01	9583.8	30047.3	0.0	0.0	32.6	241.1	0.0	29773.6
94	2.98	9566.7	29773.6	0.0	0.0	32.5	241.1	0.0	29500.0
95	2.95	9549.5	29500.0	0.0	0.0	32.4	241.1	0.0	29226.5
96	2.91	9532.4	29226.5	0.0	0.0	32.4	241.1	0.0	28953.0

Day	Initial			Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
	Depth (m)	Area (Sqm)	Storage (Cum)						
97	2.88	9515.2	28953.0	0.0	0.0	32.3	241.1	0.0	28679.6
98	2.85	9498.1	28679.6	0.0	0.0	32.3	241.1	0.0	28406.2
99	2.81	9480.9	28406.2	0.0	0.0	32.2	241.1	0.0	28132.9
100	2.78	9463.8	28132.9	0.0	0.0	32.1	241.1	0.0	27859.6
101	2.75	9446.7	27859.6	0.0	0.0	32.1	241.1	0.0	27586.4
102	2.71	9429.5	27586.4	0.0	0.0	32.0	241.1	0.0	27313.3
103	2.68	9412.4	27313.3	0.0	0.0	32.0	241.1	0.0	27040.2
104	2.65	9395.2	27040.2	0.0	0.0	31.9	241.1	0.0	26767.2
105	2.61	9378.1	26767.2	0.0	0.0	31.9	241.1	0.0	26494.2
106	2.58	9360.9	26494.2	0.0	0.0	31.8	241.1	0.0	26221.3
107	2.55	9343.8	26221.3	0.0	0.0	31.7	241.1	0.0	25948.4
108	2.51	9326.6	25948.4	0.0	0.0	31.7	241.1	0.0	25675.6
109	2.48	9309.5	25675.6	0.0	0.0	31.6	241.1	0.0	25402.9
110	2.45	9292.4	25402.9	0.0	0.0	31.6	241.1	0.0	25130.2
111	2.41	9275.2	25130.2	0.0	0.0	31.5	241.1	0.0	24857.6
112	2.38	9258.1	24857.6	0.0	0.0	31.4	241.1	0.0	24585.1
113	2.35	9240.9	24585.1	0.0	0.0	31.4	241.1	0.0	24312.6
114	2.31	9223.8	24312.6	0.0	0.0	31.3	241.1	0.0	24040.1
115	2.28	9206.6	24040.1	0.0	0.0	31.3	241.1	0.0	23767.7
116	2.25	9189.5	23767.7	0.0	0.0	31.2	241.1	0.0	23495.4
117	2.21	9172.3	23495.4	0.0	0.0	31.2	241.1	0.0	23223.1
118	2.18	9155.2	23223.1	0.0	0.0	31.1	241.1	0.0	22950.9
119	2.14	9138.0	22950.9	0.0	0.0	31.0	241.1	0.0	22678.8
120	2.11	9120.9	22678.8	0.0	0.0	31.0	241.1	0.0	22406.7
121	2.08	9103.8	22406.7	0.0	0.0	53.7	241.1	0.0	22111.9
122	2.04	9085.3	22111.9	0.0	0.0	53.5	241.1	0.0	21817.3
123	2.01	9066.9	21817.3	0.0	0.0	53.4	241.1	0.0	21522.7
124	1.97	9048.5	21522.7	0.0	0.0	53.3	241.1	0.0	21228.3
125	1.93	9030.0	21228.3	0.0	0.0	53.2	241.1	0.0	20933.9
126	1.90	9011.6	20933.9	0.0	0.0	53.1	241.1	0.0	20639.7
127	1.86	8993.2	20639.7	0.0	0.0	53.0	241.1	0.0	20345.6
128	1.83	8974.8	20345.6	0.0	0.0	52.9	241.1	0.0	20051.6
129	1.79	8956.3	20051.6	0.0	0.0	52.8	241.1	0.0	19757.7
130	1.76	8937.9	19757.7	0.0	0.0	52.7	241.1	0.0	19463.9
131	1.72	8919.5	19463.9	0.0	0.0	52.6	241.1	0.0	19170.2
132	1.68	8901.0	19170.2	0.0	0.0	52.5	241.1	0.0	18876.7
133	1.65	8882.6	18876.7	0.0	0.0	52.4	241.1	0.0	18583.2
134	1.61	8864.2	18583.2	0.0	0.0	52.2	241.1	0.0	18289.8
135	1.58	8845.8	18289.8	0.0	0.0	52.1	241.1	0.0	17996.6
136	1.54	8827.3	17996.6	0.0	0.0	52.0	241.1	0.0	17703.5
137	1.50	8808.9	17703.5	0.0	0.0	51.9	241.1	0.0	17410.4
138	1.47	8790.5	17410.4	0.0	0.0	51.8	241.1	0.0	17117.5
139	1.43	8772.1	17117.5	0.0	0.0	51.7	241.1	0.0	16824.7
140	1.40	8753.6	16824.7	0.0	0.0	51.6	241.1	0.0	16532.0
141	1.36	8735.2	16532.0	0.0	0.0	51.5	241.1	0.0	16239.4
142	1.32	8716.8	16239.4	16.1	0.0	51.4	241.1	0.0	15963.1
143	1.29	8699.1	15963.1	0.0	0.0	51.3	241.1	0.0	15670.7
144	1.25	8680.7	15670.7	99.0	0.0	51.2	241.1	0.0	15477.4
145	1.23	8667.0	15477.4	0.0	0.0	51.1	241.1	0.0	15185.2

Day	Initial			Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
	Depth (m)	Area (Sqm)	Storage (Cum)						
146	1.19	8648.5	15185.2	57.0	0.0	51.0	241.1	0.0	14950.1
147	1.16	8632.8	14950.1	0.0	0.0	50.9	241.1	0.0	14658.1
148	1.12	8614.4	14658.1	0.0	0.0	50.8	241.1	0.0	14366.2
149	1.09	8596.0	14366.2	0.0	0.0	50.7	241.1	0.0	14074.4
150	1.05	8577.6	14074.4	0.0	0.0	50.6	241.1	0.0	13782.8
151	1.02	8559.1	13782.8	0.0	0.0	50.4	241.1	0.0	13491.2
152	0.98	8540.7	13491.2	0.0	0.0	64.0	241.1	0.0	13186.1
153	0.94	8521.4	13186.1	0.0	0.0	63.8	241.1	0.0	12881.2
154	0.91	8502.2	12881.2	0.0	0.0	63.7	241.1	0.0	12576.4
155	0.87	8482.9	12576.4	0.0	0.0	63.5	241.1	0.0	12271.7
156	0.83	8463.7	12271.7	0.0	0.0	63.4	241.1	0.0	11967.2
157	0.79	8444.4	11967.2	68.8	0.0	63.3	241.1	0.0	11731.7
158	0.76	8428.5	11731.7	0.0	0.0	63.1	241.1	0.0	11427.4
159	0.73	8409.2	11427.4	0.0	0.0	63.0	241.1	0.0	11123.3
160	0.69	8390.0	11123.3	0.0	0.0	62.9	241.1	0.0	10819.3
161	0.65	8370.7	10819.3	0.0	0.0	62.7	241.1	0.0	10515.5
162	0.61	8351.5	10515.5	0.0	0.0	62.6	241.1	0.0	10211.9
163	0.58	8332.2	10211.9	0.0	0.0	62.4	241.1	0.0	9908.3
164	0.54	8313.0	9908.3	0.0	0.0	62.3	241.1	0.0	9604.9
165	0.50	8293.7	9604.9	400.2	13085.4	65.1	241.1	0.0	22784.3
166	2.01	9067.5	22784.3	0.0	0.0	67.9	241.1	0.0	22475.3
167	1.97	9048.1	22475.3	143.1	456.1	67.9	241.1	0.0	22765.4
168	2.00	9061.6	22765.4	0.0	0.0	67.9	241.1	0.0	22456.4
169	1.96	9042.3	22456.4	0.0	0.0	67.7	241.1	0.0	22147.6
170	1.92	9023.1	22147.6	0.0	0.0	67.6	241.1	0.0	21838.8
171	1.88	9003.8	21838.8	0.0	0.0	67.5	241.1	0.0	21530.3
172	1.85	8984.6	21530.3	0.0	0.0	67.3	241.1	0.0	21221.9
173	1.81	8965.3	21221.9	0.0	0.0	67.2	241.1	0.0	20913.6
174	1.77	8946.1	20913.6	0.0	0.0	67.0	241.1	0.0	20605.4
175	1.73	8926.8	20605.4	0.0	0.0	66.9	241.1	0.0	20297.5
176	1.70	8907.6	20297.5	0.0	0.0	66.7	241.1	0.0	19989.6
177	1.66	8888.3	19989.6	0.0	0.0	66.6	241.1	0.0	19681.9
178	1.62	8869.1	19681.9	0.0	0.0	66.4	241.1	0.0	19374.4
179	1.58	8849.8	19374.4	0.0	0.0	66.3	241.1	0.0	19066.9
180	1.55	8830.6	19066.9	0.0	0.0	66.2	241.1	0.0	18759.7
181	1.51	8811.3	18759.7	140.9	2.0	66.0	241.1	0.0	18595.4
182	1.48	8798.9	18595.4	324.9	7746.1	45.1	241.1	0.0	26380.2
183	2.34	9237.1	26380.2	57.0	2.0	46.1	241.1	0.0	26151.9
184	2.31	9222.2	26151.9	1581.3	168206.6	49.9	241.1	145843.0	49805.7
185	5.30	10757.6	49805.7	72.1	26.0	53.8	241.1	0.0	49608.9
186	5.27	10744.3	49608.9	143.1	456.1	53.7	241.1	107.5	49805.7
187	5.29	10755.0	49805.7	0.0	0.0	53.7	241.1	0.0	49510.9
188	5.26	10737.0	49510.9	0.0	0.0	53.6	241.1	0.0	49216.1
189	5.22	10719.0	49216.1	72.1	0.0	53.6	241.1	0.0	48993.5
190	5.20	10704.5	48993.5	0.0	0.0	53.5	241.1	0.0	48698.9
191	5.16	10686.5	48698.9	0.0	0.0	53.4	241.1	0.0	48404.4
192	5.13	10668.6	48404.4	45.2	0.0	53.3	241.1	0.0	48155.2
193	5.10	10652.8	48155.2	0.0	0.0	53.2	241.1	0.0	47860.9
194	5.06	10634.8	47860.9	0.0	0.0	53.1	241.1	0.0	47566.6

Day	Initial			Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
	Depth (m)	Area (Sqm)	Storage (Cum)						
195	5.03	10616.8	47566.6	0.0	0.0	53.0	241.1	0.0	47272.5
196	4.99	10598.9	47272.5	73.1	0.0	53.0	241.1	0.0	47051.6
197	4.96	10584.4	47051.6	0.0	0.0	52.9	241.1	0.0	46757.6
198	4.93	10566.4	46757.6	0.0	0.0	52.8	241.1	0.0	46463.7
199	4.89	10548.4	46463.7	0.0	0.0	52.7	241.1	0.0	46169.9
200	4.86	10530.5	46169.9	140.9	2.0	52.6	241.1	0.0	46019.0
201	4.84	10519.3	46019.0	0.0	0.0	52.6	241.1	0.0	45725.4
202	4.80	10501.4	45725.4	0.0	0.0	52.5	241.1	0.0	45431.8
203	4.77	10483.4	45431.8	206.5	1826.5	52.6	241.1	0.0	47171.1
204	4.92	10564.7	47171.1	0.0	0.0	52.8	241.1	0.0	46877.2
205	4.89	10546.4	46877.2	0.0	0.0	52.7	241.1	0.0	46583.4
206	4.85	10528.5	46583.4	398.0	12916.6	53.2	241.1	9798.1	49805.7
207	5.30	10757.6	49805.7	0.0	0.0	53.7	241.1	0.0	49510.8
208	5.27	10739.6	49510.8	0.0	0.0	53.7	241.1	0.0	49216.1
209	5.23	10721.7	49216.1	900.4	67772.5	53.7	241.1	67788.4	49805.7
210	5.30	10757.6	49805.7	64.5	10.8	53.8	241.1	0.0	49586.2
211	5.27	10743.2	49586.2	78.5	43.5	53.7	241.1	0.0	49413.4
212	5.25	10731.1	49413.4	1482.3	152551.0	53.7	241.1	153346.2	49805.7
213	5.30	10757.6	49805.7	0.0	0.0	39.8	241.1	0.0	49524.8
214	5.27	10740.3	49524.8	0.0	0.0	39.7	241.1	0.0	49244.0
215	5.23	10723.0	49244.0	625.0	34618.9	39.7	241.1	34401.4	49805.7
216	5.30	10757.6	49805.7	0.0	0.0	39.8	241.1	0.0	49524.8
217	5.27	10740.3	49524.8	599.2	31830.1	39.8	241.1	31867.5	49805.7
218	5.30	10757.6	49805.7	45.2	0.0	39.8	241.1	0.0	49570.0
219	5.27	10742.5	49570.0	0.0	0.0	39.7	241.1	0.0	49289.2
220	5.24	10725.2	49289.2	233.4	2846.3	39.7	241.1	2282.3	49805.7
221	5.30	10757.6	49805.7	449.6	17200.8	39.8	241.1	17369.5	49805.7
222	5.30	10757.6	49805.7	57.0	2.0	39.8	241.1	0.0	49583.8
223	5.27	10743.1	49583.8	714.3	44734.2	39.8	241.1	44945.7	49805.7
224	5.30	10757.6	49805.7	86.1	68.7	39.8	241.1	0.0	49679.6
225	5.28	10747.7	49679.6	0.0	0.0	39.7	241.1	0.0	49398.8
226	5.25	10730.4	49398.8	91.4	89.6	39.7	241.1	0.0	49299.0
227	5.23	10721.7	49299.0	208.7	1899.5	39.7	241.1	1320.6	49805.7
228	5.30	10757.6	49805.7	0.0	0.0	39.8	241.1	0.0	49524.8
229	5.27	10740.3	49524.8	50.6	0.0	39.7	241.1	0.0	49294.6
230	5.24	10725.4	49294.6	0.0	0.0	39.7	241.1	0.0	49013.8
231	5.20	10708.1	49013.8	200.1	1617.2	39.7	241.1	744.5	49805.7
232	5.30	10757.6	49805.7	73.1	28.6	39.8	241.1	0.0	49626.6
233	5.28	10745.2	49626.6	0.0	0.0	39.7	241.1	0.0	49345.8
234	5.24	10727.9	49345.8	0.0	0.0	39.7	241.1	0.0	49065.0
235	5.21	10710.6	49065.0	34.4	0.0	39.6	241.1	0.0	48818.7
236	5.18	10694.9	48818.7	0.0	0.0	39.5	241.1	0.0	48538.1
237	5.14	10677.6	48538.1	287.2	5495.8	39.7	241.1	4234.6	49805.7
238	5.30	10757.6	49805.7	60.2	4.9	39.8	241.1	0.0	49590.0
239	5.27	10743.4	49590.0	262.5	4185.7	39.8	241.1	3951.6	49805.7
240	5.30	10757.6	49805.7	0.0	0.0	39.8	241.1	0.0	49524.8
241	5.27	10740.3	49524.8	527.1	24420.4	39.8	241.1	24385.7	49805.7
242	5.30	10757.6	49805.7	0.0	0.0	39.8	241.1	0.0	49524.8
243	5.27	10740.3	49524.8	112.9	193.9	39.7	241.1	0.0	49550.9

Day	Initial			Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
	Depth (m)	Area (Sqm)	Storage (Cum)						
244	5.26	10737.7	49550.9	583.0	30120.7	31.2	241.1	30176.6	49805.7
245	5.30	10757.6	49805.7	109.7	175.8	31.2	241.1	13.2	49805.7
246	5.29	10754.3	49805.7	0.0	0.0	31.2	241.1	0.0	49533.4
247	5.26	10737.4	49533.4	302.3	6361.1	31.2	241.1	6118.8	49805.7
248	5.30	10757.6	49805.7	551.8	26896.2	31.2	241.1	27175.8	49805.7
249	5.30	10757.6	49805.7	0.0	0.0	31.2	241.1	0.0	49533.4
250	5.27	10740.7	49533.4	373.3	11042.2	31.2	241.1	10871.0	49805.7
251	5.30	10757.6	49805.7	24.7	0.0	31.2	241.1	0.0	49558.2
252	5.27	10741.9	49558.2	0.0	0.0	31.1	241.1	0.0	49285.9
253	5.24	10725.0	49285.9	344.2	9009.2	31.1	241.1	8561.3	49805.7
254	5.30	10757.6	49805.7	0.0	0.0	31.2	241.1	0.0	49533.4
255	5.27	10740.7	49533.4	481.9	20103.9	31.2	241.1	20041.3	49805.7
256	5.30	10757.6	49805.7	142.0	444.1	31.2	241.1	313.8	49805.7
257	5.30	10757.6	49805.7	0.0	0.0	31.2	241.1	0.0	49533.4
258	5.27	10740.7	49533.4	284.0	5316.8	31.2	241.1	5056.2	49805.7
259	5.30	10757.6	49805.7	0.0	0.0	31.2	241.1	0.0	49533.4
260	5.27	10740.7	49533.4	0.0	0.0	31.1	241.1	0.0	49261.2
261	5.23	10723.8	49261.2	0.0	0.0	31.1	241.1	0.0	48989.0
262	5.20	10706.9	48989.0	0.0	0.0	31.0	241.1	0.0	48716.9
263	5.17	10690.0	48716.9	0.0	0.0	31.0	241.1	0.0	48444.8
264	5.14	10673.2	48444.8	120.5	0.0	30.9	241.1	0.0	48293.2
265	5.11	10662.0	48293.2	73.1	0.0	30.9	241.1	0.0	48094.3
266	5.09	10648.6	48094.3	0.0	0.0	30.9	241.1	0.0	47822.4
267	5.05	10631.7	47822.4	0.0	0.0	30.8	241.1	0.0	47550.5
268	5.02	10614.8	47550.5	0.0	0.0	30.8	241.1	0.0	47278.6
269	4.99	10598.0	47278.6	0.0	0.0	30.7	241.1	0.0	47006.8
270	4.96	10581.1	47006.8	0.0	0.0	30.7	241.1	0.0	46735.0
271	4.92	10564.2	46735.0	0.0	0.0	30.6	241.1	0.0	46463.3
272	4.89	10547.3	46463.3	0.0	0.0	30.6	241.1	0.0	46191.6
273	4.86	10530.4	46191.6	0.0	0.0	30.5	241.1	0.0	45920.0
274	4.82	10513.5	45920.0	0.0	0.0	24.2	241.1	0.0	45654.7
275	4.79	10496.9	45654.7	0.0	0.0	24.1	241.1	0.0	45389.5
276	4.76	10480.4	45389.5	0.0	0.0	24.1	241.1	0.0	45124.3
277	4.73	10463.8	45124.3	0.0	0.0	24.0	241.1	0.0	44859.1
278	4.70	10447.2	44859.1	0.0	0.0	24.0	241.1	0.0	44594.0
279	4.66	10430.6	44594.0	55.9	0.0	24.0	241.1	0.0	44384.9
280	4.64	10416.7	44384.9	0.0	0.0	23.9	241.1	0.0	44119.8
281	4.60	10400.1	44119.8	0.0	0.0	23.9	241.1	0.0	43854.8
282	4.57	10383.5	43854.8	0.0	0.0	23.9	241.1	0.0	43589.8
283	4.54	10367.0	43589.8	0.0	0.0	23.8	241.1	0.0	43324.9
284	4.51	10350.4	43324.9	0.0	0.0	23.8	241.1	0.0	43060.0
285	4.47	10333.8	43060.0	0.0	0.0	23.7	241.1	0.0	42795.1
286	4.44	10317.2	42795.1	0.0	0.0	23.7	241.1	0.0	42530.3
287	4.41	10300.6	42530.3	0.0	0.0	23.7	241.1	0.0	42265.5
288	4.38	10284.1	42265.5	0.0	0.0	23.6	241.1	0.0	42000.8
289	4.35	10267.5	42000.8	0.0	0.0	23.6	241.1	0.0	41736.1
290	4.31	10250.9	41736.1	0.0	0.0	23.6	241.1	0.0	41471.4
291	4.28	10234.3	41471.4	0.0	0.0	23.5	241.1	0.0	41206.8
292	4.25	10217.7	41206.8	0.0	0.0	23.5	241.1	0.0	40942.2

Day	Initial Depth (m)	Initial Area (Sqm)	Initial Storage (Cum)	Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
293	4.22	10201.2	40942.2	0.0	0.0	23.4	241.1	0.0	40677.6
294	4.18	10184.6	40677.6	0.0	0.0	23.4	241.1	0.0	40413.1
295	4.15	10168.0	40413.1	0.0	0.0	23.4	241.1	0.0	40148.6
296	4.12	10151.4	40148.6	0.0	0.0	23.3	241.1	0.0	39884.2
297	4.09	10134.8	39884.2	241.0	257.4	23.3	241.1	0.0	40118.1
298	4.10	10142.8	40118.1	0.0	0.0	23.3	241.1	0.0	39853.7
299	4.07	10126.2	39853.7	0.0	0.0	23.3	241.1	0.0	39589.3
300	4.04	10109.6	39589.3	0.0	0.0	23.2	241.1	0.0	39325.0
301	4.01	10093.0	39325.0	0.0	0.0	23.2	241.1	0.0	39060.7
302	3.97	10076.5	39060.7	0.0	0.0	23.2	241.1	0.0	38796.4
303	3.94	10059.9	38796.4	0.0	0.0	23.1	241.1	0.0	38532.2
304	3.91	10043.3	38532.2	0.0	0.0	23.1	241.1	0.0	38268.0
305	3.88	10026.7	38268.0	0.0	0.0	14.0	241.1	0.0	38012.9
306	3.84	10010.6	38012.9	0.0	0.0	14.0	241.1	0.0	37757.7
307	3.81	9994.5	37757.7	0.0	0.0	14.0	241.1	0.0	37502.6
308	3.78	9978.4	37502.6	0.0	0.0	14.0	241.1	0.0	37247.6
309	3.75	9962.3	37247.6	0.0	0.0	13.9	241.1	0.0	36992.5
310	3.72	9946.1	36992.5	0.0	0.0	13.9	241.1	0.0	36737.5
311	3.69	9930.0	36737.5	0.0	0.0	13.9	241.1	0.0	36482.5
312	3.66	9913.9	36482.5	0.0	0.0	13.9	241.1	0.0	36227.5
313	3.62	9897.8	36227.5	0.0	0.0	13.8	241.1	0.0	35972.6
314	3.59	9881.7	35972.6	0.0	0.0	13.8	241.1	0.0	35717.6
315	3.56	9865.5	35717.6	0.0	0.0	13.8	241.1	0.0	35462.7
316	3.53	9849.4	35462.7	0.0	0.0	13.8	241.1	0.0	35207.8
317	3.50	9833.3	35207.8	0.0	0.0	13.8	241.1	0.0	34953.0
318	3.47	9817.2	34953.0	0.0	0.0	13.7	241.1	0.0	34698.1
319	3.44	9801.1	34698.1	0.0	0.0	13.7	241.1	0.0	34443.3
320	3.41	9785.0	34443.3	0.0	0.0	13.7	241.1	0.0	34188.5
321	3.37	9768.8	34188.5	0.0	0.0	13.7	241.1	0.0	33933.7
322	3.34	9752.7	33933.7	0.0	0.0	13.6	241.1	0.0	33679.0
323	3.31	9736.6	33679.0	0.0	0.0	13.6	241.1	0.0	33424.3
324	3.28	9720.5	33424.3	0.0	0.0	13.6	241.1	0.0	33169.6
325	3.25	9704.4	33169.6	0.0	0.0	13.6	241.1	0.0	32914.9
326	3.22	9688.2	32914.9	0.0	0.0	13.6	241.1	0.0	32660.2
327	3.19	9672.1	32660.2	0.0	0.0	13.5	241.1	0.0	32405.6
328	3.15	9656.0	32405.6	0.0	0.0	13.5	241.1	0.0	32150.9
329	3.12	9639.9	32150.9	0.0	0.0	13.5	241.1	0.0	31896.4
330	3.09	9623.8	31896.4	0.0	0.0	13.5	241.1	0.0	31641.8
331	3.06	9607.7	31641.8	0.0	0.0	13.4	241.1	0.0	31387.2
332	3.03	9591.5	31387.2	0.0	0.0	13.4	241.1	0.0	31132.7
333	3.00	9575.4	31132.7	0.0	0.0	13.4	241.1	0.0	30878.2
334	2.97	9559.3	30878.2	0.0	0.0	13.4	241.1	0.0	30623.7
335	2.93	9543.2	30623.7	0.0	0.0	6.7	241.1	0.0	30375.9
336	2.90	9527.4	30375.9	0.0	0.0	6.7	241.1	0.0	30128.2
337	2.87	9511.7	30128.2	0.0	0.0	6.7	241.1	0.0	29880.4
338	2.84	9495.9	29880.4	0.0	0.0	6.6	241.1	0.0	29632.6
339	2.81	9480.1	29632.6	0.0	0.0	6.6	241.1	0.0	29384.9
340	2.78	9464.4	29384.9	0.0	0.0	6.6	241.1	0.0	29137.2
341	2.75	9448.6	29137.2	0.0	0.0	6.6	241.1	0.0	28889.5

Day	Initial			Rainfall over pond (Cum)	Flow from Catchment (Cum)	Evaporation (Cum)	Seepage (Cum)	Spill (Cum)	Final Storage (Cum)
	Depth (m)	Area (Sqm)	Storage (Cum)						
342	2.72	9432.9	28889.5	0.0	0.0	6.6	241.1	0.0	28641.8
343	2.69	9417.1	28641.8	0.0	0.0	6.6	241.1	0.0	28394.1
344	2.66	9401.4	28394.1	0.0	0.0	6.6	241.1	0.0	28146.4
345	2.63	9385.6	28146.4	0.0	0.0	6.6	241.1	0.0	27898.7
346	2.60	9369.8	27898.7	0.0	0.0	6.6	241.1	0.0	27651.0
347	2.57	9354.1	27651.0	0.0	0.0	6.5	241.1	0.0	27403.4
348	2.54	9338.3	27403.4	0.0	0.0	6.5	241.1	0.0	27155.7
349	2.50	9322.6	27155.7	0.0	0.0	6.5	241.1	0.0	26908.1
350	2.47	9306.8	26908.1	0.0	0.0	6.5	241.1	0.0	26660.5
351	2.44	9291.0	26660.5	0.0	0.0	6.5	241.1	0.0	26412.9
352	2.41	9275.3	26412.9	0.0	0.0	6.5	241.1	0.0	26165.3
353	2.38	9259.5	26165.3	46.3	0.0	6.5	241.1	0.0	25963.9
354	2.36	9246.0	25963.9	0.0	0.0	6.5	241.1	0.0	25716.4
355	2.32	9230.2	25716.4	0.0	0.0	6.5	241.1	0.0	25468.8
356	2.29	9214.5	25468.8	0.0	0.0	6.4	241.1	0.0	25221.3
357	2.26	9198.7	25221.3	0.0	0.0	6.4	241.1	0.0	24973.7
358	2.23	9182.9	24973.7	0.0	0.0	6.4	241.1	0.0	24726.2
359	2.20	9167.2	24726.2	0.0	0.0	6.4	241.1	0.0	24478.7
360	2.17	9151.4	24478.7	0.0	0.0	6.4	241.1	0.0	24231.1
361	2.14	9135.7	24231.1	0.0	0.0	6.4	241.1	0.0	23983.6
362	2.11	9119.9	23983.6	0.0	0.0	6.4	241.1	0.0	23736.2
363	2.08	9104.1	23736.2	0.0	0.0	6.4	241.1	0.0	23488.7
364	2.05	9088.4	23488.7	0.0	0.0	6.4	241.1	0.0	23241.2
365	2.02	9072.6	23241.2	0.0	0.0	6.3	241.1	0.0	22993.8

Table - 6.6 Annual values of selected water balance components for Sohal pond

Parameter	Annual Total (Cu.m)
Rainfall in the catchment	4109874.71 Cu.m
Runoff generated from the catchment	923331.88 Cu.m
Assumed inflow tothe pond (80 %)	738665.5 Cu.m
Rainfall over the pond	16944.3 Cu.m
Evaporation loss from the pond	10998 Cu.m
Seepage losses from pond	88001.5 Cu.m
Spill from the pond	650714.6 Cu.m