

Limnological Survey of Water Bodies of the Sikkim Himalayas, India

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KEY WORDS Mountain Ecosystem. Lotic Systems. Lentic Systems. Physico-Chemical Properties. Phytoplankton. Sikkim Himalayas.

ABSTRACT A two year long investigation (1981-1983) was taken up on seven lotic systems and five lentic systems in Sikkim Himalayas for limnological investigation. Results tabulated under three seasons, viz., Pre-monsoon, Monsoon and Post-monsoon seasons indicate there is significant variation seasonally in nutrients such as calcium, magnesium, chlorides, sulfates etc. Total solid content is very high in these waters adding much abiotic turbidity. In spite of the richness of the nutrients, these waters exhibit poor planktonic concentrations. Productivity studies indicate, these exhibit lower production figures ranging between 0.810 and 2.27 gO₂ m⁻² day⁻¹ which could be comparable to that of Kashmir Himalayan lakes. The lower production and poor planktonic growth attribute to the lower temperatures, poor light conditions, abiotic turbidity and speedy flow of the waters. Nutrient concentration and production status indicate the oligotrophic nature of these waters. As far as water quality status is concerned, total coliform counts and BOD appear to be high when compared with tolerance limit set by ISI for category 'A' water. All other parameters stand much below the tolerance limits.

Plankton analyses at five sites of Rangpo stream which was subjected to the effluents reveal that the plankton concentration was high at site V followed by site III where the inflow of effluent is much diluted.

INTRODUCTION

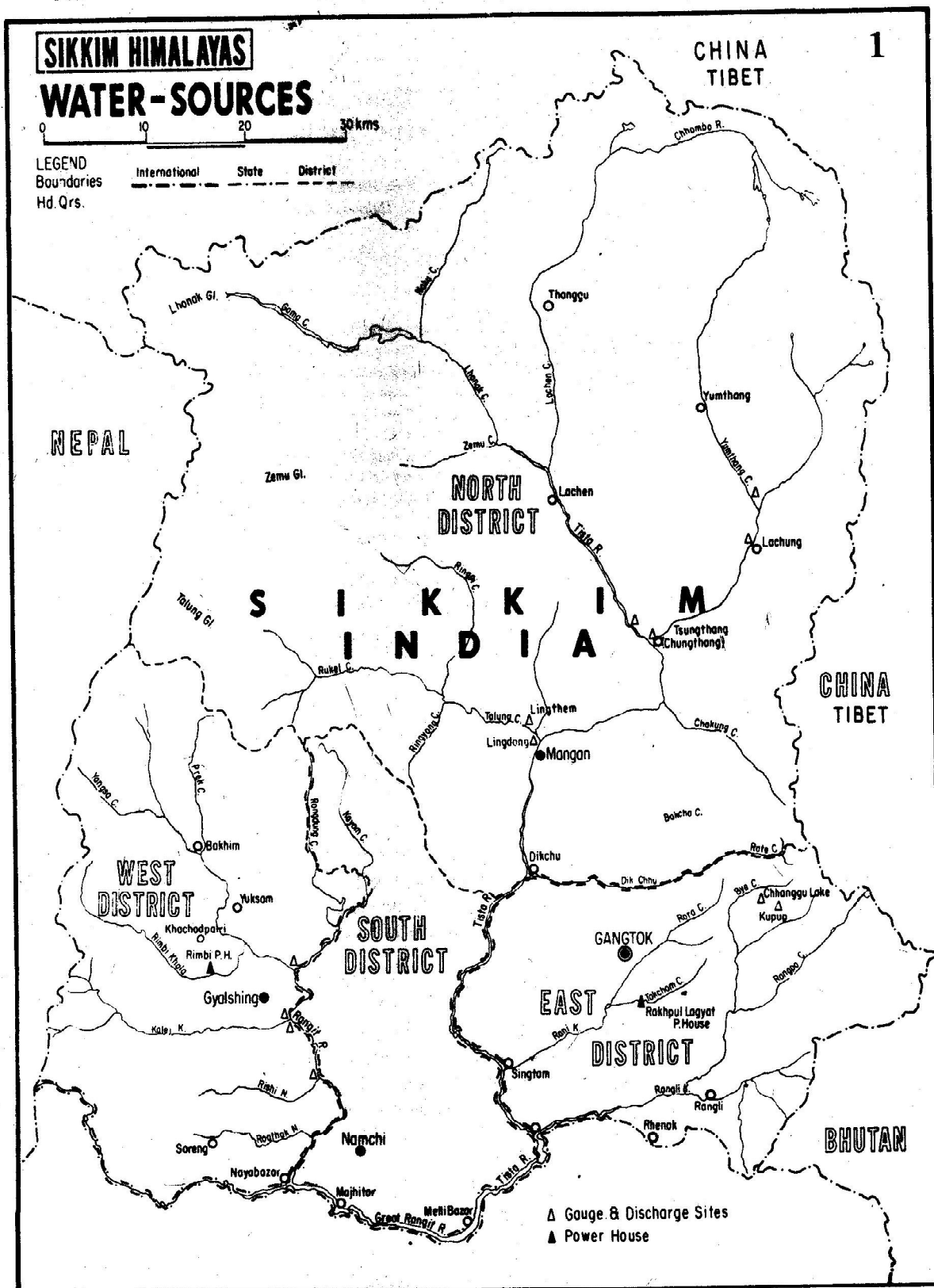
The importance of wetlands as source of greater primary productivity has been realised since long and organisations like IBP, IUCN and UNESCO have devoted attention on these areas. Though many efforts were taken by these organisations, information on the limnology of tropical water bodies is scanty and even the few studies conducted are concentrated either on phytoplankton, periphyton and macrophytes, thus lacking the comprehension of relative importance of each of these groups. The researches of Sreenivasan (1964), Hussainy (1967), Ganapathi (1972), Ganapathi and Pathak (1972), Nasar and Datta-Munshi (1975) and Gopal et al. (1978) con-

tributed much to the Indian limnology. But the Himalayan water bodies are much neglected for this study since long except the few works of Kaul (1977), Zutshi and Vass (1977) and Pande and Singh (1978) on Kashmir and Kumaun Himalayan regions. Such information on Sikkim Himalayan water bodies is absolutely nil. The present study is aimed to evaluate the trophic status of these water bodies by analysing these waters seasonally for various aspects such as physico-chemical features, and plankton analysis located at various altitudes.

STUDY PLAN

Sikkim harbours a good number of water bodies. These water bodies differ significantly in their physical, chemical and biotic environment. The great variation in the physicochemical nature of these water bodies is due to their geographical

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location, the altitude of which varies from 800 to 5000 m. As the water bodies are numerous and their approach seasonally is difficult, a few water bodies are taken up for their physico-chemical nature as well as for their planktonic content. In selecting water bodies, their relative importance to local population, such as in fisheries, irrigation and their contribution to drinking water to the region are taken into consideration. For convenience in the text, these water bodies are discussed separately under lotic and lentic systems. This survey on water chemistry and biological features of these waters can be helpful in evaluating the water quality of the area. These water bodies have not been scientifically investigated in spite of the health disorders people face owing to their ignorant intake of all nearby waters. Gastric disorders, worm infections and goitre are the main health problems. The aim of this investigation is to identify these water bodies in terms of potability and the degree of pollution. The field work was conducted during the years 1981 to 1983.

SELECTED FIELD AREAS

Lotic Systems

River Tista

River Tista is the longest river of Sikkim flowing throughout its length from north to south boundary. This is a perennial river fed by monsoon rains in the rainy season and glaciers in the summer. The river originates in the northern boundary from Talung-Kangshe glacier in the northwest corner. After flowing over a length of 50 km near Lachen, it meets with tributaries Lhonak Chu and Zemu Chu which originate from Lhonak and Zemu glaciers from the north-west corner of the State. The river flows through deep gorges and high mountains and has very steep slopes. From Lachen it flows towards south-east and meets near Chungthang, its major tributary Lachung Chu which originates from northeast glaciers of the Himalayan ranges in the State. From Chunthang onwards, the river takes

a western course up to Mangan where it meets its third tributary Tolung Chu which originates from Tolung glacier from the west boundary. After this point the river flows towards south up to Melli which is the last boundary town of the state. Near Tista Bazar, the river flows into West Bengal. The river enters into plains after a distance of about 50 km from Tista Bazar near Sevoke Bridge where it widens. It crosses India and passes into Bangladesh near Jalpaiguri and finally joins Brahmaputra, popularly known as Jamuna in Bangladesh (Fig. 1).

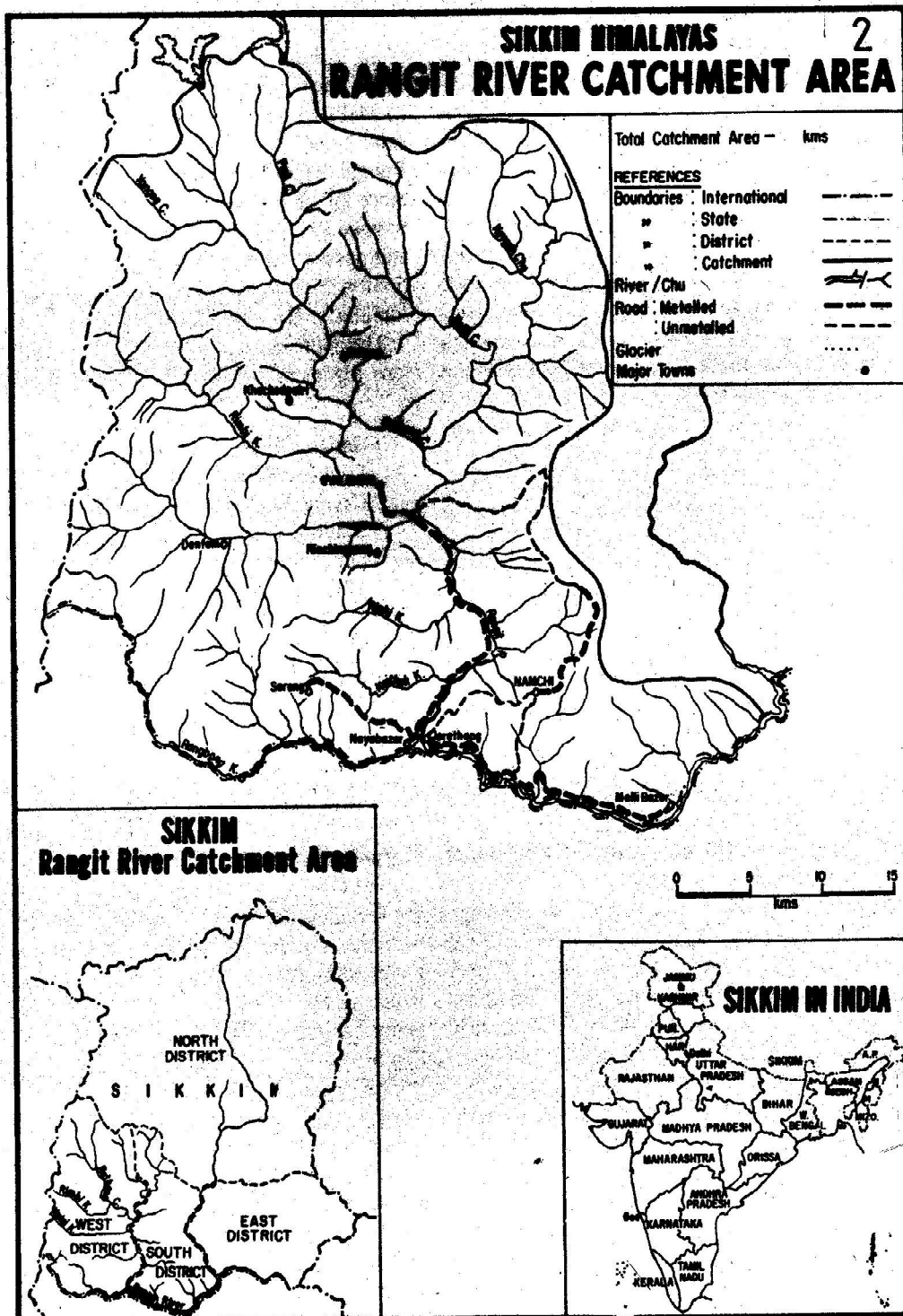
The approximate slope of the river bed in various places of the location is given below:

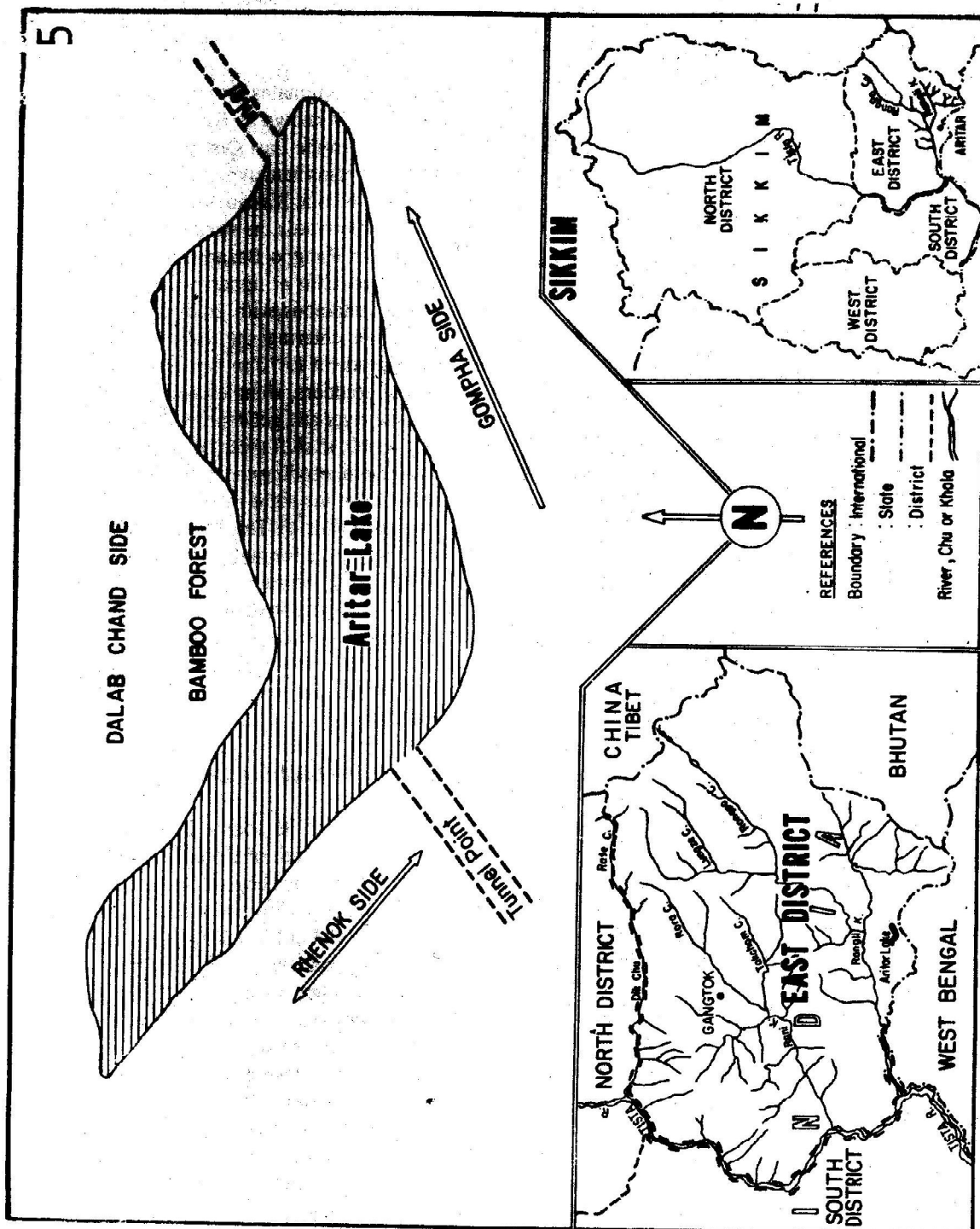
Sedang-Lachen	1 in 10.6
Lachen-Chungthang	1 in 16.4
Chungthang-Singhik	1 in 22.6
Singhik-Dikchu	1 in 71.42
Dikchu-Singtam	1 in 98.40
Singtam-Rangpo	1 in 218.6

From the above, it is clear the slope of the river bed up to Chungthang is very steep. Discharge rate near Rangpo varies between 96.34 and 1400.37 cumecs sec.⁻¹

Rangit River

Rangit river and its tributaries originate in the Talung Glacier in West Sikkim and after flowing for about 60 km joins the Tista below Melli near the boarder of Sikkim with West Bengal. River Rangit is a major tributary of river Tista from the West Sikkim. River Rangit in turn has many tributaries, the major being Ratang Chu, Rimbi Chu, Kaley Chu, Raman Chu and Little Rangit. River Rangit in its early reaches flows through very high valleys and steep slopes till it joins Rathang Chu which originates from the Rathang Glacier and is one of the biggest major tributaries of the river Rangit. The slope of river Rangit up to its confluence with Rathang Chu is of the order of 1 in 25. After the confluence, the river enters somewhat flat area with





a slope of 1 in 85. The slope just below the confluence of Rothang Chu and Rangit is of the order of 1 in 40. After joining Raman Chu and Little Rangit near Naya Bazar, the river runs in almost plain levels and becomes sufficiently wide till it meets Tista. Up to Legship, the river is filled with small pebbles and boulders whereas below this, the river bed consists of shingles and sand (Fig. 2). The discharge rate of the river was estimated by float method by central water commission. The values indicated, higher values during rainy season ($1765 \text{ cumecs sec}^{-1}$) and lower values during winter months ($70.6 \text{ cumecs sec}^{-1}$)

Rani Khola

The Ranikhola originates from the Gangtok Reserve Forest at an altitude of 1600 m in the East District. It travels along the road side via Gangtok, Tadong, Ranipul and Singtam. While travelling through Ranipul, it joins with Takchom Chu, Rora Chu and some other insignificant inflows. Finally, it runs into Tista river at Singtam Bazar. It flows with tremendous speed with boulders as big as 2 to 5 cm diameter rolling during monsoon. Rani Khola has a tendency to erode its banks particularly at fruit preservation factory (1 km upstream from Singtam) and also near Singtam Bazar (Fig. 3). Due to heavy currents every year the river is eroding a good portion of land from its banks. During rainy season, heavy currents of the stream erode a good amount of land from the banks. The average rainfall in all the area is 24.4 to 36.6 cm annually. The upper part of the stream has a very steep gradient of 200 m per km. But after reaching Ranipul, it changes its gradient to about $70\text{--}80 \text{ m km}^{-1}$. The discharge rate of the stream varies between 360 and $549 \text{ cumecs min}^{-1}$. There are occasional records of rising the discharge rate as much as to $660 \text{ cumecs min}^{-1}$. Thus the huge amount of boulders and gravels carried by the stream get deposited in heaps, go round then attacking the bank causing erosion to it. Wire meshing is being carried out in these areas to

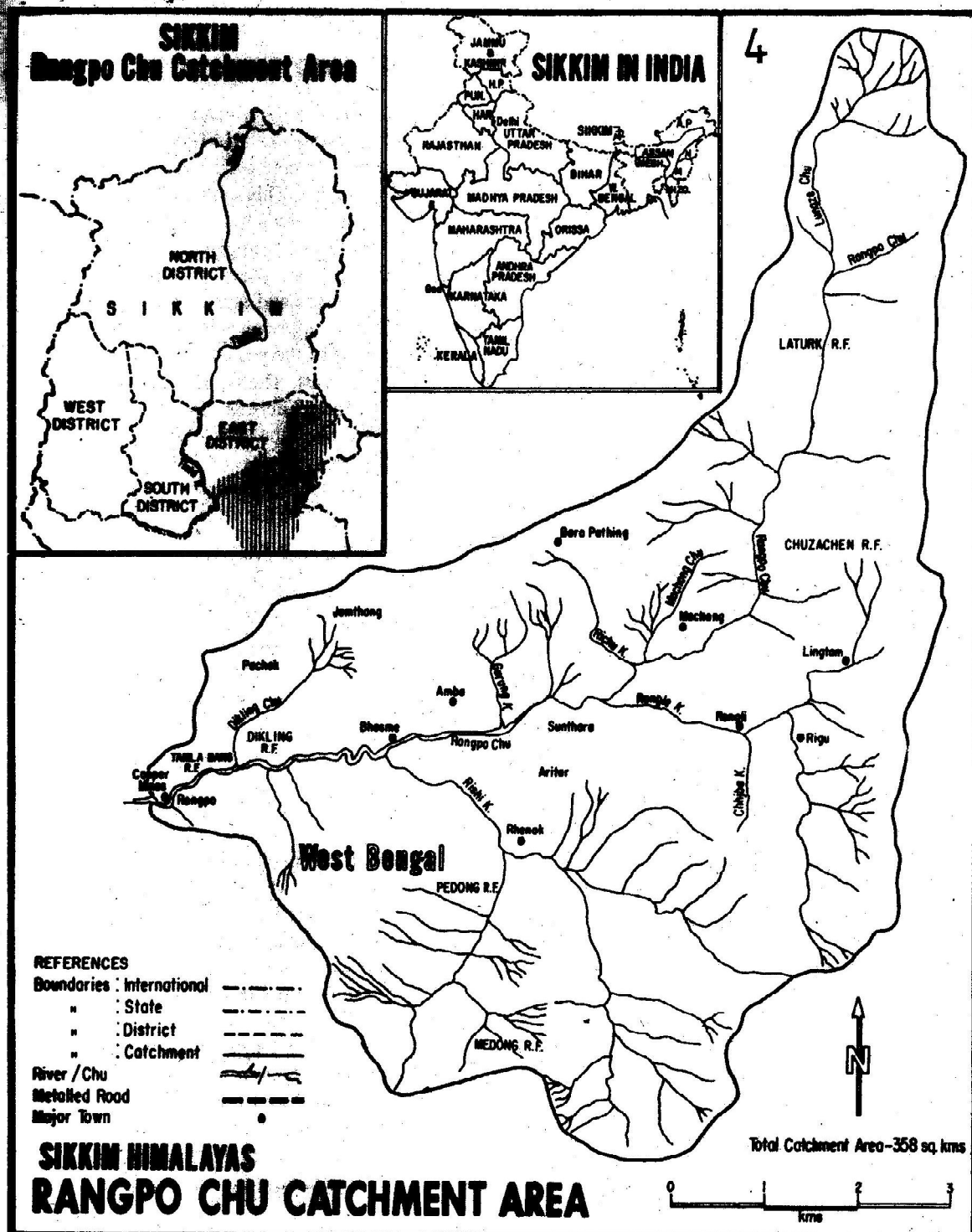
control soil erosion by Public Works Department.

Rangpo Chu

Rangpo Chu originates from Latui Reserve Forest where it is known as By achu at an altitude of 3700 m in the East District. The stream joins smaller streams namely Lungze Chu, Richu Khola, Rongli Khola, Kasem Khola, and Dickiling Khola. Afterwards the stream merges with river Tista near Rangpo Bazar. The catchment area of Rangpo Chu at upper reaches is very steep and mountainous with gradient of 200 m per km. While entering the valley, the river changes its gradient to 70 m per km. The huge quantities of boulders, shingles and gravels are carried by the river and get deposited in the area. The water unable to shift these heaps in this area goes round them, eroding the bank. The impact is particularly on the right bank where Rangpo bazar is situated (Fig. 4). This bazar is an important marketing centre for many nearby localities. Every year during the rainy season, the stream engulfs a sizeable portion of the land, thus reducing the market area. Department of Irrigation has given considerable attention to this problem and a proposal was made for the protection of the bank in this area.

Lachen Chu and Lachung Chu

Lachung Chu has its source in small lakes which are situated south of Donkila Pass while Lachen Chu has its origin beyond Sikkim in Cholomoo lakes. Lachen Chu has a steep gradient with fast flowing and turbid waters. It carries leaf litter and earthly matter, it bears all along. The road leading to Lachen village from Chungthang has three rope bridges over Lachen Chu. Above Lachen, the stream is called Zemu Chu. The mountains on the eastern side of the river are densely forest clad and with luxuriant herbage. Lachung Chu has slow pace in its run. Its gradient is relatively less and water is more clear with less organic matter and total solids. Lachung river above Lachung is called Yumthang Chu.



Lentic Systems

Lake Aritar

Lake Aritar is popularly known as "Lamba Pokhara" for its elliptical shape and is situated at an altitude of 1900 m in Aritar Busti, 10 km away from Rhenok, an important marketing place for the people around in the far South of East Sikkim. The lake is surrounded by hills with dense vegetation except on the northeast side where it is bound by slightly elevated and thickly populated bamboo forest. The main water source for the lake is from the excessively drained water from these mountains during the rainy season. Besides, there is also a perennial source of water in the form of springs in the lake itself. Though there is continuous supply of water to the lake, there could be seen marked difference in the water content between rainy and winter seasons. A downward path to the bamboo forest leads to Dalab Chand Block while the southeast ward of the lake leads to Rhenok and the northwest to "Gompha" (Fig. 5). The lake was exposed to great silting from the northeast side of the bamboo forest due to heavy soil erosion. The lake is infested with 2 dominant macrophytes namely, *Alternanthera sessilis*, and *Eichonocloa* sp. Though water was not used by the local people for drinking purpose, the lake was given importance and attention by both Fisheries and Irrigation Departments.

An annual catch, worth Rs. 10,000/- was harvested every year by the fisheries people. Department of Irrigation, Government of Sikkim has a plan to make it a man-made reservoir, channelising for 15 km the water from the Pagaci Khola to this lake through an inlet situated North eastward of the lake. In this way, water can be ultimately imparted to Rhenok Busti through a tunnel point. When completed, this project will solve the persistent water problem of Rhenok people.

Lake Chhanggu

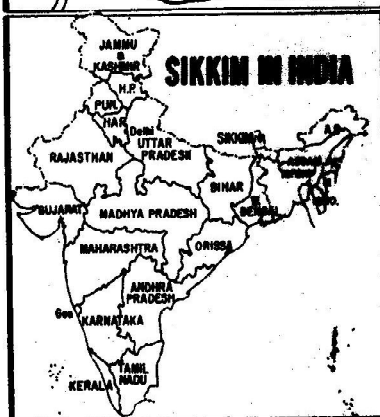
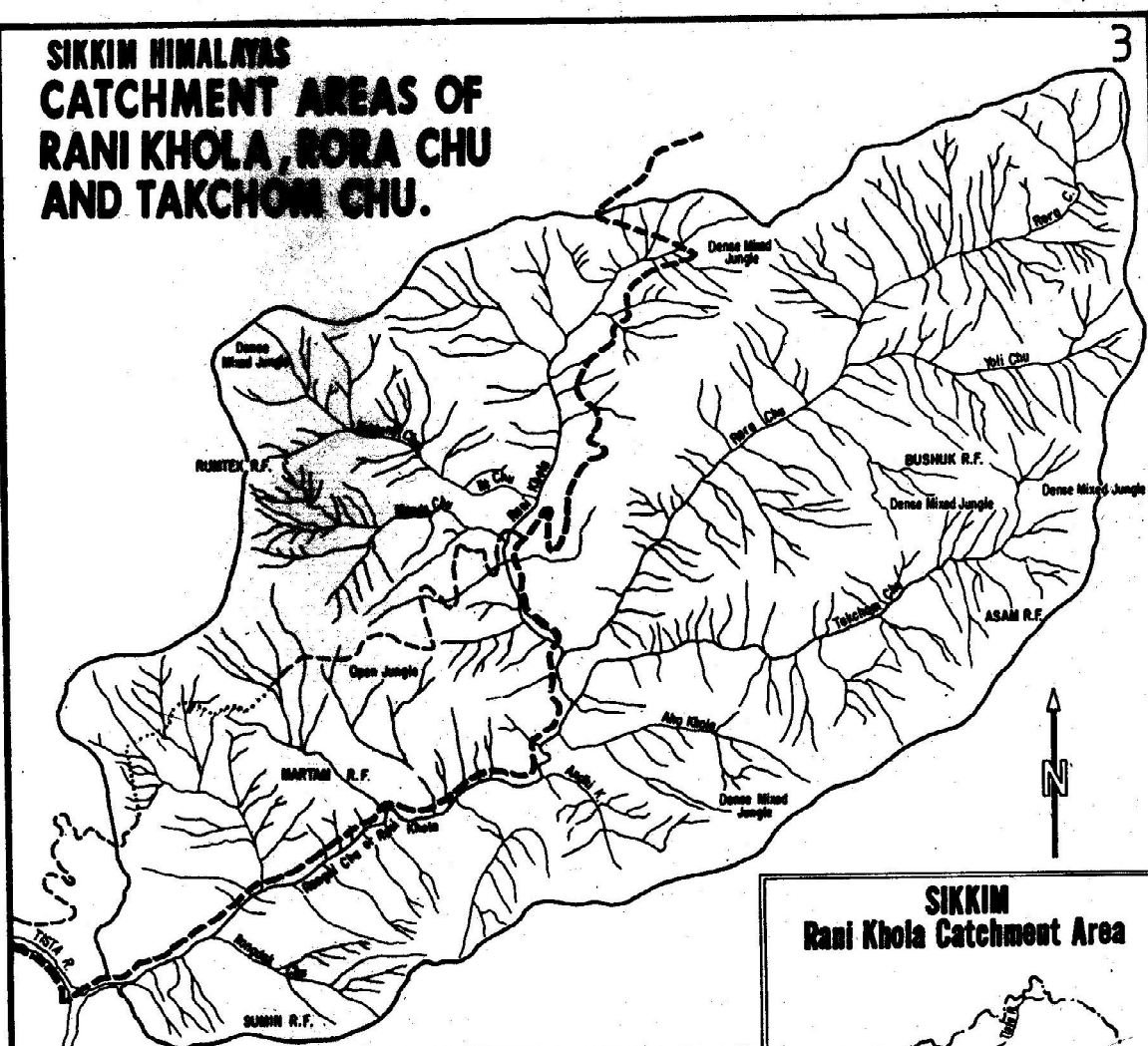
Lake Chhanggu is situated on the side of

Gangtok-Nathula highway at about an altitude of 3720 m and about 40 km away from Gangtok. It is closely triangular in shape occupying an area of about 0.5 sq. km. The western bank is bordered by high altitude range which throughout the year sheds of snow into the lake. There is an inlet from Sherthang side of the lake and an outlet towards Gangtok side. This outlet seems parallel to the Gangtok-Nathula highway for about 1 km. This is known as Chhanggu Chu. Thus the lake has more than one water source an inlet, snow from the ranges and some springs in the lake, continuously supplying water into the lake (Fig. 6). Most part of the year the lake is frozen on the surface at least. The banks exhibit clear water on the surface. There are two plants conspicuously seen around the lake (1) *Primula* spp. (2) *Rhododendron anthopogan*. *R. anthopogan* gives a pungent smell in this region. This is collected by the local people for some medicinal use.

Lake Mamen Chu and Lake Kupup

Lake Mamen Chu is situated at an altitude of 4000 m and about 20 km from Chhanggu. Gangtok-Nathula highway, after crossing Chhanggu, leads to a small village known as Sherthang which is about 3 km from Chhanggu. After travelling about 2 km from Sherthang, the road bifurcates, one metal road leads to Mamen Chu, while the other to Kupup lake. Mamen Chu is developed by the State Forest Department into a trout hatchery. The lake is about 2.8 ha in area and fed with water from Rangpo Chu. There are about 4 raceway tanks where this trout is grown up. From here, these are kept for few days in natural rearing ponds which are 12 in number (Fig. 7). From here trout is allowed to go into the lake. Mamen Chu lake is a very deep lake, exhibiting depth up to 7.5 m. Because of heavy snowfall in the region and vast temperature difference between surface and bottom waters, trout prefers to stay only in the lower layers of water, thus though there is a natural out let, trout never escapes from the lake. Thus this thermal stratification helps in confining the trout to the lake only.

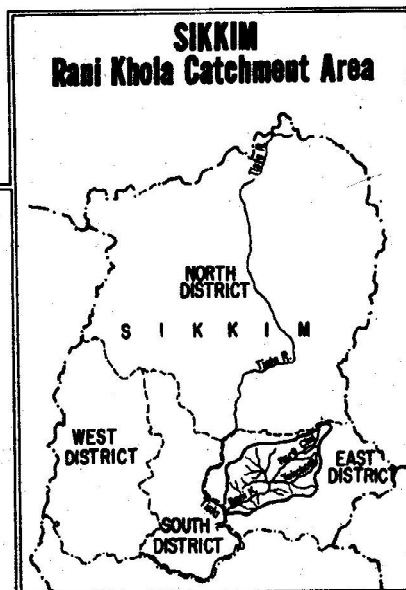
SIKKIM HIMALAYAS CATCHMENT AREAS OF RANI KHOLA, RORA CHU AND TAKCHOM CHU.

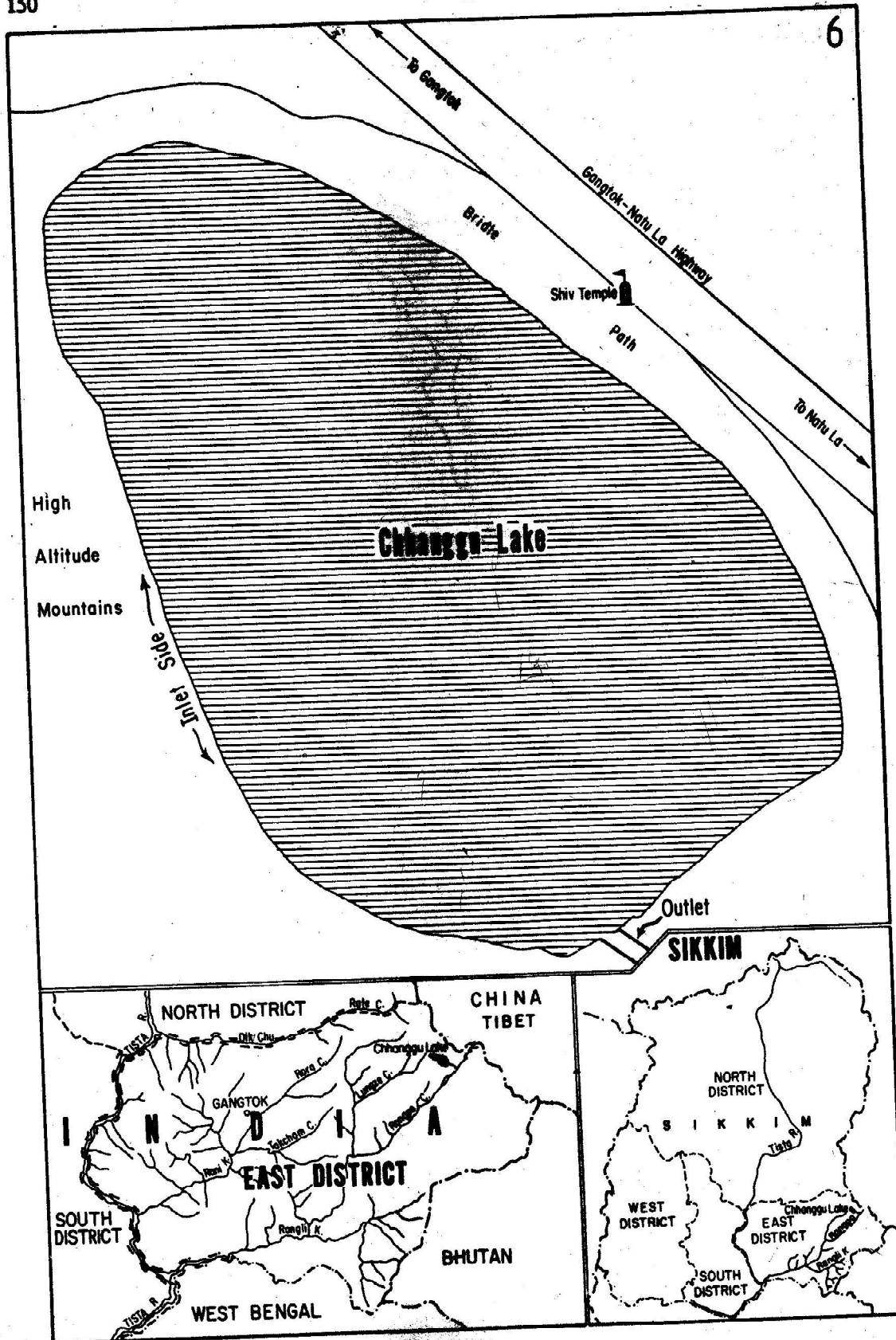


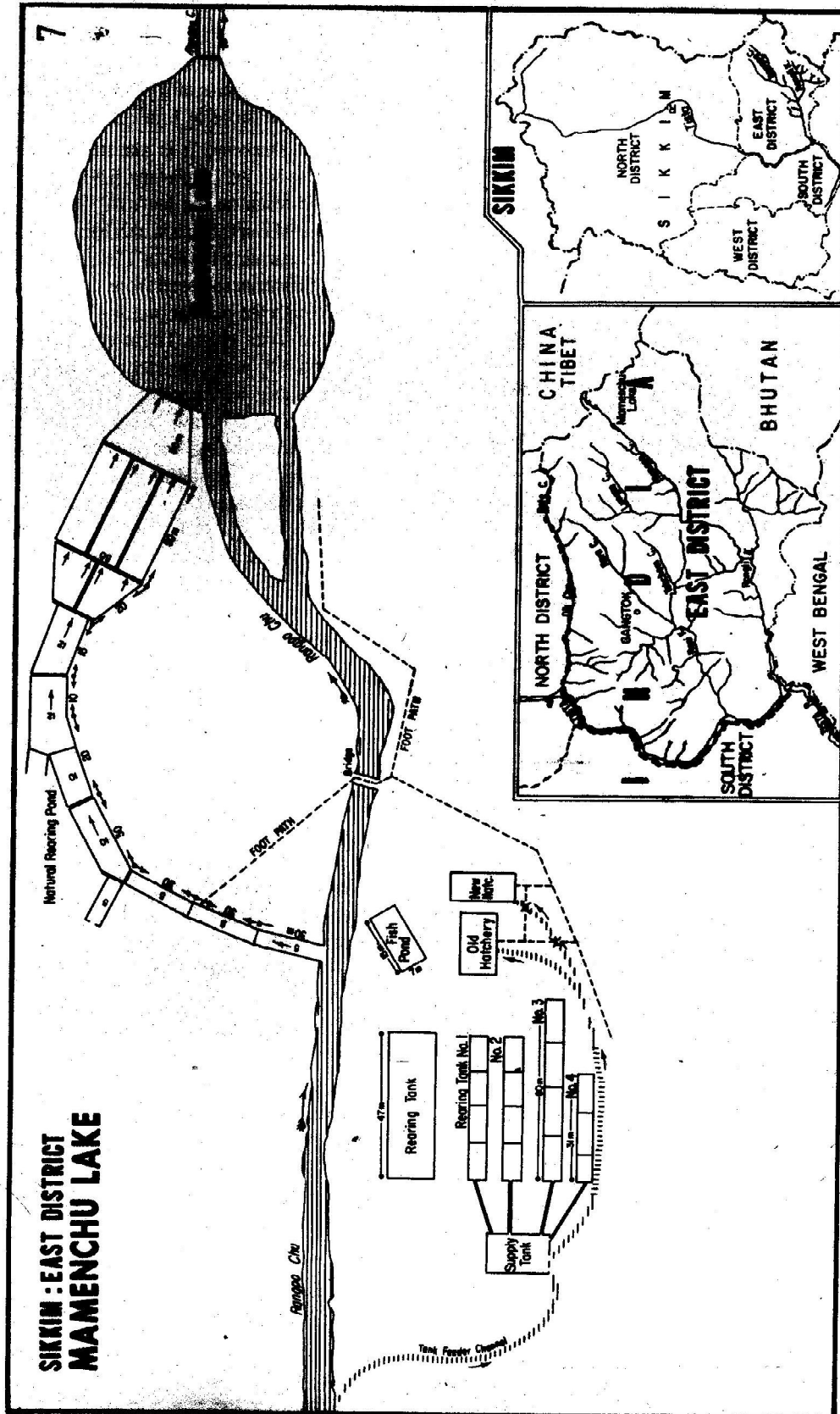
Total Catchment Area - 250 sq. kms

REFERENCES

Boundaries : International	---
" : State	- - - -
" : District	----
" : Catchment	=====
River / Chu	~~~~~
Road : Metalled	==
: Unmetalled	- - - -
: Path	
Major Towns	•







Lake Khechupheri

Lake Khechupheri is situated in small oak grove at an altitude of 1570 m. This is about 3.5 ha in area and considered to be a sacred lake in the region. There is neither an inlet nor an outlet to the lake, the sole water source being underground springs in the lake area (Fig. 8). The lake varies in depth, ranging between 1.2 to 7.6 m. The oak available in this region include *Quercus lamellosa* and *Q. pachyphylla* and the wood of this plant used in the house construction by local people. Besides the oak trees, there is *Rhododendron arboreum* on the other side of the lake (away from the road). The lake area expands and recedes depending on the season. Water exhibits dark green colour and though there is no inflow to the lake, the lake exhibits ripples all the time, perhaps due to the water release from the springs. The physico-chemical features of the lake water indicate its good potential for fish growth. Forest department is planning to develop the lake.

SITES INVESTIGATED

Sites selected for the limnological study for Rangpo stream and Tista river are as follows:

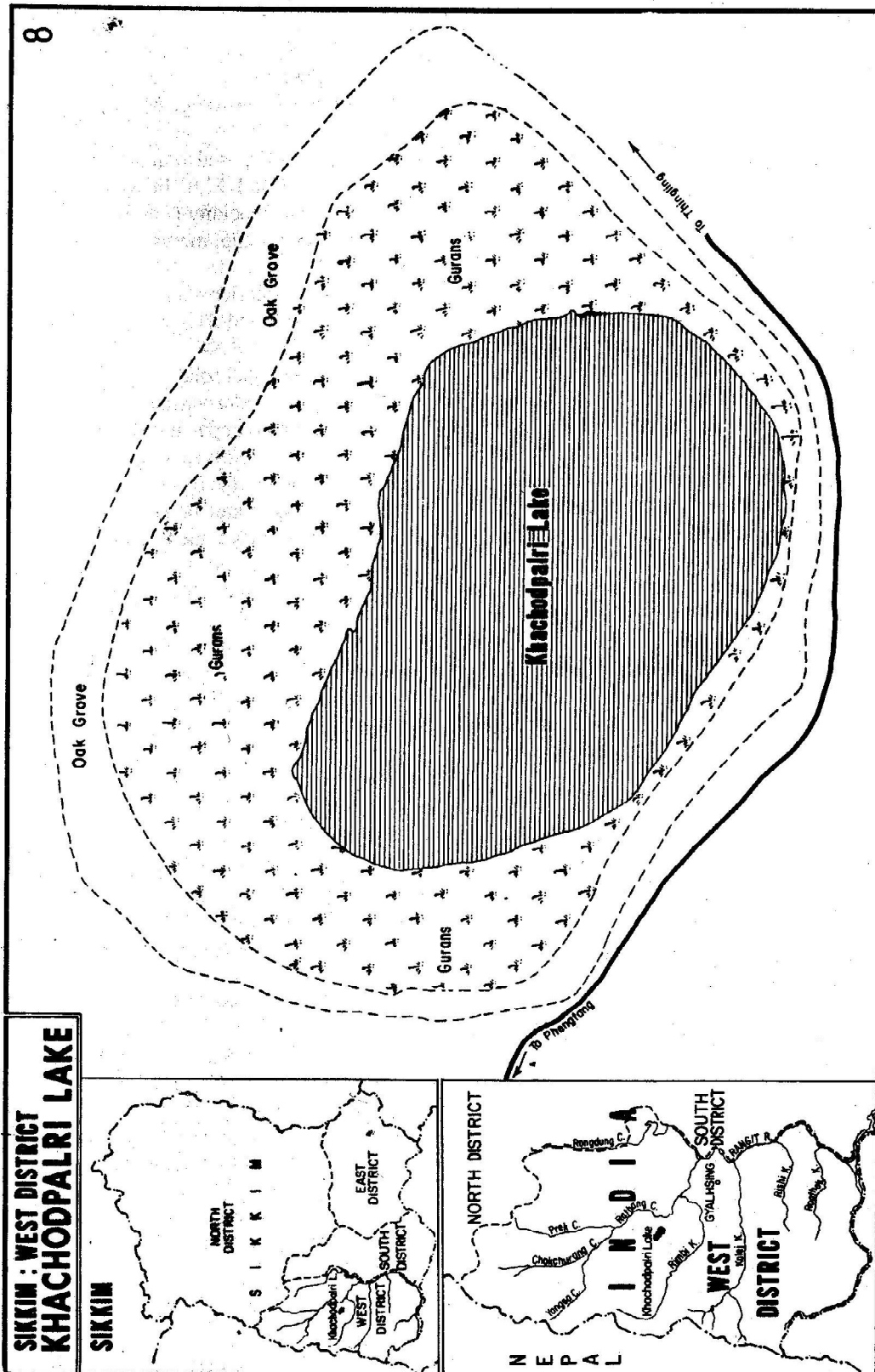
- (1) *Site near Dak Bungalow*: Here waters are green in colour and the flow of the stream is minimum. These waters harbour high amount of chlorophycean growth with low abiotic turbidity.
- (2) *Rangpo Distilleries*: This distillery is located on the bank of Rangpo Chu, a little up and about half a km from Dak Bungalow. About 20,000 liters of effluents run straight into this Khola when fermentation is carried out which is usually conducted once in a month. This results in the enhanced biological and chemical oxygen demands in these waters as effluents in this case contain more bacteria and yeast

possibly resulting in the anoxic conditions in this stream. But most of the daily run-offs are the results of the bottle washings and contain more of lime and detergents.

- (3) *Mazitar Tannery*: It is situated between Gangtok-Siliguri highway, 3.5 km before Rangpo town on the bank of Tista river. There is about 0.5 km width banana plantation separating the river Tista from Tannery. Effluents released from the Tannery go through the plantations and finally run into the Tista river. These effluents run through 400 mm diameter pipe for 5-1/2 hours a day which contain most of the washings of the raw heads. These raw heads before being washed treated with the solution containing lime (CaO), Sodium sulphide (Na_2S) and Ammonium sulphate ($(\text{NH}_4)_2\text{SO}_4$) by weight in the ratio of 90:20:10 kg in 70 cubic feet water for about 48 hours. As most of the above mentioned chemicals settle on the raw heads during their incubation, the washings contain majority of these ions. These effluents run through a open channel after leaving the factory. According to tannery official sources, most part of these run offs evaporate before they merge with Tista river.
- (4) *Tista River near Singtam*: Another site is selected for water chemistry and production studies near Singtam before the river merges with Rani Khola. Here waters are turbid with large amounts of suspended solids and medium flow.

METHODOLOGY

Sampling for water analysis was done between 9 and 10 A.M. in all the field sites. Bottom waters were collected using a modified Dussart's sampler. Temperature with a centigrade thermometer and pH with a Lavibond comparator were measured in the field itself. Water samples were



collected in plastic cans for the future analysis of alkalinity, hardness, acidity, chlorides sulfates etc. For oxygen waters were fixed in Winkler's reagents in 250 cc bottles. The methods given in the IBP Hand Book No. 8 of Golterman and Clymo (1969) were followed for the analysis of above elements.

Qualitative and quantitative analysis of the plankton was made by filtering 15 litres of water sample through bolting silk net of 25 mesh size and concentrating the plankton. Plankton counts were made following the micro-transect method of Lackey (1954). The *in situ* method of Gunder and Gran's light and dark bottle technique (1927) was employed for the productivity estimation of these waters. The light and dark bottle O_2 series were run with glass bottles of 300 cc capacity for the measurement at two levels, the surface and bottom. Enmeshed plastic floats were used to keep the bottles afloat. Productivity estimations were made at every two hour intervals from morning 9 hours to evening 17 hours. The daily production was calculated by integrating this data. As these being shallow water systems, productivity below an unit of surface has been calculated based on the average of values of surface and bottom levels multiplied by the depth of the water column. All oxygen values were converted to $gC\ m^{-2}\ day^{-1}$.

RESULTS AND DISCUSSION

Physico-Chemical Features

Pre-monsoon Season

1. *Air Temperature*: Air temperatures range from $25^{\circ}C$ to $28.0^{\circ}C$ at various situations. Water temperatures show a range from 25 to $26.5^{\circ}C$.
2. *pH*: Hydrogen ion concentration fluctuates from 7.8 to 8.6. Surface and bottom layers do not show any significant difference.
3. *Free CO_2* : Free carbondioxide is in the range from 1.64 to $14.85\ mg\ l^{-1}$ in vari-

ous water bodies studied.

4. *Alkalinity*: Total alkalinity is low and in few places, phenolphthalein alkalinity is nil. Total alkalinity is in the range between 26.5 and 66.0 ppm.
5. *Acidity*: Acidity is also quite low ranging between nil and 12.8. In Rangpo Khola phenolphthalein acidity is nil while in Tista river near Rangpo, methyl orange acidity is nil.
6. *Chlorides*: Chloride content is low ranging between 0.99 and $24.6\ mg\ l^{-1}$ on various water bodies.
7. *Total Solids*: Total solids range between 35 and $300\ mg\ l^{-1}$ in various water bodies. Suspended solids constitute higher content compared to dissolved solids. The values for the former range from 15.8 to $245.0\ mg\ l^{-1}$ in various water bodies.
8. *Silicates*: Silicates content is also high compared to many tropical systems and ranges between 18.0 and $40.2\ mg\ l^{-1}$ in many water bodies.
9. *Calcium and Magnesium*: Calcium content is always high compared to magnesium content, the values ranging from 9.80 to $38.6\ mg\ l^{-1}$ for calcium and magnesium is in the range from 0.67 to $13.5\ mg\ l^{-1}$.
10. *Nitrates*: Nitrates are also very high, values ranging from nil to $0.91\ mg\ l^{-1}$.
11. *Phosphates*: Phosphate concentrations range between nil to $0.23\ mg\ l^{-1}$ in various water bodies. The higher values are recorded for Tista river near Rangpo while the phosphates are not detected at all in Sethi Khola.
12. *Sulfates*: Sulfate content is also low ranging from 1.90 to $15.50\ mg\ l^{-1}$. These values are low compared to many tropical systems.
13. *Dissolved Oxygen*: Surface and bottom layers show more or less similar content in their oxygen concentration. Values are in the range from 1.98 to $9.08\ mg\ l^{-1}$ at surface layers. Figures for the bottom layers fluctuate from 0.60 to $7.76\ mg\ l^{-1}$.

Monsoon Season

1. *Air Temperature:* Air temperatures reduce significantly during this season compared to premonsoon season, the values fluctuate from 17° to 21°C at various situations. The higher values are recorded from river Tista near Melli while the lower values are for Jolly Khola near Ranipul.
2. *Water Temperature:* Surface and bottom layers do not show any significant variation and thermal stratification is totally absent in these fast flowing water bodies. Surface layers show a fluctuation from 16° to 19.5°C while bottom layers show a range from 15.5° to 19.5°C in various water bodies studied.
3. *pH:* Waters are slightly alkaline with pH ranging between 7.6 to 8.4. Bottom layers are in the range from 7.4 to 8.2.
4. *Alkalinity:* Total alkalinity decreases significantly during this season in various water bodies. Values are in the range from 25.6 to 40.6 mg l⁻¹, a little lower compared to the values estimated during premonsoon season.
5. *Acidity:* Acidity is also quite low ranging between nil and 28.6 mg l⁻¹ in various water bodies.
6. *Chlorides:* Chloride contents are low but the amplitude of variation is wider during this season, the figures range from 5.8 to 30.8 mg l⁻¹ in various water bodies.
7. *Total Solids:* During rainy season, total solid content increases significantly compared to premonsoon season. Total solids range from 110 to 240 mg l⁻¹. Suspended solids also increase significantly due to high velocity of water. The values for suspended solids range from 70 to 200 mg l⁻¹.
8. *Silicates:* Silicate content is significantly lowered during rainy season, the values range from 6.8 to 28.6 mg l⁻¹ in various water bodies.
9. *Calcium and Magnesium:* Calcium content

did not change significantly during monsoon season. Values observed are in the range from 15.5 to 25.5 mg l⁻¹ in various situations. Magnesium content is always lower compared to calcium levels, the values range from 7.6 to 15.5 mg l⁻¹ in various water bodies.

10. *Nitrates:* As in the case of calcium, nitrates content did not show any seasonal variation, the values range from 0.2 to 0.58 mg l⁻¹ in various water bodies. However, the amplitude of variation observed during monsoon is much low as compared to premonsoon season.
11. *Phosphates:* Phosphates are detectable in most of the water bodies studied. The values are between 0.18 and 0.28 mg l⁻¹.
12. *Sulfates:* Sulfates range from 15.5 to 25.4 mg l⁻¹ in various water bodies. These figures are much higher as compared to premonsoon values.
13. *Dissolved Oxygen:* Dissolved oxygen concentration is found quite low compared to premonsoon figures. However, surface and bottom layers do not show any significant variation in their oxygen concentration. Values for surface layers range from 4.56 to 6.58 mg l⁻¹ while for the bottom layers 3.26 to 4.56 mg l⁻¹ (Table 1).

Post Monsoon Season

1. *Air Temperature:* Air temperatures considerably decrease during post monsoon season, the values fluctuate from 13.5°C to 18.5°C at various situations.
2. *Water Temperatures:* On par with air temperatures, water temperatures also lowered significantly. Surface and bottom layers show significant variation. Surface values range from 12.5°C. to 18.5°C. while bottom layers show a range from 15.5° to 16.5°C.
3. *pH:* Water pH does not change significantly. Surface layers range from 7.2 to 8.4 while bottom layers fluctuate from 7.6 to 8.4.

Table 1: Physico-chemical nature of water bodies of Sikkim Himalayas

S. No.	Sites	Air	Water Temp			Alkalinity 1+4 (ppm)	Acidity (ppm)	Chlorides (mg l ⁻¹)	Total Solids (mg l ⁻¹)
		Temp. °C	S °C	B °C	Free CO ₂ mg l ⁻¹				
A. PRE-MONSOON SEASON									
1.	Tista river (near Singtam)	25.5	21.5	-	4.95	16.5	6.0	1.48	245
2.	Rani Khola	25.5	22.0	-	6.98	26.1	7.0	1.98	215
3.	Rani Khola SFF	26.5	22.5	-	6.98	66.0	12.0	0.99	180
4.	Jolly Khola	24.5	22.0	-	4.95	23.1	3.0	0.99	105
5.	Sethi Khola	25.5	22.5	-	4.95	33.1	3.0	1.48	125
6.	Aritar lake	24.0	22.0	-	14.85	17.0	8.0	1.98	35
7.	Tista river	26.5	23.5	-	2.86	20.5	8.4	6.6	300
8.	Rangpo Khola	27.5	24.5	-	1.64	35.2	nil	24.6	66
9.	Rangit river (Melli)	28.0	25.5	-	3.80	44.9	12.8	12.4	220
B. MONSOON SEASON									
1.	Tista river (near Singtam)	17.0	16.0	15.5	1.5	36.1	11.5	13.8	140
2.	Rani Khola	20.0	18.0	16.5	1.8	28.5	21.4	8.4	120
3.	Rani Khola SFF	20.5	18.5	17.0	nil	25.6	2.6	5.8	155
4.	Jolly Khola	20.0	18.0	17.0	0.58	25.6	nil	18.4	165
5.	Sethi Khola	19.0	19.0	17.5	2.1	28.2	18.8	16.6	210
6.	Aritar lake	17.5	18.5	18.0	1.5	26.2	12.6	25.6	240
7.	Tista river	18.5	18.0	17.5	1.2	34.6	13.4	18.6	155
8.	Rangpo Khola	18.0	17.5	17.0	1.0	30.5	28.6	30.8	170
9.	Rangit river (Melli)	18.5	17.5	17.0	1.2	28.1	13.8	13.6	185
C. POST MONSOON SEASON									
1.	Tista river (near Singtam)	17.5	17.0	-	2.50	28.0	5.0	28.5	134
2.	Rani Khola	17.0	17.0	-	2.0	25.0	8.5	21.5	128
3.	Rani Khola SFF	18.5	18.0	-	3.56	22.4	9.5	26.5	118
4.	Jolly Khola	18.0	16.5	-	6.00	25.5	5.5	20.5	125
5.	Sethi Khola	18.0	16.5	-	5.40	28.0	4.5	38.0	164
6.	Aritar lake	13.5	12.5	-	4.85	36.0	4.5	38.6	145
7.	Tista river	16.5	16.0	-	4.05	28.0	12.2	42.6	155
8.	Rangpo Khola	16.5	16.0	-	4.5	30.0	13.8	32.5	160
9.	Rangit river Melli	17.5	17.0	-	4.5	31.0	13.8	35.0	155

Suspended solids (mg l ⁻¹)	Dissolved solids (mg l ⁻¹)	Silicates (mg l ⁻¹)	Calcium (mg l ⁻¹)	Magnesium (mg l ⁻¹)	Nitrate (mg l ⁻¹)	Phosphates (mg l ⁻¹)	Sulfates (mg l ⁻¹)	Dissolved oxygen (mg l ⁻¹) surface	Dissolved oxygen (mg l ⁻¹) bottom
179.5	65.5	28.6	18.72	1.22	nil	nil	3.20	5.80	5.71
135.0	80.0	27.0	11.98	0.67	0.14	0.14	3.40	3.63	3.70
85.5	94.5	10.0	20.72	1.76	0.18	0.14	5.90	3.63	3.30
40.0	65.5	23.50	10.73	1.09	nil	0.08	1.90	6.17	5.80
70.5	54.5	18.0	10.23	0.79	0.41	0.21	2.80	6.58	5.10
15.8	19.2	18.0	9.80	0.73	0.21	0.23	15.50	1.98	0.60
245.0	-	35.6	20.6	13.5	nil	0.21	8.50	5.40	5.81
35.0	-	18.8	38.6	8.6	0.23	0.12	12.56	9.08	7.76
145.0	-	40.2	16.16	8.2	0.91	nil	12.80	6.54	4.86
115	25	6.8	19.5	7.6	0.25	0.18	16.5	5.5	4.00
70	50	8.4	15.5	9.4	0.23	0.18	15.5	4.56	3.26
125	30	13.6	18.6	9.4	0.32	0.20	17.0	6.58	4.1
115	50	28.6	17.4	8.7	0.28	0.28	17.5	5.5	4.2
120	90	18.4	16.8	12.8	0.23	0.25	18.6	5.15	4.56
200	40	14.5	25.5	15.0	0.58	0.25	25.4	5.45	3.8
125	30	13.0	20.5	15.5	0.41	0.25	19.0	6.00	4.0
95	75	13.5	20.5	13.5	0.23	0.19	21.5	6.25	4.2
115	70	18.0	21.0	13.5	0.23	0.25	21.5	6.20	4.2
25.0	109.0	4.3	20.5	6.00	0.28	0.40	22.5	10.4	8.8
45.0	83.0	18.6	25.5	2.65	0.35	0.05	20.5	7.8	7.5
55.0	63.0	15.5	42.5	6.65	0.30	0.35	25.5	8.4	7.0
65.0	60.0	13.8	32.5	7.65	0.35	0.25	25.5	10.5	9.5
45.0	119.0	8.5	30.0	8.4	0.56	0.15	30.5	12.3	10.8
70.0	75.0	12.0	35.5	9.05	0.88	0.65	28.5	10.4	8.8
15.5	139.5	12.0	36.5	5.50	0.45	0.45	30.0	11.5	12.0
25.0	135.0	12.5	40.5	5.50	0.45	0.45	30.5	12.0	11.5
35.0	120.0	13.5	40.5	5.00	0.56	0.15	30.0	10.8	12.0

4. *Free CO₂*: Free carbondioxide is detectable in many streams and show values between 2 and 6 ppm.
5. *Alkalinity*: Alkalinity values are quite low ranging from 22.4 to 36.0 ppm. Phenolphthalein alkalinity is not detected in Tista river near Singtam while other waters exhibit both phenolphthalein and methyl orange alkalinity.
6. *Chlorides*: Chlorides rise significantly during this season. Values vary from 20.5 to 42.6 mg l⁻¹ in various water bodies.
7. *Total Solids*: Total solids range from 118 to 164 mg l⁻¹ in various water bodies. The range is smaller when compared to figures shown during monsoon. Suspended solid content is low in the total solid content, major contribution of total solid content is derived from dissolved solids.
8. *Silicates*: Silicates are also high fluctuating from 4.3 to 18.6 mg l⁻¹ in various water bodies.
9. *Calcium and Magnesium*: Calcium values fluctuate from 20.5 to 42.5 mg l⁻¹ in various water bodies studied. During this season also, magnesium content is always lower as compared to calcium. The highest figures for calcium are noticed in Rani Khola near SFF while the lower values for Tista river. Values for magnesium range from 2.65 to 9.05 mg l⁻¹. These values are comparatively lower than the values observed for monsoon season.
10. *Nitrates*: Nitrate content is slightly enhanced from that of monsoon season in most of the waters. Only exception to this is Ranikhola where the values in post monsoon are relatively low compared to monsoon season. The fluctuations in the nitrates are between 0.28 and 0.88 mg l⁻¹ at various situations.
11. *Phosphates*: Phosphates are observed in detectable concentrations in all the streams during this season. The values estimated are in the range from 0.05 to 0.65 mg l⁻¹ in various situations.
12. *Sulfates*: Sulfates are also high during this season in all the streams, relative to the values estimated for monsoon season. Figures recorded are in the range from 20.5 to 30.5 mg l⁻¹ in various water bodies. Maximum values are noticed for Sethi Khola and Rangpo Khola while the minimum values are noted for Tista river near Singtam.
13. *Dissolved oxygen*: Dissolved oxygen concentration is significantly increased in these waters during this season owing to high autotrophic activity. Surface and bottom layers did not show any significant difference in their oxygen concentration. Surface layers fluctuate from 7.8 to 12.3 mg l⁻¹ while bottom layers show a range from 7.0 to 12.0 mg l⁻¹ in various waters. The maximum values are recorded for Rangpo Khola while the minimum values are noticed for Tista river near Singtam (Table 1.).

There are few water bodies which could not be studied seasonally but analysed only once during the entire period. This analysis provide a general elemental picture. The studied water bodies include (1) Lachen Chu, (2) Lachung Chu under Lotic Systems while (3) Lake Kupup (4) Lake Chhanggu (5) Lake Mamen Chu (6) Lake Khechupheri under Lentic systems. The lentic systems situated at higher altitudes in the East District do not differ much physico-chemically with water bodies in East Sikkim situated at lower altitudes. Biological activity in these waters is totally absent and indicate their oligotrophic nature. These water bodies exhibit very low nutrient concentrations, moderate oxygen levels and very low water temperatures. Alkalinities exhibited by these waters are quite low with detectable carbondioxide levels. Physico-chemical parameters of these waters are set out in the Table 2.

Table 2: Physico-chemical properties of Lachen chu, Lachung chu, Lake Chhanggu, Lake Mamenchu, Lake Kupup and Lake Khechupheri of Sikkim Himalayas

S.No.	Particulars	Lachen chu	Lachung chu	Lake Chhanggu	Lake Mamenchu (Trout Haichery)	Lake Kupup	Lake Khechupheri
1.	Air Temperature °C	21.0	22.5	10.0	14.0	8.0	25.5
2.	Water Temperature S/B °C	16.5/15.0	18.5/18.0	6.5/8.0	12.5/12.0	12.0/13.5	24.0/24.0
3.	pH S/B	7.8/8.2	8.4/8.6	8.2/8.2	8.4/8.6	8.2/7.8	8.6/8.6
4.	Phenolphthalein Alkalinity (ppm)	28.2	32.4	18.5	28.5	16.2	8.2
5.	Methyl Orange Alkalinity (ppm)	19.4	8.4	9.6	16.4	8.4	28.4
6.	Total Alkalinity (ppm)	47.6	40.8	28.1	44.9	24.6	36.6
7.	Phenolphthalein Acidity (ppm)	53	8.3	9.3	9.3	22.8	6.3
8.	Methyl Orange Acidity (ppm)	28	5.2	4.5	4.5	8.4	2.1
9.	Free Carbon dioxide (mg l ⁻¹)	0.86	1.36	0.92	1.24	1.20	2.34
10.	Chlorides (mg l ⁻¹)	28.4	-	18	24.6	18.8	32.6
11.	Total Solids (mg l ⁻¹)	270	238	30	60.0	48	96.0
12.	Suspended Solids (mg l ⁻¹)	118	195	8	18.0	13	56.0
13.	Silicates (mg l ⁻¹)	8.4	8.6	4.3	7.8	4.3	3.5
14.	Calcium (mg l ⁻¹)	104	14.3	16.2	35.5	23.2	14.6
15.	Magnesium (mg l ⁻¹)	5.3	2.4	5.3	5.4	5.4	9.8
16.	Nitrates (mg l ⁻¹)	1.1	0.64	0.31	0.44	0.53	0.38
17.	Sulfates (mg l ⁻¹)	18.5	18.4	12.6	28.5	18.6	28.60
18.	Carbonates (mg l ⁻¹)	0.85	0.78	0.35	0.45	8.36	0.34
19.	Bicarbonates (mg l ⁻¹)	1.64	0.46	0.86	1.02	6.81	2.20
20.	Dissolved Oxygen (Surface) mg l ⁻¹	7.3	8.4	6.2	6.8	5.8	7.84
21.	Dissolved Oxygen (Bottom) mg l ⁻¹		9.1				
	(i) 0.3 metre depth	7.3	-	6.2	6.8	6.3	5.62
	(ii) 0.6 metre depth	-	-	7.8	4.9	-	-
	(iii) 1 metre depth	7.1	-	-	-	6.1	-

S = Surface, B = Bottom

Primary Production Studies

Wetlands are recognised as great source of primary production and organisation like IBP, IUCN and UNESCO have devoted some attention on these areas. Phytoplankton contributes significantly to the primary productivity in many temperate wetlands. Many water bodies of Sikkim Himalaya are completely devoid of macrophytic vegetation or with scant growth. Thus plankton contributes majorly to the primary production. The present study is aimed at to evaluate the trophic status of these waters.

Productivity values are quite low in all the water bodies studied. Even negative values for gross productivity were observed between 15 and 17 hours in case of Sethi Khola and Lake Aritar.

The highest value, 0.68 mg O₂ l⁻¹ h⁻² is recorded for Rangpo Khola between 11 and 13 hours followed by Lake Aritar with a value of 0.50 mg O₂ l⁻¹ h⁻² between 11 and 13 hours. Production values at bottom level are different at different situations. In most cases it was significantly low at bottom waters compared to that of surface waters. Here also, the values range from nil to 0.55 mg O₂ l⁻¹ h⁻² in case of Lake Aritar between 9 A.M. and 11 hours (Table 3).

Waters are never anoxic and respiratory consumptions are also comparatively low. The widest fluctuation were observed for Rani khola near SFF with the values ranging from 0.10 to 0.44 mg O₂ l⁻¹ h⁻². In bottom waters, widest fluctuations are observed in case of Rani Khola

(0.05 to 0.26 mg O₂ l⁻¹ h⁻²) followed by Lake Aritar (0.02 to 0.24 mg O₂ l⁻¹ h⁻²). The lowest fluctuations in the respiratory activity are exhibited by Rani Khola near SFF, the values are in the range from 0.08 to 0.12 mg O₂ l⁻¹ h⁻². In many cases, respiratory consumptions at bottom level are quite high compared to that of surface waters (Tables 3 and 4).

Depth Integrated Productions

Depth integrated production values are highest 0.909 gC m⁻² day⁻¹ in case of Rangpo Khola followed by Lake Aritar with a value of 0.732 gC m⁻² day⁻¹. Among all the sites, Sethi Khola exhibited the lowest value of 0.304 gC m⁻² day⁻¹. Respiratory consumptions per unit area of the water surface is highest, 0.432 gC m⁻² day⁻¹ in case of Lake Aritar followed by Rangit river with a value of 0.403 gC m⁻² day⁻¹ (Table 5).

Day Time Fluctuations in Oxygen Levels

Oxygen values evaluated at every two hour intervals in various water bodies reveal that they never coincide with the values of the light bottles. Surface and bottom layers also exhibit a marked difference. The lowest values are recorded for lake Aritar. The values ranged from 1.98 to 3.38 mg l⁻¹ at surface level while for the bottom level these values ranged from 0.60 to 1.34 mg l⁻¹. The highest oxygen values are recorded for Sethi Khola, the values for surface range from 5.35 to 6.74 mg l⁻¹ while for the bottom layers ranged between 4.64 and 5.54 mg l⁻¹.

Oxygen fluctuations studied during day time in three water bodies exhibited relatively higher oxygen concentrations. The values range from 5.80 to 7.30 mg l⁻¹ for Tista near Rangpo; 6.23 to 7.80 mg l⁻¹ for Rangpo Khola and 6.18 to 7.22 mg l⁻¹ for Rangit near Melli (Table 7). Values for bottom layers show a little lower values in these water bodies.

Table 3: Production figures along with respiratory consumptions of water bodies of Sikkim Himalayas (All Values in mg O₂ l⁻¹ h⁻²)

Parameter	9 AM to 11 AM	11 AM to 1 PM	1 PM to 3 PM	3 PM to 5 PM
Sethi Khola				
SGP	0.22	0.22	0.14	Nil
BGP	Nil	0.27	0.36	0.14
SRC	0.07	0.08	0.22	0.14
BRC	0.14	0.11	0.14	0.22
Rani Khola Near SFF				
SGP	0.26	0.30	0.20	0.28
BGP	0.05	0.20	0.12	Nil
SRC	0.10	0.20	0.12	0.44
BRC	0.09	0.08	0.12	0.10
Rani Khola				
SGP	0.30	0.39	0.04	0.16
BGP	0.14	0.37	0.18	0.12
SRC	0.19	0.25	0.16	0.36
BRC	0.26	0.05	0.20	0.17
Jolly Khola				
SGP	0.05	0.24	0.34	0.18
BGP	0.32	0.18	0.26	Nil
SRC	0.18	0.16	0.16	0.14
BRC	0.22	0.06	0.19	0.18
Tista River Near Singtam				
SGP	0.44	0.23	0.11	0.20
BGP	0.13	0.25	Nil	Nil
SRC	0.27	0.18	0.10	0.16
BRC	0.20	0.08	0.14	0.10
Lake Aritar				
SGP	0.40	0.50	0.42	Nil
BGP	0.55	0.12	0.18	Nil
SRC	0.18	0.25	0.12	0.18
BRC	0.19	0.02	0.10	0.24

SGP: Surface Gross Production

BGP: Bottom Gross Production

SRC: Surface Respiratory Consumption

BRC: Bottom Respiratory Consumption

Table 4: Day time fluctuations in the production figures (mg l^{-1}) of three water bodies of Sikkim Himalayas

Parameter	9 AM to 11 AM	11 AM to 1 PM	1 PM to 3 PM	3 PM to 5 PM
Rangpo Khola Near Rangpo				
SGP	0.44	0.68	0.42	0.28
BGP	0.28	0.26	0.36	0.12
SRC	0.16	0.18	0.23	0.13
BRC	0.18	0.15	0.21	0.08
Tista River Near Rangpo				
SGP	0.36	0.28	0.32	0.19
BGP	0.18	0.16	0.29	0.21
SRC	0.15	0.18	0.28	0.18
BRC	0.09	0.13	0.11	0.13
Rangit River				
SGP	0.42	0.56	0.38	0.19
BGP	0.36	0.52	0.16	0.26
SRC	0.12	0.12	0.18	0.11
BRC	0.16	0.14	0.23	0.13

There is no organised water supply in many parts of Sikkim, particularly in rural areas. Springs are the main source of water and the second place is occupied by some kind of piped or tap water. In our extensive survey it was noted that during summer, out of 215 panchayat units, 163 have drinking water facility within one kilometer reach. While in other seasons, only 137 units will have this facility, within one kilometer reach.

Table 5: Depth integrated production figures along with respiratory consumptions of water bodies of Sikkim Himalayas

Production/Consumption	$\text{g O}_2 \text{ m}^{-2} \text{ day}^{-1}$	$\text{gC m}^{-2} \text{ day}^{-1}$
Sethi Khola		
GP	0.810	0.304
RC	0.642	0.155
Rani Khola Near SFF		
GP	1.058	0.397
RC	0.938	0.351
Rani Khola		
GP	1.020	0.383
RC	0.972	0.365
Jolly Khola		
GP	0.948	0.356
RC	0.774	0.290
Tista River Near Singtam		
GP	1.020	0.383
RC	0.840	0.315
Tista River Near Rangpo		
GP	1.485	0.594
RC	0.885	0.354
Rangpo Khola		
GP	2.272	0.909
RC	1.066	0.426
Rangit River Near Melli		
GP	1.704	0.682
RC	1.008	0.403
Lake Aritar		
GP	1.953	0.732
RC	1.152	0.432

GP: Gross Production
RC: Respiratory Consumption

Table 6: Variations in the oxygen concentration of water bodies Sikkim Himalayas during day time (All values in $\text{mg O}_2 \text{ l}^{-1}$)

Site	9 AM	11 AM	1 PM	3 PM	5 PM
Sethi Khola	6.53/5.10	6.74/5.12	6.66/5.32	6.16/5.54	5.35/4.64
Rani Khola (SAP)	4.90/4.45	5.26/5.10	5.18/4.70	5.10/4.06	5.35/4.74
Rani Khola	4.60/4.98	4.98/4.78	5.24/4.78	5.18/4.69	5.85/4.68
Jolly Khola	6.40/5.18	6.34/6.16	6.28/6.11	6.58/6.12	5.64/4.95
Tista River	6.31/5.21	6.56/6.31	6.95/6.74	5.82/6.02	4.81/4.65
Lake Aritar	1.98/0.60	2.20/1.10	2.30/1.20	3.16/1.34	3.38/0.96

* Surface/Bottom Oxygen Concentration

Table 7: Oxygen fluctuations (during day) of three water bodies of Sikkim Himalayas (in $\text{mg O}_2 \text{ l}^{-1}$)

Site	9 AM	11 AM	1 PM	3 PM	5 PM
Tista River (near Rangpo)	6.84/5.26	7.10/6.86	6.41/6.60	7.30/7.16	5.80/4.74
Rangpo Khola	7.26/5.94	6.86/5.61	6.23/5.94	7.80/7.94	6.78/5.19
Rangit River (near Melli)	6.42/5.86	7.22/5.84	6.18/6.29	7.16/7.18	6.46/5.84

In a view to understand the potability of different water sources of Sikkim, various limnological parameters of major water resources are examined in the light of set standards. Initially World Health Organisation has prescribed the desirable limits of concentration of certain constituents, eighteen in number, which are accepted internationally (Table 8).

Table 8: WHO Standards for Potable Water

S. No.	Parameter	Permissible	Excessive
1.	Total Solids (mg l^{-1})	500	1500
2.	Colour (Hazen units)	5	50
3.	Turbidity (Jackson units)	5	25
4.	Iron (mg l^{-1})	0.3	1.0
5.	Manganese (mg l^{-1})	0.1	0.5
6.	Copper (mg l^{-1})	1.0	1.5
7.	Zinc (mg l^{-1})	5.0	15
8.	Calcium (mg l^{-1})	75	200
9.	Magnesium (mg l^{-1})	50	150
10.	Sulfate (mg l^{-1})	200	400
11.	Chloride (mg l^{-1})	200	600
12.	pH Value (mg l^{-1})	7.0-8.5	6.5 or 9.2
13.	Phenolics (mg l^{-1})	0.001	0.003
14.	Lead (mg l^{-1})	-	0.1
15.	Selenium (mg l^{-1})	-	0.05
16.	Arsenic (mg l^{-1})	-	0.2
17.	Chromium (mg l^{-1})	-	0.05
18.	Cyanide (mg l^{-1})	-	0.01

In the Indian context, the general criteria for water quality required for various beneficial uses have been set by the Central Board for the Prevention and Control of Water Pollution (1979). To achieve this objective, the Board has classified water into five categories basing on ultimate use:

- Drinking water source without conventional treatment but after disinfection.
- Organised outdoor bathing
- Drinking water source with conventional treatment followed by disinfection.
- Propagation of Wildlife, fisheries etc.
- Irrigation, industrial cooling and controlled disposal.

The Board has prescribed the primary quality criteria in respect of eight basic parameters for classifying waters designated for the above mentioned five categories of use as given in the Table 9.

Table 9: Primary water quality criteria for fresh waters used for various purposes (Central Board, 1979)

Parameter	A	B	C	D	E
Dissolved Oxygen (mg l^{-1} Min.)	6	5	4	4	-
BOD (mg l^{-1} Max.)	2	3	3	-	-
Total Coliform Organisms	50	500	5000	-	-
pH Value	6.5-8.5	6.5-8.5	6-9	6.5-8.5	6-8.5
Free Ammonia (mg l^{-1})	-	-	-	1.2	-
Electrical Conductivity (micro mhos/cm Max.)	-	-	-	-	2250
Sodium Absorption Ratio, Max.)	-	-	-	-	2.6
Boron (mg l^{-1} Max.)	-	-	-	-	2

(A, B, C, D and E are the various classes of water used for various purposes)

Keeping in view the classification of waters and the primary water quality criteria adopted by the Board, the Indian Standards Institution (1982) has prescribed the tolerance limits in respect of eighteen parameters (Table 10).

While assessing the water quality, the following points are to be taken care of:

The classification arrived at on the basis of a single parameter may not necessarily be the same as that based on other parameters. In such as a case, the lowest class scored in respect of any one of the criteria should normally indicate the water quality in terms

Table 10: Tolerance limits in respect of selected pollution characteristics, for inland surface waters required for different cases as prescribed by Indian Standards Institution (1982)

Parameter	A	B	C	D	E
Total Coliform Organisms MPN/100 ml Max.	50	300	5000	-	-
Colour Hazen units Max.	10	300	300	-	-
pH Value	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5	6.5-8.5
Conductivity micromhos/cm	-	-	-	1000	2250
Dissolved oxygen (mg l^{-1} Max.)	6	5	4	4	-
BOD (mg l^{-1} Max.)	2	3	3	-	-
TDS (mg l^{-1} Max.)	500	-	500	-	2100
Chlorides (mg l^{-1} Max.)	250	-	600	-	600
Sulphates (mg l^{-1} Max.)	400	-	400	-	1000
Nitrates (mg l^{-1} Max.)	20	-	50	-	-
Free Ammonia (mg l^{-1} Max.)	-	-	-	12	-
Arsenic (mg l^{-1} Max.)	0.05	0.2	0.2	-	-
Iron (mg l^{-1} Max.)	0.3	-	5.0	-	-
Flouride (mg l^{-1} Max.)	1.5	1.5	1.5	-	-
Lead (mg l^{-1} Max.)	0.1	-	0.1	-	-
Copper (mg l^{-1} Max.)	1.5	-	1.5	-	-
Zinc (mg l^{-1} Max.)	1.5	-	1.5	-	-
Boron (mg l^{-1} Max.)	-	-	-	-	2

A, B, C, D and E are the various classes of water used for various purposes

of a particular water source.

- While assessing the ambicat water quality in terms of a particular parameter, the amount of its deviation from the set standard should be taken into account as some small deviations from the prescribed limits with regard to a parameter can well be com-

pensated by higher gradings scored in terms of some other criteria. Thus, proper assessment of stream water quality is achieved only after taking into consideration the concentration of as many parameters as possible and the degree of their deviations from the prescribed tolerance limits.

In the present study, a total of ten parameters are estimated for major streams and compared with the standards set for A category which can be used as drinking water without conventional treatment but after disinfection. Thus the deviation of each parameter with standards are discussed in the light of pollution status and potability level (Table 11).

- Among the ten parameters examined, parameters like total dissolved solids (TDS), chlorides, sulphates, nitrates, calcium and magnesium exhibit low concentrations and stand below the tolerance limits prescribed for 'A' category water by Indian Standards Institution. However, it is notable at this juncture that these waters are to be analysed at monthly intervals to have a complete picture particularly for parameters like total dissolved solids, chlorides which exhibit wider amplitude of fluctuations in the annual cycle.

- Dissolved oxygen levels are quite fluctuating and during premonsoon these values are very low and deviate from 6 mg l^{-1} which was set as minimum for 'A' category waters. However, during post monsoon season, the values are quite high and go up to 12 mg l^{-1} .

- With regard to total coliform organisms, MPN was recorded high (120-2200) in water bodies which are close to urban areas like Singtam, Rangpo, Ranipool and Gangtok. These values higher than the tolerance limit 50 prescribed for 'A' category water.

Thus many chemical parameters are within the tolerance limits of 'A' category water but parameters like BOD and total coliform counts are to be taken care of before being supplied to people.

Table 11: Water quality assessment of various streams of Sikkim Himalayas

Parameters	'A' category	Tista river	Rani Khola	Rani Khola SFF	Jolly Khola	Sethi Khola	Aritar lake	Tista river	Rangpo Khola	Rangpo river	Lachen Chu	Lachung Chu	Khechupheri
Total coliform organisms	50	2200	1850	120	-	-	-	-	-	-	-	-	-
pH Value	6.5-8.5	7.6-8.2	7.8-8.2	7.8-8.2	7.8-8.4	7.8-8.2	7.6-8.8	7.4-8.4	7.8-8.4	7.8-8.2	7.8-8.2	8.4-8.6	8.6
Dissolved Oxygen mg l ⁻¹ Min.	6.0	5.5-10.4	3.63-7.8	3.63-8.4	5.5-10.5	5.15-12.3	1.96-10.4	5.4-11.5	6.2-12.0	6.2-10.8	7.3	8.4	7.84
BOD (mg l ⁻¹ Max.)	2.0	1.5-2.8	1.0-2.5	1.5	0.8	0.8-1.2	1.04	0.6-0.8	1.5	1.2	-	-	-
TDS (mg l ⁻¹ Max.)	500	25-109	50-83	30-94.5	50-65.5	54.5-119.0	19.2-75.0	71.8-139.5	70.0-135.0	85.0-120.0	152.00	43.0	40.0
Chlorides (mg l ⁻¹ Max.)	250	148-28.5	1.98-21.5	0.99-26.5	0.99-20.5	1.48-38.0	1.98-38.6	6.6-42.6	13.6-32.5	12.4-35.0	28.4	-	32.6
Sulphates (mg l ⁻¹ Max.)	400	3.2-22.5	3.4-20.5	5.9-25.5	1.9-25.5	2.8-30.5	15.5-28.5	8.5-30.0	11.5-30.5	12.8-30.0	18.6	18.4	28.6
Nitrates (mg l ⁻¹ Max.)	20	0-0.28	0.14-0.35	0.18-0.32	0-0.35	0.23-0.56	0.21-0.88	0-0.45	0.23-0.45	0.21-0.56	1.1	0.64	0.38
Calcium (mg l ⁻¹ Max.)	75	18.7-20.5	11.9-25.5	18.6-42.5	10.7-32.5	10.2-30.0	9.8-35.5	20.5-36.5	21.0-40.5	16.2-40.5	18.4	14.3	14.6
Magnesium (mg l ⁻¹ Max.)	50	1.22-6.0	0.67-9.4	1.76-9.4	1.1-8.7	0.8-8.7	0.79-12.8	0.7-15.5	5.5-13.5	5.0-15.0	5.3	2.4	9.8

Phytoplankton Studies

The study is restricted to only one area in Sikkim: Rangpo Khola near distilleries. Plankton studies are taken up in relation to pollution level in this aquatic system. In this, chemical and biological assessment of the water pollution is made at five sites in Rangpo stream of Sikkim Himalayas. The stream receives effluents from Sikkim distilleries at Rangpo, the border town of Sikkim for West Bengal. The list of algal species occurring in the stream is made and grouped under Chlorophyceae, Cyanophyceae, Bacillariophyceae and Euglenae. The species identified and the number of different taxa appear at various sites are summarised in Table 12.

Table 12: Plankton composition in Rangpo stream at five sites (ml^{-1})

Name of the Species	Sites				
	I	II	III	IV	V
Cyanophyceae					
<i>Merismopedia</i>	0	3	5	8	13
<i>Microcystis</i>	5	2	2	12	8
<i>Chroococcus</i>	4	-	-	13	26
<i>Anabaena</i>	2	-	-	2	5
<i>Nostoc</i>	0	-	-	4	0
Chlorophyceae					
<i>Scenedesmus</i>	5	4	18	15	28
<i>Pediastrum</i>	0	3	4	3	9
<i>Chlorella</i>	8	18	64	28	78
<i>Coelastrum</i>	3	2	0	-	4
<i>Cosmarium</i>	5	-	16	9	12
<i>Closterium</i>	-	-	12	11	8
<i>Netrium</i>	-	-	8	13	18
Bacillariophyceae					
<i>Pinnularia</i>	0	2	5	8	13
<i>Navicula</i>	2	5	9	3	8
<i>Cymbella</i>	5	8	3	1	12
<i>Eunotia</i>	0	-	3	9	12
<i>Fragilaria</i>	2	4	-	-	-
<i>Gomphonemra</i>	-	-	4	5	8
Euglenae					
<i>Euglena viridis</i>	13	14	3	-	-
<i>Euglena intermedia</i>	4	3	8	-	2
Total	58	68	164	144	264

Plankton Composition

The highest number of plankton was seen at site V followed by site III with 264 and 164 ml^{-1} respectively. The maximum number of plankton was constituted by Chlorophyceae at all the sites with values ranging from 21 to 157 ml^{-1} . Eugleneae constituted the next higher number in total plankton population at site I while it was Bacillariophyceae at sites II, III and V and Cyanophyceae at site IV. Genera-wise highest number was constituted by *Euglena* at site I but at the remaining sites, *Chlorella* dominated among all the genera. Besides the plankton analysis, physico-chemical analysis of the effluent and stream waters at five sites were also conducted during the study period.

The colour of the effluent was dark brown but when it joins the stream, it turns into light brown (site I) and then dark green (site III to V). The dark green colour of the water is due to dominant growth of Chlorophyceae among all the plankton groups. pH was very high for the effluent (9.5) but stream water showed declining trend from site I (8.8) to site V (8.2). There was not much change in the acidity, the effluent showed a value of 32 mg l^{-1} while the stream water showed figures between 13.9 and 27.5 mg l^{-1} . Alkalinity was very high for the effluent (612 mg l^{-1}) but showed a declining trend in the stream water from site I to V. Chlorides were more followed by total nitrogen and phosphorus. Stream water showed a decreasing trend from site I to site V their nutrient concentration.

The possibility of using algae in classifying waters has been well studied. Ramarao et al. (1978) successfully applied the Knopp's concept of relative purity and relative loading and saprobity index of Pantle and Buck (1955) to river Khan at Indore. Like-wise Hosmani and Bharathi (1982) calculated compound quotient in classifying water bodies of Karnataka. In the present study, *Euglena* occurred dominantly at site I, the known biological indicator of polluted waters.

Table 13: Physico-chemical feature of the effluents and Rangpo stream waters at five sites

Parameter	Effluent	Sites				
		I	II	III	IV	V
1. Colour	Dark brown	Light	Light	Dark	Dark	Dark
2. Odour	Ammoniacal	brown	green	green	green	green
	Alkaline	Faint	Odour less	Odour less	Odour less	Odour less
		ammonical				
3. Temp. °C	22	21.5	21.5	21.5	21.5	21.5
4. pH	9.5	8.8	8.4	8.2	8.2	8.2
5. Total solids (mg l ⁻¹)	895	650	435	275	290	280
6. Acidity (mg l ⁻¹)	32	27.5	18.4	13.9	18.6	17.4
7. Alkalinity (mg l ⁻¹)	612	170	134	118	80.5	64.5
8. Total nitrogen (mg l ⁻¹)	29	82.5	18.6	14.6	12.5	4.6
9. Phosphorus (mg l ⁻¹)	4.8	2.9	1.15	1.06	0.85	1.21
10. Chlorides (mg l ⁻¹)	495	118	62.5	41.5	18.5	18.5
11. Dissolved oxygen (mg l ⁻¹)	-	3.5	4.2	4.8	5.9	6.8
12. Organic matter (g l ⁻¹)	4.5	1.8	1.2	1.8	1.2	1.3

Munawar (1972) feels that *Euglenoids* harbour only in deoxygenated waters. But oxygen estimations made in the present study indicate values between 3.5 and 6.8 mg l⁻¹ at various sites of the stream. Perhaps, moderate oxygen limit i.e., upto 4.5 mg l⁻¹ might be the tolerating limit for the *Euglenoid* growth. Group wise examination of the data indicate *Chlorophyceae* constituted major numbers in the total plankton populations at various sites. Kumar et al. (1978) stressed the importance of nitrogen in enhancing the *Chlorophyceae* growth and the chemical data of the stream indicate it contains high amount of nitrogen testifying Kumar's proposition.

Organic carbon content is very high, a known favouring factor for the *Cyanophyceae* growth. However in the biological analysis, this group of plankton did not contribute much to the total plankton population except at site IV where it occupied second rank among all the groups. The lower temperatures along with moderate oxygen levels prevailing in this stream might be the causative factors for the meagre *Cynophycean* growth. *Bacillaniphyceae* which was second dominant group at sites II, III and V was represented by six genera and their number considerably increase from site I to site V. Rao (1977) reported a higher percentage of diatoms in the factory pond which was strikingly rich in nitrates

and phosphates. While according to Pearsall (1923) deficiency of oxygen and silica limits the growth of diatom population. The increasing amounts of oxygen from site I to site V and a reasonably good amount of nitrogen and phosphorus explains improving number of diatoms along the down stream.

Above observations indicate that the stream was divided into a series of zones of decreasingly severe conditions of pollution level from site I to site V succeeding one another down stream and each containing characteristic dominant plankton group. The decreasing trend in the nutrients along the stream may be attributed partly to the dilution of the effluent and partly to the effective utilisation of these nutrients by the plankton harbouring the stream.

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