Chapter - VI

WATER RESOURCES OF DARJILING TOWN : PROBLEMS AND PROSPECTS

A. INTRODUCTION

A town is a major factor of environmental transformation. The concentration of people in the urban area causes significant change in the landscape. The circulation of water in Darjiling town like any other urban environment involves two interlinked systems : (i) the man-modified hydrological cycle and the man-created artificial water supply and (ii) waste water disposal system. The natural circulation of water is modified by the nature of the urban surface which encourages rapid run-off and decreases infiltration (Jens and Mc. Pherson, 1964; Douglas, 1976 and Kuprianov, 1977). Urbanisation affects stream channel , often causing water to flow through cities at higher velocities (James, 1965, and Lull and Sopper, 1969). Leopold (1968) summarizes the hydrological effects of urbanisation under the 4 major headings :
i) a change in total run-off, ii) an alteration of peak flow characteristics, iii) a decline in the quality of water and iv) a change in the hydrological amenities of streams.

The urban hydrological system collects water from the natural hydrological cycle, delivers it to the points of use and discharges it back to other sectors of the natural hydrological cycle. The water supply may be abstracted from one major river basin and the same water later, after use and passage through the waste disposal system may be discharged into a completely different river basin (Lyovich and Chernogaeva, 1977). The water supply of Darjiling town

LOCATION OF MAJOR JHORAS AND SUPPLY OF WATER FROM SENCHAL AND SINDHAP LAKES TO DARJILING TOWN

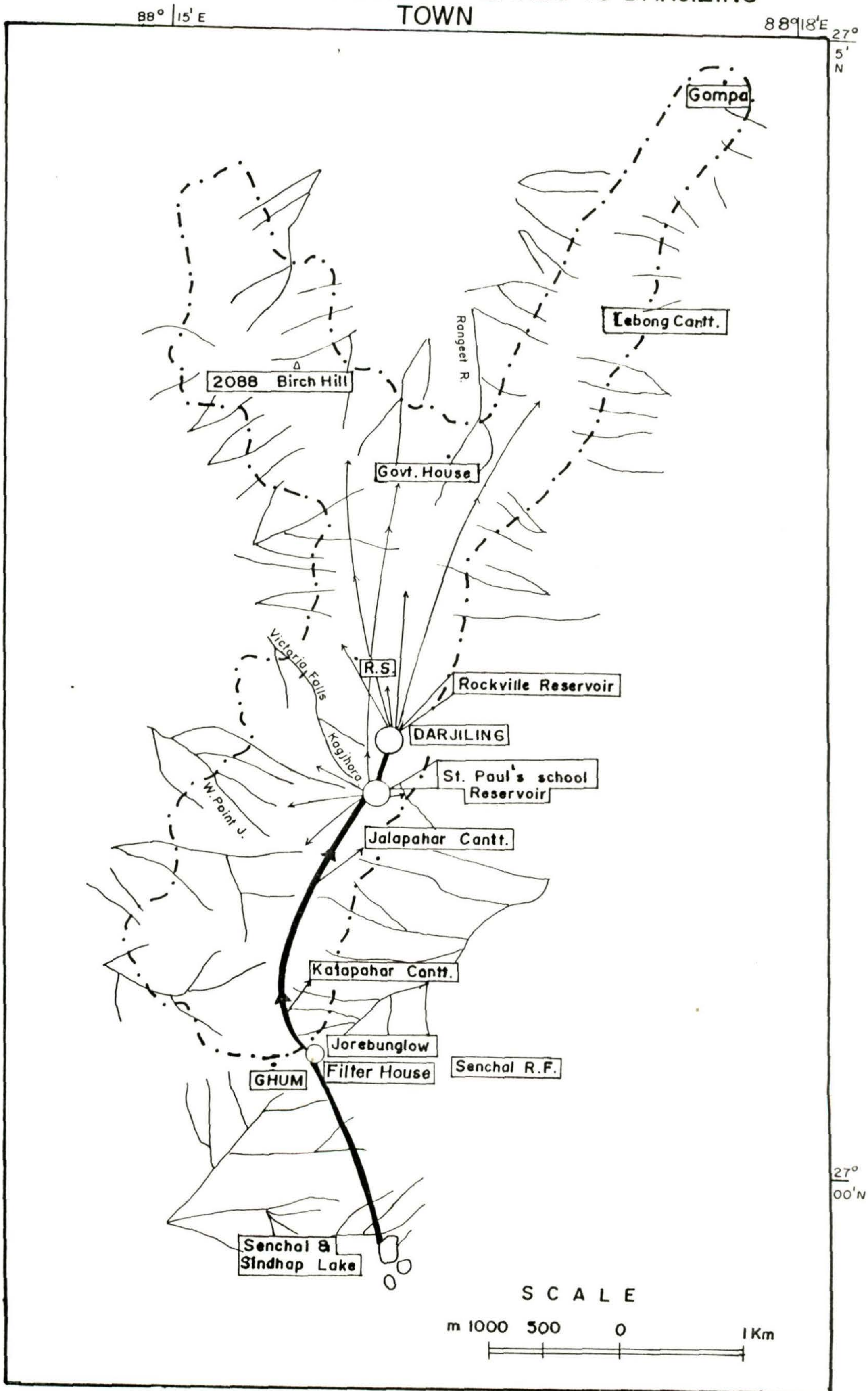

Fig — 6.1

is drawn from the Balason catchment (i.e. Senchal lake) and discharged into the tributaries of the Rangit river - a major channel of the great Tista Basin (Fig.6.1a).

1. Aim :

This chapter begins by examining the origin & characteristics of Darjiling's water supply and its problems and prospects. The next purpose is to study how the urban landscape of Darjiling town modifies the natural hydrological cycle, then assess how the artificial water circulation system affects the hydrological cycle and finally illustrates how a water balance may be estimated for urban areas and how the interaction of the natural and artificial water systems produce hydrological problems in and down streams.

2. Methodology :

The methodology adopted in this study is a rationalistic one comprising the following :

i) estimation of run-off and evaporation loss in order to estimate the total available water resources in the study area.

ii) the actual water-supply data has been collected from various institutional sources i.e. Senchal Lake authority, Darjiling Municipality etc. since 1991.

iii) an estimation has been made to apprehend the actual water requirements in the town.

iv) a number of jhoras (springs) have been studied since the last 3 years, in order to have an idea about the total water availability and their seasonal fluctuations.

v) a brief account of the existing sewer system of the town.

vi) an intensive field survey has been conducted to study the different hydrological parameters of the study area.

Thus, the subject matter of the chapter may be broadly divided into two headings :

A. The study of Water Resources : Water supply and requirements and sewer system and

B. The study of Urban hydrology and water balance of Darjiling Town.

B. ORIGIN AND CHARACTERISTICS OF WATER SUPPLY IN DARJILING TOWN

The first modern water supply system for Darjiling municipality was started in 1910 - the South Lake on Senchal ridge with a capacity of 13 million gallons. At present, the Senchal ridge of the Balason catchment has got two more lakes : (a) the North Lake (1932) with a capacity of 20 million gallons; and (b) the Sindhap Lake (1978) with a capacity of 15 million gallons (Photo 6.1). Thus, the total capacity of these lakes is estimated to be 48 million gallons. Taking the UN standard of 20 gallons per head per day for the people, the total demand for Darjiling town has been estimated by the Municipal authority as 110 million gallons (Darjiling Municipality Report, 1991). But considering the present population of 71,479 (1991) this demand will be much more which points to a perpetual crisis of water in Darjiling.(Photo 6.1b)

Before any further study in this regard, it is our duty to analyse and estimate the total amount of water resources available within the study area because, the water supply of Darjiling town is not only dependent on the Senchal Lakes but also on a good

6.1(a)

Senchal reservoirs (3)

6.1(b)

A typical scene of water crices in Darjiling town.

number of jhoras (natural springs) and the storage of rain water by individual citizen usually by collecting the rain water from the roof tops.

1. Estimation of Water Resources of Darjiling Town :

The estimation of water resources may be carried out in two ways :

i) by the estimation of run-off emperically from the long term average rainfall and temperature data (Khosla, 1950) and

ii) by the estimation of run-off from the daily discharge data of the streams.

The second method, often gives a more accurate information but can only be effectively used within a drainage basin framework. In the present case the estimation has been done based on the emperical method, proposed by Khosla in 1950.

According to Khosla (1950), the run-off is the function of precipitation and temperature :

$$R \propto P/T \text{ .... } 6.1$$

where R is the run-off, P is precipitation and T is the temperature.

The run-off is the residue of precipitation after the deduction of losses. The common loss due to evaporation and transpiration, generally known as evapo-transpiration, is the function of temperature of the area concerned. Thus, Khosla's formula reads as follows :

$$R_m = P_m - L_m \text{ .... } 6.2$$

where R_m is the monthly run-off, P_m is the monthly precipitation and L_m is the monthly evaporation loss. Again, the amount of monthly evaporation loss (L_m) is given by

$$L_m = \frac{T°C}{0.2074} \quad .... \; 6.3$$

For determining the evaporation loss and the resulted run-off following Khosla's formula, the investigator has obtained the average monthly rainfall data from the Darjiling Agricultural Office; and are represented in the following Table 6.1.

Table 6.1

Estimation of Water Resources of Darjiling Town

Months	Rainfall in mm	Temperature in °C	Evaporation loss (mm)	Evaporation loss as % of rainfall	Run-off in mm	Run-off as % of rainfall
Jan.	12.6	5.93	28.59	-	-15.99	-
Feb.	27.5	6.64	32.02	-	- 4.52	-
March	50.4	9.98	48.12	95.48	2.28	4.52
April	105.4	13.09	63.12	59.89	42.28	40.11
May	210.5	15.02	72.42	34.4	138.08	65.6
June	538.3	16.52	79.65	14.8	458.65	85.2
July	758.6	16.86	81.29	10.72	677.31	89.28
Aug.	604.8	19.84	81.20	13.43	523.60	86.57
Sept.	426.5	15.98	77.05	18.07	349.45	81.93
Oct.	136.7	14.14	68.18	49.88	68.52	50.12
Nov.	22.7	10.42	50.24	-	-27.54	-
Dec.	5.1	7.54	36.36	-	-31.26	-
	Σ 2899.3	12.41	Σ 718.22	24.77	Σ 2180.86	75.23

Source : Darjiling Agricultural Office (1915-92)

It has been estimated from Table 6.1 that the total average run-off of Darjiling town is about 2180.86 mm and the total geographical area of Darjiling municipality is 10.56 sq km . That means a total estimated water resources of the study area would be about 23.117116 million cubic metres. The availability of total water is 2.18086 $m.m^3/km^2$ in Darjiling town which is definitely much less than that of neighbouring Balason and Mahananda catchment where the amount has been estimated to be 2.6142 and 2.472 $m.m^3/km^2$ respectively. Thus, the study area definitely suffers from that of its neighbouring area. Yet, about 2.18086 m^3 water is available per sq. m. of area which seems to be enough for the domestic and other uses of the local people. But, the problems are two fold :

i) the water resource is only available during the 6 monsoon months (June to October) while, the lean months (Nov. to May) remain dry and waterless and

ii) the lack of proper and adequate storage facilities.

Thus, the so called scarcity and eventually acute water shortage develops during the lean months. To overcome this problem, the early builders of the town made alternative arrangements to supplement the water requirements by making inter-catchment transhipment of water. The construction of Senchal lake reservoirs was the right arrangement in this regard.

C. WATER SUPPLY OF DARJILING TOWN

The water supply system of Darjiling town involves the tapping of 26 springs in the catchment area of Senchal Forest and wild life sanctuary into a masonary conduit channel and collecting the discharge into three Senchal lakes (name, capacity and the year of installations have already been mentioned), the combined capacity of these lakes being 48 million gallons. From these lakes water flows to the filter house situated at Jorebunglow where filtration is done through pressure filters and then water is conveyed through large water mains to reservoirs at St. Paul's School estate and Rock Ville. The capacity of St. Paul's Reservoir is 2,35,812 gallons and that of Rockville being 1,14, 663 gallons. From these main reservoirs water is distributed over the town through subsidiary tanks located at various places and also directly through distribution mains of various diameters. There are about 19 distribution mains each from Rockville and St. Paul's Tank (Fig.6.2).

The existing water supply installations were meant for a population of about 15,000 during the year 1910-1915, thereafter a number of water supply installations like Khong Khola pumping station, Rambi water line, Bokshi Jhora and Bangla Khola were added, but these could not cope up with the rapid increase in population, as a result of which acute scarcity of potable water persists, specially the period between December to May has remained a constant feature for the last quarter century. But the the crisis during the last 15 years or so has reached a peak due to the drastic fall in the volume of water at natural springs of catchment area due to massive deforestation (Table 6.2).

However, if we consider the supply of water throughout the year, we may find that there is no crisis or shortfall in supply

DISTRIBUTION OF DRINKING WATER IN DARJILING TOWN.

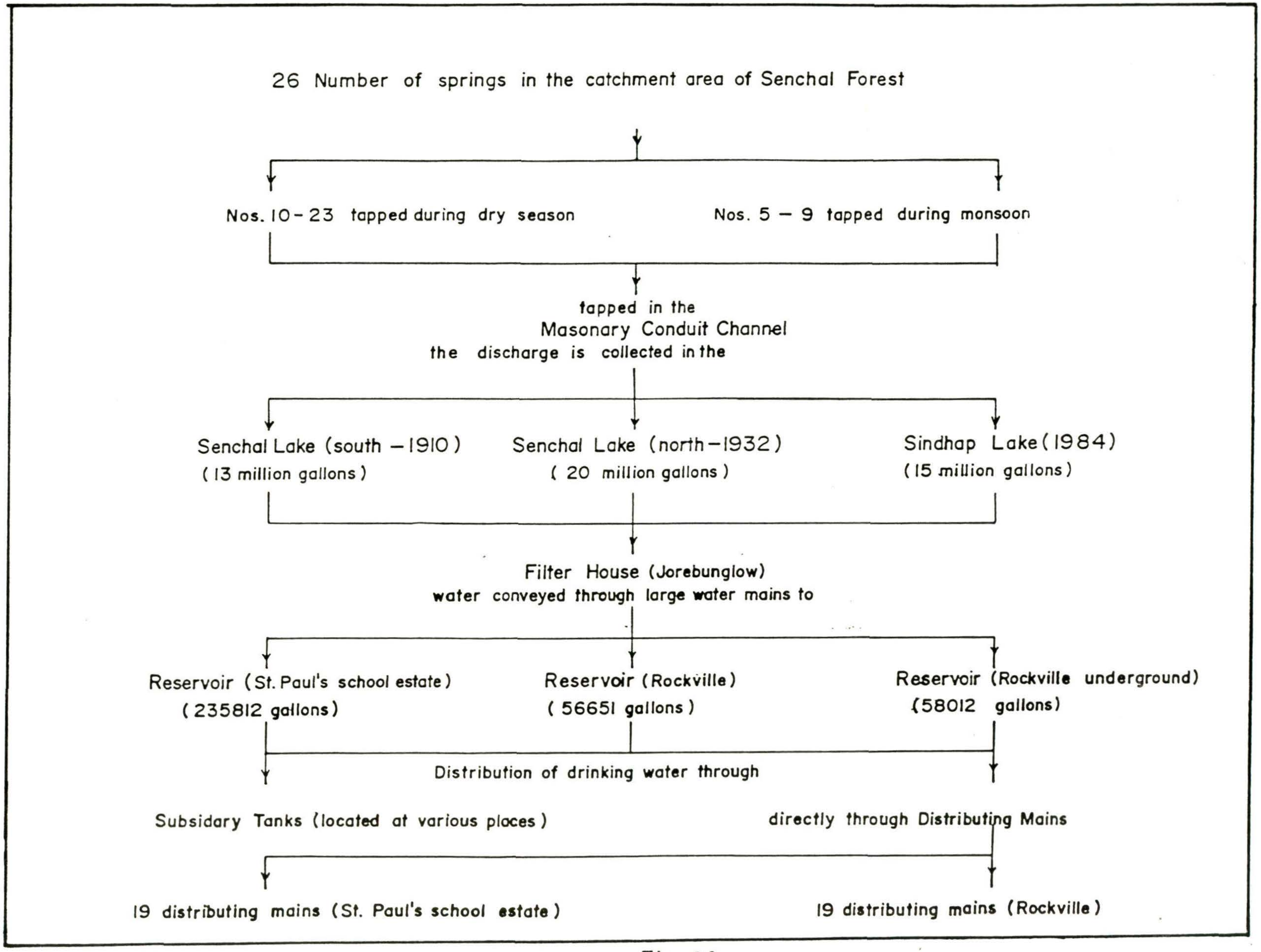

Fig – 6.2

Table 6.2

Water Supply for Senchal Lake during Lean Month

Months	1980	1981	1982	1983	1984	1985	1992	1993
Jan.	36000	32000	23000	24000	27000	28000	25000	27800
Feb.	26000	22000	22000	22000	18000	20000	18100	19930
Mar.	29000	23000	18000	18000	15000	14500	12500	13160
Apr.	DNA	DNA	DNA	DNA	DNA	DNA	14100	16500

(Data from 1986 to 1991 is not available.)

Source : Darjiling Municipalicy Report 1991 and Rumba 1986.

during the Monsoon and post-monsoon season (June to November) when the natural springs feeding Senchal lake offer a continuous supply and thereby, it is possible for the Municipal Authority to supply more water to the urban centre. Thus, a peculiar situation arises i.e. during monsoon when individual citizens may be able to collect rain-water for their daily needs i.e. the real requirement is less, yet they are getting more water from the pipe supply, while the reverse takes place during the lean months.

Table 6.3 & Fig.6.3 shows the average monthly water supply (1992-1993) in relation to the average monthly rainfall (1992-93) in Darjiling town. While Fig.6.4 shows the fluctuation of water level in the Senchal Lakes (North and South) and two storage tanks at St. Paul's School and Rockville. It also reveals the strong seasonal availability of water at Senchal Lakes and storage tanks.

Thus, it is evident from the above analysis that the

COMPARISION OF AVERAGE MONTHLY RAINFALL AND AVERAGE MONTHLY WATER SUPPLY OF DARJILING TOWN

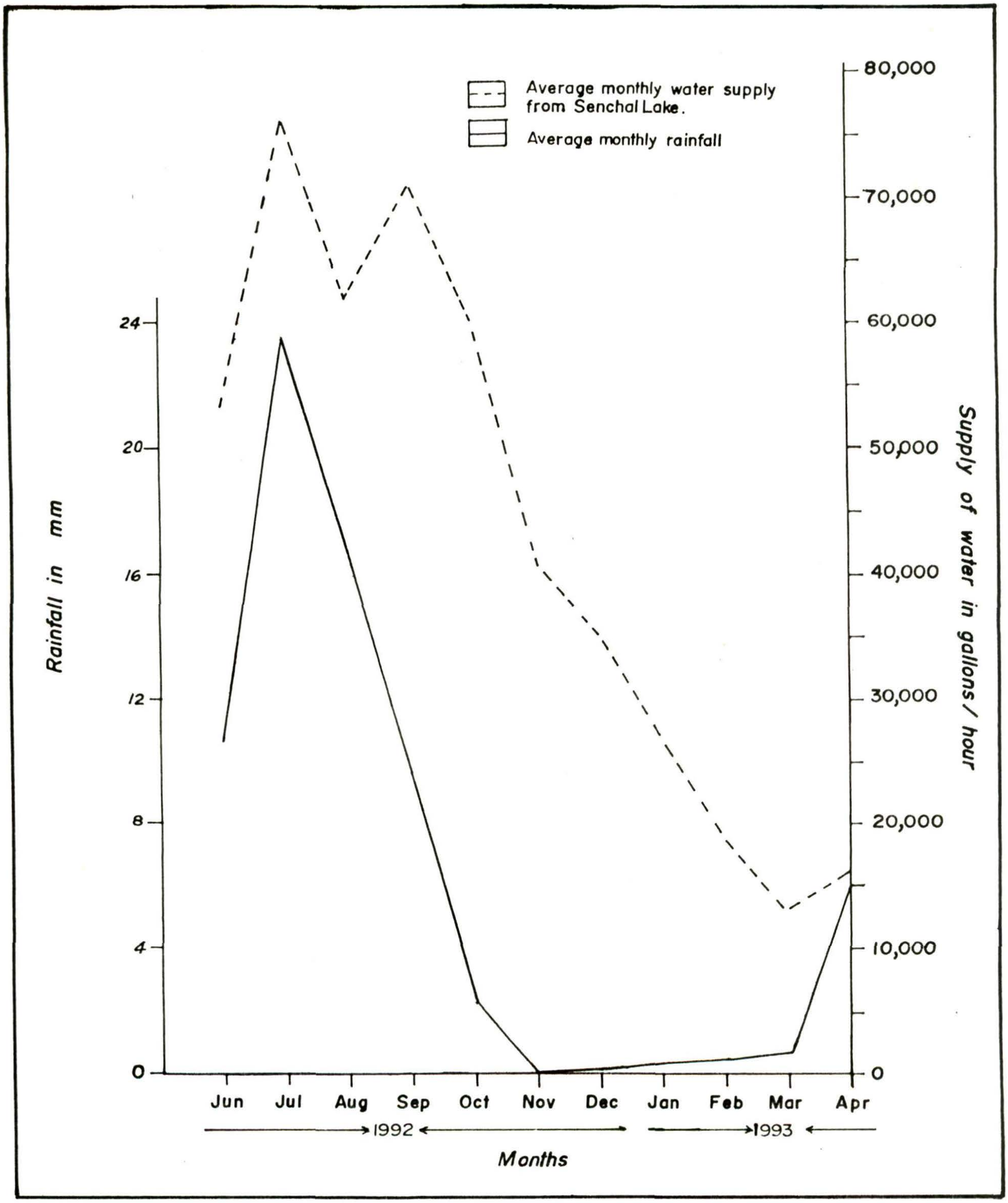

Fig-6.3

DIAGRAM SHOWING THE WATER LEVEL AT SENCHAL LAKE, St. PAUL'S AND ROCK VILLE RESERVOIR

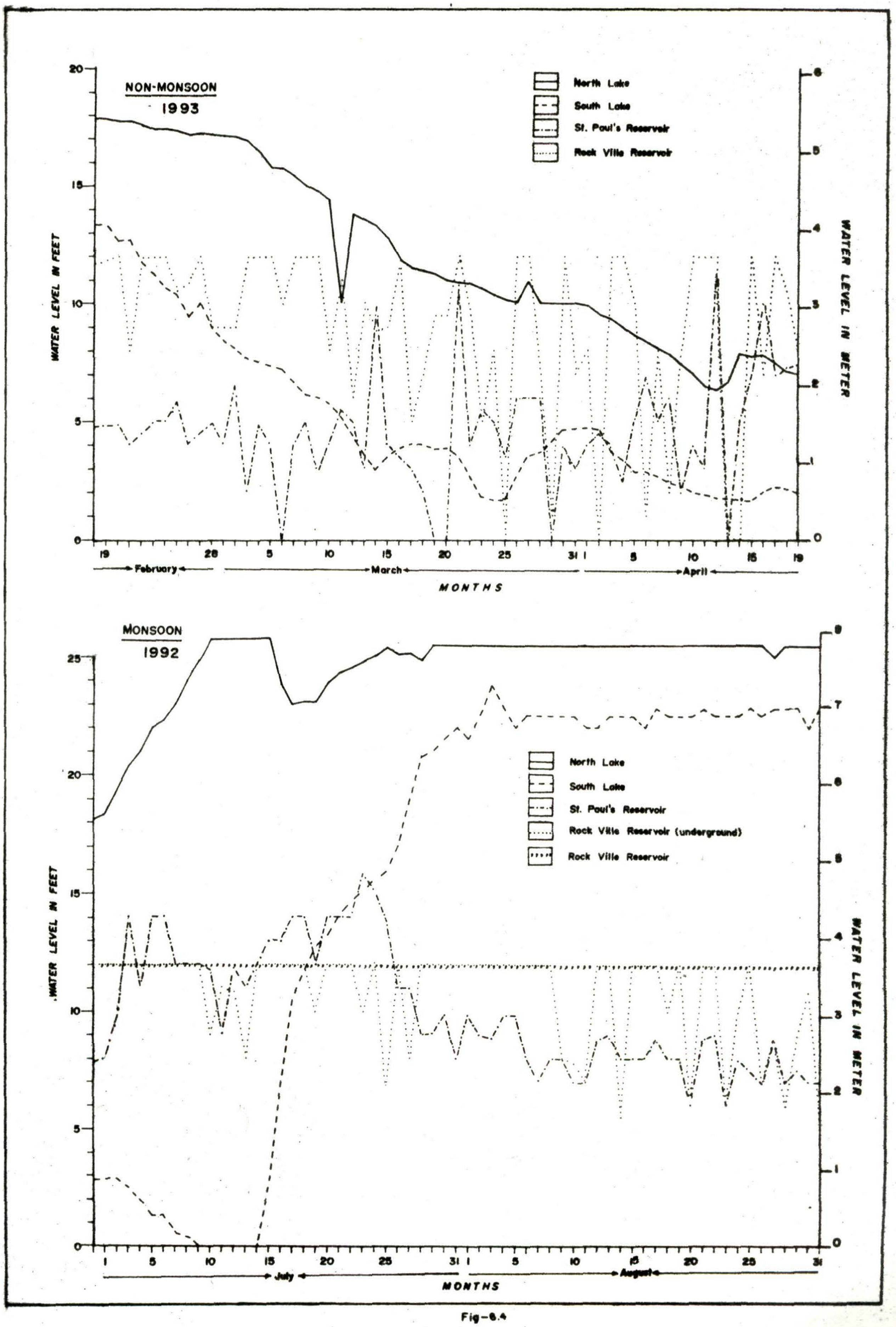

Fig-6.4

Table 6.3

Average Monthly Water Supply and Average Monthly Rainfall of Darjiling Town

Months		Average Water Supply from Senchal in gallons/hours	Average rainfall in mm.
June	1992	51303	10.46
July	"	76323	23.40
Aug.	"	62806	16.69
Sept.	"	71200	9.60
Oct.	"	60000	2.23
Nov.	"	41900	-
Dec.	"	35839	0.11
Jan.	1993	27806	0.55
Feb.	"	19928	0.66
March	"	13161	0.84
April	19 days	16684	5.82

Source : Agricultural Office and Municipality Office, Darjiling.

availability of fresh supply of water from jhoras have become bleak day by day. For a short term immediate measure it is imperative to increase the existing storage capacity from excess monsoon water which may be discharged through the conduit system during lean months. While afforestation is a must to create an environment which will boost up infiltration capacity and reduce surface run-off during monsoon so that the water stored in the soil may be available as springs or seepage during lean months and thereby, ensuring a year round modest supply.

D. TOTAL WATER REQUIREMENTS

The present population (1993) of Darjiling town and its surroundings is about 1,00,000 and with another 20,000 floating population i.e. school and college students, a total of about 1.20 lakhs of population for whom water has to be provided during the crucial dry season i.e. February to mid-June.

The approximate water demand for the population of about 1,20,000 is stated as below :

i)	Domestic demand, taking 10 gallons/head/day as against 30 gallons/head/day as per Indian Standard	12,00,000
ii)	Industrial and Commercial water demand 10% of total	1,20,000
iii)	Public Utility : 5% of total	60,000
iv)	Fire Demand	....
v)	Water required to compensate losses in leakage, waste theft etc. 20% of total	2,40,000
	Total (in gallon/day)	16,20,000

So, there is a wide gap between the demand and supply of water in Darjiling town, particularly during the dry period. It is evident from the table only 17.53% of the actual water requirement may be met through the Municipal Water supply system. Hence, there is always an acute scarcity of water during the dry period i.e. from February to mid-June.

The approximate water available during the dry period may be taken as follows :

i)	Water available through conduit (6,000 gallons x 24 hours)	1,44,000
ii)	Water available from Khong Khola pumping station 5,000 gallons x 24 hours	60,000
iii)	Water available from Sindhap lake 10,000 gallon x 10 hours	1,00,000
iv)	Water available from Rambi line 1,500 gallon x 24 hours	36,000
	Total	3,40,000 gallons
	Less drawn by Army at Alubari Pumping station 5000 gallon x 5 hrs	25,000
	(3,40,000-25,000) =	3,15,000
	Less for leakages etc @ 20%	63,000
	Total	2,52,000
v)	Water available at Bokshi Jhora (approximately)	12,000
vi)	Approximate water available through other natural springs at various places like Laldhiki jhora, Bhagyakul, Bhotay jhora, Giri jhora etc.	20,000
	Total in gallons/day	2,84,000 gallons

Besides these, the existing distribution network of water supply in Darjiling town is run by operating valves manually which are situated all over the town. Most of these valves are very old as a result of which there are perennial leakages and unequal distribution. Moreover all these valves are being manually operated they are prone to human error resulting in unequal or faulty distribution system (Photo 6.2 & 6.3).

In the said circumstances the Darjiling Municipality is of the opinion of carrying out the following measures for improvement of water supply to the town.

1. Short Term Measures :

i) Total stoppage of felling of trees at the Senchal catchment area.
ii) Massive afforestation drive at the said Senchal catchment.
iii) Realignment and reinforcement of protective works of existing Rambi pipe line.
iv) Construction of new pumping stations at Rambi Forest below Rambi village to augment the existing water suply at Rambi pipe line by 2 stage pumping.
v) Complete change of all the leaking valves and other leakages.

2. Long Term Measures :

i) Feasibility report for pumping water from Rungdung or Rangit river.
ii) Preparation of master plan for water supply management like new schemes, administratation and revenue collection and maintenance etc.

6.2

Road side pipe leakage.

6.3

iii) Alternative feeder mains via Hill Cart Rd.

iv) Construction of large storage reservoirs at suitable places.

v) Exploration of all natural springs.

vi) Separation in supply of potable water and water for other uses.

The investigator, during the field study felt that some augmentation of water availability to the town would perhaps be possible with the proper tapping of Jhoras. The water available from Bokshi jhora and Giri dhara have already been successfully tapped. The discharge of Bhotey jhora at Singamari is small, but it can still cater to some nearby houses. Laldighi is another minor source, which is already being utilised by local people and perhaps by tapping it at night, one could obtain some more water. These are minor issues when looked at from the point of view of the total requirement of the ever expanding town. (Rumba, 1986). For a permanent solution the following suggestions may be put forward.

a) To utilise the water from Rangit river by stage pumping. It involves the lifting of water from a distance of 20-30 km at an altitude of 2500 m. The required power may be available from the nearby Ramman Hydel Project at a cheaper rate. Definitely, the water so pumped will be more expensive than at present.

b) The perennial streams like Siri khola, Rithu khola, Dilpa khola, Kali khola which have sufficient water at an elevation of over 2400 m. can be tapped to augment the water supply system of Darjiling municipality. This scheme will also be of service to the people of Sukhia Pokhari, a growing town, where the water supply system is very inadequate for lack of any perennial spring nearby (Rumba 1986).

A thorough survey of the water resources in and around Darjiling municipality should be made, particularly of springs and their discharges. It is evident from the historical documents that many of the high yielding jhoras are gradually becoming dry. Headless deforestation, haphazard constructional work in other words, unplanned useage of land, have definitely altered the natural pre-urban hydrological cycle of this area. Deforestation curtails a good amount of infiltration and increases surface run-off and thereby increases the rate of soil erosion and mass-movement. This also cuts the supply of seepage water which ultimately feeds the jhoras during dry season (Fig.6.5).

Table 6.4

Monthly Average Yield of Water From

Vineeta Jhora During 1991-93

Months	No. of sampling days in a month	Average yields in gallons/hr.	Total yield of the month in gallons
January	3	52	38,688
February	5	41	27,552
March	11	30	22,320
April	8	21	15,120
May	13	15	11,160
June	6	75	54,000
July	10	115	85,560
August	4	164	122,016
September	16	126	90,720
October	9	96	71,424
November	1	85	61,200
December	7	61	45,384
			Σ645,144

SEASONAL YIELD OF WATER FROM THE JHORA NEAR ST. PAUL'S SCHOOL, DARJILING SINCE 1991-'93.

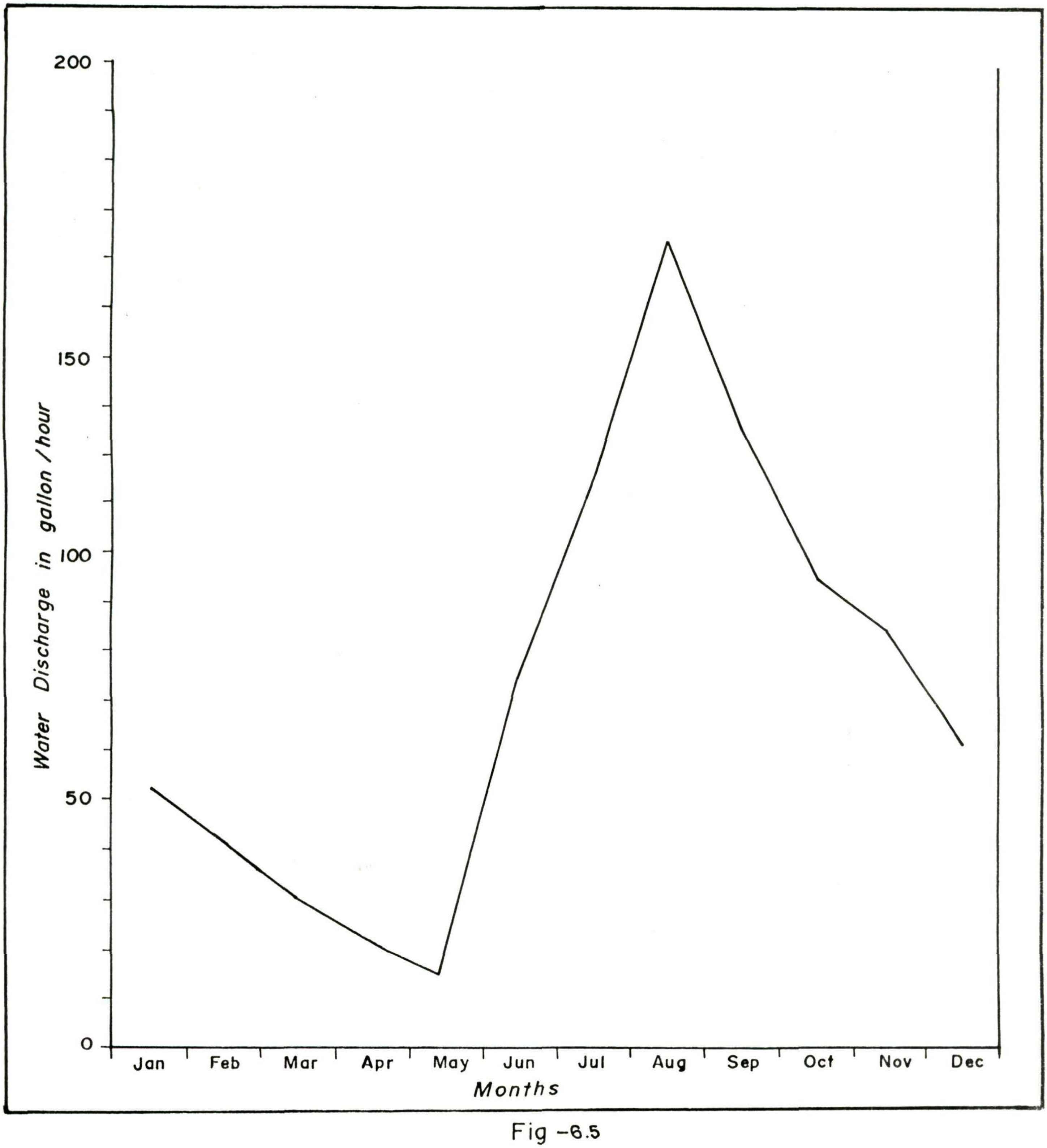

Fig -6.5

Data collected by the investigator from the jhora site with the help of a measuring bucket and a stop watch.

Fig.6.5 and table 6.4 shows that the discharge of water from Vineeta jhora is highly seasonal. The peak yield has been found during the mid-monsoon (August) which has been estimated to be 164 gallons/hour while May is the driest month when the discharge becomes as low as 15 gallons/hour i.e. about 11 times less than that of the peak discharge. Such a strong seasonal distribution of water discharge reflects i) strong seasonal distribution of rainfall and ii) lack of proper protective cover of natural vegetation which may often retain monsoon water and discharge it during lean months as springs and seepages.

E. SEWERAGE

The Sewerage system of Darjiling Town was constructed more than 50 years ago with the majority of the liquid waste of the town being disposed off by the following 5 existing Community Type Septic Tanks (Fig.6.6).

1) Bazar septic tank; (2) Wilson septic tank; (3) Kagjhora septic tank; (4) Bhutia busty septic tank and (5) Tukvar septic tank (Fig.6).

Bazar septic tank is the largest of all, situated just below Victoria Rd. in between slaughter house and the Jail (Photo 6.4). The tank is fed with 4 sewer mains and other network of sewer lines connecting about 2,000 holdings of Belombre section, parts of Gandhi Rd., parts of Dr. Zakir Hussain Rd., Rockville, Laden-la

SEWER SYSTEM OF DARJILING MUNICIPALITY

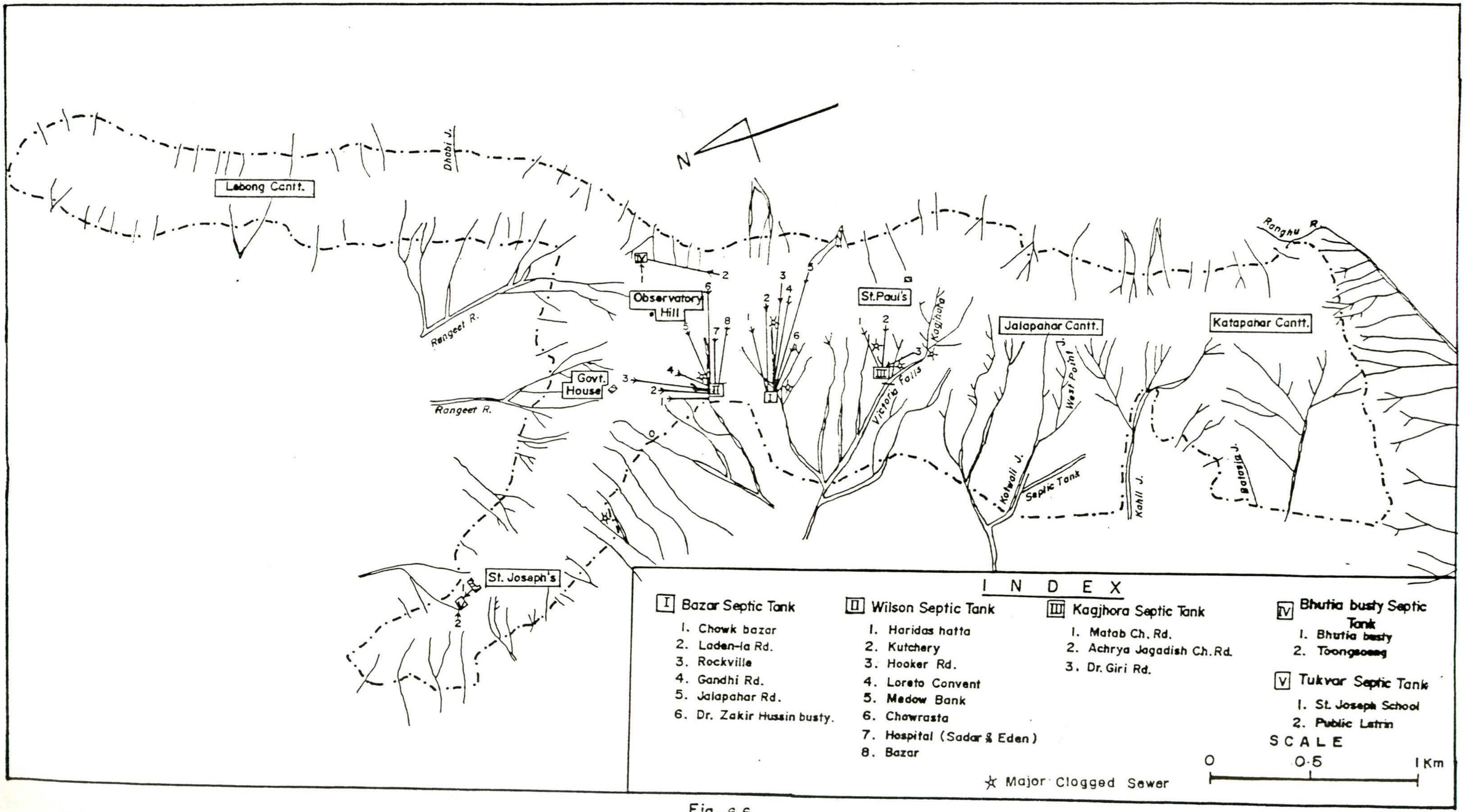

Fig-6.6

6.4

Bazar Septic Tank between the Jail and the Slaughter house.

Rd., Chowk Bazar, Dr. Zakir Hussain busty etc. comprising of schools, hotels, public latrines, Govt. offices and residential buildings.

Wilson septic tank, the second largest is also situated just below Victoria Rd. near Botanical Garden. This tank is fed with 3 sewer mains and other network of sewer lines connecting about 600 holdings of Chowrasta, Medow Bank area, Sadar and Eden Hospital area, part of Bazar, Hooker Rd., Kutchery, Loreto Convent, Haridashatta etc. comprising of hotels, schools, public latrines, Govt. offices, Govt. quarters and residential buildings.

Kagjhora septic tank is situated above Victoria Rd. in Victoria Falls (Photo 4.17). This tank is fed with 2 sewer mains with network of sewer lines connecting about 250 holdings of parts of Gandhi Rd., A.J.C. Bose Rd., Mahatabchand Rd., Queens Hill Area, Dr. Giri Rd., Forest Office etc. St. Paul's School area (now dislocated) comprising of Govt. offices and quarters, schools, public latrines, hotels and residential buildings.

Bhutia busty septic tank, situated at the lower portion of Bhutia busty is fed by 2 sewer mains with very little network of sewer lines catering only about 50 holdings comprising of residential buildings and public latrines.

Tukvar septic tank is situated at the northern side of North Point Ground and it caters the liquid waste of St. Joseph's School and the public latrine.

Rest of the areas have got service privies and few affluent houses have individual septic tanks.

All the above mentioned septic tanks do not have any soak pits, the affluents are allowed to settle within the tank for certain time for bio-chemical process and are drained off in the nearby jhoras. The existing septic tanks are catering only about 2,900 holdings within the entire municipal limit right from Jorebunglow to Ging for the last 50 years.

The existing sewer lines have remained a constant source of nuisance due to the following reasons :

i) Worn out condition due to old age.

ii) Blockage for want of water for regular flushing as well as the habit of the local people to use papers instead of water.

iii) The entire sewer main right from hill top to septic tank have got a uniform diameter pipe as such the load it carries from hill top with great velocity are often seen overflowing at different inspection pits, situated at lower level.

iv) Due to the increase in population and holdings, the existing sewer mains and its tributaries are always overloaded.

The septic tanks situated on the outskirts of the town do not cater majority of the holdings because of their sporadic location specially in Hermitage, Holmdene, Bhutia busty, Toongsoong, Ging, Singamari, Rockwood, Haridashatta, Rose Bank, Lhasa Villa, Bllomfield etc. do not have other choice but to install their own independent septic tanks which have either soak pits or are directly connected to the nearby jhoras. In many places where the topography do not permit to install septic tanks and soak pits, people have no alternative but to install a bucket system latrines. As a result of which most of the night soils are drained in the nearby jhoras, causing more and more insanitary environments. Moreover, the areas where the soak pits are constructed are becoming prone to landslips. A burning example of this situation are the areas around Rockwood, Hermitage, Singamari, Kagjhora, Rajbari, Toongsoong etc. where the land is slopy and houses as well as Septic Tank and soak pits are constructed one on top of the other (Photo 6.5 & 6.6).

The major problem of the existing sewerage system or the network for regular flushing is due to insufficient availability of water. Darjiling town has been facing the problem of drinking water since the last 15 to 20 years. Most of the public latrines connected to the main sewerage system used to get water for flushing from the drinking water mains which has now been stopped to meet the greater need of the people for drinking water.

1. Proposals of Darjiling Municipality regarding Liquid Waste Disposal :

From the Municipality report it is evident that the existing network of sewer lines is very inadequate as it mostly covers the heart of the town only. To provide a healthy sanitation within the municipality area, more septic tanks either of community type or of bigger dimension should be installed at various suitable places and accordingly the sewer main networks should be laid. Such places include Bloomfield, Lasha Villa, Nimkidara, Mary Vila, Rajbari, Rose Bank, Toongsoong, Bhanu Gram, North Point, Bhutia busty, Hermitage, Limbu busty etc.

The existing Kagjhora Septic Tank which is situated above the

Victoria Falls Bridge should be shifted further down, with a greater capacity than the existing one so that it can give a greater coverage for areas like Rockwood, Chota Kagjhora, portion of Rajbari, Dhobi tala, Mangal pur, Bhaktay busty etc. This will facilitate the installation of sewer main networks right from the hill top of St. Paul's School and down below, this region has an added advantage of having a number of jhoras with perennial source of water which can be utilised for slushing the sewerage mains.

A suitable location for the installation of a new and big septic tanks in the lower region of the Happy Valley tea garden which will cover the localities of Raj Bhawan, Kutchery, Hooker Rd., portion of Bhanu Gram, Haridashatta, Medow Bank area, Loreto Convent, St. Treasa's School etc. This will help to minimise the already overloaded Wilson septic tank and function more efficiently.

To give a wider coverage to Singamari area septic tank can be installed below Bhotey Dhara. To cover the entire portion of Toongsong, Jawahar busty, Youth Hostel, Junior B.T. College, the eastern part of Bhutia busty, Dant Kothi complex, a septic tank at Pandam tea garden will be of great use to promote a sound sanitation.

As far as Batasia area is concerned, the existing houses are at sporadic location, but is rapidly urbanising, so to provide future sanitation facilities the entire Batasia zone should be divided into two zones and accordingly, community type septic tanks at lower level below Hill Cart Rd. should be constructed.

A community type septic tank at the gorge of southern side of Bloomfield can cover the entire area of Samten Choling Monastery compelx, Bloomfield club side area, newly constructed Police barrack etc. For the other hill side of Bloomfield, West Point area and a portion of Nimkidara a community septic tank at the lower part of Bahgaykul will suffice the purpose.

A big septic tank below Shyam Cottage will cover a part of Nimkidara, Mary Villa, Limbu busty, Shyam Cottage and the upper part of Rose Bank.

The existing sewer lines of these areas should be remodelled, modified and pipes with bigger diameter should be laid along the existing alignment with inspection pits at suitable intervals.

Provisions for tapping all the available jhoras/drains of the town at higher levels with sedimentation and screening facilities of the waste water and injecting the same to the main sewer lines should be there.

All the reasonable places of installation of septpic tanks should have provision for basic treatment of liquid waste, and drying spaces for preparation of manure etc. The project as a whole should be suitably divided into phases and work should be taken up immediately.

F. HYDROLOGY OF DARJILING TOWN

The hydrology of Darjiling town has been modified during the different stages of urbanisation. These changes involve the network of water collection, treating, transmitting, regulating and distributing pipes and chambers, the urban water supply system and the culverts, gutters, drains, pipes, sewers and channels of the urban waste-water disposal and storm-water drainage systems (Kuprianov, 1977 and Lyovich and Chermogaeva, 1977). The impact of land-use changes and urbanisation on the hydrology of the study area along with its sequential changes in different stages of urbanisation have been discussed and analysed under the following headings :

1. The Impact of Urbanisation on Precipitation :

Precipitation is altered by the urban environment, but the nature and degree of such alteration is neither well established nor common to all urban centres of the world (Douglas, 1983). Urbanisation appears to affect precipitation by increasing in hygroscopic nuclii, in turbulence via the increased surface roughness, in convection because of increased surface temperatures and through the addition of water vapour of combustion sources.

Water vapour and particles carried into the atmosphere from urban affluent sources create a downwind enhancement of precipitation over large cities (Oke, 1980). Chandler (1976) shows an increase of 5-15% of annual total during downwind of urban areas. While, Tabony (1980) has argued that annual and seasonal rainfall trends in London do not display any features which can be attributed to urbanisation. Despite all these facts, in some cities, perhaps in particular topographic and weather situations, increased thunderstorm activity has been clearly demonstrated (Douglas, 1983). Such increased high intensity storm rainfall create large quantities of storm water run-off to be carried into drains and storm water disposal channels of the town. This also plays an important role in the urban hydrological cycle.

Almost every human activity involves the generation of some heat and moisture or by-products especially the burning of fossil fuels. However, in Darjiling where topography exerts a paramount impact on micro-climatological characteristics it probably overshadows the impact of urbanisation on precipitation.

The investigator has tried to establish a correlation between urbanisation and the amount of precipitation with the help of the available rainfall data (annual) of about 100 years (Fig.6.7). The result it, however, not satisfactory as its shows the annual rainfall pattern highly fluctuating in nature. The graph shows a high rainfall year followed by a low rainfall year or vis-a-vis. Whether rainfall is increasing or decreasing due to the effect of urbanisation in the study area cannot be conclusively proved from the present study. However from the study of 20 years of running average some conclusions may be drawn i.e. upto 1930 there was an increasing tendency but, since then, there is a clear indication of a decreasing tendency.

2. Evaporation from the Urban-Landscapes :

The rate of evaporation from an urban centre is not yet well understood (Douglas, 1983). Lull and Sopper (1969) estimated that annual potential evaporation would be reduced by 19, 38 and 59 percent if a forested water-shed were converted to 25, 50 and 75 percent impervious cover respectively. It should also be remembered, that a small shower may wet a paved or concrete surface

DISTRIBUTION OF RAINFALL OF DARJILING TOWN (100 YEARS)

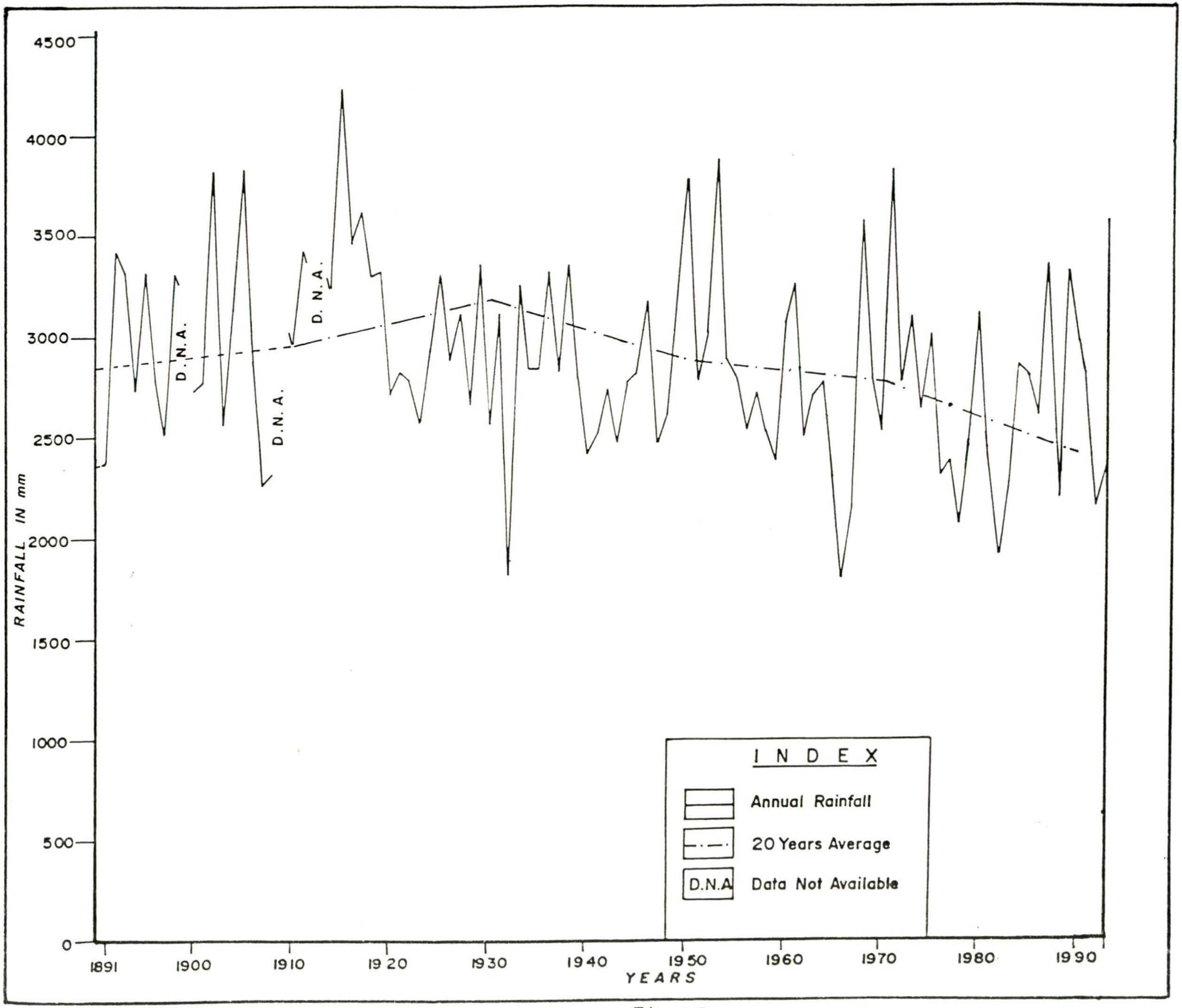

Fig-6.7

with water being held in puddles in depressions and irregularities of the surface. This water evaporates rapidly once the clouds are cleared and the sun heats the surface. Thus, the urban area of Darjiling involves less retention of moisture and rapid return of moisture to the atmosphere through evaporation.

As, the urban centre keeps the air warm by nocturnal heat loss from buildings and paved surfaces, the process of transpiraton from plants in urban areas may continue during the night, often depleting the moisture content of the soil. Despite the strain on their water regime, deep-rooted trees and shrubs on the hill-slopes and crests continue to transpire, producing a cooling effect on their urban surroundings through their use of heat energy in the conversion of water to vapour. In the present study, however, no quantitative assessment of this kind has been made.

3. Infiltration :

Paving and roofing an area reduces the opportunities for water to infiltrate. Darjiling town is not completely paved and even the paved surfaces have cracks and joints from where water can move down to the urban sub-soil. Thus, the amount of infiltration is a product of the surface cover and the water applied i.e. artificial application of water to the parks, gardens etc. may add much sub-surface water through iniltration under non-urban conditions within the urban environment.

The investigator has tried to analyse the rate of infiltration in the study area. This has been measured from 15 sample sites situated in different ecological set-ups and under different land-uses (Fig.6.8). The rate of infiltration was measured with the help of a galvanised steel tube with a diameter of 20 cm. which was inserted into the soil with a head of water of 6 mm. The results are tabulated in Table 6.5 and are analysed and diagrammetically represented in Fig.6.8.

Table 6.5

Sl. No.	Samples sites	Altitude in metres	Rates of Infiltration in milimetres				
			0-15 mts	15-30 mts	30-60 mts	60-120 mts	Total upto 2 hrs
1.	Near Batasia	2201	489	293	241	69	1092
2.	Near Ghum Quarry	2231	763	115	63	85	1026
3.	Tiger Hill	2469	179	94	63	29	365
4.	Near Senchal Lake	2432	431	193	141	93	858
5.	Near Katapahar	2317	583	308	313	105	1309
6.	(West Point) Near Petrol Pump	2164	240	150	65	31	486
7.	Near Tenzing Rock	1950	121	35	40	15	211
8.	Lebong Circular Rd.	1856	385	125	82	31	623
9.	Below Govt. College	2110	185	58	10	5	250
10.	Jalapahar Crest	2292	81	15	13	5	114
11.	Near Quarry (St. Paul's School)	2230	130	21	35	10	196
12.	Near Saila Bash	2240	95	15	10	3	123
13.	Alubari	2317	215	83	49	25	372
14.	Botanical Garden	2073	145	46	32	12	235
15.	Below the Jail	1890	161	21	15	8	205

Sample Survey was conducted during September-October 1992, by the investigator.

INFILTRATION CURVES OF 15 SAMPLE SITES
IN AND AROUND DARJILING TOWN

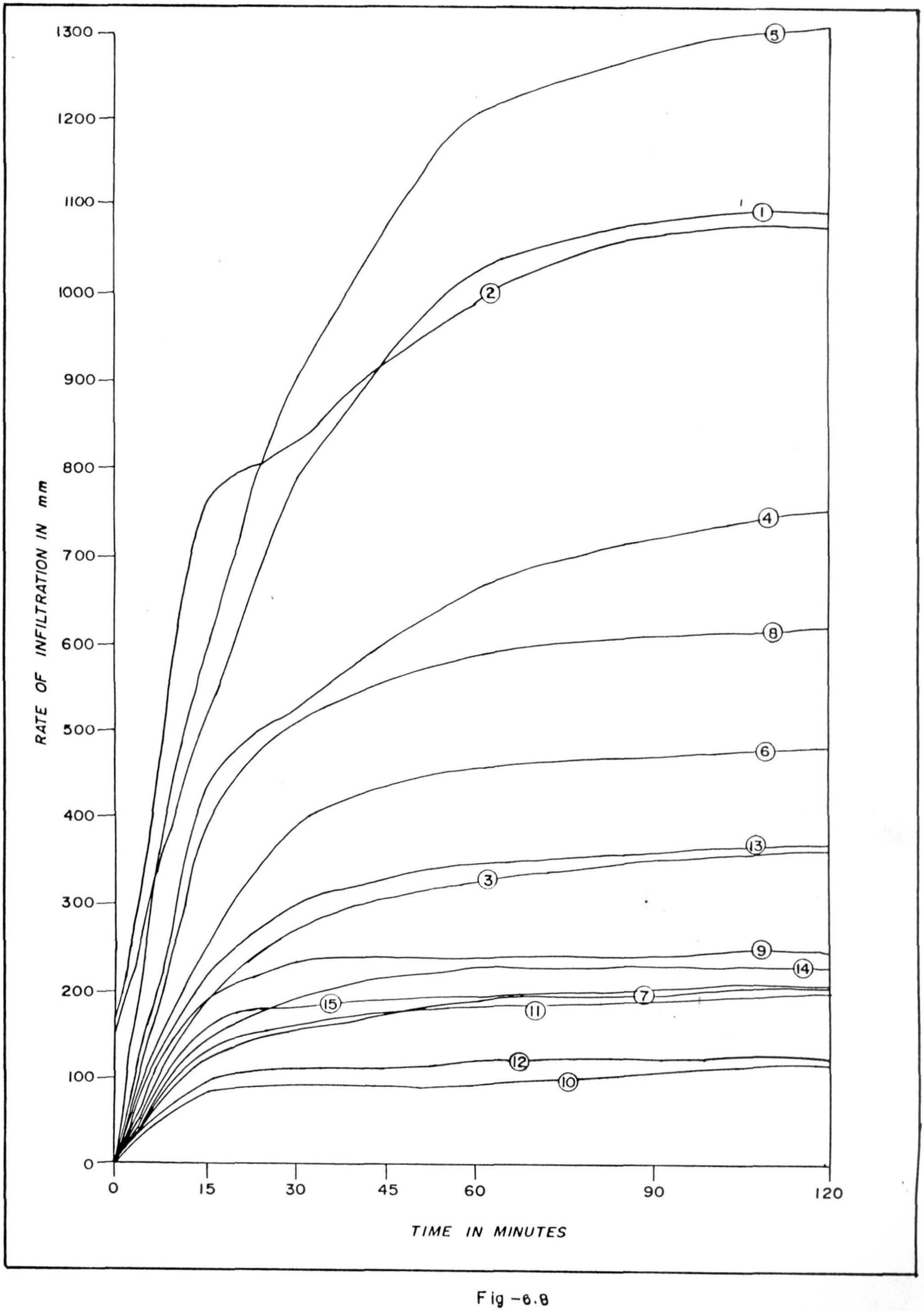

Fig -6.8

The analysis of table 6.5 and Fig.6.8 show some stiking results relating to urban infiltration. The infiltration curves (Fig.6.8) show a wide variation in its rate over time. In most cases water infiltrates most rapidly during the first 15 minutes and eventually becomes sluggish during the 2nd hour of study. This reveals that the texture of soil and/or parent materials is fine. Forested tracts without thick moss cover often show more infiltration while, moss covered soil generally retard its rate. The rate of infiltration also depends largely on the nature of soil moisture content i.e. sample sites 7, 10 and 12 show a very slow to sluggish rate due to saturated soil conditions; while a very high rate has been noticed at the sample sites 1, 2 and 4 due to coarse parent materials and gentle slope ($<3^{\circ}$).

Thus, the soil-water body vis-a-vis infiltration rate in Darjiling is extremely diverse in nature, some areas especially the intensely built-up and largely paved area (sample site No. 6, 9 and 11), being virtually devoid of replenishment by infiltration, others especially gardens, lawn and recreational grounds (sample site No. 1, 4 and 5) possibly have more infiltration than the adjacent lands.

4. Ground Water :

Most probably there is a negative correlation between ground-water sources and the rate of urbanisation. This relationship has been studied by a number of geomorphologists all over the world (Douglas, 1983). Unfortunately, due to topographic and other limitations the investigator has not been able to conduct any tangible study of ground water and its impact on Urban Hydrology.

5. Run-off :

Run-off in urban areas differ from that of the rural areas by changes in the total volume of run-off and concentration of water movement into bigger storm peak discharges (Leopold, 1968). James (1965) found 23% more run-off from a completely built-up area than from a non-urbanised area. According to Leopold (1968) the amount of discharge from a paved urban area will be 280 to 470% more than that of the non-urbanised area. However, changes in the lag-time between peak precipitation and peak discharge are crucial aspects of the urban water-balance, affecting the timing of flood peaks.

However, in the present study, the author has tried to estimate the total run-off in Darjiling town. It has already been estimated emperically, that the total amount of run-off to be 23.117116 million m^3. In addition to this a huge amount of water has regularly been input from Senchal reservoir, which has been estimated to be about 379.83 million gallons or 1.726245 million m^3. Thus, the total estimated run-off in the urban centre of Darjiling has been estimated to be 24.84336 million m^3 (i.e. 2.3437 m^3/square meter).

During the intensive field study, the investigator found that, after a heavy shower during monsoon, most of the sloping roads often act as natural way for run-off and/or overland flows. One such specific study has been conducted by the author during the monsoon of 1991. A stretch of 65 meters road near St. Paul's

School's main gate has been selected for such study (Fig.6.9). Rainfall amount has been recorded at a nearby station by the investigator herself with the help of a rain gauge and a stop watch.

Table 6.6

Rainfall Run-off relation (at the field site) near St. Paul's School's main gate, Darjiling on the 18th July, 1991

Altitude : 2200 m.

Distance from the hill crest : 350 m.

Slope : 17°

Time	Rainfall		Run-off	
	mm/h^{-1}	Total	mm/h^{-1} (peak)	Total
9.00	-	-	-	-
10.00	2.1	2.1	0.1	0.1
11.00	5.4	7.5	0.5	0.6
12.00	0.7	8.2	1.8	2.4
13.00	22.2	30.4	0.6	3.0
14.00	18.1	48.5	18.4	21.4
15.00	16.8	65.3	15.3	36.7
16.00	3.0	68.3	14.2	50.9
17.00	2.0	70.3	4.6	55.5
18.00	0.8	71.1	1.8	57.3

Data recroded by the investigator

Analysing Fig.6.10 and Table 6.6 some striking results are revealed regarding the rainfall, run-off and lag-time in an urban

LOCATION OF THE FIELD SITE FOR RAINFALL RUN-OFF STUDY

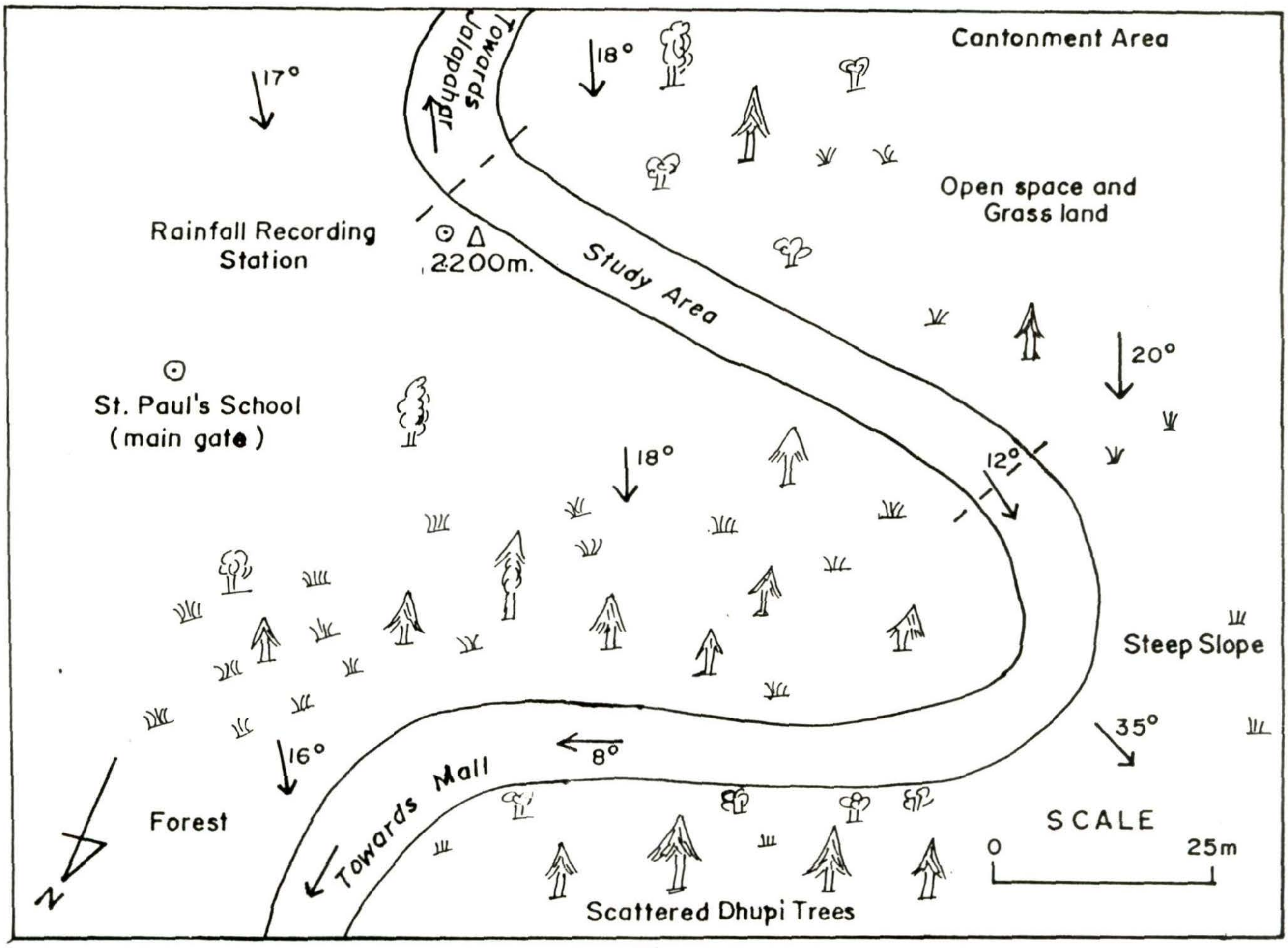

Fig – 6.9

RAINFALL RUN-OFF RELATION AT FIELD SITE NEAR ST. PAUL'S SCHOOL, DARJILING. ON 18th JULY 1991

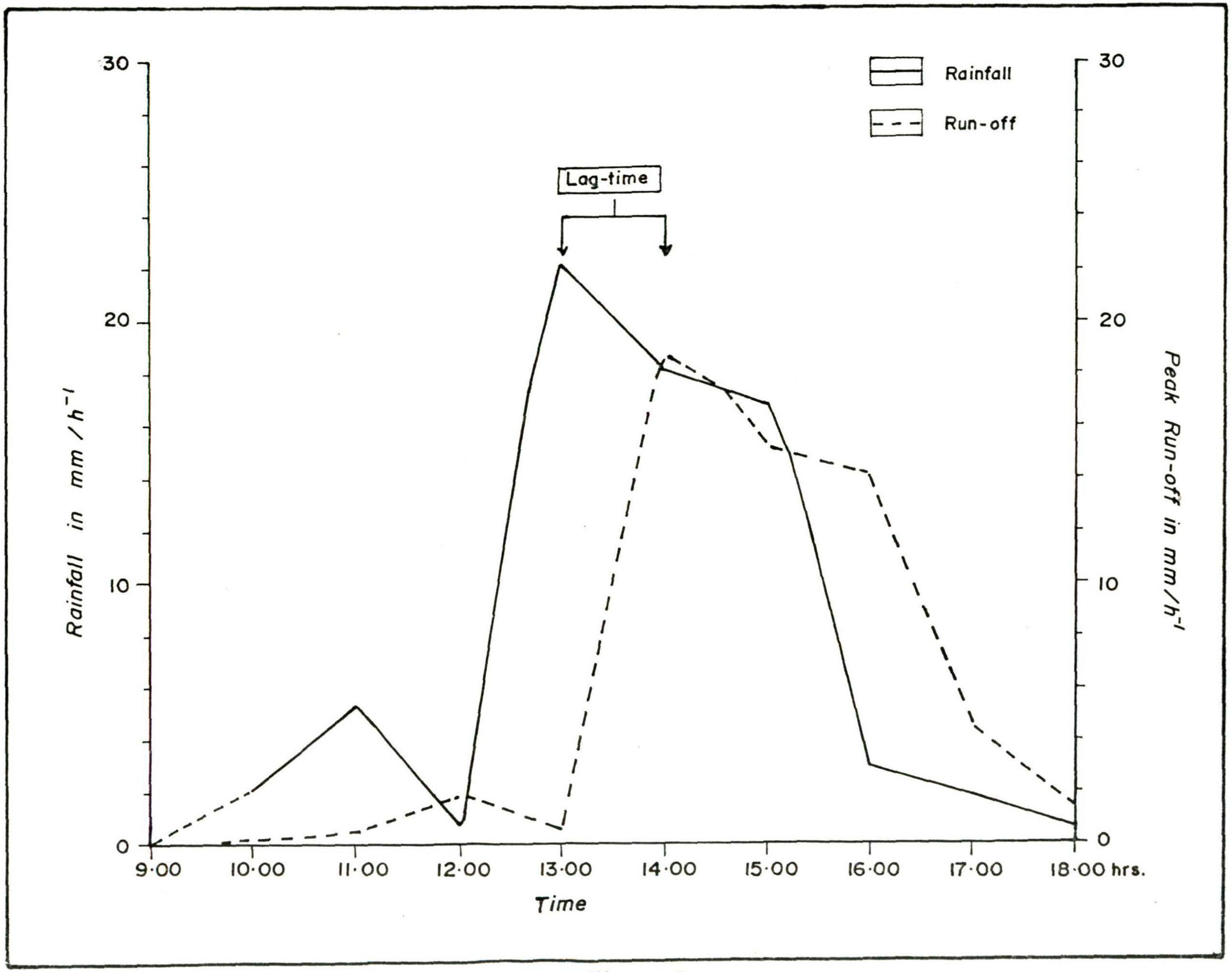

Fig-6.10

environment. The study area is situated at about 350 meters from the ridge and the average slope of the land is 17° while the slope of the studied road is 12°. The tracts have only about 25% of built-up area and paved surfaces; another 35% is under natural forests or shrubs, while the remaining 40% is under either grass cover or open-spaces. On an average 80.63 of rain water is available as run-off which is significantly high. This is perhaps explained by the fact that the ground has already been partially saturated by the rainfall that had occurred on the previous day which was estimated to be 40.0 mm on 17.7.91. The lag-time has been estimated to be about one hour, which again signifies the role of slope in the rate and timing of run-off and in particular over-land flow.

Thus, it has been apparent that the rate and movement of various hydrological parameters are associated with land-use changes and urbanisation. For instance the peak sediment production usually occurs during the modification of land-cover or land-forms. Gully erosion, channel extension and silt deposits usually occur with the removal of forest cover. Thoroughfall and surface run-off result from the removal of forest cover, bulldozing of slopes and cut-and-fill works which seem to be a common practice in an urbanisation processes. However, a detailed account of such a kind has been tabulated in table 6.7.

A careful study of table 6.7 reveals that the impact of such land-use changes and urbanisation on the hydrology of Darjiling town should not be viewed as mutually exclusive. In fact, particular types of impact are more associated with certain phases

Table No. 6.7

Impact of land-use changes and Urbanization on the hydrology of Darjiling town

Type of Effects																		
Positive increase: Major X, Minor x; Negative decrease: Major O, Minor o			Modification of landcover or landforms				Construction					Waste disposal			Channel Modifications			
			Removal of forest cover	Bulldozing of slope	Cut-and-fill	Terracing	Foundation works	Unsealed roads	Paved roads	Residential Building	Public utility Buildings	Septic Tanks	Sewer System	Waste Water	Roads & culverts	Dumping of debris	Strom water drainage	Channel realingment
HYDROLOGICAL PARAMETERS	Quality	Precipitation								x	x							
		Interception	O	O	O													
		Through fall	X	X	X													
		Surface run-off	X	X	o	o	X	X	X	X	X		x	x			X	
		Infiltration	O	o	x	x			o	o	o	x	x				o	
		Through flow	x	o	x	x	o		o	o	o							
		Evaporation	x	x	x	x	x	X	X	X	X		x					
		Transpiration	O	O	O	x		o	O	O	O							
	Water	Sediment Contration	X	X	x	o	X	X	x	o	o			x		x		
		Toxic elements										X	x	X				
	Fluvial Geomor-phology	Channel stability											x					X
		Gully erosion	X	O			X	x					x					
		Channel extension	X	o			X	x					x					
		Silt Deposits	X		x	X								x				

Based on Douglas, 1976.

of urban development, such as peak sediment production usually occurs during the construction phase, when the ground cover is least and the soil most disturbed, but the highest flood peaks and shortest lag-times between precipitation and flood peak probably occur when the paved surface and building density are greatest, and storm-water drainage is most fully developed. Decrease in tanspiration and increase in peak storm run-off and increased sedimentation of streams mostly occur during the early construction stage when removal of natural vegetation cover seem to be most widespread.

The investigator of this study has proposed 4 phases of the impact of urbanisation on hydrological system of the town. Such development of urban centres and associated hydrological impact has been studied in many parts of the world (Savini and Kammeres, 1961; Jens and Mc. Pherson, 1964 and Douglas, 1983). The investigator has tried to establish such phase-wise hydrological impact of urbanisation in the study area along with such impact stated by other scientists in the following table (Table 6.8).

G. THE URBAN WATER-BALANCE

In analysing the impact of urbanisation on the natural hydrological system, the artifical water supply and waste water disposal system should also be incorporated. The discharge to urban channels reflect not only the precipation over the catchment areas, but also waste water flows which involve long-distance inter-basin transfer. To assess these diverse sources, pathways and destination of urban water, an overall urban water balance may be calculated.

Table 6.8

Hydrological effects during the different stages of urbanization in Darjiling Town

Change in land and/or water use	Possible Hydrological effects	Hydrological effects in Darjiling
A. Transition from pre-urban to early urban-stage (1835 – 1900)		
Removal of trees or vegetation. Construction of scattered city-type houses and limited water and sewerage facilities	Decrease in transpiration and increase in peak strom run-off. Increased sedimentation of streams.	Development of gullying as in the tea gardens. Increased surface wash and soil loss. Siltation on valley floors, nearby, aggravated by decreased infiltration.
Establishment of Jalapahar-Katapahar, Lebong Cantonments, Sanatarium, Schools, Colleges, Church, Roads and Railways. Disposal of domestic and sanitary waters.	Sources of some additional soil water and contamination of nearby springs.	Contamination of nearby springs and jhoras.
B. Transition from Early-urban to middle-urban stage (1900 1950)		
Extensive cut-and-fill for construction, bulldozing of land for mass housing. Extensive cut for the construction of Mall, St. Joseph's ground, Lebong race course etc. Extensive removal of top-soil.	Accelerated land erosion, stream sedimentation and aggredation. Elimination of smaller streams. Decreased infiltration, increased strom water flows, occasional over topping and under-wearing of artificial channel banks on small streams.	Rapid removal of weathered materials. Development of dense gully network on bare-sites i.e. below Happy Valley tea-garden, Alubari, northern Ghum slope. Increased peak strom discharge and sediment concentration. The most important one is the occurrences of landslips i.e. 1899, the first recorded disastrous landslips in Darjiling hills.
Mass construction of houses, paving of streets etc.		Creation of integrated strom-water discharge system conveying run-off rapidly to major streams. Increased shear stress and decrease of shear resistance causes landslips.
C. Transition from middle-urban to late-urban stage (≥ 1950 onwards)		
Urbanization of areas completed by addition of more houses and streets, and of public, commercial and other buildings.	Reduced infiltration and lowered water table.	Small streams enclosed in narrow concrete channels. Increase in paved area, rapid strom run-off.
Larger quantities of untreated wastes discharged into local streams.	Increased pollution and consequent biological impacts.	With the growth of urban area, the scatter settlements expand with the consequent sewage disposal problems such as Victoria Falls, Dhobi tala, Kagjhora etc. Water transfers from the Senchal Lake and increases the local stream flow.
Provision of water supplies from outside the catchment area.	Increase in local stream flows.	
D. Transition from late-urban to urban-renewal state (1980 onwards)		
Afforestation and the preservation of eco-system.	Increased infiltration, erosion control measures. Reduction of run-off and stabilization of hill-slopes.	New forested tracts as well as grasslands provide new opportunities for infiltration.
Land-fill and land reclamation, removal of old waste dumps. Proper drainage, particularly for strom water discharge.		General improvement in vegetation cover, risk of erosion along the recreation tracts.

Based on Savini and Kammerer (1961) modified by Jons and Mc. Pherson (1964) and by the author.

Chandler (1976) expressed such a balance as :

$$P+D+A+W = E + Rs + S \;\ldots\ldots\ldots\; 6.4$$

where P is precipitation, D is dew or hoar frost, A is water release from Anthropo-genic sources, W is the piped-surface and sub-surface water brought into the town, E is the evaporation including transpiration, Rs is the natural and piped surface and sub-surface flow out of the town and S is the change in the water storage in the fabric of the city.

In expressing and analysing the above mentioned parameters involve in assessing the Urban water-balance, of some parameters may be done readily, such as the major artificial inputs may be obtained from the water supply authority i.e. Senchal Lake authority and the Municipality Office, Darjiling and local jhoras. Similarly, the volume of water lost during transmission may also be gathered. Water storage capacity within the town ranges from tanks and water detention structures can also be measured. The amount of precipitation (P), dew and hoar frost (D) and water released from anthropo-genic sources may also be readily available. However, the difficulties of determing the volume in some components of the water balance probably explain the scarcity of overall estimates of the balance for Darjiling.

Wolman (1965) uses figures of average direct or indirect per capita water consumption to calculate a hypothetical demand of 0.625 ton/per capita/year for an American city of which 0.5 ton/ discharge as city sewerage.

The author has tried to estimate and calculate the hydrological balance of Darjiling town. The data required for such a study has been obtained from various sources as mentioned earlier and are diagrammetically represented in Fig.6.11 while Table No. 6.9 represents the estimated volume of the various parameters of such urban water-balance study.

Table 6.9

Urban Water Balance of Darjiling Town

No.	Water gain in $m.m^3$		No.	Water loss in $m. m^3$	
1.	P. Precipitation	30.73	1.	E. Evapo-trans-piration	9.52
2.*	D. Dew & hoar frost	- N	2.	Ro. Water dis-charged from the city in-cluding sewe-rage	23.46
3.*	A. Water realeased from anthropo-genic sources	-N	3.	S. Change of storage water within urban fabrics	0.78
4.	W. Supply catct-ment Local jhoras	1.73 1.30			
		33.76 (approx.)			33.76(approx.)

*N = Negligible

The distribution of water indicated by these figures may be further broken down by considering the users of water in Darjiling town. To make a comparison with other urban centres of the world, the investigator has tabulated the consumptions of water in 6 urban systems (Table 6.10).

A SCHEMATIC REPRESENTATION OF URBAN WATER BALANCE OF DARJILING TOWN

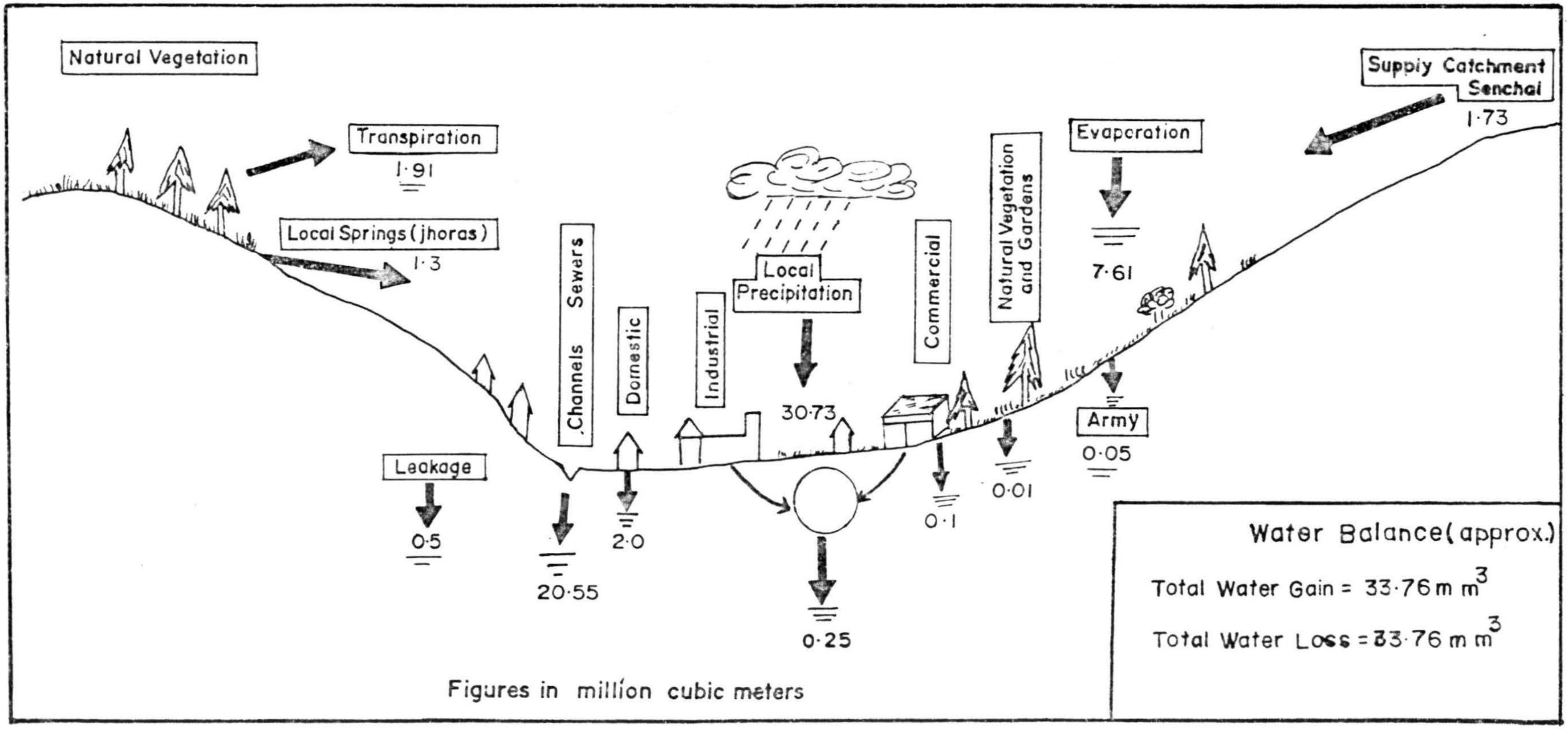

Fig-6.11

Data collected from the Municipal Report

Table 6.10

Consumption of water in six urban system; in million m^3 /yr

Urban Centre	Supply water	Domestic	Industrial and Commercial	Municipal Public utility	Leakage & other uses
Hongkong	2224	328	1146	306	444
Mexico city	2362	1252	541	231	338
Melbourne	340	187	119	15	19
Sweden	945	520	170	148	107
Sydney	402	238	104	20	40
Darjiling	3.03	2.01	0.25	0.15	0.51

Source : Douglas, 1983

In all urban centres except Hongkong, only fresh water is considered for consumption. Per capita annual domestic consumption in the cities mentioned, ranges from 87 m^3 in Sydney, 78 m^3 in Melbourne and Mexico city and 51 m^3 in Hongkong to only 19 m^3 in Darjiling. These figures may reflect living standards as well as dwelling space and industrial development. Only 10% of urban population in Darjiling town have proper sanitation facilities, only 8% enjoys the regular piped water supply and perhaps 45% households have no piped water supply. Gardens and kitchen gardens frequently receive much of the domestic water used in western cities, about 50% in Sydney; 35% in Hongkong, however in Darjiling it is estimated to be below 1%, restricted only to affluent quarters and government establishments. The above data for the study area is based on selected sample survey. Another interesting point to be noted here is that only 14.75% of the total supply is used for domestic purpose in Hongkong, 53% in Mexico city, 55% in Melbourne and Sweden, 59.2% in Sydney while, in Darjiling about 66.4% of the total supplied water has been used only for domestic purpose. It also reflects the major urban functions i.e. residential - administrative of the study area.

Darjiling provides an example of a complex urban water system which imports water from one catchment area and dispenses it to the other catchment areas.

H. CONCLUSION

The urban landscape of Darjiling town exerts an ever increasing influence upon the hydrological cycle, regime, water balance and the quality of surface and ground waters. It has been apparent from the above analysis that the hydrological features of the study area depend on a number of phenomena. The water cycle of the town involves huge water masses transferred from beyond the local basin i.e. from the Senchal Lake of Balason catchment. Thus, not only the given drainage basin participates in the formation of the hydrological regime, but also other areas with different natural and man-made characteristics. The radical change of the surface and the construction of drainage sewerage systems create new conditions of run-off formation, and the speed of water disposal into natural bodies become many times greater. The precipitation and evaporation regimes change due to changes in the natural heat regime. The large percentage of impervious surfaces influence the natural heat regime and also the natural interaction between the surface and the ground-water. There is also a marked disposal of storm-water or sewer-water into natural water bodies, creating a new man-made landscape including town structures, modified natural or new artificial water bodies.

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